COMMENTS ON THE "SUMMARY REPORT REGARDING LOW CEILINGS AND LIMITED VISIBILITY AT AIRPORT SITES NEAR MINNEAPOLIS-ST PAUL, MINNESOTA"

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ABSTRACT

A Summary Report prepared for the Metropolitan Airport Commission (MAC) by L. W. Crow to provide information concerning low ceilings and visibility at two prospective airport sites, Ham Lake and Farmington, is reviewed. The Crow report presented no observational evidence to indicate the frequency of fog and low ceilings at either of the two prospective airport sites, except for inferences that might be drawn from temperature data. The only comparative observational data given in the Crow report was temperature information, and Crow did not state any direct conclusion from these data. A conclusion was apparently precluded by errors of fact concerning station elevations above se sea level and by not taking into account the local environment of each of the shelters from which the temperature data were taken. A statement is presented, however, which says that the two temperature stations closest to the two prospective airport sites have the coldest minimum temperatures of eleven area stations. Errors in elevation plagued the Crow report, even concerning the elevations of the two prospective airport sites. Crow concluded that low ceilings would be more common at Farmington than at Ham Lake, because the elevation at Farmington is supposedly higher than at Ham Lake, but examination of topographic maps shows that the elevations at the two sites are virtually identical. In addition to comment on the Crow report, description of the environment of the ESSA cooperative temperature observing sites is made herein, their correct elevations are stated, and relationships between the observed data and micrometeorological theory is given. When this is done, it is seen that the ESSA cooperative temperature stations do show variability of climate in the Metropolitan Area which conforms to physical laws.

PURPOSE

The purpose of this paper is to comment on the "Summary Report Regarding Low Ceilings and Limited Visibility at Airport Sites near Minneapolis-St. Paul Minnesota," prepared for the Minneapolis-St. Paul Airports Commission by Loren W. Crow, Certified Consulting Meteorologist, dated 27 February 1970.

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I. INTRODUCTION

The purpose of the Crow report, as would appear from the title, was to provide information concerning low ceilings and limited visibility at airport sites in the Twin Cities Metropolitan Area. Further purpose appears in the Introduction, where it is stated that the "report contains a summary of findings made in an independent investigation of the climatic data and frequencies of low ceilings in the Minneapolis-St. Paul area."

The Crow report gives seven pages of data on low ceilings and visibilities at Wold-Chamberlain field, but gives no data concerning low ceilings and visibilities for any other site in the area. Crow examined the climatological data for eleven United States Weather Bureau climatological stations that keep records of temperature and precipitation. There is no other data, except for these temperatures, which leads to any conclusion regarding what the frequency of fog or low ceiling might be at either of the two prospective airport sites mentioned in the report, Ham Lake and Farmington. There are also errors of fact concerning the altitudes of the cooperative stations, and of the two prospective airport sites themselves, which alter conclusions that must be made concerning the evaluation of the two airport sites meteorologically, and their relation to Wold-Chamberlain field.

Examining the body of the report, we find five sections. The first part gives a review of the Twin Cities climate, the second locates the cooperative stations and prospective airport sites, the third describes flying weather, ceiling heights, and visibility at Wold-Chamberlain, the fourth is titled "Comparative Fog Frequency", and the fifth describes how fog might be dispersed. Only the fourth section suggests actual comparison between sites.

Let us then examine in detail the contents of the five sections, and the Introduction and the Summary.

2. COMMENTS ON "REVIEW OF CLIMATIC CONDITIONS"

This section is comprised of a description of the Metropolitan Area climate made by Wallace, McHarg, Roberts, and Todd in an ecological study in June 1969. Crow states that he endorses the description as a "good climatic summary."

The summary contains some deficiencies that deserve comment.

