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Turkstra, C. J.

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#### **Publisher's version / Version de l'éditeur:**

<https://doi.org/10.4224/20337985>

*Internal Report (National Research Council Canada. Division of Building Research); no. DBR-IR-162, 1959-02-01*

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NATIONAL RESEARCH COUNCIL OF CANADA

DIVISION OF BUILDING RESEARCH

SNOW LOADS IN MOUNTAINS

by

C.J. Turkstra

ANALYZED

Report No. 162

of the

Division of Building Research

Ottawa

February 1959

## PREFACE

The 1953 edition of the National Building Code of Canada gives design snow loads for all of Canada in the form of a map showing lines of equal snow loads. The loads shown are based on measurements on the ground of maximum snow depths from records taken over a period of years by meteorological observers across the country. These observations were almost all taken in centres of populations in flat country and in valleys.

In the higher mountain regions of Western Canada, however, snow loads are far greater than those shown on the map. Although the Code notes this limitation, the lines drawn across the mountain areas might mislead a designer looking for a snow load for a structure to be located in the mountains.

This report, intended as a basis for discussion, suggests a new approach to the problem of design snow loads for mountain areas based on climate (zones of similar precipitation) and elevation. This approach is based on the ways in which other countries with high mountains have tried to solve this problem.

The proposal made in this report is based on snow observations by the Water Rights Branch of the Department of Lands and Forests of B.C. Without these records this study could not have been undertaken, and this valuable contribution is gratefully acknowledged.

The author prepared this report while working as a summer student with the Building Structures Section of DBR during his third-year vacation while a student of civil engineering at Queen's University.

Comments and criticisms on this report will be sincerely welcomed.

Ottawa,  
February 1959

R. F. Legget,  
Director.

# SNOW LOADS IN MOUNTAINS

by

C.J. Turkstra

There is no adequate specification to date for design snow loads in the mountainous regions of Western Canada. As a first step in correcting this situation a review of available information on the subject has been undertaken.

This report tabulates the information and attempts to interpret the records for possible use in future editions of the National Building Code. It also points out the need for roof snow observation in mountain areas to establish the relationship of snow on the roof to snow on the ground.

## 2. PRESENT REQUIREMENTS

### National Building Code

The 1953 edition of the NBC gives snow loads for all Canada as "contour lines" drawn between meteorological stations. These loads, however, are based on snow depth measurements in the valleys only. In the higher mountain regions snow loads are far greater than these contours show. Although the Code mentions this fact, the snow loads as shown are misleading.

The following example may illustrate the present condition. In connection with a recent inquiry on the design snow load for a ski lodge in the mountains just north of Vancouver it was found that a load of the order of 400 pounds per square foot seemed advisable as a basic design load. The largest load specified by the NBC for any area in B.C. is 80 psf. The 400 psf load suggested was based on snow measurements (carried out by the B.C. Water Rights Branch) near the proposed site of the lodge.

### Requirements of Other Countries

Several other countries are taking account of the exceptional snow loads to be expected in mountain regions. In the United States (1, 2) the eastern and western mountain regions are completely excluded from snow load maps. In Norway (3) and Sweden (4) reference

is made to the fact that snow loads in the mountains are probably greater than those specified for the lower regions. In Japan (5) many zones are used to give a high rate of change of snow load over small land areas.

Austria (6), France (7) and Switzerland (8, 9) have attempted to solve the problem of specifying snow loads for mountain regions by means of empirical equations relating snow load to elevation. In Austria the country has been divided into three zones and a linear relationship is used in each zone. In Switzerland a second degree curve is used to relate snow load to elevation.

### 3. GROUND SNOW LOADS

#### Available Information

In 1935 the Water Rights Branch of the Department of Lands and Forests of the B.C. Government began a snow survey in the southern part of British Columbia. Since then 107 snow courses have been set up to measure snow depth and density on the ground and several have been measured every year since the beginning of the survey. Some courses have been discontinued; others were started only a few years ago.

At each course a number of snow depths and density measurements is made on the ground and the averages of these are published together with the elevation of the course and the date of each survey.

These records have been summarized in Table I which gives the elevation, the number of years recorded, and the average, maximum and minimum of the yearly maxima recorded water equivalents (inches water). Stations which are measured only once a year are marked in the table. To obtain the snow load on the ground from the water equivalents the figures should be multiplied by  $\frac{62.5}{12} = 5.2$ .

#### Snow Load - Elevation Relationships

The success of other countries in relating snow load to elevation suggests a similar approach for the mountains of Western Canada. It was first intended to plot the snow cover expected once in ten years against the elevation of the snow course. Several features of the available data, however, hampered this approach.

(1) Some stations have many more records than others. As the average is not as dependent on the number of years of record as the maxima are, the average values are more characteristic of the stations.

(2) Some courses are only measured once each year, supposedly when the snow cover is at its maximum, while others are measured each month during the winter season. A statistical distribution of the maximum value recorded each year for several years of record would not be reliable under these circumstances.

It was decided, therefore, to use the average of the yearly maximum recorded water equivalents in trying to establish an elevation to snow load relationship. The USSR uses the average of the maximum yearly recorded depths as a basis of comparison rather than the observed maxima. An increase factor of 1.4 is then applied to arrive at a design load (10).

The variations in climate and the large area to be covered necessitated establishing several zones. The boundaries of these zones, however, could not be determined on the basis of similar climate (mainly precipitation) and topography only, although these two factors made it possible to lay out approximate zones. Then for each of the zones the average maximum water equivalents were plotted against elevation for each snow course. The boundaries of the zones were then adjusted until each snow course was in the zone to which it seemed best suited.

This procedure finally led to the establishment of six zones (Fig. 1). The averages of the yearly maximum water equivalents for the snow courses within each of these zones are plotted against elevation in Figs. 2 to 7. Within each zone, as expected, there is a trend towards increase in snow load with elevation with a reasonable degree of correlation. To show this, the least squares straight lines were plotted through the records.

### Discussion

In each of the zones there is considerable scatter about the least squares straight lines. This might be due, in part, to the difference in type of change of elevation, i.e. the snow load might be different at two points in the same zone at the same elevation if one was in a valley and the other was on the steep slope of a mountain. Continued study of the variables involved in snowfall prediction should help to establish more exact elevation to snowfall relationship although there will always be variations in local climate and snowfall which cannot be taken into account by a practical number of zones.

It should be noted that the considerations of this report apply to mountain areas in Western Canada only, and not to low country and valleys for which the requirements of the National Building Code (1953) are intended. No effort has been made so far to arrive at an accurate delineation between mountainous and low country for snow load purposes.

At present, however, it seems highly desirable to develop a method for specifying snow loads in mountain regions. The following sections outline a possible approach to this problem, based on available data and intended as a basis for discussion.

#### 4. ROOF LOADS

The preceding sections have dealt entirely with ground loads and not with design loads for roofs. At the present time the Division of Building Research is conducting a survey across Canada to determine the relation between roof snow loads and ground loads. It is doubtful that the over-all results of this survey will be directly applicable to mountain districts. Special observations are being made at Glacier and to the north of Vancouver as a part of this survey.

##### Special Features of Mountain Roof Loads

(1) At a snow load of 400 psf (which has been measured near the West Coast) and a density of 0.3 there would be over 22 feet of snow. Thus, almost all doors and windows would be covered, in fact, many buildings would be out of sight. If a building were in use, the surrounding area would have to be cleared and the roof would probably be cleared to prevent snow sliding or damage. In regions of high snowfall people are generally aware of the danger of structural failure due to snow load and it is the custom to remove roof snow. Observations show that when failures occurred they were often in buildings which had outlived their usefulness and had been abandoned. Thus, for mountainous areas where heavy snow accumulations occur over long periods a reduction factor for snow removal should be taken into account in any design specification.

