Impacts of Severe Winter Weather during December 1989 in the Lake Erie Snowbelt*

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ABSTRACT

December 1989 was the coldest December in over 100 years in the Lake Erie snowbelt of Ohio, Pennsylvania, and New York. Mean temperatures of −9°C were 7°C lower than average and extreme minima reached −30°C. Snow fell on 20 to 25 days of the month and snowfall totals of 100 to 200 cm were twice the December average. Some locations reported record snowfalls and the greatest snow depths of this century. Several segments of society were studied to assess the impacts of this severe winter weather.

The severe weather had minimal impacts on school districts. Over half (54%) of the districts had no closures due to snow but costs for snow removal increased for schools. Ski centers reported a 50% to 100% increase in revenues over December 1988 and the best December skiing in many years. Lake ports had higher operating costs and loss of shipments. Costs for snow and ice control on Interstate 90 (I-90) in the snowbelt increased at least \$1326 km^{-1} over December 1988, but traffic flow was maintained. Person-hours spent on snow and ice control on I-90 increased 59%. An average of 111 000 kg km^{-1} (200 tons $mile^{-1}$) of salt and grit was spread on I-90, an increase of 50 000 kg km^{-1} (89 tons $mile^{-1}$) over December 1988. Colleges, airports, agriculture, hospitals, urban mass transit, electric utilities, and government agencies had only minor disruptions due to the severe winter weather.

1. Introduction

Severe weather has a range of impacts on society. These impacts are receiving more study as concern rises over possible climate changes and their effects on society (e.g., McQuirk 1982; Hare 1984; Liverman et al. 1986). Studies on the impacts of future climate change in the Great Lakes region have assumed a CO_2-induced warmer climate with less snowfall in coming decades (Crowe 1985; Cohen and Allsopp 1988). Plantico et al. (1990), however, showed that winter temperatures lowered during the past 40 years in the Great Lakes region and winters have become more severe. This research examined the societal impacts of recent severe winter weather.

Numerous societal impacts of severe winter weather have been documented, although the journal literature providing detailed analyses on the subject is sparse. Some studies have focused on the societal impacts of single blizzards (Burrows et al. 1979; Symons and Perry 1979; Perry and Symons 1980; Perry et al. 1988; Neal et al. 1988). Others have examined impacts of severe winters. Changnon (1979) surveyed residents of Illinois after the cold and snowy winter 1977/78. He focused on the impacts on households and found average added costs of \$258 per household due to home heating, home repairs, damaged landscaping, vehicle maintenance, clothing and equipment purchases, medical costs, and loss of income. Changnon (1979) also found that rural households were impacted by severe winter weather more than urban households in Illinois. Hilberg et al. (1983) summarized newspaper accounts of impacts of extreme cold and severe winter storms during the winter 1981/82 in Illinois. Total winter snowfalls of 90 to 180 cm, maximum snow depths of 40 to 80 cm, and temperatures as low as −33°C led to 34 deaths, numerous multiple vehicle accidents, stranded motorists, frozen water pipes, business closures, two to six days of school closures, and \$13 million in additional costs for snow removal and maintenance on state highways (Hilberg et al. 1983).

Still others have studied impacts of severe winter weather on particular populations. Rooney (1967, 1969) focused on the impacts of snow in urban areas. He found that the intensity of societal disruptions due to individual snowstorms decreased with increased annual average snowfall. That is, residents of snowy cities cope better with snow than residents of cities with less snowfall. Rooney (1969) also found that western cities of the United States had less disruption from snowstorms than eastern cities. He attributed this to the drier western snowfalls that are easier to remove from pavement and a "western perception" that the individual must cope with environmental hazards such as

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snow. The disruptive impacts of snowstorms in cities of eastern Canada were studied by de Freitas (1975). He reported little difference among the cities and found that snowfalls of less than 5 cm caused slight disruption, while falls of 23 cm caused severe disruptions. Snowfall can have major impacts on highway travel and costs for snow and ice control, including labor, equipment, and materials applied (Cohen 1981). Snowfalls of 25–30 cm in the British Isles have return periods of 15–20 years and are paralyzing, resulting in blocked roads, isolated communities, major absenteeism, and the need for rescue work by air (Perry and Symons 1991).

The goal of this research was to investigate the impacts of the frequent deep snowfalls and record cold of December 1989 on private and public institutions in the Lake Erie snowbelt. This offered the opportunity to study the effects of a month of uncommonly severe winter weather across urban and rural settings in a region where deep snowfall and cold winter temperatures are an expected part of the winter climate.

2. The regional setting

The Lake Erie snowbelt lies southeast of the lake from the eastern suburbs of Cleveland, Ohio, to the southern suburbs of Buffalo, New York, and extends about 80 km inland (Eichenlaub 1970). Its boundaries are not firmly defined, but may be defined as that area with a mean annual snowfall of 200 cm or more (Fig. 1). Lake-effect snow occurs outside the snowbelt but mean snowfall is roughly doubled by the influence of the lake within the boundaries indicated (Eichenlaub 1970; Changnon and Jones 1972; Schmidlin 1989). Average annual snowfall within the Lake Erie snowbelt is greatest, about 400 cm, on the highest ridges of western New York. Elevations within the snowbelt range from 175 m at the lake shore to 670 m on the highest ridges. Population in the snowbelt is approximately 1.8 million. The major population centers are Erie, Pennsylvania (1987 metropolitan population 282 000), and portions of the Cleveland and Buffalo metropolitan areas. The flat lake plain within 10 km of the shore forms a major agricultural, industrial, and transportation corridor with Interstate 90 (I-90), U.S. Route 20, and rail lines parallel to the lake. Elsewhere, the landscape in the snowbelt is rolling to hilly with a patchwork of farms, forests, and numerous small communities. Drainage is primarily through small streams into Lake Erie but includes the upper portion of the Allegheny River, which flows south into the Ohio River.