The authors state that "the available data (underlining mine) on climate at a gross statewide scale do not reveal any marked variability within the metropolitan area." Available data do, however, show considerable variability in the Metropolitan Area, although they do not show some of the more dramatic features that must exist because of the way in which climatological stations are sited, that is, to avoid the influences of the topography where desirable. The publication, "Instructions for Climatological Observers, Circular B, Eleventh Edition, Revised January 1962," states "The ground over which the shelter is located should be, in general, representitive of the surrounding area. A level open space or clearing is desirable so that the thermometers are ventilated insofar as possible by an unobstructed flow of air. An installation on a steep slope or sheltered hollow is to be avoided, unless the site is representitive of the area, or data from the particular site is desired." In looking at the particular climatological stations in the Metropolitan Area, we find that the location of the stations avoid extremities of low spots, and that they in general conform to the instructions of the Circular.

However, note of the variations in the microclimate of the Metropolitan Area date back to the first half of the nineteenth century. Ludlum(1968) writes " In considering the readings of the post (Ft. Snelling) thermometer, its location within a stockade which was situated on a steep bluff some hundred feet above the juncture of the St. Peters (Minnesota) and Mississippi Rivers should be weighed. Air drainage on calm nights, of course, would play an important role in modifying temperatures in such a location. This was realized by Surgeon B. F. Harney writing in his 1826 notes: 'Thermometer two miles from post on several occasions reads 10 to 11 lower - compared and found to agree - believe the fort with its 60 fires responsible.' Here was an early recognition of the effect of the "heat island" created by the concentration of open fireplaces in the compound. The same temperature differential between nearby localities was again pointed out in 1849 by E. S. Seymour in his Sketches of Minnesota: 'Mr. Prescott's thermometer, at his house

near Ft. Snelling, ranges 2 to 7 degrees lower than the one at the fort, the difference increasing with the intensity of the cold. On the morning of 18 February 1849, the Ft. Snelling instrument read -30, Mr. Prescott's -37, and that of Dr. Williamson, who lived on a level with the Mississippi River, -40."

Thus the effects of the heat island and the effects of air drainage in the Metropolitan Area were recognized over 120 and 140 years ago.

The authors give various general statistics on temperature and rainfall in the Metropolitan Area. They apparently did not examine the many available weather records, for they give 110 degrees and -37 degrees as the temperature extremes for the Metropolitan Area. However, the United States Weather Bureau recorded a temperature of -41 degrees in St. Paul in January 1888. In describing extreme snowfall, they give 35 inches as the greatest amount for one month. But March 1950 had a total of 40 inches. Their failure to note these true extremes of temperature and snowfall indicate that their investigation of the climate of the area was less than thorough.

The authors make an error of fact in the statement "tornadoes generally sweep in from the southwest, although such a path is not entirely reliable because of surface obstructions such as windbreaks which may, among other things, cause a tornado to frequently change course." The fact is that the direction of tornado movement is principally governed by the windflow in the layer in which it is imbedded. A tornado occurring in a southwest wind will move from the southwest; a tornado occurring in a northeast wind will move from the northeast.

They state that fog is most likely in October and December. Data presented elsewhere in the Crow report indicate otherwise, as does the data which I have.

The oft-made statement that inversions are rare in the Metropolitan Area is made by the authors once again. Located in interior North America, the Metropolitan Area has inversions rather frequently; often these inversions are quite deep. I have not been able yet to pin down the reason for the impression that inversions are rare in this area, but it may come about from temperature studies made on a local television tower about 500 feet high; over such a depth, inversions are not apparently found frequently. Were the tower higher, it would be found that inversions are not comparitively rare in this Metropolitan Area.

In their statement entitled "Variations in the Metropolitan Area," the authors remark that "because of only slight climatic variations within the metropolitan area, it is difficult to discern climatic zones." In the beginning of this entire discussion on climate, they stated that the available data did not reveal marked variability. There is a big difference between data not indicating variability and the variability not existing. Thus the comment that there is no variability or that variability is slight cannot be supported by the evidence, which is here lacking.