(2) The effect of wind on snow accumulation might be an even more critical factor in mountain regions than in the rest of the country. In sheltered locations very large snow deposits may remain on the roof, whereas in exposed areas large local drifts could occur, especially on lower roof sections (Fig. 10).

(3) Phenomena such as ice accumulation at the eaves and the bridging of snow on the roof to snow on the ground are especially significant in mountain regions.

A combination of these features will probably affect the factors to be applied with a basic uniform design load. These considerations show the need for making special observations of roof snow loads in the mountains.

### Basic Uniform Design Load

The least squares lines shown in the graphs give the average of the yearly maximum snow load. A proper design load should be one that occurs only a few times during the life of the structure. Thus a design load should be greater than the average load.

To increase the load, lines have been drawn parallel to the least squares lines enclosing all the data. Figure 8 gives the suggested line of basic snow load for Zone II as an example. By using a line parallel to the least squares line the rate of change of snow load with elevation is maintained. Equations of the lines for the six zones are given in Table II and are shown in Fig. 9. These lines give loads well above the average load for most stations and, as the snow on the roof is generally less than the snow on the ground, they result in a very conservative (perhaps too conservative) estimate of the basic roof design loads. The snow loads gradually decrease away from the coast but increase again over the high mountain ranges in the interior. This is the general pattern of rainfall in southern British Columbia.

The climate section of the National Building Code gives snow loads which are not unreasonable for low elevations. These should be used on the graphs to give a minimum load condition.

### Snow Load Reduction

If it can be assumed reliably that snow will be removed from a roof the designer might be allowed to reduce the basic uniform design load. To guard against excessive reduction a maximum reduction factor should be specified such as some maximum percentage of the specified load. An absolute minimum load should also be given.

The snow load reduction due to roof slope should probably be modified for mountain regions. If the ground depth is up to the eaves the snow could not be expected to slide off even with a 60° slope. Thus, the bridging effect may prevent snow from leaving the roof.

## 5. CONCLUSIONS

The snow loads given in the National Building Code (1953) are not applicable to the mountain regions of Western Canada. The simplest method of correcting this situation might be to eliminate the existing snow contour lines for this area and to replace them with a simple table of recorded values of snow measurements. A designer could then derive a design snow load for a particular locality from the nearest snow courses taking due account of elevation. It is believed, however, that the approach suggested in this report is preferable to the simple table.

The graphs presented show a general relationship between elevation and ground snow load. Inevitably, the final choice of design roof snow loads should depend largely on judgment and the best available information, such as records of any nearby snow course or local knowledge. The uncertainties of snow clearance coupled with wind action, radiation and bridging effects limit the value of general snow load prediction. Special snow-roof observations in the mountain regions will help to assess these factors.

As a general guide, however, the use of zones, each with a load elevation relationship and a minimum load, could give a conservative estimate of roof load.

## REFERENCES

1. American Standards Association. American Standard Building Code requirements for minimum design loads in buildings and other structures. Approved September 3, 1955.
2. United States Division of Housing Research, Housing and Home Finance Agency. Snow load studies. Housing research paper no. 19, Washington, May 1952. 19 p.
3. Byggeforskrifter, Bind I (Building Code Specifications, Volume I) Forsynings Og Gjenreisningsdepartementet, December 15, 1949. Oslo. 39 p.
4. Anvisningar Till Byggnadsstadgan (Building standards for cities). Byggnadsstyrelsens Publikationer, February 1950:1. Stockholm, 159 p.

5. Unpublished draft of a snow load specification prepared by the Comm. on Design Loads and Building Structures of the Architectural Institute of Japan dated Sept. 1956, received from Prof. Hisada, Head of the Structural Dept. of the Bldg. Research Institute in Tokyo.
6. Krapfenbauer, Robert J. Zur schneebelastung der hochbauten (Snow loads on elevated constructions). Dokumentationszentrums für Technik und Wirtschaft, Abhandlungen No. 23, Vienna, 1954, 36 p.
7. Ministère de la Reconstruction et de L'Urbanisme. Regles definissant les effets de la neige et du vent sur les constructions (Rules defining the effect of snow and wind on buildings) January 1947, Paris, 85 p.
8. Normen für die Belastungsannahmen, die Inbetriebnahme und Überwachung de Bauten (Swiss standards for design loads, acceptance and maintenance of structures) Schweizerischer Ingenieur - und Architekten-Verein. Zurich 1956. 40 p.
9. Zingg, Dr. Th. Die maximalen schneelasten und ihre abhangigkeit von der meereshöhe (Maximum snow loads and their relationship to altitude above sea level). Schweizerische Bauzeitung, Vol. 69, no. 45, 1951.
10. Building Standards and Regulations. Standards of Structural Design, Vol. II, Moscow, 1954. pp 111-21.

TABLE I

## MAXIMUM YEARLY WATER EQUIVALENTS

Course No.	Course	Elevation (ft. a.s.l.)	Yrs. Record	Yearly Maxima		
				Average (inches)	Maximum (inches)	Minimum (inches)
1a	Grouse Mt.	3800	23*	48.5	98.3	14.8
2	Cypress Lk.	1100	23*	17.9	47.9	0
3	Trout Ck.	4700	24	7.2	11.5	3.6
3a	Summerld Res.	4200	23*	8.8	12.9	4.4
4	McCulloch	4200	24	6.7	9.8	4.2
5a	Mission Ck.	6000	24*	19.8	25.6	12.6
6a	Aberdeen Ck.	4300	19*	6.4	9.4	3.4
7	Gerrard	6000	23*	15.2	21.9	6.1
8a	Sinclair Pass	4500	23*	5.3	10.3	2.3
9	Canoe Riv.	3000	6*	2.5	3.8	1.5
9a	Canoe Riv.	3000	18	5.5	9.8	2.7
10	Fernie	3500	21	9.0	16.4	3.1
10a	New Fernie	4100	8	16.0	23.7	12.3
11	Glacier	4100	22	25.1	41.7	12.5
12	Field	3800	4	4.6	5.9	3.2
12a	Field	4200	20	5.8	12.9	2.3
13	Upper Stave Riv.	450	9*	3.9	11.5	0
14	Alouette Lk.	1500	10*	2.5	9.8	0
15	Revelstoke	1850	21	12.0	20.0	3.2
15a	Revelstoke	6000	12	54.0	72.6	45.5
16	Ferguson	2900	21*	20.7	31.1	5.6
17	Farron	4000	21	13.5	19.8	7.1
18	Sandon	3500	21*	12.2	20.5	2.8
19	Nelson	3050	21	15.7	24.5	6.7
20	Kimberley	3800	21	7.1	12.2	1.6
20a	Sullivan Mine	5100	13	15.9	21.2	11.6
21	Invermere	3400	2	8.8	13.4	4.1
21a	Invermere	3500	11*	4.7	8.3	1.3
22	Blue Riv.	2250	21	11.3	15.6	2.8
23	Powell Riv.	2200	13*	24.7	43.9	5.4
23a	Powell Riv.	2650	12*	41.1	62.7	6.2
24	Powell Riv.	3400	14*	40.2	59.4	18.4
24a	Powell Riv.	3000	19*	21.6	50.0	3.4
24b	Powell Riv.	3100	14*	62.3	85.8	36.5
25	Kinbasket Lk.	2250	10*	12.9	18.5	6.5
25a	Middle Riv.	3450	4*	16.2	18.3	12.6
26	Tashme	2200	4	6.3	18.9	0
26a	New Tashme	2500	12	14.0	22.6	3.8
27	Brockmare	3200	14	10.1	13.4	3.9
28	Burwell Lk.	2900	13*	48.6	102.7	31.9
28a	Hollyburn Mt.	3350	14*	49.5	77.6	23.2
29	Palisade Lk.	2900	13*	63.0	112.0	28.0
29a	Dog Mt.	3350	14*	51.7	79.7	42.6
30	Loch Lomond	3600	13*	56.5	146.0	27.4
31	Boulevard Ck.	5000	10*	12.7	17.9	7.9
32	Marble Canyon	5000	12	15.1	22.6	11.3
33	Kicking Horse	5400	12	16.1	20.7	11.9
34	Quarret Lks.	4000	12*	16.4	24.5	7.3
35b	Klesilkwa	3700	11	18.8	31.2	7.1
37	Big Mouth Ck.	4000	2*	28.0	29.6	26.3
38	Wood Riv.	4000	2*	16.8	18.5	15.1
39	Blackwater Lookout	5500	2	17.1	17.4	16.8
39a	Blackwater Ck.	5200	2	15.3	16.3	14.3

\* Measured only once each year.