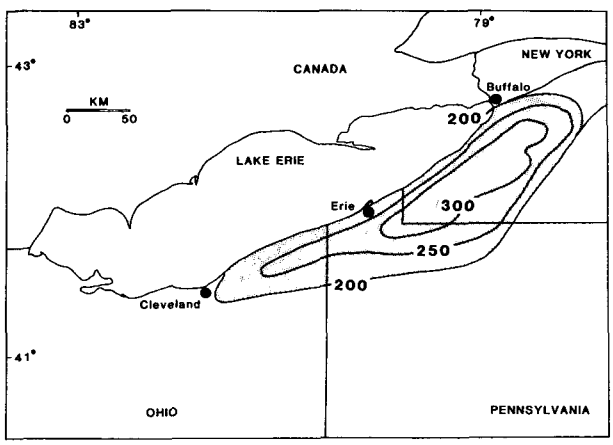

FIG. 1. The approximate area of the Lake Erie snowbelt (shaded) and mean annual snowfall (cm).

3. Weather of December 1989 in the Lake Erie snowbelt

December 1989 was the coldest December in the Great Lakes region since such record keeping began in 1883 (Climate Analysis Center 1990). Temperatures were below average for most of the month and significant thawing did not occur until the last day of December (an example from one station is shown in Fig. 2). The average temperature in the snowbelt for December 1989 was about −9°C, which was 7°C below the 1951–80 mean. Extreme minimum temperatures were −15° to −18°C along the lake and −22° to −30°C inland from the lake. Minimum temperatures of −30°C in the Ohio portion of the snowbelt were among the lowest December temperatures ever recorded in those regions. Heating degree-day totals were about 35% greater than the 1951–80 December average and all segments of society were affected by high fuel consumption and costs.

Unusually low winter temperatures generally bring excessive snowfall to the snowbelts of the Great Lakes (Eichenlaub 1970; Schmidlin 1989). This pattern held in December 1989 as the persistent flow of arctic air across the lakes brought frequent lake-effect snowfall to the snowbelts. Measurable snow fell on 20 to 25 days, with over 2.5 cm snowfall on 10 to 20 days and over 15 cm on 2 to 6 days (Fig. 3). The greatest amounts fell during 2–3 December, 14–17 December, and 20–21 December (Fig. 4). Snow totals of 50 to 70 cm were recorded at some locations during each episode. Total snowfall for December 1989 was about twice the recent average (Fig. 5) and the core of the snowbelt received 130–220 cm. The National Weather Service at Erie, Pennsylvania, measured 170 cm of snowfall, the greatest recorded for any month in 105 years of record keeping at Erie. Snow depths reached 50–75 cm across much of the region, with 99 cm on the ground at Erie on 21 December, a record for that station.

As is usual in lake-effect snowstorms, the snowfall pattern on individual days was very complex, with intense snow squalls producing 30–40 cm of snow in narrow bands 10–20 km wide. For example, a band of snow developed over Erie County, Pennsylvania, on

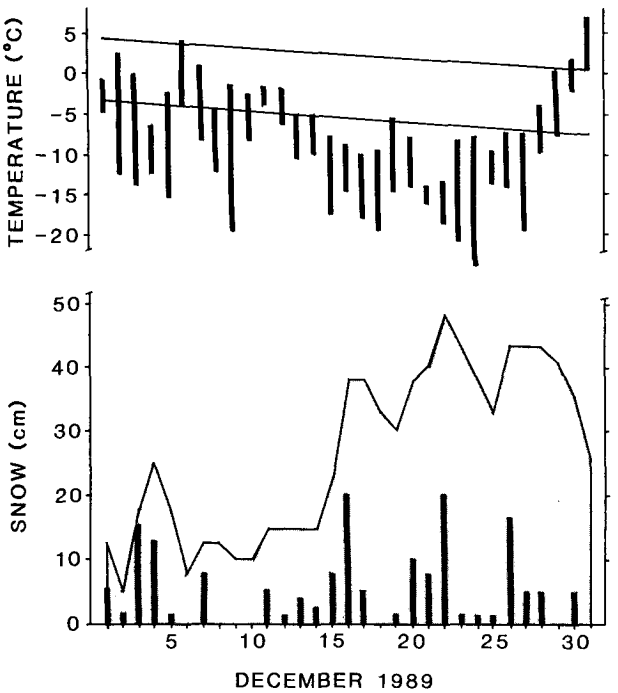

FIG. 2. Weather during December 1989 at Corry, Pennsylvania. Top: Daily maximum and minimum temperatures (vertical bars) and normal mean daily maximum and minimum temperatures (sloping lines). Bottom: Daily snowfall (vertical bars) and daily snow depth (shaded area). Data taken from *Climatological Data—Pennsylvania.*

20 December producing 49 cm of snow in 24 h, including 30 cm in just 3 h. Lake-effect snow is generally of low density with snow/water depth ratios much greater than the traditional 10:1. The 30.5 cm of snowfall measured at Erie in 3 h on 20 December melted to only 0.66 cm of water to give a snow/water depth ratio of 46:1. Snow/water ratios of 20:1 to 35:1 were common in daily snowfall. The 99-cm snowpack at Erie on 21 December had a liquid equivalent of only 5 cm of water.