The authors further state: "As would be expected, there is a minor temperature gradient from north to south with cooler temperatures in the north and warmer temperatures in the south." This is true over Minnesota as a whole, but Baker and Strub (1965) present very fine maps showing that the equator-to-pole temperature gradient at the surface is interrupted and reversed over eastern Minnesota between the general region of Olmstead County and the Twin City area. It is cooler to the north of the metropolitan area, but it is also cooler to the south, in some months to the Iowa border.

Looking over this section of the report, there is a danger that the reader is left with the impression that there is no marked variability in the microclimate of the Metropolitan Area. Evidences of the variability come from the notes made by early settlers near Ft. Snelling, from the physical laws which the atmosphere must obey relative to the topography, and from observations such as the fog appearing over the Mississippi and Minnesota Rivers just to the east and northeast of the Wold-Chamberlain - Ft. Snelling complex. I myself live on a ridge where fog is quite rare, since the air drainage is away from my house, and the area is residential, free from any important moisture sources. On numerous occasions, I have driven a few miles away to find very heavy fog caused by radiation phenomena.

3. COMMENTS ON "IDENTIFICATION OF AREA"

This section points out the location of the eleven climatic stations and the two proposed airport sites. The Forest Lake station is incorrectly located. Its true location is in a wooded area on a ridge on the far southeastern shore of the lake of Forest Lake, not in town as shown on the map. The St. Paul copperative station is also located incorrectly. Its true location is on 707 East Montana, in the north part of the city near the Maplewood line.

4. COMMENTS ON "FREQUENCY OF FLYING WEATHER, CEILING HEIGHTS, AND VISIBILITY AT MINNEAPOLIS, MINNESOTA WBAS

This section of the Crow report mainly concentrates on presenting weather statistics from Wold-Chamberlain field. Commentary also is made on the information.

A picture is presented showing ground fog at Ham Lake at 0757 (three minutes before eight o'clock in the morning). Interestingly, at Wold Chamberlain at this time, on the same date, October 26, 1968, the visibility was 7 miles, with patches of ground fog on the field. It would appear from the picture that the Ham Lake visibility is very low, the fog being much more than mere patches.

The author states that "absorbtion of heat during the previous day permits that limited area (the runways and/or black top parking aprons) to be one to four degrees warmer than areas which have absorbed less solar radiation." We might note that at Ham Lake, the warmth of the runway can help draw fog out of the adjacent swamps and forests, in a way similar to the land-and-sea breeze fog phenomenon of the coastal United States.

Crow notes that "in the fall months the peak time for low visibility is 8:00 a.m." and that "almost all of the low visibility in the summer takes place prior to 8:00 a. m." But note that eight o'clock in the morning STANDARD TIME becomes nine o'clock in the morning on DAYLIGHT SAVINGS TIME. Thus for the summer months through nearly all of October, airline schedules should be examined in light of traffic to nine o'clock, not eight o'clock. We might also note that departures before nine o'clock in the morning are perhaps more critical, for a large share of this traffic is composed of business people who have morning appointments in Chicago, Detroit, Milwaukee, and elsewhere. A delay to them can result in lost business. Daytime delays to vacationers, travelers, etc. might be less damaging economically to the individual.

5. COMMENTS ON "COMPARATIVE FOG FREQUENCY"

In the first paragraph Crow notes that "small local differences can be important when the air mass is near saturation throughout the general area". We might note here that the general vicinity of Ham Lake is largely swamp and lake, rich moisture sources.

Crow's comments on the tunnel in the fog are interesting. They are a good illustration of the effect that small differences can make in the microclimate. This recalls to mind past attempts to eliminate fog by thermal and mechanical means at some airports. Large fires have been used in some instances to destroy airport fog, although the pollution generated by them perhaps is objectionable. Less successful means have included fans, which apparently are next to useless.

The low temperature minima at Forest Lake is interesting. The shelter stands on a high ridge on the southeast edge of the lake. The ridge is forested. Thus, especially on hot days with southwest winds, the shelter is not subject to a hot layer of air which forms at most sites the first few meters above the ground.

