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SNOW PARAMETERS FROM NIMBUS-6 ELECTRICALLY SCANNED MICROWAVE RADIOMETER

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16. Abstract A study was conducted to statistically analyze the relationship between Nimbus-6 Electrically Scanned Microwave Radiometer (ESMR-6) measurements and important snowpack parameters. A number of Canadian and U.S. snow sites were identified and screened for analysis. Two sites were selected for detailed analysis of the ESMR-6/snow relationships. Site 1 is located in the Red River Drainage Basin of Southern Manitoba and Saskatchewan. Site 2 corresponds to the St. John River Basin in New Brunswick. Data were analyzed for February 1976 for Site 1 and January, February and March 1976 for Site 2. Snowpack water equivalents were less than 4.5 inches for Site 1 and, depending on the month, were between 2.9 and 14.5 inches for Site 2. A statistically significant relationship was found between ESMR-6 measurements and snowpack water equivalents for the Site 2 February and March data. Associated analysis findings presented are the effects of random measurement errors, snow site physiography, and weather conditions on the ESMR-6/snow relationship.

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CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

Section 1

INTRODUCTION

The measurement of snowpack parameters by remote sensing techniques is of scientific interest and has considerable economic importance. Presently, ground-based point measurements along with a few aircraft measurements are the primary data used for hydrologic predictions in such application areas as agriculture, electric power generation, and flood forecasting. Ground-based measurements are by necessity limited in their temporal frequency of observations and spatial coverage. Because snow cover can change quite rapidly over large areas, better estimates of important snowpack parameters require the more complete temporal and spatial coverage provided by remote sensing techniques. With more extensive temporal and spatial coverage, seasonal behavior of snowpacks could be studied and better prediction models could be developed. Reasonable estimates of the total volume of water contained in snowpacks would allow for more efficient water management and conservation practices.

Ground-based measurements, reported in Reference 24, indicate that the 37 GHz ($\lambda = 0.81$ cm) portion of the frequency spectrum is quite sensitive to changes in snowpack water equivalents (or mass per unit area) for dry snowpacks. The brightness temperature measured by the radiometer decreases as the snow water equivalent being measured increases, where the effect is approximately the same for both horizontal and vertical polarizations. The physical theory for this microwave behavior is discussed in Reference 15, which also contains additional ground-based and aircraft measurement program reports.

The source of the remote sensing data used in this study is from the Nimbus-6 Electrically Scanning Microwave Radiometer (ESMR-6) instrument mounted on the Nimbus-6 satellite. The frequency of the ESMR-6 is 37 GHz with both horizontal and vertical polarization measurements. The Nimbus-6 satellite was launched on June 11, 1975 into an 1100 kilometer sun-synchronous polar orbit with a period of approximately 107.25 minutes. The ESMR-6 antenna beam is scanned electronically through 71 discrete positions every 5-1/3 seconds. The ESMR-6 resolution (footprint) for each beam position is dependent upon the pitch angle of the spacecraft, and for pitch angles between -5° and +5° ranges from 18-22 kilometers in the cross-track direction and 35-54 kilometers in the down-track direction (Reference 25). A complete description of the ESMR-6 instrument and all associated information is given in Reference 25. Throughout the remainder of this report, the abbreviation ESMR will be used to denote data from the ESMR-6 instrument.

Several snowpack parameters are of interest which include snow depth, lateral distribution of snow, onset of melting, extent of melting, and diurnal freeze-thaw cycles. Any estimation of snowpack parameters is dependent upon establishing that a relationship (correlation) exists between ESMR brightness temperatures and, the basic snow parameter, snow water equivalent. The primary objective of this study was to answer the following questions:

a. Does ESMR brightness temperature decrease as snow water equivalent increases or equivalently does snow water equivalent versus ESMR brightness temperature show a negative correlation statistically significant from zero?

b. If a relationship exists between ESMR brightness temperature and snow water equivalent, is the relationship valid over all values of snow water equivalent or is the relationship limited to a range of snow water equivalent values?

c. If a statistically significant correlation exists, how well can snow water equivalent be estimated from ESMR brightness temperatures with a linear regression model, and can these estimates be improved by including other, regularly reported, variables along with ESMR brightness temperatures in a multiple linear regression model?

Several prospective snow sites were investigated for possible inclusion in this study. The selection of snow sites for analysis was based on a subjective evaluation in terms of the factors of snowpack/ground truth data base, temporal stability of the snowpack, uniformity of snow, areal extent of the snowpack, vegetal cover, terrain suitability and water/land boundaries for registration of the ESMR footprint. Two sites were selected for analysis: Site 1 is in the Red River Drainage Basin located in the Provinces of Manitoba and Saskatchewan, Canada, and Site 2 is in the St. John River Basin in the Province of New Brunswick, Canada. One time period (in early February, 1976) was investigated for Site 1 and three time periods (in January, February, and March, 1976) were investigated for Site 2. The snow/ESMR data from these two sites were analyzed to successfully establish the feasibility of estimating, the basic snow parameter; snow water equivalent from ESMR brightness temperature. Additionally a valid range for the snow water equivalent/brightness temperature relationship can be inferred for the 37 GHz case. The applicability of a linear regression model to the snow water equivalent estimation problem was established and the enhancement possible from a multiple linear regression model verified. Sufficient data from these two sites were not available to thoroughly study the various snow parameters associated with melting. Detailed results and analysis performed in this study are discussed in Section 2. A summary of these results is given in Section 3.

This report contains four major sections: Section 1 - Introduction, Section 2 - Technical Discussion, Section 3 - Summary and Conclusions, and Section 4 - References. Statistical methodology is given in Appendix A. A considerable amount of data were used for analysis and these data are given in tabulated and plotted form in Appendices B - F. Appendix G gives for Site 2 the location of snow observations relative to agricultural land use and also the physiographic divisions and topography for the Saint John Basin.

Section 2
TECHNICAL DISCUSSION

A complete discussion of the technical work performed with detailed analysis results is presented in the subsections of 2.1, Analysis Sites and Available Data, 2.2, Analysis Programs and Data Processing, 2.3, Linear Correlation Analysis, 2.4, Multiple Correlation and Regression Analysis, and 2.5, Single Orbit Analysis. A considerable amount of data were used in the analysis, and a number of associated factors are important in the interpretation of the analysis results. The first part of this section will briefly discuss the data used for analysis, relevant statistical concepts, and important analysis factors; appropriate correlation results will also be given. The basic data used for analysis are given in Appendices B through F in tabulated and plotted form. By necessity, to clarify the discussion, certain information, data, and/or correlation results will be repeated through all parts of this section as required.

The snow measurement used for analysis is snow water equivalent given in inches of water. Occasionally in this report, the terms snow or snow depth will be used; these terms will always refer to snow water equivalent. The term ESMR data will also be used; this term is used to designate the horizontal brightness temperature (TH), the vertical brightness temperature (TV), or both. The Julian day number in 1976 with the letter N or D will be used to identify a particular orbit of ESMR data used for analysis, e.g., the night orbit on March 1, 1976 would be denoted 61N, while the day orbit on February 10, 1976 would be denoted 41D.

Analysis was performed on two snow sites in Canada. Site 1 is located in the Provinces of Manitoba and Saskatchewan, and Site 2 is located in the Province of New Brunswick. Site 1 had snow water equivalent values between 0.7 and 4.5 inches. Site 2, depending on the month, had snow water equivalent values between 2.9 and 14.5 inches. The time period of interest for both Site 1 and Site 2 was based on availability of snow course measurements. The ESMR data used for analysis was dependent upon a sufficient number of unobscured water-land boundaries for registration of the ESMR footprints. The time period of interest for Site 1 was February 9, 1976 through February 13, 1976. Appropriate portions of two orbits of data were used for analysis, the night and day observations on February 10, 1976 (41N, 41D). The time periods of interest for Site 2 were January 5 through January 9, 1976. February 2 through February 9, 1976, and March 1 through March 3, 1976. Data were analyzed for the following: the day orbit on January 6 (6D), the day orbit on January 8 (8D), the night orbit on February 3 (34N), and the night orbit on March 1 (61N).

Analysis results for the designations 61R and 61E will also be given throughout this report. For the 61N data set, a plot of snow water equivalent versus ESMR data showed that one low and four high snow values appeared to be isolated from the main clustering of the data (outliers). The data in 61R is the same as that for 61N but with the five outliers removed. For all data sets but 61E, the ESMR data were chosen as those closest in location to the measured snow location, with certain footprint restrictions. For 61E, a snow water equivalent value was interpolated from a contour map for the March 1-3 period for every ESMR observation within the contour bounds. The analysis results for 61E were reported in the January-March Quarterly Progress Report, Reference 16, and portions of these results will be included for completeness.

The emphasis in this contract was on empirical data analysis using correlation and regression techniques. A complete discussion of the statistical techniques used for the analysis is given in Appendix A, Correlation and Regression. However, a brief review of the relevant concepts will be given as follows. Throughout the discussion the y variable will be analogous to snow water equivalent values and the x variable to either the horizontal or vertical ESMR brightness temperature. Given N paired observations of y and x, one is interested in how closely y and x are related (correlated) and/or how well changes in y, the dependent variable, can be determined from changes in x, the independent variable.

In correlation, the assumption is made that y and x are from a bivariate normal distribution which is completely defined by the means μ_x,

μ_y , the variances σ_x^2 , σ_y^2 , and the correlation coefficient between y and x , ρ . An estimate of the correlation, r , is made from the sample, and a "t" test is made to determine if r is significantly different from zero at some confidence level, $100 \cdot (1-\alpha)$, i.e., the probability that a value as large as the observed r could occur by chance is α . The value of α is usually chosen as 0.05 or 0.01. The value of r ranges from -1.0 to 1.0. In this analysis, negative values of r are desired because the ESMR values are expected to decrease as the snow water equivalent increases.

The linear regression model is given by

$$y = \beta_o + \beta_1 x + e ,$$

where e is assumed to be the error in y and is normally distributed with mean zero and variance σ^2 . The independent variable x is assumed to be free from error. If x is in error, then β_1 will always be underestimated and tend to zero as the joint errors increase. Using a circumflex, or "hat" to indicate estimated quantities, the predicted value of y_i , $\hat{y}_i$ is given by

$$\hat{y}_i = \hat{\beta}_o + \hat{\beta}_1 x_i .$$

The sample correlation coefficient r and $\hat{\beta}_1$, the estimated slope of the regression line are related through the estimated standard deviations of y and x $(\hat{\sigma}_y , \hat{\sigma}_x)$ as

$$\hat{\beta}_1 = \frac{\hat{\sigma}_y}{\hat{\sigma}_x} \cdot r ,$$

where $\hat{\beta}_1$ will have the same sign as r . A test can be made to determine if $\hat{\beta}_1$ is significantly different from zero, i.e., if the slope is not significantly different from zero, y equals a constant and x is of no value in determining changes in y . The test for $\hat{\beta}_1$ is algebraically equivalent to the test for r .

The square of the sample correlation coefficient, r^2, and the standard error of estimate $\hat{\sigma}_y$ can be used as qualitative measures of how well a model fits the data. The object of any regression is to explain as much of the total variance of y, $\hat{\sigma}_y^2$, as possible. For more than one independent variable, multiple regression, the independent variables which explain the most variance of y are the most important variables. The value of $100 \cdot r^2$ is the percent variance of y explained by the fitted model. In terms of sum of squares,

$$r^2 = 1.0 - \frac{\sum(y_i - \hat{y}_i)^2}{\sum(y_i - \bar{y})^2} ,$$

and r^2 varies from 0 to 1.

The standard error of estimate or the standard deviation of the prediction is given by

$$\sigma_{\hat{y}} = \left(\frac{1}{N-2} \sum(y_i - \hat{y}_i)^2\right)^{1/2},$$

and varies between 0 and $(N-1/N-2)^{1/2} \cdot \hat{\sigma}_y$.

All statistical results in this report include r (the sample correlation coefficient), the significance of r (NS = not significant, ** = significant at the 95 percent level, *** = significant at the 99 percent level), $100 * r^2$ (the percent variance explained), $\sigma_{\hat{y}}$ (the standard error of estimate), and $\hat{\sigma}_y$ (the standard deviation of y).

Before summarizing the analysis results, certain circumstances should be discussed. The analysis results pertain basically to an uncontrolled experiment with unknown errors in the variables. Therefore, associated information is important in assessing any results. Besides the random errors in the snow and ESMR measurements, each set of observations have local variability in terrain, surface material, vegetation, surface temperature and weather conditions.

The random error in the snow measurements is unknown but should be small. Some error will occur, especially in areas of rapid spatial changes in snow depth, because the snow is taken as a point source and the ESMR is an integrated value with a relatively large footprint. The lack of coincidence between the snow and ESMR measurement could be a source of error, but the method of selecting relevant snow data was chosen to minimize this problem (see Section 2.2).

The potential random errors in the ESMR data and their possible effect on observing a relationship between snow water equivalent and ESMR data were discussed in the January-March Quarterly Progress Report, Reference 16. Assuming 75 percent of the mean square error was a bias or calibration error, the random errors in ESMR measurements would have a standard deviation of 1.25° at the original specification of the instrument and 2.5°-3.0° as an estimated high value. Figure 2-1 shows the measured relationship of snow to brightness temperatures at various wavelengths. The curves were derived from ground-based measurements of dry snowpack at Crater Lake, Oregon in March of 1970. This figure was adapted from Figure 1-1 of Reference 15 which was based on results given in Reference 24. Of interest is the slope of both the horizontal and vertical curves for 37 GHz ($\lambda = 0.8$ cm). For snow water equivalent of 0.0-5.0 inches, the slope is approximately 6°/inch of water, and for snow water equivalent of 5.0-8.0 inches, the slope is approximately 5°/inch of water. For snow water equivalent of 8.0-11.0 inches, the slope is approximately 1.3°/inch of water equivalent, and the slope to be estimated is near the lowest expected standard deviation of the random error of the ESMR data. Hypotheses was made in Reference 16 that for high values of snow water equivalent (deeper snow) a statistical relationship between snow and ESMR temperatures could be difficult to establish and that the presence of deeper snow could degrade the correlation for other ranges of snow values. As ESMR variables in the correlation analysis are the independent variables and assumed error free, any ESMR random error will lower the estimated regression slope and correlation coefficient from their true values. Also the Crater Lake measurements were taken with uniform background conditions, terrain and surface materials.

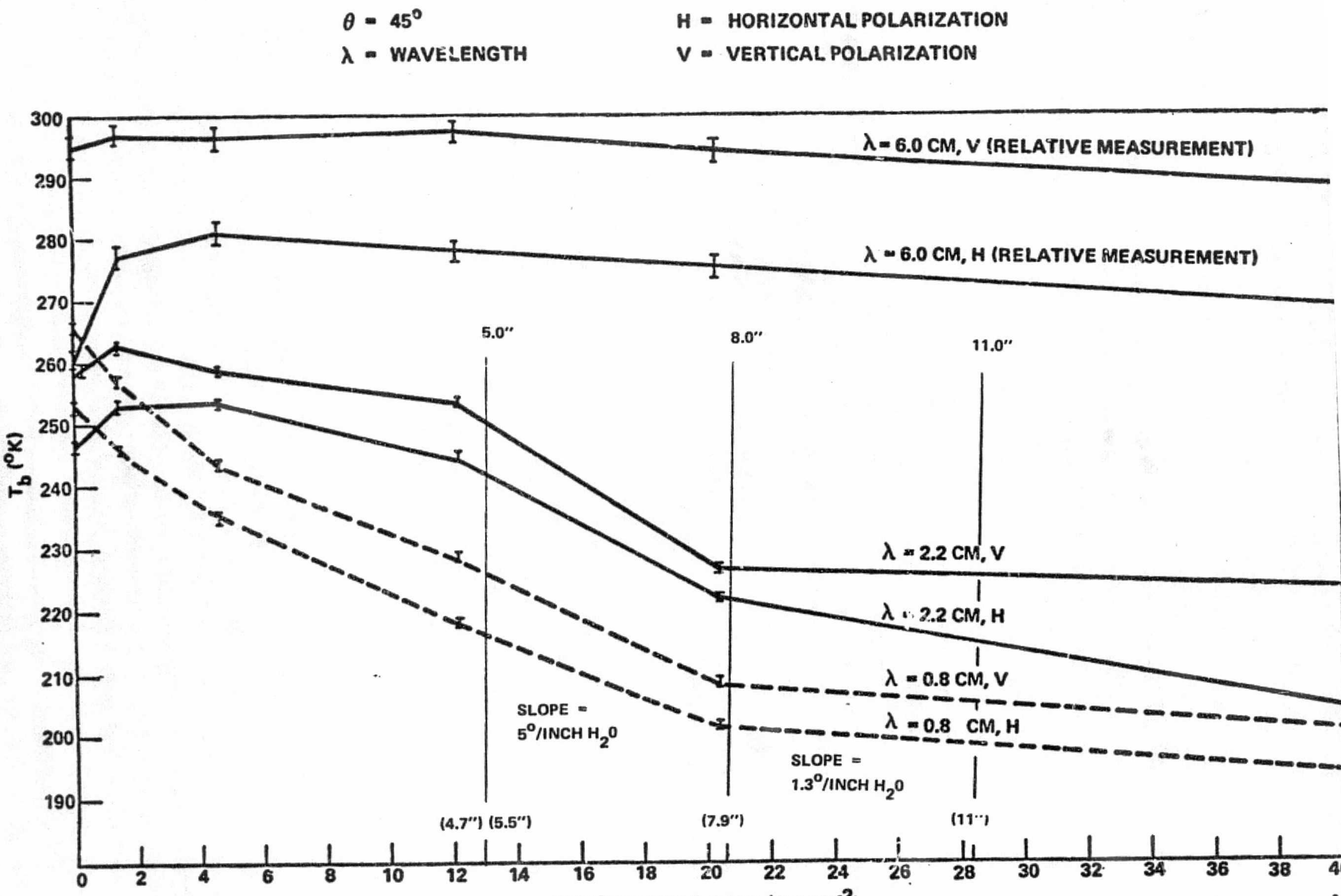


Figure 2-1. Measured Relationship of Snow to Brightness Temperature

The change in the snow-brightness temperature relationship due to heterogeneous terrain and surface material cannot be predicted but the measured relationship will certainly be degraded.

Terrain, surface material, and weather are important in examining the results for Site 1. Measurement elevations ranged from 730 feet to 2350 feet. The lower elevations are found in the river valleys and between Lake Winnipeg and Lake Manitoba. The higher elevations are in the western portion in the Turtle, Duck, and Riding Mountains and the Porcupine Hills. The higher snow values were generally associated with the mountain areas. The physiography of Site 1 is the result in major part, to continental glaciation with the eastern and northern portions having many small and large shallow lakes. Surface material is described in Reference 18 as "In the vicinity of Winnipeg unmodified glacial drift, called hard pan and forming an uneven surface varying in thickness from 30 to 50 feet, is found at depths between 4 and 60 feet below the surface. The glacial drift is generally overlain with lacustrine deposits of highly plastic clays which have the capacity to hold large quantities of moisture. At several places 5 to 10 miles downstream from the city pre-glacial limestone protrudes through the hard pan to lie close to the surface." No information could be found about the mountain regions. However, as most are provincial parks, forests would be present.

Appendix F, Meteorological Data for Sected Stations, gives daily precipitation (in 100th inches of water), maximum temperature (°F), minimum temperature (°F) and hours of bright sunshine data for five days before the observation day and one day after for all data analyzed. Table F-2 gives the Site 1 data and shows that maximum temperatures were in the high 30's to mid-40's for three days preceding the February 10, 1976 observations; on the 10th, maximum temperatures ranged from 4° to 28° over the area. According to the Canadian Weather Review (Reference 8), over the Prairie Provinces," numerous daily maximum records were established during the first half of the month," and "during the mild weather snowpacks were depleted by several inches and some southern areas became bare." No precipitation was measured in the five days preceding February 10, 1976, and no precipitation was indicated at the time of the ESMR measurements on the 10th.

For Site 2, vegetation, terrain, and weather are important considerations. Over 75 percent of the area is covered with trees, with Black Spruce being the most plentiful tree. Wet snow in the branches of non-deciduous Black Spruce trees could cause a problem. Measurement elevations in the area ranged from 130 feet to 1500 feet. For February 3 (34N) the weather was clear and below freezing. For March 1 (61N), temperatures were below freezing with some clouds.

The weather for January 6 (6D) and January 8 (8D) required some discussion. A large quantity of data was examined in selecting orbits for analysis. The original idea was to use only night orbits, which would eliminate problems of sunshine on the snow. However, the number of orbits for analysis was quite limited, and it was decided to use all available data. No night orbit was available for January 6 and the night orbit for the 8th had clouds obscuring all water-land boundaries. The initial examination of the ESMR data suggested that the day orbits for both the 6th (6D) and the 8th (8D) were taken under conditions of precipitation (higher temperatures and low polarization differences). The idea was then to include samples with precipitation conditions as an example of what would happen to snow-brightness temperature relationships. Indeed a minor front with light precipitation (see Table F-3, Appendix F) was present on the 8th and hourly precipitation data from Maine (Reference 9) showed that the last reported precipitation on the 8th was at local times of 0800, 0900, 1300, and 1200 for Caribou, Houlton, Ground Lake Stream and Eastport. As Maine is on eastern standard time, the ESMR observation would be at about 1030 EST. Upon closer examination, the weather on January 6 was clear and cold. In the area of the snow observations, compared to the surrounding area, the vertical temperature was constant around 230°-240°, but the horizontal temperature increased from below 220° to 225°-233°. The same structure had been observed in the Longfellow Mountains of Maine. Elevations in the area range from below 1000 to around 2300 feet. This suggests the higher temperatures and lower polarizations could be due to terrain effects during the daytime observation. In general, no correlation between snow and ESMR would be expected for 6D and 8D.

Several combinations of variables were used in this analysis, where detailed results are given in subsequent sections. For each of the sample sets, 41N, 41D, 6D, 8D, 34N, 61N, 61R and 61E, the sample correlation coefficient between snow water equivalent and the horizontal and vertical brightness temperatures, individually, were computed. Correlations were computed for the same data sets allowing only data points with polarization differences (Δ = TV-TH) of less than 21° into the computations. An analysis of polarization differences was performed for all data sets. Next a set of multiple correlations were computed using various other variables in conjunction with the ESMR variables to try to improve the correlation and predictability of the snow water equivalent.

The multiple regression analysis was originally started to try to better understand the ESMR data in terms of routinely reported data. Because of the magnitude of the random errors, the horizontal and vertical brightness temperatures would be the logical choices for the dependent variable in a regression analysis. If an adequate relationship for the ESMR data in terms of other variables could be established, the observed ESMR data could be adjusted to eliminate temperature variations caused by the variability in local conditions. Then the adjusted ESMR values could be used for establishing the relationship with snow water equivalent. The only routinely reported quantities of potential value are precipitation from preceding days, maximum temperature, and minimum temperature. Precipitation would tend to indicate the depth of new snow and, crudely, the condition of the snow. As the local ground temperature is important, but usually not available, the proper use of maximum and minimum temperatures could serve as an indication of relative local ground temperature. For night orbits the maximum temperature from day-1 and the minimum temperature from the day of the observation would be used. Of course, the relationship would also be conditional on the snow water equivalent. Unfortunately, the ESMR temperature relationship was much too complicated for this simplistic approach. However, it was discovered through this analysis that snow water equivalent is generally positively correlated with the elevation of the snow course measurement location, especially for Site 2, and the elevation can be helpful in predicting snow water equivalent (maximum temperature is generally negatively correlated with elevation).

The complete details of the analysis are given in tabulated form in Sections 2.3 through 2.5. The following briefly summarizes some of the correlations found. H and V will be used to denote the horizontal and vertical brightness temperature, respectively. The correlations presented are between snow water equivalent and H or V. For Site 1, no significant correlations were found for 41N. For 41D, V had a correlation of +0.28 which was significant at the 95 percent level, although only 7.9 percent variance was explained.

For Site 2, as expected, no significant correlations were found for either 6D or 8D. For 34N, V had a correlation of -0.64 which was significant at the 99 percent level with 41.3 percent variance explained. For 61N with a snow water equivalent range of 2.9-14.3 inches, H and V had correlations of -0.40 and -0.32 which were not significant at the 95 percent level. For 61R, the subset of 61N with a snow water equivalent range of 4.9-10.2 inches, H and V correlations were -0.61 and -0.75 which were significant at the 99 percent level and with a variance explained values ($100*r^2$) of 37.5 and 56.6 percent. The results for 61E, with snow water equivalent given by contour values, were given in Reference 16, but are repeated here. H and V had correlations of -0.24 and -0.53 which are significant at the 95 and 99 percent levels respectively with variance explained of 6.0 and 28.0 percent respectively. The subset of 61E with snow water equivalent in the 5.0-8.0 inch range gave H and V correlations of -0.39 and -0.65 which are significant at the 95 and 99 percent levels, respectively and had variance explained of 15.0 and 43.0 percent. The subset of 61E with snow water equivalent in the 8.0-11.50 inch range showed no significant correlations.

Restricting the data to a polarization difference of less than 21° generally improved the correlation with the horizontal more than the correlation with the vertical. For Site 1, the number of samples were reduced from 49 and 51 to 5 and 10, respectively, for 41N and 41D with no significant H and V correlations. No significant correations were found for 6D and 8D as for 6D no points were eliminated and for 8D only two points were eliminated. For 34 N, the correlations for H and V were raised from -0.32 and -0.64 to -0.55 and -0.82, with significance at the 95 and 99 percent levels respectively, and variance explained of 30.6 and 67.9 percent. For 61N, the correlations for H and V were raised from -0.40 and -0.32 to -0.59 and -0.59 which are significant at the 95 percent level and with variance explained of 35.1 and 35.3 percent. For 61R, the H and V correlations were raised and slightly degraded, respectively, from -0.61 and -0.75 to -0.71 and -0.71, both significant at the 99 percent level and with variance explained of 51.0 and 50.4 percent. For 61E, the H and V correlations were raised and slight degraded, respectively, from -0.24 and -0.53 to -0.40 and -0.46, significant at the 95 and 99 percent level, respectively, with variance explained of 16.1 and 20.8 percent.

The correlation between snow water equivalent and elevation is of interest, where one would expect a positive correlation, the higher the elevation the deeper the snow. Using the format data set (r , significance level, $100 \cdot r^2$) the correlations and associated information between snow water equivalent and elevation are for 41N (0.31, 95%, 9.3); 41D (0.27, NS, 7.2); 6D (0.90, 99%, 81.0); 8D (-0.12, NS, 1.5); 34N (0.49, 95%, 23.6); 61N (0.79, 99%, 62.5) and 61R (0.50, 95%, 25.0). No elevation analysis or multiple regression was performed on 61E because the data could not be obtained.

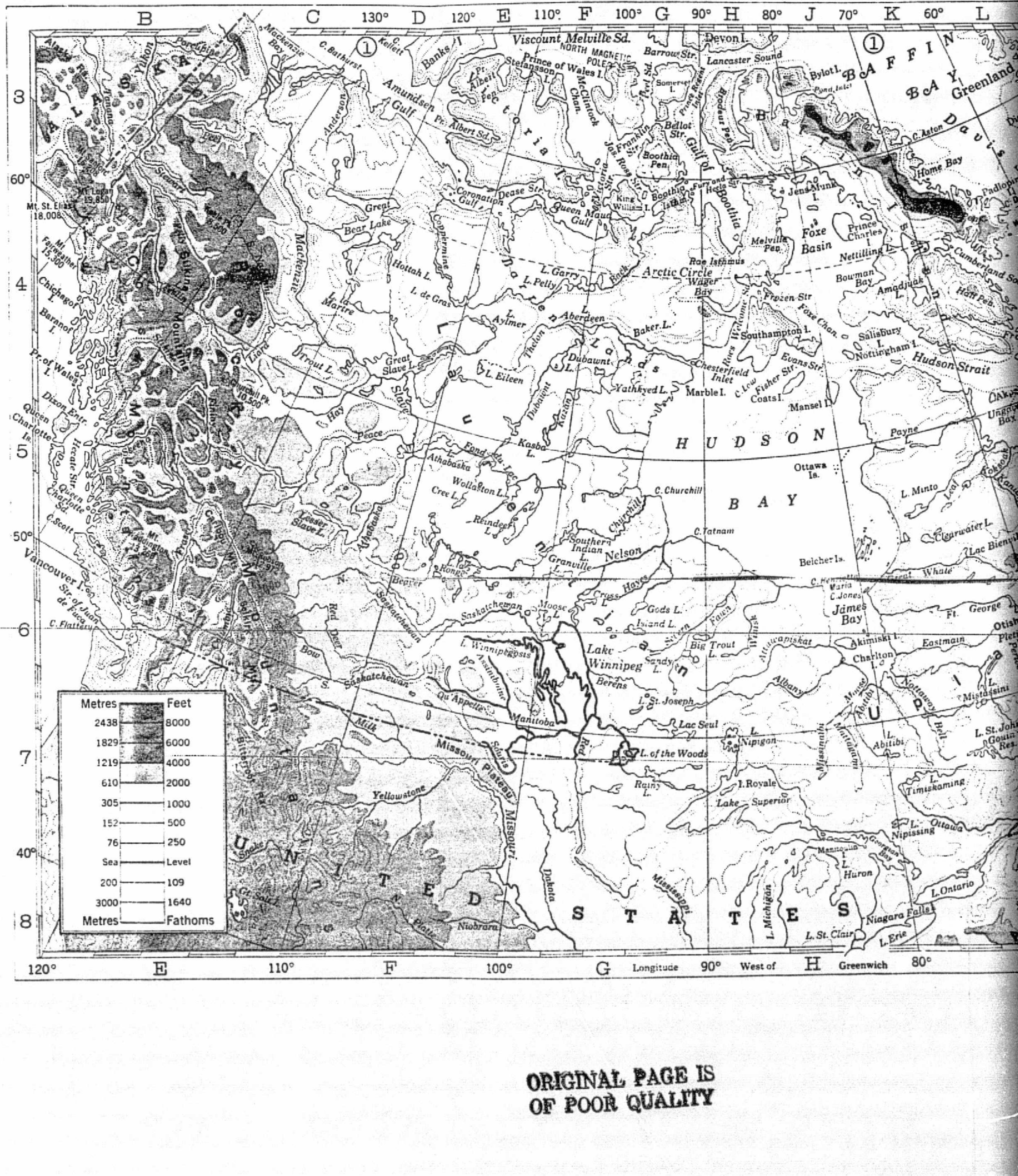
Using the horizontal, vertical and elevation as the independent variables, a multiple correlation coefficient $|r|$ can be calculated along with $100{*}r^2$, the variance explained. Generally, correlations are improved using these three independent variables. However, a little care must be exercised because in the case of 6D all the correlation is due to elevation. With the format of Day ($|r|$, significance, $100{*}r^2$) , the multiple correlation coefficient results are for 41N (0.31, NS, 9.8); 41D (0.41, 95%, 16.6); 6D (0.91, 99%, 83.5); 8D (0.47, NS, 22.5); 34N (0.78, 99%, 60.3); 61N (0.78, 99%, 63.9) and 61R (0.77, 99%, 59.7). Generally, for most data sets, the correlation and percent variance explained are only slightly lower if only the vertical brightness temperature and elevation are used as the independent variables.

2.1 ANALYSIS SITES AND AVAILABLE DATA

The two sites analyzed are located in Canada. Site 1 is located in the Provinces of Saskatchewan and Manitoba, covering an area approximately bounded by 49°N to 52°N latitude and 102°W to 96°W longitude. Site 2 is located in the Province of New Brunswick, covering an area approximately bounded by 45°N to 48°N latitude and 71°W to 65°W longitude. Figure 2-2 is a map of Canada, taken from Hammond's Ambassador World Atlas, C. S. Hammond and Company, Maplewood, New Jersey.

For Site 1, the snow observations are from the northwestern portion of Red River Drainage Basin which contains several river basins. Figure 2-3 (Ref 18) shows the Red River Drainage Basin. A major portion of the area in Manitoba is covered by Lake Winnipeg, Lake Manitoba, Lake Winnipegosis, and various other lakes. In the southwestern portion of Manitoba, the Porcupine Hills, Duck and Riding mountains separate the flat land regions of Manitoba and Saskatchewan, where elevations are 2600 to 2750 feet and generally about 1000-1500 feet above surrounding flat land. Areas in Manitoba not covered with water are characterized as treeless prairie and thickly forested parklands. Saskatchewan contains a number of rivers. The southern part of the snow area in Saskatchewan is a plain with a gradation to the north into mixed woodlands interspersed with large lakes. The two major cities in Site 1 are Regina, Saskatchewan in the west and Winnipeg, Manitoba in the east. The Hudson Bay is north-northeast of Site 1.

For Site 2, the snow observations are from the St. John River Basin, shown in Figure 2-4. In New Brunswick, Site 2 is a relatively flat area containing the St. John River, except in the northeastern portion where elevations range from 1000 to 2300 feet. Over 75 percent of the area is covered with trees, with Black Spruce being the most plentiful tree. From east to west, Site 2 progresses from flat land interspersed with many lakes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Viscount Melville Sd.
NORTH MAGNETIC POLE
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Prince of Wales I.
Devon I.
Barrow Str.
Lancaster Sound
Bylot I.
BAFFIN BAY
Greenland
Amundsen Gulf
Victoria I.
Boothia Pen.
Gulf of Boothia
Baffin I.
Davis Str.
Foxe Basin
Arctic Circle
Great Bear Lake
Mackenzie
Great Slave L.
Barren Lands
Aberdeen L.
Baker L.
Southampton I.
Hudson Strait
Chesterfield Inlet
HUDSON BAY
L. Athabaska
Reindeer L.
C. Churchill
Churchill
Nelson
Lake Winnipeg
James Bay
Mt. Logan 19,850
Mt. St. Elias 18,008
ALASKA
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Coast Mountains
Rocky Mountains
Vancouver I.
Queen Charlotte Is.
Saskatchewan
Peace
Athabaska
Missouri Plateau
Missouri
Yellowstone
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Figure 2-2. Map of Canada

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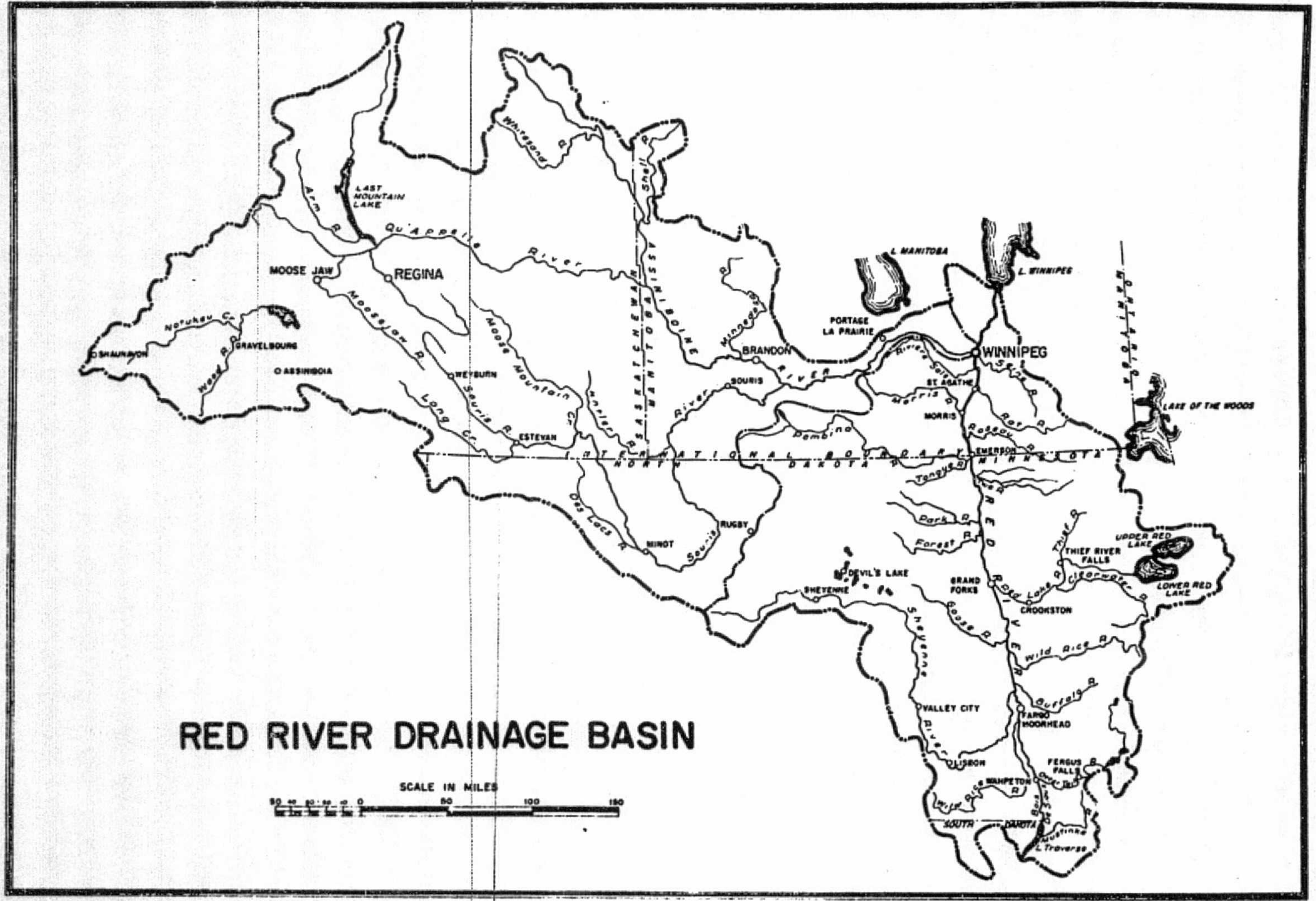
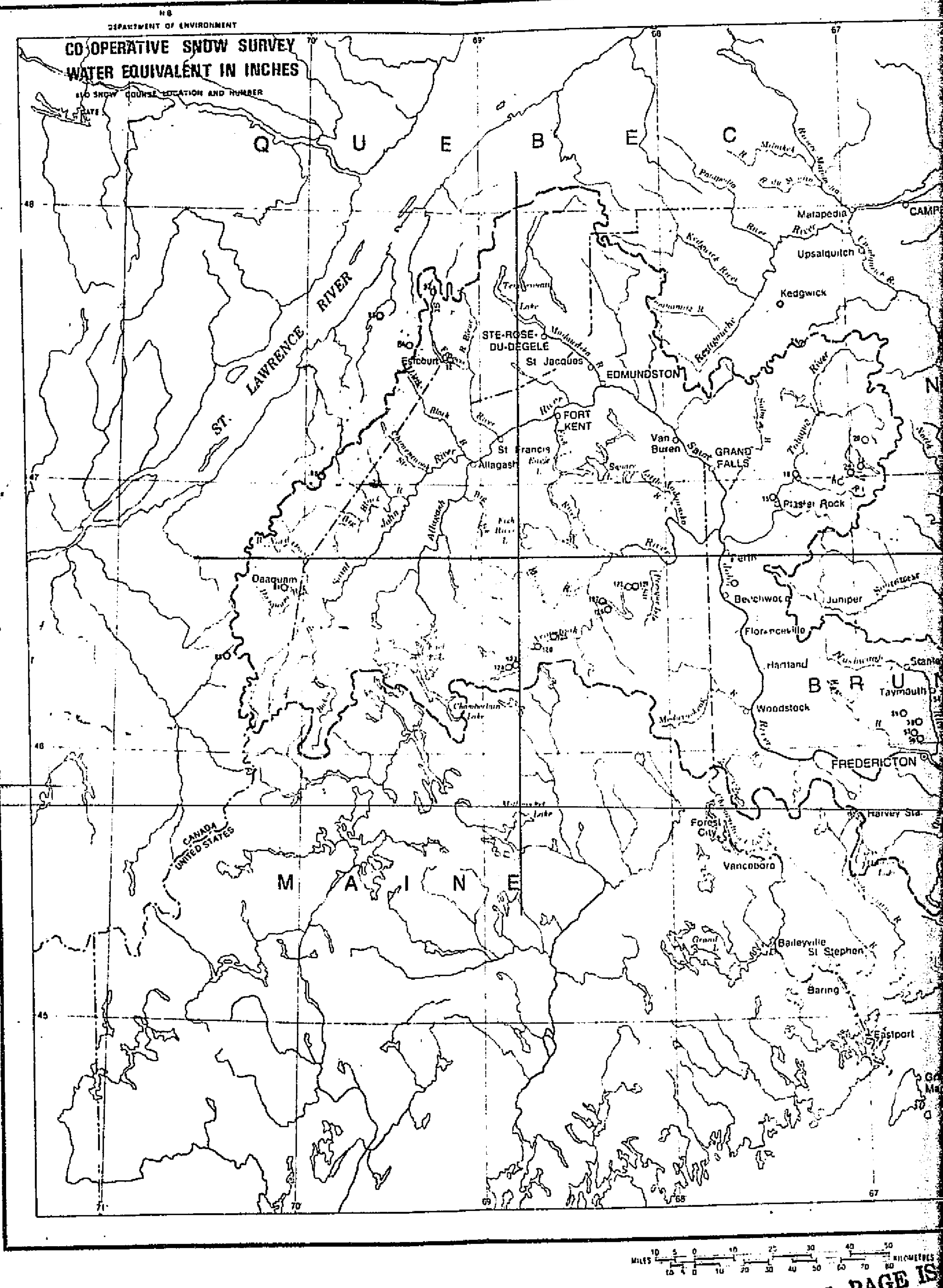


Figure 2-3. Red River Drainage Basin

SAINT JOHN RIVER BASIN

1:1,000,000



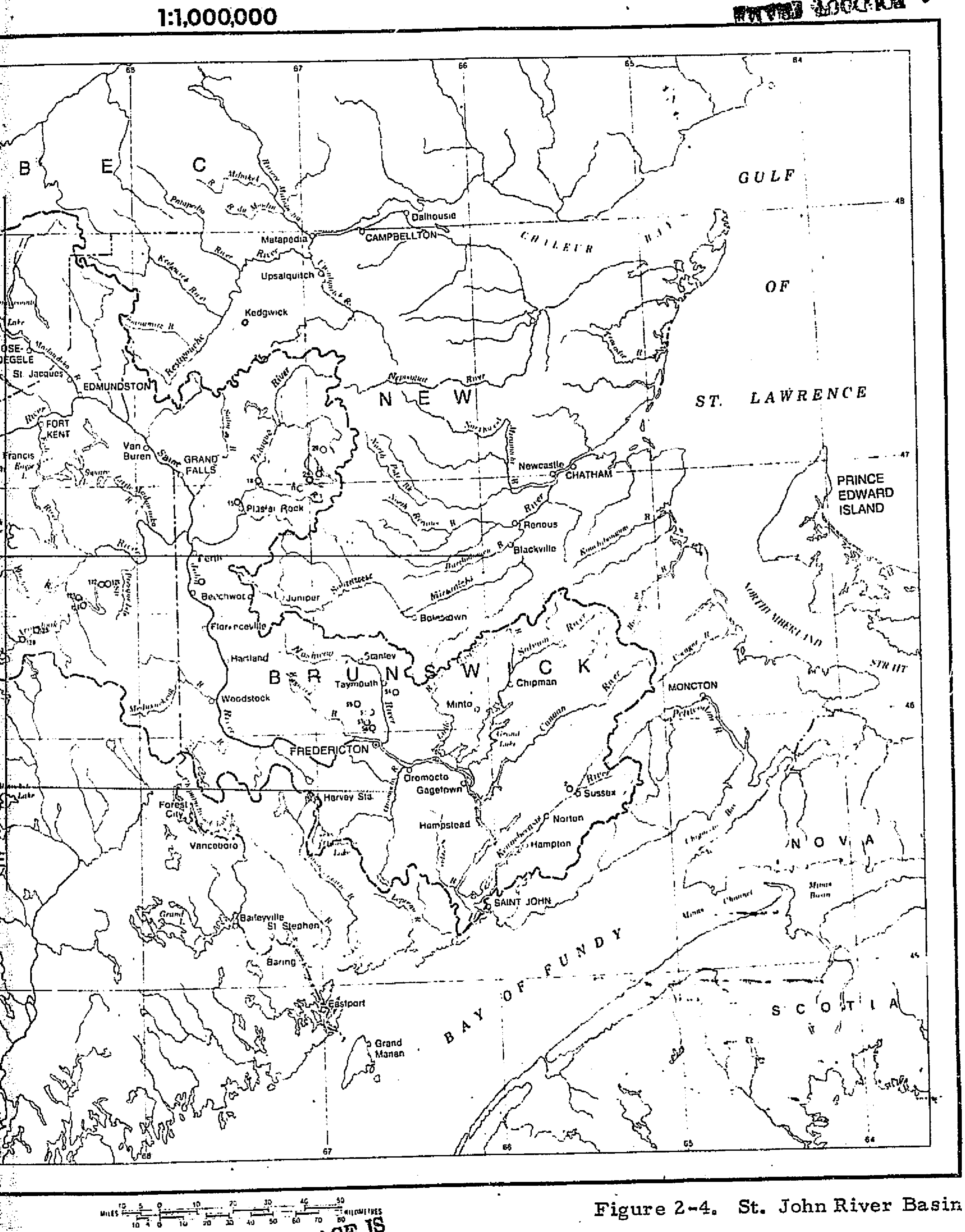


Figure 2-4. St. John River Basin

to the northern portion of the Longfellow mountains (elevations of peaks ranging from 3000 to 5200 feet) in Maine. Major water features around Site 2 are the Gulf of St. Lawrence to the north northeast and east, the Bay of Fundy to the south and the St. Lawrence River to the north northwest. Cities within the area are Caribou, Maine and Edmundston, New Brunswick in the northwestern portion and Fredericton, New Brunswick in the southeastern portion of the area.

Snow data are given in water equivalent snow depth with units of inches. Microwave (ESMR) data are for the frequency of 37 GHz with data given in degrees Kelvin for a horizontal polarization and a vertical polarization. The original time periods of interest were February 9, 1976 through February 13, 1976 for Site 1 and February 29, 1976 through March 1, 1976 for Site 2. By using published snow course data, the time periods for January 5-9, 1976 and February 2-9, 1976 were also included for Site 2. Table 2-1 gives a summary of ESMR data available for analysis in the time periods of interest. Readers familiar with the January-March 1977 quarterly progress report (Ref 16), will note that February 12, 1976 night and day orbits are not included. No attitude correction could be obtained for either the night or day orbit because the night orbit was west of the Great Lakes and had no data south of 46° latitude and the day orbit had only a small part of Lake Superior free from clouds, which was insufficient for the correction procedure.

Table 2-1

SUMMARY OF ANALYSIS DATA

Site	Julian Day	Date	GMT Time	Approx Local Time*	Time of Day Local
1	41	2/10/76	0647	0100	Night
1	41	2/10/76	1710	1100	Day
2	6	1/06/76	1511	1100	Day
2	8	1/08/76	1532	1130	Day
2	34	2/03/76	0436	0030	Night
2	61	3/01/76	0509	0100	Night

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* Site 1 Central Standard Time, six hours behind GMT; Site 2 Atlantic Standard Time, four hours behind GMT.

2.2 ANALYSIS PROGRAMS AND DATA PROCESSING

A number of computer programs were used in this study. Table 2-2 gives a mnemonic and description of each program. All computations were performed on an IBM 360/75.

Table 2-2

COMPUTER PROGRAMS

Mnemonic	Description
COPY	AESC system tape copy.
DSORT	AESC system small disk sort
STRIP	Combines all data at same time into one record.
ALBP	Prints data for every beam position with a descriptive designation (blank, water, rain) of the observation.
P61	Prints in compact form all data for a record (TH, TV, Latitude, Longitude)
ESMRPLOT	Plots the location of each observation with values of TH and TV over selected latitude and longitude ranges, $2^{\circ} \times 2^{\circ}$ per page on a scale of 5" per degree.
CRTRACK	Produces a card deck with latitude and longitude of the center beam position for each record, sets a flag if data not found.
ATTCR	Uses the data from CRTRACK to compute the attitude correction for each record, given an attitude correction at a specific initial latitude and longitude.

Table 2-2 (Continued)

COMPUTER PROGRAMS

Mnemonic	Description
DCORCT	Uses the output from ATTCR to produce an attitude corrected tape of ESMR data.
LINREG	Computes regression and correlation values for snow (H_2O) versus horizontal, vertical, or their average for both a linear and exponential model, with data screening on snow range and/or the difference of vertical minus horizontal.
MULTREG	Computes multiple regression values for any combination of two or more input variables, with the option for any variable as the dependent variable and any subset of the rest as independent variables.
PLOTW	Calcomp plot of an independent variable versus snow water equivalent
DSTATS	Computes summary statistics of variables and histograms of polarization differences (TV-TH)

In the ESMR data processing sequence, the raw ESMR data were run through the program sequence of COPY, DSORT (time and longitude), STRIP, and P61. The outputs from STRIP and P61 were used to select orbits for analysis, based on sufficient data within the required time and latitude-longitude windows. The potential orbits for analysis were then examined for the possible application of an attitude correction (to be discussed later). If no correction was possible due to lack of water-land boundary data or obscuration of water-land boundaries by clouds, the orbit was removed from further consideration. If necessary, an attitude correction was performed by running the program sequence CRTRACK, ATTCR, and DCORCT. Finally, a plot of the corrected data was made using ESMRPLOT.

The base maps for attitude correction are the World Aeronautical Charts (WAC) and the Operational Navigational Charts (ONC). Both map types have the same scale of 1:1,000,000 (1 inch = 13.7 nm) and use direction preserving Lambert Conformal conic projects with two standard parallels. The WAC charts cover the coterminous U.S., Mexico, and the Caribbean and are published and distributed by the National Ocean Survey, the ONC charts cover all foreign areas and are published by the Defense Mapping Agency Aerospace Center. Primary charts used for this study are WAC Chart CF-19 for Site 2, ONC Chart E-17 for Site 1 and WAC Chart CF-18 for obtaining attitude correction (Lake Michigan and Lake Superior) for Site 1.

The attitude correction for an orbit was performed by hand using the output from P61 and when necessary the outputs from ALBP and ESMRPLOT. Examples of the outputs from P61 and ALBP are given in Figures 2-5 and 2-6 for the night orbit on March 1, 1976, Site 2, with uncorrected data. The attitude correction procedure used is as follows:

a. A horizontal temperature was chosen as a water-land boundary delimiter. The value of 180° proved to be a good choice for this study.

b. All water-land boundary points were determined from P61 output and using ALBP and ESMRPLOT outputs as required.

c. Boundary points were plotted on a base map conforming to the ONC or WAC chart for the water areas, and the points were connected.

d. The base plot was overlaid on the appropriate ONC/WAC chart, and the base plot was shifted orthogonally keeping latitude and longitude lines of the two maps parallel until the water-land boundaries were in alignment.

e. At the center of the fitted area, the differences in latitude and longitude between the ESMR data location and the ONC/WAC location were determined, i.e., the amount of correction in latitude and longitude required to be algebraically added to the ESMR suc' that the locations of both maps agree.

```
    450 450 450 450
    660 657 655 653

                          1976         61     5  9 55

244 240 232 237 244 245 260 243 246 237 257 231 245 236 243 227 199 206 197 170 154 141 137 137 128 131 134 157 222 235 242
258 262 257 261 260 249 254 258 264 261 253 247 246 249 256 248 223 244 233 227 212 207 203 198 199 202 193 215 248 250 260
458 458 457 457 456 456 456 455 455 454 454 453 453 453 452 452 452 451 451 450 450 450 450 449 449 449 448 448 448 448 447
728 726 724 722 720 717 715 713 711 709 706 704 702 700 698 695 693 691 689 687 684 682 680 678 675 673 671 668 666 664 662


    231 234 232
    244 247 247
    447 447 447
    659 657 655

                          1976         61     5 10  0

247 232 235 246 241 242 241 242 248 247 234 227 242 227 223 206 166 161 146 132 132 131 131 141 128 137 138 155 198 222 231
262 252 255 254 264 261 268 257 259 261 261 247 247 263 252 240 220 218 218 209 207 201 197 209 202 198 205 209 237 253 256
455 454 454 453 452 452 452 451 451 451 450 450 450 449 449 449 448 448 448 447 447 447 447 447 446 446 446 446 445 445 445
728 726 724 722 720 717 715 713 711 709 706 704 702 700 698 695 693 691 689 687 684 682 680 678 676 673 671 669 667 665 662


    239 229 218
    245 245 247
    445 445 445
    660 658 656

                          1976         61     5 10  5

240 237 245 242 235 244 245 237 229 240 237 215 214 186 161 152 134 132 128 129 128 137 143 152 145 148 154 157 186 203 228
259 259 266 256 255 260 264 256 264 252 256 249 227 230 219 210 200 203 203 202 204 203 218 208 199 205 214 223 221 241 255
452 451 451 450 450 450 449 449 448 448 447 447 447 446 446 445 445 445 445 444 444 444 443 443 443 443 443 442 442 442 442
728 726 724 722 719 717 715 713 711 708 706 704 702 700 697 695 693 691 689 686 684 682 680 678 675 673 671 669 667 664 662


    205 183
    231 230
    442 442
    660 658

                          1976         61     5 10 11

251 239 254 249 247 240 245 238 242 234 237 185 157 145 133 124 119 130 137 119 121 147 148 144 136 136 135
257 260 264 258 260 259 258 260 265 260 245 229 214 216 196 202 198 201 200 196 202 214 213 212 200 200 207
449 448 448 447 447 447 446 446 445 445 444 444 444 443 443 442 442 442 441 441 441 441 440 440 440 440 440
729 727 725 723 720 718 716 714 712 710 708 706 703 701 699 697 695 693 691 688 686 684 682 680 677 675 673

                          1976         61     5 10 16

249 239 244 251 244 231 228 249 241 213 155 129 121 113
264 259 262 262 259 256 265 257 261 245 200 202 194 197
```

Figure 2-5. Example of Output from Program P61

```
54   1  1976   61    5   10    0          44.72   68.04      131  197   66     WATR
55   1  1976   61    5   10    0          44.70   67.82      141  209   68     WATR
56   1  1976   61    5   10    0          44.68   67.60      128  202   74     WATR
57   1  1976   61    5   10    0          44.66   67.38      137  198   61     WATR
58   1  1976   61    5   10    0          44.64   67.16      138  205   67     WATR
59   1  1976   61    5   10    0          44.62   66.94      155  209   54     WATR
60   1  1976   61    5   10    0          44.60   66.72      198  237   39
61   1  1976   61    5   10    0          44.58   66.50      222  253   31
62   1  1976   61    5   10    0          44.56   66.28      231  256   25
63   1  1976   61    5   10    0          44.54   66.06      239  245    6
64   1  1976   61    5   10    0          44.53   65.84      229  245   16
65   1  1976   61    5   10    0          44.51   65.62      218  247   29
33   2  1976   61    5   10    5          45.23   72.84      240  259   19
34   2  1976   61    5   10    5          45.18   72.63      237  259   22
35   2  1976   61    5   10    5          45.14   72.41      245  266   21
36   2  1976   61    5   10    5          45.10   72.20      242  256   14
37   2  1976   61    5   10    5          45.05   71.98      235  255   20
38   2  1976   61    5   10    5          45.00   71.76      244  260   16
39   2  1976   61    5   10    5          44.96   71.54      245  264   19
40   2  1976   61    5   10    5          44.91   71.32      237  256   19
41   2  1976   61    5   10    5          44.87   71.10      229  264   35
42   2  1976   61    5   10    5          44.82   70.88      240  252   12
43   2  1976   61    5   10    5          44.78   70.66      237  256   19
44   2  1976   61    5   10    5          44.74   70.44      215  249   34
45   2  1976   61    5   10    5          44.70   70.22      214  227   13
46   2  1976   61    5   10    5          44.67   70.00      186  230   44
47   2  1976   61    5   10    5          44.63   69.78      161  219   58     WATR
48   2  1976   61    5   10    5          44.60   69.56      152  210   58     WATR
49   2  1976   61    5   10    5          44.56   69.34      134  200   66     WATR
50   2  1976   61    5   10    5          44.53   69.12      132  203   71     WATR
51   2  1976   61    5   10    5          44.50   68.90      128  203   75     WATR
52   2  1976   61    5   10    5          44.47   68.68      129  202   73     WATR
53   2  1976   61    5   10    5          44.44   68.46      128  204   76     WATR
54   2  1976   61    5   10    5          44.42   68.24      137  203   66     WATR
55   2  1976   61    5   10    5          44.39   68.02      143  218   75     WATR
56   2  1976   61    5   10    5          44.37   67.80      152  208   56     WATR
57   2  1976   61    5   10    5          44.34   67.58      145  199   54     WATR
58   2  1976   61    5   10    5          44.32   67.36      148  205   57     WATR
59   2  1976   61    5   10    5          44.30   67.14      154  214   60     WATR
60   2  1976   61    5   10    5          44.28   66.92      157  223   66     WATR
61   2  1976   61    5   10    5          44.27   66.70      186  221   35
62   2  1976   61    5   10    5          44.25   66.48      203  241   38
63   2  1976   61    5   10    5          44.24   66.26      228  255   27
64   2  1976   61    5   10    5          44.22   66.04      205  231   26
65   2  1976   61    5   10    5          44.21   65.82      183  230   47
33   3  1976   61    5   10   11          44.93   72.94      251  257    6
34   3  1976   61    5   10   11          44.88   72.73      239  260   21
35   3  1976   61    5   10   11          44.84   72.51      254  264   10
36   3  1976   61    5   10   11          44.80   72.30      249  258    9
37   3  1976   61    5   10   11          44.75   72.09      247  260   13
38   3  1976   61    5   10   11          44.70   71.08      240  259   19
39   3  1976   61    5   10   11          44.66   71.67      245  258   13
40   3  1976   61    5   10   11          44.61   71.46      238  260   22
41   3  1976   61    5   10   11          44.57   71.24      242  265   23
42   3  1976   61    5   10   11          44.52   71.03      234  260   26
43   3  1976   61    5   10   11          44.48   70.82      237  245    8
44   3  1976   61    5   10   11          44.44   70.61      185  229   44
45   3  1976   61    5   10   11          44.40   70.39      157  214   57     WATR
46   3  1976   61    5   10   11          44.37   70.18      145  216   71     WATR
47   3  1976   61    5   10   11          44.33   69.96      133  [illegible]   63     WATR
48   3  1976   61    5   10   11          44.30   69.75      124  202   78     WATR
```

Figure 2-6. Example of Output from Program ALBP

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f. The program sequence CRTRACK, ATTCR, and DCORT was run to produce an attitude corrected set of data.

g. The programs P61, ESMRPLOT, and if required, ALBP, were run with the corrected data. The sequence of Steps b through e were repeated to test the correction.

In general, good corrections were obtained for Site 2 using the Bay of Fundy, Gulf of St. Lawrence, Northumberland Strait, Chaleur Bay and, in some cases, the St. Lawrence River. As the correction was made at the snow area, latitudes and longitudes over the whole area were adjusted using a constant latitude and longitude correction.

Good corrections were obtained for the February 10 orbits for Site 1. The correction for the night orbit was based on fitting the west side of Lake Superior and the day orbit was based on a fit to Lake Michigan and the west half of Lake Superior. These corrections from south of Site 1 were used to obtain the projected corrections at Site 1 on a record by record basis.

Table 2-3 presents the attitude corrections used for this study. The particular orbits are identified by Julian day and time of day, e.g., 41N is the night orbit for February 10. The base location is the center of the fitted area where the correction was found. The sign of the correction applies to the ESMR location, e.g., add -0.62° latitude to the ESMR latitude given. Two values are given for base longitude with opposite signs on the corrections. The original data gave longitude measured as 0-360°E. Because most maps for Canada and the United States give longitude measured from 0-180°W, the data in this study uses the 0-180°W designation, where the longitude transformation from one system to the other is given by 360° minus the given longitude.

