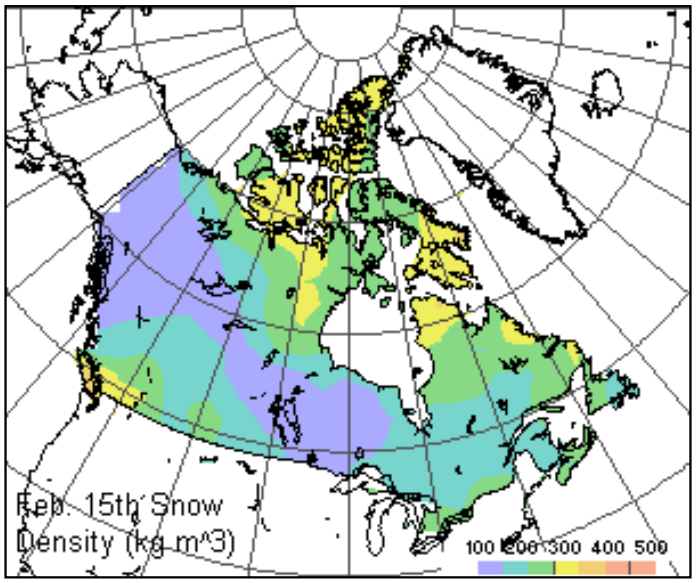
Environment Canada | Environnement Canada

Canadian Snow Water Equivalent Database
Main Documentation



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A Data Rescue Effort Sponsored By
The CRYSYS Project
(Use of the Cryospheric System to Monitor Global Change in Canada)

Database Methodology

Introduction

Reliable measurements of the "water equivalent of snow on the ground," or snow water equivalent (SWE) are important for a variety of scientific and practical applications including the calculation of building snow loads, hydrological and flood forecasting and studies of climate change. Because of these practical dimensions, large effort has historically been put into the collection of Canadian SWE data by a variety of agencies across the country including provincial environment ministries, hydro companies and federal bodies. Between 1955 and 1985, the Atmospheric Environment Service (AES) coordinated a synthesis of snow course data from agencies across Canada, including AES, through its publication of *Snow Cover Data* bulletins each year.

In 1994-95, a project was undertaken to digitize the data from the AES *Snow Cover Data* books and combine it with whatever other digital snow course data was available from other data-collecting agencies. However, because of the diversity of data standards, units and formats among the contributing agencies, unit conversion errors and keypunching errors both in the *Snow Cover Data* books and in their digitization, and the general lack of important documentation, this dataset was of poor quality and was unattractive to potential users.

In order to address this issue, in 1996-1997, a nine-month project was undertaken to perform rigorous quality control on all of the available Canadian SWE data. Systematic errors in the data units, keypunching and station locations were eliminated; data formats were harmonized; and station history files were created with all available station information. The resulting database is reliable and should be useful to a variety of users. The quality control process as well as the final products are described in this document.

The Datasets

Snow water equivalent or SWE is defined as "the depth of water resulting from the melt of a column of the snow

cover" (Schmidlin 1990). SWE measurements are more costly and time-consuming than simple ruler measurements of snow depth because multiple samples are taken along a preset tract, referred to as a snow course. Most agencies which collect snow course data, aside from AES, take about 5 to 40 samples, each consisting of a snow core and a snow depth measurement. The snow cores are weighed and a conversion factor is used to compute SWE in a depth unit. Mean values of SWE and snow depth are then calculated for the whole course.

AES conducts its snow surveys slightly differently. AES snow courses consist of five points. Snow cores taken at each point are placed in a bucket providing a total weight for the five samples. From this weight a mean is determined. This method is prone to higher error. For example, if one core is in error the entire course is in error since all the samples are integrated. If SWE is determined for each core and then all SWEs averaged, one could identify an error more readily and recompute the mean for the course.

Snow courses are laid out such that they are generally representative of the surrounding terrain. In areas of variable vegetation, often two courses are taken and averaged, one in the open and one in the forest. All snow course data consist of a station ID, name and location, a snow depth measurement and a SWE measurement. Snow density can be computed from these values by taking the SWE/snow depth ratio.

Available digital snow course data consisted of the digitized *Snow Cover Data* books, a file of snow course data for about 150 AES stations which picks up where the *Snow Cover Data* books left off, and data from five other agencies in a variety of formats. These data sources are summarized in Table 1. The bulk of the data is derived from the *Snow Cover Data* books. These books consist of snow course data submitted yearly to AES by over twenty agencies across the country between 1955 and 1985. Figure 1 summarizes the temporal and spatial distribution of the data in the Canadian SWE Dataset.

Table 1. Summary of snow course data included in digital dataset

Data Source	Period	Number of Records	% Total
AES Snow Cover Data books	1955-85	130,005	56.3%
British Columbia Environment	1935-96	42,534	18.4%
Ontario Ministry of Natural Resources	1957-93	28,358	12.3%
Atmospheric Environment Service	1985-94	12,638	5.5%
Environment New Brunswick	1955-94	8,480	3.7%
Alberta Environment	1937-90	6,714	2.9%
Indian and Northern Affairs Canada	1965-97	2,137	0.9%