4. Research methods

Research on the impacts of the severe winter weather of December 1989 was completed primarily through surveys mailed to selected segments of society (Table 1). Surveys were sent during January 1990 to school districts, colleges, ski centers, agricultural extension agents, lake port managers, airport managers, highway maintenance departments, and retail outlets of winter goods; during March 1991 to hospitals, U.S. post offices, U.S. Coast Guard stations, state police, and a state park; and during January 1992 to electric utility companies. Surveys were one page long with three or four open-ended questions. The questions were tailored to the industry surveyed, but all asked the respondents to 1) specify any negative weather impacts to their facility during December 1989, 2) specify any positive impacts, 3) estimate financial losses or gains due to the weather, and 4) comment on any other weather-related impacts during December 1989. They were asked to compare the impacts at their facility during December 1989 to those of December 1988, when snowfall was within 10% of average and temperature was within 1°C of the 1951–80 mean. In general, qualitative assessments of impacts were sought but a few of the respondents were able and willing to provide quantitative assessments. Assessments of the impacts of individual storms were not requested or examined. Telephone contacts were made with several of the respondents to gain additional information. The federal publication *Storm Data* was consulted for impacts. Local newspapers were also examined to obtain a sample of community effects. The extent of impacts on each segment of society was judged on Rooney's (1967) hierarchy of disruption by snow. Results are qualitatively summarized in the following, with detailed information where it was available.

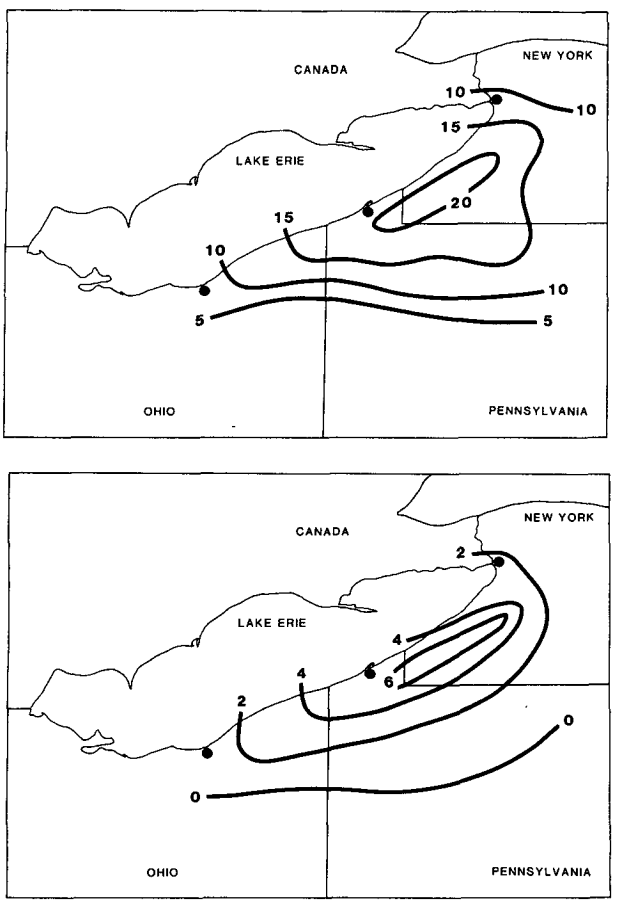

FIG. 3. Number of days with (a) 2.5 cm or more snowfall and (b) 15 cm or more snowfall during December 1989.