Crow notes that Rosemount, Cedar and Farmington 1W (the station one mile west of Farmington) have slightly cooler minimum temperature averages than the rest. Cedar is located about a mile from Ham Lake Township, and is in the same swamp-forest-lake-flatland setting that is Ham Lake Township and its environs. Farmington 1W is in the same valley region that is the proposed Farmington site. Examination of the stations and the two airport sites indicates that the two stations represent fairly well, if not very well, the temperature climate of the two airport sites. In the same air mass, we would expect fog to form most favorably at those locations where the minimum temperatures are the lowest, since the dew point would there be approached more frequently. Of course, other factors must also be considered in addition to temperature. Ham Lake would not only have the low temperatures, but also more available moisture.

Crow notes that Stillwater, St. Paul, Maple Plain, and Buffalo have the warmest temperature minima. Stillwater station is located on the slope of the hill west of the St. Croix River. The shelter is just below Highway 95 and a railroad embankment, about 35 feet and three-tenths of a mile from the river. Geiger (1950) notes "Where a railroad embankment crosses a gently inclined plain at right angles to the slope, the adjacent area above it where the air is dammed up is usually colder and more subject to frost than on the down-slope side where the air cooled by radiation is free to flow on down and make room for warmer air from above." He further states " We speak therefore of a warm slope (thermal belt)." Stillwater station furnishes an excellent example of a station in the thermal belt of a warm slope. The St. Paul station, located in the city, furnishes an example of the metropolitan heat island. Maple Plain and Buffalo are located on high ground in

the rugged countryside west of the Twin Cities. Both sites are on ground well above the general area, and inspection shows them to be free of air drainage effects. They are good illustrations of the warmth of ridges over valleys in the early morning.

Crow does not point out these micrometeorological points, which seem to show the effects of the topography on temperature variability in the Metropolitan area. His difficulty may stem from being mistaken on the altitudes of the stations. The altitude of the Stillwater station is 710 feet, not 650 feet as indicated by Crow on page 15. Also, Crow states that Cedar is 40 feet lower than Stillwater. However, Cedar is 200 feet HIGHER than the Stillwater station. Cedar, being located on the flatland of the forest-lake-swamp region north of the Twin Cities, would of course be expected to be cooler than the Stillwater site, with its warm slope environment. We would also expect Cedar to be cooler than Maple Plain in its temperature minima since Maple Plain is on the warm ridge.

In the paragraph on detailed records of minimum temperatures coincident with early-morning fog conditions at Wold-Chamberlain field, Crow again states that Cedar and Farmington 1W show up as the coldest. He does not state how much cooler; and examination of climatological data by myself reveals that differences of 4 and 5 degrees exist on calm, clear nights. Up to this point, we might note that Crow has mentioned the coolness of Cedar three times, and the coolness of Farmington twice. And here we are speaking of fog conditions, where Cedar and Farmington run colder than any station, including Wold-Chamberlain. Thus the temperature evidence itself would indicate that Cedar and Farmington would be the most fog-prone stations in the Metropolitan Area. Again, we must note that Farmington is located in a dry-surfaced, farming area while Cedar is located in the swampy lake-forest regime north of the Twin Cities. In the last part of this paragraph, Crow states that "Although Forest Lake has a low elevation, it does not have the lowest temperatures." But the fact is that only four of the eleven stations are higher than the Forest Lake station; in fact Forest Lake is higher than both Cedar and Farmington 1W. Not only is it one of the highest in absolute elevation; it is on the most sharp ridge of any of the eleven. Thus, we would not expect it to have the lowest temperatures.

But here the temperature discussion ends, with no conclusion stated. I can only surmise that the mixup in station altitudes precluded the making of a conclusion. Only Maple Plain, the highest of the eleven stations, was identified at its proper altitude with respect to all of the

others, and the relative location of each of the stations with its surroundings was never stated. But upon reassembling the stations to their proper altitude, and considering their relative location to their surroundings, we find that the temperature values as observed beautifully match micrometeorological theory, and we define variations in the climate of the Metropolitan Area.