Snow course measurements for a given area are taken over a period of a few days. Consequently, inclusion of data for days other than the ESMR observation day was necessary to provide sufficient data for analysis. The original analysis plan was to use snow water equivalent contour maps covering measurements taken from February 9, 1976 through February 13, 1976 for Site 1 and covering measurements taken from

Table 2-3

ATTITUDE CORRECTION VALUES

	Base Location			
Orbit	Latitude	Longitude	Latitude Correction	Longitude Correction
41N	47°N	90°W (270°E)	-0.62°	-0.35°(0.35°)
41D	46°N	89°W (271°E)	-0.73°	-0.81°(0.81°)
6D	47°N	65°W (295°E)	-0.52°	-0.43°(0.43°)
8D	47°N	67°W (293°E)	-0.87°	-0.32°(0.32°)
34N	47°N	65°W (295°E)	+.35°	0.00°(0.00°)
61N	46°N	68°W (292°E)	-0.60°	-0.70°(0.70°)

March 1, 1976 through March 3, 1976 for Site 2. Upon further consideration, the use of snow water equivalent contour maps became impractical. The data for Site 1 had a very small difference in magnitude between widely scattered points, making contour values quite subjective and unreliable. Although the contours could be used for March 1 at Site 2, no contour maps were available for January and February data for Site 2. Another important consideration was the problem of precipitation between the time of the ESMR observation and the time of the snow course measurement. The final snow water equivalent values used were the actual snow course measurements; this drastically reduced the sample sizes for analysis but provided a much better quality of data. The March 1, 1976, Site 2 data were analyzed using actual measured values and contour values for comparative purposes. The snow course data are given in Reference 1. Precipitation data are given in References 2-4 and 9-14. Appendix F gives meteorological data for selected stations within the Site 1 and Site 2 areas.

The snow water equivalent data was selected as follows:

a. All snow course locations were plotted on the ESMRPLOT scale (5"/degree latitude or longitude).

b. The time span of the measurement relative to the ESMR observation date was examined (the ESMR data were selected so that the observation, if available, fell within the span of the snow course measurements), and a range of snow days for inclusion was determined.

c. The snow value was eliminated if the snow data was taken after the ESMR data and precipitation occurred on any day between and if the snow data was taken before the ESMR and precipitation occurred in between*.

d. Valid snow data were plotted on the output of ESMRPLOT. If the snow location fell within the inner 50 percent footprint of an ESMR location, the snow water equivalent value was used along with the coincident ESMR values.

The dates used for snow data are given in Table 2-4.

Table 2-4

SNOW DATA SUMMARY

Orbit	Dates	Number	Comments
41N	Feb. 9-13	49	8 points, East of 96.2°, eliminated.
41D	Feb. 9-13	51	7 points, East of 96.2°, eliminated.
6D	Jan. 5, 6	10	No data before 5th, precipitation on 7th
8D	Jan. 8, 9	16	Precipitation on 8th, would reduce number to 5.
34N	Feb. 3-5	23	Precipitation on Feb. 1 and 2.
61N	March 1-3	23	Precipitation on Feb. 28 and 29.

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*Snow water equivalent values were also eliminated if part of the ESMR footprint was over open water or a frozen lake.

The variables of elevation, average precipitation days -1 and -2, maximum temperature days 0 and -1, and minimum temperature days 0 and -1 were used in the study. The elevation is given in Reference 1 for the snow course locations. For Site 2, the average precipitation for days -1 and -2 was used. To obtain precipitation for Site 2, a mix of Canadian and U. S. stations was used. In some cases, using daily totals, U. S. and Canadian stations in close proximity gave quite different values, indicating the totals were for different 24-hour periods. However, the average gave compatible numbers*. In a number of locations, especially Site 1, the weather observations are taken near the snow course observation. However, where necessary, precipitation and temperature values were obtained by contouring available data.

2.3 LINEAR CORRELATION ANALYSIS

This section presents the results for the correlation of snow water equivalent with the horizontal brightness temperature and the vertical brightness temperature, where snow water equivalent is the dependent variable and either the horizontal or vertical brightness temperature is the independent value. The linear regression model is of the form

$$y = \beta_o + \beta_1 x + e ,$$

where y is the snow equivalent water, x is either the horizontal or vertical brightness temperature, β_o is the intercept, β_1 is the slope, and e is the unknown random error in y. This section gives results in tabulated form for the basic statistics, single variable correlations, estimated regression intercepts and slopes, distribution of residuals, correlations for polarization difference restricted data, and analysis of polarization differences.

In the analysis, results were obtained for the average of the horizontal and vertical brightness temperatures as the independent variable. In

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*Precipitation data are given in Reference 2-4 and References 9-14. Canadian station locations are given in References 5-7. Daily maximum and minimum temperature data are given in References 2-4 and 9-11.

all cases, using the average gave a correlation value between the values for the horizontal and vertical individually, but never better. Therefore, the results for the average have not been included. Also, results for an exponential model were obtained; the model is of the form

$$y = \beta_o \cdot \exp(\beta_1 x) + e \quad .$$

Here, the correlation is based on the natural logarithm of y with x. In almost all cases the correlation coefficient was no better and sometimes worse than the correlation for the linear model. Results of the exponential model analysis will not be presented.

The basic data used in the analysis are given in Appendixes B-E. Appendix B presents the basic data in tabulated form along with plots of snow water equivalent versus the horizontal brightness temperature, the vertical brightness temperature, delta or polarization difference, and the elevation of the snow course measurement location. Appendix C gives plots of the relevant ESMR data as a function of latitude and longitude. Appendix D gives plots of snow water equivalent as a function of latitude and longitude. Appendix E gives residual results from the program LINREG for all significant correlations and the best correlation for data sets with no significant correlations. The multiple regression results including residuals from MULTREG for the best prediction of snow water equivalent in terms of variance explained are also given in Appendix E. As a considerable amount of data will be presented in this and the following two sections, a quick review of the material in Appendixes B-E should be of value to the reader.

Table 2-5 gives the basic statistics of the mean, the standard deviation (σ), the minimum value and the maximum value for the variables snow (equivalent inches of water), the horizontal brightness temperature, the vertical brightness temperature, the polarization difference of vertical and horizontal, and the elevation of the snow course measurement location. These statistics are given for the data sets of 41N, 41D, 6D, 8D, 34N, 61N, 61R, and 61E.

Table 2-5

BASIC STATISTICS

Day (Mnemonic)	N	Statistic	Variables				
			Snow (H_2O)	Hor.	Vert.	TV-THΔ	Elev.
41N	49	Mean	1.93	191.8	222.2	30.45	1312.8
		σ	0.77	10.9	8.3	8.06	482.6
		Min.	0.70	167.0	208.0	11.00	760.0
		Max.	4.52	212.0	240.0	49.00	2350.0
41D	51	Mean	1.87	190.5	217.4	26.92	1286.2
		σ	0.74	8.6	9.9	6.84	493.1
		Min.	0.70	172.0	198.0	13.00	730.0
		Max.	4.52	210.0	234.0	41.00	2350.0
6D	10	Mean	4.90	223.8	235.3	11.50	900.0
		σ	1.25	6.1	4.9	3.87	417.0
		Min.	3.00	209.0	224.0	4.00	250.0
		Max.	6.70	233.0	240.0	16.00	1500.0
8D	16	Mean	4.24	230.9	243.6	12.69	461.2
		σ	0.62	8.1	4.8	7.14	247.2
		Min.	3.10	217.0	237.0	1.00	130.0
		Max.	5.40	244.0	252.0	25.00	1000.0
34N	23	Mean	5.87	201.6	216.4	14.74	581.5
		σ	1.59	10.8	7.7	8.46	236.2
		Min.	2.90	185.0	205.0	0.00	200.0
		Max.	8.80	221.0	233.0	30.00	1200.0
61N	23	Mean	8.13	221.4	242.0	20.70	567.6
		σ	2.75	9.0	8.7	7.30	341.5
		Min.	2.90	202.0	230.0	8.00	130.0
		Max.	14.30	237.0	255.0	35.00	1250.0
61R	18	Mean	7.39	221.6	242.1	20.56	484.7
		σ	1.50	10.0	8.8	7.97	231.9
		Min.	4.90	202.0	230.0	8.00	200.0
		Max.	10.20	237.0	255.0	35.00	1200.0
61E	71	Mean	8.38	219.4	241.5	22.04	NA
		σ	1.54	10.3	8.7	8.46	NA
		Min.	5.10	197.0	225.0	1.00	NA
		Max.	11.50	239.0	259.0	37.00	NA

Table 2-6 presents information and statistics on the single variable correlations between snow water equivalent and the horizontal and vertical brightness temperatures. The information present are the date, the time of the orbit (night or day), the type data set (all or a subset based on snow range), the number of observations, the snow range of the data set in inches of equivalent water, the ESMR variable for the correlation (H = horizontal, V = vertical), the sample correlation coefficient (r), the significance of r (NS = not significant, ** = significant at 95% level, *** = significant at 99% level), the 95 percent confidence interval of r (if significant), the percent variance of snow water equivalent explained by the linear model ($100*r^2$), the standard error of estimate ($\sigma_{\hat{y}}$), and the standard deviation of snow water equivalent ($\hat{\sigma}_y$). The 95 percent confidence interval on r means that 95 percent of the time the true population correlation coefficient would be expected to be contained within the interval.

Table 2-7 gives the estimated intercepts and slopes for the linear regression of snow water equivalent and the horizontal brightness temperatures, the vertical brightness temperature, and the elevation of the snow course measurement location. The rate of change of the ESMR brightness temperatures per inch of equivalent water is given by the reciprocal of the slope.

Table 2-8 gives for Site 1 data sets the distribution, as percent frequency, of the residuals of the regression analysis. The residual is the difference between the observed value of snow water equivalent minus the predicted value. Table 2-9 gives the same information for Site 2 data sets. The information given is of the form residual interval (low, high), and percent frequency in each interval for the horizontal (H) and the vertical (V) as the independent variable for each data set. Because the snow range was small for Site 1, the interval of 0.2 inch was used. For Site 2 the interval of 0.5 inch was used for tabulation.

Table 2-10 gives the single variable correlations when the data are restricted to a Δ = vertical (TV) - horizontal (TH) of less than 21°. A more extensive tabulation of correlation as subsets of the total based on snow water equivalent ranges and Δ ranges are given for 61E in the January-March Quarterly Progress Report (Ref 16).

Table 2-6

SINGLE VARIABLE CORRELATIONS

Day	Orbit	Mnemonic	Type	N	Snow Range		ESMR Variable	r	Sig.	95% Confidence		100* r^2	$\sigma_{\hat{y}}$	$\hat{\sigma}_y$
					Min.	Max.				Lower	Upper			
2/10	Night	41N	All	49	0.70	4.52	H	0.07	NS			0.5	0.78	0.77
							V	0.05	NS			0.3	0.78	0.77
2/10	Day	41D	All	51	0.70	4.52	H	0.06	NS			0.4	0.75	0.74
							V	0.28	**	0.01	0.52	7.9	0.72	0.74
1/06	Day	6D	All	10	3.00	6.70	H	0.61	NS			36.6	1.05	1.25
							V	0.49	NS			24.3	1.15	1.25
1/08	Day	8D	All	16	3.10	5.40	H	0.29	NS			8.3	0.61	0.62
							V	0.46	NS			21.3	0.57	0.62
2/03	Night	34N	All	23	2.90	8.80	H	-0.32	NS			10.1	1.55	1.59
							V	-0.64	***	-0.31	-0.84	41.3	1.25	1.59
3/01	Night	61N	All	23	2.90	14.30	H	-0.40	NS			15.8	2.59	2.75
							V	-0.32	NS			10.4	2.67	2.75
		61R	Subset	18	4.90	10.20	H	-0.61	***	-0.20	-0.84	37.5	1.22	1.50
							V	-0.75	***	-0.44	-0.90	56.6	1.02	1.50
3/01	Night	61E	All Contour	71	5.10	11.50	H	-0.24	**	-0.01	-0.45	6.0	1.50	1.54
							V	-0.53	***	-0.34	-0.68	28.0	1.31	1.54
		61E(1)	Subset	29	5.10	8.00	H	-0.39	**	-0.03	-0.66	15.0	0.90	0.96
							V	-0.65	***	-0.38	-0.82	43.0	0.74	0.96
		61E(2)	Subset	42	8.30	11.50	H	-0.08	NS			0.7	0.83	0.82
							V	-0.22	NS			5.0	0.81	0.82

Table 2-7

ESTIMATED INTERCEPT AND SLOPE FOR LINEAR REGRESSION OF SNOW (H_2O) VERSUS HORIZONTAL, VERTICAL AND ELEVATION

Day (Mnemonic)	Variable	Intercept	Slope
41N	H	0.98	0.0050
	V	0.83	0.0050
	E	1.29	0.0005
41D	H	0.89	0.0051
	V	-2.70	0.0210
	E	1.35	0.0004
6D	H	-22.58	0.1228
	V	-24.44	0.1247
	E	2.48	0.0027
6D	H	-0.83	0.0220
	V	-10.09	0.0588
	E	4.38	-0.0003
34N	H	15.26	-0.0466
	V	34.72	-0.1335
	E	3.96	0.0033
61N	H	35.01	-0.1215
	V	32.87	-0.1022
	E	4.51	0.0064
61R	H	27.86	-0.0924
	V	36.46	-0.1201
	E	5.82	0.0032
61E	H	16.39	-0.0366
	V	30.88	-0.0932

Table 2-8

SITE 1 DISTRIBUTION OF RESIDUALS AS % FREQUENCY

Interval		41N		41D	
Low	High	H	V	H	V
-1.2	-1.0	10.2	8.2	5.9	-
-1.0	-0.8	4.1	6.1	5.9	9.8
-0.8	-0.6	2.0	2.0	3.9	11.8
-0.6	-0.4	12.2	10.2	13.7	3.9
-0.4	-0.2	18.4	20.4	19.6	9.8
-0.2	0.0	10.2	12.2	7.8	21.6
0.0	0.2	10.2	10.2	9.8	13.7
0.2	0.4	8.2	6.1	11.8	5.9
0.4	0.6	6.1	6.1	7.8	7.8
0.6	0.8	8.2	8.2	5.9	9.8
0.8	1.0	4.1	4.1	2.0	-
1.0	1.2	-	-	-	-
1.2	1.4	-	-	-	-
1.4	1.6	-	-	-	-
1.6	1.8	2.0	-	-	2.0
1.8	2.0	2.0	4.1	3.9	2.0
2.0	2.2	-	-	-	-
2.2	2.4	-	-	-	-
2.4	2.6	2.0	2.0	-	2.0
2.6	2.8	-	-	2.0	-

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Table 2-9

SITE 2 DISTRIBUTION OF RESIDUALS AS % FREQUENCY

Interval		6D		8D		34N		61N		61R		61E	
Low	High	H	V	H	V	H	V	H	V	H	V	H	V
-5.5	-5.0								4.3				
-5.0	-4.5							4.3	-				
-4.5	-4.0							-	-				
-4.0	-3.5							4.3	-				
-3.5	-3.0					4.3		-	-			1.4	
-3.0	-2.5					-		4.3	-	5.6		4.3	1.4
-2.5	-2.0					4.3	4.3	-	13.0	-		4.3	2.9
-2.0	-1.5					13.0	8.7	4.3	-	5.6	5.6	4.3	7.1
-1.5	-1.0	20	30	6.2		-	4.3	17.4	17.4	5.6	11.1	8.6	12.9
-1.0	-0.5	20	10	12.5	25.0	13.0	26.1	17.4	17.4	11.1	5.6	12.9	12.9
-0.5	0.0	10	10	25.0	25.0	8.7	8.7	8.7	13.0	22.2	38.9	11.4	14.3
0.0	0.5	20	10	37.5	37.5	21.7	8.7	8.7	8.7	16.7	11.1	12.9	11.4
0.5	1.0	10	10	12.5	12.5	4.3	26.1	4.3	4.3	16.7	11.1	15.7	12.9
1.0	1.5	10	20	6.2		13.0	4.3	8.7	4.3	16.7	5.6	10.0	10.0
1.5	2.0	10	10			13.0	4.3	-	-		11.1	5.7	8.6
2.0	2.5					-	-	8.7	4.3			1.4	4.3
2.5	3.0					4.3	4.3	-	4.3			5.7	-
3.0	3.5							-	-			1.4	1.4
3.5	4.0							-	-				
4.0	4.5							-	-				
4.5	5.0								-				
5.0	5.5							4.3	-				
5.5	6.0							4.3	4.3				
6.0	6.5								4.3				
6.5	7.0												

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Table 2-10

SINGLE VARIABLE CORRELATION FOR (TV-TH) < 21

Day (Mnemonic)	Snow Range		N	ESMR Variable	r	Sig.	95% Confidence Lower	95% Confidence Upper	100* r^2	$\sigma_{\hat{y}}$	$\hat{\sigma}_y$
41N	1.11	3.77	5	H	-0.35	NS			12.3	1.14	1.05
				V	-0.15	NS			2.3	1.20	1.05
41D	0.79	2.57	10	H	0.16	NS			2.5	0.63	0.60
				V	0.36	NS			12.8	0.60	0.60
6D	3.00	6.70	10	H	0.61	NS			36.6	1.05	1.25
				V	0.49	NS			24.3	1.15	1.25
8D	3.10	5.40	14	H	0.36	NS			13.4	0.62	0.64
				V	0.51	NS			26.0	0.57	0.64
34N	2.90	8.00	16	H	-0.55	**	-0.08	-0.82	30.6	1.29	1.49
				V	-0.82	***	-0.56	-0.94	67.9	0.88	1.49
61N	2.90	11.60	13	H	-0.59	**	-0.06	-0.86	35.1	1.81	2.15
				V	-0.59	**	-0.06	-0.86	35.3	1.81	2.15
61R	4.90	8.70	11	H	-0.71	***	-0.20	-0.92	51.0	.98	1.33
				V	-0.71	***	-0.19	-0.92	50.4	.99	1.33
61E	5.30	11.50	31	H	-0.40	**	-0.05	-0.66	16.1	1.40	1.51
				V	-0.46	***	-0.12	-0.70	20.8	1.36	1.51

Table 2-11 summarizes the polarization difference (delta) statistics for the difference between the vertical and the horizontal brightness temperatures. This information was also given in Table 2-5. The mean, standard deviation, minimum and maximum polarization difference values are given. Figure 2-7 shows the polarization distribution as percent frequency, for 6D, 8D, 34N, 61N, 41N and 41D. Examination of mean values shows quite a difference, with 41N and 41D being the highest, 61N in the middle, 6D and 8D being the lowest and 34N between 61N and 8D. Except for a very low value for 6D, all the standard deviations are approximately the same. The difference between the means was tested using a "t" test and the three combinations (8D, 61N),(8D, 41D) and (61N, 41D) showed a significant difference between the means at the 99 percent level. However, the test is really not valid because all the distributions are skewed and not normally distributed. Because the distribution sets (6D, 8D), (34N, 61N), (41N, 41D) are obviously different, the exact tests using the nonparametric Kolmogorov-Smirnov two sample test was not performed.

The low polarization for 8D is expected because of scattered precipitation in the area near the time of the ESMR observations. The low polarization of 6D could be due to a terrain problem, where low polarizations were sometimes observed in mountain regions of Europe under clear conditions. The relatively high polarizations for 41N and 41D could be due to a combination of free moisture in the snow, a thin layer of snow, and/or bare ground.

2.4 MULTIPLE CORRELATION AND REGRESSION ANALYSIS

This section presents results for a multiple linear correlation and regression analysis. Included in this section are results for the linear relationship of the elevation of the snow course location to other variables; multiple correlations of snow water equivalent with all combinations of the horizontal brightness temperature, vertical brightness temperature, and elevation; the best combination of independent variables for predicting snow water equivalent in terms of variance explained, $100 * r^2$, finally, multiple correlation results are given for the best prediction combination for the

Table 2-11

POLARIZATION DIFFERENCE STATISTICS

Day (Mnemonic)	Mean	St. Dev.	Minimum	Maximum
41N	30.45	8.06	11.0	49.0
41D	26.92	6.84	13.0	41.0
6D	11.50	3.87	4.0	16.0
8D	12.69	7.14	1.0	25.0
34N	14.74	8.46	0.0	30.0
61N	20.70	7.30	8.0	35.0
61R	20.56	7.97	8.0	35.0
61E	22.04	8.46	1.0	37.0

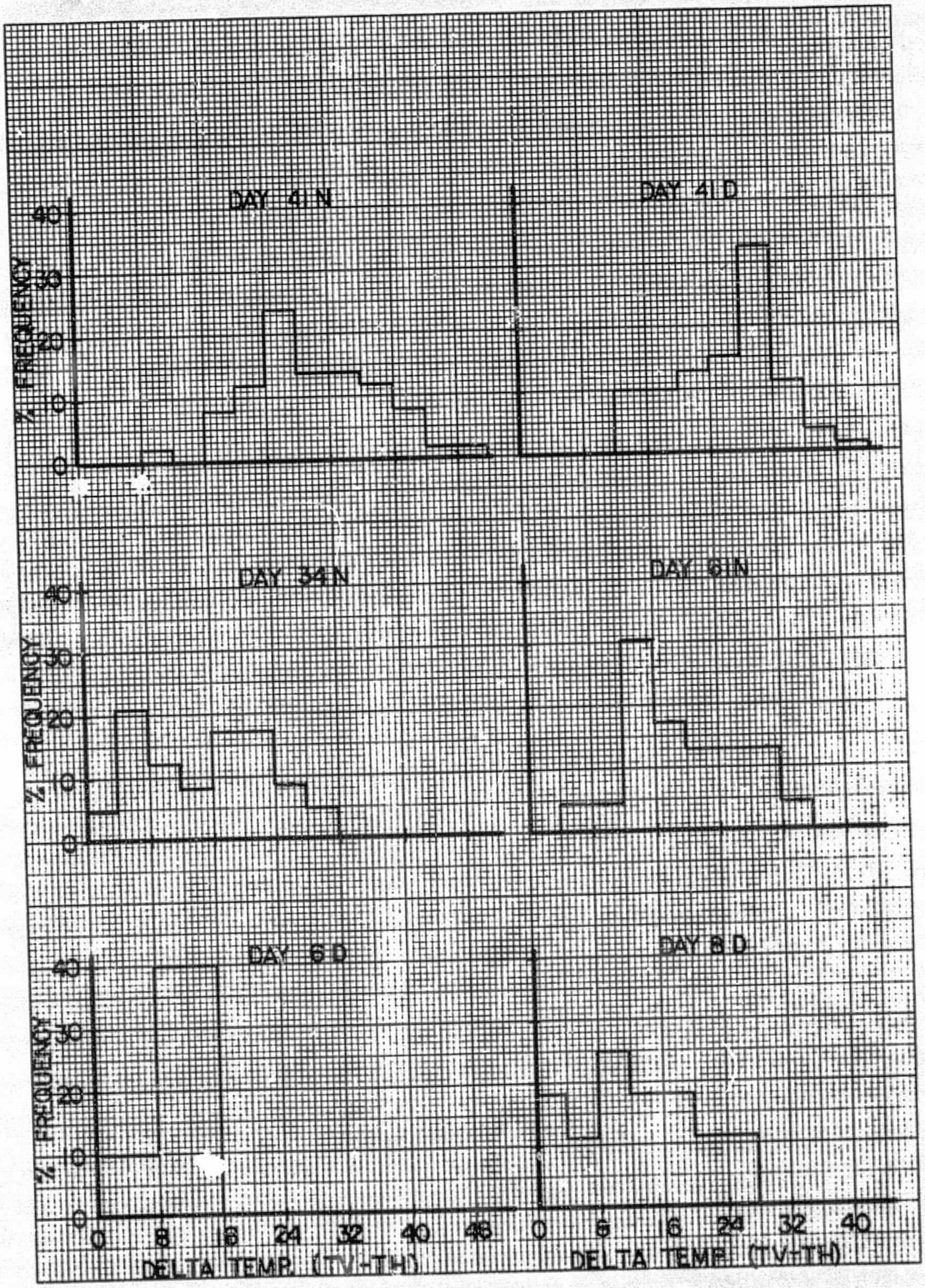

Figure 2-7. Distribution of Polarization Difference as % Frequency

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horizontal brightness temperature and vertical brightness temperature as the dependent variable. The regression coefficients and residuals for the regression of snow water equivalent with the best combination of prediction variables are given, as computer output, in Appendix E.

The multiple regression model is of the form

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p + e \ .$$

Except for the correlations with elevation as the independent variable, the following information will be given: the data set mnemonic, the independent variables, the multiple linear correlation coefficient denoted as the $|r|$, the significance (NS = not significant, ** = significant at the 95 percent level, *** = significant at the 99 percent level), the percent variance explained ($100{*}r^2$), the standard error of estimate ($\sigma_{\hat{y}}$), and the standard deviation of the dependent variable ($\hat{\sigma}_y$). Results are given for the data sets of 41N, 41D, 6D, 8D, 34N, 61N, and 61R. A multiple regression analysis was not performed for 61E because data for the associated variables were too difficult to obtain. In the case of the best prediction set of independent variables, the set was based on the highest $100{*}r^2$ value. However if a combination was within 1 percent with a lesser number of independent variables, the set with the smaller number was used. In some cases, previously tabulated information is presented to facilitate ease of comparison. Potential variables used are snow water equivalent, horizontal brightness temperature, vertical brightness temperature, elevation, average precipitation on days -1 and -2, maximum temperature (day -1 for night orbit and day 0 for day orbits), and minimum temperature (day 0 for night orbits and day -1 for day orbits). Precipitation was not used for 41N or 41D because no precipitation occurred in the preceding two days. Analysis using precipitation, maximum temperature, or minimum temperature as variables was not performed for 6D or 8D because of the small sample size and anticipated lack of relationships.

Table 2-12 gives the single variable linear correlations with elevation as the independent variable and snow water equivalent, the horizontal brightness temperature, the vertical brightness temperature, the

Table 2-12

SINGLE VARIABLE CORRELATION USING ELEVATION

Day (Mnemonic)	Dep. Variable	r	Sig.	100*r^2	$\sigma_{\hat{y}}$	$\hat{\sigma}_y$
41N	Snow	0.31	**	9.3	0.74	0.77
	Hor.	0.04	NS	0.2	11.0	10.9
	Vert.	-0.06	NS	0.4	8.4	8.3
	Max. T.	-0.28	**	7.9	2.9	3.0
	Min. T.	0.18	NS	3.3	5.6	5.7
41D	Snow	0.27	NS	7.2	0.72	0.74
	Hor.	0.24	NS	5.7	8.5	8.6
	Vert.	0.30	**	9.0	9.6	9.9
	Max. T.	-0.17	NS	2.9	7.4	7.4
	Min. T.	0.04	NS	0.2	5.2	5.2
6D	Snow	0.90	***	81.0	0.58	1.25
	Hor.	0.53	NS	27.6	5.6	6.1
	Vert.	0.46	NS	20.7	4.6	4.9
8D	Snow	-0.12	NS	1.5	0.62	0.63
	Hor.	-0.25	NS	6.4	8.1	8.1
	Vert.	-0.41	NS	17.2	4.6	4.8
34N	Snow	0.49	**	23.6	1.42	1.59
	Hor.	-0.20	NS	4.2	10.9	10.9
	Vert.	-0.14	NS	2.0	7.7	7.8
	Max. T.	-0.42	**	17.5	4.9	5.2
	Min. T.	-0.35	NS	12.4	3.8	3.9
61N	Snow	0.79	***	62.5	1.73	2.75
	Hor.	-0.36	NS	13.1	8.6	9.0
	Vert.	-0.30	NS	8.9	8.5	8.7
	Max. T.	-0.34	NS	13.1	6.0	6.3
	Min. T.	-0.36	NS	11.8	5.6	5.9
61R	Snow	0.50	**	25.0	1.34	1.50
	Hor.	-0.50	**	24.7	8.9	10.0
	Vert.	-0.52	**	27.5	8.3	9.4
	Max. T.	-0.45	NS	19.9	5.9	6.1
	Min. T.	-0.35	NS	12.2	7.6	8.8

maximum temperature, or the minimum temperature as the dependent variable. For all data sets except 41D and 8D snow water equivalent had a significant correlation with elevation. Except for 61R, no correlation was found between elevation and the horizontal brightness temperature. Except for 41D and 61R, no correlation was found between elevation and the vertical brightness temperature.

Table 2-13 gives the Site 1 multiple correlation coefficients for snow water equivalent as the dependent variable with all possible combinations of horizontal brightness temperature, vertical brightness temperature, and elevation of the snow course measurement location as the independent variables. Table 2-14 gives the same information for Site 2.

Table 2-15 presents the multiple correlation coefficients for the best combination of independent variables for predicting the snow water equivalent. The multiple correlations for 41N and 8D were not significant. The 41D value still reflects the correlation of the vertical and elevation with snow water equivalent. Two values are given for 61R. The second set is for predictions without precipitation; while temperatures are usually reliable and regularly reported, precipitation can be quite localized and information hard to obtain.

Table 2-16 gives the best prediction of the horizontal or vertical brightness temperature as the dependent variable using combinations of snow water equivalent, elevation, maximum temperature, and minimum temperature as the independent variables. The results here are not relevant to this study but might be of interest. Generally the ESMR temperatures should be the dependent variable with the standard regression model error assumptions. As can be seen, a large amount of variation is left unexplained in most cases.

2.5 SINGLE ORBIT ANALYSIS

This section will discuss each of the data sets analyzed on an individual basis. Generally, the discussion will be in terms of linear correlation, meteorological data and any other factors which might have an influence on the interpretation of the analysis results. The correlation

Table 2-13
SITE 1 MULTIPLE CORRELATION COEFFICIENTS

Day (Mnemonic)	Independent Variables			$\lvert r \rvert$	Sig.	$100 * r^2$	$\sigma_{\hat{y}}$	$\hat{\sigma}_y$	d.f. ν_1 / ν_2
	Hor.	Vert.	Elev.						
41N	X			0.07	NS	0.5	0.78	0.77	1/47
		X		0.05	NS	0.3	0.78	0.77	1/47
	X	X		0.07	NS	0.5	0.79	0.77	2/46
			X	0.31	**	9.3	0.74	0.77	1/47
	X		X	0.31	NS	9.6	0.75	0.77	2/46
		X	X	0.31	NS	9.8	0.75	0.77	2/46
	X	X	X	0.31	NS	9.8	0.75	0.77	3/45
41D	X			0.06	NS	0.4	0.75	0.74	1/49
		X		0.28	**	7.9	0.72	0.74	1/49
	X	X		0.36	**	12.7	0.71	0.74	2/48
			X	0.27	NS	7.2	0.72	0.74	1/49
	X		X	0.27	NS	7.2	0.73	0.74	2/48
		X	X	0.34	NS	11.7	0.71	0.74	2/48
	X	X	X	0.41	**	16.6	0.72	0.74	3/47

Table 2-14
SITE 2 MULTIPLE CORRELATION COEFFICIENTS

Day (Mnemonic)	Independent Variables			$\|r\|$	Sig.	$100 * r^2$	$\sigma_{\hat{y}}$	$\hat{\sigma}_y$	d.f ν_1/ν_2
	Hor.	Vert.	Elev.						
6D	X			0.61	NS	36.6	1.05	1.25	1/8
		X		0.49	NS	24.3	1.15	1.25	1/8
	X	X		0.61	NS	36.8	1.12	1.25	2/7
			X	0.90	***	81.0	0.58	1.25	1/8
	X		X	0.91	***	83.4	0.58	1.25	2/7
		X	X	0.90	***	81.9	0.60	1.25	2/7
	X	X	X	0.91	***	83.5	0.62	1.25	3/8
8D	X			0.29	NS	8.3	0.61	0.62	1/14
		X		0.46	NS	21.3	0.57	0.62	1/14
	X	X		0.47	NS	21.8	0.59	0.62	2/13
			X	0.12	NS	1.5	0.63	0.62	1/14
	X		X	0.29	NS	8.6	0.63	0.62	2/13
		X	X	0.47	NS	21.9	0.59	0.62	2/13
	X	X	X	0.47	NS	22.5	0.61	0.62	3/12
34N	X			0.32	NS	10.1	1.55	1.59	1/21
		X		0.64	***	41.3	1.25	1.59	1/21
	X	X		0.65	***	42.6	1.27	1.59	2/20
			X	0.49	**	23.6	1.42	1.59	1/21
	X		X	0.53	**	28.6	1.41	1.59	2/20
		X	X	0.76	***	57.2	1.09	1.59	2/20
	X	X	X	0.78	***	60.3	1.08	1.59	3/19
61N	X			0.40	NS	15.8	2.59	2.75	1/21
		X		0.32	NS	10.4	2.67	2.75	1/21
	X	X		0.41	NS	16.4	2.64	2.75	2/20
			X	0.79	***	62.5	1.73	2.75	1/21
	X		X	0.80	***	63.9	1.73	2.75	2/20
		X	X	0.80	***	63.3	1.75	2.75	2/20
	X	X	X	0.78	***	63.9	1.78	2.75	3/19
61R	X			0.61	***	37.5	1.22	1.50	1/16
		X		0.75	***	56.6	1.02	1.50	1/16
	X	X		0.77	***	58.9	1.03	1.50	2/15
			X	0.50	**	25.0	1.34	1.50	1/16
	X		X	0.65	**	42.6	1.21	1.50	2/15
		X	X	0.76	***	58.1	1.05	1.50	2/15
	X	X	X	0.77	***	59.7	1.05	1.50	3/14

Table 2-15

BEST PREDICTION OF SNOW (H_2O) IN TERMS OF r^2

Day (Mnemonic)	Hor.	Vert.	Elev.	Prec.	Max. T.	Min. T.	$\|r\|$	Sig.	$100 * r^2$	$\sigma_{\hat{y}}$	$\hat{\sigma}_y$
41N		X	X	NA			0.31	NS	9.8	0.75	0.77
41D	X	X		NA	X		0.52	***	27.5	0.65	0.74
6D	X		X	NA	NA	NA	0.91	***	83.4	0.58	1.25
8D		X	X	NA	NA	NA	0.47	NS	21.9	0.59	0.62
34N	X	X	X				0.78	***	60.3	1.08	1.59
61N	X		X				0.80	***	63.9	1.73	2.75
61R	X	X		X	X	X	0.92	***	84.2	0.71	1.50
61R	X				X	X	0.89	***	78.9	0.76	1.50

Table 2-16

BEST PREDICTION OF HORIZONTAL AND VERTICAL TEMPERATURE IN TERMS OF r^2

Day Mnemonic	Dep. Variable	Snow H_2O	Elev.	Max. T.	Min. T.	$\lvert r \rvert$	Sig.	100* r^2	$\sigma_{\hat{y}}$	$\hat{\sigma}_y$
41N	H	X	X	X		0.32	NS	10.4	10.7	10.9
	V	X				0.05	NS	0.3	8.3	8.4
41D	H	X	X		X	0.37	NS	13.4	8.3	8.6
	V	X	X	X	X	0.49	**	24.0	9.5	9.9
6D	H	X		NA	NA	0.61	NS	36.6	5.5	6.1
	V	X		NA	NA	0.49	NS	24.3	4.9	4.9
8D	H	X	X	NA	NA	0.36	NS	13.1	8.1	[illegible]
	V	X	X	NA	NA	0.59	NS	34.3	4.2	4.8
34N	H	X	X	X		0.44	NS	19.3	10.8	10.9
	V	X	X	X	X	0.77	***	59.1	5.4	7.7
61N	H	X	X	X		0.59	**	34.9	7.8	9.0
	V	X	X	X		0.68	***	45.7	6.9	8.7
61R	H	X	X			0.65	**	42.4	8.1	10.0
	V	X	X			0.78	***	59.5	6.4	9.4

results are given in Sections 2.3 and 2.4. ESMR data plots are given in Appendix C. Snow data plots are given in Appendix D, and meteorological data are given in Appendix F*. All temperatures are in degrees Fahrenheit.

For Site 1, the data set 41N showed no significant correlation between snow water equivalent and ESMR brightness temperatures. The data set 41D had no significant correlation between snow water equivalent and the horizontal brightness temperature, while a significant positive correlation of 0.28 was found with the vertical brightness temperature. In the Site 1 area, for the five days preceding February 10, 1976, no precipitation was observed. On the 10th, light precipitation from a trace to 0.16 inches was observed. The time of day of the precipitation is now known, but looking at precipitation on the 11th, hours of bright sunshine on the 9th, 10th and 11th and ESMR values suggest that the precipitation occurred after the daytime ESMR observation. On the 10th, the maximum temperature ranged, over the selected stations, from 4° to 28° and the minimum from -12° to 6°. However, in the three days preceding the 10th, all stations had a maximum temperature above freezing, and on the 9th, maximum temperatures ranged from 39° to 45° with minimums ranging from 20° to 36°. Generally, snow water equivalent ranged from 0.70 to 2.60 inches. The maximum snow value of 4.52 inches was found on the north side of the Turtle Mountains. The other local maximum of 3.80 inches was found on the east side of the Riding Mountains, while a local minimum of 0.79 inches was found within 0.1° in latitude and longitude of the maximum. The 3.80 inch value was at an elevation of 2300 feet and the 0.70 inch value at an elevation of 988 feet. This illustrates a problem of using point source snow values with an integrated ESMR value.

Figures 2-8 and 2-9 show a plot of the ESMR data for data sets 41N and 41D in the vicinity of Lake Winnipeg and Lake Manitoba. The lakes are shown with a solid line. Areas with vertical brightness temperatures greater than or equal to 235° are shown with a dashed line and slight

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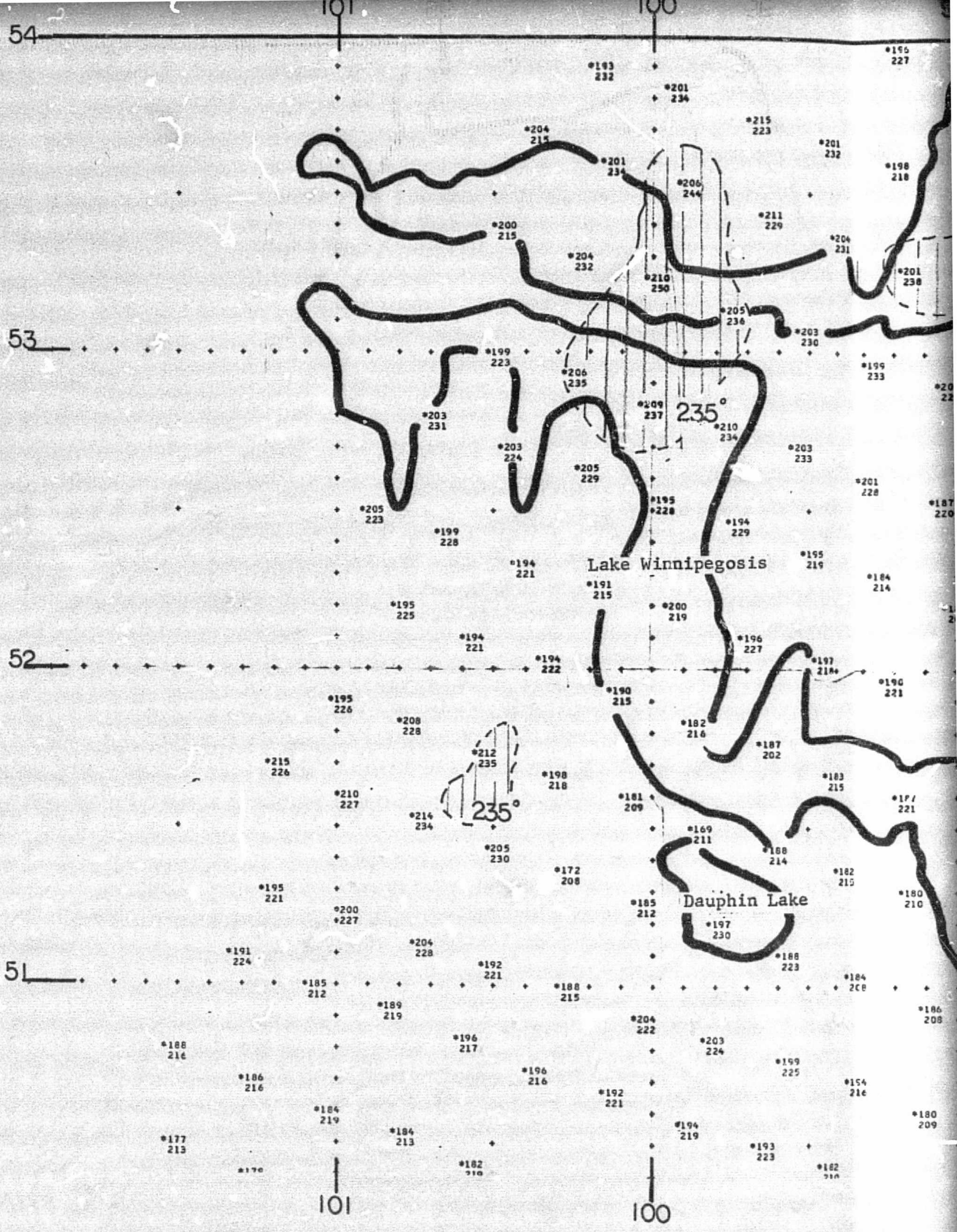
* Snow fall is generally converted to inches of water at the local station by dividing the depth by 10.


101
100
54
53
52
51
Lake Winnipegosis
Dauphin Lake
235°
235°
101
100

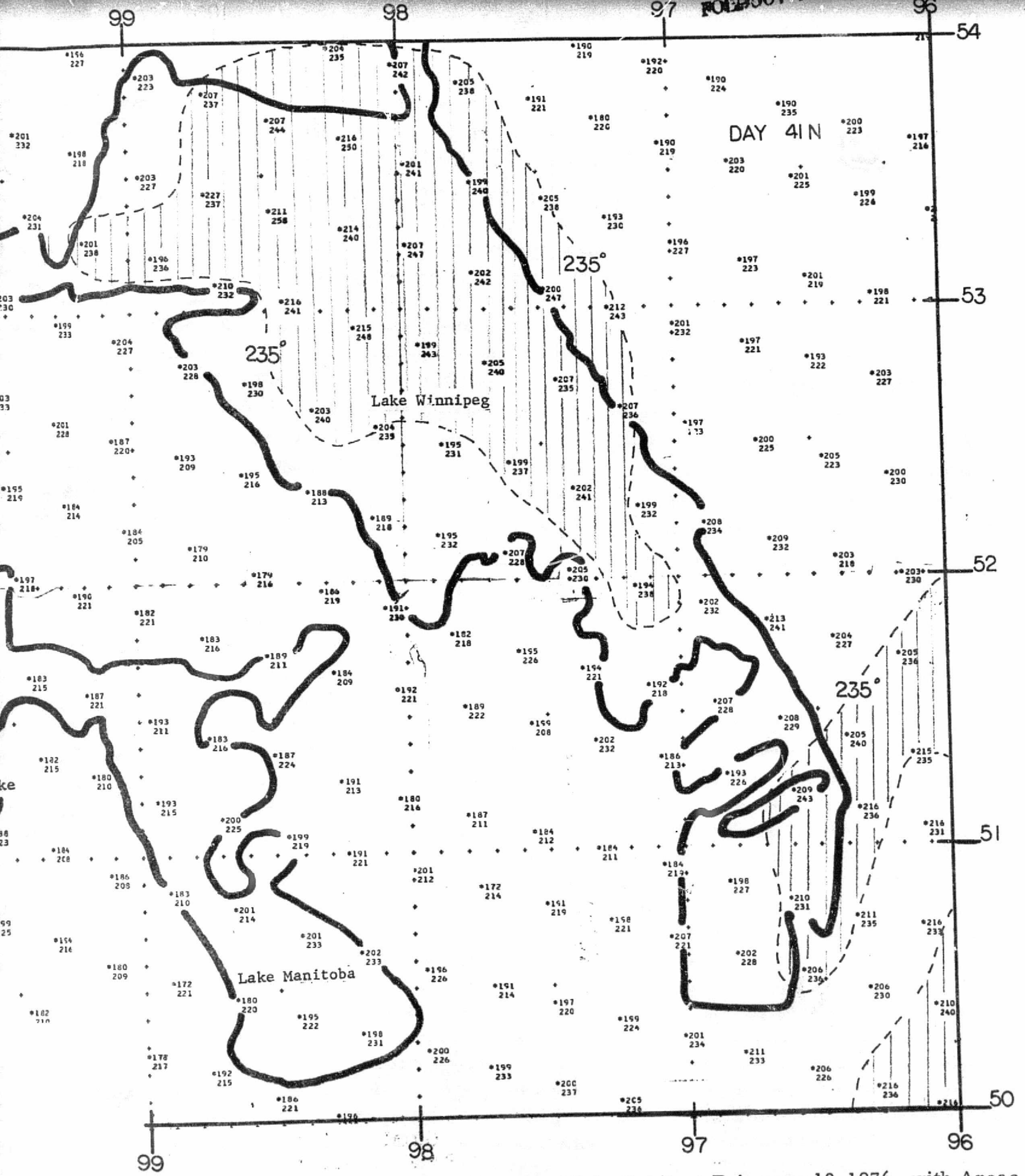
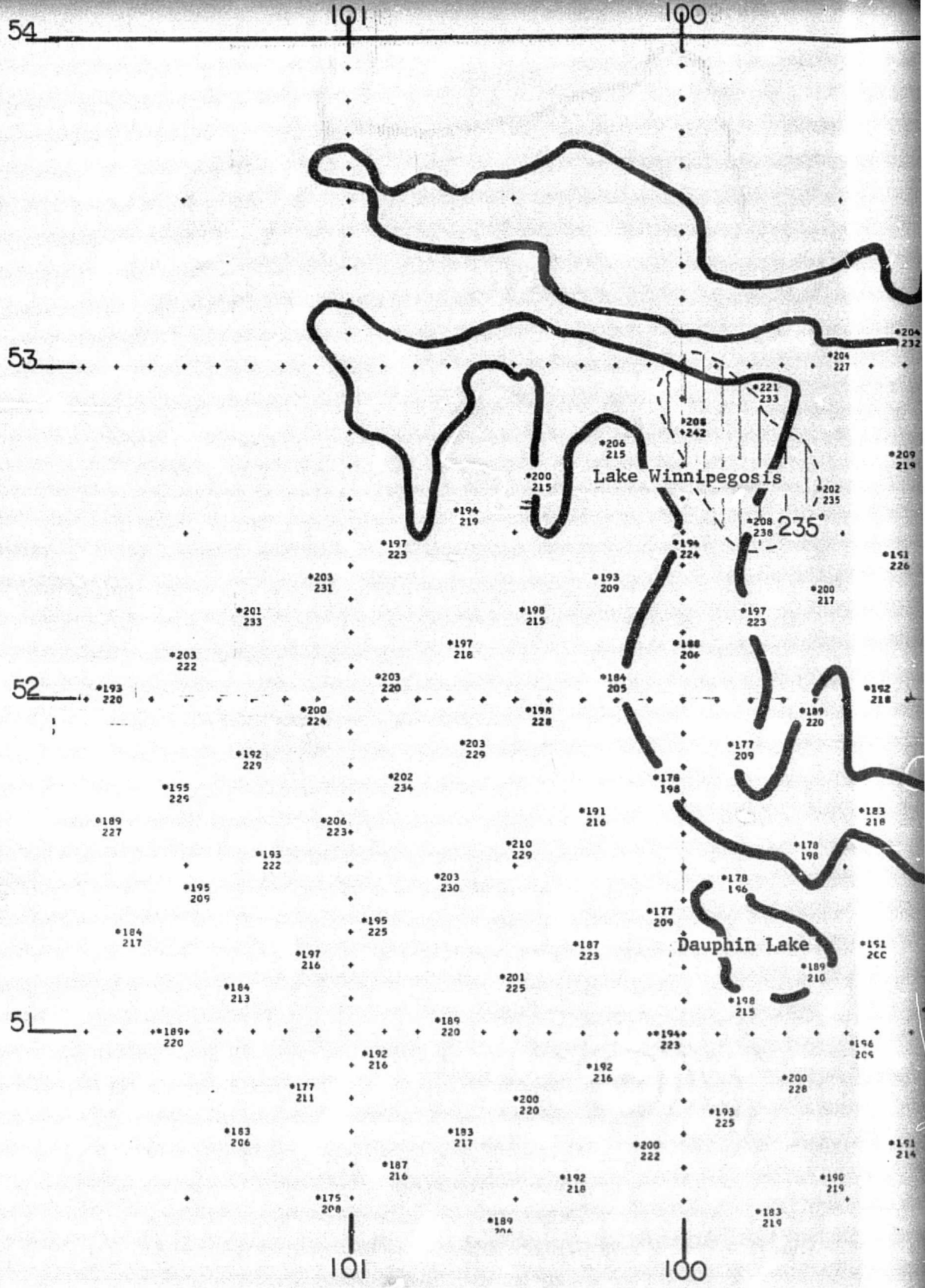


Figure 2-8. ESMR Temperatures for the Night Orbit on February 10, 1976, with Areas of Vertical Brightness Temperature ≥ 235° Delineated

FOLDOUT FRAME 1



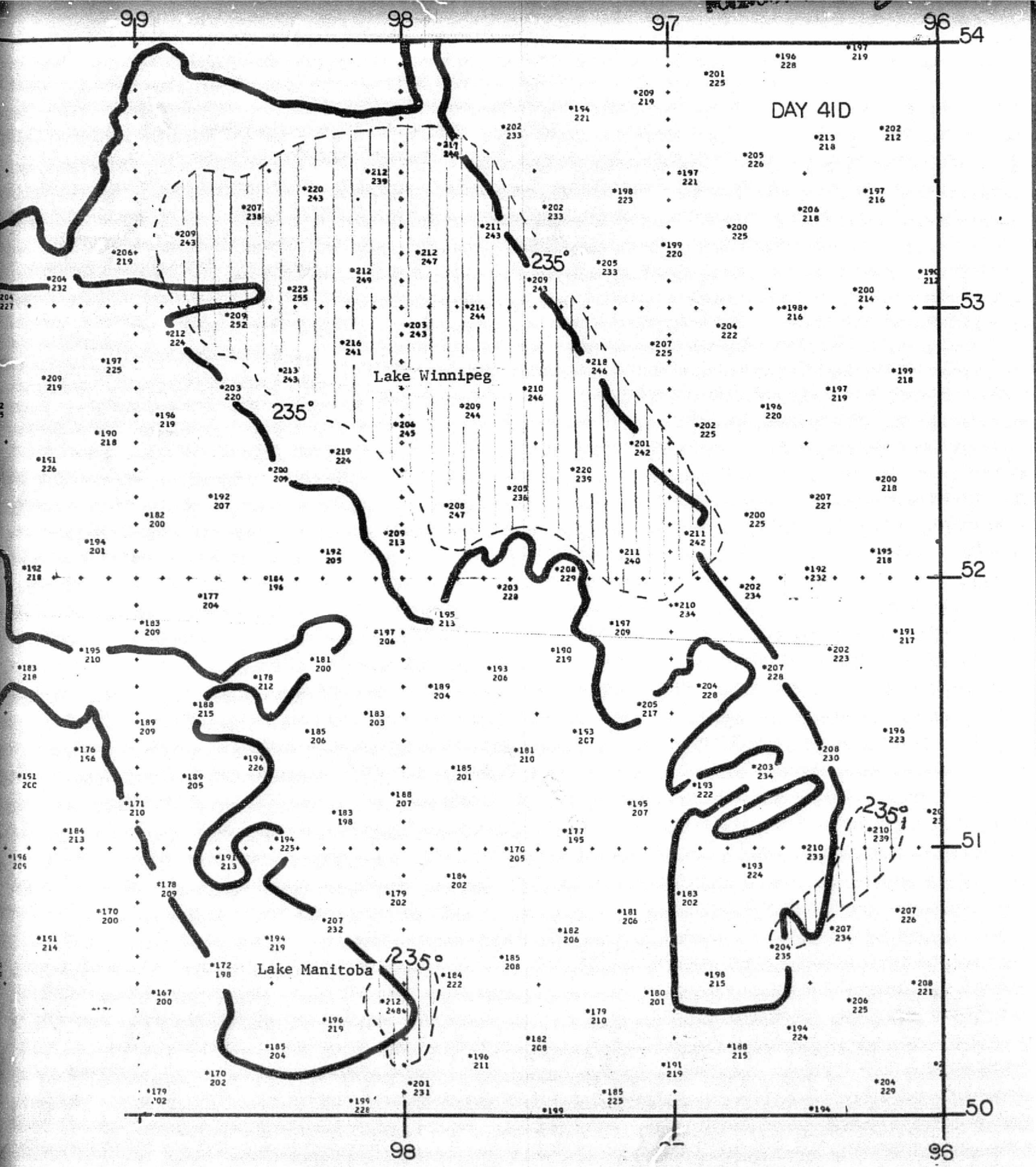


Figure 2-9. Site 1 ESMR Temperatures for the Day Orbit on February 10, 1976 with Areas of Vertical Brightness Temperature ≥ 235° Delineated

shading. For both 41N and 41D, concentrating on the west side of the north part of Lake Winnipeg, a rapid increase in both horizontal and vertical temperature can be observed as the boundary of the lake is reached. Generally, the increase is larger for the vertical brightness temperature and the polarization differences show an increase over the polarization differences to the west of Lake Winnipeg. Maximum vertical brightness temperatures of 258° (41N) and 255° (41D) were found in the northern part of Lake Winnipeg. Other areas with the vertical brightness temperature greater than or equal to 235° are found in the northern part of Lake Winnipegosis for both 41N and 41D, at one point in the Porcupine Hills for 41N, the southeast side of Lake Winnipeg for 41N, and the southeastern tips of Lake Manitoba and Lake Winnipeg for 41D.

Data in Reference 17 shows that historically lakes in the Site 1 area are completely frozen by late November and are not free of ice until early May. Ice thickness values could not be found for Lake Winnipeg or Lake Manitoba. However, historic mean ice thickness for the Lake of the Woods, southeast of Lake Winnipeg, is 32 inches and for the Red River near the City of Winnipeg is 29 inches. All lakes in the Site 1 area are quite shallow. The vertical brightness temperature in conjunction with the horizontal indicates the possibility of observing ice with some free moisture on the surface for the northern portion of Lake Winnipeg. Also of interest are the ESMR values for 41N at Dauphin Lake where the horizontal and vertical brightness temperatures (197°, 230°) increased with respect to surrounding values, indicating the possibility that the ESMR footprint exactly covered the frozen lake.

Generally, no pronounced temperature increase was observed over most of Lake Manitoba which could be due in part to the width of the lake with respect to ESMR footprint size. Large vertical temperatures to the east and southeast of Lake Winnipeg could be due to the presence of numerous small lakes and one large lake to the southeast, the Lake of the Woods. However, for 41N, the large vertical temperatures south of the City of Winnipeg are hard to explain, except perhaps on the basis of bare ground or outcropping of rock.

For Site 2, 6D, no significant correlations between snow water equivalent and ESMR temperatures were found. No precipitation was observed by the selected stations on January 6, 1976. Maximum temperatures in the five preceding days were below freezing. On the 6th, maximum temperatures ranged from 8° to 19° and minimum temperatures from -1° to 12°, and Fredericton, N.B. had 6.9 hours of bright sunshine. Factors possibly influencing this data set, with very low polarizations, are the observation time (day), the density of trees, and the local terrain. The elevations in the area of the ESMR observations range from below 1000 feet to around 2300 feet with some small lakes.

For Site 2, 8D, no significant correlations between snow equivalent water and ESMR temperatures were found. Precipitation of 0.0 to 0.37 inches was observed on the observation day of January 8, 1976. Precipitation of a trace to 0.34 inches was observed on the 7th. Hourly precipitation data from the Maine stations (Reference 12) showed that on the 8th precipitation was reported at local times of 0800, 0900, 1300 and 1200 for Caribou (46.87°N, 68.02°W), Houlton (46.13°N, 67.83°W), Grand Lake Stream (45.18°N, 67.76°W), and Eastport (44.92°N, 67.00°W). Maine is on Eastern Standard Time. For the only Site 2 station available, Fredericton, N. B., hours of bright sunshine were 0.1 and 0.0 on the 7th and 8th, respectively. Maximum temperatures on the 8th ranged from 8° to 29°, and minimum temperatures ranged from -11° to 16°.

For 34N, Site 2, the vertical brightness temperature with snow water equivalent showed a significant negative correlation of -0.64 and variance explained of 41.3 percent. The correlation using the horizontal brightness temperature was -0.32 and not significant at the 95 percent level. For the day of the observation, February 3, 1976, three of the seven stations reported a trace of precipitation. Heavy precipitation was reported on February 1st and 2nd ranging from 0.01-1.37 inches on the first to 0.37-1.89 inches on the second. A trace to 0.22 inches was reported on the 3rd. The hourly precipitation data from the Maine Stations (Ref 13) of Caribou, Houlton, Grand Lake Stream and Eastport showed the last precipitation on the 2nd was at 1400, 1500, 2100, 1700 Eastern Standard Time with no precipitation reported for the 3rd. From the ESMR data and the last reported time of precipitation, the area for 34N would appear to clear at the time of the observation. The hours of bright sunshine on the 3rd were 6.7. Maximum temperatures on February 3, 1976 ranged from 14° to 24° and minimum temperatures ranged from -8° to 2°. Maximum temperatures on the first and second were above freezing, 34°-55° on the first and 49°-56° on the second. Minimum temperatures on the first and second were at least 15° below freezing.

As 61R and 61E use the same basic data as 61N, the three data sets will be discussed together. Correlations of snow water equivalent and the horizontal and vertical brightness temperatures were -0.40 and -0.32 (not significant) for 61N, -0.61 and -0.75 (significant at the 99 percent level) for 61R and -0.24 and -0.53 (significant at the 95 and 99 percent levels, respectively) for 61E. For 61N, 17 percent of the 23 observations were associated with snow water equivalent greater than 10.2 inches. The data set 61R is the same data as 61N with one low value and four high snow other values removed. The data set 61E uses all available ESMR data with snow values obtained from a snow contour map.

For the observation day of March 1, 1976, only Fredericton, N. B. reported a trace of precipitation; the maximum temperatures of selected stations ranged from 20° to 36°, with minimum temperatures ranging from -4° to 18°. Precipitation was reported on February 29, 1976 with amounts ranging from 0.10 to 0.38 inches with maximum temperatures ranging from 22° to 37°. None of the Maine stations reported precipitation on the first (Ref 14). Caribou and Houlton, Maine reported their last precipitation at 2200 and 1500 Eastern Standard Time. Figures 2-10 and 2-11 give a detailed meteorological summary for Fredericton, N. B. at 0000 GMT and 0600 GMT on March 1, 1976. This data was provided by Mr. P. Hansen and Mr. D. Murray of the Water Resources Branch, Environment New Brunswick. The ESMR observation was at about 0500 GMT. The data indicates that the area was in the process of clearing after the weak front on February 29, 1976. As Fredericton is in the southern part of the area of interest, the six-hour hemisphere surface charts were examined to

LOCATION: Fredericton, New Brunswick DATE: 01 March 1976

DATA TITLE TIME: 0000 GMT

Sky Condition: Measured 4 hundred overcast

Visibility: 10

Weather Obstruction to Division: Light drizzle

Sea Level Pressure (mb): 1006.8

Dry Bulb Temperature - C°: 2

Dew Point Temperature - C°: 0

Wind Direction - degrees: 206

Wind Speed - knots: 10

Wind Gusts - knots: NIL

Altimeter Setting - inches: 29.73

Clouds and/or Observing Phenonema - tenths: Stratus Fractus 10

Remarks: NIL

Reduction to Sea Level: 28

Tendency - pressure character: Falling, falling less rapidly, lower than three hours ago.