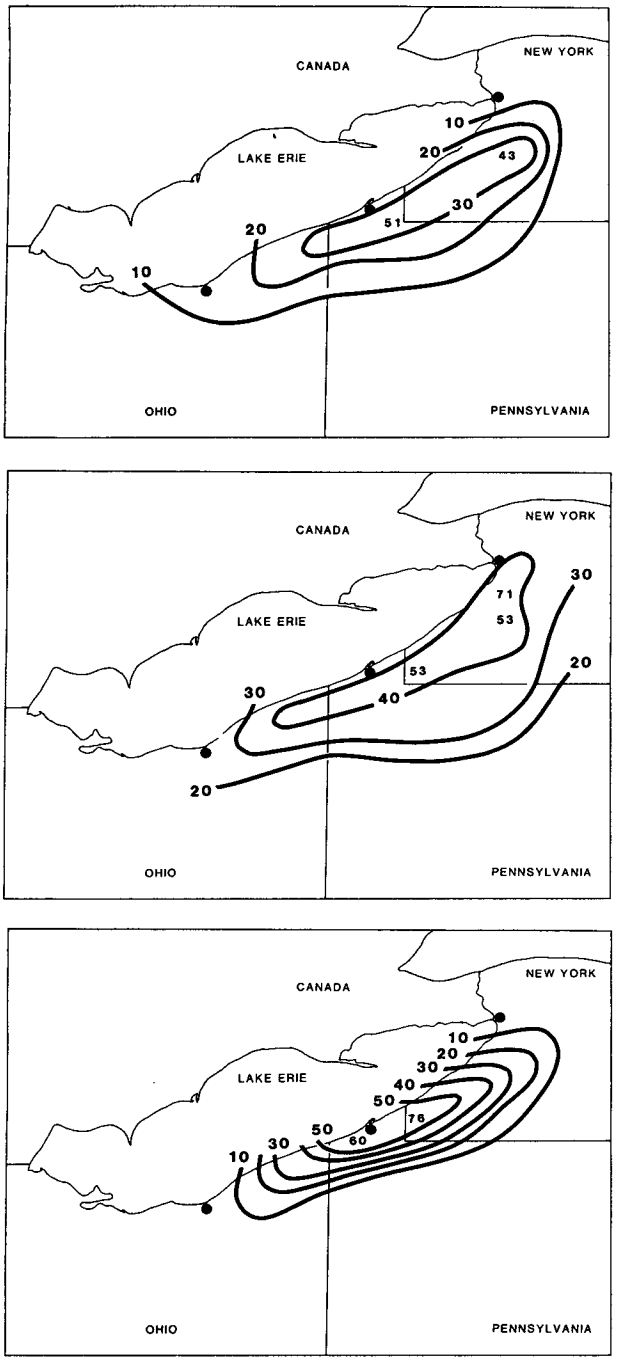

FIG. 4. Snowfall during the three periods of greatest snowfall in December 1989: (a) 2–3 December, (b) 14–17 December, and (c) 20–21 December.

5. Results

a. School districts

The last scheduled day of classes before Christmas break fell during 20–22 December for 87% of the districts. Snowfall during 1–22 December accounted for about 90% of the monthly total in the snowbelt. Impacts of the severe winter weather on schools were minor, with only third-order (inconvenience) or fourth-order (nuisance) disruptions (Rooney 1967). More than half of the districts (54%) reported no weather closures of schools during December 1989. Schools were closed for one day in 41% of the districts and for two days in 5% of the districts. More school districts reported closures in December 1989 than during December 1988 (46% vs 10%), but most of the 1989 closures were for only one day and this represented only a minor disruption. The success in maintaining nearly normal school operations may be attributed to efficient clearing of deep snow from roads, school buses that are equipped to operate in snow and cold, and bus drivers who are competent in winter conditions.

Snow removal operations on school property proceeded normally in 59% of the districts. Of the districts reporting that unusual measures were taken for snow removal, most reported that extra equipment was required to remove the snow. Others reported that more overtime was paid to employees involved in snow re-

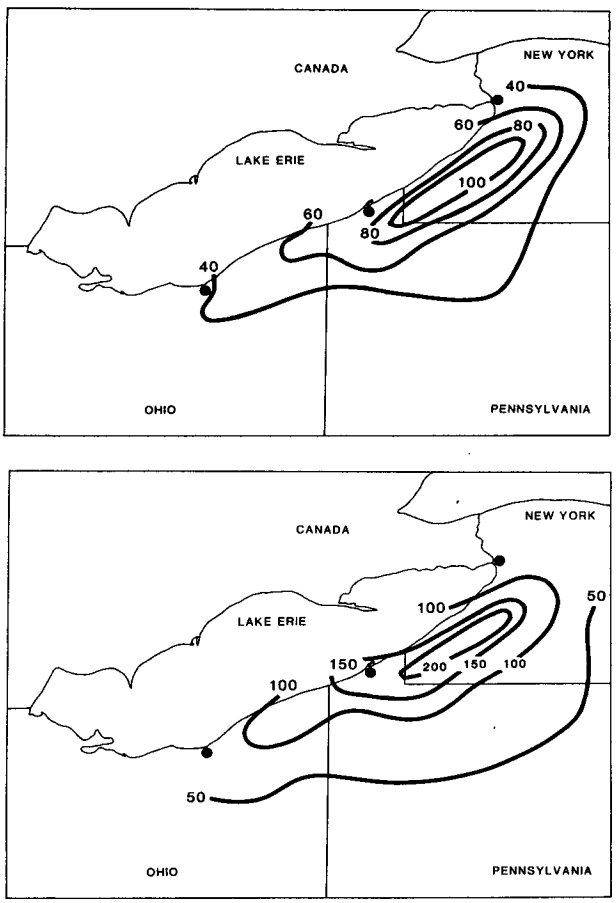

FIG. 5. (a) Recent (1984–88) average December snowfall (cm) in the Lake Erie snowbelt and adjacent areas and (b) snowfall (cm) during December 1989.

TABLE 1. Summary of surveyed institutions, responses, and disruption. Levels of disruption are based on Rooney's (1967) hierarchy of disruption, which, in descending order, are paralyzing, crippling, inconvenience, nuisance, and minimal. An asterisk is given where the disruption could not be determined.

Institution	Surveys mailed	Surveys returned	Disruption
Public school districts	52	39	inconvenience
Universities	3	3	inconvenience
Downhill ski centers	7	7	nuisance
USDA Cooperative Extension	4	4	nuisance
Lake Erie ports	2	2	crippling
Airports	7	4	inconvenience
Ohio Dept. of Tran. Districts	2	2	inconvenience
Pennsylvania Dept. of Tran.	1	1	inconvenience
New York State Thruway Authority	1	1	inconvenience
Retail outlets of winter goods	34	5	*
Hospitals	7	3	minimal
U.S. Postal Service offices	10	6	nuisance
Erie Metro. Transit Authority	1	1	nuisance
Presque Isle State Park	1	1	inconvenience
Pennsylvania State Police	1	1	nuisance
U.S. Coast Guard Stations	2	2	minimal
Electric utilities	6	3	minimal
Total	141	85 (60%)	

moval and more sand and salt were used on parking lots and sidewalks. Several (18%) districts brought in heavy equipment, such as bulldozers and front-end loaders, to move snow when piles of snow prevented further plowing. Some of these services were provided by outside contractors. Two districts explained that their schools were prepared for heavy, frequent snow, since they are in the snowbelt. Among other impacts mentioned by school superintendents were:

a) the need to remove ice dams from eaves at building entrances;
b) cancellation of after-school sporting events;
c) rescheduled Christmas concert;
d) lower attendance due to snow and illnesses;
e) weather-related distractions from schoolwork more numerous than usual.