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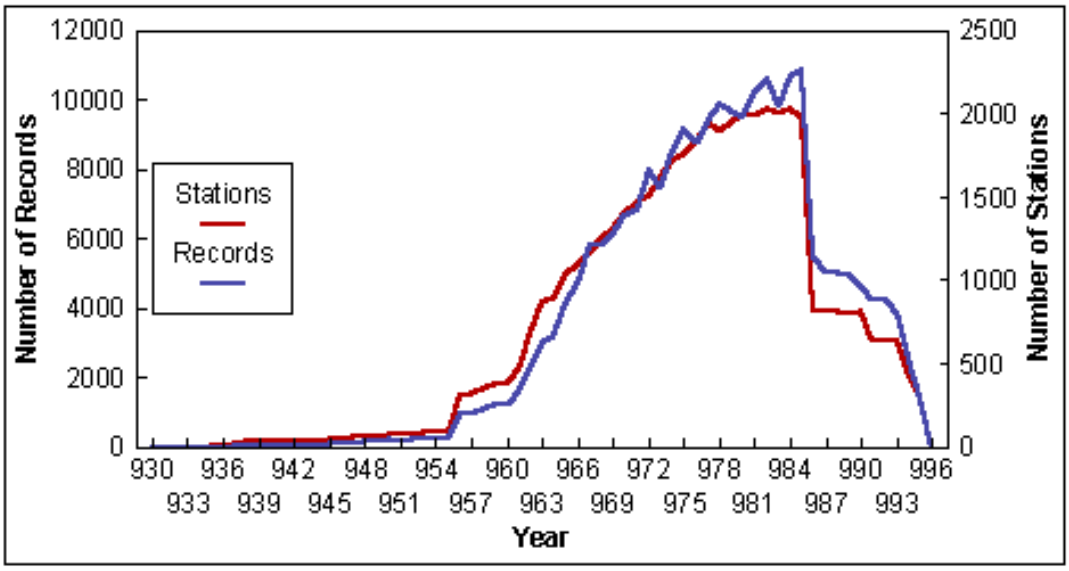
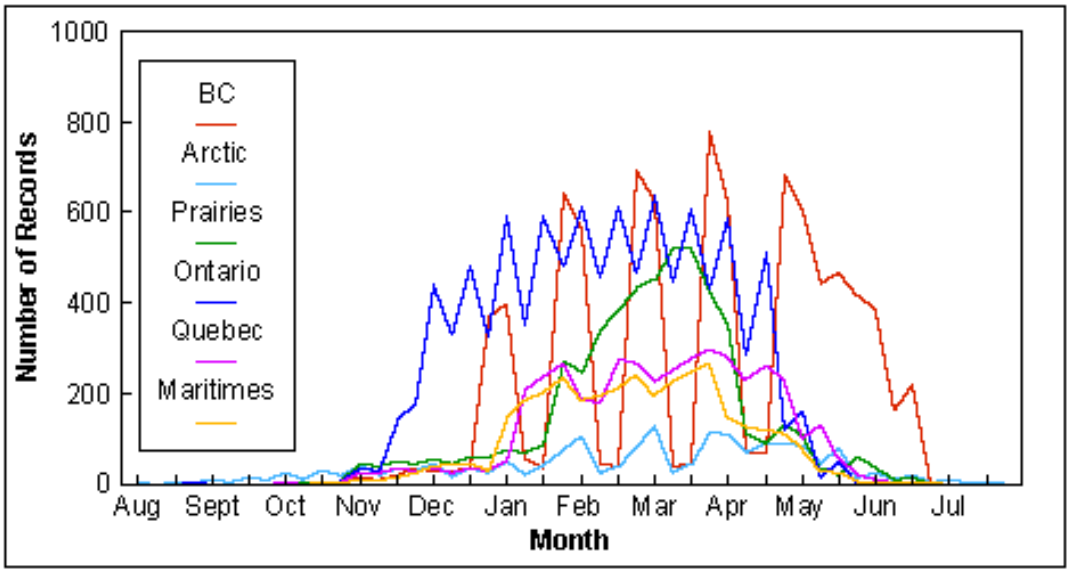
a)


Number of Records
Number of Stations
Year
Stations
Records
12000
10000
8000
6000
4000
2000
0
2500
2000
1500
1000
500
0
930 933 936 939 942 945 948 951 954 957 960 963 966 969 972 975 978 981 984 987 990 993 996

b)


Number of Records
Month
BC
Arctic
Prairies
Ontario
Quebec
Maritimes
1000
800
600
400
200
0
Aug Sept Oct Nov Dec Jan Feb Mar Apr May Jun Jul

c)

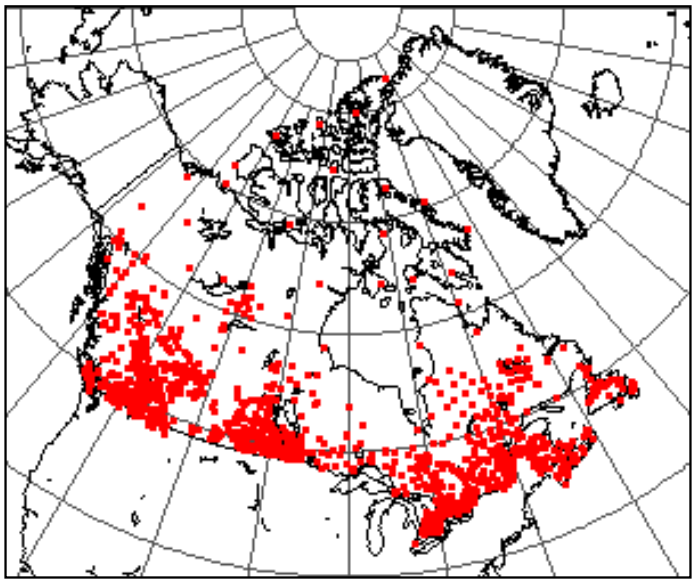


Figure 1. Spatial and temporal distribution of data in the Canadian Snow Water Equivalent Dataset: a) Numbers of stations and records by year; b) Numbers of records by week and region; c) Locations of all stations with at least ten years of data in the database (1935-1995).

Quality Control

The type of quality control technique required varied with each source of data. The general technique for all of the snow course data, however, was

- to eliminate systematic errors in the snow course measurements, through automated processes wherever possible and through manual verification when automation was not possible;
- to flag suspicious values which may be caused by random measurement or typographical errors so that these data could be avoided and;
- to correct errors in the station names and locations, concatenate stations whose data had been split among 'sub-stations', and summarize all available station information in station history files.

The particular techniques used for each type of data are described below followed by the quality control flags used to mark suspicious data which were used across all data sources.

a. Data from the Snow Cover Data Books

The data from the *Snow Cover Data* books were digitized via a roundabout route increasing the possibility of errors being made along the way. Each year, a variety of agencies would collect snow course data for their own needs. At the end of the year they would fill out AES snow course data sheets and send them into AES. The data were then converted into the correct units, rounded by hand, and typed into the *Snow Cover Data* templates. In 1994-95, these books were sent out for digitization and the data was re-typed into ASCII computer files. This process resulted in a host of errors in both the station information and the snow course data.

Station information was especially problematic because it was retyped into the *Snow Cover Data* books each year from handwritten notes at the top of the snow course data sheet, rather than being stored in a central station information file. This resulted in multiple typographical errors in station names and locations as well as many correct, yet different permutations of the same station. Table 2 shows a typical example of all the different listings in the *Snow Cover Data* books over the years for the same station. This situation presented two problems: firstly errors had be fixed; and secondly stations with

slightly different names or locations which were actually the same station had to be concatenated.

Table 2. Typical permutations of the same station in the *Snow Cover Data* books.

Name	Latitude	Longitude	Elevation
ST JEAN DE LAC-2	64 34	75 34	850
ST JEAN DU LAC	46 34	75 32	251
ST JEAN DU LAC 2	46 34	75 34	259
ST JEAN DU LAC-2	46 34	75 34	259
ST JEAN SUR LAC LIEVRE	46 34	75 32	251
ST JEAN SUR LE LAC	46 43	75 23	250
ST JOHN ON THE LAC	46 43	74 31	259
ST JEAN-DU-LAC	46 43	74 34	250

In order to correct typographical errors, stations were sorted by name and by location and every unique name-location combination was visually examined and compared to its sorted neighbours. Where errors were obvious (such as the switched digits in the latitude or the unmetricated elevation in the first example in Table 2), the change was made immediately. Where the data were suspicious but the correction less obvious (such as the longitude in the last example in Table 2), the *Snow Cover Data* books, the AES station catalogue and a Canadian atlas were consulted in that order. Of the 7,202 stations examined, 22% of the names, 9% of the positions (lat/long) and 7% of the elevations were corrected. A record was kept of every correction made and correction files were created. Database users may, if necessary, refer to this file to verify all corrections made to station information.

