Snow Loads for Structural Design in Montana (Revised 2004)

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Preface

This report provides recommended ground snow loads that can be used in the design and analysis of structures across the state of Montana. This document is a revision of an earlier publication by Dr. Fred F. Videon and James P. Schilke titled *Snow Loads for Structural Design in Montana*. Since its issue in 1989, the publication of Videon and Schilke has become an indispensable aid to building designers and building officials working in the state. This revision updates the ground snow load values for Montana based on the additional data available since the earlier work was completed in 1989, and it also takes advantage of advances in computer technology in the intervening years to offer the designer a broader overview of the results of the snow load analyses.

The authors thank the Civil Engineering Department at Montana State University, as well as the Montana Section of ASCE for their financial support in conducting this study and preparing this document. The authors would also like to thank Dr. Dan VanLuchene for reviewing the example problems and Phil Farnes for reviewing the snow loads. Dr. VanLuchene has been teaching structural engineering at Montana State University for almost 20 years. Phil Farnes has been investigating ground snow loads in Montana for over 30 years, and assembled one of the first statewide snow load maps in 1975 (Farnes, 1975).

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Introduction

The fundamental objective of this updated ground snow loads study remains the same as that of the original study prepared by Fred Videon and Jim Schilke in 1989:

> 'In mountainous regions such as Montana, snow can accumulate to great depths and cause loads on structures that may be many times greater than the loads normally used for structural design. These snow loads depend on the depth and density of the snow that accumulates on a structure under extreme conditions that occur during the lifetime of a structure. Because snow conditions are affected by differences in elevation and other factors, the loads associated with snow can vary significantly from place to place, and it is common for the snow load to double or triple between locations only a few miles apart. Thus, in order to be able to design structures at a specific location, it is essential to have reliable snow data for that location.'

This document provides the ground snow load for all locations in Montana and presents design examples for the determination of the loads that subsequently should be applied to the roof of a structure. It is intended to serve as the case study required by Section 1608.2 of the IBC 2003 for determining ground snow loads in locations where the values are not provided by the IBC. The 50-year ground snow loads to be used in structural design are presented in two formats. A contour map has been created from which the ground snow load can be determined at any location in Montana. Tabled values for ground snow loads are also reported for many sites around the state. The contour map and tables are based on a statistical analysis of data from the Natural Resources Conservation Service (NRCS) and the National Weather Service (NWS). The analysis used the data available from these sources through June 2001. In processing the data, care was exercised to exclude from consideration records with unexplainable anomalies or an unacceptable amount of missing information. While the ground snow loads provided in this document may be used with confidence, climatic conditions can vary dramatically across short distances in Montana. The designer is encouraged to carefully evaluate the appropriateness of the ground snow loads reported herein for his/her specific site.

The use of ground snow loads in building design is described in the widely used publication ASCE 7-02 *Minimum Design Loads for Buildings and Other Structures.* Therefore, this document includes examples in which the structural snow loads are calculated from ground snow loads using the methodology in ASCE 7-02. In reviewing these examples, the reader should have ASCE 7-02 available for reference.

Chapter 1 of this document outlines the process of determining the ground snow load for any location in Montana. At the conclusion of Chapter 1, tables of ground snow load values for point sampled locations are presented. Following the tables are contour maps, from which the ground snow load at any location in the state can be determined.

Chapter 2 presents a collection of design examples that illustrate the use of the snow loads available in this manual in conjunction with

ASCE 7-02.

Presented in Appendix A is a description of the method that was used to determine design snow loads with a 50-year MRI from records of annual maximum snow load. This appendix includes an expanded table of design ground snow loads (relative to those in Chapter 1) that were generated in the various analyses conducted for this study.

Appendix B outlines the process that was used to determine ground snow loads from the ground snow depth data available from the NWS stations.

Chapter 1

Ground Snow Loads

1.1 Ground Snow Loads

A ground snow load is the weight of snow per unit area that is on the ground. The unit area is taken as the horizontal projection of the actual ground surface; thus the ground snow load represents the amount of snow that would fall if the surface of the earth were perfectly flat. The ground snow load that is to be used for the design of a structure should be the largest that can reasonably be expected to occur during the design life of the structure, which typically is taken as 50 years. In structural engineering, the ground snow loads used in design specifically correspond to the load with a 2% chance of occurring in any given year. This value is also referred to as the ground snow load with a 50-year mean recurrence interval (MRI). Building codes such as the IBC 2003 and design guides such as ASCE 7-02 have adopted this load as the design standard. This design load is determined statistically from snow data that is gathered over a period of years. Note that methods are available to convert a 50-year MRI ground snow load into a snow load with a longer or shorter MRI. The reader is referred to ASCE 7-02 in this regard.

1.2 50-year Ground Snow Loads for Montana

The reader of this document can determine 50-year MRI ground snow loads at a specific location in Montana in three ways: a) select the value from the nearest monitoring station listed in Table 1.1, b) use the Snow Load Finder Tool on the World Wide Web at: `http://www.coe.montana.edu/ce/snowloads/home.html`, or c) use a contour value from the appropriate map provided at the end of this chapter.

If the site of interest is at or close to a station (in both distance and elevation) with a tabled snow load value in Table 1.1, the user should consider using the value reported for that station. This value is a result of a statistical analysis of historical data for this particular monitoring station.[1]

The web-based Snow Load Finder Tool provides a snow load value for a specific latitude and longitude. This value is the result of an interpolation of station values (normalized to elevation) that is multiplied by the actual elevation at the location of interest. This tool is the preferred method for finding the ground snow load value at a point away from a station and/or at a different elevation from a station. The Snow Load Finder Tool also provides snow load and elevation information from the three closest stations surrounding the point of interest, so that the engineer can get a sense of the local variation of the snow loads in the area of interest.

[1] The reader should note that Appendix A provides considerable background information on the methods used to arrive at the ground snow load values. Also note that the tables of Appendix A provide additional information not found in Table 1.1, such as number of years of data, max recorded depth, 50 year (MRI) depth, as well as low extreme, high extreme, and calculated snow load values by the Log-Pearson Type III and Lognormal methods.

The contour maps at the end of this chapter were generated by interpolating the sampled site data referred to in the previous paragraph. The contour maps reflect a correction of station data for proximity and elevation. Color bands are provided for clarity. The user, however, shouldn't select a value based on color. To determine the value at the point of interest, the user must interpolate between adjacent contours.

The contour maps are provided primarily to give the designer an idea of the magnitude of the snow loads and the rate at which they are changing in any given area. As previously mentioned, the preferred method for finding ground snow loads at points away from tabled stations is to use the Snow Load Finder. The interpolation routine that was used to generate the contour maps had difficulty in some areas addressing the rapid variation in snow loads that can occur in Montana with small changes in position and elevation. Notably, the routine encountered problems estimating ground snow loads in localized areas of high elevation surrounded by lower terrain when some or all of the closest available data was from low elevation stations. The Snow Load Finder, on-the-other-hand, includes an algorithm that checks for this situation, and, if necessary, implements the following adjustments:

1) the interpolation is modified to weight the results more heavily based on the elevation of the adjacent stations relative to the elevation of the point of interest (with stations closer in elevation to the point of interest having a greater influence on the estimated ground snow load), and/or

2) an additional station that is higher in elevation than the point of interest is located. The data from this station is weighted equally with that of the immediately adjacent stations in the interpolation process.

Comments on the snow loads obtained from these three sources (Table 1.1, web-based Snow Load Finder, and contour maps) are presented in Chapter 2, notably at the beginning of the solution to the first and third example problems.

In general, the snow load values obtained by these three methods for a given location will be similar but not necessarily identical in magnitude. Obviously, the value at a station is based on the specific data collected at that station. In contrast, values from the Snow Load Finder and the contour maps reflect the influence of the data collected at several stations near the point of interest. Thus, the Snow Load Finder and contour maps somewhat globally smooth through any site specific anomalies that may be present in the station data. Finally, results from the Snow Load Finder may further reflect the explicit adjustment described above for situations where station data is sparse at the elevation of interest.

In using any of these three methods, it is important to remember that elevation is a critical parameter in determining ground snow loads in Montana (snow loads increase with elevation). A check should be made to ensure that the snow load obtained is for an elevation similar to that of the actual building site.

Once the ground snow load for a specific location is determined, it is recommended that the design engineer check with local building officials (in the area of the structure) as to what minimum ground or roof snow load is to be used for design of structures in that location. Consideration should also be given to any conditions that might influence snow accumulation at the specific site of interest relative to the 'average' maximum ground snow load reported in this document. Local and/or state requirements on the ground or roof snow loads subsequently calculated from these values supersede the values provided in this document. The State of Montana requires a minimum roof snow load of 30 psf be used for design.[2] This minimum value applies to the final roof snow load that is calculated after all coefficients have been applied, and it may be revised when justified by a design professional to the satisfaction of the building official.

[2] *Administrative Rules of Montana*, Title 24, Dept. of Labor and Industry, Chapter 301, Building Codes, Section 24.301.146 Modifications to the International Building Code Applicable to Both the Department's and Local Government Code Enforcement Programs, paragraph 19.

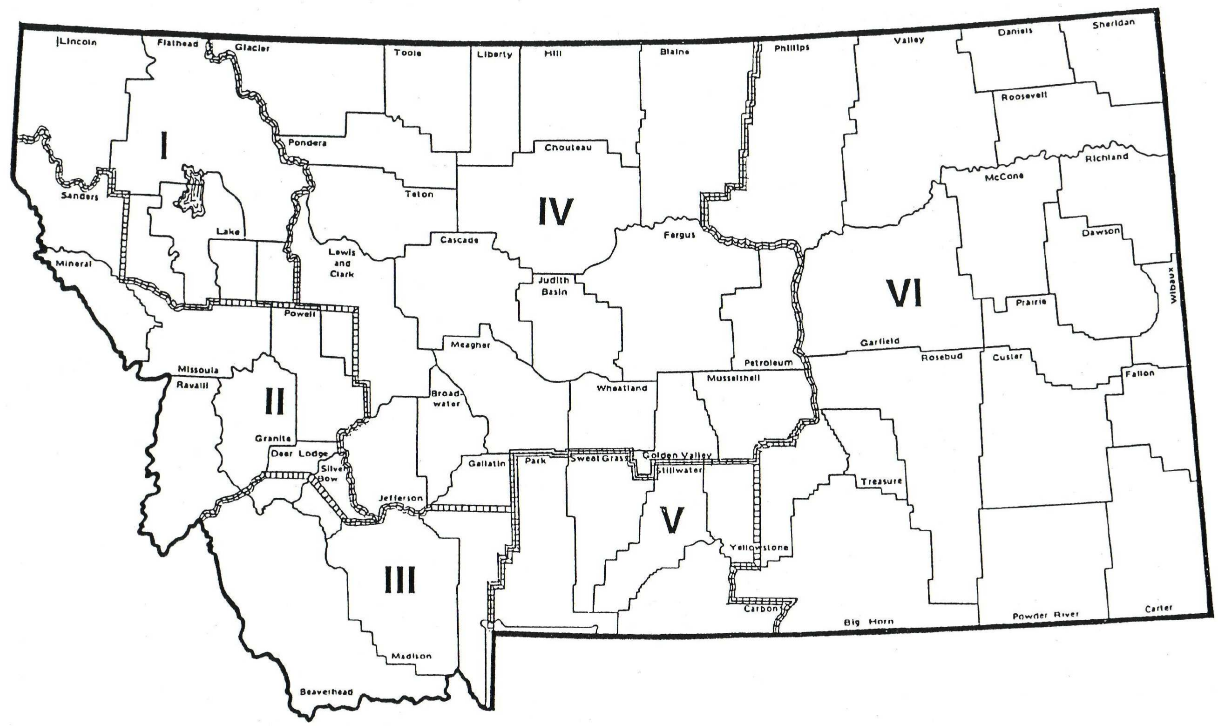


Figure 1.1: Map of Montana indicating snow load regions

Table 1.1: Design Snow Loads at Monitored Stations in Montana

Station Name	Type	County	Lat N (deg)	Lat N (min)	Long W (deg)	Long W (min)	Elev (ft)	Yrs. Data	Snow Load (psf)
Region 1									
Badger Pass	SNOTEL	Flathead	48	7	113	1	6900	23	321.3
Banfield Mountain	SNOTEL	Lincoln	48	34	115	26	5600	33	204.0
Bigfork 13 S	NWS	Lake	47	52	114	1	2910	20	54.6
Bisson Creek	SNOTEL	Lake	47	40	113	59	4920	12	110.7
Calvert Creek	SNOTEL	Flathead	45	53	113	19	6430	26	84.8
Creston	NWS	Flathead	48	11	114	8	2940	37	65.4
Emery Creek	SNOTEL	Flathead	48	26	113	56	4350	25	124.4
Eureka Ranger Station	NWS	Lincoln	48	53	115	3	2532	27	46.2
Fortine 1 N	NWS	Lincoln	48	46	114	54	3000	79	49.2
Garver Creek	SNOTEL	Lincoln	48	58	115	49	4250	33	90.6
Grave Creek	SNOTEL	Lincoln	48	54	114	45	4300	26	127.8
Hand Creek	SNOTEL	Flathead	48	18	114	50	5035	25	111.3
Hawkins Lake	SNOTEL	Lincoln	48	58	115	57	6450	33	291.9
Hungry Horse Dam	NWS	Flathead	48	20	114	1	3160	29	84.1
Kalispell Glacier Park AP	NWS	Flathead	48	18	114	15	2957	50	60.9
Kraft Creek	SNOTEL	Missoula	47	25	113	46	4750	21	150.4
Libby 1 NE RS	NWS	Lincoln	48	24	115	32	2096	26	68.0
Libby 32 SSE	NWS	Lincoln	47	58	115	13	3600	47	97.5
Lindbergh Lake	NWS	Missoula	47	24	113	42	4320	38	116.6
Lonepine 1 WNW	NWS	Sanders	47	43	114	39	2881	14	40.5
Many Glacier	SNOTEL	Flathead	48	47	113	40	4900	25	143.3
Moss Peak	SNOTEL	Lake	47	41	113	57	6780	16	380.1
Noisy Basin	SNOTEL	Flathead	48	9	113	56	6040	27	348.7
North Fork Jocko	SNOTEL	Missoula	47	16	113	45	6330	12	410.7
Pleasant Valley	NWS	Flathead	48	8	114	55	3602	23	51.8
Polebridge	NWS	Flathead	48	45	114	17	3520	36	84.4
Polson Kerr Dam	NWS	Lake	47	40	114	14	2730	18	64.6
Poorman Creek	SNOTEL	Lincoln	48	7	115	37	5100	22	339.6
St. Ignatius	NWS	Lake	47	18	114	5	2900	78	30.7
Stahl Peak	SNOTEL	Lincoln	48	54	114	51	6030	26	313.1
Summit	NWS	Flathead	48	18	113	21	5233	20	302.1
Swan Lake	NWS	Lake	47	55	113	50	3100	14	108.0
West Glacier	NWS	Flathead	48	30	113	59	3154	48	99.8
Whitefish	NWS	Flathead	48	24	114	21	3100	44	68.4
Region 2									
Anaconda	NWS	Deer Lodge	46	7	112	57	5280	15	38.1
Barker Lakes	SNOTEL	Deer Lodge	46	5	113	7	8250	22	140.0
Basin Creek	SNOTEL	Silver Bow	45	47	112	31	7180	21	92.4
Black Pine	SNOTEL	Granite	46	24	113	25	7210	36	133.7
Butte Bert Mooney AP	NWS	Silver Bow	45	57	112	30	5506	62	36.9
Butte School of Mines	NWS	Silver Bow	46	1	112	33	5774	11	33.9
Combination	SNOTEL	Granite	46	27	113	23	5600	29	58.2
Copper Bottom	SNOTEL	Lewis and Clark	47	3	112	35	5200	26	104.2
Copper Camp	SNOTEL	Lewis and Clark	47	4	112	43	6950	26	287.6
Daly Creek	SNOTEL	Ravilli	46	11	113	51	5780	21	110.2
Darby	NWS	Ravalli	46	1	114	10	3880	13	39.5

Table 1.1: Design Snow Loads at Monitored Stations in Montana

Station Name	Type	County	Lat N (deg)	Lat N (min)	Long W (deg)	Long W (min)	Elev (ft)	Yrs. Data	Snow Load (psf)
Deer Lodge	NWS	Powell	46	23	112	44	4534	26	26.3
Deer Lodge 3 W	NWS	Powell	46	23	112	47	4850	21	51.3
Drummond	NWS	Granite	46	38	113	10	4000	37	35.7
Drummond FAA AP	NWS	Granite	46	37	113	12	4242	33	54.4
Elliston	NWS	Powell	46	34	112	26	5075	21	40.2
Haugan 3 E (Deborgia)	NWS	Mineral	47	23	115	21	3100	53	102.4
Heron 2 NW	NWS	Sanders	48	4	116	0	2240	56	101.4
Hoodoo Basin	SNOTEL	Mineral	46	58	115	2	6050	35	443.0
Lincoln RS	NWS	Lewis and Clark	46	57	112	39	4575	22	63.4
Lubrecht Flume	SNOTEL	Missoula	46	52	113	19	4680	31	54.5
Missoula 2 NE	NWS	Missoula	46	53	113	58	3420	34	32.5
Missoula Int'l AP	NWS	Missoula	46	55	114	5	3192	49	33.9
Nez Perce Camp	SNOTEL	Ravalli	45	43	114	28	5650	25	128.1
North Fork Elk Creek	SNOTEL	Powell	46	52	113	16	6250	34	135.1
Ovando	NWS	Powell	47	1	113	8	4110	13	84.0
Ovando 7 WNW	NWS	Powell	47	3	113	17	4003	11	90.3
Ovando 9 SSE	NWS	Powell	46	53	113	3	4255	14	35.2
Peterson Meadows	SNOTEL	Granite	46	8	113	18	7200	31	118.4
Philipsburg	NWS	Granite	46	20	113	18	5282	40	38.2
Philipsburg RS	NWS	Granite	46	18	113	17	5270	19	37.0
Potomac	NWS	Missoula	46	52	113	34	3620	25	57.5
Seeley Lake RS	NWS	Missoula	47	12	113	31	4100	44	80.7
Skalkaho Summit	SNOTEL	Granite	46	14	113	46	7250	25	217.6
Sleeping Woman	SNOTEL	Missoula	47	10	114	20	6150	12	172.0
Stevensville	NWS	Ravalli	46	30	114	5	3375	24	47.9
Sula 3 ENE	NWS	Ravalli	45	50	113	55	4475	12	77.2
Superior	NWS	Mineral	47	11	114	53	2710	51	60.3
Thompson Falls	NWS	Sanders	47	36	115	21	2441	39	49.6
Thompson Falls PH	NWS	Sanders	47	35	115	21	2380	13	45.8
Trout Creek 2 W	NWS	Sanders	47	50	115	38	2490	36	89.6
Trout Creek RS	NWS	Sanders	47	51	115	37	2356	18	90.3
Twelvemile Creek	SNOTEL	Ravalli	46	8	114	26	5600	34	189.6
Twin Lakes	SNOTEL	Ravalli	46	8	114	30	6510	34	370.1
Warm Springs	SNOTEL	Granite	46	16	113	9	7800	24	202.1
Region 3									
Beagle Springs	SNOTEL	Beaverhead	44	28	112	58	8850	23	100.9
Beaver Creek	SNOTEL	Madison	44	57	111	21	7850	35	173.2
Belgrade Airport	NWS	Gallatin	45	47	111	9	4427	47	33.3
Black Bear	SNOTEL	Madison	44	30	111	7	8170	30	369.5
Bloody Dick	SNOTEL	Beaverhead	45	9	113	30	7600	25	111.9
Bozeman 12 NE	NWS	Gallatin	45	49	110	53	5950	44	95.7
Bozeman 6 W Exp. Farm	NWS	Gallatin	45	40	111	9	4775	27	29.8
Bozeman MSU	NWS	Gallatin	45	39	111	2	4913	46	42.3
Carrot Basin	SNOTEL	Gallatin	44	57	111	17	9000	35	255.9
Clover Meadow	SNOTEL	Madison	45	1	111	50	8600	23	167.4
Darkhorse Lake	SNOTEL	Beaverhead	45	10	113	35	8600	21	288.2
Dillon AP	NWS	Beaverhead	45	15	112	33	5216	42	19.2
Dillon WMCE	NWS	Beaverhead	45	12	112	38	5228	13	24.4

Table 1.1: Design Snow Loads at Monitored Stations in Montana

Station Name	Type	County	Lat N (deg)	Lat N (min)	Long W (deg)	Long W (min)	Elev (ft)	Yrs. Data	Snow Load (psf)
Divide	NWS	Silver Bow	45	45	112	45	5350	44	19.3
Divide	SNOTEL	Madison	44	47	112	3	7800	26	111.1
Grant 5 SE	NWS	Beaverhead	44	56	113	1	5780	36	24.4
Hebgen Dam	NWS	Gallatin	44	52	111	20	6489	40	137.1
Jackson	NWS	Beaverhead	45	22	113	24	6480	10	45.1
Lakeview	NWS	Beaverhead	44	35	111	48	6710	19	206.8
Lakeview Ridge	SNOTEL	Beaverhead	44	35	111	49	7400	23	115.3
Lemhi Ridge	SNOTEL	Beaverhead	44	59	113	26	8100	26	115.5
Lick Creek	SNOTEL	Gallatin	45	30	110	57	6860	38	155.4
Lima	NWS	Beaverhead	44	38	112	35	6273	40	26.7
Lone Mountain	SNOTEL	Madison	45	16	111	25	8880	13	200.5
Lower Twin	SNOTEL	Madison	45	30	111	55	7900	21	176.3
Madison Plateau	SNOTEL	Gallatin	44	35	111	6	7750	34	230.9
Manhattan	NWS	Gallatin	45	52	111	20	4232	24	20.7
Mule Creek	SNOTEL	Beaverhead	45	24	112	57	8300	21	141.4
Norris Madison PH	NWS	Madison	45	29	111	37	4745	54	34.9
Pony	NWS	Madison	45	39	111	53	5590	17	44.3
Saddle Mountain	SNOTEL	Beaverhead	45	41	113	58	7940	34	254.7
Short Creek	SNOTEL	Madison	44	58	111	57	7000	13	48.6
Shower Falls	SNOTEL	Gallatin	45	24	110	57	8100	36	234.7
Teepee Creek	SNOTEL	Madison	44	47	111	42	8000	30	126.8
West Yellowstone	NWS	Gallatin	44	39	111	6	6659	47	135.0
West Yellowstone	SNOTEL	Gallatin	44	39	111	5	6700	35	88.8
Whiskey Creek	SNOTEL	Gallatin	44	36	111	9	6800	30	152.6
Wise River 3 WNW	NWS	Beaverhead	45	48	113	0	5730	14	25.5
Region 4									
Augusta	NWS	Lewis and Clark	47	29	112	23	4070	10	40.8
Austin 1 W	NWS	Lewis and Clark	46	38	112	15	4790	12	38.4
Barber	NWS	Golden Valley	46	18	109	22	3730	11	45.4
Big Sandy	NWS	Chouteau	48	8	110	3	2770	27	20.8
Blackleaf	NWS	Teton	48	0	112	26	4235	18	31.8
Boulder Mountain	SNOTEL	Meagher	46	33	111	17	7950	23	164.8
Brady Aznoe	NWS	Chouteau	47	57	111	20	3333	30	24.7
Browning	NWS	Glacier	48	33	113	0	4355	25	86.1
Bynum 4 SSE	NWS	Teton	47	56	112	18	4022	24	23.1
Canyon Creek	NWS	Lewis and Clark	46	49	112	15	4314	13	29.0
Carter 14 W	NWS	Chouteau	47	47	111	13	3450	10	12.2
Cascade 5 S	NWS	Cascade	47	13	111	42	3360	76	25.2
Chinook	NWS	Blaine	48	35	109	14	2345	10	58.7
Choteau	NWS	Teton	47	49	112	11	3845	39	19.0
Crystal Lake	SNOTEL	Fergus	46	47	109	30	6050	23	109.7
Cut Bank Municipal AP	NWS	Glacier	48	36	112	22	3838	51	17.0
Daisy Peak	SNOTEL	Meagher	46	40	110	19	7600	11	104.9
Deadman Creek	SNOTEL	Meagher	46	47	110	40	6450	34	92.0
Deep Creek Pass 2	NWS	Broadwater	46	22	111	8	5440	14	71.5
Del Bonita	NWS	Glacier	48	59	112	47	4337	14	29.3
Dunkirk 15 NNE	NWS	Toole	48	42	111	36	3383	39	29.0
Dupuyer Creek	SNOTEL	Teton	48	3	112	45	5750	18	120.8