In summary, schools maintained nearly normal operations during December 1989 with increased costs for snow removal on school lots and some cancellations of special events.

b. *Colleges*

Three state universities or colleges with a total enrollment of 13 850 were surveyed—the State University of New York College at Fredonia (5400 students), Edinboro University of Pennsylvania (7500), and the Ashtabula branch of Kent State University, Ohio (950). The last day of classes before the winter break was 15 or 16 December at all three colleges. There were no weather closures at these colleges except at the Ashtabula branch of Kent State University, where the campus was closed by snow on the last day of final exams. All students with exams on that day were given "incomplete" grades for those courses and the final exams were rescheduled. Other impacts at the campuses were minor and involved increased time and expenses for maintenance staff to remove snow and an increase in fuel used for heating buildings. Overall, impacts of the severe winter weather were mostly third order (inconvenience) at colleges, in part because classes were not in session during the last two weeks of December.

c. *Ski centers*

Not surprisingly, this segment of the economy profited from the unusually cold and snowy weather. The ski centers averaged 29 days of skiing in December 1989, up from 21 days in December 1988, and four of the seven centers surveyed were open every day of the month. An increase in business over December 1988 was reported at all ski centers. One center reported that ticket sales exceeded any December in their 27 years of operation and revenues increased 110% over December 1988. In general, ticket sales and revenues were up 50% to 100% over 1988. The ski centers attributed the large increase in business to the weather and good snow conditions, rather than expansions or the general economy. Some reported the finest December skiing in years with excellent snowmaking conditions. One center noted that the weather of December 1989 allowed a deep base of snow to form that helped them survive the subsequent warm January 1990. Several ski centers reported that bitterly cold weather and brief road closures due to snow hurt their business on a few days. The severe winter weather provided substantial economic benefits to the ski industry of the snowbelt.

d. *Agriculture*

Winter is a dormant period for agriculture in the Lake Erie snowbelt. However, grapes are grown on 15 000 ha of lake shore land in the snowbelt and this perennial vine is susceptible to winter cold damage. County extension agents indicated that winter damage to grapevines was minimal. The deep snow cover was beneficial to the grapevine as an insulative cover from extreme winter cold, and minimum temperatures in the grape-growing areas were only −15° to −20°C, well above the critical winter temperature of −25°C. Persistently low temperatures during December allowed the vines to "harden" against the month's lowest temperatures on 24 December and deep snow cover protected the lower portions of vines. Negative impacts of heavy snow reported from agricultural interests included a reduction in time available for winter pruning of grapevines and an increase in time spent on snow removal on farms. Three barns collapsed from the snow

load in Erie County, Pennsylvania. Deep snow cover reduced freeze-up of rural water pipes in the extreme cold temperatures. Impacts of the severe weather of December 1989 on agriculture were minor, with only fourth-order (nuisance) disruptions (Rooney 1967).

e. *Lake ports*

Ice covered western Lake Erie by 15 December and covered virtually the entire lake by 25 December (Raymond Assel, personal communication). This was about two weeks earlier than usual and obstructed shipping on Lake Erie and between Lake Erie and the upper lakes. Shipping schedules were uncertain, so planning for port crews and facilities was difficult. At the port of Conneaut, Ohio, the combination of cold and snow increased operating costs by 240%, increased mechanical failures by 310%, and caused 33% employee absenteeism. Ice-bonding agents, used to prevent freeze-up of port conveyor systems, were used extensively and conveyors were kept running continuously after midmonth to prevent freeze-up and startup delays. The result was a 55% reduction in production levels. Approximately 500 000 gross tons of iron ore destined for the port of Ashtabula, Ohio, were not delivered during December due to ice conditions on Lake Erie. The Canadian Coast Guard icebreaker *Griffon* arrived in Conneaut, Ohio, on 27 December to escort the *Canadian Olympic* through ice to open water. Lake Erie ports were substantially affected by delayed and reduced operations during the severe winter weather of December 1989. These impacts led to second-order (crippling) disruptions to the industry (Rooney 1967).

f. *Airports*

The largest airport in the region, Erie International Airport, where snowfall was a record 170 cm, had 3258 takeoffs and landings during December 1989. This was 7% fewer than during December 1988. However, 25 611 commercial passengers moved through the airport, up 6% from December 1988. Monthly statistics on snow and ice removal costs were not kept by the Erie International Airport, but were reported to have been above average. The Erie airport was closed occasionally by snow during December but for no longer than 6 h. The Chautauqua County Airport at Jamestown, New York, maintained nearly normal operations throughout December 1989. Costs for snow removal were up 12% over 1988 and there were some flight delays due to snow. The other airports surveyed were small county facilities. The Geauga County Airport, Ohio, reported one day with a closed runway due to poor braking conditions in snow and twice as much plowing as usual for December. Activities at the Corry–Lawrence Airport, Pennsylvania, proceeded as usual for December and were not adversely affected by the weather. In summary, airports incurred mostly third-order (inconvenience) disruptions to operations. Airport traffic was maintained at near-normal levels during the severe weather of December 1989, although additional costs were incurred for snow removal.