Tendency - amount MB: 34

Station Pressure MB: 1004.0

Corrected Dry Bulb - F°: 35.3

Corrected Dew Point - F°: 32.1

Relative Humidity - %: 89

Corrected Maximum Temperature - 6 Hour - F°: 35.4

Corrected Minimum Temperature - 6 Hour - F° : 25.1

Rainfall - 6 Hour - Tenths of Inches: Trace

Snowfall - 6 Hour - Tenths of Inches: 2.4

Snowfall - water equivalent - Tenths of Inches: .24

Total Precipitation - Tenths of Inches: .24

Snow Depth - whole inches: 12

Figure 2-10. Meteorological Summary for Fredericton, New Brunswick at 0000 GMT

LOCATION: Fredericton, New Brunswick DATE: 01 March 1976

DATA TITLE TIME: 0600 GMT

Sky Condition: Measured 2 thousand broken

Visibility: 10

Weather Obstruction to Division: NIL

Sea Level Pressure (mb): 1010.5

Dry Bulb Temperature - C°: 2

Dew Point Temperature - C°: -1

Wind Direction - degrees: 274

Wind Speed - knots: 10

Wind Gusts - knots: NIL

Altimeter Setting - inches: 29.84

Clouds and/or Observing Phenonema - tenths: Stratocumulus 9

Remarks: NIL

Reduction to Sea Level: 2.7

Tendency - pressure character: falling, rising, higher than 3 hours ago.

Tendency - amount MB: 3.6

Station Pressure MB: 1007.8

Corrected Dry Bulb - F°: 36.0

Corrected Dew Point - F°: 30.8

Relative Humidity - %: 82

Corrected Maximum Temperature - 6 Hour - F°: 37.0

Corrected Minimum Temperature - 6 Hour - F°: 34.3

Rainfall - 6 Hour - Tenths of Inches: Trace

Snowfall - 6 Hour - Tenths of Inches: NIL

Snowfall - water equivalent - Tenths of Inches: NIL

Total Precipitation - Tenths of Inches: Trace

Snow Depth - whole inches: 12

Figure 2-11. Meteorological Summary for Fredericton, New Brunswick at 0600 GMT determine the movement direction of the front. Indications are that the sky in the area to the north and northwest of Fredericton would have been less cloudy than the sky at Fredericton.

Section 3

SUMMARY AND CONCLUSIONS

Based on the data sets analyzed in this study, the following conclusions are drawn:

- A significant statistical relationship can be demonstrated between snow water equivalent and ESMR brightness temperature. This relationship is evidenced by significant negative sample correlation coefficients using the measured data. At 37 GHz the relationship is valid for a bounded range of snow water equivalent values. The upper limit of the value range is around 8 to 10 inches, while the lower limit may be around 2 inches.

- For all cases studied which showed significant linear correlations, the vertical brightness temperature had better correlation and less standard error of estimate than the corresponding horizontal brightness temperature. This result was shown in Table 2-6.

- When a linear regression model was used, snow water equivalent values which exceeded the valid upper limit bound for 37 GHz were underestimated. (See 61N plots in Appendix B, B-21 and B-22 and residuals in Appendix E, Table E-6.)

- The use of a multivariate regression model which includes horizontal and vertical brightness temperatures and snow elevation can improve snow water equivalent estimates in the valid range and reduce prediction errors for values outside the valid range. Comparing the residuals shown in Figures E-16A and B with those in E-6 illustrates this point.

- Including information on the distribution of polarization difference and data screening based on polarization differences could be helpful in selecting valid ESMR data to be used for snow water equivalent estimation.

The determination of a relationship between snow water equivalent and ESMR brightness temperatures is influenced by several factors which include random errors in the ESMR temperature measurements, the spatial rate of change of the snow water equivalent point source measurements relative to the ESMR footprint size, the condition of the snow and free moisture content, local weather conditions, vegetation, topography, and for relatively shallow snow any heteorogeneity of the surface material. Any combination of these factors can affect the measurement of a valid correlation between snow water equivalent and ESMR brightness temperatures and perturb the relationship that would be expected for a uniform snowpack measured under ideal and error free conditions. In spite of potential complications, a statistically significant relationship was found between ESMR-6 measurements and snow water equivalents for data sets in two separate months.

For Site 2 (New Brunswick), a significant linear correlation of -0.64 was found between the snow water equivalent and vertical brightness temperature for the night observation on February 3, 1976 (34N). The range of snow water equivalent values for 34N was 2.9 to 8.8 inches. The night observation on March 1, 1976 (61N) had non-significant negative correlations of -0.40 and -0.32 for the horizontal and vertical with snow water equivalent values ranging from 2.9 to 14.3 inches. However, after five probable outliers were eliminated from 61N to produce 61R, the snow water equivalent values were in the range of 4.9 to 10.2 inches and significant linear correlations of -0.61 and -0.75 were found for the horizontal and vertical. For the Site 2 data sets of the day observations (January 6, 1976 (6D) and January 8, 1976 (8D)), no significant correlations were found. A complete discussion of each data set with associated factors such as weather, terrain, etc. is given in Section 2.5. Weather, snow condition, vegetation, and topography have a direct bearing on the validity of the correlation results as summarized below.

Figures G-1 through G-3 of Appendix G show the locations of snow observation data for 6D, 34N, and 61R relative to land use. The agricultural land is enclosed by the dashed lines and shaded. The land use information for New Brunswick and Maine was obtained from Reference 26. In Reference 27, it is stated that along the St. John River and the Tobique River the prime land use is for agriculture. In general, for New Brunswick (Reference 28), most of the trees near major rivers are deciduous, while the coniferous trees, which would obscure the ground, are found away from the river bottoms and at the higher elevations. Figure G-4 shows the physiographic regions and the topography of New Brunswick.

For 34N, the area appeared to be free from clouds at the time of the ESMR observation. Snow had fallen in the two days preceding the day of the ESMR observation and temperature analysis indicates that the fresh snow would not have been altered. From Figure G-2, almost all of the snow observations and associated ESMR footprints are within agricultural land, with most being close to major rivers at low elevations. Thus, obscuration of the ground by trees is probably minimal.

For 61R, the area was clearing after a weak front with light precipitation on the preceding day. Figure D-10 gives the snow conditions as dry snow. Figure G-3 shows that almost all of the observations were associated with agricultural land near major rivers at low elevations. Thus, obscuration of the ground by trees is probably minimal and the dry snow assumption for measuring a good snow/ESMR relationship appears to be valid.

For 6D, using Figures G-1 and G-4 and Table B-3, 5 out of the 10 observations were located in probable forest land with elevation above 1000 feet and in an area where terrain could be a problem. The lack of correlation can be attributed to a combination of factors including obscuration of the ground, terrain or effects from a daytime observation. For 8D, the ESMR measurements were taken under conditions of light precipitation which would tend to mask any snow/ESMR relationship.

For Site 1 (Manitoba and Saskatchewan), the snow water equivalent values were in the ranges of 0.7 to 4.5 inches. However, the majority of values were in the range of 0.7 to 2.6 inches with two local maxima of 3.8 inches and 4.5 inches being observed near the Riding Mountains and Turtle Mountain, respectively. ESMR observations from the night (41N) and day (41D) orbits on February 10, 1976 were used for analysis. No significant correlations were found for 41N, and a positive correlation of 0.28 was found for snow water equivalent with the vertical brightness temperature for 41D (Table 2-6). Although maximum ground temperatures on the 10th were below freezing, the area had temperatures well above freezing for the three days preceding the 10th. Analysis of the ESMR brightness temperatures over the northern part of Lake Winnipeg showed a well defined large increase in the vertical brightness temperature and a moderate increase in the horizontal brightness temperature over the lake as compared to the area surrounding the lake. This type behavior would be expected over an area of ice with some free water on the surface. Historically, the lakes in Manitoba are frozen from late November through April. However, the amount of the snow water equivalent at the time of the observation is not known. If snow were present, the underlying surface material could be exerting a strong influence on the ESMR measurements.

Field reports on snow conditions for several basins west of the ESMR data for 41N and 41D are of interest. The closest is for the Souris River Basin which is approximately at 49.0°-50.0°N. and 102.3°-103.0° west (near Estevan on Figure D-3). The special survey information was taken on February 2 and February 3, 1976. The general comments of the observers were "in general the entire basin has a complete snow cover except for some bare spots on fallow fields. Southern areas have experienced more melting. However, the snowpack still has the potential to produce runoff. On the average the snowpack consists of a thick ice crust covering a layer of loose crystalized snow. Soil conditions are mainly saturated with an intermittent ice layer." No precipitation occurred between the 3rd and the 10th of February. However, the warm weather on the 7-9th of February could have produced more melting and possible refreezing.

In examining the lack of correlation for the Site 1 data, several factors should be considered: the relatively high polarization difference of the observations, the condition of the snow, the inference of free moisture on ice over Lake Winnipeg, the heterogenious surface material, and the range of snow water equivalent values. The underlying surface material and the condition of the snow appear to be influencing the ESMR data for the relatively low values of snow water equivalents. Whether the surface material would influence the ESMR brightness temperatures as much for a dry snowpack is not known. The most likely reason for lack of correlation is the fact that due to random errors and heterogeneous surface material influencing brightness temperatures, that the snow/ESMR (37 GHz) relationship probably has an effective lower bound of about 2 inches for snow water equivalents.

Regarding the upper limit for the snow/ESMR relationship, the data previously shown in Figure 2-1 indicates that the snow water equivalent-ESMR brightness temperature relationship at 37 GHz tends to become weak for snow water equivalents greater than 8 inches. As discussed in Section 2, Pages 5-7, random errors in the ESMR measurements combined with the weaker relationship would effectively produce an upper bound on measuring any snow/ESMR relationship. Analysis of various subsets of the March 1, 1976 data for New Brunswick showed that for high snow water equivalents the correlation between snow water equivalent and brightness temperature was not significant and inclusion of high values degraded the otherwise significant correlation for moderate snow values. Generally, higher snow water equivalents had associated brightness temperatures which were warmer than expected.

For both sites, a significant linear correlation was found between the snow water equivalent values and the elevations of the snow course measurement locations (Table 2-12). For Site 2 data sets, using elevation along with ESMR brightness temperatures in a multiple regression model generally produced values for the multiple correlation coefficient and percent variance explained which were higher than their linear counterparts (Table 2-13). For Site 1 data sets, the multiple regression model produced little improvement over the linear model.

Analysis of polarization differences (TV-TH) showed a considerable and significant difference between mean values observed for Site 1 and Site 2 data sets (Table 2-11), and also between the weather related and non-weather related data sets for Site 2. In general, polarization differences were low for conditions of precipitation, moderate for data sets with good correlations for Site 2, and high for the Site 1 data sets.

An analysis was also performed using data screening based on the polarization difference in which only observations with a difference of less than 21°K. were allowed for linear analysis. In general, linear correlations were improved by this data screening technique (Table 2-10). The optimal screening values would have to be established for different geographic locations.

Throughout this report, the adequacy of the linear and multiple regression models was purposely never discussed. Instead, such qualitative measures of fit as the percent variance explained and the standard error of estimate were given for all results. For any model based on uncontrolled experimental data, a perfect fit would be impossible to obtain and the ultimate user is left with the decision as to what is adequate in terms of the consequences of using estimates which are in error. The analysis indicates that the estimated snow water equivalent-ESMR brightness temperature relationship is probably valid over a range of snow water equivalent values, where the range depends on the particular snow site. Using a model based on a specific range of snow water equivalent values to predict values in an area with snow water equivalent values outside the model range could produce large errors. The residuals from all the estimated linear regression models, as % frequency, are given in Tables 2-8 and 2-9 for Site 1 and Site 2 data sets. Point by point residuals values for selected linear and multiple regression estimates are given in Appendix E.

Confidence intervals for the estimated linear regression lines were not included in this report. Because both the independent variable (ESMR temperature) and the dependent variable (snow water equivalent) are in error, the meaning of the confidence intervals would be questionable under the usual statistical assumptions. The necessary data for calculating the confidence intervals have been included in the tables of Section 2.3. The equations for calculating confidence limits for estimated linear regression models are given in Appendix A and a complete discussion is given in Reference 20.

Section 4

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Appendix A

CORRELATION AND REGRESSION

This appendix presents the relevant equations for correlation and regression which were used for analysis in this report. A more complete treatment of the subject is given in References 20-23. The term linear will refer to one independent variable ($y = f(x)$), and the term multiple will refer to two or more independent variables ($y = f(x_1, x_2, \ldots x)$). Although the equations for correlation and regression are closely related, the underlying assumption are quite different. In correlation the assumption is made that variables have an underlying bivariate, or, for more than two variables, a multivariate normal distribution. In regression, the major interest is in the functional relationship between the dependent variable y and one or more independent variables.

For this analysis let y be the snow value in inches of water and x denote either the horizontal brightness temperature, or the vertical brightness temperature. The bivariate normal probability density function is completely described by μ_y, μ_x, σ_x^2, σ_y^2 and ρ, which are the means of x and y, the variances of x and y, and their correlation. Estimates of these statistics for a sample of N are given by:

$$\bar{x} = \frac{1}{N} \sum_{i=1}^{N} x_i ,$$

$$\bar{y} = \frac{1}{N} \sum y_i ,$$

$$\hat{\sigma}_x = \sqrt{\frac{1}{N-1} \sum (x_i - \bar{x})^2}$$

$$\hat{\sigma}_y = \sqrt{\frac{1}{N-1} \sum (y_i - \bar{y})^2}$$

$$\hat{\sigma}_{xy} = \sqrt{\frac{1}{N-1} \sum (x_i - \bar{x}) (y_i - \bar{y})} \, ,$$

and

$$\hat{\rho} = r = \frac{\sigma_{xy}}{\hat{\sigma}_x \, \hat{\sigma}_y}$$

The sample correlation coefficient varies between -1.0 and +1.0.

To test the hypothesis $r = 0$ at some confidence level, we use the fact that the statistic

$$T = r \left[\frac{N - 2}{1 - r^2} \right]^{1/2}$$

is distributed as a "student t" distribution with $N-2$ degrees of freedom. The hypothesis that $r = 0$ will be rejected if $|T| \geq t(N-2, 1 - \alpha/2)$.

To obtain a confidence interval for r, we use the statistic

$$Z = 1/2 \ln \left(\frac{1 + r}{1 - r} \right),$$

which is approximately normally distributed with mean

$$\epsilon = 1/2 \ln \left(\frac{1 + \rho}{1 - \rho} \right)$$

and with variance of

$$\sigma^2 = \frac{1}{N - 3} \, .$$

The 95 percent confidence interval on r would be given by

$$Z_1 = Z - 1.96 \left(\frac{1}{N - 3} \right)^{1/2}$$

and

$$Z_2 = Z + 1.96 \left(\frac{1}{N - 3} \right)^{1/2} \, .$$

Then denoting r_1 and r_2 as the 95 percent confidence interval about r,

$$r_1 = (\exp(2Z_1) - 1) \;/\; (\exp(2Z_1) + 1)$$

and

$$r_2 = (\exp(2Z_2) - 1) \;/\; (\exp(2Z_2) + 1) .$$

The linear regression model is of the form

$$y = \beta_o + \beta_1 x + e ,$$

where for testing purposes e is the error in y and is normally distributed with mean zero and variance σ^2. The least squared estimates of β_o and β_1 are given by

$$\hat{\beta}_1 = \frac{\hat{\sigma}_{xy}}{\hat{\sigma}_x^2} = \frac{\hat{\sigma}_y}{\hat{\sigma}_x} \cdot r ,$$

and

$$\hat{\beta}_o = \overline{y} - \hat{\beta}_1 \overline{x} .$$

Denoting $\hat{y}_i$ as the predicted value of y_i given $\hat{\beta}_o$, $\hat{\beta}_1$ and x_i, the scatter of the observed points about the regression line is given by the standard error of estimate, $\sigma_{\hat{y}}$, given by the positive square root of

$$\sigma_{\hat{y}}^2 = \frac{\sum (y_i - \hat{y}_i)^2}{N - 2} = \frac{N-1}{N-2} (\hat{\sigma}_y^2 - \hat{\beta}_1^2 \; \hat{\sigma}_x^2)$$

$$= \frac{N-1}{N-2} \; \hat{\sigma}_y^2 \; (1 - r^2) .$$

The precision attached to a regression line can be evaluated using the square of the correlation coefficient r^2. Starting with the identity

$$y_i - \hat{y}_i = y_i - \overline{y} - (\hat{y}_i - \overline{y}) ,$$

it can be shown that

$$\sum(y_i - \bar{y})^2 = \sum(y_i - \hat{y}_i)^2 + \sum(\hat{y}_i - \bar{y})^2 .$$

In words, using SS to denote sum of squares, the SS about the mean equals the SS about regression plus the SS due to regression. Then, it can be shown that

$$r^2 = \frac{\sum(y_i - \bar{y})^2 - \sum(y_i - \hat{y}_i)^2}{\sum(y_i - \bar{y})^2} = \frac{\sum(\hat{y}_i - \bar{y})^2}{\sum(y_i - \bar{y})^2} ,$$

where r^2 is a measure of the variation in y explained by the regression. The value of r^2 ranges from 0 to 1, where r^2 is sometimes called the coefficient of multiple determination. Also, the value of $100.0 \cdot r^2$ is the percent variance of $\hat{\sigma}_y$ explained by the regression.

As with r, $\hat{\beta}_1$ the slope can be tested for significance against some value B. Let

$$\sigma_{\hat{\beta}} = \frac{\sigma_{\hat{y}}}{\hat{\sigma}_x \sqrt{N - 1}} ,$$

Then the statistic

$$T = \frac{\hat{\beta}_1 - B}{\sigma_{\hat{\beta}}}$$

has a "student t" distribution with N - 2 degrees of freedom. Using the relationship between $\hat{\beta}_1$ and r, and between $\sigma_{\hat{y}}$ and r, it can be shown that this is exactly the same test as for correlation. In fact the "t" test for the linear correlation (regression) is a special case of the multiple correlation (regression) test of the form

$$F_c = \frac{r^2/k}{(1 - r^2) / (N - k - 1)} ,$$

where k is the number of independent variables. F_c follows an "F" distribution with $\nu_1 = k$ and $\nu_2 = N - k - 1$ degrees of freedom. The "t" distribution and "F" distribution are related, for $\nu_1 = 1$ only, as

$$t^2(\nu_2, 1 - \alpha/2) = F(1, \nu_2, 1 - \alpha).$$

The multiple regression model is of the form

$$y = b_o + b_1 x_1 + b_2 x_2 + \ldots b_k x_k + e.$$

Let the observations be in matrix form

$$Y = \begin{pmatrix} y_1 \\ y_2 \\ \cdot \\ \cdot \\ \cdot \\ y_N \end{pmatrix} \qquad X = \begin{pmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1k} \\ 1 & x_{21} & x_{22} & \cdots & x_{2k} \\ \cdot & \cdot & & & \\ \cdot & \cdot & & & \\ \cdot & \cdot & & & \\ 1 & x_{N1} & x_{N2} & \cdots & x_{Nk} \end{pmatrix}$$

Then the model in matrix form is

$$Y = X\beta + e.$$

The least squares solution for the vector $\hat{\beta}$, denoting the superscripts T as the transpose of a matrix and -1 as the inverse, is given by

$$\hat{\beta} = (X^TX)^{-1} X^TY.$$

As with the case of one independent variable, the population multiple correlation coefficient squared is defined as the fraction of the total variance of y that is accounted for by its regression on the variable $x_1, x_2, \ldots, x_k$. r^2, the sample multiple correlation coefficient squared can be computed as with the linear r^2 as

$$r^2 = \frac{\sum(\hat{y}_i - \bar{y})^2}{\sum(y_i - \bar{y})^2} = \frac{(\hat{\beta}^T X^T Y - N\bar{y}^2)}{(Y^T Y - N\bar{y}^2)}$$

The multiple correlation coefficient, r, is taken as the positive square root of r^2 and varies from 0 to 1.

The standard error of estimate is given by

$$\sigma_{\hat{y}} = \sqrt{\frac{1}{N-k-1} \sum(y_i - \hat{y}_i)^2} \quad .$$

As mentioned previously, the multiple correlation coefficient can be tested at a significance level, α, using the "F" distribution and the statistic

$$f = \frac{r^2/k}{(1-r^2)/(N-k-1)} \quad .$$

If $f \geq F(k, N-k-1, 1-\alpha)$, we reject the hypothesis $r = 0$. For testing many different values of r, it is easier to find $F(k, N-k-1, 1-\alpha)$ and solve for r_c, such that with an observed value of $r \geq r_c$ we would reject the hypothesis $r = 0$. Denoting $\nu_1 = k$ and $\nu_2 = N-k-1$, let $F_c = F(\nu_1, \nu_2, 1-\alpha)$, then

$$r_c = \sqrt{\frac{\nu_1 F_c}{\nu_1 F_c + \nu_2}} \quad .$$

Table A-1 gives the r_c values relevant to this study. The upper value of each entry is for the 95% confidence level and the lower the 99% confidence level. An example of the table use is as follows. For three independent variables and $N = 23$ we observe $r = 0.78$. $\nu_1 = 3$ and $\nu_2 = 23 - 3 - 1 = 19$. Entering the table with $\nu_1 = 3$ and $\nu_2 = 19$, r_c for 95% is 0.575 and for 99% is 0.665. If $\alpha = 0.1$, we would reject the hypothesis $r = 0$ at the 99% level.

Table A-1

CRITICAL VALUES FOR $|r|$

ν_1 ν_2	1	2	3	4	5
6	.707 .834	.795 .886	.839 .911		
7	.666 .798	.758 .855	.807 .885		
8	.632 .765	.726 .827	.777 .860		
12	.532 .661	.627 .732	.683 .773	.722 .802	.751 .824
13	.514 .641	.608 .712	.664 .755	.703 .785	.734 .807
14	.497 .623	.590 .694	.646 .737	.686 .768	.717 .792
15	.482 .606	.574 .677	.630 .721	.670 .752	.701 .777
16	.468 .590	.559 .662	.615 .706	.655 .738	.686 .762
17	.456 .575	.545 .647	.601 .691	.641 .724	.673 .749
18	.444 .561	.532 .633	.587 .678	.628 .710	.659 .736
19	.433 .549	.520 .620	.575 .665	.615 .698	.647 .723
20	.423 .537	.509 .608	.563 .652	.604 .685	.636 .711
21	.413 .526	.498 .596	.552 .641	.592 .674	.624 .700
44	.291 .376	.357 .435	.402 .474	.437 .506	
45	.288 .372	.353 .430	.397 .470	.432 .501	
46	.284 .368	.349 .426	.394 .465	.428 .496	

Table A-1 (Continued)

CRITICAL VALUES FOR $|r|$

ν_1 ν_2	1	2	3	4	5
47	.281 .365	.346 .422	.389 .461	.424 .492	
48	.279 .361	.343 .418	.386 .457	.420 .487	
49	.276 .357	.339 .414	.383 .453	.416 .483	
68	.235 .306	.290 .356			
69	.234 .304	.288 .354			

Two different but related confidence intervals can be constructed for an estimated linear regression. One is for the mean regression line and the other is a confidence interval for a new observation of the dependent variable y . The assumption for confidence intervals is that all the error is associated with y and that the independent variable x is error free. Denoting the mean of x as $\bar{x}$, N as the number of samples, $t(\nu, 1-\alpha/2)$ as the value of the student "t" distribution for $\nu = N - 2$ degrees of freedom, $\sigma_{\hat{y}}$ as the standard error of estimate, $\hat{\sigma}_x^2$ as the estimated variance of x , x_k as the value of the x for the confidence interval, and $\hat{y}_k$ as the dependent variable on the regression line, the $100 \cdot (1-\alpha)\%$ confidence interval for the mean regression line is given by

$$\hat{y}_k \pm t\left(\nu, 1 - \frac{\alpha}{2}\right) \cdot \sigma_{\hat{y}} \cdot \left[\frac{1}{N} + \frac{(x_k - \bar{x})^2}{(N-1)\hat{\sigma}_x^2}\right]^{1/2} ,$$

and the $100 \cdot (1-\alpha)\%$ confidence interval for a new y observation is given by

$$\hat{y}_k \pm t\left(\nu, 1 - \frac{\alpha}{2}\right) \cdot \sigma_{\hat{y}} \cdot \left[1 + \frac{1}{N} + \frac{(x_k - \bar{x})^2}{(N-1)\hat{\sigma}_x^2}\right]^{1/2} .$$

Appendix B

BASIC DATA AND PLOTS

In this appendix, computer listings are given for the basic data used in the analysis. Calcomp plots are given for snow water equivalent versus the horizontal brightness temperature, the vertical brightness temperature, the polarization difference (vertical minus horizontal) and the elevation of the snow course measurement location for each analysis data set. As throughout the report, the data set mnemonic of Julian day with an N or a D has been used. For example, 34N is the night observation on February 3, 1976. For all plots, the snow water equivalent has been plotted on the abscissa contrary to custom. This was done to keep a uniform scale for the snow water equivalent; the ordinate axis on a Calcomp plot is limited to 10 inches. To avoid confusion, the Site 1 data and data for 6D and 8D have a scale of 0.5 inch of snow water equivalent per 20 lines on the plots, while the remaining Site 2 data have one inch of snow equivalent water per 20 lines on the plot. For elevation, the value on the ordinate should be multiplied by 10 to obtain the correct value. Except for polarization difference, the computed linear regression line has been included on each plot.

Tables B-1 through B-8 give the basic data for analysis data sets 41N, 41D, 6D, 8D, 34N, 61N, 61R and 61E. Figures B-1 through B-28 show the plots for 41N, 41D, 6D, 8D, 34N, 61N and 61R in the sequence of snow water equivalent versus the horizontal brightness temperature, the vertical brightness temperature, their polarization difference, and elevation. Plots of snow water equivalent versus horizontal, vertical, and polarization difference are given in Figures B-29 through B-31.

Table B-1

BASIC DATA FOR 41N

SITE 1 -- DAY 41 (FEBRUARY 10, 1976) -- NIGHT OBS. (0647 GMT)

NO.	ELEV	LAT	LONG	ESMR TH	ESMR TV	SNOW H2O	PREC X 100 DAY -1	PREC X 100 DAY -2	MAX T DAY 0	MAX T DAY -1	MIN T DAY 0	MIN T DAY -1
1	960	51.37	100.02	185	212	0.70	0	0	10	45	-8	25
2	1670	50.27	99.83	192	221	0.77	0	0	5	38	5	22
3	988	50.78	99.50	199	225	0.79	0	0	7	43	0	25
4	872	51.05	99.50	188	223	0.79	0	0	7	43	0	25
5	1530	51.17	100.68	204	228	0.96	10	0	0	37	-1	29
6	2300	51.82	100.75	208	228	1.11	0	0	4	42	-4	33
7	[illegible]	51.63	100.45	212	235	1.14	2	0	4	44	-4	34
8	850	51.58	98.67	183	216	1.22	0	0	10	44	-21	10
9	1610	49.18	99.67	189	221	1.40	0	0	30	40	1	37
10	890	50.20	98.95	178	217	1.40	0	0	6	41	-5	32
11	1820	50.43	100.62	182	219	1.40	0	0	11	41	-4	28
12	870	49.27	98.00	189	229	1.42	0	0	14	41	0	31
13	760	50.90	97.25	184	211	1.48	0	0	5	44	-6	27
14	800	51.17	97.60	184	212	1.48	0	0	0	44	0	22
15	1240	49.90	99.05	187	229	1.58	0	0	12	40	0	33
16	1870	50.78	101.30	186	216	1.58	0	0	8	34	-5	26
17	1810	51.23	101.30	191	224	1.58	0	0	10	32	2	20
18	815	50.13	97.55	200	237	1.62	0	0	9	41	-4	28
19	2350	51.85	100.95	195	226	1.66	0	0	4	42	-4	33
20	950	51.15	100.07	185	212	1.67	0	0	21	45	-12	21
21	825	49.67	96.63	205	225	1.71	0	0	17	42	-2	30
22	1510	49.87	99.93	176	222	1.75	0	0	12	42	3	21
23	822	50.42	97.93	200	226	1.75	0	0	8	41	5	30
24	1600	51.65	100.65	212	235	1.75	0	0	4	43	-4	33
25	895	50.80	98.92	183	210	1.79	0	0	8	41	-2	21
26	870	50.87	98.10	201	212	1.79	0	0	4	44	4	20
27	1450	49.85	100.93	167	209	1.84	0	0	20	41	2	29
28	1710	50.43	101.05	179	209	1.84	0	0	11	41	-4	28
29	960	49.93	98.65	197	227	1.93	0	0	14	40	1	31
30	790	49.13	97.23	211	232	2.10	0	0	23	43	0	24
31	1060	49.27	96.35	194	236	2.11	0	0	20	43	2	30
32	850	49.47	98.30	196	220	2.11	0	0	28	46	-9	27
33	875	50.75	98.68	180	220	2.11	0	0	9	40	-5	27
34	780	49.37	97.37	212	239	2.17	0	0	15	41	-4	26
35	1490	50.15	101.67	182	218	2.24	0	0	20	36	1	29
36	2350	50.67	99.97	194	219	2.28	0	0	12	40	5	20
37	765	49.77	97.17	191	240	2.30	0	0	10	40	-5	30
38	2333	49.25	98.68	192	228	2.37	0	0	16	40	0	20
39	1400	49.62	100.27	186	208	2.40	0	0	23	38	9	25
40	1231	49.57	99.05	192	220	2.41	0	0	19	41	0	25
41	1460	49.98	100.62	177	220	2.54	0	0	16	38	2	20
42	1052	49.65	98.50	190	224	2.57	0	0	14	40	1	31
43	1100	50.70	99.52	199	225	2.57	0	0	7	43	0	25
44	1570	50.03	100.23	182	215	2.63	0	0	10	39	5	21
45	1437	49.23	100.83	172	211	2.76	0	0	26	36	15	21
46	2000	50.75	100.02	204	222	2.81	11	0	14	47	0	30
47	1800	51.00	100.07	204	222	3.77	0	0	21	45	-12	21
48	2350	50.72	99.60	199	225	3.80	0	0	7	43	0	25
49	1886	49.15	100.05	198	228	4.52	0	0	31	37	4	31

Table B-2

BASIC DATA FOR 41D

SITE 1 -- DAY 41 (FEBRUARY 10, 1976) -- DAY OBS. (1710 GMT)

NO.	ELEV	LAT	LONG	ESMR TH	ESMR TV	SNOW H2O	PREC X 100 DAY -1	PREC X 100 DAY -2	MAX T DAY 0	MAX T DAY -1	MIN T DAY 0	MIN T DAY -1
1	960	51.37	100.02	177	209	0.70	0	0	10	45	-8	25
2	872	51.05	99.50	196	209	0.79	0	0	7	43	0	25
3	988	50.78	99.50	196	209	0.79	0	0	7	43	0	25
4	2000	51.40	101.43	195	209	0.96	0	0	10	32	2	20
5	1445	51.57	101.90	192	219	1.05	20	0	6	35	-10	26
6	1160	51.63	100.45	210	229	1.14	2	0	4	44	-4	34
7	1450	51.90	101.27	192	229	1.19	10	0	5	40	-4	31
8	840	51.58	98.67	188	215	1.22	0	0	10	44	-21	10
9	890	51.18	98.35	193	198	1.35	0	0	4	45	-10	25
10	1040	52.40	101.10	203	231	1.37	0	0	5	40	-4	31
11	1610	49.18	99.67	198	228	1.40	0	0	30	40	1	37
12	890	50.20	98.95	179	202	1.40	0	0	6	41	-5	32
13	837	50.38	96.45	194	224	1.40	0	0	17	43	-8	27
14	1820	50.43	100.62	189	206	1.40	0	0	11	41	-4	28
15	2275	51.80	100.57	203	229	1.40	0	0	4	42	-4	33
16	760	50.90	97.25	181	206	1.48	0	0	5	44	-6	27
17	1240	49.90	99.05	185	209	1.58	0	0	12	40	0	33
18	1210	50.23	99.43	189	213	1.58	0	0	9	41	-5	32
19	1870	50.78	101.30	183	206	1.58	0	0	8	34	-5	20
20	1810	51.23	101.30	184	213	1.58	0	0	10	32	2	20
21	815	50.13	97.55	199	218	1.62	0	0	9	41	-4	28
22	730	50.50	96.98	180	201	1.66	0	0	21	44	-14	21
23	2350	51.85	100.95	202	234	1.66	0	0	4	42	-4	33
24	950	51.15	100.07	194	223	1.67	0	0	21	45	-12	21
25	2000	51.68	101.55	195	229	1.67	0	0	7	36	-4	26
26	825	49.67	96.63	205	219	1.71	0	0	17	42	-2	30
27	1510	49.87	99.93	194	222	1.75	0	0	12	42	3	21
28	895	50.80	98.92	178	209	1.79	0	0	8	41	-2	21
29	870	50.87	98.10	179	202	1.79	0	0	4	44	4	20
30	1710	50.43	101.05	175	208	1.84	0	0	11	41	-4	28
31	2200	51.52	101.25	193	222	1.90	0	0	7	36	-1	25
32	960	49.93	98.65	177	208	1.93	0	0	14	40	1	31
33	795	50.07	96.45	194	215	2.02	0	0	28	42	-13	27
34	1000	49.13	98.13	189	225	2.04	0	0	17	41	4	36
35	790	49.13	97.23	188	229	2.10	0	0	23	43	0	24
36	1060	49.27	96.35	190	222	2.11	0	0	20	43	2	30
37	850	49.97	98.30	178	209	2.11	0	0	28	46	-9	27
38	875	50.75	98.68	172	198	2.11	0	0	9	40	-5	27
39	780	49.37	97.37	196	232	2.17	0	0	15	41	4	26
40	820	49.13	96.77	190	229	2.30	0	0	23	42	4	29
41	765	49.77	97.17	199	219	2.30	0	0	10	40	-5	30
42	1333	49.25	98.68	199	232	2.37	0	0	16	40	0	20
43	1400	49.62	100.27	196	222	2.40	0	0	23	38	9	25
44	1231	49.57	99.05	185	219	2.41	0	0	19	41	0	25
45	1460	49.98	100.62	183	213	2.54	0	0	16	38	2	20
46	1052	49.65	98.50	199	218	2.57	0	0	14	40	1	31
47	1570	50.03	100.23	192	222	2.63	0	0	10	39	5	21
48	2000	50.75	100.02	193	225	2.81	11	0	14	47	0	30
49	1800	51.00	100.07	194	223	3.77	0	0	21	45	-12	21
50	2350	50.72	99.60	190	219	3.80	0	0	7	43	0	25
51	1536	49.15	100.05	200	229	4.52	0	0	31	37	4	31

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Table B-3

BASIC DATA FOR 6D

SITE 2 -- DAY 6 (JANUARY 6, 1976) -- DAY OBS. (1511 GMT)

				ESMR		SNOW	PREC X 100 AVE	MAX T DAY		MIN T DAY	
NO.	ELEV	LAT	LONG	TH	TV	H2O	-1 & -2	0	-1	0	-1
1	250	45.95	67.32	220	230	3.00					
2	500	46.78	67.70	209	224	3.40					
3	1000	46.93	67.43	224	240	4.20					
4	550	47.15	67.25	227	235	4.20					
5	550	46.92	67.40	224	240	4.30					
6	900	47.67	67.43	225	239	5.40					
7	1250	47.15	66.72	233	237	5.70					
8	1500	46.98	67.10	224	236	6.00					
9	1250	47.07	66.92	226	236	6.10					
10	1250	47.02	66.98	226	236	6.70					

Table B-4

BASIC DATA FOR 8D

SITE 2 -- DAY 8 (JANUARY 8, 1976) -- DAY OBS. (1532 GMT)

NO.	ELEV	LAT	LONG	ESMR TH	ESMR TV	SNOW H2O	PREC X 100 AVE -1 & -2	MAX T DAY 0	MAX T DAY -1	MIN T DAY 0	MIN T DAY -1
1	150	46.07	67.55	239	240	3.10					
2	725	47.45	69.17	217	237	3.20					
3	200	45.72	66.63	229	247	3.50					
4	150	46.23	67.30	225	247	3.80					
5	1000	46.93	67.43	226	237	4.20					
6	500	47.02	67.38	226	237	4.20					
7	700	46.12	66.77	232	245	4.30					
8	600	46.15	66.58	237	245	4.30					
9	475	46.22	65.72	236	247	4.30					
10	550	46.92	67.40	226	237	4.30					
11	550	47.15	67.25	225	240	4.30					
12	200	46.03	66.70	244	246	4.50					
13	130	45.92	66.62	220	245	4.70					
14	600	46.03	65.13	238	252	4.70					
15	400	46.05	66.72	244	246	5.10					
16	150	45.97	66.87	230	249	5.40					

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Table B-5

BASIC DATA FOR 34N

SITE 2 -- DAY 34 (FEBRUARY 3, 1976) -- NIGHT OBS. (0436 GMT)

NO.	ELEV	LAT	LONG	ESMR TH	ESMR TV	SNOW H20	PREC X 100 AVE -1 & -2	MAX T DAY 0	MAX T DAY -1	MIN T DAY 0	MIN T DAY -1
1	400	46.07	67.55	191	221	2.90	55		53	-6	
2	600	46.03	65.13	214	233	2.90	50		57	-4	
3	200	46.03	66.70	218	227	3.30	70		54	-3	
4	400	46.05	66.72	218	227	4.30	70		54	-4	
5	500	46.78	67.70	185	211	4.70	65		56	-4	
6	500	46.53	67.63	191	211	4.80	40		50	-2	
7	700	46.12	66.77	207	221	5.20	104		54	0	
8	450	46.23	67.30	200	228	5.30	75		52	4	
9	500	46.07	66.87	207	221	5.50	80		50	2	
10	475	46.22	65.72	221	221	5.60	55		57	-3	
11	400	47.07	67.97	190	212	5.80	80		50	-9	
12	550	47.15	67.25	205	212	5.80	80		50	-7	
13	550	47.02	67.30	205	212	5.90	75		50	-6	
14	900	47.07	67.77	205	209	6.20	80		41	-9	
15	1200	47.50	67.25	193	216	6.60	80		45	-9	
16	600	46.15	66.58	216	221	6.70	90		54	-4	
17	450	47.20	67.95	188	205	6.80	50		43	-8	
18	600	47.27	68.62	206	213	7.10	36		43	-10	
19	500	47.20	68.95	200	210	7.40	35		40	-10	
20	700	47.27	68.80	195	216	7.50	36		43	-10	
21	500	47.45	68.40	201	208	7.80	47		49	-8	
22	500	47.30	68.03	188	205	8.00	55		45	-8	
23	1200	47.50	67.25	193	216	8.80	80		45	-9	

Table B-6

BASIC DATA FOR 61N

SITE 2 -- DAY 61 (MARCH1, 1976) -- NIGHT OBS. (0509 GMT)

				ESMR		SNOW	PREC X 100 AVE	MAX T DAY		MIN T DAY	
NO.	ELEV	LAT	LONG	TH	TV	H20	-1 & -2	0	-1	0	-1
1	130	45.92	66.92	227	243	2.90	10		28	15	
2	200	46.03	66.70	235	250	4.90	14		35	21	
3	450	46.23	67.30	214	246	5.50	18		30	15	
4	200	45.72	66.68	231	253	5.80	12		36	22	
5	600	46.15	66.58	218	253	5.80	18		36	23	
6	400	46.05	66.72	235	250	6.00	15		35	21	
7	250	45.95	67.32	226	241	6.20	18		28	15	
8	500	46.07	66.87	226	249	6.50	18		33	23	
9	150	45.97	66.87	237	253	6.90	18		33	26	
10	475	46.22	65.72	224	255	7.00	8		32	15	
11	550	47.15	67.25	221	230	8.20	13		25	12	
12	500	46.53	67.63	214	231	8.30	3		28	16	
13	650	46.58	67.60	214	231	8.40	3		28	16	
14	500	47.02	67.38	213	233	8.40	12		25	11	
15	500	47.20	68.95	228	248	8.50	5		18	6	
16	600	47.27	68.62	227	235	8.70	0		18	5	
17	1200	47.50	67.25	216	232	8.70	25		23	13	
18	550	46.92	67.40	202	234	9.10	13		18	8	
19	450	47.20	67.95	207	234	10.20	3		17	6	
20	500	47.30	68.03	216	240	11.30	5		18	10	
21	1200	47.50	67.25	216	232	11.60	25		23	13	
22	1250	47.02	66.98	222	247	13.70	12		25	12	
23	1250	47.07	66.92	222	247	14.30	12		25	12	

Table B-7

BASIC DATA FOR 61R

SITE 2 -- DAY 61 (MARCH1, 1976) -- NIGHT OBS. (0509 GMT) ** SNOW 4.9-10.2 INCHES

NO.	ELEV	LAT	LONG	ESMR TH	ESMR TV	SNOW H2O	PREC X 100 AVE -1 & -2	MAX T DAY 0	MAX T DAY -1	MIN T DAY 0	MIN T DAY -1
1	200	46.03	66.70	235	250	4.90	14		35	21	
2	450	46.23	67.30	214	246	5.50	18		30	15	
3	200	45.72	66.68	231	253	5.80	12		36	22	
4	600	46.15	66.58	218	253	5.80	18		36	23	
5	400	46.05	66.72	235	250	6.00	15		35	21	
6	250	45.95	67.32	226	241	6.20	18		28	15	
7	500	46.07	66.87	226	249	6.50	18		33	23	
8	150	45.97	66.87	237	253	6.90	12		36	22	
9	475	46.22	65.72	224	255	7.00	8		32	15	
10	550	47.15	67.25	221	230	8.20	13		25	12	
11	500	46.53	67.63	214	231	8.30	3		28	16	
12	650	46.58	67.60	214	231	8.40	3		28	16	
13	500	47.02	67.38	213	233	8.40	12		25	11	
14	500	47.20	68.95	228	248	8.50	0		18	6	
15	600	47.27	68.62	227	235	8.70	0		18	5	
16	1200	47.50	67.25	216	232	8.70	25		23	13	
17	550	46.92	67.40	202	234	9.10	13		18	8	
18	450	47.20	67.95	207	234	10.20	3		17	6	

Table B-8

BASIC DATA FOR 61E

SITE 2 -- DAY 61 (MARCH 1,1976) -- NIGHT OBS. (0509 GMT) ** CONTOUR SNOW VALUES

NO.	ELEV	LAT	LONG	ESMR TH	ESMR TV	SNOW H2O	PREC X 100 AVE -1 & -2	MAX T DAY 0	MAX T DAY -1	MIN T DAY 0	MIN T DAY -1
1	0	45.70	67.17	221	255	5.10					
2	0	45.72	66.73	227	255	5.20					
3	0	46.02	66.71	235	250	5.30					
4	0	45.75	66.95	231	253	5.60					
5	0	45.50	67.40	223	256	5.60					
6	0	46.10	67.40	211	242	5.80					
7	0	45.50	67.60	231	254	5.80					
8	0	45.80	67.20	237	253	5.90					
9	0	46.10	67.20	226	249	6.10					
10	0	46.17	67.63	224	246	6.40					
11	0	46.05	67.94	218	253	6.60					
12	0	46.30	66.30	227	243	6.90					
13	0	46.32	66.52	225	253	7.10					
14	0	45.90	68.10	230	254	7.10					
15	0	46.47	67.44	213	244	7.20					
16	0	[illegible]	68.12	217	244	7.30					
17	0	46.37	66.73	227	241	7.50					
18	0	46.40	67.20	221	246	7.50					
19	0	46.52	67.90	214	231	7.50					
20	0	46.36	69.00	239	259	7.50					
21	0	46.52	69.91	216	242	7.50					
22	0	46.80	69.46	222	239	7.60					
23	0	46.50	67.66	204	235	7.70					
24	0	46.40	[illegible]	233	243	7.80					
25	0	46.77	68.17	219	225	7.80					
26	0	46.50	69.67	222	234	7.80					
27	0	46.96	69.27	228	248	7.90					
28	0	46.73	67.92	201	233	8.00					
29	0	47.67	69.50	197	234	8.00					
30	0	46.70	67.70	202	234	8.30					
31	0	46.67	67.45	207	241	8.40					
32	0	46.62	68.57	219	246	8.50					
33	0	47.19	68.83	227	235	8.50					
34	0	46.92	69.05	235	245	8.50					
35	0	46.40	69.23	234	246	8.50					
36	0	46.76	69.25	220	252	8.70					
37	0	46.46	69.44	224	251	8.70					
38	0	47.30	67.17	232	237	8.80					
39	0	47.00	67.70	213	233	8.80					
40	0	46.95	67.48	221	239	8.90					
41	0	47.32	67.31	201	237	9.00					
42	0	47.02	67.95	204	229	9.00					
43	0	46.82	68.38	236	254	9.00					
44	0	47.16	68.62	219	234	9.00					
45	0	47.22	69.07	225	249	9.00					
46	0	47.93	69.07	202	226	9.00					
47	0	47.02	69.50	216	244	9.00					
48	0	46.82	69.71	221	246	9.00					
49	0	47.37	69.73	207	237	9.00					
50	0	46.56	70.23	211	228	9.00					
51	0	46.32	70.35	202	234	9.00					
52	0	46.63	67.24	220	233	9.20					

Table B-8 (Continued)

BASIC DATA FOR 61E

53	0	46.60	66.78	230	245	9.20
54	0	47.06	68.16	207	234	9.30
55	0	47.02	68.40	216	240	9.50
56	0	47.12	69.95	204	239	9.50
57	0	46.60	67.02	214	247	9.70
58	0	46.92	70.15	213	226	9.70
59	0	46.86	69.93	217	238	9.80
60	0	47.50	68.60	210	243	10.00
61	0	46.85	68.60	229	250	10.00
62	0	46.89	68.82	226	240	10.00
63	0	46.62	70.35	211	233	10.00
64	0	47.35	67.65	216	232	10.20
65	0	47.60	69.27	213	231	10.20
66	0	46.92	67.24	222	247	10.30
67	0	47.26	66.94	228	239	11.00
68	0	47.25	69.28	230	248	11.00
69	0	47.32	69.51	229	230	11.00
70	0	47.06	69.74	221	233	11.00
71	0	47.40	67.90	207	225	11.50