Table 1.1: Design Snow Loads at Monitored Stations in Montana

Station Name	Type	County	Lat N (deg)	Lat N (min)	Long W (deg)	Long W (min)	Elev (ft)	Yrs. Data	Snow Load (psf)
East Glacier	NWS	Glacier	48	26	113	13	4806	25	184.7
Fairfield	NWS	Teton	47	36	111	59	3983	32	37.2
Flatwillow 4 ENE	NWS	Petroleum	46	51	108	18	3133	11	37.4
Fort Assinniboine	NWS	Hill	48	29	109	47	2613	22	36.1
Fort Benton	NWS	Chouteau	47	48	110	40	2636	36	27.8
Fort Logan 4 ESE	NWS	Meagher	46	39	111	5	4710	40	51.3
Frohner Meadow	SNOTEL	Jefferson	46	26	112	11	6480	29	89.9
Galata 16 SSW	NWS	Toole	48	14	111	24	3100	17	23.2
Geraldine	NWS	Chouteau	47	35	110	15	3130	39	27.7
Gibson Dam	NWS	Lewis and Clark	47	36	112	45	4590	40	51.4
Goldbutte 7 N	NWS	Toole	48	58	111	23	3498	20	25.4
Grass Range	NWS	Fergus	47	1	108	48	3490	27	32.4
Great Falls	NWS	Cascade	47	31	111	18	3353	10	31.0
Great Falls Int'l Airport	NWS	Cascade	47	28	111	22	3664	49	24.1
Harlowton	NWS	Wheatland	46	25	109	49	4162	41	28.6
Havre City/County AP	NWS	Hill	48	32	109	45	2585	35	46.8
Helena Regional AP	NWS	Lewis and Clark	46	36	111	57	3828	47	25.5
Highwood 7 NE	NWS	Chouteau	47	38	110	40	3600	26	32.2
Hobson	NWS	Judith Basin	47	0	109	52	4081	14	67.1
Hogeland 7 WSW	NWS	Blaine	48	49	108	48	3351	21	55.0
Holter Dam	NWS	Lewis and Clark	46	59	112	0	3487	28	18.3
Joplin	NWS	Liberty	48	33	110	46	3325	25	32.9
Kremlin	NWS	Hill	48	31	110	6	2860	37	37.3
Lewistown Municipal AP	NWS	Fergus	47	2	109	28	4145	51	52.3
Loma 1 WNW	NWS	Chouteau	47	56	110	31	2580	41	32.0
Lonesome Lake	NWS	Chouteau	48	15	110	12	2762	10	73.8
Loweth	NWS	Meagher	46	22	110	42	5804	11	101.9
Martinsdale 3 NNW	NWS	Meagher	46	30	110	20	4800	37	41.1
Melstone	NWS	Musselshell	46	36	107	52	2920	43	38.2
Moccasin Exp. Station	NWS	Judith Basin	47	3	109	57	4300	20	73.9
Monument Peak	SNOTEL	Park	45	13	110	14	8850	21	193.5
Mount Lockhart	SNOTEL	Teton	47	55	112	49	6400	33	209.9
Neihart 8 NNW	NWS	Cascade	47	2	110	46	5230	24	72.7
Pickfoot Creek	SNOTEL	Meagher	46	34	111	16	6650	23	128.2
Pike Creek	SNOTEL	Pondera	48	18	113	19	5930	25	265.0
Porcupine	SNOTEL	Park	46	6	110	28	6500	25	69.8
Power 6 SE	NWS	Cascade	47	39	111	35	3750	46	23.3
Raynesford 2 NNW	NWS	Judith Basin	47	17	110	44	4215	30	91.8
Rocker Peak	SNOTEL	Jefferson	46	21	112	15	8000	34	147.5
Rocky Boy	SNOTEL	Hill	48	10	109	38	4700	34	61.7
Rogers Pass 9 NNE	NWS	Lewis and Clark	47	11	112	17	4200	17	86.0
Roundup	NWS	Musselshell	46	26	108	32	3227	21	21.2
Roy 8 NE	NWS	Fergus	47	25	108	50	3445	52	66.4
Ryegate 18 NNW	NWS	Golden Valley	46	32	109	20	4440	22	32.4
Shonkin 7 S	NWS	Chouteau	47	31	110	34	4300	21	79.1
Simms 1 NE	NWS	Cascade	47	30	111	55	3590	14	11.8
Simpson 6 N	NWS	Hill	48	58	110	18	2740	51	32.5
Spur Park	SNOTEL	Judith Basin	46	44	110	37	8100	35	198.4
St Mary	NWS	Glacier	48	44	113	25	4560	12	67.5

Table 1.1: Design Snow Loads at Monitored Stations in Montana

Station Name	Type	County	Lat N (deg)	Lat N (min)	Long W (deg)	Long W (min)	Elev (ft)	Yrs. Data	Snow Load (psf)
Stanford	NWS	Judith Basin	47	9	110	13	4860	14	47.9
Stanford 2 NE	NWS	Judith Basin	47	9	110	13	4281	13	22.5
Sun River 4 S	NWS	Cascade	47	28	111	44	3600	34	18.4
Sunburst 8 E	NWS	Toole	48	53	111	43	3700	33	26.3
Tizer Basin	SNOTEL	Jefferson	46	20	111	51	6880	13	81.9
Toston 1 W	NWS	Broadwater	46	10	111	28	3934	10	34.1
Townsend	NWS	Broadwater	46	19	111	32	3840	19	10.2
Trident	NWS	Gallatin	45	56	111	28	4036	34	20.5
Utica 11 WSW	NWS	Judith Basin	46	53	110	18	5002	19	69.3
Valentine	NWS	Fergus	47	20	108	29	2910	16	27.3
Valier	NWS	Pondera	48	18	112	15	3810	25	14.2
Waldron	SNOTEL	Teton	47	55	112	47	5600	33	109.2
White Sulphur Springs	NWS	Meagher	46	32	110	54	5160	11	53.5
Whitehall AP	NWS	Jefferson	45	49	112	12	4598	11	23.5
Winnett 5 NNE	NWS	Petroleum	47	4	108	19	2923	18	36.3
Wood Creek	SNOTEL	Lewis and Clark	47	26	112	48	5960	23	94.4
Region 5									
Big Timber	NWS	Sweet Grass	45	49	109	57	4100	22	36.5
Billings Logan Int'l AP	NWS	Yellowstone	45	48	108	32	3581	52	31.7
Box Canyon	SNOTEL	Park	45	16	110	14	6670	23	96.5
Bridger 1 S	NWS	Carbon	45	17	108	55	3680	45	28.2
Cole Creek	SNOTEL	Carbon	45	11	109	21	7850	27	187.1
Cooke City 2 W	NWS	Park	45	0	109	58	7460	22	135.4
Edgar 9 SE	NWS	Carbon	45	23	108	43	4003	23	59.8
Fisher Creek	SNOTEL	Park	45	3	109	57	9100	35	342.0
Gardiner	NWS	Park	45	1	110	42	5275	12	31.5
Gibson 2 NE	NWS	Sweet Grass	46	2	109	29	4350	26	41.5
Jardine	NWS	Park	45	4	110	38	6453	10	154.1
Joliet	NWS	Carbon	45	28	108	58	3700	45	31.6
Laurel 3 WSW	NWS	Yellowstone	45	40	108	49	3319	22	35.0
Livingston 12 S	NWS	Park	45	29	110	34	4870	38	32.8
Livingston Mission Field	NWS	Park	45	41	110	27	4653	52	33.9
Mystic Lake	NWS	Stillwater	45	14	109	44	6558	35	89.6
Northeast Entrance	SNOTEL	Park	45	0	110	0	7350	35	104.7
Nye 2	NWS	Stillwater	45	26	109	48	4840	14	68.6
Placer Basin	SNOTEL	Sweetgrass	45	25	110	5	8830	21	157.5
Rapelje 4 S	NWS	Stillwater	45	54	109	15	4125	39	26.9
Red Lodge 2 N	NWS	Carbon	45	12	109	14	5500	79	105.2
S Fork Shields	SNOTEL	Park	46	5	110	26	8100	23	173.0
White Mill	SNOTEL	Park	45	2	109	54	8700	28	230.7
Wilsall 8 ENE	NWS	Park	46	1	110	30	5835	11	51.7
Region 6									
Albion 1 N	NWS	Carter	45	12	104	15	3312	17	19.4
Baker 1 E	NWS	Fallon	46	21	104	15	2940	27	45.7
Biddle	NWS	Powder River	45	5	105	20	3329	10	9.4
Biddle 8 SW	NWS	Powder River	45	2	105	29	3596	26	48.9
Birney	NWS	Rosebud	45	19	106	30	3160	11	31.8

Table 1.1: Design Snow Loads at Monitored Stations in Montana

Station Name	Type	County	Lat N (deg)	Lat N (min)	Long W (deg)	Long W (min)	Elev (ft)	Yrs. Data	Snow Load (psf)
Brandenberg	NWS	Rosebud	45	48	106	13	2770	42	24.7
Bredette	NWS	Roosevelt	48	32	105	16	2638	43	24.1
Broadus	NWS	Powder River	45	26	105	24	3032	40	46.6
Brusett 3 W	NWS	Garfield	47	27	107	18	2974	24	54.2
Busby	NWS	Big Horn	45	32	106	57	3430	44	36.2
Circle	NWS	McCone	47	24	105	35	2475	19	75.3
Circle 7 N	NWS	McCone	47	31	105	34	2431	15	25.8
Cohagen	NWS	Garfield	47	3	106	37	2727	29	47.2
Colstrip	NWS	Rosebud	45	53	106	38	3218	27	18.3
Culbertson	NWS	Roosevelt	48	9	104	30	1942	30	42.3
Custer	NWS	Yellowstone	46	8	107	32	2743	14	29.9
Dodson	NWS	Phillips	48	23	108	14	2280	14	35.7
Forks 4 NNE	NWS	Phillips	48	46	107	27	2599	50	57.8
Forsyth 2 E	NWS	Rosebud	46	16	106	37	2723	25	21.6
Glasgow No.2	NWS	Valley	48	11	106	38	2090	14	25.0
Glasgow 15 NW	NWS	Valley	48	21	106	51	2118	13	20.9
Glasgow Int'l AP	NWS	Valley	48	12	106	37	2285	51	22.6
Glendive	NWS	Dawson	47	6	104	43	2076	50	15.6
Harb	NWS	Phillips	48	14	107	24	2542	17	27.9
Hardin	NWS	Big Horn	45	43	107	36	2905	13	14.7
Haxby 18 SW	NWS	Garfield	47	34	106	42	2651	28	39.5
Huntley Exp. Station	NWS	Yellowstone	45	55	108	14	3000	21	27.3
Hysham 25 SSE	NWS	Treasure	45	56	107	8	3100	32	41.3
Ingomar 14 NE	NWS	Rosebud	46	44	107	12	2795	38	34.8
Kirby 1 S	NWS	Big Horn	45	19	106	59	3953	13	40.1
Lame Deer	NWS	Rosebud	45	37	106	39	3300	20	32.5
Lindsay	NWS	Dawson	47	13	105	9	2690	35	20.7
Lustre 4 NNW	NWS	Valley	48	27	105	56	2923	41	32.3
MacKenzie	NWS	Fallon	46	8	104	44	2810	30	26.9
Malta	NWS	Phillips	48	21	107	52	2260	29	29.6
Malta 35 S	NWS	Phillips	47	50	107	57	2605	26	60.1
Medicine Lake 3 SW	NWS	Sheridan	48	28	104	27	1942	53	48.5
Mildred	NWS	Prairie	46	41	104	57	2411	39	22.3
Miles City	NWS	Custer	46	24	105	49	2362	64	25.6
Miles City Municipal AP	NWS	Custer	46	25	105	53	2628	51	26.8
Mizpah 4 NNW	NWS	Custer	46	17	105	17	2480	42	30.4
Moorhead 9 NE	NWS	Powder River	45	10	105	45	3220	18	22.6
Mosby 18 N	NWS	Garfield	47	15	107	57	2323	23	43.2
Mosby 4 ENE	NWS	Garfield	47	1	107	49	2910	23	42.1
Nohly 4 NW	NWS	Richland	48	2	104	8	1903	20	29.1
Opheim 12 SSE	NWS	Valley	48	41	106	18	2936	45	33.1
Otter 9 SSW	NWS	Powder River	45	6	106	15	4060	11	55.0
Plevna	NWS	Fallon	46	25	104	31	2780	33	34.9
Poplar 2 E	NWS	Roosevelt	48	8	105	9	2000	22	28.4
Powderville 8 NNE	NWS	Custer	45	51	105	2	2800	15	24.1
Pryor 3 E	NWS	Big Horn	45	24	108	32	4129	18	58.9
Raymond Border Station	NWS	Sheridan	48	59	104	34	2384	10	37.8
Redstone	NWS	Sheridan	48	49	104	56	2106	23	74.4
Richey	NWS	Dawson	47	38	105	4	2503	17	23.7

Table 1.1: Design Snow Loads at Monitored Stations in Montana

Station Name	Type	County	Lat N (deg)	Lat N (min)	Long W (deg)	Long W (min)	Elev (ft)	Yrs. Data	Snow Load (psf)
Saco Nelson Reservoir	NWS	Phillips	48	30	107	31	2231	10	41.9
Savage	NWS	Richland	47	27	104	20	1975	46	20.7
Sidney	NWS	Richland	47	43	104	8	1931	46	27.1
St. Marie	NWS	Valley	48	24	106	30	2756	10	26.0
Vida 6 NE	NWS	McCone	47	52	105	22	2284	18	29.0
Volborg	NWS	Custer	45	50	105	40	2980	12	56.0
Westby	NWS	Sheridan	48	52	104	3	2120	25	76.9
Whitewater	NWS	Phillips	48	45	107	37	2333	29	55.2
Wibaux 2 E	NWS	Wibaux	46	59	104	9	2696	14	26.0
Wyola 1 SW	NWS	Big Horn	45	7	107	24	3730	26	54.2

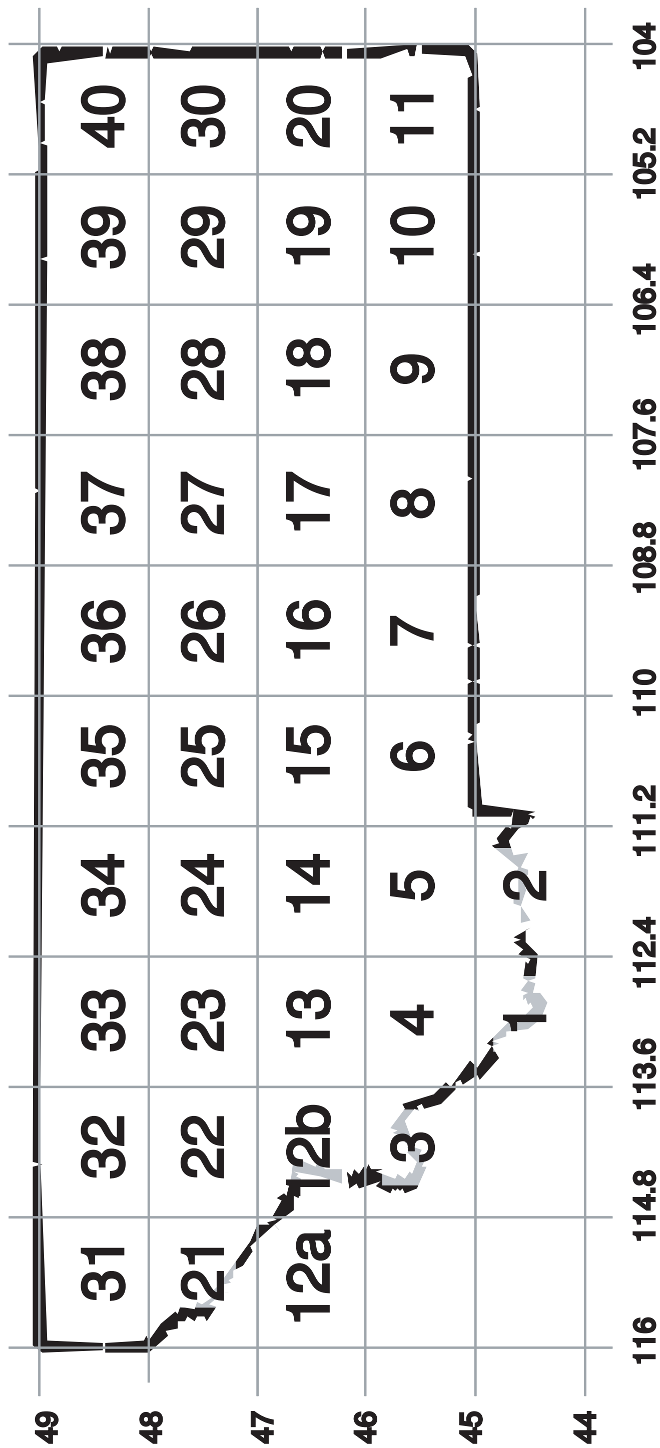
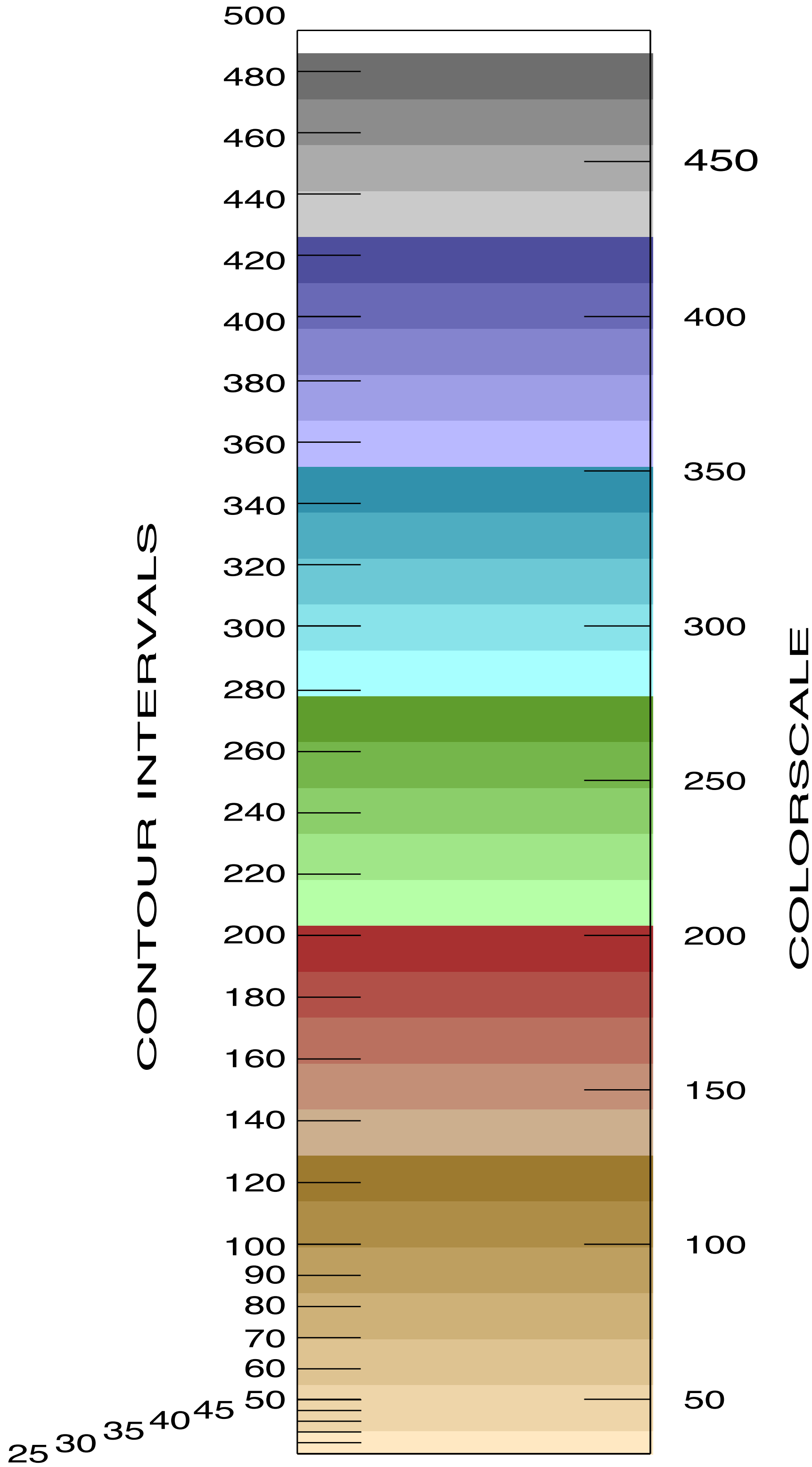


Figure 1.2: Montana Contour Map Index



Contour and Color Intervals

To significantly reduce the size of the document file “MT Snow Loads 112505 No Maps”, the snow load contour maps have been removed from this electronic version of “Snow Loads for Structural Design in Montana (Revised 2004)”. These maps are available in a second electronic version of the document entitled “MT Snow Loads 112505 with Maps”, available at

http://www.coe.montana.edu/matlabwebserver/snowloadinput.html.

