Expert Committee
on Soil Survey

Proceedings of the Fifth Annual Meeting

Ottawa, Ontario
14-16 November 1983

Canada

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Edited by J.A. SHIELDS and J.C. McMENAMIN
Land Resource Research Institute
Ottawa, Ontario

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SUMMARY

These proceedings are a record of the current stages of development of selected technical subjects related to the methodology of conducting soil surveys in Canada. It includes contributions to the improvement of methods for classifying soils, for interpreting soil information, for handling and storing large amounts of soil data, and for evaluating the extent of degradation of soils.

RESUME

Ce procès-verbal est une photo de l'état d'avancement de certains sujets techniques reliés à la méthodologie d'exécution des prospections pédologiques au Canada. Il comprend certaines contributions à l'amélioration des méthodes de classification des sols, de traitement et de stockage d'un grand nombre de données pédologiques, d'interprétation de ces données et d'évaluation du degré de dégradation des sols.

WORKSHOP OF THE SOIL DEGRADATION WORKING GROUP

EXPERT COMMITTEE ON SOIL SURVEY

November 11-16, 1983, Ottawa

Compiled and Edited by D.R. Coote, (Chairman, Soil Degradation Working Group)

SESSION 1 SOIL SALINITY

Chairman - R. Eilers

INTRODUCTION

In keeping with the aim of a workshop, it is probably useful to briefly review the mandate given to this working "subgroup" at the Victoria Meetings back in 1982. The following main points have been selected from the proceedings of last year's meeting:

(i) To prepare "overview" maps indicating the "risk" of different kinds of soil deterioration. The scale should be 1:1 Million, or larger where practical. The maps should be supplemented by information from soil survey and extension specialists at the regional and local levels to provide an assessment of the degree to which the risks indicated on the maps were actually being translated into soil problems because of management practices.

(ii) To prepare a review of literature on, and experience of, the probable data and equipment needs for the soil survey to include assessments and interpretations of current and potential soil degradation in new soil survey reports. This should include classification criteria and methodologies, manpower and research needs, user requirements and data storage needs.

This approach should enable the Working Group, for next year's meetings, to prepare a listing of the equipment and manpower needs which will have to be forthcoming in order to incorporate soil degradation measurements into soil survey procedures. It will also provide a preliminary list of research needs.

REVIEW OF ACTIVITIES SINCE THE VICTORIA MEETING

The soil salinity subsection of the soil degradation Working Group has no formal membership. In general it consists of those people particularly interested in the problem of saline soils, primarily in the prairies. At the Victoria Meetings in 1982, I agreed to put together some information on salinity and circulate it to various people in each of the prairie provinces. During the summer of 1982 discussions were held with various people both in Saskatchewan and Alberta with regard to the assigned tasks, and a very informative field tour was held in Saskatchewan to look at methods of identifying and mapping soil salinity. Subsequent to these discussions I circulated a memo (February 1983) which listed a number of key factors for the recognition and mapping of salinity as well as a map and legend of salt affected soil landscapes for Manitoba. This map and legend, which will be discussed later, was prepared as an example of a small scale salinity map which might be appropriate for the prairies.

The list of salinity indicating factors were compiled for field use by soil surveyors to assist in mapping soil salinity. I have not as yet received any comments on this list so I'm not sure whether it is complete or not.

Another point of interest. - In late November and early December of 1982 the first annual Western Provincial Conference dealing with the Rationabilization of Water and Soil Research and Management was hosted in Lethbridge, Alberta. The focus of this conference was "Soil Salinity". I think that conference accomplished very effectively part of the mandate that was given to this working group, that of: "a literature review, current status and research requirements for soil salinity". The second part however, asked for a review of "Probable data and equipment needs for soil survey to include assessments and interpretations of current and potential soil degradatation in new soil survey reports". The points that we were to address include:

1. Classification criteria and methodologies.
2. Manpower and research needs
3. User requirements
4. Data storage.

As a result of our discussions today I hope that we can develop some guidelines and recommendations covering these 4 topics.

RESEARCH CONCERNS FOR SOIL SALINITY

Data and Equipment Needs

Data

First priority is the need to have more detailed soil information on severity, extent, location, type and source of salinity.

Equipment

1. At the detailed level electro-magnetic sensing devices would be useful. At the general level, use of remote sensing capabilities would be useful.
2. For monitoring and research insitu probe sensors would be useful.

Mapping Soil Salinity

In looking for standardized or documented methods of salinity mapping, sampling, analysis and data storage, two problems in particular have arisen.
1. Control section for mapping salinity
2. Class intervals for classifying salinity

Discussion

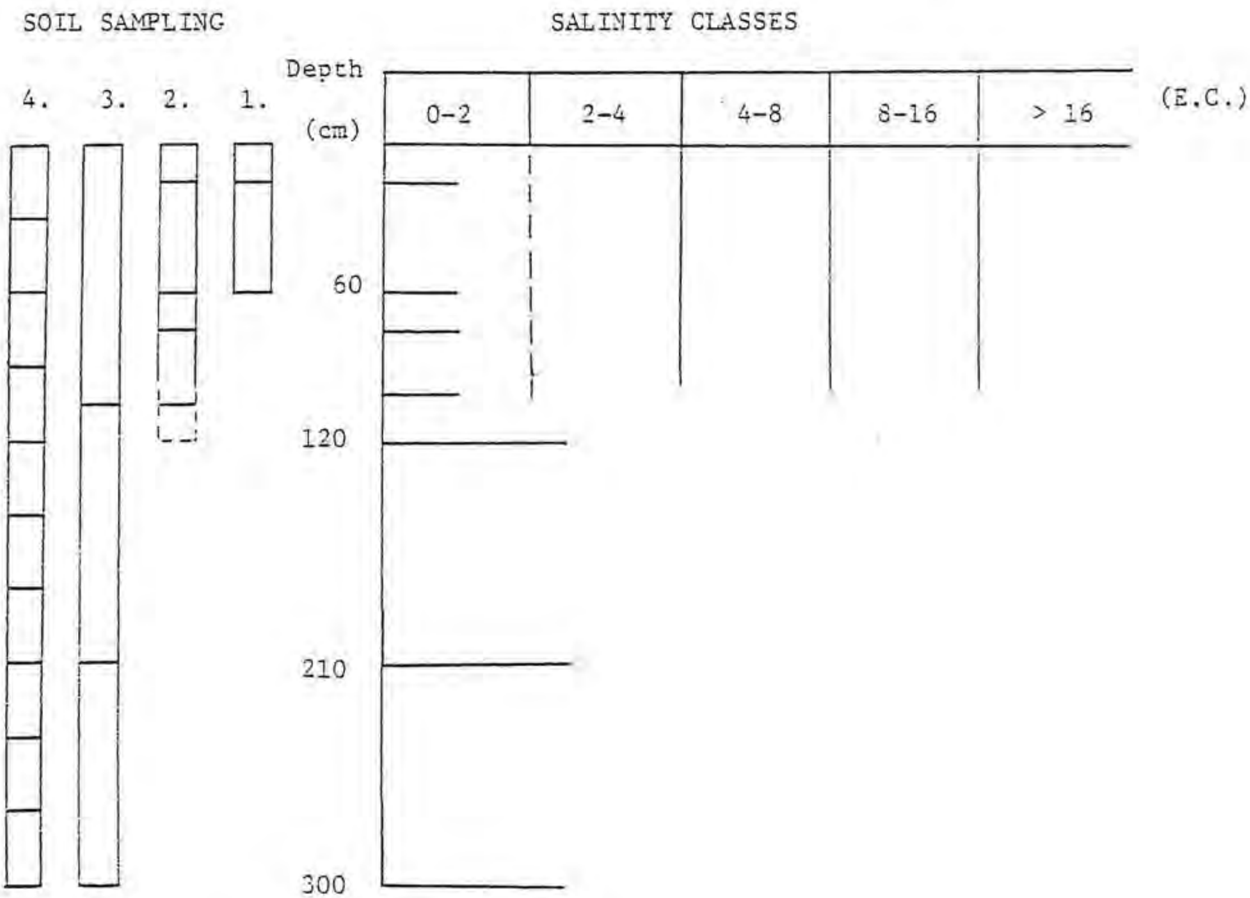
1. Depth categories for mapping soil salinity should be practical and need not necessarily be tied to solum development. The control section could be based on the biological (rooting) characteristics of plants.

2. I think we want only one rating system, but one with sufficient flexibility to be interpreted for different purposes, therefore we must have flexibility not only in the depth of the control section but also in the levels of salinity.

It is usually possible at a given site to <u>identify and describe a saline soil</u> but because of the extreme variability of salinity a map polygon can only <u>delineate a salt affected soil</u>.

Standardization is needed in sampling, analyses, interpretations, classification, mapping for severity and data storage and retrieval.

SAMPLING AND CLASSIFYING



<u>Sampling Depths</u>

1. Soil Test e.g. farmers often sample 0-2 ft)-15, 15-16 cm).
2. Soil survey - mapping and characterization - usually 0-100 cm with three or more depth intervals.
3. Soil Survey - irrigation and engineering interpret - often 0-300 cm with three or more depth intervals.
4. Soil Salinity Monitoring and Research Sites - can be 0-300 cm with ten or more depth intervals.

<u>Salinity Class</u>

e.g. 0-2 - non saline - may have some restriction for very sensitive crops.
- may have slight corrosion hazzard for some engineering uses.

As a follow-up to listing these indicator factors I would like to propose an additional idea for consideration: Would there be some merit in the W.G. producing an illustrated brochure or small bulletin entitled "Recognition Factors for Soil Salinity"?

Such a bulletin could be illustrated by appropriate slides or photos. I believe that such a bulletin would be useful to soil surveyors, extension people and farmers. What is the reaction or comments of this group? Perhaps it could be a tangible product of this working group in addition to a Prairie Regional Map.

PRAIRIE REGIONAL MAP

The other mandate for this working group was to consider the preparation of a small scale salinity map for the Prairie Region.

I believe that there was some concensus at Victoria that to arrive at such a map from scratch would be a horrendous undertaking both in terms of time and staff requirements. In view of this it was suggested that we consider using soil maps and information that were readily available, and it was further suggested that one possibility could be the generalized landscapes map, a 1:1M scale, which is presently being prepared for each province. The advantage of using this map is that we would be starting with a uniform base and legend and as well, the interprovincial map polygons would all ready have been correlated and tied together.

The next step then was to decide on a methodology for developing this map. In the process we reviewed the current activities and methodologies being used and also conducted a field tour in Saskatchewan.

As a result of these discussion a preliminary map of salt affected soil landscapes was prepared for Manitoba. As a possible approach to a Prairie Regional map and legend, copies of this map were ciculated in Feb. 1983 for review to interested people with in each province. Unfortunately, to date I have not had an overwhelming response to that map or memo.

Basically the legend was established to make use of existing soil survey maps and soil data. A salinity component was determined from known and available information and assigned to each predetermined landscape map unit or polygon. Each unit was described and labelled according to severity, extent and most probable location within the map delineation.

A brief summary of the legend is given as follows:

SUMMARY OF PRELIMINARY MAP LEGEND

for

SALT AFFECTED SOIL LANDSCAPES IN MANITOBA

Severity Classes	General E.C. Range
N - Non Saline	<4 mS/cm
W - Weakly Saline	4-8 mS/cm
M - Moderately Saline	8-16 mS/cm
S - Strongly Saline	>16 mS/cm

Extent (of Area Affected)

1- Minor	<15%of map unit
2- Significant	15-40% of map unit
3- Major	>40% of map unit

Location and Occurrence in Map Unit

c - Channels	- Discharge areas for springs and seeps in dissected lacustrine and/or morainal landscapes.
d - Depressions	- Shallow depressions in level to gently sloping lacustrine veneers and blankets.
f - Salt Flats	- Locally extensive, level to depressional, salinized shoreline areas of gently shelving lake beds of present-day lakes.
m - Salt Marsh	- Salinized marsh areas adjacent to large water bodies (lakes).
s - Sloughs	- Localized, deep depressions in hummocky morainal deposits.
a - Swales	- Directionally oriented depressional areas in patterned or ridged morainal deposits.
t - Toeslopes	- Basal areas of escarpments, wide river valleys, and long, steep, uniform slope areas with localized springs and seeps.

e.g. Map Symbols: N - Stands alone - no recognizable salinity.
W2d- Weakly saline areas occupy 15-40% of map unit. Salinity occurs in, or adjacent to shallow depressions.

Some questions for discussion and consideration when mapping salinity are:

1. At what point or depth in the soil (profile) should soil salinity be recognized and mapped? That is, what is the control section for mapping salinity?
2. What sampling techniques should be used to characterize salinity? Can or should we make a standard recommendation? In Manitoba, we have been sampling at 3 depths - 0-15 cm, 60-75 cm, and 105-120 cm in a special salinity survey.
3. Everyone probably uses either the saturated paste or the 1:1 method of analysis, with a preference for the saturated paste method. Should we evaluate factors for converting the 1:1 method data to the saturated paste equivalent according to texture, such as Saskatchewan has done?
4. Are the present classes of salinity adequate, i.e. weak, moderate and strong?
5. Can remote sensing (imagery, EM 31, etc.) be used to map salinity? At what scales would it be most useful?
6. Is chemical characterization of salinity required from the standpoint of: origin of salts, effects on soil structure, and plant toxicity potential, for interpretation of management practises?

On Sept. 12/83 I circulated a memo in preparation for this workshop, which highlighted the two major activities that this workshop was going to address. These were the Prairie Regional map and the role of soil survey in assessing soil salinity.

I have deliberately chosen to discuss the second task first because I think a lot of it will have a significant bearing on the subject of the small scale Prairie Regional salinity map.

PROVINCIAL REPORTS

In my September memo, I also raised some questions for consideration and requested that a short report be prepared by a representative from each province. These reports were to highlight the provincial emphasis on salinity and identify the role of the soil survey organization in addressing the problems related to salinity.

At this time I would like to proceed with these reports.

MANITOBA REPORT

(prepared and presented by R. Eilers)

Staff Commitment

At the present time there is no one in Manitoba working specifically on soil salinity. I would judge from the requests that we receive that the soil survey is involved in the majority of the work that is going on. This work includes:

1. Mapping and sampling
2. Characterization and research

3. Public Meetings (farm) and short courses on soils either directly or indirectly.

The present level of staff committment varies from year to year depending on local priorities. During this past year we had:

1. 2 "STEP" students conducting a salt survey for 6 weeks.
2. A 2 party soil survey project at The Pas, Manitoba, to assess the salinity conditions for a land drainage project.
3. Establishment of a bench mark site in co-operation with MDA
4. Educational Commitements which included: lectures and seminars to farm meetings; professional update course on soils; U. of Manitoba student lectures; preparation of a lesson on salinity for MDA correspondence course on "Soils 84".
5. Salinity as an integral part of ongoing S.S. Projects.

Manpower and Support Needs

With the present level of staff and priority very little additional work other than what is now being done can be expected in the near future. At a bare minimum there is sufficient need for at least 2 full time scientists and 2 support staff to work on salinity in Manitoba, one in the investigation and research area and one in the education, extension and management research area. At present there is no means to facilitate technology transfer for management of salinne soils in Manitoba.

User Requirements

1. Availability of existing information
   - many sites have been sampled several times by different people - a reference catalogue of sample sites and analyses is presently being prepared.
2. Management handbook with guidelines and recommendations
3. Identification and recognition brochure
4. Edited slide presentation discussing the principles and theories of salinity development in Manitoba. For extension purposes and farm meetings.

Data Collection and Storage Needs

A special (CANSIS compatible) form has been designed for capture and input of all salinity analysis done by the soil survey. This is currently being used to produce tabular as well as cartographic output of salinity data generated by the soil survey.

Soil Salinity Activities in Manitoba

1. Soil Survey - Detailed mapping and sampling 1:20,000 scale (on-going)
2. "STEP" - Special salt survey grid sampling 1:50,000 scale for reconnaissance soil maps. (3 yrs to complete) 2500 sites sampled to date
3. - Compilation of soil salinity data file
   - Location
   - Degree of salinity
   - Type

   Includes 2500 smaple sites to date (on-going)

4. -Compilation of soil salinity map at 1:250,000 for publication at 1:500,000 scale. It will be compiled through a series of overlay maps including data from:
   (a) Salinity data file
   (b) Soil survey maps
   (c) Soil testing data
   (d) Groundwater hydrology maps
   (e) Bedrock geology maps
   (f) Topography

   Objective of the map is to show:
   (a) Area affected by salinity
   (b) Type and Severity of Salinity
   (c) The controling factors and most probable source of salinity

   This project is "on-going" - It is planned to have working copies of some map sheets by spring 1984.

5. MDA - Has set up 2 Research-Demonstration Test Plots (1983) for management of saline soils. One of these sites is on the heavy clay soils North West of Winnipeg. The other is a loam till site West of Brandon.
   Objective is to:
   1. Characterize the soil properties and type and severity of the salinity.
   2. Identify the source and controlling factors of the salinity in the soil.
   3. Demonstrate some practical and feasible management activities for salt affected soils.

6. Soils 84 - Correspondence course on soils for farmers to be given in early 1984.
   - Will discuss the nature and management of salinized soils.
   - It is planned to prepare a slide presentation on soil salinity for use at regional farm meetings.

For the most part salt affected soils in Manitoba are just normal soils. They have good structure, fertility and moisture holding capacity. Their major problem is the high level of magnesium sulfate salts. Adopting and implementing appropriate tillage and crop management activities is the major requirement for these soils.

My guesstimate would be that the total annual staff commitment in Manitoba to soil salinity concerns would be 1 to 1.5 P/Y. This would not include PFRA or watershed conservation district activities.

Priority

The demand for information on soil salinity is rapidly increasing. I think this results in part from:

a) The desire to increase efficiencies and economics of land use (farming).

b) Increasing awareness of the nature, severity and impact of the salinity problem.
c) Introduction of new crops and management technologies, which have more critical salt tolerance requirements eg. special crops and irrigation.
d) Increasing publicity in the Media

As for the soil survey - salinity is recognized as a relatively high priority, but we are very limited in the additional things that we can do because of staff limitations and other over riding priorities. However, the assessment of salinity is an important and integral part of our detailed resurvey program.

Future Plans

I think that the Manitoba Soil Survey is presently at its capacity to respond to the requeests for salinity information. We have had to turn down requests for meetings and regional field work specific to salinity evaluation particularly at the farm level.

At the present time we are operating in a co-operative-consultative nature for some projects with the province and university.

Another plan is to make information more available to the regional specialists. This has been started and includes analysis and location of sample sites from our soil survey activities.

Another plan is to produce some audio visual information which can be sent to regional specialists to be used at farm meetings. This will reduce the demands on our resources to be present at these meetings.

Another planned activity is to compile from existing data generalized salinity maps which will cover broader areas than the detailed resurveys and be more specific about the nature of salinity than the reconnaissance soil maps.

SOIL SALINITY RESEARCH AND INVENTORY IN SASKATCHEWAN

(A statement prepared by W.D. Eilers, Pedologist, Saskatchewan Soil Survey Unit, November 10, 1983, and presented by D. Acton.)

Introduction

The current program of soil Salinity Research in Saskatchewan is comprised of four components:

1) Research into the origin of saline soils through stratigraphic and hydrologic analysis. J.L. Henry.
2) Inventory of the extent and severity of saline soils as a part of the basic soil survey program. W.D. Eilers.
3) Agronomic practices for management of saline soils. H.M. Holm and J.R. Peters.
4) Environmental monitoring of saline soils. D.W. Anderson.

Current Program

Geologic origin of saline soils - this research is being conducted under the direction of J.L. Henry, Professor, Dept. of Soil Science, University of Saskatchewan, Saskatoon through funding provided by the Saskatchewan Farmlab Program.

The objectives of this program are:

1) to provide farmers with recommendations on management programs to provide the greatest economic return on salt affected land;

2) to devise a classification system for salt affected land in Saskatchewan.

Scope of the Program

Each on-farm investigation involves a number of different steps. The first step is acquisition of all background information in terms of maps, air photos, etc. on the specific site. This is followed by a detailed interview with the farmer to determine the cropping and salinity history of the site. Diagnostic investigations include drilling and logging of selected sites augmented by field measurements of salt levels, composition and conductivity, detailed photography of the site and in selected instances the preparation of contour and water table depth maps.

Following the diagnostic studies all data are compiled and recommendations prepared.

Sites are selected based on farmer application or referral through Ag Reps or Soils and Crops Specialists. Thusfar, sites have been investigated throughout the province on a wide range of soil and landform types.

This program is currently in its second year of operation. It presently involves Professor Henry and three other support staff positions. The expertise of a groundwater hydrologist and a geologist is obtained from time to time.

Soil salinity inventory

The inventory of the extent and severity of saline soils is being conducted in conjunction with the basic resurvey of soils in Saskatchewan. During the summer and fall periods of 1983, 17 RMs in the Melville map sheet were traversed and salinity features were mapped and checked. Several RMs in the Battleford sheet were also mapped and checked. In addition to mapping the extent and severity of soil salinity in these RMs, attention was paid to the position of occurrence of saline soils in the landscape. This was done to more adequately described the saline soils in these areas and to assist in the production of an interpretative soil salinity map for each RM.

Agronomic practices

Research into agronomic practices for the management of saline soils is being conducted by J.R. Peters of the School of Agriculture. The research is aimed at determining the effectiveness of snow trapping in providing water for leaching salts from the rooting zone. Treatments include standing alfalfa and tall wheat grass barriers established on saline soils.

Monitoring of soil salinity changes on a site on which a stand of alfalfa was broken up and put back into cultivation is also being conducted.

Environmental monitoring

Monitoring of soil salinity changes has been carried out for the previous five years on a number of sites immediately downstream of the Cookson Reservoir near Coronach, Saskatchewan. This work is being conducted by D.W. Anderson of the Saskatchewan Institute of Pedology and is funded by the Saskatchewan Power Corporation. The summer of 1983 represents the final year of the five-year monitoring program. The Saskatchewan Power Corporation is presently funding an investigation aimed at divising possible remedial actions that may be taken to help alleviate the effects of soil salinity in this area.

Future program

1. Geologic Origin of Saline Soils
   - Future plans include development of a system of classification for saline soils in Saskatchewan.
   - Documentation of the classification scheme.

2. Mapping Saline Soils
   - Improve methods of mapping saline soils by the continued and expanded use of aids such as the EM38.
   - Develop methods of identifying types of saline soils in the field by rating the position of soils in the landscape.
   - Investigate the origin of saline soils in specific areas by means of stratigraphic and hydrologic investigations.

3. Agronomic Practices
   - Continued monitoring of salinity changes due to various management practices.
   - At the moment it appears that no one is doing any work on the sites established by H.M. Holm.

4. Environmental Monitoring
   - 1983 represents the final year of a five-year monitoring program at Coronach. The data will be analyzed this fall and winter and final report will be prepared for the Saskatchewan Power Corporation.

   - An investigation into possible remedial measures which could be undertaken in this area is underway and recommendations will be made. Monitoring of the effectiveness of the remedial measure then may be a possibility for the future, but no source of funding for this is apparent at this time.

SOIL SALINITY - ALBERTA REPORT

(Prepared by A. Howard, Alberta Research Council, and presented by W. Pettapiece)

Current Activities

A. Salinization of Irrigated Land

1. Alberta Agriculture Irrigation and Conservation Division

(i) Drainage Branch

- monitoring subsurface drain effluent and its impact on surface waters.
- long term reclamation studies measuring rate of salt removal.
- drain depth spacing in fine and medium textured soils to determine optimum spacing.
- develop a computerized classification system for Landsat digital data to detect, map and monitor saline water-logged areas.
- origin of sulfate in till and its relation to salinity.
- modelling impact of cultural practices on salinity.
- work on water movement through fractures in the till and its impact on salinity.

(ii) Farm Irrigation Services Branch

- effect of irrigation scheduling on crop tolerance and salt movement.
- measuring changes in soil SAR from application of groundwater with a known Na/Ca ratio - in cropped cylinders.
- modelling management practices, rain, irrigation and consumptive use and how they affect water table levels.

(iii) Land Classication Branch

- long term effects of chemical amendments on a solonetzic soil under irrigation (plot experiment).
- investigation of the capillary rise method for preparation of soil pastes for ES and SAR determination compared to the hand mixing method.
- evaluating electromagnetic induction techniques as a tool for soil mapping.

(iv) Project Planning Branch

- investigating types of canal linings (in cooperation with University of Calgary).

2. Agriculture Canada Lethbridge Research Station

(i) T. Sommerfeldt

- innvestigating means to control canal seepage.
- mapping soil salinity (irrigated land and dryland) using Landsat data at 1:250,000 scale.

(ii) C. Chang
- determining the extent of salinity in the Taber, St. Mary's, and Lethbridge irrigation districts.
- measuring salt and water movement during reclamation of saline soils (irrigated land and dryland).

3. Private Groups
- evaluation of a cut-off curtain for controllingcanal seepage.

B. Salinization of Dryland

1. Alberta Agriculture Plant Industry Division, Soils Branch
- develop drainage designs for 3 dryland saline seep discharge sites.

2. Alberta Research Council
- groundwater investigation to determine causes of salinity at Black Spring Ridge near Carmangay, Alberta (in cooperation with Alberta Agriculture, Plant Industry Division).
- Plains Hydrology and Reclamation Project - effects of surface mining on salt generation and soil and groundwater salinization.
- evaluating electromagnetic induction techniques (EM 38) for measuring, monitoring, and mapping salinity.

3. Agriculture Canada
a. Lethbridge Research Station (J. Beke)
- effect of subsurface irrigation and salinization from movement of saline seep discharge by subsurface drains.
- study of hydrologic zonations to determine patterns of salinity outbreak.
- effect of salinity on changes in land use in Warner County.
- effect of alfalfa vs. grasses on saline soil amelioration (plot study).

b. Prairie Farm Rehabilitation Administration
- investigation of geology and deep groundwater flow in 2 basins in Warner County.

4. Private Groups
a. Alberta Dryland Saline Seep Committee.
- identification of potential recharge areas (drilling program in cooperation with PFRA).
- studying continuous vs. alternate crop-fallow rotations to ameliorate effects of saline seeps.

b. Engineering and Soils Consultants
(i) General Types of Activities
- brine spill reclamation.
- mapping salt effected areas (local extent).
- monitoring moisture and salinity on reclaimed mineland.

(ii) Monenco Consultants Ltd., Calgary
- reclamation of a salt water and oil spill involving subsurface drainage installation. Soil salinity levels are being monitored while ripping and chemical treatments are applied to accelerate salt removal.
- application of electromagnetic induction techniques to measure surface and subsurface salinity distributions from brine spills.
- application of electromagnetic induction techniques to measure saline soil on irrigated and dryland.
- a sub-soil depth experiment and slope experiment on plots reclaimed land in an effort to determine which reclamation procedures will minimize soil salinization.

Staff Committment

- at present there are approximately 15 professional man-years devoted to research on soil salinity.
- Alberta Agriculture has the majority of the salinity investigators but for many, their job dictates that 50% of their time is spent on research, and 50% on services.

Priority

- expressed in terms of public awareness:
  - the whole province - not a major concern.
  - in Southern Alberta - is a major concern.
- expressed in terms of provincial government research funding:
  - two funding agencies (separate from line department activities)

1. Farming For The Future (FFTF)
   - a small percentage of their funding is devoted to salinity research.
2. Reclamation Research Technical Advisory Comm. (RRTAC)
   - the majority of their funding is indirectly devoted to salinity research through studying the effects of the processes of the hydrologic cycle upon surface mining and reclamation. (Plains Hydrology and Reclamation Project).

Future Plans

- continuing research
- a seminar early in 1984 (B. Harker is chairman) involving several provincial researchers designed to attempt to co-ordinate research activities.

Research concerns for soil Survey

A. Data and Equipment Needs

1. Data

   a. Data are needed to address these issues:
      - more detailed survey information on extent of salinity.
      - more information on salt movement dynamics.
      - need to better identify seasonal salt fluctuations from long term salinity build up.
      - effect of fertilizers on nitrates in groundwater and surface water.

   b. Types of Data Needed
      - survey data to better determine extent of soil salinization and also to provide information that can be used to determine suitable locations for more intensive salinity research.
      - monitoring data to determine salt movement processes and rates, that in turn can be used in land management models.

2. Equipment

   a. For survey data:
      - Wenner array (4 electode).
      - electromagnetic induction techniques.
      - air photo - infrared.
      - satellite.

   b. For monitoring data:
      - salinity sensors.
      - neutron probe (soil moisture).
      - piezometer (water table).
      - gamma radiation attenuation equipment (two probe density meter).
      - Wenner array.

Conclusion:
- there is a need for new equipment that can measure soil salinity in-situ.
- electromagnetic induction probe?

B. Manpower and Support
- need for more manpower and support but a greater need for a co-ordinating body such as an agency or committee.

C. User Requirements
- farming public and extension services require simple land management solutions.

D. Data Collection and Storage

- no need yet for central data bank.
- computerized data storage and data handling techniques are becoming essential.
- computerized data collection (eg. elctronic notebook) devices and techniques are becoming more desirable. They are well suited for both survey and monitoring data. They reduce:
  - field manpower and
  - keypunching time.

SALINITY SUB-GROUP

It was proposed that a sub-group, with interest in the identification and mapping of salinity, concentrate on this topic on behalf of the Working Group. It was suggested that this sub-group consist of R. Eilers (Manitoba), W. Pettapiece (Alberta), W. Eilers (Saskatchewan) and a representative from PFRA. Objectives would be to standardize methods for: sampling (esp. depths); analysis (e.g. 1:1 or saturated paste); classes of severity (e.g. "non-saline": 0-2 or 0-4 mS cm^{-1}); extent of salinity to be included in map polygons; interpretations of critical levels, plant tolerances and management recommendations.

It was also suggested that the sub-group should investigate: the use of soil-test data for estimating rates of change over time; modifying the legend of the small scale maps to include factors of interest in each province, and the suitability of remote sensing data for salinity mapping (e.g. current research at Lethbridge).

SESSION 2 SOIL CONTAMINATION

Chairman - J. MacMillan

STUDIES OF HEAVY METALS IN SOILS OF NEW BRUNSWICK (prepared and presented by J. MacMillan)

Data and results were presented on two studies: 1. Downwind contamination from a lead and zinc smelter at Belledune. Originally this was a sulphur fallout study (1966-70), then realization of heavy metal contamination led to further study. Sheep were believed to be poisoned by lead and fish affected by cadmium. There were increases in many H.M.'s from 1966 to 1980 when the zinc operation was closed, but the distribution was not readily attributed to the smelter itself (see Figure 1). Many sites had levels of cobalt, chromium, nickel and zinc above levels considered excessive by the Ontario Ministry of the Environment (Hatch Associates Ltd. 1981).

2. These results led to the question of the natural variability in soil H.M. content. A second study was carried out in 1983 and involved 15 sites around the province. Many samples exceeded the suggested Ontario recommended soil limit for arsenic but other elements, though high, were within limits.

Some possible sources believed to be associated with some of the high levels included fallout from a thermal generating station, top-killers used in potato fields, lead from vehicle exhausts and dust from ore carrying rail-cars.

SOIL DEGRADATION - HEAVY METAL CONTRIBUTIONS FROM MUNICIPAL WASTES

(Prepared and presented by M.D. Webber, Environment Canada, Environmental Protection Service, Wastewater Technology Centre, Burlington, Ontario, by invitation of the Work group)

ABSTRACT

Sewage sludge is the municipal waste most likely to cause heavy metal accumulation in soil because the heavy metal concentrations in sludge usually greatly exceed those in soil, and their is increasing disposal of sludge by application on agricultural land. Evidence is presented that land application of sludge increases heavy metal concentrations in soil, however, it is not the only factor exhibiting this effect. Concentrations vary depending upon agricultural practices, industrial activity and large natural differences in soil composition. For example, Cu, As, Pb and Hg concentrations in some Ontario soils have been greatly enhanced through pesticide and fertilizer use in crop production, and aerial deposition resulting from metal smelting operations. However, the heavy metal concentrations in uncontaminated Ontario soils generally increase with increasing clay and organic matter content and large natural variations frequently exceed increases due to contamination. It is concluded that monitoring of soil survey samples is unlikely to differentiate between soils with naturally large heavy metal concentrations and soils with enhanced concentrations due to sludge application or other human activity. This conclusion must not be confused with the need for comprehensive soil sampling and analysis to control heavy metal additions to agricultural soils at sludge application sites.

1 INTRODUCTION

Soil undergoes degradation when its value for a particular purpose is reduced. Heavy metal accumulation can degrade agricultural soil by reducing its productivity for crops and by reducing the quality of the crops for use as food or fodder.

Sewage sludge is the municipal waste most likely to cause heavy metal accumulation in soil. Heavy metal concentrations in sludge usually greatly exceed those in soil (Table 1) and there is increasing disposal of sludge by application on agricultural land. Other municipal wastes such as domestic refuse may contain heavy metals but are generally disposed of by landfilling or incineration. Consequently, sewage sludge is the only municipal waste considered in this presentation.

TABLE 1. COMPARISON OF HEAVY METAL CONCENTRATIONS (mg/kg dry wt) IN UNITED KINGDOM SEWAGE SLUDGES AND AGRICULTURAL SOILS (Webber et al, 1983a)

Element		Sludge		Soil		Ratio[a]
Name	Symbol	Range	Common Value	Range	Common Value	Sludge/ Soil
Arsenic	As	3-30	20	1-50	6	3
Boron	B	15-1000	30	2-100	10	3
Cadmium	Cd	2-1500	20	0.01-2.4	1[b]	20
Cobalt	Co	2-260	15	1-40	10	1.5
Chromium	Cr	40-14000	400	5-1000	100	4
Copper	Cu	200-8000	650	2-100	20	32
Fluorine	F	60-40000	250	30-300	150	2
Mercury	Hg	0.2-18	5	0.01-0.3	0.03	167
Molybdenum	Mo	1-40	6	0.2-5	2	3
Nickel	Ni	20-5300	100	10-1000	50[b]	2
Lead	Pb	50-3600	400	2-200	20	20
Selenium	Se	1-10	3	0.01-2	0.2	15
Zinc	Zn	600-20000	1500	10-300	50	30

[a]Based on common values

[b]Common values for Danish soils; Cd, 0.2 and Ni, 10

The objective of this report is to review information concerning heavy metal concentrations in agricultural soils and to advise whether monitoring of soil survey samples would likely identify soil degradation resulting from sludge application. Information was obtained from three sources as follows:

1. A study conducted by Webber et al, (1983b) of heavy metal concentrations in soils at selected sludge application sites in Ontario.
2. A study conducted by Frank et al, (1976) of heavy metal concentrations in agricultural soils of Ontario.
3. A study conducted by the Halton Region of heavy metal

concentrations in agricultural soils of Halton County in Ontario. A report of this study is currently in preparation for publication.

1 HEAVY METAL CONCENTRATIONS IN SOILS AT SELECTED SLUDGE APPLICATION SITES IN ONTARIO

In the study conducted by Webber et al (1983b), ten sludge application sites in Ontario were selected to represent:

(a) different locations,
(b) a range of soil types,
(c) a range of sludging histories from 1 to 21 years, and
(d) a range of heavy metal concentrations in land applied sludges.

To determine background heavy metal concentrations in the soils, control sites, which had not received sludge, adjacent to the sludge application sites were sampled.

Soil cores to a depth of 15 cm were taken using a 2 cm diameter sleeve sampler. Twenty cores taken at 20 m intervals on a 60 x 80 m grid were combined to form one composite sample. Composite samples were taken from each of four grids spaced at regular intervals within each site. The soils were air-dried and ground with a ceramic mortar and pestle prior to analysis. Total metals and plant available (0.005 M DTPA-extractable, Lindsay and Norvell, 1978) metals were measured.

Heavy Metal Loadings to the Application Sites - Estimated heavy metal loadings to the application sites are presented in Table 2. They varied widely from site to site and frequently exceeded the average contents in uncontaminated Ontario soils. Additions of Zn and Cr at Kitchener and of Ni and Mo at Stratford greatly exceeded the maximum recommended loadings to Ontario agricultural lands. Cadmium addition at the Burlington, Galt, Guelph, Oakville, and Stratford sites and Zn addition at the Oakville site exceeded the maximum recommended loadings.

Total Metals in Soils - In general, sludge treatment increased the total metal contents of soils (Table 3). Mean values for the treated soils were much larger than for the control soils. The largest increases, observed at Guelph, Kitchener, Oakville, Oshawa, and Stratford were in general agreement with estimated sludge constituent loadings (Table 2). The measurements reflected a very large Mo loading at Stratford, but did not reflect very large loadings of Zn at Kitchener or Ni at Stratford. At several locations, Zn exhibited large increases and Cu, Pb, Ni, and Cd exhibited smaller increases, in that order. Data for the Brantford location were not consistent with the observation that sludge treatment increased the metal contents of soils. It was concluded that the Brantford control soil probably had received sludge because the total metal contents generally exceeded values for the Brantford sludge treated soil, as well as the mean values for all control soils, and approximated the mean values for all sludge treated soils.

TABLE 2. A COMPARISON OF ESTIMATED HEAVY METAL LOADINGS TO THE APPLICATION SITES WITH AVERAGE CONTENTS IN UNCONTAMINATED ONTARIO SOILS AND RECOMMENDED MAXIMUM LOADINGS (Webber et al, 1983b)

Site[a]	Cd	Zn	Cu	Ni	Pb	Cr	Mo
	Estimated loadings (kg/ha)						
Brantford	1.2	119	67	11	66	38	<1.1
Burlington	1.9	45	12	3.6	11	16	<0.2
Galt	2.4	67	53	2.4	14	57	<0.9
Georgetown	0.8	12	10	0.9	21	5.7	<0.4
Guelph	1.8	65	33	0.8	13	35	0.6
Kitchener	1.1	595	59	30	55	628	<1.8
Oakville	3.0	463	102	23	91	137	<1.3
Oshawa	0.1	61	6.8	11	13	66	0.6
Stratford	3.1	258	111	118	90	145	19.4
	Average contents in uncontaminated Ontario soils[b] (kg/ha)						
	1.6	110	50	32	30	30	4
	Recommended maximum loadings to Ontario soils[b] (kg/ha)						
	1.6	330	150	32	90	210	4

[a]Data were not available for the Kingston application site.

[b]OMAF/OMOE (1981)

The Cd, Cu, and Ni contents of the control soils approximated the mean values of 0.8, 25, and 16 μg/g, respectively, reported for uncontaminated Ontario soils. Zinc and Pb contents of the control soils exceeded the 55 and 15 μg/g values, respectively, reported for uncontaminated Ontario soils, but fell within the Zn (5 to 300 μg/g) and Pb (5 to 71 μg/g) ranges reported as background levels in Canadian soils (McKeague et al, 1979). The metal contents of sludge treated soils occasionally exceeded, but generally were smaller than the recommended maximum values which are: Cd, 1.6; Zn, 220; Cu, 100; Ni, 32; and Pb, 60 μg/g for Ontario soils. The Mo content of soil treated with Stratford sludge greatly exceeded the 4 μg/g recommended maximum value.

DTPA-Extractable Metals in Soils - The 0.005 M DTPA-extractable metals in soils were highly correlated with the total metals in soils. The correlation coefficients were Cd, 0.74; Zn, 0.86; Cu, 0.91; Ni, 0.70; and Pb, 0.77 and all were significant at $P = 0.05$. Sludge treatment increased the levels of DTPA-extractable Cd, Zn, Cu, Ni, and Pb, and mean values for the treated soils were much larger than for the controls (Table 4). Large increases were observed at Guelph, Kitchener, Oakville, Oshawa, and Stratford.

2 HEAVY METAL CONCENTRATIONS IN ONTARIO AGRICULTURAL SOILS

In the study conducted by Frank et al (1976), soil samples were collected from different agricultural areas of Ontario so as to include all

TABLE 3. TOTAL METALS (μg/g, air-dry wt) IN THE SOILS[a] (Webber et al, 1983b)

Location	Treatment	Cd	Zn	Cu	Ni	Pb	Mo
Brantford	Control	1.06	222	31.6	18.6	33.0	--
	Sludge	1.19	164*[b]	30.9	18.5	28.9	--
Burlington	Control	0.54	119	28.1	23.6	26.0	--
	Sludge	0.92	107	26.5	24.4	26.8	--
Galt	Control	0.26	101	17.0	14.8	25.6	--
	Sludge	1.14**	130**	27.9**	17.6	30.1	--
Georgetown	Control	0.54	71	32.2	20.0	21.2	--
	Sludge	0.89	97**	40.9**	24.4**	27.5**	--
Guelph	Control	0.45	120	15.5	14.1	24.9	--
	Sludge	1.94**	383**	58.4**	14.1	42.9**	--
Kingston	Control	0.44	97	15.5	21.4	21.5	--
	Sludge	0.70	91	19.9	11.6*	27.0	--
Kitchener	Control	0.41	88	14.0	13.0	24.0	--
	Sludge	0.89	148	37.5**	21.4**	29.0	--
Oakville	Control	0.26	104	19.8	23.2	26.6	--
	Sludge	1.13	257**	62.9**	31.0**	36.0*	--
Oshawa	Control	0.13	126	25.5	25.2	27.0	--
	Sludge	0.62	394	62.2	77.0	96.1	--
Stratford	Control	0.32	98	21.6	22.5	23.8	ND[c]
	Sludge	1.23**	131**	44.4**	32.5**	34.0**	19.2
Mean	Control	0.44	115	22.1	19.6	25.4	--
	Sludge	1.06	190	41.1	27.2	37.8	--

[a]The data are averages of four replicates except for Oshawa control where they are averages of two replicates.

[b]Sludge treatment significantly different from control by t-test at * $P = 0.05$ and ** $P = 0.01$

[c]Not detected

types of crop production. Each sample was a composite of 10 to 20 subsamples taken to a depth of 15 cm at random locations within each site. A total of 296 samples were collected: 86 from orchards and vineyards, 82 from vegetable producing farms, 126 from hay and cash crop farms, and 15 from unimproved pastures. Sample sites were located in 34 of the 42 Ontario counties.

The soils were analyzed for 10 metals and one non-metal and a resume of mean results is presented in Tables 5 to 7. Ranges and standard deviations for the means are contained in the original publication and indicate a considerable amount of variability in the data.

TABLE 4. 0.005-M DTPA-EXTRACTABLE METALS (μg/g, air-dry wt) IN THE SOILS (Webber et al, 1983b)

Location	Treatment	Cd	Zn	Cu	Ni	Pb
Brantford	Control	0.30	9.6	3.5	0.49	3.33
	Sludge	0.36	12.1	5.2	0.54	2.94
Burlington	Control	0.12	1.7	1.1	0.35	1.98
	Sludge	0.23*[b]	2.5	1.5	0.36	2.08
Galt	Control	0.10	1.6	0.5	0.13	1.52
	Sludge	0.51**	8.8**	4.7**	0.73**	2.25*
Georgetown	Control	0.14	1.5	2.8	0.77	2.51
	Sludge	0.24*	4.5	3.8	0.78	3.12
Guelph	Control	0.12	1.5	0.5	0.13	1.84
	Sludge	1.00**	65.1**	18.8**	0.44*	4.80**
Kingston	Control	0.09	1.6	0.6	0.37	1.01
	Sludge	0.13	4.9*	3.8*	0.18*	3.92*
Kitchener	Control	0.10	1.4	0.5	0.13	1.60
	Sludge	0.41*	22.6*	9.9**	2.21*	2.66
Oakville	Control	0.09	0.7	0.6	0.42	2.07
	Sludge	0.42**	40.2**	18.3**	2.72**	5.66*
Oshawa	Control	0.18	7.2	2.0	0.76	2.92
	Sludge	0.28	64.7	16.0	9.84	22.3
Stratford	Control	0.13	1.4	1.0	0.39	2.39
	Sludge	0.45**	12.5**	8.4**	2.84**	3.85
Mean	Control	0.14	2.8	1.3	0.39	2.12
	Sludge	0.40	23.8	9.0	2.06	5.36

[a]The data are averages of four replicates except for Oshawa control where they are averages of two replicates. Oshawa data were included in the mean values but not in the statistical analyses.

[b]Sludge treatment significantly different from control at * P = 0.05 and ** P = 0.01

The concentrations of most heavy metals increased with increasing clay and organic matter contents of soils (Table 5). The Cd, Co, Cr, Fe, Mn and Zn concentrations observed were normal background levels, however, Cu concentrations in organic soils were enhanced due to the use of Cu as a trace element supplement, and fungicide. Nickel concentrations in clay and organic soils exceeded normal background levels and there was no apparent cause for these high levels. Excessive concentrations of Ni, Co and Cu in a very few soils were attributed to aerial fallout resulting from a nearby nickel-cobalt smelting operation (Table 6). Arsenic, Hg and Pb concentrations in soils exhibited wide variations which were attributed mainly to agricultural practices (Table 7). Arsenic and Pb levels were elevated in orchard soils as a result of using lead and calcium arsenate as pesticides over the past 65 years. Concentrations decreased in the order: apple orchard soils > cherry orchard soils > peach orchard soils, and were correlated with the time of pesticide use and the application rates. Arsenic levels were slightly increased in potato soils due to the use of sodium arsenite as a defoliant prior to harvesting. Mercury levels in apple orchard soils were slightly increased due to the use of phenylmercuric acetate to combat scab.

TABLE 5. EFFECT OF SOIL PROPERTIES ON MEAN HEAVY METAL CONCENTRATIONS (µg/g dry wt) IN ONTARIO AGRICULTURAL SOILS (After Frank et al, 1976)

Soil Texture	Cd	Zn	Cu	Ni	Cr	Co	Fe	Mn
Sandy (125)	0.43	40	20	7.6	10	3.4	9,030	428
Loam (98)	0.71	64	26	18	15	4.6	16,440	606
Clay (60)	0.57	62	27	28	22	6.4	22,770	662
Organic (13)	0.57	66	65	29	15	6.8	13,480	338
All (296)	0.56	54	25	16	14	4.4	14,470	530

( ) No. of samples analyzed

TABLE 6. HEAVY METAL CONCENTRATIONS (µg/g dry wt) IN SOILS NEAR A NICKEL - COBALT SMELTER (After Frank et al, 1976)

Farm	Metal	Mean	Range	Normal Background
A	Cu	664	486 - 2190 (6)	25
	Ni	6560	3260 - 14890 (6)	16
	Co	66	-	5
B	Ni	381	-	16
C	Ni	344	-	16

( ) No. of samples analyzed

3 HEAVY METAL CONCENTRATIONS IN HALTON COUNTY AGRICULTURAL SOILS

Halton Region in Ontario has recently initiated a very active land application of sewage sludge program. The program included sampling and heavy metal analysis of all agricultural soils in the County to establish the extent of the land area suitable for sludge application. The County was divided into approximately one square mile sections and a composite soil sample was taken from each quarter of each section. Each composite sample consisted of 10 soil cores to a depth of 15 cm taken in a zig-zag pattern with a 2 cm diameter sleeve sampler. The soils were air-dried, ground with a ceramic mortar and pestle and analyzed for total metals.

TABLE 7. EFFECT OF SOIL PROPERTIES AND AGRICULTURAL PRACTICES ON ARSENIC, MERCURY AND LEAD CONCENTRATIONS IN ONTARIO AGRICULTURAL SOILS (After Frank et al, 1976)

Soil and Crop Type	Number of Samples Analyzed	Concentration (μg/g dry wt) As	Pb	Hg
Sandy soils				
Apples	13	--	--	0.39
Apples, cherries	34	30	--	--
Fruit	43	--	129	--
Other crops	>80	5.8	10	0.06
Loam soils				
Apples	16	--	--	0.18
Apples, cherries	23	38	--	--
Fruit	29	--	153	--
Other crops	>65	6.1	18	0.09
Clay soils				
Apples	2	--	--	0.60
Apples, cherries	2	61	--	--
Fruit	14	--	44	--
Other crops	>45	6.4	16	0.08
Organic soils				
Vegetables	13	14	13	0.41
General crops				
Unimproved	15	5	12	0.08
Field crops	126	6	11	0.07
Vegetables				
Mineral soils	>35	5	13	0.10
Organic soils	13	14	13	0.41
Potatoes	17	9	--	--
Fruit				
Apples	31	40	247	0.29
Sweet cherries	16	30	109	0.05
Sour cherries	12	23	71	
Peaches	11	10	26	0.06
Grapes	16	8	19	0.10
All Soils	296	12	46	0.11

Halton County soils exhibited wide ranges of heavy metal concentrations (Table 8). The Cu, Ni and Cr data for both untreated and sludge treated soils were similar, however, the Cd data for sludge treated soils exhibited a wider range and higher mean than for the untreated soils. By contrast, Zn and Pb concentrations for untreated soils exhibited much wider ranges and somewhat larger means than for sludge treated soils. Except for Zn, the mean heavy metal concentrations in Halton County soils were similar to those for uncontaminated Ontario soils. The mean Zn concentration in Halton County soils was approximately twice that for uncontaminated Ontario soils.

Selected data for treated soils indicated that sludge application generally increased heavy metal concentrations in soil and that the amount of the increase was related to the amount of sludge applied (Table 9). As was mentioned previously, the maximum Zn and Pb concentrations for untreated Halton soils were much larger than for sludge treated soils (Table 8). Since Zn concentrations in uncontaminated Ontario soils seldom exceed 150 µg/g dry wt (Frank et al, 1976), the data for untreated Halton soils were divided into two groups with Zn $<$ 150 and $\geq$ 150 µg/g (Table 10). Mean heavy metal concentrations in the soils with Zn $<$ 150 µg/g were similar to the means for uncontaminated Ontario soils (Table 8). Mean Zn and Pb concentrations in the soils with Zn $\geq$ 150 µg/g greatly exceeded the means for uncontaminated Ontario soils. Plotting the sampling sites for soils with Zn $\geq$ 150 µg/g on a map indicated that, with few exceptions, they were located in the northwest corner of Halton County (Figure 1). A comparison of the soil sampling map with the soil survey map for Halton County (Gillespie et al, 1971) indicated that the soils with

TABLE 8. MEAN HEAVY METAL CONCENTRATIONS (µg/g dry wt) IN HALTON COUNTY SOILS

	Cd	Zn	Cu	Ni	Pb	Cr
			Untreated Halton Soils (256)			
Range	<0.2-1.6	50-821	10-53	4-48	9-295	13-65
Mean	<0.5	127	26	16	26	24
			Sludge Treated Halton Soils (58)			
Range	0.2-4.3	57-243	13-80	6-31	9-44	7-45
Mean	0.9	110	31	20	20	20
			Uncontaminated Ontario Soils[a] (>200)			
Mean	0.8	55	25	16	15	15

( ) No. of samples analyzed.

[a]OMAF/OMOE, 1981.

TABLE 9. EFFECT OF REPEATED SLUDGE APPLICATIONS ON HEAVY METAL CONCENTRATIONS (µg/g dry wt) IN HALTON COUNTY SOILS

Sludge Applications[a]	Cd	Zn	Cu	Ni	Pb	Cr
0 (2)	0.28	80	15	18	15	18
0.3 (3)	0.46	98	22	16	12	16
1 (6)	0.6 <u>4.27</u>	86 <u>220</u>	28 <u>80</u>	15 <u>31</u>	16 <u>44</u>	18 <u>45</u>
2 (2)	1.2	124	42	25	17	16
≈ 5 (3)	1.5	140	43	27	25	18
≈10 (2)	3.3	204	62	32	38	19

[a]Number of sludge applications each supplying 135 kg/ha ammonium plus nitrate-nitrogen as recommended in OMAF/OMOE (1981).

( ) No. of samples analyzed.

Underline: Data for 1 sample not included in (6).

high Zn and Pb concentrations were associated largely with the shaded areas, most of which are Dumfries series soil (Figure 2).

TABLE 10. HEAVY METAL CONCENTRATIONS (µg/g dry wt) IN UNTREATED HALTON COUNTY SOILS

	Cd	Zn	Cu	Ni	Pb	Cr
			256 Untreated Soils			
Range	<0.2-1.6	50-821	10-53	4-48	9-295	13-65
Mean	<0.5	127	26	16	26	24
			209 Untreated Soils with Zn <150 µg/g			
Mean	<0.5	84	26	17	15	25
			47 Untreated Soils with Zn ≥150 µg/g			
Mean	<0.5	321	23	15	76	22

DISCUSSION AND CONCLUSIONS

Land application of sewage sludge increases heavy metal concentrations in soils, however, it is not the only factor exhibiting this effect. Industrial activity such as smelting can result in aerial deposition of heavy metals and increased concentrations in nearby soils, and agricultural practices have greatly enhanced Cu, As, Pb and Hg concentrations in some Ontario soils as a result of pesticide and fertilizer use in crop production. Heavy metal concentrations in soils generally increase with increasing clay and organic matter contents and large natural variations in concentration, such as were reported for Halton County in Ontario, frequently approximate or even exceed increases due to contamination. Considering these large natural variations, it is concluded that **monitoring of soil survey samples** is unlikely to identify soils which have undergone degradation due to increased heavy metal concentrations. Information concerning agricultural practices and industrial activity is required to differentiate between soils with naturally large heavy metal concentrations and soils with enhanced concentrations due to sludge application or other human activity.

The above-stated conclusion must not be confused with the need for comprehensive soil sampling and analysis to control heavy metal additions to agricultural soil at sludge application sites.

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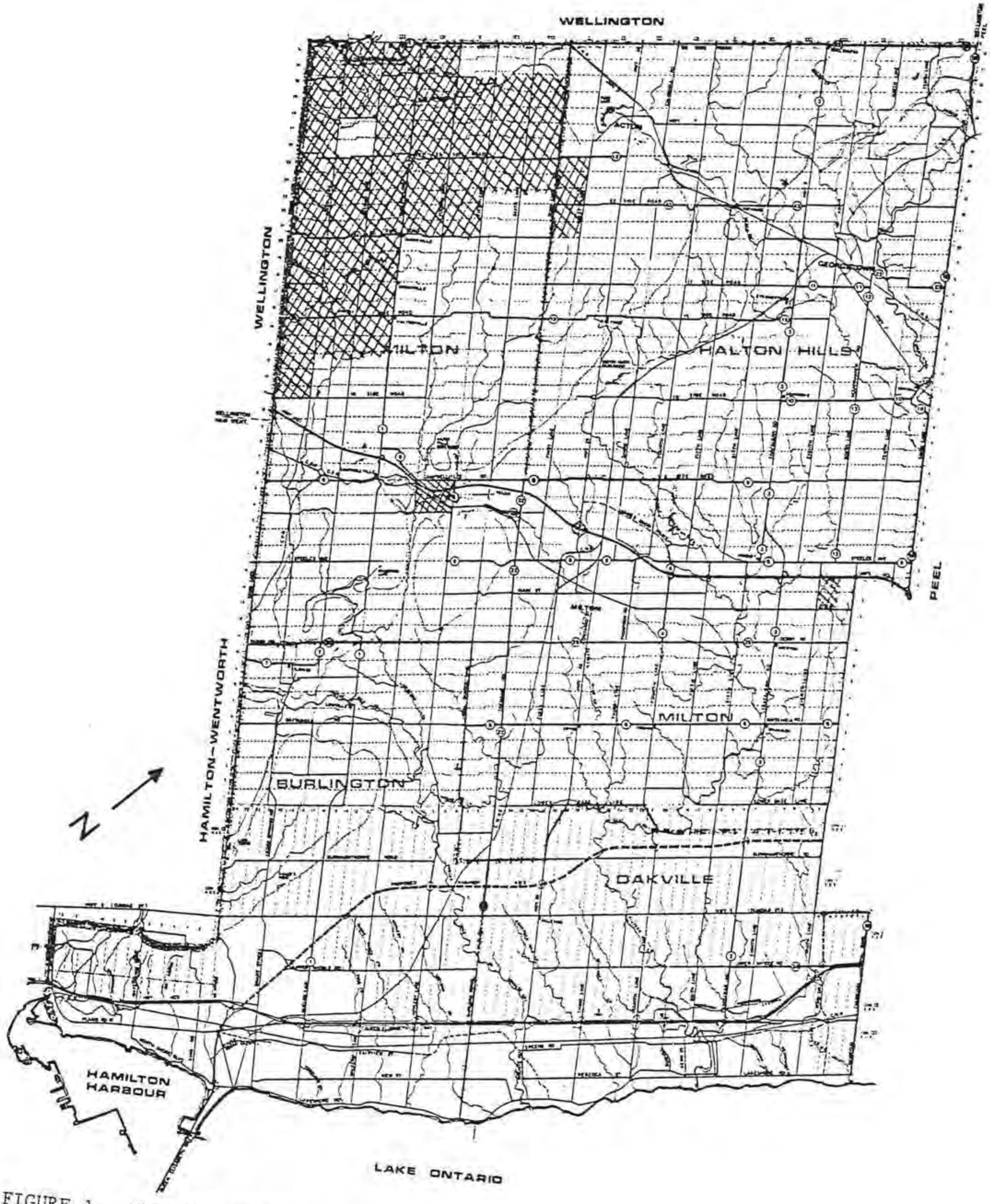

FIGURE 1. GRID MAP OF HALTON COUNTY, ONTARIO. Soil samples with Zn ≥ 150 µg/g dry wt were obtained from cross-hatched areas.

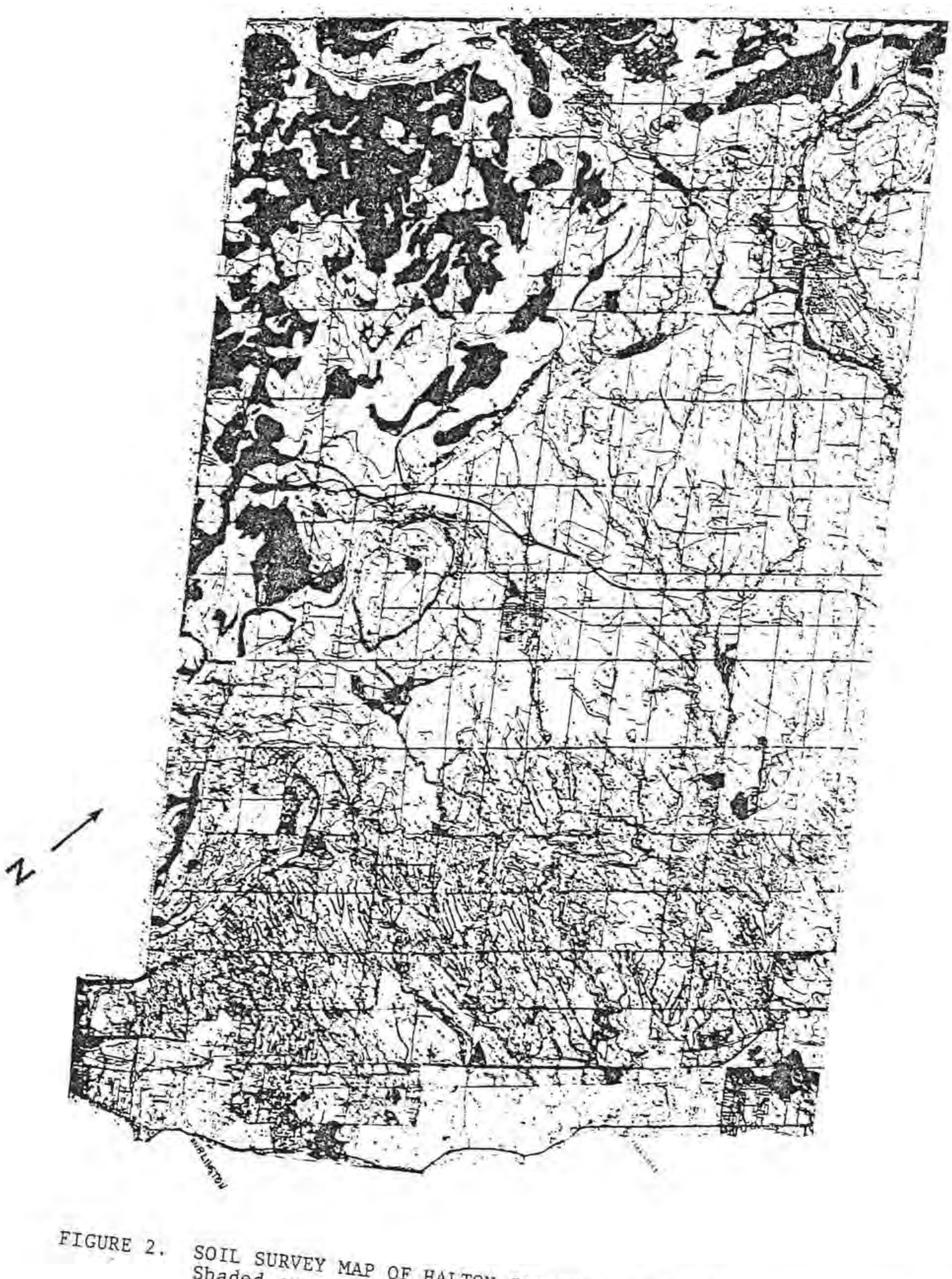

FIGURE 2. SOIL SURVEY MAP OF HALTON COUNTY, ONTARIO (Gillespie et al, 1971). Shaded areas are mainly Dumfries series soil.

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REVIEW OF PROVINCES

Apart from New Brunswick and Ontario (already discussed), it appears that only in Manitoba and Alberta were any other related studies being done (Zwarich at Winnipeg and Graveland at Lethbridge).

Discussion

Cadmium is probably the most critical heavy metal for human health, while elements such as zinc may be of greater concern for plants. For waste disposal purposes, soils in Ontario and elesewhere are supposed to be analysed to determine maximum application rates. However this is not always done. With high "natural" levels such as those found in N.B. and those identified in Webber's presentation, it may be a duty of the soil survey to identify such areas as "high hazzard" for municipal waste disposal. Who else would do it? This type of information would also be valuable for broad scale epidemiological studies. Soils could be rated based on multi-element analysis, done on a sufficient number of samples to provide a background distribution which could also be mapped. This approach may be unacceptably expensive and impractical. Atmospheric monitoring should be carried out to establish contamination from fallout sources.

SESSION 3 ACIDIFICATION

Co-Chairman - H. Rees (Eastern Canada); H. Rostad (Western Canada)

REPORT ON ACIDITY IN EASTERN CANADA (prepared and presented by H. Rees)

Introduction

Acidification is the process by which bases (Ca, Mg, K, Na, NH_4) are removed from the soil exchange complex and are replaced by hydrogen ions (H^+), lowering the pH in the soil. Acidification is inevitable in most soils--it is a natural soil forming process. Carbonic acid is produced by plant roots; organic acids producted from decomposition of organic matter, etc. However, man's activities have significantly accelerated this phenomenon to the point that it is a form of soil degradation. The adverse effect of accelerated soil acidification results chiefly from the influence of changed pH on other processes, e.g., soil biochemical reactions and N availability, organic matter turnover, mobilization of trace elements, and transformation of clay minerals. In most cases, crop growth is impaired.

In eastern Canada, accelerated acidification is attributable to three processes: (a) acid precipitation, (b) nitrogen fertilization and (c) drainage of coastal floodplain and estuary soils. This paper concentrates on soil acidification resulting from acidic deposition -- part of the overall problem of long range transport of air pollutants.

Acid rain is the term used to describe precipitation made more acidic by atmospheric pollution. It is primarily the result of emissions of oxides of sulphur, and to a lesser degree, nitrogen, released into the atmosphere from anthropogenic sources, such as power plants, smelters and other industries where combustion of fossil fuels takes place. While a large part of emitted sulphur dioxide is deposited in the dry form near the source, a significant amount is widely distributed in the atmosphere. This SO_2 is transformed, through a series of reactions, into sulphuric acid ($H_2SO_4^-$), thus creating the formation of the secondary pollutant, acidic deposition. In Atlantic Canada, dry fallout is estimated to be 40% of the wet form based on sulphur deposition data.

Levels and Areal Extent

Sources of acid-forming pollutants are concentrated in the eastern Midwest States and central Canada (Quebec and Ontario). Acid rain is not a local problem, however, since deposition areas may be in excess of 1,000 km away. Prevailing winds, being in a predominantly northeasterly flow pattern, result in long range transport of air pollutants and subsequent acidic deposition to the far eastern portions of Canada. Deposition rates tend to decrease with distance from the source--areas of heaviest deposition roughly coinciding with largest emission centers. Southern Ontario and southwestern Quebec are subjected to heavy deposition, northern Ontario, Quebec and southern New Brunswick and Nova Scotia to moderately heavy rates; and far northern Ontario and Quebec, southern Labrador and Newfoundland to low rates. Normal unpolluted water, in equilibrium with atmospheric concentrations of carbon dioxide, has a pH of approxitmately 5.6. Recent reports on acid precipitation monitoring show that in the Atlantic region the average pH of precipitation is between 4.0 and 5.0. Seasonal quantity and quality of precipitation do vary considerably. Temporal changes and spacial variation of precipitation across Canada is presently being monitored.

Impact Assessment

Acid precipitation in the form of rain, snow and dry fallout is now widely recognized in North America. In August, 1980, the governments of Canada and the United States signed a Memorandum of Intent concerning transboundary air pollution. This action was taken in response to concern for actual and potential damage resulting from the long-range transport of air pollutants between the countries and in recognition of the already serious problem of acidic deposition.

In an attempt to develop a scientific understanding of long-range transport of air pollutants and resulting environmental effects, several working documents were commissioned, one of which was in Impact Assessment. In February, 1983, the Final Report of the Impact Assessment Work Group was made public.

In summary, acidic deposition is documented and/or hypothesized to have detrimental effects on the soil in relation to:

1. Soil pH and acidity.
2. Anion mobility, base leaching and cation availability.
3. Soil biota and decomposition/mineralization activities.
4. Phosphorus availability.
5. Trace element and heavy metal mobilization and toxicity.

Acidification Due to Acidic Deposition

Various field and laboratory experiments of a simulation nature have been set up to examine the effects of acidic deposition on soil acidity. Results indicate that artificial acidic deposition of pH 4 can lead to measurable decreases in soil pH. However, in spite of the many experimental studies, it is difficult to determine, under natural field conditions, the comparative contributions of anthropogenic versus soil-derived acids to soil acidification. The number of field situations where investigators have been able to compare present with former soil pH values are extremely limited.

Soils and Their Abilities to Reduce the Effects of Acidic Pollutants

Based on depth, texture and the geologic origin of the parent material, the soils and bedrock within the affected areas in Canada have been rated by the Impact Assessment Work Group with respect to their abilities to counteract the effects of acidic deposition. Three maps, entitled "The Potential of Soils and Bedrock to Reduce the Acidity of Incoming Acidic Deposition for Eastern Canada" have been produced at a scale of 1:1,000,000.

Other Sensitivity Assessments

Because little is known (quantified) about the acidic deposition dose-response relationships, the underlying criteria for any sensitivity assessment are often imprecise. Therefore, relative sensitivity can only be approximately represented or mapped. Assessment of actual degradation levels is beyond our capabilities. Too little base line data exist to corroborate differences in present with past levels of soil acidity.

Several sets of sensitivity criteria have been proposed and used to define geographical regions most susceptible to acidic deposition effects for traget processes. Those directed towards terrestrial (soil) effects have emphasized cation exchange capacity and base saturation. Wang and Coote (Sensitivity classification of agricultural land to long-term acid precipitation in Eastern Canada, Research Branch, Agriculture Canada, 1981) have proposed a method of classifying soil sensitivity to long-term acid precipitation for agricultural land. Basically, it is a modification of a classification system proposed by McFee for the eastern U.S.

The Wang and Coote approach to agricultural soil sensitivity to long-term acid precipitation is classified according to the level of exchangeable bases in the plow layer. They suggest that a soil with less than 6 meq/100 g of exchangeable bases is sensitive, one with 6-15 meq/100 g is moderately sensitive, and one with more than 15 meq/100 g is nonsensitive. Using this criterion, they produced a map of eastern Canada (scale 1:5,000,000) indicating Sensitivity of Agricultural Land to Long-term Acid Precipitation. A field guide for determining soil sensitivity classes of acid precipitation was also proposed based on soil clay content and soil pH (in water).

ECSS Soil Degradation Working Group

Objective (i): To prepare "overview" maps indicating the risk of soil deterioration.

Two such "overview" maps exist for eastern Canada indicating risk (sensitivity or potential to reduce harmful effects of) of soil deterioration due to acidic deposition: (A) by the Impact Assessment Work Group of the Coordinating Committee of the United States-Canada Memorandum of Intent on Transboundary Air Pollution and (B) by Wang and Coote, LRRI, Agriculture Canada.

Objective (ii): To include assessments and interpretations of current and potential soil degradation (resulting from acidic deposition) in new soil survey reports.

Current levels of acidification due to acidic deposition cannot be determined accurately. The number of field situations where investigators can compare present with former pH values are extremely limited.

Several classifications exist for defining the susceptibility of soil to acidic deposition. The Wang and Coote method could easily be incorporated into soil survey programs. The applicability of this approach to forest ecosystems should be tested. Basic assumptions will have to be altered.

Research Needs (based on Impact Assessment recommendations)

1. Based on actual field observations, quantify natural H^+ ion production and consumption rates for the principal terrestrial ecosystem types, and the clear distinction of anthropogenic and natural H^+ ion production. Obtain more information on natural internal acid production and leaching for a variety of forest ecosystems.
2. Improve information, based on actual field observations on a representative range of soil types, on impact of acidic deposition in relation to acidification. Benchmark sites should be established to monitor changes. (The creation of a mechanism to monitor the state of the environment is one of the recommendations reiterated in a speech by Charles Caccia, Minister of Environment Canada in September, 1983). Improved information is required on the impact of acidic deposition on soil biota, soil mineralogy and soil organic matter.
3. Improve understanding of relationships between forest productivity and acid sensitive properties of soils.
4. Improve system of mapping terrestrial sensitivity, hopefully incorporating existent data bases, to allow further identification of key sensitive areas.

ASSESSMENT OF SOIL ACIDIFICATION SENSITIVITY MAPPING IN WESTERN CANADA

(Prepared and presented by H. Rostad)

The criteria necessary for mapping soil sensitivity to acidification have been outlined recently by several authors: Coote et al. (1981), Wang and Coote (1981), and Hollowaychuk and Lindsay (1982). All three publications stress the importance of cation exchange capacity or exchangeable bases as factors in a classification scheme. However, the methods used to calculate CEC on the prairies vary. In Saskatchewan the CEC is measured at pH 8 while in Alberta it is often measured at pH 7. Neither method is suitable for moderately acid soils. It is probable that the respective surveys in the prairies do not have adequate data to map soils according to effective CEC or total exchangeable bases. The best approach would be to estimate effective CEC or exchangeable bases from known parameters such as organic carbon, clay content, and pH. Most soil surveys in the past have used map units that allow reasonable estimates of organic carbon and clay contents; however, the data on surface pH is lacking, especially in Saskatchewan and Alberta where variable carbonate contents and presence of solonetzic soils have a strong bearing on surface pH.

The map base for "overview" maps of acidification should be at a scale of 1:1 million and should be derived from the "Shields" landscape map. In order to prepare derivative maps regarding acidification, the extended legend for each province must include organic carbon and clay content as well as surface pH for each polygon.

The four Western Provinces will be preparing acidification maps during 1984. The respective soil surveys in each province will probably have some input. The Saskatchewan Institute of Pedology will be preparing the map for Saskatchewan using the 1:1 million landscape map as the data base.

A Task Group has been established by the Western Canada Long Range Transport of Atmospheric Pollutants (LRTAP) Technical Committee to coordinate "soils and geology sensitivity mapping in Western Canada". This task group has representatives from each of the four provinces, and includes G. Padbury of the Saskatchewan Institute of Pedology. The mapping approach which has evolved is very similar to that described above for Eastern Canada. Final maps will be published at a scale of 1:2 m, and will be consistent from province to province. As with eastern Canada, these maps will show acidification risk and will not indicate past acidification. The Saskatchewan maps will be completed in the spring, 1984.

Soil Survey Data Needs

- Each provincial survey will need to add surface pH to the extended legend of the "Shields" landscape map.
- More data are needed regarding effective CEC and total exchangeable bases for representative soils.

Research Needs

- More research is needed regarding the importance of different soil properties for buffering capacity.
- The effect on crop quality of a gradual but continuous increase in soil acidity. Should we be concerned about reducing the pH of 10 million ha of soil from 6.2 to 5.7 over a period of 20 years? While this will not decrease yields, will it increase significantly the cadmium uptake of prairie soils or perhaps increase the acreage of selinium deficient soils?
- More documentation of soil acidification by ammonium and sulfur fertilizer.

Research needs - discussion

The following research was considered important in Eastern Canada:

1. Separate anthropogenic (i.e. acid rain, fertilizers) from actual process of acidification and weathering, and measure rates of change using "benchmark" sites.
2. Determine impact of acidification on soil microorganisms and microbiological activity.
3. Improve knowledge of relationships between past forest productivity and soil acidification.

For Western Canada, the following needs were re-emphasized:

1. Improve mapping of present pH levels in surface soils.
2. Predict the future lime needs of the region by obtaining and applying data in a similar way to that initiated by P.Hoyt.
3. Determine the possible detrimental effects of slight pH reductions (e.g. on Cd availability).

SESSION 4 SOIL EROSION

Co-Chairmen - G. Wall (water erosion) and G. Padbury (wind erosion).

USING ^{137}Cs TO ESTIMATE SOIL EROSION AND DEPOSITION

(prepared by E. de Jong and R.G. Kachanoski, University of Saskatchewan, and presented by E. DeJong at the invitation of the Work Group.)

Although the importance of wind- and water-erosion is generally recognized, measurements of rates of erosion are rare. This is largely due to the fact that direct measurements are costly and must be carried out over long time periods to yield representative figures. Tracers are an attractive alternative for the direct measurement of soil erosion. Tracers have been used in the form of radio-isotopes applied to small plots, but it is also possible to use environmental "contaminants" that were evenly applied to the soil surface to estimate soil movement. An example of the latter is the use of ^{137}Cs (McHenry and Ritchie, 1977; Brown et al., 1981; McCallan et al., 1980) derived from radioactive fallout from the atmospheric testing of nuclear devices in the 1950's and 1960's or the use of Cu from fungicides (Schwertmann and Schmidt, 1978).

The use of ^{137}Cs as a tracer for soil movement assumes that this isotope was initially distributed uniformly over the soil surface and that the initial ^{137}Cs value can be estimated. Since ^{137}Cs is strongly sorbed to soil particles, its current distribution in the landscape must reflect soil movement since its deposition. It is worthwhile noting that the mode of soil movement (wind, water, or tillage erosion) is not specified and the measurement is relevant for modern agricultural practices.

The methodology of sampling and counting ^{137}Cs in soils was described previously (de Jong et al., 1982). At each sampling site several cores are taken, sliced into layers, composited, air dried, ground to less than 2 mm, and counted. The results are expressed in pC/cm^2 (i.e. the ^{137}Cs is expressed per unit area of soil surface) and compared with the ^{137}Cs in non-eroded native grassland sites. In the initial method of estimating soil loss, it was assumed that non-eroded cultivated soils contained 95% of the ^{137}Cs of non-eroded native grassland control sites since the former could have lost 5% of their ^{137}Cs with blowing snow and crop removal.

For eroding sites:

$$\text{soil loss} = \frac{0.95\ ^{137}Cs_{\text{control}} - {}^{137}Cs_{\text{site}}}{0.95\ ^{137}Cs_{\text{control}}} \times (\text{mass of Ap})$$

where mass of Ap is expressed in g/cm^2. This equation cannot be used to estimated soil deposition, as there is no way to estimate the amount of ^{137}Cs moved to depressional areas by snow. Instead, the distribution of ^{137}Cs with depth is utilized to estimate soil deposition:

$$\text{soil gain} = \frac{\text{total } ^{137}Cs}{\text{concentration } ^{137}Cs \text{ in Ap}} - 10 \cdot (\text{bulk density of Ap})$$

where the constant 10 is the depth of cultivation (in cm).

The results from eight small, enclosed basins (less than 0.5 ha) showed that in the three uncultivated basins the ^{137}Cs varied little with landscape position. On the other hand, in the five cultivated basins ^{137}Cs decreased from the top to the bottom of the slopes, indicating soil losses at the upper slopes and gains on the lower slopes and depressions. Soil losses over the last two decades on the upper slopes were equivalent to 20-60 kg soil/m^2 with similar gains in the deposition areas. The inability to accurately delineate areas of erosion and deposition was one reason why attempts to draw up soil balances for each basin were only partially successful. When the composition of the soil is known, it is possible to relate soil movement to C and N movement. The method was also tested on samples collected in New Brunswick and these data illustrate clearly that on the same slope erosion can be both detachment and transport limited.

As with most experimental procedures, the ^{137}Cs method has some weaknesses. Some of these will be discussed below and possible ways to eliminate them will be indicated:

1. <u>How uniform was the initial ^{137}Cs deposition and was it all absorbed by the soil?</u> Our data for Saskatchewan show that the amount of ^{137}Cs in non-eroded soils varies from one area to another, thus in all cases a nearby non-eroded control should be sampled. The question of efficiency of absorption cannot be answered directly, however estimating erosion from changes in ^{137}Cs concentration with time (see below) suggests that this is not a serious problem.

2. Is the ^{137}Cs preferentially removed? Tests with a rainfall simulator and a wind tunnel do suggest some preferential removal of ^{137}Cs with the colloidal fraction of the topsoil. The severity of the problem depends on how long the erosion event continued and to what extent the erodable material was ulitmately removed.
3. As erosion goes on the Ap horizon of an eorded soil will not necessarily become thinner, but will definitely be impoverished as lost topsoil is replaced by infertile subsoil mixed in by tillage. That is, in consecutive erosion events the same amount of soil loss will be associated with less ^{137}Cs loss.

To overcome some of these problems, we have recently estimated erosion from a number of sites by comparing ^{137}Cs concentration in benchmark soil samples collected in the mid 1960's with the ^{137}Cs that is now present at the same sites. Treating erosion and deposition as a continuous process:

$$\frac{dA_t}{d_t} = (-k_R \cdot E_R \cdot A_t) - (k_D \cdot A_t)$$

where A_t = ^{137}Cs on the site, pC/cm^2
k_R = enrichment coefficient for ^{137}Cs in eroded material
E_R = fraction of topsoil eroded per year
$= \frac{\text{erosion rate (kg/ha/yr)}}{\text{mass of topsoil (kg/ha)}}$
k_D = coefficient reflecting the net effect of radioactive decay and continued deposition of ^{137}Cs = 0.0054 yr^{-1} for 1966 to 1981.

The soil losses thus calculated were equal to or larger than those calculated by the initial simple method. The model can be refined by dividing the year into periods of different erosivity and ^{137}Cs deposition (Kachanoski and de Jong, submitted). Parameter evaluation showed that the accuracy of the estimated erosion rates increases as the time interval between samplings increases and decreases as erosion rates decrease. For Saskatchewan this use of ^{137}Cs as a tracer is probably limited to sites with erosion rates between 0.5 and 10 kg/m^2/yr, and the optimal sampling interval is around 15 years.

A future area of study (if funding is available) is the relationship between land form and the processes of erosion and deposition. Water quality records and observations on small basins (Hall and Langham, 1970) indicate that snowmelt is the major runoff generating event in small prairie basins. Such basins have sufficient surface storage to hold most summer runoff and even though water erosion certainly occurs, the eroded soil rarely leaves the basin and is deposited in lower slope positions. The approach by Speight (1968) for landform classification (with emphasis on the effect of surface form on overland flow) can perhaps be used to delineate landscape areas that are meaningful in terms of erosion and deposition. If successful, this approach would help in calculating soil balances and in extending our understanding of erosion susceptibility of other soils. Although Speight's approach is primarily applicable to the movement of water, land form should also govern the movement of soil by wind.

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PROVINCIAL REPORTS

ONTARIO (G. Wall)

At the provincial level, there is now in the final stages of completion a 1:1 m map of soil erosion potential based on broad scale application of the Universal Soil Loss Equation (USLE) together with recent statistics on cropping practices. There has also recently been published a report on "Cropland Soil Erosion, Estimated Cost to Agriculture in Ontario" by G. Wall and G. Driver, Ontario Institute of Pedology, University of Guelph.

County level:

Most current soil surveys collect sufficient soil and slope information to permit calculation of soil erosion potential classes for the survey area. The soil loss potential ratings for a variety of crops represent a valuable addition to many soil survey reports (Expert Committee on Soil Survey, 1980, 1981).

Of recent interest in Ontario is the extent of severely eroded soils (i.e. topsoil removed, calcareous subsoil exposed to the surface) in the Province. Current research is indicating corn yield reductions averaging 30% on eroded soils as compared to adjacent uneroded soils.

The question that we are now asking is: "Can we accurately delinate these severely eroded landscapes from photo bases used in soil surveys and present this information in soil report format"? This information, combined with yield reduction data, permits simple yield loss calculations ($) that are of considerable interest to farmers and policy makers.

Proposed field information - can severely eroded cropland be accurrately delineated on air photo bases and included on soil map? Correlate color tone on air photos with soil loss levels.

Also at a similar level of detail are recent attempts by the Lands Directorate to map erosion priority areas of the Grand and Thames River Basins using the USLE. An erosion risk map is also being prepared by the Ontario Institute of Pedology for the Haldimand-Norfolk soil survey report. The Univeristy of Guelph is experimenting with the use of the GAMES model (Guelph model for evaluating the effects of Agricultural Management systems on erosion and Sedimentation) to predict priority areas for erosion control.

Field level:

A study is being conducted by the University of Guelph on the effect of past erosion on yields. Yield reductions of 10-60% have been observed on eroded slopes. A rainfall simulator is also being used to measure variability (seasonal and spacial) of soil erodibility values. The provincial agriculture, environment and natural resource ministries are carrying out a study of a localized erosion problem near Rondeau Harbour.

BRITISH COLUMBIA (L. van Vliet)

There are now 18 runoff-erosion plots in the Peace River Region (including 6 plots at Beaverlodge, Alberta). They have been used for 1 to 4 years to collect runoff and soil from fallow, small grains (including canola) and fescue plots. Results to date have been published in proceedings of B.C. Soil Degradation Workshop (Jan, 1983) and Western Canada Soil Erosion and Degradation Conference (Dec. 1983). Maps of soil erodibility (K) values have been prepared for this region at 1:1 m and work has started on more detailed maps of erosion potential.

In the Lower Fraser Valley, the Ministry of Agriculture and Food has initiated a study of erosion on small fruit (strawberries, raspberries) farms on the upland soils which are very susceptible to erosion.

Needs: Peace River Region - need continuity of funding of research program
- need to incorporate conservation practices into study.

ALBERTA (W. Pettapiece)

Soil K factor estimates are now being included in soil descriptions, and a comparison has been made between predicted and observed water erosion in Warner County (see proceedings 1983 Alberta Soil Science Workshop). Chanasyk is studying erosion and runoff plots in the Peace River Region similar to those of van Vliet at Beaverlodge. Some work is being done on erosion at the Coal Mine Reclamation Centre; the Alberta Research Council is studying sediment yields in streams in the foothills regions.

Needs: Extension to promote awareness of the problem, especially in Black soil zone.

SASKATCHEWAN (H. Rostad)

Some of the most significant erosion work in Saskatchewan is that at the University of Saskatchewan already described above by de Jong and Kachanoski. Cooperative work on 2 instrumented basins near Saskatoon has also commenced, with the objective of characterizing soil loss in terms of soils, landcape features and cropping history. Other work has been carried out by the Institute of Pedology and includes estimating erobility (K) and length and slope factors (LS) for a number of soil map polygons, with emphasis on hummocky landscapes. Data have been collected in soil survey work on the location and extent of erosion features, and these are awaiting funding for analysis.

Needs: Values to show extent of problem and promote awareness; also studies of some of the policy factors that help create the problem.

MANITOBA (R. Eilers)

Soil erosion has become a high priority for the provincial agriculture department which has an active extension program and has initiated some surveys of the extent of the problem. Specialty crops such as peas, beets, potatoes etc. on loamy soils are a particular concern. At the University of Manitoba, Shakewich has been carrying out research on yields with various depths of soil removed to simulate erosion. The Soil Survey is now adding K and LS factors to soil reports.

Needs: Erodibility mapping in the escarpment region.

QUEBEC (C. Bernard)

A study has been initiated at the Lennoxville Research Station to look at soil erosion in relation to cropping practices (such as continuous silage corn). A joint study of soil erosion potential in the Yamaska Basin has been undertaken by the Soil Survey, Ministry of the Environment and Agricultural Engineering Department at Laval University, and is to be published shortly. Corrections for snowmelt are being attempted. Environment Quebec is using the ANSWERS model (USDA) to analyse erosion problems south of Quebec city.

