Snow Collection by Possible High Speed Guideway Sections

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A program to observe the formation of snow accumulations on possible high speed transportation tracks was initiated in 1969. The track sections tested include π shaped, box, inverted Tee and channel cross section beams. At extremely low wind velocities the snowfall accumulation is equal on all beams. At high cross flow velocities the beams with vertical members rising from horizontal surfaces cause severely distorted accumulations. The vertical member(s) acts as a 100% density snow fence resulting in a parallel ridge formation. With dry snow and high wind velocity the plane surface beams accumulated little or no snow.

The accumulation of snow during the winter is one of the major causes of disruptions to traffic systems whether these are road, rail or aircraft. During the past winter the north-east portion of the U. S. suffered one of the most severe storms experienced this century and these traffic systems all encountered breakdowns that lasted from one to as many as five days according to newspaper accounts. Passengers flying by air from Miami and Fort Lauderdale were delayed in the south for one or more days because of flight cancellations to New York, Boston and other northern cities. Whether passenger delays in southern Florida due to a northern snowstorm can be classified as an inconvenience is questionable. No doubt many of those in the Boston and New York area during this storm (that has become known as the Blizzard of '78) can attest to the severity of the traffic disruptions. The photo coverage of this and an earlier storm in the New York area showed freeways with abandoned cars and trucks, and streets with mounds of buried cars. Train delays due to extremely severe snow drifts were reported in the midwest during a January storm. During early February in western Canada another blizzard caused cattle deaths due to 4.5 meters (15 ft) deep snow drifts. The same storm caused derailment of 26 cars from a train as a result of hitting a high snow drift. In the same area a train and snow plow dispatched to clear a line got stuck in the snow. Other locations in the northern hemisphere suffered from severe snowfalls in January and February of 1978. Valdez Alaska was reported to have had an 80 cm (32 in.) snowfall during one day. Parts of northern Scotland had roads buried under snowdrifts that were up to 6 meters (20 ft) deep. While the winter of '78 will be remembered in New England for some time, other areas have different years to commemorate as the most severe winter within memory.

In considering new transportation modes it is essential that the designers consider the environment of the areas for which they are intended. For the northern U. S. and Canada the requirements of a transportation system are somewhat different from that suitable for Miami or Los Angeles. In the northern parts of the country lower temperatures are experienced as well as snowstorms. The low temperature is not too difficult for traffic equipment designers to provide for in either vehicles, tracks or buildings, since this is an area in which major advances have been made in engineering during the past twenty or thirty years. Advances in dealing with the snow problem have not been as outstanding except possibly by the provision of more and larger equipment for snow removal from vehicle rights-of-way. In some instances, snow plow equipment on the railways for example, there has not been any significant improvement in fifty or sixty years in North America.

The winter season during which snowfall is experienced varies in duration across Canada, and in some areas includes both spring and autumn. For example Calgary, Alberta has a snowfall season that can extend from September to June, although the mean annual snowfall is only 150 cm (59 in.), while Saint John, New Brunswick experiences snow only over six months but has an annual average snowfall of 200 cm (80 in.) per year (1). Across Canada the mean annual snowfall varies from a minimum of 30 cm (12 in.) along the Pacific coast to over 300 cm (120 in.) along the continental divide. The prairie provinces have from 100 to 150 cm (40 to 60 in.) per year while from Ontario to the Atlantic the mean varies from a low of 80 cm (32 in.) in southwestern Ontario to 300 cm (120 in.) in several areas (1,2). Figure 1 gives the Mean Annual Snowfall for Canada. The number of days on which snow falls, and might thereby cause traffic disruption by direct snowfall, varies from a low of 10 days per year on the Pacific coast to a high of 100 days per year in an area to the east of Hudson's and James Bay. Figure 2 gives the Mean Annual Number of Days with measurable snowfall.

The minimum wind speed to transport snow is given by various authors (3) as 4 to 7 m/sec for dry snow and up 8.3 to 11 m/sec for a snow in the wet English climate. The winter season mean wind speed for a considerable area of Canada is 4.2 m/sec (10 mph), i.e. just exceeding the lower limit for snow transportation, thus considerable drifting can occur. The implication from this is that although trace snowfalls may be restricted to a limited number of days for a given area, drifting may occur all winter while a snow cover exists. Obviously for most areas it would be advantageous to employ a transportation method that is not influenced by drifting snow.

Snowfall accumulations on the ground may exceed 200 cm (80 in.) in limited locations but for much of Canada 125 to 150 cm (50 to 60 in.) is the maximum recorded depth. For drifting snow with a strong wind (16 m/sec) more than 98% of the snow transported is within one meter of the snow surface (see Table 2). It is an obvious advantage to elevate a track structure to eliminate problems resulting from the drifting of an accumulated snow cover.

During the 1960s guided air cushion vehicles were under development in the U. K., France and the U.S.A. Since then development has been undertaken on magnetic levitated and guided vehicles in the previously mentioned countries and in Japan, Germany and other countries including Canada. A variety of guideways or tracks have been considered by the various designers; however in the late 1960s the three more popular designs were the inverted Tee of Bertin & Cie. of France, the deep box beam of British Tracked Hovercraft and the channel track of two U. S. developers. All of the track sections proposed for either air cushion vehicles or magnetic levitated vehicles have employed horizontal and/or vertical surfaces for support, guidance and propulsion. Although some consideration had been given to snow and ice problems by the agencies developing these systems, the relative merits of the track designs from this aspect had not been evaluated due primarily to lack of information on the susceptibility of the various sections to snow accumulation.

In 1969 a decision was made to investigate the formation of snow on representative samples of the various track designs that were proposed at that time. Consideration was given to simulated tests using scale models in a laboratory tunnel with a snow substitute. Reports on the Simulation of Drifting Snow (4) and Scale Model Studies on Snow Drifting (5) indicated the need for further development work on simulation, thus it was decided to observe the accumulation of natural snow on full scale track sections.