Note that the database and algorithms used to generate these maps can be directly accessed using the Snow Load Finder on the internet, which is also available at

http://www.coe.montana.edu/matlabwebserver/snowloadinput.html.

The contour maps are provided primarily to give the designer an idea of the magnitude of the snow loads and the rate at which they are changing in any given area. The preferred method for finding ground snow loads at points away from tabled stations is to use the web-based Snow Load Finder. The interpolation routine that was used to generate the contour maps had difficulty in some areas addressing the rapid variation in snow loads that can occur in Montana with small changes in position and elevation. Notably, the routine encountered problems estimating ground snow loads in localized areas of high elevation surrounded by lower terrain when some or all of the closest available data was from low elevation stations. The Snow Load Finder, on-the-other-hand, includes an algorithm that checks for this situation, and, if necessary, adjusts the results.

Chapter 2

Snow Load Design Examples

2.1 Example 1 - Flat Roof Snow Load

Required: Determine the roof snow load p_f for the building shown in Figure 2.1. It is a warehouse located near the Bozeman airport at $45^o44'30"N\ 111^o11'00''W$. The site elevation is 4500 feet and there are no trees, buildings, or other obstructions within 100 feet of the building. The warehouse is unheated and it has a low-slope ($\frac{1}{4}in/ft$) roof with a distance from outside of structure to ridge of 30 feet.

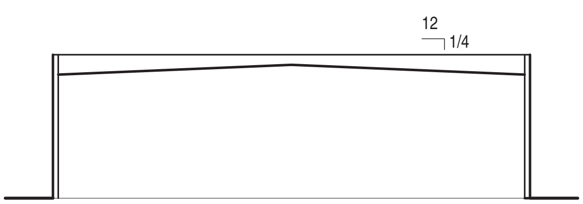


Figure 2.1: Building section - low slope roof

Solution: Because the roof has a slope less than 5^o ($\frac{1}{4}in/ft = 1.2^o$), the flat roof snow load is calculated using Equation 7-1 (ASCE 7-02):

$$p_f = 0.7C_eC_tIp_g$$

where:

$C_e = 0.9$ (from ASCE 7-02 Table 7-2 for Terrain Category C and a fully exposed roof).

Table 7-2 accounts for (2) factors. The first factor is the height of the building relative to the heights of surrounding buildings, i.e. the terrain category. The terrain category, described in Section 6.5.6 of ASCE 7-02 is the measure of surface roughness. The second factor reflects the potential for snow accumulations due to local obstructions on or near the roof. Note that the roof exposure may not necessaritly be the same as the exposure as defined for wind design. The photographs in ASCE 7-02 commentary section C6.5.6 are helpful in interpreting these factors and determining an exposure category.

The problem statement indicated that there are no obstructions around the structure. According to the foootnote describing fully exposed roofs, the roof on this structure could either be fully or partially exposed, depending on the height of the parapets; for the purposes of this example, the building will be considered to be fully exposed.

$C_t = 1.2$ (from ASCE 7-02 Table 7-3 for unheated structures)

$I = 1.0$ (from ASCE 7-02 Table 7-4 and Table 1-1 Category II, 'other structures')

$p_g = 33.3psf$ (Table 1.1 'Belgrade Airport')

Several options are available for determining p_g at locations where local jurisdictions have not specified design snow loads:

A. Use Table 1.1 for the location of interest. The values in this table are a result of a statistical analysis of historical data for the particular monitoring station. Table 1.1 has been organized by Region to enable the designer to easily review the snow loads at other stations in the same geographical area. In this area, for example, the location of interest is a little south of the Belgrade Airport. The table indicates $p_g = 33.3psf$ for 'Belgrade Airport' (Region 3). A portion of this table is shown in Table 2.1.

A second station of interest might be 'Bozeman 6 W Exp. Farm', which is itself slightly south of the location of interest. The suggested ground snow load at this location, $p_g = 29.8psf$, which in this case is similar to that at the Belgrade Airport.

Finally, the elevation at the location of interest should be compared with that of these two stations. In this case, the station elevations and the elevation at the site are close in magnitude. If the elevations do not agree, consideration should be given to finding the snow load following the procedure outlined in paragraphs B and C below.

B. Select a value from the contour map using latitude and longitude of the location of interest. A segment cropped from Map 6, shown in Figure 2.2 illustrates this method. The crosshairs mark the location of interest and the contours indicate a ground snow load value of $p_g = 30psf$. This value is a result of contouring values determined as explained in C. below. Since contours are drawn at finite intervals, this value indicates that the 'real' value lies within a contour interval range. In this case, the 'real' value is between $30 - 35psf$ since the contours are at $5psf$ intervals. The designer should interpolate between adjacent contour values to find the design ground snow load.

C. Use the Snow Load Finder Tool on the World Wide Web at:

`http://www.coe.montana.edu/ce/snowloads/home.html`

which gives a value for a specific latitude and longitude, in addition to snow load and elevation information from three surrounding stations. For the example problem, input latitude and longitude as signed, decimal values. For instance, the location of interest of $45^o44'00"N\,111^o08'00''W$ is input as $45.74^o\ -111.13^o$, North latitude values being signed positive and West longitude values being signed negative. This input returns information as indicated in Table 2.2. This value is the result of an interpolation of station values, and also corrects for the actual elevation at the point of interest. This is the preferred method for finding the ground snow load value at a point away from a station and/or at a different elevation from a station.

The point of interest has a ground snow load value of $31.5psf$ as indicated in the table.

For the example problem, $p_g = 33.3psf$ is used for instructional purposes only. Engineers-of-Record must use their own judgement in selecting from the three methods given.

Substituting all values into the flat roof snow load equation:

$$p_f = 0.7C_eC_tIp_g = 0.7(0.9)(1.2)(1.0)(33.3) = 25psf$$

Note that the State of Montana requires a minimum design snow load of $30psf$.

The flat roof snow load is to be applied as a uniform pressure to the entire roof of the building.

In this case, the state mandated minimum snow load of $30psf$ governs. Normally, engineers should check for compliance with ASCE 7-02 minimum values per Section 7.3.4. In this sample problem with $W = 30ft$, the check is:
if $slope \leq \left[\frac{70}{W} + 0.5 = \frac{70}{30} + 0.5 = 2.8^o\right]$
then check minimum snow load. Since the roof slope of this example structure is 1.2^o, the engineer must check minimum snow load values. Per Section 7.3 (ASCE 7-02),
$p_{fmin} = 20(I) = 20(1.0) = 20psf$ and as expected, the state minimum controls.

Engineers must also consider the effects of drifting, per ASCE 7-02 Section 7.7.7.8. A sample calculation is provided in Example 2.

Finally, according to ASCE 7-02 Section 7.10, since $p_g > 20psf$ rain-on-snow surcharge is not applicable.

Table 2.1: **Cutout from Table 1.1**

Station Name	Type	County	Lat N (deg)	Lat N (min)	Long W (deg)	Long W (min)	Elev (ft)	Yrs. Data	Snow Load (psf)
Belgrade Airport	NWS	Gallatin	45	47	111	9	4427	47	33.3

Table 2.2: **Output from Snow Load Finder-Belgrade**

Station	Type	Lat	Long	Elev	Snow Load
Bozeman 6 W Exp. Farm	NWS	45.67	-111.16	4775	29.8
Bozeman MSU	NWS	45.66	-111.05	4913	42.3
Belgrade Airport	NWS	45.79	-111.15	4427	33.3
point of interest	na	45.74	-111.13	4541	31.5

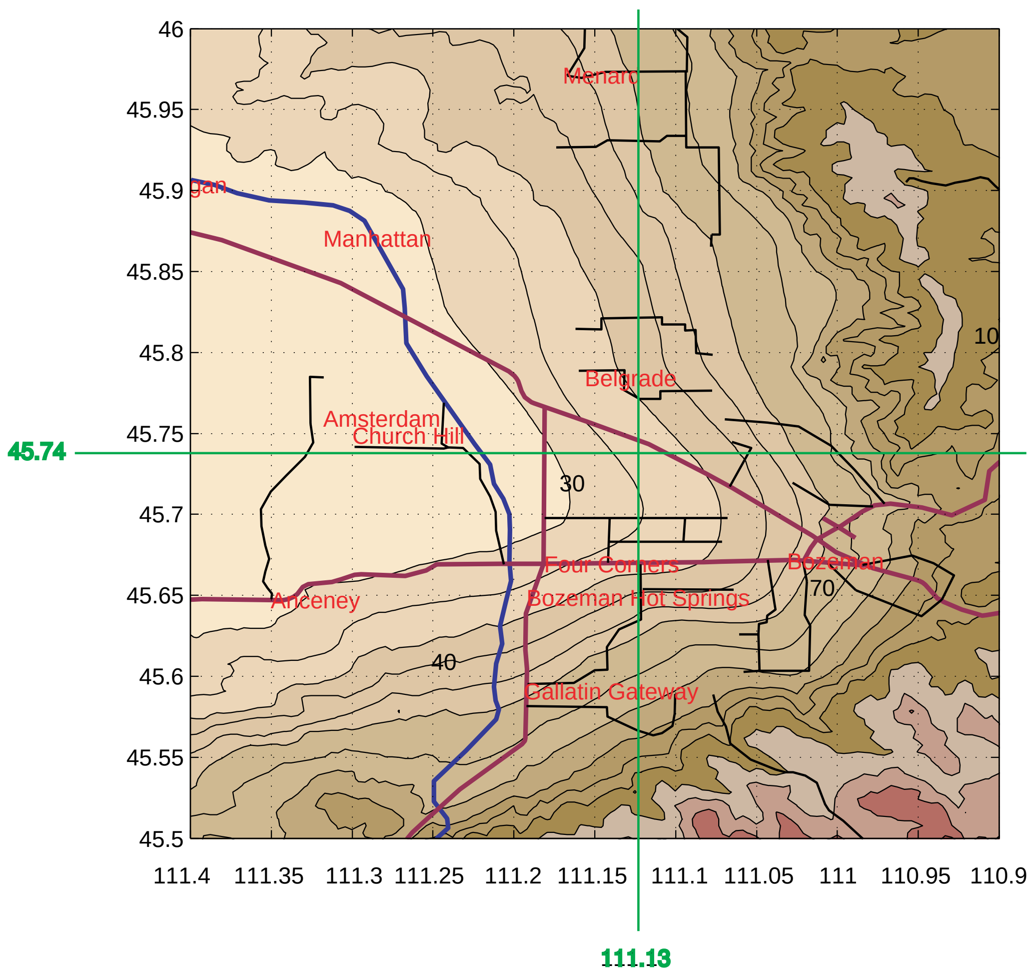


Figure 2.2: **Segment of Map 6**

2.2 Example 2 - Drifting Snow

Required: For the building described in example 1, calculate the drifting snow load at the parapets. Refer to the partial wall section in Figure 2.3.

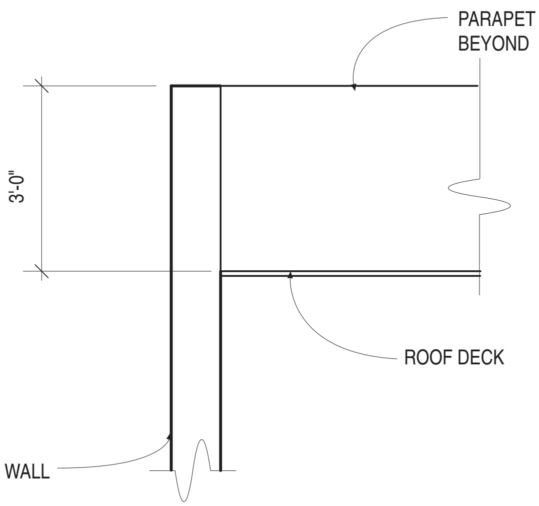


Figure 2.3: Parapet detail

Solution: Consider the windward condition where the wind is blowing across the roof and depositing snow at the parapet. According to Section 7.8 (ASCE 7-02), a drift height of $0.75h_d$ shall be used with h_d calculated according to the methods of Section 7.7.1.

$$driftheight = 0.75h_d = 0.75(2.75) = 2ft$$

where:

$h_d = 2.75ft$ (from ASCE 7-02 Figure 7-9),

$p_g = 33.3$ (from Example 1), and

$l_u = 60ft$ (conservatively twice the distance from outside of structure to ridge).

To calculate the drift width, it is necessary to calculate the height of the balanced snow load:

$$h_b = \frac{p_f}{\gamma} = \frac{30}{18.3} = 1.6ft,$$

where γ is calculated according to ASCE 7-02 Eq. 7-4:

$\gamma = 0.13p_g + 14 = 0.13(33.3) + 14 = 18.3pcf \leq 30pcf$

noting that $p_f = 30psf$ is the minimum prescribed snow load and considering that:

$driftheight > h_c$, where:

$h_c = 3 - 1.6 = 1.4ft$ (parapet height minus balanced snow load height).

Finally, the design drift height shall be $h_c = 1.4ft$ and the drift width shall be:

$w = 4\left(\frac{h_d^2}{h_c}\right) = 4\left(\frac{2.75^2}{1.4}\right) = 21.6ft.$

2.3 Example 3 - Basic Sloped Roof Snow Load (Cold Roof)

Required: Determine the design roof snow load p_s for the single family residence shown in Figure 2.4. Located in Meagher County in an area well sheltered by tall conifers at $46.1^o N$ $110.4^o W$ and approximately 9300 ft, the house has a standing seam metal roof pitched 8-on-12 over a ventilated attic. There is R38 insulation between the heated space and the attic.

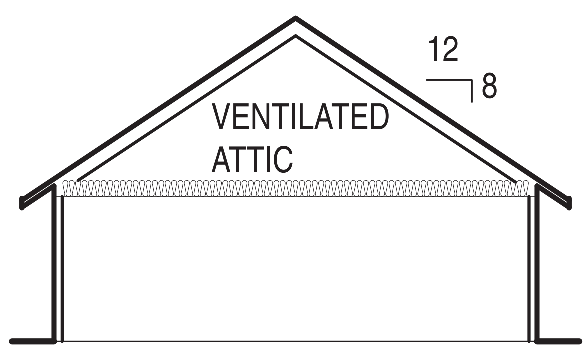


Figure 2.4: Sloped 'cold' roof

Solution: The governing equation for the sloped roof case is Equation 7-2 (ASCE 7-02):

$$p_s = C_s p_f$$

where:

$C_s = 0.62$ (from ASCE 7-02 Figure 7-2b, dashed line for metal roof being in the class of 'unobstructed slippery surfaces'; $C_t = 1.1$)

p_f is computed as before:

$$p_f = 0.7 C_e C_t I p_g$$

where:

$C_e = 1.2$ (from ASCE 7-02 Table 7-2 for Terrain Category B and a sheltered roof),

$C_t = 1.1$ (from ASCE 7-02 Table 7-3 for R38 ($38 ft^2 hr^o F/Btu$) insulation between heated space and ventilated attic),

$I = 1.0$ (from ASCE 7-02 Table 7-4 and Table 1-1 Category II, 'other structures'), and

$p_g = 198.7 psf$ from Snow Load Finder at

`http://www.coe.montana.edu/ce/snowloads/home.html`.

Note that the building site is not far from the Martinsdale 3 NNW entry in Table 1.1, where the station snow load value is 41.1 psf. Since the point of interest, at approximately 9300 ft, is at a much higher elevation than the station elevation of 4800 ft, it would be unconservative to use the tabled entry. Notice from the Snow Load Finder that the elevation returned was 9370 ft and the plot of the site location seems to indicate the correct area. The ground snow load value could also have been obtained from contour map 15, which indicates 180 psf. Recall from Example 1 that because contour intervals are not infinite, the designer must interpolate between adjacent contours to find the 'real value'. Portions of maps and tables pertinent to this example are reproduced on page 66.

Substituting all values into the flat roof snow load equation:

$$p_f = 0.7 C_e C_t I p_g = 0.7(1.2)(1.1)(1.0)(198.7) = 184 psf$$

And then into the sloped roof equation:

$$p_s = C_s p_f = 0.62(184) = 114 psf$$

Figure 2.5 shows how the sloped roof snow load should be applied to the structure in the balanced load case. Partial loading effects (ASCE 7-02 Section 7.5) and unbalanced snow effects (ASCE 7-02 Section 7.6) must also be considered. Example 4 illustrates the unbalanced snow calculation.

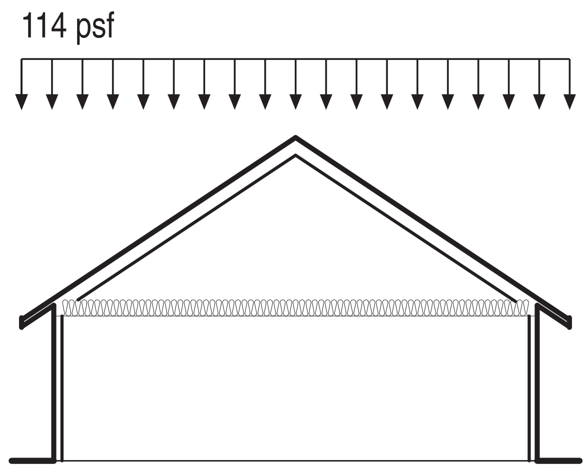


Figure 2.5: Load summary for use with sloped 'cold' roof

Table 2.3: **Cutout from Table 1.1**

Station Name	Type	County	Lat N (deg)	Lat N (min)	Long W (deg)	Long W (min)	Elev (ft)	Yrs. Data	Snow Load (psf)
Martinsdale 3 NNW	NWS	Meagher	46	30	110	20	4800	37	41.1

Table 2.4: **Output from Snow Load Finder-Martinsdale**

Station	Type	Lat	Long	Elev	Snow Load
Big Timber	NWS	45.83	-109.95	4100	36.5
S Fork Shields	SNOT	46.09	-110.43	8100	173.0
Harlowton	NWS	46.43	-109.83	4162	28.6
point of interest	na	46.10	-110.40	9370	198.7

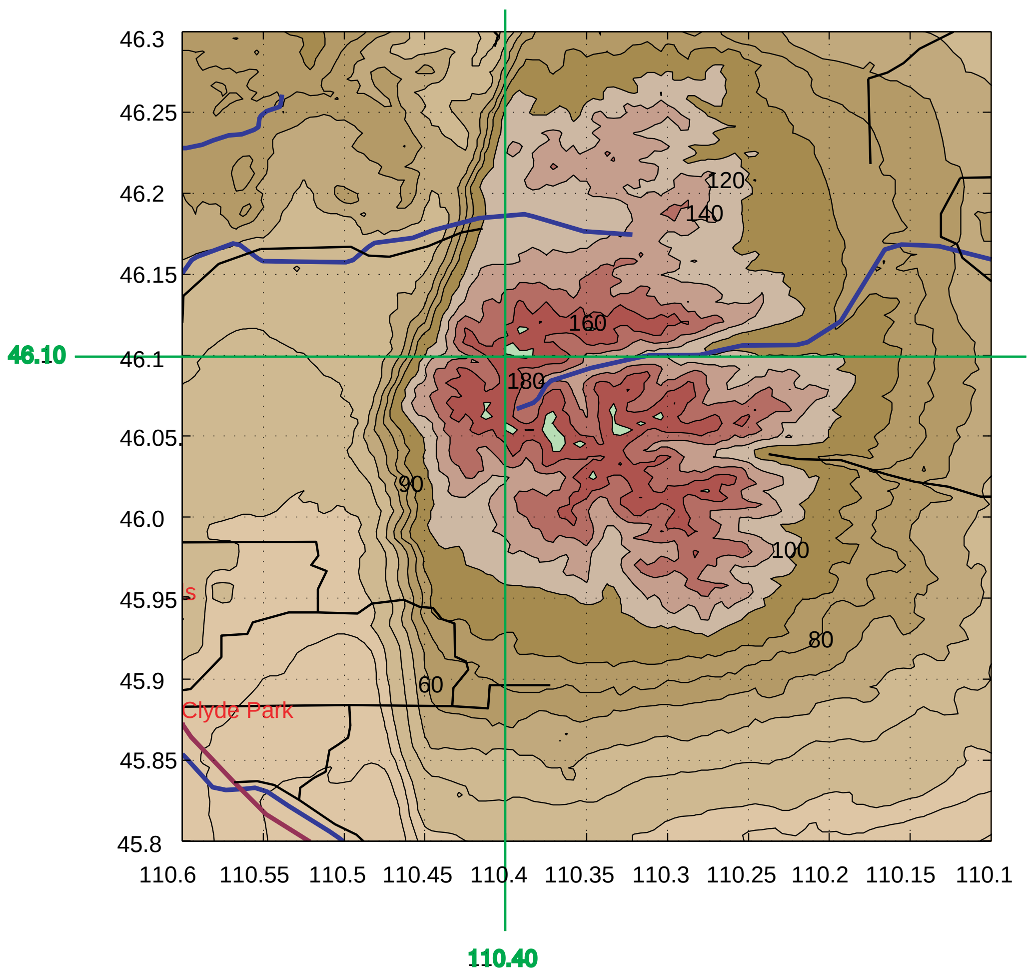


Figure 2.6: **Segment of Map 15**

2.4 Example 4 - Unbalanced Snow Load on Gable Roof

Required: Section 7.6 (ASCE 7-02) requires that unbalanced loads be analyzed separately from balanced loads. Using the house with the gable roof from Example 3, determine the unbalanced roof load that should be applied to the structure. The out-to-out dimensions of the structure are 30 feet wide and 60 feet long.

Solution: Section 7.6.1 (ASCE 7-02) provides the method for determining unbalanced snow loads for hip and gable roofs. First, determine whether unbalanced loads need to be considered:

The slope of the roof under consideration is:

$slope = \arctan\left(\frac{8}{12}\right) = 33.7^o$.

The lower threshold for considering unbalanced loads is:

$lowerlimit = \left(\frac{70}{W}\right) + 0.5 = \left(\frac{70}{15}\right) + 0.5 = 5.2^o$,

where the distance from eave to ridge, $W = 15ft$. The upper threshold is always 70^o. The 33.7^o slope of this roof falls within these limits, therefore, unbalanced loads must be considered. The roof must be designed to resist an unbalanced uniform snow load on the leeward side equal to:

$p_{unbal} = 1.5\left(\frac{p_s}{C_e}\right) = 1.5\left(\frac{114}{1.2}\right) = 142.5psf$, where p_s and C_e are taken from Example 3. This load again is applied on the horizontal projection of the roof.

For this case, with $W \leq 20ft$, it's unnecessary to apply a load to the windward side, though that would not be the case with $W > 20ft$. The reader is directed to Figure 7-5 (ASCE 7-02) for a graphic illustration of this loading condition.