Needs: Need to alert politicians that problem exists.

NEW BRUNSWICK (J. MacMillan).

Chow has erosion study plots at the Fredericton Research Station and at sites in the potato belt in cooperation with Daigle of the provincial agriculture department. The effect of snowmelt on erosion, and the effects of erosion on yield are being studied. Erodibility (K) factors have been estimated for the principal soils of the potato belt. Some on-farm work is being undertaken to evaluate management practices.

Needs: to map past erosion.

NEWFOUNDLAND

Very little being done as problem is minor. However, there is a need for greater awareness of those erosion problems that do exist.

SOIL EROSION MAPPING

Small scale maps Water and wind erosion maps are now being prepared at a scale of 1:1 m.

Water erosion (G. Wall): Use U.S.L.E. with i) slopelength from landform; ii) slope, iii) erodibility from texture; iv) crop cover factor from weighted 1981 census land use; v) rainfall factor from published maps. Result is erosion classes. For example, in Southern Ontario, 27% of land falls in 0-1 class, 27% in 1-2 class; 25% in 2-4 class; 13% in 4-8 class; and 7% in 8 class. The map is useful to compute estimates of amounts of erosion, identify locations, and select remedial practices.

Wind erosion (D.R. Coote): For the Prairie Provinces preliminary maps have been prepared using average April-May maximum 1 hr wind speed; erodibility was computed from surface texture and soil moisture estimated for April and May using the Versatile Soil Moisture Budget. The method of computation was developed from early work by Chepil in Kansas and at Swift Current. Soils were divided into 4 classes for moisture estimates. The maps only indicate "risk" and do not yet include cropping factors, but these could be added from 1981 Census of Agriculture. Estimates of crop cover and residues would permit hazardous conditions to be identified.

Discussion

Need to look into the probability of extreme events: eg. for water erosion, rainfall on saturated, freshly thawed surface soil with frost layer beneath surface; for wind erosion, high winds on freeze-dried soils with no snow cover. In Saskatchewan about 85% of runoff and erosion appears to occur in spring. The Rs (snowmelt correction factor for use with USLE) as currently applied is not accurate for Prairie conditions, and maybe not any Canadian conditions except southwestern Ontario.

Risk mapping at 1:1 m would be useful in Quebec and Maritimes, but probably not in the erosion problem area of northwestern New Brunwick.

Risk mapping of this sort is very inexpensive and provides a valuable tool for increasing awareness among public and policy makers.

For wind erosion risk mapping, provincial specialists need to study maps to see if prediction method is reasonably correct. Special land use surveys may be needed in critical areas. At this time there does not appear to be a need to do wind erosion risk maps for other parts of Canada, except possibly southern Ontario.

Detailed Maps

These maps are valuable for the preparation of recommendations for control of erosion - Climatic data should be in terms of probabilities of erosive events. Concern was expressed about making recommendations with economic impact on farmers, and the responsibility if they are wrong. Monitoring of water eroison can be used to check mapping, but for wind erosion this is impractical or impossible. Mapping of eroded areas is possible using air photos at selected wave lengths. Protz, at the U. of Guelph, is working on spectral signatures of eroded areas. In the field it can be done by comparing horizonation, texture, colour, carbonates and site position. A study in the Waterloo region of Ontario showed significant erosion (>30%) in map polygons indicating no erosion.

Research needs:

- Freeze-thaw effects on soil erodibility (wind and water);
- Effects of management on erodibility (wind and water);
- Seasonal probabilities of erosive weather conditions;
- Effectiveness of erosion control practices;
- Soil conservation measures for long, narrow fields as are common in Quebec (and some parts of Maritimes) where cross-slope conservation practices are impractical;
- Cost effectiveness of remedial practices.

Discussion

Large plots may be needed on long slopes such as those of Peace River Region. Rainfall simulators can be used to reduce time in obtaining data (eg. for frozen and thawing soils). N.B. Plot studies have added benefit of providing demonstration sites.

SESSION 5 ORGANIC MATTER

Chairman - G. Patterson

SOIL ORGANIC MATTER LOSS - W. McGill, University of Alberta
(prepared from notes taken by C. Acton and D.R. Coote)

Issues:

1. How much have O.M. Levels changed? This a sampling and analysis problem.
2. Where have changes occurred? Are they due to decomposition? There have been few measurements of loss of organic matter by erosion or of spacial relations - i.e. are changes due to loss or relocation.
3. When did loss occur? Is it going to continue? If erosion is a major factor, the expected "levelling off" of O.M. loss rates may not occur.
4. What are critical levels?
   - need to be objective - i.e. for what reason is O.M. important to the soil system?
   - Relationship with susceptibility to erosion.
   - relationship with crop nutrition - totals less important than organic matter cycling, i.e. system is dynamic.
   - relationship with water holding properties and soil density.

History:

1940's - Newton, Wyatt and others did original work on this topic in the prairies.

1976 - Nitrogen Symposium used some of the available data
- model to link inputs of O.M. to rates of loss
- whole of western Canada considered on basis of one soil site; tendency to over-extrapolate.

1977 - Mathematics of OM change (McGill)
- % OM loss in different parts of prairies and different provinces
- until 1981, these estimates were best available (i.e. 39-44%)

1982 - Campbell and Souster estimated losses in Saskatchewan based on soil zones (similar to McGill's estimates except in Gray soils).

Currently a new project using 75 paired sites - cultivated vs. uncultivated (very difficult to find truly uncultivated areas). Five cores are being taken at each site. Management information is being provided by farmers (manure data difficult to obtain). Quality of data not high, but very valuable. Measuring total C and organic C in terms of concentration and mass per horizon. Changes in concentration of 45-50% have been confirmed. Change in concentration often greater than change in mass (e.g. Dormaar found 50% loss in % C but increase in mass of C, in a Lethbridge study). Zonal effects can be predicted, but are not significant. The considerable variability, therefore need 25-30% difference in C content before difference significant.

Research Needs:

1. Loss mechanisms - we must know why losses are occurring.
   - C dating of resistant fractions of soil; measurement of dynamics
   - data on losses by erosion.
2. Mapping methodologies
   - measurements are point specific, how can extrapolation be made to landscapes (e.g. by colour?)
3. Continuous record of C, pH etc at some specific sites.

Soil Survey Activities:

- Useful to have single variable maps at various scales.
- How much change has there been on unit areas?
- Other groups (e.g. Environment Canada) interested in effect on global CO_2 balance.

Discussion

Soil test carbon data have limitations - sometimes just a visual estimate. Should these labs be doing proper analyses? On composite samples? Sometimes farmers record area represented; often they are told to avoid areas such as eroded slopes. Bulk density significantly different between cultivated and uncultivated sites - must be careful what is termed "density". What kind of data are critical? Amount of O.M. eroding? C movement equal to soil movement. Kachanoski has estimated 50% of loss of OM is by erosion, and 50% by decomposition. ^{137}Cs method can be valuable tool.

Is there too much nitrogen work and not enough on soil physical parameters? Fertilizer N costs are high; organic matter should be better related to erosion, water, density etc. (allocation of research funds an important issue). "Active" fraction of OM may be most important - poor relationship between total OM and soil structure. Some loss of OM is inevitable, but must it continue? Research at Lethbridge shows that nutrient and OM status can be improved.

Soil test labs could be used for monitoring, but this is not their mandate. Soil survey work now taking more samples for OM in Ontario (new survey areas) and cropping practices are being noted. In New Brunswick OM data needed for erodibility. Some potato farmers don't want increase in OM as disease problems increase. In Nova Scotia there is little concern - OM was low after land cleared. Additions have not beeen observed to have much effect an structure in Prince Edward Island. In Newfoundland an effort is being made to retain OM during land clearing. Some soils used for continuous corn in Quebec and eastern Ontario show high organic matter levels on a mass basis. Concern in Lower Fraser Valley of B.C. that compaction problems are related to loss of OM.

Research Needs: For mapping, data are needed to the bottom of the B horizon. Cannot use much of the older data as ditch banks and fence rows were often sampled. Paired (cultivated and uncultivated) sites are needed and data should include profile descriptions. Sampling and analyses should be standardized, and improvements made in the selection of sites. Need to determine dependent factors, such as resistance to erosion, in soils at equilibrium OM Levels. Sampling and data collection in regular detailed soil surveys should be improved.

For eastern Canada, research is needed on the effects of OM additions, not on changes from "original". Mapping only feasbile on the basis of cropping and management practices. Use of OM incorporation to improve dense sub-soils (e.g. fragipans) needs to be further researched.

SESSION 6 SOIL COMPACTION

CHAIRMAN - L. van VLIET

SOIL COMPACTION IN CANADA (prepared and presented by L. van Vliet)

I PRINCIPLES, PROCESSES, CAUSES AND EFFECTS

Soil compaction is the least understood soil degradation parameter. No experience is available on mapping soil compaction in the field. To better understand what soil compaction entails, I will first spend some time describing compaction, its factors, the compaction process under different soil conditions and major causes of compaction, and then define it.

1. Principles

At first thought, soil compaction (also called structure deterioration) may appear to be a relatively simple concept, an easily described and measured soil property. This is not the case. Actually, it is claimed by many (ASAE, 1971) to be one of the most complex and involved soil features which has significant interrelationships with most of the physical, chemical and biological properties of soils as well as with external factors such as climate, tillage, agronomic practices and crop use. We are concerned with soil compaction because it affects soil conditions that influence all phases of crop growth and production by limiting water movement and root development in soils.

2. Processes

The compaction process could simply be described as: a change in volume for a given mass of soil (ASAE, 1971). This change in volume may be expressed (defined) directly in terms of certain key parameters. These are: 1) Bulk density; 2) Particle density; 3) Porosity; 4) Void ratio. It may be estimated indirectly by soil shear strength, penetration resistance, oxygen diffusion rates, aggregate stability, to name a few.

The compaction process is reversible under different management practices. This has implications for the mapping aspects of compaction (which will be discussed below).

Four possible factors to which the change in soil volume (or compaction) could be attributed (ASAE, 1971) are:

1) a compression of the solid particles
2) a compression of the liquid and gas within the pores
3) a change in the liquid and gas contents of pore spaces
4) a rearrangement of the soil particles (changing position by rolling, slipping or sliding), resulting in a change of pore volume.

The compaction process involves forces that act on the soil mass and result in changes in state of compaction. There are 2 kinds of forces (stresses):

a) Internal or natural forces: eg. freezing, thawing, drying, wetting, swelling. Difficult to identify and measure.
b) External or manmade forces: vehicles, implements. Mechanical forces. Easy to identify and measure.

We can basically distinguish 3 circumstances in which different processes (compaction factors) dominate, causing a change in soil volume depending on soil texture and degree of saturation:

a) In partly saturated, coarse textured soils, compaction is a direct function of the compression of individual particles and of differential particle movement. In general, soils with high porosity are more compressible than those with low porosity.
b) For partly saturated, medium to fine textured soils, the compaction process is a function of the decrease in void ratio which is due to a combination of solution of gas into the liquid phase, movement of both gas and liquid within the soil mass and particle reorientation.
c) For saturated soils, a large change in volume is a function of the rate at which liquid moves within the soil mass. Undoubtedly, for many soils, a combination of these factors occurs. Although compaction was earlier described as simply a change in volume, it is now obvious that the compaction process is a difficult one to describe analytically.

The soil conditions most seriously affected by compaction are those that control the content and transmission of:

- water (pore size distribution altered, water retention)
- air (air filled pores)
- heat (increased thermal conductivity)
- nutrients (increased rate of nutrient movement to roots, decreased amounts of nutrients mineralized from soil O.M. requires more fertilizers);

and those that change:

- soil strength (increases with soil compaction).

3. Causes

A. Vehicular Traffic (both agriculture and forestry): Heavier weight of machinery, excessive weights or speed of machinery, causing compaction of both surface and subsurface soil;

B. Field operations (traffic) on wet soils (inadequate drainage): Includes cultivation, manure spreading, harvesting (including logging) and livestock grazing.

Note: Combination of the above two causes results in most compaction.

C. Mechanical disturbance of soil through tillage (surface compaction): Breaks down soil structure, reduces aggregation. Use of rototiller pulverises soil aggregates.

Same tillage depth, creating "pans". Excessive tillage.

D. Declining O.M. content due to oxidation (natural and accelerated by man through tillage);

- Cropping systems (monoculture vs. rotations with pasture)
- Additions from manure, crop residues
- Affects aggregate stability, structure loss (deterioration).

Note: Recent studies have indicated that type of organic matter may be more important than the quantity.

I do recognize that the order of importance of soil compaction causes may change for different regions in Canada (climate!).

4. Effects

Soil compaction results in high soil density and a reduction in porosity, mainly of macropore space, which in turn will limit water movement (infiltration, percolation) and/or plant root extension. Compacted soil is defined as a state at which water movement and root development is restricted by artificial (man-induced) reduction in soil volume. I must mention that compaction does not always have a negative effect on crop production. There are cases where compaction is enhancing crop yields (coarse textured soil).

It has been well established in long term experiments and measurements (40-50 yrs) that cropping (cultivation) of soils will reduce total pore space by reducing % macro pore space (up to half) and disproportionally increasing % micro pore space (Robertson and Erickson, 1978). Since macro pores mostly affect the infiltrability and permeability of the soil, pore size distribution is more important than total pore space. For example, investigations in Michigan on a Fox sandy loam soil showed that in fence rows the soil contained 15.5% more macro pore space (18.5% more total pore space) and was much less compact (B.D. 1.11 g/cm^3) compared to the same soil in the adjacent cultivated field (B.D. 1.48 g/cm^3).

Several authors have indicated that millions of hectares of good productive agricultural soils in the USA have already been compacted to the point where yields are reduced and tillage costs are increased. Many long term experiments have indicated B.D. increases of 15-20%, and significant pore space and waterholding capacity decreases after many years of cultivation (Robertson and Erickson, 1978).

In forestry, similar trends have been reported. For example, an average reduction of volume yield of about 15% after tractor logging in Australia (Greacen and Sands, 1980) was predicted and soil bulk density increases of 20% or more are not uncommon after logging by skidders (Dickerson, 1976; Chatterton, 1983).

In Canada, soil compaction appears to be increasing with the use of monoculture, especially with corn and horticultural crops (incl. potatoes) (Coote, 1983). Coote concludes: "if these crops continue to be shifted into wetter areas, the problem of compaction is almost certain to increase".

In addition, heavier weight of machinery that do the job faster will cause more compaction over time, especially while operating on wet soils. This applies to both agriculture and forestry.

II METHODS OF MEASURING SOIL COMPACTION

1. Bulk density

The most widely used and universally applied method of measuring (expressing) soil compaction is by determining the Bulk Density (BD) of the soil. The question now is: what critical (or threshhold) values for B.D. will restrict or prevent root penetration and development, hence crop production? In other words, at what B.D. value do we consider the soil to be compacted? My review of the literature yielded the following table in which this question is being addressed. This table is a very incomplete list of critical B.D. values. However, it clearly indicates how specific these values are for each crop.

CRITICAL B.D. VALUES FOR SOME CROPS (g/cm^3)

CROP	LOCATION	ROOT PENETRATION RESTRICTED	ROOT PENETRATION PREVENTED
Cotton	Mexico	1.8 at 20 cm	
Corn	Iowa	1.3	
Sunflowers	California		1.75 (sandy soil) 1.46-1.63 clay soil
Douglas fir	B.C.	1.2	1.5
Agric. Crops	Canada	1.6 (Ap horizon)	
Agric. Crops	Michigan	1.46-1.66 (subsoil)	
Agric. Crops	Sweden	1.3-1.8 (depending on soil type)	

2. Penetration resistance

Another frequently used method of expressing soil compaction is by means of a penetrometer that measures penetration resistence. Resistance of a soil to penetration (force on soil) of a probing instrument is an integrated index of soil compaction, soil moisture content, texture and type of clay mineral. In other words, it is an index of soil strength under the conditions of measurement. It is a determination that involves both soil consistence and soil structure.

The main advantage of a penetrometer is that frequent measurements (readings) can be made in a very short time to characterize the compaction problem for an area (e.g. map polygon). The main disadvantage is the effect of soil moisture content on the readings. Penetrometers have not been used extensively in Canada. In the Netherlands, a self recording penetrometer (penetrograph) has been successfully used to detect and map soil compaction (e.g. plow pans) during soil survey (Van Soesbergen and Vos, 1972).

III. PROVINCIAL EXPERIENCE

In this section, compaction problems that have been encountered in different regions of B.C. (both in agriculture and forestry) were presented, and compaction research by Prof. Jan de Vries and graduate students, Univ. of British Columbia, was reported. For details, the reader is referred to a paper "Degradation Effects of Soil Compaction" (De Vries, 1983).

IV COMPACTION ASSESSMENT DURING SOIL SURVEY

In this section, ways and means by which soil compaction can be evaluated during routine soil surveys are described and proposed.

The purpose of compaction assessment during soil survey is to map the state of compaction for 2 reasons: 1) so that distribution and extent of presently compacted areas can be identified; and 2) geographical comparisons of the degree of compaction can be made. In addition to producing a compaction inventory, soil management techniques that will reduce or remedy soil compaction can then be applied to these identified areas.

In order to accomplish this purpose, we need polygon specific information on soil compaction. Polygon specific evaluation of compaction is only meaningful when at least one inspection per polygon takes place. Because of this condition, compaction mapping should be restricted to soil surveys at Survey Intensity Level (SiL) 1 and (SiL) 2 (up to 1:40,000). The best way of expressing information that will affect the management of a polygon is by means of the soil phase. I therefore propose the compacted phase symbol cp (lower case).

In order to determine when to use the compaction phase symbol on a polygon, we first need to establish the criteria we use, what are the class limits and at what combination of those classes do we use compacted phase on the polygon. I have attempted this in the following 2 tables. The purpose of this matrix table is to ascertain between surveys (and between mappers) as to when to use the compacted phase symbol (cp) on the polygon or map units.

USE OF COMPACTED PHASE (cp) ON POLYGON

A. DEGREE OF RESTRICTION FOR ANNUAL CROPS

	Slight			Moderate			Severe		
Depth(cm)	0-25	25-50	50	0-25	25-50	50	0-25	25-50	50
>80	YES	NO	NO	YES	YES	NO	YES	YES	NO
% 60-80	NO	NO	NO	YES	NO	NO	YES	YES	NO
of 40-60	NO	NO	NO	NO	NO	NO	YES	NO	NO
Polygon <40	NP	NO	NO	NO	NO	NO	NO	NO	NO

B. DEGREE OF RESTRICTION FOR PERENNIAL CROPS (TREES)

	Slight			Moderate			Severe		
Depth(cm)	0-50	50-100	50	0-50	50-100	50	0-50	50-100	50
>80	YES	NO	NO	YES	YES	NO	YES	YES	NO
% 60-80	NO	NO	NO	YES	NO	NO	YES	YES	NO
of 40-60	NO	NO	NO	NO	NO	NO	YES	NO	NO
Polygon <40	NO	NO	NO	NO	NO	NO	NO	NO	NO

The degree of restriction (or compaction) is a subjective judgement by the soil surveyor, unless these 3 classes could be quantified, e.g. in terms of penetration resistance (see also Research Needs). For both tables it is assumed that for annual crops, compaction would not significantly restrict growth and yield when it occurs below 50 cm from the surface. For perennials, this is assumed to be below 100 cm. When less than 40% of the polygon area is estimated to be affected by any degree of soil compaction, compacted phase symbol (cp) will not be used, since it is felt that applications of special soil and cropping management techniques will not be feasible in overcoming the compaction problem or a low proportion of the polygon area affected. Frequent observations with a penetrometer would greatly facilitate the estimation of percentage of the polygon affected by soil compaction.

At each inspection during soil survey, the absence or presence of soil compaction should be recorded in the compaction part of the daily field sheets. When present, the degree of compaction (severe, moderate, slight), depth at which it occurs and type of compaction (e.g. plow pan, massive structure, pedogenic or man-made, etc should be recorded). Based on these inspections, the percentage of the polygon affected by compaction can be estimated, and the previous table will then be consulted to determine if the compacted phase symbol (cp) should be applied to the polygon. If yes, cp will appear on the soil symbol for the polygon and will be recorded on the polygon (map unit) form. Compaction information will be retrievable from daily field sheet records.

Next question is, what parameters are we looking for in order to evaluate soil compaction in the field and what are the visual symptons of compaction. "Symptoms of compact soil are visible in both crops and soil. They are most easily seen when conditions are extreme. When diagnosing such conditions, care should be taken with interpretations, because similar symptoms are also caused by dry weather, early planting, nutrient deficiencies, high watertables and crop diseases" (Robertson and Erickson, 1978).

External Symptoms

a) Surface crusts and clods, most widespread crusts become strong and physically limit seed emergence when dry (also on sandy soils)
b) Cracks in wheel marks
c) Puddled soil, causing surface ponding after rains
d) Excessive erosion by water, because low infiltrability leads to runoff
e) Partly decomposed crop residues months after incorporation (slow decomposition)
f) Slow plant emergence, variable sized plants, off-coloured leaves (nutrient deficiency).

Soil Properties most suitable for compaction identification

a) Structure (massive, platy), pans
b) Roots (abundance, size, orientation, distribution)
c) Pores (abundance, size, orientation, distribution, continuity, morphology, type (shape))
d) Effective rooting depth to root restricting layer
e) Depth to root restrictive layer.

These parameters may identify soil compaction, but they may also identify pedogenic processes (cementation, massive structure) that will restrict the movement of water and root development. The experimenced soil surveyor should be able to differentiate between these two processes. Example 1) Bt hohrizon in fine textured soil, usually subangular blocky structure. Surveyor observers massive structure which he will identify as being attributed to soil compaction. Example 2) Root restricted layer at 30 cm, cementation or a plow pan? Once identified as being caused by soil compaction, the surveyor will then fill in the compaction section on his daily field sheet.

Since recognition of rooting patterns is very important for compaction evaluation, soil surveyors should familiarize themselves with the rooting habbits of crops occurring in the survey area. This will greatly facilitate the identification of compaction problems in soils.

Regarding the amount of detail of recording soil properties that are most suitable for compaction identification (above) I feel it is unfair to expect soil surveyors to describe in detail roots and pores on his daily field sheet at each inspection (too time-consuming). Therefore, I have proposed the minimum amount of information on compaction (as discussed above) to be entered on the daily field sheets which will still enable the soil surveyor to assess and map the present state of soil compaction. It is assumed that elsewhere on the form effective rooting depth and depth to root restricting layer will be recorded. If not, these 2 parameters should be added to the compaction portion of the daily field sheet.

Recommended compaction mapping

For new soil surveys in humid areas of Canada (at SiL 1 and SiL 2) that comprise dominantly poorly drained and imperfectly drained soils of medium to fine texture, which are (or have been) subject to cultivation and/or tree harvesting, the survey should be designed to include mapping of soil compaction as a soil phase used on polygons.

V. PREDICTING COMPACTION

Probability or compaction risk mapping can be very useful for a specific purpose. We are all familiar with Dick Coote's compaction risk mapping in Assessment of Soil Degradation in Canada, based on soil texture, water deficiency and % of row crops.

The only example I could find in which soil survey information was interpreted for compaction prediction was by Keith Valentine, Lac la Hache - Clinton Soil Survey in Interior B.C. (1:125,000). The forestry people in this area requested information on the probability of compacting landings if logged in winter.

The compaction rating for each soil was based on 3 parameters:

1) Texture (Coarse, Medium, Fine)
2) Moisture regime
3) Freezes in winter to support machinery (yes, no)

This results in a map, showing for each polygon a HIGH, MEDIUM or LOW probability of compacting landings if logged in winter.

A similar simple approach could be used for compaction risk mapping for Canada, based on the 1:1 m landscape maps.

VI. RESEARCH NEEDS

1) Paired B.D. measurements to quantify relative compaction on similar soils between non-cultivated and cultivated fields
2) Experimentation on the application of a penetrograph (recording penetrometer) to detect compacted layers and to quantify the degree of compaction
3) Establish critical values at which root penetration is being restricted for different crops and different soils by simulation of penetration resistance of roots (e.g. micro penetrometer). Relate these observations to larger penetrometer (penetrograph)
4) Effect of frost penetration on improvement of compacted soils.

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DICUSSION

Risk mapping is more feasible than documented current extent of compaction, which would take 100 yrs unless a special project was initiated. There was no agreement that risk could be mapped from texture, organic matter and drainage information. It was proposed that a special survey like those undertaken in the U.S. Resource Inventory should be seriously considered. However, consistency between surveys was questioned, as compaction is still poorly defined in terms of measurable parameters. Penetrometer values were considered useful for plow-pan identification, but bulk density was believed by some to be a poorer measurement than visual observations of morphology. There was little agreement that small scale maps would serve any useful purpose. It was agreed that compaction is easily induced, but may take many years of additions of organic matter or other soil amendments to correct it. It may even be considered as a symptom of drainage or other problems.

Research needs were agreed to be: for comparisons of paired sites with different management; for critical values of any measurable parameters, differentiated by soil types or by crops; and for the examination of the role of frost in relieving compaction.

Proceedings of the

SOIL CLIMATE WORKSHOP

held in conjunction with the

Fifth Annual Meeting of the

EXPERT COMMITTEE ON SOIL SURVEY

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Edited and Coordinated by

G. F. Mills

Chairman

Soil Climate Working Group

FOREWARD

A 2½ day workshop was held by the Soil Climate Working Group of the Expert Committee on Soil Survey (ECSS) in November 1983. The Soil Climate Working Group first met as an "ad hoc" working group in 1980 and then in 1981 and 1982 as a formally constituted working group in conjunction with ECSS annual meetings.

The objective of the workshop format for the third working group meeting was to provide the opportunity for working group members to discuss in greater detail progress to date, to present and discuss soil temperature data currently available in the regions, deal more adequately with concerns raised at previous working group meetings and to set short term priorities and develop a long-term work plan for future program.

The workshop was attended by 18 people (see list in Appendix) who contributed to presentation of papers, discussion of data and formulation of priorities and recommendations to ECSS. The progress reports and papers presented at the workshop are published in this "Proceedings" and recommendations emerging from the workshop were presented to the ECSS annual meeting following the workshop.

In order to enable working group members to prepare for topics at the workshop, regional representatives were asked to present a progress report of activitives in their region since the 1982 meeting and to present their analysis of longer term data. Working group members were also asked to review the Provisional Methodology for Monitoring Soil Temperature in order to update and revise it for eventual publication by the ECSS. Discussion on data handling concerns centered on recent steps which had been taken towards computerizing soil climatic data in the Canada Soil Information System (CanSIS). Working group members also participated in a general discussion comparing the criteria and parameters used to characterize soil temperatures in the Canadian System of Soil Classification and in the U.S. Soil Taxonomy.

I would like to acknowledge input to the workshop provided by regional representatives and by all others who participated in the workshop discussion. I would also like to thank Dr. J. Shields, Secretary of the ECSS for his support of the workshop and assistance provided towards publishing these "Proceedings".

G.F. Mills
Chairman
Soil Climate Working Group

CONTENTS

REGIONAL PROGRESS REPORTS

PROGRESS REPORT - BRITISH COLUMBIA

R. Trowbridge
B.C. Ministry of Forests

The various organizations involved in monitoring soil temperatures in British Columbia are unchanged from the listing provided to the Soil Climate Working Group meeting in 1982, (See Table 1 of the Soil Climate Working Group report in the Proceedings of the Fourth Annual Meeting of the Export Committee on Soil Survey, Victoria, British Columbia, April 1982). A map of British Columbia showing the location of current soil temperatures recording is included with this report. Documentation of all soil temperature sites in the Prince Rupert Forest Region has been compiled in tabular form and work is underway to provide this kind of description for all sites in the Province. Analysis of data from the B.C. soil temperature network is ongoing. A list of selected soil temperature references has been prepared for the ECSS Soil Climate Working Group and is included in the Appendex of this workshop proceedings.

SOIL CLIMATE STATION HISTORY - E.P. 920

PRINCE RUPERT FOREST REGION, BRITISH COLUMBIA

Oct. 27, 1983
R. Trowbridge

Zonation	Station #	Name	Depths (cm)	Readings (Yr/Mon/Day) First	Last	# Months	System[1]	Atmos-pheric Station on site[2]
CCPH	358	W. Diana Ck.	50,100	79/10/18	82/12/1	39	ST	No
	359	Oliver Ck.	50	79/10/19	82/12/1	39	ST	No
	360	Diana Ck.	50	79/10/19	82/12/1	39	ST	No
ICHg	48	Causqua Ck.	10,50,100	80/11/13	82/10/15	24	ST	No
	560F	Lower Corduroy CK - Forested	10,50,100	80/11/13	82/ 9/16	23	ST	Yes
	"	" "	25,50,75	82/10/15	Active	(14)	ADM	Yes
	560C	Lower Corduroy Ck - Clear	10,50	80/11/13	82/ 9/16	23	ST	Yes
	"	" "	25,50,75	82/10/15	Active	(13)	ADM	Yes
	773F	Bulkley Forested	10,50	81/10/15	82/ 8/18	23	ST	Yes
	"	" "	25,50,75	82/ 9/16	Active	(14)	ADM	Yes
	773C	Bulkley Clear	10,50	81/10/15	82/ 9/16	23	ST	Yes
	"	" "	25,50,75	82/10/15	Active	(13)	ADM	Yes
	774F	Upper Corduroy Forested	10,50	81/10/13	82/ 8/18	23	ST	Yes
		"	25,50,75	82/ 9/16	Active	(14)	ADM	Yes
ESSF	74	Little Joe Ck.	10,50,100	79/10/15	80/10/16	(11)	ST	No
	85	Hudson Bay Mt.	10,50 (35)	79/ 9/15	82/ 8/18	24	ST	No
		" "	25,50 (45)	82/ 9/15	Active	(12)	ADM	No
	500F	Cronin Rd - Forested	10,50,100	80/11/17	82/ 8/16	31	ST	Yes
		"	25,50,75	82/ 9/14	Active	(14)	ADM	Yes
	500C	Cronin Rd - Clear	10,50,100	80/11/17	82/ 8/16	31	ST	Yes
		"	25,50,75	82/ 9/14	Active	(14)	ADM	Yes
SBSd	15	Natural gas pipeline	10,50,100	79/10/15	82/10/14	37	ST	No
	26	Hubert Rd.	10,50 (35)	79/ 9/15	80/10/20	(14)	St	No
	38F	Lawson Rd - Forested	10,50,100	80/11/14	82/ 8/17	22	ST	Yes
		"	25,50,100	82/ 9/15	Active	(14)	ADM	Yes
	38C	Lawson Rd - Clear	10,50	81/10/15	82/ 8/17	11	ST	Yes
		"	25,50,75	82/ 9/15	Active	(13)	ADM	Yes
	88	Trout Creek	10,50,100	79/10/16	80/10/20	13	ST	No
	342	Round Lake	10,50,100	79/ 9/15	82/ 8/17	36	ST	No
		" "	25,50,100	82/ 9/14	Active	(14)	ADM	No
	512F	Toboggan Ck - Forested	10,50,100	80/11/13	82/ 8/18	22	ST	Yes
		"	25,50,100	82/ 9/15	Active	(14)	ADM	Yes
	512C	Toboggan Ck - Clear	10,50	81/10/15	82/ 8/18	22	ST	Yes
		"	25,50,100	82/ 9/15	Active	(14)	ADM	Yes

... 2

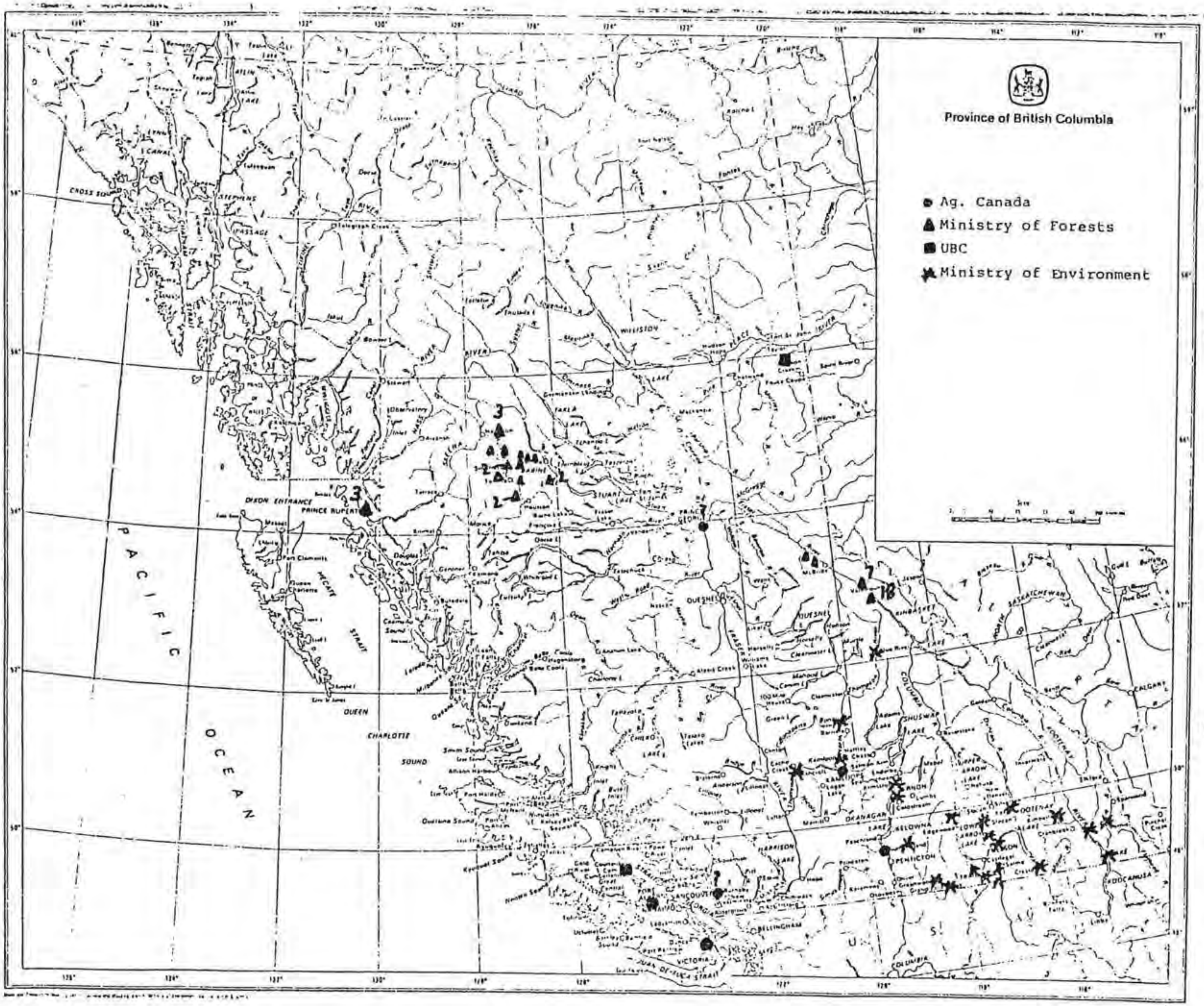
Cont'd

Zonation	Station #	Name	Depths (cm)	Readings (Yr/Mon/Day) First	Last	# Months	System[1]	Atmospheric Station on site[2]
SBSd	118	Toman's swamp	50	79/10/16	80/10/20	13	ST	No
(cont'd)	121	Hyw 16	50	79/10/16	80/ 8/14	11	ST	No
SBSe	2	Burnt Cabin Rd.	10,50,100	79/10/15	82/11/15	38	ST	No
	9	Walcott	10,50,100	79/10/15	82/10/14	37	ST	No
	77	Doris Lake	10,50	79/10/15	80/10/16	11	ST	No
	634	Chapman Lk. Rd.	10,50,100	80/11/17	82/10/14	24	ST	(Yes)
		"	25,50,75	82/11/16	Active	(12)	ADM	(Yes)
	635F	Fulton Forested	10,50,100	80/11/17	82/10/14	24	ST	Yes
		" "	25,50,75	82/11/16	Active	(12)	ADM	Yes
	635C	Fulton Clear	10,50,100	80/11/17	82/10/14	24	ST	Yes

1 ST = Soil Test Meter 302 + Calibrated Themistors
ADM = Atkins Digital Meter + Calibrated Thermistors

2 Stations include continuous daily temperature, min. and max. and two ppt. guages.

B.C. Soil Temperature Recording Sites[1]



[1] This base map has been reduced

R. Trowbridge
B.C. Ministry of Forests

PROGRESS REPORT - ALBERTA

R.W. Howitt

SUMMARY

The locations of soil climate monitoring sites that are maintained by the soil survey in Alberta are presented in Figure 1. The distribution of sites is a function of soil survey activities. Sites are located with proximity to recording meteorological stations and generally measurements of soil moisture and rainfall are taken in conjunction with soil temperature measurements.

Eight soil temperature sites, maintained by the Atmospheric Environment service, do not appear in Figure 1.

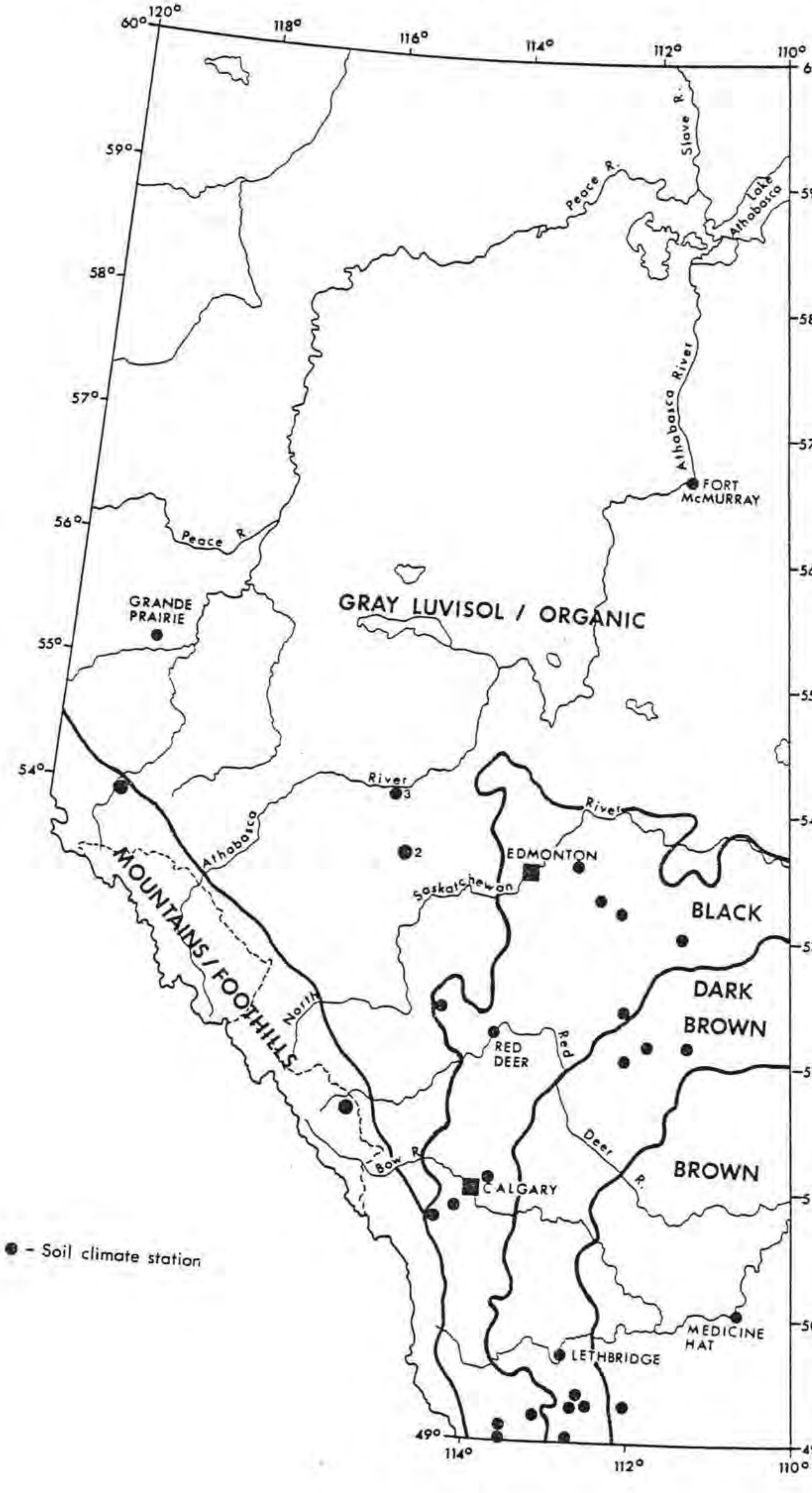
Table 1 is a summary of the location of climate monitoring sites, the length of record, and what other data is being collected at each site.

SUMMARY OF SOIL TEMPERATURE MONITORING SITES IN ALBERTA

LOCATION	ACTIVE STATIONS	LENGTH OF RECORD	OTHER DATA COLLECTED
Banff National Park	3	2-5 years	- air temperature by thermograph and max/min thermometers at all stns. - snow depth
Calgary Urban Perimeter	3	4 years	- soil moisture
County of Beaver	4	4 years	- soil moisture - 3 stns. - air temperature by thermograph and/or max/min thermometers at 2 stns. - rainfall at all stns.
County of Paintearth	4	1.5 years	- soil moisture - air temperature by thermograph at 1 stn. - rainfall at all stns.
County of Warner	3	4 years	- rainfall at all stns.
Evansburg	2	1 year	
Municipal District of Cardston	3	2 years	- rainfall at all stns. max/min temperature at 1 stn.
Eckvilie	1	2 years	- rainfall
Grande Cache	1	1 year	- using micro logger(CR21) to monitor surface temperatures of different slope aspects
Whitecourt	4	1 year	- rainfall - air temperature by max/min thermometer at one stn.

Total Active Sites 29
New sites since Victoria 11

*Note: Depths at which temperature is measured are generally 10, 20, 50, 100 cm with some variability depending on purpose.



GRAY LUVISOL / ORGANIC
MOUNTAINS / FOOTHILLS
BLACK
DARK BROWN
BROWN
GRANDE PRAIRIE
FORT McMURRAY
EDMONTON
RED DEER
CALGARY
LETHBRIDGE
MEDICINE HAT
Peace R.
Slave R.
Lake Athabasca
Athabasca River
Athabasca River
North Saskatchewan River
Red Deer R.
Bow R.
● - Soil climate station

PROGRESS REPORT--SASKATCHEWAN

R.J. St. Arnaud

In Saskatchewan, soil climate measurements are being taken at several sites, mostly in conjunction with ongoing research programs. In general, these measurements are only taken during the growing season under crop, fallow, and occasionally native grass. The fourteen AES sites provide continuous temperature measurements on a year-round basis. A list of the other sites from which soil temperature measurements are available include:

(1) Farm Lab Sites: Number: 4; Depths: 2, 10, 20, 50 cm; during the growing season; some winter measurements; two years' data.

(2) St. Denis Hydrology Site: Number: 20 probes (thermocouples) at the one site, various slope positions; depths: 10, 20, 30, 40, 50, 100, 150 cm; every two weeks during the growing season; some winter measurements; one year's data.

(3) Matador Farm: Data for 2-3 year period during the I.B.P. program; depths: 1, 2, 5, 10, 20, 50, 100 and 200 cm; manual reading 1968-1969; automatic readout after May, 1969.

(4) Goodale Farm: On sandy soils near Saskatoon; several slope positions; depths: 10, 20, 50 cm; summer measurements every 2-3 weeks; about three years' data.

(5) Kernen Farm: On Sutherland clay, near Saskatoon, one well-drained and one poorly-drained site; depths: 0, 10, 20, 50 cm; summer measurements; three years' data.

(6) Other sites: Soil temperature measurements are also being collected at the Melfort and Swift Current Research Stations; recent studies on snow retention and cultural practices include temperature measurement at shallow depths.

SOIL CLIMATE MONITORING ACTIVITIES IN MANITOBA

G.F. Mills

Canada-Manitoba Soil Survey

INTRODUCTION

The investigation of soil temperature by the Canada-Manitoba Soil Survey was initiated in 1971. This project has served various purposes including the study of soil climate factors affecting corn growth in southern Manitoba and permafrost phenomena in northern soils. The project has also contributed to the objectives defined by the Soil Climate Working Group of the Expert Committee on Soil Survey. As such it is part of a national effert to develop a better understanding of the relationships between soil, soil temperature and aerial temperature. The long term objectives of the national program are to better define the role of soil temperature in the System of Soil Classification for Canada and in particular the function it may serve for soil correlation, soil interpretation and land evaluation (Mills, 1981).

SOIL CLIMATE MONITORING NETWORK

As of October 1983, a total of 104 soil temperature sites are being monitored in Manitoba. The sites vary as to frequency and duration of monitoring as well as land use and vegetative cover. In addition, some sites have instrumentation to record aerial climate, water tables and soil moisture data. The active sites in Manitoba as of October 1983, are summarized by length of record and cooperating agency in Table 1. Soil temperature site locations in Manitoba are shown in Figure 1 and the location, texture, drainage and land use for all sites, active and terminated are listed in Table 2.

Table 1. Active Soil Temperature Sites in Manitoba (October, 1983).

Affiliation	Duration of record, Years							Total Sites
	<1	+1	2-4	5-7	8-10	<10	>10	
AES						2	2	4
Soil Survey	5	11	27	16	5		19	83
University of Manitoba								
-Soil Science		5		6				11
-Land Evaluation		3		3				6
Total	5	19	27	25	5	2	21	104

1. AES, Atmospheric Environment Service records compiled to 1978 and derived mainly from daily operations-observations ongoing.
2. Soil survey monitoring ranges from 4-6 week frequency.
3. Soil Science monitors 11 subsites at 2 Detail Sites.

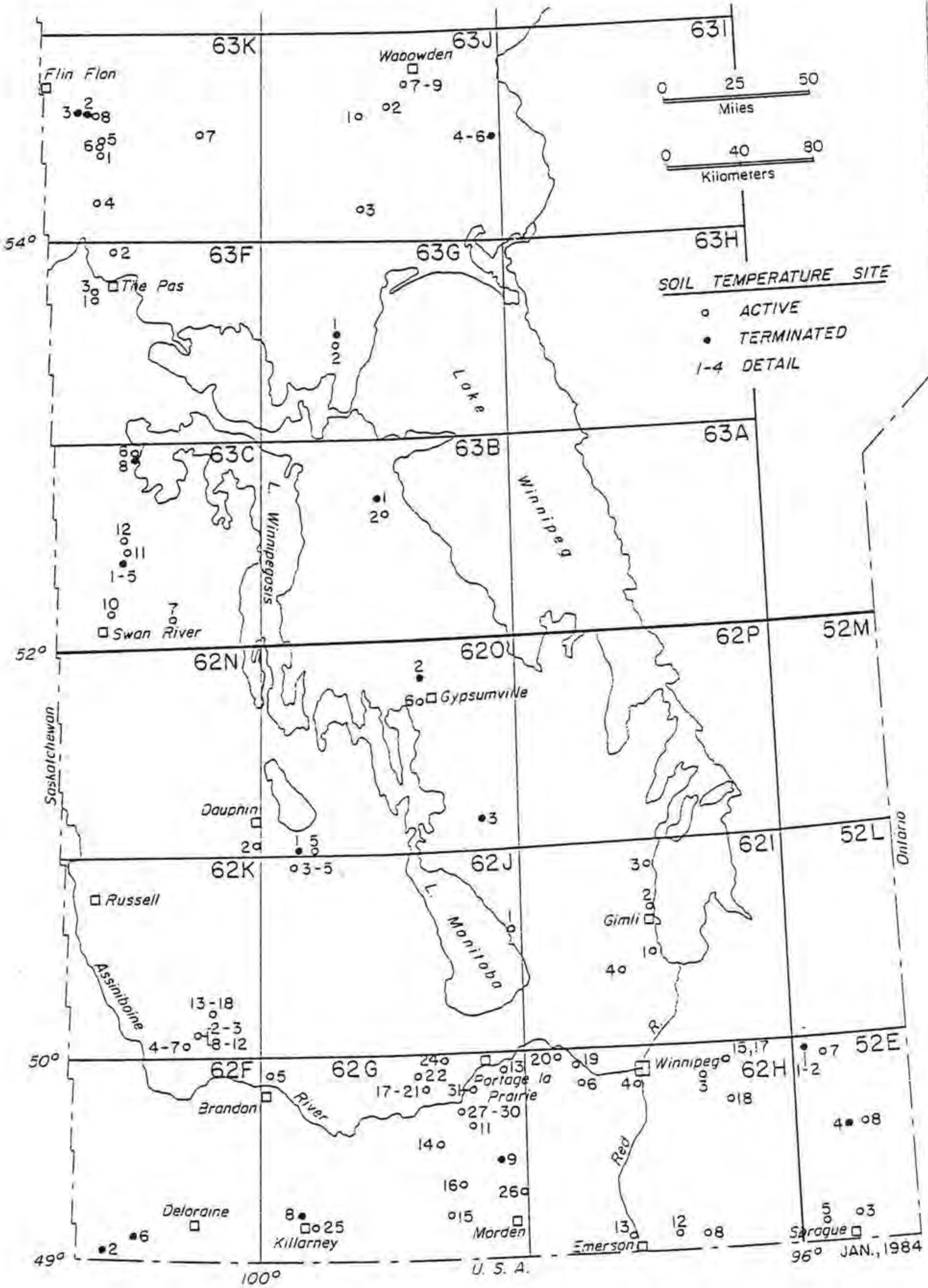


Figure 1. Soil temperature site locations in Manitoba.

INSTRUMENTATION AND SENSORS

Thermocouples manufactured from copper-constantan wire are the sensors used at most sites in Manitoba. Four sites maintained by the Atmospheric Environment Service and a detailed research site established by the Department of Soil Science, University of Manitoba use thermistor type sensors. Sites with additional instrumentation such as frost tubes and water table observation wells are identified in Table 2.

RECENT MONITORING ACTIVITIES (1982-1983)

Most additions to the soil climate monitoring network in Manitoba over the last 2 years have been established as a cooperative effort with other agencies. The trend has been to establish detail sites usually consisting of several subsites within a short distance often over a toposequence. The toposequence may be at a macro-(over several kilometers) or micro-(over a few hundred meters) scale, usually with several kinds of instrumentation and often with multipurpose objectives. Single sites are usually installed to replace old or destroyed sites and so maintain efficiency of monitoring for the broadly based geographic network. A brief description of selected detail sites follows.

a) Northern soils and bog veneer landforms (Thompson area)

Two detail sites were established on gently sloping portions of a clayey lacustrine blanket. Natural drainage ranges from well to very poor; lower slopes are characterized by thin organic bog veneer landforms. One site supports mature coniferous black spruce forest typical of the northern Boreal. The second site is characterized by 15 year old jackpine regeneration following fire. Each site covers 2.25 ha and was surveyed on a 50 m grid determining soil type, vegetation and permafrost characteristics and soil moisture regime at each grid point. The dominant soils along the center transect of each detail site were instrumented with thermocouples, frost tubes, observation wells and piezometers. The main objectives for these sites are to study:

1) permafrost - soil - vegetation relations
2) hydrology and moisture regimes in the discontinuous permafrost zone
3) genesis of Cryosolic soils
4) potential for agricultural development

These sites were established and maintained by the soil survey and are being monitored by regional staff of the Manitoba Department of Agriculture.

b) Tile Drainage study - (Dauphin area)

A detail study on drainage control using plastic tile at various depths was established by regional staff of the Manitoba Department of Agriculture. The soil survey cooperated in designing groundwater and hydrology studies to monitor the effectiveness of the tiles.

Soil temperature monitoring was included in this portion of the project. Alfalfa forage was established on the drainage area and regional staff measured production from the stand and monitored the associated soil temperatures and groundwater levels. Data from this study are being used by the Soil Climate Working Group and the Soil Water Interest Group.

c) Soil Morphological and Hydrology Study (Hamiota area)

This detail site is in an area of hummocky moraine and has been used as a graduate student PhD Thesis project. The site was established over several toposequences and is maintained by the Soil Science Department with advice and assistance on instrumentation provided by Soil Survey staff. Monitoring activities are shared by the two agencies and include records of soil temperature (thermocouples), frost penetration (frost tubes), groundwater (shallow wells) and hydrology (piezometers). Data from this site serves the objectives of both the Soil Climate Working Group as well as the Soil Water Interest Group.

d) Land Evaluation Studies for Crop Production (Agro-Manitoba)

A project to monitor soil and climate conditions in relation to crop yield is maintained by the Soil Science Department of various locations in southern Manitoba. In order to provide required input for development and testing of a crop yield model for Manitoba conditions, all sites are characterized as to soil type, soil physical properties, nutrients, precipitation, groundwater, soil moisture, soil temperature and frost penetration. The major objective of this work is to provide data for the crop modelling exercise. However, soil survey staff, by cooperating in the project have had access to much useful soil climate and soil moisture data on well documented soil types. Most of the monitoring is handled by personnel working on the crop modelling project.

e) Soil Management Studies (southern Manitoba)

Another project in which soil survey staff are cooperating with the Soil Science Department deals with the management of the Almasippi soils. This project also serves as a "deluxe" site for soil water interest group activities in Manitoba. The objective of the study is to research and demonstrate techniques for managing the shallow groundwater in these sandy soils. Nine toposequences were instrumented with water table observation wells. Wells and neutron moisture meter access tubes were located at upper, mid and lower slope positions and monitored at weekly intervals during the growing season. Thermistors, thermocouples and frost tubes were installed on five of the toposequences. Six automatic water table recorders, a continuous recording main gauge and minimum and maximum temperature recorders are also maintained at the site. All the major soil types have been sampled and characterized. Soil temperature, soil moisture and water table fluctuations are observed under three different cropping systems on the toposequences. Finally, soil drainage in portions of the study area has been controlled at two depths by tile drainage.

Several smaller projects have been initiated and maintained by Manitoba Department of Agriculture staff:

i) soil temperature and water table fluctuations are being monitored on organic soils

ii) soil temperature measurements at fixed distances from windbreaks

iii) soil temperature measurements under various snow entrappment methods to study overwintering conditions for fall rye and winter wheat

The monitoring for these projects is done mainly by M.D.A. staff. To date, mostly short term records have accumulated. These observations, although not always continuous, do provide "point data" which may be useful if the soil type and site conditions are known.

SUMMARY

Experience with soil climate monitoring in Manitoba indicates two levels of monitoring are required: 1) broadly based geographic coverage to achieve a relatively quick assessment of the range of conditions in an area. and, 2) more intensive instrumentation and monitoring derived from "detail" sites where a range of conditions at one site are examined. Many of the detail sites in Manitoba have been coordinated with soil water studies over the range of soil and landscape conditions at each site enabling more efficient data collection. Additional resources can often be allocated to establishment, maintenance and monitoring of the network if sites are multipurpose serving other objectives such as for soil management or crop modelling studies. Although there is a recognized need for both soil climate, soil moisture and water table data for Manitoba soils, there are no plans to increase the effort devoted to these projects unless additional resources become available.

Table 2. Identification Code and Location of Soil Temperature Sites in Manitoba

SITE NO.	NAME	LEGAL DESCRIPTION	LAT	LONG	SOIL NAME	SOIL TEXTURE	SUB GROUP	VEG	START Y M D	TERM Y M D	W FT	PROV I.D.	FIELD DATA	LAB DATA	REMARKS
52E 1	Whitemouth 1	NE 22-11-12E	49°56'	95°53'	Baynham	O	TY.M	1	72-06-27	78-11-21		72-122	x		
2	Whitemoth 2	NE 22-11-12E	49°56'	95°53'	Baynham	O	TY.M	1	72-06-27	79-09-26					
3	Sprague	NC 33-01-14E	49°05'	95°39'	Arnes	C	O.GL	1	72-07-13			72-123	x		
4	East Braintree	SW 04-06-15E	49°27'	95°31'	MacArthur	L	O.GL	1	71-11-02	80-05-07					
5	South Junction	SE 21-01-13E	49°03'	95°49'	Baynham	O	TY.M	1	71-11-02			73-15	x	x	
6	Whitemouth Town	SE 01-12-11E	49°58'	95°58'	Whitemouth	CL	D.GL	1	73-05-28	74-02-05					
7	Whitemouth 3	NW 23-11-12E	49°56'	95°52'	Baynham	L	TY.M	1	79-06-19						Replaces 52E-1
8	North West Angle	SW 06-06-16E	49°27'	95°26'	Pine Ridge	S	E.EB	1	81-05-15						
62F 1	Goodlands	NW 15-02-24W	49°08'	100°37'	Waskada	L	O.BL	2	71-05-24	73-10-10		71-72	x		
2	Lyleton	NW 16-01-28W	49°02'	101°10'	Cameron	L	O.BL	2	71-05-24	77-05-16		71-70	x		
3	Tilston	NE 20-05-29W	49°24'	101°21'	Medora	L	CA.BL	2	71-05-24	74-04-12		71-69	x		
4	Virden 1	SW 23-10-28W	49°51'	101°11'	Medora	L	CA.BL	2	71-05-14	73-04-06		71-73	x		
5	Virden 2	NE 16-11-26W	49°56'	100°58'	Ryerson	L	O.BL	2	73-05-09	74-06-03					
6	Waskada G.D.A.	SE 04-02-26W	49°06'	100°54'	Bearford	CL	O.BL	2	73-05-04	82-06-02		80-75	x	x	
7	Sinclair 1	NC 22-07-28W	49°35'	101°12'	Medora	L	CA.BL	2	75-11-06	78-05-04		75-007	x	x	
8	Sinclair 2	NC 22-07-28W	49°35'	101°12'	Hathaway	L	GLR.BL	2	75-11-06	78-09-28		75-008	x	x	
9	Sinclair 3	WC 22-07-28W	49°35'	101°12'	Tilston	L	HU.LG	2	75-11-07	78-09-28		75-009	x	x	

Identification Code and Location of Soil Temperature Sites in Manitoba

SITE NO.	NAME	LEGAL DESCRIPTION	LAT	LONG	SOIL NAME	SOIL TEXTURE	SUB GROUP	VEG	START Y M D	TERM Y M D	W	FT	PROV I.D.	FIELD DATA	LAB DATA	REMARKS
62G 1	Elm Creek 1	NW 14-08-05W	49°40'	98°03'	St. Claude	LFS	GLR.BL		70-09-24	72-11-16					x	
2	Elm Creek 2	NW 14-08-05W	49°40'	98°03'	Lelant	LFS	R.HG		70-09-24	72-11-16					x	
3	Elm Creek 3	SE 26-07-05W	49°36'	98°02'	Willowcrest	FS	GL.BL		70-11-19	72-11-16					x	
4	Morden	NE 04-03-05W	49°12'	98°05'	Horndean	CL	GL.BL		73-04-27	75-11-24						
5	Brandon	NE 28-10-19W	49°52'	99°59'	Agnew	CL	GL.BL	2	71-05-14		88		71-83	x		
6	Carberry	NE 11-11-15W	49°55'	99°25'	Wellwood	L	O.BL	2	71-05-12	74-04-12			71-79	x		
7	Glenboro	SW 02-07-14W	49°32'	99°17'	Glenboro	SL	O.BL	2	71-05-27	75-04-24			71-71	x		
8	Killarney	SE 29-03-17W	49°14'	99°44'	Waskada	L	O.BL		75-07-31	81-05-20						
9	Graysville	SE 14-06-06W	49°29'	98°08'	Reinland	LVFS	GLR.BL	2	72-06-19	81-11-17						
10	Carman	NE 13-06-05W	49°29'	98°01'	Neuenberg	VFSL	GLR.BL		73-01-13	75-08-12						
11	St. Claude	NW 02-08-07W	49°38'	98°20'	Reinland	LVFS	GLR.BL(C)	2	74-06-06			x				
12	Haywood	SW 25-08-06W	49°41'	98°09'	Almasippi Assoc.	SL	GLR.BL		73-10-15	76-04-13						
13	Newton	NW 13-11-06W	49°56'	98°10'	Gervais	L	GLCU.R	2	72-05-17			x	72-124	x		
14	Notre Dame	NE 14-07-09W	49°34'	98°35'	Pembina	L	O.DG	1	75-11-10							
15	Manitou	NW 02-04-08W	49°17'	98°27'	Brundis	C	O.BL	1	76-01-15							
16	Miami	SE 31-05-06W	49°26'	98°15'	Neuenberg	LVFS-L	GLR.BL(C)	3	77-11-01		40	x				
17	Lavenham 1	SW 02-10-10W	49°48'	98°44'	Shilox	FS	O.R	3	78-11-01		30		78-47	x	x	
18	Lavenham 2	NW 11-10-10W	49°49'	98°44'	Halstead	VFSL	O.DG	3	78-11-02		31	x	78-42	x	x	
19	Lavenham 3	WC 21-10-10W	49°51'	98°44'	Lelant	SL	R.HG	2	78-11-02		12	x	78-53	x	x	
20	Lavenham 4	NW 26-10-10W	49°52'	98°44'	Almasippi	LS	GLR.BL	3	78-11-01		13	x				
21	Lavenham 5	NW 35-10-10W	49°53'	98°44'	Lelant	LFS	R.HG	3	78-11-01		14			x	x	
22	Lavenham 6	WC 15-11-10W	49°55'	98°46'	Reinland	LFS	GLR.BL(C)	3	78-11-01		15	x	78-56	x	x	
23	Carberry 2	SW 17-11-14W	49°55'	99°21'	Wellwood	L	O.BL	3	78-11-01				78-68	x	x	
24	Bagot G.D.A.	SE 06-12-09W	49°58'	98°41'	Graysville	SL	GLR.BL	2	81-08-06		39	x	80-61	x	x	
25	Killarney Lake	SE 01-03-17W	49°11'	99°38'	Ryerson	L	O.BL	3	81-11-06					x	x	
26	Jordan	NW 01-05-05W	49°22'	98°01'	Morris	C	GLSZ.BL	2	81-11-12		45					

Identification Code and Location of Soil Temperature Sites in Manitoba

SITE NO.	NAME	LEGAL DESCRIPTION	LAT	LONG	SOIL NAME	SOIL TEXTURE	SUB GROUP	VEG	START Y M D	TERM Y M D	W FT	PROV I.D.	FIELD DATA	LAB DATA	REMARKS
62G 27	AWSM	NE 10-09-08W	49°44'	98°28'				2	81-12-02						
28	"	NE 10-09-08W	49°44'	98°28'				2	81-12-02						
29	"	SE 10-09-08W	49°44'	98°28'				2	81-12-02						
30	"	NW 10-09-08W	49°44'	98°28'				2	81-12-02						
31	"	NE 11-10-8W	45°54'	98°27'				2	81-12-02						

Identification Code and Location of Soil Temperature Sites in Manitoba

SITE NO.	NAME	LEGAL DESCRIPTION	LAT	LONG	SOIL NAME	SOIL TEXTURE	SUB GROUP	VEG	START Y M D	TERM Y M D	W FT	PROV I.D.	FIELD DATA	LAB DATA	REMARKS
62H 1	Letellier	NC 15-02-02E	49°07'	97°14'	Emerson Assoc.	SiCL	GLR.BL	1	75-11-10	79-11-15					
2	Altona	SE 24-02-02W	49°18'	97°36'	Altona	VFSCL	GLR.BL	2	74-06-05	76-01-19					
3	Anola	SW 05-11-07E	49°53'	96°37'	Fairford	L	E.EB	1	72-05-30			72-125	x		
4	Fort Garry	NW 28-09-03E	49°47'	97°08'	Fort Garry	C	O.BL	1	72-11-15						
5	Menisino	SE 01-02-10E	49°06'	96°07'	Vassar	S	O.GL	2	74-05-17	74-09-14					
6	Starbuck	SE 27-09-01W	49°46'	97°31'	Red River	C	GLR.BL	3	75-11-03						
7	Glenlea Corn	(RL)09-08-03E	49°37'	97°07'	Red River	C	GLR.BL	1	73-11-14	76-01-28					
8	Stuartburn	NE 17-02-07E	49°08'	96°37'	Inwood	L	GL.DG	1	75-05-22			75-53	x		
9	Homewood	NE 26-06-04W	49°31'	97°54'	Rignold	CL	GL.BL	3	77-11-01	78-05-01					
10	Domain 1	SE 29-07-01E	49°36'	97°25'	Red River	C	GLR.BL	2	77-11-01	78-11-21					
11	Domain 2	SE 29-07-01E	49°36'	97°25'	Osborne	C	R.HG(C)	2	77-11-04	79-07-23					
12	Woodmore	NE 17-02-05E	49°08'	96°53'	Kittson Assoc.	FSL/Sic	GL Ca.BL	2	79-06-12		13	79-15	x	x	
13	Letellier 2	NW 15-02-02E	49°08'	97°15'	Emerson Assoc.	SiCL	GLR.BL	1	80-05-07						
14	Vivian 4	NW 09-11-08E	49°54'	96°27'	Fyala	C	R.HG(C)	2	82-05-13	83-09-28					
15	Vivian 3	NW 09-11-08E	49°54'	96°27'	Fyala	C	R.HG(C)	2	82-05-13						
16	Vivian 2	NW 09-11-08E	49°54'	96°27'	Fyala	C	R.HG(C)	2	82-05-13	83-09-28					
17	Vivian 1	NW 09-11-08E	49°54'	96°27'	Cayer	O	T.M	2	82-05-13		x				
18	Richer	NW 04-08-08E	49°38'	96°27'	Stead	O	TY.M	2	82-10-06		x				
19	Lido Plage	NW 34-10-01W	49°53'	97°31'	Red River	C	GLR.BL	2	83-11-07		x				
20	Elie	NE 06-11-02W	49°54'	97°43'	Red River	C	GLR.BL	3	83-11-07		x				

Identification Code and Location of Soil Temperature Sites in Manitoba

SITE NO.	NAME	LEGAL DESCRIPTION	LAT	LONG	SOIL NAME	SOIL TEXTURE	SUB GROUP	VEG	START Y M D	TERM Y M D	W FT	PROV I.D.	FIELD DATA	LAB DATA	REMARKS
62I 1	Winnipeg Beach	WC 32-17-04E	50°30'	97°01'	Inwood	L	GL.DG	3	78-11-08		9	77-007	x	x	
2	Gimli	SW 29-19-04E	50°39'	97°01'	Lakeland	SiL	GLR.BI	3	78-11-08		3	77-001	x	x	
3	Hnausa	EC 05-22-04E	50°52'	97°00'	St. Norbert	C	O.DG	3	78-11-08		11	77-009	x	x	
4	Teulon	NC 24-16-02E	50°23'	97°12'	Dencross	SiC	GLR.BL(C)	2	81-09-09		14	80-076	x	x	GDA
62J 1	Lundar	NE 11-19-05W	50°37'	98°03'	Isafold	L	R.BL	1	71-08-30			71-80	x		
2	Neepawa	NW 21-15-15W	50°18'	99°28'	Carroll	CL	R.BL	1	73-05-14	75-08-20					
3	Makinak 1	NE 10-23-17W	50°58'	99°46'	Ochre River	C	GLR.BL	2	79-11-01						
4	Makinak 2	NE 10-23-17W	50°58'	99°46'	Ochre River	C	GLR.BL	1	79-11-01						
5	Makinak 3	NE 10-23-17W	50°58'	99°46'	Ochre River	C	GLR.BL	1	79-11-01						

Identification Code and Location of Soil Temperature Sites in Manitoba

SITE NO.	NAME	LEGAL DESCRIPTION	LAT	LONG	SOIL NAME	SOIL TEXTURE	SUB GROUP	VEG	START Y M D	TERM Y M D	W FT	PROV I.D.	FIELD DATA	LAB DATA	REMARKS
62K 1	Hamiota 1	SW 26-13-24W	50°08'	100°39'	Newdale	L-CL	O.BL	2	71-05-18	73-11-07			x		
2	Hamiota 2	SW 11-13-23W	50°10'	100°31'	Newdale Assoc.	L-CL	HU.LG	3	78-11-01	83-11-10	1		x	x	
3	Hamiota 3	SW 11-13-23W	50°10'	100°31'	Newdale Assoc.	L-CL	HU.LG	1	78-11-01	83-11-10	3		x		
4	Hamiota 4	SE 30-13-23W	50°08'	100°36'	Newdale Assoc.	L-CL	GLD.GL	2	78-11-02		7		x	x	
5	Hamiota 5	SE 30-13-23W	50°08'	100°36'	Newdale Assoc.	L-CL	O.BL	2	78-11-02		8		x	x	
6	Hamiota 6	SE 30-13-23W	50°08'	100°36'	Newdale Assoc.	L-CL	O.BL(S)	2	78-11-02		9		x	x	
7	Hamiota 7	SE 30-13-23W	50°08'	100°36'	Newdale Assoc.	L-CL	GLR.BL(C)	3	78-11-02		10		x	x	
8	Hamiota 8	SW 11-14-23W	50°10'	100°31'	Newdale Assoc.	L-CL	GLR.BL	3	82-06-21		4		x		
9	Hamiota 9	SW 11-14-23W	50°10'	100°31'	Newdale Assoc.	L-CL	R.HG	3	82-05-26	83-11-10	5		x	x	
10	Hamiota 10	SW 11-14-23W	50°10'	100°31'	Newdale Assoc.	L-CL	O.BL	2	82-05-27		12		x		
11	Hamiota 11	SW 11-14-23W	50°10'	100°31'	Newdale Assoc.	L-CL	GL.BL(S)	2	82-05-27		13		x		
12	Hamiota 12	SW 11-14-23W	50°10'	100°31'	Newdale Assoc.	L-CL	GL.BL(S)	2	82-05-27		15		x		
13	Strathclair 1	NE 10-15-22W	50°16'	100°25'	Newdale Assoc.	L	O.BL	2	82-11-16		1				
14	Strathclair 2	NE 10-15-22W	50°16'	100°25'	Newdale Assoc.	L	O.BL	2	82-11-16		2				
15	Strathclair 3	NE 10-15-22W	50°16'	100°25'	Newdale Assoc.	L	O.BL	2	82-11-16		3				
16	Strathclair 4	NE 10-15-22W	50°16'	100°25'	Newdale Assoc.	L	O.BL	2	82-11-16		4				
17	Strathclair 5	NE 10-15-22W	50°16'	100°25'	Newdale Assoc.	L	O.BL	2	82-11-16		5				
18	Strathclair 6	NE 10-15-22W	50°16'	100°25'	Newdale Assoc.	L	O.BL	2	82-11-16		6				

Identification Code and Location of Soil Temperature Sites in Manitoba

SITE NO.	NAME	LEGAL DESCRIPTION	LAT	LONG	SOIL NAME	SOIL TEXTURE	SUB GROUP	VEG	START Y M D	TERM Y M D	W FT	PROV I.D.	FIELD DATA	LAB DATA	REMARKS
62N 1	Dauphin A	NC 04-24-19W	51°04'	100°04'	Turtle River	L	GLCU.R	2	73-05-02	76-04-12					
2	Dauphin G.D.A.	NW 23-24-19W	51°06'	100°02'	Paulson	C	R.G	2	79-10-31		GDA	79-003	x	x	
3	Eclipse	SC 36-24-19W	51°07'	100°00'	Halicz	C/S	GLR.BL	2	79-06-15	80-05-13					
620 1	Ochre River	SC 07-24-16W	51°03'	99°42'	Fairford	L	E.EB	1	71-07-03	81-03-23		77-066	x	x	
2	Gypsumville	SC 12-33-10W	51°49'	98°45'	Fairford	L	E.EB	1	71-07-13	81-07-09		65-213	x	x	
3	Ashern	SC 11-25-07W	51°08'	98°20'	Aneda	L	O.DG	1	71-07-22	79-09-25		77-058	x	x	
4	The Narrows	SW 18-24-09W	51°04	98°43'	Fairford	L	E.EB	1	79-11-05	81-03-23			x	x	
5	Ste Rose	SW 07-24-15W	51°03'	99°34'	Plum Ridge	VFSL	GLR.BL(C)	2	81-10-02		1	81-78	x	x	
6	Homebrook	NE 11-32-10W	51°44'	98°46'	Homebrook	C	O.DG	1	81-11-05						

Identification Code and Location of Soil Temperature Sites in Manitoba

SITE NO.	NAME	LEGAL DESCRIPTION	LAT	LONG	SOIL NAME	SOIL TEXTURE	SUB GROUP	VEG	START Y M D	TERM Y M D	W FT	PROV I.D.	FIELD DATA	LAB DATA	REMARKS
63B 1	Devils Lake	SW 14-43-11W	$52^{\circ}42'$	$98^{\circ}58'$	Cedar Lake	C	O.GL	1	71-07-16	80-09-05		77-060	x	x	
2	Mile 68	SE 35-42-11W	$52^{\circ}39'$	$98^{\circ}56'$	Cedar Lake	C	O.GL	1	83-07-02						
63C 1	Porcupine 1	SW 31-40-26W	$52^{\circ}29'$	$101^{\circ}12'$	Sinnott	L	R.HG (P)	3	71-09-14	78-06-19		71-076	x	x	
2	Porcupine 2	SW 31-40-26W	$52^{\circ}39'$	$101^{\circ}12'$	Tee Lake	L	GL.GL	1	71-09-14	78-08-14		71-077	x	x	
3	Porcupine 3	SW 31-40-26W	$52^{\circ}39'$	$101^{\circ}12'$	Waitville	L	O.GL	1	71-09-14	78-06-19		71-078	x	x	
4	Porcupine 4	SW 31-40-26W	$52^{\circ}39'$	$101^{\circ}12'$	Tee Lake	L	GL.GL	1	71-09-14	78-08-14		71-075	x		
5	Porcupine 5	SW 31-40-26W	$52^{\circ}39'$	$101^{\circ}12'$	Tee Lake	L	GL.GL	1	71-09-16	78-08-14		71-074	x		
6	Dawson Bay 1	SE 21-46-25W	$52^{\circ}39'$	$101^{\circ}12'$	Atikameg	L	E.EB	1	71-08-23			71-108	x	x	
7	Cowan	SW 20-36-23W	$52^{\circ}06'$	$100^{\circ}43'$	Garson	L	O.GL	1	71-07-09			77-059	x	x	
8	Dawson Bay 2	SE 21-46-25W	$52^{\circ}58'$	$101^{\circ}42'$	Atikameg	L	E.EB	1	73-07-18	80-06-25					
9	Bell Lake 1	NE 13-41-27W	$52^{\circ}33'$	$101^{\circ}14'$	Waitville	L	O.GL	1	78-09-28	80-04-21					
10	Kirkpatrick	SE 10-37-27W	$52^{\circ}09'$	$101^{\circ}14'$	Valley	L	GLR.BL	2	79-08-27		I	79-014	x	x	
11	Bell Lake Road	SW 18-41-26W	$52^{\circ}32'$	$101^{\circ}13'$	Waitville	L	O.GL	1	80-10-14						
12	Bell Lake 2	NE 13-41-27W	$52^{\circ}32'$	$101^{\circ}14'$	Waitville	L	O.GL	1	80-07-22						

Identification Code and Location of Soil Temperature Sites in Manitoba

SITE NO.	NAME	LEGAL DESCRIPTION	LAT	LONG	SOIL NAME	SOIL TEXTURE	SUB GROUP	VEG	START Y M D	TERM Y M D	W FT	PROV I.D.	FIELD DATA	LAB DATA	REMARKS
63F 1	LeSann Farm	NW 36-54-28W	53°42'	101°28'	Big Lake Series		R.G (D)	2	77-06-01		1				
2	The Pas Moraine	SW 34-57-26W	53°57'	101°14'	Chitek	L	GLE.EB	1	77-08-10			77-057	x	x	
3	The Pas G.D.A.	NW 05-55-27W	53°43'	101°27'	Big Lake Series	SiCL	R.G (D)	2	83-06-21		3		x	x	
63G 1	Buffalo Lake 1	SW 32-52-13W	53°32'	99°21'	Limestone Point	L	E.EB(Li)	1	71-07-16	79-06-06		71-082	x	x	
2	Buffalo Lake 2	SW 29-52-13W	53°31'	99°21'	Atikameg	L	E.EB	1	79-09-16						

Identification Code and Location of Soil Temperature Sites in Manitoba

SITE NO.	NAME	LEGAL DESCRIPTION	LAT	LONG	SOIL NAME	SOIL TEXTURE	SUB GROUP	VEG	START Y M D	TERM Y M D	W FT	PROV I.D.	FIELD DATA	LAB DATA	REMARKS
63J 1	Ponton	NW 28-65-12W	54°39	99°13	Kiski	C	GL.SC	1	71-08-04			77-068	x	x	
2	Kiski Creek	NW 07-66-10W	54°42'	98°58'	Sipiwesk	C	O.GL	1	72-10-18			77-061	x	x	
3	Minago River	NW 22-60-12W	54°12'	99°11'	Sipiwesk	C	O.GL	1	72-10-19						
4	Jenpeg 1	NW 07-64-04W	54°32'	98°01'	Wabowden	C	SZ.GL	1	73-06-21	78-08-15		73-013	x		
5	Jenpeg 2	NW 07-64-04W	54°32'	98°01'	Wabowden	C	SZ.GL	1	73-06-21	78-08-15					
6	Jenpeg 3	NW 07-64-04W	54°32'	98°01'	Thompson	C	GL.GL	1	73-06-21	78-08-15		73-014	x		
7	Braun A	SW 16-67-09W	54°48'	98°46'	Pipun	C	O.GL	2	82-06-09						
8	Braun B	SW 16-67-09W	54°48'	98°46'	Wabowden	C	SZ.GL	2	82-06-09						
9	Braun Forest	SW 16-67-09W	54°48'	98°46'	Pipun	C	O.GL	1	82-06-18						
63K 1	Simonhouse	SE 31-63-26W	54°29'	101°22'	Nekik Lake	O	ME.OC	1	71-08-01						
2	Mistik Creek 1	NE 25-65-28W	54°39'	101°33'	Nekik Lake	O	ME.OC	1	71-07-31	81-03-24					
3	Mistik Creek 2	NE 25-65-28W	54°39'	101°34'	Fay Lake	SL	E.DYB	1	71-07-31	81-03-24		71-066	x	x	
4	Wanless	SE 24-60-27W	54°12'	101°22'	Wabowden	C	SZ.GL	1	71-08-01		I	71-065	x	x	
5	Cranberry 1	SE 07-64-26W	54°32'	101°22'	Egg Lake	L	O.GL	1	71-08-01			71-068	x	x	
6	Cranberry 2	NE 06-64-26W	54°31'	101°22'	Nekik Lake	O	ME.OC	1	71-08-01			71-067	x	x	
7	Reed Lake	C 30-64-20W	54°34'	100°29'	Hargrave	O	TY.M	1	72-10-17			77-063	x	x	
8	Neso Lake	NE 25-65-28W	54°39'	101°33'	Nekik Lake	O	ME.OC	1	81-07-07						
63O 1	Joey Lake	NW 03-75-05W	55°28'	98°09'	Nekik Lake	O	ME.OC	1	71-08-04			77-064	x	x	
2	Ospwagan Lake	C 32-75-04W	55°32'	98°03'	Sipiwesk	C	O.GL	1	71-08-05			77-065	x	x	

Identification Code and Location of Soil Temperature Sites in Manitoba

SITE NO.	NAME	LEGAL DESCRIPTION	LAT	LONG	SOIL NAME	SOIL TEXTURE	SUB GROUP	VEG	START Y M D	TERM Y M D	W	FT	PROV I.D.	FIELD DATA	LAB DATA	REMARKS
63P 1	Thompson Airport	NW 27-78-03W	55°47'	97°51'									77-057	x	x	man made soil
2	Dam B 1	SW 23-77-03W	55°41'	97°49'	Thompson Lake	C	GL.GL	1	76-09-	78-09-			76-020	x	x	
3	Dam B 2	SW 23-77-03W	55°41'	97°49'	Thompson Lake	C	GL.GL	1	76-09-	78-09-			76-021	x	x	
4	Dam B 3	SW 23-77-03W	55°41'	97°49'	Medard	C	R.G.(P)	1	76-09-	78-09-			76-022	x	x	
5	JCT 391 (1)	NE 06-79-03W	55°49'	97°54'	Wabowden	C	SZ.GL	1	78-08-14	79-11-07			78-069	x	x	Black Spruce
6	JCT 391 (2)	NE 06-79-03W	55°49'	97°54'	Wabowden	C	SZ.GL	1	78-08-14				78-070	x	x	Jack Pine
7	Stable Road 1	SW 22-78-03W	55°46'	97°50'	Wabowden	C	SZ.GL	1	78-08-14				78-071	x	x	Black Spruce
8	Stable Road 2	SW 22-78-03W	55°46'	97°50'	Sipiwesk	C	O.GL	1	78-08-14							Jack Pine
9	Birch Tree North 1	C 30-77-03W	55°42'	97°55'	Wabowden	C	SZ.GL	1	78-08-14				78-072	x	x	Black Spruce
10	Birch Tree North 2	C 30-77-03W	55°42'	97°55'	Wabowden	C	SZ.GL	1	78-08-14				78-073	x	x	Jack Pine
11	Birch Tree South 1	NE 29-77-03W	55°42'	97°52'	Sipiwesk	C	O.GL	1	78-08-14				78-074	x	x	Black Spruce
12	Birch Tree South 2	NE 29-77-03W	55°42'	97°52'	Sipiwesk	C	O.GL	1	78-08-14				78-075	x	x	Jack Pine
13	SCTC-1 C-10	SE 09-80-02W	55°55'	97°42'	Wabowden	C	SZ.GL	1	81-09-17		13	x	81-082	x		
14	SCTC-1 C-9	SE 09-80-02W	55°55'	97°42'	Pelletier Lake	C	O.LG	1	81-09-17		14	x	81-082	x		
15	SCTC-1 C-7	SE 09-80-02W	55°55'	97°42'	--	C	O.TC	1	81-09-17		15	x		x		
16	SCTC-1 C-5	SE 09-80-02W	55°55'	97°42'	--	O	TFi.OC	1	81-09-17		16	x	81-077	x		
17	SCTC-1 C-3	SE 09-80-02W	55°55'	97°42'	Parlee	O	R.HG(P)	3	81-09-17		17	x	81-080	x		
18	SCTC-1 C-1	SE 09-80-02W	55°55'	97°42'	Ospwagon	O	GL.SC	1	81-09-17		18	x	81-079	x		
19	SCTC-1 E10	SE 09-80-02W	55°54'	97°43'	Wabowden	C	SZ.GL	1	82-09-19		19	x				
20	SCTC-2 H10	SE 09-80-02W	55°54'	97°43'	Wabowden	C	SZ.GL	1	82-09-21		20	x				
21	SCTC-2 H7	SE 09-80-02W	55°54'	97°43'	--	C		1	82-09-21		21					
22	SCTC-2 H5	SE 09-80-02W	55°54'	97°43'	--	C		1	82-09-21		22	x				
23	SCTC-2 H3	SE 09-80-02W	55°54'	97°43'	--	C		1	82-09-21		23					
24	SCTC-2 H1	SE 09-80-02W	55°54'	97°43'	--	O		1	82-09-21		24	x				
25	SCTC-2 G-7	SE 09-80-02W	55°54'	97°43'	--	C			83-09-22		x	x				

Identification Code and Location of Soil Temperature Sites in Manitoba

SITE NO.	NAME	LEGAL DESCRIPTION	LAT	LONG	SOIL NAME	SOIL TEXTURE	SUB GROUP	VEG	START Y M D	TERM Y M D	W FT	PROV I.D.	FIELD DATA	LAB DATA	REMARKS
64A 1	Orr Lake 1	NE 19-81-03E	$56^{\circ}04'$	$97^{\circ}09'$	Arnot Siding	C	SZ.GL	1	78-11-24			77-062	x	x	
2	Orr Lake 2	NE 19-81-03E	$56^{\circ}04'$	$97^{\circ}09'$	Monk Siding	C	GLSZ.GL	1	78-11-29						
3	Orr Lake 3	NE 19-81-03E	$56^{\circ}04'$	$97^{\circ}09'$	Brannigan Creek	C	O.G(P)	1	78-11-29			72-067	x	x	
4	Split Lake 1	NE 08-84-09E	$56^{\circ}17'$	$96^{\circ}09'$	--	Si-C	LU.TC	1	79-08-27			79-013	x	x	
5	Split Lake 2	NC 08-84-09E	$56^{\circ}17'$	$96^{\circ}10'$	--	C	GL.TC	1	79-08-27				x		

VEGETATION CODE

Appendix 1

TREED - 1 CULTIVATED - 2 GRASS/BRUSH - 3

Feb. 84

SOIL CLASSIFICATION

SUB GROUP

CA Calcareous
CU Cumulic
CR Cryic
E Eluviated
Fi Fibric
GL Gleyed
GL Gleysolic (Cryosols only)
HU Humic
LU Luvisolic
ME Mesic
O Orthic
R Rego
SZ Solonetzic
TY Terric
T Typic
D Dark

GREAT GROUP

.BL Black
.DG Dark Gray
.DY Dystric
.EB Eutric Brunisol
.G Gleysol
.GL Gray Luvisol
.HG Humic Gleysol
.LG Luvic Gleysol
.M Mesisol
.OC Organic Cryosol
.R Regosol
.SC Static Cryosol
.TC Turbic Cryosol

SOIL TEXTURE

C Clay
CL Clay Loam
F Fine
L Loam(y)
S Sand
SL Sandy Loam
Si Silt
V Very
O Organic

PHASES

(C) Carbonated
(D) Drained
(Li) Lithic
(P) Peaty
(S) Saline

Notes

W - Well Data Available
FT Frost Tube Data Available
X Soil Site Data Available

PROGRESS REPORT - ONTARIO

D. Aspinal
Ontario Institute of Pedology

A list of data sources representing current activities directed toward monitoring soil temperatures in Ontario is attached. Soil temperature studies of various kinds and scales are being monitored by the following organizations:

Ontario Institute of Pedology

Great Lakes Forest Research Center

Lands Directorate

Atmospheric Environment Services

University of Guelph

Maps showing the location of monitoring sites are included.