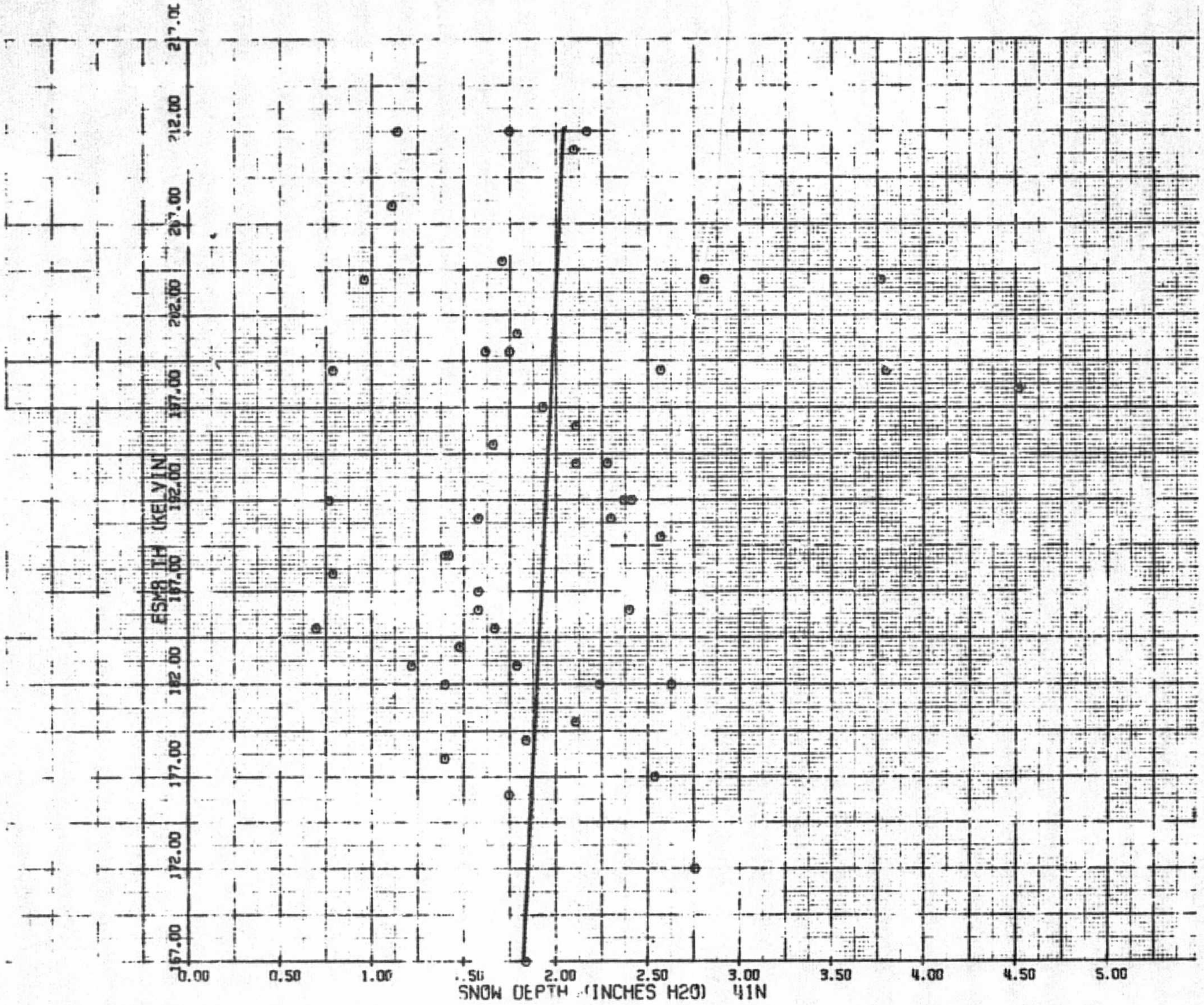

Figure B-1. 41N - Snow Depth versus Horizontal Temperature

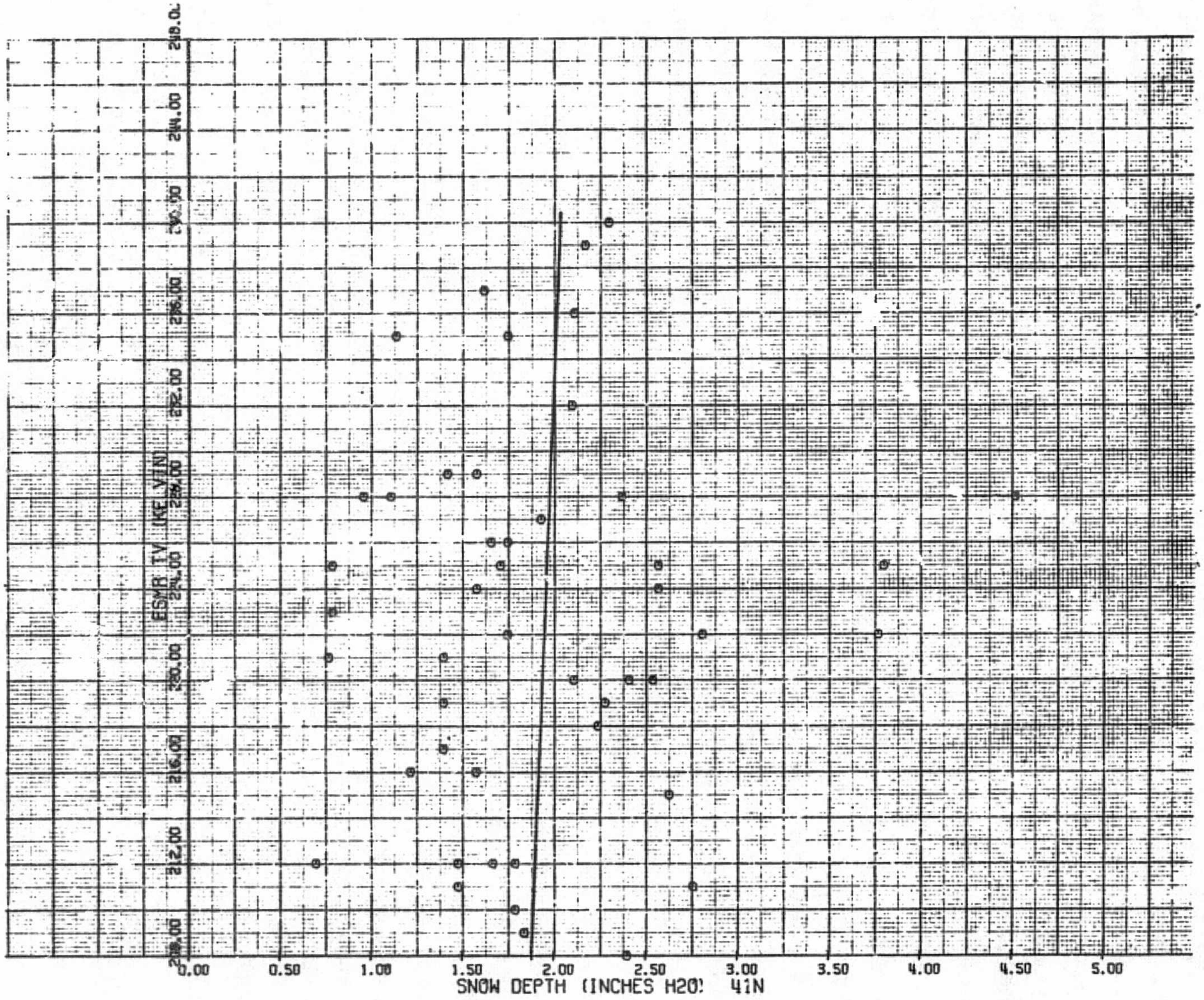

Figure B-2. 41N - Snow Depth versus Vertical Temperature

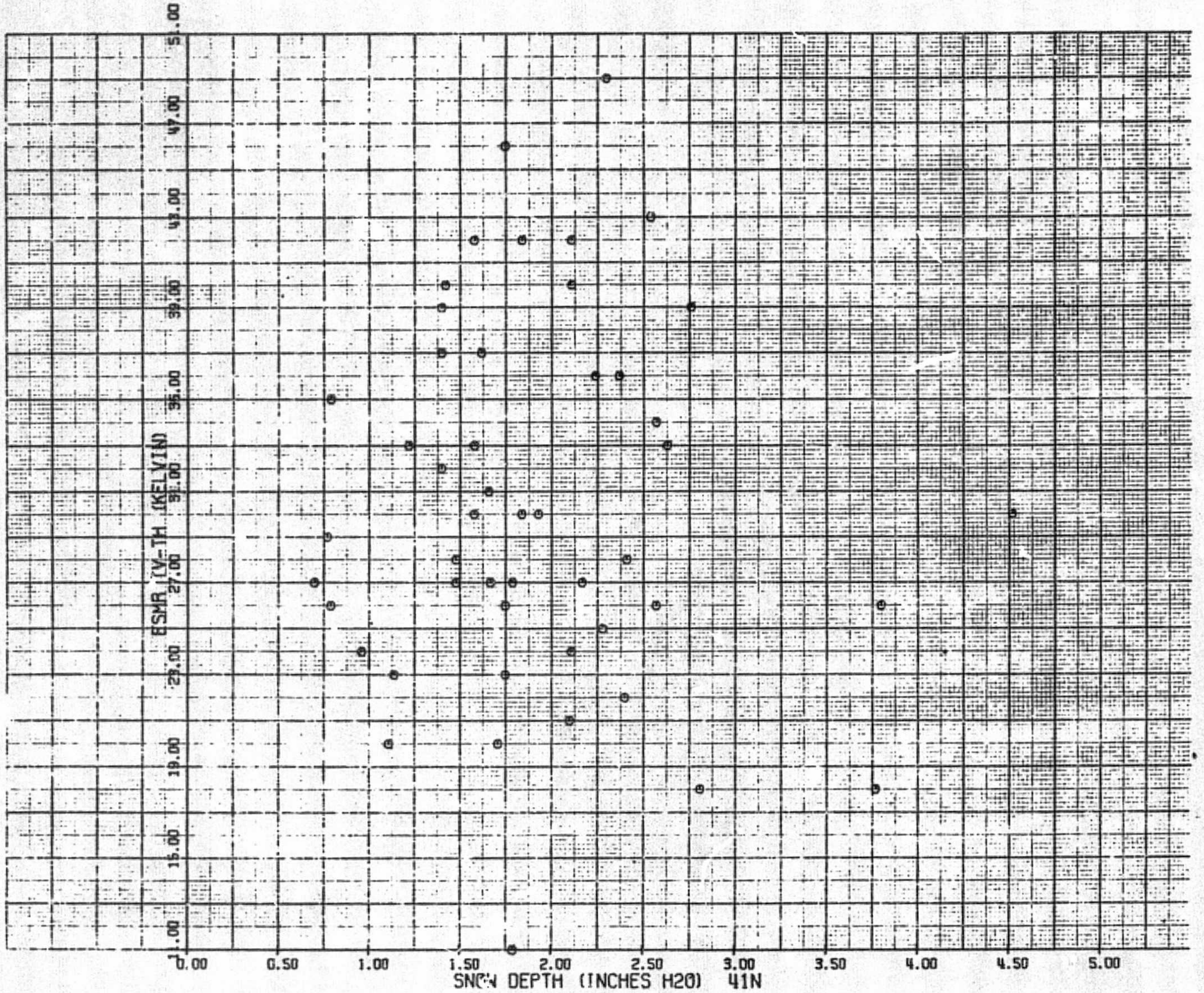

Figure B-3. 41N - Snow Depth versus Polarization Difference

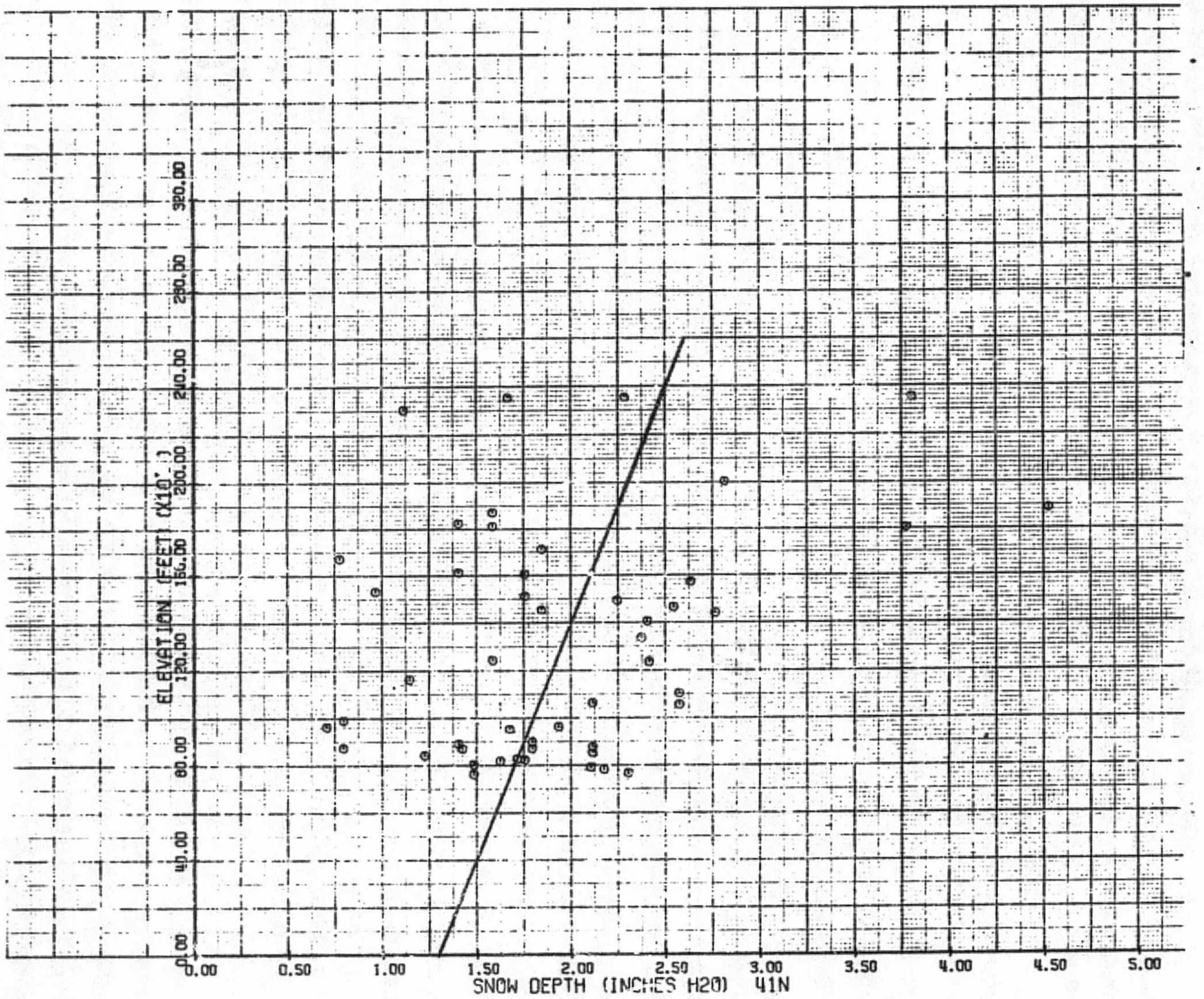

Figure B-4. 41N - Snow Depth versus Elevation

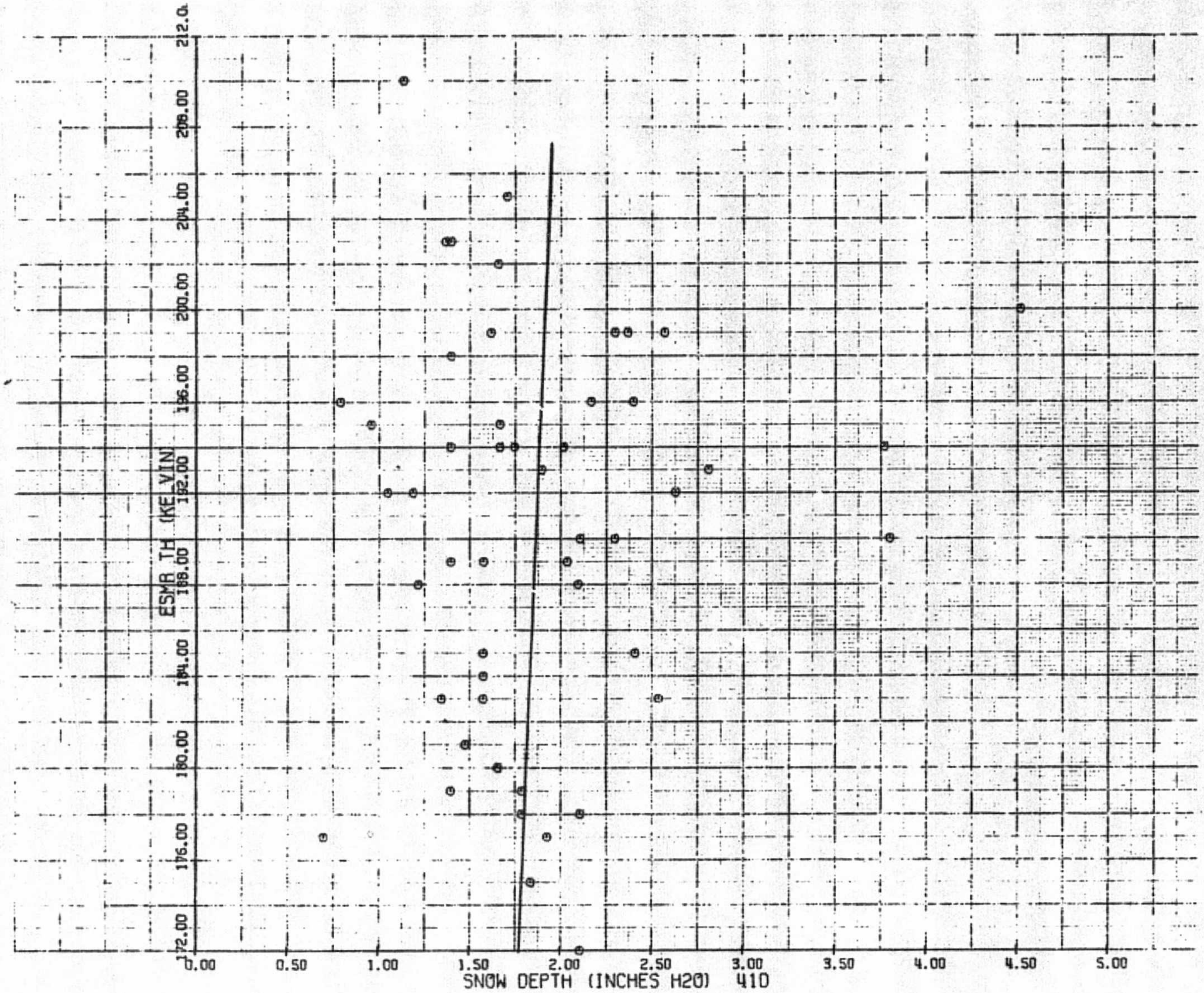

Figure B-5. 41D - Snow Depth versus Horizontal Temperature

C-2

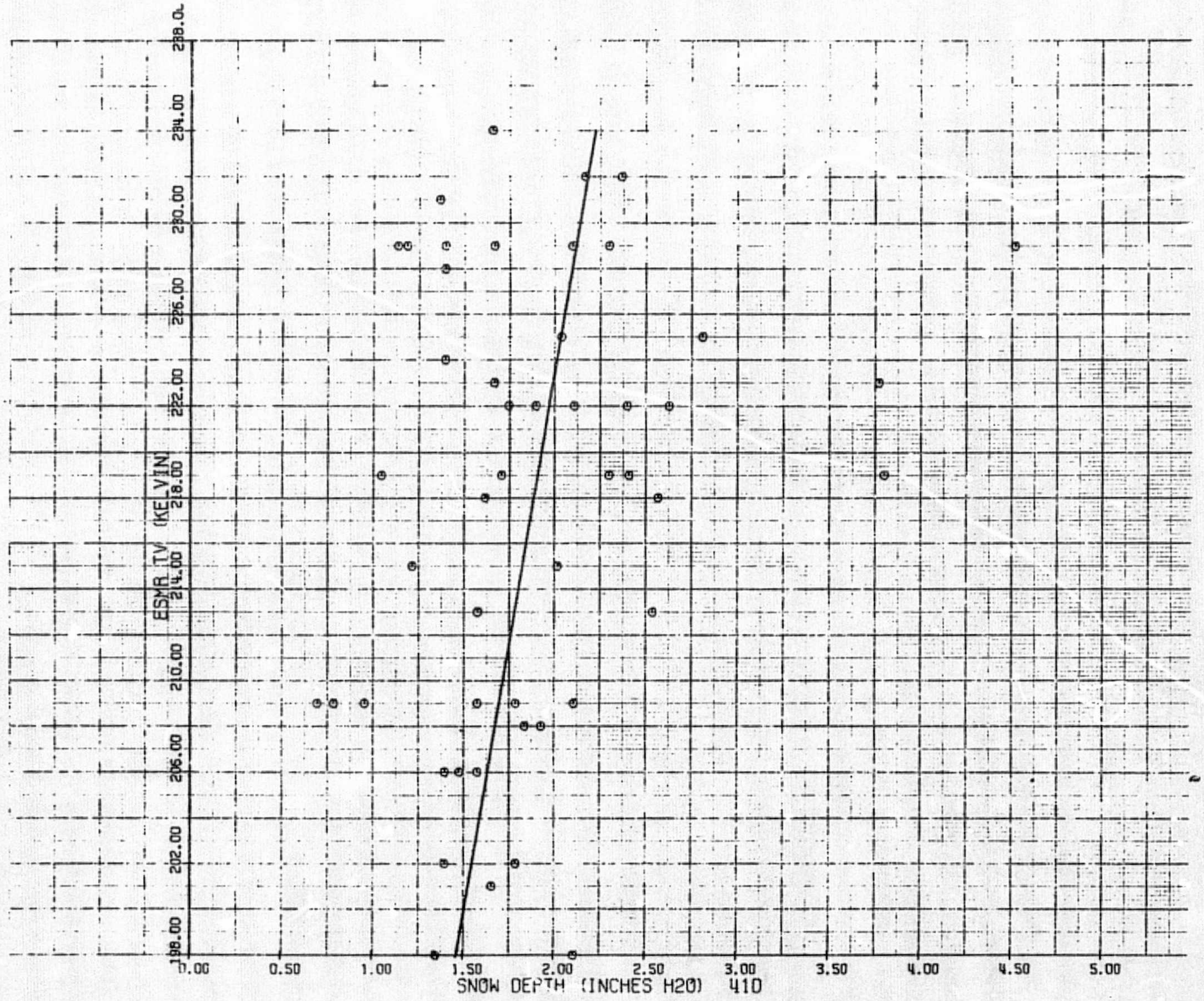

Figure B-6. 41D - Snow Depth versus Vertical Temperature

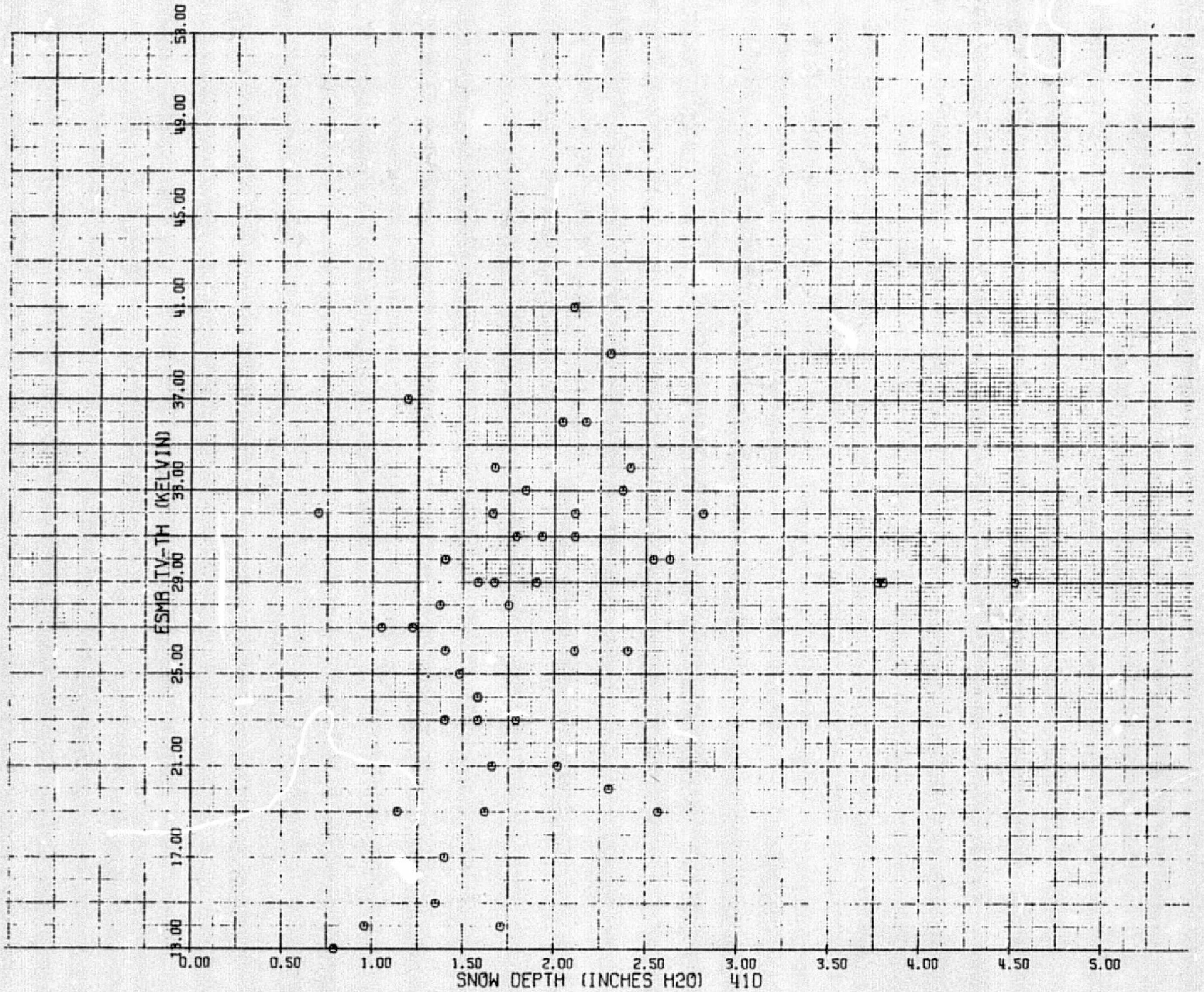

Figure B-7. 41D - Snow Depth versus Polarization Difference

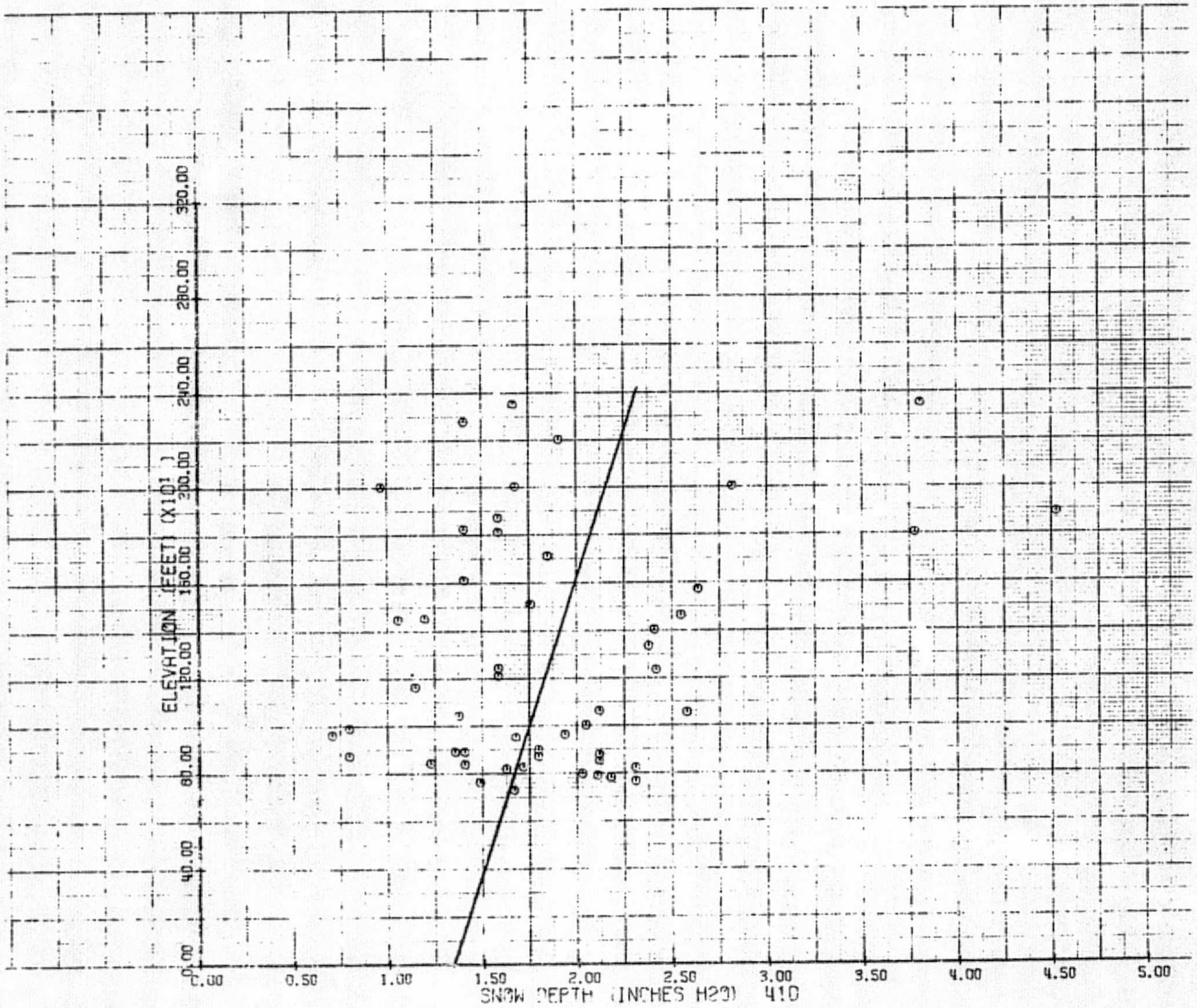

Figure B-8. 41D - Snow Depth versus Elevation

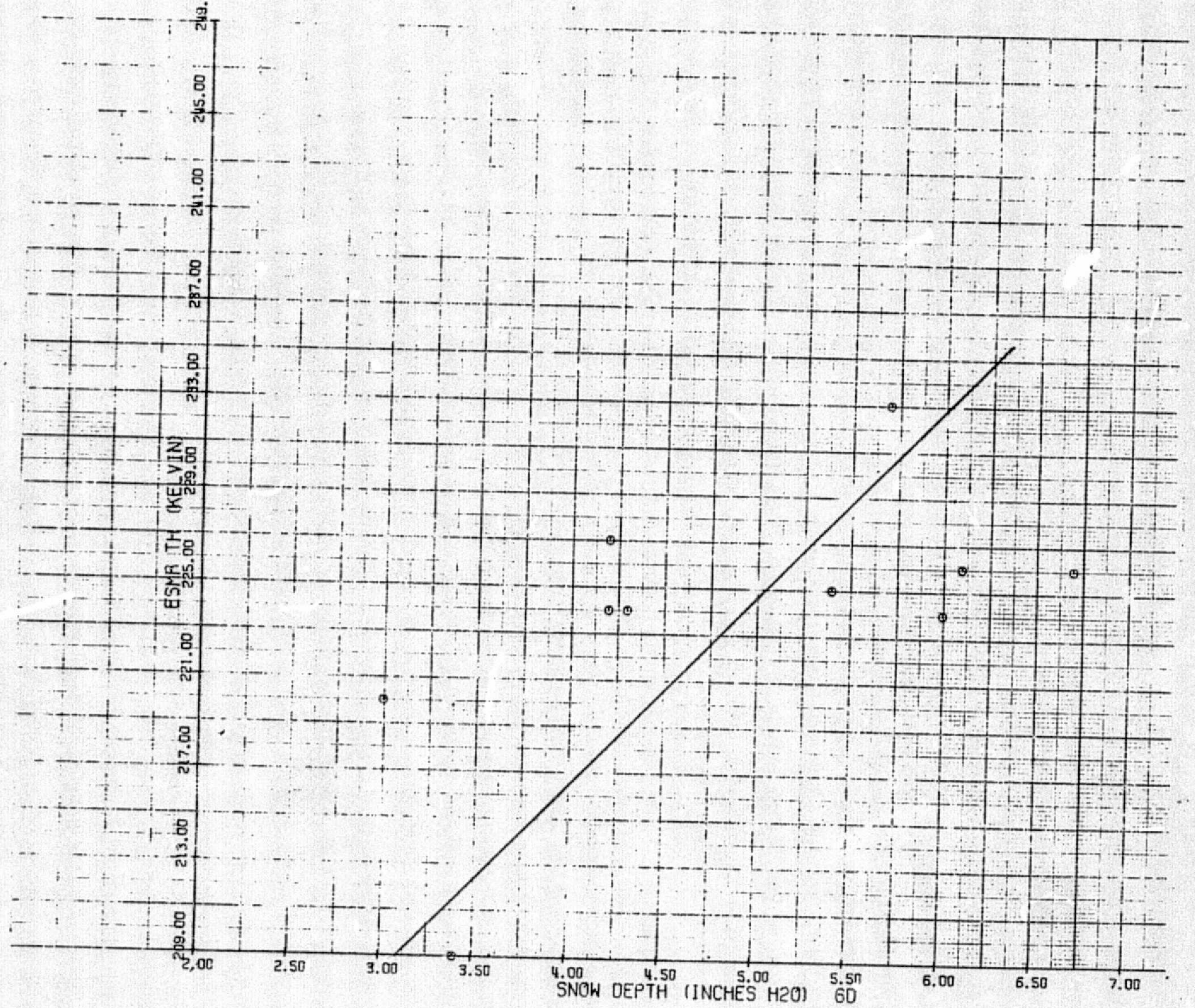

Figure B-9. 6D - Snow Depth versus Horizontal Temperature

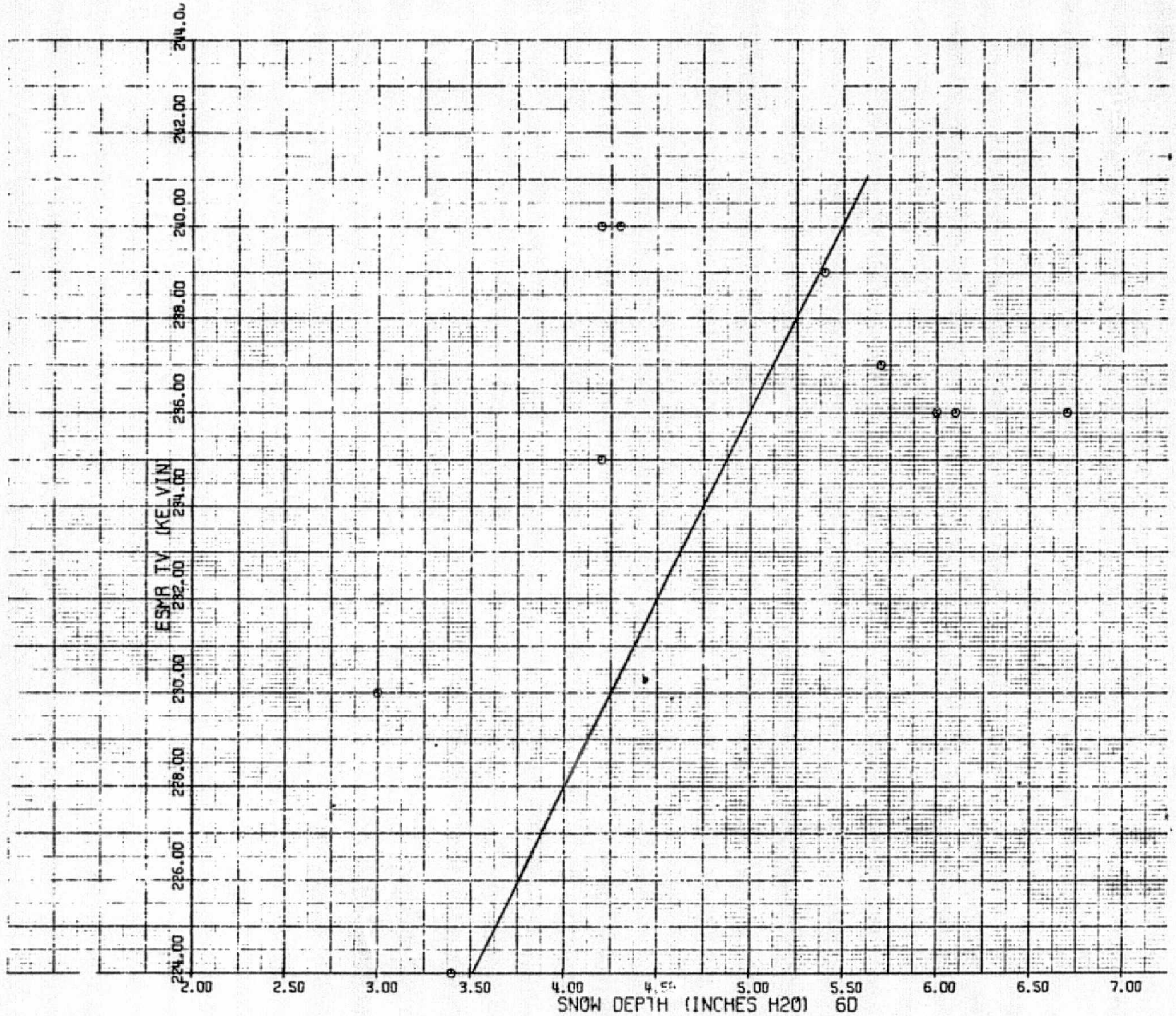

Figure B-10. 6D - Snow Depth versus Vertical Temperature

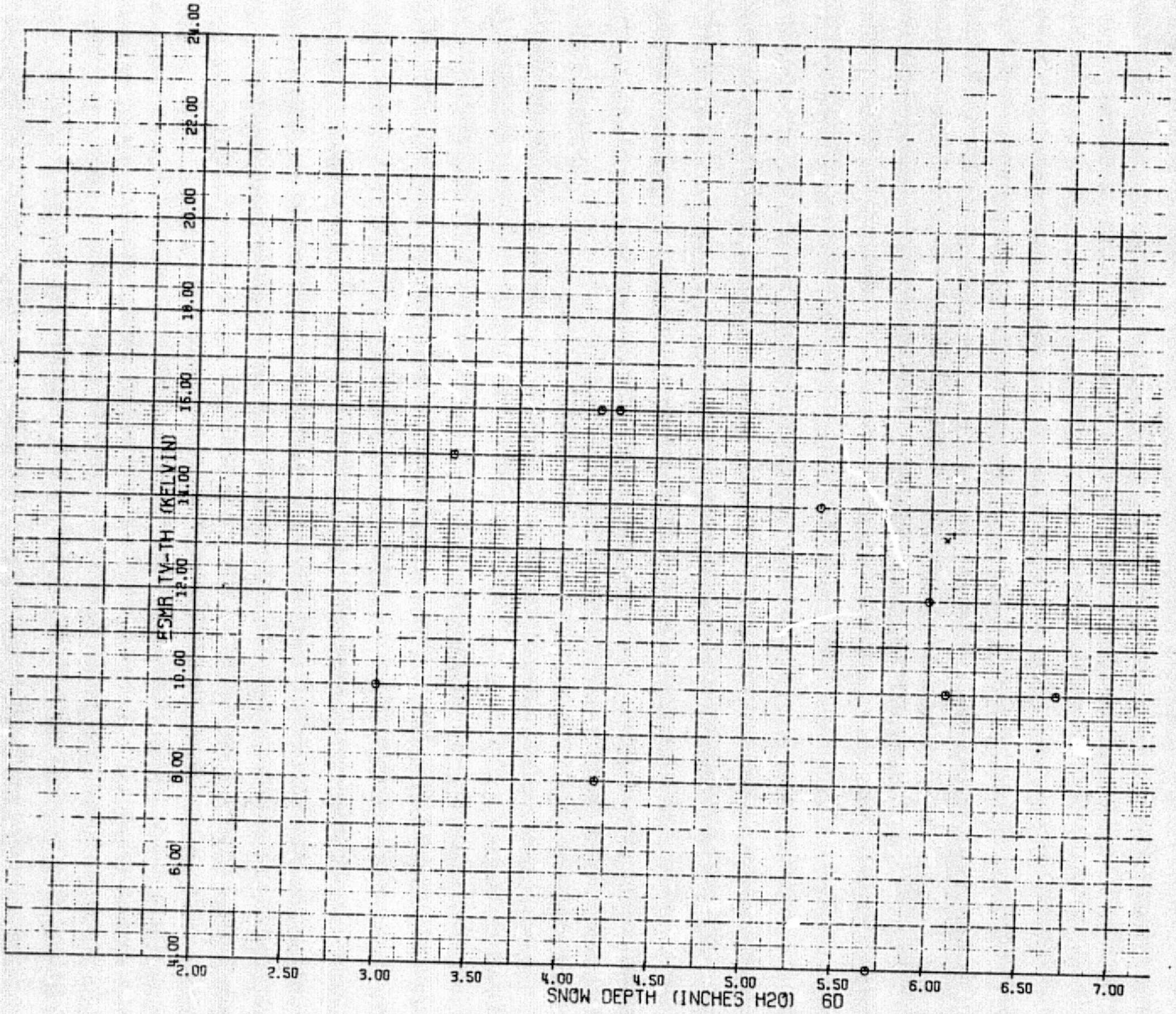

Figure B-11. 6D - Snow Depth versus Polarization Difference

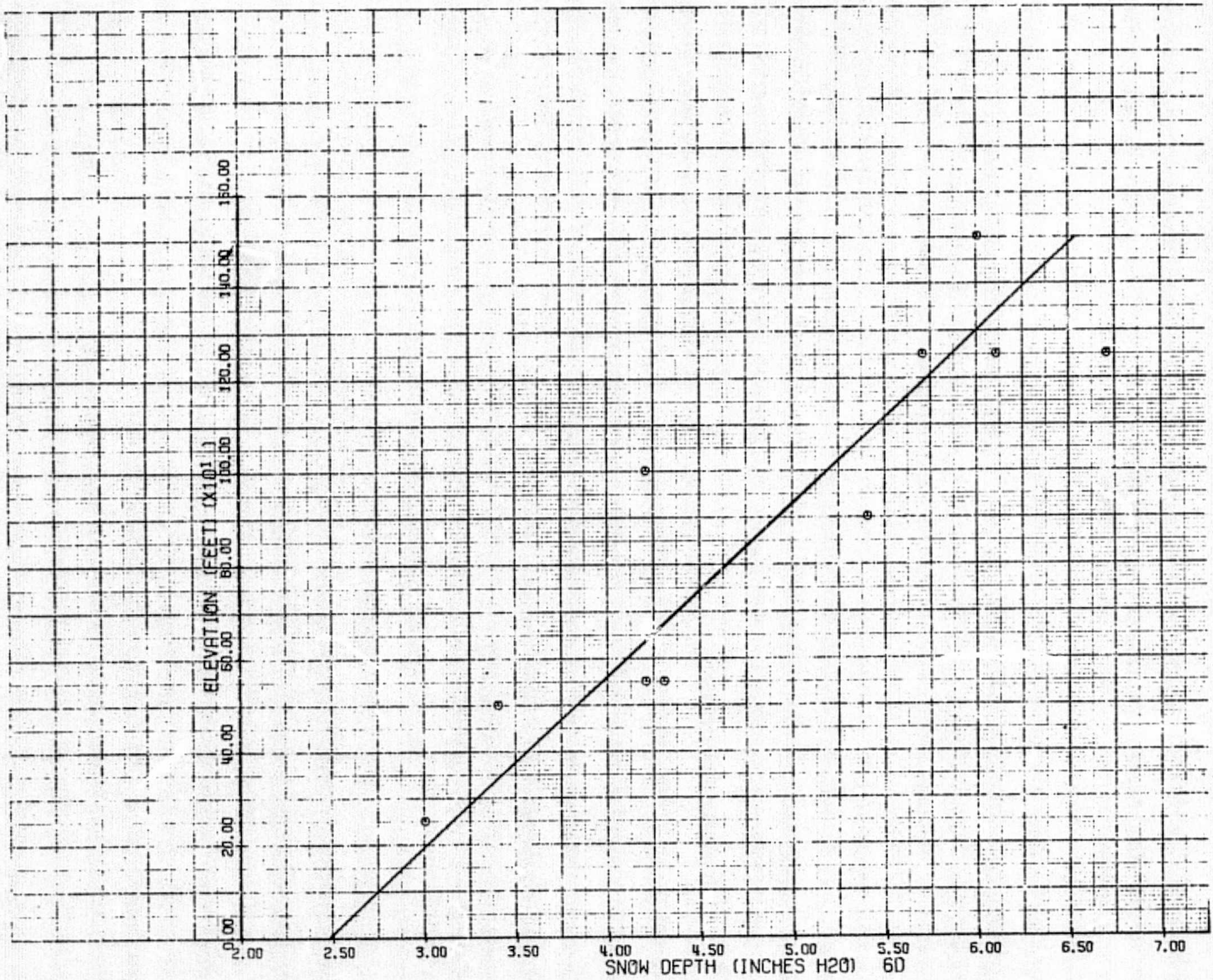

Figure B-12. 6D - Snow Depth versus Elevation

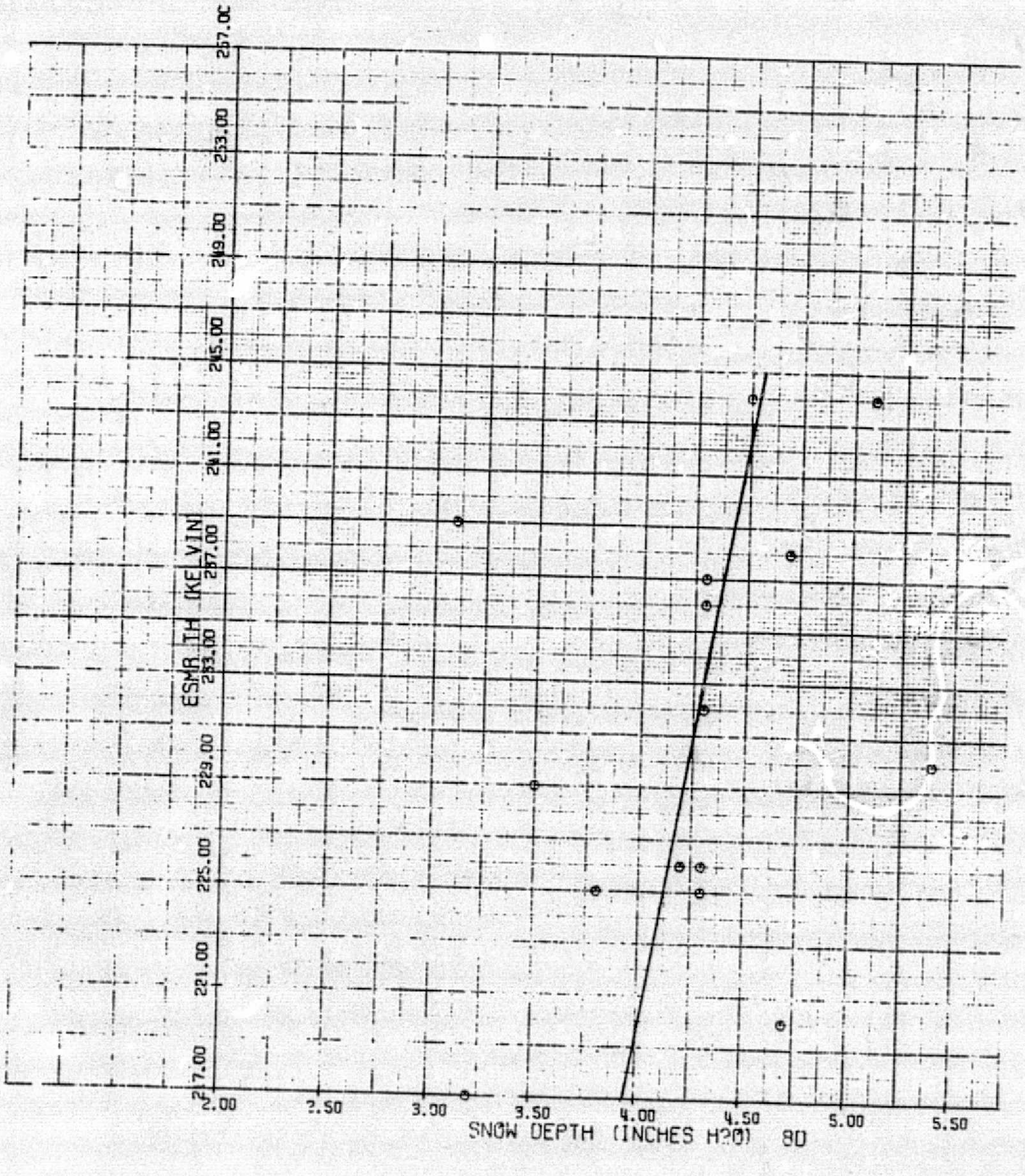

Figure B-13. 8D - Snow Depth versus Horizontal Temperature

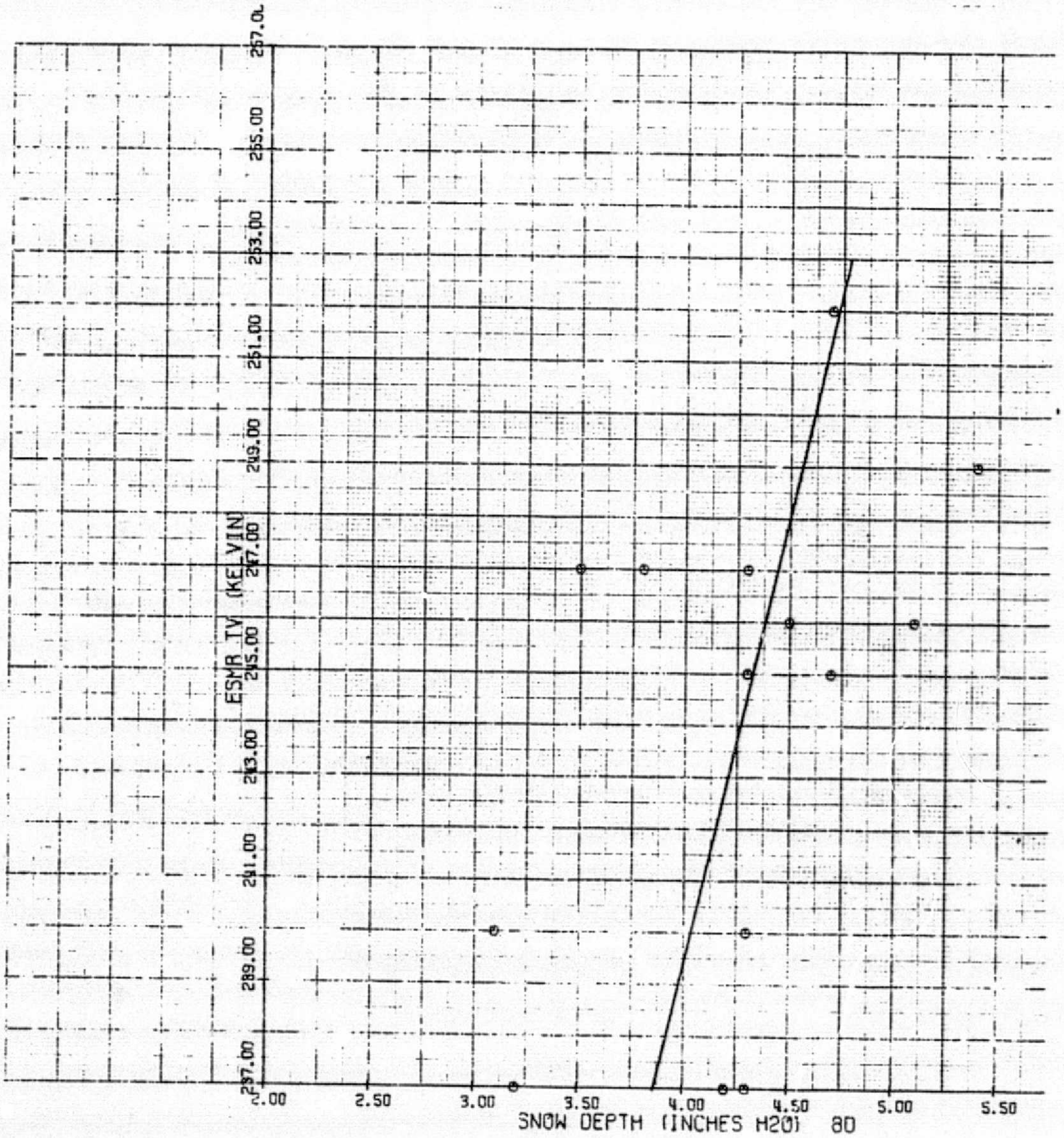

Figure B-14. 8D - Snow Depth versus Vertical Temperature

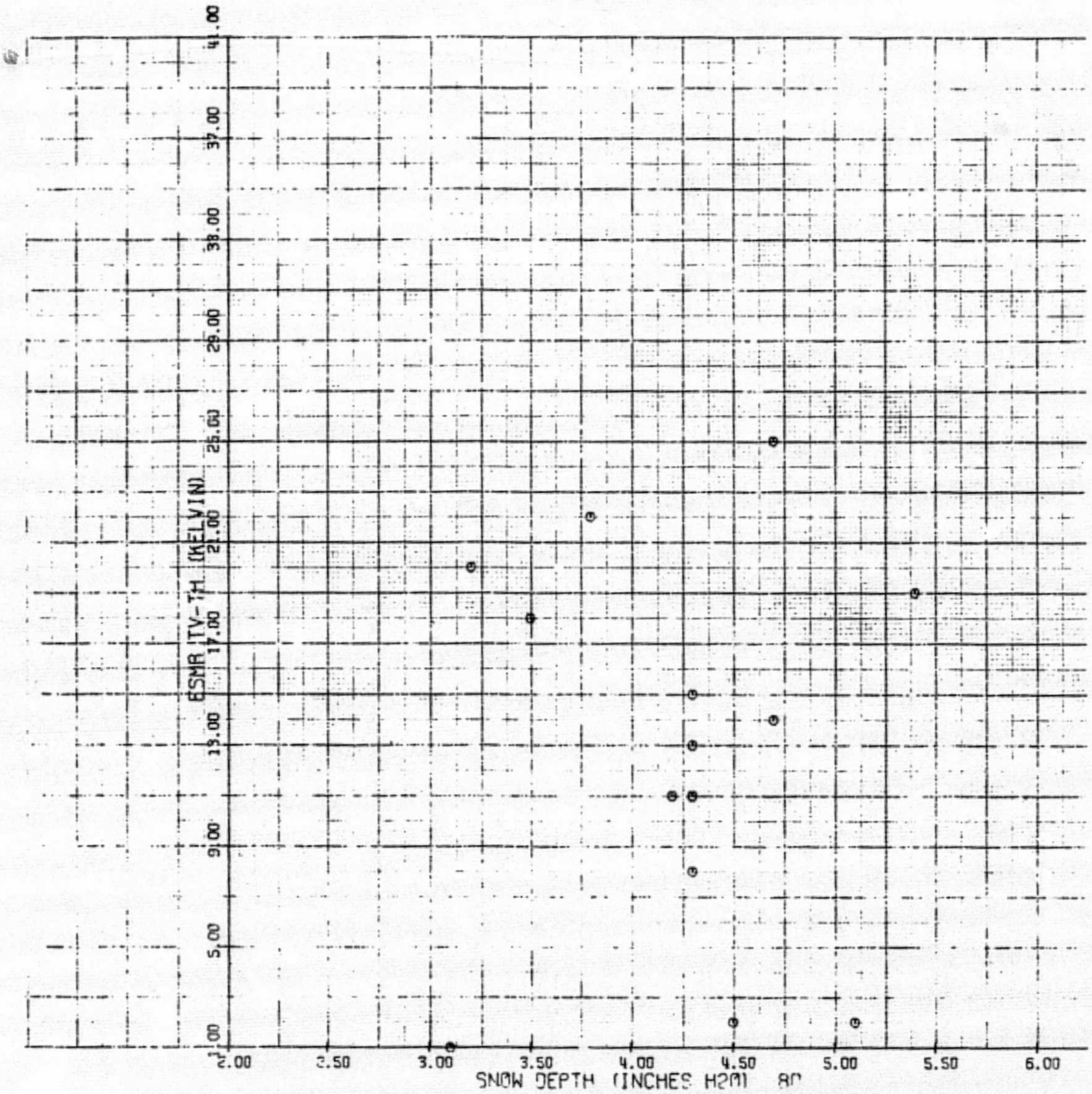

Figure B-15. 8D - Snow Depth versus Polarization Difference

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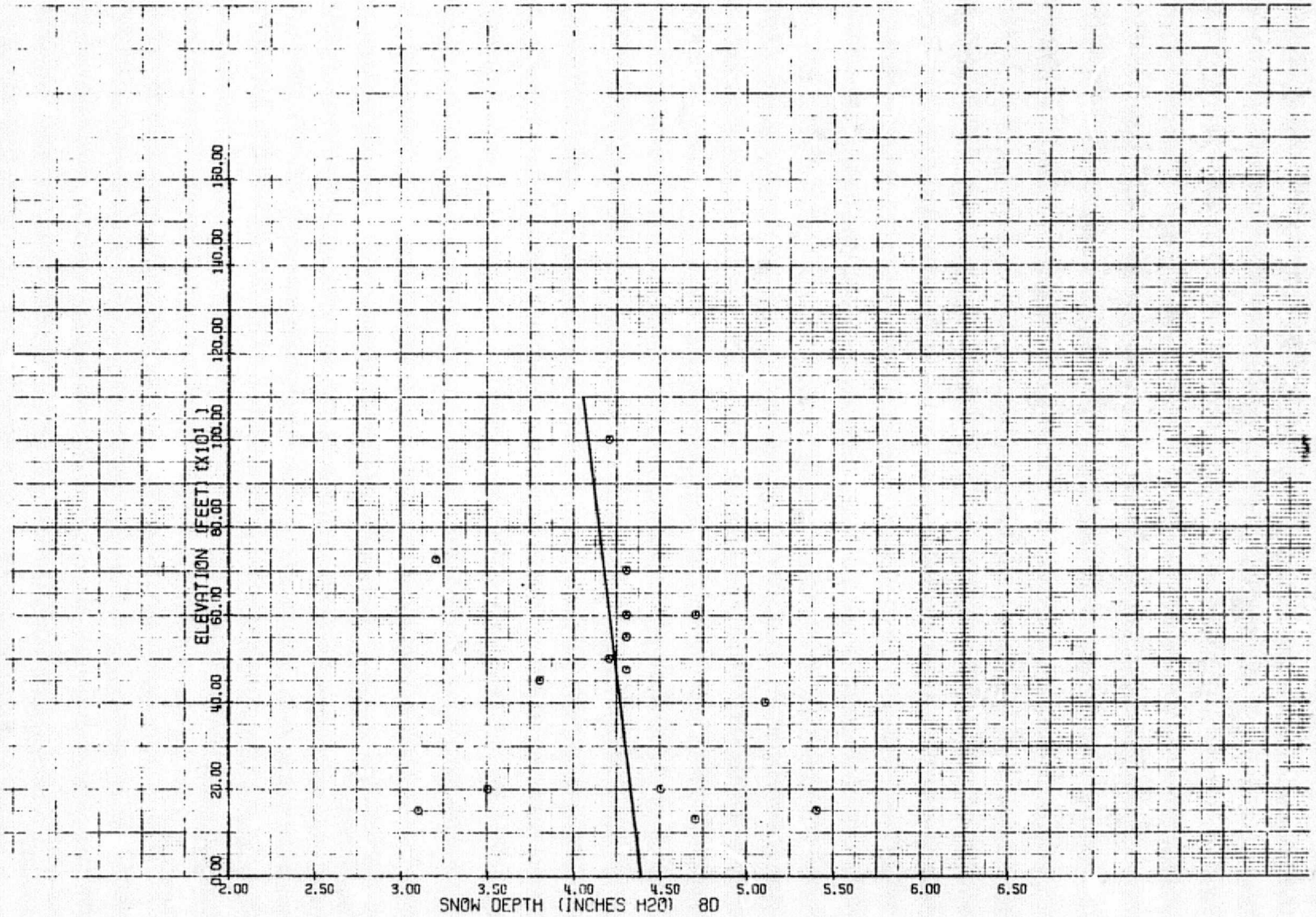

Figure B-16. 8D - Snow Depth versus Elevation

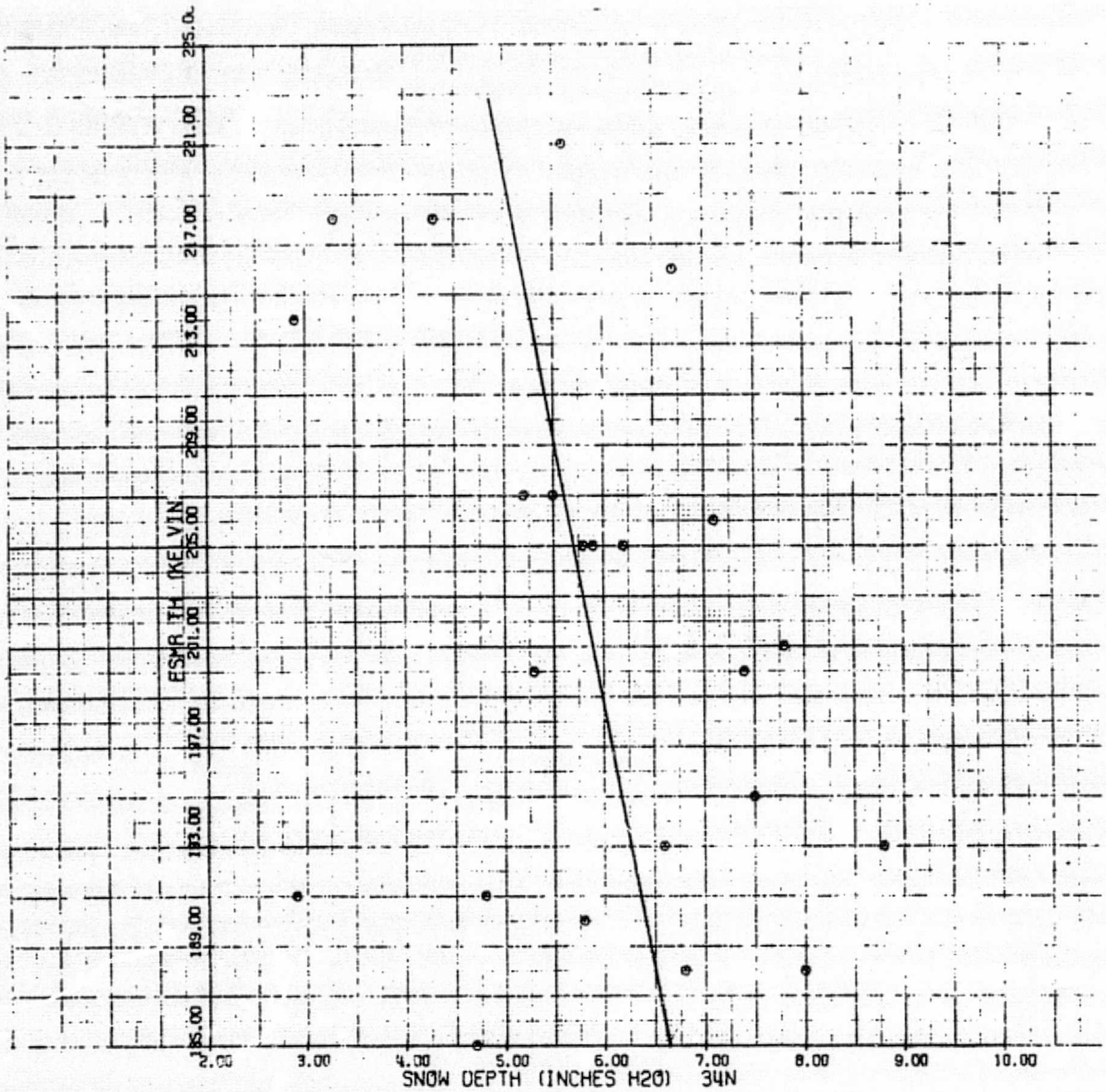

Figure B-17. 34N - Snow Depth versus Horizontal Temperature

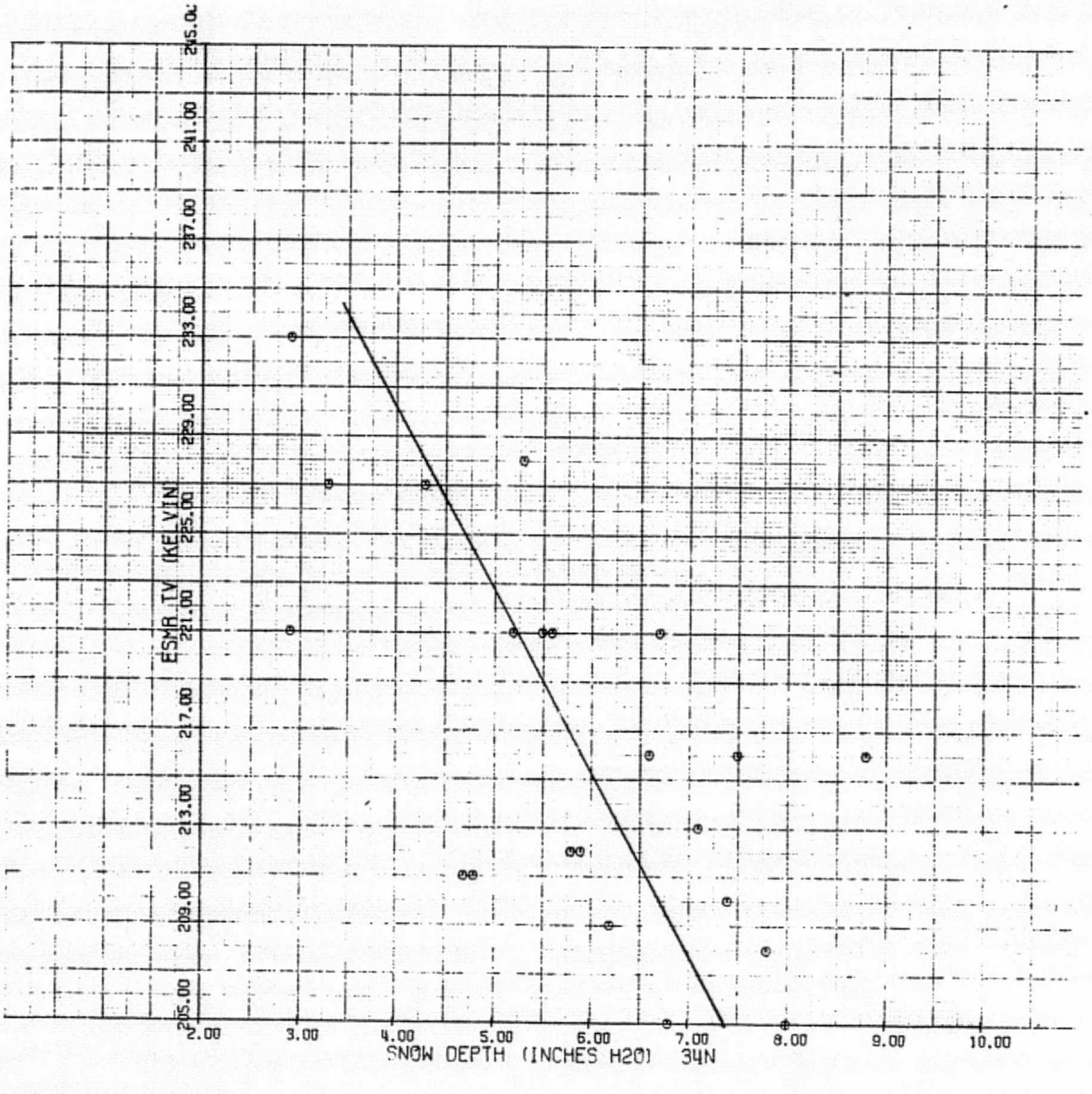

Figure B-18. 34N - Snow Depth versus Vertical Temperature

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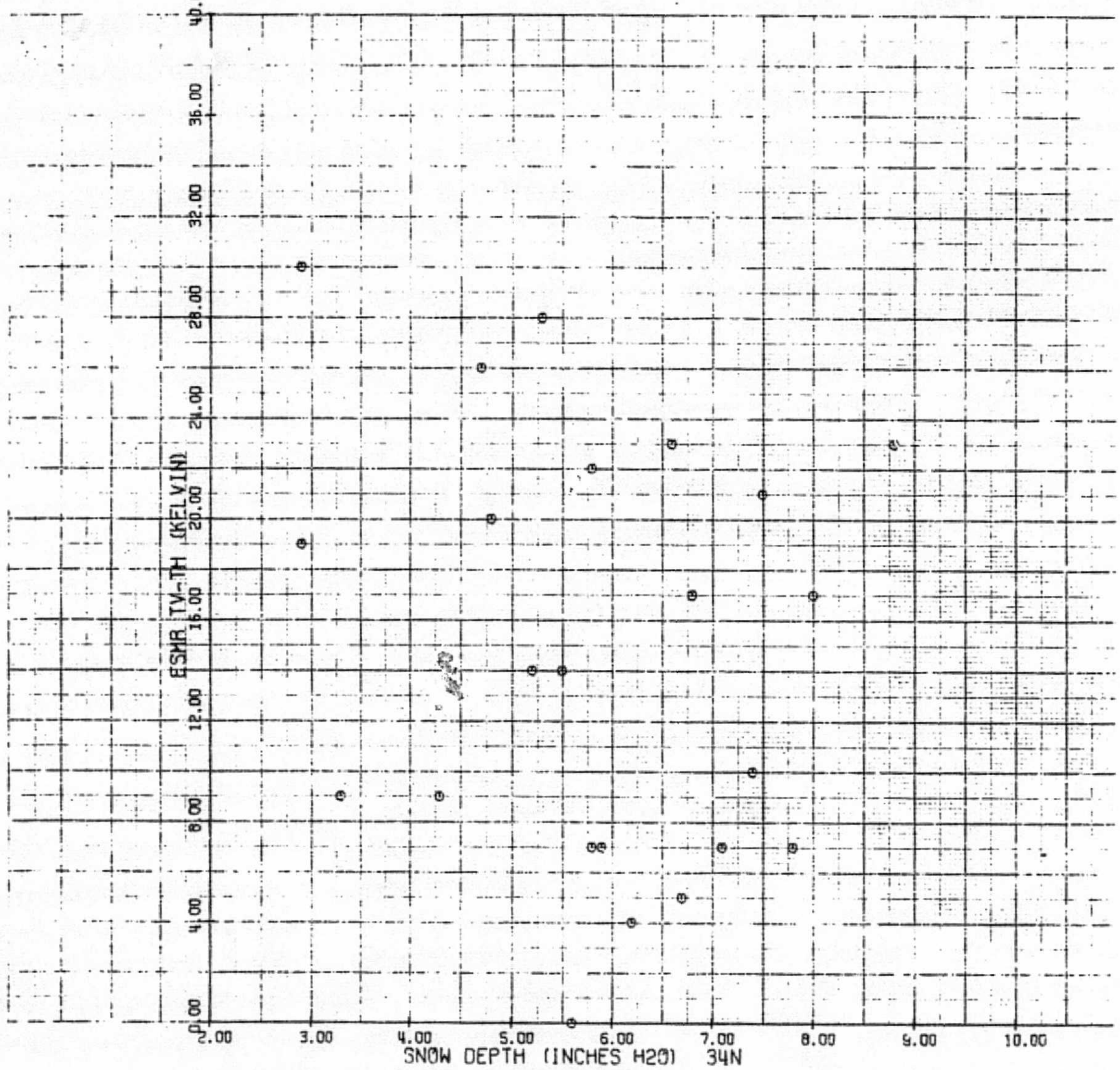