TABLE I - Cont'd

MAXIMUM YEARLY WATER EQUIVALENTS

Course No.	Course	Elevation (ft. a.s.l.)	Yrs. Record	Yearly Maxima		
				Average (inches)	Maximum (inches)	Minimum (inches)
40	Beaverfoot	6200	3*	6.7	6.8	6.5
41	Upper Elk	4400	11	9.3	14.5	5.3
42	Old Glory Mt.	7000	10	32.4	38.9	24.7
43	Gray Ck.	5100	11	21.2	24.8	17.5
45	Steel Head	1900	3	2.8	4.7	0.5
46	Copper Mt.	4300	10	7.5	10.2	4.8
47	Nickel Plate Mt.	6200	10	7.4	10.7	4.6
48a	Monashee Pass	4500	6*	12.8	15.6	11.1
49	Porcupine Ridge	6000	2*	12.1	15.0	9.1
50	Mt. Cook	6000	9	62.4	77.8	52.0
51	Trophy Mt.	6250	9	26.0	32.6	16.1
52	Yellowhead	6100	8	20.1	22.7	17.9
53	Albreds Mt.	6300	9*	29.5	35.4	25.0
54	McBride	5300	8	19.2	25.7	11.1
55	Postill Lk.	4500	9	8.9	12.1	5.5
56	Tranquille Lk.	4650	8	10.4	15.0	7.2
57	Pass Lk.	2850	8	4.5	7.6	2.1
58	Freda Lk.	2300	5*	28.5	30.5	25.2
59	Barkerville	5000	8	18.6	21.6	16.1
60	Tatlayoko	5600	7*	11.0	14.3	8.4
61	Wells Mt.	4900	6	14.9	20.7	4.5
62	Kidprice Lk.	4500	7	27.5	40.0	18.8
63	Tahatsa Lk.	4275	7	35.8	51.4	18.3
66	Nechako	3100	7	3.3	4.5	1.6
67	McGillvary Pass	5900	7	29.7	44.0	16.8
68	Fernie Ridge	5600	2	24.7	25.2	24.1
69	Penticton Res.	5300	6*	8.0	10.6	4.5
70	White Rocks Mt.	6000	4*	17.9	21.5	14.3
71	Longworth	5700	6	34.0	42.0	37.4
72	Hansard	2100	6	11.5	14.0	6.6
73	Precipice	4300	1	8.3		
74	Tenquille Lk.	5500	6	53.0	69.7	45.3
75	Garibaldi Pk.	5300	1	29.8		
76	Forbidden Plateau	3700	4	58.1	70.9	45.2
78	Labour Day Lk.	3350	5*	20.6	29.3	13.7
79	Elk Riv.	1200	4	6.7	10.4	0
80	Knouff Lk.	3950	4	6.2	8.1	4.5
81	Pavillion	4050	4	4.0	5.8	3.2
82	Ft. St. James	2650	4	6.9	8.5	5.0
83	Upper Quinsam	3000	3	17.2	19.6	13.7
84	Anglemont	3900	3	17.9	20.0	16.5
85	Le Jeune Lk.	4500	3	7.0	9.6	5.5
86	Tripp Meadows	2700	2	14.2	19.6	8.7
87	Alligator Meadows	1700	2	6.3	12.6	0
88	Nazko	4500	2*	5.0	5.6	4.3
89	Whatsan Lk.	3400	2*	22.0	23.1	21.0
90	Barnes Ck.	5300	1	17.5		
91	Park Mt.	6200	1	33.5		
92	Highland Valley	5100	1	3.8		
93	June Lk.	3200	1	25.2		
94	Burman Lk.	4100	1	62.4		
95	Upper Thelwood Lk.	3200	1	59.2		
96	Memory Lk.	4200	1	71.2		
97	Log Cabin	2880	1	8.9		
US <sub>1</sub>	Baree Mt.	6000	6	53.0		
US <sub>2</sub>	Blue Bird Basin	6800	7*	43.0		

\* Measured only once each year.

TABLE II

EQUATIONS OF SNOW LOAD - ELEVATION RELATIONSHIPS

Zone	Snow Load Equation	Minimum
I	$L = \frac{H}{7.5} - 27$	From N.B.C.
II	$L = \frac{H}{12.5} - 110$	From N.B.C.
III	$L = \frac{H}{30} - 50$	From N.B.C.
IV	$L = \frac{H}{31} + 15$	From N.B.C.
V	$L = \frac{H}{15} - 33$	From N.B.C.
VI	$L = \frac{H}{12} - 220$	From N.B.C.

L = Snow load - psf.

H = Elevation - ft.