ONTARIO INSTITUTE OF PEDOLOGY 1.

SOURCE:	Brian Hohner
# STATIONS:	4, all active
LOCATION:	Regional Municipality of Niagara
RECORDING DEPTHS:	Air, 2.5, 5, 10, 20, 40, 80 cm
FREQUENCY:	Every two weeks, year round
# YEARS:	Four years data for two stations One year data for two stations
NOTES:	Sites are located on a) poorly drained clayey soil, b) an imperfectly drained loamy soil, c) a well drained sandy soil and d) an imperfectly drained sandy soil. Data file stored on computer.

SOURCE:	Keith Jones
# STATIONS:	225, nonactive
LOCATION:	Claybelt, Northern Ontario
RECORDING DEPTHS:	10, 25, 50 cm
FREQUENCY:	One reading for each depth between June and September
# YEARS:	One reading only
NOTES:	Organic and mineral soils under forested conditions Data is available.

GREAT LAKES FOREST RESEARCH CENTRE 2.

SOURCE:	Neil Foster
# STATIONS:	3, active
LOCATION:	Turkey Lake
RECORDING DEPTHS:	Approximately 5 cm
FREQUENCY:	Continuous recording from May into November
# YEARS:	2
NOTES:	3 sites, each replicated 4 times in the forest floor of a mature sugar maple/yellow birch forest, likely to be discontinued. Data is in tabular form and is available.

SOURCE:	Neil Foster
# STATIONS:	2, nonactive
LOCATIONS:	Nipigon
RECORDING DEPTHS:	L and F Horizons
FREQUENCY:	Continuous recording from May into November
# YEARS:	3, 1978-1981
NOTES:	Sites located in a cutover stand and a mature black spruce stand. Data in tabular form and is available.

SOURCE:	Fred Havistro
# STATIONS:	3, nonactive
LOCATION:	Kennedy Township, 15 miles N.E. of Cochrane
RECORDING DEPTHS:	1-2 cm and 5 cm
FREQUENCY:	Continuous recording over growing season
# YEARS:	3, 1969-1971
NOTES:	Stations located on an uncut stand, cut over and a burn, data available.

SOURCE:	Fred Havistro
# STATIONS:	1, nonactive
LOCATION:	Weather Station, Kennedy Township
RECORDING DEPTHS:	1-2 cm and 5 cm
FREQUENCY:	Continuous recording over growing season
# YEARS:	7, 1965-1971
NOTES:	Also thermocouple stack, 0-30 cm at 3 cm intervals 8 years, data available.

GREAT LAKES FOREST RESEARCH CENTRE (cont'd) 3.

SOURCE:	Fred Havistro
# STATIONS:	?
LOCATION:	Sangster Township, 52 miles N. of Iroquois Falls
RECORDING DEPTH:	Surface 10 cm
FREQUENCY:	Continuous recording during growing season
# YEARS:	7, 1972-1978
NOTES:	Data Available.

LANDS DIRECTORATE,

ENVIRONMENT CANADA 4.

SOURCE:	Greg Wickware
# STATIONS:	250, nonactive
LOCATION:	Hudson Bay Lowlands
RECORDING DEPTHS:	10, 25, 50 cm
FREQUENCY:	1 reading only for each depth in July or August
# YEARS:	1 reading only
NOTES:	80% of samples are organic soils.

SOURCE:	Greg Wickware
# STATIONS:	29, nonactive
LOCATION;	Turkey Lake
RECORDING DEPTHS:	10, 25, 50 cm
FREQUENCY:	1 reading only for each depth in July or August
# YEARS:	1 reading only
NOTES:	All mineral soils, data is available.

ATMOSPHERIC ENVIRONMENT SERVICES 5.

# STATIONS:	11, 9 are active
LOCATION AND # YEARS:	Atikokan, 17 years Elora, 14 years Harrow, 25 years Kapuskasing, 18 years Merivale, 5 years nonactive Ottawa, Exp. Farm, 34 years Pickle Lake, 7 years Simcoe, 13 years Toronto, 12 years, nonactive Toronto, Met. Res. Stn., 16 years Vineland Stn., 14 years
RECORDING DEPTHS:	5, 10, 20, 50, 100, 250, 300 cm
FREQUENCY:	Twice daily, year round
NOTES:	Data published by Environment Canada on a quarterly basis.

UNIVERSITY OF GUELPH 6.

SOURCE:	Hugh Martin
# STATIONS:	2, nonactive
LOCATION:	Woodslee and Tilbury, Ontario
RECORDING DEPTHS:	5 cm from surface
FREQUENCY:	Every hour, continuous recording, May 27 to June 13, 1981
# YEARS:	16 days
NOTES:	Both sites on Brookston clay Stations placed in no-till, conventional, and ridge tillage plots.

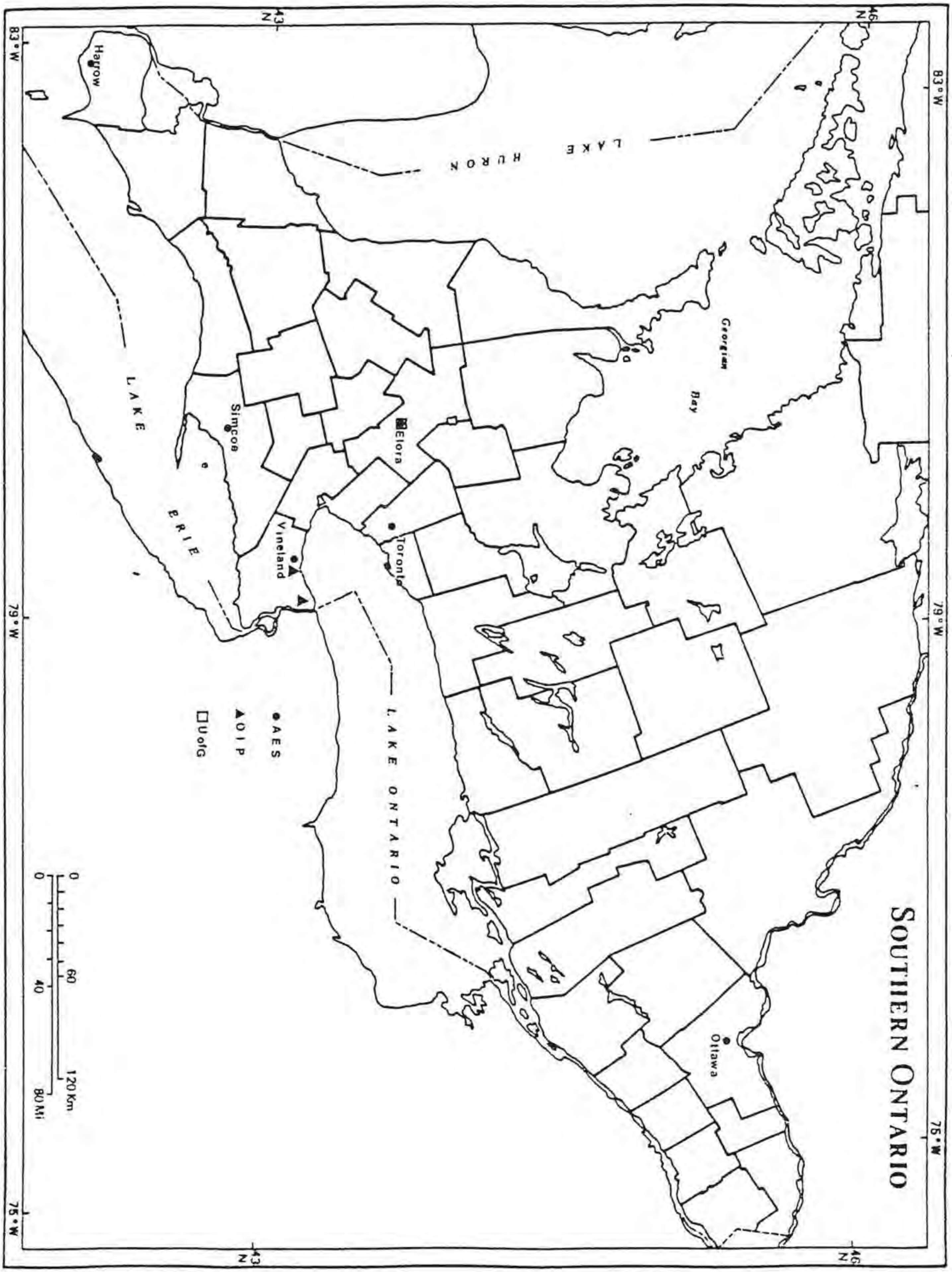
SOURCE:	Cam Grant
# STATIONS:	2, nonactive
LOCATION:	Elora and Milton
RECORDING DEPTHS:	0 to 60 cm at 5 cm intervals
FREQUENCY:	Once a week, December to April
# YEARS:	2
NOTES:	Sites located in zero and conventional tillage plots silt loam and silty clay and clay soils data is available.

SOURCE:	J. van Roestel
# STATIONS:	1, nonactive
LOCATION:	Elora
RECORDING DEPTH:	5 cm
FREQUENCY:	Every hour continuous recording from May 28 to June 30
# YEARS:	1 year
NOTES:	Temperatures taken in different tillage plots with varying amounts of residue cover, results to be published in thesis.

SOURCE:	Jack Ketcheson
# STATIONS;	Several, nonactive
LOCATION:	Puslinch Field, Hydrology Field, U. of G., Elora
RECORDING DEPTH:	5 cm
FREQUENCY:	Every hour, continuous recording over growing season
# YEARS:	1
NOTES:	Stations located on tillage plots.

UNIVERSITY OF GUELPH (cont'd) 7.

SOURCE:	Graham Walker
# STATIONS:	1, active
LOCATION:	Cambridge Res. Stn.
RECORDING DEPTH:	2.5, 10, 20 cm
FREQUENCY:	Every hour, continuous recording May to September
# YEARS:	1
NOTES:	Sandy soils, corn growth plots.


SOUTHERN ONTARIO
LAKE HURON
Georgian Bay
LAKE ERIE
LAKE ONTARIO
Harrow
Simcoe
Elora
Vineland
Toronto
Ottawa
AES
OIP
UofG
0
60
120 Km
0
40
80 Mi
83°W
79°W
75°W
43°N
46°N


NORTHERN ONTARIO
MANITOBA
JAMES
BAY
QUEBEC
PICKLE LAKE
KENORA
FORT FRANCES
Atikokan
FORT WILLIAM
HEARST
Kapuskasing
COCHRANE
TIMMINS
KIRKLAND LAKE
NEW LISKEARD
SUDBURY
NORTH BAY
SAULT STE MARIE
MINNESOTA
LAKE SUPERIOR
MICHIGAN
MILES

●AES

REGIONAL PROGRESS REPORT - QUEBEC

R. Baril*

The measurement of soil temperature in Quebec currently involves 10 monitoring sites including a new site established in 1983. Other research activities related to soil climate studies in Quebec are:

- a graduate study (Ph.D) program on soil climate,
- a program to study frost heave in alfalfa as related to macroclimate,
- a comparison of macroclimate properties with the Provincial Soil Family Map using overlay techniques,
- a statistical comparison of mean soil temperature values determined from monthly means and from monthly values determined from single readings taken on the fifteenth day of selected months. (Preliminary evaluation of this analysis is presented in this Proceedings).

Nova Scotia Progress Report 1983-84

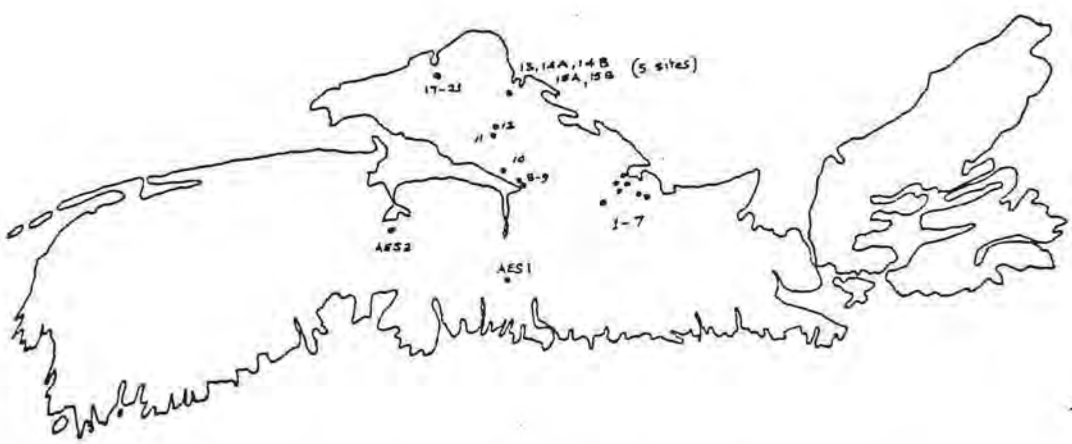
K. T. Webb

Since the last meeting of the Soil Climate Subcommittee in Victoria the Canada-Nova Scotia Soil Survey has expanded its temperature site network from 14 to 24 sites.

Sites 1 - 9 (Fig. 1) have been in operation since 1981. Sites 10 - 13, 14A and 15A were established in the spring of 1982. Sites 14B, 15B, 17 - 21, AES1 and AES2 were established in the fall of 1982.

Fig. 1

NOVA SCOTIA SOIL TEMPERATURE SITES
1981 - 1983



No new sites were established in field season 1983 due to equipment supply problems.

Methodology

The use of diodes in Nova Scotia to measure soil temperature has been described by Webb and Langille (1982) in a report to the Soil Climate Subcommittee. The following is a summary of the information presented in that report.

The Canada-Nova Scotia Soil Survey (C-NSSS) uses FD300 silicon diodes as soil temperature sensors. These diodes are soldered to wires and encased in epoxy resin for protection from moisture and abrasion (Fig. 2).

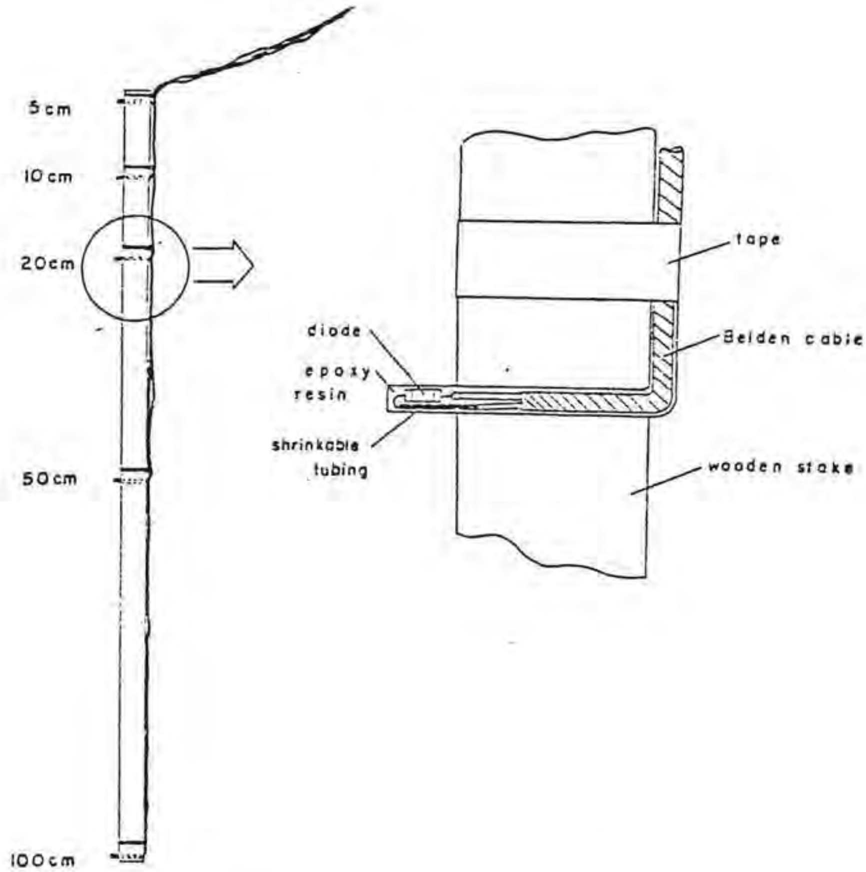


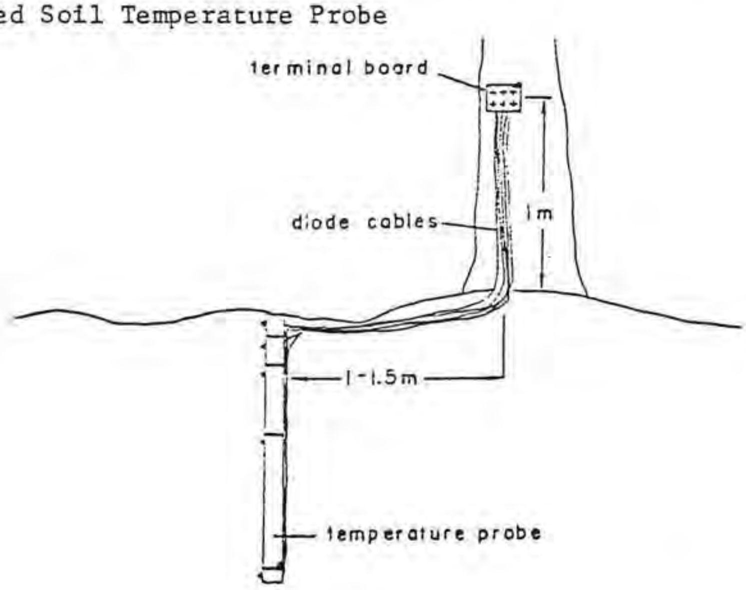
Fig.2 The Soil Temperature Probe

The diodes and wires are then mounted on a wooden stake at 5, 10, 20, 50 and 100 cm and taped in place. This assembly is called a soil temperature probe.

The temperature probe is buried in the soil by placing it in an augered hole or, in stony soils, by digging a pit and burying the probe in place.

The wires are run 1 - 1.5 m underground and are secured above ground to a stake or tree trunk (Fig. 3).

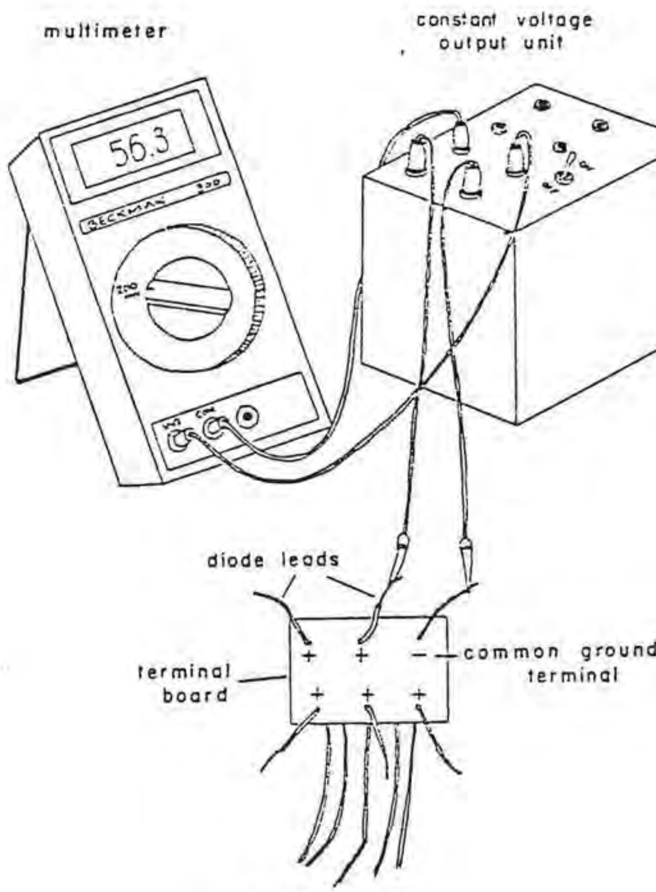
Fig. 3 Installed Soil Temperature Probe



The wire leads from each diode are arranged on a terminal board where they can be assessed for monitoring.

The leads of each diode are connected to a constant voltage output unit which in turn is connected to a multimeter which reads out in millivolts (Fig. 4).

Fig. 4 Soil Temperature Monitoring Equipment



The read out in millivolts (mV) is recorded for each diode on the data sheet for that site along with the date, weather, time, air temperature, and water table readings if the site has wells (Fig. 5).

Fig. 5 Nova Scotia Soil Temperature Data Sheet

Site No.: NSST 5
UTM: 20T NF 1310 4670

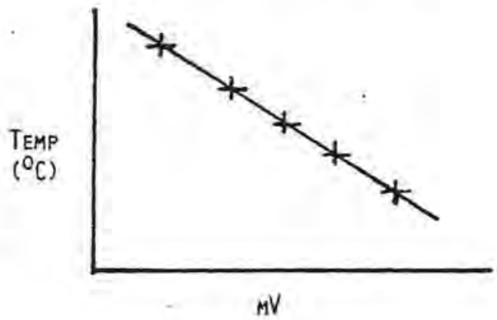
Location: West River, Pictou County
Soil: coarse loamy well drained Pugwash

				Depth (cm)		5		10		20		50		100	
Date	Weather	Sample Time	Air Temp.	diode #		159		160		161		162		163	
				Watertable long	Watertable short	mV	°C	mV	°C	mV	°C	mV	°C	mV	°C
14/6/82	Rain	11:34	14°C	----	----	51.5	6.6	56.4	5.6	60.1	5.0	59.6	4.1	68.3	4.3
22/6/82	Sunny	10:50	19°C	----	----	44.1	10.5	51.3	8.5	54.7	7.9	57.4	5.3	67.5	4.7
28/6/82	Overcast	10:32	21°C	----	----	45.7	9.7	51.5	8.4	53.6	8.4	55.2	6.6	64.9	6.1
05/7/82	Sunny	10:56	21°C	----	----	45.7	9.7	52.2	8.0	54.4	8.0	55.8	6.2	65.5	5.8

The soil temperature is calculated from the mV readings back at the office using regression equations that express the inverse linear relationship between °C and mV (Fig. 6).

Fig. 6. Example of the regression equation for Diode #159

FOR DIODE # 159, $T(^{o}C)=34.038 - 0.533x \quad x=mV$



These equations have been derived for each diode after it has been calibrated. Each diode has to be calibrated and each has its own equation. Computer programs are used to determine the regression equations and to solve them.

After several months of data collection, temperature values are transferred from the data sheet to a Soil Temperature Record for storage and distribution (TABLE 1).

TABLE 1. Nova Scotia Soil Temperature Record

Site #: NSST7 — Site Name: Moderately well drained upper Mt. Thom, Pictou Co.

Location: UTM 20T NF 0253 3985 — Soil Name: Thom

Established: 15/06/81 — Land Use: Productive woodland

Year	Month	Day	Day No.	Air temp C°	5	10	20	50	100
1981	6	15	166				8.5	7.4	7.1
1981	6	25	176				10.3	8.4	7.2
1981	7	17	198				11.4	9.6	9.0
1981	7	30	212				11.6	10.5	9.8
1981	8	17	229				14.5	11.1	10.2
1981	9	3	246				12.0	10.5	10.1
1981	10	9	282				7.7	8.0	8.8
1981	10	23	296				7.9	7.2	8.1
1981	11	5	309				4.4	5.7	7.6
1981	11	20	324				4.6	7.4	6.6
1981	12	3	337				2.2	3.1	5.4
1981	12	14	348				1.4	3.3	5.3
1982	1	7	7				-0.2	0.5	2.8
1982	1	21	21				0.4	1.3	3.3
1982	2	4	35				-0.9	-0.7	1.4
1982	2	18	49				-0.2	0.6	3.4
1982	3	4	63				-0.5	0.3	3.4
1982	3	18	77				-0.9	-0.3	1.5
1982	4	1	91				-1.1	-0.6	1.2
1982	6	9	160	20	6.6	3.7	4.1	0.3	0.8
1982	6	14	165	10	4.9	3.1	4.0	0.5	0.2
1982	6	22	173	16	9.0	6.2	7.1	1.7	1.7
1982	6	28	179	21	8.9	7.4	7.8	3.6	3.5
1982	7	5	186	19	8.1	6.4	7.0	3.1	3.3
1982	7	19	200	26	13.9	11.9	10.6	5.1	4.3
1982	7	26	207	23	12.3	11.5	11.3	6.6	6.4

After 2 - 3 years data has been collected, monthly averages at the various depths are calculated and presented in tabular form (TABLE 2).

TABLE 2. Nova Scotia Average Soil Temperature (Deg C)
1981 - 1983

Site #: NSST 2 Soil: Poorly Drained Joggins
Elevation: 60 m Land Use: Abandoned Farmland

DEPTH CM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
5	-2.0	-1.6	8.6		12.5	13.0	19.7	17.7	15.8	9.6	-1.0	-2.0
10	-1.3					12.0	17.0	16.7	15.9	9.8	1.7	0.7
20	-1.5	-2.1	-1.1	1.2	10.1	12.8	16.8	17.4	15.2	10.3	4.3	1.9
50	0.6	-0.3	3.0	3.0	9.7	12.3	16.2	17.2	15.6	11.5	6.6	4.4
100	0.6	0.8	0.1	1.6	7.1	9.9	13.8	14.9	15.1	12.5	8.6	6.3

Site #: NSST 3 Soil: Poorly Drained Pugwash
Elevation: 15 m Land Use: Black Spruce Forest

DEPTH CM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
5	-4.4	-4.5	-3.3		4.7	6.9	12.0	11.7	12.3	6.6	-0.8	-1.8
10	-2.5	-2.7	-2.7		4.5	4.4	10.4	11.9	11.5	6.4	2.1	0.9
20	1.4	0.5	-0.7	1.1	3.9	10.5	12.4	14.5	11.7	9.3	6.4	4.3
50	1.5	-0.4	-0.7	-0.2	3.6	6.0	8.8	10.0	10.2	8.1	5.9	4.2
100	6.2	2.4	0.9	1.4	4.1	5.9	8.6	10.2	10.2	9.1	7.4	6.2

Proposed Methodology Modifications

Preliminary data comparing readings from the soil temperature probe or staked diodes versus non staked diodes at the same site, gave some cause for concern as to the best method of diode installation (TABLE 3).

TABLE 3. COMPARISON OF STAKED AND NON STAKED DIODE
MONTHLY TEMPERATURE AVERAGES @ 50 CM.
1982 - 1983

NSST 14A STAKED

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
4.8	2.5	5.3	---	6.4	11.2	10.8	12.6	12.0	7.8	9.1	8.0

NSST 14B NON-STAKED

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1.5	-0.9	---	---	9.0	13.7	14.1	14.6	14.2	8.7	6.0	4.5

Staked diodes gave warmer readings than non staked diodes from late fall to late winter and cooler readings through the warmer parts of the year.

Due to the problems incurred with installing staked diodes into stony soils by augering, probe frost heaving, and the adverse affects of wooden stakes on temperature readings, future temperature site installations in Nova Scotia will utilize non staked or "free" diodes.

"Free" diodes are inserted 10 cm into the upslope face of a soil pit at the appropriate depths. An effort is made to backfill soil materials to their original depth and density.

Future Plans

The Canada-Nova Scotia Soil Survey plans to:-

- expand its soil temperature site network to other AES sites.
- expand to other major soil types in the southern regions of the province.
- expand the network to important agricultural soils.

REFERENCE

Webb, K.T. and D.R. Langille, 1982 Soil Temperature Monitoring In Nova Scotia. Canada-Nova Scotia Soil Survey, Truro, Nova Scotia. Unpublished report to the Soil Climate Subcommittee of the Expert Committee On Soil Survey.

Report on Soil Climate Monitoring Activities in New Brunswick
to the
Soil Climate Working Group of the Expert Committee on Soil Survey
November, 1983

H. Rees - Atlantic Soil Survey Unit

As of November, 1983, there are 29 soil temperature monitoring sites in New Brunswick. Those agencies involved include Environment Canada's Atmospheric Environment Service, Agriculture Canada's Research Station and Agriculture Canada's L.R.R.I. New Brunswick Soil Survey Unit.

The Atmospheric Environment Service is presently operating three (3) stations which collect soil temperatures in addition to standard atmospheric data. Records date from 1958, 1981 and 1982. Type of equipment, soil depths and frequency of readings are consistent with AES practices. Equipment consists of A.E.S. Remote Temperature Indicator with Thermister and balancing resistor. Depths are 5, 10, 20, 50, 100, 150 and 300 centimeters. All depths are read in the morning and the 5, 10 and 20 cm depths are read again in the afternoon. The data is recorded on a standard Monthly Record/Soil Temperature form.

A research site consisting of a topo-sequence with four (4) individual stations has been monitored by Agriculture Canada Research Station personnel since 1980. Sensors consist of FD 300 diodes installed at depths of 2, 5, 10, 20, 30, 50, 70 and 90 cm and nylon cell temperature sensors at 5, 10, 20 and 30 cm. Frequency of readings is variable, from continuous to seasonally. A dip well for monitoring watertable levels is associated with each station.

During 1982, L.R.R.I.'s New Brunswick Soil Survey Unit established 21 new sites in western central and south eastern New Brunswick. Site selection was based on van Groenewoud's climatic regions of New Brunswick (van Groenewoud, 1983). Other site criteria included parent material particle size distribution, drainage and proximity to a permanent weather station. Each site consists of six FD 300 silican diodes located at 5, 10, 20, 50 and 100 cm depths and the center of the forest floor, and a dip well (1 1/2" diameter). Readings are taken monthly. Two sites have been vandalized.

In 1983, one additional site was installed by the L.R.R.I. Soil Survey Unit in cooperation with the Atmospheric Environment Service. Soil survey unit personnel installed the sensors at an established AES station and provided the monitoring equipment. AES observers are recording the readings. If this arrangement proves satisfactory and other suitable AES stations are available, similar cooperative sites may be established in the future. Monitoring equipment consists of a multimeter ($100-150) and a constant voltage output unit (cost of components approximately $70-75) for a total cost of $200.

Appended information

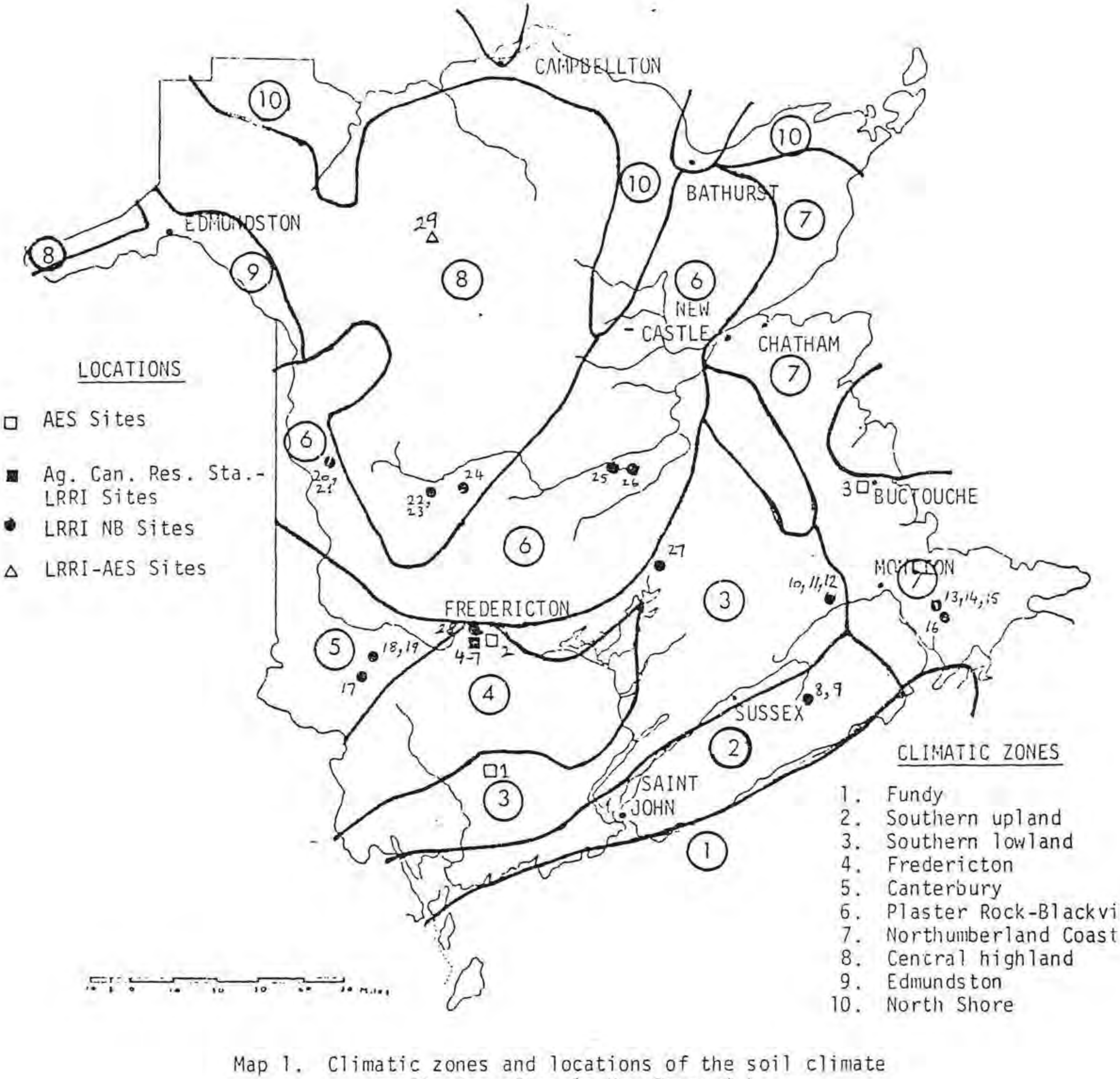
1. Map of N.B. showing soil climate monitoring site locations.

2. Table summarizing N.B. soil climate monitoring sites.

References: van Groenewoud, H. 1983. Summary of Climatic Data Pertaining to the Climatic Regions of New Brunswick. Information Report M-X-146, Maritime Forest Research Centre, Canadian Forestry Service, P.O. Box 4000, Fredericton, New Brunswick. 70 p.

Table 1. Active Soil Temperature Sites in New Brunswick

Site No's.	Responsible Agency	Dates Established	Type of Sensors	Sensor Depths (cm)	Frequency of Observations	Land Use
1-3	Atmospheric Environment Service (AES)	1958, 1981, 1982	thermister	5, 10, 20, 50, 100, 150, 300	twice daily	agriculture
4-7	Agriculture Canada Research Station-L.R.R.I.	1980	FD-300 diode	2, 5, 10, 20, 30, 50, 70, 90	variable	agriculture
			Nylon cell	5, 10, 20, 30		
8-28	Agriculture Canada-L.R.R.I.	1981	FD-300 diode	org. layer, 5, 10, 20, 50, 100	monthly	forestry
29	L.R.R.I.-AES	1982	FD-300 diode	org. layer, 5, 10, 20, 50, 100	monthly	forestry



Map 1. Climatic zones and locations of the soil climate monitoring sites in New Brunswick

REPORT ON THE SOIL TEMPERATURE MONITORING IN THE NORTHWEST TERRITORIES

Charles Tarnocai

A soil temperature study is being carried out in the Inuvik area by the Land Resource Research Institute in cooperation with the Department of Indian and Northern Affairs. This study has now been in progress for five years and it is planned to be continued with major repairs to the equipment to be carried out in the summer of 1984. The data accumulated during the first half of this five-year period has been evaluated and is to be published in the book *Northern Ecology and Resources Management*. Some of this information has been presented at the Soil Climate Working Group meeting in November of 1983 and is included elsewhere in these proceedings.

The A.E.S. soil temperature sites will continue to be monitored. The data collected from these sites are to be published in the A.E.S. climatic summaries.

A long-term soil temperature monitoring study is planned by E.M.R. and I.N.A.C. in conjunction with the Norman Wells-Zama oil pipeline in order to assess the effects of the pipeline on the soil temperatures within areas of discontinuous and sporadic permafrost terrain. The objectives of the study are as follow:

A monitoring program should seek to:

1. Assess the short and long term modifications to the active layer, permafrost and stability of the alignment area resulting from both development and natural climatic changes, and identify improvements which may be made in alignment selection, land stabilization and restoration.

2. Assess the thermal disturbance caused by the pipeline installation and operation.

3. Assess the ground disturbance caused by pipeline installation and operation.

4. Monitor the thermal regime of the natural setting.

5. Monitor the thermal regime of the cleared right of way.

To achieve the above requires:

1. A long term program to collect data on the thermal regime of both the natural setting and the cleared right of way at selected sites.

2. A long term program to collect data on water distribution and movement in the active layer and below and on distribution and redistribution of ground ice.

3. A long term program to monitor micro-climate at selected sites along the right of way.

4. A long term program to monitor snow distribution at selected sites.

5. A long term program to measure surface modifications and long term revegetation of the right of way at selected sites.

6. A long term program for the detailed mapping of the vegetation cover in and around the selected sites.

7. A program for detailed mapping and measurement of the physical characteristics of the surficial material in and around the selected sites.

During this project to monitor soil temperatures multi-thermistor cables will be used. These thermistor cables will be installed in small diameter PVC pipes filled with a non-freezing liquid. A minimum of one set of readings a month will be taken at each site. Twelve areas, on various representative terrain types, have been selected in the vicinity of the N.W.T. portion of the pipeline. Soil temperatures will be monitored at a number of sites in these 12 areas. Thermistor cables will be installed in approximately half of these sites during the winter of 1984 with the remainder to be installed in the winter of 1985.

In addition to these soil temperature studies, ground temperatures are being continuously monitored by E.M.R. at a number of sites throughout the north. On these sites temperatures are collected at greater depths and, in most cases, the near surface of the soil is not being monitored.

Soil temperatures are also being collected by Dr. Ross Mackay on a year-round basis at several sites in the Mackenzie Delta area. One of his major study areas is the Illisarvik site, located on Richards Island in the Mackenzie Delta. The soil temperatures at these sites are collected for permafrost studies.

Yukon - S. Smith

At present there is no systematic collection of soil climate data in the Yukon. The establishment of a Yukon Soil Survey Unit makes it feasible to implement a territory-wide soil climate network. Initially, 10-12 stations in five geographic locations are planned for installation in 1984 (figure 1). Co-operators are being contacted to monitor sites in outlying regions. Future additions to the network are anticipated.

Thermistors are being used for temperature data collection and in some permafrost free areas frost tubes are also being utilized. A number of methods for moisture determination are being considered for the Whitehorse sites. Each station in the network will be linked to an existing AES weather station. At present AES measures soil temperature only at the Whitehorse airport. The distribution of soil climate stations is designed to cover both subarctic and northern boreal regions of the territory.

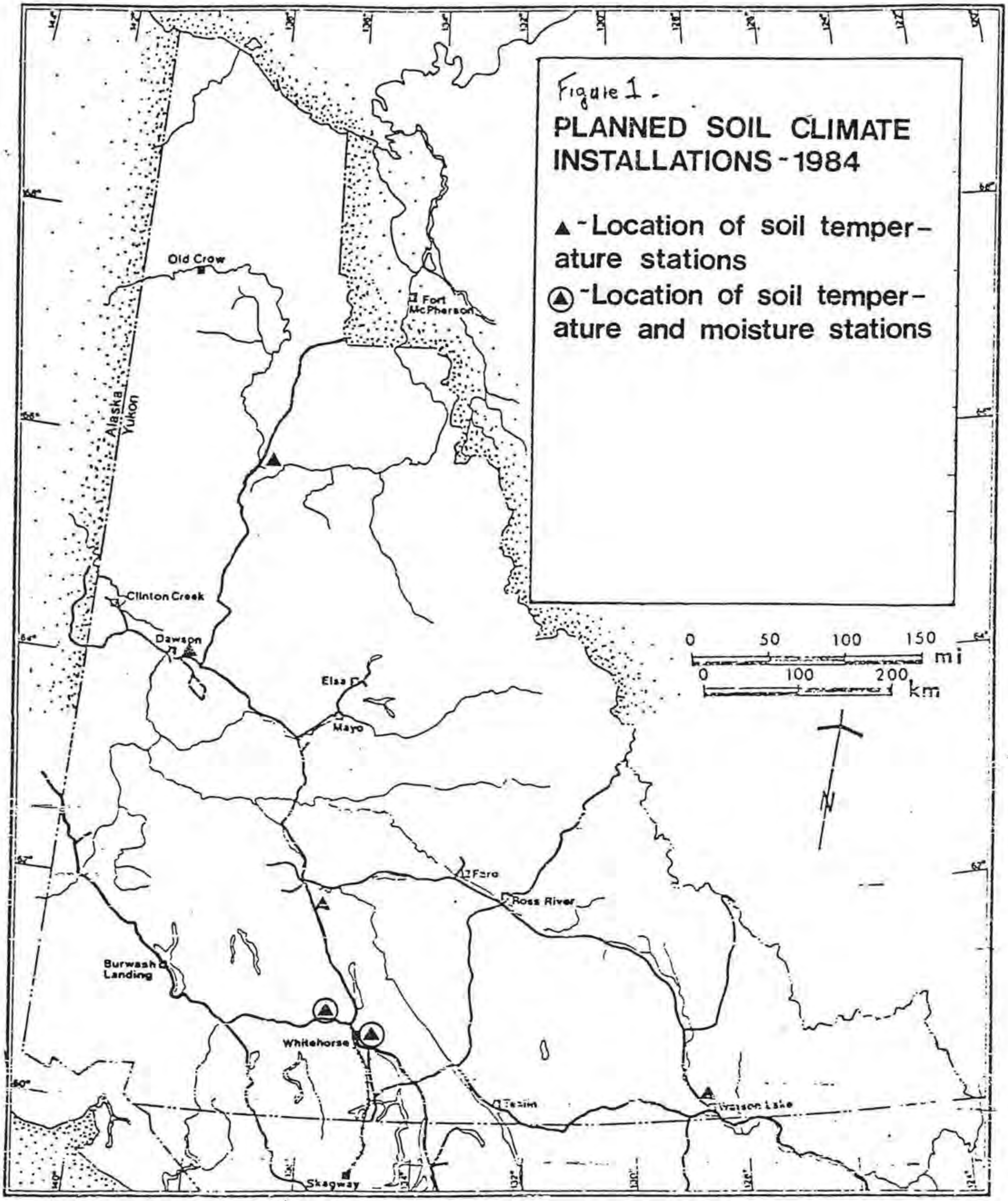


Figure 1.
PLANNED SOIL CLIMATE INSTALLATIONS - 1984

DATA HANDLING CONCERNS

The Monitoring Relation
of CanSIS

By: B. Lacelle
K.B. MacDonald

Table of Contents

Reports

Purpose

This paper summarizes a discussion presented to the Soil Climate Working Group of the ECSS at the Workshop, Nov/83. It illustrates the data management procedures currently in place in CanSIS to input, store and manipulate monitoring or time series data such as soil temperature observations. This capability has been developed in association with the Soil Data (Detail) File. A highly flexible input data format has been developed.

The procedures were tested and illustrated with soil temperature data for four sites in Manitoba. In the course of the testing, programs were developed to emulate data manipulation capabilites in place in Manitoba. These programs, indicated as desirable by the Soil Climate Working Group, were developed in a generalized fashion using SAS (Statistical Analysis System) as the programming language. As a consequence they should be easy to transfer to other installations and easy for a user to understand and modify.

The following programs have been developed:

MT02REP1-A program to print out a detailed listing of soil temperature data. Corresponds to TEMPDETAIL in Manitoba package.

MT02REP2-A program to process and graph soil temperature data. Corresponds to TEMPGRAPH in Manitoba package.

MT02RP3A and MT02RP3B-A program to calculate and display thermal values derived from the observed data Corresponds to TEMPCOFE in Manitoba package.

Introduction to the Soil Data File of CanSIS

The Soil Data File of CanSIS is part of a national computerized information system which contains data on soils and related resources. Detailed environmental, morphological, chemical and physical aspects of representative soil profiles are described. This file has been organized into four relations in RAPID, the data base management system developed by Statistics Canada. The first being site, the second morphological, chemical, physical, mineralogical and special data, the third notes and the final time series data.

The fourth relation in the Soil Data File, MT02 or the monitoring relation, has been established so that observations of specific variables, measured as a function of time, can be recorded. It can be used to store observations of cyclic properties of the soil profile such as temperature, frost depth, moisture content, water table levels etc. It is possible to record progressive changes (e.g. organic matter loss, phosphate build-up). In short, the monitoring relation has the capability to record, over time, any property related to specific depths or horizons which can be characterized on the soil data (detail-green and gold) forms. In addition, it can be used for associated properties such as air temperature, weather conditions and for most soil properties not accomodated within the Soil Data (Detail) File format.

The data are keyed in a computerized format and are loaded directly into the monitoring relation to ensure standardization of format for storage. In this form they may be directly accessed on-line for a quick sample look at the data. Alternatively, selected portions of the data can be selected and reformatted using programs written with generalized software. Programs have been written to carry out statistical manipulations and produce reports to specifications of the soil climate working group. Because of the direct flow of data, relatively rapid turn-around times can be achived.

Since it is defined within the context of the Soil Data (Detail) File, all data can be related back to the detailed profile descriptions for combined manipulation.

In this report, data handling procedures associated with MT02 are described in the first segment and the specific applications to soil temperature data are presented in the latter half with listings. Example output is found in the reports section.

A QUICK SAMPLE LOOK AT DATA IN THE SOIL DATA FILE

SDOI

DUMMYKEY	LOCUTMGB	LOCEAST	LOCNORTH	SLPCLS	CLASSDP	AGCLIGB
01720017211				2-5	0.GL	
01720036503	13UFJ	3650	4330	0.5-2	CA.DG	
01730033202	11UNH	3550	0560	6-9	GLCU.R	
01740004212				2-5	DU.HFP	
01740054202	11UNH	1755	0655	2-5	0.HFP	
01750007612				BLANK	0.R	
01750010612				0-0.5	0.HG	2W
01750100202	11UNG	4325	8135	10-15	0.HFP	
01750101202	11UNG	3340	9260	46-70	CU.R	
01750102202	11UNG	4520	9625	31-45	E.EB	
01750333102				6-9	SZ.DG	2C
01750334102				2-5	E.EB	2C
01750335102				2-5	E.BL	2C
01750336102				2-5	0.GL	
01750337102				16-30	BR.GL	6PT
01770004612				0-0.5	0.R	
01781667211				6-9	0.DG	
01782767211				31-45	0.R	
01782768211				BLANK	T.M	
01782769211				2-5	GLCU.R	

SD02

NUMBR	GLBLHORZ			DEPTHUP	DEPTHLO	PTY	PTYMD	QUANTOBS	QUALOBS
01	L			5	0	ROOT	ABUND	-100	ABUNDANT
01	L			5	0	ROOT	SIZE	-100	MEDIUM
01	L			5	0	VON-POST-SCALE		-100	01
02	A	HE		0	4	COLOUR	ASPECT1	-100	MATRIX MOIST
02	A	HE		0	4	COLOUR	VALUE1	-100	10YR3020
02	A	HE		0	4	CONSISTENCE	WET	-100	SLIGHTLY STICKY
02	A	HE		0	4	EFFERVESCENCE		-100	
02	A	HE		0	4	ROOT	ABUND	-100	ABUNDANT
02	A	HE		0	4	ROOT	ORIENTN	-100	OBLIQUE
02	A	HE		0	4	ROOT	SIZE	-100	FINE
02	A	HE		0	4	TEXTURE		-100	LOAM
03	C		1	4	7	COARSE-FRAGMENTS	KIND1	-100	GRAVELLY
03	C		1	4	7	COARSE-FRAGMENTS	VOLUME	-100	10%
03	C		1	4	7	COLOUR	ASPECT1	-100	MATRIX MOIST
03	C		1	4	7	COLOUR	VALUE1	-100	050Y 4025
03	C		1	4	7	EFFERVESCENCE		-100	
03	C		1	4	7	ROOT	ABUND	-100	PLENTIFUL
03	C		1	4	7	ROOT	ORIENTN	-100	OBLIQUE
03	C		1	4	7	ROOT	SIZE	-100	FINE
03	C		1	4	7	STRUCT-PRIMARY	KIND1	-100	MASSIVE
03	C		1	4	7	TEXTURE		-100	CLAY LOAM
04	C	GZ	2	7	51	COARSE-FRAGMENTS	KIND1	-100	GRAVELLY
04	C	GZ	2	7	51	COARSE-FRAGMENTS	VOLUME	-100	10%
04	C	GZ	2	7	51	COLOUR	ASPECT1	-100	MATRIX MOIST
04	C	GZ	2	7	51	COLOUR	VALUE1	-100	050Y 4025
04	C	GZ	2	7	51	CONSISTENCE	WET	-100	STICKY
04	C	GZ	2	7	51	EFFERVESCENCE		-100	
04	C	GZ	2	7	51	PH	FIELD	-100	SL ACID
04	C	GZ	2	7	51	ROOT	ABUND	-100	VERY FEW
04	C	GZ	2	7	51	ROOT	SIZE	-100	FINE
04	C	GZ	2	7	51	STRUCT-PRIMARY	KINDMOD	-100	BEDDED
04	C	GZ	2	7	51	STRUCT-PRIMARY	KIND1	-100	MASSIVE
04	C	GZ	2	7	51	TEXTURE		-100	LOAM

SDO2

```
NUMBR   GLBLHORZ          DEPTHUP        DEPTHLO PTY            PTYND        QUANTUPS UNITS   QUALOBS
--------------------------------------------------------------------------------------------------
04        C  GZ   2              7             51 PARTICLE-SIZE  SAND-F          1300 WT-PCT
04        C  GZ   2              7             51 PARTICLE-SIZE  SAND-M           500 WT-PCT
04        C  GZ   2              7             51 PARTICLE-SIZE  SAND-VC          500 WT-PCT
04        C  GZ   2              7             51 PARTICLE-SIZE  SAND-VF         1300 WT-PCT
04        C  GZ   2              7             51 PARTICLE-SIZE  SANDTOT         4200 WT-PCT
04        C  GZ   2              7             51 PARTICLE-SIZE  SILT-50         4000 WT-PCT
04        C  GZ   2              7             51 PH             VALUE2           410
          1000 ROWS, NO HITS
          2000 ROWS, NO HITS
          3000 ROWS, NO HITS
          4000 ROWS, NO HITS
          5000 ROWS, NO HITS
          6000 ROWS, NO HITS
(RETRIEVAL COMPLETE)
ENTER 'END' OR NEXT REQUEST
?:
```

Data Handling Procedures

The following discussion will describe data input and handling procedures associated with the monitoring relation.

Input Form-General Form

The input form contains many areas of flexibility to allow the user to adapt it to his requirements. Two areas of the form are fixed; namely columns 1-14 and columns 25-46. The former contain a header key, identical in form and information content to the soil data (detail-green and gold forms) records. The latter, columns 25-46, record the property being measured, (column 25-40) the number of lines in which the property has occured (column 41-42) and sample depth (column 43-46) the upper or actual sampling depth in centimeters. In general, it is set up so that each monitoring observation requires one line on the form.

Table #1 gives the complete record layout and illustrates the areas in which options exist. A seperate line on the input data form is necessary for each option required. The fields indicated with an asterisk are those which would normally be used for routine monitoring. The remaining fields represent items which tend to be more constant such as global horizon designation, methods of analysis etc. The monitoring input form provides a format where these options can be added to the records to provide a complete detailed description, if desired.

Soil Temperature Input Form

The input document used to capture the soil temperature data collected by the Manitoba Soil Survey Unit, is shown in Table #2. Soil temperature data for seven depths plus air temperature, snow depth and weather conditions were observed on a regular basis over a number of years.

Developing an Input Form

When designing an input form for the monitoring relation of CanSIS, please follow the steps outlined below.

Step1: Go to Table #1 and decide which fields are required. The fields marked with an asterisk are those which are normally used for routine monitoring.

Step2: Look at Table #2 (example input form for soil temperature data) and Table #3 to get an idea of the format required.

Step3: The information contained in columns 1-24 pertains to each visit to the site. Because of this, we do not have to repeat it for each observation taken at that particular time. Table #2 illustrates the design. If you are recording global horizon designation, HOUR, DDMM and MNTRYR cannot be recorded.

Step4: Place field headings and insert your property names.
e.g. Table #2 WEATHER
AIR-TEMP etc

Step5: Make field choices according to the data being recorded The choices are listed in Table #1.
i.e If you are recording soil temperature data or water table depths, you will require a QUANTOBS and a UNITS field in columns 47-62 because the resulting observation will be numeric.

Step6: NUMBR is an important field and should be designed with care. Each observation must have a unique number assigned to it. For example, in Table #2, number 30 is associated with weather, which is a site description, while 02 corresponds to soil temperature at the second depth, 5 cm.

Step7: Make sure that you print in as much of the information as you can so that, when you are out in the field, you only have to record the data that changes consistently such as site, time and quantitative observation.

Step8: If you want to record a comment, that is associated with a specific observation, just insert another line on your form that has the same PTY, NUMBR and DEPTHUP.

Step9: Once an input form is complete and before using it to collect data, please send a copy to CanSIS for verification.

CanSIS: Monitoring File
Land Resource Research Institute
Institut de Recherche sur les Terres
Central Experimental Farm
Ferme Experimentale Centrale
Ottawa, Ontario
Canada
K1A 0C6

ATTN: B.Lacelle

TABLE #1 Input Data Format to the Monitoring Relation of CanSIS

Columns 1-14:Equivalent to the key found in the Soil Data File (Detail-green and gold forms). The definitions for these fields and some properties can be found in the Manual for Describing Soils in the Field.

FIELD NAME	COLUMNS	COMMENT
* PROVINCE	1-2	Province
* YEAR	3-4	Year of site description
* PROFID	5-8	Profile ID number
* UNIT	9	Survey Unit
* LAB	10-11	Regional Lab
* SOLSERCD	12-14	Soil Series Code

Columns 15-24:Two choices of input.
Choice #1

* HOUR	15-18	Time of Observation
* DDMM	19-22	Day and Month of Observation
* MNTRYR	23-24	Year of Observation

Choice #2

GLBLHORZ	15-24	Global Horizon Designation

Columns 25-46:Mandatory input.

* PTY	25-40	Property being observed
* NUMBR	41-42	Number of lines in which the property has occured.
* DEPTHUP	43-46	Sampling Depth or Upper Depth

Columns 47-62:Six choices of input. Note: The field QUANTOBS is numeric with 2 decimal places.
Choice #1

* QUANTOBS	47-53	Quantitative value of the property observed. e.g. Soil Temp
* UNITS	55-62	Units associated

Choice #2

QUALOBS	47-62	Qualitative value of the property observed. e.g. Weather conditions

Choice #3

MTHD1	47-62	Method of sample preparation and analysis (description #1).

Choice #4

MTHD2	47-62	Method of sample preparation and analysis (description #2).

Choice #5

MTHD3	47-62	Method of sample preparation and analysis (description #3).

Choice #6

COMMENT	47-78	Comment

Note: If inputting a comment in columns 47-78, the fields for columns 63-78 listed below cannot be accomodated.

Columns 63-78:Two choices of input. These fields are not usually required.

Choice #1

DEPTHLO	63-66	Lower Depth
PTYMD	67-73	Property modifier
REMOVALS	74-77	Removals for sample preparation. See documentation on SD02 for input codes.

Choice #2

ANALCLS	63-78	Analytical Class description

Agriculture Canada

DATA RECORDS
ENREGISTREMENT D'INFORMATION

Table #2

SOIL TEMPERATURE INPUT DOCUMENT
FOR MANITOBA

PROV	YEAR	PROF I.D #	UNIT	LTD	SOIL SERIES CODE	HOUR	DAY	MTH	MON. YEAR
04			1	04					

	PROPERTY	NO	SAMPLING DEPTH	OBSERVATIONS	UNITS
1	WEATHER	30			
2	AIR-TEMP	31			C
3	SNØW-DEPTH	32			CM
4	SØIL-TEMP	01	3		C
5		02	5		C
6		03	10		C
7		04	20		C
8		05	50		C
9		06	100		C
10		07	150		C

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TABLE #3

INPUT DOCUMENT - OPTIONS

PROV | YEAR | PROFILE ID # | 1-3 | LAB | SOIL SERIES CODE

HOUR | DAY | MTH | YR

GLOBAL HORIZON DESIGNATION

PROPERTY

NO. | SAMPLING DEPTH

QUANTITATIVE OBS. | UNITS

QUALITATIVE OBS

DEPTH (LOWER) | PROPERTY MODIFIER | REMOVALS

METHOD OF ANALYSIS 1

ANALYTICAL CLASS

METHOD OF ANALYSIS 2

METHOD OF ANALYSIS 3

COMMENT

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Definition to Computer

Once the data is collected on the input form and keyed it is loaded into the monitoring relation, MT02. Prior to being loaded, the file is split into separate members according to NUMBR (i.e. if there are two or more types of fields in the same columns). If you look at Table #2 again, you will notice that the property weather, number 30, is associated with a qualitative observation and the other properties are all related to quantitative observations. Therefore before loading this data, a split was done which placed all records with a number of 30 into one file and the remaining records into another. The two files were then loaded one at a time and the fields contained in each file were specified to the computer as the data were loaded.

Instead of loading the data into the monitoring relation, it is possible to write the files, produced above, to a disk or tape. These can then be defined immediately to SPSS or SAS (Statistical Package for the Social Sciences or Statistical Analysis System respectively). This type of procedure would be done in the case of inconsistency with the required format of the monitoring relation or when data storage is not important.

Standard Format of the Monitoring Relation

The monitoring relation stores time series data in a standardized format. Each observation is a record and each field described in Table #1 is a part of that record. This means for example that the property soil temperature at a depth of 5 cm, at a specific time of day, at a specific site etc is a record. While this format facilitates the recording and storage of all types of data, it may not be the best for interpretation. Standard software packages (e.g. SAS and EASYTRIEVE) are available to manipulate and reformat the data. Table #4 exemplifies the standard storage format of the monitoring relation. The field PTY is a description of the property and the field QUANTOBS records the actual readings.

Accessing the Data

DREAM is a user-friendly software package which provides fast retrieval from a single relation such as MT02. A few observations for one particular site are shown in Table #4. The retrievals available through this method are displays, counts and sums. (Note: DREAM does not recognize decimal points. Thus for the field QUANTOBS, there should be two decimal places.) There are no facilities through DREAM to reformat data. Thus it is usually only used to take a quick look at the data. After this step you can design the type of report or manipulation that would benefit you in making decisions. For more information on how to use DREAM, refer to the General CanSIS User's Manual.

It is also possible to create a computer file that contains selected portions of the data contained in MT02. Only the observations and fields of interest are written to your file. After this stage you can use more sophisticated software to reformat or perform manipulations on the data selected.

Soil Temperature Reports

The following section describes the procedures and programs which produce the Soil Temperature Reports. SAS (Statistical Analysis System) and EASYTRIEVE were the two computer software packages used to develop these programs. The former is a data analysis system and the latter, a report writing facility. This last section describes each program and in the reports section, there is an example of each report.

Selecting Data from MT02

The first program MT02REP1 (see Table #5) did not require any data analysis. It was simply obtained by accessing the relation through the RAPID-EASYTRIEVE interface, selecting the desired records and fields, reformatting the data and printing it.

The only purpose of the EASYTRIEVE program MT02DISK (see Table #6) was to select the required fields and records from MT02 and store the information on a disk file, AG230.SIS01.MT02SAS, for subsequent input to SAS.

Loading the Data into SAS

The SAS program, MT02SAS (see Table #7) loads the data stored on the disk file, AG230.SIS01.MT02SAS, into a SAS library member called SAVE.MT02SAS. It also defines the format of the disk file and gives a list of variables and definitions found in the SAS programs, MT02REP2, MT02RP3A, and MT02RP3B (see Tables #8, 9 and 10 respectively).

It is also possible to input a data file into a SAS member that will not be loaded into the monitoring relation. Lines 17-32 of the program MT02SAS defines the format of the input file using standard SAS conventions. The number after the "@" gives the first position of the field. The third column defines the length of the field and if there is a "$" sign associated with it, it is a character field otherwise it is numeric. If there is a number after the period, this indicates the number of decimal places for that field. DEPTHUP and QUANTOBS are defined as packed decimal fields. This is the way that they are stored in the monitoring relation. They can be defined as numeric fields with the third column being equal to 4. and 7.2 respectively. The fields PROFID, NUMBR< PTY, HOUR, DAY, MONTH, MNTRYR, DEPTHUP and QUANTOBS are used in the SAS programs.

Developing Programs in SAS

Once the data set, SAVE.MT02SAS, was created, SAS programs were developed that performed statistical analysis on the soil temperature data. In some cases SAS procedures were used to compute statistics and merge data sets. When the PROC statements were not suitable, SAS statements were used in the DATA step to manipulate the data.

Each time a program is run, the programmer must specify the items which are unique to his/her data set. In program MT02REP2 (see Table #8, Selection Criteria), all observations for a particular site, property and depth are selected. The titles for each report must also be changed to reflect the data (all titles are followed by the word TITLE in the SAS programs). After the data are loaded into a SAS data set and the selection criteria and titles are modified, one or all of the SAS programs can be run.

Table #4 MT02 Dream Output

HOUR	DDMM	PIT	NUMBR	DEPTHUP	QUANTOBS	UNITS	QUALOBS
0905	0311	WEATHER	30	-1	-100		PT.CLOUDY
0900	0707	WEATHER	30	-1	-100		CLEAR
0855	1205	WEATHER	30	-1	-100		CLEAR
0912	1301	WEATHER	30	-1	-100		PT.CLOUDY
1630	1507	WEATHER	30	-1	-100		CLOUDY
0943	1512	WEATHER	30	-1	-100		PT.CLOUDY
0930	1908	WEATHER	30	-1	100		PT.CLOUDY
0905	0311	SOIL-TEMP	01	3	210	C	
0900	0707	SOIL-TEMP	01	3	1270	C	
0855	1205	SOIL-TEMP	01	3	300	C	
0912	1301	SOIL-TEMP	01	3	-320	C	
1630	1507	SOIL-TEMP	01	3	1670	C	
0943	1512	SOIL-TEMP	01	3	-720	C	
0930	1908	SOIL-TEMP	01	3	1720	C	
0905	0311	SOIL-TEMP	02	5	270	C	
0900	0707	SOIL-TEMP	02	5	1620	C	
0855	1205	SOIL-TEMP	02	5	260	C	
0912	1301	SOIL-TEMP	02	5	-180	C	
1630	1507	SOIL-TEMP	02	5	1670	C	
0943	1512	SOIL-TEMP	02	5	-390	C	
0930	1908	SOIL-TEMP	02	5	1670	C	
0905	0311	SOIL-TEMP	03	10	390	C	
0900	0707	SOIL-TEMP	03	10	1370	C	
0855	1205	SOIL-TEMP	03	10	260	C	
0912	1301	SOIL-TEMP	03	10	-160	C	
1630	1507	SOIL-TEMP	03	10	1440	C	
0943	1512	SOIL-TEMP	03	10	-120	C	
0930	1908	SOIL-TEMP	03	10	1440	C	
0905	0311	SOIL-TEMP	04	20	470	C	
0900	0707	SOIL-TEMP	04	20	1200	C	
0855	1205	SOIL-TEMP	04	20	320	C	
0912	1301	SOIL-TEMP	04	20	-30	C	
1630	1507	SOIL-TEMP	04	20	1170	C	
0943	1512	SOIL-TEMP	04	20	60	C	
0930	1908	SOIL-TEMP	04	20	1330	C	
0905	0311	SOIL-TEMP	05	50	420	C	
0900	0707	SOIL-TEMP	05	50	840	C	
0855	1205	SOIL-TEMP	05	50	220	C	
0912	1301	SOIL-TEMP	05	50	60	C	
1630	1507	SOIL-TEMP	05	50	890	C	
0943	1512	SOIL-TEMP	05	50	180	C	
0930	1908	SOIL-TEMP	05	50	1110	C	
0905	0311	SOIL-TEMP	06	100	530	C	
0900	0707	SOIL-TEMP	06	100	540	C	
0855	1205	SOIL-TEMP	06	100	260	C	

MISSING VALUES

DEPTHUP -1

QUANTOBS -100

Table #5 Program MT02REP1

```
//MT02REP1 JOB (AG230-1200,NB30),'LACELLE'
/*SERVICE OVERNIGHT
//PROCLIB DD DSN=AG230.SIS01.PROCLIB,DISP=SHR
//  EXEC AGSISREZ,RELN=MT02
//REQIN DD *
*************************************************
*                                               *
*THIS EASYTRIEVE PROGRAM PRINTS AND REFORMATS THE *
*DATA CONTAINED IN THE MONITORING RELATION OF     *
*CANSIS.  SEE REPORT #1 FOR AN EXAMPLE OF THE     *
*REPORT FOR SITE #65, 1971.                       *
*                                               *
*************************************************
PARM SCANCOL=72
MT02 RAPID(RELN)
*************************************************
*                                               *
*SETTING UP WORKING FIELDS USED TO REFORMAT DATA. *
*                                               *
*************************************************
DYMTH      W-1    4   N
DAY        W-1    2   N
MTH        W-3    2   N
DAYNO      W-5    3   N
WTHCOND    W-8    14  A
AIRTEMP    W-24   7   N2
SNOWDPH    W-31   7   N2
TEMPDPH1   W-38   7   N2
TEMPDPH2   W-45   7   N2
TEMPDPH3   W-52   7   N2
TEMPDPH4   W-59   7   N2
TEMPDPH5   W-66   7   N2
TEMPDPH6   W-73   7   N2
TEMPDPH7   W-80   7   N2
HOLDNUMBR W-136 2 N
HOLDMNTR  W-138 2 A
HOLDHOUR  W-140 4 A
9999
*************************************************
*                                               *
*    SELECTION CRITERIA                         *
*                                               *
*************************************************
IF SORTED EQ NO
AND YEAR EQ 71
AND PROFID EQ **65
   SUCCESS
*************************************************
*                                               *
*CHECKS FOR END OF THE INPUT FILE AND WHEN THIS IS*
*TRUE THE DATA IS PRINTED.                       *
*                                               *
*************************************************
```

```
.
IF SORTED EQ YES AND EOF = YES
     PUTLIST
     STOP
***************************************************
*                                                 *
*SENDS WORKING FIELDS TO BE INITIALIZED           *
*                                                 *
***************************************************
IF SORTED EQ YES
AND HOLDNUMBR EQ *
    GOTO INIT
***************************************************
*                                                 *
*CHECKS IF THE RECORD HAS BEEN REFORMATTED AND IF *
*SO SENDS THE NEXT RECORD TO THE INITIALIZING     *
*STAGE WHERE THE WORKING FIELDS ARE INITIALIZED   *
*AGAIN.                                           *
*                                                 *
***************************************************
IF SORTED EQ YES
AND NUMBR LS HOLDNUMBR
AND HOLDNUMBR NQ *
     PUTLIST
     GO TO INIT
***************************************************
*                                                 *
*ONCE THE WORKING FIELDS HAVE BEEN INITIALIZED,  *
*THE RECORD IS SENT TO A PART OF THE PROGRAM      *
*WHICH REFORMATS IT.                              *
*                                                 *
***************************************************
IF SORTED EQ YES
     GO TO BUILD
***************************************************
*                                                 *
*PART OF THE PROGRAM WHICH INITIALIZES WORKING    *
*FIELDS AND CALCULATES THE DAY NUMBER.            *
*                                                 *
***************************************************
INIT:
WTHCOND = *
AIRTEMP = 0
SNOWDPH = 0
TEMPDPH1 = 0
TEMPDPH2 = 0
TEMPDPH3 = 0
TEMPDPH4 = 0
TEMPDPH5 = 0
TEMPDPH6 = 0
TEMPDPH7 = 0
HOLDNUMBR = NUMBR
HOLDMNTR = MNTRYR
HOLDHOUR = HOUR
DYMTH = DDMM
IF HOLDMNTR = 72,76,80
AND MTH > 02
DAY = DAY + 1
```

```
IF MTH = 01 THEN DAYNO = DAY + 0
IF MTH = 02 THEN DAYNO = DAY + 31
IF MTH = 03 THEN DAYNO = DAY + 59
IF MTH = 04 THEN DAYNO = DAY + 90
IF MTH = 05 THEN DAYNO = DAY + 120
IF MTH = 06 THEN DAYNO = DAY + 151
IF MTH = 07 THEN DAYNO = DAY + 181
IF MTH = 08 THEN DAYNO = DAY + 212
IF MTH = 09 THEN DAYNO = DAY + 243
IF MTH = 10 THEN DAYNO = DAY + 273
IF MTH = 11 THEN DAYNO = DAY + 304
IF MTH = 12 THEN DAYNO = DAY + 334
**************************************************
*                                                *
*   SECTION WHICH REFORMATS THE DATA.            *
*                                                *
**************************************************
BUILD:
*
HOLDNUMBR = NUMBR
IF PTY = WEATHER
   WTHCOND = QUALOBS
   FLUNK
IF PTY = (AIR-TEMP)
   AIRTEMP = QUANTOBS
   FLUNK
IF PTY = (SNOW-DEPTH)
   SNOWDPH = QUANTOBS
   FLUNK
IF PTY = (SOIL-TEMP)
   AND DEPTHUP = 3
   TEMPDPH1 = QUANTOBS
   FLUNK
IF PTY = (SOIL-TEMP)
   AND DEPTHUP = 5
   TEMPDPH2 = QUANTOBS
   FLUNK
IF PTY = (SOIL-TEMP)
   AND DEPTHUP = 10
   TEMPDPH3 = QUANTOBS
   FLUNK
IF PTY = (SOIL-TEMP)
   AND DEPTHUP = 20
   TEMPDPH4 = QUANTOBS
   FLUNK
IF PTY = (SOIL-TEMP)
   AND DEPTHUP = 50
   TEMPDPH5 = QUANTOBS
   FLUNK
IF PTY = (SOIL-TEMP)
   AND DEPTHUP = 100
   TEMPDPH6 = QUANTOBS
   FLUNK
IF PTY = (SOIL-TEMP)
   AND DEPTHUP = 150
   TEMPDPH7 = QUANTOBS
   FLUNK
**************************************************
*                                                *
*   SORTS THE DATA.                              *
*                                                *
**************************************************
```

```
SORT DUMMYKEY MNTRYR DDMM HOUR NUMBR
***************************************************
*                                                 *
*   TITLE                                         *
*                                                 *
***************************************************
T1NTS MAP AREA: 63K4    SE 24 60 27 W    WANLESS
T2DATE INSTALLED: AUG 1971
SPACE 1
**************************************************
*                                                *
*   PRINTS THE DATA.                             *
*                                                *
**************************************************
LIST DETAIL HOLDMNTR 'YR' MTH 'MT' DAY 'DY' DAYNO 'DAY,NO' MORE
HOLDHOUR 'HOUR' WTHCOND 'WEATHER,CONDITION' AIRTEMP 'AIR,TEMP' MORE
SNOWDPH 'SNOW,DEPTH' TEMPDPH1 'TEMP*AT,2.5CM' MORE
TEMPDPH2 'TEMP*AT,5CM' TEMPDPH3 'TEMP*AT,10CM' MORE
TEMPDPH4 'TEMP*AT,20CM' TEMPDPH5 'TEMP*AT,50CM' MORE
TEMPDPH6 'TEMP*AT,100CM' TEMPDPH7 'TEMP*AT,150CM'
```

Table #6 Program MT02DISK

```
//MT02DISK JOB (AG230-5400,NB30),'LACELLE MT02'
//PROCLIB DD DSN=AG230.SIS01.PROCLIB,DISP=SHR
//  EXEC AGSISREZ,RELN=MT02
//FILEB DD DSN=AG230.SIS01.MT02SAS,DISP=(NEW,CATLG),
//    UNIT=UD3350,LABEL=EXPDT=11111,SPACE=(TRK,(10,2),RLSE)
//REQIN DD *
*********************************************************
*                                                       *
*THIS PROGRAM SELECTS DATA FROM MT02 AND WRITES IT TO   *
*DISK.  FROM THERE IT IS DEFINED INTO A SAS DATA BASE.  *
*                                                       *
*********************************************************
PARM SCANCOL=72
MT02SAS RAPID(RELN)
9999
IF PROVINCE = MANITOBA
T1LIST OF SELECTED DATA
SPACE 1
WRITE
LIST PROVCD YEAR PROFID UNIT LAB SOLSERCD NUMBR PTY HOUR MORE
DDMM MNTRYR DEPTHUP QUANTOBS UNITS
```

Table #7 Program MT02SAS

```
//MT02SAS JOB (AG230-5700,NB30),'LACELLE'
/*SERVICE OVERNIGHT
// EXEC SAS
//SAVE DD DSN=AG230.SIS01.BL.SAS,DISP=OLD
//INDATA1 DD DSN=AG230.SIS01.MT02SAS,DISP=OLD
//SYSIN DD *
***********************************************
*                                             *
*THE FOLLOWING STATEMENTS DEFINE THE LAYOUT OF *
*THE INPUT FILE:AG230.SIS01.MT02SAS CREATED    *
*EARLIER TO SAS.  A PERMANENT SAS FILE CALLED  *
*SAVE.MT02SAS, WHICH CONTAINS THE SOIL CLIMATE *
*DATA, IS ESTABLISHED.                         *
*                                             *
**********************************************;
DATA SAVE.MT02SAS2;
INFILE INDATA1;
INPUT @9      PROVINCE     $16.
      @25     PROVCD       $2.
      @27     YEAR          2.
      @29     PROFID         4.
      @33     UNIT         $13.
      @46     LAB          $13.
      @59     SOLSERCD     $3.
      @62     NUMBR         2.
      @64     PTY          $16.
      @80     HOUR          4.
      @84     DAY           2.
      @86     MONTH         2.
      @88     MNTRYR        2.
      @90     DEPTHUP       PD3.
      @93     QUANTOBS      PD4.2
      @97     UNITS        $8.;
***********************************************
*                                             *
*THIS SECTION CALCULATES THE DAY NUMBER FOR    *
*EACH RECORD.                                  *
*                                             *
**********************************************;
IF MNTRYR=72 OR MNTRYR=76 OR MNTRYR=80
AND MONTH>02 THEN DAY=DAY+1;
IF MONTH=01 THEN DAYNO=DAY+0;
IF MONTH=02 THEN DAYNO=DAY+31;
IF MONTH=03 THEN DAYNO=DAY+59;
IF MONTH=04 THEN DAYNO=DAY+90;
IF MONTH=05 THEN DAYNO=DAY+120;
IF MONTH=06 THEN DAYNO=DAY+151;
IF MONTH=07 THEN DAYNO=DAY+181;
IF MONTH=08 THEN DAYNO=DAY+212;
IF MONTH=09 THEN DAYNO=DAY+243;
IF MONTH=10 THEN DAYNO=DAY+273;
IF MONTH=11 THEN DAYNO=DAY+304;
IF MONTH=12 THEN DAYNO=DAY+334;
```

```
******************************************************************
*                                                                *
*              DEFINITION OF VARIABLES                           *
*                                                                *
*QUANTOBS=ACTUAL TEMP READINGS                                   *
*ANGLE=ANGLE CORRESPONDING TO DAYNUMBER(6.28*DAYNO/365)          *
*CSANGLE=COS(ANGLE)                                              *
*SNANGLE=SIN(ANGLE)                                              *
*SQCOS=SQUARE OF COS(ANGLE)                                      *
*SQSIN=SQUARE OF SIN(ANGLE)                                      *
*TEMPTOT=SUM OF THE ACTUAL TEMP READINGS                         *
*SUMCOS=SUM OF DAY NUMBERS EXPRESSED AS THE COSINE OF THE        *
*          EQUIVALENT ANGLE                                      *
*SUMSIN=SUM OF DAY NUMBERS EXPRESSED AS THE SINE OF THE          *
*          EQUIVALENT ANGLE                                      *
*SUMCRSIN=SUM OF THE CROSS PRODUCTS OF SIN(ANGLE) BY TEMP        *
*SUMCRCOS=SUM OF THE CROSS PRODUCTS OF COS(ANGLE) BY TEMP        *
*SUMSQCOS=SUM OF SQUARES OF DAY NUMBER EXPRESSED AS THE COSINE *
*          OF THE EQUIVALENT ANGLE                               *
*SUMSQSIN=SUM OF SQUARES OF DAY NUMBER EXPRESSED AS THE SINE OF*
*          THE EQUIVALENT ANGLE                                  *
*COUNT=NUMBER OF OBSERVATIONS                                    *
*AVT=AVERAGE TEMP                                                *
*AVSIN=AVERAGE SIN(ANGLE)                                        *
*AVCOS=AVERAGE COS(ANGLE)                                        *
*E=SLOPE E IN EQUATION:TEMP=CONST+E*SIN(ANGLE)                   *
*F=SLOPE F IN EQUATION:TEMP=CONST+F*COS(ANGLE)                   *
*CONSIN=CONSTANT IN EQUATION:TEMP=CONST+E*SIN(ANGLE)             *
*CONCOS=CONSTANT IN EQUATION:TEMP=CONST+F*COS(ANGLE)             *
*SDAY=SIN(ANGLE+ALPHA)                                           *
*SQDAY=SQUARE OF SIN(ANGLE+ALPHA)                                *
*STDAY=CROSS PRODUCTS OF SIN(ANGLE)*TEMP                         *
*SUMSDAY=SUM OF SIN(ANGLE+ALPHA)                                 *
*SUMSQDAY=SUM OF SQUARES OF SIN(ANGLE+ALPHA)                     *
*SUMSTDAY=SUM OF CROSS PRODUCTS OF SIN(ANGLE)*TEMP               *
*B=B IN EQUATION:TEMP=A+B*SIN(ANGLE+ALPHA)                       *
*AVTEMP=AVERAGE TEMP, A IN EQUATION:TEMP=A+B*SIN(ANGLE+ALPHA)    *
*TPRED=PREDICTED TEMP                                            *
*DIFF=DIFFERENCE BETWEEN ACTUAL AND PREDICTED TEMP READINGS      *
*DAYAV1=DAY ON WHICH AVERAGE TEMP OCCURS:FALL                    *
*DAYAV2=DAY ON WHICH AVERAGE TEMP OCCURS:SPRING                  *
*AVSUM=AVERAGE SUMMER TEMP                                       *
*DAYMIN=DAY ON WHICH MINIMUM TEMP OCCURS                         *
*DAYMAX=DAY ON WHICH MAXIMUM TEMP OCCURS                         *
*TEMPMIN=MINIMUM TEMP                                            *
*TEMPMAX=MAXIMUM TEMP                                            *
*DAYZERO1=DAY ON WHICH ZERO OCCURS:SPRING                        *
*DAYZERO2=DAY ON WHICH ZERO OCCURS:FALL OR WINTER                *
*FROST=FROST FREE DAYS                                           *
*DATE5C1=DAY ON WHICH 5C OCCURS:SPRING                           *
*DATE5C2=DAY ON WHICH 5C OCCURS:FALL                             *
*DEGDAY5=NUMBER OF DEGREE DAYS ABOVE 5C                          *
*DAYSGT5C=NUMBER OF DAYS ABOVE 5C                                *
*DATE15C1=DAY ON WHICH 15C OCCURS:SPRING                         *
*DATE15C2=DAY ON WHICH 15C OCCURS:FALL                           *
*DEGDAY15=NUMBER OF DEGREE DAYS ABOVE 15C                        *
*DAYGT15C=NUMBER OF DAYS ABOVE 15C                               *
*                                                                *
******************************************************************
```

```
*                                                              *
*PROGRAM MT02REP1=REFORMATTING AND PRINTING OF DATA (REPORT#1) *
*PROGRAM MT02REP2=PROCESS AND GRAPH SOIL TEMP DATA (REPORT#2,3)*
*PROGRAM MT02RP3A=CALCULATING COEFFICIENTS OF EQUATIONS USED   *
*                 TO ANALYSE SOIL TEMPERATURE.                 *
*PROGRAM MT02RP3B=DISPLAYING COEFFICIENTS OF EQUATIONS USED TO *
*                 ANALYSE SOIL TEMPERATURE.   (REPORT#4)       *
*                                                              *
****************************************************************;
```