Test Site

The choice of a convenient test site was limited by the availability of readily accessible locations with good exposure to winds and preferably some distance from buildings or wooded areas. The requirement to photograph the accumulations after each snowfall and to clean the beams after each storm with a minimum labor input further restricted the choice. Of the available NRC locations in the Ottawa area that were considered, the site of the Helicopter Icing Research facility in the northwest section of Ottawa International Airport was chosen as the most suitable. This site has office space, a workshop, power and steam generating capacity, together with a reasonable amount of space to the north of the helicopter icing spray rig. The installation of the test tracks at this location allowed the same staff as used for icing work to observe, photograph and maintain the high speed vehicle tracks.

The test beams are located along a height of land at an elevation approximately 108 meters (360 ft) above sea level. To the east of this ridge the land drops approximately 150 cm (5 ft) over a distance of about 100 meters (several hundred feet). The only structure adjacent to the test beams is a weather radar unit to the southeast. On the west side the land falls away rapidly with a change of 6 to 9 meters (20 to 30 ft) in elevation within 30 meters (100 ft) of the track sections. The nearest buildings to the west are all well below the elevation of the test site. To the south and southwest there is an extensive wooded area; however, this is on land approximately 9 to 12 meters (30 to 40 ft) lower in elevation and over 100 meters (several hundred feet) from the test site. Figure 5 shows the location of Uplands Airport at Ottawa while Figure 6 shows the location of the test site on the airport. Figure 7 is an aerial photograph of the test site showing the location of the track sections and the surrounding area. During the winter the predominant direction of the winds is west and northwest. The direction frequency of winter winds for Ottawa is given in Figure 8.

Test Track Sections

Four different cross-section track sections comprising nine test beams were installed on the test site. During the 1969-70 season four test beams were installed at temporary locations, and while an additional five beams were received in 1970, it was not until 1971 that all beams were installed on their final test locations. The test sections were mounted on concrete columns at a height sufficient to allow for ground drifting without effect but at a convenient height for photography and maintenance. In practice the tracks would be mounted somewhat higher to allow for vehicle underpasses.

The cross-sectional dimensions of the various test beams are given in Figures 9 to 12 inclusive. The box beam was actually two short sections mounted end-to-end to form a 10.5 meter (35 ft) long test section. All other test pieces are 12 meters (40 ft) long. The π-shaped beams were precast sections chosen to provide simple horizontal surfaces of approximately the same width as the box beam. One inverted Tee is a slightly modified version of the Bertin track. Three of the inverted Tees were precast inverted roof beams. The dimensions are slightly different from those of the Bertin track. The channel track consists of two precast inverted Tees mounted in parallel to form a channel with horizontal external fins.

Snowfall Accumulations

During the winters 1969-70 and 1970-71 the test beams were on temporary sites with only timber supports above the surrounding ground level. In one storm during 1969-70 it was observed that snow can accumulate to depths varying from 22.5 to 47.5 cm (9 to 19 in.) on the inverted Tee beam while only 5 cm (2 in.) had deposited on the π-shaped beams. It was noted during the 1970-71 season that snow did not accumulate on the horizontal surface

Figure 1. Mean annual snowfall.

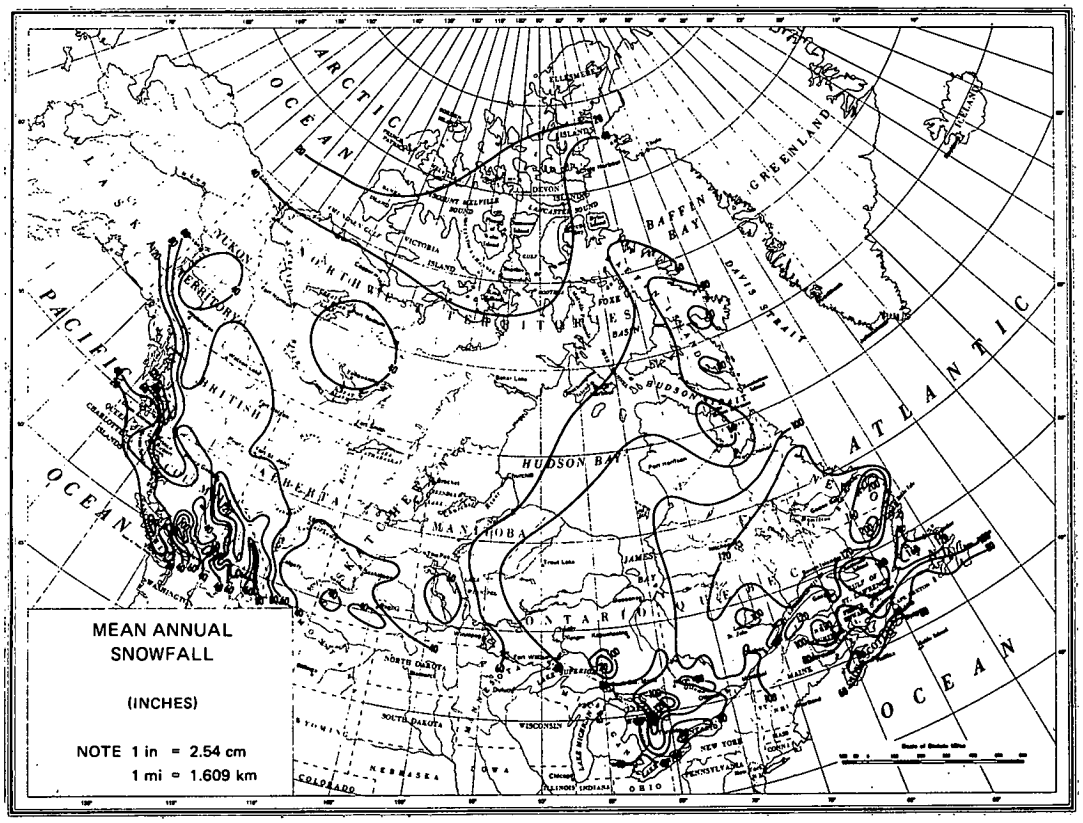


Figure 2. Mean annual number of days with measurable snowfall.