2.5 Example 5 - Sloped Roof Snow Load (Warm Roof)

Required: Determine the design roof snow load p_s for a building similar to that of Example 3, same site and elevation, but for a residential garage/workshop occupancy. Clad with asphalt shingles, the roof will have R19 insulation between the rafters. The garage/workshop will be intermittently heated. A cross section of this building is shown in Figure 2.7.

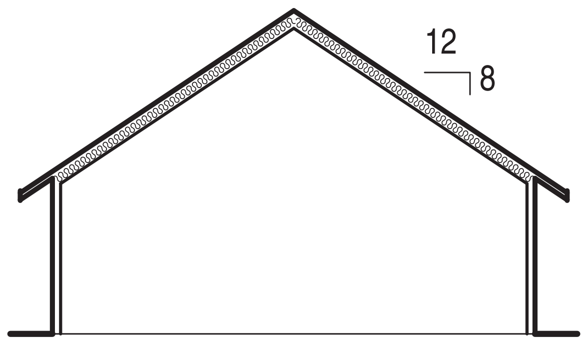


Figure 2.7: Sloped 'warm' roof

Solution: The governing equation for the sloped roof case is Equation 7-2 (ASCE 7-02):

$$p_s = C_s p_f$$

where:

$C_s = 0.95$ (from ASCE 7-02 Figure 7-2a, warm roof, 'all other surfaces' line, $C_t = 1.0$).

p_f is computed as before:

$$p_f = 0.7 C_e C_t I p_g$$

where:

$C_e = 1.2$ (same as example 3),

$C_t = 1.0$ (from ASCE 7-02 Table 7-3 for 'All structures except as indicated below'),

$I = 1.0$ (from ASCE 7-02 Table 7-4 Category II, 'other structures'), and

$p_g = 198.7psf$ (same as example 3).

Substituting all values into the flat roof snow load equation:

$p_f = 0.7C_eC_tIp_g = 0.7(1.2)(1.0)(1.0)(198.7) = 167psf$

And then into the sloped roof equation:

$$p_s = C_sp_f = 0.95(167) = 159psf$$

According to Section 7.4.5 (ASCE 7-02), the eaves must have the capacity to sustain a uniformly distributed load of $2(p_f) = 2(167) = 334psf$. Figure 2.8 shows how the design loads should be applied to this roof.

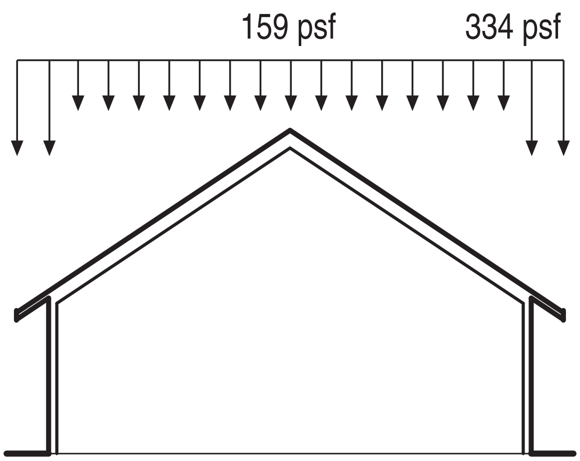


Figure 2.8: Load summary for use with sloped 'warm' roof

2.6 Example 6 - Curved Roof Snow Load

Required: Determine the design roof snow load p_s for the residence described in Example 3, but with the arched roof shown in Figure 2.9.

Solution: The governing equation for the curved roof case is Equation 7-2 (ASCE 7-02):

$$p_s = C_sp_f$$

, where:

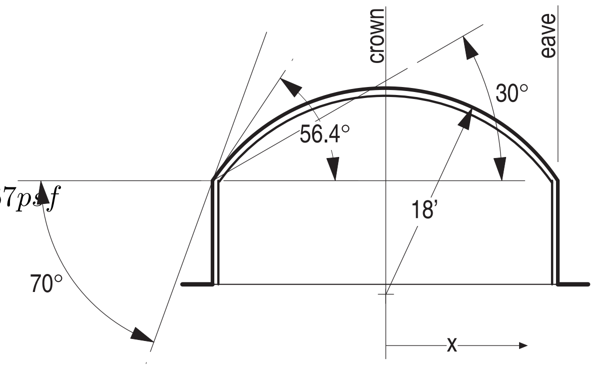


Figure 2.9: Curved roof

$p_f = 167psf$ (from Example 3), and

$C_s = varies.$

Figure 7-3 (ASCE 7-02) illustrates three load distributions for use with curved roofs. The distribution selected depends on the roof slope at the eaves. For the example problem, the slope at the eaves $\theta = 56.4^o$, therefore, the example problem falls under the 'Case 2' provisions from Figure 7-3 (ASCE 7-02).

The curves in Figure 7-2 (ASCE 7-02) must be used to determine C_s. Theoretically C_s continuously changes with the slope of the roof however, ASCE 7-02 recommends calculating C_s at four locations: where the factor $C_s = 1.0$, where the slope of the roof $\theta = 30^o$, where $\theta = 70^o$, and at the eaves.

For the balanced Case II snow load, a uniform load of $p_s = p_f$ is applied between the two locations across the roof where $C_s = 1.0$. Linearly varying loads are applied to the remainder of the roof, sequentially stepping down from the $C_s = 1.0$ location to the location at which $\theta = 30^o$ to the eaves. Both the balanced load and the unbalanced load distributions are illustrated in Figure 7-3 (ASCE 7-02).

In calculating the magnitudes of these various snow loads and their location of application, the following relationships between roof slope and position may be useful. For roofs that are arcs of a constant radius (i.e., portions of a circle), the following equations can be used to evaluate the slope θ at any location x:

$$\theta = \arctan\left(\frac{x}{\sqrt{R^2 - x^2}}\right)$$

and

$$x = \sqrt{\frac{R^2 \tan^2\theta}{1 + \tan^2\theta}}$$

where:

$\theta =$ the roof slope at position x,

$x =$ the position on the horizontal projection of the roof, measured with $x = 0$ at the crown and

$R =$ the radius of the curved roof.

Using these formulas to calculate boundary values of x and θ, C_s values are obtained from Figure 7-2a (ASCE 7-02) and $p_s = C_s p_f$. Table 2.5 indicates these results.

θ	x (ft)	C_s	p_s (psf)
5	1.6	1.0	167
30	9	0.62	104
56.4	15	0.2	33.4

Table 2.5: Balanced snow load

The assumption was made that there is no ventilated attic beneath the arched roof (i.e. warm roof case) and that the roof cladding is metal. The dashed line in Figure 7-2a (ASCE 7-02) indicates that $C_s = 1.0$ for $\theta \leq 5^o$. The rest of the values are read from the left side of Figure 7-2a at the point where the slope of interest intersects the dashed line.

For the unbalanced load case, the load distribution indicated in Figure 7-3 (ASCE 7-02) is followed and the results presented in Table 2.6.

Roof Location	C_s	EQ	p_s (psf)
Crown	1.0	$0.5p_f$	84
30^opoint	0.62	$2p_f\frac{C_s}{C_e}$	173
Eaves	0.2	$2p_f\frac{C_s}{C_e}$	28

Table 2.6: Unbalanced snow load

2.7 Concluding Remarks

The ground snow loads presented in Table 1.1 of this document represent reasonable values to use for the design of buildings and other structures in Montana. These loads meet the requirements of the ASCE 7-02 *Minimum Design Loads for Buildings and Other Structures* for determining ground snow loads by case study. While the reported ground snow loads are based on a statistical analysis of National Weather Service and Natural Resources Conservation Service data, there is the possibility of larger ground snow loads occurring than those published. Similarly, the contour maps at the end of Chapter 1 provide ground snow loads across the state, based on the stations listed in Table 1.1. While every effort has been made to ensure that the contours give accurate values, they are subject to some variability, especially in areas of steep terrain.

Engineers and architects involved with the design of structures should always consider local conditions and their specific structural configuration when developing snow loads to apply to a building. The examples presented in this document are an interpretation of the guidelines set forth in ASCE 7-02 for applying snow loads to structures.

2.8 References

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Appendix A

Snow Load Tables-NWS and SNOTEL

A.1 Use of the Snow Load Tables

The tables included in this appendix list the ground snow loads calculated from historical data at the National Weather Service (NWS) stations and the Natural Resources Conservation Service (NRCS) SNOTEL stations. These values may be used directly to find the ground snow load for buildings located in the immediate vicinity of one of the stations. Note that the NWS stations have been grouped geographically into six regions. These regions are defined in Figure A.1, which precedes the tables.

The ground snow loads reported in this document are a direct reflection of several assumptions that had to be made in their derivation. One major assumption is in regards to the nature of the underlying distribution that was used to describe the probability of occurrence of extreme snow load events. The snow load values in the main body of this report (Table 1.1) are based on a log-Pearson type III distribution. This appendix includes a second set of snow loads calculated using a log-Normal distribution. The log-Pearson distribution is believed to be more appropriate for snow conditions in Montana. A more detailed discussion of this choice is presented in Section A.2.4 of this report.

The raw data available from the NWS stations is for snow depth, rather than snow load. Some uncertainties are involved in converting snow depth to snow weight, therefore, three snow load values are reported for the NWS stations. These values correspond to using the highest, average, and the lowest realizations of the depth/density equations for each region. The snow load values reported in the main body of this report were calculated using the 'average' depth/density relationship for each region. This issue is discussed in more detail in Appendix B of this report.

Each NWS table extends from the left page across the binding over to the right page, thus taking up both pages on each side of the binding. The left page of each table lists basic information regarding each station and includes the recommended ground snow load at the station. Specifically, this page of each table includes:

Station	NWS station name. The stations are generally named for nearby cities or terrain features.
County	County in Montana where the station is located.
Latitude	Latitude coordinate (degrees, minutes, seconds) where the station is located, north of the Equator.
Longitude	Longitude coordinate (degrees, minutes, seconds) where the station is located, west of the Prime Meridian.
Elevation	Elevation (in feet) above sea level where the station is located.
Number of Years of Data*	Total years of yearly maximums that were used to determine the 50-year snow load.
Max. Recorded Depth*	Out of all of the yearly maximums for the station, the maximum depth (in inches) that the station ever experienced.
Calculated Snow Load*	The calculated ground snow load (in psf) based on the log-Pearson type III distribution, using the actual regression equation from the depth/density data.

* Two values may be shown as entries for these items. The second value, if present, is in parentheses. Two values are included if the year containing the maximum snow depth at a site did not meet the screening criteria for inclusion in the analysis. The second value, in parentheses, denotes this snow depth, as well as the resulting design snow load when this additional year was included in the analysis.

The entries on the right page of the table consist of additional information from the snow load analysis performed at each station that could be of interest to a designer. Information presented on this page consists of:

Station	NWS station name. Provided to make identification of the correct row easier for the user.
	Log-Pearson Type III Columns
50 Year (MRI) Depth*	The depth of snow (in inches) that has a 2% chance of occurring in any given year, as calculated by the LP III analysis.
Low Extreme Snow Load	The ground snow load (in psf) that results when the equation that bounds the depth/density data on the low side is used to convert the 50-year snow depth into snow load.
Calculated Snow Load*	The calculated ground snow load (in psf), using the actual regression equation from the depth/density data.
High Extreme Snow Load	The ground snow load (in psf) that results when the equation that bounds the depth/density data on the high side is used to convert the 50-year snow depth into snow load.
	Lognormal Columns
50 Year (MRI) Depth*	The depth of snow (in inches) that has a 2% chance of occurring in any given year, as calculated by the LP III analysis.
Low Extreme Snow Load	The ground snow load (in psf) that results when the equation that bounds the depth/density data on the low side is used to convert the 50-year snow depth into snow load.
Calculated Snow Load*	The calculated ground snow load (in psf), using the actual regression equation from the depth/density data.
High Extreme Snow Load	The ground snow load (in psf) that results when the equation that bounds the depth/density data on the high side is used to convert the 50-year snow depth into snow load.

* Two values may be shown as entries for these items. The second value, if present, is in parentheses. Two values are included if the year containing the maximum snow depth at a site did not meet the screening criteria for inclusion in the analysis. The second value, in parentheses, denotes this snow depth, as well as the resulting design snow load when this additional year was included in the analysis.

Snow loads for the SNOTEL stations are presented in Table A.7 and Table A.1. Although the 50-year (MRI) snow-water equivalent was actually what resulted from the statistical analysis of the data from these stations, only the ground snow load was reported rather than the snow-water equivalents. The ground snow load was determined by taking the 50-year snow-water equivalent and multiplying by 5.2 lb/ft2/in. The information reported in Table A.7 for the SNOTEL stations consists of:

Station	SNOTEL station name. The stations are generally named for nearby terrain features.
County	County in Montana where the station is located.
Latitude	Latitude coordinate (degrees, minutes, seconds) where the station is located, north of the Equator.
Longitude	Longitude coordinate (degrees, minutes, seconds) where the station is located, west of the Prime Meridian.
Elevation	Elevation (in feet) above sea level where the station is located.
Number of Years of Data	Total years of yearly maximums that were used to determine the 50-year snow load.
Max. Recorded Snow Load	Out of all of the yearly maximums for the station, the maximum snow load (in psf) that the station ever experienced.
50-year (MRI) Snow Load	The calculated ground snow load (in psf) based on the log-Pearson type III distribution or lognormal distribution.

Note that information for the SNOTEL stations is presented on a single page; thus, the page directly across the binding does not contain more information for the stations listed on the left side.

For further explanation on how the values in these tables were derived,read the text that follows the tables in this appendix and also refer to Appendix B. The method and decisions made as these tables were constructed is outlined in detail.

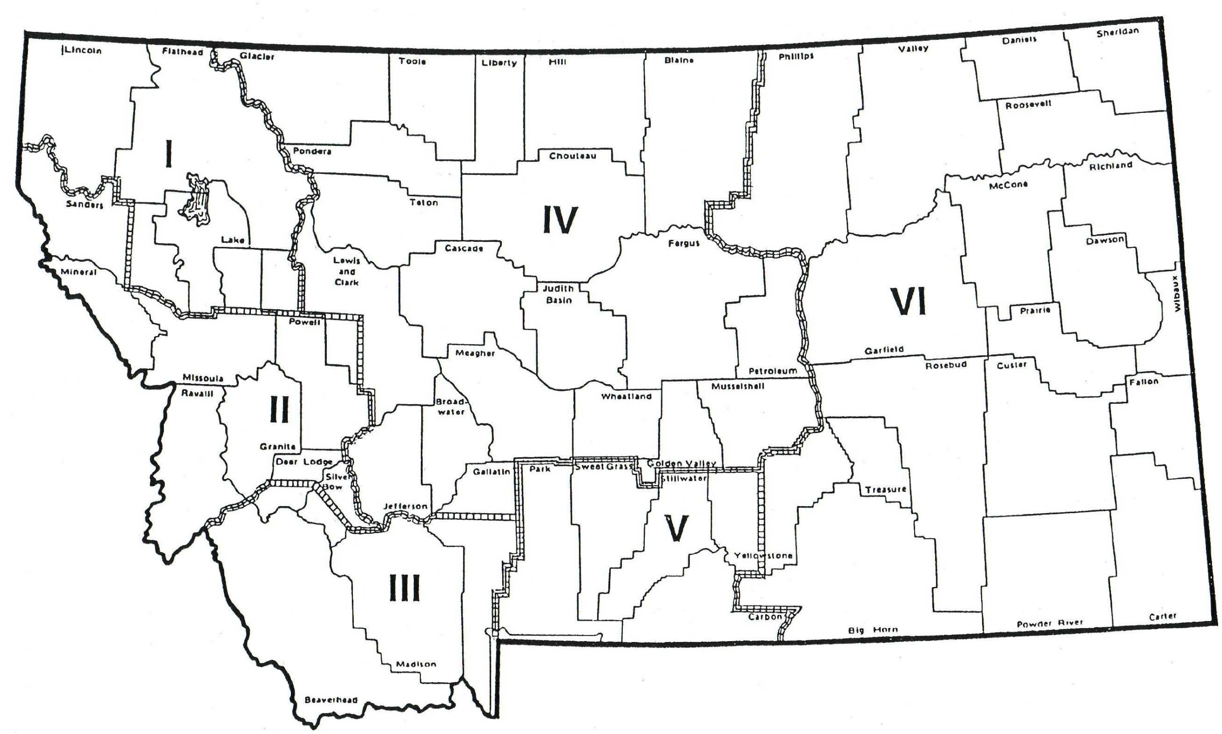

Figure A.1: Map of Montana indicating regions for which snow load relationships were developed

Table A.1: Snow load data for NWS stations in Region 1

Station	County	Latitude °	'	"	Longitude °	'	"	Elevation (ft)	Number of Years of Data		Max. Recorded Depth (inches)		Calculated Snow Load (psf)	
Bigfork 13 S	Lake	47	52	30	114	1	59	2910	20	-	29	-	54.6	-
Creston	Flathead	48	11	22	114	8	14	2940	37	-	35	-	65.4	-
Eureka Ranger Station	Lincoln	48	53	54	115	3	32	2532	27	-	31	-	46.2	-
Fortine 1 N	Lincoln	48	46	42	114	54	2	3000	79	-	42	-	49.2	-
Hungry Horse Dam	Flathead	48	20	34	114	1	18	3160	29	-	50	-	84.1	-
Kalispell Glacier Park AP	Flathead	48	18	15	114	15	49	2957	50	-	61	-	60.9	-
Libby 1 NE RS	Lincoln	48	24	13	115	32	21	2096	26	27	36	38	68.0	(74.8)
Libby 32 SSE	Lincoln	47	58	24	115	13	26	3600	47	-	55	-	97.5	-
Lindbergh Lake	Missoula	47	24	33	113	42	44	4320	38	-	65	-	116.6	-
Lonepine 1 WNW	Sanders	47	43	0	114	39	0	2881	14	-	26	-	40.5	-
Pleasant Valley	Flathead	48	8	0	114	55	0	3602	23	-	35	-	51.8	-
Polebridge	Flathead	48	45	54	114	17	7	3520	36	-	54	-	84.4	-
Polson Kerr Dam	Lake	47	40	39	114	14	31	2730	18	-	28	-	64.6	-
St. Ignatius	Lake	47	18	54	114	5	54	2900	78	-	24	-	30.7	-
Summit	Flathead	48	18	54	113	21	18	5233	20	-	147	-	302.1	-
Swan Lake	Lake	47	55	13	113	50	22	3100	14	-	54	-	108.0	-
West Glacier	Flathead	48	30	2	113	59	7	3154	48	-	60	-	99.8	-
Whitefish	Flathead	48	24	29	114	21	34	3100	44	-	40	-	68.4	-

	Log - Pearson Type III						Lognornal					
Station	50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)	50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)
Bigfork 13 S	33.8	-	20.3	54.6	-	80.6	49.9	-	51.0	85.3	-	111.3
Creston	39.7	-	31.1	65.4	-	91.4	39.7	-	31.2	65.6	-	91.6
Eureka Ranger Station	29.1	-	11.9	46.2	-	72.2	25.9	-	6.4	40.8	-	66.8
Fortine 1 N	30.8	-	14.9	49.2	-	75.2	33.1	-	19.1	53.4	-	79.4
Hungry Horse Dam	49.3	-	49.7	84.1	-	110.1	51.1	-	53.4	87.7	-	113.7
Kalispell Glacier Park AP	37.2	-	26.6	60.9	-	86.9	43.5	-	38.5	72.8	-	98.8
Libby 1 NE RS	41.0	(44.6)	33.7	68.0	(74.8)	94.0	40.5	(43.7)	32.7	67.1	(73.2)	93.1
Libby 32 SSE	55.9	-	63.2	97.5	-	123.5	73.8	-	101.8	136.1	-	162.1
Lindbergh Lake	66.0	-	80.2	116.6	-	148.8	70.1	-	89.1	125.5	-	157.8
Lonepine 1 WNW	25.8	-	6.1	40.5	-	66.5	36.3	-	24.8	59.1	-	85.1
Pleasant Valley	32.2	-	17.4	51.8	-	77.8	42.1	-	35.6	70.0	-	96.0
Polebridge	49.5	-	50.1	84.4	-	110.4	60.6	-	72.9	107.3	-	133.3
Polson Kerr Dam	39.2	-	30.3	64.6	-	90.6	45.7	-	42.6	76.9	-	102.9
St. Ignatius	20.0	-	0.0	30.7	-	56.7	28.7	-	11.2	45.5	-	71.5
Summit	138.4	-	251.2	302.1	-	375.4	145.2	-	269.4	320.4	-	393.7
Swan Lake	61.0	-	73.7	108.0	-	134.0	68.2	-	89.4	123.7	-	149.7
West Glacier	57.1	-	65.5	99.8	-	125.8	57.4	-	66.3	100.6	-	126.6
Whitefish	41.3	-	34.1	68.4	-	94.4	44.1	-	39.6	74.0	-	100.0

Table A.2: Snow load data for NWS stations in Region 2

Station	County	Latitude			Longitude			Elevation	Number of Years of Data		Max. Recorded Depth		Calculated Snow Load	
		°	'	"	°	'	"	(ft)			(inches)		(psf)	
Anaconda	Deer Lodge	46	7	53	112	57	25	5280	15	-	20	-	38.1	-
Butte Bert Mooney AP	Silver Bow	45	57	53	112	30	2	5506	62	-	27	-	36.9	-
Butte School of Mines	Silver Bow	46	1	0	112	33	0	5774	11	-	21	-	33.9	-
Darby	Ravalli	46	1	29	114	10	37	3880	13	-	22	-	39.5	-
Deer Lodge	Powell	46	23	0	112	44	0	4534	26	-	16	-	26.3	-
Deer Lodge 3 W	Powell	46	23	28	112	47	51	4850	21	-	28	-	51.3	-
Drummond	Granite	46	38	18	113	10	34	4000	37	-	31	-	35.7	-
Drummond FAA AP	Granite	46	37	0	113	12	0	4242	33	-	55	-	54.4	-
Elliston	Powell	46	34	0	112	26	0	5075	21	22	27	35	40.2	(51.5)
Haugan 3 E (Deborgia)	Mineral	47	23	0	115	21	0	3100	53	-	61	-	102.4	-
Heron 2 NW	Sanders	48	4	48	116	0	4	2240	56	-	51	-	101.4	-
Lincoln RS	Lewis & Clark	46	57	23	112	39	21	4575	22	-	42	-	63.4	-
Missoula 2 NE	Missoula	46	53	54	113	58	5	3420	34	35	22	25	32.5	(36.7)
Missoula Int'l AP	Missoula	46	55	15	114	5	33	3192	49	50	23	27	33.9	(37.5)
Ovando	Powell	47	1	0	113	8	0	4110	13	14	36	48	84.0	(106.2)
Ovando 7 WNW	Powell	47	3	0	113	17	0	4003	11	-	42	-	90.3	-
Ovando 9 SSE	Powell	46	53	49	113	3	43	4255	14	-	22	-	35.2	-
Philipsburg	Granite	46	20	0	113	18	0	5282	40	-	24	-	38.2	-
Philipsburg RS	Granite	46	18	57	113	17	58	5270	19	20	21	22	37.0	(41.4)
Potomac	Missoula	46	52	54	113	34	28	3620	25	26	32	49	57.5	(75.5)
Seeley Lake RS	Missoula	47	12	50	113	31	20	4100	44	45	52	54	80.7	(86.1)
Stevensville	Ravalli	46	30	51	114	5	24	3375	24	-	28	-	47.9	-
Sula 3 ENE	Ravalli	45	50	52	113	55	37	4475	12	-	40	-	77.2	-
Superior	Mineral	47	11	34	114	53	25	2710	51	-	44	-	60.3	-
Thompson Falls	Sanders	47	36	0	115	21	0	2441	39	-	30	-	49.6	-
Thompson Falls PH	Sanders	47	35	36	115	21	34	2380	13	-	21	-	45.8	-
Trout Creek 2 W	Sanders	47	50	0	115	38	0	2490	36	-	51	-	89.6	-
Trout Creek RS	Sanders	47	51	59	115	37	38	2356	18	-	45	-	90.3	-