An automated process for combining data records from each year into stations with continuous temporal records was made difficult by the slight variations in the name and position listed for the same station from year. The process was further complicated by more than one agency collecting data at the same location, and similar names (like Spring Creek, Clear Lake, Field, etc.) proliferating all over the country. These factors made it necessary to use a manual station concatenation technique similar to the error-fixing process. Sorted lists of station names and positions were produced along with summaries of the period of data for each 'sub-station'. These lists were perused and in consultation with the *Snow Cover Data* books, stations with similar information and with complementary periods of data were merged. In all, 7,202 unique station name-location combinations were manually examined and merged into 2,128 stations. After concatenation, each station was assigned a unique ID and all station shifts and name change data were recorded in a station history file.

The convoluted route to digitization of the data in the *Snow Cover Data* books also resulted in many systematic errors in the actual snow course data. Several methods were used to identify these systematic errors:

- Density time series were plotted for a sampling of stations from across the country to look for step changes;
- Snow depths were compared to those at surrounding stations with snow depth measurements in the AES Canadian Climatological Data archive;
- Where overlap existed, data from the *Snow Cover Data* books was compared to data from the other five agencies;
- Data were compared to other measurements at the same station and same time period and outliers were identified and;
- Values which were outside of reasonable limits were identified.

From this process, four major systematic problems with the data were identified:

- Non-winter data had been entered into the wrong columns and thus the wrong months for five of the books;

- In certain years and regions unit conversions were not always made when the books said they were;
- In certain years and regions decimals were used inconsistently and, as decimals had been ignored in the keypunching process, this resulted in many errors of a factor of 10;
- Provision had not been made in the keypunching template for summer data (from July-October) and it had not been punched at all. This was only important at Arctic stations.

It was possible to fully automate correction of the first problem by re-extracting the data from the keypunched files with a 'smarter' extraction program. For the fourth problem no automation was possible and all summer data (July - October) were entered manually.

Fixing the second and third problems was more complicated. The sheer volume of data affected precluded a manual approach but there was also no way to fully automate the process. The solution was to use a paritially-automated approach. Because both problems resulted in a factor of ten error in the computed density (before unit conversion, both snow depth and SWE were in inches, but after conversion snow depth was reported in cm while SWE was reported in mm), obviously incorrect densities could be used to detect affected records. However, this routine only worked where densities were unambiguously wrong. For example densities greater than 1000 kg m^{-3} had to be incorrect because they are physically impossible. A density of 500 kg m^{-3}, however, is ambiguous because it could be correct - but so could 500/10 or 50 kg m^{-3}. Such ambiguous densities had to be manually verified. By scrutinizing the *Snow Cover Data* books, it was possible to reduce this manual work by isolating only a few years and regions where each problem occurred. Fortunately, there was no instance where the problems overlapped.

b. AES Data

AES snow course data were received in digital form for the period after publication of the *Snow Cover Data* books had halted (1986-1994). These data continued the record for approximately 150 AES stations published in the *Snow Cover Data* books. In order to merge these data with the previous dataset, an automated station search was performed based on station name, agency and position. Where the search results produced only one possibility, data were merged immediately. If more than one station was identified by the search routine, the correct station was selected manually with the aid of the AES station catalogue. Station history files were then updated with the new station information.

Similar checks to those used for the data from the *Snow Cover Data* books (described above) were done for the AES snow course measurements and one systematic error was found affecting approximately one quarter of the data. A unit conversion factor had been applied to the wrong column in the data-entry software. A routine was written to automatically correct this error. After the application of this routine, the data appeared to be free of systematic problems.

c. Data From the Other Five Agencies

Generally, snow course data from the other five agencies were of a much higher quality than either the data from the *Snow Course Data* books and AES. Each of the contributing agencies had already applied their own quality control standards and corrected most errors. Most of the agencies had provided station information files and these were simply extracted and converted to a common format. The station files were scanned manually for problems and a few obvious errors in station locations or unmetricated station elevations were detected and corrected. The snow course measurements were also examined for systematic errors using the methods described above. The only problem detected was a difference in the definition of the snow season at three of the agencies (where fall data were actually listed with the same year as winter data for that snow season, eg. December 15 1960 actually referred to December 15 1959). This problem was easily corrected through an automated routine.

d. Quality Control Flags for Random Errors

After systematic errors had been eliminated in the snow course data, quality control flags were used to flag suspicious

values possibly caused by random measurement or typographical errors. A one character quality control flag was assigned to each of snow depth and SWE. Three sorts of flags were used: green flags indicating that there was no detected problem with the data; yellow flags indicating that the data were suspicious but not necessary wrong; and red flags indicating that the data were almost certainly incorrect. Please see Table 3 for a summary of these flags.

Table 3. Summary of quality control flags assigned to snow course data

Flag	Interpretation	
blank	GREEN FLAG	No detectable problem with measurement
3,4,5,6,7,8,9	YELLOW FLAG	Measurement is a suspicious outlier. Flag = 3-8 - measurement is between flag and flag+1 standard deviations from the mean for that two-week period at that station. Flag = 9 - measurement is greater than 9 standard deviations from mean.
R,D	RED FLAG	Measurement is outside reasonable limits and is likely wrong. Flag=R - SWE or snow depth are outside limits as follows Snow depth: 0-300 cm (0-800 cm for Rocky Mountain stations) SWE: 0-3000 mm (0-8000 mm for Rocky Mountain stations) Flag=D - computed density is outside of 10-1000 kg m-*3*.

To assign the yellow flags, each SWE and snow depth measurement was compared to those in the same two-week period at the same station for all years . Each outlier, defined as a measurement which was more than three standard deviations from the mean, was assigned a yellow flag consisting of a number between 3 and 9. A QC flag of between 3 and 8 means that the measurement in question is between *flag* and *flag+1* standard deviations away from the mean of all measurements in the same two-week period at the same station. A flag of 9 means that the measurement is greater than 9 standard deviations from the mean.

Red flags, R or D, were assigned based on reasonable limits for each of the parameters. An R flag indicates that the measurement is outside of reasonable limits and a D flag means that the snow density calculated using this measurement exceeds preset bounds. For snow depth in most of the country, values outside 0-300 cm were flagged. This is the standard range for snow depth used in the Canadian Climate Archive. It was found, however, that this flag was often triggered by apparently correct measurements in the Rocky Mountains. For stations in the Rockies (defined as any station west of 113° W longitude), manual verification revealed that values exceeding 700 cm were not uncommon and 800 cm was set as the maximum bound.

Density flags were assigned when densities were either below the minimum of 10 kg m^{-3}, given by McKay and Gray (1981) for wild snow and used by Schmidlin (1994) in his quality control of snow course data, or above 1,000 kg m^{-3}, the value for pure ice. Many researchers suggest a maximum snow density of around 700 kg m^{-3} (eg. McKay and Gray 1981; Schmidlin 1995). However, when this value was used for the upper density bound, the density flag was triggered frequently, particularly for stations with low snow depths and stations located in the St.-Lawrence Valley. Verification of several original paper snow course reporting forms for AES stations with high densities revealed that densities between 700 kg m^{-3} and 1,000 kg m^{-3} are in fact possible when icy conditions prevail, although densities may be exaggerated by greater measurement and rounding errors at low snow depths.