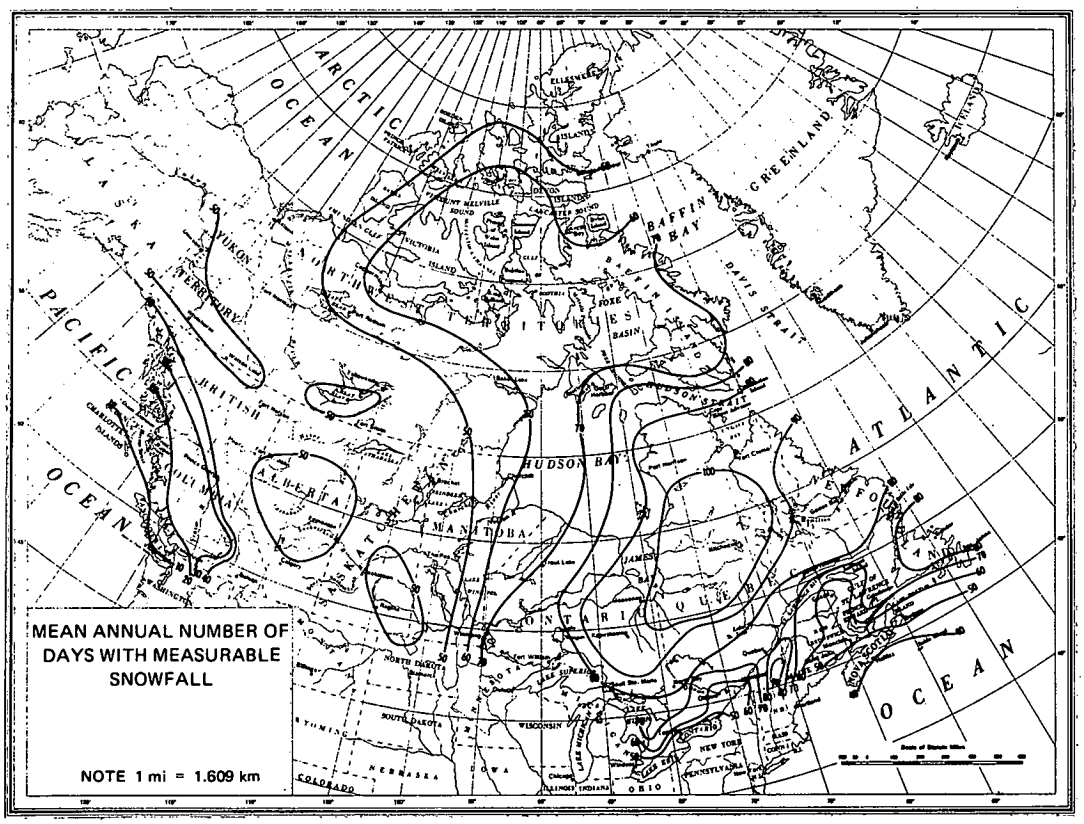


Figure 3. Mean winter season wind speed.

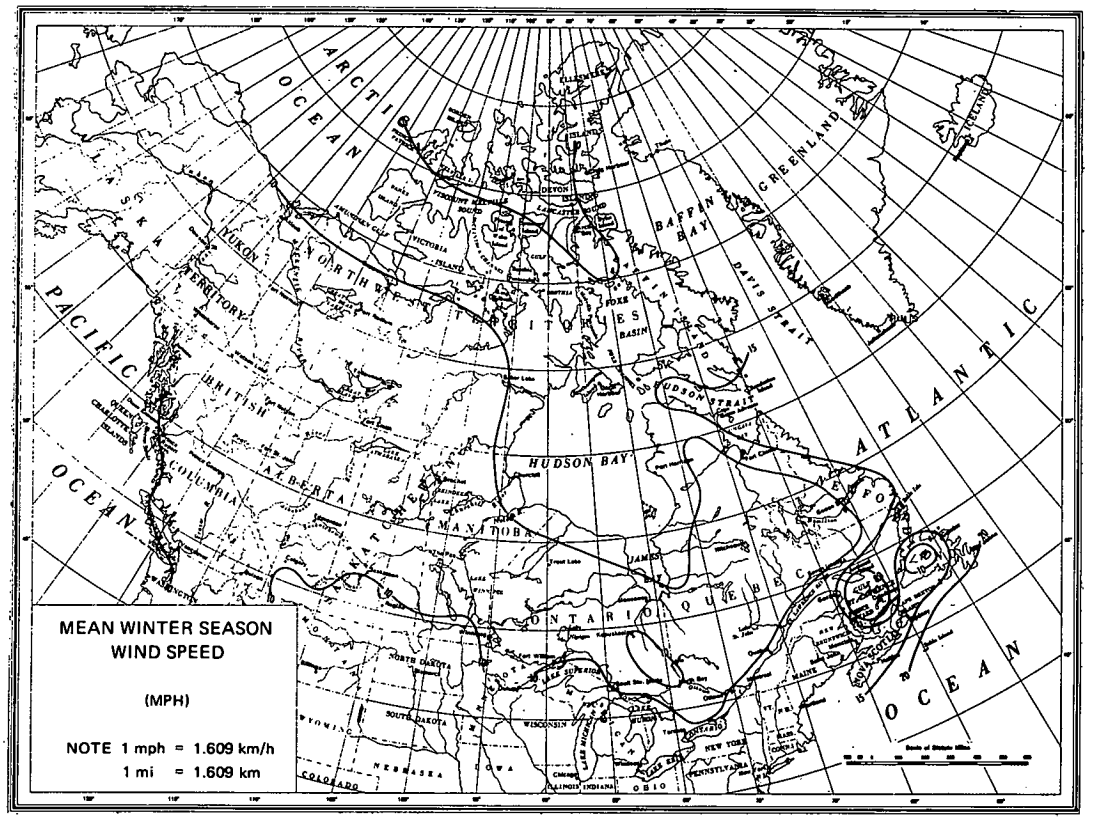


Figure 4. Maximum recorded depth of snow on the ground 1941-50.