Table #8 Program MT02REP2

```
//MT02REP2 JOB (AG230-5400,NB30),'LACELLE'
/*SERVICE OVERNIGHT
// EXEC SAS
//SAVE DD DSN=AG230.SIS01.BL.SAS,DISP=OLD
//SYSIN DD *
*************************************************
*                                               *
*THIS PROGRAM IS DESIGNED TO PROCESS AND GRAPH   *
*SOIL TEMPERATURE DATA, TO PRINT A TABLE WITH    *
*PREDICTED AND ACTUAL TEMPERATURE READINGS, AND  *
*TO CALCULATE THE COEFFICIENTS OF EQUATIONS USED *
*TO ANALYZE SOIL TEMPERATURE FOR A PARTICULAR    *
*DEPTH.                                          *
*                                               *
*************************************************;
DATA MT02A;
SET SAVE.MT02SAS2;
****************************
*                          *
*  SELECTION CRITERIA      *
*                          *
****************************;
IF YEAR=71;
IF PROFID=65;
IF PTY='SOIL-TEMP';
IF DEPTHUP=50;
***************************************************
*                                                 *
*THIS PART OF THE PROGRAM CONVERTS THE DAY OF THE *
*YEAR TO AN ANGLE AND TAKES THE SINE AND COSINE OF *
*THAT ANGLE.  THE PROGRAM CALCULATES THE BEST FIT- *
*TING RELATIONSHIP ACCORDING TO THE MODEL:        *
*   TEMP=A+B*SIN(ANGLE+ALPHA)                     *
*TO DO THIS IT MAKES USE OF THE EQUALITY:         *
*   SIN(ANGLE+ALPHA)=SIN(ANGLE)*COS(ALPHA)        *
*                 +SIN(ALPHA)*COS(ANGLE)          *
*THUS THE FIRST STEP IS TO FIND EQUATIONS OF THE  *
*FORM:    TEMP=CONST+E*SIN(ANGLE)                 *
*         TEMP=CONST+F*COS(ANGLE)                 *
*                                                 *
*SINCE THE SUM OF THESE TWO SOLUTIONS IS ALSO A SOL-*
*TION, THE VALUES OF E AND F CAN BE SUBSTITUTED FOR *
*COS(ALPHA) AND SIN(ALPHA) RESPECTIVELY.          *
*HENCE IT IS POSSIBLE TO SOLVE FOR ALPHA IN THE   *
*EXPRESSION SIN(ANGLE+ALPHA).                     *
*                                                 *
***************************************************;
FLAG=1;
SITE='027WWANL';
ANGLE=6.28*DAYNO/365;
CSANGLE=COS(ANGLE);
SNANGLE=SIN(ANGLE);
CROSSIN=SNANGLE*QUANTOBS;
CROSCOS=CSANGLE*QUANTOBS;
```

```
SQCOS=CSANGLE*CSANGLE;
SQSIN=SNANGLE*SNANGLE;

****************************************************
*                                                  *
*CALCULATING THE SUM OF EACH VARIABLE LISTED       *
*AFTER THE VAR STATEMENT AND PUTTING THEM INTO A   *
*TEMPORARY FILE.                                   *
*                                                  *
****************************************************;
PROC SUMMARY DATA=MT02A;
VAR QUANTOBS CSANGLE SNANGLE CROSSIN CROSCOS SQCOS SQSIN;
OUTPUT OUT=SUMSTAT SUM=TEMPTOT SUMCOS SUMSIN
SUMCRSIN SUMCRCOS SUMSQCOS SUMSQSIN N=COUNT;
****************************************************
*                                                  *
*   MERGING THE TWO FILES                          *
*                                                  *
****************************************************;
DATA SUMSTAT2;
SET SUMSTAT;
FLAG=1;
*;
DATA MT02B;
MERGE MT02A SUMSTAT2;
BY FLAG;
*;
DATA MT02C;
SET MT02B;
AVT=TEMPTOT/COUNT;
AVSIN=SUMSIN/COUNT;
AVCOS=SUMCOS/COUNT;
E=(SUMCRSIN-AVT*SUMSIN)/(SUMSQSIN-AVSIN*SUMSIN);
F=(SUMCRCOS-AVT*SUMCOS)/(SUMSQCOS-AVCOS*SUMCOS);
CONSIN=AVT-E*AVSIN;
CONCOS=AVT-F*AVCOS;
****************************************************
*                                                  *
*THERE ARE FOUR POSSIBLE VALUES OF ALPHA, EACH OF   *
*WHICH IS DEFINED BY ONE OF THE FOLLOWING EQUATIONS.*
*TWO OF THESE VALUES MUST BE IDENTICAL. ALPHA IS    *
*DEFINED AS THAT VALUE WHICH OCCURS TWICE.          *
*                                                  *
****************************************************;
ALPHA1=ARSIN(F/SQRT(E*E+F*F));
ALPHA2=ARSIN(-F/SQRT(E*E+F*F));
ALPHA3=ARCOS(E/SQRT(E*E+F*F));
ALPHA4=ARCOS(-E/SQRT(E*E+F*F));
D1=ALPHA1-ALPHA2;
IF 0<=ABS(D1)<=0.001 THEN GO TO OK1;
D2=ALPHA1-ALPHA3;
IF 0<=ABS(D2)<=0.001 THEN GO TO OK1;
D3=ALPHA1-ALPHA4;
IF 0<=ABS(D3)<=0.001 THEN GO TO OK1;
X1=ALPHA2-ALPHA3;
IF 0<=ABS(X1)<=0.001 THEN GO TO OK2;
X2=ALPHA2-ALPHA4;
IF 0<=ABS(X2)<=0.001 THEN GO TO OK2;
Y1=ALPHA3-ALPHA4;
IF 0<=ABS(Y1)<=0.001 THEN GO TO OK3;
```

```
OK1:ALPHA=ALPHA1;
GO TO CONTINUE;
OK2:ALPHA=ALPHA2;
GO TO CONTINUE;
OK3:ALPHA=ALPHA3;
CONTINUE:
*************************************************
*                                               *
*HAVING CALCULATED THE VALUE OF ALPHA THE PROGRAM *
*NOW DOES A LINEAR REPRESSION OF TEMPERATURE ON  *
*   SIN(ANGLE+ALPHA)                            *
*                                               *
*************************************************;
SDAY=SIN(ANGLE+ALPHA);
SQDAY=SDAY*SDAY;
STDAY=SDAY*QUANTOBS;
*************************************************
*                                               *
*CALCULATING THE SUM OF EACH VARIABLE LISTED    *
*AFTER THE VAR STATEMENT AND PUTTING THEM INTO A *
*TEMPORARY FILE.                                *
*                                               *
*************************************************;
PROC SUMMARY DATA=MT02C;
VAR SDAY SQDAY STDAY;
OUTPUT OUT=SUMSTAT3 SUM=SUMSDAY SUMSQDAY SUMSTDAY;
*************************************************
*                                               *
*   MERGING THE TWO FILES                       *
*                                               *
*************************************************;
DATA SUMSTAT4;
SET SUMSTAT3;
FLAG=1;
*;
DATA MT02D;
MERGE MT02C SUMSTAT4;
BY FLAG;
*;
DATA MT02E;
SET MT02D;
B=(SUMSTDAY-TEMPTOT*SUMSDAY/COUNT)/(SUMSQDAY-SUMSDAY*SUMSDAY/COUNT);
AVTEMP=AVT-B*SUMSDAY/COUNT;
*************************************************
*                                               *
*THE PREDICTED TEMPERATURE VALUES ARE NOW PREDICT-*
*ED FROM THE DERIVED REGRESSION EQUATION.       *
*                                               *
*************************************************;
TPRED=AVTEMP+B*SDAY;
DIFF=QUANTOBS-TPRED;
*************************************************
*                                               *
*PLOTTING PREDICTED AND ACTUAL TEMPERATURE READ- *
*INGS BY DAYNUMBER.   SEE REPORT #2.            *
*                                               *
*************************************************;
```

```
PROC PLOT DATA=MT02E;
PLOT QUANTOBS*DAYNO='X' TPRED*DAYNO='*'/OVERLAY;
TITLE **63K4    SE246027W WANLESS    AUG 1971    50 CM DEPTH;

***************************************************
*                                                 *
*PRINTING OF PREDICTED AND ACTUAL SOIL TEMPERATURE*
*READINGS PLUS THE DIFFERENCE.SEE REPORT #3.      *
*                                                 *
***************************************************;
PROC SORT DATA=MT02E;
BY SITE MNTRYR DAYNO;
PROC PRINT DATA=MT02E;
VAR MNTRYR DAYNO QUANTOBS TPRED DIFF;
TITLE **63K4    SE246027W WANLESS    AUG 1971    50 CM DEPTH;
***************************************************
*                                                 *
*THE FOLLOWING CALCULATIONS ARE MADE USING THE    *
*BEST FITTING SINE CURVE OF TEMP AS A FUNCTION    *
*OF THE DAY OF THE YEAR.  CALCULATION OF THE DAYS *
*ON WHICH THE AVERAGE TEMPERATURE OCCURS.         *
*                                                 *
***************************************************;
DATA MT02F;
SET MT02E;
BY SITE;
DAYAV1=365-ALPHA*365/6.28;
DAYAV2=182.5-ALPHA*365/6.28;
***************************************************
*                                                 *
*MOST OF THE FOLLOWING CALCULATIONS ARE MADE USING*
*THE BEST FITTING SINE CURVE AND INTEGRATING BE-  *
*TWEEN CERTAIN LIMITS OF THE CURVE.  THE NEXT CAL-*
*CULATION IS THAT OF THE AVERAGE SUMMER TEMP.  IT *
*IS CALCULATED BY TAKING THE AREA UNDER THE CURVE *
*FROM JUNE 1 TO AUGUST 31 AND DIVIDING THAT AREA  *
*BY THE NUMBER OF DAYS DURING THAT PERIOD.        *
*                                                 *
***************************************************;
AVSUM=(COS(6.28*151/365+ALPHA)-COS(6.28*243/365+ALPHA))*
B*(365/6.28)/92+AVTEMP;
***************************************************
*                                                 *
*CALCULATING MINIMUM AND MAXIMUM TEMPS AND DATES  *
*ON WHICH THEY OCCUR.                             *
*                                                 *
***************************************************;
DAYMIN=(1.5708-ALPHA)*365/6.28;
DAYMAX=(4.7124-ALPHA)*365/6.28;
TEMPMIN=AVTEMP+B*SIN(6.28*DAYMIN/365+ALPHA);
TEMPMAX=AVTEMP+B*SIN(6.28*DAYMAX/365+ALPHA);
***************************************************
*                                                 *
*CALCULATING WHEN SOIL TEMP EQUALS ZERO AND FROST *
*FREE DAYS.                                       *
*                                                 *
***************************************************;
```

```
IF TEMPMAX>0 AND -AVTEMP/B>1 THEN DO;
   ZERO1=ARSIN(1);
   ZERO2=ARSIN(-1);
   END;
IF TEMPMAX>0 AND -AVTEMP/B<=1 THEN DO;
   ZERO1=ARSIN(-AVTEMP/B);
   ZERO2=ARSIN(AVTEMP/B);
   END;
DAYZERO2=(ZERO1-ALPHA)*365/6.28+365;
DAYZERO1=(ZERO2-ALPHA)*365/6.28+182.5;
FROST=DAYZERO2-DAYZERO1;
IF DAYZERO2>=365 THEN DAYZERO2=DAYZERO2-365;
**************************************************
*                                                *
*TO CALCULATE THE DEGREE DAYS ABOVE 5C,THE PROGRAM*
*DETERMINES THE DATES ON WHICH A TEMP OF 5C OCCURS*
*INTEGRATES THE BEST FITTING EQUATIONS BETWEEN TH-*
*OSE LIMITS, SUBTRACTES THE AREA OF THE RECTANGLE *
*FORMED BY THE 5C AND 0C LINES AND THE DATES ON   *
*WHICH THE TEMP CROSSES THE 5C LINE.              *
*                                                *
**************************************************;
IF TEMPMAX>5 THEN DO;
FIVE2=ARSIN(-(AVTEMP-5)/B);
FIVE1=ARSIN((AVTEMP-5)/B);
DATE5C2=(FIVE2-ALPHA)*365/6.28+365;
DATE5C1=(FIVE1-ALPHA)*365/6.28+182.5;
DEGDAY5=(COS(6.28*DATE5C1/365+ALPHA)-COS(6.28*
DATE5C2/365+ALPHA))*B*365/6.28-(DATE5C2-DATE5C1)*(5-AVTEMP);
DAYSGT5C=DATE5C2-DATE5C1;
END;
**************************************************
*                                                *
*CALCULATION OF DEGREE DAYS ABOVE 15C.  THE PROCE-*
*DURE IS ANALOGOUS TO THAT USED FOR DEGREE DAYS   *
*ABOVE 5C.                                       *
*                                                *
**************************************************;
IF TEMPMAX>15 THEN DO;
FIF2=ARSIN(-(AVTEMP-15)/B);
FIF1=ARSIN((AVTEMP-15)/B);
DATE15C2=(FIF2-ALPHA)*365/6.28+365;
DATE15C1=(FIF1-ALPHA)*365/6.28+182.5;
DAYGT15C=DATE15C2-DATE15C1;
DEGDAY15=(COS(6.28*DATE15C1/365+ALPHA)-COS(6.28*DATE15C2/365+
ALPHA))*B*365/6.28-DAYGT15C*(15-AVTEMP);
END;
**************************************************
*                                                *
*   ROUNDING VARIABLES.                          *
*                                                *
**************************************************;
DAYAV1=ROUND(DAYAV1);
DAYAV2=ROUND(DAYAV2);
DAYMAX=ROUND(DAYMAX);
DAYMIN=ROUND(DAYMIN);
DAYZERO1=ROUND(DAYZERO1);
DAYZERO2=ROUND(DAYZERO2);
```

```
DATE5C1=ROUND(DATE5C1);
DATE5C2=ROUND(DATE5C2);
DEGDAY5=ROUND(DEGDAY5);
DATE15C1=ROUND(DATE15C1);
DATE15C2=ROUND(DATE15C2);
DEGDAY15=ROUND(DEGDAY15);
TEMPMAX=ROUND(TEMPMAX,.1);
TEMPMIN=ROUND(TEMPMIN,.1);
FROST=ROUND(FROST);
DAYSGT5C=ROUND(DAYSGT5C);
DAYGT15C=ROUND(DAYGT15C);

AVTEMP=ROUND(AVTEMP,.1);
AVSUM=ROUND(AVSUM,.1);
IF LAST.SITE THEN OUTPUT;
***************************************************
*                                                 *
*PRINTING OF COEFFICIENTS OF EQUATIONS USED TO    *
*ANALYZE SOIL TEMPERATURE.SEE REPORT #4.          *
*                                                 *
**************************************************;
PROC PRINT DATA=MT02F;
VAR AVTEMP DAYAV2 DAYAV1 AVSUM TEMPMIN TEMPMAX DAYMAX DAYMIN
DAYZERO1 DAYZERO2 FROST DATE5C1 DATE5C2 DAYSGT5C DEGDAY5
DATE15C1 DATE15C2 DAYGT15C DEGDAY15;
TITLE **63K4    SE246027W WANLESS    AUG 1971    50CM DEPTH;
*;
```

Table #9 Program MT02RP3A

```
//MT02RP3A JOB (AG230-5400,NB30),'LACELLE'
/*SERVICE OVERNIGHT
// EXEC SAS
//SAVE DD DSN=AG230.SIS01.BL.SAS,DISP=OLD
//SYSIN DD *
***************************************************
*                                                 *
*THIS PROGRAM CALCULATES THE COEFFICIENTS OF      *
*EQUATIONS USED TO ANALYZE SOIL TEMPERATURE FOR   *
*A PARTICULAR DEPTH AND STORES THE VALUES IN A SAS*
*FILE.  RUN THIS PROGRAM FOR EACH SITE AND EACH   *
*DEPTH CHANGING THE OUTPUT SAS FILE AND SELECTION *
*CRITERIA EACH TIME.                              *
*                                                 *
**************************************************;
DATA MT02A;
SET SAVE.MT02SAS;
*****************************
*                           *
*  SELECTION CRITERIA       *
*                           *
****************************;
IF YEAR=77;
IF PROFID=64;
IF PTY='SOIL-TEMP';
IF DEPTHUP=50;
*****************************************************
*                                                   *
*THIS PART OF THE PROGRAM CONVERTS THE DAY OF THE   *
*YEAR TO AN ANGLE AND TAKES THE SINE AND COSINE OF  *
*THAT ANGLE.  THE PROGRAM CALCULATES THE BEST FIT-  *
*TING RELATIONSHIP ACCORDING TO THE MODEL:          *
*   TEMP=A+B*SIN(ANGLE+ALPHA)                       *
*TO DO THIS IT MAKES USE OF THE EQUALITY:           *
*   SIN(ANGLE+ALPHA)=SIN(ANGLE)*COS(ALPHA)          *
*                +SIN(ALPHA)*COS(ANGLE)             *
*THUS THE FIRST STEP IS TO FIND EQUATIONS OF THE    *
*FORM:    TEMP=CONST+E*SIN(ANGLE)                   *
*         TEMP=CONST+F*COS(ANGLE)                   *
*                                                   *
*SINCE THE SUM OF THESE TWO SOLUTIONS IS ALSO A SOL-*
*TION, THE VALUES OF E AND F CAN BE SUBSTITUTED FOR *
*COS(ALPHA) AND SIN(ALPHA) RESPECTIVELY.            *
*HENCE IT IS POSSIBLE TO SOLVE FOR ALPHA IN THE     *
*EXPRESSION SIN(ANGLE+ALPHA).                       *
*                                                   *
****************************************************;
FLAG=1;
SITE='504WJOEY';
ANGLE=6.28*DAYNO/365;
CSANGLE=COS(ANGLE);
SNANGLE=SIN(ANGLE);
CROSSIN=SNANGLE*QUANTOBS;
CROSCOS=CSANGLE*QUANTOBS;
SQCOS=CSANGLE*CSANGLE;
SQSIN=SNANGLE*SNANGLE;
```

```
****************************************************
*                                                  *
*CALCULATES THE SUM OF EACH VARIABLE LISTED AFTER  *
*THE VAR STATEMENT AND PUTS THEM INTO A TEMPORARY  *
*FILE.                                             *
*                                                  *
***************************************************;
PROC SUMMARY DATA=MT02A;
VAR QUANTOBS CSANGLE SNANGLE CROSSIN CROSCOS SQCOS SQSIN;
OUTPUT OUT=SUMSTAT SUM=TEMPTOT SUMCOS SUMSIN
SUMCRSIN SUMCRCOS SUMSQCOS SUMSQSIN N=COUNT;
****************************************************
*                                                  *
*   MERGING THE TWO FILES                          *
*                                                  *
***************************************************;
DATA SUMSTAT2;
SET SUMSTAT;
FLAG=1;
*;
DATA MT02B;
MERGE MT02A SUMSTAT2;
BY FLAG;
*;
DATA MT02C;
SET MT02B;
AVT=TEMPTOT/COUNT;
AVSIN=SUMSIN/COUNT;
AVCOS=SUMCOS/COUNT;
E=(SUMCRSIN-AVT*SUMSIN)/(SUMSQSIN-AVSIN*SUMSIN);
F=(SUMCRCOS-AVT*SUMCOS)/(SUMSQCOS-AVCOS*SUMCOS);
****************************************************
*                                                  *
*THERE ARE FOUR POSSIBLE VALUES OF ALPHA, EACH OF   *
*WHICH IS DEFINED BY ONE OF THE FOLLOWING EQUATIONS.*
*TWO OF THESE VALUES MUST BE IDENTICAL. ALPHA IS    *
*DEFINED AS THAT VALUE WHICH OCCURS TWICE.          *
*                                                  *
***************************************************;
ALPHA1=ARSIN(F/SQRT(E*E+F*F));
ALPHA2=ARSIN(-F/SQRT(E*E+F*F));
ALPHA3=ARCOS(E/SQRT(E*E+F*F));
ALPHA4=ARCOS(-E/SQRT(E*E+F*F));
D1=ALPHA1-ALPHA2;
IF 0<=ABS(D1)<=0.001 THEN GO TO OK1;
D2=ALPHA1-ALPHA3;
IF 0<=ABS(D2)<=0.001 THEN GO TO OK1;
D3=ALPHA1-ALPHA4;
IF 0<=ABS(D3)<=0.001 THEN GO TO OK1;
X1=ALPHA2-ALPHA3;
IF 0<=ABS(X1)<=0.001 THEN GO TO OK2;
X2=ALPHA2-ALPHA4;
IF 0<=ABS(X2)<=0.001 THEN GO TO OK2;
Y1=ALPHA3-ALPHA4;
IF 0<=ABS(Y1)<=0.001 THEN GO TO OK3;
```

```
OK1:ALPHA=ALPHA1;
GO TO CONTINUE;
OK2:ALPHA=ALPHA2;
GO TO CONTINUE;
OK3:ALPHA=ALPHA3;
CONTINUE:

****************************************************
*                                                  *
*HAVING CALCULATED THE VALUE OF ALPHA THE PROGRAM   *
*NOW DOES A LINEAR REPRESSION OF TEMPERATURE ON     *
*   SIN(ANGLE+ALPHA)                                *
*                                                  *
***************************************************;
SDAY=SIN(ANGLE+ALPHA);
SQDAY=SDAY*SDAY;
STDAY=SDAY*QUANTOBS;
**************************************************
*                                                *
*CALCULATING THE SUM OF EACH VARIABLE LISTED      *
*AFTER THE VAR STATEMENT AND PUTTING THEM INTO A  *
*TEMPORARY FILE.                                  *
*                                                *
*************************************************;
PROC SUMMARY DATA=MT02C;
VAR SDAY SQDAY STDAY;
OUTPUT OUT=SUMSTAT3 SUM=SUMSDAY SUMSQDAY SUMSTDAY;
**************************************************
*                                                *
*   MERGING THE TWO FILES                        *
*                                                *
*************************************************;
DATA SUMSTAT4;
SET SUMSTAT3;
FLAG=1;
*;
DATA MT02D;
MERGE MT02C SUMSTAT4;
BY FLAG;
*;
PROC SORT DATA=MT02D;
BY SITE;
*;
DATA SAVE.DPH1A;
SET MT02D;
BY SITE;
B=(SUMSTDAY-TEMPTOT*SUMSDAY/COUNT)/(SUMSQDAY-SUMSDAY*SUMSDAY/COUNT);
AVTEMP=AVT-B*SUMSDAY/COUNT;
**************************************************
*                                                *
*THE FOLLOWING CALCULATIONS ARE MADE USING THE    *
*BEST FITTING SINE CURVE OF TEMP AS A FUNCTION    *
*OF THE DAY OF THE YEAR.  CALCULATION OF THE DAYS *
*ON WHICH THE AVERAGE TEMPERATURE OCCURS.         *
*                                                *
*************************************************;
```

```
DAYAV1=365-ALPHA*365/6.28;
DAYAV2=182.5-ALPHA*365/6.28;
***************************************************
*                                                 *
*MOST OF THE FOLLOWING CALCULATIONS ARE MADE USING*
*THE BEST FITTING SINE CURVE AND INTEGRATING BE-  *
*TWEEN CERTAIN LIMITS OF THE CURVE.  THE NEXT CAL-*
*CULATION IS THAT OF THE AVERAGE SUMMER TEMP.  IT *
*IS CALCULATED BY TAKING THE AREA UNDER THE CURVE *
*FROM JUNE 1 TO AUGUST 31 AND DIVIDING THAT AREA  *
*BY THE NUMBER OF DAYS DURING THAT PERIOD.        *
*                                                 *
**************************************************;
AVSUM=(COS(6.28*151/365+ALPHA)-COS(6.28*243/365+ALPHA))*
B*(365/6.28)/92+AVTEMP;
***************************************************
*                                                 *
*CALCULATING MINIMUM AND MAXIMUM TEMPS AND DATES  *
*ON WHICH THEY OCCUR.                             *
*                                                 *
**************************************************;
DAYMIN=(1.5708-ALPHA)*365/6.28;
DAYMAX=(4.7124-ALPHA)*365/6.28;
TEMPMIN=AVTEMP+B*SIN(6.28*DAYMIN/365+ALPHA);
TEMPMAX=AVTEMP+B*SIN(6.28*DAYMAX/365+ALPHA);
***************************************************
*                                                 *
*CALCULATING WHEN SOIL TEMP EQUALS ZERO AND FROST *
*FREE DAYS.                                       *
*                                                 *
**************************************************;
IF TEMPMAX>0 AND -AVTEMP/B>1 THEN DO;
   ZERO1=ARSIN(1);
   ZERO2=ARSIN(-1);
   END;
IF TEMPMAX>0 AND -AVTEMP/B<=1 THEN DO;
   ZERO1=ARSIN(-AVTEMP/B);
   ZERO2=ARSIN(AVTEMP/B);
   END;
DAYZERO2=(ZERO1-ALPHA)*365/6.28+365;
DAYZERO1=(ZERO2-ALPHA)*365/6.28+182.5;
FROST=DAYZERO2-DAYZERO1;
IF DAYZERO2>=365 THEN DAYZERO2=DAYZERO2-365;
***************************************************
*                                                 *
*TO CALCULATE THE DEGREE DAYS ABOVE 5C,THE PROGRAM*
*DETERMINES THE DATES ON WHICH A TEMP OF 5C OCCURS*
*INTEGRATES THE BEST FITTING EQUATIONS BETWEEN TH-*
*OSE LIMITS, SUBTRACTES THE AREA OF THE RECTANGLE *
*FORMED BY THE 5C AND 0C LINES AND THE DATES ON   *
*WHICH THE TEMP CROSSES THE 5C LINE.              *
*                                                 *
**************************************************;
```

```
IF TEMPMAX>5 THEN DO;
FIVE2=ARSIN(-(AVTEMP-5)/B);
FIVE1=ARSIN((AVTEMP-5)/B);
DATE5C2=(FIVE2-ALPHA)*365/6.28+365;
DATE5C1=(FIVE1-ALPHA)*365/6.28+182.5;
DEGDAY5=(COS(6.28*DATE5C1/365+ALPHA)-COS(6.28*
DATE5C2/365+ALPHA))*B*365/6.28-(DATE5C2-DATE5C1)*(5-AVTEMP);
DAYSGT5C=DATE5C2-DATE5C1;
END;
***************************************************
*                                                 *
*CALCULATION OF DEGREE DAYS ABOVE 15C.  THE PROCE-*
*DURE IS ANALOGOUS TO THAT USED FOR DEGREE DAYS   *
*ABOVE 5C.                                        *
*                                                 *
**************************************************;
IF TEMPMAX>15 THEN DO;
FIF2=ARSIN(-(AVTEMP-15)/B);
FIF1=ARSIN((AVTEMP-15)/B);
DATE15C2=(FIF2-ALPHA)*365/6.28+365;
DATE15C1=(FIF1-ALPHA)*365/6.28+182.5;
DAYGT15C=DATE15C2-DATE15C1;
DEGDAY15=(COS(6.28*DATE15C1/365+ALPHA)-COS(6.28*DATE15C2/365+
ALPHA))*B*365/6.28-DAYGT15C*(15-AVTEMP);
END;
***************************************************
*                                                 *
*   ROUNDING VARIABLES.                           *
*                                                 *
**************************************************;
DAYAV1=ROUND(DAYAV1);
DAYAV2=ROUND(DAYAV2);
DAYMAX=ROUND(DAYMAX);
DAYMIN=ROUND(DAYMIN);
DAYZERO1=ROUND(DAYZERO1);
DAYZERO2=ROUND(DAYZERO2);
DATE5C1=ROUND(DATE5C1);
DATE5C2=ROUND(DATE5C2);
DEGDAY5=ROUND(DEGDAY5);
DATE15C1=ROUND(DATE15C1);
DATE15C2=ROUND(DATE15C2);
DEGDAY15=ROUND(DEGDAY15);
TEMPMAX=ROUND(TEMPMAX,.1);
TEMPMIN=ROUND(TEMPMIN,.1);
FROST=ROUND(FROST);
DAYSGT5C=ROUND(DAYSGT5C);
DAYGT15C=ROUND(DAYGT15C);
AVTEMP=ROUND(AVTEMP,.1);
AVSUM=ROUND(AVSUM,.1);
IF LAST.SITE THEN OUTPUT;
```

Table #10 Program MT02RP3B

```
//MT02RP3B JOB (AG230-5400,NB30),'LACELLE'
/*SERVICE OVERNIGHT
//  EXEC SAS
//SAVE DD DSN=AG230.SIS01.BL.SAS,DISP=OLD
//SYSIN DD *
*************************************************
*                                               *
*THE PURPOSE OF THIS PROGRAM IS TO DISPLAY THE  *
*COEFFICIENTS OF EQUATIONS CALCULATED IN MT02RP3A.*
*THE FOLLOWING SECTION APPENDS THE SAS DATA SETS *
*CREATED IN MT02RP3A INTO ONE SAS FILE AND SORTS *
*IT.                                            *
*                                               *
************************************************;
PROC APPEND BASE=SAVE.MT025A DATA SAVE.DPH1A;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH1B;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH1C;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH1D;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH1E;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH1F;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH1G;
PROC APPEND BASE=SAVE.MT025A DATA SAVE.DPH2A;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH2B;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH2C;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH2D;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH2E;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH2F;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH2G;
PROC APPEND BASE=SAVE.MT025A DATA SAVE.DPH3A;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH3B;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH3C;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH3D;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH3E;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH3F;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH3G;
PROC APPEND BASE=SAVE.MT025A DATA SAVE.DPH4A;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH4B;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH4C;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH4D;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH4E;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH4F;
PROC APPEND BASE=SAVE.MT025A DATA=SAVE.DPH4G;
*;
PROC SORT DATA=SAVE.MT025A;
BY SITE DEPTHUP;
*************************************************
*                                               *
*PRINTING COEFFICIENTS OF EQUATIONS USED TO ANAL- *
*YZE SOIL TEMPERATURE.  SEE REPORT #5.          *
*                                               *
************************************************;
```

```
PROC PRINT DATA=SAVE.MT025A;
BY SITE;
VAR SITE DEPTHUP AVTEMP DAYAV1 DAYAV2 AVSUM DAYZERO1
DAYZERO2 FROST TEMPMAX DAYMAX TEMPMIN DAYMIN DATE5C1
DATE5C2 DAYSGT5C DEGDAY5 DATE15C1 DATE15C2 DAYGT15C
DEGDAY15;
***************************************************
*                                                 *
*DELETING THE STRAY SAS DATA SETS.                *
*INTO ONE SAS DATA SET.                           *
*                                                 *
**************************************************;
PROC DELETE DATA=SAVE.DPH1A;
PROC DELETE DATA=SAVE.DPH1B;
PROC DELETE DATA=SAVE.DPH1C;
PROC DELETE DATA=SAVE.DPH1D;
PROC DELETE DATA=SAVE.DPH1E;
PROC DELETE DATA=SAVE.DPH1F;
PROC DELETE DATA=SAVE.DPH1G;
PROC DELETE DATA=SAVE.DPH2A;
PROC DELETE DATA=SAVE.DPH2B;
PROC DELETE DATA=SAVE.DPH2C;
PROC DELETE DATA=SAVE.DPH2D;
PROC DELETE DATA=SAVE.DPH2E;
PROC DELETE DATA=SAVE.DPH2F;
PROC DELETE DATA=SAVE.DPH2G;
PROC DELETE DATA=SAVE.DPH3A;
PROC DELETE DATA=SAVE.DPH3B;
PROC DELETE DATA=SAVE.DPH3C;
PROC DELETE DATA=SAVE.DPH3D;
PROC DELETE DATA=SAVE.DPH3E;
PROC DELETE DATA=SAVE.DPH3F;
PROC DELETE DATA=SAVE.DPH3G;
PROC DELETE DATA=SAVE.DPH4A;
PROC DELETE DATA=SAVE.DPH4B;
PROC DELETE DATA=SAVE.DPH4C;
PROC DELETE DATA=SAVE.DPH4D;
PROC DELETE DATA=SAVE.DPH4E;
PROC DELETE DATA=SAVE.DPH4F;
PROC DELETE DATA=SAVE.DPH4G;
```

REPORTS

REPORT 1

9712783 — TS MAP AREA: 63K4 SE 24 60 27 W WANLESS — PAGE 1

DATE INSTALLED: AUG 1971

YR	MT	DY	DAY NO	HOUR	WEATHER CONDITION	AIR TEMP	SNOW DEPTH	TEMP AT 2.5CM	TEMP AT 5CM	TEMP AT 10CM	TEMP AT 20CM	TEMP AT 50CM	TEMP AT 100CM	TEMP AT 150CM
71	08	01	213	1625	PT.CLOUDY	17.80	1.00-	14.10	13.40	11.30	11.10	9.10	6.10	4.40
71	12	02	336	0925	CLEAR	14.40-	1.00-	6.10-	2.40-	.90-	1.20	2.70	4.20	4.90
71	08	03	215	1130	CLEAR	20.00	1.00-	13.60	12.20	10.80	10.50	8.60	6.10	4.70
71	08	22	234	1430	CLEAR	21.50	1.00-	17.20	15.50	12.80	12.10	10.00	7.50	5.60
72	03	02	061	0950	CLOUDY	24.40-	41.00	2.70-	4.60-	3.70-	3.60-	2.00-	1.20	2.30
72	08	04	216	1500	CLOUDY	23.90	1.00-	18.20	16.20	11.80	10.00	8.80	6.60	5.00
72	09	08	251	1045	PT.CLOUDY	12.20	1.00-	6.10	7.80	7.60	8.00	9.00	8.50	6.50
72	01	12	012	0945	CLEAR	33.40-	41.00	5.10-	3.70-	2.50-	1.60-	1.60	2.40	3.60
72	12	13	347	0905	CLEAR	10.00-	11.00	5.60-	3.40-	1.20-	.30	2.60	4.30	5.10
72	10	18	291	1000	CLEAR	3.20-	1.00-	3.60-	1.80-	1.30	2.70	5.30	6.10	6.20
72	04	19	109	0925	CLEAR	2.40	1.00-	.00	.10-	.80-	1.20-	1.70-	1.10-	.10-
72	06	28	179	1000	CLOUDY	17.60	1.00-	14.90	13.20	10.00	8.80	4.70	.20	.00
72	05	31	151	1455	CLEAR	26.00	1.00-	19.80	14.40	5.40	3.00	.00	.40-	.00
73	05	03	123	0830	CLEAR	.20	105.00	.60-	.60-	.80-	.90-	.90-	.70-	.20-
73	06	06	157	1910	CLOUDY	10.60	1.00-	6.80	6.20	4.80	4.00	1.00	.20	.50
73	09	12	255	1900	RAIN	7.60	1.00-	6.60	7.60	9.30	9.80	9.80	8.40	7.10
73	08	14	226	1750	PT.CLOUDY	29.80	1.00-	23.00	20.60	16.20	14.60	11.70	6.80	6.60
73	07	17	198	1855	CLOUDY	17.20	1.00-	14.00	13.30	11.40	10.40	7.70	4.80	2.90
73	02	21	052	0910	CLOUDY	5.50-	28.00	6.30-	5.60-	4.60-	4.10-	2.40-	.20-	.80
73	09	27	270	1305	CLEAR	17.50	70.00	10.90	9.20	7.80	7.80	7.60	7.30	6.90
74	01	24	024	0930	CLEAR	28.40-	46.00	4.20-	2.90-	1.90-	1.20-	.20	1.50	2.50
74	05	28	148	1710	PT.CLOUDY	17.00	40.00	9.90	7.40	3.10	1.20	.00	.00	.60
75	12	03	337	0810	SNOW	17.00-	3.00	11.60-	10.00-	7.20-	3.40-	.90	3.10	4.00
75	07	09	190	0805	CLEAR	10.50	1.00-	11.30	11.90	12.60	13.20	12.00	7.80	4.50
75	10	22	295	0830	CLOUDY	2.00	1.00-	.00	.70	2.20	3.40	3.80	4.30	4.00
75	08	27	239	0805	CLEAR	6.00	1.00-	7.00	7.80	9.80	10.60	10.30	8.40	6.80
76	06	02	153	0730	CLOUDY	15.50	1.00-	12.40	11.30	9.10	6.30	1.20	.20	.60
76	03	04	063	0755	SNOW	12.00-	21.00	8.00-	6.80-	6.40-	5.30-	3.10-	.20-	1.10
76	11	10	314	0715	CLEAR	.00	1.00-	1.70-	.90-	.10-	1.40	2.70	4.40	5.20
76	04	14	104	0750	CLEAR	6.00	1.00-	.80	.20	.00	.20-	.80-	.80-	.00
76	07	14	195	0810	RAIN	15.00	1.00-	13.30	12.60	12.40	11.40	8.60	5.80	3.30
76	01	21	021	0800	CLEAR	17.00-	13.00	7.40-	6.80-	5.00-	3.80-	2.30-	.00	1.10
76	08	25	237	0755	CLOUDY	17.50	1.00-	14.80	14.70	14.30	13.40	10.90	8.20	6.40
76	09	29	272	0815	CLEAR	9.50	1.00-	8.00	8.00	8.40	7.70	7.90	7.90	7.50
77	06	02	153	1045	PT.CLOUDY	16.00	1.00-	13.30	11.70	9.40	7.80	5.60	2.20	2.20
77	01	05	005	0830	CLOUDY	15.60-	18.00	8.30-	5.60-	3.30-	1.10-	.60	2.20	2.80
77	04	05	095	0725	CLEAR	6.70-	1.00-	5.60-	4.40-	3.30-	2.80-	1.10-	.00	1.10
77	10	19	292	0810	PT.CLOUDY	3.30	1.00-	2.20	2.80	4.40	7.20	6.10	7.80	7.20
77	02	23	054	0740	CLOUDY	9.00-	24.00	3.90-	3.90-	3.90-	2.80-	1.10-	.00	.60
77	06	28	179	1230	CLEAR	26.30	1.00-	19.60	17.40	13.50	10.50	8.30	4.80	3.00
77	11	29	333	0825	CLOUDY	7.20-	8.00	7.20-	5.60-	2.80-	.60-	1.70	2.80	3.30
78	10	06	279	1130	CLOUDY	10.60	1.00-	4.40	6.10	6.10	7.80	8.90	8.90	8.30
78	05	09	129	0820	CLEAR	8.00	1.00-	3.30	2.80	1.70	.60	.00	.00	.00
78	08	15	227	0830	CLOUDY	13.00	1.00-	11.10	10.60	10.60	10.60	10.00	7.20	5.60
78	01	18	018	0910	CLEAR	27.00-	17.00	15.60-	11.70-	7.20-	3.90-	.60-	1.70	2.20
78	06	20	171	0820	CLEAR	14.40	1.00-	10.60	10.00	8.30	6.90	7.20	2.80	2.80
78	03	21	080	0900	CLEAR	1.00	22.00	2.20-	2.20-	2.80-	2.20-	1.70-	.60-	1.10
78	09	26	269	0830	PT.CLOUDY	6.00	1.00-	3.30	2.80	5.00	8.30	8.90	7.80	7.20
78	11	28	332	0900	SNOW	4.00-	20.00	16.10-	15.60-	9.40-	3.90-	.00	2.20	2.80
79	06	05	156	0820	CLOUDY	13.00	1.00-	11.70	11.10	8.30	4.40	1.10	1.10	1.70
79	11	06	310	0835	CLOUDY	1.70-	1.00-	.60-	.60-	.60	2.80	4.40	6.10	6.10

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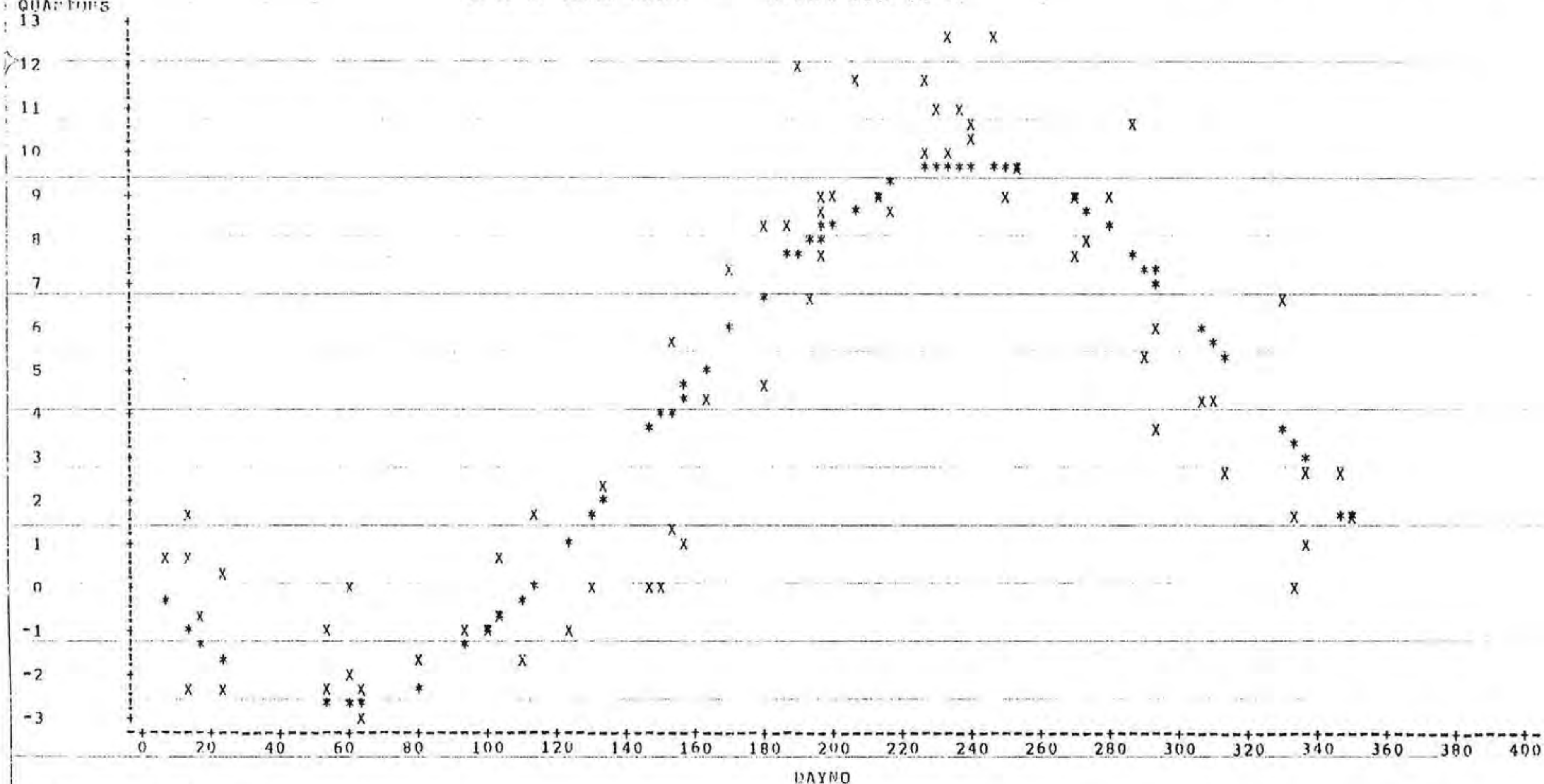
YR	MT	DY	DAY NO	HOUR	WEATHER CONDITION	AIR TEMP	SNOW DEPTH	TEMP AT 2.5CM	TEMP AT 5CM	TEMP AT 10CM	TEMP AT 20CM	TEMP AT 50CM	TEMP AT 100CM	TEMP AT 150CM
79	04	10	100	0835	CLOUDY	1.00-	44.00	2.20-	2.20-	2.20-	1.10-	1.10-	.00	.00
79	07	18	199	0655	CLEAR	19.00	1.00-	17.80	17.20	16.10	13.30	8.90	2.80	2.80
79	08	28	240	0900	CLOUDY	13.30	1.00-	13.90	13.30	13.30	11.70	10.60	8.30	7.20
80	09	04	247	0910	PT.CLOUDY	14.00	1.00-	13.30	13.90	13.90	13.30	12.80	15.00	9.40
80	03	05	064	0905	CLEAR	10.00-	36.00	10.60-	9.40-	7.20-	3.90-	2.20-	.00	.60
80	06	11	152	0905	CLEAR	18.30	1.00-	17.80	17.80	16.10	9.40	4.40	1.70	1.70
80	10	15	288	0925	RAIN	7.00	1.00-	5.60	6.10	8.30	10.00	10.60	11.10	10.60
80	01	15	015	0915	CLOUDY	16.10-	15.00	10.00-	9.40-	7.20-	5.00-	2.20-	.60	1.70
80	08	20	232	0900	CLEAR	23.90	1.00-	21.70	21.10	19.40	16.10	12.80	10.60	8.90
80	04	23	113	0840	CLEAR	7.80	1.00-	6.10	6.10	4.40	1.70	1.70	1.70	1.70
80	07	24	205	0925	PT.CLOUDY	24.40	1.00-	22.20	22.20	21.70	16.10	11.70	8.30	7.20
80	11	26	330	0905	PT.CLOUDY	10.00-	1.00-	1.10-	.60	3.90	6.10	6.70	7.20	6.10
81	11	03	307	0905	PT.CLOUDY	.50	1.00-	2.10	2.70	3.90	4.70	4.20	5.30	5.80
81	07	07	188	0900	CLEAR	20.50	1.00-	17.70	16.20	13.70	12.00	8.40	5.40	4.10
81	05	12	132	0855	CLEAR	8.50	1.00-	3.00	2.60	2.60	3.20	2.20	2.60	3.00
81	01	13	013	0912	PT.CLOUDY	6.50-	1.00-	3.20-	1.80-	1.60-	.30-	.60	2.00	2.50
81	07	15	196	1630	CLOUDY	14.00	1.00-	16.70	16.70	14.40	11.70	8.90	6.10	4.40
81	12	15	349	0943	PT.CLOUDY	33.00-	1.00-	7.20-	3.90-	1.20-	.60	1.80	4.00	3.30
81	08	19	231	0930	PT.CLOUDY	17.80	1.00-	17.20	16.70	14.40	13.30	11.10	8.30	7.20
82	03	02	061	0900	CLEAR	29.50-	40.00	4.90-	3.20-	3.40-	2.30	.00	.60	1.40
82	07	13	194	1445	CLOUDY	20.60	1.00-	18.90	17.80	13.90	10.00	6.70	3.30	2.20
82	04	14	104	0908	PT.CLOUDY	5.50	1.00-	1.20	1.10	1.20	.90	.80	1.60	1.00-

73 RECORDS PRINTED

REPORT 2

**63K4 SE246027W WALLESS AUG 1971 50 CM DEPTH 20:20 MONDAY, NOVEMBER 7, 1983 1

PLOT OF QUARTOBS*DAYNO SYMBOL USED IS X
PLOT OF IPRED*DAYNO SYMBOL USED IS *



NOTE: 19 OBS HIDDEN

REPORT-3.

OBS	DATEYR	DAYNO	QUANTOBS	TPRED	DIFF
1	71	213	9.1	9.1529	-0.0529
2	71	215	8.6	9.2435	-0.6435
3	71	234	10.0	9.7557	0.2443
4	71	336	2.7	2.9729	-0.2729
5	72	13	1.6	-1.0024	2.6024
6	72	61	-2.0	-2.6695	0.6695
7	72	109	-1.7	-0.3316	-1.3684
8	72	151	0.0	3.8654	-3.8654
9	72	179	4.7	6.7139	-2.0139
10	72	216	8.8	9.2862	-0.4862
11	72	251	9.0	9.6568	-0.6568
12	72	291	5.3	7.4769	-2.1769
13	72	347	2.6	1.8153	0.7847
14	73	52	-2.4	-2.6654	0.2654
15	73	123	-0.9	0.9445	-1.8445
16	73	157	1.0	4.5053	-3.5053
17	73	198	7.7	8.2707	-0.5707
18	73	226	11.7	9.6186	2.0814
19	73	255	9.8	9.5569	0.2431
20	73	270	7.6	8.9342	-1.3342
21	74	24	0.2	-1.7228	1.9228
22	74	148	0.0	3.5437	-3.5437
23	75	190	12.0	7.6677	4.3323
24	75	239	10.3	9.7819	0.5181
25	75	295	3.8	7.1348	-3.3348
26	75	337	0.9	2.8662	-1.9662
27	76	22	-2.3	-1.6052	-0.6948
28	76	63	-3.1	-2.6501	-0.4499
29	76	104	-0.8	-0.7365	-0.0635
30	76	153	1.2	4.0794	-2.8794
31	76	195	8.6	8.0545	0.5455
32	76	237	10.9	9.7769	1.1231
33	76	272	7.9	8.8231	-0.9231
34	76	314	2.7	5.3075	-2.6075
35	77	5	0.6	-0.3747	0.9747
36	77	54	-1.1	-2.6792	1.5792
37	77	95	-1.1	-1.3837	0.2837
38	77	153	5.6	4.0794	1.5206
39	77	179	8.3	6.7139	1.5861
40	77	292	6.1	7.3931	-1.2931
41	77	333	1.7	3.2939	-1.5939
42	78	18	-0.6	-1.3517	0.7517
43	78	80	-1.7	-2.1937	0.4937
44	78	129	0.0	1.5421	-1.5421
45	78	171	7.2	5.9472	1.2528
46	78	227	10.0	9.6421	0.3579
47	78	269	8.9	8.9874	-0.0874
48	78	279	8.9	8.3857	0.5143
49	78	332	0.0	3.4011	-3.4011
50	79	100	-1.1	-1.0378	-0.0622
51	79	156	1.1	4.3991	-3.2991
52	79	199	8.9	8.3400	0.5600
53	79	240	10.6	9.7816	0.8184
54	79	310	4.4	5.7146	-1.3146
55	80	15	-2.2	-1.1463	-1.0537
56	80	64	-2.2	-2.6376	0.4376

OBS	MOTHYR	DAYNO	QUARTOBS	TPRED	DIFF
57	80	113	1.7	0.0132	1.6868
58	80	162	4.4	5.0310	-0.6310
59	80	205	11.7	8.7254	2.9746
60	80	232	12.8	9.7324	3.0676
61	80	247	12.8	9.7278	3.0722
62	80	288	10.6	7.7214	2.8786
63	80	330	6.7	3.6156	3.0844
64	81	13	0.6	-1.0024	1.6024
65	81	132	2.2	1.8493	0.3507
66	81	188	8.4	7.5043	0.8957
67	81	196	8.9	8.1279	0.7721
68	81	231	11.1	9.7180	1.3820
69	81	307	4.2	6.0133	-1.8133
70	81	349	1.8	1.6103	0.1897
71	82	61	0.0	-2.6695	2.6695
72	82	104	0.8	-0.7365	1.5365
73	82	194	6.7	7.9797	-1.2797

REPORT - 4

OBS	AVTEMP	DAYAV2	DAYAV1	AVSUM	TEMPMIN	TEMPMAX	DAYMAX	DAYMIN	DAYZERO1	DAYZERO2	FROST	DATE5C1	DATE5C2	DAYSGT5C	DEGDAY5	DATE15C1	DATE15C2	DAYGT15C	DEGDAY15
1	3.5	148	330	7.7	-2.7	9.8	239	57	113	1	253	162	317	155	479	.	.	.	.

REPORT 5

---------- SITE=027WWANL ----------

OBS	SITE	DEPTH	AVTEMP	DAYAV1	DAYAV2	AVSUM	DAYZERO1	DAYZERO2	FROS1	TEMPMAX	DAYMAX	TEMPMIN	DAYMIN	DATE5C1	DATE5C2	DAYSGT5C	DEGDAY5	DATE15C1	DATE15C2	DAYGT15C	DEGDAY15
1	027WWANL	3	2.9	293	111	14.6	98	306	209	16.0	202	-10.2	19	120	284	164	1157	179	224	45	30
2	027WWANL	5	3.2	296	114	13.6	98	312	214	14.9	205	-8.6	23	123	287	164	1045	.	.	.	.
3	027WWANL	10	3.3	305	122	11.7	102	325	222	13.0	214	-6.5	31	132	294	162	839	.	.	.	.
4	027WWANL	20	3.6	315	132	10.1	105	342	237	11.6	224	-4.4	41	142	305	163	695	.	.	.	.
5	027WWANL	50	3.5	330	148	7.7	113	1	253	9.8	239	-2.7	57	162	317	155	479	.	.	.	.
6	027WWANL	100	3.5	352	170	5.4	118	39	286	8.1	261	-1.0	78	189	333	145	291	.	.	.	.
7	027WWANL	150	3.4	364	182	4.2	107	74	332	6.9	273	-0.1	91	209	337	128	162	.	.	.	.

---------- SITE=106WPORT ----------

OBS	SITE	DEPTH	AVTEMP	DAYAV1	DAYAV2	AVSUM	DAYZERO1	DAYZERO2	FROS1	TEMPMAX	DAYMAX	TEMPMIN	DAYMIN	DATE5C1	DATE5C2	DAYSGI5C	DEGDAY5	DATE15C1	DATE15C2	DAYGT15C	DEGDAY15
8	106WPORT	3	7.1	282	100	22.8	76	307	231	24.6	191	-10.5	9	93	289	196	2437	127	255	128	807
9	106WPORT	5	6.6	284	102	21.7	78	308	230	23.4	193	-10.1	11	96	290	194	2255	132	254	122	668
10	106WPORT	10	6.3	287	105	20.0	80	312	232	21.5	196	-8.9	14	100	292	192	2010	140	252	112	476
11	106WPORT	20	6.1	295	112	18.1	85	322	237	19.6	204	-7.4	21	107	299	192	1773	154	253	99	298
12	106WPORT	50	6.7	306	124	16.6	88	342	254	18.3	215	-4.9	33	115	315	199	1667	170	260	89	192
13	105WPORT	100	6.6	326	143	13.0	95	10	280	15.5	235	-2.3	52	133	336	204	1349	214	255	40	14
14	106WPORT	150	6.6	342	160	10.2	83	54	336	13.3	251	-0.2	69	146	356	210	1096	.	.	.	.

---------- SITE=107EANOL ----------

OBS	SITE	DEPTH	AVTEMP	DAYAV1	DAYAV2	AVSUM	DAYZERO1	DAYZERO2	FROST	TEMPMAX	DAYMAX	TEMPMIN	DAYMIN	DATE5C1	DATE5C2	DAYSGT5C	DEGDAY5	DATE15C1	DATE15C2	DAYGT15C	DEGDAY15
15	107EANOL	3	6.7	293	111	17.6	77	328	251	18.8	202	-5.4	20	103	302	199	1735	155	250	95	239
16	107EANOL	5	6.8	296	113	16.7	75	334	258	18.0	205	-4.4	22	104	305	201	1643	161	248	87	170
17	107EANOL	10	6.6	304	121	14.9	76	348	272	16.2	212	-2.9	30	111	314	203	1424	183	241	58	45
18	107EANOL	20	6.9	308	125	14.2	70	362	292	15.5	216	-1.6	34	112	321	209	1371	197	236	39	12
19	107EANOL	50	7.1	317	135	12.6	43	43	365	14.1	226	0.2	43	116	335	219	1240	.	.	.	.
20	107EANOL	100	7.4	328	145	11.3	54	54	365	13.0	237	1.7	54	120	353	232	1149	.	.	.	.
21	107EANOL	150	7.4	338	156	10.1	65	65	365	12.1	247	2.6	65	125	369	244	1058	.	.	.	.

--- SITE=504WJOEY ---

OBS	SITE	DEPTHUP	AVTEMP	DAYAV1	DAYAV2	AVSUM	DAYZERO1	DAYZERJ2	FROS1	TEMPMAX	DAYMAX	TEMPMIN	DAYMIN	DATE5C1	DATE5C2	DAYSGI5C	DEGDAY5	DATE15C1	DATE15C2	DAYGT15C	DEGDAY15
22	504WJOEY	3	3.2	294	112	15.4	98	308	210	16.8	203	-10.4	20	119	286	167	1268	173	233	61	73
23	504WJOEY	5	3.5	294	111	14.7	95	310	215	16.0	203	-9.1	20	118	287	168	1190	179	226	47	32
24	504WJOEY	10	2.8	304	121	11.0	104	321	217	12.3	213	-6.7	30	135	290	155	731	.	.	.	.
25	504WJOEY	20	2.0	314	132	8.0	115	330	215	9.4	223	-5.3	40	156	290	134	381	.	.	.	.
26	504WJOEY	50	0.3	340	158	1.6	149	348	199	2.6	249	-2.0	66	.	.	.	.	.	.	.	.
27	504WJOEY	150	0.2	364	181	0.3	141	39	264	0.5	273	-0.1	90	.	.	.	.	.	.	.	.

REGIONAL ANALYSIS OF DATA

PREDICTION OF SOME SOIL THERMAL REGIMES IN NORTHWESTERN BRITISH COLUMBIA WITH COMPARISONS TO THE SOIL CLIMATE MAP OF CANADA AND SOIL TEMPERATURE CLASSES USED FOR CANADA

Submitted to Gordon Mills, Chairman
of the Soil Climate Working Group of
the Expert Committee on Soil Survey

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February, 1984

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INTRODUCTION

Late in 1979, the British Columbia Ministry of Forests began to collect soil temperature data in order to quantify soil climate in relation to its ecologic classification program. Some of that data is used in this report to provide the Soil Climate Working Group of the Expert Committee on Soil Survey (Day 1981) with comments on:

1. The Soil Climate Map of Canada (Canada Dept. of Ag. 1977),
2. The Soil temperature classes used for Canada (Ibid.)and,
3. preliminary results of using the DREAM program to predict soil thermal regimes from measured observations.

STUDY AREA

The data selected for use in this report was collected from climate stations in the Prince Rupert Forest Region (an administrative unit) in northwest British Columbia (see Figure 1). A discussion and description of the B.C. Ministry of Forests biogeoclimatic (BGC) classification and zonation can be found in the fourth edition of the Forestry Handbook for British Columbia (Watts, ed. 1983). Descriptions of the subzones, variants and zonal ecosystems are currently in unpublished manuscripts that can be provided by myself on request. In Figure 1 the BGC zonation abbreviations are used. The capital letters are zones, the lowercase letters are subzones, and the numerals are variants. For the general purposes of this report, the reader need only know that the SBS, ESSF, ICH, and CCPH refer to the Sub-Boreal Spruce, Engelmann Spruce Subalpine Fir, Interior Cedar Hemlock, and Coastal

Figure 1. Study area, Climate Station number and name, and the B.C. Ministry of Forests BGC zonation.

Cedars Pine Hemlock zones. Table 1 (ref.) gives some representative climatic characteristics of the zones, but not necessarily from within the study area of this report.

METHODS

Soil climate stations were monitored once a month for an average period of three years. Monitoring equipment was a Soil Test 302 meter and thermisters, or a Atkins # 44000-C meter and thermisters. All measurements in this report are from 50 cm below the top of the surface soil horizon (generally the F horizon). Sites were selected as being the model concept of the zonal ecosystem association at the subzone or variant level. In theory, these sites reflect the average regional climate inputs through a characteristic combination of plants and soil development. All parent materials are glacial till.

The data was sent to the Land Resource Institute and run using the DREAM program. The output was used to calculate the temperature classes and then compared to the Soil Climate Map of Canada and to the generalized characteristics of the temperature classes. Comments on the predicted values of the DREAM output are my own opinion based on the graphical output of DREAM and a few calculations of the SBS data independent of the DREAM output.

Zone	Range and Reference Station	Elev. (m)	Mean Annual Precip. (mm)	Mean summer Precip (mm) (May-Sept)	Mean precip. of driest month (mm)	Mean Precip. of wettest month (mm)	Driest month	Wettest month	Potential Evap. transpiration (mm)	Mean Annual Snowfall (cm)	No. of months with snow	Mean Annual Temp (C)	Mean Temp coldest month (C)	Extreme min Temp (C)	Mean Temp warmest month (C)	Extreme Max Temp (C)	No of months with mean temp (C) >10	<0	No. of frost free Days	Frost free period (Days)	Accumulated Degree (C) Days Above 5	Above 10
CCHH	Max		2969.9	960.4	125.0	416.8				113.2	7	8.5	3.6	-12.2	14.3	32.2	4	0	344	263		
	Min		1433.4	402.8	59.9	188.5				35.6	5	7.6	1.8	-21.1	12.9	25.6	4	0	294	169		
	Prince Rupert	51.8	2414.5	739.7	107.2	359.2	June	Dec	294.3	113.2	7	7.7	1.8	-21.1	13.9	32.2	4	0	294	199	1358.9	402.0
ESSF	Max		2402.0	587.0	94.0	379.0		-		1071.2	12	2.2	-8.0	-35.6	13.6	35.6	2	7	131	66		
	Min		418.9	213.3	12.0	54.9				167.1	9	-1.9	-13.6	-51.1	9.4	27.2	0	5	88	12		
	Barkerville	1274.1	1148.8	473.7	64.5	117.9	May	Aug	372.1	581.4	10	1.4	-9.8	-46.7	12.3	35.6	2	5	115	49	738.2	210.6
ICH	Max		1492.8	409.7	64.0	227.3				969.5	9	8.7	-2.4	-27.2	20.9	42.8	5	5	244	186		
	Min		479.6	160.0	15.0	54.5				110.7	6	2.1	-11.3	-48.9	13.3	33.3	3	2	108	20		
	Revelstoke	456.3	1096.3	322.6	51.3	157.7	May	Dec		411.7	7	7.2	-5.9	-34.4	19.4	40.6	5	3	215	140	1872.1	977.5
SBS	Max		931.0	344.4	32.0	85.3				374.5	9	4.4	-5.3	-41.1	16.4	40.6	5	5	172	99		
	Min		336.8	81.8	13.9	47.2				155.0	8	0.3	-17.5	-51.7	11.7	30.6	2	3	68	12		
	Prince George A	676.0	620.5	287.5	29.5	73.4	April	Aug	539.6	233.4	9	3.3	-11.8	-50.0	14.9	34.4	3	5	162	78	1190.6	433.4

Table 1. Climatic Characteristics of the biogeoclimatic zones
(taken from Watts, ed. 1983).

RESULTS AND DISCUSSION

Soil Climate Map of Canada

Given the scale of the map it seems to generally convey the appropriate level of correct information at lower elevations and valley bottoms for mean annual soil temperature at 50 cm (MAST) and mean summer soil temperature at 50 cm (MSST). These are the primary classifiers for the temperature classes. It does generally convey correct information for total days $\geq 5^{o}C$, but not for degree days $\geq 5^{o}C$ at 50 cm which are the secondary classifiers.

I assume the base data for the map was collected from atmospheric data at airports or other locally populated areas and modeled to predict soil temperatures. I know of no published measured soil temperatures in northwestern British Columbia, or of any other active measurements except my own. If this is the case, the mapping should be given credit for conveying the information as accurate as it does. However, the map classified all the selected stations in the same class - 3.1 Cryoboreal, cold (Table 3). Four of the eight stations would be most appropriately classified as the map indicates using the DREAM output (Tables 2 and 3). These stations are all in the valley bottoms of their respective landscapes. The remaining four stations would be classified colder, they are at mid to upper macro slope positions close to or in the subalpine but below the alpine regions. This represents a significant portion of the 3.1 map unit, 50% plus in total land area would be my estimate.

Table 2. Output Summary from DREAM analyses of data, predicted values.

Station No.	Station Name	BGC	Mean Annual Temperature °C[1]	Mean Annual Temperature Day occurring First	Mean Annual Temperature Day occurring Last	Aug. summer Temp °C[1]	Yearly Min-Max. Min. °C	Yearly Min-Max. Min. Day	Yearly Min-Max. Max. °C	Yearly Min-Max. Max. Day	0°C Day Occurring First	0°C Day Occurring Last	"Frost" free days	5°C Day Occurring First	5°C Day Occurring Last	5°C Total[2] days ≥ 5°C	5°C Degree[2] days ≥ 5°C	No. of quant. observ.
1	Round Lake	SBSd	3.6	136	319	7.9	-1.9	45	9.1	228	360	95	265	151	304	153	404	46
2	Burnt Cabin Rd.	SBSe	2.0	156	339	3.9	-1.5	65	5.4	248	9	122	252	219	276	57	16	33
3	Cronin Rd.	ESSFk	2.6	146	329	4.9	-0.6	55	5.9	238	19	91	293	194	281	87	50	33
4	Hudson's Bay Mt.	ESSFk	2.3	152	335	4.1	-0.5	61	5.2	244	25	97	292	224	263	39	4	44
5	Corduroy Ck. 910 m	ICHg1	2.5	155	338	4.6	-1.2	64	6.2	247	15	113	267	199	294	95	72	20
6	Corduroy 530 m	ICHg2	3.8	141	323	7.8	-1.5	49	9.2	232	4	94	275	153	310	157	425	28
7	Bulkley River	ICHg3	4.5	140	323	8.7	-1.2	49	10.1	231	10	88	287	146	317	171	566	20
8	Diana Ck.	CCPH	5.0	145	328	7.9	0.8	54	9.2	237	54	54	365	145	328	183	406	32

[1] Primary classifier for temperature classes
[2] Secondary classifier for temperature classes

Table 3. Summary of station temperature classes from soil climate map of Canada and from predicted values.

Station			Classifier values for classes[1]				Temperature Classes		
			Primary		Secondary				
No.	Name	BGC	Mean Annual soil temperature (MAST)	Mean summer soil temperature (MSST)	Growing season days	Growing season degree days	Classified from predicted values	Classified from soil climate map of Canada	Classification problems
1	Round Lake	SBSd	3.6	7.9	153	404	3.1 Cryoboreal, cold	3.1 Cryoboreal, cold	MSST less than 8^{0}, degree days less than 555
2	Burnt Cabin Rd.	SBSe	2.0	3.9	57	16	Does not classify, may be: 2 - Subartic, very cold	3.1 Cryoboreal, cold	MAST = $2^{0}C$, MSST less than $5^{0}C$, no permafrost in this region.
3	Cronin Rd.	ESSFK	2.6	4.9	87	50	Does not classify, may be: 2 - Subartic, very cold	3.1 Cryoboreal, cold	MAST greater than 2^{0}, MSST less than $5^{0}C$, no permafrost in this region.
4	Hudson's Bay Mtn.	ESSFk	2.3	4.1	39	4	Does not classify, may be: 2 - Subartic, very cold	3.1 Cryoboreal, cold	MAST greater than $2^{0}C$, MSST less than $5^{0}C$, no permafrost in this region.
5	Corduroy Ck 910 m	ICHg1	2.5	4.6	95	72	Does not classify, may be: 2 - Subartic, very cold	3.1 Cryoboreal, cold	MAST greater than 2^{0}, MSST less than $5^{0}C$, no permafrost in this region.
6	Corduroy Ck 530 m	ICHg2	3.8	7.8	157	425	3.1 Cryoboreal, cold	3.1 Cryoboreal, cold	MSST less than 8^{0}, degree days less than 555.
7	Bulkley River	ICHg3	4.5	8.7	171	566	3.1 Cryoboreal, cold	3.1 Cryoboreal, cold	None
8	Diana Ck.	CCPH	5.0	7.9	183	486	3.1 Cryoboreal, cold	3.1 Cryoboreal, cold	MSST less than $8^{0}C$, degree days less than 555.

[1] Predicted values from DREAM Output.

Soil Temperature Classes

The stations selected for analyses in this report are representative of discrete landscapes climatically (Table 1), physically, and biologically (Watts ed. 1983). The predicted values from the DREAM output (Table 2) were derived from measured monthly data recorded in Experimental Project 920, B.C. Ministry of Forests. The sites were classified using the characteristics of temperature classes (Canada Dept. of Ag. 1977) as class limits (Table 4).

One site (Bulkley River) has no classification problems, all the rest had some amount of discrepancy for both primary and secondary class limits (Table 3). There were generally fewer classification problems using the class limits for the primary classifiers than for the secondary ones. The supplementary information did not prove useful.

Table 4. Class Limits of the Temperature Classes used to classify the Stations (taken from Canada Department of Agriculture 1977).

Classes	Characteristics				
	Primary		Secondary		Supplementary
	MAST °C	MSST °C	Days ≥ 5°C	Degree Days ≥ 5°C	
2. Subarctic, very cold	-7 to 2	5 to 8	120	555	widespread permafrost
3. Cryoboreal					
3.1 Cold	2 to 8	8 to 15	120 to 180	555 to 1110	N.A.
3.2 Moderately cold	2 to 8	8 to 15	220	1110 to 1250	N.A.

The MAST and MSST Class limits were problems in Stations 2,3,4, and 5 if classified as Subartic. The MAST values are higher and the MSST are lower than they should be. However, values of the $\geq 5^{o}C$ days and degree days are so small that the Cryoboreal (Soil Map of Canada) class seems inappropriate. The Supplementary characteristics are also inappropriate here as there is no permafrost at all in these subalpine and near-subalpine environments. The predicted MSST of stations 1,6, and 8 are so close to the lower class limit of $8^{o}C$ that I disregarded the discrepancy in classification.

Of particular interest are the values of the secondary classifier - degree days. For management interpretation, this characteristic is highly significant and is classified incorrectly in three of the four (stations 1,6,7, & 8) Cryoboreal classifications. Stations 1,6, and 8 are on the average 117 degree days below the lower limit of 555 degree days. However, the Cryoboreal, cold classification appears most appropriate given all classifier values.

DREAM Output

All of the proceeding comments on the Soil Climate Map and temperature classes were based on the results of the predicted values from the DREAM program output. At the same time the Land Resource Research institute was running my data, I was calculating some pararellel values and graphing the data for stations in the SBS (stations 1 and 2 and others not reported here).

In predicting values, I believe DREAM generally predicts colder winter and summer temperatures and warmer spring and fall temperatures. The Round Lake (#1) and Burnt Cabin Rd. (#2) stations are examples (Tables 5 and 6). Using three years of observed monthly data points to estimate MAST, Round Lk. and

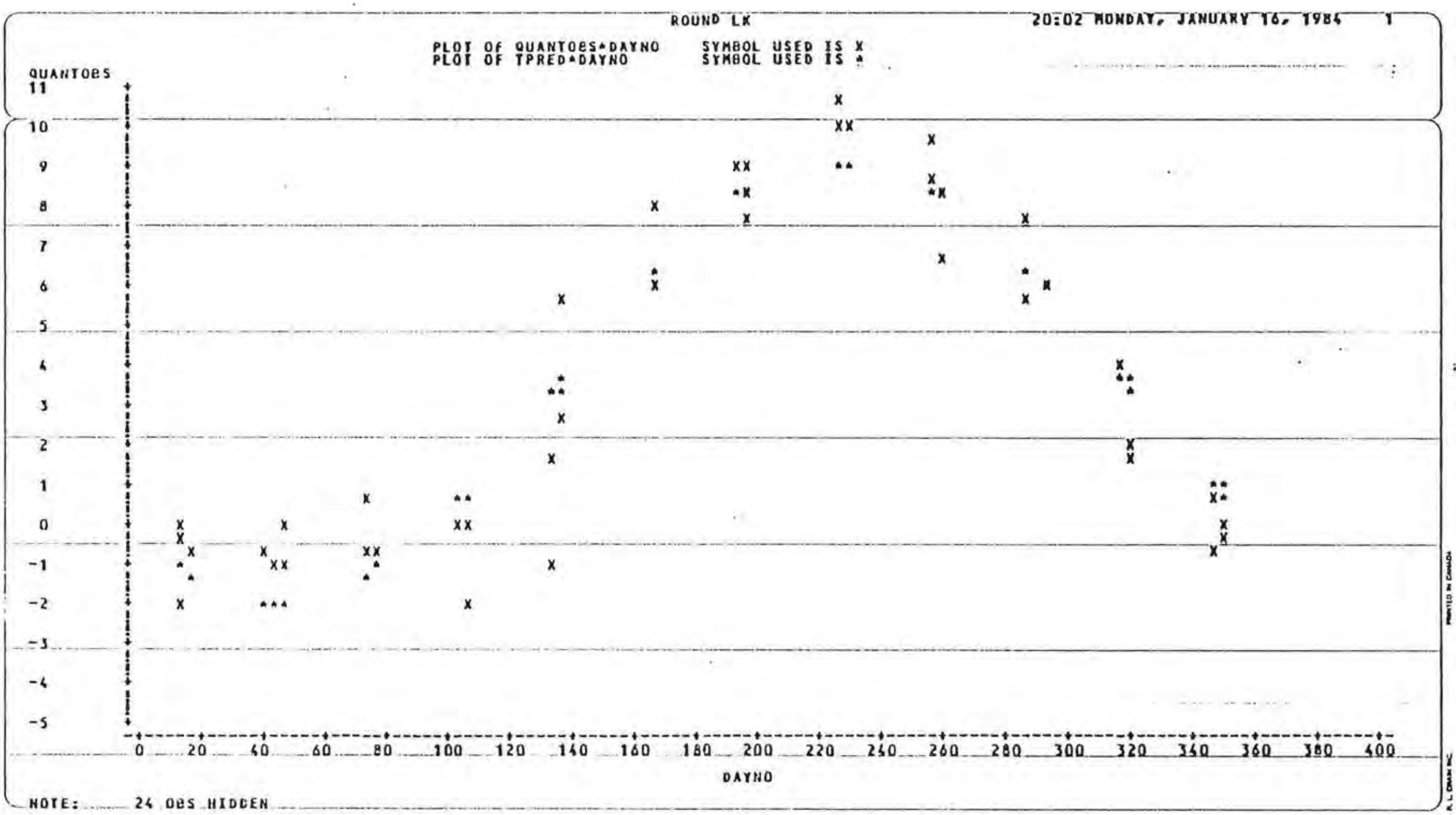

Table 5. Plotted observations and predicted values for Station 1, Round Lake.

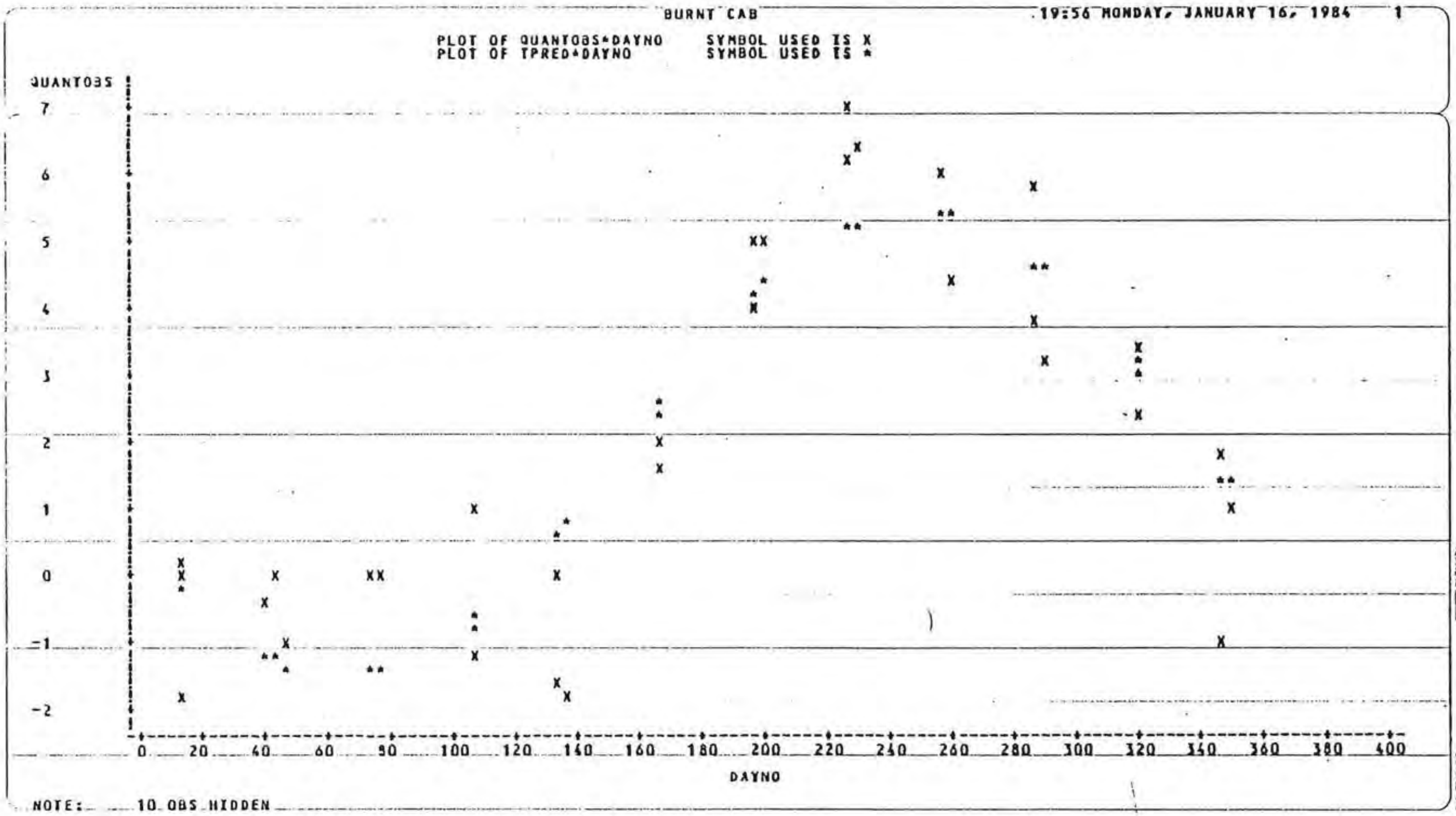

Table 6. Plotted observations and predicted values for Station 2, Burnt Cabin Rd.

Burnt Cabin Rd. have values of $3.8^{o}C$ and $2.8^{o}C$ respectively as compared to $3.6^{o}C$ and $2.0^{o}C$ from the predicted values. The $\geq 5^{o}C$ days and degree days were estimated graphically from measured observations for these two sites as 144 days/508 degree days (Round Lk.) and 94 days/187 degree days (Burnt Cabin Rd.). The predicted values (DREAM) are 153 days/404 degree days (Round Lk.) and 57 days/16 degree days. My experience in this geographic region and in comparing the plotted values in Tables 5 and 6 lead me to suspect the over and under estimations in the DREAM output as previously mentioned.

CONCLUSIONS AND RECOMMENDATIONS

In the specific locations that I tested, the Soil Map of Canada generally conveys correct information about the primary classifiers in the major valley bottom-lands of the map, however, a large portion of the 3.1 map unit, the mid and upper macro slopes, are of a colder class. The secondary classifier - $\geq 5^{o}C$ degree days - cannot be extracted from the map with confidence which severely limits the interpretive value of the map for forestry and agricultural productivity. I suggest that the map include locations and type of data used and note the probable discrepencies due to elevation, aspect, and scale.

All but one of the sites tested had classification problems using the predicted values. The classifiers with the most interpretive value (secondary classifiers) were also the values in which these selected sites had the most classification problems. Of particular interest is the $\geq 5^{o}C$ degree days, I recommend that the taxonomic level and limits for that classifier be studied in greater detail.

The DREAM program is very valuable and essential for classification and interpretive work. However, the classification problems encountered with the selected stations may in part be a result of predicted rather than the actual values. I recommend that we study this in closer detail.

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REGIONAL ANALYSIS OF DATA--SASKATCHEWAN

R.J. St. Arnaud

In view of the minimal amounts and sporadic nature of soil temperature data available, few evaluations of the data have been attempted. A cursory look at some of the soil temperature data being generated at the AES stations in the province is presented below.

(a) Saskatoon: Mean annual soil temperatures (MAST) recorded at various soil depths at the Saskatoon station (Sask. Research Council) from 1977 to 1982, inclusive, are tabulated in Table 1. The MAST values calculated for the shallow soil depths were somewhat higher than those below the 50 cm depth. The mean annual air temperature (MAAT) for the same period was 2.3 $\pm$ 1.20 degrees Calcius. The long-term MAAT is reported as 1.8°C. It is apparent that the MAAT is about four degrees lower than the MAST. The temperature regime at Saskatoon would be classified as FRIGID (see Table 2) according to the USDA Soil Taxonomy, and straddles the cold-cool Canadian soil temperature classes.

(b) Saskatchewan sites: Soil temperature data for five Saskatchewan sites shown on the Zonal Map (Figure 1) provide an indication of the variation of soil temperature values at the 50 cm depth (Table 3). Due to incomplete data, the values represent 2 to 3 year averages from data collected over the 1977 to 1982 period. The data illustrated the range of MAST, MSST (mean summer soil temperature) and MWST (mean winter soil temperature) across a wide range of sites in the province.

Table 1. Mean Annual Soil Temperatures Recorded at Saskatoon (°C)

	1977	1978	1979	1980	1981	1982	Mean
Air	2.6	1.3	0.6	2.4	4.5	2.6	2.3 ± 1.20
10 cm	5.73	5.27	5.16	6.40	8.19	7.42	6.30 ± 1.15
50 cm	6.55	6.25	6.95	6.39	7.25	6.18	6.59 ± 0.38
100 cm	6.74	6.03	5.44	6.34	6.53	5.30	6.06 ± 0.53
150 cm	5.47	5.85	5.49	6.05	6.11	5.15	5.68 ± 0.34
300 cm	6.57	5.93	5.17	6.09	6.08	5.29	5.85 ± 0.48
						MAST	6.09 ± 0.32

MSST = 15.42 ± 0.38

MWST = -4.06 ± 1.93

Diff = 19.48°

Table 2. Criteria for Soil Temperature Regimes used in the USDA Soil Taxonomy

	MAST	MSST	(MSST - MWST)*
PERGELIC	$< 0^{\circ}$		
CRYIC	$> 0, < 8^{\circ}$	$< 15^{\circ}$	
FRIGID	$< 8^{\circ}$	$> 15^{\circ}$	$> 5^{\circ}$
MESIC	8° to $< 15^{\circ}$	--	$> 5^{\circ}$
THERMIC	15° to $< 22^{\circ}$	--	$> 5^{\circ}$
HYPERTHERMIC	22° and higher	--	$> 5^{\circ}$

* For ISO-(FRIGID, MESIC, THERMIC, HYPERTHERMIC) regimes, the (MSST-MWST) values are less than 5°C.

Table 3. Soil Temperatures recorded at various locations in Saskatchewan.*

	MAST	MSST	MWST	MSST-MWST
Estevan	6.74	15.3	-0.7	16.0
Swift Current	5.44	14.5	-1.91	16.4
Yorkton	5.67	13.0	-3.1	16.1
Saskatoon	6.09	15.4	-4.1	19.5
Hudson Bay	5.18	12.9	-0.7	13.6

* Tentative values reflect 2-3 year averages from AES data collected between 1977 and 1982. All measurements reported are for the 50 cm depth.

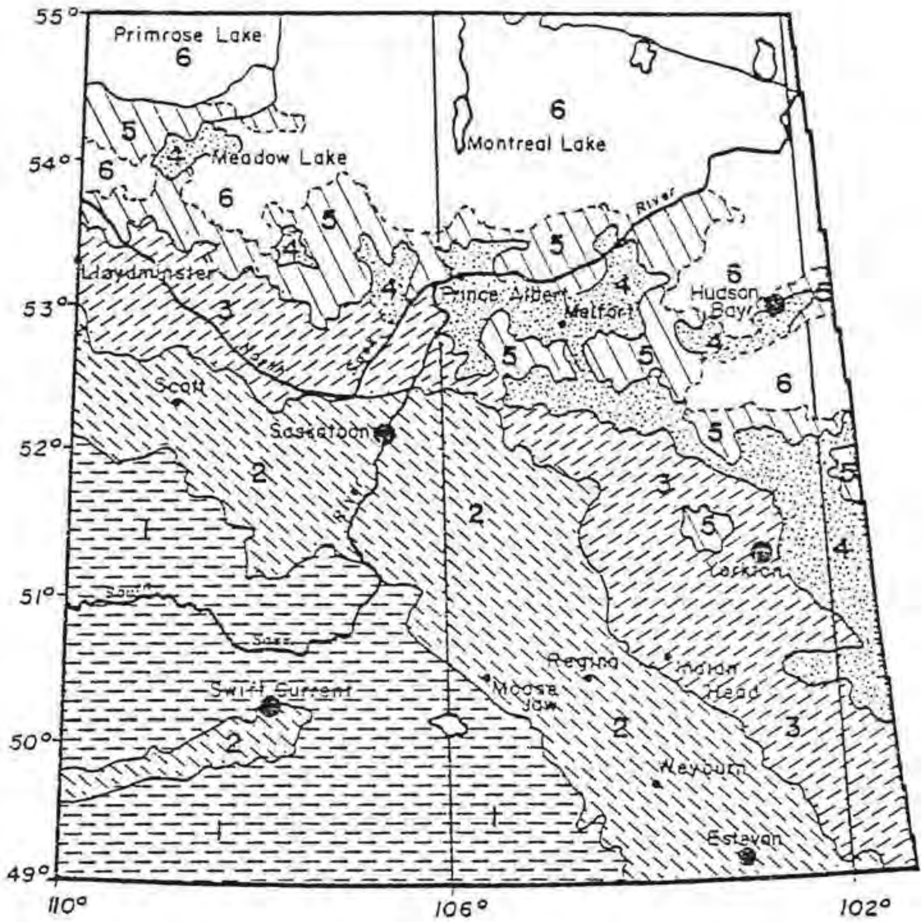


Figure 1. Major Soil Zones of Saskatchewan (1--Brown Soils of the Short Grass Prairie; 2--Dark Brown Soils of the Mixed Grass Prairie; 3--Black Soils of the Parkland Region; 4--Black and Dark Grey Soils of the Parkland-Forest transitional area; 5--Gray and Dark Gray Soils of the agricultural region of Southern Forest; 6--Gray Soils of the Northern Forest.

REGIONAL ANALYSIS OF DATA - MANITOBA

G.F. Mills

INTRODUCTION

Prior to 1965, only minimal amounts of soil temperature data based on sporadic measurements were available in Manitoba. Most of these data were collected in conjunction with ongoing research programs.

Recognizing this deficiency, the Atmospheric Environment Service established a soil temperature site at the Winnipeg International Airport in 1965 and a second site at the Glenlea Research Station in 1967. More recently, sites have been established at Gimli and Thompson. The soil temperatures measured from these sites, although not under natural conditions do provide high quality data collected under standardized conditions.

The Canada-Manitoba Soil Survey also recognizing the scarcity of data, began an investigation of soil temperature in 1971. Since this project was initiated a network consisting of 100 sites is currently maintained and monitored by the soil survey and cooperating agencies.

The frequency of monitoring and therefore the quality of the data being obtained at each site varies with the objectives for particular sites, ranging from detailed weekly measurements to much less frequent quarterly or semi-annual readings. Results from soil temperature studies in Manitoba have been reported previously (Mills et. al., 1977 and 1978 and Krpan, 1982).

The study of soil temperature is similar to that of other climatic related variables and must be monitored over extended time periods. Because large volumes of data accumulate over the monitoring period, there is need to periodically assess and analyse the available data.

The purpose of this paper is to analyze selected aspects of soil temperature data currently available in Manitoba. Analysis will emphasize aspects of the data which have not been evaluated previously due to insufficient length of record. In addition some portions of the data are re-evaluated in light of the greater length of record now available. As such, analysis and discussion of the available soil temperature data appears under a series of topics which are not always related other than they are all derived from the same data base.