The red flag for SWE was assigned when measurements lay outside of 0-3000 mm for most of the country and 0-8000 mm

for the Rocky Mountains. These values are simply the combination of the maximum snow depths and densities.

A summary of QC flags by region, data source and year revealed no obvious trends indicating that all of the systematic errors in the snow course data have likely been removed. Table 4 summarizes the flags by data source and reveals that error levels are low, less than 1% in all cases.

Table 4. Summary of red and yellow quality control flags assigned by data source

Data Source	% Of Total Flagged Red or Yellow
AES/Snow Cover Data books	-
BC	0.21
Arctic	0.43
Prairies	0.34
Ontario	0.12
Quebec	0.16
Maritimes	0.23
British Columbia Environment	0.03
Ontario Ministry of Natural Resources	0.18
Environment New Brunswick	0.14
Alberta Environment	0.04
Canadian Ministry of Indian and Northern Affairs	0.00

Gridded Snow Density Normals

A database of gridded snow density normals was created from the snow course data. Grids were created for the 1st and 15th of the month between November 15th and May 15th inclusive. There was insufficient data to create grids before November 1st or after May 15th. All measurements were used which were within one week of the date of calculation. Snow densities were averaged over the entire period of record for all stations with a least five years of measurements for the calculation date. Average snow densities were then interpolated to a 200 km grid using the Shephard interpolation routine. Although snow course stations do not fully represent the actual topographical range of the Canadian terrain, snow density is a smooth variable and can be interpolated across topography more successfully than snow depth or SWE.

Estimated Snow Water Equivalent Data

Snow depths from the Canadian Daily Snow Depth Database were used with snow density measurements from the Canadian Snow Water Equivalent Database to create an estimated snow water equivalent dataset. This dataset was created at a biweekly frequency with measurements on the 1st and 15th of the month. Snow depth measurements had to be either observed values or reconstructed values within one week of an observed snow depth to be used.

SWE was calculated at snow depth observing stations by interpolating snow density from surrounding snow course stations using an inverse distance weighted average of all snow courses within 200 km and one week of the snow depth measurement date. Where there were no stations fitting this description, the gridded snow density normals (described in previous section of this document) were used to estimate snow density by performing an inverse distance weighted average of the four nearest grid points. An SWE flag was used to specify which method was used for each estimated SWE value. A flag of 'I' means that the density was interpolated from surrounding stations with data on the same date. A flag of 'C'

indicates that densities were based on the gridded snow density climatology.

It is argued that this approach is more successful than simply interpolating SWE values to stations in the Canadian Daily Snow Depth Database. The snow course stations do not fully represent the actual topographical range of the Canadian terrain. Since SWE is strongly linked to elevation, interpolating it across topography could result in large errors. However, because snow density is a much smoother variable, it interpolates better across changing elevation. By combining interpolated snow densities with measured snow depths, it is therefore possible to provide much better estimates of SWE than would result from directly interpolating the SWE measurements in the SWE database.

The estimated SWE data were subjected to the same quality control flagging as the observed dataset to detect errors. Estimated SWE data are maintained in a separate dataset in the same format as the observed dataset.

Sample Products

Several plots were produced from the Canadian SWE Dataset to provide examples of possible output. Figure 2 shows plots of gridded snow density normals for three dates. Figure 3 shows interpolated SWE for a five-year period between 1969 and 1973 in southern Ontario. Data from all stations with at least three years of data within this period were interpolated to a 32 km grid also using the Shephard interpolation routine. The density of stations and lack of significant relief in southern Ontario makes interpolation of SWE in this local area reasonable.

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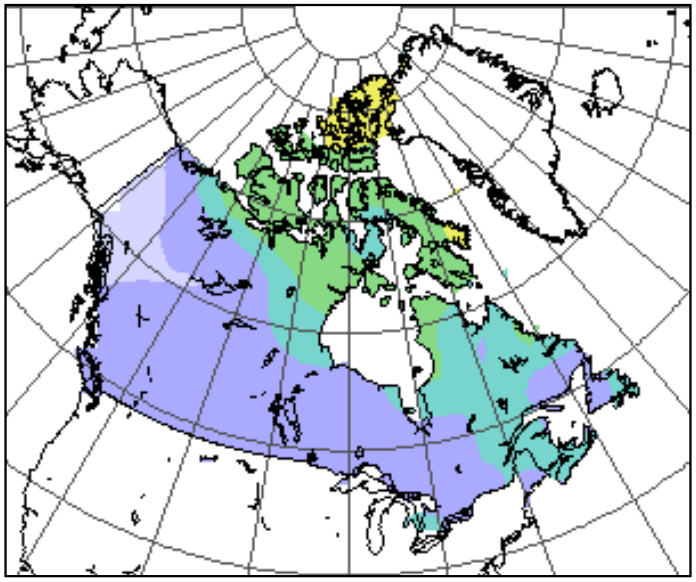
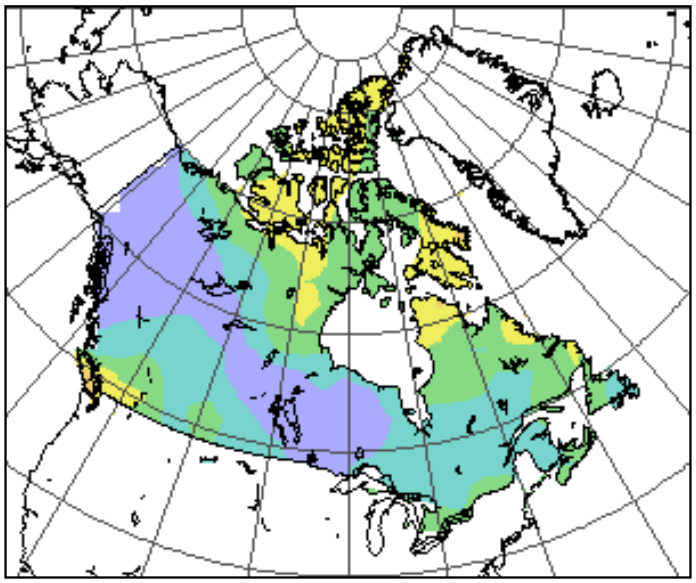
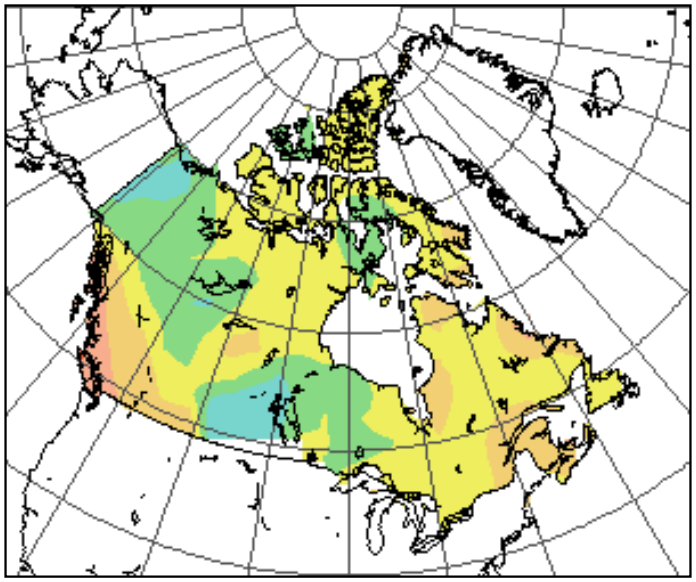
a) December 1st



b) February 15th



c) May 1st



d) Legend (in kgm^{-3})

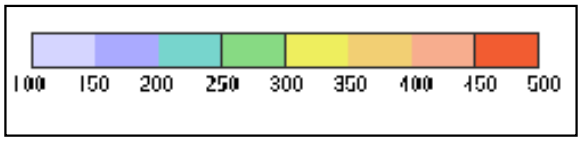


Figure 2. Sample Canadian snow density climatologies for: a) Dec. 1st, b) Feb. 15th and c) May 1st, with d) the corresponding legend.