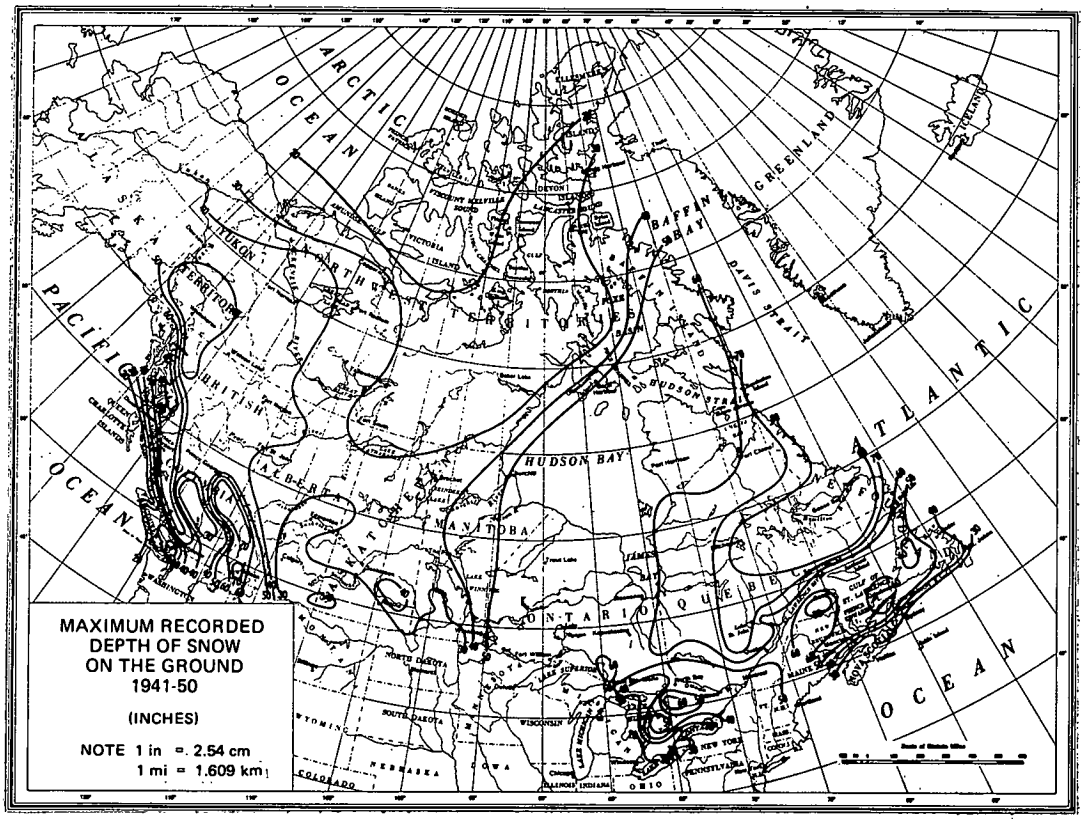


Table 1. Mean monthly and annual snowfall at selected major cities.

City	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.	May	June	Annual
Vancouver, B. C.			2.5	10.1	25.4	15.2	5.1				58.3
Victoria, B. C.			2.5	5.1	12.7	5.1	2.5				27.9
Calgary, Alta.	7.6	12.7	15.2	15.2	17.8	20.3	25.4	25.4	7.6	2.5	149.7
Edmonton, Alta.	2.5	10.1	20.3	22.8	22.8	20.3	20.3	15.2	2.5		136.8
Regina, Sask.	2.5	7.6	17.8	15.2	17.8	17.8	17.8	10.1	2.5		109.1
Winnipeg, Man.		7.6	22.8	20.3	25.4	20.3	20.3	10.1	2.5		129.3
London, Ont.		2.5	25.4	40.6	43.2	38.1	27.9	7.6			185.3
Ottawa, Ont.		2.5	17.8	45.7	43.2	43.2	35.6	7.6			195.6
Toronto, Ont.			12.7	25.4	35.6	33.0	25.4	7.6			139.7
Montreal, Que.		2.5	20.3	53.3	58.4	58.4	48.3	10.1			251.3
Quebec, Que.		2.5	33.0	58.4	73.7	66.0	53.3	27.9			314.8[a]
Saint John, N. B.			12.7	40.6	50.8	48.3	35.6	15.2			203.2[a]
Halifax, N. S.			5.1	33.0	45.7	48.3	35.6	12.7			180.4
St. John's, Nfld.		2.5	12.7	63.5	73.7	68.6	48.3	15.2	5.1		289.6[a]

Note: 1 cm = 0.3937 inch.

[a]Period 1921-1950, all other data based on standard 30-year period from 1931-1960.

Source: Department of Transport, CIR-3977, TEC-503, 24 Jan./64.

Table 2. Drifting snow density vs height.

Height Above Ground (cm)	Strong Wind (16m/sec) Snow Density %
100-200	1.3
50-100	2.0
30-50	1.6
20-30	1.8
10-20	5.9
0-10	87.4

Note: 1 cm = 0.3937 inch. 1 m/sec = 3.28 ft/sec.

Source: National Research Council of Canada, TT-1038.