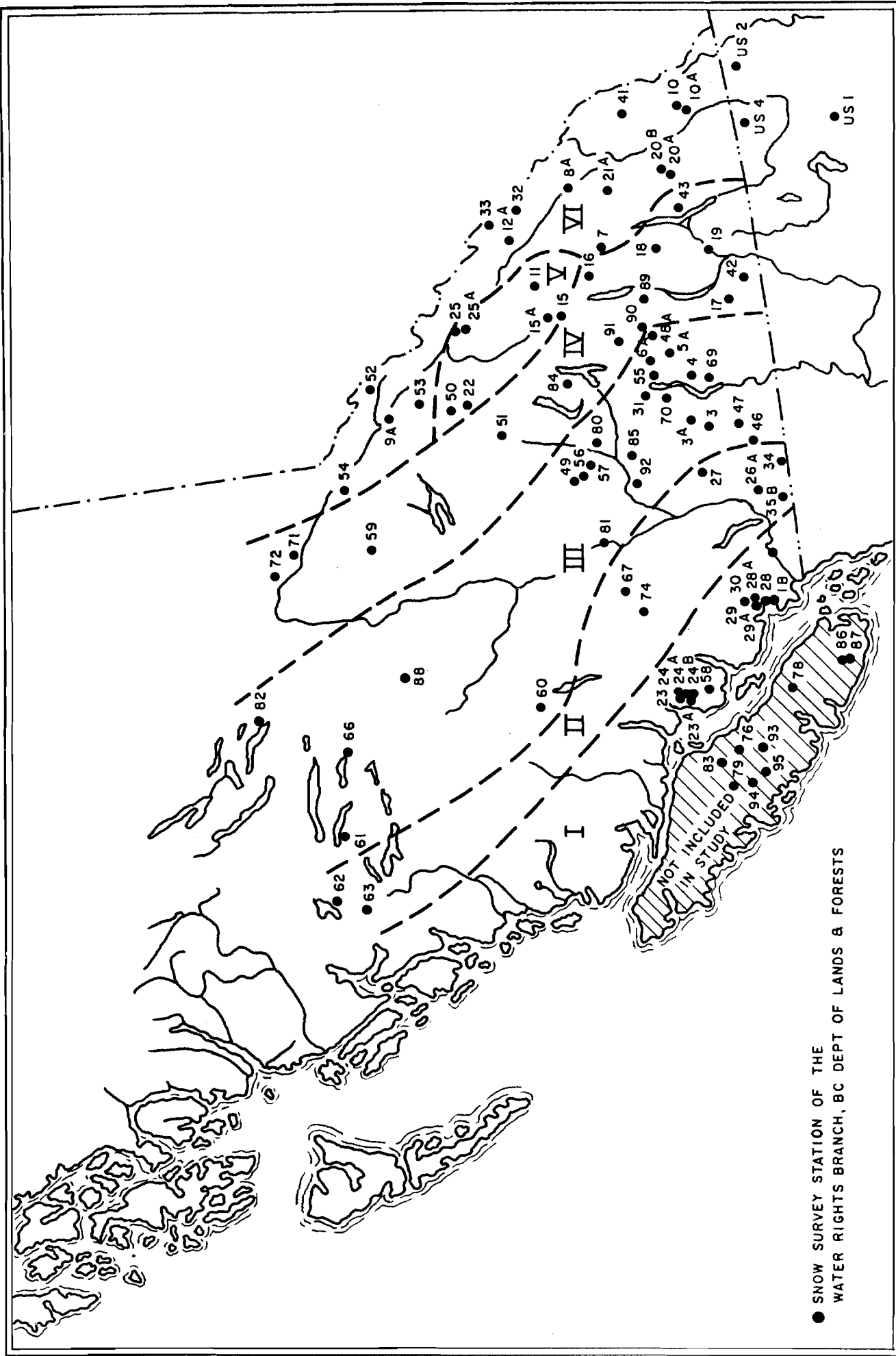


FIGURE I SUGGESTED LOAD-ELEVATION ZONES FOR SOUTHERN B.C.

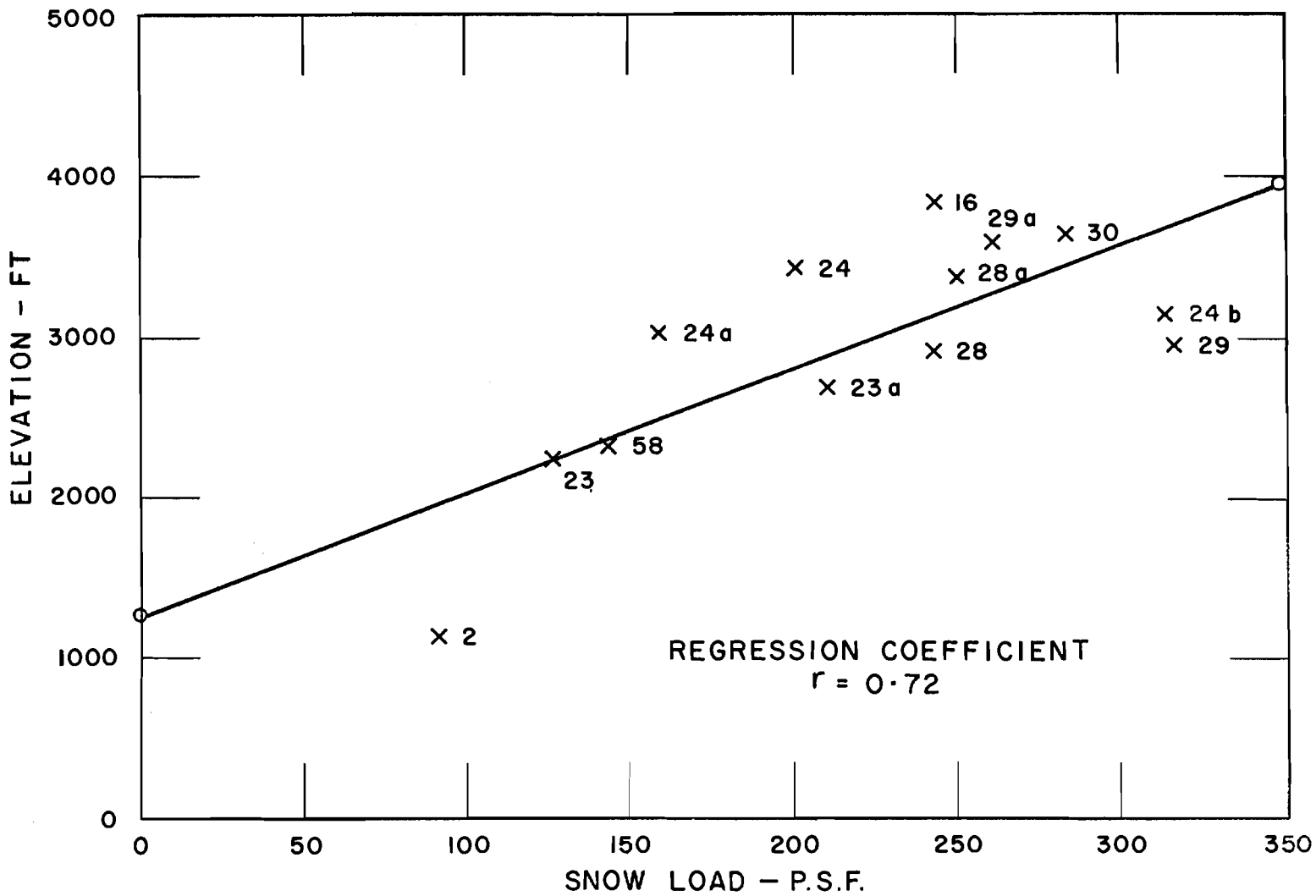
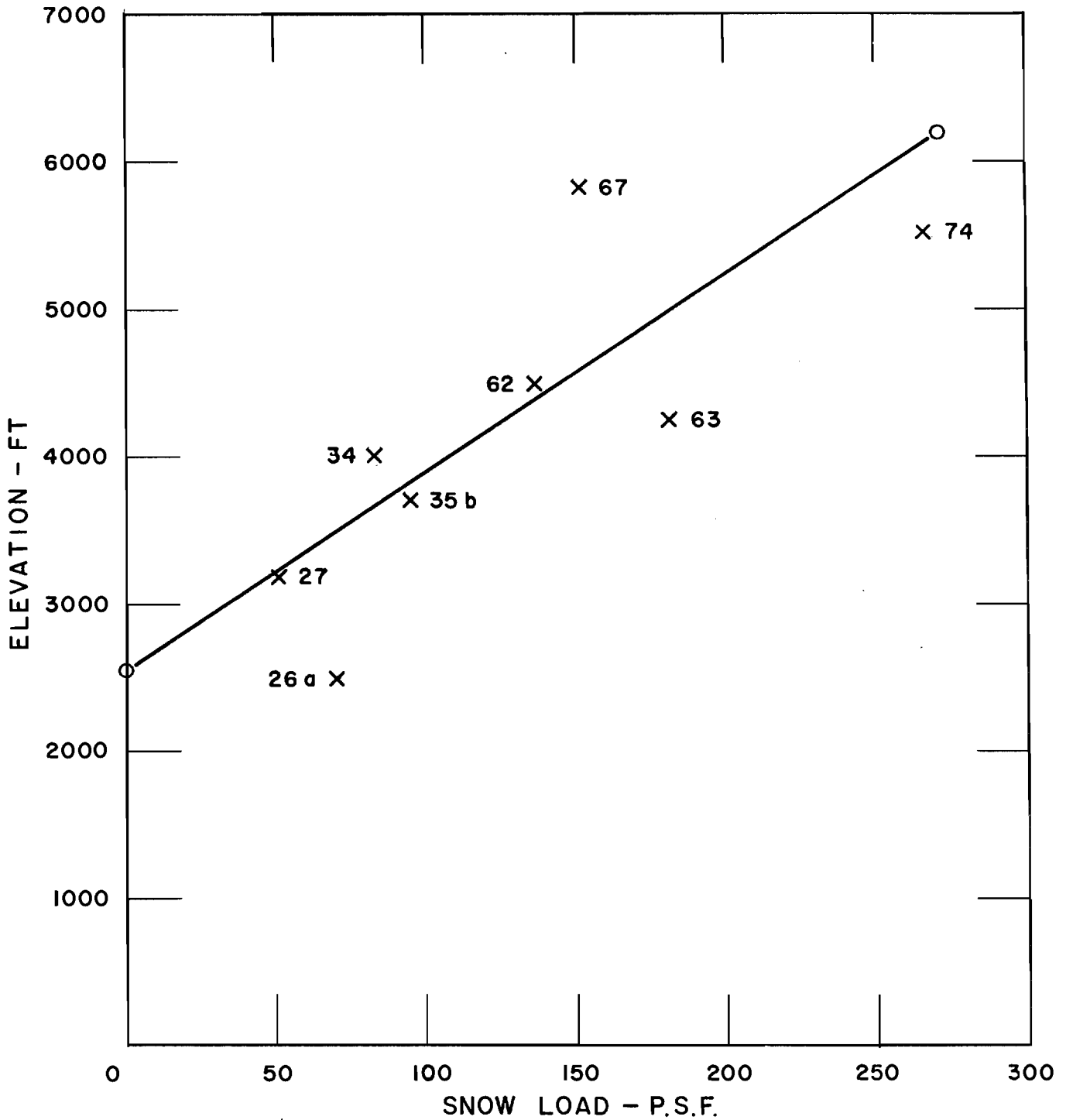