g. *Highway maintenance*

Press reports indicated that rural state routes were closed for several hours by drifting snow on numerous occasions during December 1989. The *Conneaut News-Herald* reported that municipal snow removal crews began late in the month to remove piles of snow that had narrowed roads and mounds of snow that obstructed motorists' visibility downtown and at intersections. Detailed summaries of impacts of December 1989 weather on maintenance of 90 km of I-90 were obtained from the Ohio Department of Transportation and for 45 km of I-90 from the New York State Thruway Authority. The Pennsylvania Department of Transportation does not maintain separate maintenance records for interstate highways but provided general information on impacts to 80 km of I-90 during December 1989. Interstate 90 was kept open to traffic in the snowbelt throughout December. A few brief (<1 h) closures resulted while multiple-vehicle traffic accidents were cleared from the highway. The count of 321 630 vehicles that crossed the Pennsylvania–New York border on I-90 during December 1989 was only 3.5% fewer than during December 1988. The cost of this effort involved greater amounts of material spread on the highway, overtime paid to road maintenance crews, and more truck use for snow and ice removal (Table 2). The average of 111 000 kg km^{-1} (200 tons mile^{-1}) of salt and grit spread on I-90 in the snowbelt during December was 50 000 kg km^{-1} (89 tons mile^{-1}) greater than during December 1988. Using estimates

TABLE 2. Comparison of snow and ice control operations on Interstate 90 in Lake and Ashtabula counties, Ohio, and Chautauqua County, New York, during December 1988 and December 1989. Statistics are combined for all three counties unless specified.

	December		
	1988	1989	Increase
Days working snow and ice control			
Lake County	17	26	53%
Ashtabula County	19	28	47%
Chautauqua County	10	22	120%
Regular person-hours expended	2882	4738	64%
Overtime person-hours expended	2822	4314	53%
Truck kilometers	95 918	149 944	56%
Materials applied			
Salt (kg)	5 278 622	8 493 842	61%
Ice grits (kg)	2 996 927	6 532 602	118%

Note: Ice grits are a mix of gravel, limestone, cinders, and other abrasives that are mixed with salt to provide traction. The use of ice grits is increasing due to environmental concerns over use of highway salt, abandonment of the "bare-pavement" policy on I-90 in Ohio, and the lower cost of ice grits compared to salt, so the 118% increase shown is not due entirely to weather.

of direct costs for wages and materials, the highway departments spent an additional \$1326 km^{-1} on snow and ice control on I-90 in Lake, Ashtabula, and Chautauqua counties during December 1989 compared to 1988. If this figure is extrapolated over the entire 280 km of I-90 in the snowbelt, an additional expense of \$371 000 was incurred for snow and ice control on this highway during December 1989. This estimate is likely to be low because only direct costs were considered. Costs for increased equipment time on loaders in the maintenance yards and for repair of increased weathering of potholes and joint cracking were not available. Interstate highway traffic flow was maintained in the snowbelt during the severe winter weather of December 1989 but substantial additional labor and materials were expended in this effort. In spite of record snow and cold, only third-order (inconvenience) disruptions occurred in interstate travel.

h. Retail sales of winter goods

An increase in sales of winter goods was reported from all respondents. The sporting goods stores reported a 15% to 65% increase in sales. One sporting goods store in a small town attributed its increase in sales to the fact that local residents were inhibited by snowy roads and did not drive to larger cities to make purchases. Similarly, the *Conneaut News-Herald* reported on 18 December that retailers in Ashtabula County, Ohio, were pleased with the cold and snow because shoppers were spending money locally instead of driving to malls in Erie or Cleveland. One hardware store reported a 20% increase in sales of snow-related equipment but decreased sales overall due to the frequent snowfall. Among items that sold well in hardware stores were snow shovels, snow blowers, sidewalk salt, and gutter heat tape (to prevent ice dams). The *Conneaut News-Herald* reported on 28 December that sales of snow blowers at a local hardware store had doubled in December 1989 compared to 1988; snow shovel sales tripled; and other winter items such as snow brushes, car batteries, wiper blades, tire chains, antifreeze, and sleds sold well. One sporting goods store in the survey made extra efforts to remain open even in the worst weather because its skiing customers expected that service from a dealer of winter sporting goods. In summary, retail sales of winter goods increased due to the severe weather but general retail sales may have been depressed. The level of disruptions (Rooney 1967) could not be judged from this sample.

i. Urban mass transit

The Erie (Pennsylvania) Metropolitan Transit Authority uses 54 buses on regular schedules and has an average December ridership of about 305 000 persons. They reported no significant stoppages of their buses during December 1989 and buses ran their regular schedules the entire month. Minimal delays of an hour or less occurred when buses or other traffic became stuck in snow. There were increased maintenance costs for plowing the routes during severe weather and for additional diesel fuel. These were fourth-order (nuisance) disruptions to mass transit. Total passengers carried decreased 7% from the previous December and the number of senior citizens carried was down 10 000 (20%) in December 1989 compared to 1988. This was attributed primarily to the severe weather and the reluctance of senior citizens to venture outside. The decrease in mass transit use during severe winter weather reported here is in contrast to the 10%–25% increase in riders reported by Hilberg et al. (1983) for commuter systems in Chicago during the severe winter of 1981/82.