MINIMUM LENGTH OF RECORD

In order to plan the necessary logistics and resources for monitoring soil temperature, it is helpful to have some idea of the minimum length of record required to adequately characterize the soil thermal regime. Obviously, data that is measured more frequently and over a longer time period will account for a greater portion of the natural variation and the assessment of the soil thermal regime will be more reliable.

The data presented in Table 1, were obtained over a 10 year period from a cultivated loamy Gleyed Cumulic Regosol (62 G13) near Portage la Prairie. By encorporating measurements from a single year with data from the previous 5 years it is seen that mean annual and mean summer values are not measurably affected. The addition of each subsequent years data appears to have only minimal effect on the mean values, at least at the 50 cm depth. It appears that a minimum of 5 years data accumulated at the minimum frequencies of observation obtained from this site provides characterization of a soil's thermal regime which is adequate to serve many purposes.

Table 1. MINIMUM LENGTH OF RECORD FOR RELIABLE SOIL TEMPERATURE DATA

TIME PERIOD	NO. OF RECORDS	SOIL TEMPERATURE, 50 cm	
		MEAN ANNUAL	MEAN SUMMER
1972-1977	70	6.8	16.6
1972-1978	75	7.0	16.5
1972-1979	78	6.9	16.5
1972-1980	87	7.0	16.7
1972-1981	95	7.1	16.8
1972-1982	110	6.8	16.4

COMPARISON OF MEASURED AND ESTIMATED SOIL TEMPERATURE

An important use projected for measured soil temperatures is to provide a test or validation of estimated soil temperatures. Soil temperatures can be estimated quite readily for any part of Canada using modern modelling techniques. A close fit between estimated values and actual measurements will increase the confidence with which estimated values may be used and as well greatly increase the data base of usable soil temperatures across Canada.

Soil temperatures measured at 3 depths from selected Manitoba stations are compared with estimated values from the nearest meteorological station (Table 2). This preliminary comparison was made by J. Shields of the Land Resource Research Institute using estimated values provided by Ouelette (1972) and measured values reported by Mills et. al., (1977). The comparison indicates a fairly close similarity between the data sets although a statistical evaluation is not available.

Table 2. COMPARISON OF MEASURED** AND ESTIMATED*

SOIL TEMPERATURES (MSST)

FOR SOME MANITOBA STATIONS

Station	20 cm	50 cm	100 cm
Brandon CDA*	17.1	15.7	12.8
62G5**	17.1	14.9	10.8
Cypress River*	17.4	15.7	12.9
62G7**	17.0	15.3	11.3
Hamiota*	16.6	14.7	10.9
62K1**	16.0	13.5	8.9
Portage*	18.0	16.3	12.9
62G13**	18.5	16.6	13.1
Winnipeg Airport*	17.6	15.9	12.9
62H6**	19.1	15.9	13.0
Dauphin Airport*	16.5	14.5	11.4
62N1**	17.8	15.7	12.5
Sprague*	16.8	15.1	12.4
62E3**	8.8	9.8	8.4

Comparison Courtesy of Jack Shields - January, 1983

* Estimated in Ag. Tech. Bull #85

** Measured as reported by Man. Soil Science Meeting 1977

The estimated data from Sprague show the greatest divergence from the measured values (Site 62E3). Much of this difference can be attributed to the affect of the heavy forest cover on Site 62E3. The computer model used to estimate soil temperature utilizes soil temperature relations observed under standard grass-covered sites maintained at a 5 cm length. All other sites were monitored under various kinds of agricultural land use which would more closely approximate the conditions under which the computer model estimates soil temperature.

The comparison presented in Table 2 should be repeated with more current Manitoba data (an additional 5 years of measurements are now available for some sites). Similar comparisons should also be made in other parts of Canada to provide a more widely based test of the computer model and where necessary a means of adjusting the model for specific soil and site conditions ie forest vegetation, poor drainage, sand and clay textures.

FREQUENCY AND INTENSITY OF OBSERVATIONS

Characterization of the soil thermal regime will obviously be more accurate and precise if based on a large number of observations. However, many applications of soil temperature data may not require such great accuracy and precision. Prior to establishment of a monitoring program it is useful to know what difference there is in mean soil temperature calculated from a very large number of observations as opposed to using relatively less frequent observations.

The data presented in Table 3 are from two sites separated by about 8 km near Portage la Prairie. The mean summer soil temperatures from the Plant Science research plot are based on very frequent observations (measured automatically every 3 hours, night and day) through the growing seasons of 1980 and 1981. The soil type is an imperfectly drained Neuhorst clay loam subjected to various tillage treatments. The mean summer soil temperature from the Newton Siding site (62G13) is derived from relatively infrequent observations measured randomly throughout 1972-1982. The soil type at Newton Siding is an imperfectly drained Gervais silty clay loam. Tillage and cropping history was not determined during the duration of monitoring.

Observations at the Plant Science research plot constitute a relatively large data base (in excess of 1000 measurements) accumulated over a fairly short time period (growing season). This data has highest reliability for calculation of soil temperature means which are closely related to the period being monitored and applicable to the objectives of that particular study. On the other hand, the mean temperature for the Newton Siding site is calculated from much less data (110 observations), distributed over a 10 year period. These less detailed measurements may be more appropriate for characterizing the long term soil temperature regime.

Table 3. EFFECT OF FREQUENCY AND INTENSITY OF OBSERVATIONS ON MEAN SUMMER SOIL TEMPERATURE

Plant Science Research Plot[1]	MSST (20 cm)	
(Neuhorst clay loam)	1980	1981
- conventional tillage (spring)	17.38°C	17.19°
- zero till (straight coulter straw retained)	16.52°C	16.97°C
Newton Siding 62G13[2]	1972 - 1982	
(Gervais silty clay loam)		
- tillage and cropping not determined	18.2°C	

1. Wall, D.A., Reduced tillage field corn (Zea mays L.) production in Manitoba. M.Sc. Thesis. Plant Science Department, University of Manitoba. 1982

2. Canada-Manitoba Soil Survey - Soil Climate Monitoring program.

Unfortunately, the comparison of data bases presented in Table 3 cannot be examined statistically. The data indicate however, that mean temperature values derived from a small number of observations are adequate to serve some objectives. The mean developed from the 110 observations differs by 0.8°C to 1.7°C from the means derived from the intensively monitored sites.

Frequency and intensity of observation is an important part of a monitoring program because it affects suitability of the data to serve the objective as well as the cost of the monitoring program. It is suggested that data from several soil temperature sites in Canada should be analyzed to determine how the level of accuracy and precision changes as the number of observations are reduced. This analysis could utilize procedures developed to analyze data from St. Augustin, Quebec, (Baril, this proceedings).

WINTER SOIL TEMPERATURE

Measurement - Most soil temperature measurements in Manitoba have been obtained using thermocouple instrumentation. The reliability of these measurements is satisfactory throughout the growing season but accuracy of the data decreases during winter when air temperatures fall below the ambient range of the potentiometer instrument. The difficulties with obtaining winter measurements were partially overcome by operating the instrument within a portable insulated and heated wood box. Even with such precautions, deviations between observed and actual soil temperature occurred. The amount of deviation increases as air temperatures fall below the ambient operating range of the instrument. The maximum discrepancy noted is between 1.5°C and 2.0°C warmer than the actual soil temperature.

Soil layers which probing show to be frozen or permafrost layers which are known to be at or only slightly below $0^{\circ}C$ are used as a reference point to gauge the accuracy of the instrumentation.

The data in Table 4 and Figure 1 are measured from a Black Lake soil on the Plant Science research plots at the University of Manitoba. The Black Lake soil is a moderately well drained Cumulic Regosol developed on moderately calcareous fine textured alluvium. The site was instrumented with thermocouples at 5 cm intervals from the surface to 20 cm, 10 cm intervals from 20 cm to 200 cm and 25 cm intervals from 200 to 300 cm deep. A frost tube was installed to 3 m and was monitored with the thermocouples two times per week from when the soil began to freeze in the fall.

The differential in soil temperature readings when the potentiometer is read from the heated box is compared to the readings obtained with the instrument used from within a heated vehicle using long lead cables is shown in Table 4. The ambient air temperature was $-8^{\circ}C$.

Table 4. INSTRUMENTATION CHECK

December 27, 1982 11.37 AM Air-Temp. $-8^{\circ}C$
Snowdepth 5.5 cm

Frost depth in tube=72.5 cm

Soil Temperature $^{\circ}C$					
Depth	Instrument In Truck	Instrument Outside	Depth	Instrument In Truck	Instrument Outside
2.5	-4.4	-4.4	110	+1.6	
5	-3.7	-3.8	120	2.0	
10	-4.2	-4.1	130	2.4	
15	-3.6	-3.5	140	2.8	
20	-3.3	-3.2	150	3.2	
30	-2.7	-2.5	160	3.6	
40	-2.1	-1.8	170	3.8	
50	-1.4	-1.1	180	4.1	
60	-0.6	-0.5	190	4.4	
70	-0.1	-0.1	200	4.7	
80	+0.4	+0.4	225	5.1	
90	+0.7	+1.0	250	5.7	
100	+1.2	+1.5	275	6.0	
			300	6.3	6.6

Measurement of winter soil temperatures appears to be most reliable using thermistor instrumentation. However, a network using thermistors is quite costly to establish and maintain, particularly at sites which do not involve a cooperator and some degree of protection for the installation. Problems with accuracy and reliability associated with thermocouple instrumentation can be partially offset by combining such data with frost-tube measurements. In addition the latest digital readout potentiometer (thermoelectric MICROMITE Model No. 31151-TO-100) is sufficiently reduced in size that it can be protected by the operators winter clothing using body heat to maintain a suitable temperature around the instrument. The ambient temperature range for operating this instrument has also been increased. This potentiometer is being tested during the winter of 1983-84 under Manitoba conditions.

Pattern of freeze and thaw - The pattern of freezing and thawing in the Black Lake soil during the winter of 1982-1983 is shown in Figure 1. The penetration of seasonal frost is shown by both the thermocouple and the frost tube data. The frost tube shows the position of the frozen-nonfrozen interface ($0^{o}C$ isoline) but does not indicate the absolute temperature on either side of the freezing front. The position of the freezing front as shown by the frost tube data corresponds very closely with the thermocouple data measured at 10 cm intervals. This close agreement creates confidence in both kinds of instrumentation. The agreement between the data would be less if the potentiometer were not adequately protected from subzero air temperatures.

Minor variations noted in the topography of the freezing front is attributable to changes in energy flow and heat balance in the soil. Shifts in the energy balance result from changing air temperatures combined with change in snow depth and the insulating properties of the snow.

Recession of the seasonal frost in the spring takes place mainly from the soil surface with only minor thawing from below. This trend is shown by both kinds of instrumentation.

NORTH-SOUTH SOIL TEMPERATURE GRADIENT

While monitoring the Manitoba soil temperature network there have been occasions when temperatures were measured at all sites from the most southerly to the most northerly within a time interval of a few days. This data enables a comparison of soil temperatures over a distance of 800 km and a range of climate extending from latitude 49^{o}N to latitude 56^{o} 17' N. All sites in this comparison occur on well drained clay textured soils.

Two of these gradients were measured in the fall of the year during September 17-24, 1982 (Table 5 and Figure 2) and September 21-28, 1983 (Table 6 and Figure 3). These data indicate that the near surface soil temperatures are very much a function of time of day and the local climatic conditions preceding the date of observation. Temperatures at the lower depths follow a more predictable pattern related to increasing latitude. However, even the temperatures at 150 cm exhibit variations between years that result from attempting to compare single point-in-time measurements.

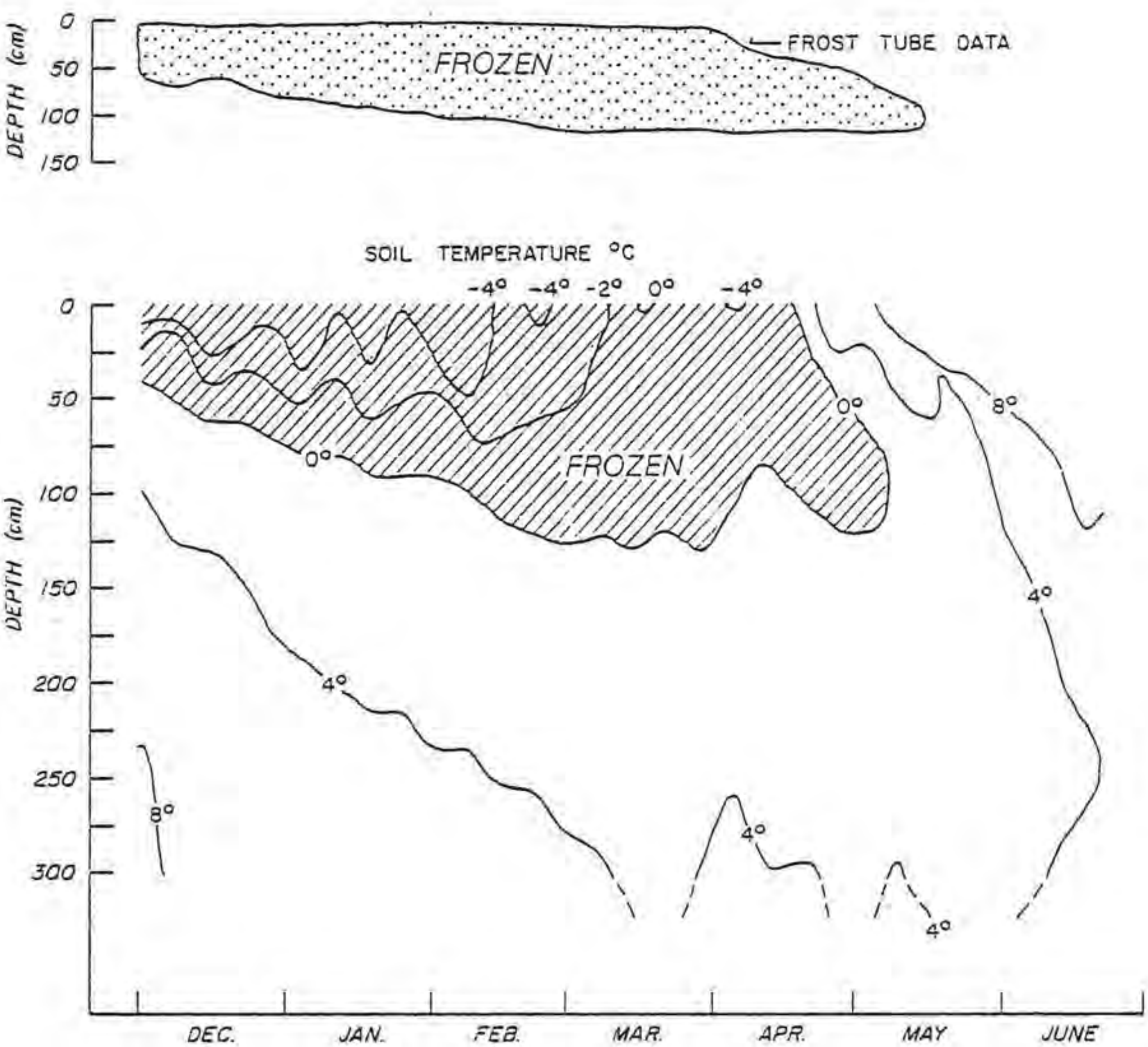


Figure 1. Pattern of freeze and thaw - Winter 1982-83, Black Lake Series (Personal communication C. Onofrei, 1983).

Table 5. Soil temperature data, Manitoba Latitude 49°N to 56°17'N
September 17 to 24, 1982.

Site No	Site Name	Ordering by... Lat.	Long.	Date YR MO DA	Time	Soil Temperature, °C Depth, cm 10	20	50	100	150	Ordering at 50 cm	150 cm
64A4	Split Lake	56°17'	96°09'	82/09/17	14:12	6.7	4.3	2.7	-0.9	-0.6	1	1
64A2	Orr Lake	56°02'	97°08'	82/09/17	17:06	7.2	7.1	6.5	5.9	4.8	5	5
63P13	Thompson	55°55'	97°42'	82/09/19	17:45	6.2	5.7	5.3	4.3	3.6	3	4
6302	Ospwagan	55°32'	98°03'	82/09/22	9:25	7.4	7.0	5.0	4.1	3.0	2	2
63J9	Wabowden	54°47'	98°47'	82/09/22	11:15	8.6	7.9	6.9	5.9	5.1	6	6
63J2	Kiski Creek	54°42'	78°58'	82/09/22	11:40	10.8	6.4	5.6	4.4	3.3	4	3
63J3	Minago	54°12'	99°11'	82/09/22	13:15	16.4	8.1	7.2	6.5	5.7	7	7
6206	Homebrook	51°44'	98°46'	82/09/22	16:40	12.3	11.2	10.9	?	9.9	8	9
62H4	Fort Garry	49°47'	97°08'	82/09/23	8:40	10.9	10.9	10.5	10.3	9.6	9	8
62H13	Letellier	49°08'	97°15'	82/09/24	16:00	13.8	12.8	13.0	13.2	12.1	10	10

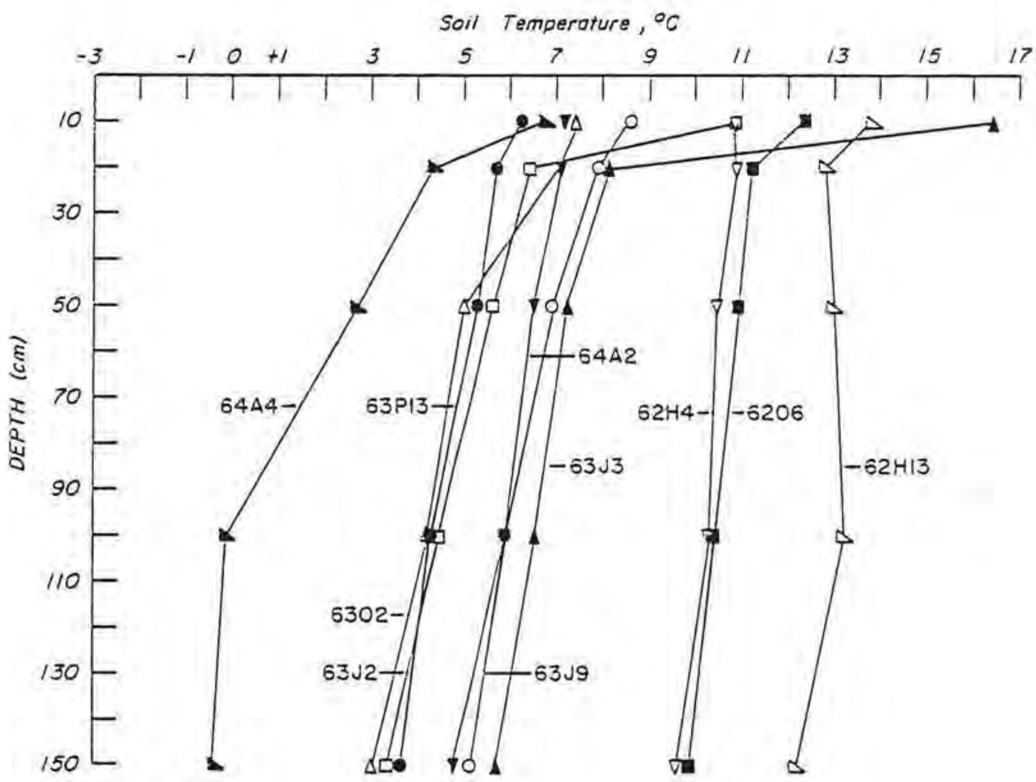


Figure 2. Soil temperature gradients - September 17-24, 1982

Table 6. Soil Temperature Data, Manitoba Latitude 49°N to 56°17'N
September 21-28, 1983.

Site No.	Site Name	Ordering by... Lat.	Long.	Date YR MO Da	Time	Soil Temperature, °C Depth, cm 10	20	50	100	150	Ordering at 50 cm	150 cm
64A4	Split Lake	56°17'	96°09'	83/09/21	11:00	1.8	2.8	2.3	0.6	-0.4	1	1
64A2	Orr Lake	56°02'	97°08'	83/09/21	14:05	3.3	4.2	6.2	5.7	4.3	3	2
63P13	Thompson	55°55'	97°42'	83/09/22	16:50	6.6	6.8	7.4	6.8	5.7	7	5
6302	Ospwagan	55°32'	98°03'	83/09/23	08:40	4.7	5.7	6.5	5.7	4.7	4	4
63J9	Wabowden	54°47'	98°47'	83/09/23	10:55	6.3	6.3	6.6	7.2	7.0	5	7
63J2	Kiski Creek	54°42'	98°58'	83/09/23	12:30	10.6	5.6	5.5	5.3	4.3	2	3
63J3	Minago	54°12'	99°11'	83/09/23	14:05	7.1	6.1	6.7	6.8	6.2	6	6
6206	Homebrook	51°44'	98°46'	83/09/23	17:30	8.1	7.5	8.5	-	8.5	8	8
62H4	Fort Garry	49°47'	97°08'	83/09/28	14:30	13.2	12.6	11.2	10.7	10.2	10	10
62H13	Lettellier	49°08'	97°15'	83/09/28	12:35	12.8	11.8	10.1	9.3	8.8	9	9

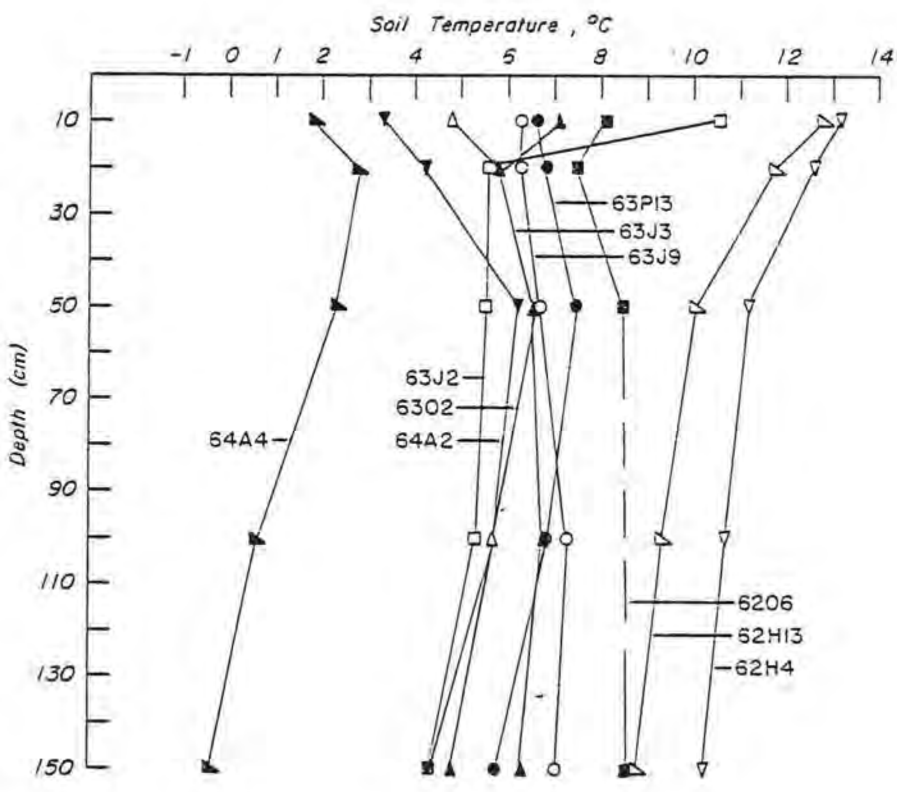
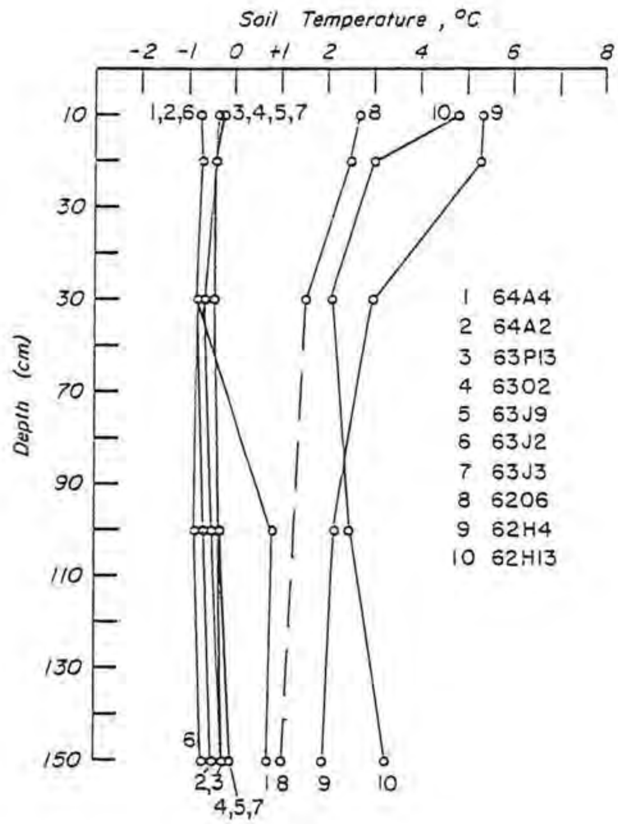


Figure 3. Soil temperature gradients - September 21-28, 1983

Table 7. Soil Temperature data, Manitoba, Latitude 49°N to 56°17'N
May 4 to 13, 1983

Site No.	Site Name	Ordering by... Lat.	Long.	Date YR MO DA	Time	Temperature, °C Depth, cm 10	20	50	100	150	Ordering at 50 cm	150 cm
64A4	Split Lake	56°17'	96°09'	83/05/12	16:15	-0.7	-0.7	-0.8	0.9	0.8	7	7
64A2	Orr Lake	56°02'	97°08'	83/05/12	14:50	-0.7	-0.7	-0.8	-0.6	-0.4	1	2
63P13	Thompson	55°55'	97°42'	83/05/12	10:45	-0.4	-0.4	-0.7	-0.5	-0.2	2	3
6302	Ospwagan	55°32'	98°03'	83/05/13	9:05	-0.3	-0.4	-0.4	-0.3	-0.2	5	4
63J9	Wabowden	54°47'	98°47'	83/05/13	10:30	-0.3	-0.4	-0.6	-0.2	0.0	4	6
63J2	Kiski Creek	54°42'	98°58'	83/05/13	11:15	-0.7	-0.7	-0.7	-0.8	-0.6	3	1
63J3	Minago	54°12'	99°11'	83/05/11	17:05	-0.4	-0.4	-0.3	-0.4	-0.1	6	5
6206	Homebrook	51°44'	98°46'	83/05/11	13:15	2.7	2.5	1.5	-	1.1	8	8
62H4	Fort Garry	49°47'	97°08'	83/05/11	10:30	5.3	5.3	3.0	2.2	2.0	10	9
62H13	Letellier	49°08'	97°15'	83/05/04	17:25	4.8	3.0	2.1	2.5	3.3	0	10



- Figure 4. Soil temperature gradients - May 4-13, 1983

A third north-south gradient was obtained from the same clay textured soils during May 4-13, 1983, (Table 7 and Figure 4). Latitudinal gradients are not well exhibited in these data mainly because all of the sites north of 50°44' N were snow covered. This situation is not considered normal as this portion of Manitoba experienced extremely high snowfall during the previous winter in addition to a very late spring. Attempts to interpret such single point-in-time measurements emphasizes the need for repetitively monitored data in dealing with climatic variables.

DETAIL TRANSECT STUDIES

Most additions to the soil climate monitoring network in Manitoba over the last 2 years are detail sites consisting of several subsites, usually over a toposequence. Some preliminary findings from a soil management study on the Almasippi soils in southern Manitoba and a soil characterization study near Thompson in northern Manitoba are presented.

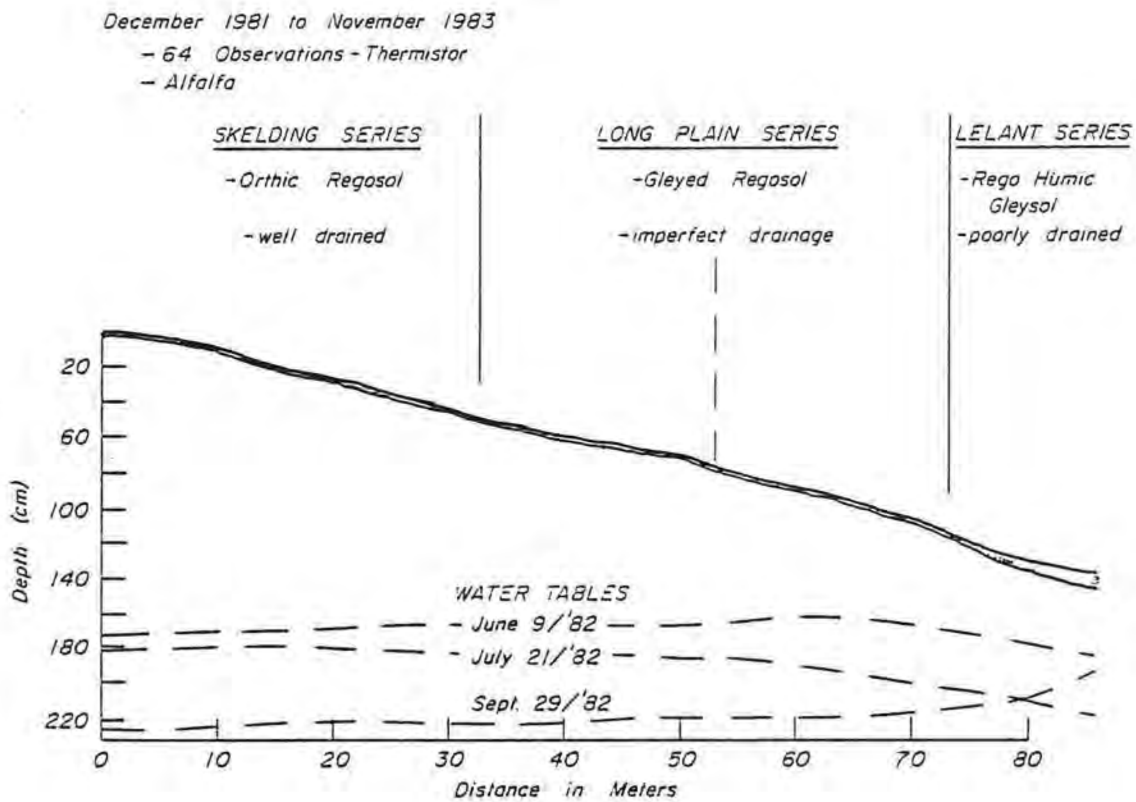
Almasippi Wet Sands - The soil climate data for these soils results from a cooperative study with the Soil Science Department on the management of the shallow groundwater conditions common to the Almasippi soils in this part of Manitoba.

Soil temperature and water table data were monitored from a toposequence of sandy soils including a well drained Orthic Regosol, two Gleyed Regosols with imperfect drainage and a Rego Humic Gleysol with poor drainage. Soil temperature data presented in Figure 5 were measured over a 2 year period based on 64 observations using thermistor instrumentation. Water table fluctuations were measured with shallow automatic well recorders.

Warmest soil temperatures and highest heat accumulation occur in the well drained soil. Thermal values decrease in the imperfectly drained soils and are lowest in the Gleysol. Water tables are relatively flat due to the high permeability of the soils and slowly decrease throughout the growing season. The water table and capillary fringe associated with depressional portions of the landscape is sufficiently close to the soil surface throughout much of the growing surface to affect the soil temperatures on these poorly drained soils.

Thermal and Moisture relations in the Thompson Clay Belt of northern Manitoba- A detail study site in northern Manitoba was established in September 1981 on a toposequence of soils developed on gently sloping, clayey lacustrine sediments. Natural drainage ranges from well to very poor; lower slopes are characterized by thin organic bog veneer land forms. Preliminary analysis of the soil temperature data has been possible although soil and site characterization and related soil climate monitoring studies are continuing. The following observations resulting from study of a well drained Solonetzic Gray Luvisol soil developed on deep lacustrine clay sediments are of interest.

Several years of reconnaissance soil survey in this area of northern Manitoba indicate permafrost occurrence in organic materials and poorly drained mineral soils. The occurrence of permafrost in better drained portions of the landscape was suspected but was not supported by any field evidence.



SELECTED THERMAL VALUES

MAST:	20 cm	5.0	4.8	5.0	4.6
	50 cm	4.7	5.3	5.3	4.7
MSST:	20 cm	15.8	13.0	13.5	12.6
	50 cm	14.2	11.1	12.7	10.4
DD 5°:	20 cm	1405	1089	1206	1068
	50 cm	1203	974	1199	909
DD15°:	20 cm	97	–	7	–
	50 cm	12	–	1	–

Figure 5. Soil temperature data - Almasippi Wet Sands.

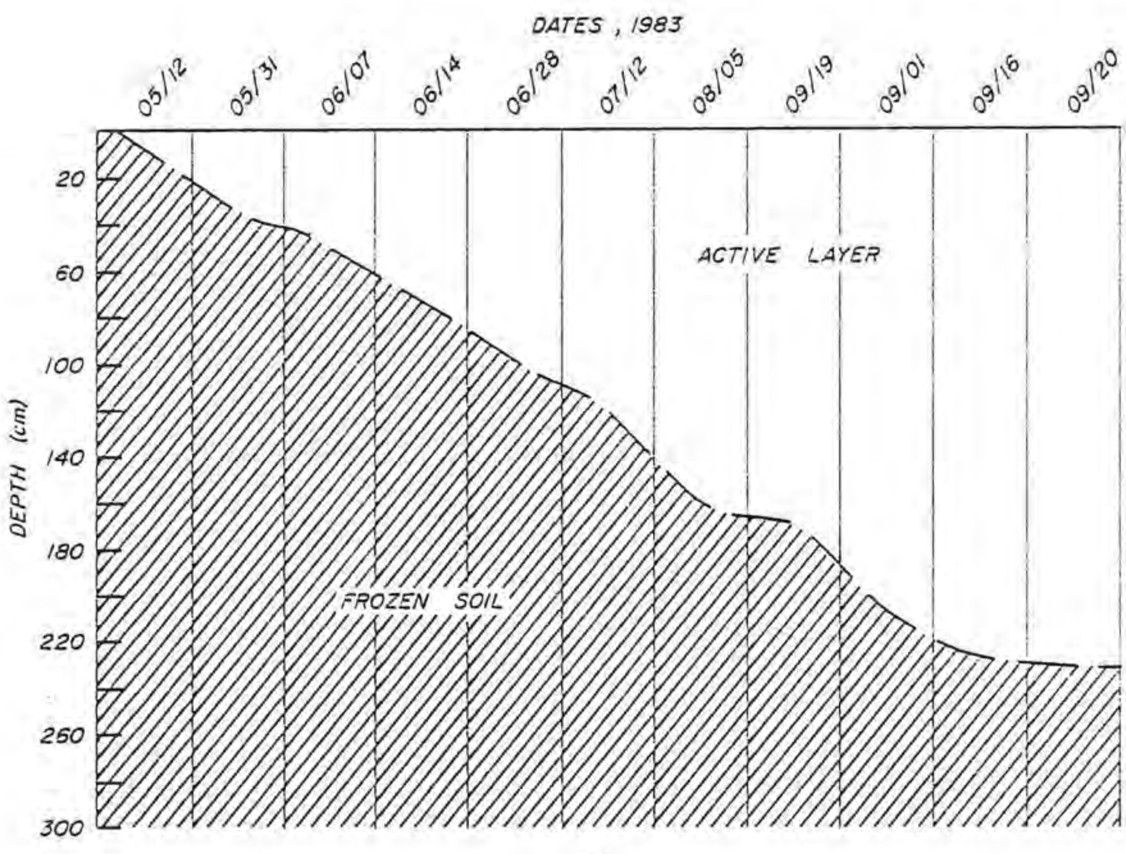


Figure 6. Pattern of thaw and active layer in Solonetzic Gray Luvisol developed on clay lacustrine sediments.

Instrumentation of this site in 1981 did not indicate any permafrost. Installation was in the fall of the year to a depth of 1.5 cm. Subsequent work while installing a shallow dip well in 1982 encountered ice lensing between 2 and 3 metres. Therefore a frost tube was installed to the 3 m depth at the same time. The measurements obtained from the frost tube during 1983 indicate the persistence of permafrost at 237 cm (Figure 6). This preliminary monitoring indicates the occurrence of permafrost at sites in the landscape not identified by previous work in the area. Continued monitoring should verify whether the relatively deep active layer encountered on these soils is a long term characteristic or rather an anomalous feature related to local climatic conditions during the short term that measurements have been taken.

SUMMARY

Many of the results discussed in this paper are preliminary because much of the soil climate data is still based on relatively short term observations. Soil temperature is a climate related property which must be monitored over a longer term in order to encounter and measure a full range of the natural variability. Available data indicate that a fairly complete picture of soil temperature variation can be obtained from a monitoring period which may be substantially shorter than that required to adequately characterize aerial climatic properties.

Trends and relationships which are indicated from the limited data base now available are:

1. A minimum of 5 years of data accumulated as monthly measurements result in a fairly reliable representation of a soil's thermal regime.

2. A close similarity between estimated and observed soil temperatures is noted for sites evaluated to date. More sites should be compared and the difference between estimated and measured temperatures should be tested statistically.

3. A large number of soil temperature observations, intensively monitored provides the best data base for characterizing the soil thermal regime. For some purposes, however, adequate data can be obtained from much fewer observations if they are well distributed throughout the monitoring period.

4. Thermocouple sensors provide reliable soil temperature data if measured when air temperature and humidity conditions are within the ambient range of the potentiometer instrument. Errors up to ±1°C result with thermocouple instrumentation when measurements are taken during winter if air temperature and humidity exceed the range of the potentiometer. The error may be reduced if the potentiometer is operated from an insulated heated box. Experience to the present time indicates that thermistor instrumentation is the most reliable method for monitoring soil temperature during the winter.

5. Soil temperatures measured by thermocouples correspond fairly closely with frost tube data if the potentionmeter instrument is adequately protected for cold weather operation.

6. Soil temperature gradients observed at 10 sites along an 800 km south to north transect within a few days of the fall equinox in two consecutive years are closely similar in terms of shape of the gradients and ordering of the sites.

7. Detail transect studies provide an efficient means of monitoring soil climate and related soil and site conditions and help to establish relationships in the landscape rather than provide isolated bits of data.

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REGIONAL ANALYSIS OF DATA - QUEBEC

R. Baril*

Estimation of Mean Soil Temperature from Minimal Observations

INTRODUCTION

A comparison of measured soil temperatures obtained at several observation intervals with means calculated from daily measurements at St. Augustin, Quebec was attempted in 1982. This comparison was provided as input to the second meeting of the Soil Climate Working Group (ECSS, 1982), but was not included in the Proceedings. Therefore, this data has been summarized in several tables and presented to the Soil Climate Workshop. The objectives of the study were:

*Thanks are expressed here to Jean-Marc Cossette and Gordon F. Mills, Chairman, for their help in the collection of data and the preparation of this article.

1) to test the guidelines contained in Soil Taxonomy (Soil Survey Staff, 1975) for estimating soil temperature for Quebec soils,and
2) to determine the feasibility of estimating soil temperature during routine soil survey work using a minimum number of observations and still provide reliable data.

Several comparisons are made using soil temperature data measured daily from 1965 to 1972 at St. Augustin Experimental Station in Portneuf County, Quebec. Correlations are shown between mean temperature values determined from the daily readings at 50 cm and mean temperatures derived from observations selected at less frequent intervals. Mean monthly soil temperature calculated from the daily data (Table 1) and from measurements observed on the fifteenth day of each month (Table 2) are compared in Table 3.

Mean Annual Soil Temperature (MAST) calculated from daily readings for the months of March, June, September and December are contrasted with single soil temperature readings made on the fifteenth day for the months of March, June, September and December in Table 4.

A similar analysis was conducted comparing Mean Summer Soil Temperature (MSST) derived from the daily observations at 50 cm during June, July and August. Monthly means of soil temperature for the three Summer months are presented in Table 5. Monthly mean soil temperatures measured on the fifteenth day of the 3 Summer months for the same 7 year period are shown in Table 6. These data are compared in Table 7.

A recent study in Nevada also estimates soil temperature using various observations (Schmidlin et. a., 1983). Results from this study indicate that MAST and MSST for well-drained soils in Nevada can be made from two, or better three, four or six equally spaced monthly readings. These authors have constructed a Soil Temperature Regime Map for the entire State of Nevada. Regression of MAST (^{o}C) against elevation (altitude), in meters, and latitude, in decimal degrees, using 84 well-drained sites with 15% slope allows estimation of MAST for similar Nevada soils. Also, a regression of MSST (^{o}C) against elevation (altitude), in meters, and latitude, in decimal degrees, was derived. The data collection of Soil temperature with a precision of $\pm$ 0.5^{o}C was measured at 50 cm depth with copper-constantan thermocouples. The ST readings ordinarily were read within 2 or 3 days of the 15th of the month and treated as if read mid-monthly.

NOTE: In many cases, readings immediately after heavy rains should be avoided. A general essay for 5 years could be done in various Provinces, in at least two Provinces: one in the EAST and one in the Western Canada to start.

RESULTS AND DISCUSSION

The results given in Table 4 show that the estimation of MAST calculated from daily temperature readings made the 15th day, at 50 cm depth, on the basis of any individual months or in the basis of four readings, (Table 4) that is one in each of the selected months during the year for a period of seven years did not show any significant difference at 95 and 99% level when compared to the MAST calculated from daily observations for the same period of time.

Besides, the Mean Summer Soil Temperature, in Table 5, (MSST at 50 cm depth, for June, July and August, for 7 years that is 1966 to 1972 inclusively) calculated from daily observations were compared to single readings made the 15th day during each of the 3 Summer Months of June, July and August, (Table 6). A remarkable correlation (Table 7) with the "t" test for paired values between MSST calculated for seven years (1966-1972) and that of the MSST estimated for the same period with three single equidistant readings made at 50 cm depth the 15th of each of the Summer months. The calculated "t" value being smaller, that is 0.0534 when compared to tabulated values of 2.45 (95%) and 3.71 (99%) there is no significant difference at 5 and 1 per cent security levels between the tedious daily readings made during the three Summer months of June, July and August with those single readings done over a month, that is the 15th day for each of the three Summer months.

Correlation established between Mapping Units at the Series and Family levels including climatic parameters, between the Soils adjacent the Quebec-New York State MAP (U.S.A.-CANADA BOUNDARY).

In figure 1 is shown, in a sketchy manner, what would give a soil correlation, from the standpoint of some soil climate parameters, between the soils properties of Canada and United States respectively. Besides, as an adjunct, in Table 8, is given the United States Mapping Units (from the General Soil Map of New York) expressed with their taxonomic names (Soil Taxonomy, USDA, 1975) on one part and the Mapping Units of Quebec, at both the Family and the series level. Note that the phases i.e. stoniness, slopes etc. are given with appropriate hachures and signs on the New York Generalized Map of Cline and Marshall (1975). These details are not shown here. This comparison is being done to invite colleagues of the Climate Committee not to reject with the back of the hand such a correlation between soils on both sides of the canadian-U.S.A. boundary. Besides, these soil series could be the object of Benchmark Soils to investigate in a proper manner the real place of the soils in both soil taxonomies: the U.S.D.A. and the Canadian.

RECOMMENDATIONS

Soil surveyors may well be able to determine soil temperature during the course of soil survey work. Reading on the fifteenth day of each Summer month may approximate the MSST and readings of the fifteenth day of March, June, September and December may provide reliable estimates of MAST.

The soil Climate Working Group should consider applying this kind of analysis to soil temperature from established longer term AES stations distributed throughout Canada. In addition longer term soil temperature measurements collected under field conditions by soil survey units in Canada should also be analyzed using this technique.

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of each year during the period extending from december 15, 1965 to and inclusively december 15, 1972 (7 years or 28 months). At-Augustin (near Quebec), Portneuf county, Que.

Tableau 5 : Températures moyennes mensuelles du sol, à une profondeur de 50 cm, pour les trois mois d'été : juin, juillet et août. Période de 1966 à 1972, inclusivement.

Table 5 : Monthly means of soil temperatures at 50 cm depth, for three summer months : June, July, August. Period of 7 years (1966 to 1972 inclusively). At St-Augustin experimental farm (near Quebec city).

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Table 6 : Monthly and mean monthly soil temperature at 50 cm depth on the 15th day for the three summer months : June, July and August. Period of 7 years (1966 to 1972 inclusively). At St-Augustin experimental farm (near Quebec city).

Tableau 7 : Test de "t" pour valeurs pairées : températures moyennes mensuelles du sol à 50 cm (MSST, voir tableau 5) et température moyenne du sol à 50 cm calculée le quinzième jour ($MSST_{15}$, voir tableau 6) de chacun des mois d'été : juin, juillet et août. Période de 7 années, de 1966 à 1972 inclusivement. St-Augustin, près de Québec.

Table 7 : "t" test for paired values between mean summer soil temperature (MSST, in table 5) and mean monthly soil temperature the 15th day of each of the three summer months ($MSST_{15}$, in table 6). Period of 7 years (1966-1972 inclusively). St-Augustin, near Quebec city.

TABLEAU 1 : Moyenne mensuelle de la température du sol (^{O}F) à 50 cm (avant-midi). Station de St-Augustin. Québec

TABLE 1 : Mean Montnly Soil Temperature (^{O}F) at 50 cm. Lecture 8.00 every day. At St. Augustin, Porteneuf County, Quebec

Mois Month	YEARS			ANNEES					N	$\overline{X}M$	SM	CV
	1965	66	67	68	69	70	71	72				
Janvier January		35.1	34.3	--	35.5	33.8	33.0	35.0	6	34.5	[illegible]	2.7
Février February		34.5	33.5	31.0	35.0	33.0	33.0	34.6	7	33.5	1.37	4.1
Mars March		34.2	33.0	29.4	34.5	33.0	33.0	34.0	7	33.0	1.72	5.2
Avril April		37.1	33.0	31.8	35.5	33.0	33.0	34.0	7	33.9	1.81	5.3
Mai May		43.8	40.7	41.8	45.5	44.4	42.6	42.8	7	43.1	1.62	3.8
Juin June		55.8	54.1	54.3	55.6	56.7	53.1	54.4	7	54.9	1.23	2.2
Juillet July		63.0	62.6	60.3	60.8	62.7	60.0	61.2	7	61.5	1.24	2.0
Août August		61.9	63.9	57.9	63.5	64.9	61.7	61.2	7	62.1	2.30	3.7
Septembre September		57.0	58.9	58.8	57.7	57.6	58.9	59.4	7	58.3	0.89	1.5
Octobre October		50.0	50.1	52.7	50.1	52.5	52.1	48.5	7	50.9	1.59	3.1
Novembre November		42.0	41.7	41.3	43.0	43.3	42.2	39.7	7	41.9	1.19	2.9
Décembre December	36.3	37.0	--	36.7	36.2	[illegible]	36.1	35.4	7	36.1	0.70	[illegible]

$\overline{X}M$ = Moyenne mensuelle de chaque mois évaluée à partir de 6 à 7 année de mesure
Mean monthly soil temperature measured at 50 cm (Fo), dec. 1965 - dec. 1972

SM = Ecart-type
Standard deviation

CV = Coefficient de variation (SM/$\overline{X}M$)
Coefficient of variation (SM/$\overline{X}M$)

MAST = Temperatures moyennes annuelles du sol (7 années) 45.3^{O}F
Mean annual soil temperatures observed from December 1965 to December 1972 (7 years) 45.3^{O}F

TABLEAU 2 : Température (^{o}F) du sol à 50 cm prise le quinzième jour de chaque mois (avant-midi : 8:00 h). Station de St-Augustin

TABLE 2 : Soil temperature (^{o}F) observed at 50 cm on the fifteen day of each month, 8:00 o'clock, morning, St-Augustin, Portneuf, Quebec.

Mois / Month	YEARS ANNEES 1965	66	67	68	69	70	71	72	N	$\bar{X}_{15}$	S_{15}	CV
Janvier / January		35.0	34.0	--	36.0	34.0	33.0	35.0	6	34.5	1.05	3.0
Février / February		34.5	34.0	30.3	35.0	33.0	33.0	34.0	7	33.4	1.55	4.6
Mars / March		34.2	33.0	28.0	35.0	33.0	33.0	34.0	7	32.9	2.29	7.0
Avril / April		36.8	33.0	32.0	34.0	33.0	33.0	34.0	7	33.7	1.54	4.6
Mai / May		41.6	41.0	43.0	44.0	45.0	44.0	43.0	7	42.8	1.40	3.3
Juin / June		56.0	54.0	55.0	58.0	57.0	52.0	53.0	7	55.0	2.16	3.9
Juillet / July		64.0	61.0	59.0	60.0	64.0	59.0	61.0	7	61.1	2.12	3.5
Août / August		62.0	64.0	58.0	64.0	66.0	62.0	60.0	7	62.3	2.69	4.3
Septembre / September		59.0	50.0	57.0	57.0	57.0	60.0	60.0	7	58.3	1.38	2.4
Octobre / October		49.0	50.0	52.0	51.0	55.0	51.0	49.0	7	51.0	2.08	4.1
Novembre / November		43.0	41.0	41.0	44.0	45.0	41.0	41.0	7	42.3	1.70	4.0
Décembre / December	36.3	37.0	--	37.0	36.0	35.0	36.0	35.0	7	36.0	0.82	2.3

$\bar{X}_{15}$ = Moyenne de la température du sol de la quinzième journée de chaque mois évaluée à partir de 6 à 7 années de mesure
Mean soil temperature observed the 15th day of each month for 7 years

S_{15} = Ecart-type
Standard deviation

CV = Coefficient de variation ($S_{15}/\bar{X}_{15}$)
Coefficient of variation ($S_{15}/\bar{X}_{15}$)

MAST = 45.3 températures moyennes annuelles du sol à 50 cm de profondeur, le 15ième jour de chaque mois
Mean annual soil : temperatures : 45.3 at 50 cm depth, The 15th day of each month

TABLEAU 3 : Test de "t" pour données pairées. Moyennes mensuelles de la température du sol observées à 50 cm de profondeur quotidiennement et la température du sol à 50 cm observée une seule fois le 15ième jour de chaque mois. Décembre 1966 à Décembre 1972 (7 années). St-Augustin, Comté de Portneuf, P.Qué.

TABLE 3 : "t" test for paired values. Mean monthly soil temperatures observed daily at 50 cm depth compared to single observations made the fifteen of each month at 50 cm depth also. December 1966 to December 1972. St-Augustin, Portneuf county, P.Qué.

Mois Moths	$\bar{x}_M$		$\bar{x}_{15}$	
	(^oF)	(^oC)	(^oF)	(^oC)
Janvier January	34.5	1.39	34.5	1.39
Février February	33.5	0.83	33.4	0.83
Mars March	33.0	0.55	32.9	0.50
Avril April	33.9	1.06	33.7	0.94
Mai May	43.1	6.17	42.8	6.00
Juin June	54.9	12.72	55.0	12.77
Juillet July	61.5	16.39	61.1	16.17
Août August	62.1	16.39	62.3	16.83
Septembre September	58.3	14.61	58.3	14.61
Octobre October	50.9	10.50	51.0	10.55
Novembre November	41.9	5.50	42.3	5.72
Décembre December	31.6	0.22	36.0	2.22

	Nombre d'observations Number of observations	Moyenne Mean	Variance Variance	Ecart-type Std-deviation
$\bar{x}_M$	12	44.93333	143.3461	11.9727
$\bar{x}_{15}$	12	45.2750	134.7748	11.6093
Différence :		0.3417	1.6808	1.2965

"t" calculé : : 0.9129
"t" calculated : 0.9129
$t_{(0.05;11)}$: 2.20 (Bilatéral)
$t_{(0.01;11)}$: 3.11 (")

Conclusion : Etant donné que la valeur de "t" calculée, soit 0.9129, est inférieure aux valeurs tabulaires 2.20 et 3.11 correspondant à $t_{(0.05;11)}$ et $t_{(0.01;11)}$ respectivement, il n'y a pas de différence significative aux seuils de confiance mentionnés, entre les valeurs moyennes mensuelles de la température du sol observée à 50 cm de profondeur quotidiennement et la température du sol observée à 50 cm une seule fois : soit le quinzième jour de chaque mois, pour la période de décembre 1965 à décembre 1972.

Conclusion : Since the "t" calculated value, that is 0.9129, is smaller than 2.20 and 3.11 values tabulated at $t_{(0.05;11)}$ and $t_{(0.01;11)}$ respectively, there is no significant difference between the mean monthly soil temperature observed daily at 50 cm depth and those values observed only once, that is the fifteen day of each month at 50 cm depth, during the period of december 1965 to december 1972.

TABLEAU 4* : Le test de "t" pour valeurs pairées : les températures moyennes annuelles (MAST) calculées d'après les lectures quotidiennes (8.00 a.m.), à 50 cm de profondeur, pour les mois de mars, juin, septembre et décembre, de chaque année pour la période du mois de décembre 1965 au mois de décembre 1972, inclusivement (7 années ou 28 mois), comparées à une seule lecture faite le 15ième jour pour chacun des mois suivants : mars, juin, septembre et décembre. La période d'observation s'étend du mois de décembre 1965 au mois de décembre 1972, inclusivement, (7 années ou 28 mois). A la station expérimentale de l'Université Laval, à St-Augustin, comté de Portneuf, Qué.

TABLE 4* : "t" test for paired values : the mean annual soil temperatures (MAST) calculated from daily temperature readings (8.00 a.m.), at 50 cm depth, for the months of march, june, september and december of each year for the period of december 1965 to december 1972 (7 years or 28 months) as compared to single soil temperature readings made the 15th day for the months of march, june, september and december of each year during the period extending from december 15, 1965 to and inclusively december 15, 1972 (7 years or 28 months). St-Augustin (near Quebec), Portneuf county, Que.

Année Years	Mois	Months	MAST (4 mois) MAST (4 months)		MAST 15 (4 mois) MAST 15 (4 months)	
			(^{o}F)	(^{o}C)	(^{o}F)	(^{o}C)
1965 :	Décembre	December	36.6	2.34	36.3	2.34
1966 :	Mars	March	34.2	1.22	34.2	1.22
	Juin	June	55.8	13.22	56.0	13.33
	Septembre	September	57.0	13.89	59.0	15.00
	Décembre	December	37.0	2.78	37.0	2.78
1967 :	Mars	March	33.0	0.55	33.0	0.55
	Juin	June	54.1	12.28	54.0	12.22
	Septembre	September	58.9	14.94	58.0	14.44
	Décembre	December	--	--	--	--
1968 :	Mars	March	29.4	-1.44	28.0	-2.22
	Juin	June	54.3	12.39	55.0	12.78
	Septembre	September	58.8	14.89	57.0	13.89
	Décembre	December	36.7	2.61	37.0	2.78
1969 :	Mars	March	34.5	1.39	35.0	1.67
	Juin	June	55.6	13.11	58.0	14.44
	Septembre	September	57.7	14.28	57.0	13.89
	Décembre	December	36.2	2.33	36.0	2.22
1970 :	Mars	March	33.0	0.55	33.0	0.55
	Juin	June	56.7	13.72	57.0	13.89
	Septembre	September	57.6	14.22	57.0	13.89
	Décembre	December	35.0	1.67	35.0	1.67
1971 :	Mars	March	33.0	0.55	33.0	0.55
	Juin	June	53.1	11.72	52.0	11.11
	Septembre	September	58.9	14.94	60.0	15.55
	Décembre	December	36.1	2.28	36.0	2.22
1972 :	Mars	March	34.0	1.11	34.0	1.11
	Juin	June	54.4	12.44	53.0	11.67
	Septembre	September	59.4	15.22	60.0	15.55
	Décembre	December	35.4	1.89	35.0	1.67

	Nombre d'observations Number of observations	Moyenne Mean	Variance Variance	Ecart-type Std-deviation
MAST (4 mo)	28	45.5750	129.9560	11.3998
MAST 15 (4 mo)	28	45.5536	132.9907	11.5322
Différence :		0.0214	00.8343	0.9134

t calc. : 0.1241
$t_{(0.05;27)}$: 2.05
$t_{(0.01;27)}$: 2.77

Intervalle de confiance de la différence
Interval confidence of the difference :
à / to 95% : 0.354 à / to 99% : 0.479

* : FORMER Table 8 - sent to G.F. Mills, April 1982

TABLEAU 5 : Températures moyennes mensuelles du sol, à une profondeur de 50 cm, pour les trois mois d'été juin, juillet et août. Période de 1966 à 1972, inclusivement

TABLE 5 : Monthly means of soil temperatures at 50 cm depth, for three summer months : June, July, August. Period of 7 years (1966 to 1972 inclusively). At St-Augustin experimental farm (near Quebec city).

Années Years	Juin June		Juillet July		Août August		MSST(1)	
	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)
1966	55.8	13.22	63.0	17.22	61.9	16.61	60.2	16.67
1967	54.1	12.28	62.6	17.00	63.9	17.72	60.2	16.67
1968	54.3	12.39	60.3	15.72	57.9	14.39	57.5	14.17
1969	55.6	13.11	60.8	16.00	63.5	17.50	60.0	15.55
1970	56.7	13.72	62.7	17.05	64.9	18.28	61.4	16.33
1971	53.1	11.72	60.0	15.55	61.7	16.50	58.3	14.61
1972	54.4	12.44	61.2	16.22	61.2	16.22	58.9	14.94

(1) MSST = Moyennes mensuelles de la température du sol à 50 cm de profondeur, pour 7 années : 59.5 °F (15.27 °C).
Mean summer soil temperature (3 months) for 7 years : 59.5 °F (15.27 °C).

TABLEAU 6 : Température du sol le quinzième jour à 50 cm : valeurs mensuelles et moyennes calculées observées pour les trois mois d'été : juin, juillet et août. Période de 7 années. Ferme expérimentale de St-Augustin, (près de Québec)

TABLE 6 : Monthly and mean monthly soil temperature at 50 cm depth on the 15th day for the three summer months : June, July and August. Period of 7 years (1966 to 1972 inclusively).At St-Augustin experimental farm (near Quebec city).

Années Years	Juin June		Juillet July		Août August		$MSST_{15}$(1)	
	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)
1966	56.0	13.33	64.0	17.78	62.0	16.67	60.7	15.94
1967	54.0	12.22	61.0	16.11	64.0	17.78	59.7	15.39
1968	55.0	12.78	59.0	15.00	58.0	14.44	57.3	14.05
1969	58.0	14.44	60.0	15.55	64.0	17.78	60.7	15.94
1970	57.0	13.89	64.0	17.78	66.0	18.89	62.3	16.83
1971	52.0	11.11	59.0	15.00	62.0	16.67	57.7	14.28
1972	53.0	11.67	61.0	16.11	60.0	15.55	58.0	14.44

(1) $MSST_{15}$ = Moyenne des températures du sol à 50 cm pour les trois mois d'été : juin, juillet, août. 7 années : 59.4857°F (15.269°C).
Mean summer soil temperature observed the fifteen day of the summer months (June, July and August) at 50 cm. Period of 7 years. Value : 59.4857°F (15.269°C).

TABLEAU 7 : Test de "t" pour valeurs pairées : températures moyennes mensuelles du sol à 50 cm (MSST, voir tableau 5) et température moyenne du sol à 50 cm calculée le quinzième jour ($MSST_{15}$, voir tableau 6) de chacun des mois d'été : juin, juillet et août. Période de 7 années, de 1966 à 1972 inclusivement. St-Augustin, près de Québec.

TABLE 7 : "t" test for paired values between mean summer soil temperature (MSST, in table 5) and mean monthly soil temperature the 15th day of each of the three summer months ($MSST_{15}$, in table 6). Period of 7 years (1966-1972 inclusively). St-Augustin, near Quebec city.

Années Years	MSST		$MSST_{15}$	
	(^{o}F)	(^{o}C)	(^{o}F)	(^{o}C)
1966	60.2	16.67	60.7	15.94
1967	60.2	16.67	59.7	15.39
1968	57.5	14.17	57.3	14.05
1969	60.0	15.55	60.7	15.94
1970	61.4	16.33	62.3	16.83
1971	58.3	14.61	57.7	14.28
1972	58.9	14.94	58.0	14.44

MSST : voir signification tableau 5.
Mean summer soil temperature (3 months). See table 5.

$MSST_{15}$: voir signification tableau 6.
Mean summer soil temperature calculated from only reading the 15th day of the three months of June, July and August. See table 6 for details.

Details :

	nombre d'observations number of observations	Moyenne Mean	Variance Variance	Ecart-type Std-deviation
MSST	7	59.5000	1.7733	1.3317
$MSST_{15}$	7	59.4857	3.5148	1.8748
Différence :		0.0143	0.5014	0.7081

"t" calc. : 0.0534

$t_{(0.05;6)}$: 2.45

$t_{(0.01;6)}$: 3.71

Intervalle de confiance de la différence
Confidence interval of the difference ; 95% : 0.6551 ; 99% : 0.9933

Conclusion : Les valeurs de "t" calculées (0.0534) étant inférieures aux valeurs tabulaires 2.45 et 3.71 correspondant respectivement à $t_{(0.05;6)}$ et $t_{(0.01;6)}$, il n'y a pas de différence significative aux seuils de sécurité de 5 et 1 pour cent entre les valeurs obtenues de la température du sol à 50 cm de profondeur par la méthode habituelle des lectures quotidiennes et les lectures uniques faites le 15ième jour de chacun des mois d'été : juin, juillet et août. Pour la période de 1966 à 1972 inclusivement.

Conclusion : The calculated "t" value being smaller, that is 0.0534 than the tabulated values of 2.45 (95%) and 3.71 (99%) there is no significant difference at 5 and 1 per cent security levels between the three summer months of June, July and August and single readings done once the 15th day of each of the three summer months, for the period of 1966 to 1972 inclusively.

<u>Conclusion</u> : Puisque la valeur "t" calculée, soit 0.1241, est inférieure aux valeurs tabulaires 2.05 et 2.77 correspondant à $t_{(0.05;27)}$ et $t_{(0.01;27)}$ respectivement, il n'y a pas de différence significative entre les moyennes annuelles de la température du sol à 50 cm de profondeur, calculées d'après les observations quotidiennes durant 4 mois équidistants de l'année (soit mars, juin, septembre et décembre) et les lectures uniques faites le quinzième jour du mois durant les 4 mois mentionnés.

<u>Conclusion</u> : Since the calculated "t" value, that is 0.1241 is smaller than those tabulated at $t_{(0.05;27)}$ and $t_{(0.01;27)}$ which are 2.05 and 2.77 respectively, there is non significant difference between the mean annual soil temperature calculated from daily observations during 4 equidistant months (March, June, September and December) and a single reading made the 15th day of each of four selected equidistant months of year.

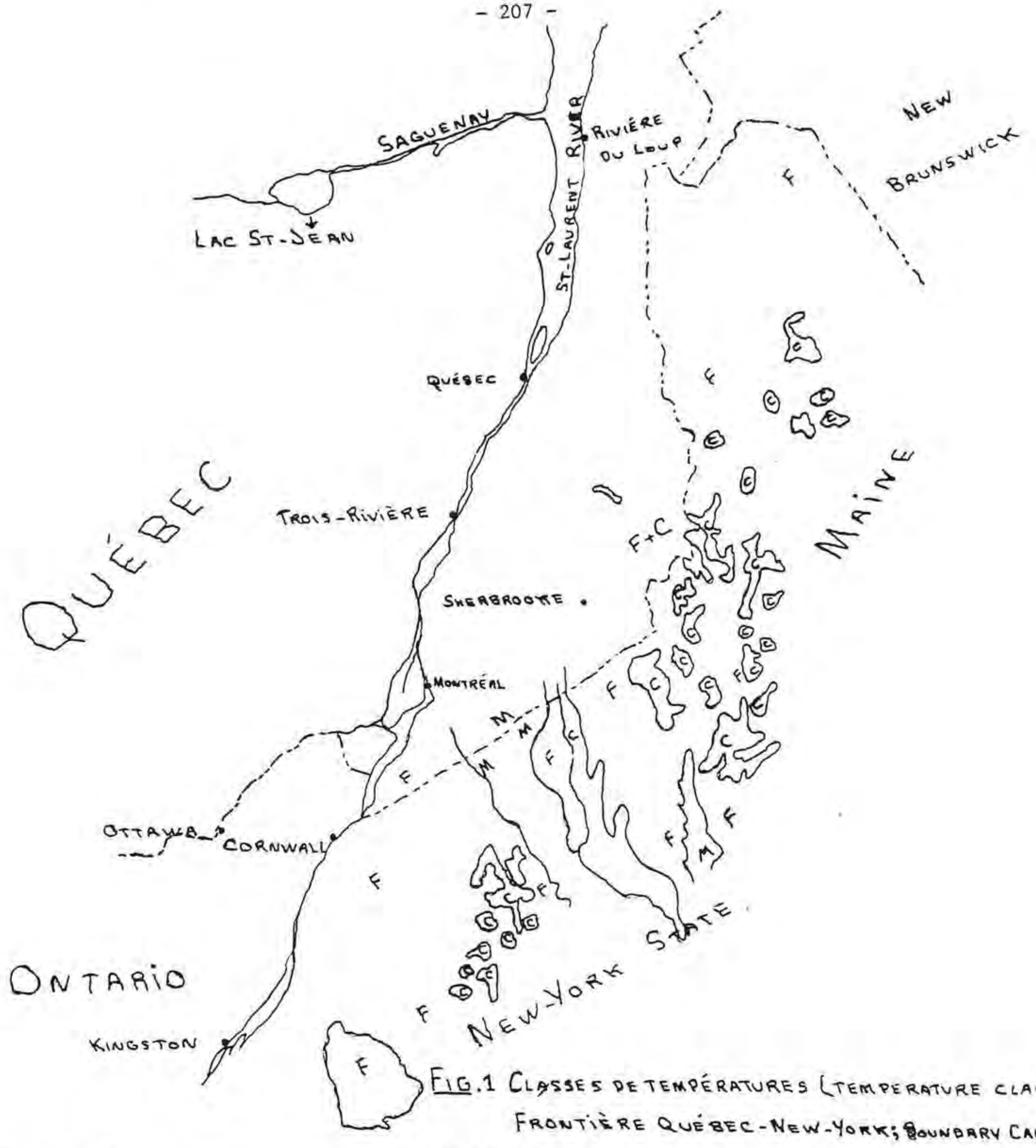


FIG.1 CLASSES DE TEMPÉRATURES (TEMPERATURE CLASSES)
FRONTIÈRE QUÉBEC-NEW-YORK; BOUNDARY CANADA-U.S

NOTE : FOR THE CORRESPONDING NAMES OF SOILS SEE TABLE: 8

LÉGENDE (LEGEND)

C = CRYIQUE (CRYIC): T° 0-8°C ÉTÉ FROID (COLD SUMMER)

F = FRIGIDE (FRIGID): T° < 8°C DIFFÉRENCE > 5°C ENTRE L'ÉTÈ ET L'HIVER (BETWEEN SUMMER AND WINTER MONTHS)

M = MÉSIQUE (MESIC): T° : ENTRE (BETWEEN) 8°-15°C DIFFÉRENCE DE > 5°C ENTRE LES TEMPÉRATURES D'ÉTÈ ET D'HIVER (BETWEEN SUMMER AND WINTER TEMPERATURES)

29/02/84

Table 8: Family Classification of Soils along New York-Canadian Border*

Quebec Soil Series Equivalents (approx.) (areas)	U.S.A. Names-(Map Symbol)* (areas)	Family Classification (s) USDA (and Canada) **
Covey-like- Rockburn	Westbury- Coveytown V. stony (Fs2)	Coarse-loamy, mixed, frigid Typic Fragiaquods Sandy over loamy, mixed, non acid, frigid Aeric Haplaquents
Covey- Herdman-like	Westbury- Brayton (Fw2)	Coarse-loamy, mixed, frigid Typic Fragiaquods Coarse-loamy, mixed, frigid Aeric Fragiaquepts
St-Jude (Massueville)-like	Naumburg (Kw)	Sandy, mixed, frigid Aeric Haplaquods
Ste-Rosalie-like	Kingsbury (Lw2)	Very fine, illitic, mesic Aeric Ochraqualfs
St-Damase- Ste-Rosalie (part)-like	Swanton- Rhinebeck (Lw5)	Coarse-loamy over clayey, mixed, non acid, mesic Aeric Haplaquepts Fine, illitic, mesic Aeric Ochraqualfs
Ste-Rosalie (Part) Mathilda-like	Kingsbury - Hogansburg (LwC)	Very fine, illitic, mesic Aeric Ochraqualfs Coarse-loamy, mixed, mesic Aquic Eutrochrepts
Ste-Rosalie-like Rock outcrop	Kingsbury- Rock outcrop (LwR)	Very fine, illitic, mesic Aeric Ochraqualfs
Rock	Rock Outcrop-Sloping (R)	

*: From N.Y. State General Soil Map and Soil Taxonomy (USDA, 1975).

**: Note: Adoption of the same climatic parameters for Canada and USDA would favor correlation at the Series and Families levels. Essay and Project Research along the Canadian-USA boundary is proposed by our group. (R.W. Baril).

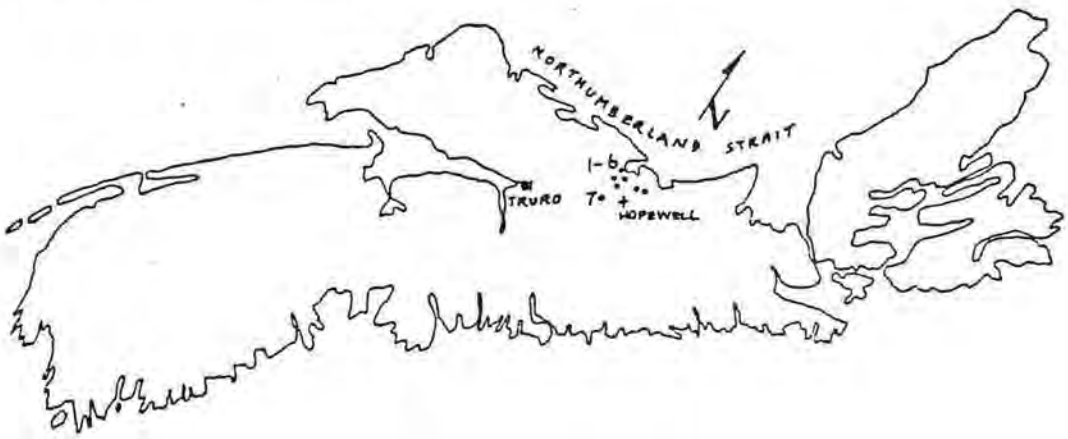
Analysis of Soil Temperature Data from Nova Scotia

K. T. Webb

The following figures are graphs of mean monthly soil temperatures at 50 cm for Nova Scotia soil temperature (NSST) Sites 1 to 7. These time-temperature curves are derived from data collected bi-monthly since 1981 and should be interpreted as preliminary trends. The air temperature curves on figures 2 to 8 are the mean monthly air temperatures for the same period of time as the soil temperature. The air temperature data is from the Hopewell AES station and is considered representative of the NSST sites 1 to 7 (Fig. 1).

The soil temperature sites are classified according to the Soil Temperature Classification of the Canadian System of Soil Classification (1978). The assigned class is compared to the class for the site as indicated on the Soil Climates of Canada Map. (Clayton etal, 1977)

Fig. 1 Location of NSST sites 1 to 7



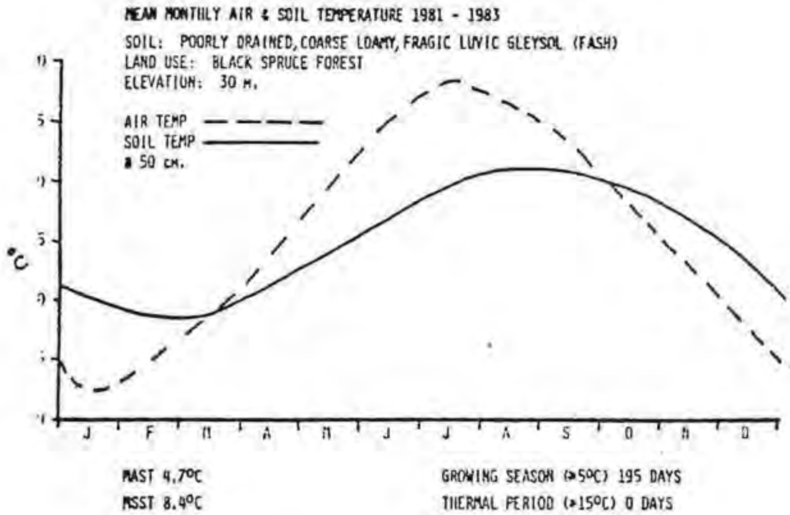
NSST sites 1 - 6 are located on the Maritime Plain of Nova Scotia within 20 km of the Northumberland Strait. NSST site 7 is located in the Cobequid Mountains within 30 km of the ocean (Fig. 1).

NSST-1 is installed in a poorly drained, coarse loamy, Fragic Luvic Gleysol on a 3% slope under black spruce forest at an elevation of 30 meters. The soil material is lacustrine.

NSST-1 has a mean annual soil temperature (MAST) of 4.7°C; a mean summer soil temperature (MSST) for June, July and August of 8.4°C; a growing season with soil temperatures greater or equal to 5°C of 195 days; and a thermal period with soil temperatures greater or equal to 15°C of 0 days (Fig.2).

Fig. 2

NSST-1



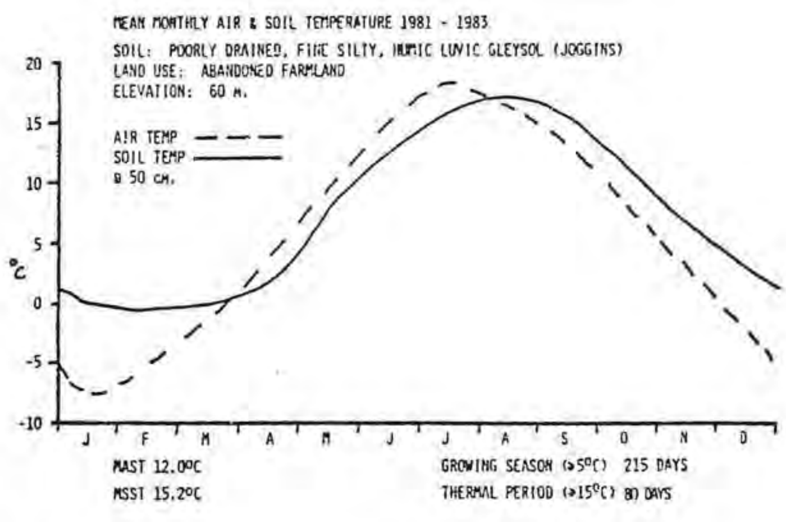
Based on this information NSST-1 is classified as having a COLD soil temperature regime. On the Soil Climates Map of Canada the site location has been mapped as COOL.

NSST-2 is installed in a poorly drained, fine silty, Humic Luvic Gleysol on a 2% slope under grass at an elevation of 60 meters. The soil material is glacial till.

The site has a MAST of 12°C; a MSST of 15.2°C; a growing season of 215 days and a thermal period of 80 days (Fig. 3).

Fig. 3

NSST-2



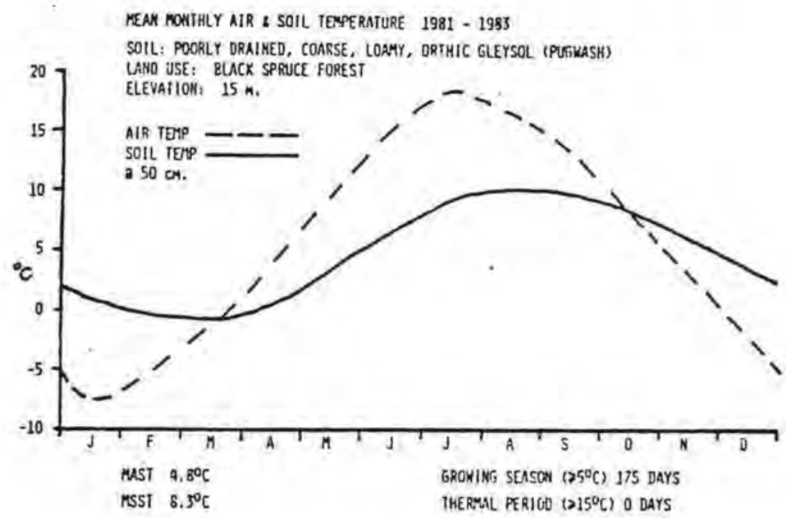
NSST-2 has a MILD soil temperature regime and has been mapped as COOL on the Soil Climate Map of Canada.

NSST-3 is installed in a poorly drained, coarse loamy, Orthic Gleysol on a 3% slope under black spruce forest at an elevation of 15 meters. The soil material is glacial till.

The site has a MAST of $4.8^{\circ}C$; a MSST of $8.3^{\circ}C$; a growing season of 175 days and no thermal period (Fig. 4).

Fig. 4

NSST-3



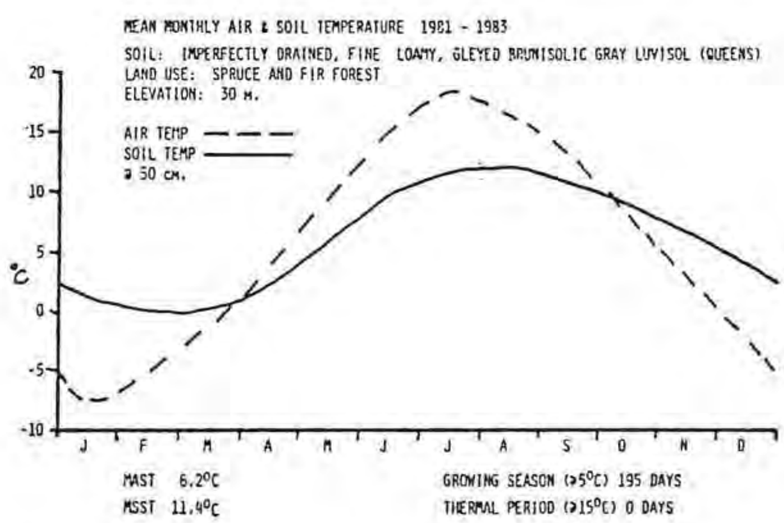
NSST-3 has a COLD soil temperature regime and has been mapped as COOL on the Soil Climate Map of Canada.

NSST-4 is installed in an imperfectly drained, fine loamy, Gleyed Brunisolic Gray Luvisol on a 4% slope under spruce-fir forest at an elevation of 30 meters. The soil material is glacial till.

The site has a MAST of $6.2^{\circ}C$; a MSST of $11.4^{\circ}C$; a growing season of 195 days and no thermal period (Fig. 5).

Fig. 5

NSST-4



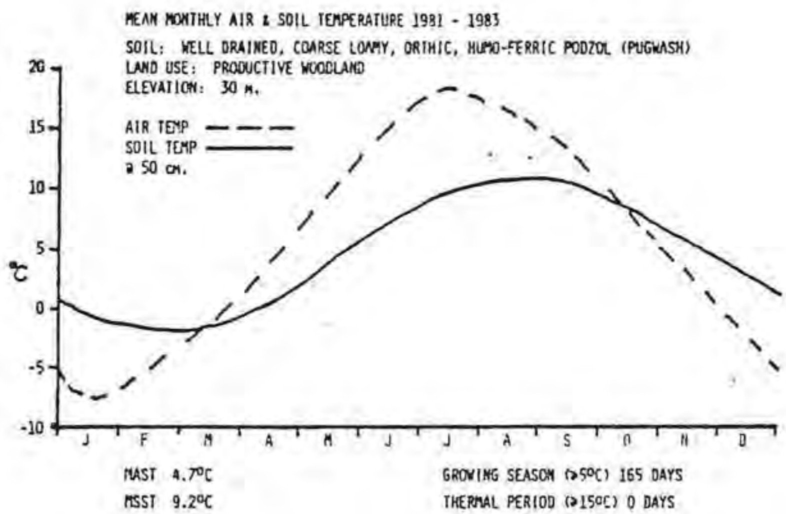
NSST-4 has a COLD soil temperature regime and has been mapped as COOL on the Soil Climate Map of Canada.

NSST-5 is installed in a well drained, coarse loamy, Orthic Humo-Ferric Podzol on a 4% slope under fir-white birch forest at an elevation of 30 meters. The soil material is glacial till.

The site has a MAST of 4.7°C; a MSST of 9.2°C; a growing season of 165 days and no thermal period (Fig. 6).

Fig. 6

NSST-5



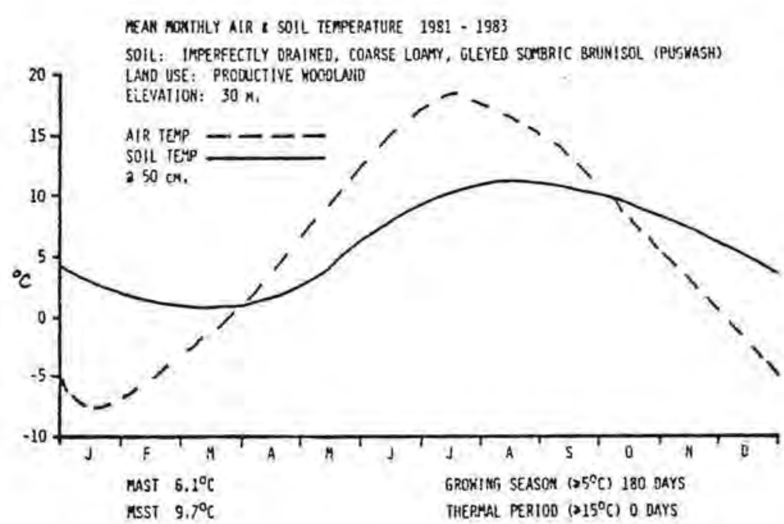
NSST-5 has a COLD soil temperature regime and has been mapped as COOL on the Soil Climate Map of Canada.

NSST-6 is installed in an imperfectly drained, coarse loamy, Gleyed Sombric Brunisol on a 7% slope under fir-white birch forest at an elevation of 30 meters. The soil material is glacial till.

The site has a MAST of 6.1°C; a MSST of 9.7°C; a growing season of 180 days and no thermal period (Fig. 7).

Fig. 7

NSST-6



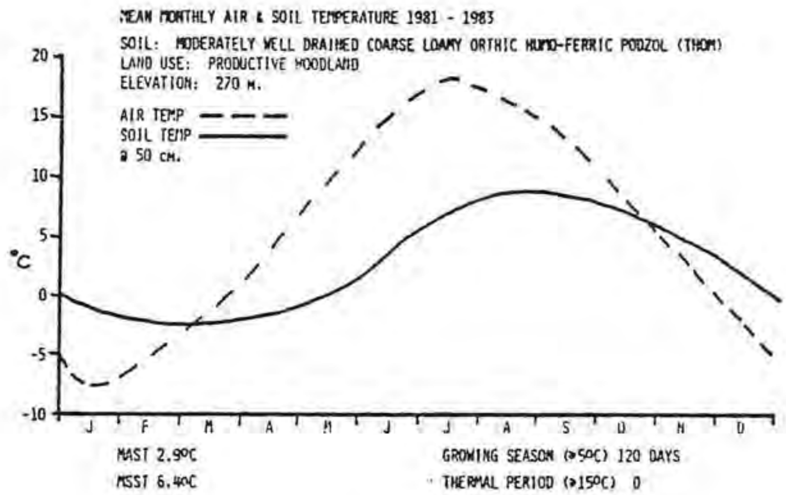
NSST-6 has a COLD soil temperature regime and has been mapped as COOL on the Soil Climate Map of Canada.

NSST-7 is installed in a moderately well drained, coarse loamy, Orthic Humo-Ferric Podzol on a 3% slope under spruce-fir forest at an elevation of 270 meters. The soil material is glacial till.

The site has a MAST of 2.9°C; a MSST of 6.4°C; a growing season of 120 days and no thermal period (Fig. 8).