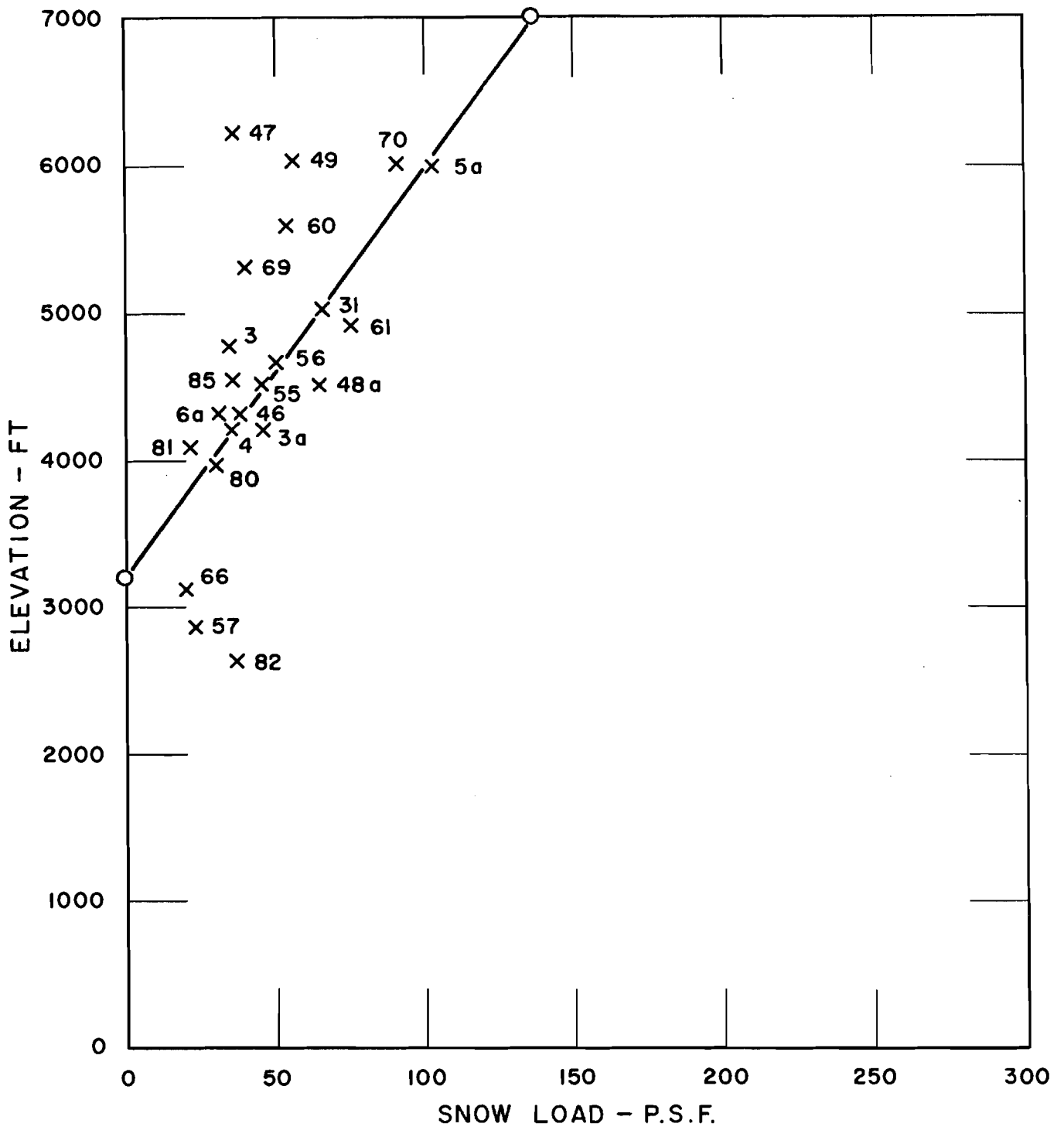
FIGURE 2    GROUND SNOW LOAD, ZONE I

DATA FROM B.C. SNOW SURVEY, WATER RIGHTS BRANCH,  
DEPT. OF LANDS AND FORESTS, B.C.