Cedar and Farmington 1W, the two coldest stations, illustrate the temperature regime to be found on flat ground where the urban heat island does not exist. Farmington, in the flat, dry plain of the Vermillion River Valley (the Vermillion River, incidentally, is but two or three yards wide) presents an excellent example of the effects of air drainage. The station one mile west of Farmington runs about 4 or 5 degrees cooler in its temperature minima on clear, calm mornings than does the station three miles northwest of Farmington. The station three miles northwest of Farmington is on a gentle ridge at about 980 feet above sea level, or about 65 feet higher than the station one mile west of Farmington. Here we have two stations in close proximity, and we clearly see the effects of cold air drainage. Cedar, which has its minimum temperatures very close to that of the station one mile west of Farmington, is also on flat ground, from which air cannot drain away. Here we get a cold buildup of air at night. Stillwater indicates the warmth of the slope, and Maple Plain the warmth of the ridge. Wold-Chamberlain, adjacent to Ft. Snelling on the high bluff over the Minnesota and Mississippi Rivers, keeps fairly warm because of air drainage away from the region. St. Paul station shows the effect of the urban heat island.

Crow notes the incidences of fog over the Minnesota and Mississippi Rivers when Wold-Chamberlain itself is free of fog. For over the river air drainage and moisture combine to create fog in the valley. While Wold-Chamberlain is high above the valley floor, in a dry, residential-surrounded area, we have Ham Lake, in an environment of flat land surrounded by numerous woods, swamps, and lakes.

Crow states that the "current frequency of fog formation in any totally rural grass covered surface area should not be compared directly with conditions at Wold-Chamberlain Field. As soon as an airport would come into existence the surface material and area covered by black top and/or streets would change considerably. This would cause a corresponding change in the tendency for fog formation and/or density of fog."

Farmington is indeed a rural grass-covered area. But the Ham Lake site and its environs is not a rural, grass-covered area but swamp,

forest, and lake over most of the region. Indeed, the addition of the airport could well increase the fog incidence in the morning at a Ham Lake airport, with the airport heating up faster than the adjacent forested wetlands. In discussing the climate of the stand border, Geiger states: "The temperature action exerted by the forest is an active influence bearing on the wind distribution. This is a question of winds which the forest itself generates. When during the day the layer near the ground becomes heated over the open country but remains cool in the forest under the screen of the tree tops, the cooler air of the trunk space may flow out into the open as a diurnal forest wind. L. Herr and also K. Doerffel have demonstrated it by means of the cooling and moistening of the air which it brings out. In its origin it is very similar to the sea breeze which during the day blows from the cool sea in over the hot land. Even in 1920 A. Schmauss mentioned 'Sea Breezes without a Sea'." Thus on moist mornings with fog, the fog from the land adjacent to a Ham Lake airport might well drift onto the runways in the fashion of sea breeze fogs along the coastal United States. This could create additional hours of fog at the airport after the airport fog itself had dissipated.

Upon being drained and cleared of trees, the Ham Lake site could become colder because of the improved radiation field that would be generated. This cooling would enable the dew point to be more often reached than now, increasing the incidence of fog. Geiger notes that "drainage of the moors intensified generally the microclimate disadvantages, especially the frost dangers".

But at Wold-Chamberlain the fog over the river is mostly due to air drainage and the moisture source, and not so much due to the fact that the area is not "built up". Wold-Chamberlain benefits from its location on the ridge above these rivers. Ham Lake would not have this benefit. Admittedly, the situation as regards fog at Ham Lake might improve if the adjacent wetland forests were also destroyed. In time building around the airport might help the situation, although some objection to changing Carlos Avery Game Refuge to dry land might be expected.

6. COMMENTS ON THE "SUMMARY"

Paragraph 1. We might again note that 9:00 am becomes ten o'clock in the morning on daylight time, and 8:00 a m becomes nine o'clock in the morning.