Station	Log - Pearson Type III						Lognornal					
	50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)	50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)
Anaconda	23.6	-	0.0	38.1	-	107.2	24.5	-	0.0	39.7	-	108.8
Butte Bert Mooney AP	22.9	-	0.0	36.9	-	106.0	22.5	-	0.0	36.3	-	105.5
Butte School of Mines	21.1	-	0.0	33.9	-	103.1	22.4	-	0.0	36.1	-	105.2
Darby	27.0	-	24.4	39.5	-	58.8	55.6	-	80.5	95.6	-	114.8
Deer Lodge	18.9	-	11.2	26.3	-	45.6	19.5	-	12.2	27.3	-	46.5
Deer Lodge 3 W	33.7	-	36.3	51.3	-	70.6	30.6	-	30.8	45.8	-	65.1
Drummond	24.7	-	20.6	35.7	-	54.9	30.4	-	30.4	45.5	-	64.7
Drummond FAA AP	35.4	-	39.3	54.4	-	73.7	26.7	-	23.9	39.0	-	58.2
Elliston	24.8	(31.3)	0.0	40.2	(51.5)	109.3	29.1	(33.0)	0.0	47.6	(54.6)	116.8
Haugan 3 E (Deborgia)	58.7	-	87.3	102.4	-	121.7	74.0	-	124.0	139.0	-	158.3
Heron 2 NW	58.2	-	86.3	101.4	-	120.6	62.3	-	95.5	110.6	-	129.8
Lincoln RS	40.1	-	48.3	63.4	-	82.7	43.8	-	55.6	70.6	-	89.9
Missoula 2 NE	22.8	(25.3)	17.4	32.5	(36.7)	51.8	23.9	(25.9)	19.3	34.4	(37.6)	53.6
Missoula Int'l AP	23.6	(25.8)	18.8	33.9	(37.5)	53.2	24.5	(26.1)	20.3	35.4	(38.0)	54.7
Ovando	50.3	(60.4)	68.9	84.0	(106.2)	103.2	87.4	(103)	159.7	174.8	(220.1)	194.0
Ovando 7 WNW	53.2	-	75.2	90.3	-	109.6	60.0	-	90.2	105.3	-	124.6
Ovando 9 SSE	24.4	-	20.1	35.2	-	54.4	26.2	-	23.0	38.1	-	57.4
Philipsburg	23.6	-	0.0	38.2	-	107.4	29.2	-	0.0	47.9	-	117.0
Philipsburg RS	22.9	(25.5)	0.0	37.0	(41.4)	106.1	20.9	(23.1)	0.0	33.5	(37.2)	102.7
Potomac	37.0	(46.2)	42.4	57.5	(75.5)	76.7	37.1	(42.8)	42.5	57.6	(68.6)	76.8
Seeley Lake RS	48.7	(51.3)	65.6	80.7	(86.1)	100.0	54.1	(55.9)	77.1	92.1	(96.2)	111.4
Stevensville	31.8	-	32.8	47.9	-	67.1	35.0	-	38.7	53.8	-	73.0
Sula 3 ENE	47.0	-	62.1	77.2	-	96.5	32.3	-	33.7	48.8	-	68.1
Superior	38.5	-	45.2	60.3	-	79.5	49.3	-	66.8	81.9	-	101.2
Thompson Falls	32.7	-	34.5	49.6	-	68.9	37.0	-	42.4	57.5	-	76.7
Thompson Falls PH	30.6	-	30.7	45.8	-	65.0	59.5	-	89.2	104.3	-	123.5
Trout Creek 2 W	52.9	-	74.6	89.6	-	108.9	68.8	-	111.1	126.1	-	145.4
Trout Creek RS	53.2	-	75.2	90.3	-	109.6	54.0	-	76.9	92.0	-	111.3

Table A.3: Snow load data for NWS stations in Region 3

Station	County	Latitude °	'	"	Longitude °	'	"	Elevation (ft)	Number of Years of Data		Max. Recorded Depth (inches)		Calculated Snow Load (psf)	
Belgrade Airport	Gallatin	45	47	37	111	9	8	4427	47	-	29	-	33.3	-
Bozeman 12 NE	Gallatin	45	49	0	110	53	0	5950	44	-	60	-	95.7	-
Bozeman 6 W Exp. Farm	Gallatin	45	40	30	111	9	18	4775	27	-	20	-	29.8	-
Bozeman MSU	Gallatin	45	39	44	111	2	43	4913	46	-	28	-	42.3	-
Dillon AP	Beaverhead	45	15	0	112	33	0	5216	42	-	15	-	19.2	-
Dillon WMCE	Beaverhead	45	12	46	112	38	41	5228	13	14	14	19	24.4	(31.4)
Divide	Silver Bow	45	45	4	112	45	17	5350	44	-	14	-	19.3	-
Grant 5 SE	Beaverhead	44	56	28	113	1	41	5780	36	-	18	-	24.4	-
Hebgen Dam	Gallatin	44	52	0	111	20	21	6489	40	-	79	-	137.1	-
Jackson	Beaverhead	45	22	5	113	24	33	6480	10	-	24	-	45.1	-
Lakeview	Beaverhead	44	35	58	111	48	45	6710	19	-	99	-	206.8	-
Lima	Beaverhead	44	38	22	112	35	26	6273	40	-	24	-	26.7	-
Manhattan	Gallatin	45	52	0	111	20	0	4232	24	-	14	-	20.7	-
Norris Madison PH	Madison	45	29	8	111	37	57	4745	54	-	27	-	34.9	-
Pony	Madison	45	39	26	111	53	55	5590	17	-	25	-	44.3	-
West Yellowstone	Gallatin	44	39	0	111	6	0	6659	47	-	76	-	135.0	-
Wise River 3 WNW	Beaverhead	45	48	11	113	0	49	5730	14	-	16	-	25.5	-

Station	Log - Pearson Type III						Lognornal					
	50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)	50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)
Belgrade Airport	23.3	-	18.3	33.3	-	52.6	24.0	-	19.5	34.6	-	53.8
Bozeman 12 NE	57.6	-	36.5	95.7	-	164.4	59.3	-	40.0	99.3	-	168.0
Bozeman 6 W Exp. Farm	21.1	-	14.7	29.8	-	49.0	21.9	-	16.0	31.1	-	50.3
Bozeman MSU	28.6	-	27.2	42.3	-	61.6	27.6	-	25.4	40.5	-	59.8
Dillon AP	14.2	-	0.0	19.2	-	87.8	16.1	-	0.0	21.9	-	90.5
Dillon WMCE	17.8	(22.3)	0.0	24.4	(31.4)	93.0	17.9	(21.4)	0.0	24.5	(29.9)	93.1
Divide	14.4	-	0.0	19.3	-	88.0	15.3	-	0.0	20.7	-	89.3
Grant 5 SE	17.8	-	0.0	24.4	-	93.1	17.9	-	0.0	24.6	-	93.3
Hebgen Dam	76.3	-	77.8	137.1	-	205.7	72.7	-	69.5	128.8	-	197.4
Jackson	30.7	-	0.0	45.1	-	113.7	37.4	-	0.0	56.7	-	125.4
Lakeview	103.6	-	147.5	206.8	-	275.4	119.3	-	192.7	252.0	-	320.6
Lima	19.3	-	0.0	26.7	-	95.4	18.5	-	0.0	25.5	-	94.1
Manhattan	15.2	-	5.7	20.7	-	40.0	21.3	-	15.0	30.1	-	49.4
Norris Madison PH	24.3	-	19.9	34.9	-	54.2	23.3	-	18.3	33.4	-	52.6
Pony	30.3	-	0.0	44.3	-	113.0	33.4	-	0.0	49.6	-	118.2
West Yellowstone	75.3	-	75.7	135.0	-	203.6	82.1	-	91.9	151.2	-	219.8
Wise River 3 WNW	18.5	-	0.0	25.5	-	94.2	19.7	-	0.0	27.4	-	96.0

Table A.4: Snow load data for NWS stations in Region 4

Station	County	Latitude °	Latitude '	Latitude "	Longitude °	Longitude '	Longitude "	Elevation (ft)	Number of Years of Data		Max. Recorded Depth (inches)		Calculated Snow Load (psf)	
Augusta	Lewis & Clark	47	29	35	112	23	47	4070	10	-	20	-	40.8	-
Austin 1 W	Lewis & Clark	46	38	20	112	15	31	4790	12	13	19	35	38.4	(67.0)
Barber	Golden Valley	46	18	39	109	22	19	3730	11	-	26	-	45.4	-
Big Sandy	Chouteau	48	8	6	110	3	39	2770	27	28	17	25	20.8	(27.8)
Blackleaf	Teton	48	0	46	112	26	13	4235	18	19	22	36	31.8	(53.3)
Brady Aznoe	Chouteau	47	57	0	111	20	0	3333	30	-	20	-	24.7	-
Browning	Glacier	48	33	34	113	0	39	4355	25	-	40	-	86.1	-
Bynum 4 SSE	Teton	47	56	0	112	18	0	4022	24	-	15	-	23.1	-
Canyon Creek	Lewis & Clark	46	49	0	112	15	0	4314	13	-	18	-	29.0	-
Carter 14 W	Chouteau	47	47	31	111	13	10	3450	10	11	11	16	12.2	(18.8)
Cascade 5 S	Cascade	47	13	10	111	42	36	3360	76	-	28	-	25.2	-
Chinook	Blaine	48	35	6	109	14	1	2345	10	-	29	-	58.7	-
Choteau	Teton	47	49	14	112	11	31	3845	39	-	20	-	19.0	-
Cut Bank Municipal AP	Glacier	48	36	30	112	22	34	3838	51	-	18	-	17.0	-
Deep Creek Pass 2	Broadwater	46	22	0	111	8	0	5440	14	-	39	-	71.5	-
Del Bonita	Glacier	48	59	54	112	47	19	4337	14	15	18	25	29.3	(42.9)
Dunkirk 15 NNE	Toole	48	42	0	111	36	0	3383	39	-	27	-	29.0	-
East Glacier	Glacier	48	26	49	113	13	26	4806	25	-	83	-	184.7	-
Fairfield	Teton	47	36	55	111	59	8	3983	32	33	29	30	37.2	(44.7)
Flatwillow 4 ENE	Petroleum	46	51	4	108	18	48	3133	11	12	23	25	37.4	(55.7)
Fort Assinniboine	Hill	48	29	54	109	47	50	2613	22	23	28	29	36.1	(46.0)
Fort Benton	Chouteau	47	48	51	110	40	19	2636	36	-	26	-	27.8	-
Fort Logan 4 ESE	Meagher	46	39	17	111	5	38	4710	40	-	36	-	51.3	-
Galata 16 SSW	Toole	48	14	45	111	24	21	3100	17	-	19	-	23.2	-
Geraldine	Chouteau	47	35	52	110	15	56	3130	39	-	26	-	27.7	-
Gibson Dam	Lewis & Clark	47	36	6	112	45	13	4590	40	-	30	-	51.4	-
Goldbutte 7 N	Toole	48	58	34	111	23	58	3498	20	21	19	25	25.4	(36.2)
Grass Range	Fergus	47	1	32	108	48	12	3490	27	-	29	-	32.4	-
Great Falls	Cascade	47	31	0	111	18	0	3353	10	-	18	-	31.0	-
Great Falls Int'l Airport	Cascade	47	28	24	111	22	56	3664	49	-	24	-	24.1	-
Harlowton	Wheatland	46	25	59	109	49	50	4162	41	-	24	-	28.6	-
Havre City/County AP	Hill	48	32	34	109	45	48	2585	35	-	28	-	46.8	-
Helena Regional AP	Lewis & Clark	46	36	20	111	57	49	3828	47	-	23	-	25.5	-
Highwood 7 NE	Chouteau	47	38	32	110	40	5	3600	26	-	27	-	32.2	-
Hobson	Judith Basin	47	0	0	109	52	0	4081	14	-	38	-	67.1	-
Hogeland 7 WSW	Blaine	48	49	0	108	48	0	3351	21	-	30	-	55.0	-
Holter Dam	Lewis & Clark	46	59	29	112	0	44	3487	28	29	14	21	18.3	(22.8)
Joplin	Liberty	48	33	37	110	46	15	3325	25	-	26	-	32.9	-
Kremlin	Hill	48	31	18	110	6	27	2860	37	-	28	-	37.3	-
Lewistown Municipal AP	Fergus	47	2	57	109	28	0	4145	51	-	33	-	52.3	-

	Log - Pearson Type III						Lognornal					
Station	50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)	50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)
Augusta	26.1	-	0.0	40.8	-	70.5	25.5	-	0.0	39.6	-	69.3
Austin 1 W	24.9	(38.9)	0.0	38.4	(67.0)	68.1	26.3	(35.3)	0.0	41.2	(59.1)	70.8
Barber	31.9	-	40.2	45.4	-	53.8	24.7	-	26.1	31.3	-	39.6
Big Sandy	18.4	(22.7)	15.6	20.8	(27.8)	29.2	20.8	(23.7)	19.5	24.7	(29.5)	33.0
Blackleaf	21.2	(32.5)	0.0	31.8	(53.3)	61.5	23.0	(28.7)	0.0	34.9	(45.7)	64.6
Brady Aznoe	20.9	-	19.5	24.7	-	33.1	18.8	-	16.2	21.4	-	29.7
Browning	47.2	-	43.5	86.1	-	115.8	55.4	-	64.1	106.8	-	136.4
Bynum 4 SSE	16.1	-	0.0	23.1	-	52.7	18.5	-	0.0	27.2	-	56.8
Canyon Creek	19.6	-	0.0	29.0	-	58.7	17.6	-	0.0	25.6	-	55.2
Carter 14 W	12.3	(17.1)	7.0	12.2	(18.8)	20.5	13.4	(16.3)	8.4	13.6	(17.7)	22.0
Cascade 5 S	21.2	-	20.0	25.2	-	33.5	21.5	-	20.6	25.8	-	34.1
Chinook	37.8	-	53.5	58.7	-	67.0	30.6	-	37.6	42.8	-	51.1
Choteau	17.2	-	13.8	19.0	-	27.3	16.2	-	12.3	17.5	-	25.9
Cut Bank Municipal AP	15.8	-	11.8	17.0	-	25.3	15.3	-	11.1	16.3	-	24.6
Deep Creek Pass 2	39.9	-	0.0	71.5	-	126.1	38.8	-	0.0	69.2	-	123.8
Del Bonita	19.8	(27.2)	0.0	29.3	(42.9)	59.0	18.5	(23.2)	0.0	27.1	(35.4)	56.8
Dunkirk 15 NNE	23.4	-	23.8	29.0	-	37.3	26.0	-	28.5	33.7	-	42.0
East Glacier	81.8	-	142.1	184.7	-	214.4	83.8	-	148.5	191.1	-	220.8
Fairfield	27.8	(31.6)	32.0	37.2	(44.7)	45.5	27.3	(30.1)	30.9	36.1	(41.6)	44.4
Flatwillow 4 ENE	27.9	(36.5)	32.2	37.4	(55.7)	45.7	21.8	(28.6)	21.1	26.3	(38.8)	34.6
Fort Assinniboine	27.3	(32.2)	30.9	36.1	(46.0)	44.4	25.3	(28.9)	27.2	32.4	(39.3)	40.7
Fort Benton	22.7	-	22.6	27.8	-	36.1	23.4	-	23.8	29.0	-	37.3
Fort Logan 4 ESE	31.5	-	8.7	51.3	-	81.0	29.9	-	5.6	48.2	-	77.8
Galata 16 SSW	19.9	-	18.0	23.2	-	31.5	22.3	-	22.0	27.2	-	35.5
Geraldine	22.7	-	22.5	27.7	-	36.0	24.5	-	25.7	30.9	-	39.2
Gibson Dam	31.6	-	8.8	51.4	-	81.1	34.8	-	15.5	58.1	-	87.8
Goldbutte 7 N	21.3	(27.3)	20.2	25.4	(36.2)	33.7	17.9	(21.8)	14.9	20.1	(26.2)	28.4
Grass Range	25.3	-	27.2	32.4	-	40.7	26.5	-	29.5	34.7	-	43.0
Great Falls	24.5	-	25.8	31.0	-	39.4	24.1	-	25.0	30.2	-	38.5
Great Falls Int'l Airport	20.5	-	18.9	24.1	-	32.4	20.6	-	19.0	24.2	-	32.5
Harlowton	19.3	-	0.0	28.6	-	58.2	21.3	-	0.0	32.0	-	61.7
Havre City/County AP	32.5	-	41.6	46.8	-	55.1	30.4	-	37.1	42.3	-	50.7
Helena Regional AP	21.3	-	20.3	25.5	-	33.8	22.1	-	21.6	26.8	-	35.1
Highwood 7 NE	25.2	-	27.0	32.2	-	40.5	31.2	-	38.8	44.0	-	52.4
Hobson	39.0	-	24.5	67.1	-	96.8	33.0	-	11.7	54.3	-	84.0
Hogeland 7 WSW	36.2	-	49.8	55.0	-	63.3	34.7	-	46.4	51.6	-	59.9
Holter Dam	16.7	(19.7)	13.1	18.3	(22.8)	26.6	19.5	(21.6)	17.2	22.4	(25.9)	30.8
Joplin	25.5	-	27.7	32.9	-	41.2	23.9	-	24.7	29.9	-	38.2
Kremlin	27.9	-	32.1	37.3	-	45.7	24.7	-	26.2	31.4	-	39.7
Lewistown Municipal AP	32.0	-	9.7	52.3	-	81.9	29.1	-	3.9	46.6	-	76.2

Station	County	Latitude °	'	"	Longitude °	'	"	Elevation (ft)	Number of Years of Data		Max. Recorded Depth (inches)		Calculated Snow Load (psf)	
Loma 1 WNW	Chouteau	47	56	39	110	31	51	2580	41	-	30	-	32.0	-
Lonesome Lake	Chouteau	48	15	0	110	12	0	2762	-	10	-	33	-	(73.8)
Loweth	Meagher	46	22	0	110	42	0	5804	11	-	42	-	101.9	-
Martinsdale 3 NNW	Meagher	46	30	0	110	20	16	4800	37	-	26	-	41.1	-
Melstone	Musselshell	46	36	3	107	52	10	2920	43	44	34	36	38.2	(46.1)
Moccasin Exp. Station	Judith Basin	47	3	27	109	57	5	4300	20	-	41	-	73.9	-
Neihart 8 NNW	Cascade	47	2	29	110	46	34	5230	24	-	36	-	72.7	-
Power 6 SE	Cascade	47	39	16	111	35	53	3750	46	-	20	-	23.3	-
Raynesford 2 NNW	Judith Basin	47	17	50	110	44	44	4215	30	-	46	-	91.8	-
Rogers Pass 9 NNE	Lewis & Clark	47	11	24	112	17	26	4200	17	-	40	-	86.0	-
Roundup	Musselshell	46	26	59	108	32	30	3227	21	-	18	-	21.2	-
Roy 8 NE	Fergus	47	25	55	108	50	42	3445	52	-	56	-	66.4	-
Ryegate 18 NNW	Golden Valley	46	32	0	109	20	39	4440	22	-	20	-	32.4	-
Shonkin 7 S	Chouteau	47	31	55	110	34	37	4300	21	-	50	-	79.1	-
Simms 1 NE	Cascade	47	30	22	111	55	12	3590	14	-	11	-	11.8	-
Simpson 6 N	Hill	48	58	46	110	18	16	2740	51	-	27	-	32.5	-
St Mary	Glacier	48	44	18	113	25	46	4560	12	13	36	37	67.5	(84.5)
Stanford	Judith Basin	47	9	17	110	13	26	4860	14	15	28	40	47.9	(74.1)
Stanford 2 NE	Judith Basin	47	9	0	110	13	0	4281	13	-	16	-	22.5	-
Sun River 4 S	Cascade	47	28	40	111	44	26	3600	34	-	19	-	18.4	-
Sunburst 8 E	Toole	48	53	13	111	43	39	3700	33	-	21	-	26.3	-
Toston 1 W	Broadwater	46	10	0	111	28	0	3934	10	-	19	-	34.1	-
Townsend	Broadwater	46	19	51	111	32	16	3840	19	-	11	-	10.2	-
Trident	Gallatin	45	56	49	111	28	29	4036	34	35	15	18	20.5	(23.9)
Utica 11 WSW	Judith Basin	46	53	0	110	18	0	5002	19	-	29	-	69.3	-
Valentine	Fergus	47	20	20	108	29	46	2910	16	-	18	-	27.3	-
Valier	Pondera	48	18	32	112	15	4	3810	25	26	14	18	14.2	(17.9)
White Sulphur Springs	Meagher	46	32	33	110	54	15	5160	11	-	25	-	53.5	-
Whitehall AP	Jefferson	45	49	0	112	12	0	4598	11	-	14	-	23.5	-
Winnett 5 NNE	Petroleum	47	4	0	108	19	0	2923	18	-	28	-	36.3	-