Table 3. Meteorological data - winter season 1969/70

Date	Duration (hours)	Snow Thickness (cm)	Average Snowfall Rate (cm/h)	Wind Direction	Average Wind Velocity(km/h)	Temperature (°C)
22/12/69	4	4.6	1.14	S	16	-3
29/12/69	44	26.4	.61	NW	64	-8
9/1/70	6	3.0	.51	SW	16	-16
13/1/70	21	.2	.10	NE	8	-15
27/1/70	15	13.7	.91	E	24	-7
3/2/70	16	15.7	.99	NW	40	-9
10/2/70	30	48.3	1.60	W	32	-7
2/3/70	27	24.6	.90	E	32	0

Note: 1 cm = 0.3937 inch. 1 cm/h = 0.3937 inch/hr. 1 km/h = 0.6214 mph. °C = 5/9 (°F-32).

Table 4. Meteorological data - winter season 1970/71

Date	Duration (hours)	Snow Thickness (cm)	Average Snowfall Rate (cm/h)	Wind Direction	Average Wind Velocity (km/h)	Temperature (°C)
16/11/70	24	12.7	.51	NNE	24	.6
4/12/70	10	13.0	1.30	ENE	29	-12
7/12/70	14	7.1	.51	NW	32	-14
10/12/70	20	25.9	1.27	ENE	32	-13
14/12/70	8	10.2	1.27	ENE	19	-14
18/12/70	6	11.7	1.96	ENE	42	-8
21/12/70	16	14.0	.86	W	39	-11
23/12/70	18	11.7	.69	ENE	34	-22
29/12/70	36	15.7	.43	NNW	26	-16
11/1/71	18	16.3	.89	NNW	16	-12
12/1/71	8	6.6	.81	NNW	27	-19
22/1/71	18	10.4	.56	W	31	-6
26/1/71	8	10.9	1.37	SW	37	-6
21/1/71	12	8.9	.74	W	68	-19
28/1/71		Results of Blowing Snow		W	37	-24
1/2/71	17	13.0	.76	ENE	39	-11
8/2/71	13	17.8	1.37	ENE	21	-10
9/2/71	10	21.6	2.16	W	42	-3
15/2/71	38	58.7	1.98	W	40	-9
22/2/71	27	28.7	1.07	ENE	35	-4
26/2/71	24	31.2	1.40	ENE	26	-2
5/3/71	16	31.2	1.93	WNW	48	-4
9/3/71	12	20.8	1.93	WNW	35	-9

Note: 1 cm = 0.3937 inch. 1 cm/h = 0.3937 inch/hr. 1 km/h = 0.6214 mph. °C = 5/9 (°F-32).

Table 5. Meteorological Data - winter season 1971/72

Date	Duration (hours)	Snow Thickness (cm)	Average Snowfall Rate (cm/h)	Wind Direction	Average Wind Velocity (km/h)	Temperature (°C)
7/11/71	14	2.0	.15	WSW	26	-4
10/11/71	23	8.1	.36	NNW	19	-5
12/11/71	17	2.8	.15	NNE	11	-4
21/11/71	16	7.6	.48	NNW	24	-2
27/11/71	26	4.1	.15	E	27	-7
30/11/71	34	10.4	.30	NNE	27	-8
6/12/71	22	9.7	.43	E	26	-11
15/12/71	8	2.8	.36	ESE	40	-7
20/12/71	23	5.8	.25	ENE	19	-13
27/12/71	10	10.2	1.02	ENE	19	-19
30/12/71	14	14.2	1.02	ENE	42	-18
2/1/72	13	6.6	.51	W	34	-9
4/1/72	23	4.1	.18	NE	24	-10
6/1/72	33	2.8	.08	E	16	-23
13/1/72	6	2.8	.46	NW	58	-10
17/1/72	13	11.7	.89	SSW	27	-20
20/1/72	12	9.9	.81	W	24	-13
28/1/72	7	3.0	.43	SW	18	-11
3/2/72	32	42.4	1.32	ENE	39	-14
13/2/72	18	14.2	.79	ENE	32	-8
19/2/72	36	16.3	.46	ENE	37	-11
21/2/72	20	8.1	.41	E	26	-22
26/2/72	11	2.5	.23	ENE	26	-12
29/2/72	12	4.1	.33	N	23	-7
1/3/72	43	28.2	.66	ENE	35	-11
4/3/72	10	2.5	.25	E	24	-19
5/3/72	5	2.8	.56	WNW	31	-12
7/3/72	20	4.1	.20	ENE	34	-17
18/3/72	33	3.0	.10	NNW	35	-9
22/3/72	34	16.2	.38	ENE	37	-5

Note: 1 cm = 0.3937 inch. 1 cm/h = 0.3937 inch/hr. 1 km/h = 0.6214 mph. °C = 5/9(°F-32).

Figure 5. Ottawa area.