Fig. 8

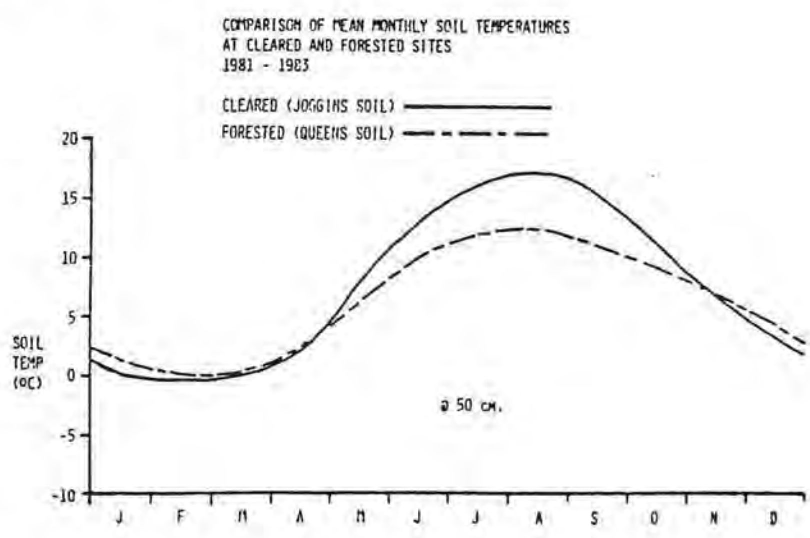
NSST-7



NSST-7 has characteristics of both the COLD and VERY COLD soil temperature classes. It's MAST is within the COLD temperature class and it's MSST and growing season are more representative of the VERY COLD class. The site is located within a COOL unit on the Soil Climate Map of Canada.

Figure 9 compares the mean monthly soil temperatures of a cleared and forested site. The cleared site is NSST-2 and the forested site is NSST-4. The sites are similar in texture but differ by one drainage class. Although the cleared site has poorer drainage than the forested site, it has a much warmer soil temperature regime.

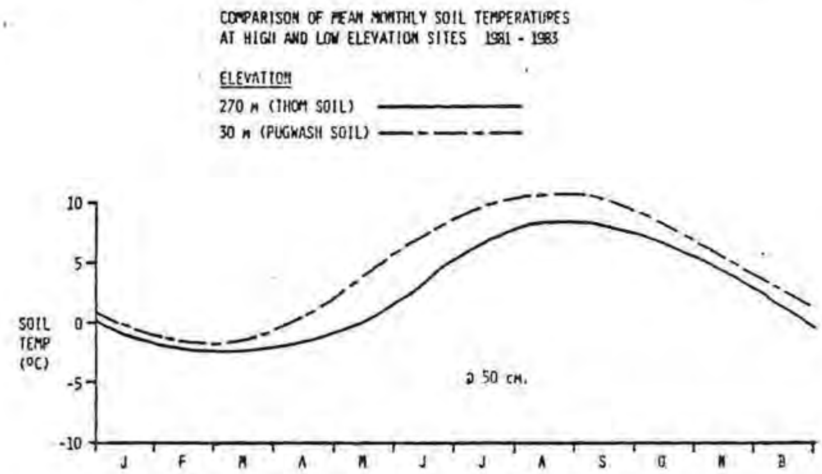
Fig. 9



The cleared site is slightly colder in the winter and late fall but warms faster in May and reaches higher soil temperatures from May to October than the forested site. From September to January the cleared site cools faster than the forested site.

Figure 10 compares the mean monthly soil temperatures of similar soils at high and low elevations. The low elevation site is NSST-5 and the high elevation site is NSST-7. Both sites have similar textures, drainages and land use.

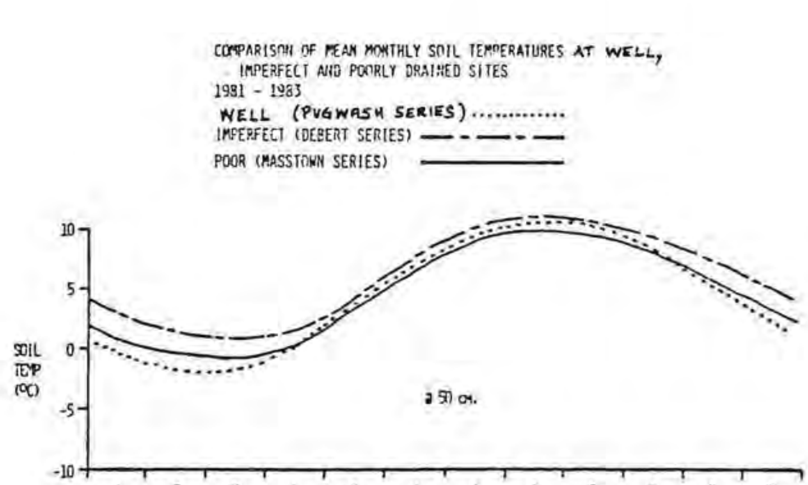
Fig. 10



The lower elevation site is warmer throughout the year and warms up earlier in the spring than the higher elevation site.

Figure 11 compares the mean monthly soil temperatures of the well (NSST-5), the imperfect (NSST-6), and the poorly drained series (NSST-3) of the Pugwash Association.

Fig. 11



The imperfectly drained site is slightly warmer throughout the year than both the well and poorly drained sites. The well drained site is slightly colder from late October to mid April than both the poorly and imperfectly drained sites. The well drained site warms up faster in early spring and cools off faster in the fall and early winter than the imperfectly and poorly drained sites.

Table 1 presents a preliminary comparison of mean monthly soil temperatures at 50 cm for two sites at the Nappan Research Farm with estimated mean monthly data from the Agrometeorology Technical Bulletin 85 (Ouellet et al, 1975).

TABLE 1. COMPARISON OF MEASURED MEAN MONTHLY SOIL TEMPERATURES (@ 50 CM.) AND ESTIMATES FROM AGMET. BULLETIN 85 FOR NAPPAN

BULLETIN 85	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
	1.6	1.1	1.3	2.6	7.7	12.7	15.5	15.9	14.6	10.9	6.7	3.3
NSST 17	3.6	---	---	---	7.3	15.8	12.7	15.1	13.5	10.1	6.1	2.8
NSST 18	0.0	-3.6	-1.1	-0.1	6.8	11.4	12.6	14.3	12.8	8.6	4.5	3.2

NSST 17 - FORAGE ON KINGSVILLE SERIES

NSST 18 - FORAGE ON QUEENS SERIES

NSST-17 is a poorly drained, fine loamy, Orthic Gleysol developed on glacial till on a 8% slope under forage. NSST-18 is a tile drained, fine loamy, Humic Luvic Gleysol developed on glacial till on a 7% slope under forage.

Insufficient data for the Nappan sites precludes an evaluation of Bulletin 85 estimates for Nappan at this time.

REFERENCES

Canada Soil Survey Committee 1978. The Canadian System of Soil Classification. Research Branch, Canada Department of Agriculture, Pub. 1646.

Clayton, J.S., W.A. Ehrlich, D.B. Cann, J.H. Day and I.B. Marshall, 1977 Soils of Canada. Research Branch, Canada Department of Agriculture.

Ouellet, C.E., R. Sharp, and D. Chaput. 1975 Estimated Monthly Normals of Soil Temperature in Canada. Agrometeorology Research Technical Bulletin 85, Research Branch, Canada Department of Agriculture.

SOIL TEMPERATURES OF THE INUVIK AREA

C. Tarnocai

INTRODUCTION

The near surface temperature is a very important property of soils in the permafrost region. In this area the soil temperatures not only influence the biological processes and most of the chemical and physical processes, but the low soil temperatures also trigger the cryogenic processes. The most common effects of these cryogenic processes are cryoturbation and frost heave. If, however, because of surface disturbance, the soil temperature increases, degradation of permafrost occurs, resulting in severe erosion or subsidence. Thus, for land use decisions and for construction of roads or buildings on permafrost soils, a knowledge of the thermal regime of the soil (active layer and the near surface permafrost) is very important. This knowledge is vital for determining the method of land use or construction which will cause the least change in the thermal regime of the soil.

Judge (1973) measured soil temperatures at a number of sites in the Mackenzie Delta area. All of these temperatures were taken in deep bore holes at various depths, beginning several metres below the surface. Soil temperatures were also measured under buildings and roads and under the airport landing strip in the Inuvik area by the National Research Council. Soil temperature studies were carried out in the Mackenzie Delta by Gill (1971) and on hummocky terrain near Inuvik by Mackay and MacKay (1976).

This study was initiated in 1978 to monitor the soil temperatures of the most common soils occurring in the Inuvik area. This paper presents characteristics of the thermal regime of the active layer and the near surface permafrost and their relationship to soil properties, patterned ground type, vegetation and snow cover, based on data collected between September, 1978 and March, 1981.

AREA AND CLIMATE

The study area is located in the Inuvik and Arctic Red River areas in the N.W.T. The area encompasses two different terrain types, the Mackenzie Delta and the rolling to hilly area of the Caribou and Campbell Lake Hills (Mackay 1963).

The Mackenzie Delta is a maze of channels and lakes with the dominant soil material being a silt loam textured alluvium. The rolling to hilly terrain of the Caribou Hills, where Inuvik is located, is composed dominantly of glacial till. The Campbell Lake Hills area (south of Inuvik) is an upland where bedrock either occurs as outcrops or lies close to the surface. In this area glacial drift of variable thickness is composed mainly of moderately fine textured till with local areas of outwash and ice-contact deposits. Peat deposits are commonly found in depressions.

The vegetation of the Mackenzie Delta portion of the study area presents a contrast to that of the rolling till uplands. A close canopy of white spruce (*Picea glauca*) with a continuous feather moss carpet grows on the least frequently inundated areas of the Mackenzie Delta. This association resembles the forests of the Boreal Forest Region. The vegetation on areas of the Mackenzie Delta which are periodically inundated is dominated by horsetails (*Equisetum* spp.), willows (*Salix* spp.), and alder (*Alnus* spp.). A more detailed description of the vegetation occurring on the Mackenzie Delta can be obtained from Gill (1971).

The rolling till upland area between Inuvik and Arctic Red River supports an open subarctic forest of stunted black spruce (*Picea mariana*) with some willow (*Salix* spp.) and has a lichen (*Cladonia* spp.) and moss ground cover. Black spruce growing on severely cryoturbated soils associated with earth hummocks are usually tilted in all directions by the frost-heaved soil. The vegetation on peatlands is either dwarf shrubs, lichens, and mosses or open black spruce, ericaceous shrubs, lichens, and mosses.

The dominant soils on the alluvial deposits in the Mackenzie Delta area are Regosolic Static Cryosols and Gleyed Cumulic Regosols (soil classification system according to Canada Soil Survey Committee 1978) with the latter occurring along the channels which are periodically inundated. The remainder of the area is dominated by Regosolic Static Cryosols. The till upland area of the Caribou and Campbell Lake Hills is dominated by Turbic Cryosols with the Orthic and Brunisolic subgroups being the most common. The soils on the coarse textured ice-contact deposits are Eluviated Dystric Brunisols. Most of the Turbic Cryosols are associated with a thin layer of surface peat.

The study area has a continental climate but does not have the temperature extremes exhibited further inland in the Mackenzie Valley (as, for example, at Fort Good Hope). The aerial climatic data presented by Burns (1973) indicates that Inuvik has a mean annual temperature of -9.6°C and total annual precipitation of 260 mm, of which 1740 mm occurs as snowfall and 102 mm as rainfall. The coldest month is February with a mean temperature of -29.2°C (-23.9°C maximum and -35°C minimum) and the warmest month is July with a mean temperature of 13.2°C (19.2°C maximum and 7.4°C minimum). The extreme maximum and minimum temperatures recorded at Inuvik are 31°C and -57°C, respectively.

According to Brown (1956, 1967), the entire study area lies within the continuous permafrost zone. Mackay (1963), however, points out that when the depths of the Mackenzie Delta channels or lakes exceed the thickness of winter ice, the subjacent bottom sediments will remain unfrozen. In addition to this, Gill (1971) indicates that permafrost-free soil also exists both where large channels have undergone recent shifts and in newly deposited slipoff slopes. These areas, according to Gill (1971), coincide with the *Salix-Equisetum* communities in the Mackenzie Delta.

MATERIALS AND METHODS

Location of Sites

Soil temperatures are being monitored on eight sites. Site I1 is located approximately 5 km north of Inuvik, sites I2 to I6 are located along the Dempster Highway between Inuvik and Arctic Red River, and sites I7 and I8 are located on the southwest side of Bombardier Channel near its confluence with the East Channel in the Mackenzie Delta, approximately 8 km north of Inuvik.

Sites I1, I3 and I6 are located on undulating morainal terrain which is associated with earth hummocks. Site I4 is situated on the top of an esker while sites I2 and I5 are associated with a polygonal peat plateau and peat plateau, respectively. Polygonal peat plateaus and peat plateaus are perennially frozen peat landforms which commonly occur in the subarctic (Zoltai and Tarnocai 1975). Sites I7 and I8 are both located on a recent fluvial terrace on the Mackenzie Delta.

These sites are situated on the most common soils in the area: Brunisolic and Orthic Turbic Cryosols associated with earth hummocks on fine textured till (sites I1, I3 and I6); Mesic Organic Cryosol associated with a polygonal peat plateau (site I2) and with a peat plateau (site I5); Eluviated Dystric Brunisol, cryic phase, associated with a coarse textured sandy deposit (site I4); and Regosolic Static Cryosol associated with loam textured alluvium (sites I7 and I8).

Some of the properties of these sites, together with the associated soils, landforms, and vegetation, are listed in Table 1.

Instrumentation

The thermistor cables were constructed by using Yellow Spring epoxy-coated thermistor beads #44033. These thermistor beads were positioned on the cable so as to allow the soil temperatures to be read at the 2.5, 5, 10, 20, 50, and 100 cm depths (Figure 1).

The installation of thermistor cables was done with as little disturbance as possible to the site and the soil. The thermistor cables were fastened to half-round dowelling and then coated with plastic to prevent them from becoming moist. These coated cables were then placed in holes drilled by a 2.7 cm diameter permafrost auger. The half-round wooden dowelling was then placed in the auger hole in such a manner that the round part of the dowelling, where the thermistors were fastened, made contact with the auger hole wall. The contact was further secured by packing soil material in the other half of the auger hole.

The terminals were fastened to a wooden post placed approximately 50 cm away from the wooden dowelling (Figure 2). The post was positioned on the site in such a manner that the terminals were not facing the temperature site so as to avoid disturbance of the site while the readings were being carried out.

A Data Precision Model 245 digital multimeter was used to monitor soil temperatures weekly at all sites except at site I6 which was monitored biweekly.

Analysis of Data

Computerized techniques were utilized to streamline data processing. For each location, analysis of data was based on measurements obtained from all six depths. For each depth a measure of temperature fluctuation throughout the year was achieved by mathematically calculating the best fitting line to the data, i.e. by determining an equation of the form: Temperature = A Function of Date (Mills et al. 1977). After determining this equation the following parameters were derived:

- mean annual soil temperature (MAST)
- mean summer soil temperature (MSST)
- date of spring thaw - 0°C
- date of fall freeze - 0°C
- number of frost-free days
- maximum (XST) and minimum (MST) soil temperature and dates of occurrence
- date in spring and fall when soil temperature rises above and falls below 5°C
- length of season when soil temperature was above 5°C.

RESULTS

Mean Annual Soil Temperature

The highest mean annual soil temperature (MAST), 0.7°C, was found at the 2.5 cm depth in soil I1 while the lowest MAST, -3.8°C, was found at the 100 cm depth in soil I6 (Figure 3, Table 2). All MAST values were below 0°C with the exception of those for soils I1 and I5. For both of these soils the MAST was slightly above 0°C at the 2.5 cm and 5 cm depths. Soils I1 and I5 had the highest MAST values and soils I6, I7 and I8 had the lowest MAST values at all depths.

Soil texture and patterned ground type had little effect on the MAST values in mineral soils. Fine textured soil I1 had the highest MAST values of all soils at nearly all depths. On the other hand, fine textured soil I3 and coarse textured soil I4 had similar, moderate MASTs in the active layer, but soil I3 had a lower MAST value at the 100 cm depth than did soil I4. The coldest MAST values were associated with soils I6, I7 and I8. All of these soils were medium textured loams and silt loams. Soils I1 (silty clay), I3 (clay) and I6 (loam) were all associated with earth hummocks but their MAST values differed significantly (Figure 3, Table 2) with the highest being soil I1 (-2.1°C at the 50 cm depth and -1.9°C at the 100 cm depth) and the lowest being I6 (-3.4°C at the 50 cm depth and -3.8°C at the 100 cm depth). Soil I4 (sand) had the coarsest texture of all mineral soils monitored but its MAST values were only slightly higher than those of all finer textured mineral soils except soil I1.

On peat deposits, however, the MAST values were lower on soil I2, associated with polygonal peat plateaus, than on soil I5, associated with peat plateaus, in spite of the fact that both of these soils were composed dominantly of moderately decomposed sedge peat.

The MAST values of the two soils (I7 and I8) occurring on the Mackenzie Delta were among the lowest measured but the near surface portion of the active layer of soil I8 was somewhat cooler than that of soil I7. Both of these soils were silt loam in texture.

Mean Summer Soil Temperature

The highest mean summer soil temperature (MSST), 10.8°C, was associated with the 2.5 cm depth in soil I1 while the lowest MSST, -1.8°C, was associated with the 100 cm depth in soil I6 (Figure 4, Table 2). The MSST values were above 0°C in all soils at a depth of 20 cm or less and above 0°C in soils I1, I3, I4, I6, and I7 to a depth of 50 cm.

The highest MSST values were associated with soil I1 (silty clay in texture with earth hummocks). These high MSST values for soil I1 are probably due to its western exposure and the very thin surface organic layer. Soil I3 and I6, which were also fine textured soils associated with earth hummocks, have lower MSST values. Both of these soils had much thicker surface organic layers than did soil I1 (Table 1). At the 20 cm depth, for example, MSST values for these soils were 5.1°C (I1), 2.6°C (I3) and 1.9°C (I6).

The MSST value of the active layer of soil I2 was somewhat higher than that of the active layer of soil I5. These soils were both associated with mesic peat materials but their vegetation cover differed. Soil I5 had a thick, continuous lichen cover while for soil I2 this lichen cover was discontinuous, the vegetation cover was not as heavy and, in some areas, dark peat surfaces were exposed. The reverse was true of the MSST values of the near surface permafrost layer (100 cm depth) of these two soils, however, with soil I2 having a lower MSST (-1.6°C) than soil I5 (-0.8°C).

The MSST values of the active layers of the two Mackenzie Delta soils were also different although their MSST values at the 2.5 cm depth were very similar (6.1°C and 7.7°C). At lower depths, however, soil I7 had higher MSST values than had soil I8. Soil I7 was still periodically inundated by the Mackenzie River in late May and June. This may have helped to accelerate the thawing process and caused these slightly higher summer soil temperatures as compared to soil I8 which was inundated only during the extreme spring high water levels in some years.

Minimum Soil Temperatures

The lowest minimum soil temperature (MST), -17.5°C, was measured at the 2.5 cm depth in soil I2 while the highest MST, -5.2°C, was recorded at the 100 cm depth in soil I5 (Figure 5, Table 2). This soil (I5) had the highest MST values at all depths of all eight soil studied. Soil I2 had the lowest MST values at the 2.5, 5 and 10 cm depths. At greater depths (20, 50 and 100 cm) soil I7 had the lowest MST values.

For the three hummocky soils, soil I1 had the highest MST and soil I6 had the lowest MST at all depths. Although the near surface MST values of these three soils were similar, at lower depths (50 and 100 cm) the differences were greater. At the 50 cm depth the temperature difference between soils I1 and I6 was 2.4°C and at the 100 cm depth, 3.8°C. Soil I6 had the lowest temperature even though it had the deepest snow cover, 55 cm as compared to 30 cm for I1 and 39 cm for I3.

Organic soils associated with polygonal peat plateaus (I2) have much lower MST values than do organic soils associated with peat plateaus. Although the differences were especially large at near surface depths, at lower depths (50 and 100 cm) soil I5 was still more than 3°C warmer than soil I2. The snow cover on these soils was similar (28 cm on soil I2 and 21 cm on soil I5).

When the MST values of the two Mackenzie Delta soils (I7 and I8) were compared, it was found that soil I7 had the lowest MST at all depths. When the MST occurred, the snow covers were 45 cm (I7) and 31 cm (I8).

Soils I6 and I7 were both associated with the lowest MST in spite of the fact that they had deeper snow cover than other sites. In the case of soil I6 this difference in snow depth was 25 cm when compared to soil I1 and 16 cm when compared to soil I3, all these soils occurring on hummocky sites. This added snow cover probably did not provide sufficient extra insulation to prevent greater cooling of soil I6. This was probably also the case with soil I7 which had 14 cm more snow than soil I8. Soil I7 is situated close to the channel and is more exposed to the winds than is soil I8. Thus, the snow on soil I7 was more wind-packed and, therefore, of lower insulating capacity than the soft, low density snow associated with soil I8.

Maximum Soil Temperatures

The highest maximum soil temperature (XST), 24°C, was measured at the 2.5 cm depth in soil I1 and the lowest XST, -0.4°C, was recorded at the 100 cm depth in soil I8 (Figure 6, Table 2). Soil I1 had the highest XST values at all depths except 100 cm where soil I4 had the highest XST. The lowest XST values were observed in soil I8 at all depths except at 50 cm where soil I5 was 0.1°C cooler than I8.

For the three soils (I1, I3 and I6) associated with earth hummocks, soil I1 had the highest XST values at depths between 2.5 and 50 cm. At the 100 cm depth these soils had very similar XST values.

Organic soils (I2 and I5) had very similar XST values. Near the surface (10 cm or less), however, soil I2 had the higher XST.

For the two soils located on the Mackenzie Delta (I7 and I8) soil I7 had the higher XST. This was especially noticeable at the 10, 20 and 50 cm depths.

Frost-Free Days

The greatest number of frost-free days (151) occurred in soil I3 at the 2.5 cm depth. Below this depth the greatest number of frost-free days were: 136 days (soil I1) at the 5 cm depth; 132 days (soil I2) at the 10 cm depth; 136 days (soil I6) at the 20 cm depth; 140 days (soil I4) at the 50 cm depth; and 78 days (soil I4) at the 100 cm depth (Table 2).

Of the three soils (I1, I3 and I6) associated with earth hummocks, soil I1 had the greatest number of frost-free days. Soil I1, which thawed to the 100 cm depth for slightly over one month, is the only hummocky soil to thaw to this depth.

The length of the frost-free period (approximately 130 days) in the near surface layers (2.5 to 10 cm) of the two organic soils was very similar. At greater depths, however, soil I5 had a significantly longer frost-free period than soil I2.

The number of frost-free days in the two Delta soils (I7 and I8) were very similar at all depths. In the near surface layer (2.5 to 10 cm) the number of frost-free days ranged from 116 to 134; at greater depths (20 to 50 cm) it ranged from 87 to 113.

The thawing of the soil surface generally began in May with rapid thawing in the near surface soil. The thaw reached the 50 cm depth in early June in soil I6, in mid-June in soils I1 and I4, in late June in soils I2, I3 and I5 and in early July in soils I7 and I8. In the fall the freezing process occurred much more quickly in mineral soils than in organic soils. At the 50 cm depth the soil froze in early October in soils I1, I7 and I8, in mid-October in soils I3 and I6, in early November in soils I2 and I4 and in early January in soil I5 (Table 2).

Since these soils froze from both the surface and the permafrost table, the middle portion of the active layer usually froze last. Soils I1, I7 and I8 froze quickly, generally taking less than one week. On the other hand, the freezing process took approximately 10 days in soil I6, 3 weeks in soil I3, four weeks in soils I2 and I4, and 11 weeks in soil I5.

During the period of thawing, especially in the late summer, freeze-back occurred in mineral soils in periods of cool weather. This was especially noticeable in soils I1 and I8 during late August and early September. The magnitude of this freeze-back was 14 cm in soil I1 and 4 cm in soil I8. No freeze-back was observed in any of the organic soils monitored.

Days Above 5°C

The greatest number of days above 5°C were found in soil I1 at depths of 20 cm or less with 111 days at 2.5 cm, 108 days at 5 cm, 94 days at 10 cm and 76 days at 20 cm (Table 2). The least number of days above 5°C were: 70 days for soil I7 at 2.5 cm; 63 days for soil I8 at 5 cm; 34 days for soil I3 at 10 cm; and 27 days for soil I3 at 20 cm. Only soils I1 and I4 had temperatures above 5°C (25 days and 21 days, respectively) at the 50 cm depth and no soils had temperatures above 5°C at the 100 cm depth.

DISCUSSION

The temperature regimes of Cryosolic soils (soils associated with permafrost) are not necessarily controlled by the factors (e.g. soil texture and type of soil material) that control the temperature regimes of soils without permafrost. In temperate regions oganic and fine textured mineral soils have much lower MAST and MSST values than coarser textured mineral soils occurring in a similar climatic region (Mills et al. 1977). In this study the organic and mineral Cryosols were found to have similar soil temperature regimes. Soil temperature regimes of the mineral soils, however, were greatly influenced by their topographical location and vegetation cover. Patterned ground types had little influence on the soil temperatures of these subarctic mineral soils.

Earth hummocks are common in the Mackenzie Valley. Soils associated with these earth hummocks have a variety of temperature regimes. The MAST and MSST values of soil I1, located north of Inuvik, were the highest of all eight soils studied. This soil was one of the warmest monitored in the area, probably because of its topographic position on a slight (less than 2%) westerly slope and the very thin surface organic layer. On the other hand, soil I6, which was located 136 km south of Inuvik and which was also associated with earth hummocks, had the lowest values for both the MAST and the MSST. The location of this soil in a depression was partly responsible for the cooler soil temperatures.

In organic Cryosolic soils the patterned ground type correlated much better with soil temperature regimes than it did in the mineral Cryosolic soils. Soils associated with a polygonal peat plateau had a lower MAST than soils associated with a peat plateau in the same area. The MSST of the near surface permafrost was also lower in the soil associated with the polygonal peat plateau. The MSST values of the active layer of these soils were lower in the soil associated with the peat plateau where the surface was covered with a thick, continuous lichen cover and they were higher in the soil associated with the polygonal peat plateau where the vegetation cover was discontinuous and not as heavy as on the peat plateau. Thus it can be seen that the vegetation cover has a significant effect on the MSST values of the near surface active layer (0-20 cm depth) of these organic soils. Thick lichen, moss and forest cover decrease the MSST. This was also the case in soil I4 which had relatively low MSST values in the near surface soil due to both the heavy forest canopy and the thick lichen layer.

The moisture content of the soils monitored in this study affects their thermal regime in several ways. The low moisture (ice) content in soil I4 is responsible for deeper active layer development since the very low ice content facilitates thawing to a greater depth. On the other hand, the high moisture content in organic soils retards the freezing process in the fall because of the higher latent heat associated with high water content.

The lack of correlation between soil texture and the soil temperature regime of these subarctic soils is probably due to the low rate of evapotranspiration in this region. Evapotranspiration is the main factor in soil temperature differences in the temperate region where coarse textured soils are generally dryer than fine textured soils. Evaporation of this higher moisture content in the fine textured soils produces cooler soil temperatures than in the coarser, and dryer, soils. In cooler regions the rate of evapotranspiration is low and thus differences in soil temperature due to soil texture are minimal (Clarke Topp, personal communication).

The lowest minimum temperatures were observed in those soils located in depressions on soils I2, I6 and I7. The snow cover, which varied from site to site, does not seem to correlate with the lowest minimum temperature. This may indicate either that the snow cover was not deep enough to provide sufficient insulation from the cold air temperatures or that the snow was a high density type due to wind-packing.

Using the 50 cm depth for the purpose of comparison, the highest number of frost-free days were found in soils I4 and I5 (140 and 133 days, respectively). Soils I1 and I6 occurred in the mid-range of frost-free days (108 and 103 days, respectively) while the lowest number was found in soils I2, I3, I7 and I8 (84, 91, 88 and 87 days, respectively).

The two Mackenzie Delta soils were found to be generally cooler than the other soils, possibly because of their low topographic positions. When these two soils were compared to each other it was found that soil I7, located in the willow-alder zone, was colder in the winter and warmer in the summer than soil I8 which was located in a relatively higher position under white spruce vegetation. The colder winter soil temperatures of soil I7 result from this soil being more exposed during the winter and associated with a higher density of wind-packed snow which provides less insulation than the soft, low density snow associated with I8. The higher summer soil temperatures in soil I7 may result from the location of this soil in the willow-alder zone being subjected to nearly annual spring inundation which speeds up the thawing process in the soil. Soil I8 is inundated only during exceptionally high spring floods and, based on the small amount of alluvial material deposited by these floods, it appears that the length of this inundation is much shorter than that of site I7. The thickness of the surface organic layer is only 2 cm on soil I7 as compared to 10 cm on soil I8. The thinner organic surface layer on soil I7 allows the soil to warm up much more during the summer than is possible on soil I8 which is insulated with a thicker blanket of organic matter. The alder-willow type of vegetation associated with soil I7 provides less shading, especially in the early part of the summer, than does the white spruce vegetation on soil I8 and hence more incoming radiation is able to reach soil I7.

Although the MSST of the rooting zone (0-30 cm) of soil I8 was the lowest of all eight soils monitored in this study its forest productivity is probably the highest. This would suggest that forest growth is controlled more by the nutrient status of the soil and to a lesser extent by the soil temperature. The higher nutritive and pH values result from periodic inundation by the Mackenzie River. A similar phenomenon was also found on disturbed sites in Alaska by Chapin and Shaver (1981).

The active layer of these Cryosolic soils had very little buffering capacity and responded quickly to a change in air temperature. This was due both to the shallow active layer, which was capable of containing only small amounts of stored heat, and to the underlying permafrost, which acted as a heat sink and removed heat from the active layer as long as this layer had a higher temperature. In fact, when the temperature regime of the near surface permafrost layer (100 cm depth) was compared with the temperature regime of the active layer, it was found that mineral soils I6, I7 and I8, and organic soil I2 had the lowest MAST values at the 100 cm depth and these soils had the lowest MAST values and the shortest frost-free period in the active layer. This would indicate that the temperature regime of the active layer was controlled not only by the aerial climate and other environmental factors but also by the temperature of the permafrost layer.

In subarctic Cryosolic soils the occurrence of freeze-back, which takes place during the period of cooler weather long before the surface soil freezes, is neither as rapid nor as common as in Cryosolic soils in the arctic region (Tarnocai 1980). Freeze-back is a thermal process during which soil materials become frozen (having temperatures below 0°C). This freeze-back was especially noticeable for two of the mineral soils (soils I1 and I8). In organic soils, however, no freeze-back was observed.

Results obtained during this study indicate that the main factors affecting the soil temperature are topographic location, moisture content, vegetation and surface organic matter. Depressional topography, high moisture content, dense vegetation cover and any surface organic matter have a negative effect on the soil temperatures. If any of these conditions do not occur, the soil temperature will be increased. For land use decisions, especially in areas where the soil is affected by these negative conditions, these factors should be considered in order to avoid long-lasting degradation and disturbance of the land. This is especially critical when the soil is associated with high ice content, as is the case with the majority of the soils in the study area. If land use practices affect these conditions, soil temperatures will increase, resulting in rapid melting of the ice-rich subsoil and serious degradation of the environment.

SUMMARY

Temperatures in eight soils, all associated with permafrost, were monitored over a period of two and a half years. It was found that topographic position, vegetation, and thickness of the surface organic matter had the greatest effect on the temperature regime of these soils. Soil moisture affected not only the rate of both thawing and freezing but also the depth of the active layer development. Soil texture and soil material had little effect on soil temperature since the cold, subarctic climate is associated with a low rate of evapotranspiration and these two soil properties have an effect only when evapotranspiration is high.

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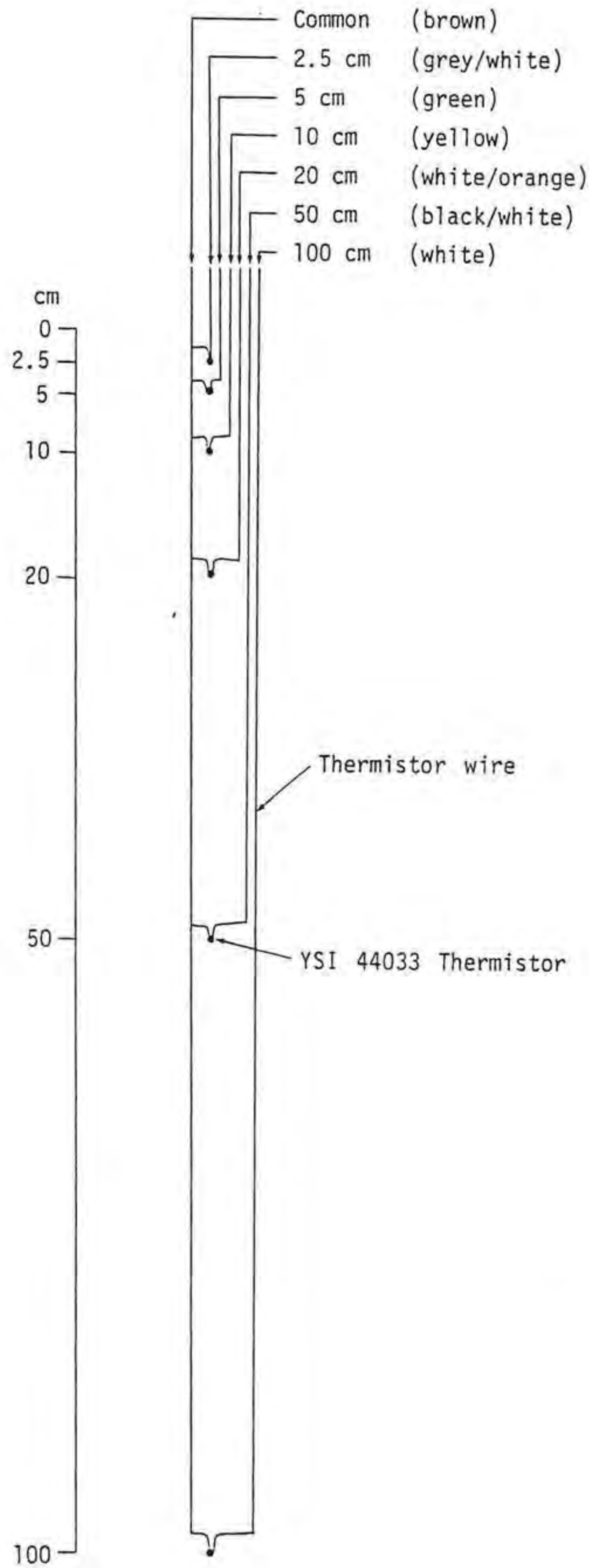

Figure 1. Diagram showing the construction of the thermistor cable.

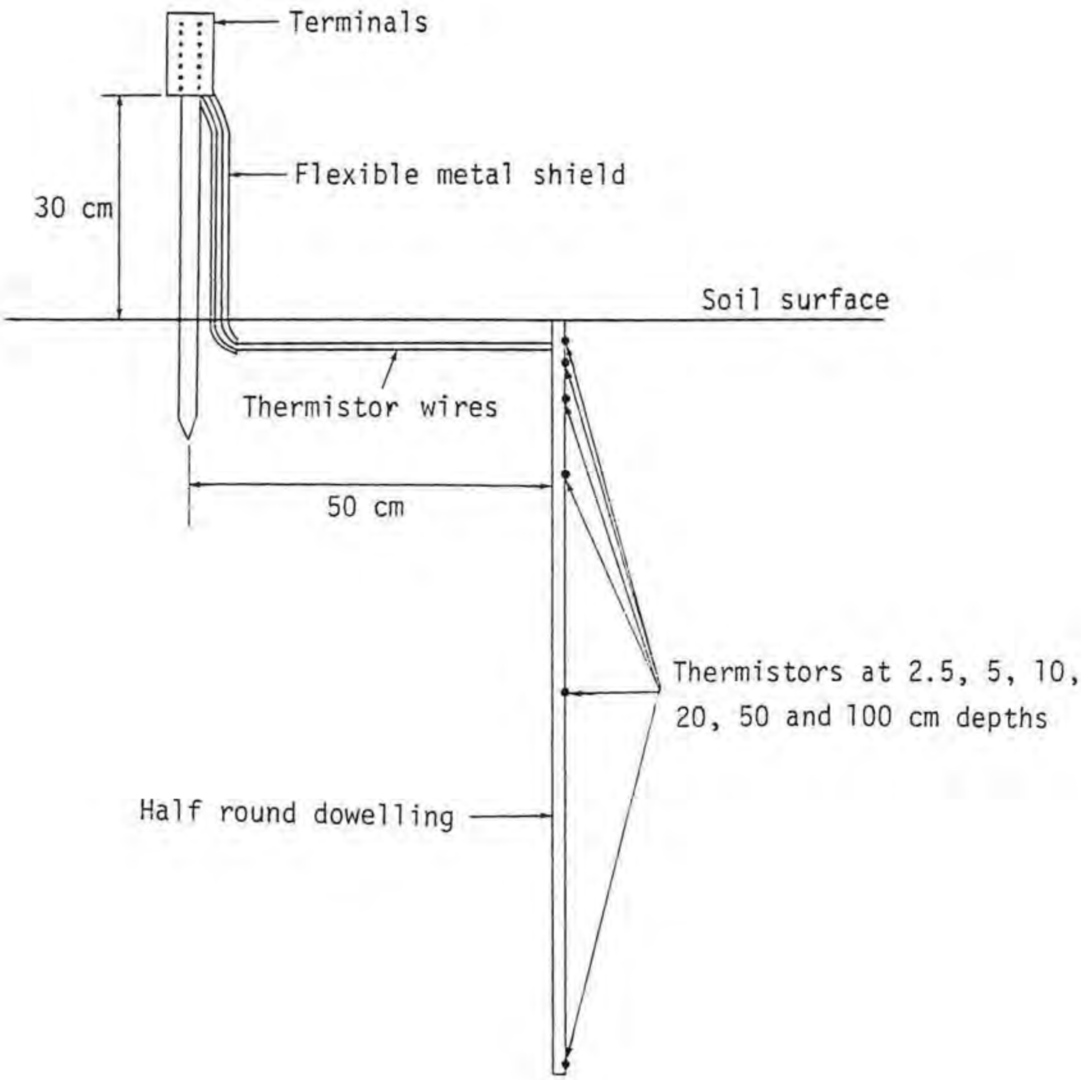

Figure 2. Installation of thermistor cable at a soil temperature site.

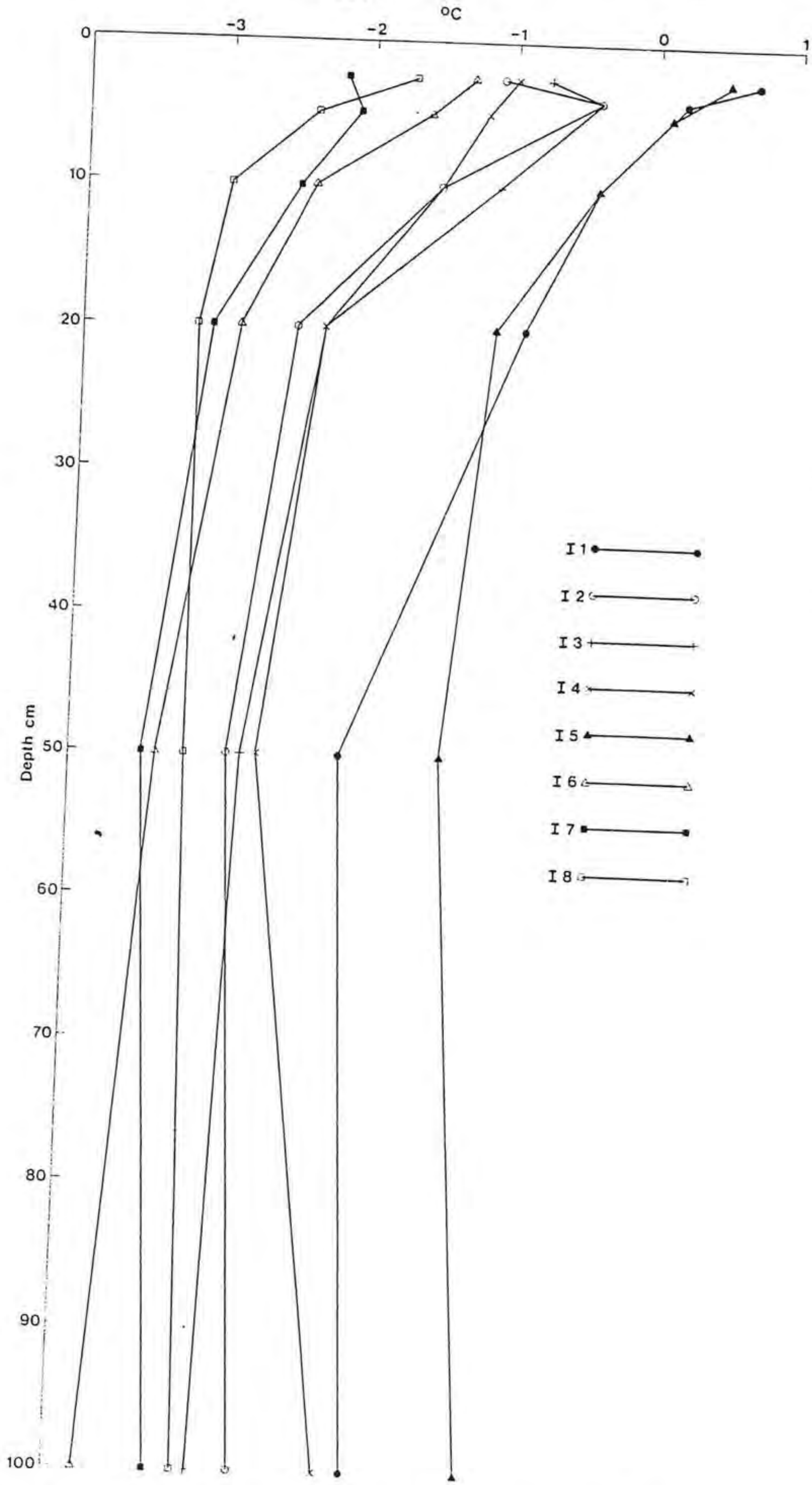

Figure 3. Mean annual soil temperatures for soils I1 to I8.

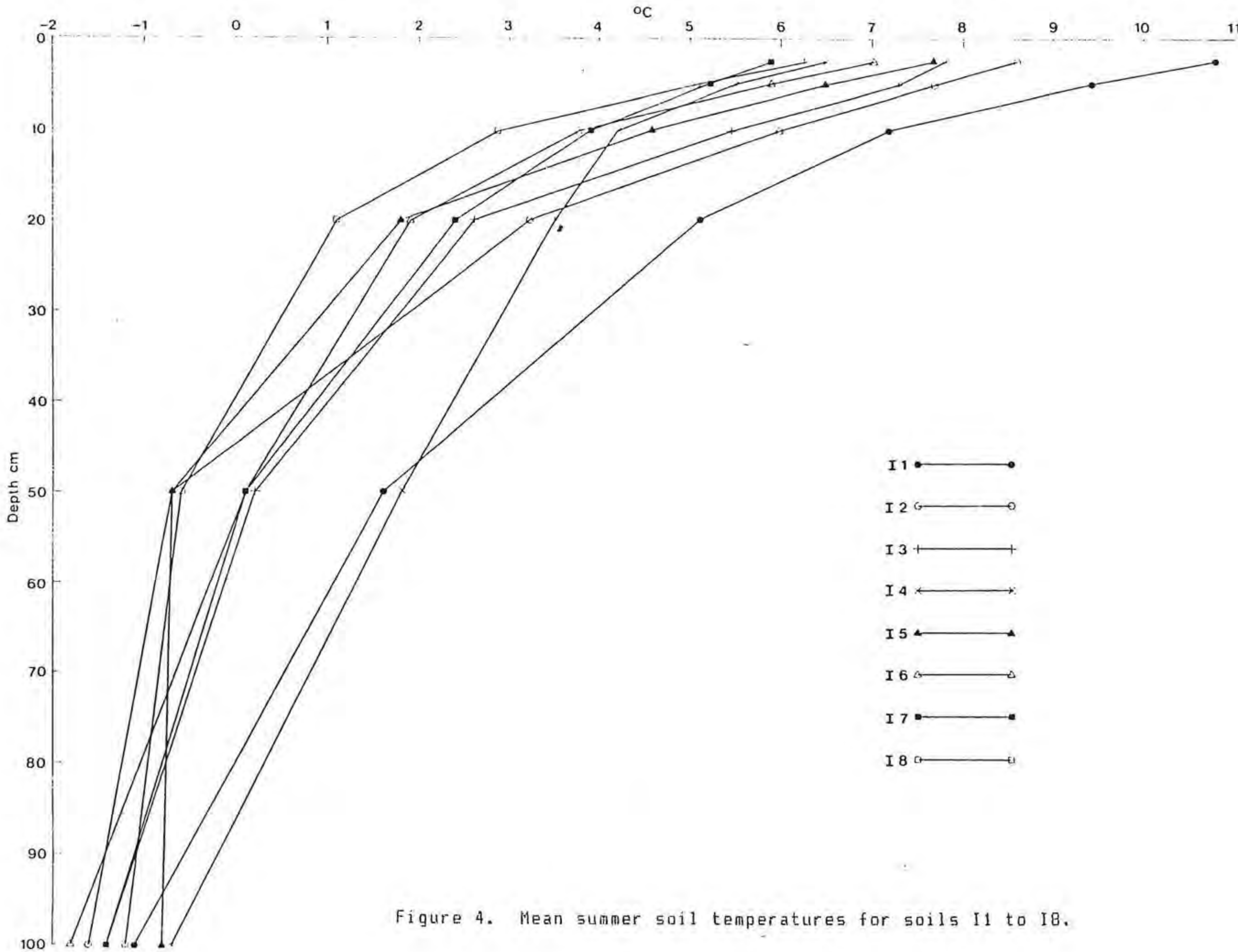

Figure 4. Mean summer soil temperatures for soils I1 to I8.

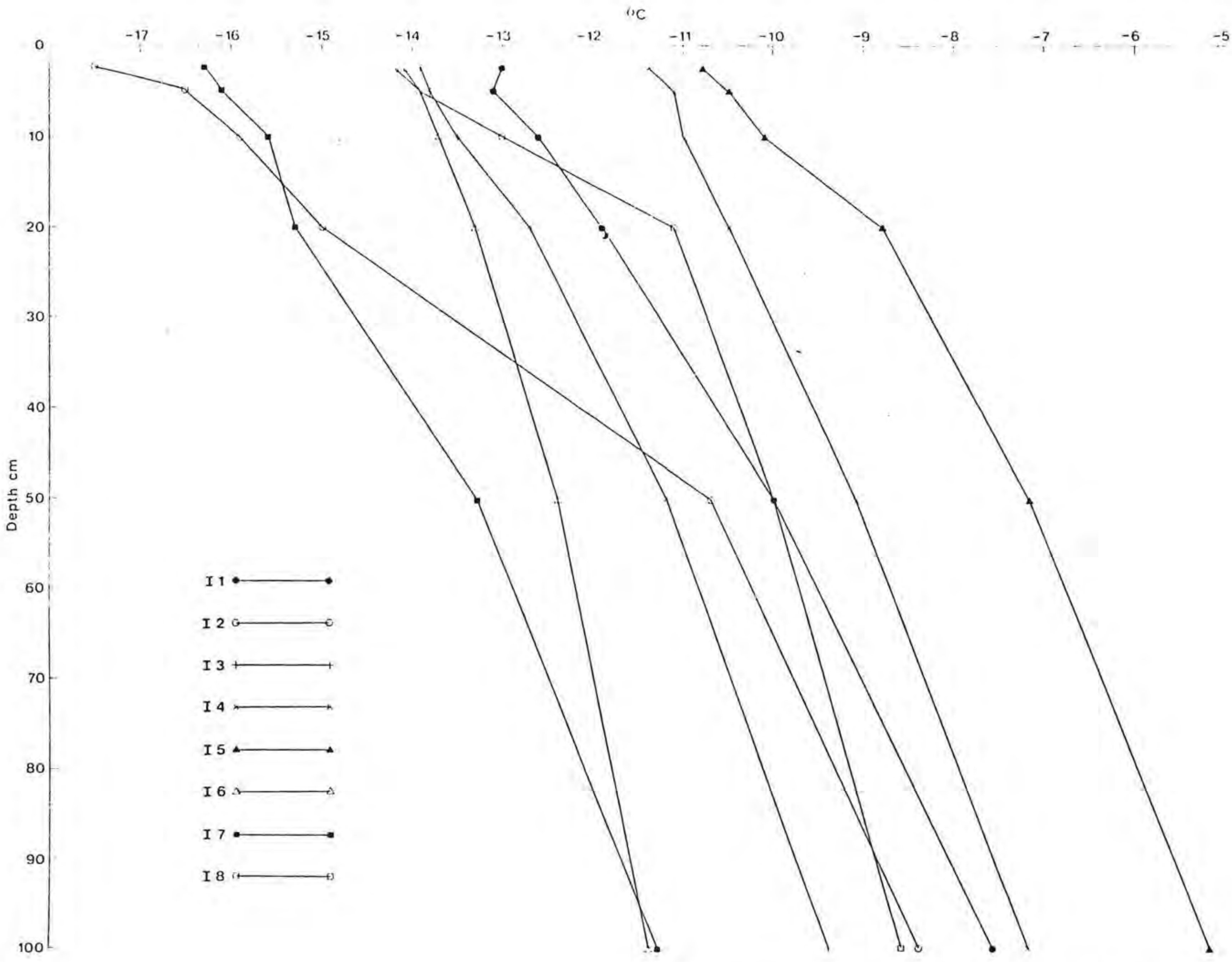

Figure 5. Minimum soil temperatures for soils I1 to I8.

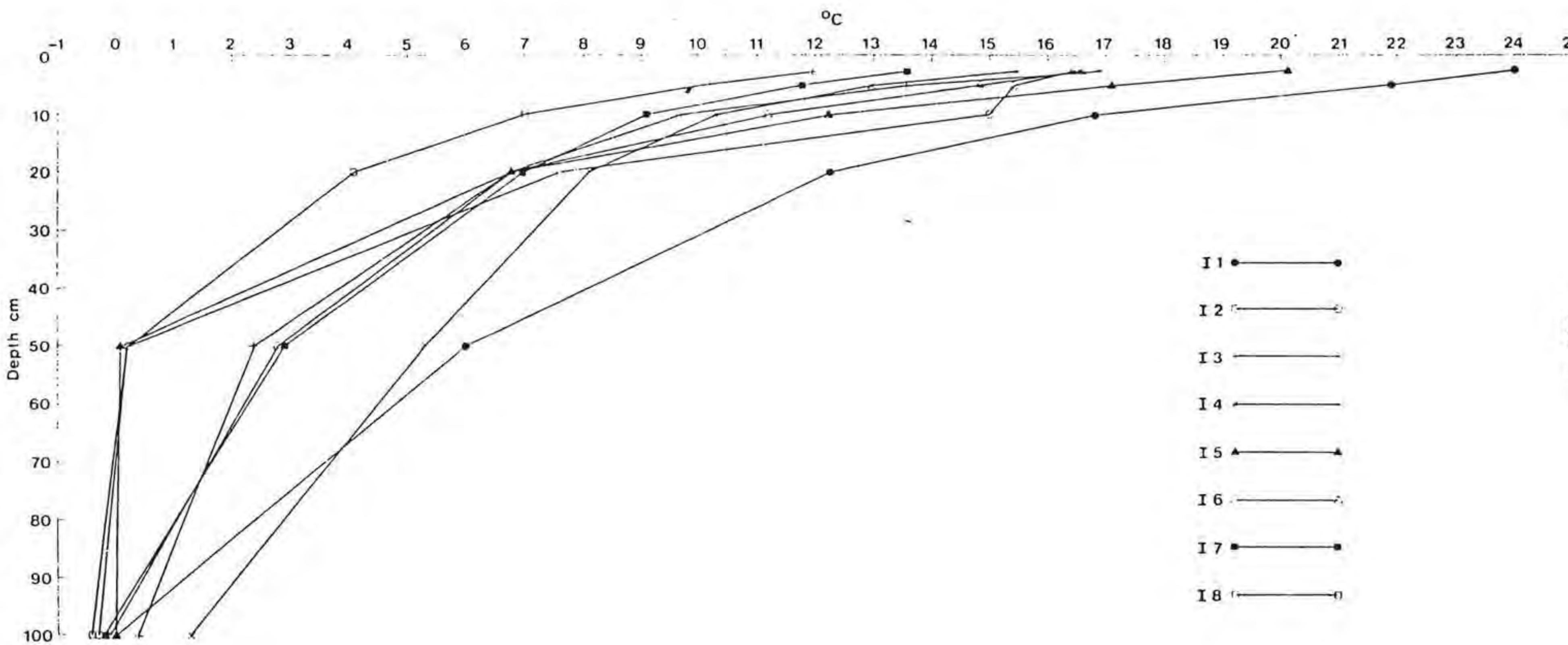

Figure 6. Maximum soil temperatures for soils I1 to I8.

Table 1. Description of soil temperature sites.

Site No.	Location Lat.N	Location Long.W.	Elev. m(a.s.l.)	Landform	Material	Topography Aspect	Topography Slope%	Soil Subgroup	Soil Texture	Soil Drainage	Thickness of Surface Organic Layer cm	Ice Content %	Active Layer cm	Patterned ground	Vegetation
11	62°23'	133°44'	25	Undulating morainal blanket	Colluviated till	W	2	Brunisolic Turbic Cryosol	Silty clay	Imperfect	less than 1	High	98	Earth hummock	Black spruce-ericaceous-lichen
12	68°19'	133°25'	100	Polygonal peat plateau	Mesic fen peat	-	0	Mesic Organic Cryosol	-	Imperfect to poor	+	High	39	Polygonal peat plateau	Dwarf shrubs-lichens-moss
13	68°08'	133°27'	30	Undulating morainal blanket	Till	SW	3	Orthic Turbic Cryosol	Clay	Moderately well to poor	6*	High	65	Earth hummock	Black spruce-ericaceous-lichen
14	69°07'	133°26'	40	Ridged glacio-fluvial (esker)	Glacio-fluvial	-	0	Eluviated Dystric Brunisol, cryic phase	Sandy loam to sand		3	Low	100	-	Black spruce-lichen
15	67°57'	133°28'	75	Peat plateau	Mesic sedge fen peat	-	0	Mesic Organic Cryosol	-	Imperfect to poor	+	High	45	-	Dwarf shrubs-lichen-moss
16	67°30'	133°46'	46	Undulating morainal blanket	Till	E	2	Brunisolic Turbic Cryosol	Loam	Moderately well to imperfect	5*	High	68	Earth hummock	Black spruce-ericaceous-lichen
17	68°25'	133°52'	8	Fluvial terrace	Fluvial	-	0	Regosolic Static Cryosol	Silt loam	Well	2*	Medium	71	-	Willow-alder
18	68°25'	133°52'	10	Fluvial terrace	Fluvial	-	0	Regosolic Static Cryosol	Silt loam	Well	10*	Medium	35	-	White spruce-willow-alder

* Thickness of organic layer measured at the top of hummock

\+ Organic soil

Table 2. Soil temperature parameters for soils I1 to I8.

Site No.	Depth cm	MAST °C	MSST °C	Number of Frost-Free Days	Date of 0°C Spring	Date of 0°C Fall	Min. Temp. °C	Min. Temp. Date	Max. Temp. °C	Max. Temp. Date	Date of 5°C Spring	Date of 5°C Fall	Number of Days Above 5°C
I1	2.5	0.7	10.8	136	May 18	Oct. 1	-13.0	March 16	24.0	Aug. 17	May 22	Sept. 10	111
	5	0.2	9.4	136	May 18	Oct. 1	-13.1	March 16	21.9	Aug. 17	May 25	Sept. 10	108
	10	-0.4	7.2	129	May 25	Oct. 1	-12.6	March 16	16.8	July 23	June 5	Sept. 7	94
	20	-0.9	5.1	122	June 1	Oct. 1	-11.9	March 16	12.2	Aug. 17	June 22	Sept. 1	71
	50	-2.1	1.6	108	June 15	Oct. 1	-10.0	March 16	6.0	Aug. 17	July 23	Aug. 17	25
	100	-1.9	-1.1	34	Aug. 3	Sept. 6	-7.6	March 23	0.0	-	-	-	0
I2	2.5	-1.1	8.6	132	May 18	Sept. 27	-17.5	Feb. 21	17.5	Aug. 2	May 30	Sept. 10	103
	5	-0.4	7.7	132	May 18	Sept. 27	-16.5	Feb. 21	15.4	Aug. 17	June 7	Sept. 10	95
	10	-1.5	6.0	132	May 18	Sept. 27	-15.9	March 14	15.0	July 19	June 2	Sept. 2	92
	20	-2.5	3.2	98	June 21	Sept. 27	-15.0	March 14	7.6	July 26	July 14	Aug. 15	42
	50	-2.9	-0.7	84	Aug. 17	Nov. 9	-10.7	March 16	0.2	Sept. 6	-	-	0
	100	-2.7	-1.6	0	-	-	-8.4	March 23	-0.3	-	-	-	0
I3	2.5	-0.8	7.8	151	May 3	Oct. 1	-13.9	March 15	16.9	July 26	June 19	Sept. 7	80
	5	-0.4	7.3	130	May 29	Oct. 1	-13.8	March 15	13.6	July 26	June 20	Sept. 7	79
	10	-1.1	5.5	116	June 7	Oct. 1	-13.5	March 15	9.7	July 26	June 30	Aug. 3	34
	20	-2.3	2.6	110	June 30	Oct. 18	-12.7	March 15	6.8	Aug. 16	July 24	Aug. 20	27
	50	-2.8	0.2	91	July 19	Oct. 18	-11.2	March 15	2.4	Aug. 23	-	-	0
	100	-3.0	-1.4	0	-	-	-9.4	March 22	0.4	-	-	-	0
I4	2.5	-1.0	6.5	133	May 24	Oct. 4	-11.4	March 15	15.5	Aug. 16	June 18	Sept. 2	76
	5	-1.2	5.5	133	May 24	Oct. 4	-11.1	March 15	13.0	Aug. 16	June 21	Sept. 2	73
	10	-1.5	4.2	127	May 31	Oct. 5	-11.0	March 15	10.3	Aug. 16	July 1	Aug. 30	60
	20	-1.3	3.5	125	June 7	Oct. 10	-10.5	March 15	8.1	Aug. 16	July 5	Aug. 30	56
	50	-1.7	1.8	140	June 21	Nov. 8	-9.1	March 15	5.3	July 26	July 26	Aug. 16	21
	100	-2.1	-0.7	78	July 19	Oct. 5	-7.2	April 19	1.3	Aug. 23	-	-	0
I5	2.5	0.5	7.7	141	May 17	Oct. 5	-10.8	March 15	20.1	Aug. 16	June 20	Sept. 10	81
	5	0.1	6.5	128	May 30	Oct. 5	-10.5	March 15	17.1	Aug. 16	June 20	Sept. 2	74
	10	-0.4	4.6	127	May 31	Oct. 5	-10.1	March 15	12.2	Aug. 16	July 4	Sept. 2	60
	20	-1.1	1.8	112	June 20	Oct. 10	-8.8	March 15	6.8	Aug. 16	July 20	Aug. 20	31
	50	-1.4	-0.7	133	Aug. 23	Jan. 3	-7.2	March 15	0.1	-	-	-	0
	100	-1.1	-0.8	0	-	-	-5.2	March 30	0.0	-	-	-	0
I6	2.5	-1.3	7.0	133	June 2	Oct. 13	-14.1	Feb. 15	16.6	Aug. 23	June 6	Sept. 5	91
	5	-1.6	5.9	133	June 2	Oct. 13	-13.9	Feb. 15	14.8	Aug. 23	June 6	Sept. 5	91
	10	-2.4	3.8	127	June 5	Oct. 10	-13.7	Feb. 15	11.2	Aug. 23	July 1	Sept. 2	63
	20	-2.9	1.9	136	June 8	Oct. 22	-13.3	Feb. 15	6.8	Aug. 16	July 19	Aug. 20	32
	50	-3.4	0.1	103	July 1	Oct. 12	-12.4	March 22	2.8	Aug. 16	-	-	0
	100	-3.8	-1.8	0	-	-	-11.4	March 22	-0.1	-	-	-	0
I7	2.5	-2.2	5.9	130	May 26	Oct. 3	-16.3	March 16	13.6	Aug. 17	June 29	Sept. 7	70
	5	-2.1	5.2	128	May 28	Oct. 3	-16.1	March 16	11.8	Aug. 17	July 5	Sept. 7	64
	10	-2.5	3.9	123	June 4	Oct. 5	-15.6	March 16	9.1	Aug. 17	July 6	Sept. 12	68
	20	-3.1	2.4	113	June 15	Oct. 6	-15.3	March 16	7.0	Aug. 17	July 15	Aug. 29	45
	50	-3.5	0.1	88	July 9	Oct. 5	-13.3	March 16	2.9	Aug. 17	-	-	0
	100	-3.3	-1.4	0	-	-	-11.1	March 23	-0.3	-	-	-	0
I8	2.5	-1.7	6.3	134	May 22	Oct. 3	-14.2	March 16	12.0	Aug. 10	June 24	Sept. 7	75
	5	-2.4	5.1	126	May 30	Oct. 3	-13.8	March 16	10.1	Aug. 10	July 6	Sept. 7	63
	10	-3.0	2.9	116	June 11	Oct. 5	-13.0	March 16	7.0	Aug. 10	July 9	Aug. 28	50
	20	-3.2	1.1	110	June 24	Oct. 3	-11.1	March 22	4.1	Aug. 17	-	-	0
	50	-3.2	-0.6	87	July 10	Oct. 5	-10.0	March 16	0.2	Sept. 1	-	-	0
	100	-3.1	-1.2	0	-	-	-8.6	March 22	-0.4	-	-	-	0

Soil Temperature Maps

Prepared by: W.K. Sly, Jan. 1984

Several thematic maps for Canada based on soil temperatures estimated using the techniques developed by Ouellet (1973) have been produced in manuscript forms. Their titles are listed below. An asterisk has been placed beside those that have been published and are available for distribution.

Soil temperatures are not widely observed and Ouellet undertook the development of regression equations to estimate monthly normals from meso- and macro-climatic data in order to partially overcome the lack of soil temperature data until more records could be accumulated on a Canada-wide basis. Once the monthly normals of soil temperature have been estimated their distribution is such that the interpolation technique developed by Brooks (1943) for approximating daily values can be applied. Once the long time averages of daily temperatures have been estimated it is a simple matter to select the temperature averages on specific dates as well as to select the dates on which soil temperatures at certain depths climb to critical values. These depths and values can be related to the threshold values for biological activity.

The sets of data used in developing the estimating equations were obtained from published records of soil temperatures and corresponding climatic variables. The soil temperatures were taken under short grass in soils of sandy loam to clayey loam texture. The estimated temperatures, whether for monthly or daily values, are normals and as such will not provide information on monthly or daily extremes. Because the temperatures are estimates the mapped data is not intended to provide exact information for a particular location but rather to allow for ready comparison between locations.

A complete description of the development of the estimating equations and the determination of daily values are found in the following publications:

Ouellet, C.E. 1973. Estimation of monthly soil temperatures from climatic data. Tech. Bull. 82. Agrometeorology Research and Service, Chemistry and Biology Research Institute, Research Branch, Agriculture Canada, Ottawa, Ontario K1A 0C6. 9pp.

Ouellet, C.E. 1975. Estimated monthly normals of soil temperature in Canada. Tech. Bull. 85. Agrometeorology Research and Service, Chemistry and Biology Research Institute, Research Branch, Agriculture Canada, Ottawa, Ontario K1A 0C6. 148pp.

Brooks, C.E.P. 1943. Interpolation tables for daily values of meteorological elements. Q.J.R. Meteorol. Soc. 69(300):160-162.

Soil temperature maps:

For all Canada (scale 1:5,000,000)

* mean annual temperatures at 10, 20 and 50 cm
* mean summer soil temperatures at 10, 20 and 50 cm

Dates when soil temperature at the 10 cm and 20 cm depth reaches 5°, 10°, 15°, 18° and $22^{\circ}C$

Number of days when temperature at the 10 cm and 20 cm depth is equal to or greater than 15° and $18^{\circ}C$

Degree days of temperatures equal to or greater than 0°, 5° and $15^{\circ}C$ at the 10 cm and 20 cm depths.

For the Prairie Provinces (scale 1:2,000,000)

Temperature at 10, 20, 50 cm on May 1

Temperature at 10, 20, 50 cm on May 20

APPENDIX

SOIL CLIMATE WORKSHOP
Original Agenda

Monday, November 14, 1983

8:30 Introductions, objectives, review agenda

9:00 - 12:15 Regional Progress Reports

9:00 - 9:15	British Columbia	R. Trowbridge
9:15 - 9:30	Yukon, N.W.T.	C. Tarnocai
9:30 - 9:45	Alberta	R. Howitt
9:45 -10:00	Saskatchewan	R. St. Arnaud
10:00 -10:30	COFFEE	
10:30 -10:45	Manitoba	G.F. Mills
10:45 -11:00	Ontario	D. Aspinall
11:00 -11:15	Quebec	R. Baril
11:15 -11:30	Nova Scotia	K. Webb
11:30 -11:45	New Brunswick	H. Rees
11:45 -12:00	Newfoundland	A. Stewart
12:00 -12:15	General Discussion	
12:15 - 1:30	LUNCH	

1:30 - 3:00 Soil Climate Classification: Review of Criteria and Principles

1:30 - 2:30	Soil Climate Classification in U.S. and Canada	R.Baril, G. Mills, R. St. Arnaud
2:30 - 3:00	Discussion	
3:00 - 3:30	COFFEE	

3:30 - 4:30 Data Handling Concerns

3:30 - 4:00	Progress report from CanSIS	B. MacDonald
4:00 - 4:30	Discussion	

Tuesday, November 15, 1983

9:00 - 12:00 Regional Analysis of Data

9:00 - 9:30	British Columbia	R. Trowbridge
9:30 -10:00	Northwest Territories	C. Tarnocai
10:00 -10:30	COFFEE	
10:30 -11:00	Manitoba	G.F. Mills
11:00 -11:30	Quebec	R. Baril
11:30 -12:00	Maritimes	K. Webb
12:00 -12:15	Mapping of Computer Derived Soil Temperatures	W. Sly
12:15 -12:30	Discussion	
12:30 - 1:45	LUNCH	

1:45 - 4:00 Methods Manual
- establish Editorial Board
- decide on content
- deadline for submissions of revisions
- procedure for publication
- others

4:00 - 4:30 Summary and recommendations
- review longer term objectives and develop workplan to meet objectives
- formulate report to ECSS

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SELECTED SOIL TEMPERATURE REFERENCES - NUMBER 2, 1983

Prepared for the Working Group on Soil Climate, ECSS

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REVIEW OF PFRA PILOT PROJECTS FOR CONTROL OF LAND DEGRADATION ON CANADIAN PRAIRIES

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1.0 INTRODUCTION

The purpose of this paper is to provide a brief review of recent activities undertaken by the Soil and Water Conservation Branch of PFRA related to land degradation issues on the Canadian Prairies. An overview assessment of these issues was prepared by the Branch and published in November, 1982. Subsequent to the report an extensive round of consultations and discussions were held by PFRA officials with researchers, government officials and farm organizations. During the period 1981 to 1983 PFRA has also received requests from groups of farmers for assistance in diagnosing and treating local problems of degradation by salinity and erosion. As an extension of our present planning process and within the constraints of present resources PFRA has become involved with several pilot projects that attempt to diagnose localized areas of degradation and to provide advice to farmers on possible remedial actions.

Soil survey and monitoring are considered by PFRA to be a vital component of the overall scheme of research, technology transfer and information dissemination activities necessary to fully address problems of land degradation in the West. Hopefully, the present paper might stimulate a further discussion on possible avenues of mutual interaction between survey and technical services programs.

2.0. THE TOBACCO CREEK SOIL EROSION PILOT PROJECT

2.1 Background

A serious flooding problem occurs in many watersheds downstream of the Pembina Escarpment in Manitoba. The Tobacco

Creek Watershed, located 110 km southwest of Winnipeg, is characteristic of the problem (Figure 1). In this area the escarpment drops from an elevation of 490 to 350 m in 6 to 10 km. Runoff is rapid cutting deeply into the erodible shale formations of the escarpment and depositing the silt into drainage channels as the gradient levels. This causes flooding during spring runoff and after heavy rains. Preliminary estimates indicate that some 7800 ha of class 2 farmland is subject to flooding resulting in crop loss and damage to property.

Detailed studies by the PFRA following requests by the Manitoba Government have concluded that the useful life of proposed detention reservoirs would be greatly reduced by silt deposition. The PFRA is currently active in the development of a long term land and water management strategy for the Watershed. The Soil Erosion Pilot Project is part of the study with the primary goals of: (1) determining, and if necessary reducing the contribution of field erosion to the total silt load in the system, and (2) conserving the maximum quantity of precipitation for crop use thus reducing runoff from farmland and thereby flooding in the Watershed.

2.2 Current Project Activities

The project has been staffed for one year by an agrologist and a summer student. Fieldwork has concentrated mainly on the South Tobacco Creek Watershed west of the village of Miami, it comprises some 5700 hectares.

A land use study has been undertaken to assess current farm practices and their effects on runoff and erosion, areas at risk to erosion, and, producer attitudes to soil conservation.

The 1982 land use for the Watershed was:

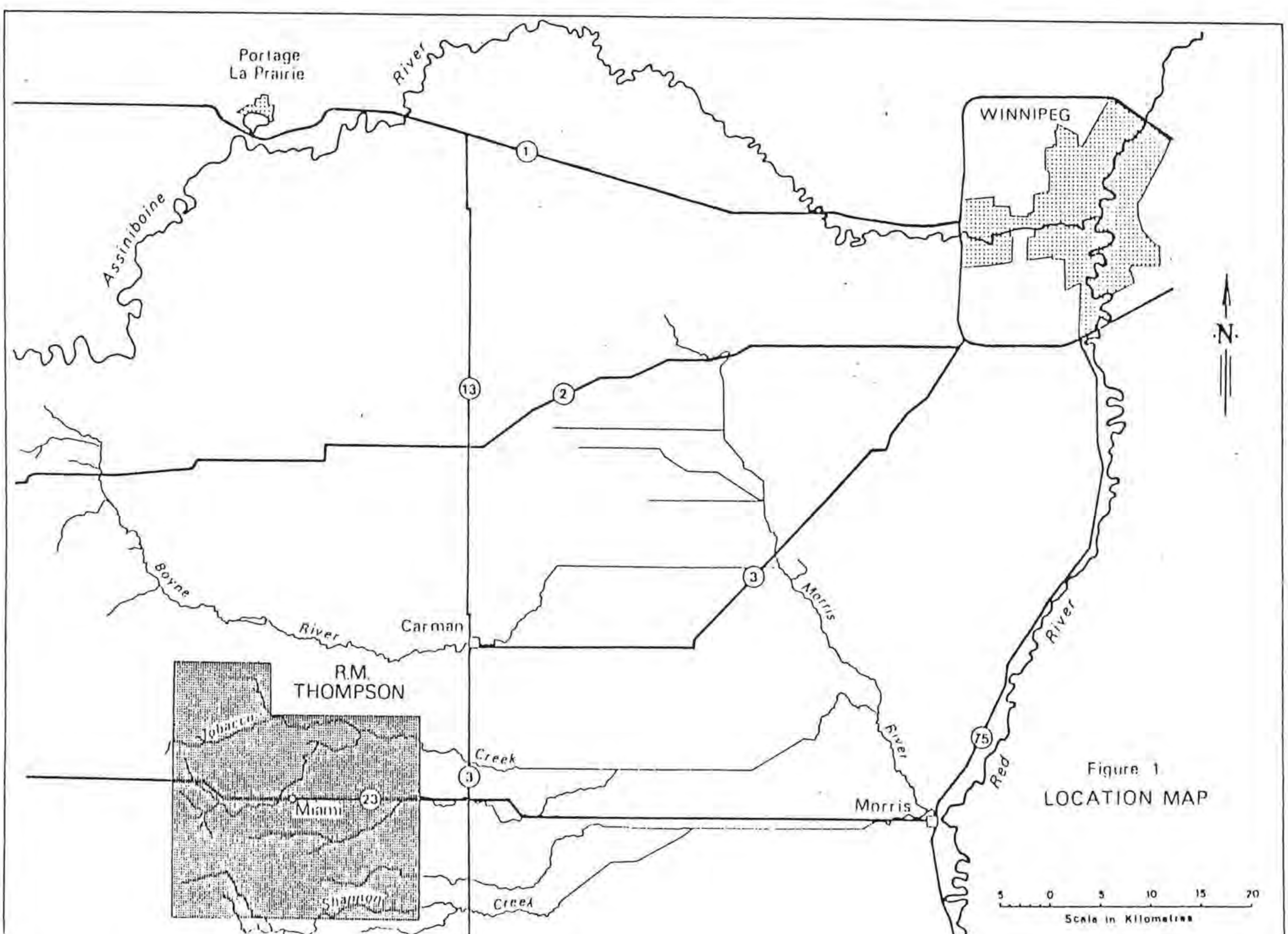


Figure 1
LOCATION MAP

Total area of watershed	5726 ha
Eroded Slopes	21%
Woodland and Farmyards	8%
Pasture and Forage	9%
Cultivated Land	62%

(Small grains 35%, Canola 9%, Flax 7%, Corn 4%, Sunflowers 3%, Summerfallow 4%)

The rotations in the area are strongly influenced by fluctuations in commodity prices and climatic conditions, however the usual pattern is 2 to 3 years of cereals followed by 1 year of flax, sunflowers, canola or buckwheat. Continuous corn is grown on some fields. Beyond varying degrees of trash management in the fall and the infrequent use of grassed waterways few conservation measures are employed.

The farmers in the area generally believe that a switch to continuous cropping and better trash management over the past 10 years has reduced erosion drastically. They feel that some erosion is inevitable and that farming practices are adequate to control erosion under "average" conditions. They take few measures to accommodate the occasional drought or flash flood.

A crop cover and trash management study has been initiated to permit use of the Universal Soil Loss Equation (USLE) in order to estimate soil erosion losses from fields. Sample sites were set up in 28 locations and will be monitored for a number of years. Early data indicates that crops provide less erosion protection than anticipated with small grains seldom achieving more than 75 percent coverage. Early data from the trash management study suggests that accepted percentages of trash retained following passes with tillage equipment may be optimistic for this area. Further data will be collected to confirm these tentative findings.

A slope length and percentage study was conducted for application in the USLE. The complexity of the topography resulted in the reading of approximately 50 slopes per section. This data is being analyzed in order to rationalize this problem and reduce the fieldwork requirement.

Measurement of recent streambank erosion in the entire Watershed west of Miami has been completed. For the South Tobacco Creek it is estimated that some 500 000 cubic meters of soil has been lost by streambank erosion within the last 25 years, 20 000 cubic meters per year. This compares well to a previous PFRA report which estimated total annual losses of 17 000 cubic meters per year from both field and streambank erosion.

Estimates of annual soil loss on two sections have been made by application of the USLE. The sections were divided into topographical and rotational units and the soil loss estimated. Whereas the average soil loss was 6.8 and 7.7 t/ha individual units lost up to 36.5 t/ha. The USLE can therefore be used to help delineate areas at particular risk to erosion. Extrapolating this data to the entire Watershed (using accepted sediment delivery ratios) would indicate that the cropland in the Watershed may contribute 4200 tonnes of sediment to the South Tobacco Creek annually or approximately 13 percent of the total siltload. This confirms visual assessments and suggests that reduction of the siltload in the South Tobacco Creek would best be achieved by streambank stabilization combined with measures to reduce runoff from cropland.

2.3 Future Project Activities

Future project activities include further manipulation of existing data to confirm these tentative results, extension of the land use study to the sub escarpment area where erosion occurs when the creek overflows, and continuation of the crop cover and trash management study. In addition plots will be set up to monitor soil erosion and runoff, conservation planning with interested farmers will be initiated, and the extent and severity of salinity and wind erosion will be studied. The main elements of the study will be completed in 4 years.

3.0 THE WARNER SOIL SALINITY PILOT PROJECT

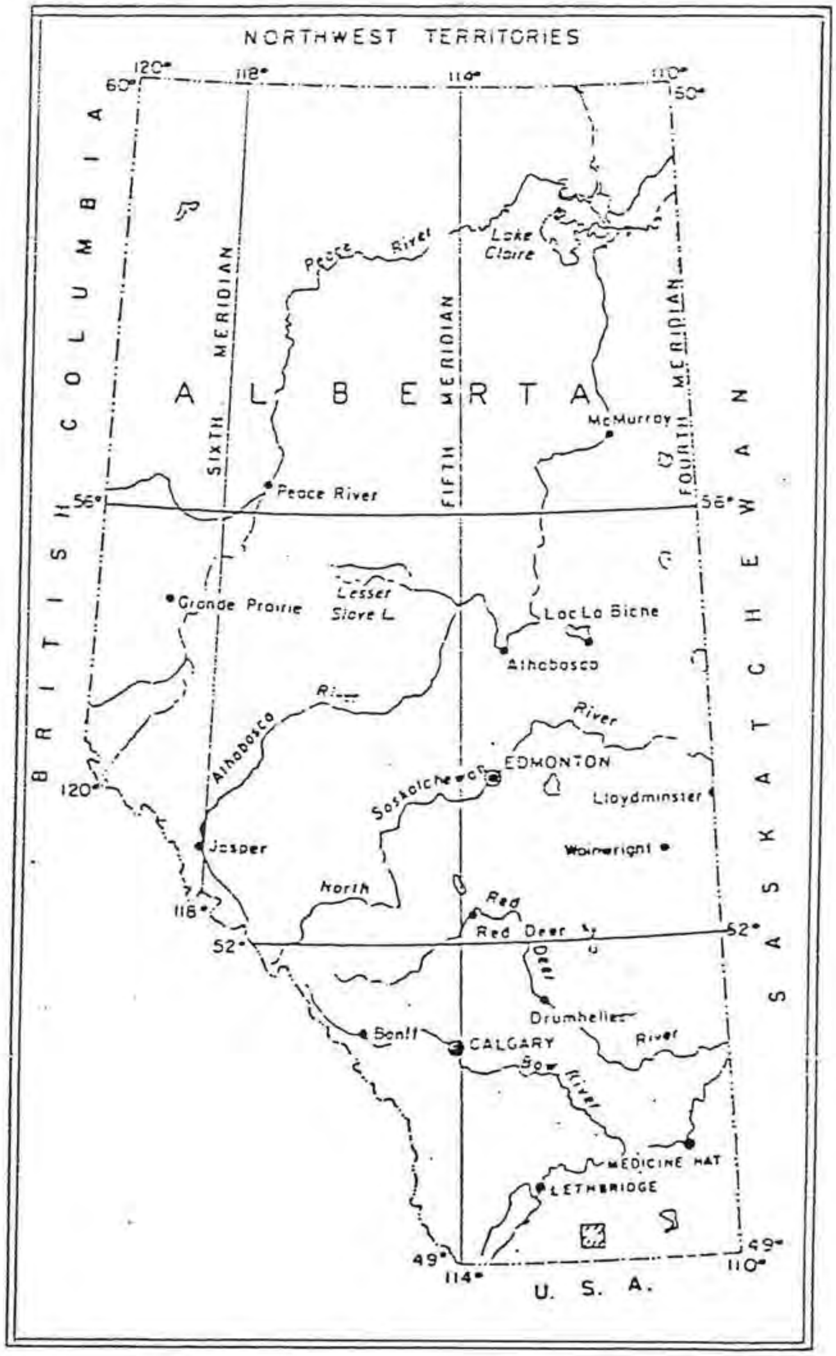
3.1 Background

Dryland salinity, commonly referred to as 'saline seeps', is a major problem on the prairies. Rapid increase in its severity and extent particularly in Southern Alberta is alarming and has caused a great concern to farmers. It is estimated that approximately 25 to 30 thousand hectares of arable land are currently affected by saline seeps in the Warner County area approximately 60 kilometers south of Lethbridge, Alberta (Figure 2).

In July, 1981, Mr. G. S. Clark, Director of the Plant Industry Branch of the Alberta Department of Agriculture proposed that a fairly large scale pilot project should be established in the County of Warner, preferable located on Mr. Bill Norris' farm. Mr. Norris was, in fact, very active in promoting this idea and was instrumental in convincing a large number of farmers in this area as to the severity of the problem. As a follow up of the foregoing project proposals, a rural meeting of the Government agencies, County officials and interested farmers was held in Warner on November 4, 1981. Just prior to this meeting, farmers of the County of Warner formed an Alkali Association, later renamed the Dryland Salinity Control Association (DSCA) with a total membership of 112 by October 26, 1981. Representatives of this Association requested technical and/or financial assistance from all levels of Governments participating in the November 4 meetings.

In response to farmers requests an Inter-Agency Technical Advisory Group was formed to (a) coordinate the technical assistance provided to each farmer and group of farmers regarding the prevention or reclamation of dryland saline seeps (b) to discuss and

2



INDEX MAP

Scale in Miles

50 0 50 100

LEGEND

Area of study

Towns

Rivers

DESIGNED	SUBMITTED	Government of Canada / Regional Economic Expansion	Gouvernement du Canada / Expansion Économique Régionale	WARNER COUNTY — SALINITY STUDY
DRAWN	DATE			LOCATION MAP
CHECKED	APPROVED			

resolve special technical and operational problems with regard to equipment, soils, hydrology, cropping, rotations, etc.
(c) exchange general technical and operational information
(d) standardize procedures and recommendations amongst the various teams. Participants of the Inter-Agency Group include PFRA, Alberta Agriculture, Alberta Environment and Agriculture Canada - Research Branch.

The active players of field investigation and advisory service include:

1. District Agriculturalists - promote the program, receive the application, screen and priorize the applications as per specific guidelines, visit the affected area with the farmer and complete the application by entering into an agreement (see Appendix A) with the farmer (termed Cooperator). The District Agriculturalists orders aerial photographs of the saline seep and its associated suspected recharge area to be used by the participants.

2. Investigative Teams - Currently there are three teams in the County of Warner, one each from Alberta Agriculture, Alberta Environment and PFRA. Each team consists of a drill operator, a drill helper, a technologist and a professional (leader). The teams develop an investigative plan, carry out the field investigations, install a groundwater monitoring network and outline recharge areas.

   Investigation team leaders collect water level data, soil and groundwater information, chemical analysis, hydraulic conductivity measurements, elevations, etc. Within a few weeks they prepare a report outlining the main problem recharge areas (on overlays of 6 x 6 inch aerial photographs) and indicate crop types, and varieties, planting and management procedures. The crop plans are discussed with the farmer, and in the presence of the affected neighbours, the D.A. and a DSCA executive member, if needed. The farmer and his neighbours are persuaded to accept all or most of the recommendations. Copies of the crop plan are distributed to the farmers, the D.A. and Crop/Soil Specialist.

3. Crop/Soil Specialist - prepares and presents a cropping plan, obtains groundwater, precipitation and crop yield data from the farmer, analyzes it, and together with the farmer prepares and discusses each year another crop plan. He attempts to persuade the farmer to follow as many of the recommended controls as possible. He visits the farmer during the summer, assesses the crop and prepares new crop plan for the following year advising on chemical applications, economics, crop varieties, etc.

4. Farmers - will assist with drilling, surveying and monitoring and implement all or a large portion of the recommendations. He will be responsible for the protection of instrumentation on his field.

   The farmer also measures groundwater levels and rates of precipitation. This is done once a month, except between April 1 and June 30, when measurements are made every two weeks. The data is sent to the Crop/Soil Specialist on self-addressed post cards.

Technical problems (e.g. soil and groundwater interpretations, equipment etc.) are discussed at the Coordinating Committee meetings. The Committee meets each month and Members report on the progress of their assigned activity. Progress Report twice a year by the Chairman and distributed to the cooperating agencies.

All available data will be compiled, computerized and analyzed in order to determine effects of the controls on the salinity and water level of the region.