Station	Log - Pearson Type III: 50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)	Lognornal: 50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)
Loma 1 WNW	25.1	-	26.8	32.0	-	40.3	23.4	-	23.8	29.0	-	37.3
Lonesome Lake	-	(43.8)	-	-	(73.8)	-	-	(35.2)	-	-	(52.7)	-
Loweth	53.6	-	5.7	101.9	-	156.5	45.4	-	0.0	83.3	-	137.9
Martinsdale 3 NNW	26.3	-	0.0	41.1	-	70.8	30.6	-	6.9	49.5	-	79.1
Melstone	28.4	(32.2)	33.0	38.2	(46.1)	46.6	29.2	(31.7)	34.8	40.0	(45.1)	48.3
Moccasin Exp. Station	42.0	-	31.2	73.9	-	103.5	38.8	-	24.0	66.7	-	96.3
Neihart 8 NNW	40.5	-	0.0	72.7	-	127.3	43.5	-	0.0	79.2	-	133.8
Power 6 SE	20.0	-	18.1	23.3	-	31.6	20.2	-	18.4	23.6	-	31.9
Raynesford 2 NNW	49.5	-	49.1	91.8	-	121.4	47.7	-	44.6	87.2	-	116.9
Rogers Pass 9 NNE	47.1	-	43.3	86.0	-	115.6	45.9	-	40.4	83.1	-	112.7
Roundup	18.6	-	16.0	21.2	-	29.5	26.2	-	28.9	34.1	-	42.4
Roy 8 NE	40.9	-	61.2	66.4	-	74.7	38.8	-	56.0	61.2	-	69.5
Ryegate 18 NNW	21.5	-	0.0	32.4	-	62.0	21.5	-	0.0	32.3	-	61.9
Shonkin 7 S	44.2	-	36.4	79.1	-	108.7	47.9	-	45.2	87.9	-	117.5
Simms 1 NE	12.0	-	6.6	11.8	-	20.2	14.3	-	9.7	14.9	-	23.2
Simpson 6 N	25.4	-	27.3	32.5	-	40.8	26.2	-	28.8	34.0	-	42.3
St Mary	39.2	(46.5)	24.9	67.5	(84.5)	97.2	43.1	(50.3)	33.7	76.4	(93.7)	106.0
Stanford	29.8	(42.1)	5.3	47.9	(74.1)	77.6	35.1	(43.9)	16.2	58.8	(78.4)	88.4
Stanford 2 NE	15.7	-	0.0	22.5	-	52.2	19.9	-	0.0	29.5	-	59.1
Sun River 4 S	16.8	-	13.2	18.4	-	26.7	16.9	-	13.4	18.6	-	26.9
Sunburst 8 E	21.9	-	21.1	26.3	-	34.7	19.4	-	17.2	22.4	-	30.7
Toston 1 W	26.2	-	28.9	34.1	-	42.5	22.1	-	21.5	26.7	-	35.1
Townsend	10.6	-	5.0	10.2	-	18.5	11.5	-	6.1	11.3	-	19.6
Trident	14.5	(16.6)	0.0	20.5	(23.9)	50.2	16.1	(17.6)	0.0	23.2	(25.5)	52.8
Utica 11 WSW	38.8	-	0.0	69.3	-	123.9	33.8	-	0.0	58.9	-	113.5
Valentine	22.4	-	22.1	27.3	-	35.6	24.7	-	26.1	31.3	-	39.6
Valier	13.8	(16.4)	9.0	14.2	(17.9)	22.5	16.2	(18.0)	12.3	17.5	(20.2)	25.8
White Sulphur Springs	31.0	-	0.0	53.5	-	108.1	28.7	-	0.0	49.0	-	103.6
Whitehall AP	16.3	-	0.0	23.5	-	53.1	18.5	-	0.0	27.2	-	56.8
Winnett 5 NNE	27.4	-	31.1	36.3	-	44.6	26.5	-	29.4	34.6	-	42.9

Table A.5: Snow load data for NWS stations in Region 5

Station	County	Latitude °	'	"	Longitude °	'	"	Elevation (ft)	Number of Years of Data		Max. Recorded Depth (inches)		Calculated Snow Load (psf)	
Big Timber	Sweet Grass	45	49	58	109	57	5	4100	22	23	21	24	36.5	(42.4)
Billings Logan Int'l AP	Yellowstone	45	48	25	108	32	32	3581	52	-	33	-	31.7	-
Bridger 1 S	Carbon	45	17	14	108	55	5	3680	45	-	30	-	28.2	-
Cooke City 2 W	Park	45	0	55	109	58	16	7460	22	-	70	-	135.4	-
Edgar 9 SE	Carbon	45	23	0	108	43	0	4003	23	-	34	-	59.8	-
Gardiner	Park	45	1	54	110	42	13	5275	12	13	20	25	31.5	(45.9)
Gibson 2 NE	Sweet Grass	46	2	21	109	29	42	4350	26	-	23	-	41.5	-
Jardine	Park	45	4	0	110	38	0	6453	10	-	69	-	154.1	-
Joliet	Carbon	45	28	51	108	58	35	3700	45	-	30	-	31.6	-
Laurel 3 WSW	Yellowstone	45	40	0	108	49	0	3319	22	-	29	-	35.0	-
Livingston 12 S	Park	45	29	1	110	34	8	4870	38	-	24	-	32.8	-
Livingston Mission Field	Park	45	41	51	110	27	15	4653	52	-	22	-	33.9	-
Mystic Lake	Stillwater	45	14	44	109	44	3	6558	35	-	63	-	89.6	-
Nye 2	Stillwater	45	26	6	109	48	29	4840	14	-	36	-	68.6	-
Rapelje 4 S	Stillwater	45	54	54	109	15	12	4125	39	40	18	40	26.9	(41.6)
Red Lodge 2 N	Carbon	45	12	47	109	14	15	5500	79	-	71	-	105.2	-
Wilsall 8 ENE	Park	46	1	44	110	30	37	5835	11	12	26	42	51.7	(74.9)

Station	Log - Pearson Type III 50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)	Lognornal 50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)
Big Timber	23.8	(26.9)	0.0	36.5	(42.4)	66.1	24.0	(26.6)	0.0	36.8	(41.6)	66.5
Billings Logan Int'l AP	24.9	-	26.5	31.7	-	40.0	22.3	-	22.0	27.2	-	35.5
Bridger 1 S	22.9	-	23.0	28.2	-	36.5	23.6	-	24.2	29.4	-	37.7
Cooke City 2 W	76.3	-	39.2	135.4	-	192.1	75.5	-	37.5	133.7	-	190.3
Edgar 9 SE	35.6	-	17.2	59.8	-	89.4	34.7	-	15.2	57.9	-	87.5
Gardiner	22.3	(31.3)	0.0	31.5	(45.9)	88.1	20.7	(27.1)	0.0	28.9	(39.0)	85.6
Gibson 2 NE	26.5	-	0.0	41.5	-	71.1	26.8	-	0.0	42.0	-	71.7
Jardine	84.3	-	57.9	154.1	-	210.8	71.3	-	28.0	124.2	-	180.9
Joliet	24.9	-	26.4	31.6	-	40.0	25.9	-	28.3	33.5	-	41.8
Laurel 3 WSW	26.7	-	29.8	35.0	-	43.3	22.0	-	21.5	26.7	-	35.0
Livingston 12 S	21.7	-	0.0	32.8	-	62.4	24.3	-	0.0	37.4	-	67.0
Livingston Mission Field	22.4	-	0.0	33.9	-	63.6	22.6	-	0.0	34.4	-	64.0
Mystic Lake	55.0	-	0.0	89.6	-	146.3	53.1	-	0.0	85.9	-	142.5
Nye 2	39.6	-	25.9	68.6	-	98.2	34.4	-	14.7	57.4	-	87.0
Rapelje 4 S	18.4	(26.5)	0.0	26.9	(41.6)	56.5	19.5	(23.0)	0.0	28.8	(35.0)	58.4
Red Lodge 2 N	62.6	-	9.0	105.2	-	161.9	57.9	-	0.0	95.5	-	152.2
Wilsall 8 ENE	34.6	(47.4)	0.0	51.7	(74.9)	108.4	34.7	(43.3)	0.0	51.8	(67.2)	108.5

Table A.6: Snow load data for NWS stations in Region 6

Station	County	Latitude °	'	"	Longitude °	'	"	Elevation (ft)	Number of Years of Data		Max. Recorded Depth (inches)		Calculated Snow Load (psf)	
Albion 1 N	Carter	45	12	39	104	15	59	3312	17	18	16	24	19.4	(29.4)
Baker 1 E	Fallon	46	21	59	104	15	32	2940	27	-	32	-	45.7	-
Biddle	Powder River	45	5	54	105	20	17	3329	10	-	9	-	9.4	-
Biddle 8 SW	Powder River	45	2	26	105	29	10	3596	26	-	36	-	48.9	-
Birney	Rosebud	45	19	29	106	30	45	3160	11	12	20	26	31.8	(45.8)
Brandenberg	Rosebud	45	48	58	106	13	53	2770	42	43	20	22	24.7	(27.1)
Bredette	Roosevelt	48	32	51	105	16	14	2638	43	-	19	-	24.1	-
Broadus	Powder River	45	26	36	105	24	30	3032	40	-	28	-	46.6	-
Brusett 3 W	Garfield	47	27	53	107	18	41	2974	24	-	34	-	54.2	-
Busby	Big Horn	45	32	23	106	57	35	3430	44	-	27	-	36.2	-
Circle	McCone	47	24	44	105	35	42	2475	19	-	33	-	75.3	-
Circle 7 N	McCone	47	31	0	105	34	0	2431	15	-	16	-	25.8	-
Cohagen	Garfield	47	3	24	106	37	0	2727	29	-	35	-	47.2	-
Colstrip	Rosebud	45	53	40	106	38	1	3218	27	28	16	16	18.3	(19.6)
Culbertson	Roosevelt	48	9	1	104	30	33	1942	30	31	27	34	42.3	(54.6)
Custer	Yellowstone	46	8	0	107	32	0	2743	14	-	21	-	29.9	-
Dodson	Phillips	48	23	32	108	14	36	2280	14	-	21	-	35.7	-
Forks 4 NNE	Phillips	48	46	40	107	27	13	2599	50	-	37	-	57.8	-
Forsyth 2 E	Rosebud	46	16	0	106	37	0	2723	25	-	15	-	21.6	-
Glasgow #2	Valley	48	11	34	106	38	18	2090	14	-	19	-	25.0	-
Glasgow 15 NW	Valley	48	21	4	106	51	25	2118	13	-	16	-	20.9	-
Glasgow Int'l AP	Valley	48	12	50	106	37	17	2285	51	-	21	-	22.6	-
Glendive	Dawson	47	6	23	104	43	6	2076	50	51	17	27	15.6	(20.2)
Harb	Phillips	48	14	0	107	24	38	2542	17	-	18	-	27.9	-
Hardin	Big Horn	45	43	57	107	36	33	2905	13	14	15	35	14.7	(42.2)
Haxby 18 SW	Garfield	47	34	0	106	42	0	2651	28	-	28	-	39.5	-
Huntley Exp. Station	Yellowstone	45	55	22	108	14	42	3000	21	22	22	24	27.3	(33.4)
Hysham 25 SSE	Treasure	45	56	7	107	8	15	3100	32	-	27	-	41.3	-
Ingomar 14 NE	Rosebud	46	44	21	107	12	31	2795	38	-	25	-	34.8	-
Kirby 1 S	Big Horn	45	19	0	106	59	0	3953	13	-	25	-	40.1	-
Lame Deer	Rosebud	45	37	33	106	39	51	3300	20	-	24	-	32.5	-
Lindsay	Dawson	47	13	31	105	9	8	2690	35	-	22	-	20.7	-
Lustre 4 NNW	Valley	48	27	0	105	56	0	2923	41	-	25	-	32.3	-
MacKenzie	Fallon	46	8	32	104	44	7	2810	30	-	23	-	26.9	-
Malta	Phillips	48	21	0	107	52	0	2260	29	30	25	26	29.6	(35.4)
Malta 35 S	Phillips	47	50	30	107	57	20	2605	26	-	39	-	60.1	-
Medicine Lake 3 SW	Sheridan	48	28	58	104	27	5	1942	53	-	33	-	48.5	-
Mildred	Prairie	46	41	0	104	57	0	2411	39	-	22	-	22.3	-
Miles City	Custer	46	24	0	105	49	0	2362	64	-	29	-	25.6	-
Miles City Municipal AP	Custer	46	25	41	105	53	10	2628	51	-	21	-	26.8	-

Station	Log - Pearson Type III						Lognornal					
	50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)	50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)
Albion 1 N	17.5	(23.6)	14.2	19.4	(29.4)	27.7	19.8	(23.9)	17.8	23.0	(29.9)	31.4
Baker 1 E	32.0	-	40.5	45.7	-	54.0	38.5	-	55.2	60.4	-	68.7
Biddle	9.9	-	4.2	9.4	-	17.7	10.8	-	5.3	10.5	-	18.8
Biddle 8 SW	33.5	-	43.7	48.9	-	57.3	32.5	-	41.6	46.8	-	55.2
Birney	25.0	(32.1)	26.6	31.8	(45.8)	40.2	26.3	(32.2)	29.0	34.2	(46.1)	42.5
Brandenberg	20.8	(22.3)	19.5	24.7	(27.1)	33.0	23.4	(24.6)	23.7	28.9	(31.1)	37.2
Bredette	20.5	-	18.9	24.1	-	32.4	21.8	-	21.1	26.3	-	34.6
Broadus	32.5	-	41.4	46.6	-	55.0	31.9	-	40.2	45.4	-	53.8
Brusett 3 W	35.9	-	49.0	54.2	-	62.5	40.3	-	59.7	64.9	-	73.2
Busby	27.3	-	31.0	36.2	-	44.5	28.7	-	33.7	38.9	-	47.2
Circle	44.4	-	70.1	75.3	-	83.6	41.5	-	62.6	67.8	-	76.2
Circle 7 N	21.5	-	20.6	25.8	-	34.1	23.6	-	24.1	29.3	-	37.6
Cohagen	32.7	-	42.0	47.2	-	55.5	28.1	-	32.5	37.7	-	46.0
Colstrip	16.7	(17.6)	13.1	18.3	(19.6)	26.6	16.8	(17.7)	13.2	18.4	(19.7)	26.8
Culbertson	30.4	(36.1)	37.1	42.3	(54.6)	50.6	27.8	(31.7)	31.9	37.1	(45.0)	45.4
Custer	23.9	-	24.7	29.9	-	38.2	21.9	-	21.3	26.5	-	34.8
Dodson	27.1	-	30.5	35.7	-	44.0	22.7	-	22.6	27.8	-	36.1
Forks 4 NNE	37.4	-	52.6	57.8	-	66.2	38.0	-	54.0	59.2	-	67.5
Forsyth 2 E	18.9	-	16.4	21.6	-	29.9	20.0	-	18.1	23.3	-	31.6
Glasgow #2	21.0	-	19.8	25.0	-	33.3	20.8	-	19.4	24.6	-	32.9
Glasgow 15 NW	18.5	-	15.7	20.9	-	29.2	18.5	-	15.8	21.0	-	29.3
Glasgow Int'l AP	19.5	-	17.4	22.6	-	30.9	27.6	-	31.5	36.7	-	45.0
Glendive	14.8	(18.0)	10.4	15.6	(20.2)	23.9	17.9	(19.6)	14.8	20.0	(22.7)	28.3
Harb	22.8	-	22.7	27.9	-	36.2	26.2	-	28.8	34.0	-	42.3
Hardin	14.2	(30.4)	9.5	14.7	(42.2)	23.0	22.0	(31.7)	21.4	26.6	(45.0)	34.9
Haxby 18 SW	29.0	-	34.3	39.5	-	47.8	28.9	-	34.0	39.2	-	47.5
Huntley Exp. Station	22.4	(25.8)	22.1	27.3	(33.4)	35.6	23.2	(25.9)	23.5	28.7	(33.4)	37.0
Hysham 25 SSE	29.9	-	36.1	41.3	-	49.6	31.0	-	38.4	43.6	-	51.9
Ingomar 14 NE	26.6	-	29.6	34.8	-	43.1	25.8	-	28.2	33.4	-	41.7
Kirby 1 S	29.3	-	34.9	40.1	-	48.5	28.1	-	32.4	37.6	-	45.9
Lame Deer	25.4	-	27.3	32.5	-	40.8	28.2	-	32.7	37.9	-	46.2
Lindsay	18.3	-	15.5	20.7	-	29.0	28.0	-	32.3	37.5	-	45.8
Lustre 4 NNW	25.2	-	27.1	32.3	-	40.6	28.0	-	32.2	37.4	-	45.8
MacKenzie	22.2	-	21.7	26.9	-	35.2	29.6	-	35.6	40.8	-	49.1
Malta	23.7	(26.9)	24.4	29.6	(35.4)	37.9	24.1	(26.4)	25.0	30.2	(34.5)	38.5
Malta 35 S	38.4	-	54.9	60.1	-	68.4	38.7	-	55.8	61.0	-	69.3
Medicine Lake 3 SW	33.3	-	43.3	48.5	-	56.8	31.6	-	39.7	44.9	-	53.2
Mildred	19.4	-	17.1	22.3	-	30.6	19.7	-	17.6	22.8	-	31.1
Miles City	21.4	-	20.4	25.6	-	34.0	22.3	-	21.9	27.1	-	35.4
Miles City Municipal AP	22.1	-	21.6	26.8	-	35.1	25.5	-	27.6	32.8	-	41.2

Station	County	Latitude °	'	"	Longitude °	'	"	Elevation (ft)	Number of Years of Data		Max. Recorded Depth (inches)		Calculated Snow Load (psf)	
Mizpah 4 NNW	Custer	46	17	8	105	17	35	2480	42	-	27	-	30.4	-
Moorhead 9 NE	Powder River	45	10	30	105	45	8	3220	18	19	18	24	22.6	(30.6)
Mosby 18 N	Garfield	47	15	0	107	57	0	2323	23	-	26	-	43.2	-
Mosby 4 ENE	Garfield	47	1	18	107	49	21	2910	23	-	27	-	42.1	-
Nohly 4 NW	Richland	48	2	0	104	8	0	1903	20	-	20	-	29.1	-
Opheim 12 SSE	Valley	48	41	44	106	18	55	2936	45	-	24	-	33.1	-
Otter 9 SSW	Powder River	45	6	0	106	15	0	4060	11	-	25	-	55.0	-
Plevna	Fallon	46	25	2	104	31	0	2780	33	34	24	32	34.9	(43.1)
Poplar 2 E	Roosevelt	48	8	0	105	9	0	2000	22	-	23	-	28.4	-
Powderville 8 NNE	Custer	45	51	6	105	2	2	2800	15	16	18	21	24.1	(30.9)
Pryor 3 E	Big Horn	45	24	59	108	32	16	4129	18	-	36	-	58.9	-
Raymond Border Station	Sheridan	48	59	41	104	34	31	2384	10	-	23	-	37.8	-
Redstone	Sheridan	48	49	11	104	56	34	2106	23	-	38	-	74.4	-
Richey	Dawson	47	38	0	105	4	0	2503	17	-	18	-	23.7	-
Saco Nelson Reservoir	Phillips	48	30	0	107	31	0	2231	10	-	21	-	41.9	-
Savage	Richland	47	27	13	104	20	16	1975	46	-	19	-	20.7	-
Sidney	Richland	47	43	42	104	8	48	1931	46	-	25	-	27.1	-
St. Marie	Valley	48	24	32	106	30	52	2756	10	-	16	-	26.0	-
Vida 6 NE	McCone	47	52	48	105	22	7	2284	18	-	26	-	29.0	-
Volborg	Custer	45	50	37	105	40	51	2980	12	-	28	-	56.0	-
Westby	Sheridan	48	52	15	104	3	0	2120	25	-	42	-	76.9	-
Whitewater	Phillips	48	45	35	107	37	30	2333	29	-	42	-	55.2	-
Wibaux 2 E	Wibaux	46	59	16	104	9	24	2696	14	-	17	-	26.0	-
Wyola 1 SW	Big Horn	45	7	18	107	24	22	3730	26	-	40	-	54.2	-

	Log - Pearson Type III						Lognornal					
Station	50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)	50 Year (MRI) Depth (inches)		Low Extreme Snow Load (psf)	Calculated Snow Load (psf)		High Extreme Snow Load (psf)
Mizpah 4 NNW	24.2	-	25.2	30.4	-	38.7	28.4	-	33.0	38.2	-	46.6
Moorhead 9 NE	19.6	(24.3)	17.4	22.6	(30.6)	31.0	24.4	(28.2)	25.6	30.8	(38.0)	39.1
Mosby 18 N	30.8	-	38.0	43.2	-	51.5	26.6	-	29.7	34.9	-	43.2
Mosby 4 ENE	30.3	-	36.9	42.1	-	50.4	25.8	-	28.1	33.3	-	41.7
Nohly 4 NW	23.5	-	23.9	29.1	-	37.4	22.3	-	22.0	27.2	-	35.5
Opheim 12 SSE	25.7	-	27.9	33.1	-	41.4	24.5	-	25.7	30.9	-	39.2
Otter 9 SSW	33.3	-	12.4	55.0	-	84.7	37.0	-	20.3	62.9	-	92.5
Plevna	26.6	(30.8)	29.7	34.9	(43.1)	43.2	27.3	(30.1)	30.9	36.1	(41.7)	44.4
Poplar 2 E	23.1	-	23.2	28.4	-	36.8	22.2	-	21.7	26.9	-	35.2
Powderville 8 NNE	20.5	(24.5)	18.9	24.1	(30.9)	32.4	23.0	(26.5)	23.0	28.2	(34.7)	36.6
Pryor 3 E	35.2	-	16.2	58.9	-	88.5	30.9	-	7.5	50.1	-	79.8
Raymond Border Station	28.1	-	32.6	37.8	-	46.1	35.6	-	48.5	53.7	-	62.0
Redstone	44.0	-	69.2	74.4	-	82.7	46.9	-	77.0	82.2	-	90.5
Richey	20.3	-	18.5	23.7	-	32.0	26.3	-	29.0	34.2	-	42.5
Saco Nelson Reservoir	30.2	-	36.7	41.9	-	50.2	39.1	-	56.7	61.9	-	70.2
Savage	18.4	-	15.5	20.7	-	29.0	20.3	-	18.6	23.8	-	32.1
Sidney	22.3	-	21.9	27.1	-	35.4	27.5	-	31.3	36.5	-	44.9
St. Marie	21.7	-	20.8	26.0	-	34.3	20.1	-	18.3	23.5	-	31.8
Vida 6 NE	23.4	-	23.8	29.0	-	37.3	50.0	-	85.9	91.1	-	99.4
Volborg	36.7	-	50.8	56.0	-	64.4	32.7	-	41.9	47.1	-	55.4
Westby	45.0	-	71.7	76.9	-	85.2	53.9	-	97.5	102.7	-	111.0
Whitewater	36.3	-	50.0	55.2	-	63.5	40.7	-	60.6	65.8	-	74.1
Wibaux 2 E	21.7	-	20.8	26.0	-	34.3	19.1	-	16.7	21.9	-	30.2
Wyola 1 SW	35.9	-	49.0	54.2	-	62.5	30.7	-	37.7	42.9	-	51.2