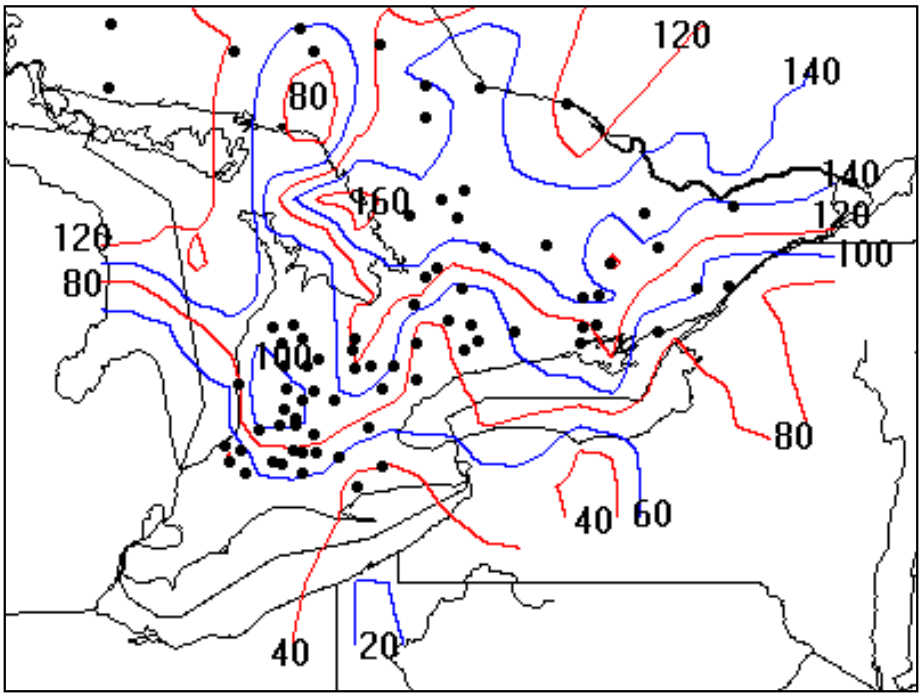


Figure 3. Sample gridded snow water equivalent for Southern Ontario 1969-73 (mm). Dots represent locations of stations used in the computations

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References

Ferguson, H.L and B.E. Goodison. 1975. Mean snowpack water equivalent and snow course data problems over Southern Ontario. *Proceedings of the Eastern Snow Conference 1975*. 91-110

Hartman, R.K., A.A. Rost and D.M. Anderson. 1996. *Spatial distribution of snow water equivalent observations in mountainous terrain.* Unpublished paper from National Operational Hydrologic Remote Sensing Center, Office of Hydrology, National Weather Service (USA).

McKay, G.A. and D.M. Gray. 1981. The distribution of snowcover. *Handbook of Snow: Principles, Processes, Management and Use*. D.M. Gray and D.H. Male, Eds., Pergamon, 153-190.

Reuna, M. 1994. An operational grid method for estimation of the areal water equivalent of snow. *Geophysica*. **30**, 107-121.

Schmidlin, T.W. 1995. Automated quality control procedure for the "water equivalent of snow on the ground" measurement. *Journal of Applied Meteorology*. **34**, 143-151.

Schmidlin, T.W. 1990. A critique of the climatic record of "water equivalent of snow on the ground" in the United States. *Journal of Applied Meteorology*. **29**, 1136-1141.

Other Sources of North American Snow Survey and SWE Information

Canada

The British Columbia Ministry of the Environment maintains a web page with updated BC snow survey measurements: British Columbia Ministry of Environment: Water Home Page

Snow survey data collected by Environnement Québec are available for a small fee. Please contact:

M. Paul Lamb
Environnement Québec
Direction du milieu atmosphérique
Édifice Marie-Guyart, 5e étage
675, boulevard René-Lévesque Est
Québec (Québec)
G1R 5V7
plamb@riq.qc.ca
(418) 521-3826 extension 4583

United States

Snow survey data for several states is available on the World Wide Web:

California Department of Water Resources: California Snow Page

State of Maine Snow Surveys

USDA Utah Snow Surveys

USDA Idaho Snow Surveys

USDA Colorado Snow Surveys

USDA Montana Snow Surveys

USDA Oregon/Washington Snow Surveys

Also two sources from the Northeast Regional Climate Center:

McKay, M., D.S. Wilks and T.W. Schmidlin, 1994. *Quality-controlled snow water equivalent data for the Northeastern United States*. Northeast Regional Climate Center Data Set DS 93-1. 5 pp.

Wilks, D.S. and M. McKay. 1994. *Atlas of extreme snow water-equivalent for the Northeastern United States*. Northeast Regional Climate Center Research Publication RR 94-1, 11 pp.

Database Description

Database Structure

The database consists of the following file types:

- **Observed SWE Data**
  - **Observed SWE Files** - Snow depth and SWE measurements from snow courses taken by six agencies across Canada.
  - **Station Catalogue File** - Station information and history for all stations with observed SWE data.
  - **File/Record Index File** - File location, start record and end record of data for each station with observed SWE data. Used for direct access.
- **Estimated SWE Data**
  - **Estimated SWE Files** - Biweekly snow depth measurements and SWE estimates at stations from the Canadian Daily Snow Depth Database. SWE estimates are based on snow depth measurements from the Canadian Daily Snow Depth Database and interpolated snow densities from the Observed SWE Dataset.
  - **Station Catalogue File** - Station information and history for all stations with estimated SWE data.
  - **File/Record Index File** - File location, start record and end record of data for each station with estimated SWE data. Used for direct access.
- **Gridded Snow Density Normals Files** - Gridded snow density normals at biweekly frequencies computed from the Observed SWE Dataset.
- **Original Raw Data Files** - The original raw data files from the six agencies used to create the observed SWE Dataset. All files are in the original format as received from the contributing agencies.
- **FORTRAN Files** - Sample FORTRAN extraction software and sample FORTRAN code for reading data files. Not compiled.

Data Extraction

This CD-ROM is intended to be a data archive only and extensive data extraction tools are not provided. **Data extraction is the responsibility of the CD-ROM user**. As a data extraction aid, this CD-ROM contains some sample FORTRAN 77 software for data summary and extraction and sample code for reading each data file type. These programs are intended as examples of possible data manipulation software and may be modified to suit the user's needs. All software is provided uncompiled and may have to be modified to operate on different platforms. The code was originally written for a PC-DOS system using Microsoft FORTRAN Powerstation 4.0.