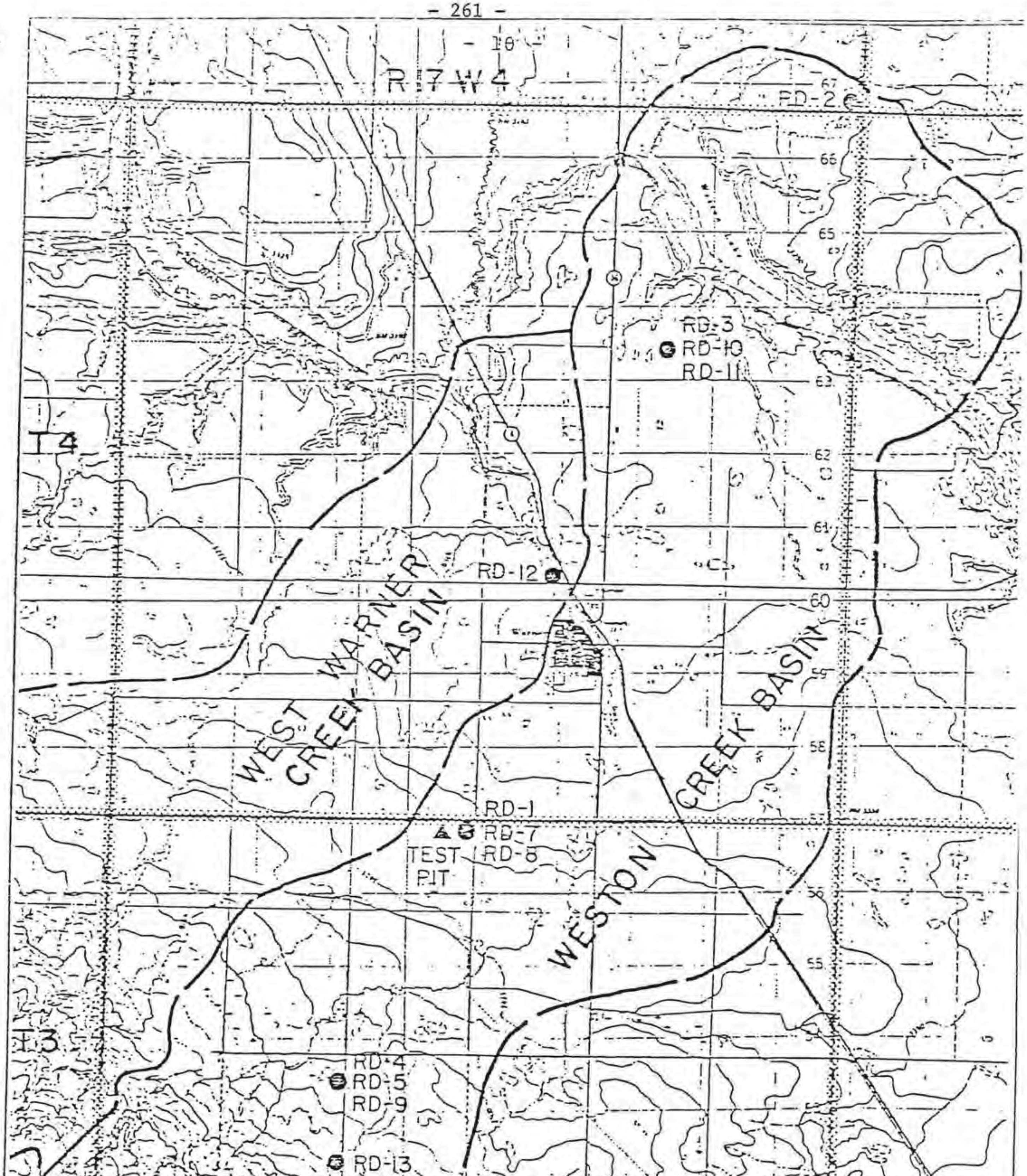
3.2 Geohydrological Special Study Area

During the early phase of this project PFRA undertook a detailed hydrogeological study during 1982 in a selected portion of the County. This study area covers about 14 500 hectares located in the central portion of Warner County (Figure 3). It has its back up against the Milk River Ridge and extends northeastwardly to just beyond Weston Lake in the Verdegris Coulee, the latter a glacial meltwater channel carved about 40-45 m below the surrounding prairie level. The area is covered by ground moraine, lake deposits, alluvium, and on the ridge, shallow till on rock. Till depths vary from 5 to 30 m.

The Milk River Ridge rises to an elevation of 1220 m above sea level, and 91 to 122 m above prairie level. The flanks of the Milk River Ridge are cut by numerous draws and gullies which open onto prairie level. The drainage pattern is generally northeastward off the Milk River Ridge to Verdigris Coulee, which in turn drains into the Milk River. There are several seasonal sloughs located within the study area, some of which have been dammed by landowners to provide reliable storage and stable water source.

The elevation has given rise to differences resulting in thin black soils on top of the ridge to the west of the area and the dark brown-brown transition crossing the area north-south.

The greater part of the area has a semi-arid continental climate, having an average annual precipitation of between 33 and 40 cm of which the greater percentage falls between May and July. The July mean temperature is 20^{o} while the January mean temperature is - 11^{o} C, reflecting the influence of warming chinooks. The frost free period is from 110 to 120 days.



DESIGNED J.O	SUBMITTED	Government of Canada / Gouvernement du Canada	WARNER COUNTY – SALINITY STUDY
DRAWN W.L.Z.	DATE	Regional Economic Expansion / Expansion Economique Regionale	WARNER COUNTY STUDY AREA TESTHOLE LOCATIONS
CHECKED	APPROVED		

3.3 Geology and Stratigraphy

Prairie level and flanks of the Milk River Ridge have been glaciated depositing a mantle of glaciated drift, primarily till, of varying thickness directly above the bedrock surface (Figure 4).

Five geologic units significant to this investigation underlie the study area. From youngest to oldest these are:

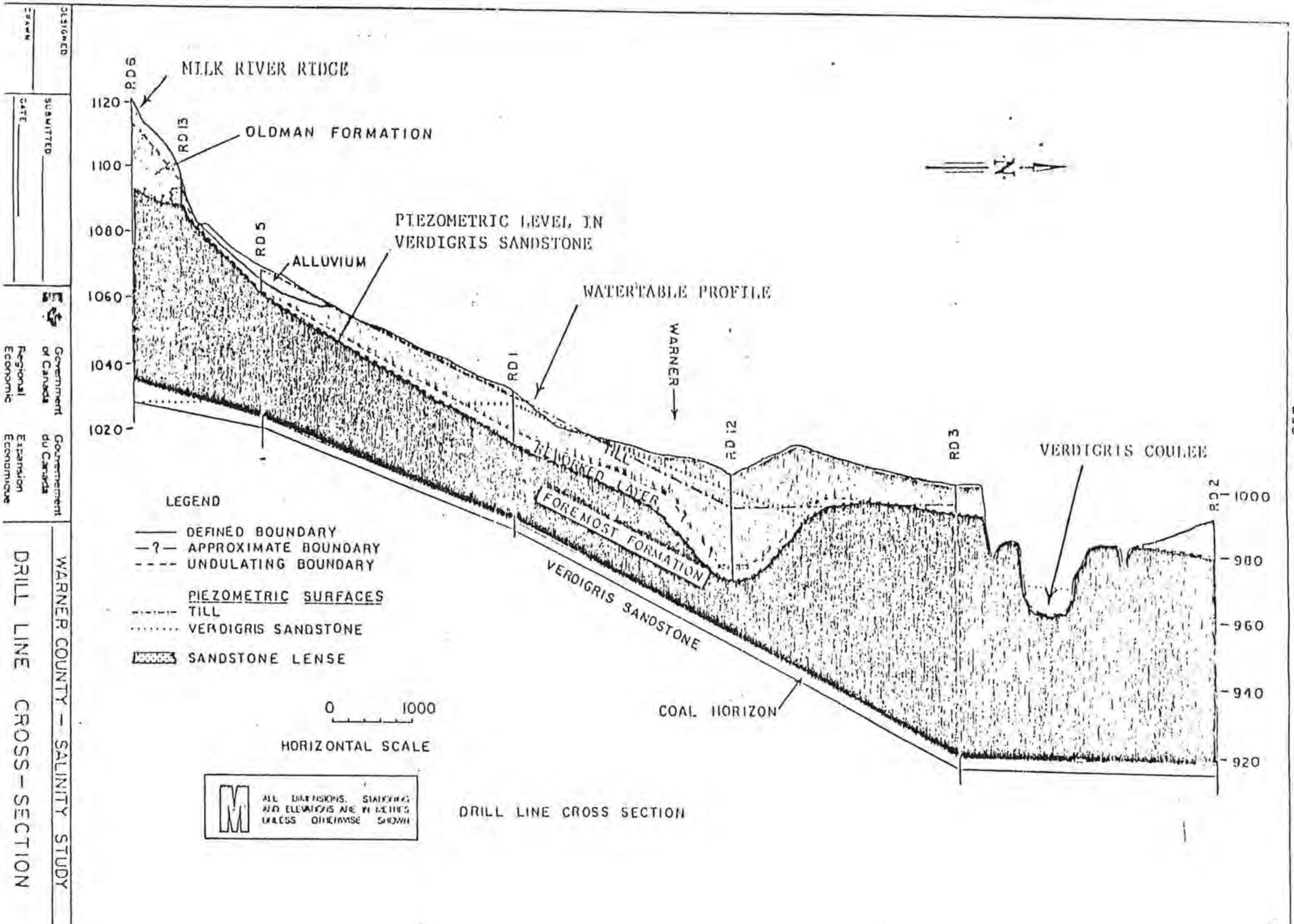
- Surficial soil deposit
- Till
- Reworked layer
- Oldman formation
- Foremost formation

These units are shown on the drill line cross-section, Figure 4.

Based on the data of 13 test-holes (totalling 538 m) and 13 piezometers, it appears that the Milk River Ridge constitutes the recharge area and maintains a relatively high water table at prairie level where the salinity problem occurs. The Foremost formation, comprised of dense, low permeability shales, basically acts as an aquitard preventing downward movement of surface waters into lower aquifers, and as a consequence, the reworked layer provides the best hydraulic route for water to migrate in a horizontal direction northeastward from the Milk River Ridge. In conjunction with this flow, the till imparts a vertical flow component along the vertical jointing and allows water to move to the surface by means of hydrostatic rise and capillary rise. The swell-and-swale topography results in increased groundwater discharge in the low areas. Finally, the net moisture deficit of the region results in salt concentrations at the surface due to evaporation.

3.4 On-Farm Soil Investigations

PFRA has, so far, covered some 3300 hectares and put in 251 wells on some 20 farms. Recommended cropping strategies have been initiated for eight of these farms. About 16 percent of the area serviced is saline.



MILK RIVER RIDGE
OLDMAN FORMATION
PIEZOMETRIC LEVEL IN VERDIGRIS SANDSTONE
ALLUVIUM
WATERTABLE PROFILE
WARNER
VERDIGRIS COULEE
TILL
WEATHERED LAYER
FOREMOST FORMATION
VERDIGRIS SANDSTONE
COAL HORIZON
RD 6
RD 13
RD 5
RD 1
RD 12
RD 3
RD 2
N
1120
1100
1080
1060
1040
1020
1000
980
960
940
920
LEGEND
DEFINED BOUNDARY
—?— APPROXIMATE BOUNDARY
UNDULATING BOUNDARY
PIEZOMETRIC SURFACES
TILL
VERDIGRIS SANDSTONE
SANDSTONE LENSE
0 1000
HORIZONTAL SCALE
ALL DIMENSIONS, STATIONING AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE SHOWN
DRILL LINE CROSS SECTION
DESIGNED
DRAWN
SUBMITTED
DATE
Government of Canada
Gouvernement du Canada
Regional Economic Expansion
Expansion Économique Régionale
WARNER COUNTY — SALINITY STUDY
DRILL LINE CROSS-SECTION

A combination of tools are used in seep investigation--air photos, EM31 and to a lesser extent, the EM38, earth auger, groundwater observation wells, topographic maps, survey levels, soil and water analysis, field observation, and judicious guess-work.

The air photos available are stereo coverage of various dates from 1939 to 1979 and at a scale from the 1:80,000 1970 lift photos to 1979 color photos at a scale of 1:10,000's. They are an excellent base on which to see detail and confirm present findings.

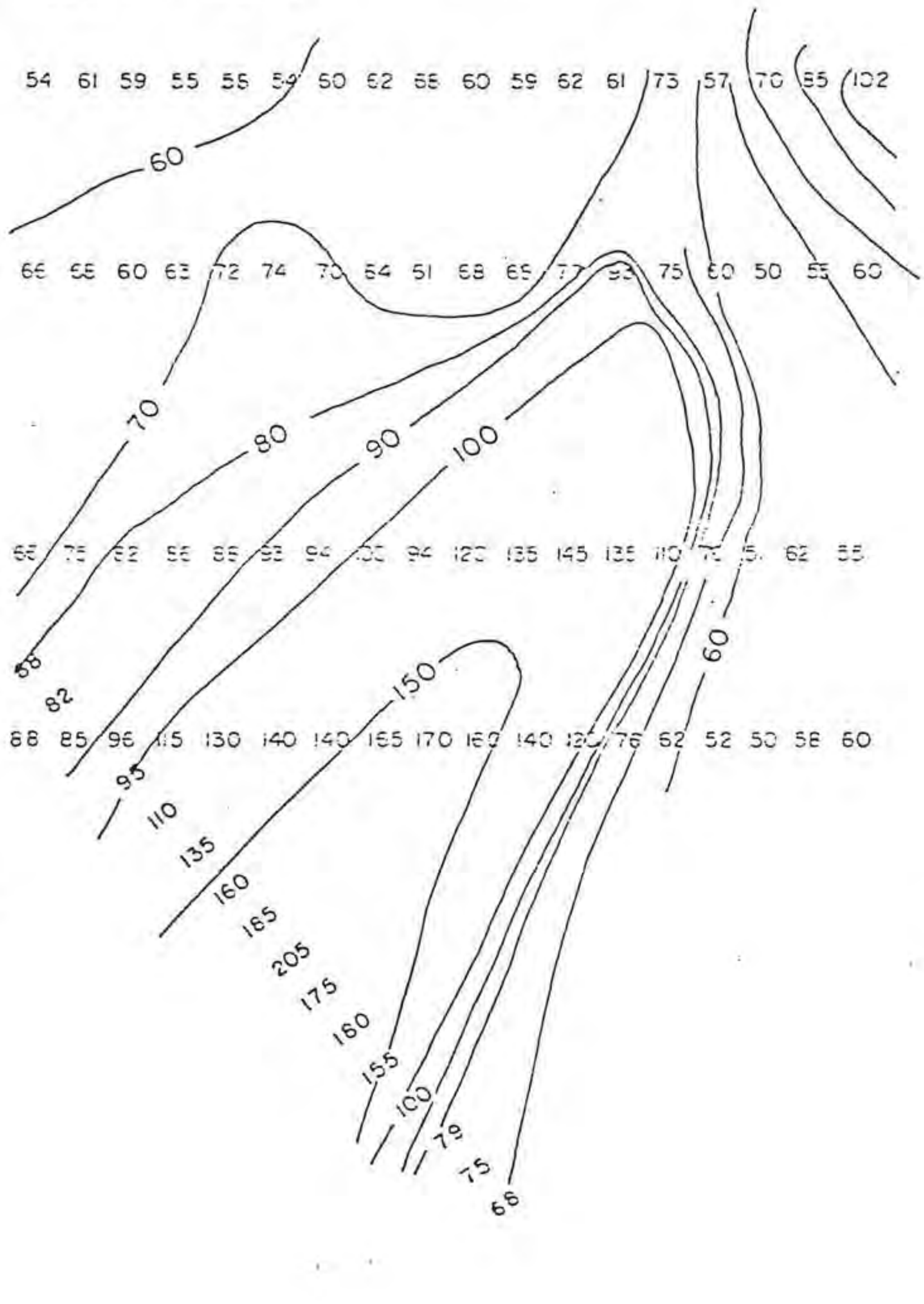
With the EM31, 6 to 8 traverses are made through each section with additional or side traverses made through areas of interest. Meter readings are taken at every 30 meters along the traverse and plotted on film overlays on the 1:10,000 photos. The boundaries of the saline areas are extended through photo interpretations.

Figure 5 illustrates lines drawn of approximate equal meter reading for a seep on Sec. 5-4-16-W4. A cross-section through the seep with the EM31 and EM38 show a more gradual build up of salinity on the high side and this is presumed to also indicate the direction from which the groundwater is moving.

Drilling is conducted in and around the seep to determine if the cause is readily apparent. Observations are made on the kind of surficial deposit, depth of rock, texture, and moisture conditions. Soil samples are taken for chemical analysis. Groundwater wells have been installed at most drilling sites, groundwater levels recorded at about monthly intervals, and water sampled for analysis. Figures 6 and 7 illustrate two varying degrees of salinization in the County as determined by results of the foregoing procedures.

Figure 5

EM 31 READINGS FOR PART OF SEEP
SEC. 5-4-16-W4



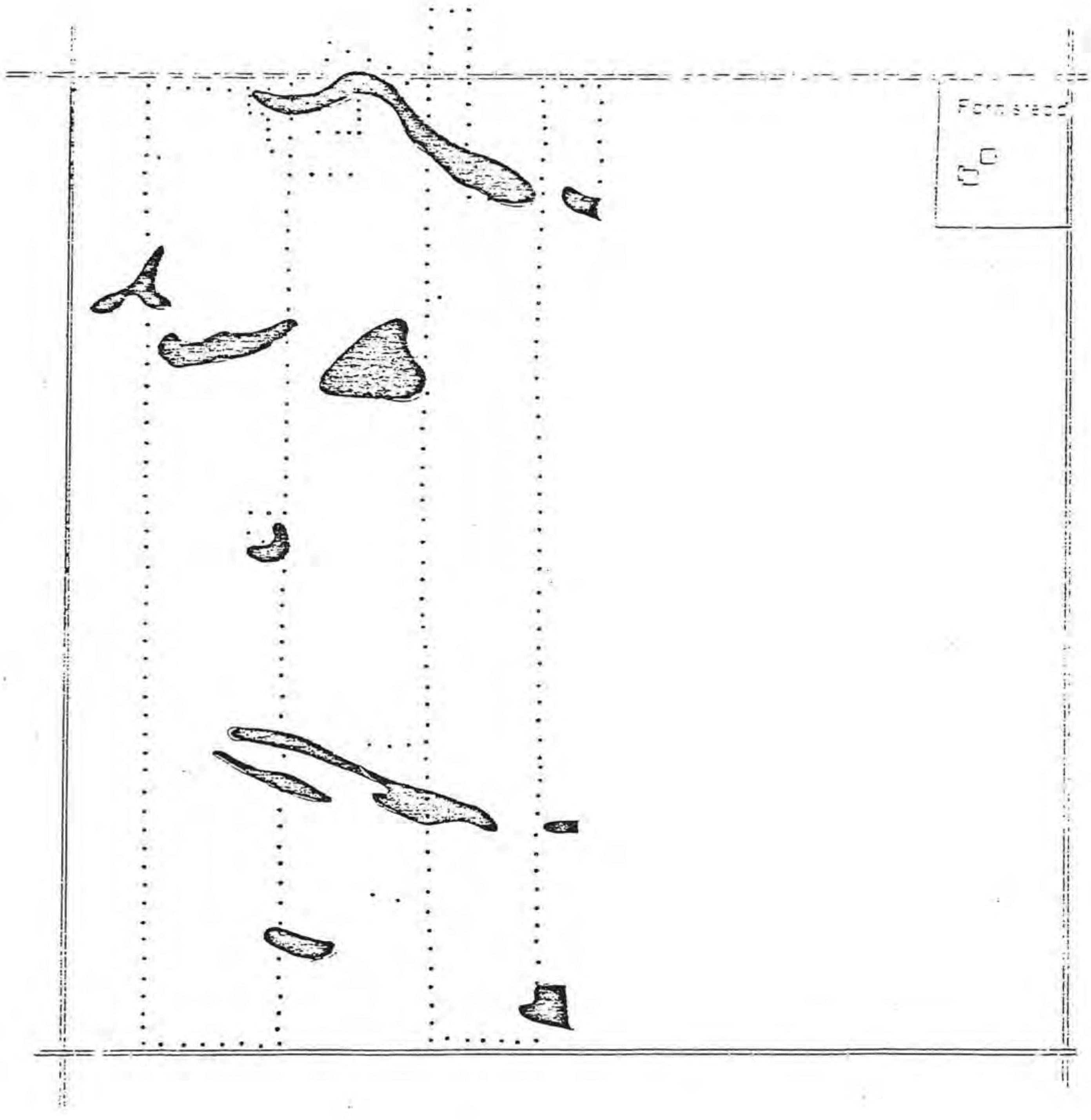


FIGURE 6: Vic Pittman W 1/2 5-4-17-W4

.... — EM reading sites

— Areas of EM31 readings over 100

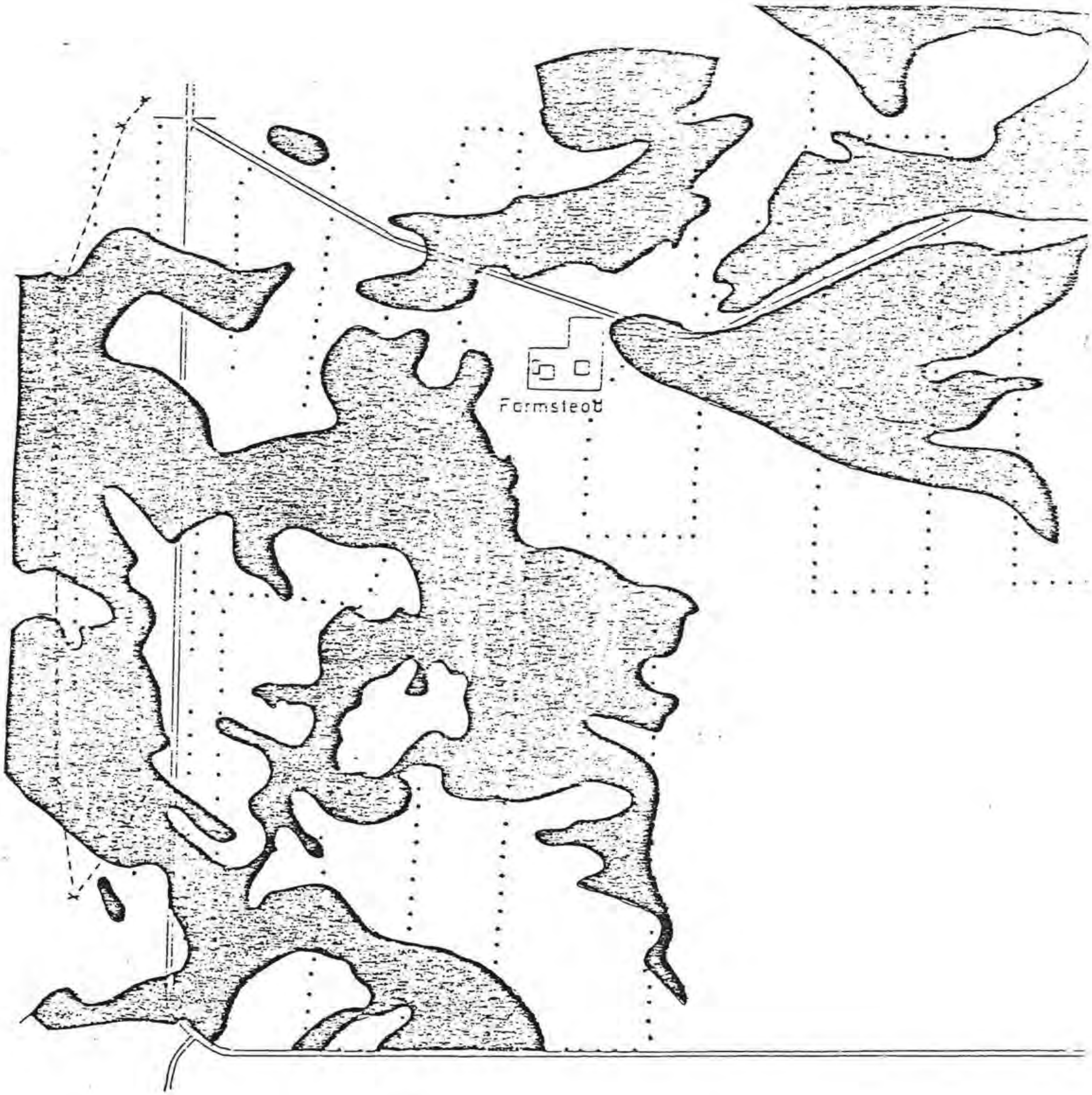


FIGURE 7: Bruce Atkins Sec. 1 - 4 - 18 - W4

• • • • — EM reading site

— Areas of EM31 readings over 100

× Location of Wells ×------× Transect Locations

3.5 Remedial Programs

Remedial measures employing intensive or flexible cropping together with periodic use of deep rooted legume crops have been successfully used in salinity control in Montana some 150 km to the south of Warner County. A typical example of salinity in that region in 1969 and the original cropping practices is shown in Figure 8.

In 1971, 32 ha of Ladak 65 alfalfa was seeded on the northern half of the site. The alfalfa was left in for 5 years (1971-1975), and since then the fields were cropped annually, rotating barley and winter wheat. The changes brought about during the period of 1971 to 1979 are illustrated in Figure 9 and can be summarized as follows:

a) During the period 1971 to 1975, water levels had dropped an average of 2.9 m in the discharge areas and 2.0 m in the recharge area, indicating that alfalfa used all current precipitation as it fell and dried out the deep subsoil as well.

b) In 1976, soil samples showed that alfalfa roots had penetrated to 4.6 m and had extracted 480 mm of water from the soil.

c) Once water levels dropped in the discharge area, the surface salts were leached back down, reducing the soil salinity in the upper 0.6 m of soil by 70 percent.

d) The size of the saline seep was reduced from 12 ha to less than 0.4 ha. During the same period, seep area on the south half increased in size (non-treated).

e) In 1976 and 1977, barley and winter wheat seeded into the discharge area yielded 70 percent of normal, and by 1979 yielded 100 percent of normal.

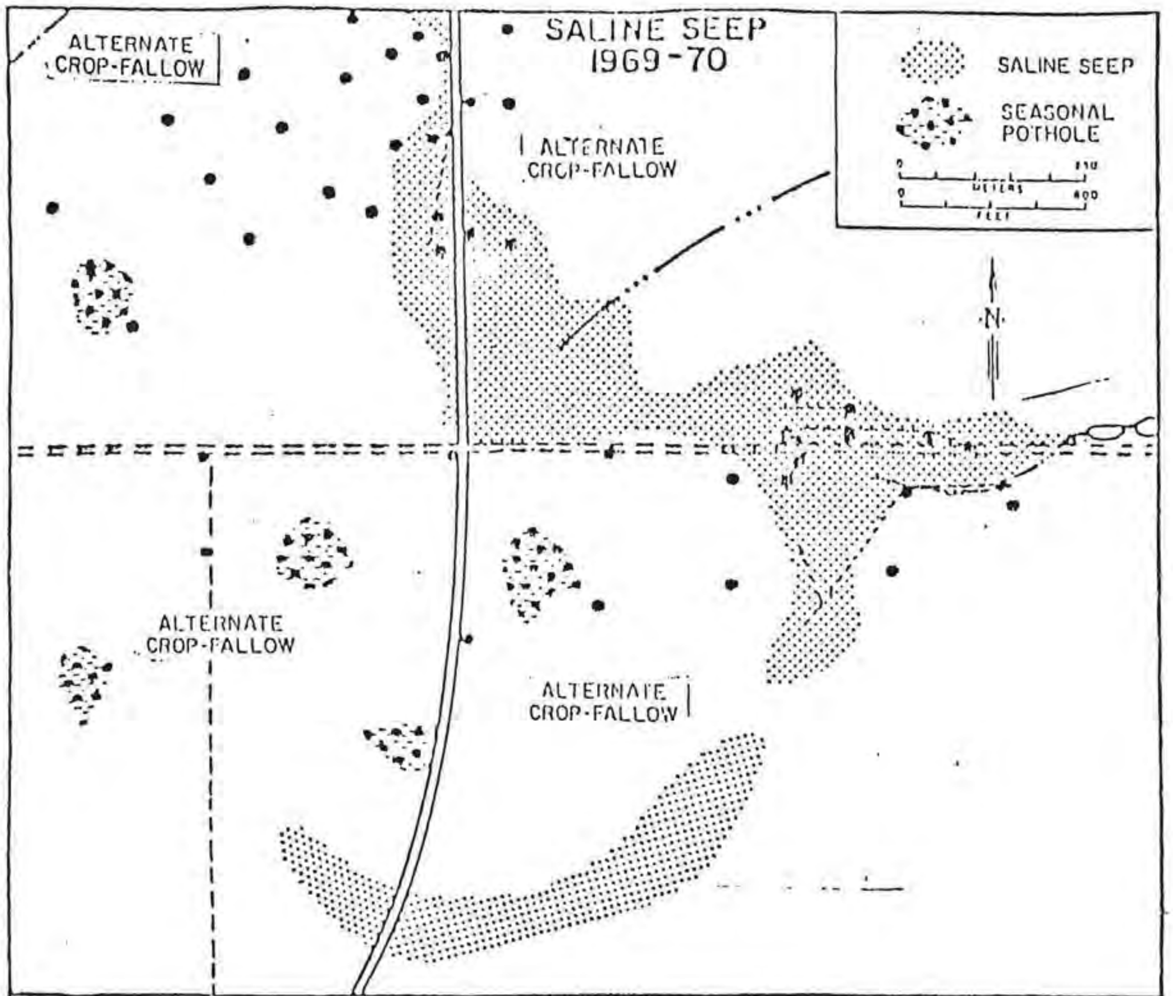


Figure 8

Distribution of saline seep on the Hanford-Bramlette test area 1969 to 1970.

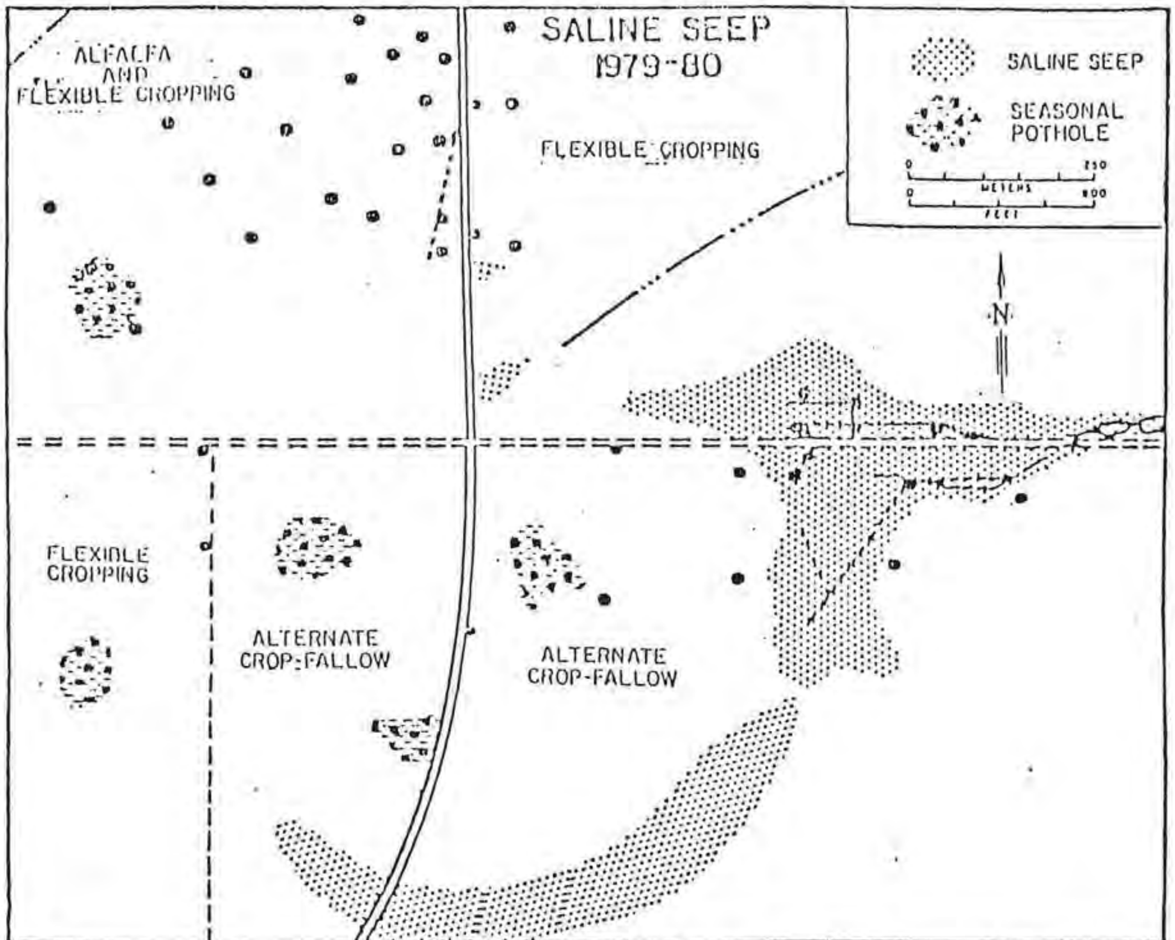


Figure 9

Distribution of saline seep on the Hanford-Bramlette test area 1979 to 1980.

Because the hydrogeology of the Warner County area is very similar to that found in the Montana situation we are confident that these types of remedial measures can be applied with equal success in Warner County. As indicated earlier, specific on-farm recommendations are in the process of preparation and will be undertaken by a number of farmers in the 1984 cropping season. Data collection will be continued to evaluate the effectiveness of such measures.

4.0 WELLINGTON SOIL SALINITY PROJECT

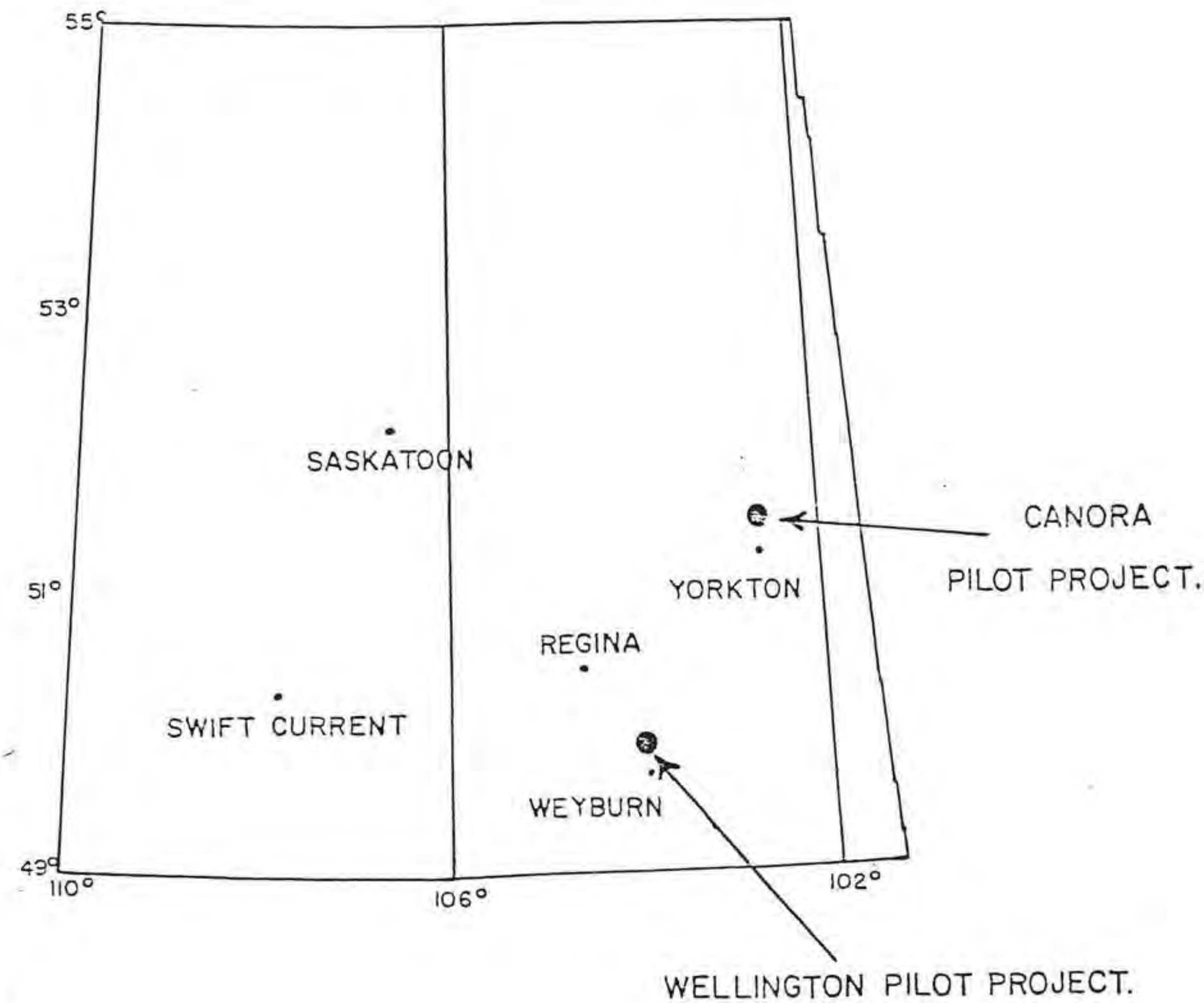
At the request of farmers in the Rural Municipality of Wellington, PFRA together with Saskatchewan Agriculture initiated a Pilot Project near Cedoux located about 25 km north of Weyburn, Saskatchewan (Figure 10). Soil salinity is presently affecting about 10,000 hectares of farmland in the Municipality. The study area is confined to Township 11, Range 14, W2nd. The area, according to a recently prepared map by A. Ballantyne, has a moderate to high risk of salinity. At present approximately 7 to 10 percent of the study area is affected by salinity with some individual quarters reaching 30 to 40 percent of the cultivated acreage. A comparison of 1958 and 1976 municipal assessment data indicate that the salt-affected area increased from 1804 ha in 1958 to 3234 ha in 1976, a 79 percent increase in 18 years.

The main soil types in the project area include Estevan (Es), Hanley (Hy) and Tuxford (Tu) Associations and a combination of these. They are classified as Dark Brown Solonetzic soils and are developed on clay loam to silty clay textured resorted till (Es) and lacustrine deposits (Hy and Tu). They have thin A horizons and tough B horizons and occur on level to undulating lands.

Results of drilling done by PFRA (about 58 observation wells were installed during last spring), along with the findings from laboratory analysis and EM31 survey of selected sites indicate

FIGURE:10.

LOCATION OF PILOT PROJECTS IN SASKATCHEWAN.



that soils in the area investigated contain large amounts of soluble salts and have solonetzic features. They are underlain by a thick and almost impermeable shale at a depth of about 2½ to 3 meters. Typical results from laboratory analysis for two sites are shown in Table 1.

The major finding of the study is that high amounts of predominant sodium sulfate salts are almost uniformly distributed in the soils of the entire area and there are no definite recharge/discharge sites like the situation prevalent in the saline areas of the Warner County. PFRA will be drilling on few selected sites in the adjacent Community Pasture in order to confirm whether or not the salt distribution and geological conditions are, in fact, similar to the ones in the present study area. This extended investigation will also help us understand the impact of land use on salt distribution. After having completed this investigation the recommendations will then be worked out.

5.0 CANORA SOIL EROSION PILOT PROJECT

PFRA has been approached by Saskatchewan Agriculture in the Canora area for help in a project to combat wind erosion and land use problems in the Tadmore-Crystal Lake area north of Canora (Figure 10). The proposed project area consists of some 25 000 ha of sandy soils astride the Assiniboine River which have been chronically plagued by wind erosion.

The Tree Nursery Section of PFRA is currently planning shelterbelts on 23 farms in the area and will assist in their establishment. The Soil Conservation Planning Unit has conducted a preliminary survey of the area in order to map problem soils and will assist in developing an action plan for the area.

It is proposed that Saskatchewan Agriculture will conduct a demonstration program through FarmLab to encourage the

TABLE 1: SOIL CHARACTERISTICS IN THE WELLINGTON SOIL SALINITY PROJECT AREA

Sample	Depth (cm)	Texture	pH	EC mmhos/cm	Water Soluble Ions (PPM) NA	CA	MG	SAR
				SITE 1				
BB-3	0-20	SiL	6.3	1.7	340	52	24	9.8
	20-40	SiL	7.2	4.3	820	148	92	13.0
	40-80	SiL	8.2	10.9	2220	480	360	18.7
	80-120	VFSL	8.5	10.0	2100	400	276	19.8
	120-160	VFSL	8.7	13.3	2100	208	356	20.5
	160-170	VSFL	8.7	13.2	3200	188	328	32.6
	170-200	VFSL	8.7	16.5	4500	260	480	38.2
	200-220	G & L	8.8	16.1	4400	340	440	37.1
	220-260	SiC	8.1	12.8	3100	480	360	26.1
	280-320	Shale	6.3	8.9	1780	400	252	17.2
	320-370	Shale	5.5	8.1	1570	348	204	16.5
	370-430	Shale	5.5	9.1	1720	360	268	16.7
				SITE 4				
SM-4	0-25	L	7.4	1.7	97	260	56	1.4
	25-40	CL	7.4	10.4	1780	680	560	12.2
	40-80	CL	8.6	13.4	2700	600	760	17.3
	80-120	CL	8.5	11.5	2230	600	560	15.7
	120-170	CL	8.3	12.5	2480	640	560	17.3
	220-280	CL	8.2	11.6	2330	560	480	17.5
	280-320	CL	8.1	13.0	2800	600	560	19.8
	320-360	Shale	7.4	10.9	2180	600	440	16.5.
	360-400	Shale	5.9	10.6	2100	520	400	16.8
	400-440	Shale	5.6	11.4	2260	560	440	17.4
	440-480	Shale	6.0	11.0	2170	600	400	16.8
	480-520	Shale	5.8	11.1	2180	600	400	16.9
	520-560	Shale	4.9	10.5	2080	560	360	16.9
	560-600	Shale	4.5	9.6	1930	440	280	17.7

adoption of soil conservation practices and that the Soil Conservation Planning Unit will coordinate with Saskatchewan Agriculture and the Tree Nursery to develop soil conservation plans for co-operating farmers.

APPENDIX A

AGRO SALINITY ASSOCIATION

AGREEMENT

This Agreement is made and entered into this _________ day of _______________, 19___, between the Agro Salinity Association, hereinafter referred to as Association, and ____ hereinafter referred to as Cooperator, and Cooperating Government Agencies hereinafter referred to as Agencies. This agreement applies to the following described land _____, _____, _____, _____ ¼ Sec. _____ Tp _____ Rg _____ W _____, and will be in effect for the 5 years starting at the above date.

The parties to this Agreement, in consideration of the mutual covenants and stipulations set out herein agrees as follows:

Cooperator Agrees:

1. that I understand the purpose of the Association, its' objectives, and program.
2. to develop a saline seep control plan including those management and structural measures which might reclaim present saline seeps and prevent further outbreaks. To apply to the best of my ability the control plan agreed upon with the Association and maintain all structural and management measures put into effect on my land.
3. to provide proof of land and water rights to the Association and Agencies upon request and to furnish any easements, and access or egress as may be necessary to comply with the agreement; and secure all permits or documents of approval as necessary to apply those management and structural measures; to comply with all Federal, Provincial and local laws governing the discharge and beneficial use of water and water quality.
4. to inform the Association and Agencies, any person furnishing technical assistance to the Association and equipment operators of the location of any known buried pipelines or communication cables within the area included within this agreement.
5. to provide assistance in the field during investigations, soil sampling, equipment installation and with the monitoring of waterwells, piezo meters, and discharge flow recorders.
6. to pay for the watertable level measuring tube, aerial photographs, and the replacement of any observation wells. The latter will be left intact for the duration of this agreement, unless otherwise agreed upon with the teamleader.

Association and Agencies Agree:

1. to provide technical assistance and information regarding dryland saline seep control specific to the above parcel of land as may be available through the Association's program.

All Parties Agree:

1. that no party shall be liable for damage or injury on the others property while complying with the provisions of this Agreement, unless such damage results from negligence or misconduct.

2. that the Association and Agencies shall not be liable for any loss of income or production loss as a result of applying the saline seep control plan, unless such loss results from negligence or misconduct.

3. that, should any land included under this Agreement be sold, the Cooperator, new owner and operator, Association and Agencies will not be under any obligation to comply with the provisions of this Agreement relative to that land.

This Agreement shall become effective on the date above written and shall be automatically renewed from year to year, unless either party hereto shall give written notice to the other at least thirty (30) days prior to the date of intended termination or until that time when the District disbands, then this Agreement is null and void.

IN WITNESS WHERE OF, the parties hereto have signed their names on the day and year above written, and acknowledge to have read and understood the above.

Cooperator	Association	Agencies
Address	Address	Address
Date	Date	Date

Agencies

Address

Date

Agencies

Address

Date

SOIL INTERPRETATION FOR FORESTRY WORKING GROUP

Chairman's Report to ECSS
November 17, 1983
H. Krause

The Forestry Working Group was formed in 1980, and given the following mandate:

1. To develop guidelines for the interpretaion of soil information from surveys at various levels of intensity, and to publish them at the earliest feasible time;

2. To develop improved methods and criteria for conducting surveys and for evaulation of forest lands at various levels of intensity;

3. To determine the need for research projects in support of improved soil-forestry interpretations and to promote their undertaking by qualified scientists.

Its members have met three times in conjunction with the ECSS meetings. In the spring of 1981, in Ottawa, approaches to be taken were mapped out and soil evaluations deemed useful and feasible under Canadian conditions were identified. These included evaluations for (1) logging road construction, (2) off-road transportation or equipment limitations, (3) forest productivity, (4) species suitability, (5) forest regeneration, (6) potential for erosion and (7) windthrow hazard, (8) danger of frost action and (9) probability of flooding.

In the spring of 1982, at Victoria, B.C., the Working Group conducted a half-day session which was attended by approximately 50 persons, and held an evening meeting attended by members only. During these meetings, existing information was reviewed, tentative methods for some of the above evaluations were proposed, and problems relating to others were exposed.

The workshop of the last three days has allowed us to critically examine information and methods proposed so far by members of the Group, exchange information on a regional basis, and to identify present limitations. Following is a summary of progress by type of evaluation:

Logging road construction (Ken Webb, N.S. Soil Survey Unit). Soil factors relevant to the evaluation have been selected and suitability classes from good to unsuitable have been established. The proposed method was found acceptable and near completion.

Off-road transportation (Herb Rees, N.B. Soil Survey Unit). The proposal involves a similar approach as the previous one and was also judged acceptable and near completion.

Productivity (D.J. Pluth, University of Alberta, V. Timmer, University of Toronto and W. Carmean, Lakehead University). A proposal, accepted in principle, is based on the determination of site index (height of dominant trees in a stand at reference age), classification of mapping unit or individual according to site index curves and reporting of mean annual increments of wood for normal stands where yield tables are available.

Species suitability (Hugo Veldhuis, Manitoba Soil Survey Unit and Keith Jones, Ontario Soil Survey Unit). Soil and land factors important to describing the autecology of tree species were identified. However, since susceptibility to disease and insect pest, and economic value often impose overriding constraints, the Working Group could not agree on the validity of soil evaluation for species suitability at this time.

Forest regeneration(T.M. Ballard, University of British Columbia). Soil factors to be considered as Variables have been identified, but since it cannot be predicted how these interact in a given set of circumstances, a recommendation for a rational classification of mapping unit of individual with respect to limitations for forest regeneration has not yet been forthcoming. This is a subject for which research is urgently needed.

Erosion and mass movement of soil (Dave Moon, B.C. Soil Survey Unit). Appreciable work has been carried out in Coastal British Columbia. Criteria of evaluation have been tested with varying success. Additional research and verification is required if same criteria are to be used at other locations.

Windthrow, frost action and flooding hazards (W. Holland, Canadian Forestry Service, Alberta). Proposals for these evaluations were accepted in principle, but were found to require further attention from the author. Mechanisms of frost action, the difference between frost action and frost injury, and criteria of evaluation for flooding are points needing clarification.

It should be pointed out that information compiled under any one of the above headings was derived from many sources or generated within an area of limited extent. Any method proposed here must, therefore, be considered preliminary until tested and, where necessary, adapted to existing conditions within a region.

The importance of soil evaluations for different forestry purposes was reviewed on a regional basis. According to a limited survey of potential users and as perceived by the regional representatives, the need for silvicultural evaluations ranked among the top priorities of most lists. This was not unexpected as incentives for intensive forest management have recently been created in at least two provinces by new industry-government agreements. A need for productivity rating of soils was indicated by all provinces from which reports were received. Similarly, soil information for planning forest regeneration appeared in nearly all of the priority listings. Species suitability, a questionable concept in earlier discussions, was listed by all but one of the reporting provinces. Three of the provinces (Ontario, Alberta and British Columbia) included evaluations for trafficability (equipment limitations) and susceptibility of soils to damage in harvesting operations. Road location and projection of cost were listed by Nova Scotia and British Columbia. In the latter province, and presumably other mountainous regions too, soil evaluations for slope stability to parks, recreation, fisheries, and wildlife agencies.

The group felt that attempts to develop regional guidelines for forestry interpretations should be made at first by the federal soil survey units in cooperation with forestry agencies within their administrative districts, i.e., the provinces. Experience gained in the individual provinces may subsequently be combined to form guidelines for physiographically and ecologically distinct regions.

It is believed that the information generated by the Working Group to this date could effectively form the basis for a national document on soil evaluations for forestry. Taking into consideration present constraints, an outline has been prepared as follows:

Section I. Introduction
Reasons why forestry interpretations should be made; limitations.

Section II. Methodology
With emphasis on rational, principles and theory;
Standardization of terminology and classes where appropriate;
Scales, Validity, Methods of Verification;
Presentation of interpretive information (legends).

Section III. Regional Approaches
Examples, information gaps.

Section IV. Summary, Conclusions.

A principal part of this outline is Section II. It is to suggest criteria for the various evaluations and provide the theories upon which their choice is based. It is not supposed to be a compilation of ready-to-use methods, but to provide the interpreter with the information necessary to choose or modify existing methods for application in his region. It will further aim to standardize terminology and interpretive classes to a degree permitted by the diverse regional conditions and needs. The need for tests of validity will be emphasized and methods of verification will be described.

Information to be contained in Section III is of equal importance. It is intended to be a listing of well documented examples of evaluations, with some degree of verification, from different parts of the country. Examples from one region are offered for testing and adaptation in other regions. As the number of such case studies grows, the knowledge necessary for establishing regional guidelines will be gained.

The major sections are to be composed of individual contributions from members of the Working Group. Contributing authors are to be identified. To assure continuity in text, format specification are to be made available to contributors.

The proposed outline signifies a cautious approach to soil interpretations for forestry. The Working Group expects that difficulties will be encountered when such interpretations are made today. These difficulties are due to gaps in basic and local information on soil forest growth interrelationships, and to the fact that most soil surveys in forested areas have been carried out at intermediate and low levels of intensity. Projects reviewed during this workshop have indicated that surveys must be conducted at the highest level of intensity and maps produced at scales $\geq$ 1:20,000 if the information is to be applied at the operational level. Soil surveys at intermediate and low levels of intensity and interpretive maps at scales < 1:20,000 are seen to be useful in regional planning and will also provide useful information for planning of special surveys on forest lands and interpretation of the results.

The Working Group submits the above outline of a manual on soil evaluations for forestry for approval by the ECSS and recommends that arrangements be made by the Land Resource Research Institute for the effective production of this manual.

It is further recommended that the Forestry Working Group cease to be a high-priority Working Group, but remain in existence to deal with questions relating to parts 2 and 3 of its original mandate[1] and to provide guidance for periodic revision of the manual.

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1. See next page

SOIL INTERPRETATION FOR FORESTRY WORKING GROUP

Mandate 1980	Degree of Accomplishment 83/11/17	Action Required
1. To develop guidelines for the interpretation of soil information from surveys at various levels of intensity and to publish them at the earliest feasible time.	Information has been compiled for a manual which is to relate principles and theories of forestry interpretations, describe general methods and offer examples for regional verification.	Obtain final copies from contributors (members of Working Group) following standard format; follow through review process, go to press.
2. To develop improved methods and criteria for conducting surveys and for evaluation of forest lands at various levels of intensity.	Some work in forest land classification and survey was reviewed in connection with part 1 of the mandate.	Compilation and critical evaluation of methods of forest land evaluation in Canada and other areas of interest. Specification of criteria for classification and methods of survey based upon above review and information in the manual.
3. To determine the need for research projects in support of improved soil-forestry interpretations and to promote their undertaking by qualified scientists.	Information gaps relating to the interrelationship between soil factors and forest growth, and to the response of soil and forest vegetation to management were disclosed in work on part 1 of the mandate.	Establish a priority list of research projects for consideration by CFS, Faculties of Forestry at Canadian Universities and other institutions.

ECSS WORK GROUP ON SOIL DEGRADATION

REPORT OF PROGRESS SINCE APRIL, 1982

The first meetings of the Work Group on Soil Degradation, held in Victoria in April, 1982, outlined an approach to the identification and inventory of soil degradation problems across Canada. This approach consisted of two main areas of concentration; i) preparation of small scale maps to indicate the extent and severity of different soil degradation problems ("National Level"); and ii) the incorporation of degradation measurements and interpretations with routine soil survey work ("Regional Level"). Individual members of the Work group (see Appendix A) agreed to investigate a soil degradation problem and report on the minimum requirements for small scale mapping and for the identification of each in the field. From the contributions of W.G. members a set of preliminary criteria and procedures was prepared and circulated prior to the 1983 field season (Appendix B). At the same time, plans were made for a three-day workshop to preceed the November 1983 ECSS meeting. It was anticipated that work group members' experience with the identification of degradation problems would form the basis of the workshop, supplemented by a small number of special presentations.

The Workshop was held in Ottawa on November 14, 15 and 16, 1983. Each Work Group member associated with a specific topic was the chairman and discussion leader for the session dealing with that topic. Invited speakers were: Dr. Mel Webber, Environment Canada, Burlington, Ontario; Dr. Eeltje DeJong, University of Saskatchewan; and Dr. Bill McGill, University of Alberta.

The following is a brief summary of the Workshop:

Salinity (Bob Eilers, chairman):

Activities related to this problem since the last meeting included the preparation of a preliminary map of salinity in Manitoba based on the 1:1 million soil landscapes map. Identification of four levels of salinity with 3 degrees of coverage and 7 types of occurrence was based on field experience and available soil survey data. Classes and criteria were established in consultation with specialists in the other affected provinces, but they are not yet used outside Manitoba. Areas in Manitoba identified as "salt-affected" have also been the subject of a more detailed salt survey mapped at 1:50,000. The Manitoba Department of Agriculture has established bench-mark test plots to be monitored for at least 5 years.

In Alberta there are several institutions and about 15 professional person years working on the problem. The soil survey provided the initial salinity map for the PFRA Warner County Project, based on salt at the soil surface. Salinity is considered by many to be the most serious soil degradation problem in the province. Some form of permanent monitoring network is needed, together with a standardized system of classification and severity rating. No province wide mapping has yet been undertaken, but some remote sensing work for this purpose has been initiated.

In Saskatchewan a map has been prepared of the southern part of the agricultural area which presents an estimate of both the present extent of salinity and the risk of further salinization. The routine survey program includes plotting groundwater flow patterns to estimate changes in salinity. A mapping methodology is being developed. Some monitoring activities are underway. Others in the province are studying the causes of salinization, critical levels, classification systems, crop tolerance and agronomic practices to cope with the problem.

For small scale mapping (1:1 million), a map comparable to that prepared in Manitoba could also be done in Alberta, using the Soil Landscapes map as a base. The Saskatchewan approach is different, and might not be readily modified to conform with the Manitoba classification. Alterations to the Manitoba legend might be considered to accommodate some of the saline seep conditions mapped in Saskatchewan.

Data needs for salinity interpretations include standardization of sampling (depth, frequency); analyses (1:1 moisture or saturated paste; EM 38 readings); classification (possibly to include salinity between 2 and 3 mS/cm to which some "special" crops are sensitive); interpretation; mapping (e.g. degree of severity); and data processing. Soil test lab data should also be examined.

Contaminated soils (John MacMillan, chairman):

The problem of soils contaminated by atmospheric deposition downwind of a smelter in New Brunswick was described. A survey has just been completed to assess the soil content of a range of trace elements. No pattern was established relative to the smelter, but levels of some heavy metals over recommended limits (Ontario criteria) were found in some areas. Factors involved may include fallout from a thermal generating station, top-killers used in potato fields, lead from vehicle exhausts, and dust from uncovered ore trains.

Mel Webber (Environment Canada) presented the results of three studies in southern Ontario related to sewage sludge disposal and agricultural practices. Crop uptake of heavy metals and PCB's from sewage sludge was only slightly increased even where soil limits for concentration were exceeded. Only some leafy vegetables take up enough metals to be of concern. Past use of pesticides in orchards and top-killers on potatoes had contributed to elevated levels of Pb, Cu and As, with levels in clays and organic soils higher than those in sands. In a third study, samples were collected on a grid pattern throughout Halton county. Not much difference was found between soils treated with sewage sludge and those never treated. Very high levels of Pb and Zn were subsequently associated with a particular soil series, and were evidently natural in origin. Nevertheless, they were over Ontario limits, and therefore would be considered unsuitable for sludge disposal.

A review of provincial activities suggested that only in Manitoba and Alberta were any other studies being done. Soil analyses are supposed to be done in Ontario before any sewage sludge is spread, but it was believed that this was not always the case. Wide-area sampling and multi-element analyses for trace elements mapping was considered desirable for suitability ratings for sludge disposal and for those doing epidemiological studies. However, this approach was not believed to be acceptably practical. Atmospheric monitoring might be more cost-effective in some areas.

Acidification (Co-chairmen Harold Rostad and Herb Rees)

There are two eastern Canada maps currently available - one of agricultural areas only at 1:5 million, and a more recent 1:1 million map of all eastern Canada prepared for the Canada-U.S. Acid Rain Impact Assessment. The criteria for these acidification risk maps were considered suitable for either acid rain or fertilizer induced acidification. These assessments could be done in routine soil surveys since data requirements (i.e. organic matter, pH, texture, CEC) were usually met.

In Western Canada a committee is in the process of preparing maps at a scale of 1:2 million for all four provinces. Criteria and input data will be very similar to those used in Eastern Canada. In the agricultural area of the Prairie Provinces the 1:1 million soil landscape map will be used as a base map.

In both east and west Canada, maps will only indicate acidification risk, and no attempt will be made to amp past acidification. Research needs include: the separation of anthropogenic from natural acidification; impact of acidification on soil biota; relationships between forest productivity and acidification; long-term monitoring sites; future lime requirements; and availability of toxic minor elements.

Wind and Water Erosion (Co-chairmen - Glen Padbury and Greg Wall)

Eltje DeJong presented a review of his research on soil ^{137}Cs concentrations. He has measured erosion over the last 20-25 years at upper, middle and lower slope positions with success, and is currently working in 2 monitored basins to relate soil loss to landscape features. He plans to look at soil productivity effects of erosion, but cannot separate wind from water erosion. Greg Wall described various levels of soil erosion prediction used in Ontario by different agencies, and his research on erodibility variability using a portable field rainfall simulator. The 18 plots of Laurens van Vliet in the Peace river Region were described along with his small scale mapping of soil erodibility and potential erosion in this region.

A brief review of provincial activities showed that in each province (except Newfoundland) there is some sort of erosion monitoring or estimation study. Examples are:

B.C.	-	Lower Fraser Valley study by Ministry of Agriculture.
Alta.	-	K factors are being added to soil data files
	-	Comparisons of potential with observed erosion in Warner County.
	-	Chanasyk's plots in Peace River Region.
Sask.	-	S.S. looking at length and slope factors in hummocky landforms for possible USLE use.
Man.	-	U. of M. study of crop yields after simulated soil loss
	-	Soil survey adding erodibility into soil survey.
Quebec	-	New study of soil loss at Lennoxville Research Station
	-	Quebec Environment Ministry working with SS to estimate erosion in Yamaska River basin.
N.B.	-	New runoff plots at Fredericton R.S. and in potato belt. Includes effect of erosion on yields
	-	K factors have been determined for main soils of potato belt.
N.S.	-	Some runoff plots and K values have been mapped.
P.E.I.	-	Status of erosion plots established some years ago is not clear.

Awareness is a real problem in most provinces, so activities aimed at increasing farmer and public awareness of the problem are needed.

Coote described briefly the wind erosion risk maps prepared as input to the prairie soil landscapes map data base. The utility of a "risk" map was discussed and it was agreed that land use factors should be applied (from 1981 Census) to high risk areas to see if risk was actually likely. The inability of a risk map of this type to take account of coincidence of winter freeze-dried soil, lack of snow cover and high winds was discussed, more climatic data probability analysis is required to find locations of high risk areas under these conditions.

Wall described his mapping of predicted soil erosion at the 1:1,000,000 scale in Ontario, and the value of these maps in promoting awareness of the problem and directing focus on areas needing remedial practices. The utility of the approach was questioned for the Prairie Region since 85% of the runoff occurs in the spring in Saskatchewan and current estimates of snow melt factors were believed by many to be meaningless. This problem was identified as a high priority research requirement, but it was also proposed that the relative values of erosion potential (not absolute) were still valid, and that there were distinct advantages of maps of this type which are relatively quick and inexpensive to prepare.

For other regions (Quebec and Maritimes) there was agreement that such maps would be valuable, at least in some areas (e.g. southern part of N.B.) and that small scale soil maps are generally available except in Quebec.

For detailed mapping detailed climatic probability data are needed for each area, as well as cropping practice factors. Greg Wall gave a review of an Ontario project in which past erosion was carefully assessed from air photos and by ground truthing using horizonation, texture, colour, carbonates and site observations. Map polygons originally considered not to have significant erosion were found to contain as much as 30% eroded areas.

The relative merits of research using long-term field plots and small rainfall simulator studies were discussed with no concensus of opinion - there is evidently a place for both. Research needs relating to freeze-thaw cycles, spring runoff, extreme event analysis, effects of soil management on erodibilities (wind and water) and remote sensing were proposed.

Organic Matter Loss (Chairman - Gary Patterson)

Bill McGill made a presentation on his work with O.M. in Alberta. Questions requiring answers included:

1. How much change has occurred? - this presents a sampling and analysis problem.
2. When have changes occurred and why? - are changes due to decomposition or erosion?
3. When did the losses occur? - and will they continue?
4. WHat are critical levels? - for resistance to erosion, crop nutrition, soil moisture relationships, soil density? The system is dynamic and total values may not be important - just the active portion. If erosion is main factor, decline will continue - but maybe translocation by erosion is not a concern.

The most recent studies by Campbell et al. more or less confirm McGills' earlier estimates of 39-44% loss since cultivation. In a new project he has paired cultivated and uncultivated sites at 75 locations in Alberta. Data show that changes in OM concentrations are greater than changes in total mass, which can be seen in some cases to have increased under cultivation. They also exhibit great variability so that large differences are needed before they become significant.

Research needs include studies of loss mechanisms, carbon dating, OM dynamics, and mapping methodologies. Long term monitoring of changes are also needed.

Suggested Soil Survey related activities include the need for single variable overview maps. Concern for global carbon balances is leading people in other agencies (e.g. Environment Canada) to look at this type of mapping.

Discussion included: limitations of soil test lab data (agreement); applicabiity of ^{137}Cs methods (could be used); caution needed in using bulk density for calculation of mass of C; how much loss is from erosion (10% to 50% loss); relationships between structure and aeration and total or active portion of OM; Lethbridge study shows organic matter can be increased, this may be on isolated extreme cases; some loss of OM from virgin conditions is inevitable, but must it continue? Eastern Canada is not really concerned, fertility is mostly a fertilizer need anyway. Original OM was often low, after land cleaning. Structure relationships are still too unclear to make a case. Improved OM data collection in routine soil surveys was suggested as best way to keep track of changes. Old SS cannot be used as sampling sites were not chosen for this purpose. More paired sampling (cultivated vs uncultivated) is one approach to loss estimation. For present OM levels, can use existing soil maps and OM data.

Soil Compaction (Chairman - L. van Vliet)

Laurens van Vliet presented a review of soil compaction processes, recognizing this topic as probably one of the least understood, and identifying the concern as primarily man-induced problems - not natural inherited compact subsoils. It was defined as "a condition when water movement and root development are restricted as a result of man's activities".

Major causes were identified as 1) vehicular traffic; 2) field operations on wet soils; 3) disturbance during tillage; and 4) oxidation of OM. The chairman reviewed some data which have been gathered in Canada and the U.S. in terms of increases in BD (mainly) - one study used pore space. He also brought in the forestry problem, showing the large %-ages of land compacted during harvesting operations. He presented some of the results of Jan DeVries studies in the Lower Fraser Valley illustrating them with a "viscious cycle of compaction on wet soils", and an alternative brought about by drainage.

A proposal was presented for a routine survey approach to include a "compacted phase" on soil polygons of new survey maps down to a 1:40,000 scale. The chairman presented identification features of compacted soils and a list of alternative parameters which could be measured and most of which would normally be recorded in a detailed survey.

Discussion mostly centred on whether or not there were reasonably reliable parameters of soil compaction to be used. There was no agreement, but enough doubts were raised to make any approach at this time of questionable value. It was also suggested that compaction *per se* may not be a problem, it was more a symptom of other problems - drainage and organic matter loss for example. Research needs were clearly for the establishment of relationships between soil physical parameters (including visual estimates) and "compaction" and the determination of critical values. Work may then be needed on new instrumentation. The role of frost and soil management in reducing soil compaction was also in research need.

"Benchmark sites"

A number of suggestions were made including: specific sites in farmers fields operated cooperatively with other agencies; special sites at Research Stations; long-term rotation sites at R.S.; farms owned and leased out by universities or governments; met stations, etc. The pros and cons of these were discussed. It was concluded that there was real interest in this concept and that a subgroup of the Working Group should take a look at the alternatives before the next meeting.

RECOMMENDATIONS

The Work Group considered the need to make recommendations to the ECSS. These have been divided into four categories:

i - Recommendations for small scale mapping of soil degradation parameters, extent and severity (or risk where extent cannot be readily mapped).
ii - Recommendations for routine soil surveys.
iii - Recommendations for further soil degradation studies.
iv - Recommendations for benchmark sites for soil degradation

i) Recommendations for Small Scale Mapping:

First Priority: Water erosion maps. This problem is the most widespread involving all agricultural land in Canada to some degree. It is believed to be having the greatest impact, nationally, of all soil degradation processes. Maps of estimated water erosion can be prepared at a scale of 1:1 million (or similar) by applying the Universal Soil Loss Equation to each map polygon with representative values of slope, slope length, erodibility, rainfall and snowmelt factors, and incorporating current (1981) land use data from Statistics Canada with representative management factors. The maps provide an indication of the current probability of water erosion at different degrees of severity of any area for which small scale soil maps are available. Such maps have already been prepared for Ontario and are in preparation for the British Columbia Peace River Region. Small scale soil maps adaptable to this purpose are available in all regions except Québec. In Québec interest has been expressed in the use of larger scale maps with this approach. In the Prairie Provinces, factor values can be added to the extended legend of the Soil Landscapes map for processing.

Second Priority: Acidification (risk); Salinity; Wind Erosion. These soil problems have been placed in second priority because: a) acidification maps are either completed or scheduled for early completion; b) Salinity affects one region only and maps are already available for much of the area; and c) wind erosion risk maps are nearly completed for the area in which the problem is most severe. When land use factors have been compiled for water erosion assessment, they can be modified and applied to wind erosion risk to identify areas of high probability of wind erosion.

Third Priority: Organic matter levels and losses. This was placed in third priority because existing soil survey data can be applied in the Prairie Provinces to soil map polygons at 1:1 million to estimate current organic matter levels. Only in Alberta does a data base exist from which losses in O.M. since the beginning of cultivation can be assessed (and this data base does not belong to the soil survey). To provide a similar data base in Saskatchewan and Manitoba would be valuable, but was not given a high priority. Little value was placed on this approach elsewhere in Canada as organic matter was considered too dependent on soil management and manure use practices, and is not viewed as a reliable indication of soil degradation.

No Present Priority: Compaction; Contamination. These problems were believed to have such large new data requirements as to be impractical for small scale mapping at this time. In the case of compaction, further research is needed to establish suitable parameters and criteria before a map would be feasible.

ii) - Recommendations for Routine Soil Surveys:

First Priority: Develop satisfactory standardized methods for quantifying erodibility by wind and degree of compaction, and for characterizing compaction in the field. These characteristics of soils are inadequately defined in terms of measurable parameters. Research is needed to determine reliable relationships between these soil conditions and measurable soil physical data.

Second Priority: Standardize classification criteria for salinity and water erosion. The parameters are already established and minor variation in classification of severity and extent need only to be eliminated by general agreement. Validation of predictive parameters is needed in specific locations.

Third Priority: Acidity, Contamination and Organic Matter can be better characterized through the improvement in the quantity of samples collected and analysed. Adequate analytical capability and sufficient personnel are required for these improvements to be made.

Fourth Priority: Standardize classification criteria for compaction and wind erosion, once research on relationships with measurable parameters is completed.

iii) - Recommendations for future soil degradation studies:

A number of research projects have been proposed which are related to the interpretation of soil degradation information and development of control measures. These are probably not directly Soil Survey responsibility, although any attempt to incorporate into soil surveys recommendations for soil management to control degradation will need to draw on the results of these research projects. These projects are not priorized here but grouped by type of soil degradation, the priorities of which follow those above for small scape mapping and routine surveys.

Water erosion:

- Research on the effect of freeze-thaw cycles on soil erodibility, especially under prairie conditions.

- Research on spring runoff probabilities, especially in regard to extremely erosive conditions composed of combinations of snowmelt, heavy rains, freeze-thaw cycles, frozen sub-surface conditions and high soil moisture.

- Effect of soil management on soil erodibility, especially at that time of year when extremely erosive climatic events are most likely.
- Improved, economically viable conservation practices.
- Effect of soil erosion on soil productivity.
- Historical erosion rates from ^{137}Cs studies and by identification of eroded landscapes, including research into remote sensing techniques.

Wind erosion:

- Research on role of freeze-drying and freeze-thaw cycles on erodible fraction of soil aggregates in the Prairies.
- Research on extreme wind event probabilities in combination with erosion susceptible soil aggregation conditions.

Salinity:

- Wide range of research needed on identification and management of recharge areas, hydrologic patterns related to salinization, and better methods to predict salinization rates.
- Research is also needed on crop sensitivities, especially among crops which may be highly sensitive to salinity.
- Management of salinity related to type and severity.

Acidification:

- Research is needed on the quantification of anthropogenic and natural acidification rates.
- Research needed to determine effect of increasing acidity on soil biota and productivity, especially in forested soils.
- Determine lime requirements in soils of the Prairie Region.

Organic matter loss:

- Research is needed to establish critical levels of organic matter for soil fertility and structure.
- Determine on organic matter loss mechanisms and rates.
- Research on role of erosion in organic matter loss.
- Develop methods of readily assessing "quality" of organic matter rather than total quantity, as related to soil fertility, structure, resistance to erosion etc.

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Gregory J. Wall (Water Erosion), Ontario Institute of Pedoloigy, University of Guelph, Guelph, Ontario N1G 2W1

Soil Structure and Compaction:

- Research is needed to establish critical values of bulk density, penetrometer resistance, porosity etc. in different soils and climatic zomes.

- Quantify rates of change in parameters related to compaction.

- Improve soil survey instrumentation to measure compaction in the field.

- Determine soil management practices to control compaction.

Soil Contamination:

- Research is needed to determine present ranges in background soil trace-element levels linked to parent materials.

- Research to better assess critical levels in different soils for different crops.

- Determine different source inputs (eg. atmospheric deposition) which might be mapped together with background levels to show areas sensitive to certain crops or management practices (eg. sewage sludge disposal).

iv) Recommendations for Benchmark Sites for Soil Degradation:
High quality current detailed soil surveys, with adequate sampling and data collection, already form broad-scale "benchmark areas".

A subgroup should be established to check existing research stations (federal, provincial, university) for available long-term rotation sites for possible benchmark degradation monitoring. Other sites such as acid rain monitoring areas, met. stations, etc, should be evaluated for potential soil degradation monitoring in cooperation with other agencies.

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SOIL CLIMATE

G.F. Mills

INTRODUCTION

The third meeting of the Soil Climate Working Group was held as a 2½ day workshop in conjunction with the Fifth Annual Meeting of the Expert Committee on Soil Survey. The workshop had representation from all Provinces and the Yukon and Northwest Territories. Excellent participation by Working Group members and interested observers contributed to in depth discussion of priority concerns identified at the 1982 meeting of the Working Group (ECSS 1982). A detailed account of the Working Group activities is contained in the Workshop Proceedings published as part of the Proceedings of the Fifth Annual Meeting of the Expert Committee on Soil Survey.

REGIONAL PROGRESS REPORTS

Reports from the different regions were presented as follows:

Yukon - C. Tarnocai and S. Smith
Alberta - R. Howitt
Saskatchewan - R.J. St. Arnaud
Manitoba - G.F. Mills
Ontario - D. Aspinall
Quebec - R. Baril and J.M. Cossette
New Brunswick - A. Rees
Nova Scotia - K. Webb
Newfoundland - A. Stewart
British Columbia - In R. Trowbridge's absence, G.F. Mills summarized the report which had been submitted

The various reports presented a summary of activities in each province relative to soil climate investigations. It was evident that instrumentation for temperature measurements varied across the country. While thermocouple sensors appeared to be most widely used, thermistors and diodes are also being used. Discussion of the instrumentation techniques indicated that thermistors were probably the preferred method of measuring soil temperature. Of particular interest were details of electronic data gathering in Alberta and the use of diodes in Nova Scotia and New Brunswick.

It was also evident that several regions do not have the level of data that will be required to meet some of the Working Group objectives. For example, Newfoundland at present does not have any soil temperature sites and Manitoba presently collects data from 104 sites.

DATA HANDLING

B. MacDonald and B. Lacelle outlined the steps which had been taken in computerizing soil climatic data in CanSIS. They outlined the procedures for programming data in the Detail II format and showed sample outputs from the file. The method presented appeared to have sufficient flexibility to allow future additions and/or changes. It is designed to handle any kind of soil data measured on a repetitive basis. Working Group members agreed that there is a definite need for a national repository of soil climatic data and agreed to examine the suggested procedural format to determine if any refinements were required. Regions would be allowed the opportunity to mount the software on their own computer systems if desired. The program characterizes soil thermal regimes in terms of 11 parameters and generates plots of soil temperature measurements and the corresponding best fitting mean monthly soil temperature curve at various depths.

SOIL CLIMATE CLASSIFICATION

A general overview of the parameters used in the Canadian System and in the U.S. Soil Taxonomy were presented and discussed. R. Baril presented some of the work being carried out in New York State in refining the soil temperature classes for soil families and series. Correspondence with Soil Conservation staff in the United States indicated that although there is no nationwide program to measure soil climate, many states have soil temperature and moisture studies statewide and by soil survey areas. At this time, there is no movement to revise soil temperature or soil moisture criteria in Soil Taxonomy. They feel that the soil climate criteria will remain as a parameter of soil classification and not be separated and removed outside Soil Taxonomy.

REGIONAL ANALYSIS OF DATA

Several regions with longer term soil temperature measurements presented analysis of their data to the Working Group. The present status of a contract research project sponsored by the Agrometeorology Section was summarized by W. Sly. This project deals with analysis of estimated soil temperature normals for Canada. The various regional reports are included in the Workshop proceedings.

METHODOLOGY FOR MONITORING SOIL TEMPERATURE

A lengthy discussion of this topic established a definite need to publish a "Methods Manual" as soon as possible. The Provisional Manual circulated in 1982 was reviewed and the following modifications were suggested:

1) Expansion of the Objectives Section of the Manual.

2) Inclusion of a definition for "benchmark sites" (standardized as to texture, drainage, aspect, cover types.) and the need to stress that monitoring should occur on sites which are fully characterized as to soil, site and associated vegetation using the format recommended in the CanSIS field manual.

3) Provide a standardized approach for the collection and manipulation of soil temperature data to meet specific requirements regarding:

    a) site selection

    b) depths of observation

    c) frequency and duration of monitoring

    d) methods of installation

    e) choice of instruments and sensors

    f) data handling procedures

4) Define the minimum acceptable standards for inclusion of the data in a national repository.

5) Provide an indication of possible levels of accuracy and precision for each of the types of thermal sensors.

6) Provide helpful hints for the selection, installation maintenance of sites and construction of soil temperature probes.

Members of the Working Group were asked to submit revisions to the Chairman by February 1, 1984 in order to complete the final draft of the Manual early in 1984.

The Soil Climate Working Group developed a short term and long term plan to deal with the overall Working Group objectives.

The short term priorities are as follows:

1) Finalize the Methodology for Monitoring Soil Temperature for publication in 1984 by the Land Resource Research Institute.

2) Submit samples of regional soil temperature data to CanSIS to help evaluate currently available software.

3) On completion of this evaluation, regional representatives should begin input of their data to a central repository in CanSIS.

4) Based on level of support resulting from Working Group recommendations to ECSS, soil survey organizations should develop and maintain monitoring networks according to standards defined in the Methods Manual.

The long term priorities of the Working Group, because of implications to other ECSS Working Groups and to other Expert Committees are formulated in the following recommendations to the Expert Committee on Soil Survey:

1) ECSS is requested to increase support to monitoring activities in the soil survey program in terms of:

   - PY allocation to monitoring activities
   - Funding required to upgrade present and future monitoring installations to standards possible through thermistor installation.
   - Publication of the Methodology for Monitoring Soil Temperature in 1984.

A major objective of the Working Group is to achieve better characterization of soil climate through a national monitoring network. There are distinct advantages in establishing a monitoring network to uniform, nationally accepted standards. There is further advantage in utilizing thermistor instrumentation which is compatible with sensors used by the Atmospheric Environment Service. These advantages can only be achieved in the short term if additional support is available for monitoring activities by the soil survey

2) ECSS is requested to forward a recommendation to the Expert Committee on Agrometeorology to support expansion of the existing AES soil temperature network. The soil survey should offer assistance to AES in site selection and characterization.

Data from the soil temperature network maintained by the Atmospheric Environment Service provides standard measurements distributed across Canada which are invaluable for comparison with soil survey data collected less frequently and under less standardized conditions.

3) ECSS is requested to encourage the Land Resource Research Institute and the Agrometeorology Section to provide continuing support for analysis of soil climate data collected by the soil survey organization.

The Agrometeorology Section through contract research has recently provided further analysis of soil temperature data estimated from Oullett's model applied to long term normals of air temperature in Canada. This data is valuable resource material for soil climate characterization but should be evaluated in terms of measured long term soil temperatures. There is also need to allocate agrometeorology expertise to serve regional and local needs and concerns.

4) The ECSS should facilitate all necessary liaison between the Soil Climate Working Group and working groups on Soil Classification, Soil Water and Forestry Interpretations through publication of the Proceedings of the 1983 Workshop and the Methodology for Monitoring Soil Temperature.

Soil climate data resulting from activities of the Soil Climate Working Group may impact on the ECSS working groups on Soil Classification, Soil Water and Forestry Interpretations. These working groups should be aware of developments in soil climate characterization.

5) At the time of the next revision of the Canadian System of Soil Classification, the Soil Classification Working Group should consider the inclusion of soil climate properties as criteria within the soil taxonomic system.

At present, soil climatic data is used in the soil classification at the Order level in the Cryosols, Great Group level in other orders with provision for inclusion at the Family level in all orders. Where at all possible, soil climate criteria should be represented in the soil classification on a uniform, consistent basis.

6) The ECSS should establish liaison with the Expert Committee on Soil and Water Management and the Expert Committee on Soil Water to insure awareness of soil survey activities in characterizing soil climate and determine if this data is of interest and meets their needs.

7) ECSS should recommend that soil survey organizations test techniques for calculating mean annual and mean summer soil temperatures from a minimum quantity of key observations. These mean values can be evaluated against longer term data with greater frequency of observations obtained by soil survey and the Atmospheric Environment Service.

The Soil Climate Working Group does not expect to meet for 2 years unless requested to react to, or interact with working groups on Soil Classification, Soil Water or Forestry Interpretations.

REFERENCES

ECSS 1982. Progress Report of the Soil Climate Working Group pp. 13 - 18. Expert Committee on Soil Survey Proceedings, Fourth Annual Meeting April 19-23, 1982, Victoria B.C.

ACKNOWLEDGEMENTS

The chairman of the Soil Climate Working Group acknowledges regional input provided to the Workshop and to the preparation of this report: R. Trowbridge (British Columbia), R. Howitt (Alberta), R. J. St. Arnaud (Saskatchewan), D. Aspinall (Ontario) R. Baril and J.M. Cossette (Quebec), K. Webb (Nova Scotia), H. Rees (New Brunswick), A. Stewart (Newfoundland), C. Tarnocai and S. Smith (Yukon and Northwest Territories), B. MacDonald and B. Lacelle (Land Resource Research Institute) and A. Bootsma and H. Hayhoe (Agrometeorology Section).

The Working Group Membership wishes to acknowledge all other individuals who participated in the workshop discussion.

9.7

REPORT TO ECSS

November, 1983

IRRIGATION CLASSIFICATION WORKING GROUP OF ECSS

R.G. EILERS

This Working Group has been established to review and revise the method of interpreting soil suitability for irrigation on the prairies. As this is a new working group since the last ECSS (Victoria) meetings, the following background may be of interest.

On October 28, 1981 a meeting of soil scientists, irrigation specialists and engineers interested in the development of new soil classification criteria for irrigation was held in Saskatoon. At that time, Dr. H.M. Hill, Director General of PFRA, stated that "the 'Handbook for the Classification of Irrigated Land in the Prairie Provinces', published in 1964, is now outdated. New technology has lifted or altered many of the topographic and soil type constraints. A new system or a revision to the old system is needed. PFRA would like the assistance of the soil science and irrigation community to carry out the task of determining a new system". (Minutes of meeting circulated Dec. 2, 1981). This statement met with the general concensus of those in attendance, and a small task force was established to lay out a strategy to update the 1964 system and to develop a Suitability Classification for Irrigation in western Canada. The members of this task force included: R.G. Eilers, J. Ellis, W. Nicholaichuk (CDA), P. Karkanis (ADA), F. Kraft (PFRA), L. Chambers (PFRA). Since this meeting, the following chronology of events has occurred:

November 23, 1981 (Regina) - The first meeting of task force.

- Identified major areas of concern for irrigation assessment:
  a) soil criteria
  b) water quality
  c) engineering design requirements
  d) economic requirements
- Emphasized the importance of considering automation (computer facilities) for data storage and analysis

The task force recommended that it would have much greater impact and credibility if it were sanctioned under the umbrella of the ECSS.

April 19-23, 1982 - ECSS meeting, Victoria

- PFRA requests assistance from ECSS to review and revise Irrigation Classification System

May 13, 1982 - Final meeting of task force (PFRA), Regina

- Review of recently revised method of land classification for irrigation in Alberta
- Review of other methods - Saskatchewan, Manitoba, and North Dakota
- Meeting dealt mainly with content of manual

December 10, 1982 - Establishment of ECSS Working Group (R.G. Eilers, Chairman)

- This working group replaces the aforementioned task force.

Objectives of Working Group

This working group was given the responsibility of reviewing the status of irrigation classification in the prairie region. The general mandate of the working group is to:

1. "Revise the soil suitability rating system for irrigation to meet the regional needs of PFRA as well as other irrigation applications".
2. To provide a standardized methodology and guidelines for rating irrigation suitability.

This standardized methodology should have local and regional flexibility within a broad (prairie) framework, and it should also have sufficient flexibility to encompass changing irrigation technology. This will attempt to minimize overnight obsolescence as technological advances in irrigation occur.

The Present Members of the Working Group include:

R.G. Eilers, Canada-Manitoba Soil Survey (Chairman)

L. Chambers, PFRA (Secretary)

J.G. Ellis, Saskatchewan Inst. of Pedology

D. Anderson, " " " "

W.W. Pettapiece, Alberta Inst. of Pedology

W. Nicholaichuk, Canada Dept. of Agriculture, Swift Current

K. Pohjakas, Head, Land Classification Br., Alberta Dept. of Agriculture

(K. Pohjakas replaced P. Karkanis - ADA)

It was proposed that the working group confine their activities to the soils, their physical, chemical, surface and subsurface characteristics as they might affect land use for irrigation. The other components such as engineering design, agronomy, water quality, climate, economics, etc. would be recognized, but would not be dealt with in depth under the present terms of reference for this working group.