Table A.7: Snow load data for SNOTEL stations in Montana

Station	County	Latitude °	Latitude '	Latitude "	Longitude °	Longitude '	Longitude "	Elevation (ft)	Number of Years of Data	Max. Recorded Snow Load (psf)	50-year (MRI) Snow Load (psf) LP III	50-year (MRI) Snow Load (psf) LN
Badger Pass	Flathead	48	7	51	113	1	26	6900	23	303.2	321.3	307.0
Banfield Mountain	Lincoln	48	34	13	115	26	34	5600	33	186.7	204.0	202.0
Barker Lakes	Deer Lodge	46	5	50	113	7	50	8250	22	137.8	140.0	144.7
Basin Creek	Silver Bow	45	47	52	112	31	15	7180	21	84.2	92.4	90.6
Beagle Springs	Beaverhead	44	28	21	112	58	59	8850	23	87.4	100.9	99.2
Beaver Creek	Madison	44	57	0.6	111	21	27	7850	35	162.8	173.2	182.0
Bisson Creek	Lake	47	40	56	113	59	49	4920	12	103.0	110.7	95.4
Black Bear	Madison	44	30	29	111	7	43	8170	30	384.3	369.5	402.5
Black Pine	Granite	46	24	52	113	25	49	7210	36	129.0	133.7	128.4
Bloody Dick	Beaverhead	45	9	50	113	30	4.8	7600	25	104.5	111.9	110.1
Boulder Mountain	Meagher	46	33	31	111	17	19	7950	23	165.9	164.8	170.3
Box Canyon	Park	45	16	20	110	14	57	6670	23	93.6	96.5	93.7
Calvert Creek	Flathead	45	53	1.8	113	19	32	6430	26	88.4	84.8	80.2
Carrot Basin	Gallatin	44	57	43	111	17	37	9000	35	244.4	255.9	288.4
Clover Meadow	Madison	45	1	6.6	111	50	44	8600	23	152.9	167.4	161.8
Cole Creek	Carbon	45	11	43	109	21	3	7850	27	166.4	187.1	188.6
Combination	Granite	46	27	58	113	23	36	5600	29	54.6	58.2	56.8
Copper Bottom	Lewis & Clark	47	3	26	112	35	41	5200	26	105.6	104.2	100.6
Copper Camp	Lewis & Clark	47	4	56	112	43	47	6950	26	251.7	287.6	288.3
Crystal Lake	Fergus	46	47	25	109	30	44	6050	23	108.7	109.7	111.6
Daisy Peak	Meagher	46	40	9.6	110	19	50	7600	11	87.9	104.9	99.2
Daly Creek	Ravilli	46	11	59	113	51	12	5780	21	102.4	110.2	97.0
Darkhorse Lake	Beaverhead	45	10	28	113	35	6	8600	21	262.6	288.2	287.0
Deadman Creek	Meagher	46	47	35	110	40	33	6450	34	90.0	92.0	97.0
Divide	Madison	44	47	35	112	3	24	7800	26	107.1	111.1	111.2
Dupuyer Creek	Teton	48	3	45	112	45	31	5750	18	123.2	120.8	123.8
Emery Creek	Flathead	48	26	3	113	56	13	4350	25	133.6	124.4	114.8
Fisher Creek	Park	45	3	31	109	57	0.6	9100	35	313.0	342.0	344.0
Frohner Meadow	Jefferson	46	26	8.4	112	11	34	6480	29	105.6	89.9	77.6
Garver Creek	Lincoln	48	58	33	115	49	9	4250	33	96.7	90.6	93.9
Grave Creek	Lincoln	48	54	51	114	45	59	4300	26	134.7	127.8	125.2
Hand Creek	Flathead	48	18	28	114	50	25	5035	25	111.3	111.3	105.0
Hawkins Lake	Lincoln	48	58	20	115	57	14	6450	33	280.8	291.9	289.5
Hoodoo Basin	Mineral	46	58	31	115	2	2.4	6050	35	458.1	443.0	447.4
Kraft Creek	Missoula	47	25	39	113	46	31	4750	21	157.6	150.4	136.4
Lakeview Ridge	Beaverhead	44	35	20	111	49	25	7400	23	124.8	115.3	116.3
Lemhi Ridge	Beaverhead	44	59	29	113	26	43	8100	26	106.6	115.5	111.4
Lick Creek	Gallatin	45	30	16	110	57	58	6860	38	150.8	155.4	147.8
Lone Mountain	Madison	45	16	31	111	25	41	8880	13	168.5	200.5	195.6
Lower Twin	Madison	45	30	17	111	55	19	7900	21	159.6	176.3	174.3

Station	County	Latitude °	'	"	Longitude °	'	"	Elevation (ft)	Number of Years of Data	Max. Recorded Snow Load (psf)	50-year (MRI) Snow Load LP III (psf)	LN
Lubrecht Flume	Missoula	46	52	56	113	19	22	4680	31	65.0	54.5	70.2
Madison Plateau	Gallatin	44	35	13	111	6	58	7750	34	231.4	230.9	245.2
Many Glacier	Flathead	48	47	49	113	40	17	4900	25	139.4	143.3	137.2
Monument Peak	Park	45	13	3	110	14	33	8850	21	189.3	193.5	192.8
Moss Peak	Lake	47	41	3.6	113	57	40	6780	16	378.6	380.1	349.9
Mount Lockhart	Teton	47	55	0.6	112	49	22	6400	33	208.5	209.9	205.2
Mule Creek	Beaverhead	45	24	27	112	57	34	8300	21	138.8	141.4	141.1
North Fork Elk Creek	Powell	46	52	21	113	16	35	6250	34	131.6	135.1	121.8
Nez Perce Camp	Ravalli	45	43	52	114	28	48	5650	25	122.7	128.1	119.0
Noisy Basin	Flathead	48	9	25	113	56	46	6040	27	383.8	348.7	347.4
North Fork Jocko	Missoula	47	16	16	113	45	23	6330	12	368.7	410.7	378.2
Northeast Entrance	Park	45	0	23	110	0	50	7350	35	94.6	104.7	110.9
Peterson Meadows	Granite	46	8	-	113	18	-	7200	31	119.6	118.4	112.2
Pickfoot Creek	Meagher	46	34	49	111	16	6.6	6650	23	116.5	128.2	117.8
Pike Creek	Pondera	48	18	11	113	19	41	5930	25	250.6	265.0	250.6
Placer Basin	Sweetgrass	45	25	7.8	110	5	19	8830	21	152.4	157.5	165.6
Poorman Creek	Lincoln	48	7	31	115	37	25	5100	22	299.5	339.6	334.5
Porcupine	Park	46	6	41	110	28	8.4	6500	25	74.4	69.8	75.8
Rocker Peak	Jefferson	46	21	26	112	15	44	8000	34	152.9	147.5	151.9
Rocky Boy	Hill	48	10	27	109	38	50	4700	34	59.8	61.7	62.8
S Fork Shields	Park	46	5	26	110	26	4.2	8100	23	188.8	173.0	185.3
Saddle Mountain	Beaverhead	45	41	35	113	58	6	7940	34	234.0	254.7	262.4
Short Creek	Madison	44	58	33	111	57	9	7000	13	45.2	48.6	46.3
Shower Falls	Gallatin	45	24	4.2	110	57	28	8100	36	221.5	234.7	242.1
Skalkaho Summit	Granite	46	14	34	113	46	21	7250	25	223.6	217.6	224.9
Sleeping Woman	Missoula	47	10	43	114	20	5.4	6150	12	159.1	172.0	144.1
Spur Park	Judith Basin	46	44	47	110	37	20	8100	35	191.9	198.4	211.6
Stahl Peak	Lincoln	48	54	32	114	51	47	6030	26	311.0	313.1	324.2
Teepee Creek	Madison	44	47	7.2	111	42	38	8000	30	126.4	126.8	142.7
Tizer Basin	Jefferson	46	20	57	111	51	11	6880	13	77.5	81.9	79.9
Twelvemile Creek	Ravalli	46	8	35	114	26	51	5600	34	170.6	189.6	187.2
Twin Lakes	Ravalli	46	8	38	114	30	20	6510	34	364.0	370.1	361.3
Waldron	Teton	47	55	13	112	47	26	5600	33	100.4	109.2	109.2
Warm Springs	Granite	46	16	28	113	9	53	7800	24	194.5	202.1	195.3
West Yellowstone	Gallatin	44	39	29	111	5	26	6700	35	83.7	88.8	99.9
Whiskey Creek	Gallatin	44	36	39	111	9	0	6800	30	144.6	152.6	166.4
White Mill	Park	45	2	42	109	54	37	8700	28	224.1	230.7	238.2
Wood Creek	Lewis & Clark	47	26	58	112	48	47	5960	23	86.3	94.4	94.6

A.2 National Weather Service (NWS) Stations

National Weather Service stations are part of the network of National Weather Service Cooperative Stations. A station in this network, designated by a COOP ID number, can be a single site or a series of sites. If a station's records are a combination of a series of sites, the sites must be within 2 miles horizontally and 100 feet vertically of each other. Exceptions to this rule are made if climatic compatibility is determined by the NWS field manager. Snow depth, not the snow-water equivalent of snow, is measured at these locations. Thus, to determine snow loads from this data, the snow depth is multiplied by a unit weight to obtain a load. The snow depth used in this calculation is that snow depth which has an acceptably small probability of being exceeded during the life of the structure. Typically, the snow depth with a mean recurrence interval of 50 years is used for this purpose. This depth is determined by statistically analyzing the snow depth data in the NWS records. The snow depth analyses done in this study are described in detail below. Development of the depth/density relationships used to convert snow depth to snow loads is described in Appendix B.

A.2.1 Data Retrieval

The determination of the ground snow load for the NWS Stations began with the retrieval of measured snow depths at various locations around Montana. While over 800 stations are listed in Montana by the National Climatic Data Center (NCDC),[1] it was determined that not all 800 stations would be able to be used. Several stations were repeated in the list as a result of a slight change in the the station's location, while others did not contain sufficient years of record for a statistical analysis of the data to be performed. A minimum of 10 years of data were required for a station to be included in these analyses.

Data eventually was downloaded for over 350 stations and saved in a text file (.txt format). The data was listed in the file from the beginning to the end of the period of record, with a snow-depth value for each day. Note that not all of the daily values were meaningful, in that snow depth measurements were not necessarily made on every day over the period of record. If a snow depth measurement was not taken on a particular day, a "-9999" was listed in that day's spot.

A.2.2 Preprocessing the Data

To calculate the 50-year MRI ground snow depth at each station, it was first necessary to determine the maximum ground snow depth measured each year at each site from the daily snow depth data described above. The goal of this effort was to obtain a list of maximum annual ground snow depths at each station, which could then be statistically analyzed to generate the 50-year MRI ground snow depth. While this task appears simple, some questions had to be answered before it could be accomplished, namely:

1) Should maximum snow depths be determined for each calendar year (January through December) or each snow year (e.g. October through May)?

2) Which months should be considered as constituting the snow season?

3) How many missing measurements can occur in any given year before the probability is unacceptable that the maximum snow depth occurred on a day with no measurement (and thus the year should be removed from further consideration)?

[1] The National Climatic Data Center, located in Asheville, North Carolina, is the 'World's Largest Archive of Weather Data.' The data for each NWS station is stored by this entity.

For reference, the earlier snow load guide from Videon and Schilke was based on a 243-day snow season (January through May and October through December), with the data sorted based on the calendar year (months all in the same year), with 10 days of data allowed to be missing in any individual year. Note that the authors of that publication did not have a choice with respect to the calendar year versus snow year issue. The data was given to them in a form that had already incorporated that aspect of the sorting process into it.

With regard to answering the above questions, the calendar year versus snow year issue was resolved first. Typically, when hydrologic analyses are done, the water year is used. The water year is a 12-month period, extending from October 1 of one year to September 30 of the next year, created to bound the seasonal rise and fall of the typical streamflow exhibited as a result of snowmelt. This concept was extended to this snow study. A snow year was created that extended from a period of no snow in one year to a period of no snow in the next year. At this point, the snow year was considered to be from July 1 of one year to June 30 of the following year.

A study was then done using 10 NWS stations, in which the usable years of record and the log-Pearson type III, 50-year MRI ground snow depth values were compared when the data was organized in calendar years versus snow years. This comparison revealed that the choice of year had little effect on the number of usable years of record or the calculated 50-year MRI ground snow depth. However, in some instances, the maximum snow depth in one winter season would mask the maximum snow depth of the previous or next winter season when the calendar year sorting routine was used. Therefore, as it seemed reasonable to use seasonal maximum snow depths, the decision was made to use the snow year in processing the data.

Next, it was decided which months should be included in the snow year. Notably, in answering the final question regarding how many days should be allowed to be missing in each year, it seemed unreasonable to consider the summer months as part of the year to be analyzed. Typically, there is no snow on the ground during the summer in most locations in Montana (which is entirely true for the lower elevations where most, if not all, NWS stations are located); therefore, if some days were missing measurements during these months, it was assumed that the maximum snow depth for the year would not have been missed. Thus, the summer months (June through September) were not included in the snow year. The resulting snow season of October through May matched the same months that were used by Videon and Schilke in their earlier study on Montana snow loads.

The effect of the selected snow season on the study results was evaluated by observing the changes in the number of years of useable record and the magnitude of the 50-year MRI ground snow depths when snow seasons of different durations were used in the analyses. This evaluation was specifically performed for a sample of 20 different NWS stations using three different durations of snow season: October through May, November through May, and October through April. The number of usable years of record did not increase in 12 out of the 20 stations as the length of the snow year was varied. For 7 out of the 20 stations, the November through May snow year had 1 more year of record available, and in 4 out of the 20 stations, the October through April snow year had 1 more year of record available. The log-Pearson type III 50-year (MRI) snow depth that resulted from the different durations of snow season never varied more than 1 or 2 inches for each station, and in most cases the 50-year snow depth estimate stayed the same. The same held true for the lognormal 50-year (MRI) snow depth. Based on the various observations made above, it was concluded that the duration of the snow season did not have a large effect on the 50-year (MRI) snow depth values as long as the core winter months (November through April) were included in the snow season.

Therefore, a snow season consisting of October through May (total of 243 days) was selected for the sorting process.

Finally, the question regarding the number of missing measurements that would be allowed per year was addressed. The same 20 NWS stations that were used above in evaluating the duration of the snow season were used to study the effect of missing daily data on the resulting years of useable records and the calculated 50-year MRI ground snow depth. In analyzing the data from these stations, the number of missing measurements allowed per year was varied between 10, 15, 20, and 30. As expected, the number of usable years of record increased as the number of missing measurements allowed per year increased. In one case, 14 more years of record were available when 30 measurements were allowed per year to be missing rather than only 10. However, even though more years of record were available, the 50-year (MRI) values (both log-Pearson type III and lognormal) hardly changed in some cases. In that one instance where 14 more years of record were available, the log-Pearson type III 50-year (MRI) value changed 0.4 inches, and the lognormal value changed 0.6 inches. Not all stations, however, behaved in this manner. In one case, the 50-year (MRI) snow depth values changed by 10 inches as the number of missing measurements allowed per year was cycled from 10 to 30. One trend, however, was observed in almost all cases. The 50-year (MRI) snow depth values were almost identical when 20 missing measurements were allowed per year as compared to 30. This fact, coupled with the qualitative judgment that allowing 30 missing measurements per year was too many, resulted in selecting 20 missing measurements per year as the criteria to exclude any given year from further consideration.

In the interest of keeping as many years as possible in the final data sets, consideration was given to individually examining the data for each year that was excluded under the 20 missing measurements criteria. The conclusion was reached that such a review would require an extraordinary amount of time (up to 20,000 annual records might have to be reviewed), and the results would be dependent on subjective judgments of the reviewer. Therefore, the decision was made to simply and impartially apply the quantitative 20 missing measurement criteria.

All of the data was subsequently processed to obtain maximum annual snow depth values for each snow year using a snow season from October of one year through May of the following year. If more than 20 measurements were missing out of 243 possible measurements occurred in any given year, that year was removed from consideration. A list of years with their annual maximums was obtained for each station following this process. If this process resulted in less than 10 values of maximum annual snow depth for a station, that station was removed from further consideration. The log-Pearson type III analysis can only be applied to data sets with 10 or more values. If the overall maximum snow depth measured across the entire record for a given station was not included in the data set and it was determined to be valid, a second data set was created that included this overall maximum value. In all, 214 NWS stations in Montana had snow depth data that could be further analyzed.

A.2.3 Problems With the Data

As the preprocessing methodology was being developed, and different trials were run, it was noticed that occasionally the maximum snow depth that the station had ever experienced (in its entire history) was not included in the usable years of record because it occurred in a year with too many missing measurements. It was thought, however, that the overall maximum depth would be very important, regardless if the rest of the year in which it occurred met the sorting criteria. Adding another year of record, with that year having the maximum snow depth that the station had ever experienced, would almost certainly increase the 50-year MRI snow load for the station. Therefore, these values were initially included in the analysis, if the validity of the snow depth could in some manner be substantiated.

As the final snow load values were being calculated, it was observed that several stations had 50-year MRI snow loads that were considerably higher than those previously published by Videon and Schilke. The reason for the increase in snow loads was traced back to the inclusion of the overall maximum snow depths when they occurred in years that did not meet the original sorting criteria. Therefore, the decision was made to give the user of the manual the option of using a snow load that either included or excluded this value from consideration. Two values have been provided for the following columns in the tables: Number of Years of Data, Max. Recorded Depth, Calculated Snow Load, 50-Year (MRI) Depth, LP III Calculated Snow Load, and LN Calculated Snow Load. Note that not all stations have 2 values in these columns. If the stations overall maximum value could not be verified or was already included in the data set, a - was listed in the columns. The primary snow load reported in the tables was determined by excluding the absolute maximum snow depth measured at a site, if it occurred in a year with more than 20 missing measurements. The secondary value reflects the results obtained when this value was included. Note that in the majority of cases, the maximum snow depth was measured in a year automatically included in the analysis, so the primary value was determined with the absolute maximum snow depth ever reported at the site as part of the analysis.

As the final snow load calculations were being performed, another problem was discovered related to the 50-year MRI snow depths used in the analysis. The snow load values determined at three stations were enormously high. For example, the Helena Airport station ground snow load was calculated to be over 500 psf. The previously published, and generally accepted, ground snow load at the Helena Airport is around 30 psf. The high snow load was again traced back to the ground snow loads determined by processing the NWS data. In these cases, closer inspection of the data was performed. On record at Montana State University's Library are Climatological Records from 1898 to the present that list the data that was being used in this analysis. Using these records, the data from each of the stations that had extraordinarily high snow load values were examined in detail. In each case, it was discovered that some of the data included in the analysis was obviously in error. Reasonable snow loads resulted when these records were removed from consideration.

A.2.4 Determining the 50-year (MRI) Ground Snow Depth

The 50-year Mean Recurrence Interval (MRI) snow depth is the snow depth at a given location that has a 2% chance of being exceeded in any given year. Note that over a 50-year period, the location has a 64 percent probability of experiencing at least the 50-year MRI snow depth. By convention, the 50-year MRI snow depth is used for building design. ASCE 7-02, as well as the IBC 2003, requires any case study that is done regarding snow loads in areas with unpublished values to use the 50-year MRI snow load. The 50-year MRI snow load is proportional to the 50-year MRI snow depth, which can be determined from the NWS station data using statistical analysis.

In order to determine the 50-year MRI ground snow depths, a probability distribution function had to be selected that accurately described the probability of occurrence of all possible snow depths at a given location. Once a distribution was selected, the computation of the 50-year MRI ground snow depth was simple. Probability distributions that have been used in the past for snow load data are the Frechet (type II), log-Pearson type III, Gumbel (type I), and lognormal distribution (Sack, 1989). The two distributions of interest in this analysis were the lognormal and the log-Pearson type III distributions. The lognormal and the log-Pearson type III distributions are similar in nature, both having longer upper tails than the other distributions mentioned above. The fact that the upper tails are longer indicates they will be more conservative in the prediction of the 50-year MRI value relative to the other distributions (Ellingwood & Redfield, 1984). The lognormal and the log-Pearson type III distributions offer different advantages in this application, and to choose one distribution over the other was a difficult task.

Studies have shown that for weather stations in the northeastern part of the United States, the lognormal distribution provides the best fit to the data according to the maximum probability plot correlation coefficient (MPPCC) (Ellingwood & Redfield, 1984). Other studies using other goodness-of-fit tests came to the same conclusion. Additionally, most national codes, such as ASCE 7-02 and the IBC 2003, present ground snow load maps that were developed using the lognormal distribution. The decision to develop these maps based on the lognormal distribution most likely resulted from the same studies that found the lognormal distribution to work the best.

The log-Pearson type III distribution is commonly used to predict the 50-year MRI ground snow load in the northwestern United States, in states such as Washington, Idaho, and Montana. The authors of the previous Montana snow load publication selected the log-Pearson type III distribution to determine their values. This distribution includes a parameter that allows for the distribution to curve a little more than the lognormal distribution, which aids in the fit of the line for data sets that have a few high values with mostly moderate and low values. This feature of the log-Pearson type III distribution was also noted by Ellingwood and Redfield during one of their studies (1984).

While goodness-of-fit of tests could have been run to determine which probability distribution provided the best fit to the snow depth data from Montana's NWS Stations, such tests were not performed. The criteria used in various goodness-of-fit tests are different, which can result in different tests selecting different distributions. Furthermore, the reliability with which a particular test selects the best distribution is questionable. Ellingwood and Redfield (1984), for example, did a study of the MPPCC fit criteria using 100 data sets, each with 28 points, that were generated from a lognormal parent population using Monte Carlo techniques. The data was fit with a lognormal distribution and a Type I distribution, and the MPPCC criterion was used to test goodness of fit. In 25 sets out the 100, the MPPCC criterion returned the Type I as the distribution that provided the best fit. The experiment was retried using a Type I parent population, and the MPPCC criterion returned that the lognormal distribution provided the best fit for 29 out of the 100 generated data sets.

Due to the somewhat enhanced capability of the log-Pearson type III (relative to the lognormal distribution) to fit a curve to the data, as well as the fact that it is the distribution commonly used in the Northwest, the authors adopted the log-Pearson type III probability distribution function as the one to determine the 50-year (MRI) ground snow load for the stations in Montana. These values are presented in the main body of this report. However, in light of the significant use of the lognormal distribution in other snow load publications, both distributions were used to calculate the 50-year (MRI) snow depth. Both snow depth values have been provided in the table, to allow the user to compare values if he/she should so choose, and select whichever one they feel is appropriate.

A.2.5 Determining the 50-year MRI Ground Snow Load

Once the 50-year MRI ground snow depth value was determined from both probability distributions, this snow depth was converted to an equivalent depth of water using a depth/density relationship. As explained in Appendix B, equations were developed which related snow depth to snow-water equivalent for six different regions of Montana for four different elevation ranges. From these equations, similar equations were developed that converted snow depth into snow load. With these equations, the 50-year MRI ground snow depths that were determined for each station were converted into the 50-year MRI ground snow loads.