Figure B-19. 34N - Snow Depth versus Polarization Difference

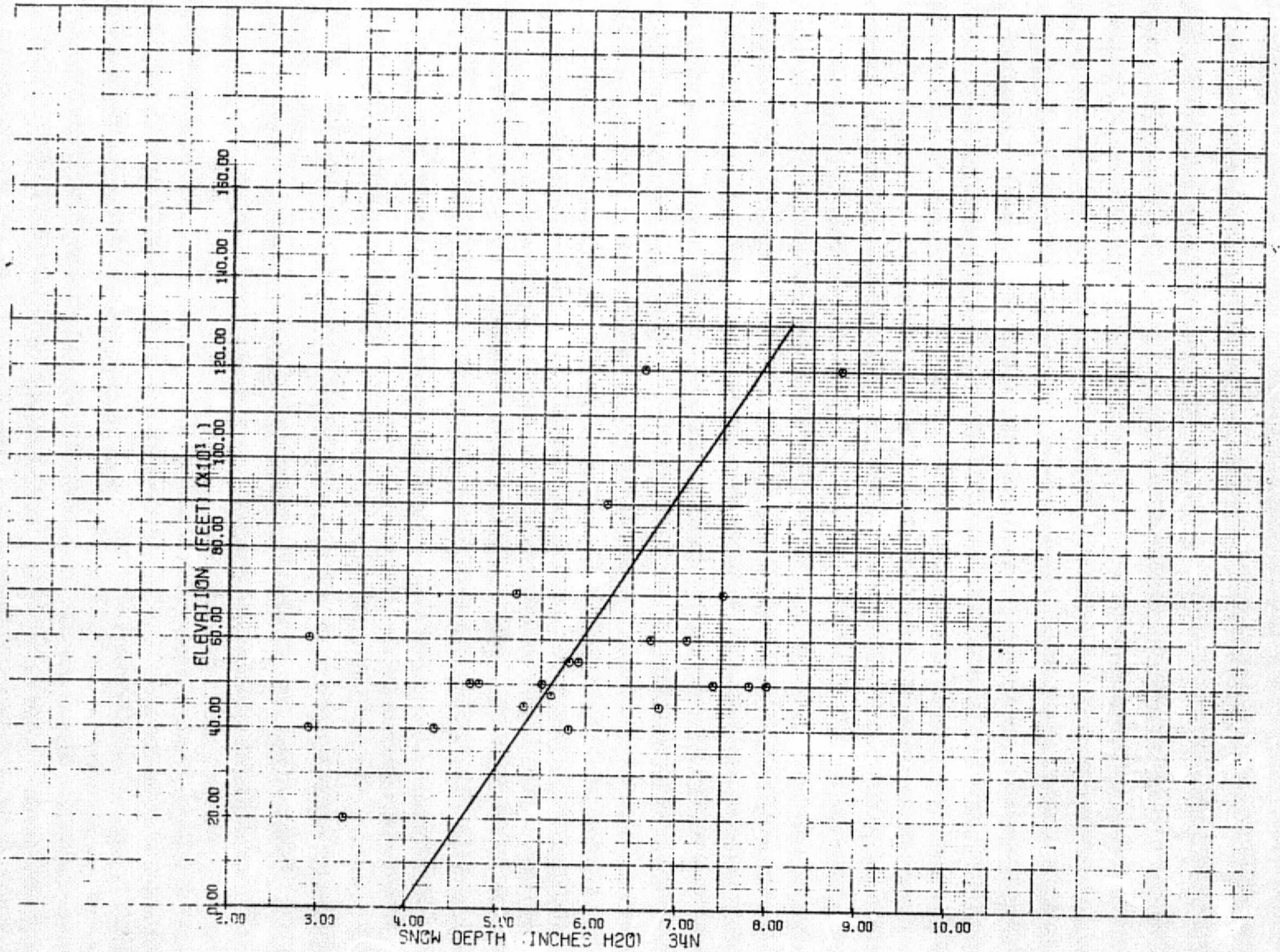

Figure B-20. 34N - Snow Depth versus Elevation

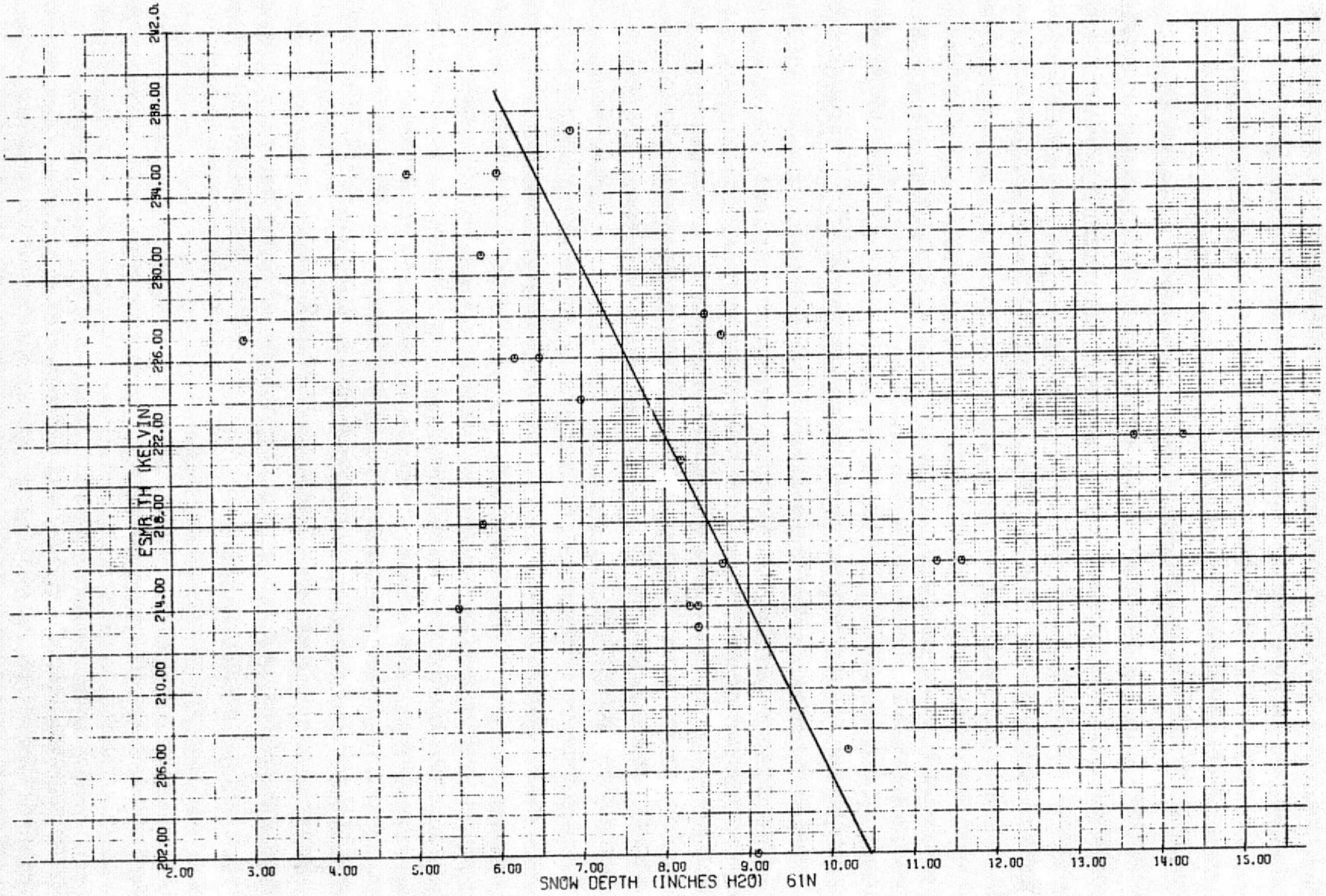

Figure B-21. 61N - Snow Depth versus Horizontal Temperature

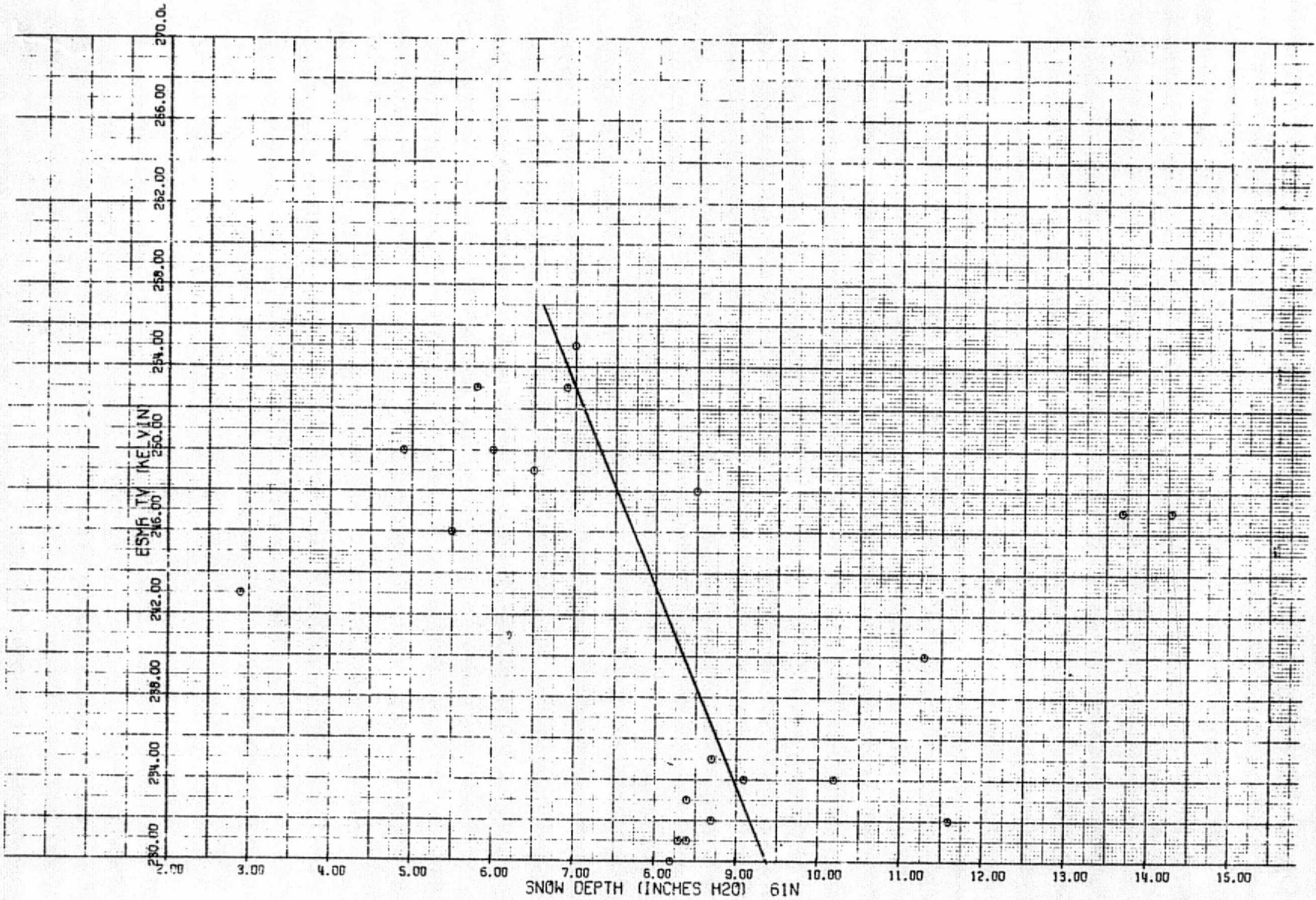

Figure B-22. 61N - Snow Depth versus Vertical Temperature

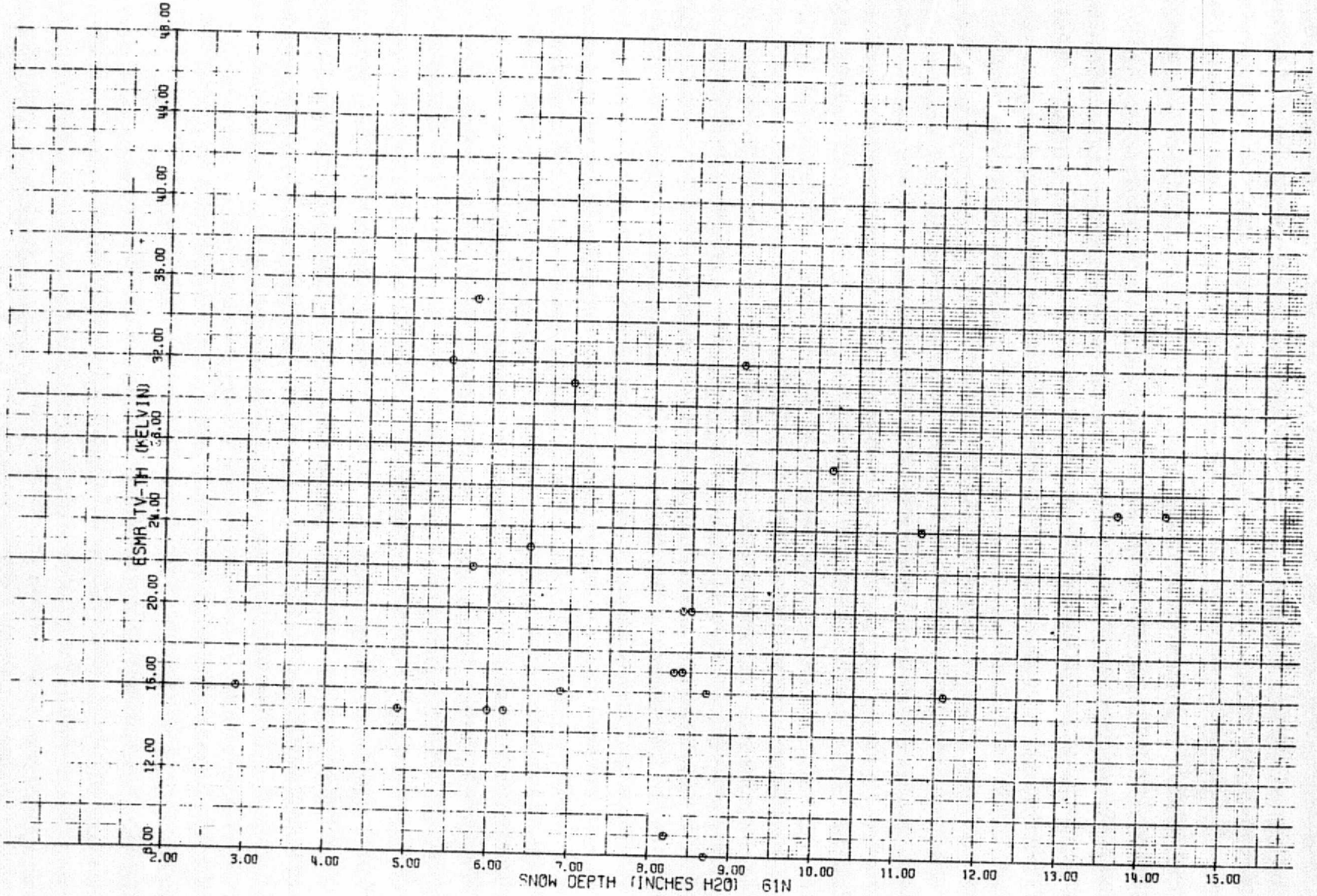

Figure B-23. 61N - Snow Depth versus Polarization Difference

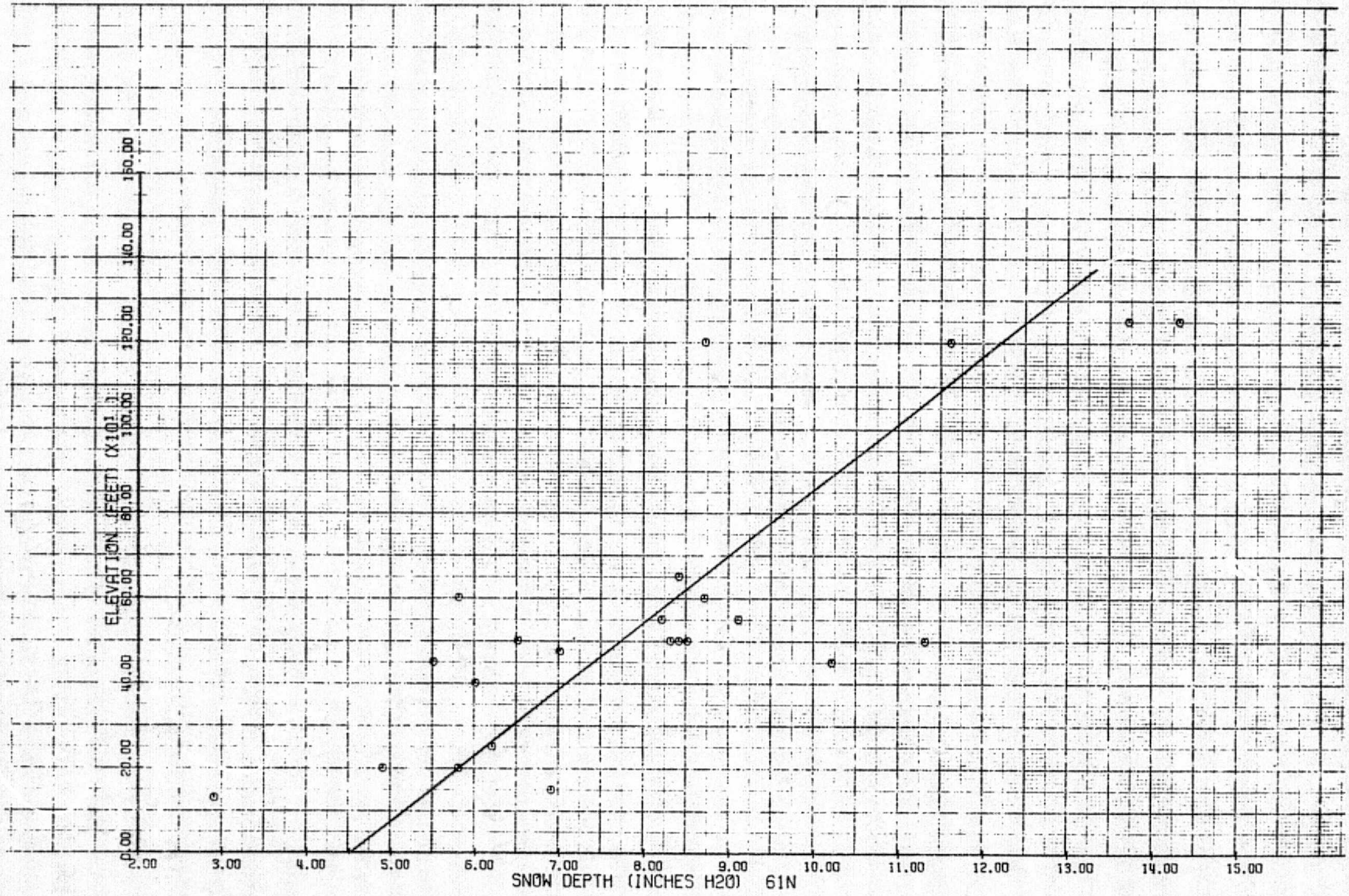

Figure B-24. 61N - Snow Depth versus Elevation

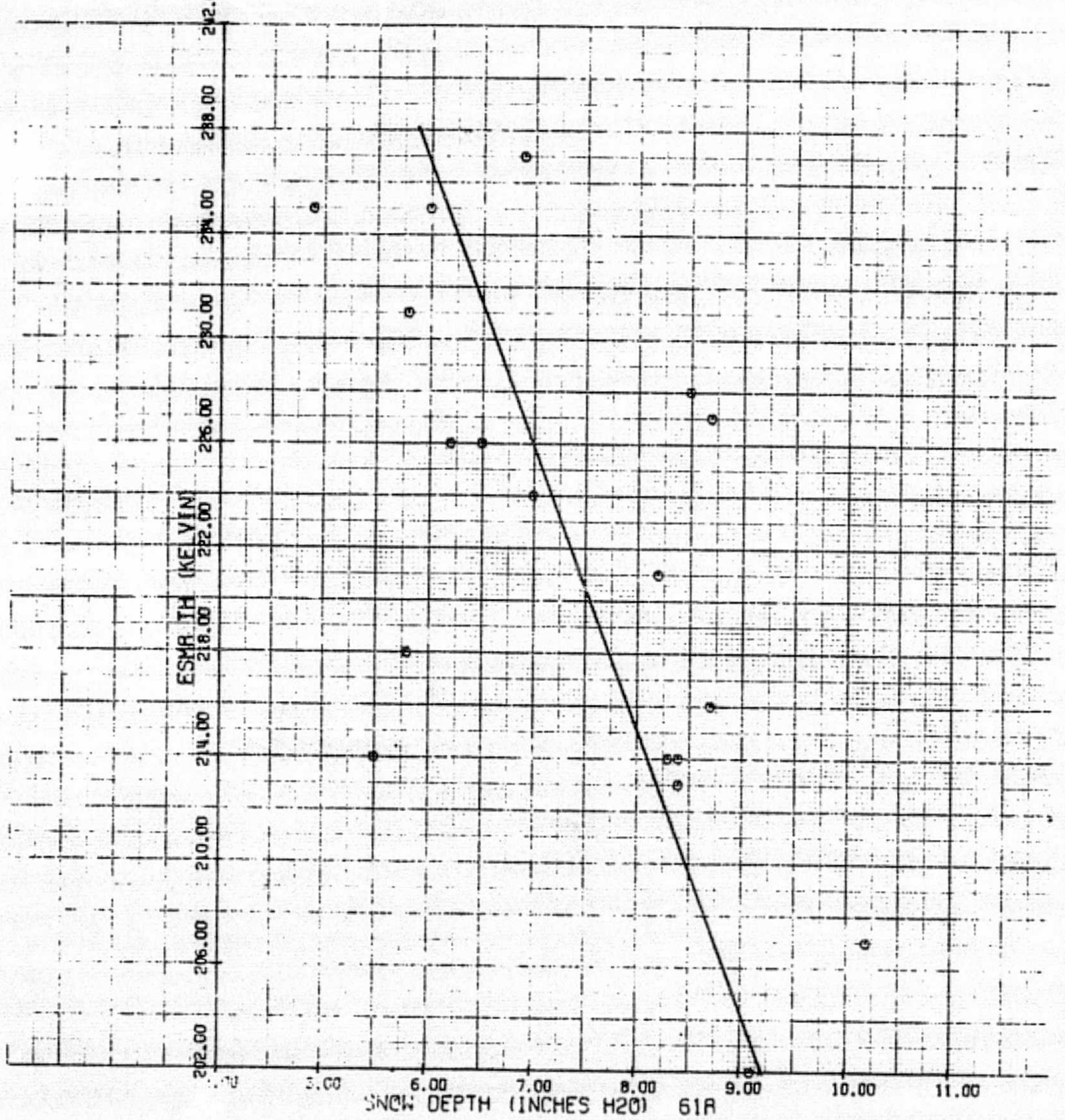

Figure B-25. 61R - Snow Depth versus Horizontal Temperature

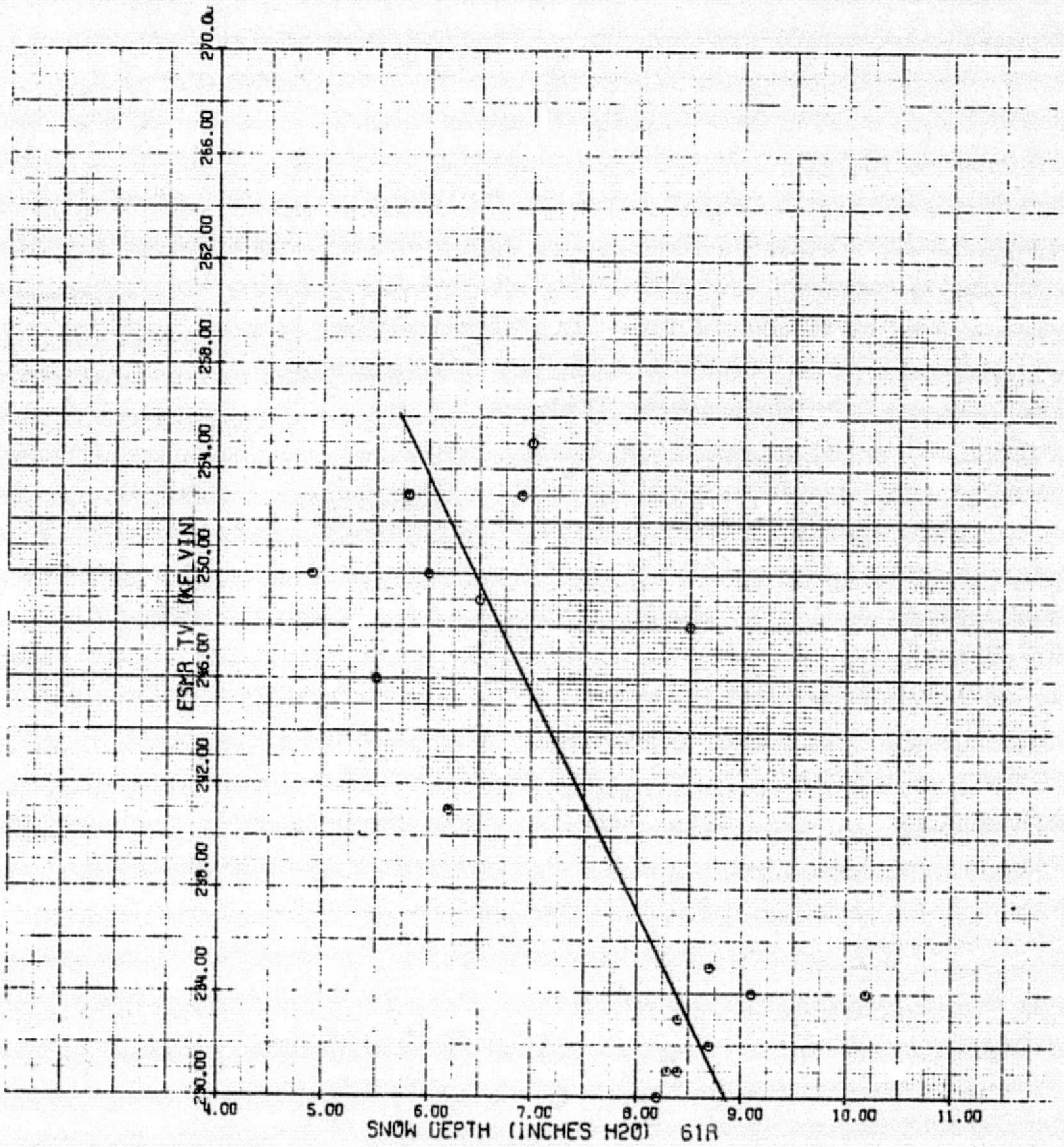

Figure B-26. 61R - Snow Depth versus Vertical Temperature

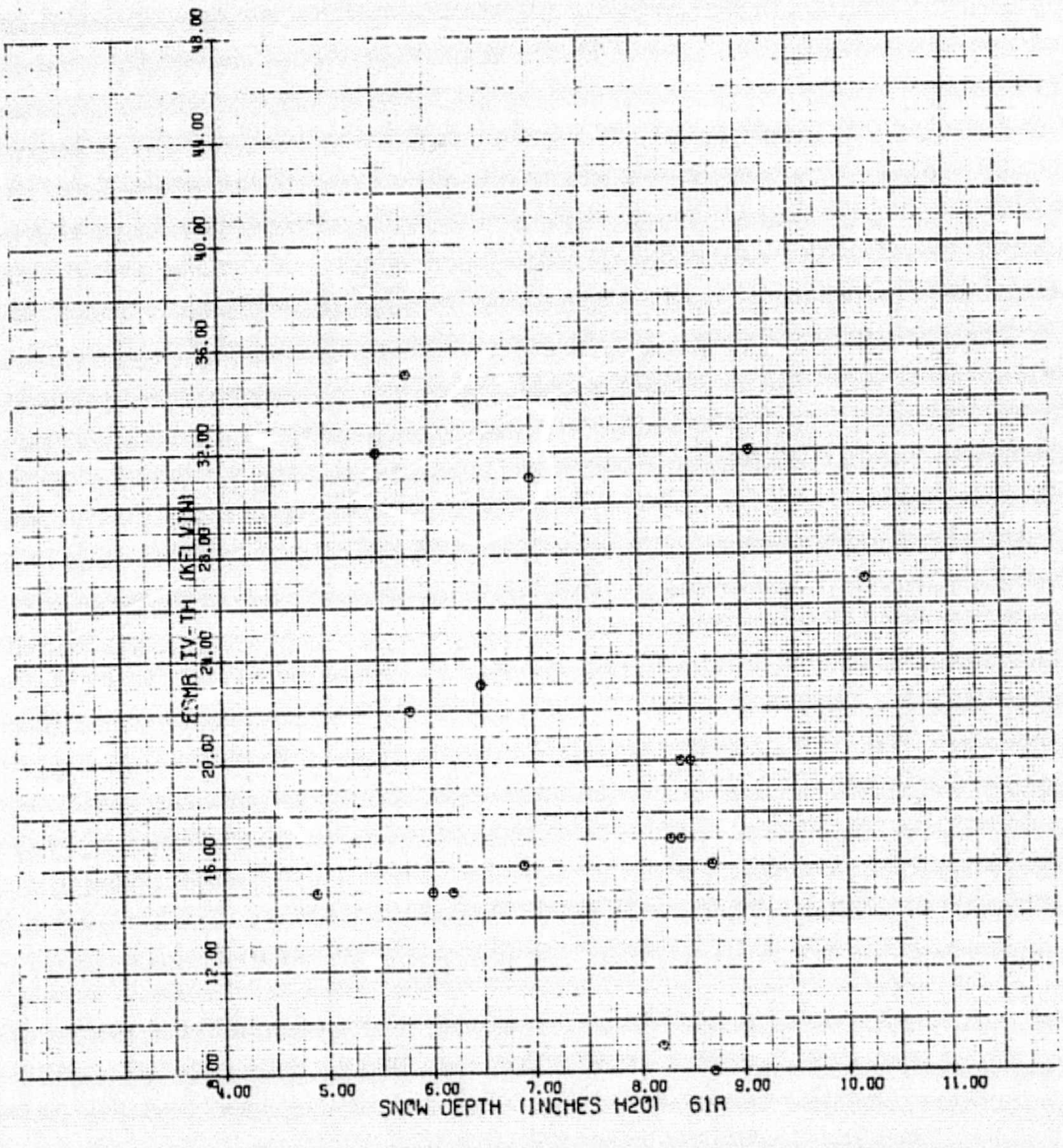

Figure B-27. 61R - Snow Depth versus Polarization Difference

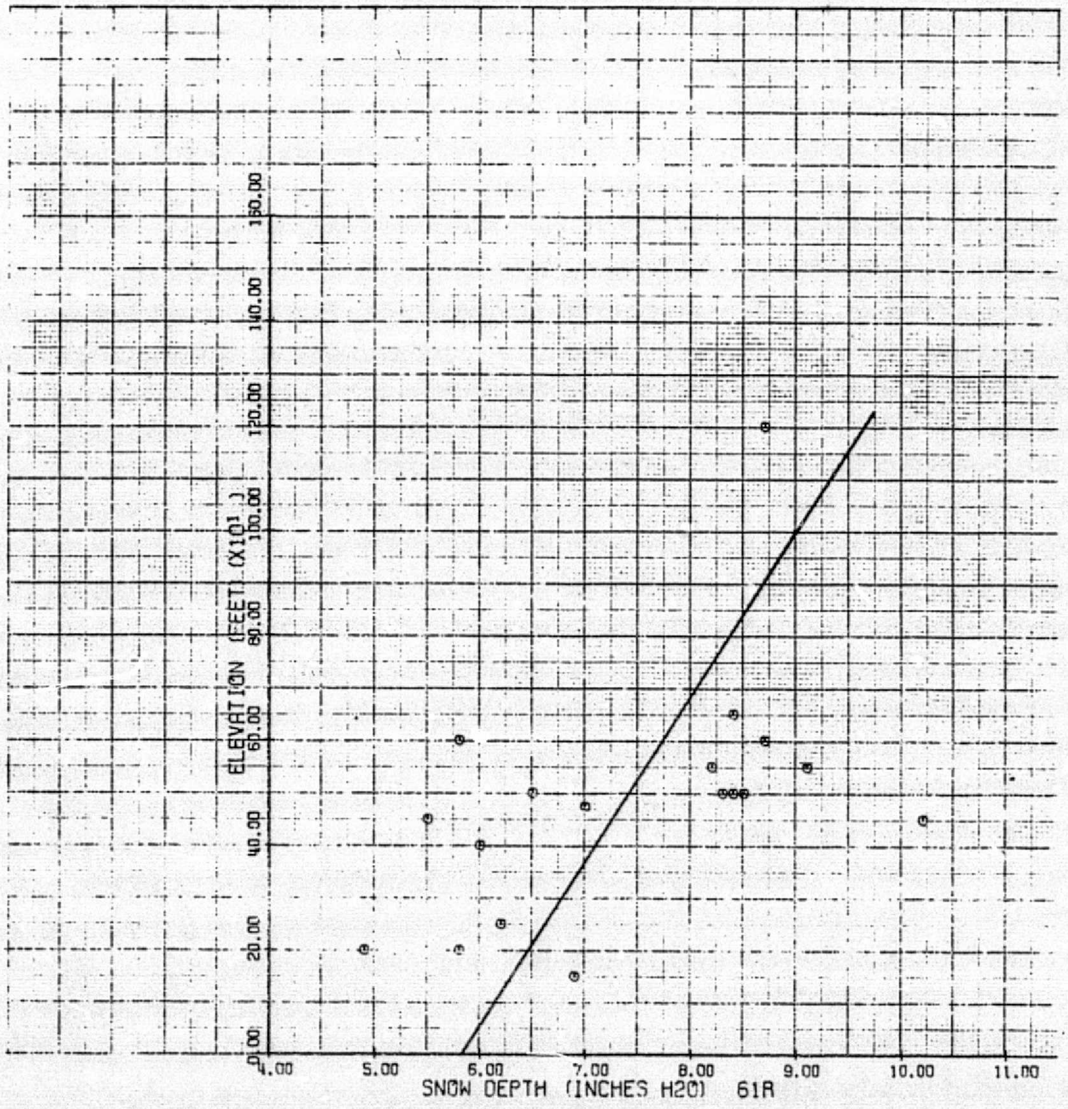

Figure B-28. 61R - Snow Depth versus Elevation

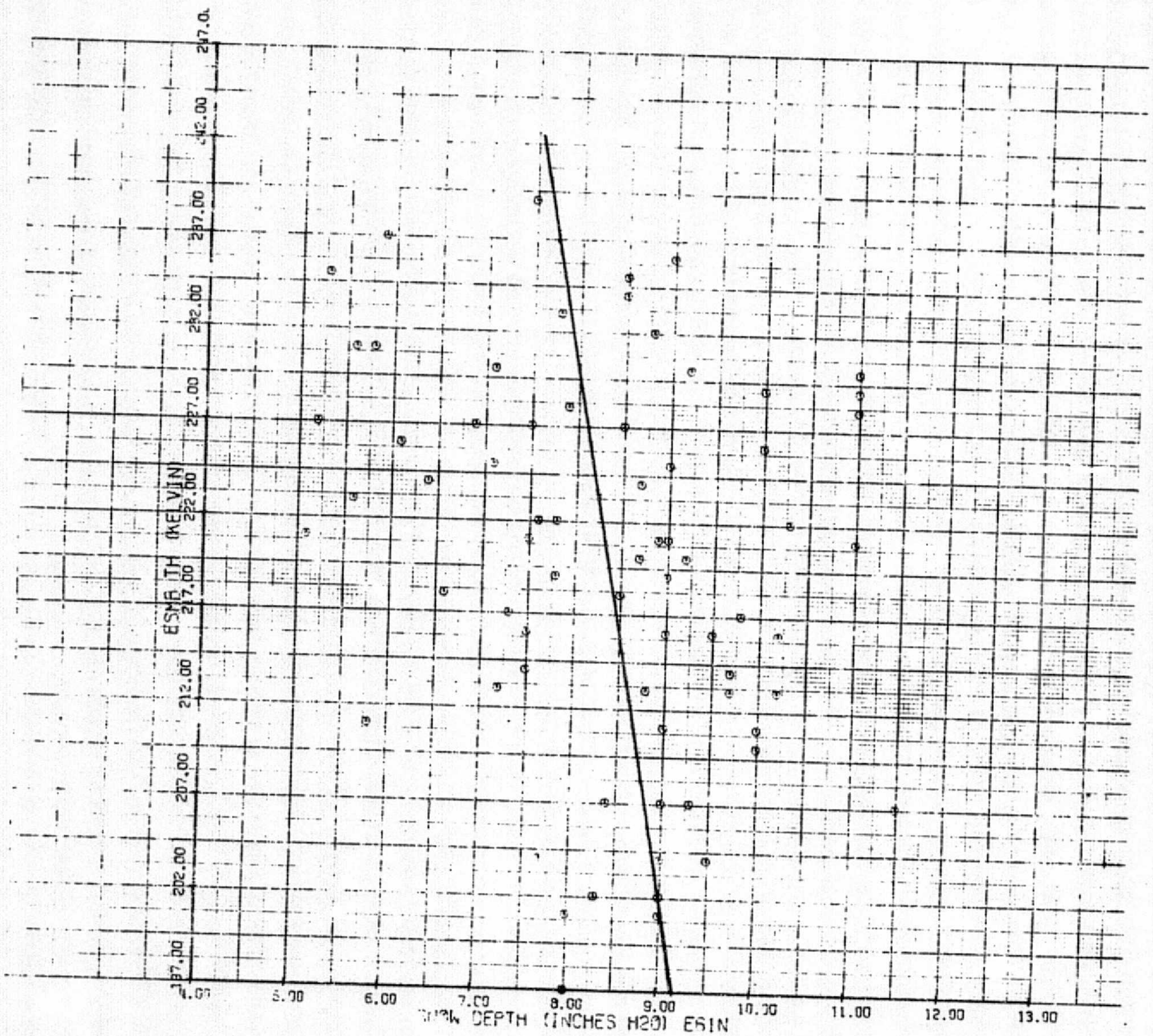

Figure B-29. 61E - Snow Depth versus Horizontal Temperature

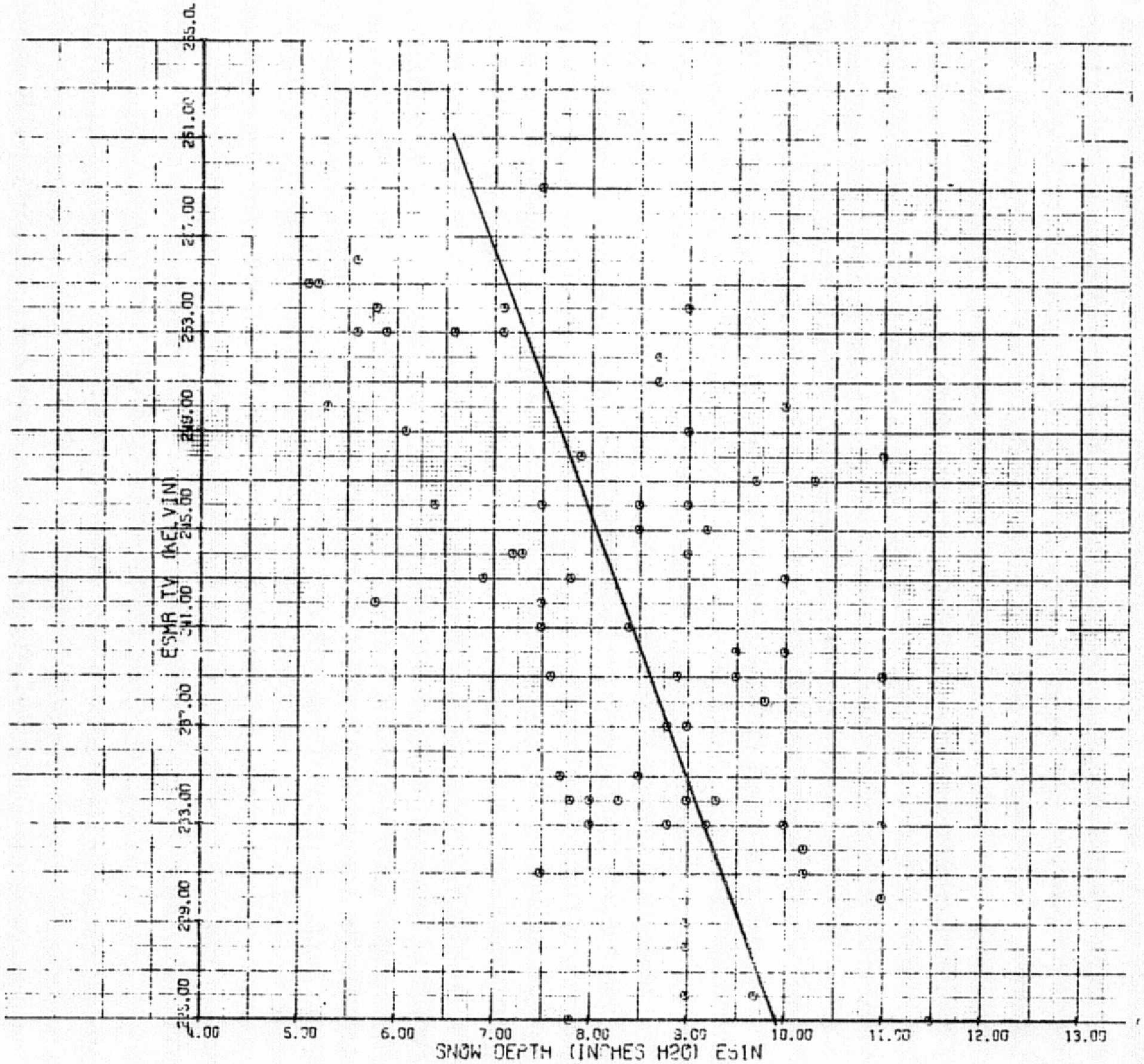

Figure B-30. 61E - Snow Depth versus Vertical Temperature

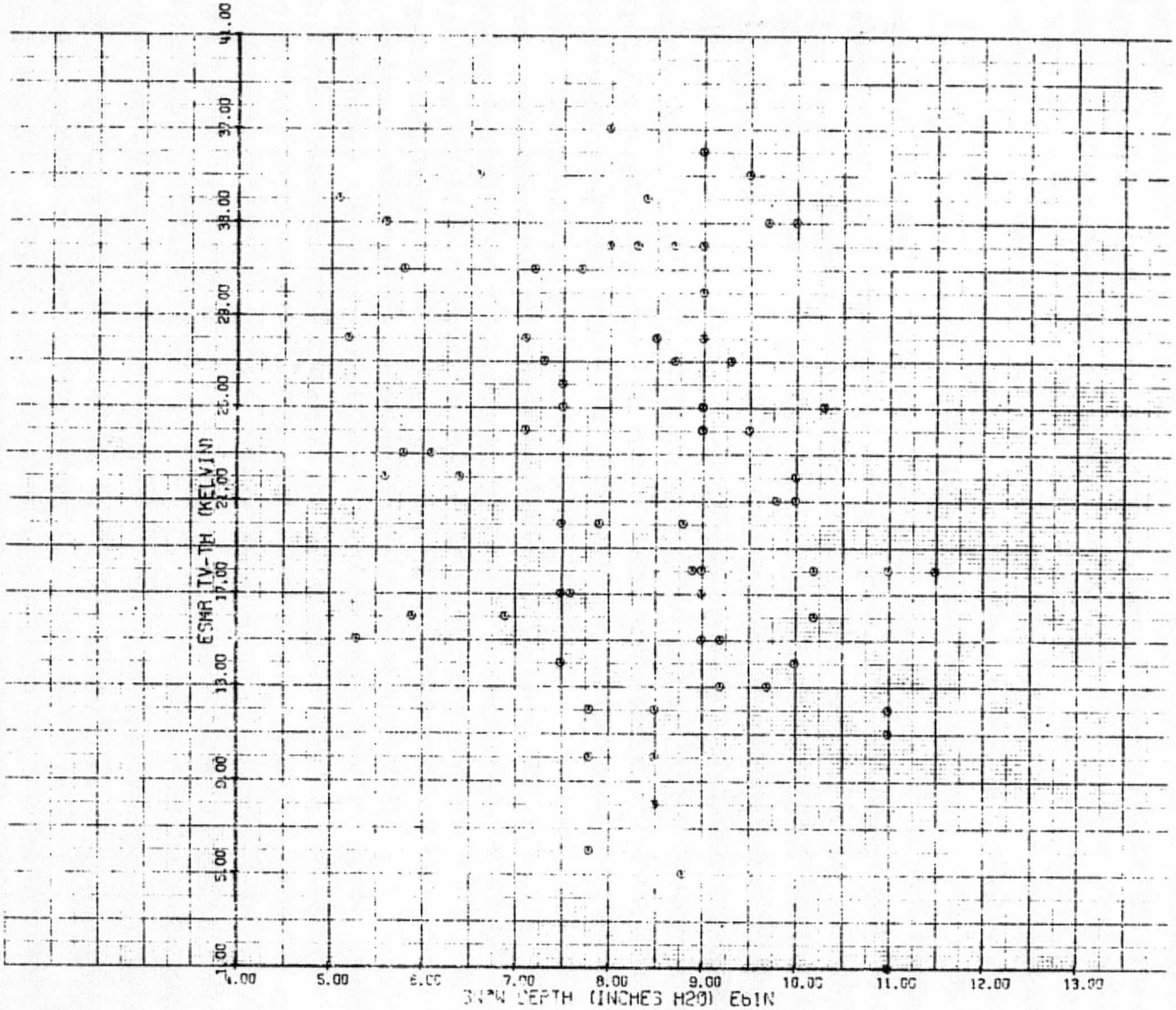

Figure B-31. 61E - Snow Depth versus Polarization Difference

Appendix C

ESMR PLOTS

Plots of ESMR data from the program ESMRPLOT are presented in this appendix. The plots cover the snow course measurement area and the surrounding area. Figures C-1 through C-6 are the plots for the night orbit on February 10, 1976 (41N) for Site 1, the day orbit on February 10, 1976 (41D) for Site 1, the day orbit on January 6, 1976 (6D) for Site 2, the day orbit on January 8, 1976 (8D) for Site 2, the night orbit on February 3, 1976 (34N) for Site 2 and the night orbit on March 1, 1976 (61N) for Site 2.

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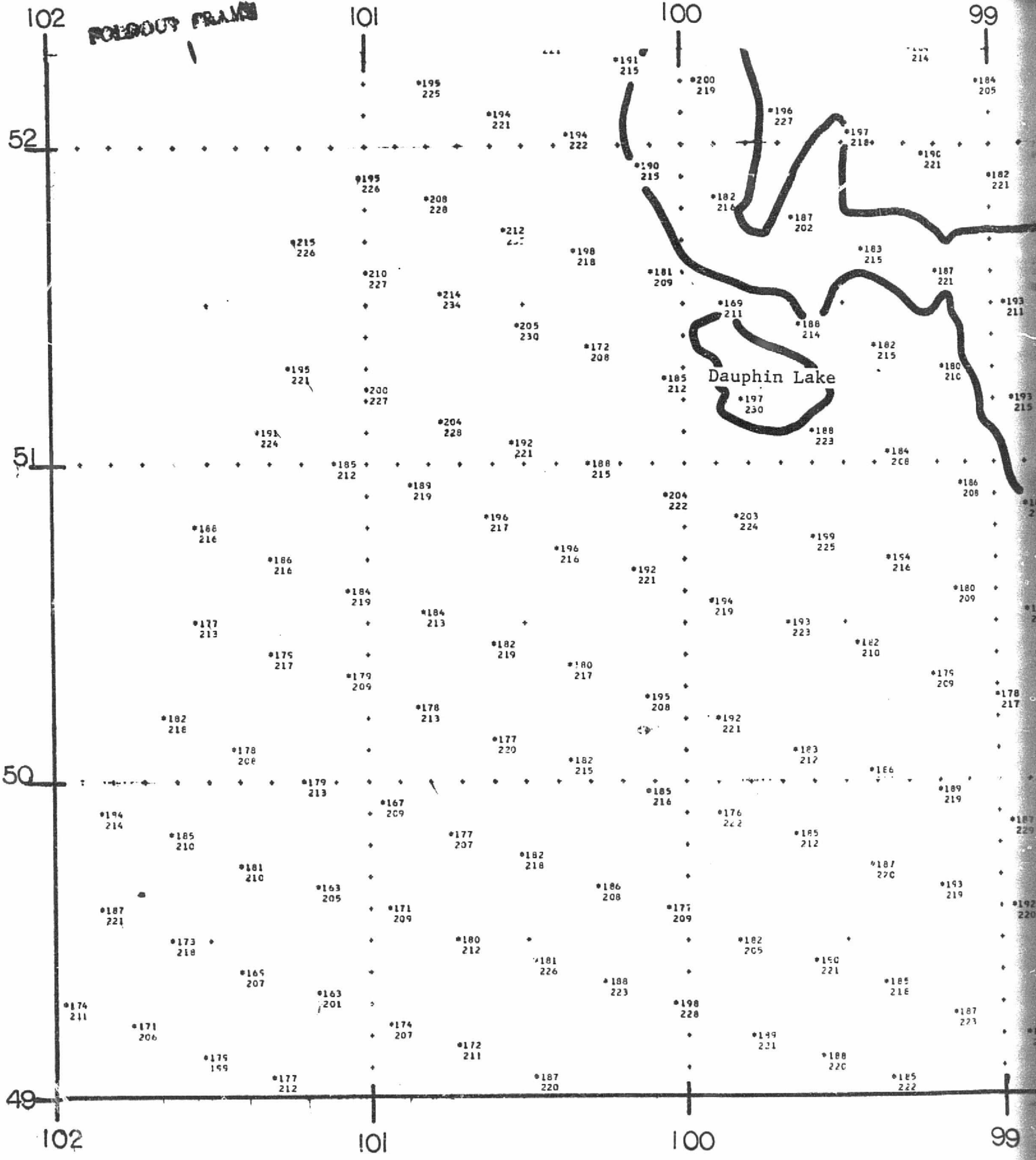

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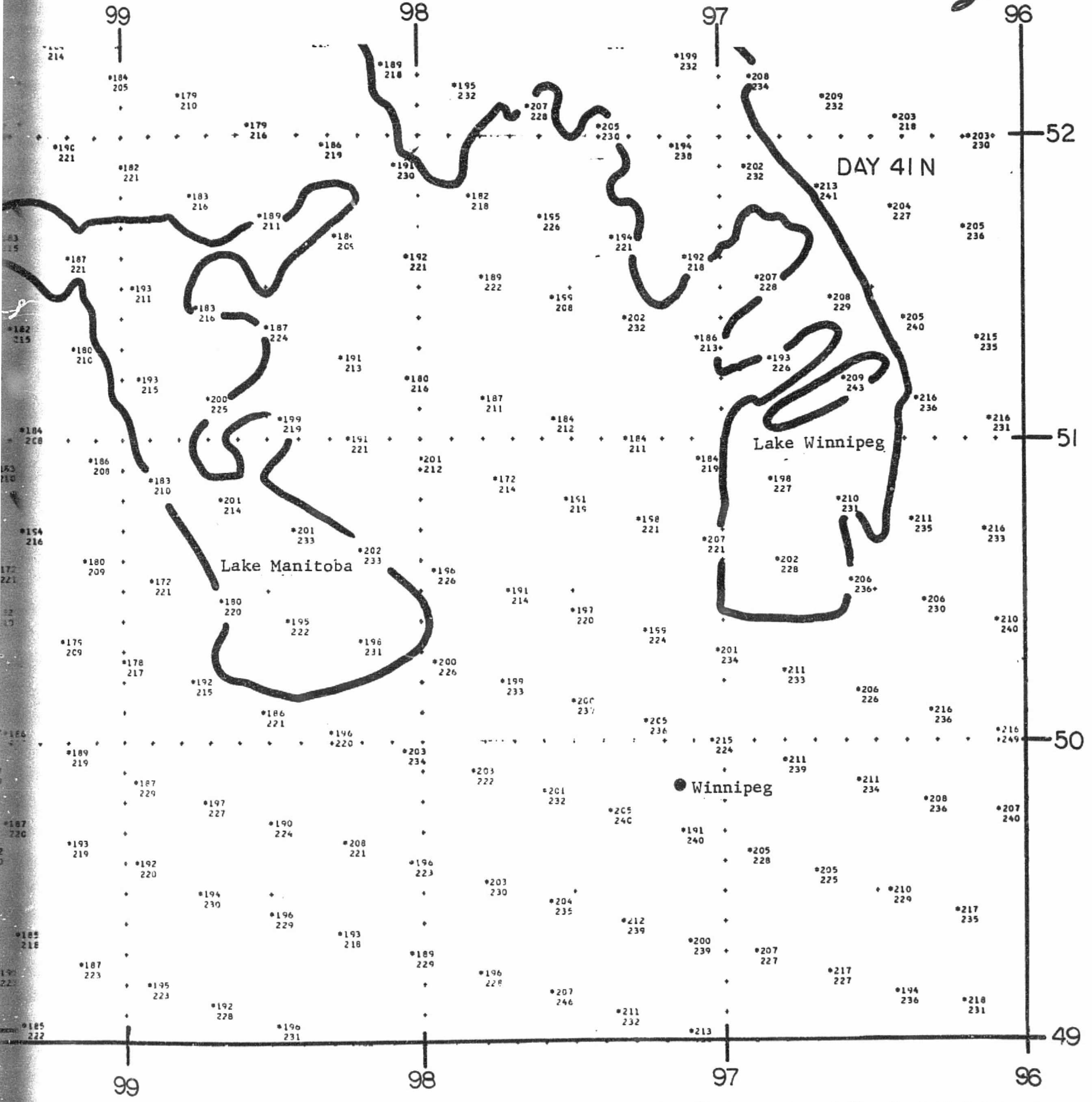
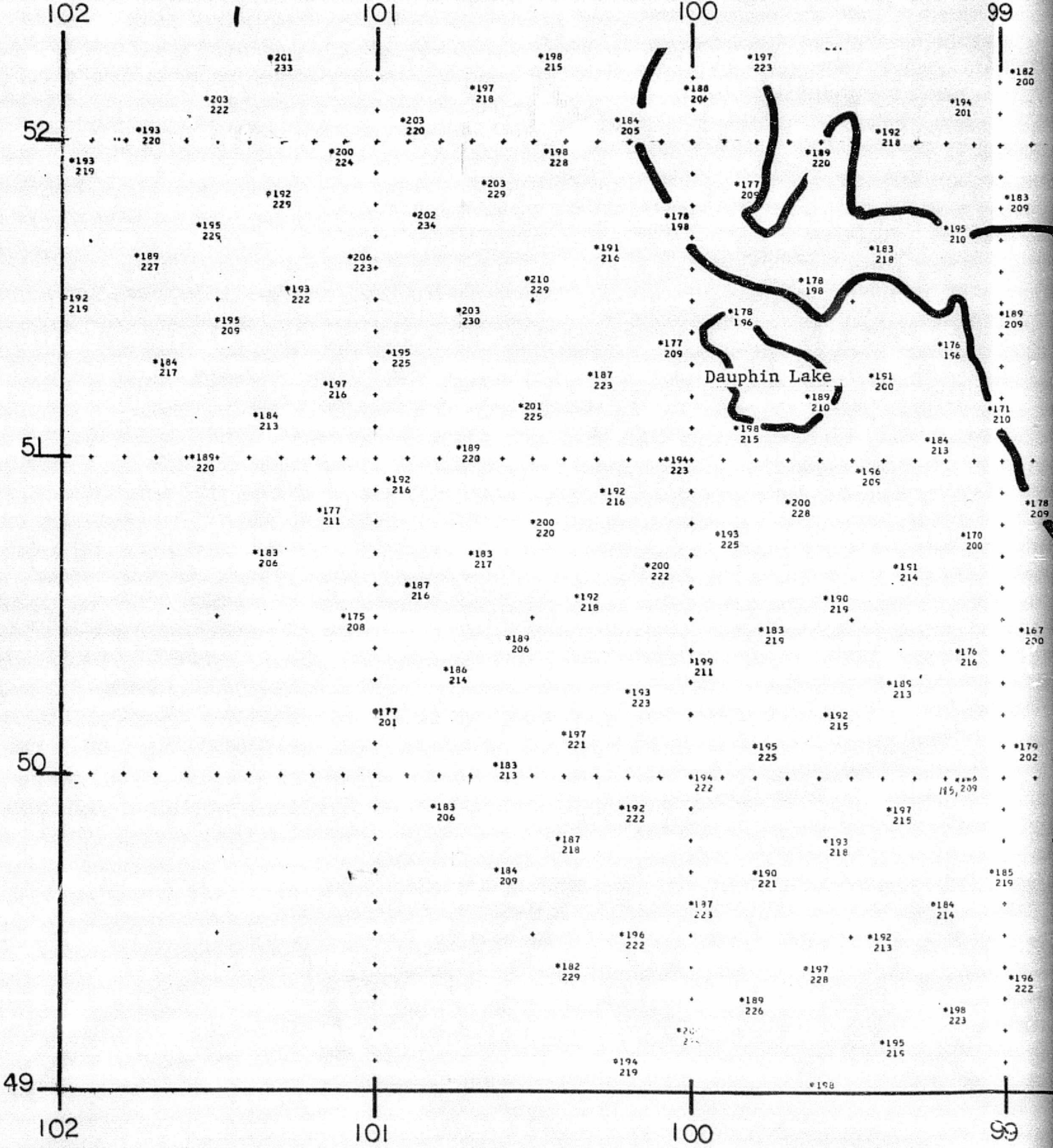


Figure C-1. Horizontal and Vertical Brightness Temperatures, Night Obs., February 10, 1976 (41N)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51
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49
Dauphin Lake
201 233
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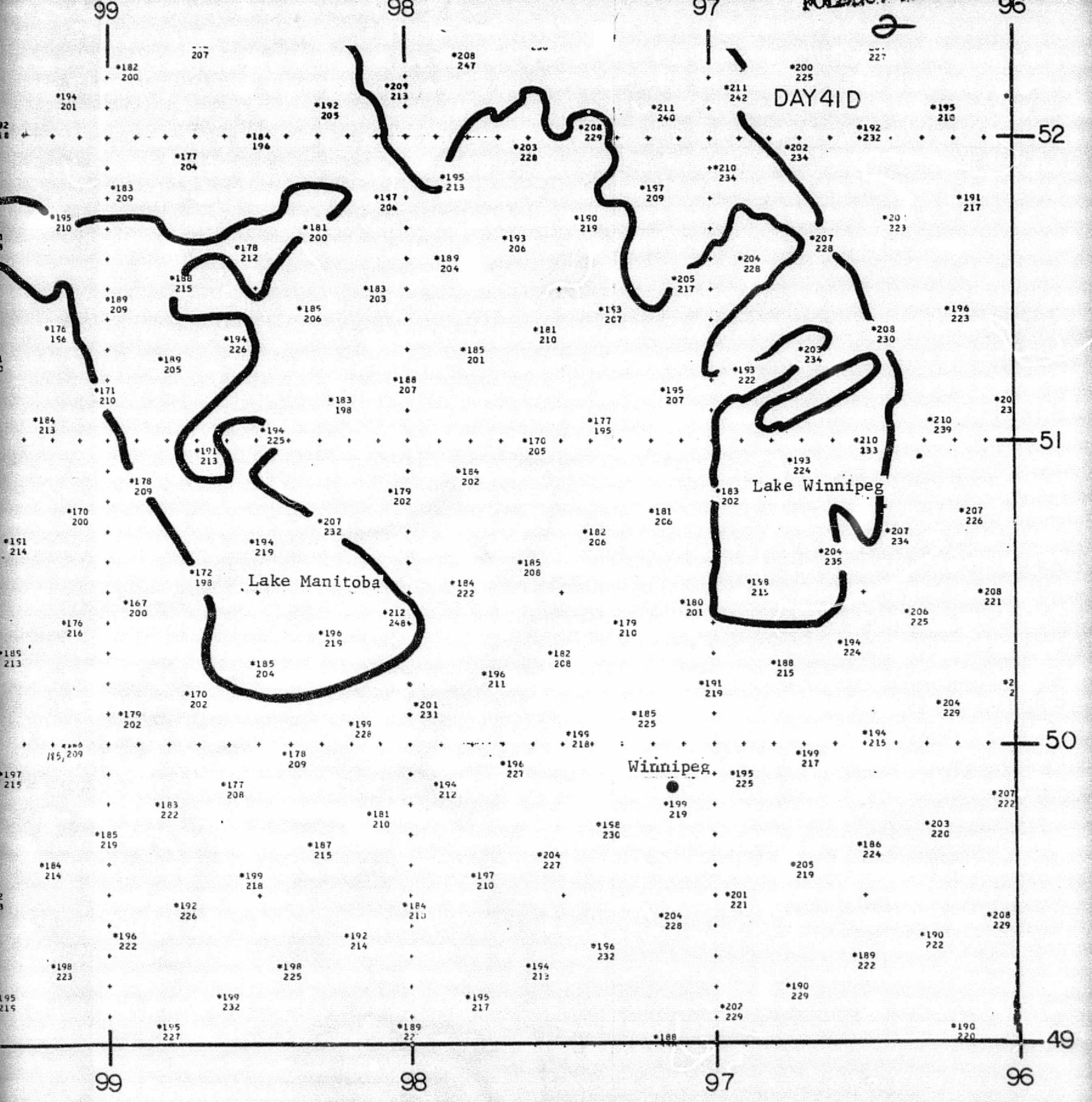