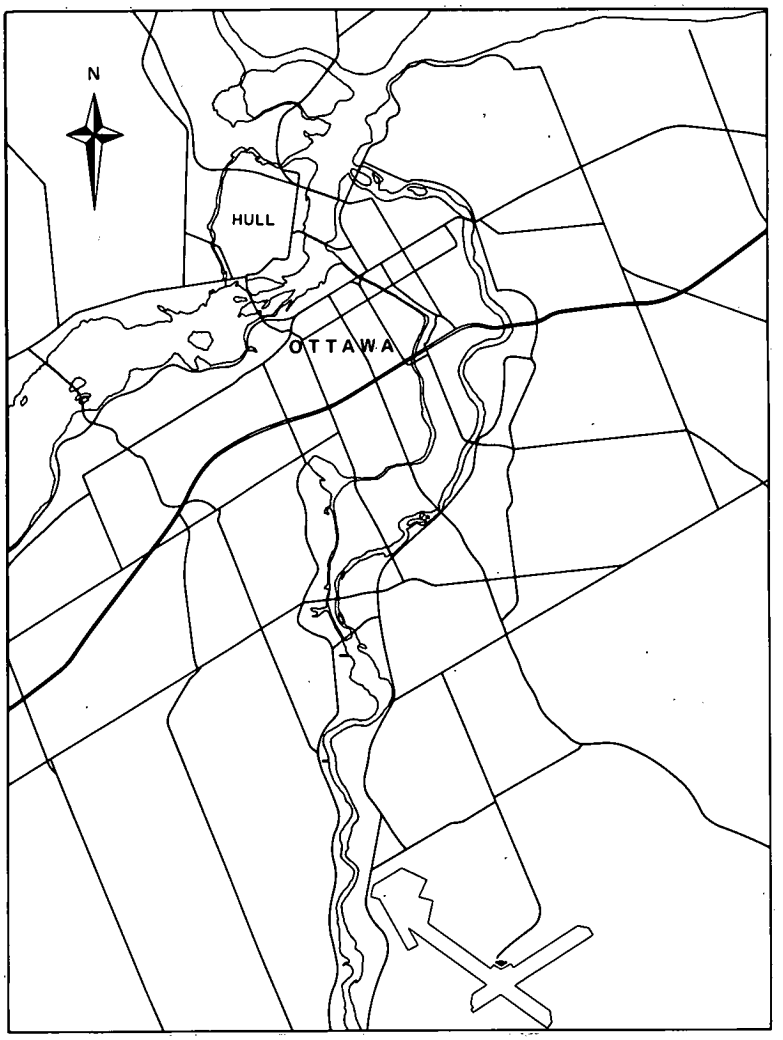


Figure 6. Ottawa International Airport (Uplands)

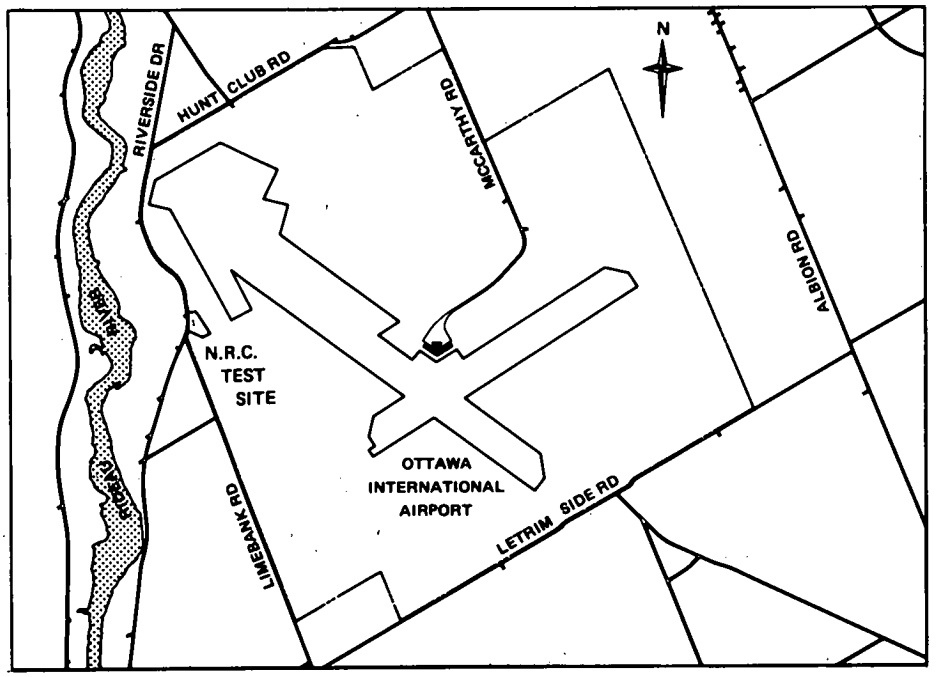


Figure 7. Test site.