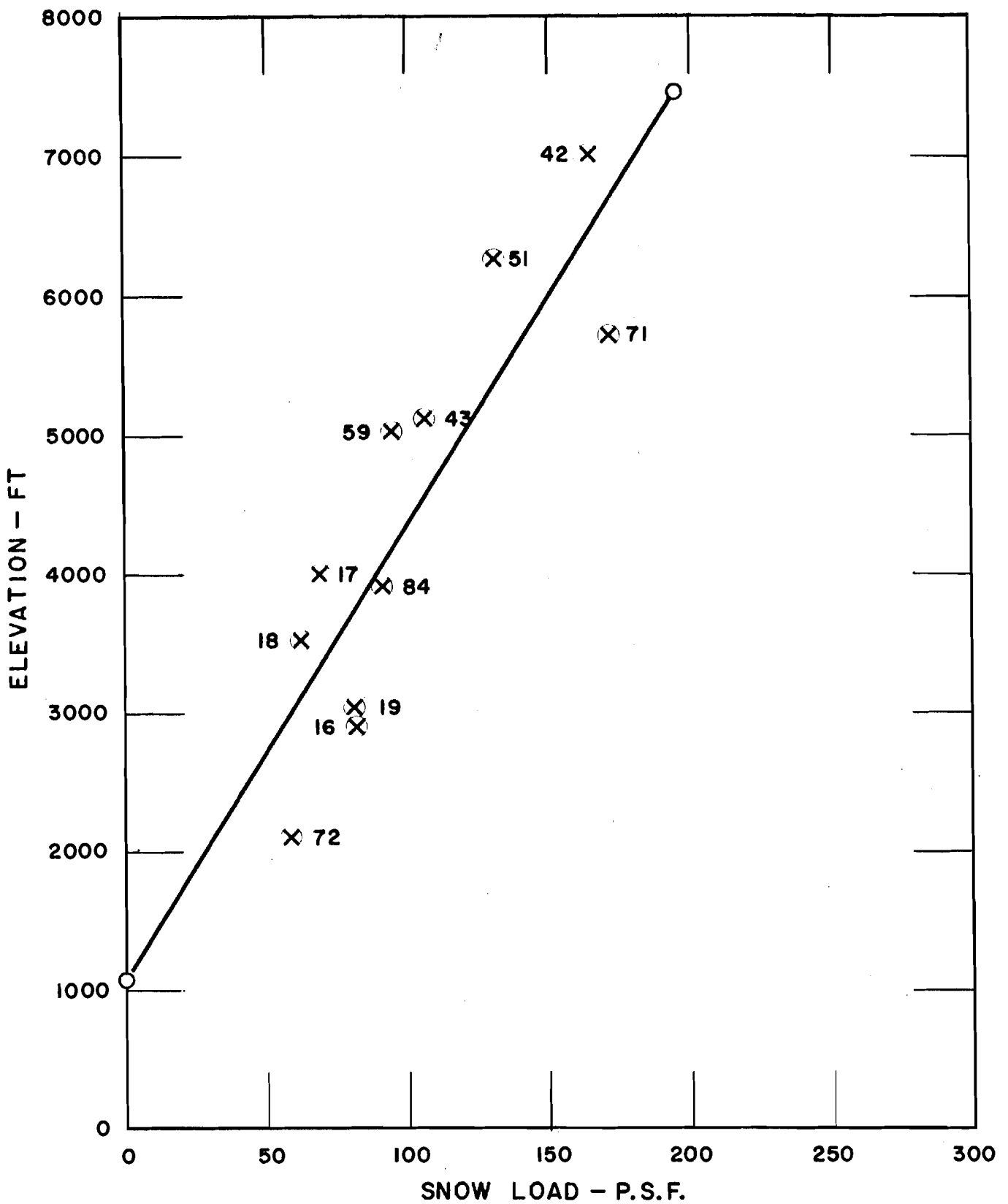
**FIGURE 3   GROUND SNOW LOAD, ZONE II**

DATA FROM B.C. SNOW SURVEY, WATER RIGHTS  
BRANCH, DEPT. OF LANDS AND FORESTS, B.C.



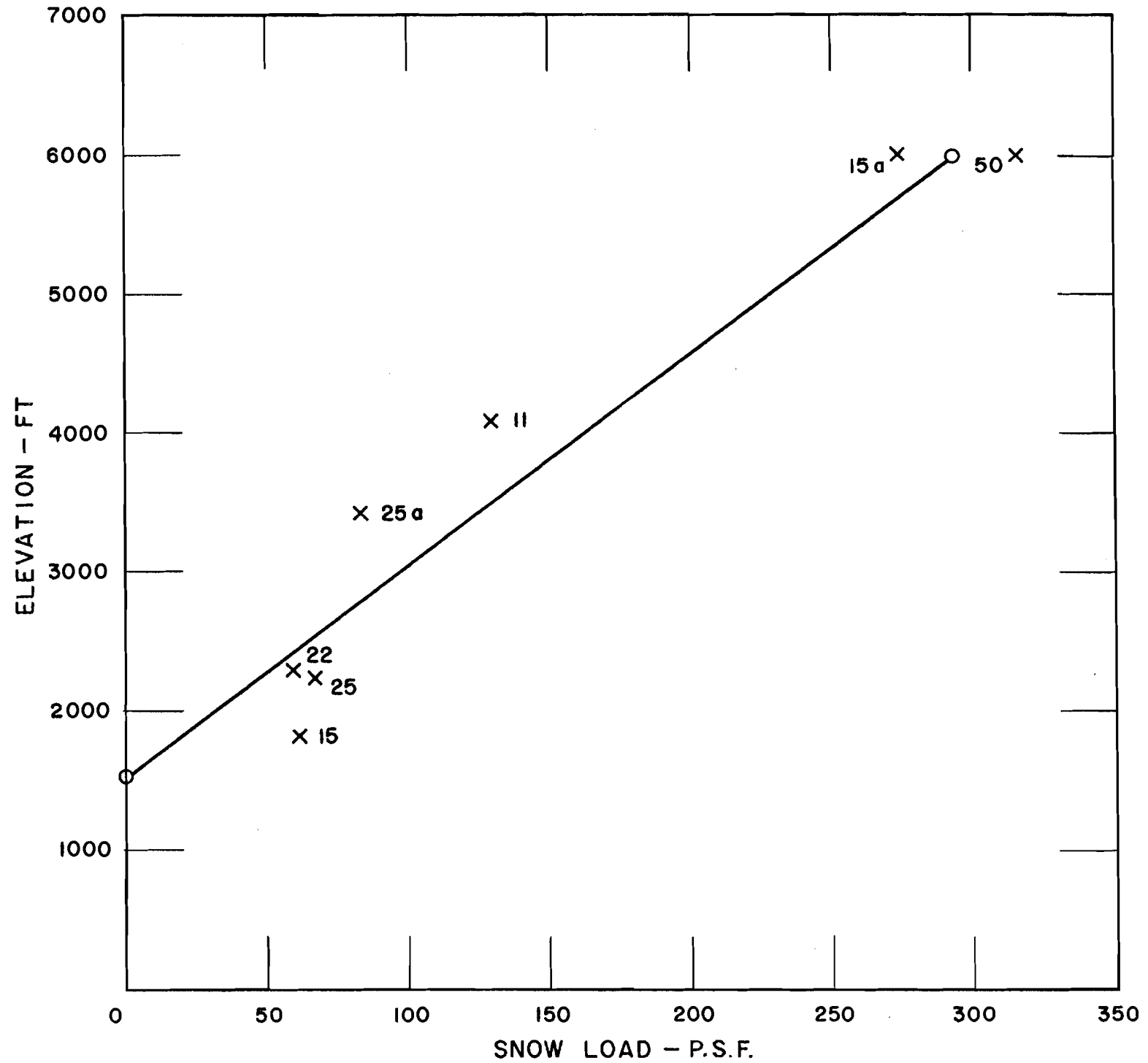
**FIGURE 4** GROUND SNOW LOAD, ZONE III

DATA FROM B.C. SNOW SURVEY, WATER RIGHTS  
BRANCH, DEPT. OF LANDS AND FORESTS, B.C.