j. Hospitals

A hospital in Erie and another in Dunkirk, New York, reported no impacts of the cold and snow on their operations and no weather-related injuries or illness. St. Vincent Health Center in Erie provided data on admissions for cold-related diagnoses during December 1988, 1989, and 1990 (Table 3). The number of patients admitted with pneumonia was higher during the severe December of 1989 but patients admitted with frostbite/hypothermia or myocardial infarction actually declined during December 1989, compared to the adjacent years. Newspapers did not report significant health problems, injuries, or deaths from the severe weather. *Storm Data* also reported no fatalities in the snowbelt, although at least 61 persons died in the United States from the cold during December (Anonymous 1989). The severe cold and snow of December 1989 had fifth-order (minimal) impacts on the operations of hospitals and the health of local residents in the snowbelt.

k. Post offices

No significant weather-related delays in mail delivery, major additional costs, or other impacts of the severe weather were reported. An exception was a post office in Ashtabula County, Ohio, where about 1000

TABLE 3. Number of cold-related diagnoses of persons admitted to St. Vincent Health Center in Erie, Pennsylvania (provided by Cynthia Sebak, planning/marketing associate).

Diagnosis	Numbers of patients		
	Dec 1988	Dec 1989	Dec 1990
Fracture and injuries	1	2	0
Frostbite/hypothermia	4	1	0
Myocardial infarction	45	46	64
Pneumonia and flu	0	8	1
Totals	50	57	65

extra person-hours were used during December 1989 to complete mail delivery and employees found it difficult to keep up on vehicle maintenance in the severe weather. These were fourth-order (nuisance) disruptions. The response from the Corry, Pennsylvania, post office summarized the general tone of the respondents: "Inclement winter weather is a fact of life at this office that we have become accustomed to."

l. Electric utilities

Six electric utilities serve customers in the Lake Erie snowbelt. Survey responses from three of these (Cleveland Electric Illuminating Company, Pennsylvania Electric Company, and Pennsylvania Power Company) indicated that peak loads and total energy demand for December 1989 were 4% to 10% above other recent December values. Electric demand generally peaks during summer in this region, so the electric demand during December 1989, while higher than normal for winter, was within the normal range for these electric utilities. No unusual measures were taken to maintain electric service to customers, no unusual expenses were incurred by electric utility companies, and no extensive electric power outages occurred due to the weather of December 1989. These were fifth-order (minimal) disruptions.

m. Other impacts

The Pennsylvania State Police at Erie reported the usual winter problems of traffic flow and accidents during the snowy weather of December 1989. The number of traffic accidents was 15% fewer than in December 1988, but accidents in December 1990 fell another 15% from the severe December 1989. Thus, it is unlikely that weather played a major role in the decreased accident rate. Criminal activity during December 1989 under the jurisdiction of the Pennsylvania State Police in Erie was 21% less than in 1988 and 33% less than in December 1990. While other factors may also be important, the severe weather may have reduced the opportunities and inclination for crime in the snowbelt. Presque Isle State Park, Pennsylvania, which extends into Lake Erie, had three weather-related closures during December 1989. In two cases, the usual 0500–2000 LT winter hours were interrupted by early closures, while in the third case the morning opening was delayed for three hours. The park paid 37 h in overtime to employees to plow snow, compared to the normal of 10 h overtime for December. This was an additional labor cost of about $350. No other impacts were noted in the state park. The two U.S. Coast Guard stations in the snowbelt, at Ashtabula, Ohio, and Erie, Pennsylvania, reported normal winter operations and no weather-related search and rescue.

6. Discussion

This research sampled segments of society in the Lake Erie snowbelt for impacts of the record cold and snowy weather of December 1989. Negative impacts of severe winter weather in the Lake Erie snowbelt were most evident in transportation. These impacts took the form of substantially increased costs to a) highway maintenance departments for labor, truck use, and surface materials to prevent traffic disruptions; b) the Lake Erie shipping industry, where delays and obstructions were encountered; and c) airport maintenance departments, which maintained nearly normal operations at Erie International Airport and other smaller airports. Positive impacts were most evident in the skiing industry, where the persistent cold, snowy weather allowed nearly continuous operation and income rose substantially over recent Decembers. From this research, it appears that most segments of society in the Lake Erie snowbelt had minimal impacts from the severe winter weather, beyond higher fuel bills for heating. The expensive but successful efforts to maintain highway traffic flow likely allowed ski centers to profit from the severe winter weather of December 1989 and allowed other segments of our vehicle-oriented society, such as schools, colleges, retail stores, and government agencies, to maintain nearly normal operations.

Using Rooney's (1967) hierarchy of snow disruptions, the Lake Erie snowbelt displayed mostly third-order (inconvenience) or fourth-order (nuisance) disruptions from the severe weather of December 1989. Second-order (crippling) disruptions occurred only in the lake shipping industries. Rooney (1967, 1969) has shown that societies in climates where significant snow is experienced each year cope relatively well with snowstorms. Rooney (1967) also suggested that snowfall with a low water content, as was typical in the Lake Erie snowbelt during December 1989, is easier to cope with than heavy, dense snowfall. The results of this study of severe winter weather impacts agree with those earlier conclusions.