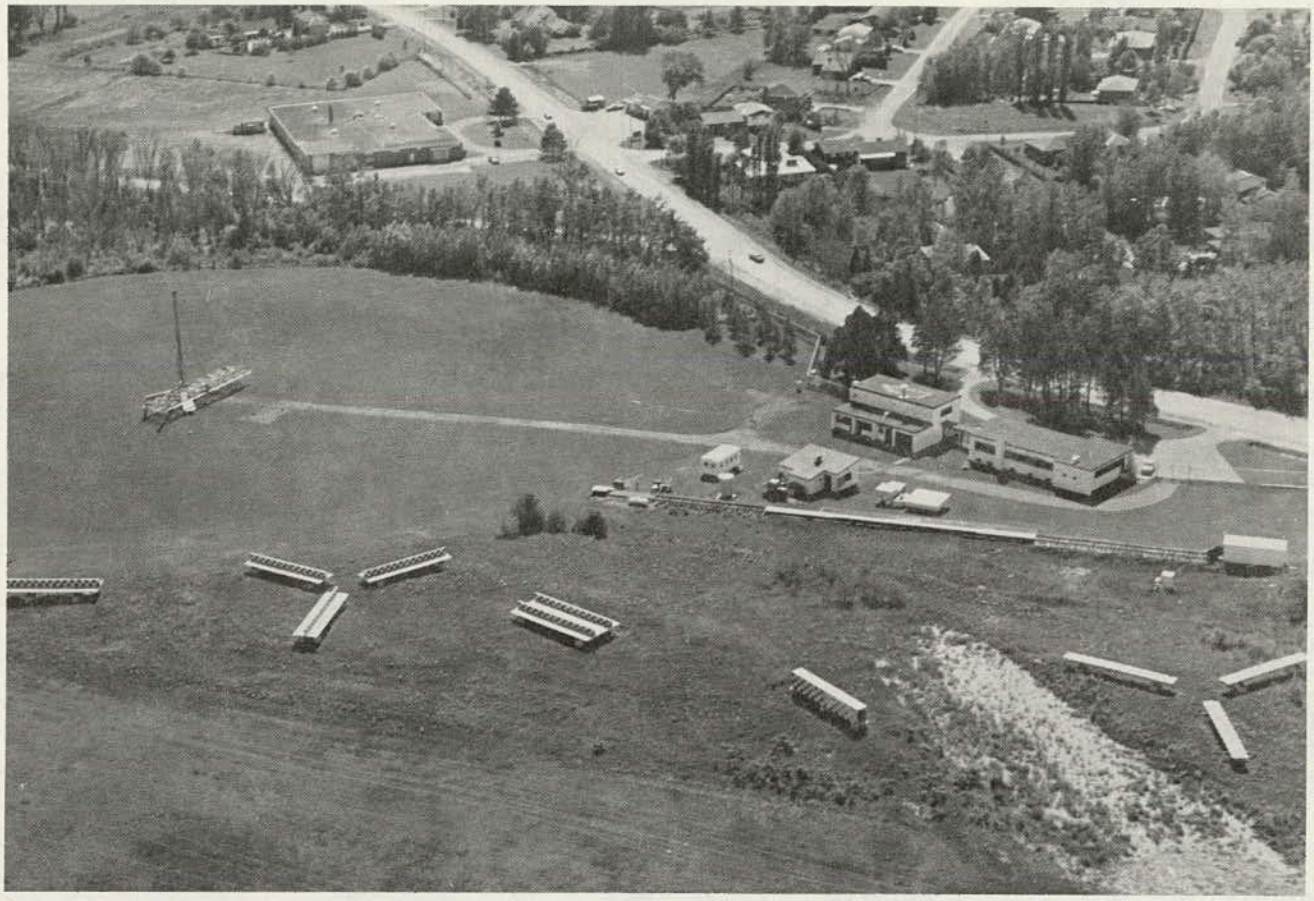


Figure 8. Direction frequencies of winter winds for Ottawa.

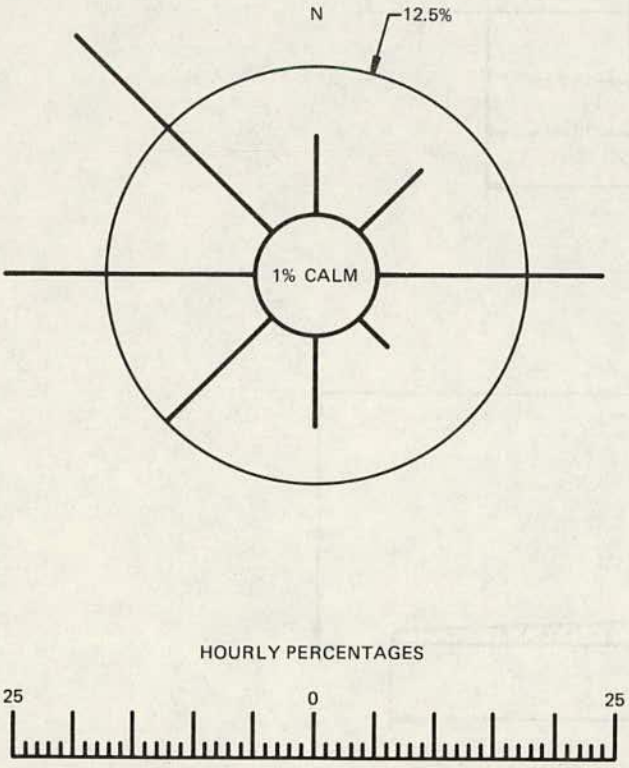


Figure 9. Box beam section.

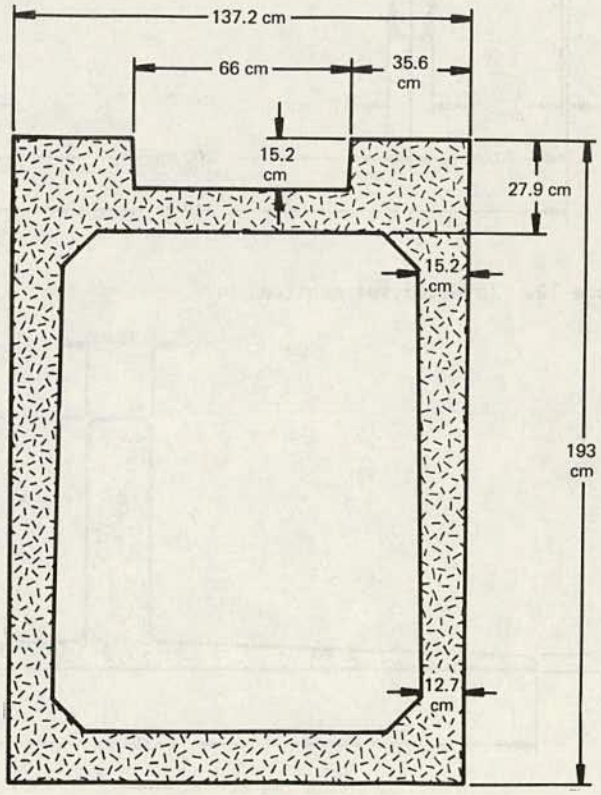


Figure 10. π section.

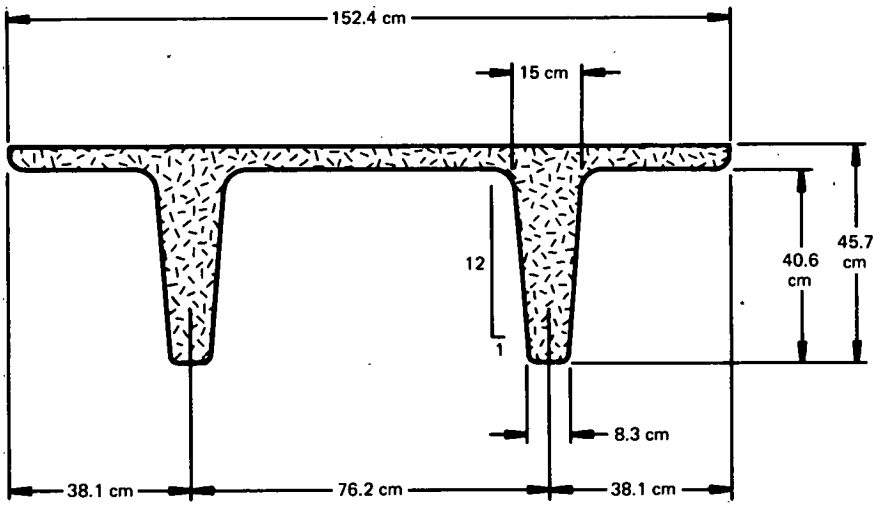


Figure 11. Bertin beam (modified) section.