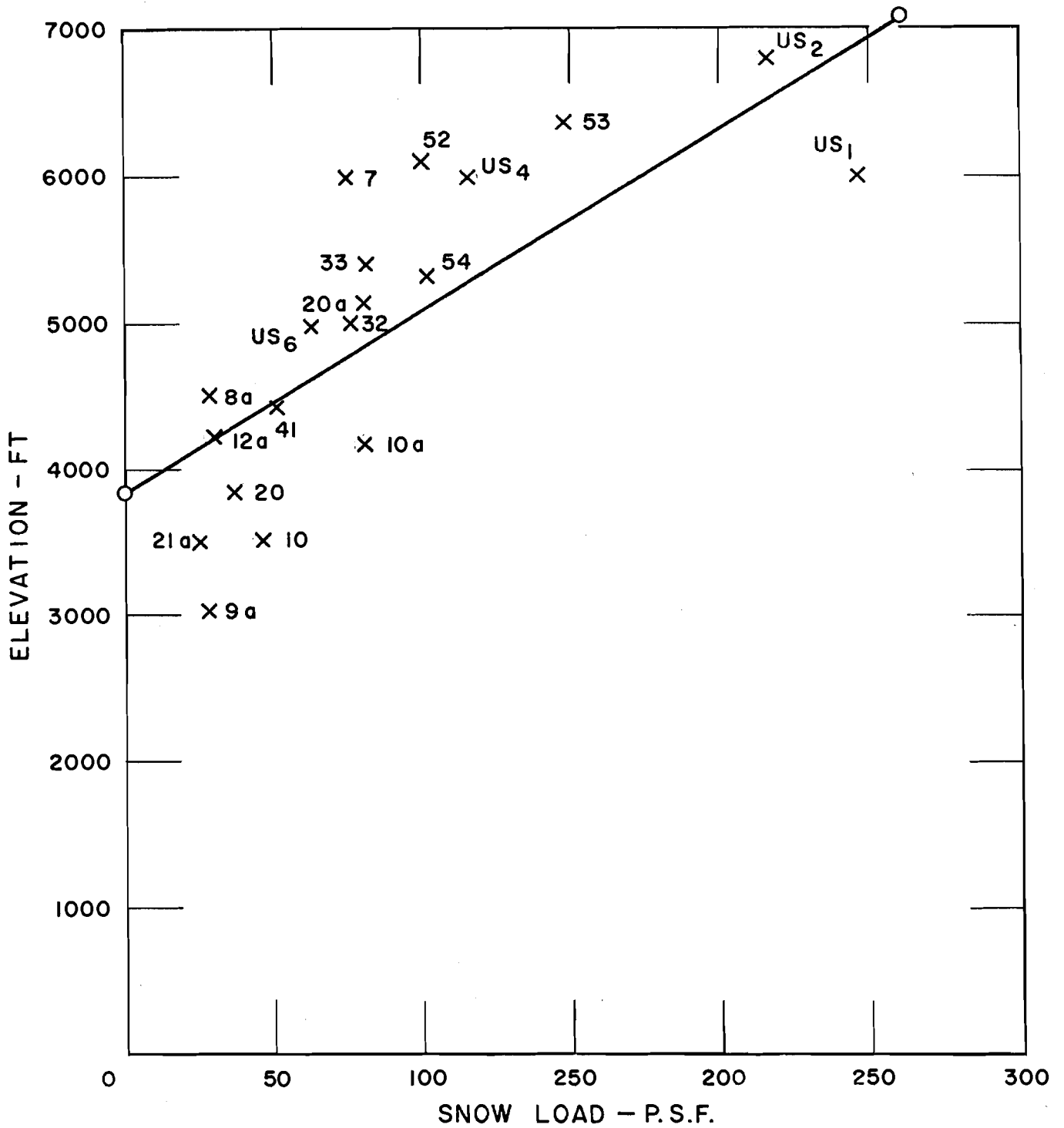
**FIGURE 5** GROUND SNOW LOAD, ZONE IV

DATA FROM B.C. SNOW SURVEY, WATER RIGHTS BRANCH,  
DEPT. OF LANDS AND FORESTS, B.C.



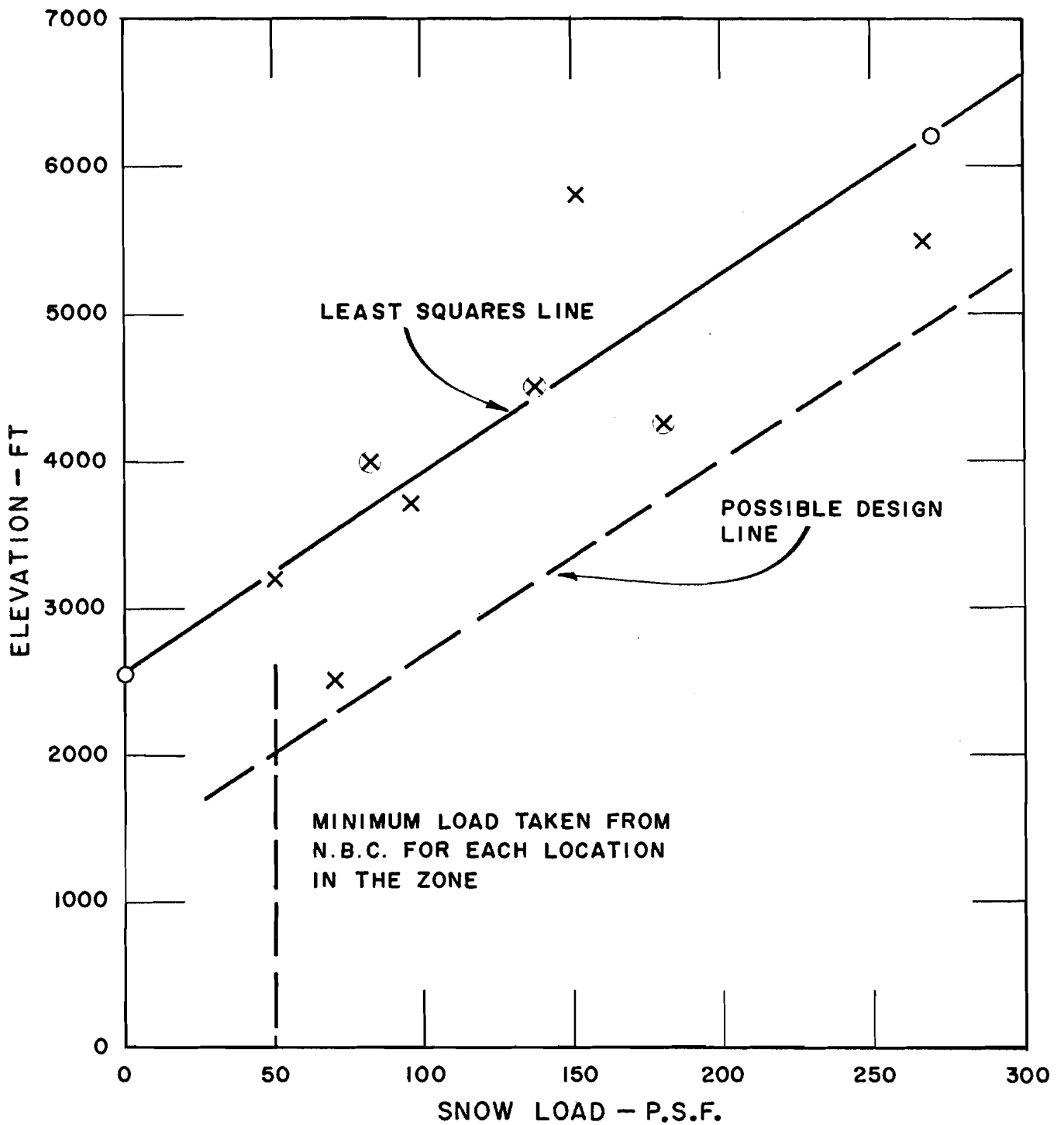
**FIGURE 6    GROUND SNOW LOAD, ZONE V**

DATA FROM B.C. SNOW SURVEY, WATER RIGHTS BRANCH,  
DEPT. OF LANDS AND FORESTS, B.C.