Station IDs

Eleven-character station IDs are used in both the observed and estimated SWE datasets.

Station IDs for the observed SWE data are a composite of the agency of origin and the original station ID assigned by that agency where available. The first three characters specify the data's origin as follows:

ALE Alberta Ministry of Environment
BCE British Columbia Ministry of Environment
ENB Environment New Brunswick
INA Canadian Ministry of Indian and Northern Affairs
ONR Ontario Ministry of Natural Resources
SCD Data collected by the Atmopheric Environment Service from agencies across the country and archived in the *Snow Cover Data* publication series from 1956 to 1986. These data were keypunched and combined in a 1995 AES project. Stations which are operated by AES have been updated to 1994.

The last seven characters contain, where available, the original station ID assigned to that station by the agency of origin. In the case of data from AES/*Snow Cover Data*, for which no IDs were provided, the two character postal abbreviation for

the data's province is used followed by a three digit number. The Environment New Brunswick data also had no IDs and a three digit number was assigned to this field. The ID "ONR-0308" thus refers to data collected by the Ontario Ministry of Natural Resources at a station identified by that organization by the code "0308". "SCD-NT001" refers to an AES/*Snow Cover Data* station in the Northwest Territories and "ENB-001" refers to a station maintained by Environment New Brunswick for which no original ID is available.

Station IDs for the estimated SWE data consist of the prefix "AES", followed by the original AES station ID from the Canadian Daily Snow Depth Database (eg. AES-2100100).

File Descriptions

The Canadian Snow Water Equivalent Database is located in the \SWE Directory on the CD-ROM. All files are in formatted ASCII format with fixed record length. Zeros are not used as placeholders.

Observed SWE Data

Overview

Observed SWE data are located in the \SWE\OBS_SWE directory on the CD-ROM. The files are organized by source. The filename extension is .OBS and the filename body specifies the data's source as follows:

SWE_ALE Alberta Ministry of Environment
SWE_BCE British Columbia Ministry of Environment
SWE_ENB Environment New Brunswick
SWE_INA Canadian Ministry of Indian and Northern Affairs
SWE_ONR Ontario Ministry of Natural Resources
SWE_SCD Data collected by AES from agencies across the country and archived in the *Snow Cover Data* publication series from 1956 to 1986. These data were keypunched and combined in a 1995 AES project. Stations which are operated by AES have been updated to 1994.

Organizing the data by agency of origin is useful because it avoids mixing data which have different measurement techniques, keypunching processes and quality control histories. However, this means that there are some redundant records caused by agencies submitting the same data twice, once in paper format to the *Snow Cover Data* books, and again in digital format. It was reasoned that these redundant data should be retained to maintain station completeness.

A station catalogue is provided in the file SWE_OBS.STN. An index to the file/record location of the data for each station is provided in the file SWE_OBS.REC. Sample FORTRAN software is provided in the files: OBSEX.FOR (extraction utility), OBSSRCH.FOR (station search utility) and READOBS.FOR (sample code for reading data files).

Please see following file descriptions for more information about each file type.

Observed SWE Files

Filenames

SWE_BCE.OBS, SWE_ALE.OBS, SWE_INA.OBS, SWE_ONR.OBS, SWE_ENB.OBS, SWE_SCD.OBS

File Location

\SWE\OBS_SWE

File Sample

```
INA-07NB01 19781115   7     8
INA-07NB01 197812 1   7     8
INA-07NB01 1979 1 1  29    41
INA-07NB01 1979 2 1  30    56
INA-07NB01 1979 3 1  40    56
INA-07NB01 1979 4 1  12    66E
INA-07NB01 1979 415  34    64
INA-07NB01 1979 5 1  22    61
```

File Format

Column(s)	Variable	Variable Type	Variable Length (no. of characters)	Missing Data Code
1-11	Station ID	alphanumeric	11	n/a
12-15	Year	integer	4	n/a
16-17	Month	integer	2	n/a
18-19	Day	integer	2	n/a
20-23	Snow Depth (cm)	integer	4	-999
24	Original agency snow depth flag*	alphanumeric	1	n/a
25	Snow depth quality control flag*	alphanumeric	1	n/a
26-29	Snow water equivalent (mm)	integer	4	-999
30	Original agency SWE flag*	alphanumeric	1	n/a
31	SWE quality control flag*	alphanumeric	1	n/a

*Described in following two charts

Quality Control Flags Used

Flag	Interpretation	
blank	GREEN FLAG	No detectable problem with measurement
3,4,5,6,7,8,9	YELLOW FLAG	Measurement is a suspicious outlier. 3 < or = Flag < or = 8 - measurement is between flag and flag+1 standard deviations from the mean for that two-week period at that station. Flag=9 - measurement is greater than 9 standard deviations from mean.

R,D	RED FLAG	Measurement is outside reasonable limits and is likely wrong. Flag=R - SWE or snow depth are outside limits as follows Snow depth: 0-300 cm (0-800 cm for Rocky Mountain stations) SWE: 0-3000 mm (0-8000 mm for Rocky Mountain stations) Flag=D - computed density is outside of 10-1000 kg m-*3*.

Original Agency Flags

Agency/Source	**Flag and Meaning**
Snow Cover Data books/ Atmospheric Environment Service (SCD before 1986)	E - Estimated T - Trace M - Missing P - Patches
Atmospheric Environment Service (SCD after 1985)	T - Trace S - Suspect
British Columbia Environment (BCE)	A - Sampling problems were encountered B - Early or late sampling C - Early or late sampling with problems encountered (A & B) E - Estimated based on areal average
Alberta Environment (ALE)	M - Missing
Canadian Ministry of Indian and Northern Affairs (INA)	E - Estimated S - Special X - Exclude
Environment New Brunswick (ENB)	no flags
Ontario Ministry of Natural Resources (ONR)	no flags

Observed SWE Station Catalogue File

Filename

SWE_OBS.STN

File Location

\SWE\OBS_SWE

File Sample

```
ALE-14Z07   AKAMINA                49  2 114  3 1800 19800131 19900531  54
ALE-14Z03   ALLISON PASS           49 44 114 36 1980 19630328 19900501  57
ALE-16X01   BOW RIVER              51 25 116 11 1580 19370330 19900326 102
ALE-16X18   BOW SUMMIT (NEW)       51 42 116 28 2080 19680229 19900530  86
ALE-16W02   BROWN CREEK            52 45 116 33 1340 19770301 19900329  28
```

```
ALE-16X08   CHATEAU LAWN              51 25 116 13 1740 19400329 19900326  93
ALE-15X07   CUTHEAD LAKE              51 27 115 46 2210 19790328 19900606  45
ALE-13A19   FLAT TOP PILLOW           48 48 113 51 1920 19700101 19900601 115
```

File Format

Multiple entries for a single station indicate a position shift or name change. Spaces appear between fields in this file.