Figure C-2. Horizontal and Vertical Brightness Temperatures, Day Obs., February 10, 1976 (41D)

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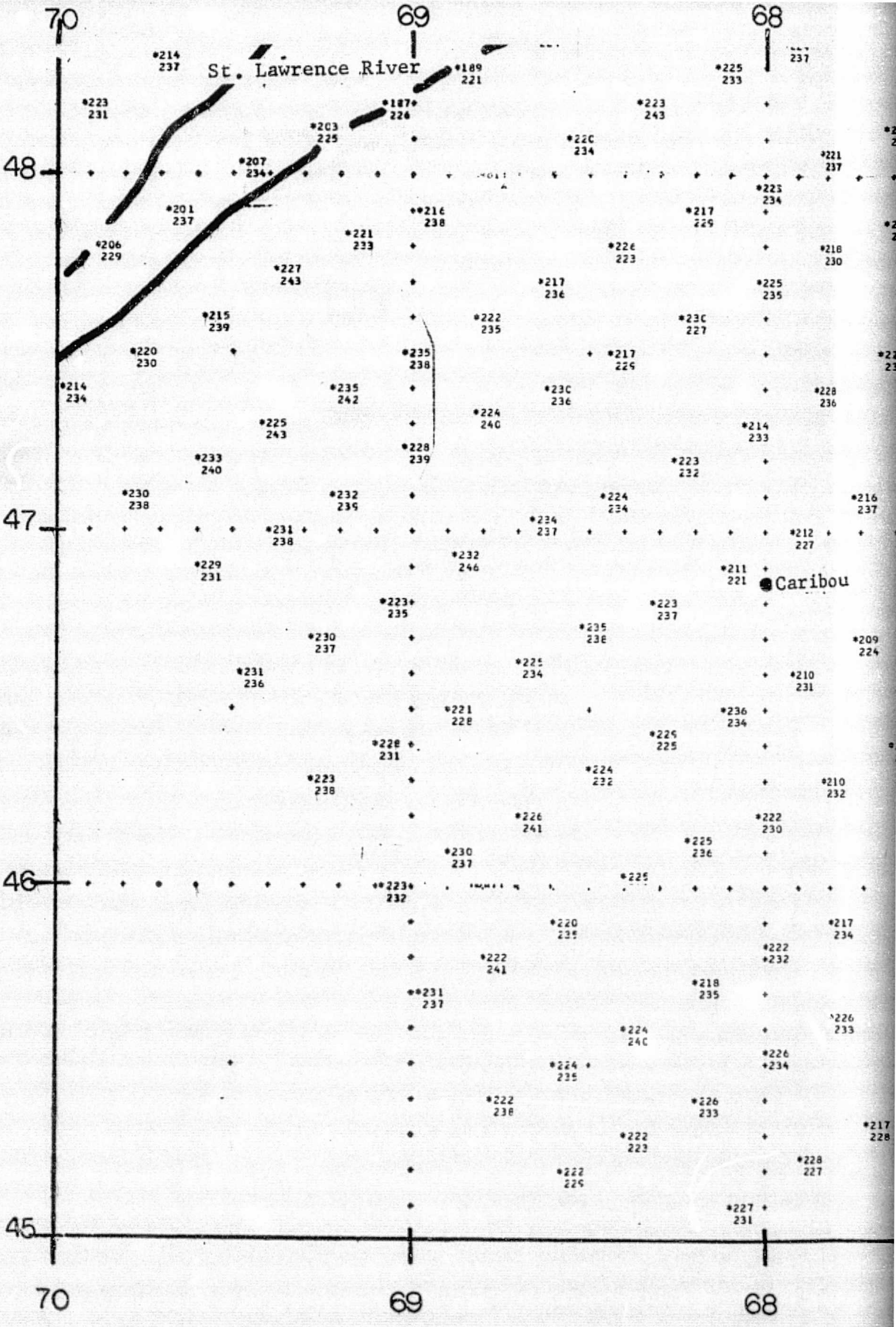

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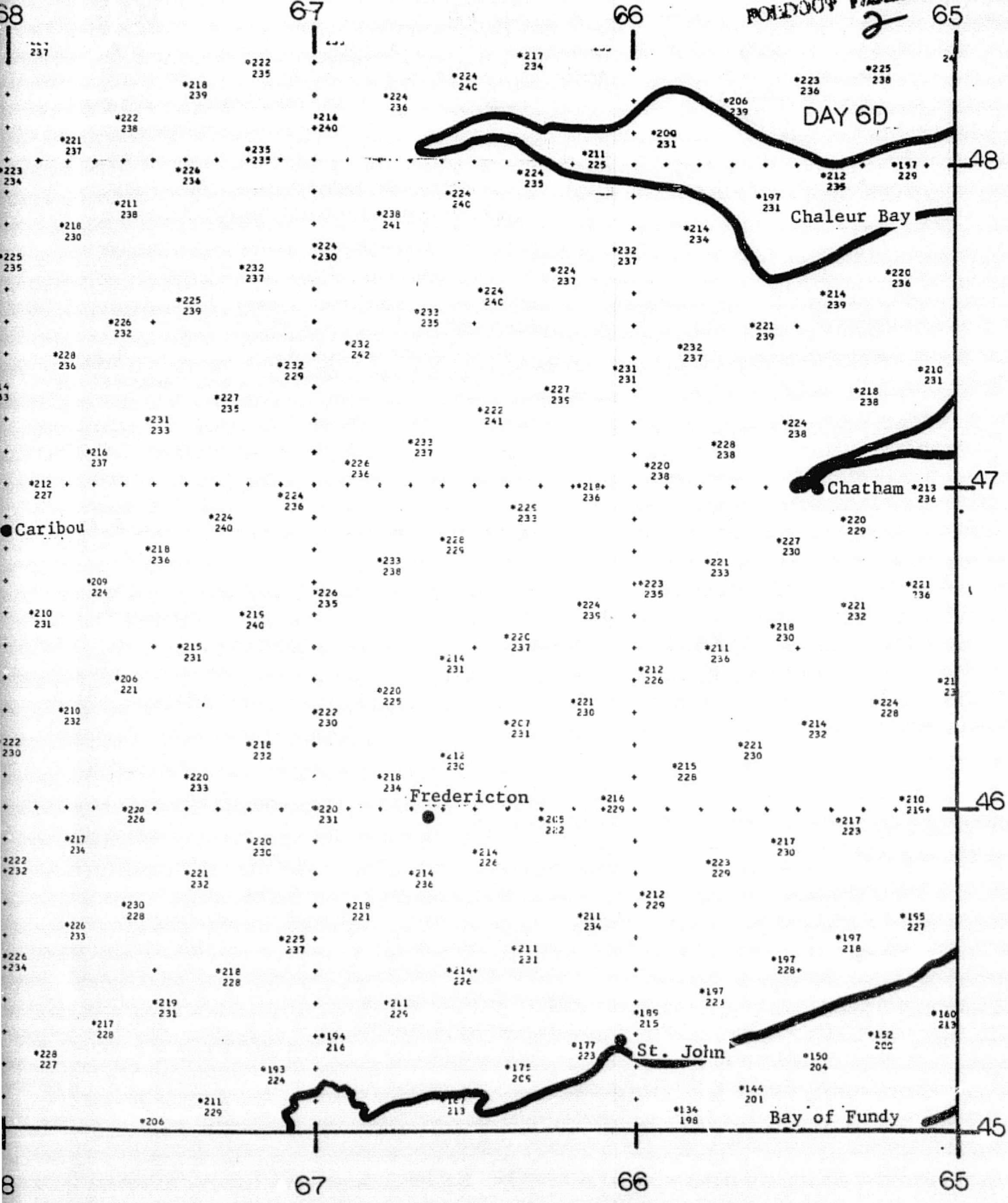
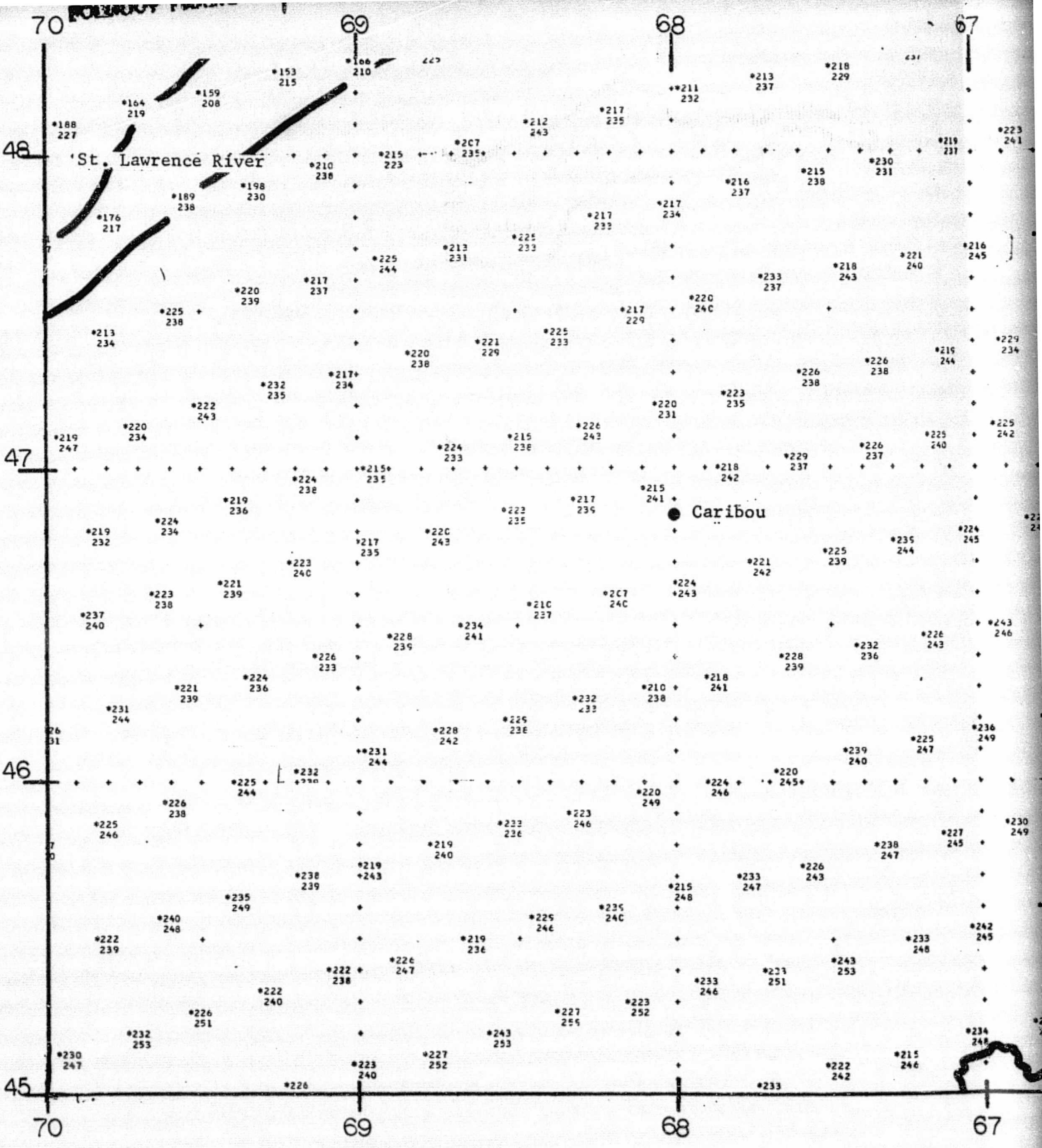


Figure C-3. Horizontal and Vertical Brightness Temperatures, Day Obs., January 6, 1976 (6D)



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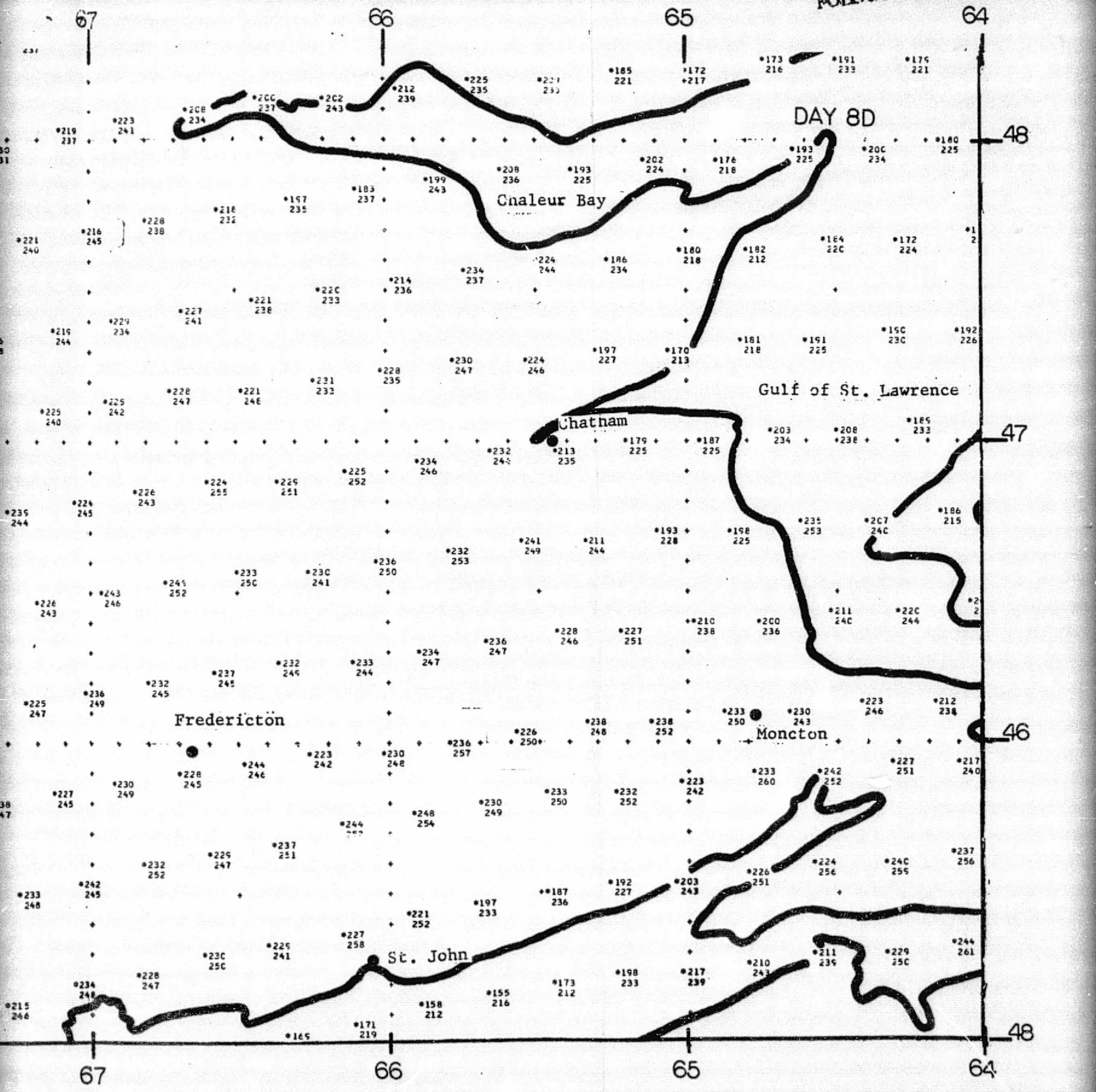

Figure C-4. Horizontal and Vertical Brightness Temperatures, Day Obs., January 8, 1976 (8D)

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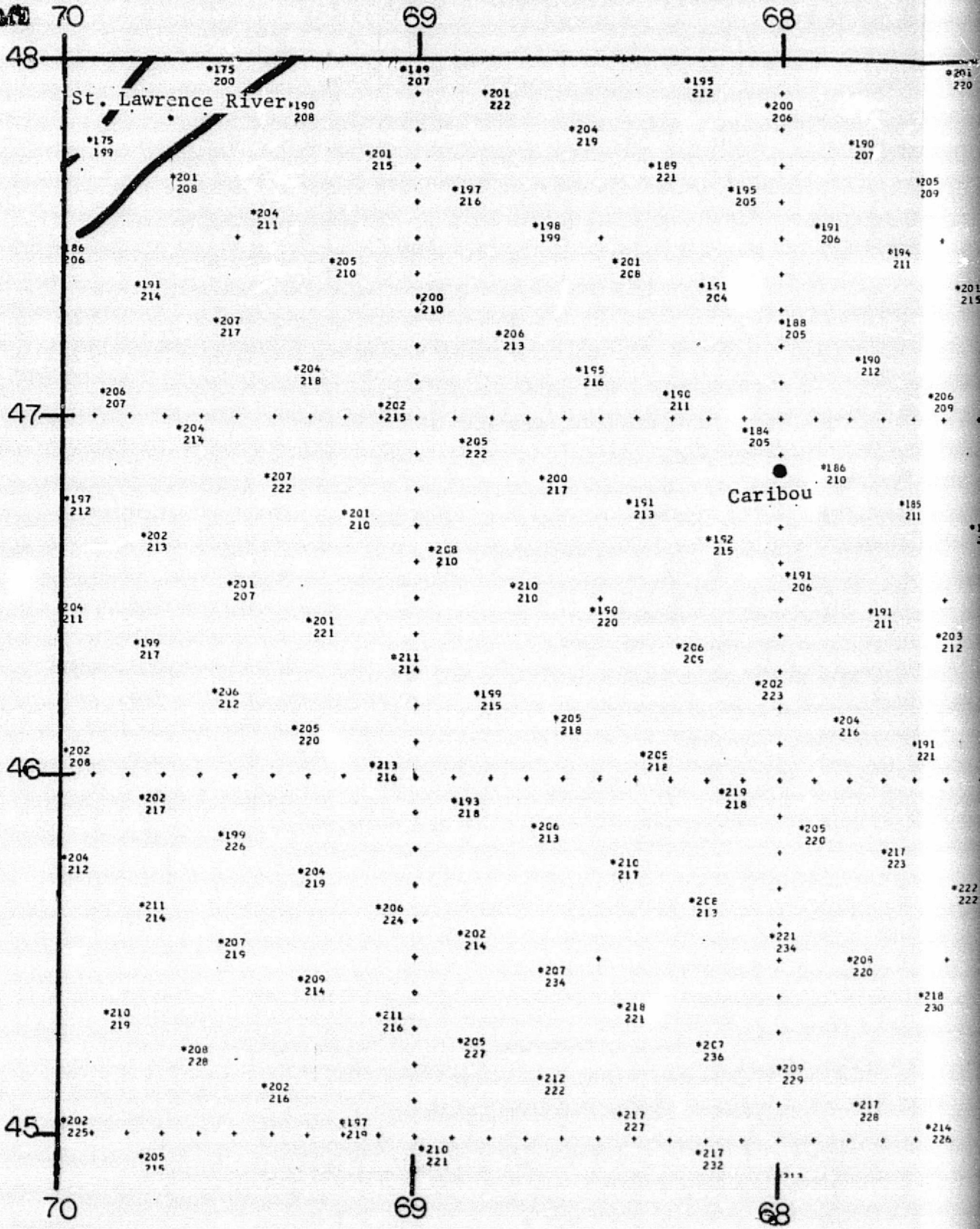

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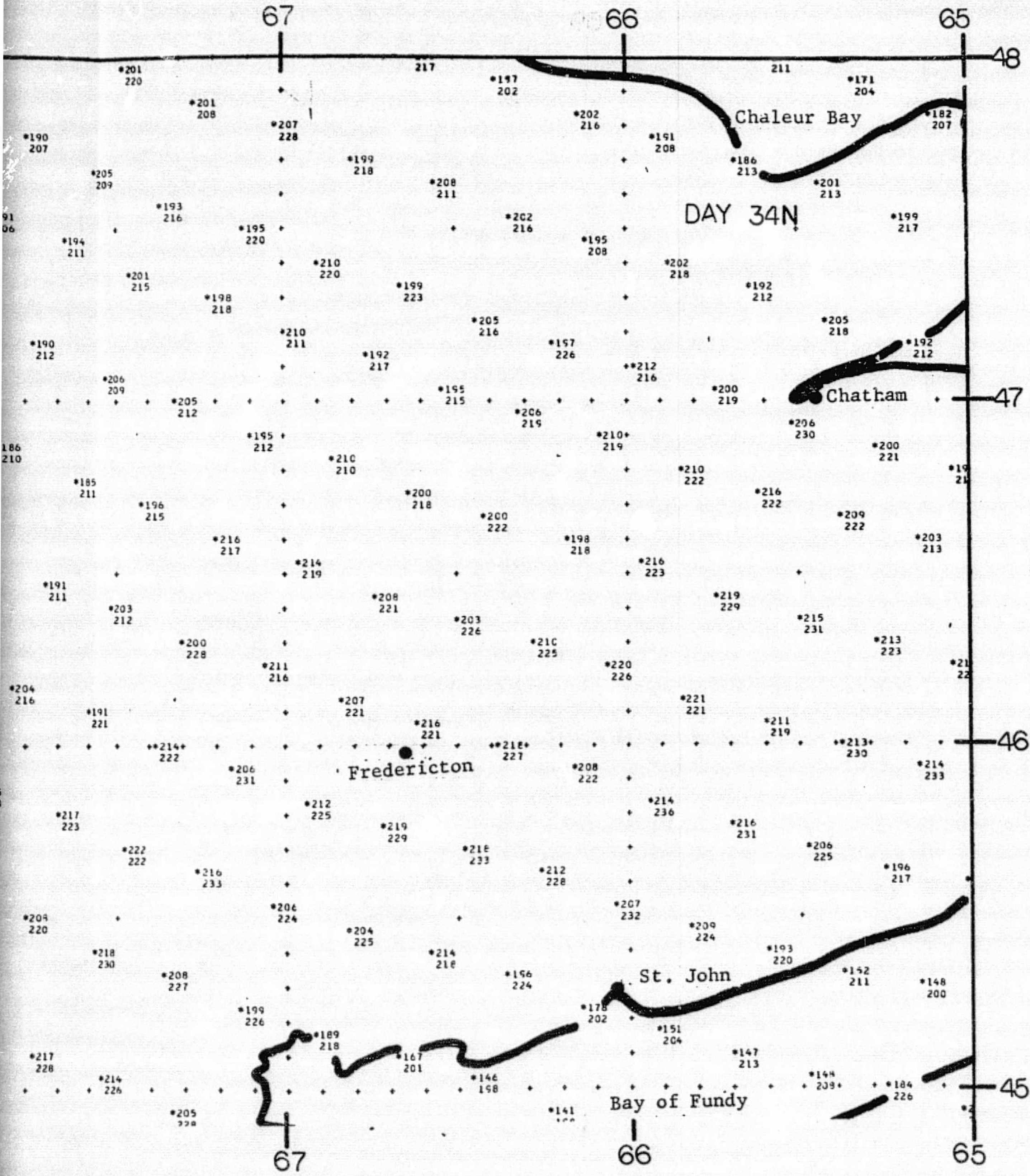
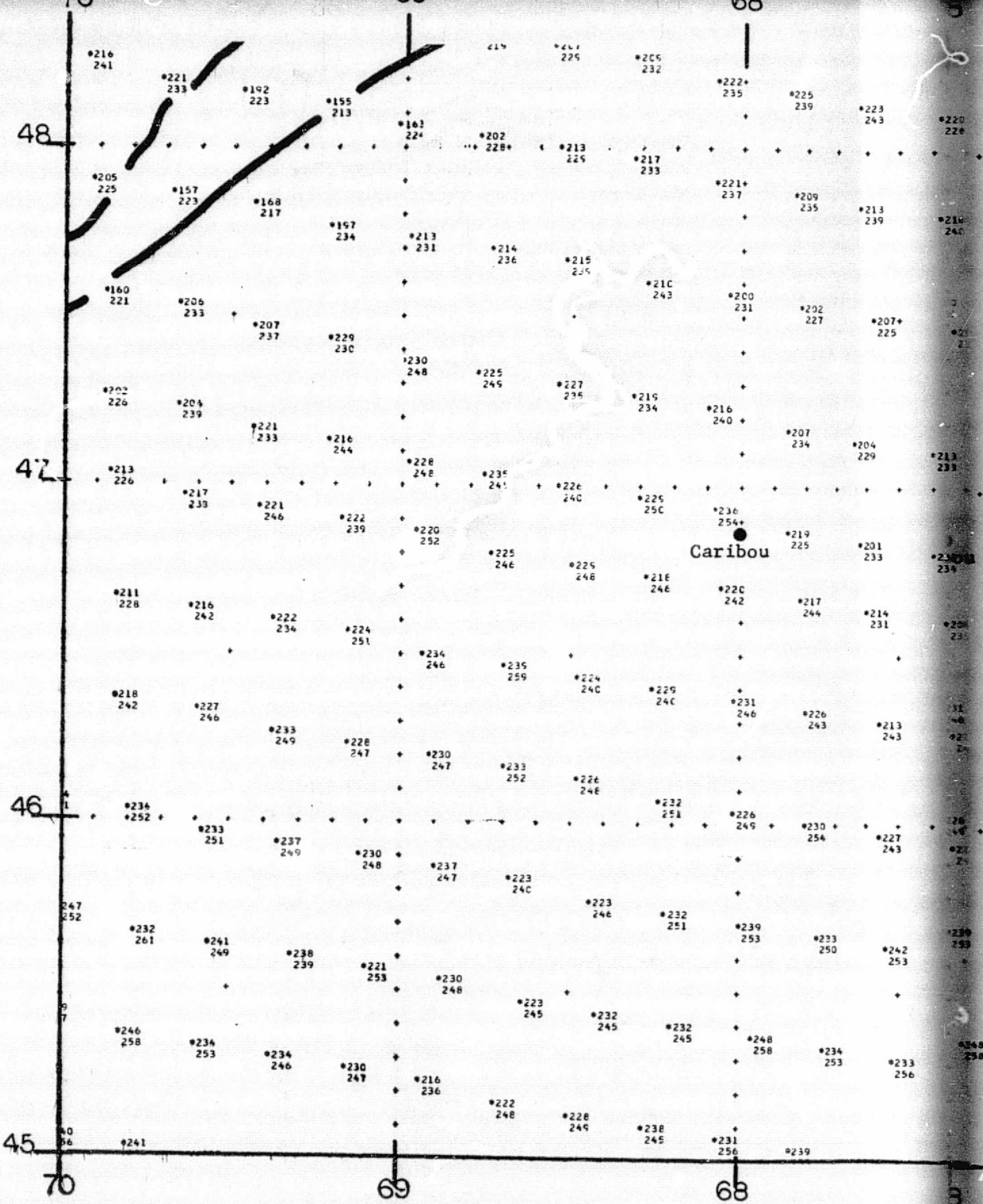


Figure C-5. Horizontal and Vertical Brightness Temperatures, Night Obs., February 3, 1976 (34N)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Caribou

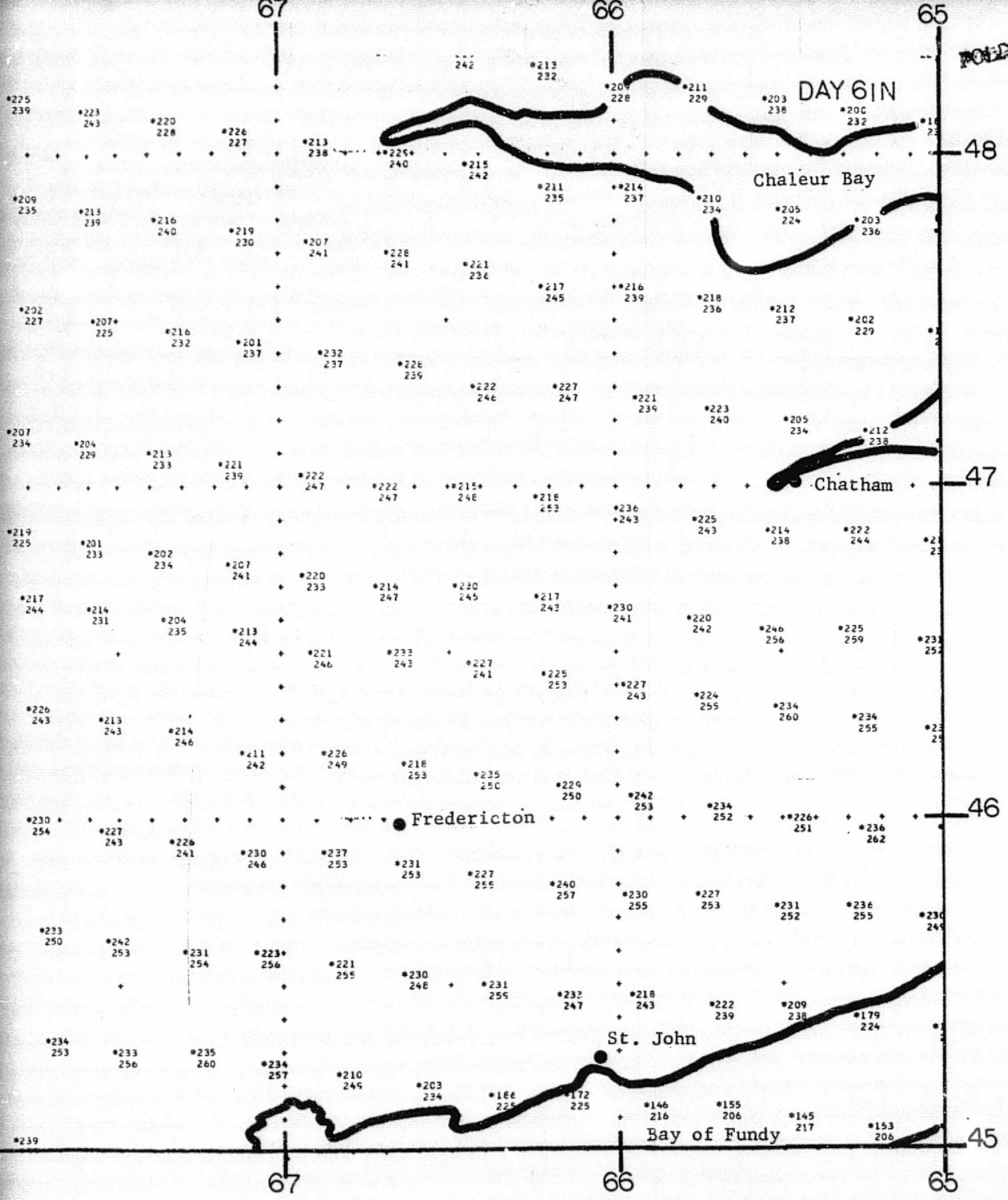

Figure C-6. Horizontal and Vertical Brightness Temperatures, Night Obs., March 1, 1976 (6iN)

Appendix D
SNOW PLOTS

Plots of the snow values, water equivalent in inches, are presented in this appendix. Plots of data used are the same scale as the ESMR plots of Appendix C, and the data has been contoured using 1" or 2" of water equivalent as the contour interval. Also included are the original contour plot for Site 1, February 9-13, and the March 1-3 contour plot for Site 2; both were supplied by the Water Resources Branch in Canada. Figure D-1 and Figure D-2 are plots of the snow values for data sets 41N and 41D. Figure D-3 is the original Site 1 contour map for the survey period February 9 through February 13, 1976. Figures D-4 through D-8 are snow plots for data sets 6D, 8D, 34N, 61N adn 61R. Figure D-9 is the contour plot for the survey period March 1 through March 3, 1976.

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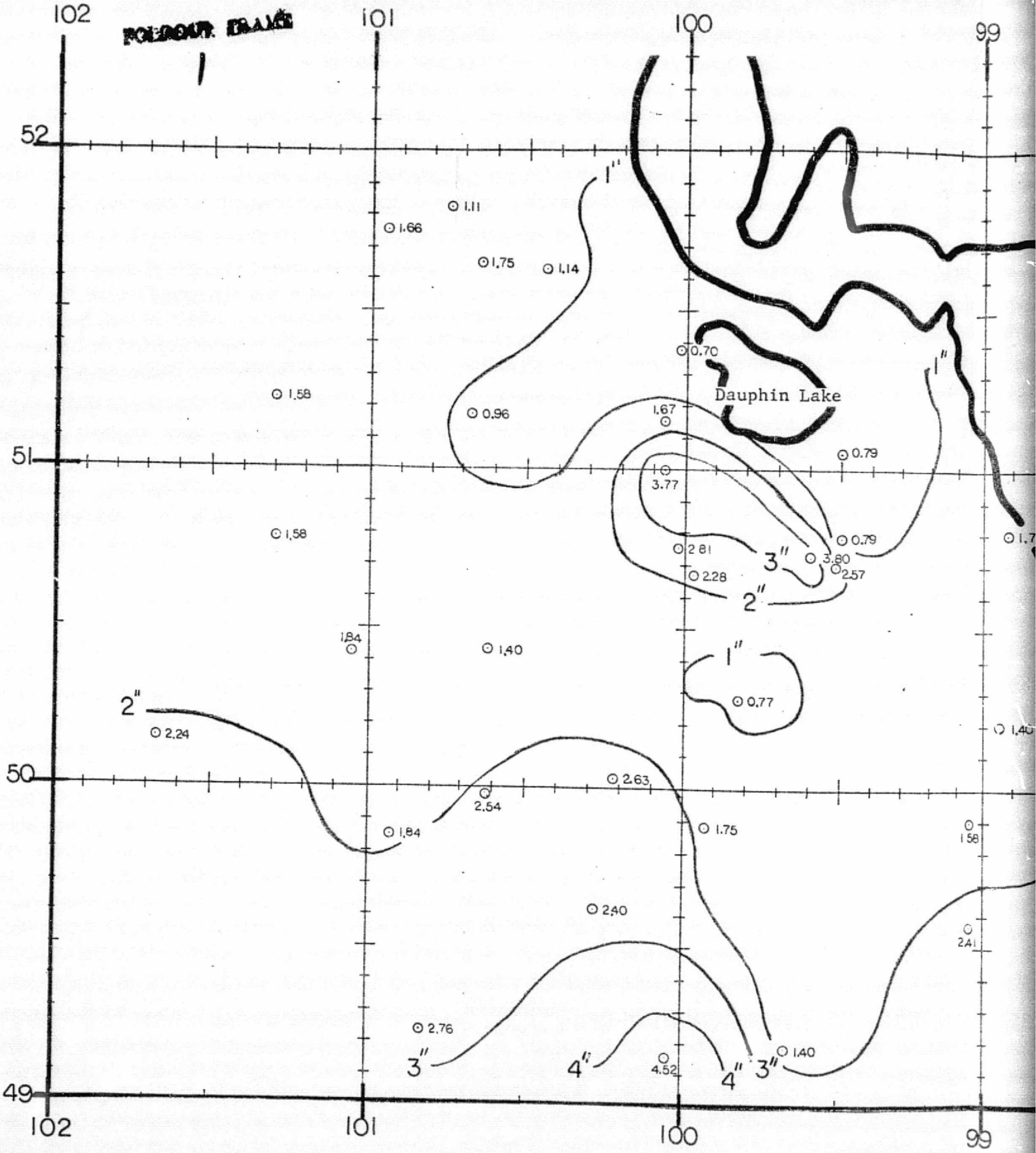

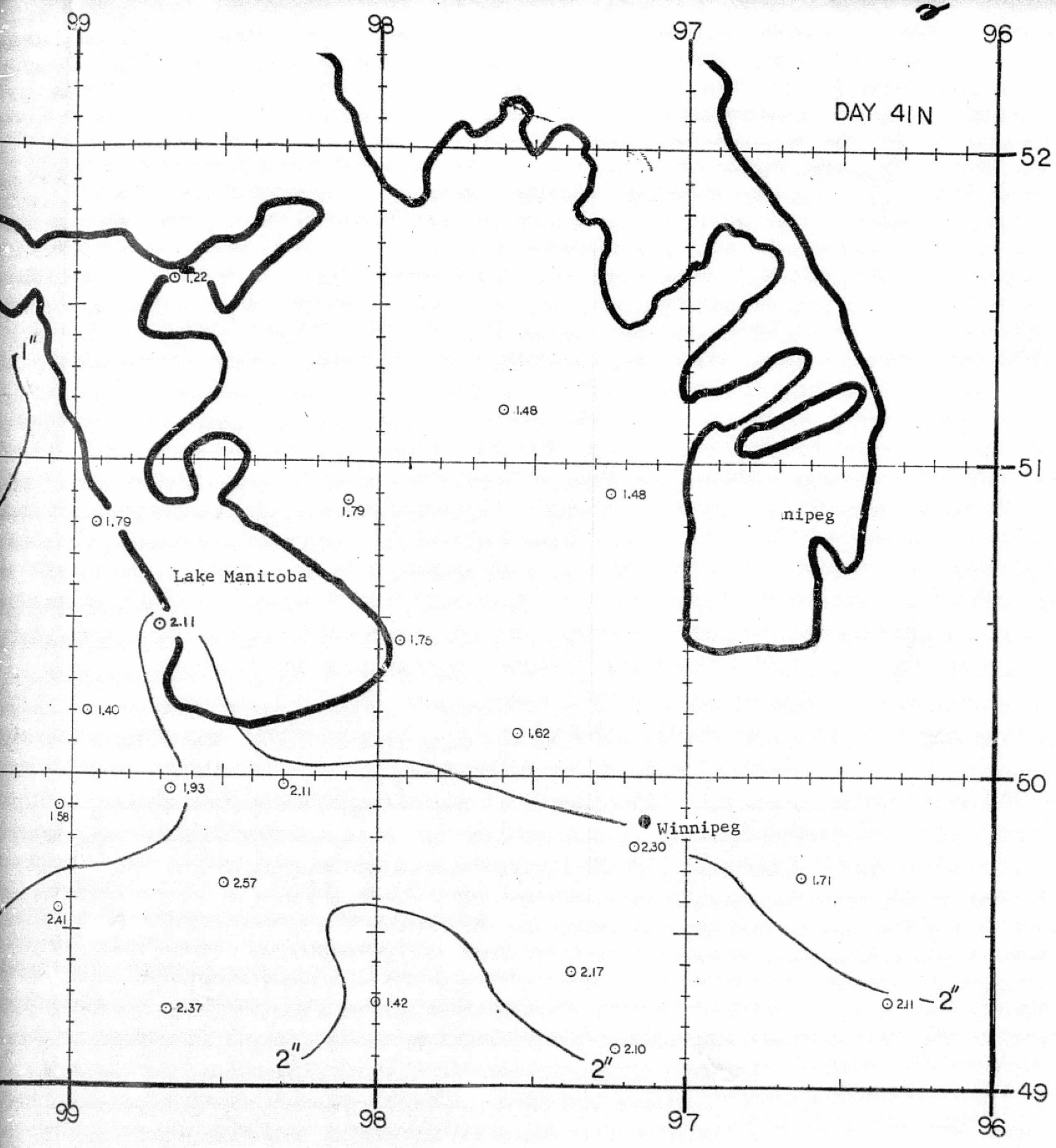

Figure D-1. Snow Water Equivalent (Inches) Values for 41N

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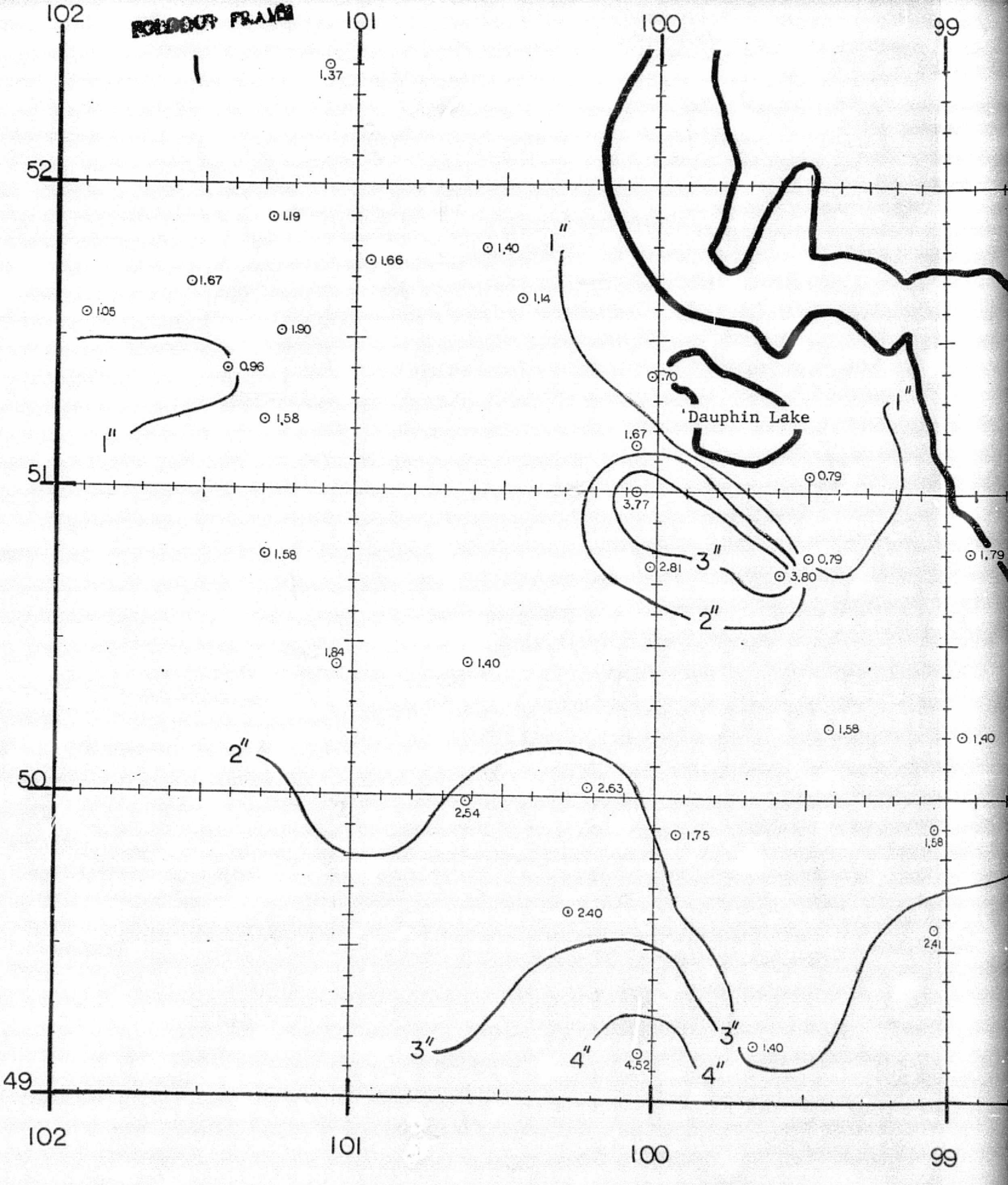

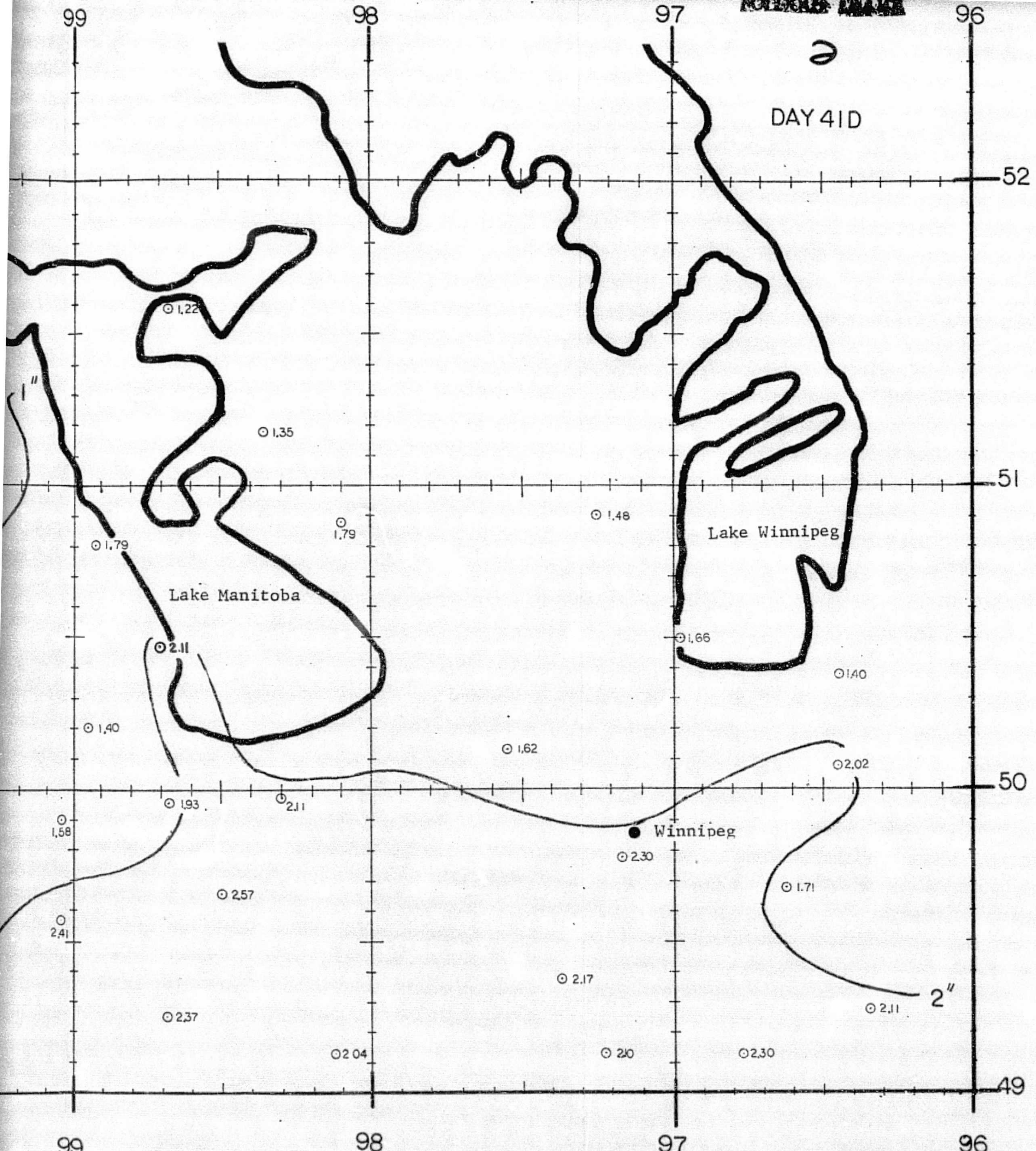

Figure D-2. Snow Water Equilvalent (Inches) Values for 41D

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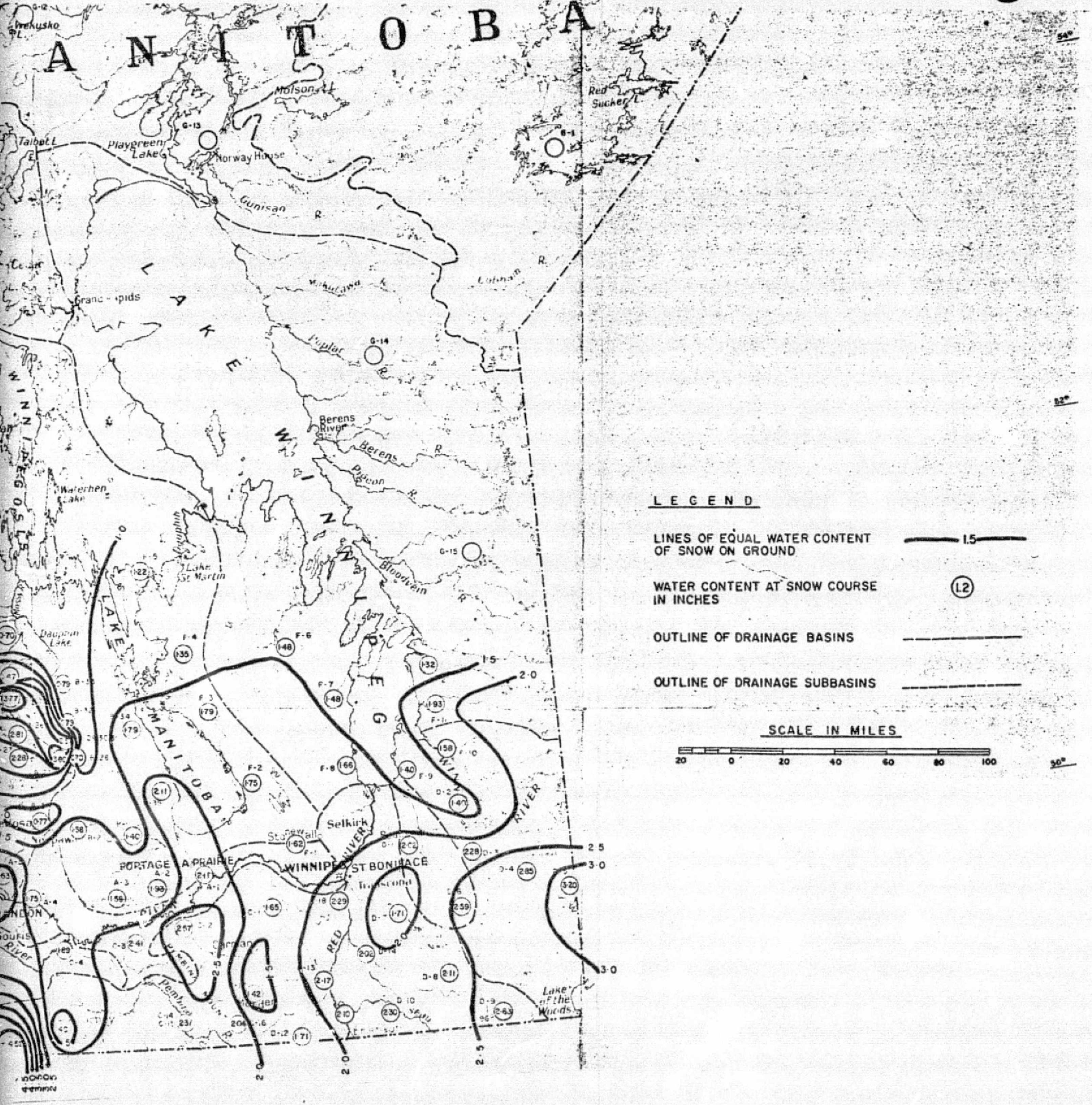

Figure D-3. Snow Water Equivalent (Inches) Values for the Snow Survey, Site 1, February 9 through February 13, 1976

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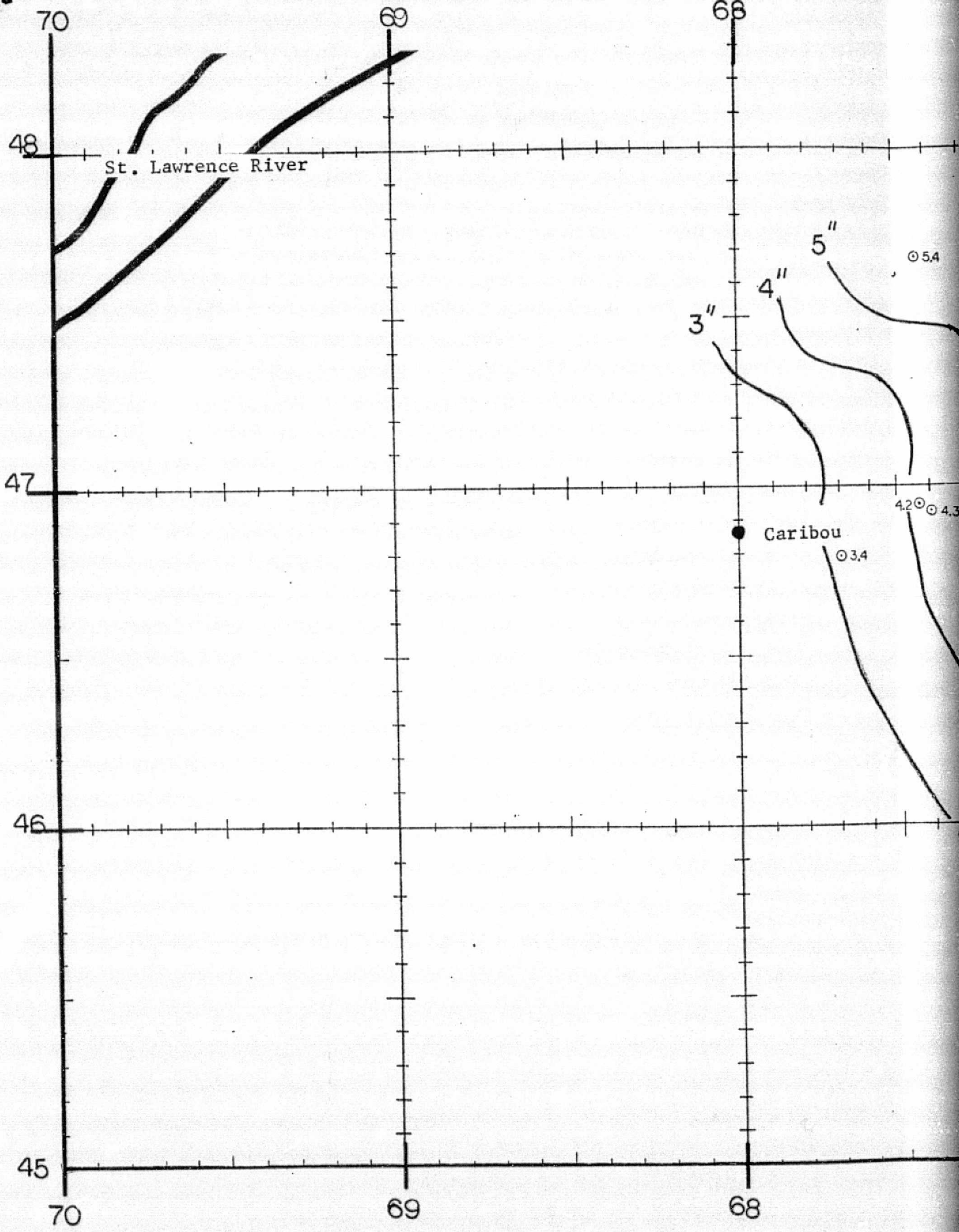

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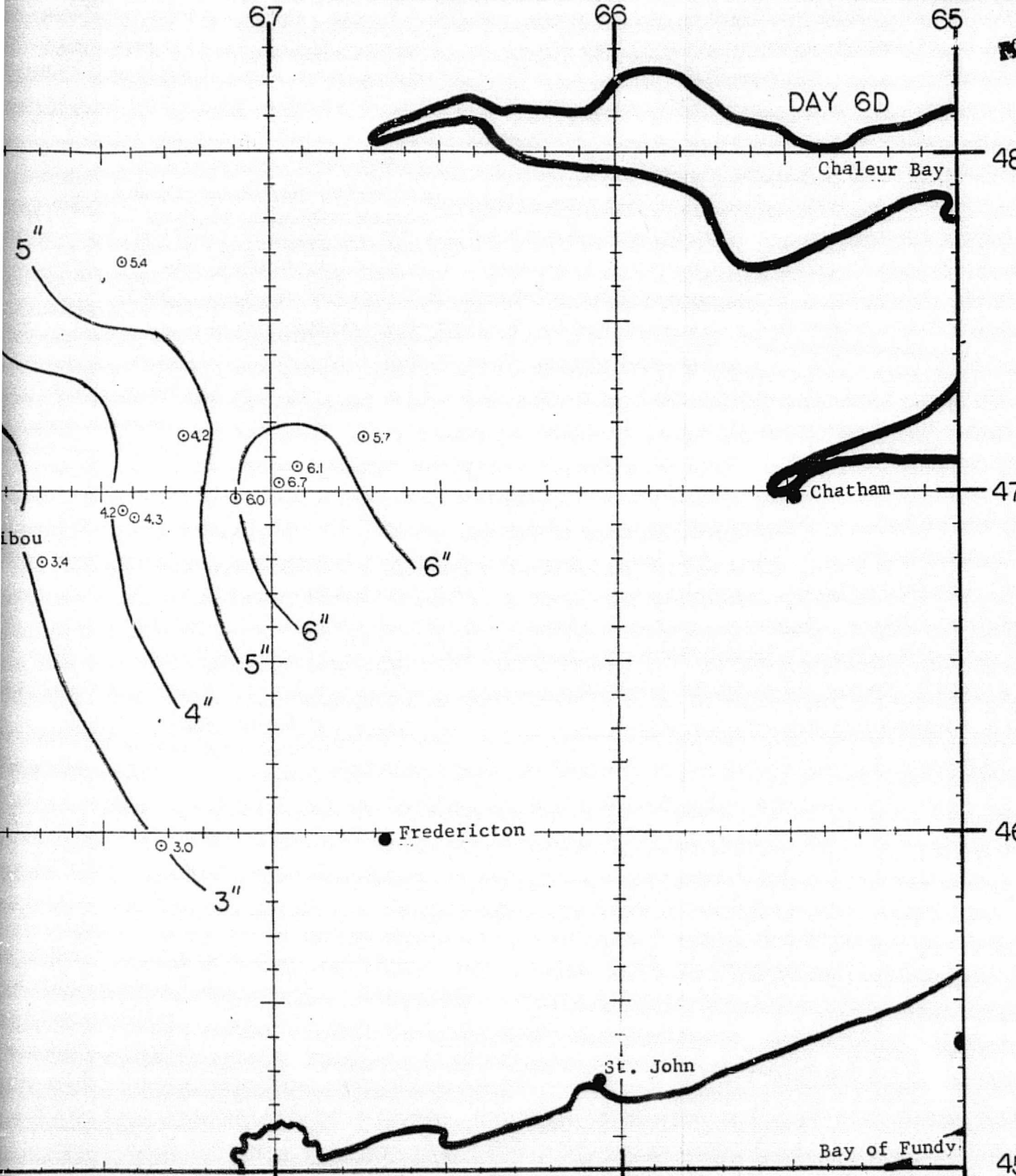
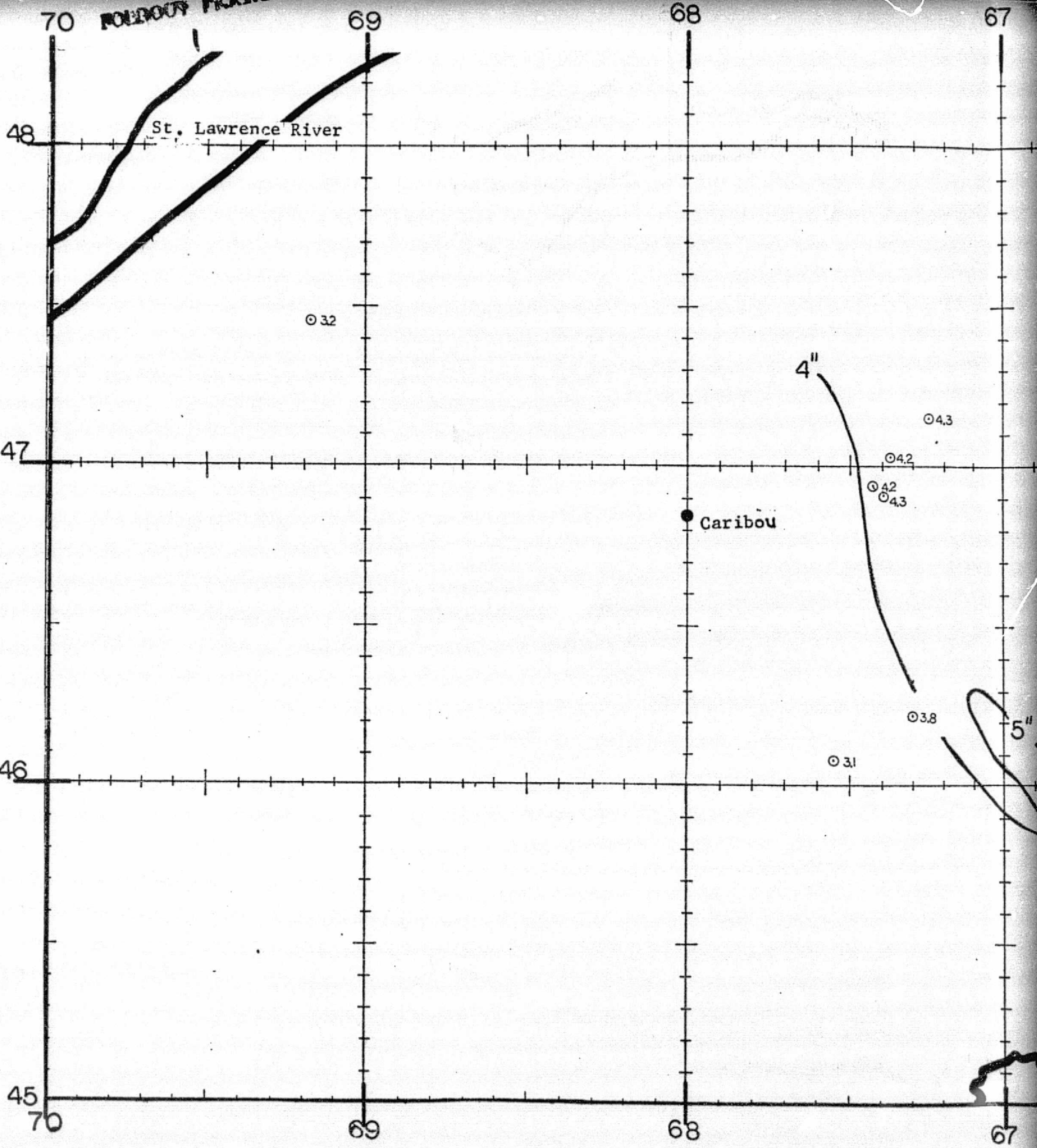