Paragraph 2. October is mostly a daylight savings time month.

Paragraph 3. It cannot be said that the airport would create a dominant change in potential for low visibility periods due to fog. Ham Lake is not predominantly a grass-covered area, and the changes in fog conditions because of the airport may not be for the better. In the main body of the report, Crow did not say that a dominant change would result, so that such a strong conclusion does not seem justified in the summary.

Paragraph 4. Crow states here that there is a close similarity of early morning temperatures at 11 climatic stations surrounding the Metropolitan Area. Nowhere in the report were we given any numbers to indicate the values were similar. We did glean enough information to know that influences of the microclimate do occur; influences that make sense when the station altitudes are correctly stated and when the particular relationships with surrounding topography are made. The influence of the drainage wind is shown even by the qualitative information given, when the correct elevations of the stations are considered.

Paragraph 5. Crow has not demonstrated this expectation in the body of the report. There was no data on fog at any site other than Wold-Chamberlain. The only comparative data used was temperature data, and these data led to no conclusion. If Crow had the stations' proper elevation, he might have concluded that the data support microclimatic theory; he surely would have done so had he considered the individual characteristics of each site. Combining the fact that Cedar vies with Farmington as the coolest site, and the fact that the Ham Lake site has the most available moisture, and the fact that Carlos Avery will probably always be kept in wetland, we can only conclude that it would appear from the evidence now available that Ham Lake is the least desirable site, meteorologically, for a new airport.

The last sentence in this paragraph is not a matter of fact, again involving elevations above sea level. Farmington and Ham Lake are both at nearly the same elevation. It is a tossup, once the areas were flattened, whether Farmington or Ham Lake would be higher in elevation, at least according to the Geological Survey maps. Both are near 900 feet elevation, according to these maps. Thus, Crow's statement "The Farmington area, due to its slightly higher elevation would be subject to slightly lower ceilings during periods of winter precipitation than the lower ground near Ham Lake" should

be deleted.

Paragraph 6. Crow here states an opinion. This is not a conclusion supported by any evidence brought forth in the report. It is also difficult to see how the Vermillion River, a few yards across, could have a higher incidence of fog than much of the adjacent valley. There is no comparison of the great magnitude of water in the Ham Lake area with the little bit in the Vermillion.

Paragraph 7. This statement is true.

Paragraph 8. As Crow states, both the Ham Lake and Farmington sites would be relatively free from pollution generated by the Twin Cities. Of course, Wold Chamberlain itself is not greatly affected, visibility-wise from industrial pollution. An airport site itself (Watson 1970) is of course itself a pollution source, due not so much to the aircraft perhaps, but because of the automobile traffic that is generated and various service facilities that spring up around airports. Because of its location above the river valleys, Wold-Chamberlain air is helped in being kept clean by air drainage away from the site.

7. CONCLUDING REMARKS

The Crow report, 17 pages in length, had nine of its pages taken up by 6 tables, 2 illustrations, and 1 map. One page consisted of a short introduction and a listing of data sources (one listed data source, "Daily Observations at Onoka (sic) County Airport", did not appear in the text). One and a quarter pages consisted of the quote on the climate of the area from Wallace, et al.

Of the remaining five and one-quarter pages, two discussed the illustrations and the tables of data pertaining to Wold-Chamberlain field. Another half page discussed the potential for fog dispersal by artificial means. Nearly a page was filled with a summary of the report.

None of the pages mentioned above, except of course for the Summary, discussed the fog problem at sites other than Wold-Chamberlain.

The remaining one and three-quarter page consisted of the section entitled "Comparative Fog Frequency". One third of this section discussed how fog can be formed and a personal experience of the author in noticing the effects of small temperature differences on fog. Another third discussed temperatures from the different climatic stations in the Metropolitan Area, but no conclusion was drawn, perhaps largely due to the fact that Crow did not have the correct altitudes of the stations. Somewhat less than a third discussed relations between the environment and the microclimate.