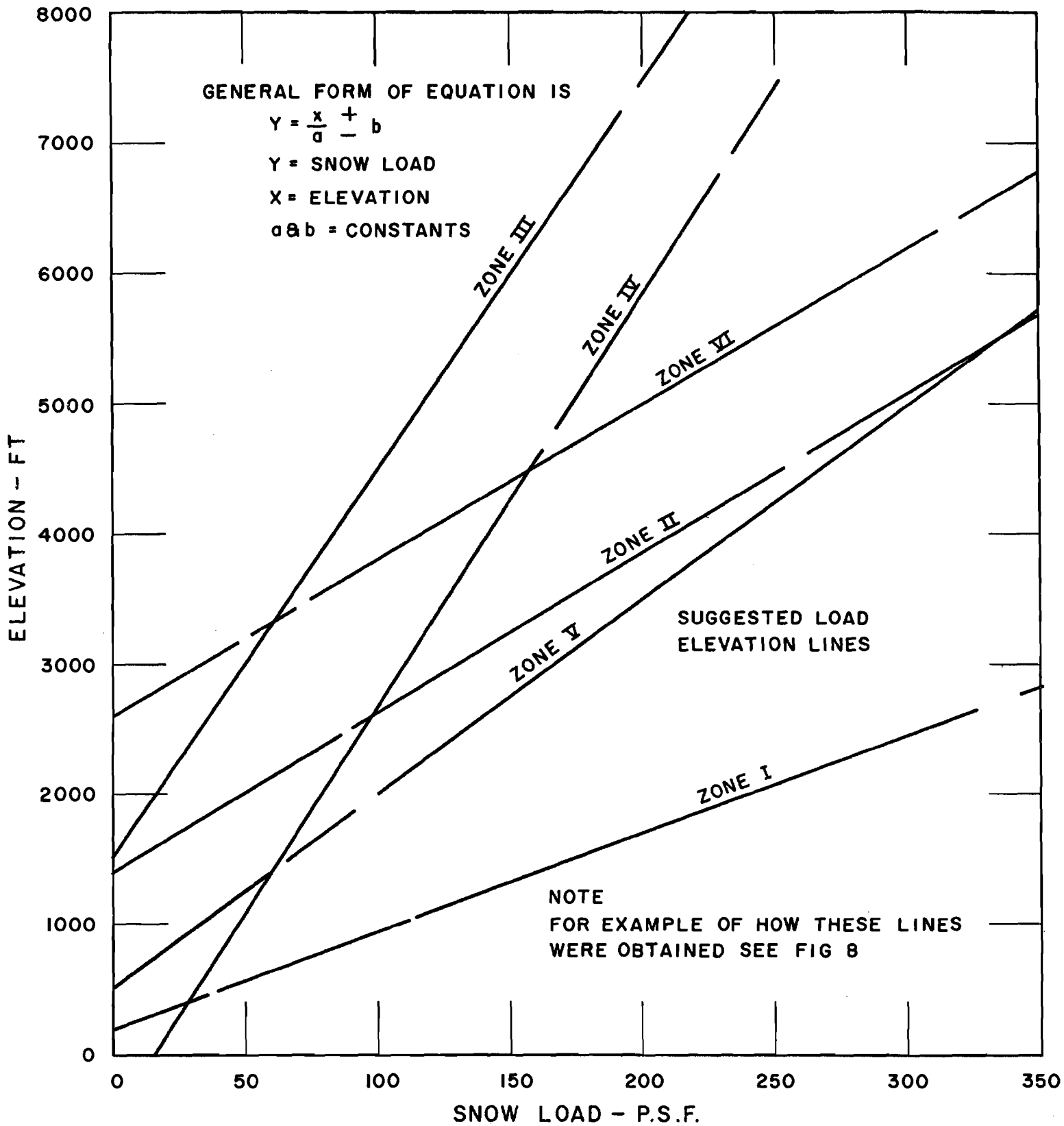


**FIGURE 7 GROUND SNOW LOAD, ZONE VI**

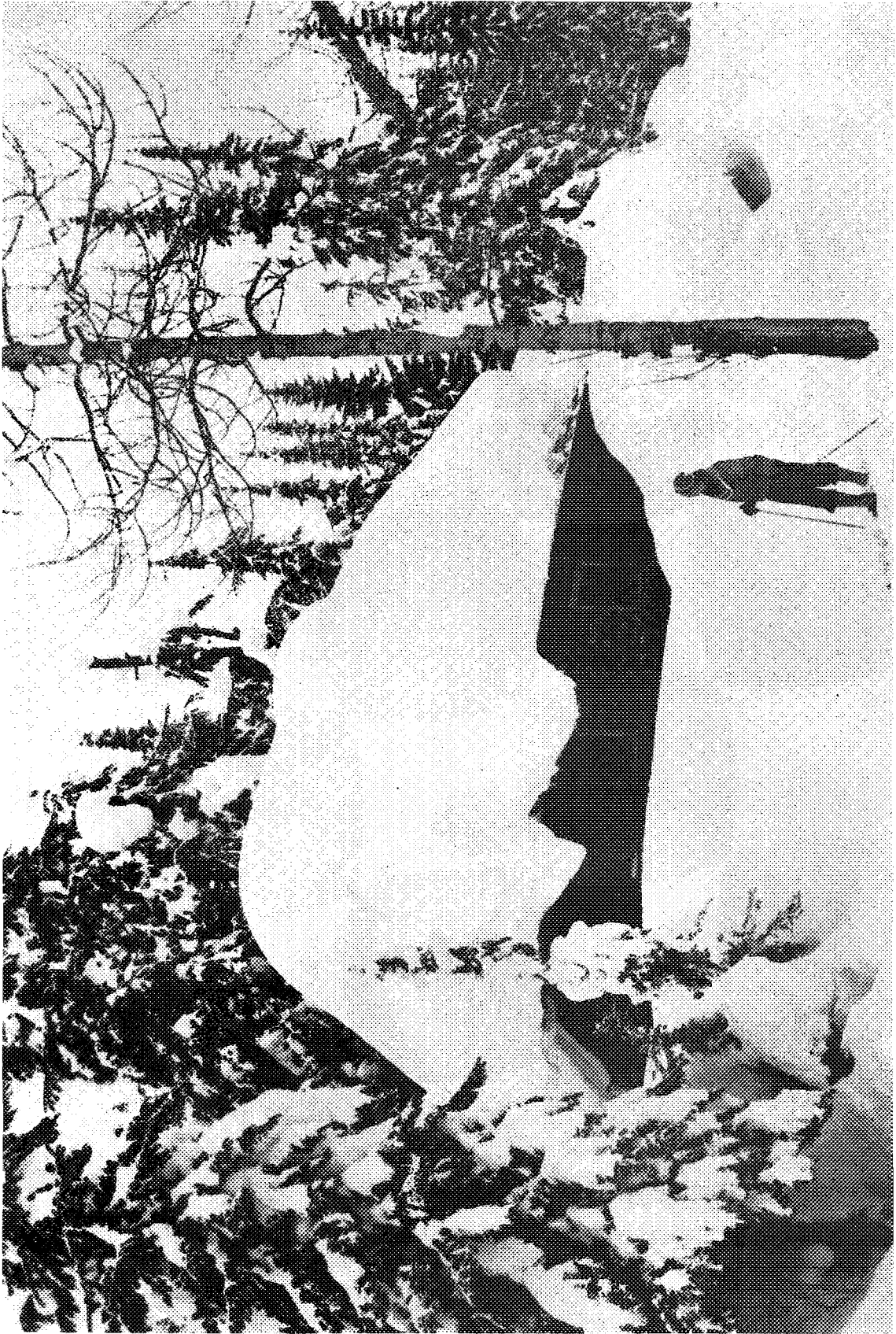
DATA FROM B.C. SNOW SURVEY, WATER RIGHTS  
BRANCH, DEPT. OF LANDS AND FORESTS, B.C.



**FIGURE 8    SUGGESTED LINE OF BASIC SNOW  
LOAD FOR ZONE II (EXAMPLE)**



**FIGURE 9 SUGGESTED BASIC DESIGN SNOW LOADS**



(Photo by B. Engler, Banff)

Figure 10 Alpine Club Lodge, looking northwest (January 29, 1958)