Impacts of the severe weather of December 1989 in the Lake Erie snowbelt were much less than reported for Illinois during the severe winter of 1981/82 (Hilberg et al. 1983). Although the period of exposure to severe weather was shorter in the present case (four weeks compared to four months), the impacts in Illinois may have been greater due to the much lower average snowfall in that region compared to the Lake Erie snowbelt and inability of residents and transportation systems to cope with frequent deep snowfalls. While the Illinois study (Hilberg et al. 1983) found 34 deaths directly due to the severe winter weather of 1981/82, thousands of motorists stranded in rural communities, hundreds of abandoned vehicles, declaration of disaster areas, and a call-up of the National Guard to clear

snow, this study found no deaths due to the severe weather of December 1989 in the Lake Erie snowbelt, few stranded motorists or abandoned vehicles, and no large-scale emergency societal responses. The societal impacts found in this study were also much less than reported for 25–30-cm snowfalls in the British Isles, where such snows have a 15–20-year recurrence interval (Perry and Symons 1991).

In spite of the coldest mean December temperatures in 105 years and monthly snowfalls of 130 to 220 cm that were double the average (100-year record snowfall in some cases), society in the Lake Erie snowbelt coped well during December 1989. Costs for adjusting to the severe winter weather increased over recent years, but serious disruptions were minimal. In this climate where mean winter snowfall is 200 to 400 cm, the public and private infrastructure has evolved so that material, equipment, finances, and attitudes are sufficient to allow a nearly normal pace of society, even during a winter month of cold and snow that is substantially more intense than usual.

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REFERENCES

Anonymous, 1989: Record cold in the central and eastern United States during December 1989. *Storm Data,* **31**(12), 6–10.

Burrows, W. R., R. A. Treidl, and R. G. Lawford, 1979: The southern Ontario blizzard of January 26 and 27, 1978. *Atmos.–Ocean,* **17,** 306–320.

Changnon, S. A., Jr., 1979: How a severe winter impacts on individuals. *Bull. Amer. Meteor. Soc.,* **60,** 110–114.

——, and D. M. A. Jones, 1972: Review of the influences of the Great Lakes on weather. *Water Resour. Res.,* **8,** 360–371.

Climate Analysis Center, 1990: *Weekly Climate Bulletin.* Number 90/02, January 13, 1990, National Weather Service/NOAA, Washington, DC.

Cohen, S. J., 1981: User oriented climatic information for planning a snow removal budget. *J. Appl. Meteor.,* **20,** 1420–1427.

——, and T. R. Allsopp, 1988: The potential impacts of a scenario of CO_2-induced climatic change on Ontario, Canada. *J. Climate,* **1,** 669–681.

Crowe, R. B., 1985: Effect of carbon dioxide warming scenarios on total winter snowfall and length of winter snow season in southern Ontario. *Canadian Climate Centre Rep. No. 85-19,* Atmospheric Environment Service, Downsview, Canada, 55 pp.

de Freitas, C. R., 1975: Estimation of the disruptive impact of snowfalls in urban areas. *J. Appl. Meteor.,* **14,** 1166–1173.

Eichenlaub, V. L., 1970: Lake effect snowfall to the lee of the Great Lakes: Its role in Michigan. *Bull. Amer. Meteor. Soc.,* **51,** 403–412.

Hare, F. K., 1984: Changing climate and human response: The impact of recent events on climatology. *Geoforum,* **15,** 383–394.

Hilberg, S. D., P. G. Vinzani, and S. A. Changnon, Jr., 1983: *The severe winter of 1981–82 in Illinois.* Report on Investigation 104, Illinois State Water Survey, Champaign, 52 pp.

Liverman, D. M., W. H. Terjung, J. T. Hayes, and L. O. Mearns, 1986: Climatic change and grain corn yields in the North American Great Plains. *Clim. Change,* **9,** 327–347.

McQuirk, J. P., 1982: A century of precipitation variability along the Pacific coast of North America and its impact. *Clim. Change,* **4,** 41–56.

Neal, D. M., J. B. Perry, Jr., K. Green, and R. Hawkins, 1988: Patterns of giving and receiving help during severe winter conditions: A research note. *Disasters,* **12,** 366–372.

Perry, A. H., and L. J. Symons, 1980: The economic and social disruption arising from the snowfall hazard in Scotland—the example of January 1978. *Scottish Geographical Magazine,* **96,** 20–25.

——, and ——, 1991: The winter maintenance of highways. *Highway Meteorology,* A. H. Perry and L. J. Symons, Eds., Chapman and Hall, 209 pp.

Perry, J. B., Jr., R. Hawkins, and D. M. Neal, 1988: The blizzard of 1978 in Wood County, Ohio. *Northwest Ohio Quarterly,* **60,** 3–16.

Plantico, M. S., T. R. Karl, G. Kukla, and J. Gavin, 1990: Is recent climate change across the United States related to rising levels of anthropogenic greenhouse gases? *J. Geophys. Res.,* **95,** 16 617–16 637.

Rooney, J. F., Jr., 1967: The urban snow hazard in the United States. *Geogr. Rev.,* **57,** 539–559.

Rooney, J., 1969: The economic and social implications of snow and ice. *Water, Earth, and Man.* R. J. Chorley, Ed., Methuen and Company, Ltd., 389–401.

Schmidlin, T. W., 1989: Climatic summary of snowfall and snow depth in the Ohio snowbelt at Chardon. *Ohio J. Sci.,* **89,** 101–108.

Symons, L., and A. Perry, 1979: The blizzards of early 1978 and the use of helicopters to alleviate the resulting economic and social disruption. *Disasters,* **3,** 8–12.