This leaves one three-sentence paragraph in the report, without any comparison of ceilings and visibility at either Ham Lake or Farmington having yet been drawn.

The first sentence of this paragraph reads "Detailed records of minimum temperatures coincident with early morning fog conditions at Wold-Chamberlain Field have been examined for eleven climatic stations." The last sentence of the paragraph is the statement about the Forest Lake elevation, which I discussed earlier.

The one remaining sentence in the Crow report is:

> "The locations with the two coldest temperatures under current exposed surface conditions are at Cedar and at the station one mile west of Farmington."

Cedar is one mile from Ham Lake, and Farmington 1 W is a mile from Farmington.

If Crow used this temperature data to indicate the relationship between fog and the cooler parts of the metropolitan area, then we must consider that Ham Lake and Farmington are, from a temperature standpoint, the two most fog-susceptible areas in the metropolitan area. But of course low temperature alone cannot describe fog susceptibility. The total environment, including topography, moisture sources, soiltype, and vegetation must be considered. But if Crow used the temperature data to study the microclimate of the Metropolitan Area, he could not succeed because of the mixup in his report over station elevations and because of the lack of relating each station to its surroundings. Overcoming these deficiencies, we find that the stations' data confirm the theory. But Crow never makes it clear why he introduces the temperature data. He gives no numbers; just qualitative descriptions. He gives no conclusion about what the temperature data indicate. He talks of the influences on fog density that small temperature differences can make, but does not relate such to the Cedar and Farmington sites.

We see in the report no description of the physical nature of the two sites, despite the fact that Farmington is a dry agricultural region, and Ham Lake is a swampy, extensively forested, lake region.

RECCOMMENDATION

I recommend that a study be made of the two sites which take into account the physical and vegetative characteristics of the two sites, which discusses the implications of the meteorological information available from the climatological stations (with the altitude and environment of each accurately described), and which utilizes information available from the two sites concerning more than just temperature data.

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Ludlum, D. M., 1968: Early American Winters, II, 1821 to 1870, American Meteorological Society, Boston, Massachusetts.

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OTHER DATA SOURCES CONSULTED IN STUDY

U. S. AIR FORCE A& B Summaries

Geological Survey Maps for the Metropolitan Area

Local Climatological Data for Minneapolis St. Paul, published monthly by ESSA

Climatological Data for Minnesota, published monthly by ESSA

FOREST LAKE 4 SE
Located at 45 15.7 N, 92 54.7 W Elevation 935 feet. The shelter is located on a high, forested ridge overlooking the lake. Air drainage is well away from the shelter in all directions. All winds with westerly components pass over the lake before reaching the shelter.

STILLWATER 1S
Located at 45 15.7 N, 92 47.3 W. Elevation 710 feet. The shelter is in the open, and on the slope of the St. Croix Valley. It is on a small terrace beneath Highway 95 and a railroad embankment. The shelter is about 40 feet above the St. Croix River.

ST. PAUL
Located at 44 59.3 N, 93 4.2 W. Elevation 920 feet. The shelter is on the high ground of a ridge in a residential neighborhood. Air drainage would be well away from the site, with no higher ground anywhere nearby.

BUFFALO

Located at 45 10.8 N, 93 52.5 W. Elevation 1010 feet. The shelter is located on relatively high ground of the entire vicinity, except for slightly higher ground to the north. Buffalo Lake, to the southwest of the station, is at an elevation of 914 feet.

CHASKA 1 NE
Located at 44 47.9 N, 93 35.0 W. Elevation 740 feet. Shelter located on slope of Minnesota River Valley. Slope is not too great in the immediate vicinity, the shelter being about 30 feet above the river surface.

MAPLE PLAIN
Located at 45 00.8 N, 93 39.7 W. Elevation 1030 feet. The shelter is on high ground, generally higher than everywhere in the vicinity, except for roadway of Highway 12 about 150 feet north of shelter.

Picture not of reproducable quality

Foreset Lake MN