Column(s)	Variable	Variable Type	Variable Length (no. of characters)	Missing Data Code
1-11	Station ID	alphanumeric	11	n/a
12	Continuation character: '+' if more entries for this station follow; *blank* if final entry for this station.	alphanumeric	1	n/a
13-36	Station name	alphanumeric	24	n/a
38-39	Latitude degrees North	integer	2	-9
41-42	Latitude minutes	integer	2	-9
44-46	Longitude degrees West	integer	3	-9
48-49	Longitude minutes	integer	2	-9
51-54	Elevation (m)	integer	4	-999
56-63	Start date (YYYYMMDD)	integer	8	n/a
65-72	End date (YYYYMMDD)	integer	8	n/a
74-76	Number of records associated with this entry	integer	3	n/a

---

Observed SWE File/Record Index File

Filename

SWE_OBS.REC

File Location

\SWE\OBS_SWE

File Sample

```
ALE-14Z07  SWE_ALE.OBS      1    54
ALE-14Z03  SWE_ALE.OBS     55   111
ALE-16X01  SWE_ALE.OBS    112   213
ALE-16X18  SWE_ALE.OBS    214   299
ALE-16W02  SWE_ALE.OBS    300   327
ALE-16X08  SWE_ALE.OBS    328   420
ALE-15X07  SWE_ALE.OBS    421   465
ALE-13A19  SWE_ALE.OBS    466   580
```

File Format

Column(s)	Variable	Variable Type	Variable Length (no. of characters)	Missing Data Code
1-11	Station ID	alphanumeric	11	n/a
12-23	Name of file containing observed SWE data for this station	alphanumeric	12	n/a
24-29	Start record	integer	2	n/a
30-35	End record	integer	2	n/a

File with Duplicates Eliminated

The snow course database contains some overlap due to the compilation of data from source agancies as well as from the annual snow cover summaries perpared by AES. This overlap was specifically left to permit station-based data enquiries with IDs from either the national summaries or the originating agencies. However, for many applications, this duplication is undersirable and a separate data set was created with duplicates eliminated.

The elimination of duplicates was carried out in four passes:

Pass 1 - elimination of records with identical data (date, location, elevation, sdep, swe). Where duplicates with the AES book values occurred, records from the originating agency were kept. Where overlap occurred between two agencies such as ALE and BCE, the first record of the duplicate pair was used.

Pass 2 - eliminate almost identical records created by data rounding. The process of data punching the AES books introduced some slight differences due to rounding. Records with the same date, and location where snow depth and SWE values differed by not more than 1 were considered to be identical.

Pass 3 - eliminate duplicates due to rounding and punching errors in station elevation. Records with the same date, location and snow data but where elevations differ by less than 10 m

Pass 4 - eliminate duplicates caused by rounding errors in latitude and longitude (lat/long difference <= 0.02 degrees).

The above procedure may eliminate valid data e.g. co-located snow courses. However, it would be unusual for two co-located snow courses to have virtually identical data because of the sampling variability of snow cover. Each pass was repeated several times to ensure that multiple data entries (e.g. triplicates) were removed.

Results: Total reords in: **226,556** Total records out: **193,431** (14.6% duplicates)

Output Dataset: sort_undup.swe (sorted by date)

Ross Brown, January 7, 1999

Estimated SWE Data

Overview

Estimated SWE data are located in the \SWE\EST_SWE directory on the CD-ROM. The files are organized by region. The filename extension is .EST and the filename body specifies the region as follows:

SWE_ARC Arctic
SWE_BC British Columbia
SWE_ALTA Alberta
SWE_SASK Saskatchewan
SWE_MAN Manitoba
SWE_ONT Ontario
SWE_QUE Quebec
SWE_MAR Maritimes

A station catalogue is provided in the file SWE_EST.STN. An index to the file/record location of the data for each station is provided in the file SWE_EST.REC. Sample FORTRAN software is provided in the files: ESTEX.FOR (extraction utility), ESTSRCH.FOR (station search utility) and READEST.FOR (sample code for reading data files).

Please see following file descriptions for more information about each file type.

Estimated SWE Files

Filenames

SWE_ARC.EST, SWE_BC.EST, SWE_ALTA.EST, SWE_SASK.EST, SWE_MAN.EST, SWE_ONT.EST, SWE_QUE.EST, SWE_MAR.EST

File Location

\SWE\EST_SWE

File Sample

```
AES-2100100196412 15   3     4C
AES-21001001965 1 1  15    22C
AES-21001001965 115  15    23C
AES-21001001965 2 1  15    24C
AES-21001001965 215  23    40C
AES-21001001965 3 1  28    43C
AES-21001001965 315  10    19I
AES-21001001965 4 1   8    15C
AES-21001001965 415   5    14I
```

File Format

Column(s)	Variable	Variable Type	Variable Length (no. of characters)	Missing Data Code
1-11	Station ID	alphanumeric	11	n/a
12-15	Year	integer	4	n/a

16-17	Month	integer	2	n/a
18-19	Day	integer	2	n/a
20-23	Snow Depth (cm)	integer	4	-999
24	Original AES snow depth flag*	alphanumeric	1	n/a
25	Snow depth quality control flag*	alphanumeric	1	n/a
26-29	Snow water equivalent (mm)	integer	4	-999
30	SWE calculation method flag*	alphanumeric	1	n/a
31	SWE quality control flag*	alphanumeric	1	n/a

*Described in following three charts

Quality Control Flags Used

Flag	**Interpretation**	
blank	GREEN FLAG	No detectable problem with measurement
3,4,5,6,7,8,9	YELLOW FLAG	Measurement is a suspicious outlier. 3 < or = Flag < or = 8 - measurement is between flag and flag+1 standard deviations from the mean for that two-week period at that station. Flag=9 - measurement is greater than 9 standard deviations from mean.
R,D	RED FLAG	Measurement is outside reasonable limits and is likely wrong. Flag=R - SWE or snow depth are outside limits as follows Snow depth: 0-300 cm (0-800 cm for Rocky Mountain stations) SWE: 0-3000 mm (0-8000 mm for Rocky Mountain stations) Flag=D - computed density is outside of 10-1000 kg m-*3*.

Original AES Snow Depth Flags

Flag	**Interpretation**
blank	Valid Data
E	Estimated
M	Missing
T	Trace

SWE Calculation Method Flags

Flag	**Interpretation**
blank	Zero snow depth. Not necessary to estimated SWE.
M	Insufficient snow density data to estimate SWE.

I	SWE was computed from snow depth by interpolating snow density measurements for the same date from surrounding snow survey stations
C	Insufficient data were available for interpolation from surrounding snow survey stations. SWE was computed from snow depth by referring to the gridded snow density normals.