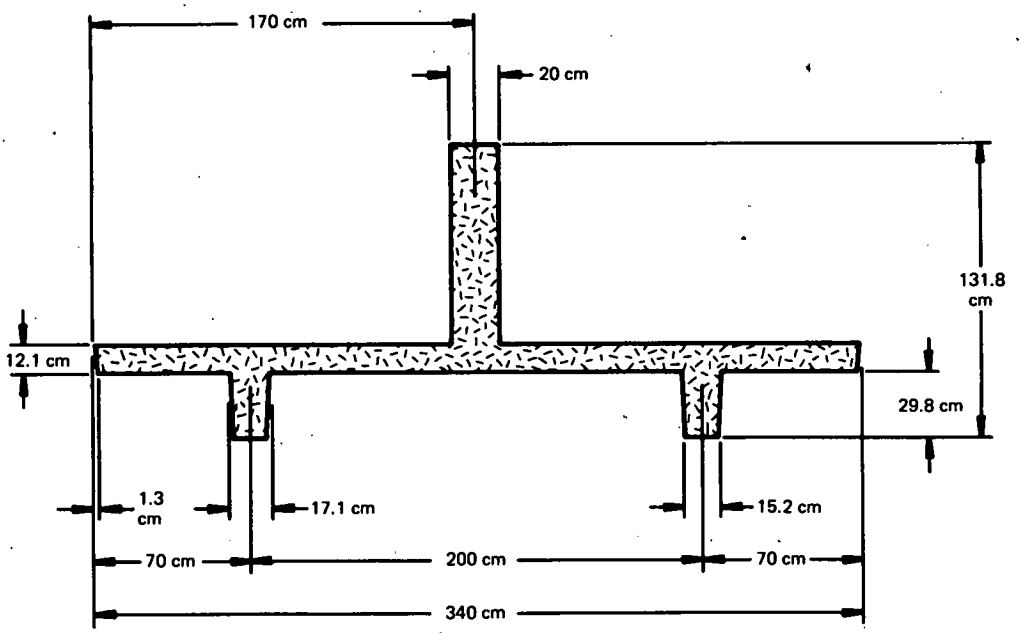
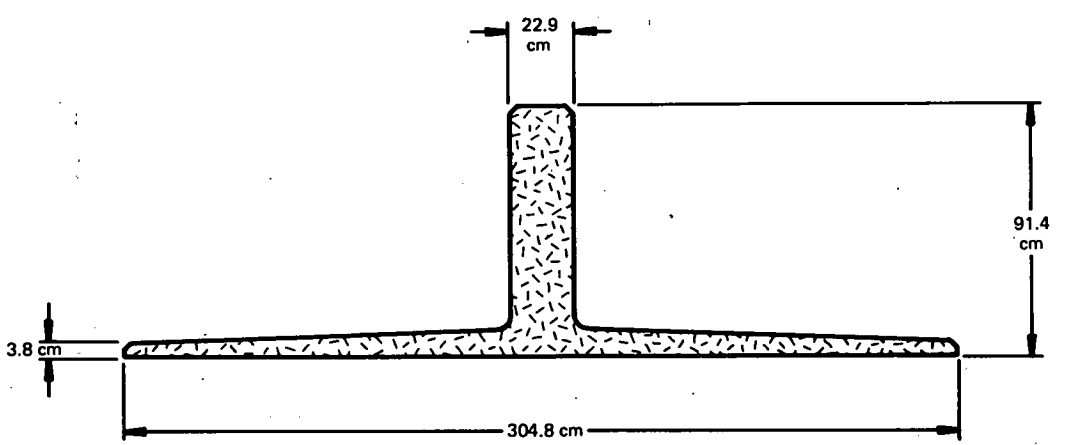


Figure 12. Inverted tee section.



of the π-shaped beam at wind velocities over 16 km/h (10 mph).

During the years subsequent to 1971 it has been observed that the depths of snowfall accumulations are always much less on the box beam and the π-shaped beam except when the wind velocity is very low. Snowfalls during a calm period or at low velocities have deposited equivalent depths on all beams; however, these storms have been the exceptions in the Ottawa area.

With a wet sticky snow both the horizontal and vertical surfaces of the test beams accumulated a cover. Wind driven wet snow also accumulated on the horizontal surface of the π and box beams.

The channel section generally accumulated an average depth somewhat less than the inverted Tee beams with the same orientation to the wind. The maximum depths of accumulations were similar, although the extent of coverage was somewhat less for the channel during wind conditions.

Conclusions and Recommendations

With a snowfall at low wind velocity all track sections accumulated snow at the same rate and obviously from a materials handling aspect the track with the narrowest width has a major advantage for snow clearance.

With snowfall at high wind velocities in cross flow to the track the plane horizontal surface design accumulated much less snow and has the minimum distortion. With dry snow and velocities of 24 km/h (15 mph) or greater there is little or no snow accumulation.

Track sections with vertical members extending above a horizontal surface cause distorted accumulations in snowfalls with winds of more than 11 km/h (7 to 8 mph). In cross flow a vertical member acts as a 100% density snow fence causing a snow deposit with a ridge parallel to the vertical member.

The track sections tested were not sufficiently long to examine the effects of wind driven snow in the longitudinal direction.

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