Figure D-4. Snow Water Equivalent (Inches) Values for 6D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St. Lawrence River
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4"
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⊙4.2
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Caribou
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46
⊙3.1
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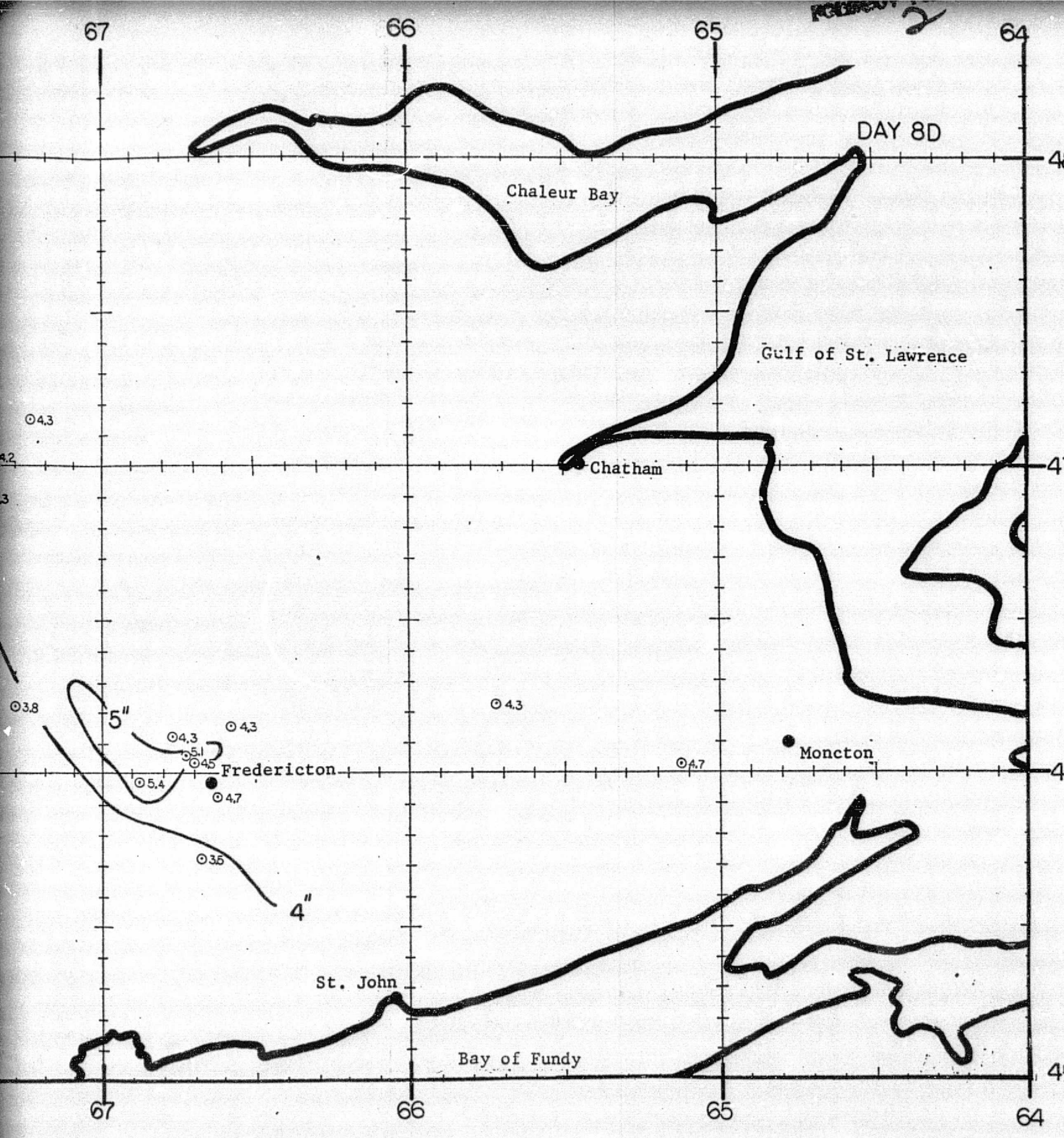
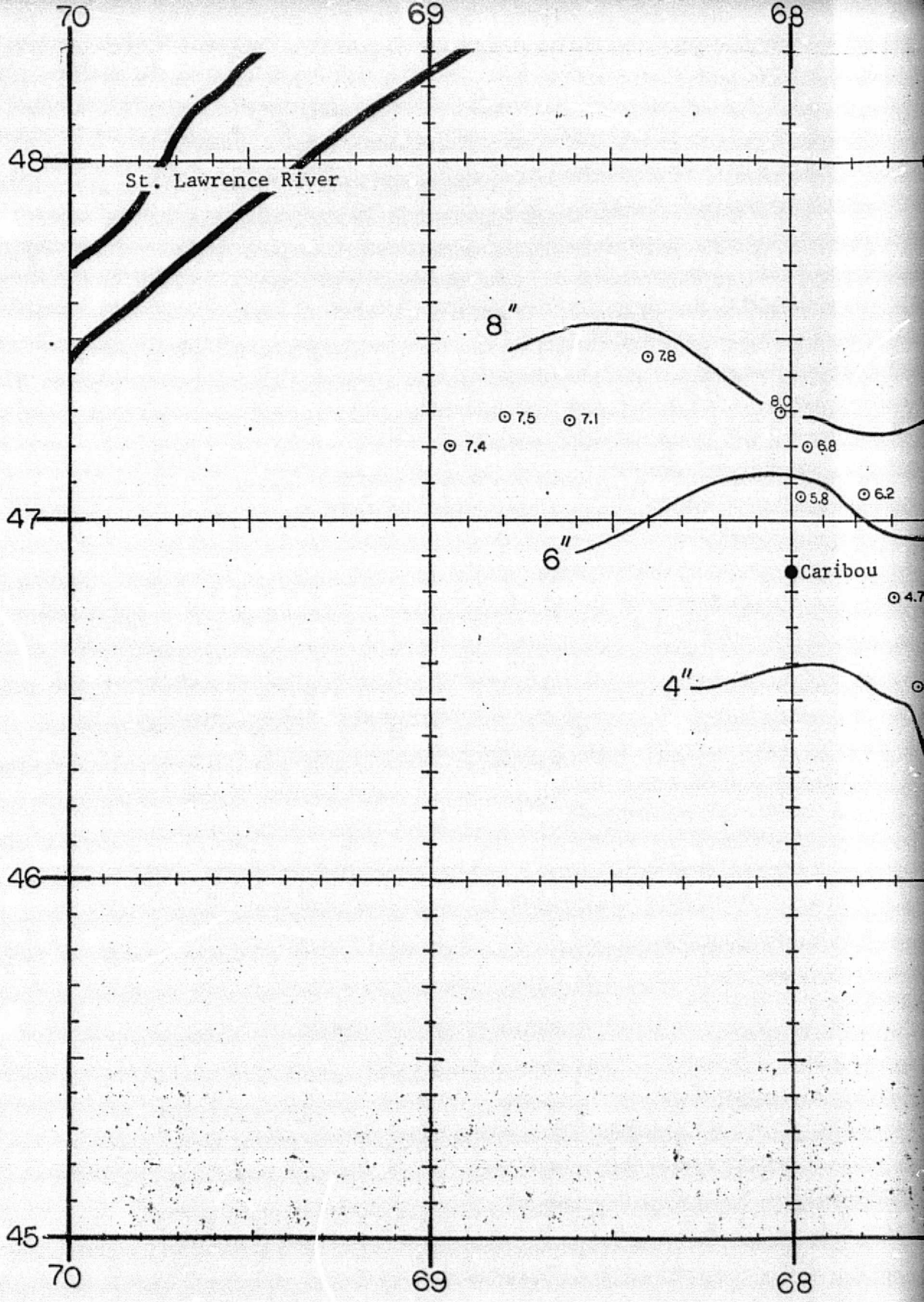


Figure D-5. Snow Water Equivalent (Inches) Values for 8D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St. Lawrence River
8"
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8.0
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7.1
7.4
6.8
5.8
6.2
6"
Caribou
4.7
4"
70
69
68

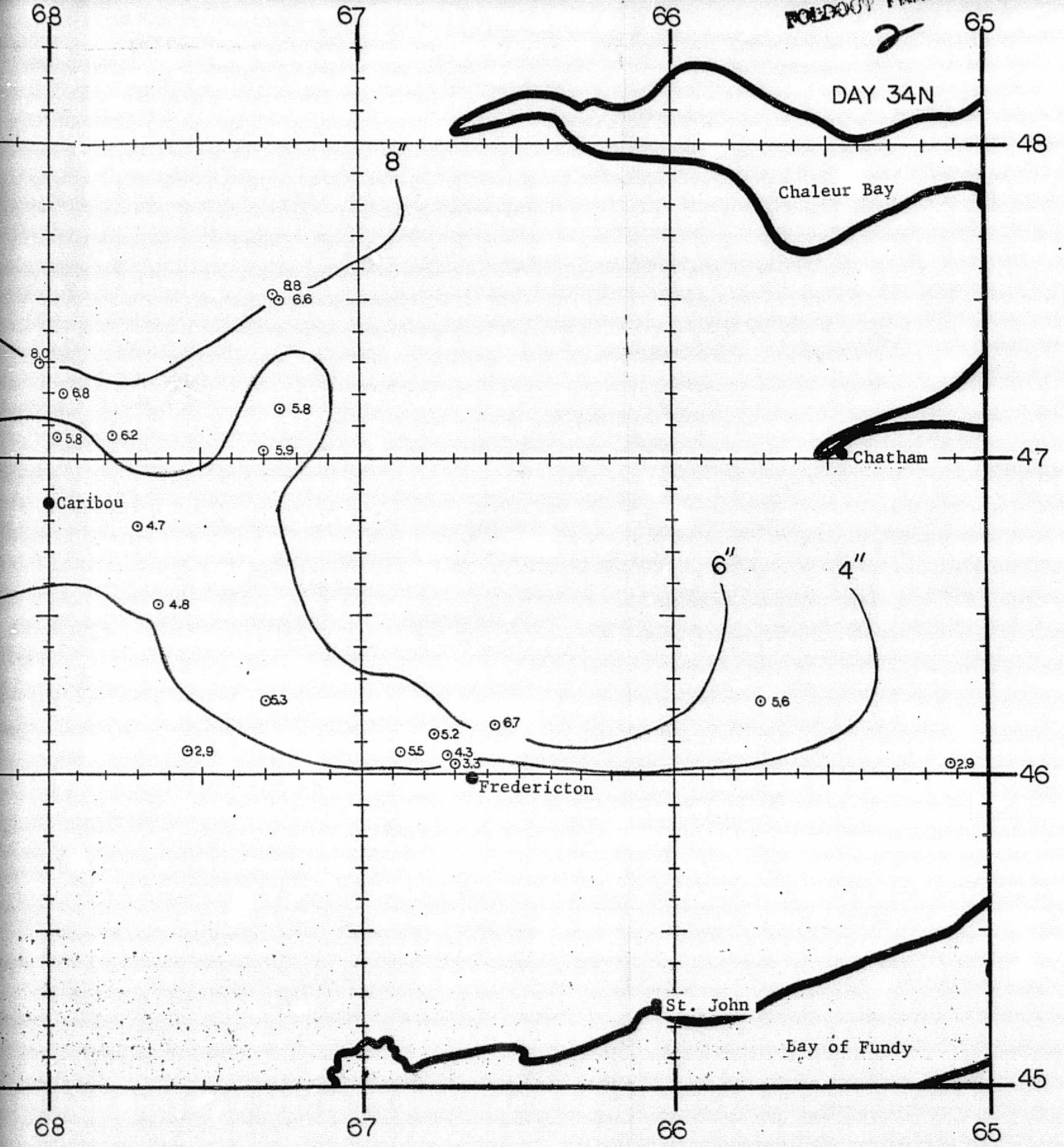

Figure D-6. Snow Water Equivalent (Inches) Values for 34 N

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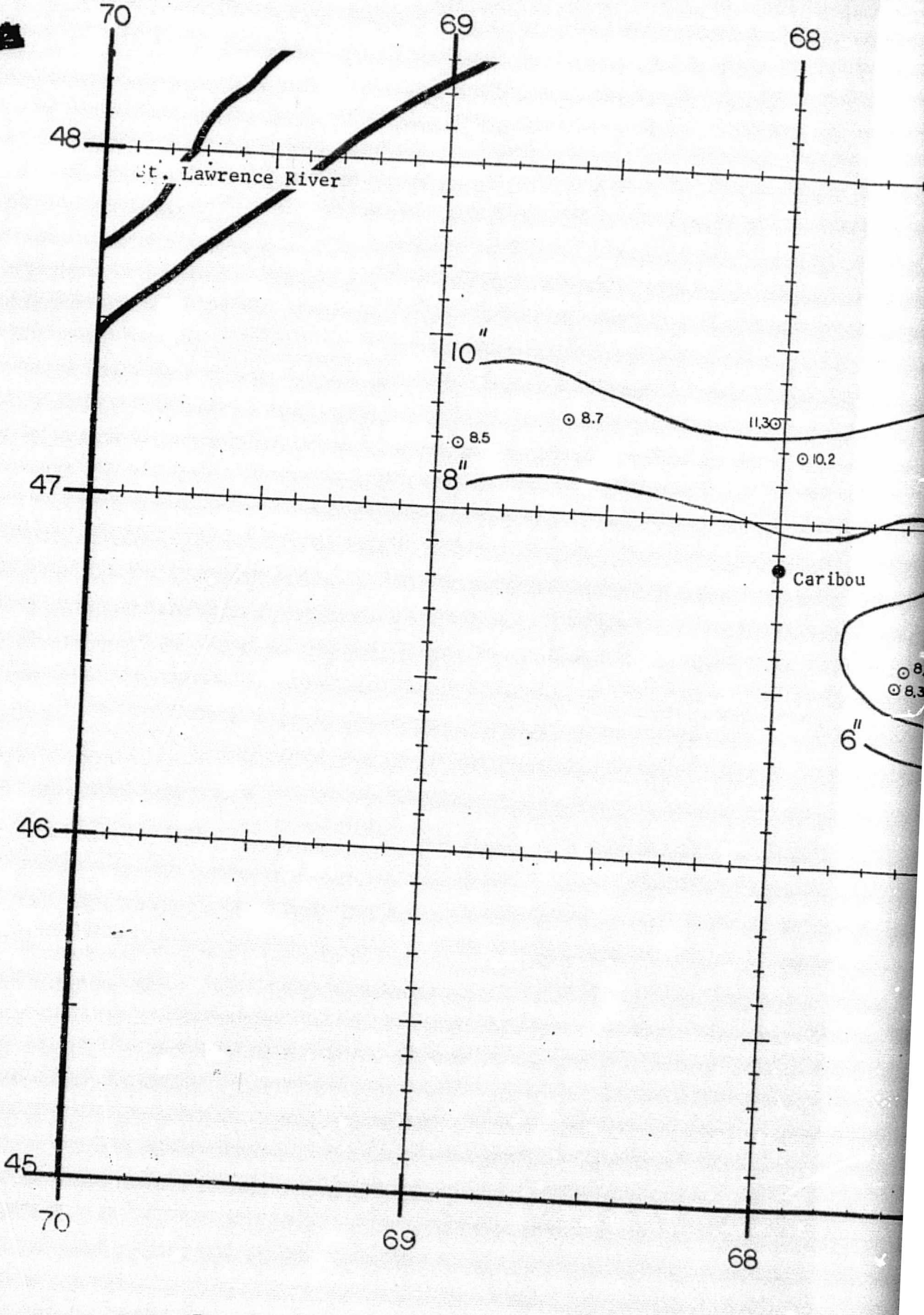

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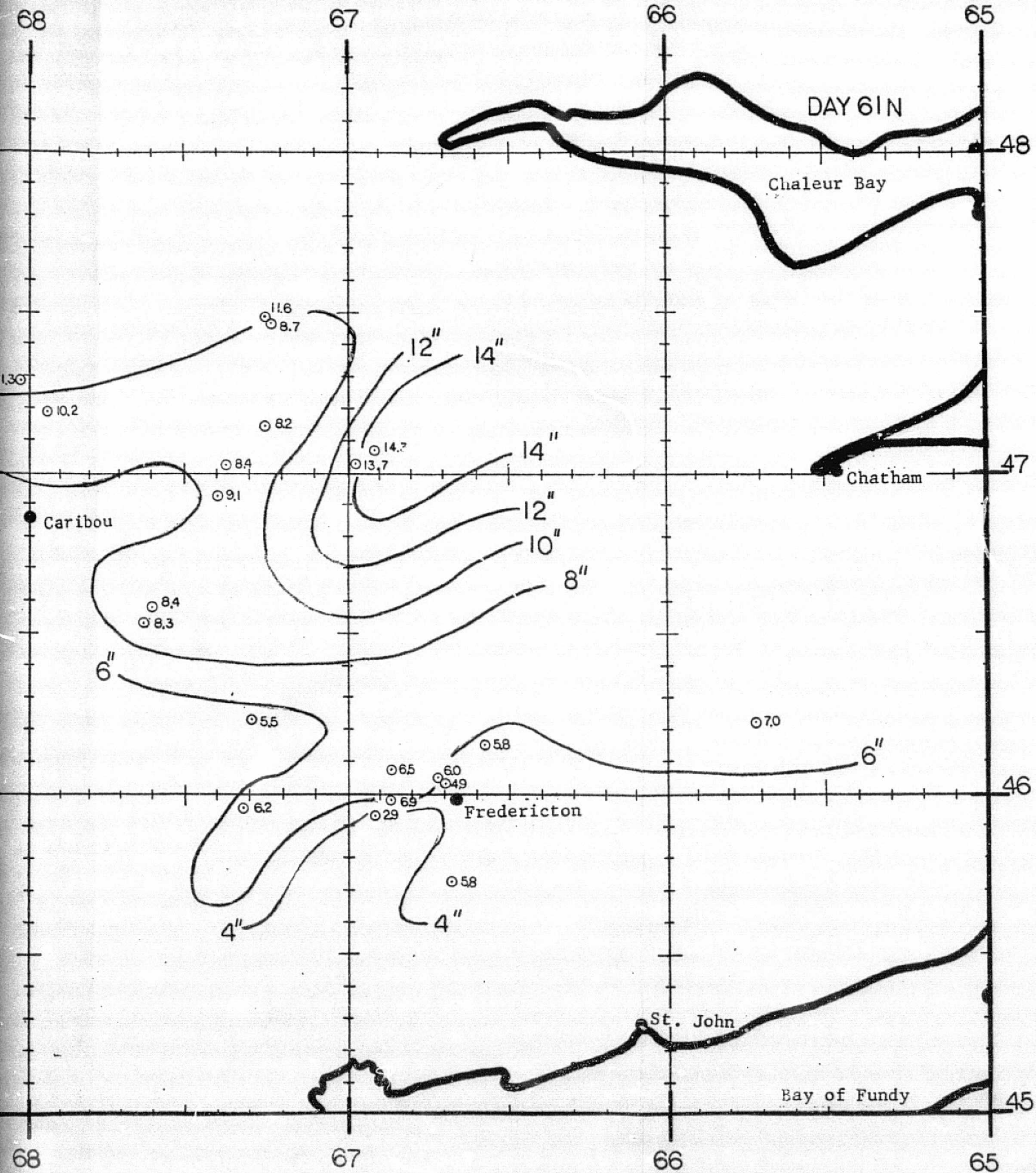

Figure D-7. Snow Water Equivalent (Inches) Values for 61N

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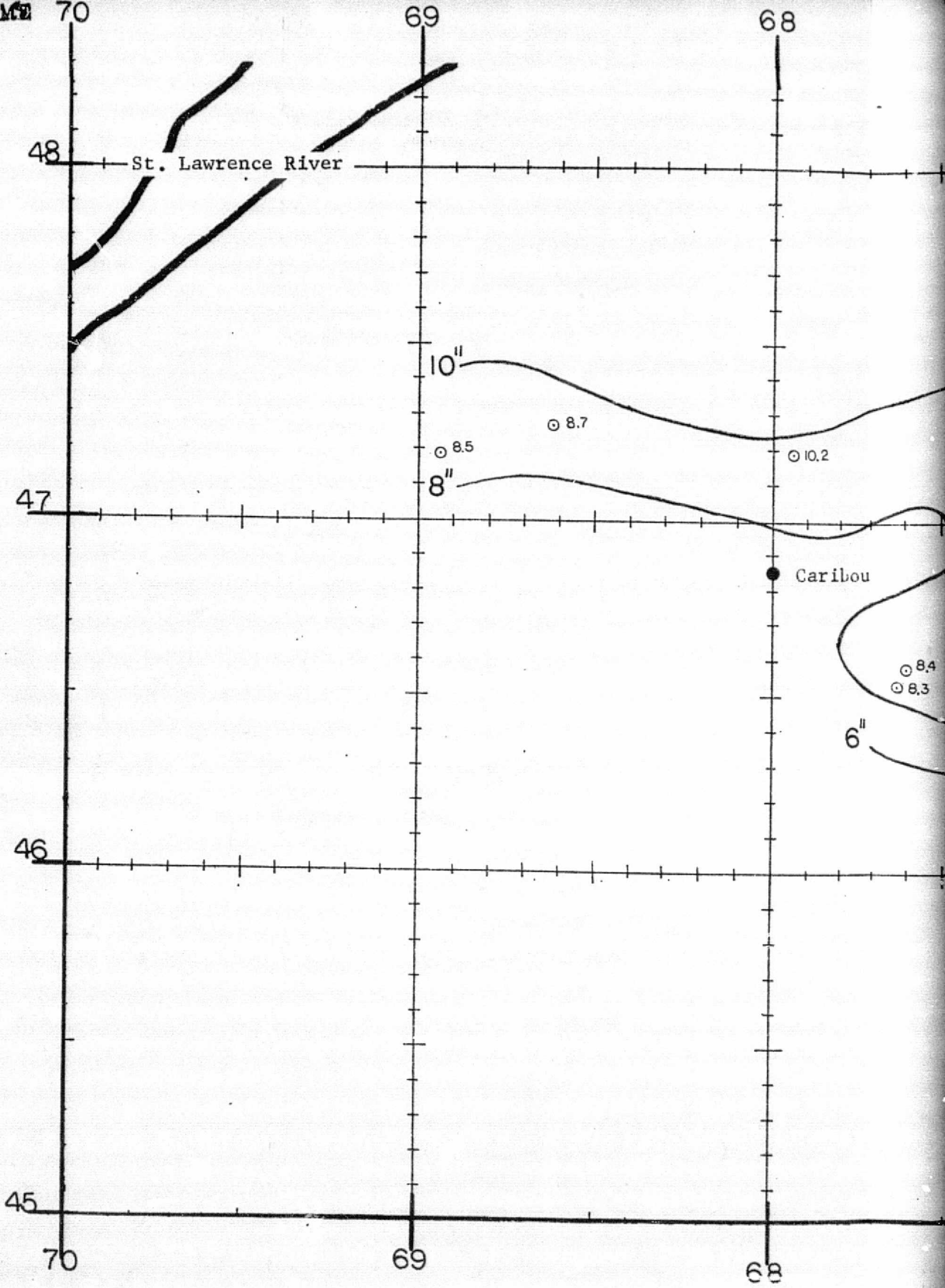

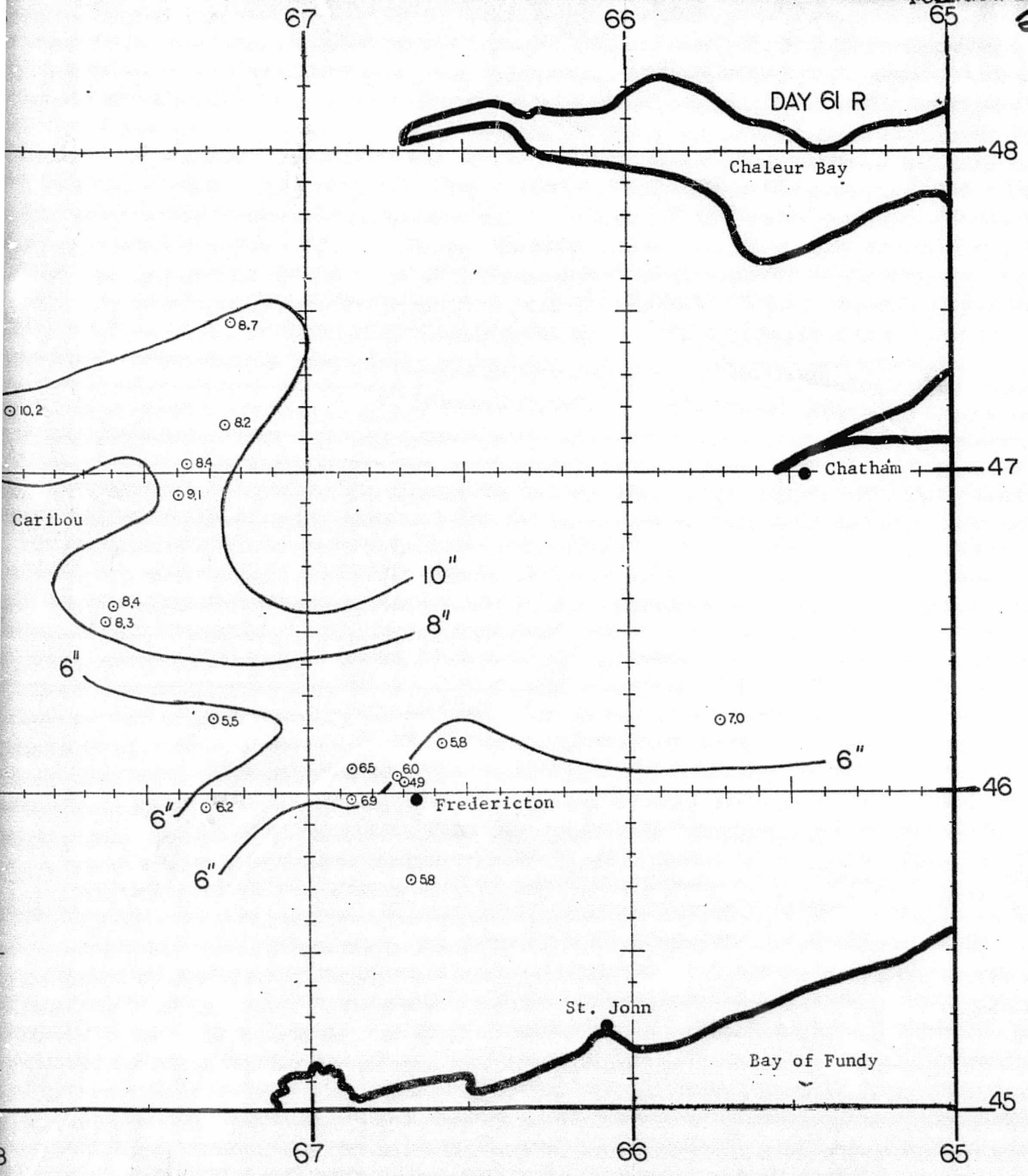

Figure D-8. Snow Water Equivalent Inches) Values for 61R

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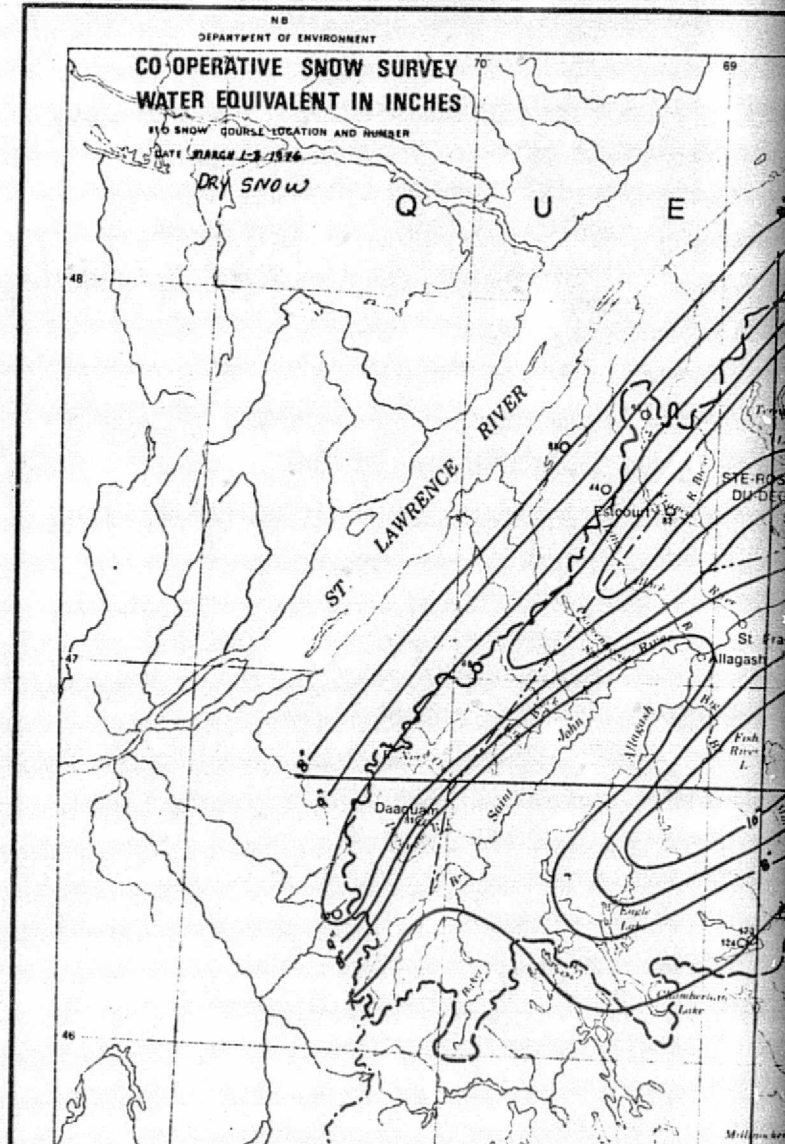

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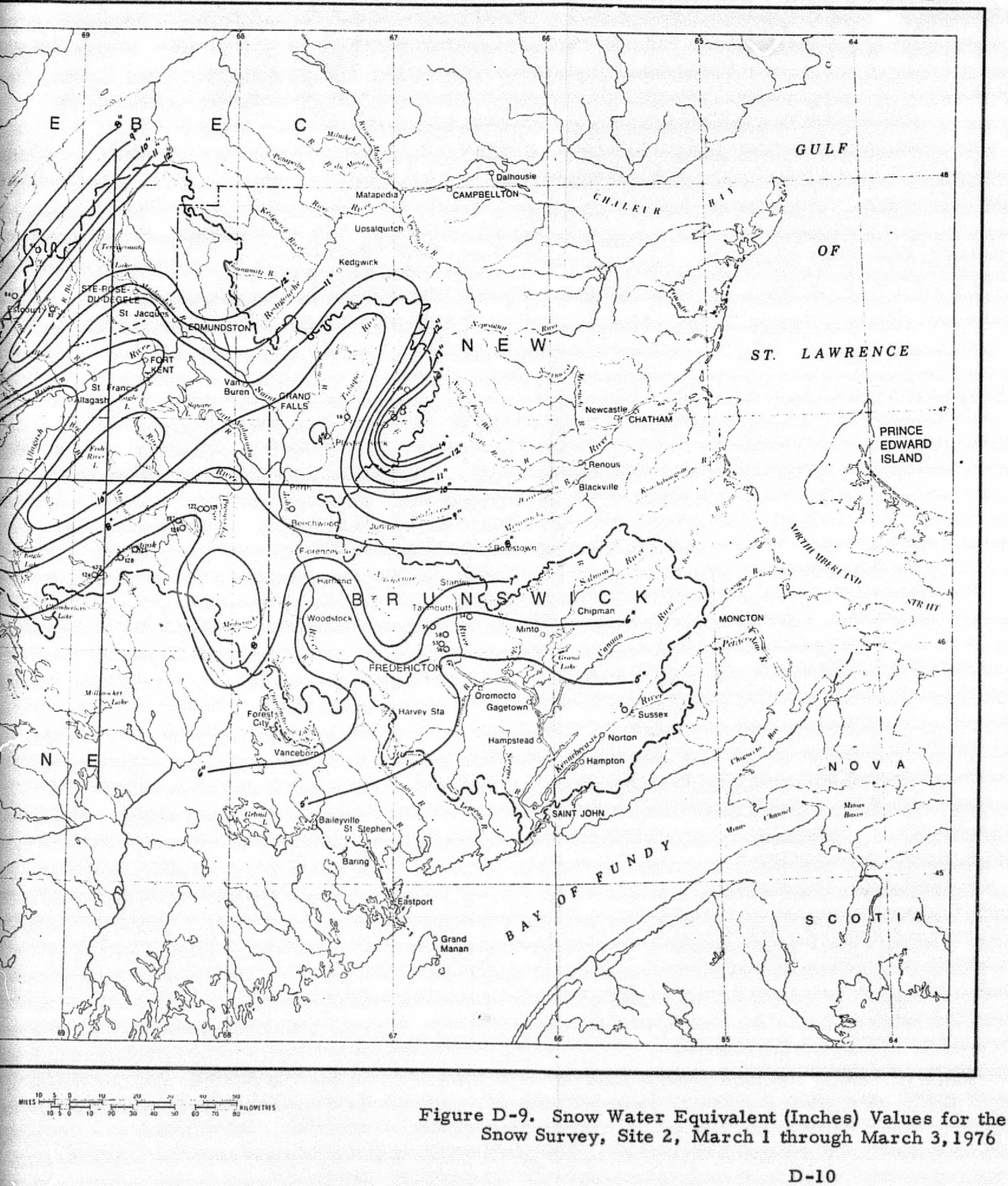

Figure D-9. Snow Water Equivalent (Inches) Values for the Snow Survey, Site 2, March 1 through March 3, 1976

Appendix E

REGRESSION RESULTS WITH RESIDUALS

In this appendix, the residuals (observed minus predicted) for linear regression are given for all data sets. All other information about the linear regressions including the distribution of residuals was given in Section 2.3. The residuals are given for any significant correlation, and the highest correlation if a data set does not have a significant correlation between snow water equivalent and either the horizontal or vertical brightness temperature. The residuals, as output from the program LINREG, are given in Tables E-1 through E-10 for the following data sets and independent variables (H = horizontal, V = vertical): 41N(H), 41D(V), 6D(H), 8D(V), 34N(V), 61N(H), 61R(H), 61R(V), 61E(H), and 61E(V). The linear regression was not significant for 41N, 6D, 8D and 61N.

The outputs from the program MULTREG are present for the best prediction of snow water equivalent for each data set using multiple regression. The first figure for each data set gives the statistical results (intercept, regression coefficients, analysis of variance table, etc.) and the second figure gives the residual values. Multiple regression data are given for data sets 41N, 41D, 6D, 8D, 34N, 61N, and 61R in Tables E-11A and E-11B; E-12A and E-12B; E-13A and E-13B; E-14A and E-14B; E-15A and E-15B; E-16A and E-16B; and E-17A and E-17B. The second set for 61R, without precipitation, are given in Tables E-18A and E-18B. The sample multiple correlation coefficient was not significant for 41N and 8D.

Table E-1

41N LINEAR REGRESSION RESIDUALS FOR HORIZONTAL

SITE I -- DAY 41 (FEBRUARY 10, 1976) -- NIGHT OBS. (0647 GMT)

RESIDUAL VALUES FOR SNOW VS HORZ

NO.	LAT	LONG	HORZ	Y OBS	Y EST	DIFF
1	51.37	100.02	185.	0.70	1.89	-1.19
2	50.27	99.83	192.	0.77	1.93	-1.16
3	50.78	99.50	199.	0.79	1.96	-1.17
4	51.05	99.50	188.	0.79	1.91	-1.12
5	51.17	100.68	204.	0.96	1.99	-1.03
6	51.82	100.75	208.	1.11	2.01	-0.90
7	51.63	100.45	212.	1.14	2.03	-0.89
8	51.58	98.67	163.	1.22	1.88	-0.66
9	49.18	99.67	189.	1.40	1.91	-0.51
10	50.20	98.95	178.	1.40	1.86	-0.46
11	50.43	100.62	182.	1.40	1.88	-0.48
12	49.27	98.00	189.	1.42	1.91	-0.49
13	50.90	97.25	184.	1.48	1.89	-0.41
14	51.17	97.60	184.	1.48	1.89	-0.41
15	49.90	99.05	187.	1.58	1.90	-0.32
16	50.78	101.30	186.	1.58	1.90	-0.32
17	51.23	101.30	191.	1.58	1.92	-0.34
18	50.13	97.55	200.	1.62	1.97	-0.35
19	51.85	100.95	195.	1.66	1.94	-0.28
20	51.15	100.07	185.	1.67	1.89	-0.22
21	49.67	96.63	205.	1.71	1.99	-0.28
22	49.87	99.93	176.	1.75	1.85	-0.10
23	50.42	97.93	200.	1.75	1.97	-0.22
24	51.65	100.65	212.	1.75	2.03	-0.28
25	50.80	98.92	183.	1.79	1.88	-0.09
26	50.87	98.10	201.	1.79	1.97	-0.18
27	49.85	100.93	167.	1.84	1.81	0.03
28	50.43	101.05	179.	1.84	1.86	-0.02
29	49.93	98.65	197.	1.93	1.95	-0.02
30	49.13	97.23	211.	2.10	2.02	0.08
31	49.27	96.35	194.	2.11	1.94	0.17
32	49.97	98.30	196.	2.11	1.95	0.16
33	50.75	98.68	180.	2.11	1.87	0.24
34	49.37	97.37	212.	2.17	2.03	0.14
35	50.15	101.67	182.	2.24	1.88	0.36
36	50.67	99.97	194.	2.28	1.94	0.34
37	49.77	97.17	191.	2.30	1.92	0.38
38	49.25	98.68	192.	2.37	1.93	0.44
39	49.62	100.27	186.	2.40	1.90	0.50
40	49.57	99.05	192.	2.41	1.93	0.48
41	49.98	100.62	177.	2.54	1.85	0.69
42	49.65	98.50	190.	2.57	1.92	0.65
43	50.70	99.52	199.	2.57	1.96	0.61
44	50.03	100.23	182.	2.63	1.88	0.75
45	49.23	100.83	172.	2.76	1.83	0.93
46	50.75	100.32	204.	2.81	1.99	0.82
47	51.00	100.07	204.	3.77	1.99	1.78
48	50.72	99.60	199.	3.80	1.96	1.84
49	49.15	100.05	198.	4.52	1.96	2.56

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Table E-2

41D LINEAR REGRESSION RESIDUALS FOR VERTICAL

SITE 1 -- DAY 41 (FEBRUARY 10, 1976) -- DAY OBS. (1710 GMT)

RESIDUAL VALUES FOR SNW VS VERT

NO.	LAT	LONG	VERT	Y OBS	Y EST	DIFF
1	51.37	100.02	209.	0.70	1.69	-0.99
2	51.05	99.50	209.	0.79	1.69	-0.90
3	50.79	99.50	209.	0.79	1.69	-0.90
4	51.40	101.43	209.	0.96	1.69	-0.73
5	51.57	101.90	219.	1.05	1.90	-0.85
6	51.63	100.45	229.	1.14	2.11	-0.97
7	51.90	101.27	229.	1.19	2.11	-0.92
8	51.58	98.67	215.	1.22	1.82	-0.60
9	51.18	98.35	198.	1.35	1.46	-0.11
10	52.40	101.10	231.	1.37	2.16	-0.79
11	49.18	99.67	228.	1.40	2.09	-0.69
12	50.20	98.95	202.	1.40	1.55	-0.15
13	50.38	96.45	224.	1.40	2.01	-0.61
14	50.43	100.62	206.	1.40	1.63	-0.23
15	51.80	100.57	229.	1.40	2.11	-0.71
16	50.90	97.25	206.	1.48	1.63	-0.15
17	49.90	99.05	209.	1.58	1.69	-0.11
18	50.23	99.43	213.	1.58	1.78	-0.20
19	50.78	101.30	206.	1.58	1.63	-0.05
20	51.23	101.30	213.	1.58	1.78	-0.20
21	50.13	97.55	218.	1.62	1.88	-0.26
22	50.50	96.98	201.	1.66	1.53	0.13
23	51.85	100.95	234.	1.66	2.22	-0.56
24	51.15	100.07	223.	1.67	1.99	-0.32
25	51.68	101.55	229.	1.67	2.11	-0.44
26	49.67	96.63	219.	1.71	1.90	-0.19
27	49.87	99.93	222.	1.75	1.97	-0.22
28	50.80	98.92	209.	1.79	1.69	0.10
29	50.87	98.10	202.	1.79	1.55	0.24
30	50.43	101.05	208.	1.84	1.67	0.17
31	51.52	101.25	222.	1.90	1.97	-0.07
32	49.93	98.65	208.	1.93	1.67	0.26
33	50.07	96.45	215.	2.02	1.82	0.20
34	49.13	98.13	225.	2.04	2.03	0.01
35	49.13	97.23	229.	2.10	2.11	-0.01
36	49.27	96.35	222.	2.11	1.97	0.14
37	49.97	98.30	209.	2.11	1.69	0.42
38	50.75	98.68	198.	2.11	1.46	0.65
39	49.37	97.37	232.	2.17	2.18	-0.01
40	49.13	96.77	229.	2.30	2.11	0.19
41	49.77	97.17	219.	2.30	1.90	0.40
42	49.25	98.68	232.	2.37	2.18	0.19
43	49.62	100.27	222.	2.40	1.97	0.43
44	49.57	99.05	219.	2.41	1.90	0.51
45	49.98	100.62	213.	2.54	1.78	0.76
46	49.65	98.50	218.	2.57	1.88	0.69
47	50.03	100.23	222.	2.63	1.97	0.66
48	50.75	100.02	225.	2.81	2.03	0.78
49	51.00	100.07	223.	3.77	1.99	1.78
50	50.72	99.60	219.	3.80	1.90	1.90
51	49.15	100.05	229.	4.52	2.11	2.41

Table E-3

6D LINEAR REGRESSION RESIDUALS FOR HORIZONTAL

SITE 2 -- DAY 6 (JANUARY 6, 1976) -- DAY OBS. (1511 GMT)

RESIDUAL VALUES FOR SNOW VS HORZ

NO.	LAT	LONG	HORZ	Y OBS	Y EST	DIFF
1	45.95	67.32	220.	3.00	4.43	-1.43
2	46.78	67.70	209.	3.40	3.08	0.32
3	46.93	67.43	224.	4.20	4.92	-0.72
4	47.15	67.25	227.	4.20	5.29	-1.09
5	46.92	67.40	224.	4.30	4.92	-0.62
6	47.67	67.43	225.	5.40	5.05	0.35
7	47.15	66.72	233.	5.70	6.03	-0.33
8	46.98	67.10	224.	6.00	4.92	1.08
9	47.07	66.92	226.	6.10	5.17	0.93
10	47.02	66.98	226.	6.70	5.17	1.53

Table E-4

8D LINEAR REGRESSION RESIDUALS FOR VERTICAL

SITE 2 -- DAY 8 (JANUARY 8, 1976) -- DAY OBS. (1532 GMT)

RESIDUAL VALUES FOR SNOW VS VERT

NO.	LAT	LONG	VERT	Y OBS	Y EST	DIFF
1	46.07	67.55	240.	3.10	4.03	-0.93
2	47.45	69.17	237.	3.20	3.86	-0.66
3	45.72	66.68	247.	3.50	4.45	-0.95
4	46.23	67.30	247.	3.80	4.45	-0.65
5	46.93	67.43	237.	4.20	3.86	0.34
6	47.02	67.38	237.	4.20	3.86	0.34
7	46.12	66.77	245.	4.30	4.33	-0.03
8	46.15	66.58	245.	4.30	4.33	-0.03
9	46.22	65.72	247.	4.30	4.45	-0.15
10	46.92	67.40	237.	4.30	3.86	0.44
11	47.15	67.25	240.	4.30	4.03	0.27
12	46.03	66.70	246.	4.50	4.39	0.11
13	45.92	66.62	245.	4.70	4.33	0.37
14	46.03	65.13	252.	4.70	4.74	-0.04
15	46.05	66.72	246.	5.10	4.39	0.71
16	45.97	66.87	249.	5.40	4.56	0.84

Table E-5

34N LINEAR REGRESSION RESIDUALS FOR VERTICAL

SITE 2 -- DAY 34 (FEBRUARY 3, 1976) -- NIGHT OBS. (0436 GMT)

RESIDUAL VALUES FOR SNOW VS VERT

NO.	LAT	LONG	VERT	Y OBS	Y EST	DIFF
1	46.07	67.55	221.	2.90	5.24	-2.34
2	46.03	65.13	233.	2.90	3.64	-0.74
3	46.03	66.70	227.	3.30	4.44	-1.14
4	46.05	66.72	227.	4.30	4.44	-0.14
5	46.78	67.70	211.	4.70	6.58	-1.88
6	46.53	67.63	211.	4.80	6.58	-1.78
7	46.12	66.77	221.	5.20	5.24	-0.04
8	46.23	67.30	228.	5.30	4.31	0.99
9	46.07	66.87	221.	5.50	5.24	0.26
10	46.22	65.72	221.	5.60	5.24	0.36
11	47.07	67.97	212.	5.80	6.45	-0.65
12	47.15	67.25	212.	5.80	6.45	-0.65
13	47.02	67.30	212.	5.90	6.45	-0.55
14	47.07	67.77	209.	6.20	6.85	-0.65
15	47.50	67.25	216.	6.60	5.91	0.69
16	46.15	66.58	221.	6.70	5.24	1.46
17	47.20	67.95	205.	6.80	7.38	-0.58
18	47.27	68.62	213.	7.10	6.31	0.79
19	47.20	68.95	210.	7.40	6.71	0.69
20	47.27	68.80	216.	7.50	5.91	1.59
21	47.45	68.40	208.	7.80	6.98	0.82
22	47.30	68.03	205.	8.00	7.38	0.62
23	47.50	67.25	216.	8.80	5.91	2.89

Table E-6

61N LINEAR REGRESSION RESIDUALS FOR HORIZONTAL

SITE 2 -- DAY 61 (MARCH1, 1976) -- NIGHT OBS. (0509 GMT)

RESIDUAL VALUES FOR SNOW VS HORZ

NO.	LAT	LONG	HORZ	Y OBS	Y EST	DIFF
1	45.92	66.92	227.	2.90	7.44	-4.54
2	46.03	66.70	235.	4.90	6.47	-1.57
3	46.23	67.30	214.	5.50	9.02	-3.52
4	45.72	66.68	231.	5.80	6.95	-1.15
5	46.15	66.58	218.	5.80	8.53	-2.73
6	46.05	66.72	235.	6.00	6.47	-0.47
7	45.95	67.32	226.	6.20	7.56	-1.36
8	46.07	66.87	226.	6.50	7.56	-1.06
9	45.97	66.87	237.	6.90	6.22	0.68
10	46.22	65.72	224.	7.00	7.80	-0.80
11	47.15	67.25	221.	8.20	8.17	0.03
12	46.53	67.63	214.	8.30	9.02	-0.72
13	46.58	67.60	214.	8.40	9.02	-0.62
14	47.02	67.38	213.	8.40	9.14	-0.74
15	47.20	68.95	228.	8.50	7.32	1.18
16	47.27	68.62	227.	8.70	7.44	1.26
17	47.50	67.25	216.	8.70	8.78	-0.08
18	46.92	67.40	202.	9.10	10.48	-1.38
19	47.20	67.95	207.	10.20	9.87	0.33
20	47.30	68.03	216.	11.30	8.78	2.52
21	47.50	67.25	216.	11.60	8.78	2.82
22	47.02	66.98	222.	13.70	8.05	5.65
23	47.07	66.92	222.	14.30	8.05	6.25

Table E-7

61R LINEAR REGRESSION RESIDUALS FOR HORIZONTAL

```
SITE 2 -- DAY 61 (MARCH1, 1976) -- NIGHT OBS. (0509 GMT) ** SNOW 4.9-10.2 INCHES


                 RESIDUAL VALUES FOR SNOW VS HORZ
                 --------------------------------

NO.     LAT      LONG      HORZ       Y OBS    Y EST     DIFF
---     ---      ----      ----       -----    -----     ----
  1    46.03    66.70     235.        4.90     6.15    -1.25
  2    46.23    67.30     214.        5.50     8.09    -2.59
  3    45.72    66.68     231.        5.80     6.52    -0.72
  4    46.15    66.58     218.        5.80     7.72    -1.92
  5    46.05    66.72     235.        6.00     6.15    -0.15
  6    45.95    67.32     226.        6.20     6.98    -0.78
  7    46.07    66.87     226.        6.50     6.98    -0.48
  8    45.97    66.87     237.        6.90     5.97     0.93
  9    46.22    65.72     224.        7.00     7.17    -0.17
 10    47.15    67.25     221.        8.20     7.45     0.75
 11    46.53    67.63     214.        8.30     8.09     0.21
 12    46.58    67.60     214.        8.40     8.09     0.31
 13    47.02    67.38     213.        8.40     8.18     0.22
 14    47.20    68.95     228.        8.50     6.80     1.70
 15    47.27    68.62     227.        8.70     6.89     1.81
 16    47.50    67.25     216.        8.70     7.91     0.79
 17    46.92    67.40     202.        9.10     9.20    -0.10
 18    47.20    67.95     207.       10.20     8.74     1.46
```

Table E-8

61R LINEAR REGRESSION RESIDUALS FOR VERTICAL

SITE 2 -- DAY 61 (MARCH1, 1976) -- NIGHT OBS. (0509 GMT) ** SNOW 4.9-10.2 INCHES

RESIDUAL VALUES FOR SNOW VS VERT

NO.	LAT	LONG	VERT	Y OBS	Y EST	DIFF
1	46.03	66.70	250.	4.90	6.45	-1.55
2	46.23	67.30	246.	5.50	6.93	-1.43
3	45.72	66.68	253.	5.80	6.09	-0.29
4	46.15	66.58	253.	5.80	6.09	-0.29
5	46.05	66.72	250.	6.00	6.45	-0.45
6	45.95	67.32	241.	6.20	7.53	-1.33
7	46.07	66.87	249.	6.50	6.57	-0.07
8	45.97	66.87	253.	6.90	6.09	0.81
9	46.22	65.72	255.	7.00	5.85	1.15
10	47.15	67.25	230.	8.20	8.85	-0.65
11	46.53	67.63	231.	8.30	8.73	-0.43
12	46.58	67.60	231.	8.40	8.73	-0.33
13	47.02	67.38	233.	8.40	8.49	-0.09
14	47.20	68.95	248.	8.50	6.69	1.81
15	47.27	68.62	235.	8.70	8.25	0.45
16	47.50	67.25	232.	8.70	8.61	0.09
17	46.92	67.40	234.	9.10	8.37	0.73
18	47.20	67.95	234.	10.20	8.37	1.83

Table E-9

61E LINEAR REGRESSION RESIDUALS FOR HORIZONTAL

SITE 1 -- DAY 61 (MARCH 1,1976) -- NIGHT OBS. (0509 GMT) ** CONTOUR SNOW VALUES

RESIDUAL VALUES FOR SNOW VS HORZ

NO.	LAT	LONG	HORZ	Y OBS	Y EST	DIFF
1	45.70	67.17	221.	5.10	8.32	-3.22
2	45.72	66.73	227.	5.20	8.10	-2.90
3	46.02	66.71	235.	5.30	7.81	-2.51
4	45.75	66.95	231.	5.60	7.95	-2.35
5	45.50	67.40	223.	5.60	8.25	-2.65
6	46.10	67.40	211.	5.80	8.69	-2.89
7	45.50	67.60	231.	5.80	7.95	-2.15
8	45.80	67.20	237.	5.90	7.73	-1.83
9	46.10	67.20	226.	6.10	8.14	-2.04
10	46.17	67.63	224.	6.40	8.21	-1.81
11	46.05	66.94	218.	6.60	8.43	-1.83
12	46.30	66.30	227.	6.90	8.10	-1.20
13	46.32	66.52	225.	7.10	8.17	-1.07
14	45.90	68.10	230.	7.10	7.99	-0.89
15	46.47	67.44	213.	7.20	8.61	-1.41
16	46.56	68.12	217.	7.30	8.47	-1.17
17	46.37	66.73	227.	7.50	8.10	-0.60
18	46.40	67.20	221.	7.50	8.32	-0.82
19	46.52	67.90	214.	7.50	8.58	-1.08
20	46.36	69.00	239.	7.50	7.66	-0.16
21	46.52	69.91	216.	7.50	8.50	-1.00
22	46.80	69.46	222.	7.60	8.28	-0.68
23	46.50	67.66	204.	7.70	8.94	-1.24
24	46.40	66.98	233.	7.80	7.88	-0.08
25	46.77	68.17	219.	7.80	8.39	-0.59
26	46.50	69.67	222.	7.80	8.28	-0.48
27	46.96	69.27	228.	7.90	8.06	-0.16
28	46.73	67.92	201.	8.00	9.05	-1.05
29	47.67	69.50	197.	8.00	9.20	-1.20
30	46.70	67.70	202.	8.30	9.01	-0.71
31	46.67	67.45	207.	8.40	8.83	-0.43
32	46.62	68.57	218.	8.50	8.43	0.07
33	47.19	68.83	227.	8.50	8.10	0.40
34	46.92	69.05	235.	8.50	7.81	0.69
35	46.40	69.23	234.	8.50	7.84	0.66
36	46.76	69.25	220.	8.70	8.36	0.34
37	46.46	69.44	224.	8.70	8.21	0.49
38	47.30	67.17	232.	8.80	7.92	0.88
39	47.00	67.70	213.	8.80	8.61	0.19
40	46.95	67.48	221.	8.90	8.32	0.58
41	47.32	67.31	201.	9.00	9.05	-0.05
42	47.02	67.95	204.	9.00	8.94	0.06
43	46.82	68.38	236.	9.00	7.77	1.23
44	47.16	68.62	219.	9.00	8.39	0.61
45	47.22	69.07	225.	9.00	8.17	0.83
46	47.93	69.07	202.	9.00	9.01	-0.01
47	47.02	69.50	216.	9.00	8.50	0.50
48	46.82	69.71	221.	9.00	8.32	0.68
49	47.37	69.73	207.	9.00	8.83	0.17
50	46.56	70.23	211.	9.00	8.69	0.31
51	46.32	70.35	202.	9.00	9.01	-0.01
52	46.63	67.24	220.	9.20	8.36	0.84
53	46.60	66.78	230.	9.20	7.99	1.21
54	47.06	68.16	207.	9.30	8.83	0.47
55	47.02	68.40	216.	9.50	8.50	1.00
56	47.12	69.95	204.	9.50	8.94	0.56
57	46.60	67.02	214.	9.70	8.58	1.12
58	46.92	70.15	213.	9.70	8.61	1.09
59	46.86	69.93	217.	9.80	8.47	1.33
60	47.50	68.60	210.	10.00	8.72	1.28
61	46.85	68.60	229.	10.00	8.03	1.97
62	46.89	68.82	226.	10.00	8.14	1.86
63	46.62	70.35	211.	10.00	8.69	1.31
64	47.35	67.65	216.	10.20	8.50	1.70
65	47.60	69.27	213.	10.20	8.61	1.59
66	46.92	67.24	222.	10.30	8.28	2.02
67	47.26	66.94	228.	11.00	8.06	2.94
68	47.25	69.28	230.	11.00	7.99	3.01
69	47.32	69.51	229.	11.00	8.03	2.97
70	47.06	69.74	221.	11.00	8.32	2.68
71	47.40	67.90	207.	11.50	8.83	2.67

Table E-10

61E LINEAR REGRESSION RESIDUALS FOR VERTICAL

.ITE 2 -- DAY 61 (MARCH 1,1976) -- NIGHT OBS. (0509 GMT) ** CONTOUR SNOW VALUES

RESIDUAL VALUES FOR SNOW VS VERT

NO.	LAT	LONG	VERT	Y OBS	Y EST	DIFF
1	45.70	67.17	255.	5.10	7.12	-2.02
2	45.72	66.73	255.	5.20	7.12	-1.92
3	46.02	66.71	250.	5.30	7.58	-2.28
4	45.75	66.95	253.	5.60	7.30	-1.70
5	45.50	67.40	256.	5.60	7.02	-1.42
6	46.10	67.40	242.	5.80	8.33	-2.53
7	45.50	67.60	254.	5.80	7.21	-1.41
8	45.80	67.20	253.	5.90	7.30	-1.40
9	46.10	67.20	249.	6.10	7.68	-1.58
10	46.17	67.63	246.	6.40	7.95	-1.55
11	46.05	66.94	253.	6.60	7.30	-0.70
12	46.30	66.30	243.	6.90	8.23	-1.33
13	46.32	66.52	253.	7.10	7.30	-0.20
14	45.90	68.10	254.	7.10	7.21	-0.11
15	46.47	67.44	244.	7.20	8.14	-0.94
16	46.56	68.12	244.	7.30	8.14	-0.84
17	46.37	66.73	241.	7.50	8.42	-0.92
18	46.40	67.20	246.	7.50	7.95	-0.45
19	46.52	67.90	231.	7.50	9.35	-1.85
20	46.36	69.00	259.	7.50	6.74	0.76
21	46.52	69.91	242.	7.50	8.33	-0.83
22	46.80	69.46	239.	7.60	8.61	-1.01
23	46.50	67.66	235.	7.70	8.98	-1.28
24	46.40	66.98	243.	7.80	8.23	-0.43
25	46.77	68.17	225.	7.80	9.91	-2.11
26	46.50	69.67	234.	7.80	9.07	-1.27
27	46.96	69.27	248.	7.90	7.77	0.13
28	46.73	67.92	233.	8.00	9.17	-1.17
29	47.67	69.50	234.	8.00	9.07	-1.07
30	46.70	67.70	234.	8.30	9.07	-0.77
31	46.67	67.45	241.	8.40	8.42	-0.02
32	46.62	68.57	246.	8.50	7.95	0.55
33	47.19	68.83	235.	8.50	8.98	-0.48
34	46.92	69.05	245.	8.50	8.05	0.45
35	46.40	69.23	246.	8.50	7.95	0.55
36	46.76	69.25	252.	8.70	7.40	1.30
37	46.46	69.44	251.	8.70	7.49	1.21
38	47.30	67.17	237.	8.80	8.79	0.01
39	47.00	67.70	233.	8.80	9.17	-0.37
40	46.95	67.48	239.	8.90	8.61	0.29
41	47.32	67.31	237.	9.00	8.79	0.21
42	47.02	67.95	229.	9.00	9.54	-0.54
43	46.82	68.38	254.	9.00	7.21	1.79
44	47.16	68.62	234.	9.00	9.07	-0.07
45	47.22	69.07	249.	9.00	7.68	1.32
46	47.93	69.07	226.	9.00	9.82	-0.82
47	47.02	69.50	244.	9.00	8.14	0.86
48	46.82	69.71	246.	9.00	7.95	1.05
49	47.37	69.73	237.	9.00	8.79	0.21
50	46.56	70.23	228.	9.00	9.63	-0.63
51	46.32	70.35	234.	9.00	9.07	-0.07
52	46.63	67.24	233.	9.20	9.17	0.03
53	46.60	66.78	245.	9.20	8.05	1.15
54	47.06	68.16	234.	9.30	9.07	0.23
55	47.02	68.40	240.	9.50	8.51	0.99
56	47.12	69.95	239.	9.50	8.61	0.89
57	46.60	67.02	247.	9.70	7.86	1.84
58	46.92	70.15	226.	9.70	9.82	-0.12
59	46.86	69.93	238.	9.80	8.70	1.10
60	47.50	68.60	243.	10.00	8.23	1.77
61	46.85	68.60	250.	10.00	7.58	2.42
62	46.89	68.82	240.	10.00	8.51	1.49
63	46.62	70.35	233.	10.00	9.17	0.83
64	47.35	67.65	232.	10.20	9.26	0.94
65	47.60	69.27	231.	10.20	9.35	0.85
66	46.92	67.24	247.	10.30	7.86	2.44
67	47.26	66.94	239.	11.00	8.61	2.39
68	47.25	69.28	248.	11.00	7.77	3.23
69	47.32	69.51	230.	11.00	9.45	1.55
70	47.06	69.74	233.	11.00	9.17	1.83
71	47.40	67.90	225.	11.50	9.91	1.59