Estimated SWE Station Catalogue File

Filename

SWE_EST.STN

File Location

\SWE\EST_SWE

File Sample

```
AES-1010066 ACTIVE PASS                  BC   48 52 123 17    4 19840701 19951031
AES-1010235 ALBERT HEAD                  BC   48 24 123 29 -999 19710801 19910701
AES-1010235+ALBERT HEAD                  BC   48 24 123 29   17 19910701 19950430
AES-1010595 BAMBERTON BC CEMENT          BC   48 35 123 31   85 19610201 19640301
AES-1010595+BAMBERTON OCEAN CEMENT       BC   48 35 123 31   85 19640301 19801130
AES-1010720 BEAR CREEK                   BC   48 28 124  0 -999 19110801 19570501
AES-1010720+BEAR CREEK                   BC   48 30 123 59 -999 19570501 19590401
AES-1010720+BEAR CREEK                   BC   48 29 123 59 -999 19590401 19640201
```

File Format

Multiple entries for a single station indicate a position shift or name change. Spaces appear between fields in this file.

Column(s)	Variable	Variable Type	Variable Length (no. of characters)	Missing Data Code
1-11	Station ID	alphanumeric	7	n/a
12	Continuation character: '+' if more entries for this station follow; *blank* if final entry for this station.	alphanumeric	1	n/a
13-42	Station name	alphanumeric	30	n/a
44-47	Province	alphanumeric	4	n/a
49-50	Latitude degrees North	integer	2	-9
52-53	Latitude minutes	integer	2	-9
55-57	Longitude degrees West	integer	3	-9
59-60	Longitude minutes	integer	2	-9
62-65	Elevation (m)	integer	4	-999
67-74	Start date (YYYYMMDD)	integer	8	n/a
76-83	End date (YYYYMMDD)	integer	8	n/a

Estimated SWE File/Record Index File

Filename

SWE_EST.REC

File Location

\SWE\EST_SWE

File Sample

```
AES-1010066SWE_BC.EST       1   231
AES-1010235SWE_BC.EST     232   320
AES-1010595SWE_BC.EST     321   324
AES-1010960SWE_BC.EST     325   504
AES-1011467SWE_BC.EST     505   815
AES-10114F6SWE_BC.EST     816  1174
AES-1011500SWE_BC.EST    1175  1278
AES-1011743SWE_BC.EST    1279  1357
```

File Format

Column(s)	Variable	Variable Type	Variable Length (no. of characters)	Missing Data Code
1-11	Station ID	alphanumeric	11	n/a
12-23	Name of file containing estimated SWE data for this station	alphanumeric	12	n/a
24-29	Start record	integer	2	n/a
30-35	End record	integer	2	n/a

Gridded Snow Density Normals Files

Gridded snow density normals at biweekly intervals from November 15th to May 15th for the period 1961-90 are located in the \SWE\DENSITY directory on the CD-ROM. There is one file for each date with snow density data. The date is specified in the filename body and the filename extension is .GRD. For example the NOV15DEN.GRD contains gridded snow density normals for November 15th. Sample FORTRAN 77 code for reading the gridded density normals files is contained in the file READGRD.FOR.

Filenames

DENNOV15.GRD, DENDEC01.GRD, DENDEC15.GRD, DENJAN01.GRD, DENJAN15.GRD, DENFEB01.GRD, DENFEB15.GRD, DENMAR01.GRD, DENMAR15.GRD, DENAPR01.GRD, DENAPR15.GRD, DENMAY01.GRD, DENMAY15.GRD

File Location

\SWE\DENSITY

File Sample

```
44 55  85 44 204
44 53  85  8 206
44 51  84 32 208
44 49  83 56 209
44 46  83 19 210
44 35  81 32 212
44 31  80 56 211
44 27  80 20 209
```

File Format

Column(s)	Variable	Variable Type	Variable Length (no. of characters)	Missing Data Code
1-2	Latitude degrees North	integer	2	n/a
4-5	Latitude minutes	integer	2	n/a
7-9	Longitude degrees West	integer	3	n/a
11-12	Longitude minutes	integer	2	n/a
14-16	Snow density (kg/m^3)	integer	3	n/a

Original Raw Data

The original snow survey data provided by the contributing agencies are also provided on this CD-ROM in the directory \SWE\RAW_DATA. All files are in the original formats used by the contributing agencies. The data are stored in subdirectories are follows:

\SWE\RAW_DATA\ALE Original raw data from Alberta Ministry of Environment
\SWE\RAW_DATA\BCE Original raw data from British Columbia Ministry of Environment
\SWE\RAW_DATA\ENB Original raw data from Environment New Brunswick
\SWE\RAW_DATA\INA Original raw data from Ministry of Indian and Northern Affairs
\SWE\RAW_DATA\ONR Original raw data from Ontario Ministry of Natural Resources
\SWE\RAW_DATA\SCD Original keypunched data from the *Snow Cover Data* publication series and updated data for stations operated by AES. Data from the *Snow Cover Data* books are in files named SNOW????.TXT. AES data are in the files AESSWE1.PRN, AESSWE2.PRN, and AESSWE3.PRN.

A file called CAN_SCD.COR is also provided with the raw SCD data in the same directory. This file is a record of all corrections made to the station information from the *Snow Cover Data* books and AES. Each record in this file contains the original keypunched station information, the corrected information and the station ID which was assigned. Where no changes were made, dashes appear instead of the corrected information.

In quality control of the AES/*Snow Cover Data* station information, around 30% of the station information was changed and 7,202 'sub-stations' were merged into 2,128 complete stations. These alterations were made based on the best available information combined with educated guesses. However the user may wish to refer to this file to verify these changes.

Sample FORTRAN Code

Sample FORTRAN 77 programs are provided for both observed and estimated SWE data in the \SWE\OBS_SWE and \SWE\EST_SWE directories respectively. Equivalent software is provided for each dataset. Programs for use with the observed SWE dataset have "OBS" as the first three letters of the filename and programs for use with estimated have "EST" at the beginning of the filename. The programs are:

- \SWE\OBS_SWE**OBSSRCH.FOR** and \SWE\EST_SWE**ESTSRCH.FOR**
  -These programs compile an inventory of station data based on a user-specified time and location or based on a wildcard in the station name or ID. The programs prompt the user for the station search parameters and write the station information for all matching stations to a file called STNSUM.OUT in the same directory as the program.

- \SWE\OBS_SWE**OBSEX.FOR** and \SWE\EST_SWE**ESTEX.FOR**
  -These programs extract SWE data either based on a user-specified time and location or for a given station ID The programs prompt the user for the extraction parameters and write the resulting data to a file called DATA.OUT in the same directory as the program.

To use these programs, they must be copied from the CD-ROM to a writable directory and compiled using a FORTRAN compiler. Modifications may be necessary for different operating platforms. The code was originally written for a PC-DOS system using Microsoft FORTRAN Powerstation 4.0. These programs are not meant to be exhaustive extraction utilities; rather they are intended as examples of possible data manipulation software.

Sample FORTRAN 77 code is also provided for reading the observed and estimated SWE data files using direct access in the following files:

- /SWE/OBS_SWE/**READOBS.FOR** For reading observed SWE files (eg. SWE_SCD.OBS)
- /SWE/EST_SWE/**READEST.FOR** For reading estimated SWE files (eg. SWE_ARC.EST)

These programs do not perform any operations on the data or produce any output. They simply read the snow data to arrays and link it to the station information. They are intended to be a starting point for users who wish to create their own data analysis and extraction software.

For more information about this dataset, please contact:

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