It was also proposed that the completed document be prepared in a format suitable for inclusion as a chapter (or section) in a revised PFRA Handbook for Classification of Irrigated Land, or as a stand-alone document such as the Agriculture Capability Classification System.

Review of Activities for 1983

The first meeting of the ECSS working group was held March 14, 1983 in Regina. At this meeting, the working group reviewed the progress of the previous task force and the present "state-of-the-art" for criteria and methodologies for rating irrigation suitability in each of the prairie provinces. Many of the inconsistencies and shortcomings of the present irrigation classification systems were identified and discussed. Some of the concerns identified were:

1. Soil ratings are often too subjective and site specific.
2. Soil drainage and drainability are very important for planning but are not consistently nor adequately addressed.
3. Present soil and landscape criteria are too restrictive for sprinkler methods of irrigation.
4. The rationale for arriving at a basic soil rating is not used systematically.

The committee also felt strongly that a revised system should lend itself to automation, so as to take advantage of computer capabilities such as CanSIS for soil data storage and evaluation.

As a result of this meeting, a document entitled "Towards a Revised System of Irrigation Suitability Classification for the Canadian Prairies" was prepared and circulated to the working group members. This document outlined a possible new approach to standardizing the soil and landscape properties and criteria using a "tabular - nomographic" technique.

On June 20, 1983 the working group met again in Saskatoon to review and discuss the concept and content of this new proposal. After considerable discussion, there was a general concensus that the new proposal had some merits. However, because there had not been sufficient lead time to fully assess the document, the working group decided to seek a wider review of the proposed presentation and methodology. This document is presently under review by numerous people in each of the prairie provinces and by PFRA engineering and soil conservation staff.

Future Plan

The present plan for the working group is to:

1. Prepare a second draft of this document as a result of these reviews, as soon as possible.
2. Convene a workshop meeting of the working group to review and discuss this second draft, and to finalize the criteria tables.
3. The resulting revisions and methodologies will be presented to the membership of the meeting originally convened in 1981 by PFRA.

No specific dates have been set as yet for these next two workshop meetings, but a final document will be prepared for testing and approval prior to April, 1984.

Report to ECSS, November, 1983

9.6

SOIL WATER REGIME CLASSIFICATION 1983

R.G. Eilers

The Soil Water Interest Group (SWIG) is focusing on two main activities. The first is the testing, evaluation, and integration of the new Soil Water Regime Classification System into the routine soil survey program of all soil survey units across Canada. The second major activity involves the compilation of a Soil Water Investigation Methods Manual (SWIMM).

Soil Water Regime Classification

The new Soil Water Regime Classification System utilizes the factors soil drainage, aridity, hydraulic conductivity, impeding layers for both reduced and increased porosity, least and greatest depth of saturated zone (water table) and its duration, as well as seepage, and man-made modifiers such as under-drainage. This system was adopted in 1981 for testing and evaluation and, in 1983, it was included in the revisions of the 1982 CanSIS Manual for Describing Soils in the Field. In addition, a SWIG field tour was conducted from July 18 to 22, 1983 and focused on the three Maritime provinces - Nova Scotia, New Brunswick, and Prince Edward Island. The tour consisted of visits to numerous soil water benchmark sites (SWABS) in each province. The SWIG criteria were discussed relevant to the soil and water data for each site. As a result of these discussions, some concern was expressed regarding the adequacy of the presently defined persistence classes.

As presently defined, the persistence classes refer to the annual period for moisture regimes. This is in keeping with the annual highest water table levels. For many soils, the persistence of wet soils and high water tables is longest in the non growing season. Persistence classes, based on this consideration, do not adequately reflect growing season (April to October) conditions. Also, the persistence periods are apparently too broad for Maritime conditions.

Two possible solutions could be:

1. Adopting a seasonal (S) (April 15 to October 1) or annual (A) modifier to the persistence class while maintaining the duration classes, e.g.

				(days)
SS	short seasonal	SA	short annual	2-20
MS	medium seasonal	MA	medium annual	20-60
PS	prolonged seasonal	PA	prolonged annual	>60

(Seasonal is more specific. Annual would include the seasonal).

OR

2. The persistence classes themselves could be adjusted while still maintaining the seasonal (S)/annual (A) option. For example: First select S or A for the persistence interval you wish to recognize, then choose appropriate duration with two options of detail.

S or A		Days	
S - Short		2-20	
S1	2-10		
S2	10-20		
M - Medium		20-60	e.g. SS1
M1	20-40		or
M2	40-60		AM2
P - Prolonged		>60	
P1	60-120		
P2	>120		

At the moment, a 3-symbol code could not be used for persistence in the proposed amendment to the Detailed File. This points out the need for close cooperation with the CanSIS Working Group to ensure that when these SWIG criteria get encoded into the CanSIS File, that there is sufficient flexibility for regional adjustments. (Note: Other examples of persistence classes were given in ECSS Proc. 1979, 1980 and 1981).

Since the last ECSS meetings, SWIG has recruited another interested worker. R. DeJong has agreed to evaluate a computer model for predicting water table levels. An initial evaluation is presently underway using some water table records from several sites in Manitoba.

The plans for the upcoming year (1984) for SWIG include:

1. Continued data gathering from SWABS in each province.
2. Continued testing of computer model for water table prediction.
3. Incorporation of SWIG into revised detailed CanSIS files.
4. Investigate the options for incorporation of SWIG into Soil Taxonomy, probably at the Family level.

Soil Water Investigation Methods Manual "SWIMM"

A tentative proposal for a SWIMM outline was presented at the last ECSS meetings in Victoria (see Proc. April, 1982). In the absence of any alternative suggestions and recognizing that it is generally easier to shoot if there is a target to aim at, a first draft of SWIMM was prepared (Dec. 13, 1982) following a modified version of the tentative outline. This draft was circulated January 14, 1983 to every soil survey unit, as well as a number of other interested groups, universities and research stations. The response to date has been most gratifying. At the present time, I have received more than a dozen reviews with a few more that have been promised.

A summary of the reviews indicate:

1. There is unanimous support for the compilation of a SWIMM.
2. There is a concensus that, with a few minor adjustments in the organization, the present structure is satisfactory.

For those who have not yet seen the first draft, it follows the approach of "observe - estimate - measure (monitor) - interpret". The general intent of the manual is that it should be a "How To Do" Field Oriented Soil Water Investigation Methods Manual for Soil Surveyors.

3. There needs to be a rigorous edit of the methodologies that were included in the first draft.

Shortly, I will be approaching various individuals to assist in the rewriting of individual chapters. Work on these revisions and the compilation of a second draft will begin in 1984.

As a result of the first reviews, a revised outline has been prepared and circulated to the Working Group.

In summary, I believe that the new methodology for Soil Water Regime Classification is gradually gaining support. Some soil surveyors, agricultural drainage engineers, and land irrigation specialists have commented favorably on the new system. Most provincial soil survey units have initiated some type of soil water measuring and monitoring activities to acquire data for the various drainage factors. This data will be used to evaluate the appropriateness of the proposed SWIG criteria.

At this time, the major activities across Canada are focused on data gathering. At some stage in the near future, these data will have to be brought together for evaluation and interpretation. One method of doing this might be to hold a national workshop for SWIG in which regional data can be summarized and discussed in relation to the new classification procedures. The data, interpretations, and evaluations could be compiled in a proceedings. These proceedings could then serve as a reference document for any final changes in criteria. The final adoption of the new drainage classification scheme would then rest with the ECSS and could be based, in part, on the evidence and recommendations evolving from the workshop. Since the Expert Committee has agreed on a 5-year testing period, (1981-1985), a SWIG workshop and proceedings could highlight the culmination of the long struggle to revise and implement a new more comprehensive soil drainage classification system for Canada.

Revised Outline for SWIMM

October, 1983

TITLE: SOIL WATER INVESTIGATION METHODS MANUAL

CHAPTER 1

Introduction
Review of Soil Drainage Classification in Canada
Reasons for Manual
2.8 Cont'd Objectives

CHAPTER 2 Field Estimates of Soil Water Properties

Introduction
Soil Moisture Regimes
 Significance to Soil Classification
 Estimation
Estimating K Sat. from Soil Morphology
Feel and Appearance Method of Estimating Soil Moisture
A Flow Diagram for Teaching Texture by Feel Analysis
Field Identification of - Soil Texture
 - Soil Color
 - Soil Structure
 - Soil Porosity
 - Soil Bulk Density
 - Other

CHAPTER 3 Field Measurements of Soil Water Properties (Above a Water Table "Unsaturated Zone")

Introduction
Soil Moisture Measurements
 Gravimetric
 Electrical Resistence Blocks
 Tensiometers
 Neutron Moisture Meter Method
 Time Domain Reflectometry Method
Infiltration Measurements
 Basin or Cylinder Method
Hydraulic Conductivity
 Shallow Well Pump in Test
 Ring Permeameter Test
 Test Pit Method
 Air-Entry Permeameter Method
 Double Tube Method
 Double Ring Tests
Soil Porosity
Soil Bulk Density
Soil Capillary Potential

CHAPTER 4 Field Measurements of Soil Water Properties (Below a Water Table "Saturate Zone")

Observation Wells and Piezometers
 Construction, Installation, Monitoring, and Maintenance
Hydraulic Conductivity Tests
 Auger-Hole Test
 Piezometer Tests

IAPTER 5

Laboratory Procedures

The general concensus of reviewers is that this chapter should be deleted since we already have a laboratory procedures manual. However, I propose that this chapter be retained but renamed "Guidelines for Selection of Monitoring Sites". This might be a rather difficult chapter to write, since it will likely be based largely on experience of numerous individuals. However, it is a very important topic in view of our goal to standardize procedures.

CHAPTER 5 Guidelines for Selection of Monitoring Sites

- Objective of Monitoring Site
- General Description of Monitoring Site
  - Regional Relevance of Site (Climatic)
  - Local Relevance of Site (Climatic)
  - Site Characteristics
    - Surface Deposits
    - Vegetation
    - Topography
    - Accessibility - Annual - Seasonal
Weekly - Daily
    - Soil Variability
    - Soil Hydrology
- Instrumentation of Monitoring Site
  - Design and Layout of Site
  - Equipment to be Installed
  - Equipment Construction, Installation and Testing
  - Equipment Protection, Monitoring and Servicing (Maintenance)
- Data Storage and Analysis

CHAPTER 6

- Data Presentation and Interpretation
  - Water Table - Contour Maps
    - Isobath Maps
    - Hydrographs
    - Frequency Graphs
  - Interpretation of Hydraulic Head Data
  - Integrated Precipitation - Soil Temperature - Water Table Response Charts
- Interpretation of Soil Water Regimes - For Land Use and Evaluation
  - Estimating Soil Drainage Requirements
  - Estimating Amount of Available Soil Water
  - Estimating Soil Water Supplying Potential of High Water Tables
  - Estimating Critical Water Table Levels For:
    - Cereal Crops
    - Forage Crops
    - Special Crops
    - Irrigation
    - Subsurface Drainage Design

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- Supplemental Procedures

2.9

Memorandum to:
Members
Soil Mapping System Working Group

From: Keith Valentine

October 31, 1983

Re: Expert Committee on Soil Survey
Meeting Nov. 14-18 Ottawa

We have to present a brief report of our activities over the past year at the coming meeting. Here it is. Let me know if you want anything changed.

As you will see on the first page, I have not yet asked that long list of people to work on our six priorities. I make no apologies for this. I have simply had no time. But this does mean that we will have made little headway since May. So is there any need to have a meeting sometime between 14-18 November? Does anyone have anything to report or suggest. I could tell you about a small mapping project I did this summer using the approach of recording polygon descriptions. I kept a careful record of progress. However, this is hardly earth shattering and could wait.

Lastly, I enclose a thoughtprovoking letter from Bob MacMillan. I think you will enjoy reading it.

Looking forward to seeing at least some of you in Ottawa.

Kind Regards,

Yours sincerely,

Keith Valentine,
Pedologist.

KV/jm

SØIL MAPPING SYSTEM WORKING GROUP REPORT 1982-1983

The Soil Mapping System Working Group that reports to the Canada Expert Committee on Soil Survey met in Ottawa on 25 and 26th May 1983. Having attempted, in the publication "A proposed soil mapping system for Canada: Revised 1981", to standardize our traditional survey procedures we now have some new terms of reference:

"To recommend methods of survey that can comprise a cost effective and efficient system of mapping soils in Canada; that can be used and applied by any competent soil scientist, regardless of where or for whom he is working; that are applicable to both the major objectives for which soils are mapped (biological and engineering); and to consider the future implications of such a system to educating soil scientists, to organzing soil survey and to publishing the results."

At the meeting in May we proposed that the following aspects of soil survey should be upgraded or developed to attain efficient and cost effective soil survey.

1. Standardize interpretation procedures and develop minimum data sets of differentiating properties for mapping.
2. Improve information packaging: categories, formats, production procedures.
3. Define the structure of soil survey data; develop computer compatible recording and analysis techniques; study recording data by depth not horizon.
4. Survey design and definition of survey intensity.
5. Reorganization of professional and technical roles.
6. User involvement.

We also proposed a number of people to work on each topic. The Chairman was to write to each person with a list of guidelines that we prepared for each topic. This has not been done yet through lack of time. The groups proposed for each topic (headed by the name underlined) are:

1. J. Dumanski, G. Coen, <u>J. Shields</u>, D. Holmstom, R.K. Jones
2. <u>J. Nowland</u>, J. Day, D. Holmstrom
3. <u>K.B. MacDonald</u>, D. Aspinall, D. Moon, G. Padbury, M. Sondheim
4. <u>K. Valentine</u>, C. Wang, E. Mackintosh, G. Coen
5. <u>J.S. Clark</u>, G. Mills, P.N. Sprout
6. <u>J.M. Cossette</u>, E. Presant, E. Pottinger

At first the Working Group was kept small, but recently some provincial representatives have been added (and some original members dropped). The present Group comprises:

D. Aspinall (Ontario)
D. Holmstom (Maritimes)
M. Langman (Manitoba)
K.B. MacDonald (Ottawa)
R. MacMillan (Alberta) (T. Macyk till 1984)
J. Nowland (Ottawa)
G. Padbury (Saskatchewan)
J. Shields (Ottawa)
M. Sondheim (British Columbia)
A. Stewart (Newfoundland)
K. Valentine (British Columbia)

So far we have received a number of letters about soil mapping from people across the country. We wish to thank you all for your interest, and to assure you that we will take note of your points of view. Periodicially we intend to distribute a short information note telling you what we have been doing.

K. Valentine, Chairman,
LRRI, Vancouver, British Columbia

Mapping System Working Group: Address List, Nov. 1983

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SOIL SURVEY HANDBOOK

Gerald Coen

INTRODUCTION

The Soil Survey Handbook was conceived to record and suggest procedures useful in undertaking soil surveys in Canada. It attempts (and will attempt) to document those things which, until now have been accepted practice, but not necessarily well recorded. The existing manuals on Taxonomy, Mapping, etc. have concentrated on the most pressing needs but some aspects of the procedures have been neglected. With consistent, well documented procedures managers and surveyors can more easily examine their programs for quality and efficiency.

Judging from the responses received to date the Handbook has not received a high priority from the Editorial Lead Committee. This may reflect the fact that the lack of a handbook does not interfere with progress of existing projects. There does, however, appear to be a concensus that once completed the Handbook will contribute appreciably to the standardization of soil surveys in Canada. Incidentally, I have received several inquiries about the progress and availability of the Soil Survey Handbook from Soil Science professors and consultants. Therefore, acting on the recommendations to the 1982 ECSS meetings we have continued to proceed with the development of the Handbook as quickly as the availability of personnel has allowed.

ACCOMPLISHMENTS

In response to recommendations to the 1982 ECSS meetings the following Editors have been selected:

Section 100 (Soil surveys in Canada) - J.H. Day
Section 200 (Planning for soil surveys) - J.H. Day
Section 300 (Project planning and management) - W.W. Pettapiece
Section 400 (Conducting soil surveys) - G.M. Coen
Section 500 (Application of soil survey information) - R.E. Smith
Section 600 (Soil survey investigation) - J.A. McKeague
Section 700 (Information and display system)
- 701 (Media used to inform the public) - G.M. Coen
- 702 (Automating soil survey and other information) - J. Dumanski
- 703 (Guides for preparing and reviewing soil survey reports and maps) - T. Lord with J.A. Shields.

In addition several persons have agreed to write portions of various sections. Anyone currently working on a project that might be applied nation-wide as a topic in one of the Sections is urged to contact the appropriate Section Editor and offer his or her services (e.g. if you are working on "Interpretations for Septic Tank Effluent Disposal" - contact R.E. Smith). If possible we would like to avoid asking people to take on contributions to the Handbook that are not related to their ongoing responsibilities.

To date complete drafts of Sections 1, and 3 have been distributed to the Editorial Lead Committee for evaluation. A draft of most of Section 400 has also been distributed for evaluation. A revised outline has been proposed for Section 500 and several potential authors have submitted comments and ideas. A modified outline for Section 600 has also been developed and a "plan for attack" formulated. The Editors in Section 700 have had difficulty working the duties into their time-tables, but will begin to actively undertake their responsibilities April 1, 1984.

RECOMMENDATIONS

1. That Sections 100 through 400 be evaluated by the Editorial Lead Committee over the next six months and then printed as an interim document in sufficient copies to be distributed for testing to all members of soil survey units in Canada plus copies to be made available to interested individuals in Universities and Consulting Firms.

2. That as Sections, or segments of Sections, become completed and evaluated by the Editorial Lead Committee they should be printed as supplements to the above and distributed for testing.

ACKNOWLEDGEMENTS

I gratefully acknowledge the time and effort given by a number of ECSS members, especially those that have agreed to act as Section Editors and/or Authors. Special recognition to J.H. Day and W.W. Pettapiece for the extra effort in getting their contributions ready for distribution to the Editorial Lead Committee prior to these meetings.

3.1

BROCHURES FOR NON-AGRONOMIC INTERPRETATIONS

R.E. Smith

1. Brochures

The working group for Non-agronomic Interpretations has limited its activities almost exclusively to the production of the "Soil Surveys Can Help You" series of brochures, since the 4th ECSS meetings in Victoria, April, 1982. These activities basically have been the assembling and editing of texts and suitable illustrations for the brochures. This task, coordinated in Winnipeg, was completed by October, 1982 as a result of the excellent cooperation from all participating provincial representatives on the working group. Except for minor edits and suggestions, assembled texts were found to be acceptable for use in all provinces. Suitable illustrations for the brochures were, as expected, difficult to find. All assembled material was forwarded to J. Day to manage production logistics with the Cartography Unit and Research Program Services people.

To date, two brochures with marginally different formats than those submitted have been published and distributed. Approximately 125,000 copies, 100,000 in English and 25,000 in French have been printed at a total cost of $17,045. The more general Survey brochure consists of four, 8½-inch x 3½-inch panels and is illustrated using 5 colored photos and one colored map graphic. Color runs were confined to one side of the brochure. The cost of this brochure was $9,734.

The "Farmers and Ranchers" brochure consists of 3, 8½-inch x 3½-inch panels and employs 4 colored photos on both sides of the pamphlet. Unfortunately, the color runs on both sides of the pamphlet elevated the cost substantially to $7,311. All costs have been borne by Research Program Services, since the brochures are sponsored by ECSS rather than LRRI.

Future plans call for the publication of 50,000 English copies and 10,000 French copies of the "Foresters" and "Land Use Planners" brochures at a total cost of about $9,500, hopefully this fiscal year. The release of the 4 remaining brochures, i.e. "Homebuyers", "Recreation Planners", "Septic Filter Fields" and "Engineers" will depend upon limited available departmental funds for publication and will likely extend the time required to complete the job over the next several years.

Technical Bulletins

The current development of more comprehensive technical bulletins explaining soil survey procedures and the application of soil survey information to specific non-agronomic uses is an uncoordinated and sporadic program activity in Canada today. It will remain as such, so long as the Land Evaluation Section in LRRI is unable to provide needed national coordination and leadership. This coordination is required for forest land evaluation, wildlife habitat assessment, the wide range of non-agricultural land use planning concerns ranging from urban development to watershed management, as well as for environmental impact studies to which survey information can be applied.

However, in the absence of a national program, regional activity has been encouraging, particularly in British Columbia through the efforts of the Resource Analysis Branch of the B.C. Ministry of Environment and the Ontario Institute of Pedology in Ontario.

In B.C., for example, over 80 people are active in various phases of soil and terrain analysis. They include the federal and provincial survey groups, the Ministry of Forestry (active in site classification, silviculture, engineering interpretations, planning), the Agriculture Land Commission, DOE Land Directorate, forest companies, etc. As one would expect, many bulletins of varying usefulness for local and provincial application have emerged, interpreting soils and terrain for many biological, environmental and engineering applications.

The major activity in Alberta is the development of guidelines for use in reclaiming land affected by coal and tar sands strip mining activities. The Banff-Jasper Ecological Land Classification project provides valuable information for use in assessing land for major park and recreation development and wildlife habitat interpretations.

The Saskatchewan soil survey program is currently focusing on the development of soil survey publications for each rural municipality in the province. Each publication provides information suitable for both agricultural and non-agricultural land development planning and management by providing soil and terrain information at various levels of generalization.

In Manitoba, development of non-agronomic interpretation guidelines has been restricted to an evaluation of soils for forestry purposes.

soil quality is expressed in terms of tree species suitability and productivity for survey projects in the forested region of the province. A technical monograph dealing with the application of available soil survey information in the province to various engineering uses is being planned for completion by 1986. We are planning to utilize the 1:1 M scale soil map of Manitoba as the basis for providing soil and terrain information useful to the design engineer, the geotechnical engineer and to the planner. USDA engineering interpretation guidelines will be employed in this project.

In Ontario, considerable activity by the University of Guelph and the Ontario Institute of Pedology appears to be underway in terms of estimating soil properties and rating soils for various uses. Among the more interesting activities are: a) the development of field guides for conducting soil surveys and forest ecosystem classification and land evaluation, b) the use of soil water data to predict engineering soil properties, c) guidelines for reclaiming pipeline sites and mined aggregate lands to an agricultural after-use, d) soil interpretations for forest land management, e) guides for assessing surficial erosion and sedimentation control.

Activities in Quebec are restricted to the use of USDA guidelines for engineering applications in soil survey reports.

In New Brunswick, little or no activity appears to be underway except for Dr. H. Krause who is coordinating the development of interpretive guidelines for forest land management nationally.

In Nova Scotia, guidelines for assessing soil suitability for logging road construction have been prepared.

Little or no activity to develop guidelines or to publish technical bulletins dealing with survey information applications for non-agronomic uses appears to be underway in P.E.I. or Newfoundland.

SOIL CORRELATION WORKING GROUP J.H. Day

Soil Survey Form 1 (Planning document) has been finalized and completed for new projects in Alberta, Saskatchewan, Manitoba and Nova Scotia.

It is acknowledged that completion of Form 1 not only serves a very useful purpose as a soil survey planning tool but also sets the stage for subsequent documentation of correlation activities. It is necessary to complete Form 1 for all new projects.

Soil Survey Form 2 (Correlation document) has been completed for new project areas in Alberta, Saskatchewan and Manitoba. Experience has shown that this Form should be completed on location in the project area on the morning following the Field Review. It provides a structured format for discussion and healthy debate of correlation activities by correlators (regional and provincial), project leaders and mapping personnel. The time required ranges from 2 1/2 - 3 hours. There are still a few items requiring either clarification, reworking or possibly deletion. It is now important this document be utilized and evaluated by soil survey personnel in Central and Atlantic Canada.

SOIL CLASSIFICATION C. Tarnocai

This Working Group remains intact. Problems relating to the classification of Gleysols, Folisols, Humus Forms and the definition of contrasting horizons continue to be documented. Other problems concerning the classification clay soils in the Prairies have been raised and await documentation.

The first printing of the Canadian System of Soil Classification has been depleted and a second printing (unchanged) has been authorized.

QUALITY CONTROL IN SOIL SURVEY LABS P. Haluschak

Progress is being made on several of the objectives presented at the 1982 ECSS Meetings. A brief outline of methods is being compiled. It will be circulated to laboratories shortly. Error values for methods are being determined and this information will be distributed for discussion.

Laboratories are incorporating standard samples in routine analysis and an unknown sample has been distributed for analysis as a check on quality of data. Methods of analysis are being reviewed. It would appear that revision of the Methods Manual is not necessary at this time. Activities are also continuing on other objectives outlined at the previous meeting.

CanSIS Working Group Report
B. MacDonald

Introduction

Activities of the CanSIS working group over the past 18 months consist primarily of CanSIS activities. CanSIS has made progress as described in this report to the point where input and reaction is required. The working group is being asked to involve the regions and to communicate regional reactions and needs.

Status Report

All data in CanSIS are grouped into two types of files -- national files and project files. For most national files, data are submitted on an ongoing basis by federal, provincial, university and industry researchers. The data are input to the computer as they are recieved and stored on tape. Periodically, normally one to two times per year, they are reformated and stored on disk for on-line access and manipulation as one or a series of RAPID relations. Project files are generally interest to a limited group of users and are frequently similar to one or other national file although there is no set format.

All national files have been coverted to one or a series of RAPID relations. The way in which the data are organized into relations is summarized as follows:

a) Soil Data (DETAIL) File

SD01 - Site relation
SD02 - Morphology, physical and chemical analysis relation
SD03 - Notes and free format relation
MT02 - Monitor relation -- similar to SD02 but with the ability to record data and time to facilitate monitoring activities (e.g. soil climate, water table) carried out in association with detail sites.

b) Soil Names File

SL01 - Soil Names relation

c) Performance Management File

PMA1 - Site relation

PMB1 - Global management relation

PMC1 - Weather relation

PMD1 - Horizon relation

PME1 - Factor relation

PMF1 - Factor - Level relation

PMG1 - Treatment relation

PMH1 - Soil physical and chemical analysis relation

PMI1 - Crop yield and quality relation

PMI2 - Crop growth stages and damage relation

PMI3 - Notes and free format relation

d) Wetlands Registry

WT01 - Area relation

WT02 - Site relation

WT03 - Hydrology, morphology, physical and chemical analysis relation

WT04 - Vegetation relation

WT05 - Notes and free format relation

Project files including computer legends have been developed as requested by unit offices for Saskatchewan, Manitoba, Ontario, Nova Scotia, and New Brunswick as well as for the Soils of Canada and generalized soil landscape maps.

These project files consist of one or a series of RAPID relations which like the relations for the national files are accessible on-line.

The Cartographie file remains unchanged in format. Maps are input at a rate of about 150 per year and the current archive consists or approximately 750 maps.

Communications

Communications between CanSIS and regional users has been primarily a one way street (with one or two much appreciated exceptions); namely, from CanSIS to the users. Two sample soil names reports were distributed along with a manual and an invitation to the units to access the data themselves or at least to define what was good or unacceptable in the sample reports. Notes of the CanSIS planning meetings have been distributed for information and comment. Comments have been nil, it is to be hoped that the information content is somewhat higher. Immediately prior to this meeting a draft of the General CanSIS Users' Manual has been distributed and a report comparing the soil names file to the soil data (DETAIL) file. It indicates series codes in the soil data file which are inconsistent with those in the soil names, soil names for which no detailed profile description exists in CanSIS, and for soil names which correspond it lists the each detailed description available.

Development Areas

The major development area is the Cartographic Subsystem. The data input functions are being transferred from the outmoded PDP 11/10 minicomputers to IBM personal computers. Activities are under way to regionalize the data collection through the use of these microcomputer-based stand alone digitizing stations.

Reports and reporting procedures are under development for both the soil data (DETAIL) relations and wetlands relations. The capabilities of the monitor file are being tested and evaluated by the soil climate working group.

Documentation is being prepared for the reporting procedures as they are developed and the computer legend documentation is being revised to reflect current operating procedures.

Direct Regional Involvement

W. Fraser is spending brief periods of time for training in the development and use of RAPID relations. He will be evaluating their suitability for regional project and daily type files. In view of the following project most files which Wally considers will be organized so that they could be put up on a micro computer if desired.

D. Moon will be working in Ottawa over the winter evaluating and testing available micro computer software for use in regional project and daily files. Dave will also be looking at communication links to shift data files from a micro to a larger computer e.g. VAX or Datacrown.

These two studies explore the range of possibilities where data are entered and manipulated in a micro computer over a field season but are then transferred to a larger unit in the fall to take advantage of either the increased capacity or manipulation and reporting capabilities of a larger system.

Associated Data

The CanSIS programmers represent the programming support available to LRRI; consequently, they have been called upon to store and manage a wide range of data types some of which may be of interest to regional users.

(a) The Census of Agriculture tape has been purchased.

(b) In association with the Land Potential Data Base (the computerized extended legend for the Soil of Canada) there are computer files on climate, modelled yield for 9 crops, actual yields by administrative region yearly from 1961.

(c) The 10 km grid climatic data base is being associated the the generalized soil landscape maps as these become available.

(d) The Land Evaluation Data files from the Ontario land evaluation project have been transferred to CanSIS. These include for Ontario-land availability grouped into some 300 land types, estimated crop yields for 18 crops etc. Currently this project is working to address the problem of a national system for land evaluation. This project will rely much more on the LRRI both for data (primarily as managed within CanSIS) and for expert advice and reaction to define and develop the requirements and capabilities of a national system.

Questions:

1) Is the current composition of the CanSIS working group correct and adequate?

2) Within the national files what level of data accurracy and reliability is acceptable and/or desirable? How is it achieved and maintained?

3) Is the current policy acceptable -- that the data are freely available and accessable?

4) What are the appropriate schedules for data submission to the national files? What should be the frequency and timing of the updates to the on-line RAPID relations?

GENERALIZED SOIL LANDSCAPE MAPS J.A. Shields

Progress Report to ECSS, Nov./83

To date, generalized mapping has been completed for all of Manitoba and the agricultural region of Saskatchewan, Alberta and Ontario. However, only the map for Saskatchewan has been digitized and merged with the extended computer legend so that single factor or multiple factor derivative maps can be retrieved. Digitizing of the Manitoba map is in progress. Some local checking is required on the Alberta map before commencing with digitizing.

The computer legend format has been extended to include aridity indices for perrennials and wheat, surface pH, soil salinity, Shawinigan grid square numbers, and soil temperature data. A complete list of the soil landscape and climatic properties coded to date within each Province is given in Table 1.

Another alternative for the publication legend has been prepared. Basically, it contains the same information shown previously. However, an attempt has been made to make the map symbol more explicit by showing genetic origin of material and its texture separately. Thereby, the map symbol sequence includes soil development, soil texture, followed by genetic material, its surface form and slope class.

For example, the map symbol A cl/Mh4 indicates a Brown soil developed on clay loam morainal material with hummocky surface form and slopes of 4-9%. Note that connotative symbols have been chosen for both the texture class and slope class as follows:

ie	sd for sand	1- for 1-3 %
	sl for sandy loam	4- for 4-9 %
	lm for loam	10- for 10-15 %
	cl for clay loam	16- for 16-30 %
	cy for clay	

The open, controlled and closed legend formats for this alternative are shown in Tables 2,3 and 4, respectively. For brevity, only portions of the controlled and closed legend are given.

Jack Shields
Land Resource Research Institute

JS/dt

Enclosure

Table 1 Progress report on map compilation, data coding and map retrieval

Soil Landscape and Climatic Properties Coded	Dom Soil	Sub Dom Soil	Man (Prov)	Alta (Agric Region)	B.C. (Peace River)	Ont (South)	Sask (Agric Region)
Soil Capability	✓	✓	✓	✓	✓	✓	✓
Land Use	✓	✓	✓	✓	✓		✓
Genetic Parent Material	✓	✓	✓	✓	✓	✓	✓
Texture of Parent Material	✓	✓	✓	✓	✓	✓	✓
Soil Development	✓	✓	✓	✓	✓	✓	✓
Surface Form	✓	✓	✓	✓	✓	✓	✓
Slope Gradiant	✓	✓	✓	✓	✓	✓	✓
Surface Texture	✓	✓	✓	✓	✓	✓	✓
Avail. Water Capacity	✓		✓	✓	✓		✓
Calcareousness	✓		✓	✓	✓	✓	✓
Depth to Water Table	✓		✓	✓	✓		✓
Soil Inclusions	✓		✓	✓	✓	✓	✓
Regional Landform	✓		✓	✓	✓		✓
Soil Drainage	✓	✓	✓	✓	✓	✓	✓
Aridity Index-Perrennials	✓						✓
Aridity Index-Wheat	✓						✓
pH-surface	✓	✓					✓
Salinity-Ballantyne	✓	✓					✓
Kind of Salts-Ballantyne	✓	✓					✓
Salinity-Eilers	✓		✓				
Ecoregion						✓	
Ecodistrict						✓	
Forest Site						✓	
Shawinigan Grid Sq.	✓						✓
Date, Soil Temp at 10 cm is 5°	✓	✓					✓
10°	✓	✓					✓
15°	✓	✓					✓
18°	✓	✓					✓
22°	✓	✓					✓
# Days, Soil Temp at 10 cm is 15°	✓	✓					✓
18°	✓	✓					✓
Mean Summer Soil Temp at 10 cm	✓	✓					✓
Soil Temp at 10 cm on May 20	✓	✓					✓
Soil Temp at 10 cm on May 1	✓	✓					
Other Information :							
Map Compiled			✓	✓		✓	✓
Map Digitized							✓
Data Key Punched							✓
Single Factor Map Retrievable							✓

Table 2. Alternate map symbol and legend (open format)

MAP SYMBOL

Example: A 1m / M h 4 / 1 5 0 — refers to EXTENDED LEGEND INFORMATION

SOIL DEVELOPMENT	texture group[1]	GENETIC MATERIAL	surface form[2]	SLOPE CLASS (%)
A— Brown Chernozemic	sd—sand	A—Alluvium	d—Dissected	1- 1 to 3 %
B— Dark Brown Chernozemic	sl—sandy loam	E—Eolian	h—Hummocky	4- 4 to 9 %
C— Black Chernozemic	lm—loam	F—Glacio-fluvial	k—Knob & Kettle	10-10 to 15 %
D— Dark Grey Chernozemic	cl—clayloam	L—Lacustrine	l—Level	16-16 to 30 %
F— Gray Luvisolic	cy—clay	M—Morainal	m—Rolling	
G— Brown Solonetz			r—Ridged	
H— Dark Brown Solonetz			u—Undulation	
J— Black Solonetz				
K— Gray Solonetz				
M— Eutric Brunisolic				
R— Regosolic				
U— Gleysolic				
X— Organic Fibrisol				
Y— Organic Mesisol				

EXPLANATION OF ABOVE SYMBOL: Brown soils (A) developed on loam (lm) morainal material (M) with hummocky surface form (h) and slopes of 4-9% (4)

FOOTNOTES:

1 Texture Groups:
Sand or Gravel or Loamy sand;
Sandy loam or Fine sandy loam or Gravelly sandy loam;
Loam or Very fine sandy loam or silt loam;
Clay loam or Very fine sandy loam or silty clay loam;
Clay or silty clay or Heavy clay.

2 SURFACE FORMS:
D - Dissected or gullied pattern providing external drainage for an area;
H - Hummocky pattern with chaotic sequence of pronouced knolls and swales;
K - Hummocky pattern with chaotic sequence of knolls and numerous kettles (or sloughs) which occupy 15-20% of an area;
L - Level or nearly flat featureless pattern;
M - Rolling pattern with a regular sequence of long, moderate slopes rising to broad convexities;
R - Ridged pattern with a sequence of long narrow sharp crested ridges and accompanying swales;
U- Undulating pattern with a regular sequence of gentle slopes.

Table 3. Alternative Legend (controlled format)

TOP LINE: DOMINANT SOIL DEVELOPMENT AND TEXTURE

A. BROWN CHERNOZEMIC SOILS DEVELOPED ON:

Asl	sandy loam textured material
Alm	loam
Acl	clay loam
Acy	clay

B. DARK BROWN CHERNOZEMIC SOILS DEVELOPED ON:

Bsl	sandy loam textured material
Blm	loam
Bcl	clay loam
Bcy	clay

C. DARK CHERNOZEMIC SOILS DEVELOPED ON:

Csl	sandy loam textured material
Clm	loam
Ccl	clay loam
Ccy	clay

D. DARK GRAY CHERNOZEMIC OR LUVISOLIC SOILS DEVELOPED ON:

Dsl	sandy loam textured material
Dlm	loam
Dcl	clay loam
Dcy	clay

Table 3. Continued

BOTTOM LINE: GENETIC ORIGIN OF MATERIAL, SURFACE FORM AND SLOPE CLASS

GENETIC ORIGIN OF PARENT MATERIALS:

A Alluvial (or Fluvial)
C Colluvial
E Eolian
F Fluvioglacial
L Lacustrine
M Morainal
W Marine
U Undifferentiated

SURFACE FORMS

D - Dissected or gullied pattern providing external drainage for an area;
H - Hummocky pattern with chaotic sequence of pronounced knolls and swales;
K - Hummocky pattern with chaotic sequence of knolls and numerous kettles (or shoughs) which occupy 15-20% of an area;
L - Level or nearly flat featureless pattern;
M - Rolling pattern with a regular sequence of long, moderate slopes rising to broad rounded convexities;
R - Ridged pattern with a sequence of long narrow sharp crested ridges and accompanying swales;
U - Undulating pattern with a regular sequence of gentle slopes.

SLOPE GRADIANT CLASSES

1 1-3 %
4 4-9 %
10 10-15%
16 16-30%

FOOTNOTES

1 Texture Groups:
Sand or Gravel or Loamy sand;
Sandy loam or Fine sandy loam or Gravelly sandy loam;
Loam or Very fine sandy loam or silt loam;
Clay loam or Very fine sandy loam or silty clay loam;
Clay or silty clay or Heavy clay

MAP SYMBOL	$\frac{\text{Acl}}{\text{Mh4}}$	Brown soil (A) developed on clay loam (Cl) morainal (M) material with humocky surface form (h) and slopes of 4-9%.
	150	The polygon number (150) refers to extended legend information.

Table 4. Alternative Legend (closed format)

MAP LEGEND

MAP SYMBOL AND COLOR	TEXTURE[1] GROUP	GENETIC MATERIAL	SURFACE[2] FORM	SLOPE CLASS
A. BROWN CHERNOZEMIC SOILS DEVELOPED ON:				
Asl/Gh4	sandy loam	GLACIOFLUVIAL	hummocky	4-9 %
Asl/Gk10	sandy loam	GLACIOFLUVIAL	knoll and kettle	10-15%
Asl/Gul	sandy loam	GLACIOFLUVIAL	undulating	1-3 %
Asl/Gu4	sandy loam	GLACIOFLUVIAL	undulating	4-9 %
Alm/Ld4	loam	LACUSTRINE	dissected	4-9 %
Alm/Lh4	loam	LACUSTRINE	hummocky	4-9 %
Alm/Lk16	loam	LACUSTRINE	knoll and kettle	16-30%
Alm/Lul	loam	LACUSTRINE	undulating	1-3 %
Alm/Md4	loam	MORAINAL	dissected	4-9 %
Alm/Md10	loam	MORAINAL	dissected	10-15%
Alm/Mh4	loam	MORAINAL	hummocky	4-9 %
Alm/Mh16	loam	MORAINAL	hummocky	16-30%
Alm/Mk4	loam	MORAINAL	knoll and kettle	4-9 %
Alm/Mk10	loam	MORAINAL	knoll and kettle	10-15%
Alm/Mk16	loam	MORAINAL	knoll and kettle	16-30%
Alm/Mm4	loam	MORAINAL	rolling	4-9 %
Alm/Ed4	loam	EOLIAN	dissected	4-9 %
Acl/Lh4	clay loam	LACUSTRINE	hummocky	4-9 %
Acl/Md4	clay loam	MORAINAL	dissected	4-9 %
Acl/Md10	clay loam	MORAINAL	dissected	10-15%
Acl/Md16	clay loam	MORAINAL	dissected	16-30%
Acl/Mh4	clay loam	MORAINAL	hummocky	4-9 %
Acl/Mh10	clay loam	MORAINAL	hummocky	10-15%
Acl/Mh16	clay l oam	MORAINAL	hummocky	16-30%
Acl/Mk4	clay loam	MORAINAL	knoll and kettle	4-9 %
Acl/Mk10	clay loam	MORAINAL	knoll and kettle	10-15%
Acl/Mk16	clay loam	MORAINAL	knoll and kettle	16-30%
Acl/Mm4	clay loam	MORAINAL	rolling	4-9 %
Acl/Mul	clay loam	MORAINAL	undulating	1-3 %
Acl/Mu4	clay loam	MORAINAL	undulating	4-9 %
Acy/Lh4	clay	LACUSTRINE	hummocky	4-9 %
AcY/Lul	clay	LACUSTRINE	undulating	1-3 %
Acy/Lu4	clay	LACUSTRINE	undulating	4-9 %
B. DARK BROWN CHERNOZEMIC SOILS DEVELOPED ON:				
Bsl/Gh4	sandy loam	GLACIOFLUVIAL	hummocky	4-9 %
Bsl/Gul	sandyd loam	GLACIAL FLUVIAL	undulating	1-3 %
Bsl/Mk10	sandy loam	MORAINAL	knoll and kettle	10-15%
Blm/Lk4	loam	LACUSTRINE	knoll and kettle	4-9 %
Blm/Lul	loam	LACUSTRINE	undulating	1-3 %
Blm/Md4	loam	MORAINAL	dissected	4-9 %
Blm/Mh4	loam	MORAINAL	hummocky	4-9 %

British Columbia Report to ECSS - November, 1983, Ottawa

H. Lutterding

First of all, I would like to extend my thanks and appreciation to Terry Lord for acting in my stead as the official B.C. representative at the 1983 ECSS meetings. Restraint policies in B.C. prevent my attendance - travel authority for provincial employees to attend functions outside of BC is effectively curtailed, particularily if the costs are to be borne by the provincial government. In this regard it would be beneficial for ECSS to consider making funds available for official representatives to attend national meetings. This would free them from the dependance on policies, whims and budgets of their individual organizations whose priorities may not place ECSS very high on the list. Similar comments can apply to members of Working Groups although it is realized that funding could become expensive - perhaps Working Group chairmen could be assured funds so they periodically can meet with their Group members on a regional or local level.

Some highlights re soil survey and related progress since the 1982 meeting include:

1) CAPAMP (Computer Assisted Planning and Map Production) is operational with soil polygon and soil descriptive data now entered in the system for Lower Fraser Valley, parts of Vancouver Island and Similkameen areas. Computer derived/interpreted maps and summaries for erosion potential (based on USLE), irrigation requirements, soil sensitivity to acidification and wildlife habitat have been produced. Agricultural soil management groupings and crop suitability maps are currently under development.

2) A revised Soil Capability for Agriculture methodology manual has been developed and adopted for use in B.C. The manual, a modification from the CLI, gives definitive limits regarding subclasses in relation to capability classes, especially with regard to available soil water holding capacity, climate moisture deficit, coarse fragment content and topography. It also incorporates the notion of ease (or difficulty) of soil management

and also includes a modification for application in areas climatically suited for tree fruit and grape production.

3) Approximately two 1:250,000 map-sheets in northwestern BC have been mapped at a Survey Intensity 5 as part of an overview of soil and terrain conditions for input into a now-shelved Ministry of Environment strategic plan for the area. Part of the area, with some funding from B.C. Hydro, was mapped to provide a basis for wildlife habitat evaluation and wildlife capability. In conjunction, a methodology manual for conducting broad scale soil survey is in preparation.

4) Wildife related surveys and providing soil-terrain basis for wildife interpretations are increasingly becoming priorities with the provincial survey organization, partially because both are within the same Ministry. Surveys for other resource users seem to be decreasing due in part, I feel, to a "charge-back" system being initiated for the soil survey services. Existing reconnaissance soil surveys were updated during 1983 to provide more soils detail in the Similkameen-Ashnola, Riske Creek and Salmon River areas as a basis for wildlife habitat, capability and enhancement studies.

5) The detailed soil survey of eastern Vancouver Island has so far escaped severe funding cuts and is on-going. The project, funded mainly by Ministry of Agriculture and Food, is designed to provide detailed agriculture capability information for "fine-tuning" Agricultural Land Reserves as well as other soils related information required for agricultural and urban uses. Field work this year concentrated in the Qualicum Beach-Courtenay area while the interim report covering the Duncan-Nanaimo portion is nearing completion.

6) A parallel high intensity soil survey of the Gulf Islands by the federal soil survey unit has produced digitized soil maps and a draft report for Saltspring Island. Field surveys have been completed on the Penders, Mayne, Saturna, and Galiano island groups. Surveys to complete work on Gabriola and intermediate islands south of Nanaimo will be carried

out in 1984-85. The reports and soil maps covering these five project areas of the southern Gulf Islands Group provide important soils information and interpretations to land planners, farmers, the Land Commission and other resource users.

7) Further activities of the Vancouver Pedology Unit were concentrated in the interior and northeast parts of the Province as follows:

- In the Cariboo area, publication of the Quesnel soil report and completion of companion reports of medium intensity surveys for the Horsefly and Barkerville areas has aided foresters and other resource managers at the regional planning level. Follow-up studies were carried out on identification and interpretation of interior wetland systems throughout the plateaus.
- In the northeast, revised soil maps and a report for Fort St. John-Dawson Creek were completed and field checking and revisions were done under contract for the McAllister-Graham area in high priority coal lands of the foothills. These lands that are now under pressure from logging, strip mining and hydroelectric power development include sensitive fish and wildlife habitats. In addition to continuing soil erosion studies in the Dawson Creek-Beaverlodge area, the B.C. pedology Unit met a request from the provincial ministry of agriculture for detailed soils information and revised agriculture capability in the Pine valley west of Chetwynd. A late news flash (Nov. 8) claimed that flooding of prime (Class 1 and 2) agricultural lands in the Peace valley has been deferred for at least 10 years by placing the Site C dam on hold.

The federal unit cooperated in the provincial CAPAMP program to provide expertise and editing service for derived and interpretive maps in federally surveyed areas.

As you know BC has their own Soil Information System in place. The system however is not directly compatible with CanSIS and much of the data in the BC system is not in CanSIS . Providing the compatability between BCSIS and CanSIS is not a priority of the province, particularly in light of current funding and staffing restrictions and cutbacks. I feel, however, that a substantial data gap exists in the national CanSIS file because of the limited BC data that it contains. I would therefore like to suggest that CanSIS explore the ramifications and perhaps provide the mechanisms for conversion of data (especially detailed profile descriptions and associated laboratory analyses) from BCSIS to CanSIS.

Substantial progress is being made in developing a Soil Survey Course at UBC which emphasizes the field aspects of survey-identification, mapping and description, together with interpretations. The course, being spear-headed by Keith Valentine and others of LRRI in Vancouver, in conjunction with the Soils Dept., UBC results from concerns expressed regarding the lack of practical soil survey field experience available to many soils graduates.

In February, 1983, more than 150 enthusiastic participants attended a 2-day Soil Science workshop on soil degradation at Harrison Hot Springs in the Fraser Valley. The meeting, sponsored jointly by the Land Resource Science and Engineering Science lead committees, was convened by Agriculture Canada, the Department of Soil Science, U.B.C., and the B.C. Ministry of Agriculture and Food. The occasion also marked the inaugural meeting of the newly incorporated Pacific Regional Society of Soil Science under its first president Charlie Rowles. The 113 charter members include four Albertans and two Americans.

H.A. Luttmerding

November 1983

Expert Committee on Soil Survey

Manitoba Report

G. F. Mills

This report briefly outlines Manitoba's position regarding program and service requirements related to land resource research, development and management. The direction and emphasis for soil survey activities is discussed in terms of coordinating 3 main program components with emerging provincial issues and concerns.

The scope of provincial concerns is currently being identified by a Soil and Water Resources Task Group formulated to initiate discussion leading to a federal-provincial agreement on agricultural development in Manitoba. Although 17 "issues" of either soil or water management have been identified, no priorization has been made at the present time. In addition, the provincial Soil Survey Advisory Subcommittee has priorized three components of the soil survey program for input to an updated Land Resource Research Strategy for Manitoba. The Research Strategy is currently being revised by the Soil Science Lead Committee and is to be submitted to the Manitoba Agricultural Services Coordinating Committee as the main research and development recommendation for 1984. The three components of the Research Strategy directly related to the soil survey program in Manitoba are:

1. Accelerated soil inventory
2. Land evaluation
3. Data handling systems

Current Issues and Concerns

1. Inventory

Basic soil inventory continues to be a research priority in Manitoba. The provincial emphasis for soil survey continues to reflect as it has for many years, the need to maintain a strong inventory program. A perennial shortfall between inventory capability and requests for soil survey data has been documented in Manitoba for several years and reinforces the need to accelerate the survey program.

Resurvey of high priority areas in southern Manitoba has been the main emphasis of the survey program in recent years. These high intensity surveys provide detailed soil information for planning purposes for agricultural land use and for resolving rural-urban land use allocation problems in the agricultural sector of the Province. Although the Province is making every effort to maintain the existing survey effort, to date no progress has been made in accelerating the rate of survey.

The Province recognizes the need to improve the interpretation and application of soil survey information. Detailed surveys with adequate interpretation are critical for planning intensive land use in agriculture and all urban-rural conflect areas. The soil survey is responding to this need by devoting greater effort to soil characterization studies. More quantitative soil data derived from these studies, particularly information concerning soil physical properties, provides the information required for planning and developing soil management programs related to issues identified by the Soil and Water Resources Task Group. Some of these issues are:

1) The need to reduce soil erosion by wind and water.
2) The need to develop irrigation technology for Manitoba conditions.
3) The need for water management in terms of drainage control and improvement and soil moisture management in terms of moisture conservation.
4) The need to maintain or enhance productivity on salt affected soils.
5) The need to develop optimum water management techniques and cultural practices as they relate to agricultural use of organic soils.

Programs to deal with each of these issues depend on detail soil inventory data or more detailed soil characterization studies or both. The soil information required to deal with these issues is also critical for interpreting soil data for non-agricultural uses related to urban planning and development.

To date, increased effort in the area of soil characterization has been achieved mainly with existing staff supplemented by casual and part-time technical assistance to the survey. The need to accelerate soil survey activities to provide detailed description of Manitoba soils earlier than present rates of activity will permit, has been identified as an issue by the Soil and Water Resources Task Group. Two potential initiatives are proposed to deal with this isue:

1) Examine alternative possibilities to increase the rate of acquiring soil survey field data and the preparation of accompanying reports. This responsibility would be assumed by the soil survey.

2) Establish a program activity to fund financial and manpower requirements of an accelerated soil survey program. This initiative would be assumed by the Federal and Provincial departments of agriculture currently responsible for the soil survey program.

2. Land Evaluation

The soil survey has been cooperating for the past 3 years with the Department of Soil Science at the University of Manitoba in developing a quantitative land productivity modelling procedure for Manitoba. Allocation of soil survey resources to development of this land evaluation technique recognizes a need identified in the updated Land Resource Research Strategy for a more quantitative measure of soil productivity for agriculture.

The land evaluation project currently in place takes into account soil characteristics of mapped soil units, climate and soil management. The model has potential for wide application as it can be used for determining new land potential for increased production as well as assessing individual farm field productivity under various systems of management.

Soil survey data is required as critical input to the land productivity model. The model is now moving beyond the research and development phase into a validation phase in which its application will be tested on a wide range of agricultural soils. Cooperation by soil survey will continue through this phase to:

1) Participate in evaluating the adequacy of the model to predict potential yields on a wide range of soil types.
2) Establish homogeneous land units for applying the model on a province-wide basis.
3) Provide soil survey data required by the model, and,
4) To increase the level of detailed soil characterization, particularly of soil physical properties, which is a critical input to the model.

The land evaluation program and the opportunities it presents for enhancing agricultural production in Manitoba is also identified as an issue by the Soil and Water Resources Task Group. The Task Group has identified several potential initiatives requiring support as use of the model moves into a testing and validation phase. Among the potential activities are:

1) To assist the Manitoba Crop Insurance Corporation in establishing premium rates which reflect potential crop yields based on soil information, management and the probability of obtaining these yields as these factors are considered by the computer model.

2) To provide a standard model emphasizing improved productivity indices upon which tax assessment may base taxes of agricultural land.

3) To assist the Provincial Soil Testing Laboratory in advising farmers by providing them with more accurate information about obtaining expected yields related to fertilizer inputs in each unique soil-climate situation.

4) To provide the Canadian Wheat Board with probable yields and total production of specific areas as weather changes.

Support for the land evaluation program has been derived mainly from an operating grant from Agriculture Canada to the Soil Science Department. There has been no provincial support to the program to date other than participation by soil survey personnel. However initiatives identified by the Soil and Water Resources Task Group indicate growing interest by the Province and hopefully support will be forth coming.

3. Data Handling Systems

Automated data handling capability continues to develop for in-house use by soil survey. Development and utilization of an effective data information system is essential to the land inventory, to a successful land resource research program and ultimately to effective communication with users of soil survey data.

Manitoba currently makes use of all files available in the Canada Soil Information System (CanSIS). However the operational capability of certain files in the system is often limited by inadequate programming support. Support for the data handling component of the soil survey program is shared by the Provincial Department of Agriculture and Agriculture Canada. The source of this support relates to the location of particular files and hardware and whether the file deals with national concerns or local or regional concerns. Some files are completely operational, others require additional programming to become operational and some files require greater adaptability by survey staff to maximize the usefulness of the data in the file. Specific requirements for increasing the operational capability of CanSIS are outlined in the updated Land Resource Research Strategy for Manitoba (1984). A major recommendation contained in the Research Strategy to be submitted by the Soil Science Lead Committee to the Manitoba Agricultural Services Coordinating Committee (MASCC) is "to support maintenance of CanSIS at the University of Manitoba." The intent would be in using computer facilities at the University of Manitoba, to retain use of programming expertise currently provided by the Province in support of CanSIS. This arrangement would make most effective use of computerized soil and land resource data for land use interpretations and evaluations.

The soil survey organization has recognized the need to utilize automated data processing techniques as an essential part of its program for several years and much progress has been achieved to date. However, progress towards becoming operational in several new files has been slow. In addition, the Province has not identified as a current issue, any increase in level of support to CanSIS.

It appears however that research initiatives proposed to deal with various Provincial issues identified by the Land and Water Resource Task Group are dependent on increased use of a quantitative land and soil information base. Potential activities arising from these issues require automated data processing techniques to effectively utilize available soil and land resource data for specific uses such as:

1) Land degradation studies - soil erosion
   - soil salinization
   - soil sensitivity to acidification
2) Water Management programs related to drainage improvement and control (surface and groundwater) and to soil moisture management.
3) Irrigation technology relating to scheduling, tile drainage design, crop water use, and soil salinity control.
4) Provision of soil information required by quantitative programs of land evaluation.

Provincial programs established to address these kinds of soil and water related issues require access to quantitative soil and land resource data. Much of this data is stored in soil survey computer files reinforcing the need to increase support to CanSIS in Manitoba and bring all files up to an operational status. Clearly any acceleration of the soil survey program should ideally be balanced by increased support to the data handling component of the program.

PROVINCIAL CONCERNS IN SASKATCHEWAN

J.G. Ellis

- Formulated by the Soil Survey section of the Saskatchewan Institute of Pedology

CONCERN NO.1 Saskatchewan needs an increase in professional and technical staff if the inventory and interpretation of the soils in the province is to be accomplished at an adequate rate to assist the need for increased agricultural production. We estimate that with our present staff we would require 25 years provided they have no additional commitments. This situation is compounded by the need to carry out interpretative research and provide interpretative maps on acid soils, salinity, erosion, etc., and incorporate these into ongoing inventory.

It is therefore respectfully submitted that provisions be made for additional support to be provided for surveys, interpretations, analyses, cartography, data handling, so that the following ongoing projects can be resolved and new projects initiated.

1. Inventory and Research on acid soils of west-central Saskatchewan (73C).

2. Inventory and Research on the soils of south-eastern Saskatchewan (62L and K).

3. Basic and Northern Soil Survey Publication Series:

Green Lake-Waterhen River	(73J-K)
Amisk-Cormorant Lake	(63K-L)
Hudson Bay-Swan Lake	(63C-D)
Swift Current	(72J)
Weyburn-Virden	(62E-F)

4. Soil Correlation and Mapping Research (classification, nature and origin of Saskatchewan soils).

5. Evaluation of Agricultural Land.

6. Properties and Distribution of Saline Soils in Saskatchewan.

7. Long-Time Effects of Agriculture on Saskatchewan Soils.

In Saskatchewan, we have taken the approach that we will try to continue with all these projects simultaneously. While this decreases the rate of basic inventory collection it does address provincial and farm operator concerns and allows the production and incorporation of recent research in interpretative maps on salinity, acid soils, erosion, etc. The latter approach seems to be an essential function of the Saskatchewan Soil Survey: it slows up map production but produces a more meaningful map.

CONCERN NO.2 That working Groups and their membership are established without sufficient Provincial consultation. This has resulted in an under-representation of University and Provincial personnel in the composition of the ECSS executive and working groups.

CONCERN NO.3 That the present format of ECSS meetings be reviewed to identify why:

1. Working Groups cannot meet regionally in locales where the problem and the researchers are most available instead of concurrently with annual meeting.

2. The need for annual ECSS meetings.

CONCERN NO.4 That there is a lack of interaction between the ECSS and ECSM; and the ECSS and ECA.

CONCERN NO.5 The "Mechanism" for implementation and reporting back to the Provincial representatives needs to be improved.

CONCERN NO.6 That the proposal to house the "Prairie Soil and Water Institute" might not be confirmed for the University of Saskatchewan Campus.

QUEBEC

Dominique Carrier

Dans le domaine de la pédologie, les activités des trois composantes de l'IRPQ peuvent se résumer comme suit:

1. Equipe provinciale (Service de recherche en sols du MAPAQ)

A - <u>Inventaire et cartographie des sols</u> (Etat d'avancement des travaux et publications)

Le bulletin technique et la carte pédologique du comté d'Arthabaska sont déposés pour publication. Les levers pédologiques du comté de Mégantic ($\simeq$190,000 ha) sont terminés et une première rédaction du rapport va être effectuée au cours de l'année. Les travaux de cartographie ont débuté dans le comté de Beauce; toute la partie au nord de St-Joseph a été couverte durant l'été, soit un secteur d'environ 52,000 ha. La cartographie des sols dans le comté de Frontenac est aussi à un stade avancé. Toutes ces études sont réalisées à l'échelle 1:50,000e. Entrepris au printemps 1983, le projet "Abitibi-Témiscamingue" est une réponse au voeu et au désir de l'Union des Producteurs agricoles de cette région de se doter d'une étude pédologique apte à orienter le développement agricole et à guider la diversification des cultures. A date, l'équipe pédologique a effectué une tournée générale de ce vaste territoire en vue d'apprécier globalement l'éventail des principaux sols sous culture. Les principaux sols décrits et cartographiés dans les secteurs limitrophes de l'Ontario ont également été visités en vue d'en évaluer l'équivalence et l'extension en territoire québécois.

B - <u>Projets spéciaux</u>

— Le besoin d'une meilleure caractérisation des différentes roches-mères de sols développés sur les tills des Appalaches a amené les pédologues à établir un programme d'échantillonnage en vue de corriger cette déficience. Actuellement, près de 400 échantillons de ces horizons de sols provenant des comtés d'Arthabaska, Mégantic, Lotbinière, Beauce, Frontenac et Dorchester ont été prélevés pour analyses.

— Les sols à horizons fragiques, duriques, à ortstein et cimentés-intergrades sont en étendue considérable au Québec. Des recherches sont en cours pour déterminer la nature des agents liants en cause et leurs pourcentages relatifs, de même que pour évaluer les propriétés minéralogiques, micromorphologiques et ultramicroscopiques spécifiques à chacune de ces couches indurées. Parallèlement à ces travaux, des cases lysimétriques ont été installées en vue d'évaluer l'importance du cycle biogéochimique sur la formation des horizons B-podzoliques.

2 - Equipe fédérale (Institut de Recherches sur les Terres au Ministère de l'Agriculture du Canada)

A - Inventaire et cartographie des sols

La carte préliminaire du comté de Richelieu est disponible sur demande. Elle est publiée sous forme de mosaïque photographique au 1:20,000e et comprend une légende sous forme de tableau. Durant l'été 1983, la cartographie détaillée (1:20,000e) du comté de Verchères a été complétée à 85%, tandis que celle de reconnaissance (1:50,000e) a été effectuée dans le comté de Chambly. D'autre part, dans le cadre d'un projet d'inventaire des tourbières, vingt dépôts organiques de la Vallée du St-Laurent ont pu être étudiés et caractérisés.

B - Projets spéciaux

— Deux projets d'Eté-Canada ont été supervisés par les membres de cette équipe. Le premier avait pour but de mesurer les propriétés physiques de certains sols sous culture de betterave à sucre et le second visait à développer un logiciel en APL pour faire des rapports statistiques sur les sols et unités cartographiques caractérisés par la méthode des transects.

— Un membre de l'équipe s'est également occupé à mettre à jour la classification pédologique de 15 sites au Centre d'Interprétation Ecologique de Port-aux-Saumons dans Charlevoix.

C - Divers

— Une tournée pédologique dans les comtés de Richelieu et Yamaska a permis de réunir de nombreux utilisateurs de la carte, de leur faire connaître les travaux en cours et de discuter de différents aspects de la classification et de l'utilisation des sols de cette région.

— D'après les nombreuses demandes acheminées au bureau de cette équipe, il existe un grand besoin de cartes interprétatives pour aider les Municipalités régionales de Comté à établir leur plan d'aménagement et aussi de cartes d'aptitudes de sols aux cutlures, en particulier pour celle de la betterave sucrière.

3 - Equipe de l'Université (Département des Sols de la Faculté des Sciendes de l'Agriculture et de l'Alimentation de l'Université Laval)

A - Inventaire et cartographie des sols

Deux projets ont été réalisés dans ce secteur. L'un a consisté à développer des unités de possibilités agricoles et d'aménagement pour les sols de l'Ile d'Orléans, l'autre a résulté en la proposition d'une nouvelle méthode de classement du potentiel agricole de sols marginaux et des sols très productifs dans les Basses-Terres du St-Laurent.

B - Projets spéciaux

— Des travaux de recherches sont effectués sur l'altération des minéraux argileux et sur la caractérisation des sols argileux.

— Des études micromorphologiques sont également poursuivies sur certains horizons diagnostiques.

— Des techniques de l'analyse multivariable ont été utilisées pour la classification des séries de sols.

— Des propriétés pédogénétiques ont été mises en relation avec la coloration des sols.

C - Divers

Tel qu'énoncé dans son plan triennal, le Département des sols désire avoir une équipe permanente en pédologie afin d'être considéré vraiment comme un membre à part entière et devenir plus actif au sein de l'IRPQ.

Priorités de recherches de l'IRPQ

Les besoins de recherche s'identifient en définitive à ceux présentés par la section de pédologie à la Commission des Sols du CPVQ (Conseil des Productions végétales du Québec). Ces priorités comprennent la cartographie détaillée et semi-détaillée des sols minéraux et organiques; l'évaluation et l'utilisation des sols et des terres; la dégradation et la réhabilitation des sols.

1983-11-08.

Nova Scotia

Department of Agriculture and Marketing

Soils and Crops Branch

PO Box 550
Truro, Nova Scotia
B2N 5E3

902 895-1571

MEMORANDUM

4.5

TO: Delmar Holmstrom

FROM: A. Schori A Schori

DATE: November 8, 1983

RE: Concerns re soil survey and related matters

This is in response to your request last week regarding concerns of this department in the area of soil survey and related activities. I understand that you will bring these items to the attention of the Expert Committee on Soil Survey.

Our concerns are listed in priority under the headings of Staffing and Tasks.

STAFFING:

(1) We are pleased that the position of Head, Nova Scotia Soil Survey has now been filled. The vacant position (formerly Mr. Webb) should be filled immediately.

TASKS:

(1) The process to select a consultant(s) for the Soil Evaluation and Mapping Project under the AFDA Agreement is now underway. Staff of the Federal Soil Survey Unit at Truro have responsibility as scientific authority. This work must be given very high priority as quality control is essential to ensure that the final product will be useful to farmers, planners and others.

(2) The soil map and report for Colchester County must be completed as soon as possible.

(3) The soil map and report for Pictou Co. must be completed as soon as possible

(4) Correlation for the Hants County Soil Survey must be completed in the early summer of 1984.

(5) NSDAM does not foresee a requirement for additional 1;50,000 scale soil surveys in Nova Scotia. However, the Federal Soil Survey Unit must maintain a capability to conduct detailed (scale 1:20,000, etc.) surveys for selected areas of the province. It will probably be necessary to conduct detailed surveys upon request from time to time in areas other than which will be mapped under item #1 above.

(6) The soil research effort in Nova Scotia must be increased. The major research requirements are in the areas of: management of wet soils; the impact of soil

physical properties (inherent and induced) on soil productivity and means of alleviating these impacts; and cost effective comprehensive soil management practices.

AS/cl

c.c.: J. D. Johnson
K. T. Webb
J. Day

NOT FOR PUBLICATION

EXPERT COMMITTEE ON SOIL SURVEY

Annual Report presented
to CCLRS
December 1983

Note: This report is an internal working document and does not reflect the view of the federal or provincial department of Agriculture, the university or other federal department of industry.

SUMMARY OF ECSS HIGHLIGHTS SINCE LAST REPORT

Brochures	- Soil Surveys Can Help You and Soil Surveys For Ranchers and Farmers were published.
Soil Survey Handbook	- Compilation was completed for Sections 100 (Soil Surveys in Canada), 200 (Planning) and 400 (Operations).
Generalize Soil Landscapes	- Maps compiled for Saskatchewan and Manitoba were merged with extended computer legends to facilitate retrieval of single or multi factor derivative maps.
Soil Degradation	- Criteria were tested in the field. Estimates of costs due to erosion in Ontario were shown to exceed $68 M annually.
CanSIS	- Manual for describing soils in the field (including the SWIG classification) was revised and published in English and French.
Correlation	- Soil survey form 1 was published and used extensively for documenting new project plans.
Methods Manuals	- Draft copies were documented for SWIMM, Irrigation suitability and Soil Temperature Measurement.

ANNUAL REPORT OF ECSS 1982-83

The Fifth Annual Meeting of the ECSS included both working group sessions and a business meeting. The priority working groups dealing with soil degradation, forestry interpretations and soil climate were held concurrently on Monday, November 14 to Wednesday, November 16, 1983. Progress reports and business items were presented during the Business Meeting on November 17-18.

SOIL DEGRADATION

The major soil degradation causes were addressed including erosion, salinity, acidification, compaction, contamination and organic matter loss. Each working group member associated with a specific cause served as chairman and discussion leader for the session dealing with that topic. All aspects of soil survey involvement in soil degradation was discussed. Invited speakers included Dr. M. Webber, Environment Canada, Burlington; Dr. E. de Jong, University of Saskatchewan, Saskatoon; and Dr. B. McGill, University of Alberta, Edmonton.

Actions:

1. National level:

   Small scale "overview" maps have been prepared as follows:

   - water erosion in Ontario (1:1,000,000)
   - salinity in Manitoba (1:1,000,000)
   - salinity risk in Saskatchewan (1:500,000)
   - water erosion in B.C. Peace River region (1:100,000 to be compiled at 1:1,000,000)
   - wind erosion risk in Alberta (excluding Peace River Region), Saskatchewan and Manitoba (1:1,000,000).

2. Regional level:

   i) In routine survey procedures, the following actions have been taken:
      - List of tentative soil degradation identification methods were prepared and evaluated during 1983 field season.
      - All surveys (except Newfoundland) are making estimates of soil erodibility in ongoing soil surveys.
      - Salinity is being mapped in the Prairie Provinces. Steps were taken to standardize methods and criteria, including a field identification tour held in Saskatchewan.

   ii) Special studies:
      - A project has been carried out in Ontario to determine past erosion and develop methodologies which may be used elsewhere by soil surveys.

- A special salt survey at 1:50,000 has been undertaken in Manitoba to be compiled with salinity data from soil surveys and the soil testing lab for eventual publication at a scale of 1:500,000.

- A special study carried out in Ontario estimated the cost of soil erosion to the agricultural sector to be $68 M annually.

Requirements:

1. National level:

   Small scale map preparation will proceed to the extent possible. This requires:

   - agreement to be obtained on a standard classification system, set of criteria and legend for salinity, water erosion and acidification.
   - investigation of land use data for 1981 Census at a level sufficiently detailed to apply to wind and water erosion maps to estimate current (1981) soil movement.
   - data compilation to prepare preliminary wind and water erosion hazard maps at a scale of 1:1,000,000 for those areas still not covered.
   - preparation of an adequate 1:1,000,000 soil base map of Québec for degradation assessment purposes.

2. Regional level

   Improve utility of routine soil surveys for degradation assessment and interpretations by:

   - continuing all sampling and analyses of soils at an improved frequency and with adequate analyses for organic matter, structure, acidity, salinity and contamination to be assessed.
   - relating soil structure observations and soil physical data whenever possible to identify structure degradation (compaction) in the field.

3. Both National and Regional

   Prepare a set of criteria for evaluating potential "benchmark" sites for degradation monitoring. Compile a list of existing sites that might serve as degradation "benchmark sites".

FORESTRY INTERPRETATION

Priority interpretations previously identified by the Group included those pertinent to engineering, silviculture and hazzards due to mass movement windthrow, flooding or erosion resulting from forest management. It was concluded that regional guidelines for interpretive purposes should be based on Geographic Administrative Regions rather than natural physiography.

Actions:

- Engineering interpretations for logging road construction and off-road transportation were reviewed and concluded to be near completion.
- Methodologies for silvicultural interpretations to site productivity and for windthrow hazzard were accepted in principle.
- An outline for a Manual on the above Forestry Interpretations was prepared. It is to include case histories documenting methodologies used in the various "Regions" and the current information gaps.
- Postponed some silvicultural interpretation for species suitability pending further clarification of their relationship to soil and other biological factors.
- Postponed interpreting soil limitation for forest regeneration and slope stability.

Concerns:

- The cautious approach concerning the latter two Actions reflect basic information data gaps relating vegetation response to both soil and management factors.
- Operational forestry requires information from soil surveys conducted at high intensity levels. In contrast, surveys in forested areas are usually conducted at low intensity levels. Consequently, mapping methodologies for forestry interpretations must be reviewed.
- To liaise and integrate with the Canadian Forestry Inventory Committee.

This working group suggested that it cease to be on the priority list, but continue to provide guidance to periodic revision of the Interpretation Manual.

SOIL CLIMATE

Working group activities focussed on regional progress reports, a review of criteria and principles used in soil climate classification schemes, data handling concerns and the requirements for a more comprehensive methods manual.

Actions:

- By 1984, to expand the provisional manual documenting methods for measuring soil temperature to include benchmark site descriptions and CanSIS compatible data collection procedures.
- Maintain soil temperature monitoring network according to procedures described in the methods manual.
- Test techniques for estimating mean annual soil temperatures from quarterly measurements.
- Input soil temperature backlog data to CanSIS.

Concerns:

- Increased support be allocated to soil survey multi-purpose benchmark monitoring activities according to documented procedures.
- Increased liaison be developed with the Expert Committee on Soil and Water Management and the Expert Committee on Soil and Water of the CCAES.
- Expansion of existing AES soil temperature network.

This Working Group suggested that it cease to be on the Priority list but persist on a continuing basis during the data collection period.

Thursday, November 17. The Business Meeting consisted of progress reports and invited papers which will be published in the Proceedings:

Soil Organic Matter Loss in Alberta	W.B. McGill
Prairie Soil and Water Research Institute	J.L. Nowland
Forestry Interpretations	H. Krause
Soil Degradation	R. Coote
Soil Climate	G. Mills
Irrigation Suitability Rating	R. Eilers
Soil Water Investigations Group	R. Eilers
Mapping Systems	K. Valentine
Soil Survey Handbook	G. Coen
PFRA Soil Degradation Program in the Prairies	C. Arshad

Friday, November 18. A closed Business Meeting was attended by ECSS members and several resource persons. Opportunity was given to express concerns arising from progress reports presented on Thursday or those of relevance provincially or nationally. Some of the concerns are summarized as follows:

- Lack of provincial representation on each working group; this matter will be reviewed.
- Liaison be established with the Canadian Forestry Inventory Committee; the chairman will pursue this concern.
- Lack of coordination among Agencies investigating soil salinity in the Prairies; advice and coordination is required from the provinces.
- Increase in backlog of Detailed Soil Descriptions input to CanSIS; the provincial representatives were supportive of continuing entry of these descriptions to CanSIS on a timely basis. Federal soil survey management is also assigning data input responsibilities.
- Vacant positions not being refilled create problems impacting on all soil survey activities; documented support from provincial Deputy Ministers is desirable.

Working Group Priorities were then reviewed:

Forestry Interpretations
Soil Degradation
Soil Climate
Mapping Systems
Handbook
Irrigation Suitability
Soil Water Investigations Group

Brochures
Classification
Generalized Soil Landscape Maps
Correlation
Laboratory Quality Control
CanSIS - Computer Application
Agronomic Interpretation (a new one)

The following Working Groups were established as Priorities for the next three years:

Soil Degradation
Mapping Systems
CanSIS - Computer Applications
Agronomic Interpretations.

It was also concluded that Working Groups documenting as Manuals, etc. should continue in an active mode to the publication stage within the next year or two:

Irrigation Suitability
Soil Water Investigations Group
Forestry Interpretation
Soil Climate

Correlation
Brochures
Handbook

RECOMMENDATIONS: A number of recommendations were put forward. They were arranged in two groups:

1. Those pertaining to internal ECSS Working Group activities:

   1.1 That the northern portion of Soils of Canada Map be updated.

   1.2 That the landform classification be reviewed and organic landforms be added.

   1.3 That all soil survey units submit Detailed Profile Descriptions to CanSIS on a timely basis.

   1.4 That the Correlation Group compile an inventory of multipurpose Benchmark Monitoring Sites.

   1.5 That formal liaison and coordination with the National Forest Inventory Committee, the Expert Committee on Soil and Water Management and the Expert Committee on Soil and Water (CCAES) be pursued.

2. RECOMMENDATIONS submitted to CCLRS for R and D:

   2.1 That Canada Agriculture through the Canada Committee on Land Resource Services, undertake to develop a cooperative federal-provincial land resource research program involving the reassigning of priorities and reallocation of resources to achieve the objectives for effective land management and to implement the land resource development priorities of the Agri-Food strategy.

   Background: The requirement to improve and conserve the land resources of Canada to meet world challenges for food production have been recognized in the CARC Strategy for Land Resource Research, the Agri-Food Strategy and the Canada Wheat Board Symposium on market potential for grain production in Canada. Proposals have been put forward for funding a program for the development, management, and conservation of agricultural lands under the Agri-Food Strategy. With the current economic situation, there is little likelihood of obtaining major additional resources, and new initiatives will have to be achieved by the reallocation of existing resources according to priorities. The importance of sound land resource management, the orderly development of the country's agricultural land reserves, and the improvement and preservation of all agricultural land resources have been clearly recognized as key components of any future development programs for Canadian Agriculture. It is considered critical that steps be taken as soon as possible to implement the above reallocation in order that Canada can respond to the market opportunities for agricultural products.

2.2 That Agriculture Canada support research required for the preparation of generalized provincial or regional maps showing salinity, acidificaton sensitivity, critical levels of organic matter and hazzard for wind and water erosion.

Background: Soil surveys in Canada are improving dramatically in systematics, applications and benefit/costs, but now encounter a major constraint in displaying the extent of land degradation and conservation needs. There is rapidly growing awareness among resource agencies and the informed public of the seriousness of land degradation for the future of agricultural production and environmental quality. Some priorities for evaluation of degradation, and technical constraints to be overcome, have been determined, others require enhanced research, and only a small portion of the required inventory and research can be accomplished by reallocation of existing resources.

2.3 That Agriculture Canada expand its research programs in soil management in all regions of Canada. It is also recommended that the current work in soils and all expanded activities be developed under the soil-management objective of the Research Branch to ensure the appropriate focus and orientation to soil research.

Background: Efforts are being made in all regions of Canada to improve the viability, efficiency and productivity of agriculture. The effective utilization, improvement and preservation of the soil and water resources is a fundamental requirement if these objectives are to be realized. The importance of improving soil and water management practices in Agriculture, if Canada is to achieve its Agri-Food objectives, has been fully and clearly documented in the Land Resource Research Strategy prepared for CARC. Little progress has been made in the implementation, the strategy, and the current level of work in all areas of soils is considered seriously inadequate.

Work on all aspects of soil management must be rapidly expanded. Information on tillage, maintenance of fertility, improved drainage techniques, more efficient water use, management of salinity, prevention of acidification, control of erosion and the general degradation of soils, is urgently required as a basis for planning and managing agricultural development and production in all regions of the country. It is also considered essential that work on soil management be developed on an interdisciplinary basis to ensure that research in soils and related fields of economics, engineering and plant science is integrated to assure the establishment of viable farming systems that allow the effective utilization, preservation, and enhancement of soil and water resources.

2.4 That Agriculture Canada establish a national soil conservation program to provide applied research, technology development, conservation planning, and farm development services to ensure the maintenance, improvement and development of Canada's land resources.

Background: There is growing concern over the general deterioration of the land resources. Water erosion is a serious problem in all regions of Canada. Dryland salinity is increasing due to current agricultural practices. Improvement of agricultural production in eastern Canada requires improved land drainage. In all regions there is a requirement to adapt and apply existing technology to develop improved production technology and new farming systems.

The soil conservation program must embody both technology development and liaison with provincial agricultural extension agencies. It must also provide developmental support to allow implementation of regional and on-farm programs, and practices, that will ensure the maintenance or improvement of agricultural productivity and the protection and preservation of Canada's agricultural land resources.

In the view of the Committee, the program requires initiation without delay. It is proposed that the program could be established by the reorganization and redeployment of existing staff and resources in the departement supplemented by appropriate orientation of development programs.

2.5 That Agriculture Canada provide the required resources to allow acceleration of soil survey and the development of the required data handling and land evaluation capability for the application of land resource information for agricultural planning and management.

Background: Soil Survey information is essential for planning, implementing and managing agricultural production. In all regions of Canada there is a serious lack of sufficiently detailed and up to date information required to meet the needs for planning and directing agricultural development, for the effective management of farm operations, for erosion and salinity control, for preserving agricultural land, and other agricultural and non-agricultural applications.

There is need for an accelerated soil survey program and an increased capability to manage and apply soil survey and related resource information, policy planning development, and production management needs.

It is considered essential that Agriculture Canada undertake to expand its activities in soil survey and land evaluation in order to provide leadership in directing policies and programs for agricultural development and improvement in all regions of Canada.

2.6 That Agriculture Canada financially support attendance of provincial representatives at ECSS meetings during times of severe provincial financial restraint.

Background: Participation of provincial and university representatives at ECSS meetings is highly desirable to ensure that provincial concerns are put forward and incorporated into Committee activities. Those Provincial inputs comprise an important contribution to the sustenance and growth of essential Committee involvements.

The Provinces have provided financial support for their representatives under normal economic circumstances. However, severe financial constraints currently in effect in some provinces, prevented their members from attending this meeting. To avoid recurrence of this unfortunate problem it is proposed that a fund be provided to finance attendance of such provincial members similar to that which provides for attendance of University members.

OTHER BUSINESS

Membership: The term of the following members ended after the CASCC meeting in June 1983.

R.E. Smith; R. Baril; K. Webb; J.S. Clark

Appointments include G. Mills; D. Carrier; D. Holmstrom and J.S. Clark.

The current membership list is given in Appendix 1

LOCATION OF NEXT MEETING:

Place: Guelph, Ontario
Time: Mid-late November 1984

Government of Canada   Gouvernement du Canada

MEMORANDUM   NOTE DE SERVICE

SECURITY - CLASSIFICATION - DE SÉCURITÉ	
OUR FILE — N / RÉFÉRENCE	
YOUR FILE — N / RÉFÉRENCE	
DATE	September 26, 1983

TO / À: J. Dumanski
Secretary CCLRS

FROM / DE: Jack Shields
Secretary ECSS

SUBJECT / OBJET: Membership List of Expert Committee For Soil Survey

The current members, full addresses and termination dates are listed below:

	Regional members	Term ends*
B.C.	H.A. Luttmerding Terrestrial Studies Branch B.C. Ministry of the Environment 1873 Spall Road Kellowna, B.C. V1Y 4R2	1985
Alta.	T.M. Macyk Soil Survey Unit, Agr. Canada 6th Floor, Terrace Plaza Tower 445 Calgary Trail South Edmonton, Alberta T6H 5C3	1984
Sask.	J.G. Ellis Research Scientist Saskatchewan Institute of Pedology University of Saskatchewan Saskatoon, Saskatchewan S7N OWO	1985
Man.	G.F. Mills Canada Manitoba Soil Survey Soil Science Building University of Manitoba Winnepeg, Manitoba	1986
Ont.	R. van den Broek Ontario Institute of Pedology Guelph Agriculture Centre University of Guelph, Box 1030 Guelph, Ontario N1H 6N1	1985

	Regional members	Term ends*
Que.	D. Carrier Service de la recherche en sol du MAPA 2700, rue Enstein, B-1-28 Saint-Foy Québec, G1P 3W8	1986
N.B.	J.L. MacMillan Land Resources Division N.B. Dept. of Agriculture Research Station P.O. Box 6000 Fredericton, N.B.	1984
N.S.	D.A. Holmstrom Canada Soil Survey Res. Branch, Agr. Canada Nova Scotia Agricultural College Truro, Nova Scotia B2N 5E3	1986
P.E.I.	A.T. Raad Pland and Industry Branch P.E.I. Dept. of Agriculture Box 1600 Charlottetown, P.E.I.	1985
Nlfd.	A. Stewart Soil & Land Management Div. Dept. of Rural, Agricultural & Northern Dev. Prov. Agricultural Building Brookfield Road Mount Pearl, Nfld. A1C 5T7	1985
	Departmental representatives	
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INA	I. Sneddon Resource Inventory Manager Land Management Division Northern Water, Lands and Forests Indian and Northern Affairs Hull, PQ K1A 0H4	

EMR	R. Fulton Terrain Sciences Division E.M.R. 601 Booth Street Ottawa, Ontario	
P.F.R.A.	L. Chambers P.F.R.A. Motherwell Building 1901 Victoria Ave. Regina Saskatchewan S4P 0R5	
	Departmental representatives	Term ends*
Chairman	J.S. Clark (Reappointed) Land Resource Research Institute Central Experimental Farm Ottawa, Canada K1A 0C6	1986
Secretary	J.A. Shields Land Resource Research Institute Central Experimental Farm Ottawa, Canada K1A 0C6	1985

* End of term occurs following the spring meeting of CASCC

Attendance

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C.A.S. Smith	Canada Yukon Soil Survey	Whitehorse

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T. Ballard	Dept. of Soil Science	Vancouver
L. Lavkulich	Dept. of Soil Science	Vancouver
R.H. Louie	B.C. Ministry of the Environment	Kelowna
T.M. Lord	Canada Soil Survey	Vancouver
H.A. Luttmerding	Terrestrial Studies, M. of Envir.	Kelowna
D. Moon	Canada Soil Survey	Vancouver
P.N. Sprout	Ministry of Environment	Victoria
R. Trowbridge	B.C. Forestry Service	Smithers
K. Valentine	Canada Soil Survey	Vancouver
L. Van Vliet	Canada Soil Survey	Vancouver
T. Vold	Ministry of Environment	Victoria

Alberta

G. Coen	Alberta Canada Soil Survey	Edmonton
R. Fessenden	Soil Survey Unit	Edmonton
W. Holland	Northern Forest Research Centre	Edmonton
R. Howitt	Soil Survey Unit	Edmonton
T.M. Macyk	Soils Dept. Alberta Res. Council	Edmonton
W.B. McGill	Dept. of Soil Science	Edmonton
G. Patterson	Alberta Canada Soil Survey	Edmonton
W.W. Pettapiece	Alberta Canada Soil Survey	Edmonton
D.J. Pluth	Dept. of Soil Science	Edmonton

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L. Chambers	P.F.R.A.	Regina
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W.R. Fraser	Canada Manitoba Soil Survey	Winnipeg
G.F. Mills	Canada Manitoba Soil Survey	Winnipeg
R.E. Smith	Canada Manitoba Soil Survey	Winnipeg
H. Velhuis	Canada Manitoba Soil Survey	Winnipeg

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