Table E-11A

41N MULTIPLE REGRESSION RESULTS

```
MULTIPLE REGRESSION.....DAY4IN

    SELECTION..... 1


VARIABLE      MEAN          STANDARD        CORRELATION      REGRESSION      STD. ERROR       COMPUTED
  NO.                       DEVIATION         X VS Y         COEFFICIENT     OF REG.COEF.     T VALUE
   2       222.20407         8.33161         0.05358          0.00672         0.01296         0.51884
   4      1312.77539       482.59131         0.30482          0.00049         0.00022         2.20504
DEPENDENT
   3         1.92795         0.76962


INTERCEPT                      -0.21368

MULTIPLE CORRELATION            0.31336
(R SQUARED)*100                 9.81919

STD. ERROR OF ESTIMATE          0.74658


                        ANALYSIS OF VARIANCE FOR THE REGRESSION

   SOURCE OF VARIATION          DEGREES        SUM OF            MEAN               F VALUE
                              OF FREEDOM      SQUARES           SQUARES
ATTRIBUTABLE TO REGRESSION         2           2.79171           1.39585            2.50432
DEVIATION FROM REGRESSION         46          25.63942           0.55738
     TOTAL                        48          28.43112

                        VARIABLES FOR THIS SELECTION
                        ----------------------------

                          DEPENDENT
                          ---------
                             3  -  SNOW DEPTH-WATER EQUIVALENT INCHES

                          INDEPENDENT
                          -----------
                            2  -  VERTICAL ESMR TEMPERATURE
                            4  -  ELEVATION IN FEET AT SNOW LOCATION
```

Table E-11B

41N MULTIPLE REGRESSION RESIDUALS

```
MULTIPLE REGRESSION.....DAY41N

    SELECTION..... 1

                       TABLE OF RESIDUALS

CASE NO.        Y VALUE        Y ESTIMATE        RESIDUAL
     1          0.70000         1.68531          -0.98531
     2          0.77000         2.09608          -1.32608
     3          0.79000         1.78653          -0.99653
     4          0.79000         1.71586          -0.92586
     5          0.96000         2.07408          -1.11408
     6          1.11000         2.45394          -1.34394
     7          1.14000         1.93862          -0.79862
     8          1.22000         1.65301          -0.43301
     9          1.40000         2.06648          -0.66648
    10          1.40000         1.68440          -0.28440
    11          1.40000         2.15663          -0.75663
    12          1.42000         1.75521          -0.33521
    13          1.48000         1.57992          -0.09993
    14          1.48000         1.60638          -0.12638
    15          1.58000         1.93774          -0.35774
    16          1.58000         2.16113          -0.58113
    17          1.58000         2.18532          -0.60532
    18          1.62000         1.78187          -0.16187
    19          1.66000         2.46516          -0.80516
    20          1.67000         1.68038          -0.01038
    21          1.71000         1.70612           0.00388
    22          1.75000         2.02388          -0.27388
    23          1.75000         1.71136           0.03864
    24          1.75000         2.15568          -0.40568
    25          1.79000         1.63980           0.15020
    26          1.79000         1.64091           0.14909
    27          1.84000         1.90687          -0.06687
    28          1.84000         2.03513          -0.19513
    29          1.93000         1.78617           0.14383
    30          2.10000         1.73592           0.36408
    31          2.11000         1.89601           0.21399
    32          2.11000         1.68484           0.42516
    33          2.11000         1.69717           0.41283
    34          2.17000         1.77805           0.39195
    35          2.24000         1.98711           0.25288
    36          2.28000         2.41810          -0.13810
    37          2.30000         1.77737           0.52262
    38          2.37000         1.97690           0.39310
    39          2.40000         1.67548           0.52452
    40          2.41000         1.87279           0.53721
    41          2.54000         1.98576           0.55424
    42          2.57000         1.81138           0.75862
    43          2.57000         1.84178           0.72822
    44          2.63000         2.00641           0.62359
    45          2.76000         1.91390           0.84610
    46          2.81000         2.26560           0.54440
    47          3.77000         2.16694           1.60306
    48          3.80000         2.45844           1.34156
    49          4.52000         2.24971           2.27029
```

Table E-12A

41D MULTIPLE REGRESSION RESULTS

```
MULTIPLE REGRESSION.....DAY410

    SELECTION..... 1


VARIABLE      MEAN          STANDARD        CORRELATION       REGRESSION       STD. ERROR      COMPUTED
  NO.                       DEVIATION         X VS Y          COEFFICIENT      OF REG.COEF.    T VALUE
   1       190.49019         8.63567          0.05995         -0.01736          0.01604       -1.08205
   2       217.41176         9.90790          0.28168          0.02516          0.01436        1.75143
   5        32.92157         7.41577          0.47525          0.04033          0.01300        3.10124
DEPENDENT
   3         1.87117         0.73945


INTERCEPT                          -0.81282

MULTIPLE CORRELATION                0.52442
(R SQUARED)*100                    27.50121

STD. ERROR OF ESTIMATE              0.64939


                            ANALYSIS OF VARIANCE FOR THE REGRESSION

   SOURCE OF VARIATION         DEGREES      SUM OF            MEAN               F VALUE
                             OF FREEDOM     SQUARES           SQUARES
ATTRIBUTABLE TO REGRESSION        3          7.51858           2.50619            5.94289
DEVIATION FROM REGRESSION        47         19.82050           0.42171
     TOTAL                       50         27.33907


                            VARIABLES FOR THIS SELECTION
                            ----------------------------

                              DEPENDENT
                              ---------
                                 3  -  SNOW DEPTH-WATER EQUIVALENT INCHES

                              INDEPENDENT
                              -----------
                                1  -  HORIZONTIAL ESMR TEMPERATURE
                                2  -  VERTICAL ESMR TEMPERATURE
                                5  -  MAXIMUM TEMPERATURE DAY 0
```

Table E-12B

41D MULTIPLE REGRESSION RESIDUALS

```
MULTIPLE REGRESSION......PAY41D

    SELECTION...... 1

                    TABLE OF RESIDUALS

CASE NO.      Y VALUE      Y ESTIMATE      RESIDUAL
    1         0.70000       1.77549       -1.07549
    2         0.79000       1.32512       -0.53512
    3         0.79000       1.32512       -0.53512
    4         0.96000       1.46347       -0.50347
    5         1.05000       1.60577       -0.55578
    6         1.14000       1.46425       -0.32425
    7         1.19000       1.81700       -0.62700
    8         1.22000       1.73590       -0.51590
    9         1.35000       1.15306        0.19694
   10         1.37000       1.67639       -0.30639
   11         1.40000       2.69594       -1.29594
   12         1.40000       1.40376       -0.00377
   13         1.40000       2.14046       -0.74046
   14         1.40000       1.53247       -0.13247
   15         1.40000       1.58575       -0.18575
   16         1.48000       1.42935        0.05065
   17         1.58000       1.71769       -0.13769
   18         1.58000       1.62790       -0.04790
   19         1.58000       1.51562        0.06438
   20         1.58000       1.75501       -0.17501
   21         1.62000       1.58011        0.03989
   22         1.66000       1.96619       -0.30619
   23         1.66000       1.72889       -0.06889
   24         1.67000       2.27663       -0.60663
   25         1.67000       1.84559       -0.17559
   26         1.71000       1.82376       -0.11376
   27         1.75000       1.88851       -0.13851
   28         1.79000       1.67787        0.11213
   29         1.79000       1.32311        0.46689
   30         1.84000       1.82577        0.01423
   31         1.90000       1.70422        0.19578
   32         1.93000       1.91205        0.01795
   33         2.02000       2.35769       -0.33769
   34         2.04000       2.25240       -0.21240
   35         2.10000       2.61236       -0.51236
   36         2.11000       2.28057       -0.17057
   37         2.11000       2.48446       -0.37446
   38         2.11000       1.54563        0.56437
   39         2.17000       2.22634       -0.05634
   40         2.30000       2.57765       -0.27765
   41         2.30000       1.64560        0.65440
   42         2.37000       2.21460        0.15540
   43         2.40000       2.29742        0.10258
   44         2.41000       2.25155        0.15845
   45         2.54000       2.01435        0.52565
   46         2.57000       1.78176        0.78824
   47         2.63000       1.84256        0.78744
   48         2.81000       2.06199        0.74801
   49         3.77000       2.27663        1.49337
   50         3.80000       1.68082        2.11918
   51         4.52000       2.72672        1.79328
```

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Table E-13A

6 D MULTIPLE REGRESSION RESULTS

```
MULTIPLE REGRESSION.....DAY 6D

    SELECTION..... 1


VARIABLE      MEAN         STANDARD          CORRELATION       REGRESSION       STD. ERROR       COMPUTED
  NO.                      DEVIATION          X VS Y           COEFFICIENT      OF REG.COEF.     T VALUE
   1      223.79999         6.14274           0.60520           0.03719          0.03666         1.01445
   4      900.00000       416.99976           0.90006           0.00240          0.00054         4.44921
DEPENDENT
   3        4.90000         1.24633


INTERCEPT                        -5.58487

MULTIPLE CORRELATION              0.91348
(R SQUARED)*100                  83.44449

STD. ERROR OF ESTIMATE            0.57501


                      ANALYSIS OF VARIANCE FOR THE REGRESSION

   SOURCE OF VARIATION          DEGREES        SUM OF           MEAN              F VALUE
                               OF FREEDOM      SQUARES          SQUARES
ATTRIBUTABLE TO REGRESSION         2           11.66554          5.83277          17.64099
DEVIATION FROM REGRESSION          7            2.31446          0.33064
     TOTAL                         9           13.98000

                      VARIABLES FOR THIS SELECTION
                      ---------------------------

                        DEPENDENT
                        ---------
                           3  -  SNOW DEPTH-WATER EQUIVALENT INCHES

                        INDEPENDENT
                        -----------
                          1  -  HORIZONTIAL ESMR TEMPERATURE
                          4  -  ELEVATION IN FEET AT SNOW LOCATION
```

Table E-13B

6D MULTIPLE REGRESSION RESIDUALS

```
MULTIPLE REGRESSION.....DAY 6D

    SELECTION..... 1

                    TABLE OF RESIDUALS

CASE NO.        Y VALUE        Y ESTIMATE        RESIDUAL
     1          3.00000          3.19701        -0.19701
     2          3.40000          3.38859         0.01141
     3          4.20000          5.14769        -0.94769
     4          4.20000          4.17810         0.02190
     5          4.30000          4.06653         0.23347
     6          5.40000          4.94462         0.45538
     7          5.70000          6.08302        -0.38302
     8          6.00000          6.34898        -0.34898
     9          6.10000          5.82271         0.27729
    10          6.70000          5.82271         0.87729
```

Table E-14A

8D MULTIPLE REGRESSION RESULTS

```
MULTIPLE REGRESSION.....DAY 8D

    SELECTION..... 1


VARIABLE      MEAN         STANDARD       CORRELATION     REGRESSION     STD. ERROR      COMPUTED
  NO.                      DEVIATION        X VS Y        COEFFICIENT    OF REG.COEF.    T VALUE
   2       247.56250        4.64391        0.46152        0.06322        0.03434        1.84111
   4       451.25000      247.20099       -0.12245        0.00021        0.00067        0.30816
DEPENDENT
   3         4.24374        0.61749


INTERCEPT                  -11.24963

MULTIPLE CORRELATION         0.46767
(R SQUARED)*100             21.87114

STD. ERROR OF ESTIMATE       0.58628

                     ANALYSIS OF VARIANCE FOR THE REGRESSION

    SOURCE OF VARIATION        DEGREES       SUM OF           MEAN             F VALUE
                              OF FREEDOM     SQUARES          SQUARES
ATTRIBUTABLE TO REGRESSION        2          1.25089          0.62545          1.81959
DEVIATION FROM REGRESSION        13          4.46848          0.34373
     TOTAL                       15          5.71937

                     VARIABLES FOR THIS SELECTION
                     ----------------------------

                       DEPENDENT
                       ---------
                          3  -  SNOW DEPTH-WATER EQUIVALENT INCHES

                       INDEPENDENT
                       -----------
                         2  -  VERTICAL ESMR TEMPERATURE
                         4  -  ELEVATION IN FEET AT SNOW LOCATION
```

Table E-14B

8D MULTIPLE REGRESSION RESIDUALS

```
MULTIPLE REGRESSION.....DAY 8D

     SELECTION..... 1


                    TABLE OF RESIDUALS

CASE NO.       Y VALUE       Y ESTIMATE        RESIDUAL
      1        3.10000        3.95399         -0.85399
      2        3.20000        3.88356         -0.68356
      3        3.50000        4.40689         -0.90689
      4        3.80000        4.45873         -0.65873
      5        4.20000        3.94057          0.25943
      6        4.20000        3.83690          0.36310
      7        4.30000        4.38412         -0.08412
      8        4.30000        4.36339         -0.06339
      9        4.30000        4.46391         -0.16391
     10        4.30000        3.84727          0.45273
     11        4.30000        4.03693          0.26307
     12        4.50000        4.34367          0.15633
     13        4.70000        4.26594          0.43406
     14        4.70000        4.80592         -0.10592
     15        5.10000        4.38514          0.71486
     16        5.40000        4.52296          0.87704
```

Table E-15A

34N MULTIPLE REGRESSION RESULTS

```
MULTIPLE REGRESSION.....DAY34N

    SELECTION..... 1


VARIABLE      MEAN        STANDARD       CORRELATION      REGRESSION     STD. ERROR      COMPUTED
  NO.                     DEVIATION        X VS Y         COEFFICIENT    OF REG.COEF.    T VALUE
   1       201.60869      10.64912        -0.31764         0.03339        0.02764        1.20826
   2       216.34782       7.67290        -0.64264        -0.15051        0.03864       -3.89557
   4       581.52173     236.23671         0.48613         0.00290        0.00100        2.91395
DEPENDENT
   3         5.86521       1.59220


INTERCEPT                      30.00812

MULTIPLE CORRELATION            0.77656
(R SQUARED)*100                60.30417

STD. ERROR OF ESTIMATE          1.07945


                 ANALYSIS OF VARIANCE FOR THE REGRESSION

   SOURCE OF VARIATION         DEGREES        SUM OF           MEAN              F VALUE
                              OF FREEDOM      SQUARES          SQUARES
ATTRIBUTABLE TO REGRESSION         3          33.63286         11.21095           9.62133
DEVIATION FROM REGRESSION         19          22.13916          1.16522
     TOTAL                        22          55.77202

                 VARIABLES FOR THIS SELECTION
                 ----------------------------

                  DEPENDENT
                  ---------
                     3  -   SNOW DEPTH-WATER EQUIVALENT INCHES

                  INDEPENDENT
                  -----------
                    1  -   HORIZONTIAL ESMR TEMPERATURE
                    2  -   VERTICAL ESMR TEMPERATURE
                    4  -   ELEVATION IN FEET AT SNOW LOCATION
```

Table E-15B

34N MULTIPLE REGRESSION RESIDUALS

```
MULTIPLE REGRESSION.....DAY34N

    SELECTION..... 1


                    TABLE OF RESIDUALS

CASE NO.       Y VALUE       Y ESTIMATE         RESIDUAL
     1         2.90000          4.28424         -1.38424
     2         2.90000          3.82628         -0.92628
     3         3.30000          3.70268         -0.40268
     4         4.30000          4.28278          0.01722
     5         4.70000          5.87900         -1.17900
     6         4.80000          6.07935         -1.27935
     7         5.20000          5.68867         -0.48867
     8         5.30000          3.67625          1.62375
     9         5.50000          5.10857          0.39143
    10         5.60000          5.50354          0.09646
    11         5.80000          5.60541          0.19459
    12         5.80000          6.54136         -0.74136
    13         5.90000          6.54136         -0.64136
    14         6.20000          8.00805         -1.80805
    15         6.60000          7.42396         -0.82396
    16         6.70000          5.69914          1.00086
    17         6.80000          6.73719          0.06281
    18         7.10000          6.56926          0.53074
    19         7.40000          6.53038          0.86962
    20         7.50000          6.04048          1.45952
    21         7.80000          6.86479          0.93521
    22         8.00000          6.88222          1.11778
    23         8.80000          7.42396          1.37604
```

Table E-16A

61N MULTIPLE REGRESSION RESULTS

```
MULTIPLE REGRESSION.....DAY61N

    SELECTION...... 1


VARIABLE       MEAN          STANDARD         CORRELATION       REGRESSION      STD. ERROR      COMPUTED
  NO.                        DEVIATION          X VS Y          COEFFICIENT     OF REG.COEF.    T VALUE
   1        221.34782         8.99296         -0.15668          -0.03908         0.04411       -0.38589
   4        5[illegible]7.50464       341.44653          0.79040           0.00600         0.00116        5.16353
DEPENDENT
   3          8.12608         [illegible].75222


INTERCEPT                     13.37058

MULTIPLE CORRELATION           0.79931
(R SQUARED)*100               63.88997

STD. ERROR OF ESTIMATE         1.73458

                        ANALYSIS OF VARIANCE FOR THE REGRESSION

   SOURCE OF VARIATION        DEGREES       SUM OF          MEAN             F VALUE
                             OF FREEDOM     SQUARES         SQUARES
ATTRIBUTABLE TO REGRESSION       2         106.46890       53.23445         17.69313
DEVIATION FROM REGRESSION       20          60.17525        3.00876
     TOTAL                      22         166.64415

                        VARIABLES FOR THIS SELECTION
                        ----------------------------

                          DEPENDENT
                          ---------
                             3  -  SNOW DEPTH-WATER EQUIVALENT INCHES

                          INDEPENDENT
                          -----------
                            1  -  HORIZONTIAL ESMR TEMPERATURE
                            4  -  ELEVATION IN FEET AT SNOW LOCATION
```

Table E-16B

61N MULTIPLE REGRESSION RESIDUALS

```
MULTIPLE REGRESSION.....DAY61N

    SELECTION ..... 1

                    TABLE OF RESIDUALS

CASE NO.       Y VALUE        Y ESTIMATE         RESIDUAL
      1         2.90000          5.26013         -2.38013
      2         4.90000          5.38743         -0.48743
      3         5.50000          7.70770         -2.20770
      4         5.80000          5.54373          0.25626
      5         5.80000          8.45121         -2.65121
      6         6.00000          6.58717         -0.58717
      7         6.20000          6.03905          0.16095
      8         6.50000          7.53873         -1.03873
      9         6.90000          5.00934          1.89066
     10         7.00000          7.46691         -0.46691
     11         8.20000          8.03404          0.16596
     12         8.30000          8.00764          0.29236
     13         8.40000          8.90745         -0.50745
     14         8.40000          8.04672          0.35328
     15         8.50000          7.46057          1.03943
     16         8.70000          8.09952          0.60048
     17         8.70000         12.12858         -3.42858
     18         9.10000          8.77649          0.32351
     19        10.20000          7.98124          2.21876
     20        11.30000          7.92949          3.37051
     21        11.60000         12.12858         -0.52858
     22        13.70000         12.19406          1.50594
     23        14.30000         12.19406          2.10594
```

Table E-17A

61R MULTIPLE REGRESSION RESULTS

```
MULTIPLE REGRESSION.....DAY61R

    SELECTION..... 1


VARIABLE       MEAN        STANDARD        CORRELATION      REGRESSION      STD. ERROR      COMPUTED
  NO.                      DEVIATION         X VS Y         COEFFICIENT     OF REG.COEF.    T VALUE
   1       221.55554         9.96595        -0.61268        -0.01947         0.02429       -0.80163
   2       242.11110         9.41143        -0.75214        -0.03635         0.02918       -1.24560
   5        11.38889         7.14668        -0.50931        -0.05736         0.02949       -1.94497
   6        27.83333         6.85350        -0.85991        -0.22385         0.11220       -1.99510
   7        15.00000         6.13572        -0.79895         0.13053         0.11890        1.09780
DEPENDENT
   3         7.39444         1.50234


INTERCEPT                      25.43510

MULTIPLE CORRELATION            0.91739
(R SQUARED)*100                84.16075

STD. ERROR OF ESTIMATE          0.71165


                         ANALYSIS OF VARIANCE FOR THE REGRESSION

   SOURCE OF VARIATION          DEGREES        SUM OF           MEAN               F VALUE
                               OF FREEDOM      SQUARES          SQUARES
ATTRIBUTABLE TO REGRESSION          5         32.29193          6.45839           12.75222
DEVIATION FROM REGRESSION          12          6.07742          0.50645
     TOTAL                         17         38.36935


                         VARIABLES FOR THIS SELECTION
                         ----------------------------

                           DEPENDENT
                           ---------
                              3  -  SNOW DEPTH-WATER EQUIVALENT INCHES

                           INDEPENDENT
                           -----------
                             1  -  HORIZONTIAL ESMR TEMPERATURE
                             2  -  VERTICAL ESMR TEMPERATURE
                             5  -  AVERAGE PRECIPITATION FOR DAYS -1 AND -2
                             6  -  MAXIMUM TEMPERATURE DAY -1
                             7  -  MINIMUM TEMPERATURE DAY 0
```

Table E-17B

61R MULTIPLE REGRESSION RESIDUALS

```
MULTIPLE REGRESSION.....DAY61R

     SELECTION..... 1

                    TABLE OF RESIDUALS

CASE NO.        Y VALUE        Y ESTIMATE        RESIDUAL
     1          4.90000          5.87498        -0.97498
     2          5.50000          6.53596        -1.03596
     3          5.80000          5.86523        -0.06524
     4          5.80000          5.90473        -0.10473
     5          6.00000          5.81762         0.18238
     6          6.20000          6.93172        -0.73172
     7          6.50000          6.56588        -0.06588
     8          6.90000          5.74838         1.15162
     9          7.00000          6.14002         0.85998
    10          8.20000          7.99570         0.20430
    11          8.30000          8.51985        -0.21986
    12          8.40000          8.51985        -0.11985
    13          8.40000          7.96929         0.43071
    14          8.50000          8.73463        -0.23463
    15          8.70000          9.09611        -0.39611
    16          8.70000          7.91025         0.78975
    17          9.10000          9.26515        -0.16515
    18         10.20000          9.70421         0.49579
```

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Table E-18A

61R MULTIPLE REGRESSION RESULTS, WITHOUT PRECIPITATION

```
MULTIPLE REGRESSION.....DAY61R

    SELECTION..... 2


VARIABLE      MEAN        STANDARD        CORRELATION       REGRESSION      STD. ERROR      COMPUTED
  NO.                     DEVIATION         X VS Y          COEFFICIENT     OF REG.COEF.    T VALUE
   1       221.55554       9.96595        -0.61268          -0.02303         0.02424       -0.95016
   6        27.83333       6.85350        -0.85991          -0.24395         0.11597       -2.10350
   7        15.00000       6.13572        -0.79855           0.08646         0.12320        0.70178
DEPENDENT
   3         7.39444       1.50234


INTERCEPT                       17.99057

MULTIPLE CORRELATION             0.87662
(R SQUARED)*100                 76.84711

STD. ERROR OF ESTIMATE           0.79658


                     ANALYSIS OF VARIANCE FOR THE REGRESSION

   SOURCE OF VARIATION        DEGREES        SUM OF          MEAN           F VALUE
                             OF FREEDOM     SQUARES         SQUARES
ATTRIBUTABLE TO REGRESSION       3          29.48573        9.82858         15.48919
DEVIATION FROM REGRESSION       14           8.88362        0.63454
     TOTAL                      17          38.36935


                     VARIABLES FOR THIS SELECTION
                     ----------------------------

                      DEPENDENT
                      ---------
                        3 -  SNOW DEPTH-WATER EQUIVALENT INCHES

                      INDEPENDENT
                      -----------
                        1  -  HORIZONTIAL ESMR TEMPERATURE
                        6  -  MAXIMUM TEMPERATURE DAY -1
                        7  -  MINIMUM TEMPERATURE DAY 0
```

Table E-18B

61R MULTIPLE REGRESSION RESIDUALS, WITHOUT PRECIPITATION

```
MULTIPLE REGRESSION.....DAY61R

    SELECTION..... 2


                    TABLE OF RESIDUALS

CASE NO.      Y VALUE      Y ESTIMATE       RESIDUAL
    1         4.90000        5.85521        -0.95521
    2         5.50000        7.03990        -1.53990
    3         5.80000        5.78985         0.01015
    4         5.80000        6.17573        -0.37574
    5         6.00000        5.85521         0.14479
    6         6.20000        7.25140        -1.05140
    7         6.50000        6.72332        -0.22332
    8         6.90000        5.65165         1.24835
    9         7.00000        6.32168         0.67832
   10         8.20000        7.83904         0.36096
   11         8.30000        7.61426         0.68574
   12         8.40000        7.61426         0.78574
   13         8.40000        7.93685         0.46315
   14         8.50000        8.86671        -0.36671
   15         8.70000        8.80329        -0.10329
   16         8.70000        8.52856         0.17144
   17         9.10000        9.63848        -0.53848
   18        10.20000        9.59435         0.60565
```

Appendix F

METEOROLOGICAL DATA FOR SELECTED STATIONS

This appendix presents daily data for precipitation, maximum temperature, minimum temperature and hours of bright sunshine for selected reporting stations in the analysis area for Sites 1 and 2. The stations were selected to provide data distributed over the analysis area and to include as many stations as possible reporting hours of bright sunshine.

Table F-1 gives the station names, an identification mnemonic (ID) for each station, and the latitude and longitude of each station. Figure F-1 is a plot of the stations for Site 1. Figure F-2 is a plot of the stations for Site 2.

In the meteorological data tables, the station ID is given, the type data, and the day of the month. The analysis observation day is shown by a double underline. Data is always given for five preceding the analysis day and one day after. The abbreviations of Prec., Max. T., Min. T., and Hrs Sun indicate total precipitation for the day in hundreths of inches of water, the maximum temperature for the day in degrees Fahrenheit, the minimum temperature for the day in degrees Fahrenheit, and hours of bright sunshine. Table F-2 gives February meteorological data appropriate to Site 1. Table F-3 gives the January meteorological data appropriate to Site 2. Table F-4 gives the meteorological data for late January and early February appropriate to Site 2. Table F-5 gives meteorological data for late February and early March appropriate to Site 2.

Table F-1

LOCATION OF SELECTED WEATHER STATIONS

Name	ID	Latitude	Longitude
<u>Site 1</u>			
Brandon CDA, Manitoba	BN	49.87	99.97
Dauphin A, Manitoba	DN	51.10	100.05
Ericksdale, Manitoba	EE	50.87	98.17
Harding, Manitoba	HG	50.03	100.50
Morden CDA, Manitoba	MN	49.19	98.08
Pine River, Manitoba	PR	51.77	100.32
Wasagaming, Manitoba	WG	50.65	99.97
Winnipeg International A, Manitoba	WP	49.54	97.14
<u>Site 2</u>			
Aroostook, New Brunswick	AK	46.78	67.73
Canterbury, New Brunswick	CY	45.88	67.45
Edmundston Frasier Co, N.B.	EF	47.37	68.33
Fredericton CDA, N.B.	FN	45.87	66.53
Little River Mine, N.B.	LR	47.28	66.07
Caribou WSO AP, Maine	CU	46.87	68.02
Houlton FAA AP, Maine	HN	46.13	67.83

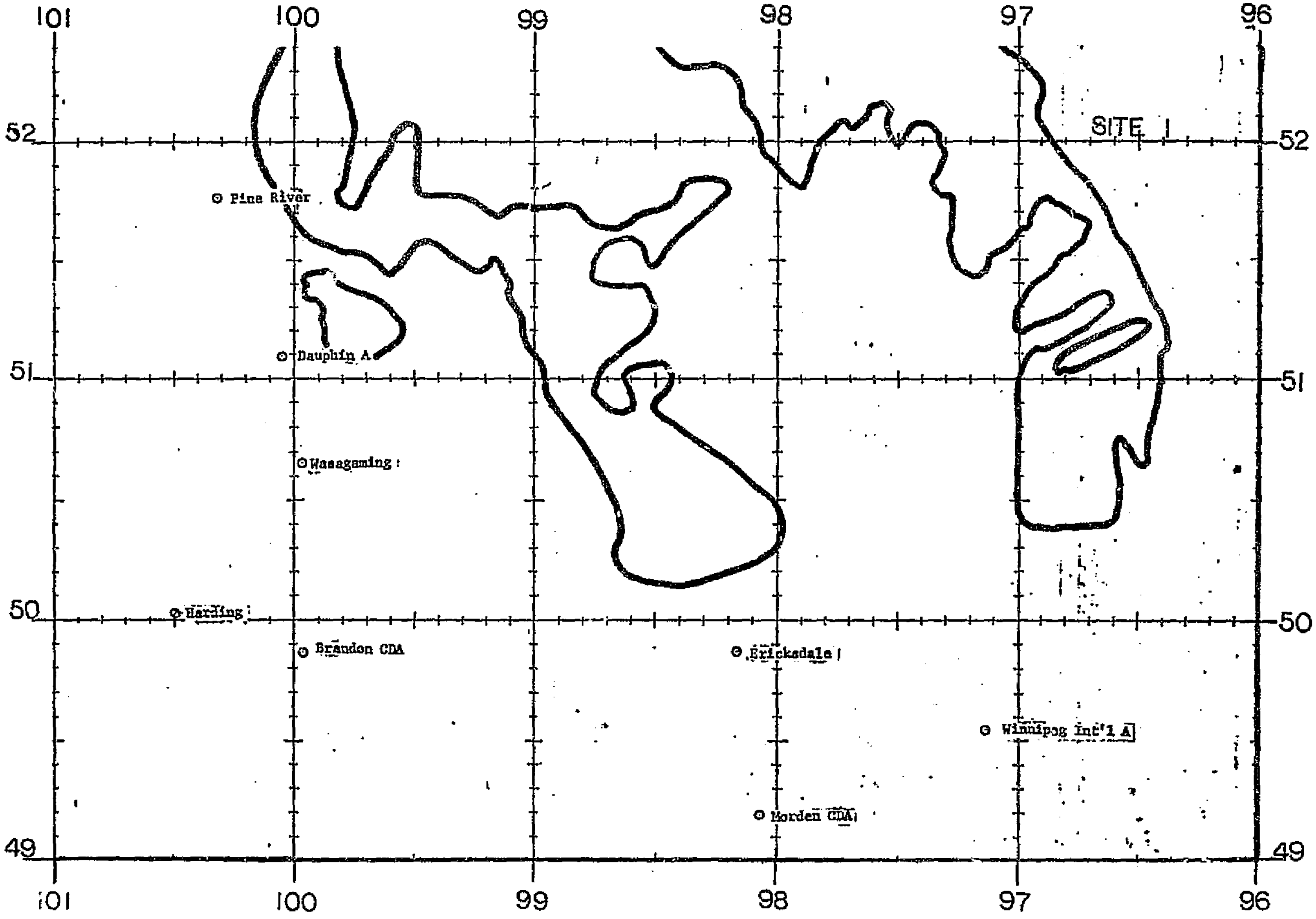

Figure F-1. Site 1 Meteorological Stations

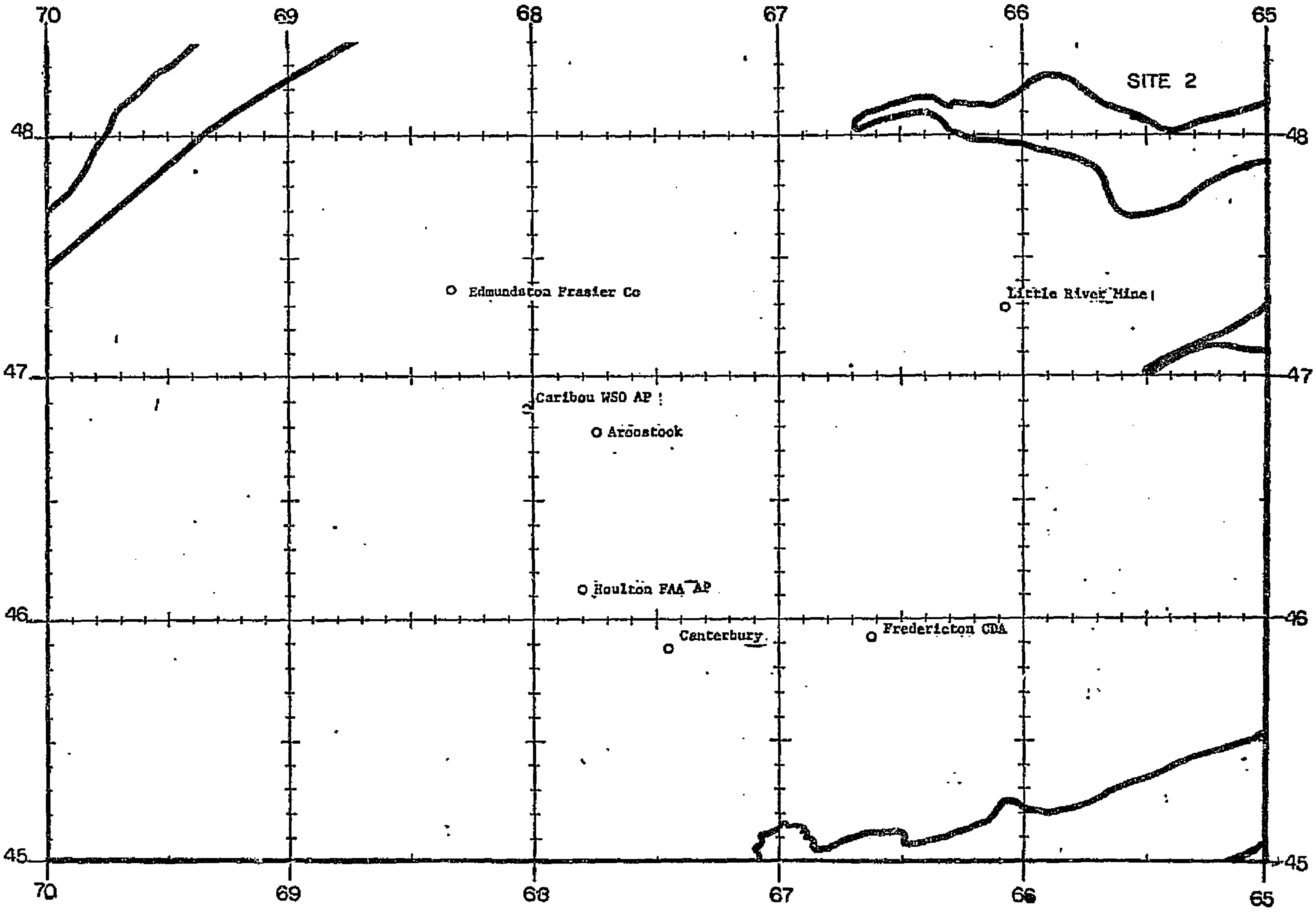

Figure F-2. Site 2 Meteorological Stations

Table F-2

SITE 1, FEBRUARY, METEOROLOGICAL DATA FOR SELECTED STATIONS

Station (Mnemonic)	Data for	2/5	2/6	2/7	2/8	2/9	2/10	2/11	2/12	2/13
BN	Prec.	0	0	0	0	0	6	0	0	0
DN	Prec.	T	0	0	0	0	16	T	6	0
EE	Prec.	0	0	0	0	0	15	T	10	0
HG	Prec.	0	0	0	0	0	T	T	0	T
MN	Prec.	0	0	0	0	0	3	T	0	0
PR	Prec.	0	0	0	0	2	9	3	1	6
WG	Prec.	0	0	0	0	0	22	3	15	9
WP	Prec.	0	0	0	0	0	22	T	T	0
BN	Max. T.	4	32	36	42	42	12	21	21	36
DN	Max. T.	10	32	39	45	45	21	16	17	14
EE	Max. T.	9	26	36	39	44	4	12	17	24
HG	Max. T.	5	31	34	40	39	17	21	20	29
MN	Max. T.	9	33	38	41	41	17	27	31	27
PR	Max. T.	11	36	40	44	44	4	15	18	16
WG	Max. T.	5	29	35	38	40	12	12	19	22
WP	Max. T.	6	14	35	31	42	28	17	17	16
BN	Min. T.	-30	-9	6	15	21	3	-16	3	-4
DN	Min. T.	-10	0	25	23	21	-12	-14	0	5
EE	Min. T.	-26	-25	-6	5	20	4	-26	-12	-8
HG	Min. T.	-28	-20	-15	13	20	6	-18	4	-9
MN	Min. T.	-14	-1	10	20	36	4	-14	11	8
PR	Min. T.	-17	6	18	33	34	-4	-20	1	-2
WG	Min. T.	-38	-38	-19	10	20	5	-27	0	-10
WP	Min. T.	-22	1	12	15	28	-12	-13	-1	-1
BN	Hrs Sun	7.8	8.1	7.9	2.9	6.6	2.4	2.1	5.2	7.3
DN	Hrs Sun	6.1	8.3	6.5	0.0	8.5	3.3	0.3	6.2	8.2
MN	Hrs Sun	8.3	7.9	7.2	3.1	5.5	2.4	1.7	3.0	7.9
WP	Hrs Sun	8.5	8.0	3.4	0.5	7.0	1.8	0.6	3.7	7.7

Table F-3

SITE 2, JANUARY, METEOROLOGICAL DATA FOR SELECTED STATIONS

Station (Mnemonic)	Data for	1/1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9
AK	Prec.	T	5	85	T	0	0	5	5	T
CY	Prec.	6	10	52	0	0	0	34	4	4
EF	Prec.	0	5	45	10	0	0	T	0	0
FN	Prec.	8	0	51	T	T	0	4	37	0
LR	Prec.	30	20	40	T	0	0	T	T	0
CU	Prec.	2	0	49	0	0	0	0	4	0
HN	Prec.	0	0	52	2	0	0	0	6	0
AK	Max. T.	22	17	24	26	5	16	27	15	-2
CY	Max. T.	25	21	28	30	6	20	32	25	9
EF	Max. T.	21	16	23	24	3	8	27	8	-1
FN	Max. T.	27	27	32	30	12	19	36	29	10
LR	Max. T.	20	22	17	23	4	18	23	23	1
CU	Max. T.	22	18	25	26	8	20	24	25	-4
HN	Max. T.	30	20	25	25	17	11	25	25	6
AK	Min. T.	0	1	-1	12	-2	-22	12	4	-29
CY	Min. T.	14	9	-1	21	-3	-20	8	2	-22
EF	Min. T.	9	7	2	16	-5	-17	12	0	-26
FN	Min. T.	16	6	4	11	-3	-9	-2	-1	-12
LR	Min. T.	7	13	1	11	0	-7	-1	16	12
CU	Min. T.	8	4	4	8	-11	-13	9	-11	-25
HN	Min. T.	16	6	2	17	-4	-15	9	0	-22
FN	Hrs Sun	6.7	5.9	0.0	2.3	7.6	6.9	0.1	0.0	6.6

Table F-4

SITE 2, JAN.-FEB. METEOROLOGICAL DATA FOR SELECTED STATIONS

Station (Mnemonic)	Data for	1/29	1/30	1/31	2/1	2/2	2/3	2/4
AK	Prec.	0	0	0	68	85	T	T
CY	Prec.	0	0	0	137	37	0	0
EF	Prec.	5	0	0	50	43	0	22
FN	Prec.	2	0	T	1	189	T	1
LR	Prec.	T	0	0	87	58	0	T
CU	Prec.	0	0	0	12	100	T	0
HN	Prec.	2	T	0	2	56	0	T
AK	Max. T.	29	11	3	42	56	18	23
CY	Max. T.	28	20	17	55	51	21	26
EF	Max. T.	26	6	7	36	49	16	22
FN	Max. T.	31	27	16	36	56	24	28
LR	Max. T.	24	13	13	41	50	14	23
CU	Max. T.	28	21	5	34	49	17	22
HN	Max. T.	35	30	10	35	51	20	25
AK	Min. T.	16	5	-10	0	6	-6	4
CY	Min. T.	19	7	-3	-1	9	-5	8
EF	Min. T.	16	0	-15	-2	17	-8	2
FN	Min. T.	21	9	3	4	0	2	10
LR	Min. T.	15	11	-7	-2	5	-8	-1
CU	Min. T.	13	-1	-9	4	-7	-3	8
HN	Min. T.	16	6	-7	6	10	-4	12
FN	Hrs. Sun	1.8	5.4	8.1	0.1	0.0	6.7	1.2

Table F-5

SITE 2, FEB.-MARCH METEOROLOGICAL DATA FOR SELECTED STATIONS

Station (Mnemonic)	Data for	2/25	2/26	2/27	2/28	2/29	3/1	3/2
AK	Prec.	0	0	10	0	10	0	0
CY	Prec.	0	0	5	0	38	0	0
EF	Prec.	0	1	20	0	19	0	0
FN	Prec.	0	0	2	T	25	T	0
LR	Prec.	0	0	12	0	35	0	0
CU	Prec.	0	0	8	0	17	0	0
HN	Prec.	0	0	10	0	15	0	0
AK	Max. T.	43	44	39	19	28	21	11
CY	Max. T.	46	43	46	24	31	27	13
EF	Max. T.	39	46	39	19	22	20	15
FN	Max. T.	43	40	48	27	37	36	14
LR	Max. T.	31	46	47	18	27	20	12
CU	Max. T.	39	42	42	22	27	26	11
HN	Max. T.	48	46	46	23	36	35	12
AK	Min. T.	14	22	35	13	-7	17	-10
CY	Min. T.	4	26	34	18	-1	18	-1
EF	Min. T.	10	26	32	7	-5	11	-5
FN	Min. T.	20	23	27	9	6	7	0
LR	Min. T.	0	18	22	6	2	5	-6
CU	Min. T.	18	30	22	2	0	-4	-7
HN	Min. T.	12	28	23	3	-5	0	-4
FN	Hrs Sun	9.8	0.5	2.4	1.3	1.8	5.2	0.0

APPENDIX G

SITE 2 LAND USE AND TOPOGRAPHY

Plots of snow water equivalent values in conjunction with land use are given in Figures G-1, G-2 and G-3 for data sets 6D, 34N and 61R. The land within the dashed lines and with slight shading is used for agricultural purposes. Land outside the dashed lines is primarily forest. The land use data were taken from maps given in Reference 26. For New Brunswick, Canada, the land within the dashed lines is used for the following: cereals, livestock; dairy; potatoes; general framing, livestock; and pasture, livestock. For Maine, the land within the dashed lines is used for the following: dairy, poultry, mixed farming; dairy, general farming; and potatoes, general farming.

Figure G-4 shows the major physiographic divisions and topography for the Saint John Basin. This figure was taken directly from Figure 3-1 of Reference 27.

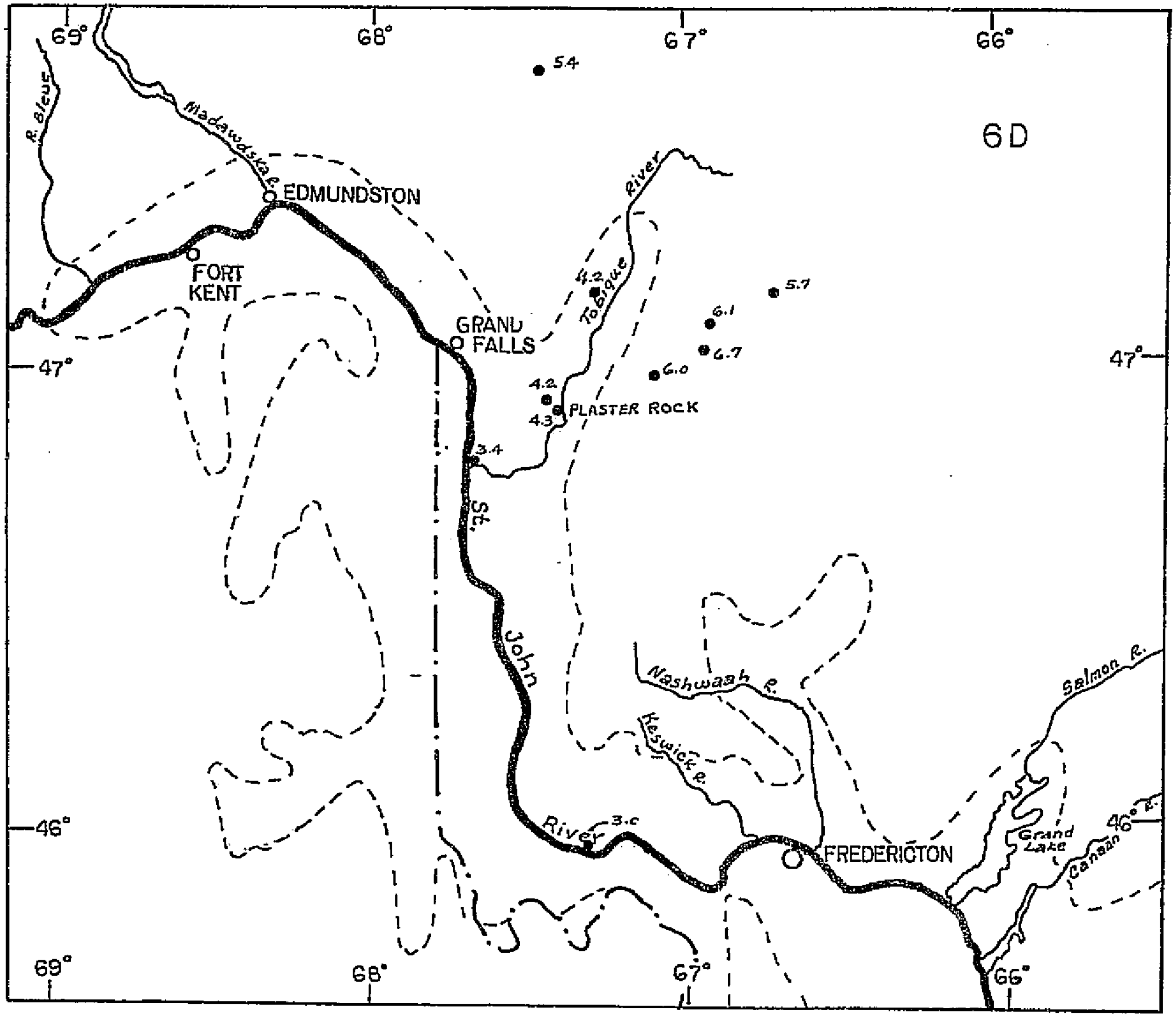

Figure G-1. Snow Water Equivalent (Inches) for 6D with Agricultural Land Use Outlined

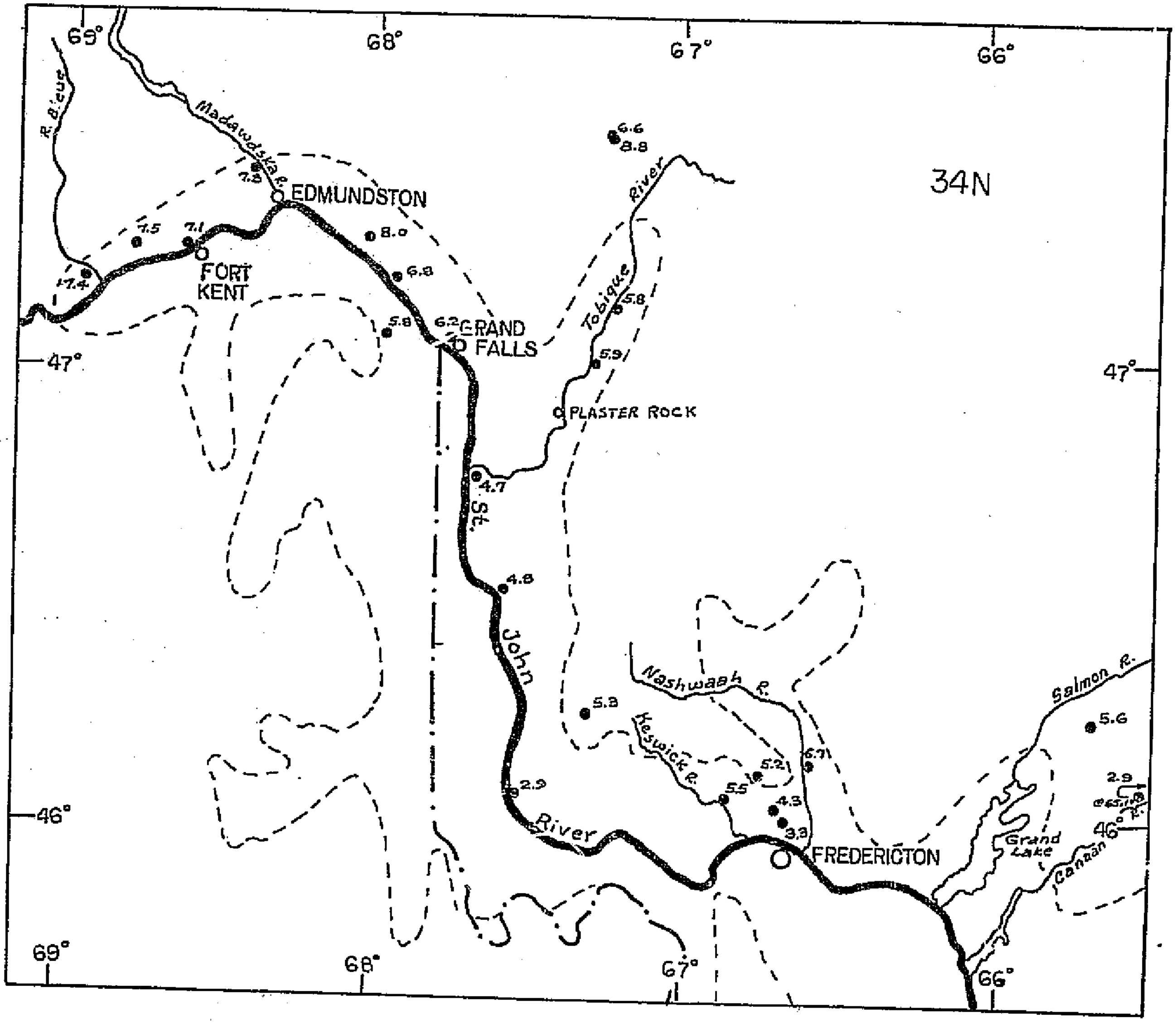

Figure G-2. Snow Water Equivalent (Inches) for 34N with Agricultural Land Outlined

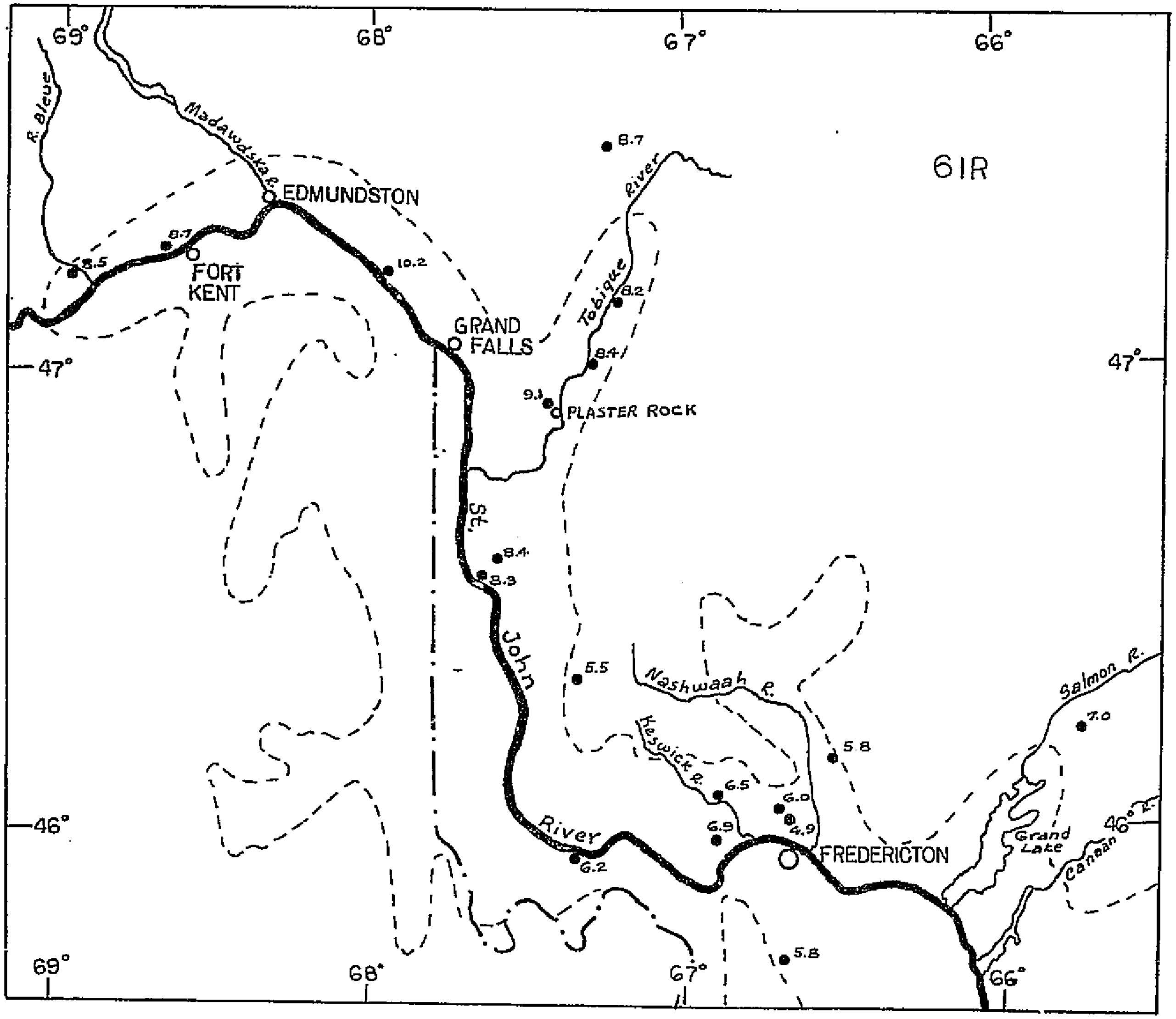

Figure G-3. Snow Water Equivalent (Inches) for 61R with Agricultural Land Outlined

C-3

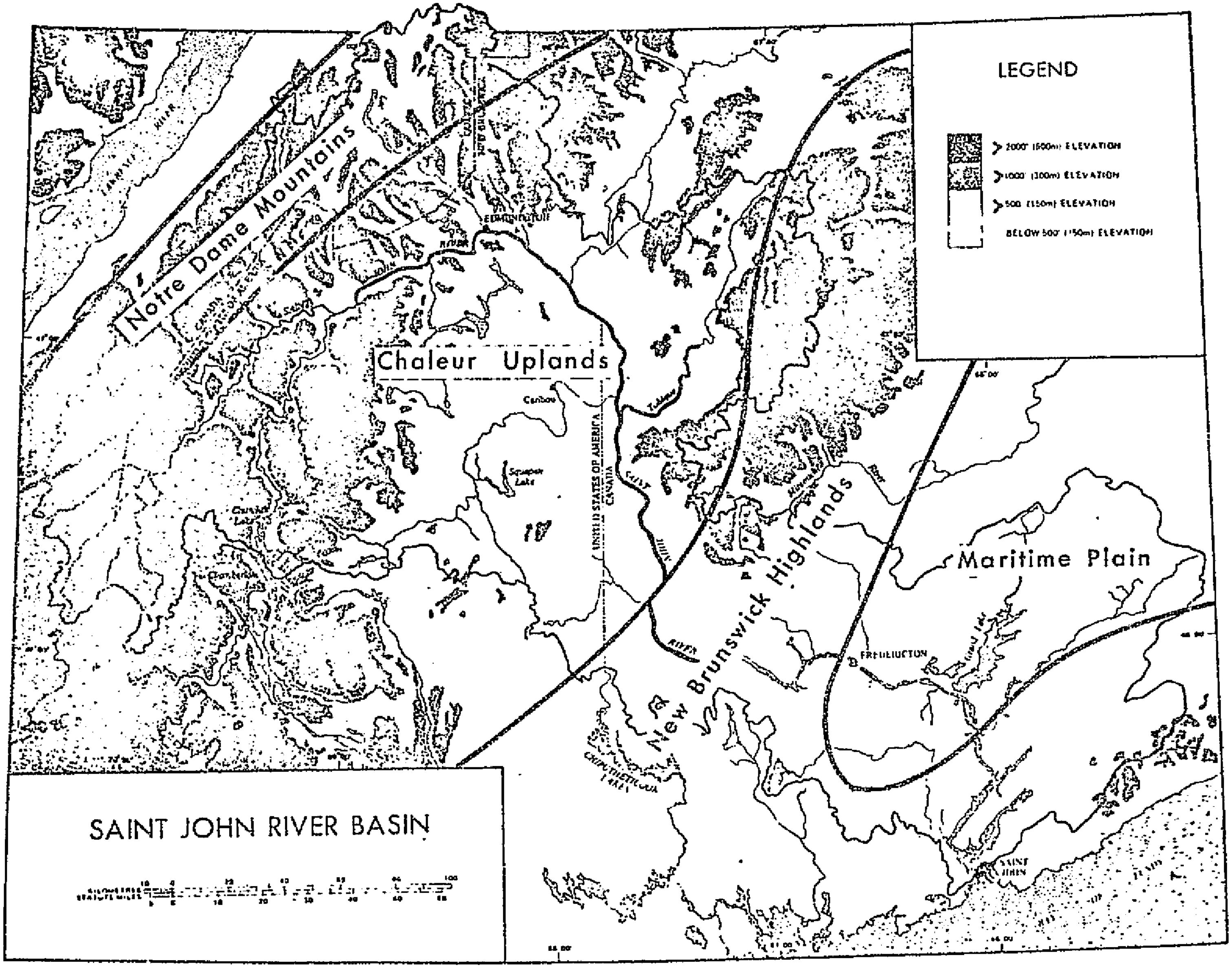

Figure G-4. Topography of the Saint John Basin