For each probability distribution (lognormal or log-Pearson type III), there are three different snow load values shown in the table for each station. These values are the Low Extreme Snow Load, the Calculated Snow Load, and the High Extreme Snow Load. The Low Extreme Snow Load and the High Extreme Snow Load values were determined using adjusted snow depth/snow-water equivalent equations that bound the best-fit regression equation calculated for that specific region and elevation. Some scatter existed in the snow depth/snow-water equivalent data; therefore, lines parallel to the best-fit regression equation were calculated to go through the high and low outliers of the data. It is with these equations that the 50-year MRI ground snow depths were converted into the Low and High Extreme Snow Loads.

A.3 SNOTEL Stations

The Snowpack Telemetry (SNOTEL) stations are operated by the Natural Resources Conservation Service (NRCS), which was formerly the Soil Conservation Service. These stations evolved from a Congressional mandate during the mid-1930s to measure snowpack in the mountains of the West and forecast the water supply. The stations are at high-elevation locations in the Western United States. These stations directly measure the snow-water equivalent of snow. Thus, the determination of 50-year MRI snow loads from this data is simplified somewhat relative to the procedure used for the NWS stations, where only snow depth data was available. Notably, the raw data can be processed to obtain annual maximum snow-water equivalents at each station, which can subsequently be statistically analyzed to obtain the 50-year MRI snow-water equivalent. These depths can then be directly converted to a snow load using the unit weight of water.

A.3.1 Data Retrieval

Determination of the 50-year MRI ground snow load at all SNOTEL stations in Montana began with retrieving the historical data and station information from the Montana NRCS website. For each station location, the daily snow-water equivalent measurements over the period of record were printed out into a hardcopy format. These records were compiled and saved for determination of the annual maximum snow-water equivalent.

A.3.2 Preprocessing the Data

The snow-water equivalent for each station was presented in a water year format, listing the data from October 1 of one year to September 30 of the following year. This format was consistent with the format selected for sorting the NWS data. The annual maximum water equivalent depth was determined for each year for each station by hand, and a list of usable years of record was created for each station. The same number of missing measurements that was allowed during the NWS sorting procedure (20) was used as the criteria for determining whether or not the year was usable. This requirement was rarely invoked since the NRCS has automated the snow-water equivalent measurement system and not many measurements are missed.

A.4 Determining the 50-year MRI Ground Snow Load

Snow-water equivalent is directly convertible into snow load (multiply by a factor of $5.2\frac{lb}{ft^2in}$). Therefore, the 50-year MRI ground snow-water equivalent was determined first, and then multiplied by $5.2\frac{lb}{ft^2in}$ to get the 50-year ground snow load for each SNOTEL station. As previously explained in the NWS section, the log-Pearson type III and lognormal probability distribution functions were used to determine the 50-year water equivalent depth of each station. The log-Pearson type III values were selected as the ones to determine the 50-year MRI ground snow load for the SNOTEL stations in Montana, although both values have been provided in the table. The NWS section on this topic explains how this decision was made.

Appendix B

Snow Depth - Snow Water Equivalent Relationships For National Weather Service Stations

B.1 NRCS Snow Course Data

The Natural Resources Conservation Service (NRCS) has 267 Snow Course stations primarily located in the Western half of the state. At these locations, snow depth and the corresponding snow-water equivalent are measured. Using this data, relationships between snow depth and snow-water equivalent may be created that will allow the transformation of snow depth into snow load. Development of such relationships was essential if the information from the NWS stations was to be used in the development of snow loads, as this data consists only of snow depths.

The NRCS used to take measurements at their stations once a month, typically from January to June. Occasionally, they took readings as early as November, and for a while, they would take measurements more than twice a month. During the early to mid 1990s, the number of measurements taken per year at some stations was reduced to three per year (typically February, March, and April) since by that time the SNOTEL network was providing real-time, automated monitoring. In the late 1990s, some stations only had one measurement taken per year.

The data set of matched snow and snow-water equivalents from the snow course sites was downloaded from the Montana NRCS website and the data was used without modification. Some data points only had a snow depth reported, in which case the data point was neglected.

B.2 Creation of Snow Depth to Snow-Water Equivalent Relationships

In their 1989 study, Videon and Schilke developed snow depth/snow-water equivalent relationships from the snow course station data for different regions and elevation zones across the state. This same approach was used in this update with the same geographical divisions and elevation categories used by Videon and Schilke (1989). These geographical divisions were established to separate areas that have significantly different snow loads for a given elevation. The division of the state into six regions is shown in Figure A1 in Appendix A. The elevation divisions are: $< 4000ft, 4000 - 5000ft, 5000 - 6000ft, and > 6000ft$. Snow Course data was available in 13 out of 24 possible combinations of geographic region and elevation category. In general, each of the regional/elevation divisions had almost twice as many data points to use for the creation of the snow depth/snow-water equivalent relationship than were used in the previous snow load study. Note that in this analysis, no snow course station data could be located for Region II below 4000 ft, whereas the last publication had 48 data points available.

The next step in the process of developing the snow depth to snow-water equivalent relationships was to determine what measure would specifically be used from the yearly data to develop this relationship. Surprisingly, the data available to relate these parameters can be sorted in a variety of ways when creating these relationships. Since the snow depth data that is being converted into snow load is similar to a maximum snow load, a snow depth/snow-water equivalent relationship that relates these two parameters for a maximum snow load case is desired.

Measures considered for representing the relationship between snow depth and snow-water equivalent included:

> *Maximum Density*: The reading (snow depth and corresponding snow-water equivalent) that had the heaviest snow density was taken for that year's measurement.
>
> *Maximum SWE*[1]: The reading that had the largest snow-water equivalent (ie, largest snow load) along with the corresponding snow depth was used for that year's measurement.
>
> *Data sorted by month*: All of January's readings lumped together, all of February's readings lumped together, etc.
>
> *Maximum SWE/Max Snow Depth*: The maximum snow-water equivalent for the year was paired with the maximum snow depth for the year, regardless of whether or not they occurred at the same time (in this case, whether or not they occurred in the same month).

There are inherent benefits of each of these methods of representing the data. The maximum density method gives a relationship for the heaviest snow for each year. The maximum SWE method gives a relationship for the type of snow that existed when the station experienced its heaviest load. Sorting the data by month is an attempt to account for the affect that temperature has on snow density. Matching maximum SWE and maximum snow depth values for each year does not have any apparent physical meaning. Measurements that aren't even taken on the same day may be paired together, so this seems like a poor choice upon which to base a relationship between these two parameters. However, the logic behind this method is that an average density is obtained rather than using the higher density that occurred at maximum weight or the lower density that occurred at maximum depth (Harris, 1988). A similar analysis found this sorting method to be the 'most accurate method of predicting annual weight of snowpack from data on maximum depth' (Harris, 1988).

Data sets were created for each of the four representations of the depth/density relationships introduced above, for each elevation and each region.[2] Each data set was regressed using four different regression equations: linear, power law, quadratic, and quadratic through the origin (0,0). From the coefficient of determination (R^2) for each equation, as well as observing the fit of the line to the data, the best method for representing the snow depth/snow-water equivalent relationship was selected.

Since snow density is directly related to the ambient air temperature and snow depth, it was expected that the monthly sorting method would result in the best snow depth/snow-water equivalent relationship. However, the correlation coefficients were generally lower and the data appeared more scattered compared to the other sorting methods. Had daily measurements, along with temperature readings taken at the

[1] Snow-Water Equivalent

[2] The station locations resulted in only 13 out of the possible 24 elevation/region divisions having data.

time of the measurement been available, this level of detail may have been more useful. Therefore, this method was dropped from further consideration.

Concentrating only on the correlation coefficient of the regression analysis, the quadratic regression equation provided the best fit for 9 of the 13 data sets, where as the power law regression equation provided the best fit for the other 5 data sets. By visual inspection, the power law regression equation predicted unconservative snow loads for large snow depth values in some cases. Therefore, a quadratic regression equation was selected to model the relationship between snow depth and snow-water equivalent. Correlation coefficient values were typically around 0.95, which represents a good fit.

One concern with using a pure quadratic equation, however, is that it is not required to pass through the point (0,0). Physically, this condition should be a requirement of the snow depth/snow-water equivalent relationship. A quadratic regression equation that goes through (0,0) was examined, and the correlation coefficient was typically within a few thousandths of the pure quadratic fit, with almost no visual difference in the shape of the graph. As a result, a quadratic equation that passes through (0,0) was used to model the relationship between snow depth and snow-water equivalent.

From the above results, the quadratic equation through (0,0) was examined for the remaining three sorting routines to determine which sorting routine was to be used for the snow depth/snow-water equivalent relationship. Looking strictly at the (R^2) value, the Max SWE/Max Snow Depth sorting routine provided the best fit for 7 out of the 9 remaining data sets (Power Law Regression had the best fit for 5 of the original 13 data sets; since Power Law had been excluded at this point, 9 possible data sets remained). The Max Density sorting routine provided the best fit for the remaining two data sets. It was noted that for one data set the equation that described the snow depth/snow-water equivalent relationship was concave down rather than concave up when the Max Density sorting routine was used. This type of equation would predict unconservative snow load values for large snow depths. Therefore, due to the high correlation coefficients of the Max SWE/Max Snow Depth sorting routine, and the possible unconservative nature of the Max Density sorting routine, the Max SWE/Max Snow Depth sorting routine was selected.

B.2.1 Adjustments

Although the snow depth/snow-water equivalent data fall within a relatively narrow band around the equation used to relate them, variations are present within the data that could cause heavier snow loads than what the 'average' relationship predicts. Therefore, in order to give the design engineer a little latitude when determining the 50-year (MRI) snow load, a set of upper and lower bounds were created to give the engineer an idea how much the snow load could vary.

The upper and lower bounds, which can be seen on the graphs later in this appendix, were created by simply moving the equation that predicts the relationship up or down on the graph so that it runs through the highest or lowest extreme of the data. For instance, in Region 1 for $elevations < 4000ft$, the original equation was moved up by 5.0 (inches of water) and down by 6.6 (inches of water) to bound the entire data set. This same process was done for all relationships that were created.

The tables in Appendix A include the snow loads calculated using the upper and lower bounds on the snow depth to snow-water equivalent relationships discussed above. The right page of each of the NWS tables has the log-Pearson type III and lognormal snow loads. Within each of the probability distribution sets, a Low Extreme, Calculated, and High Extreme snow load have been given. These values represent the snow loads that result when the same 50-year (MRI) snow depths were transformed into snow loads using the upper bound, average, and lower bound equations.

Note that low and high extreme snow loads were only calculated for the primary data sets from each station (recall that in a few situations, this data set did not include the absolute maximum snow depth ever observed at a site). Table B.1 below shows the equations that were developed for the 13 regional/elevation divisions that had data.

B.2.2 Extrapolating Data Sets to Other Regions

Equations from nearby regions or elevation divisions were used to convert snow depth into snow load in the regions without snow course stations. During the creation of the snow depth/water equivalent depth equations, it was noticed that the elevation divisions of $< 4000ft$ and $4000 - 5000ft$ were similar, and $5000ft - 6000ft$ and $> 6000ft$ were similar. Where data was available, the equations that were developed were very close for these two adjacent elevation divisions (three out of five). Therefore, it was decided that before equations were extrapolated to other geographic regions, if an equation (that was trusted) was available in an adjacent elevation division, it would be used in that elevation division. Using this method, the following regional/elevation divisions were given snow depth/snow-water equivalent equations.

$RegionII, 4000ft - 5000ft \Rightarrow RegionII, < 4000ft$
$RegionIII, > 6000ft \Rightarrow RegionIII, 5000ft - 6000ft$
$RegionV, > 6000ft \Rightarrow RegionV, 5000ft - 6000ft$

Equations from similar regions were then used to fill in remaining gaps in the snow depth/snow-water equivalent relationship. Region II equations were extended to Region III (for any remaining gaps), Region IV equations were extended to Region V (for any remaining gaps), and Region IV equations were extended to Region VI. Table B.2 shows the final snow depth/snow-water equivalent equations that were used for each region and elevation division. The bold equations are the original equations.

Note that the equations in Table B.1 and Table B.2 relate snow depth to snow-water equivalent (not snow load). To find the snow load from a snow-water equivalent, the snow-water equivalent is multiplied by $5.2\frac{lb}{ft^2in}$. Figures B.1 through B.6 show the graphs of the data sets for each region and elevation division where data existed. The center line is the quadratic line through (0,0) which is used to calculate the 50-year snow load. The top line is the same center line (shape) moved up by a specific value to bound the data on the high side. The lower line is the same center line (shape) moved down by a specific value to bound the data on the low side.

Region		Data Points	Snow Depth/ Water Equivalent Depth Equations Low Extreme	Actual	High Extreme
I	< 4000 ft	353	W_e = Actual - 6.6	$W_e = 0.0011*D^2+0.2737*D$	W_e = Actual + 5.0
	4000 to 5000 ft	537	W_e = Actual - 7.0	$W_e = 0.0011*D^2+0.2673*D$	W_e = Actual + 6.2
	5000 to 6000 ft	720	W_e = Actual - 9.8	$W_e = 0.0007*D^2+0.3228*D$	W_e = Actual + 14.1
	> 6000 ft	572	W_e = Actual - 14.5	$W_e = 0.0007*D^2+0.3208*D$	W_e = Actual + 10.9
II	< 4000 ft		-	-	-
	4000 to 5000 ft	201	W_e = Actual - 2.9	$W_e = 0.0017*D^2+0.2358*D$	W_e = Actual + 3.7
	5000 to 6000 ft	442	W_e = Actual - 15.4	$W_e = 0.0008*D^2+0.2919*D$	W_e = Actual + 13.3
	> 6000 ft	1171	W_e = Actual - 11.6	$W_e = 0.0012*D^2+0.2597*D$	W_e = Actual + 8.0
III	< 4000 ft		-	-	-
	4000 to 5000 ft		-	-	-
	5000 to 6000 ft		-	-	-
	> 6000 ft	2440	W_e = Actual - 11.4	$W_e = 0.0014*D^2+0.2390*D$	W_e = Actual + 13.2
IV	< 4000 ft	50	W_e = Actual - 1.0	$W_e = 0.0042*D^2+0.1401*D$	W_e = Actual + 1.6
	4000 to 5000 ft	183	W_e = Actual - 8.2	$W_e = 0.0024*D^2+0.2377*D$	W_e = Actual + 5.7
	5000 to 6000 ft	737	W_e = Actual - 18.5	$W_e = 0.0015*D^2+0.2850*D$	W_e = Actual + 10.5
	> 6000 ft	1292	W_e = Actual - 12.8	$W_e = 0.0015*D^2+0.2372*D$	W_e = Actual + 8.3
V	< 4000 ft		-	-	-
	4000 to 5000 ft		-	-	-
	5000 to 6000 ft		-	-	-
	> 6000 ft	929	W_e = Actual - 18.5	$W_e = 0.0013*D^2+0.2421*D$	W_e = Actual + 10.9
VI	< 4000 ft		-	-	-
	4000 to 5000 ft		-	-	-
	5000 to 6000 ft		-	-	-
	> 6000 ft		-	-	-

-indicates no data available

Table B.1: Original snow depth/snow-water equivalent equations

Region		Data Points	Snow Depth/ Water Equivalent Depth Equations: Low Extreme	Actual	High Extreme
I	< 4000 ft	353	W_e = Actual - 6.6	$W_e = 0.0011*D^2+0.2737*D$	W_e = Actual + 5.0
	4000 to 5000 ft	537	W_e = Actual - 7.0	$W_e = 0.0011*D^2+0.2673*D$	W_e = Actual + 6.2
	5000 to 6000 ft	720	W_e = Actual - 9.8	$W_e = 0.0007*D^2+0.3228*D$	W_e = Actual + 14.1
	> 6000 ft	572	W_e = Actual - 14.5	$W_e = 0.0007*D^2+0.3208*D$	W_e = Actual + 10.9
II	< 4000 ft		W_e = Actual - 2.9	$W_e = 0.0017*D^2+0.2358*D$	W_e = Actual + 3.7
	4000 to 5000 ft	201	W_e = Actual - 2.9	$W_e = 0.0017*D^2+0.2358*D$	W_e = Actual + 3.7
	5000 to 6000 ft	442	W_e = Actual - 15.4	$W_e = 0.0008*D^2+0.2919*D$	W_e = Actual + 13.3
	> 6000 ft	1171	W_e = Actual - 11.6	$W_e = 0.0012*D^2+0.2597*D$	W_e = Actual + 8.0
III	< 4000 ft		W_e = Actual - 2.9	$W_e = 0.0017*D^2+0.2358*D$	W_e = Actual + 3.7
	4000 to 5000 ft		W_e = Actual - 2.9	$W_e = 0.0017*D^2+0.2358*D$	W_e = Actual + 3.7
	5000 to 6000 ft		W_e = Actual - 11.4	$W_e = 0.0014*D^2+0.2390*D$	W_e = Actual + 13.2
	> 6000 ft	2440	W_e = Actual - 11.4	$W_e = 0.0014*D^2+0.2390*D$	W_e = Actual + 13.2
IV	< 4000 ft		W_e = Actual - 1.0	$W_e = 0.0042*D^2+0.1401*D$	W_e = Actual + 1.6
	4000 to 5000 ft	183	W_e = Actual - 8.2	$W_e = 0.0024*D^2+0.2377*D$	W_e = Actual + 5.7
	5000 to 6000 ft	737	W_e = Actual - 18.5	$W_e = 0.0015*D^2+0.2850*D$	W_e = Actual + 10.5
	> 6000 ft	1292	W_e = Actual - 12.8	$W_e = 0.0015*D^2+0.2372*D$	W_e = Actual + 8.3
V	< 4000 ft		W_e = Actual - 1.0	$W_e = 0.0042*D^2+0.1401*D$	W_e = Actual + 1.6
	4000 to 5000 ft		W_e = Actual - 8.2	$W_e = 0.0024*D^2+0.2377*D$	W_e = Actual + 5.7
	5000 to 6000 ft		W_e = Actual - 18.5	$W_e = 0.0013*D^2+0.2421*D$	W_e = Actual + 10.9
	> 6000 ft	929	W_e = Actual - 18.5	$W_e = 0.0013*D^2+0.2421*D$	W_e = Actual + 10.9
VI	< 4000 ft		W_e = Actual - 1.0	$W_e = 0.0042*D^2+0.1401*D$	W_e = Actual + 1.6
	4000 to 5000 ft		W_e = Actual - 8.2	$W_e = 0.0024*D^2+0.2377*D$	W_e = Actual + 5.7
	5000 to 6000 ft		W_e = Actual - 18.5	$W_e = 0.0015*D^2+0.2850*D$	W_e = Actual + 10.5
	> 6000 ft		W_e = Actual - 12.8	$W_e = 0.0015*D^2+0.2372*D$	W_e = Actual + 8.3

Table B.2: Final snow depth/snow-water equivalent equations

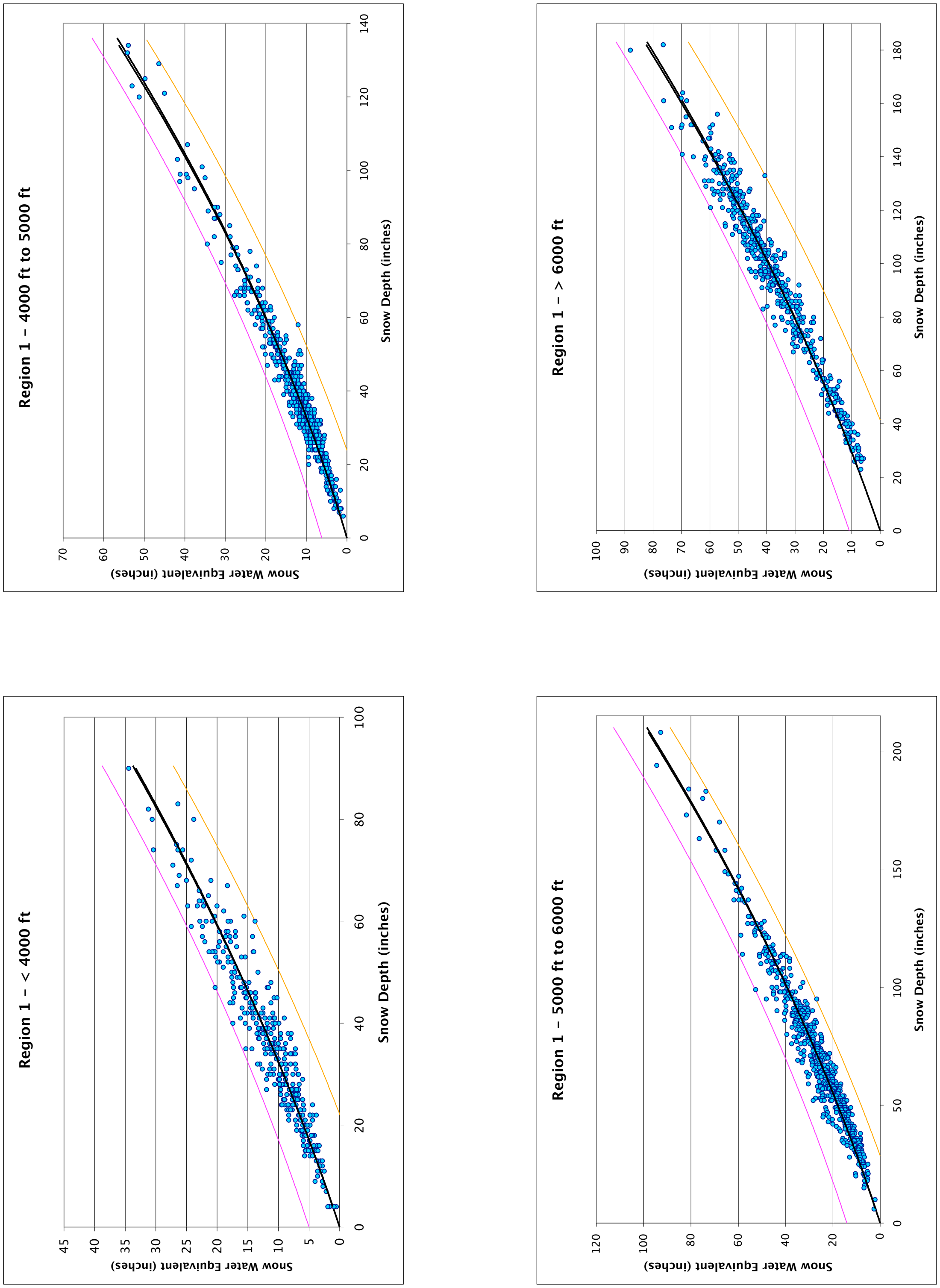

Figure B.1: Snow depth/Snow water equivalent relationships for Region 1

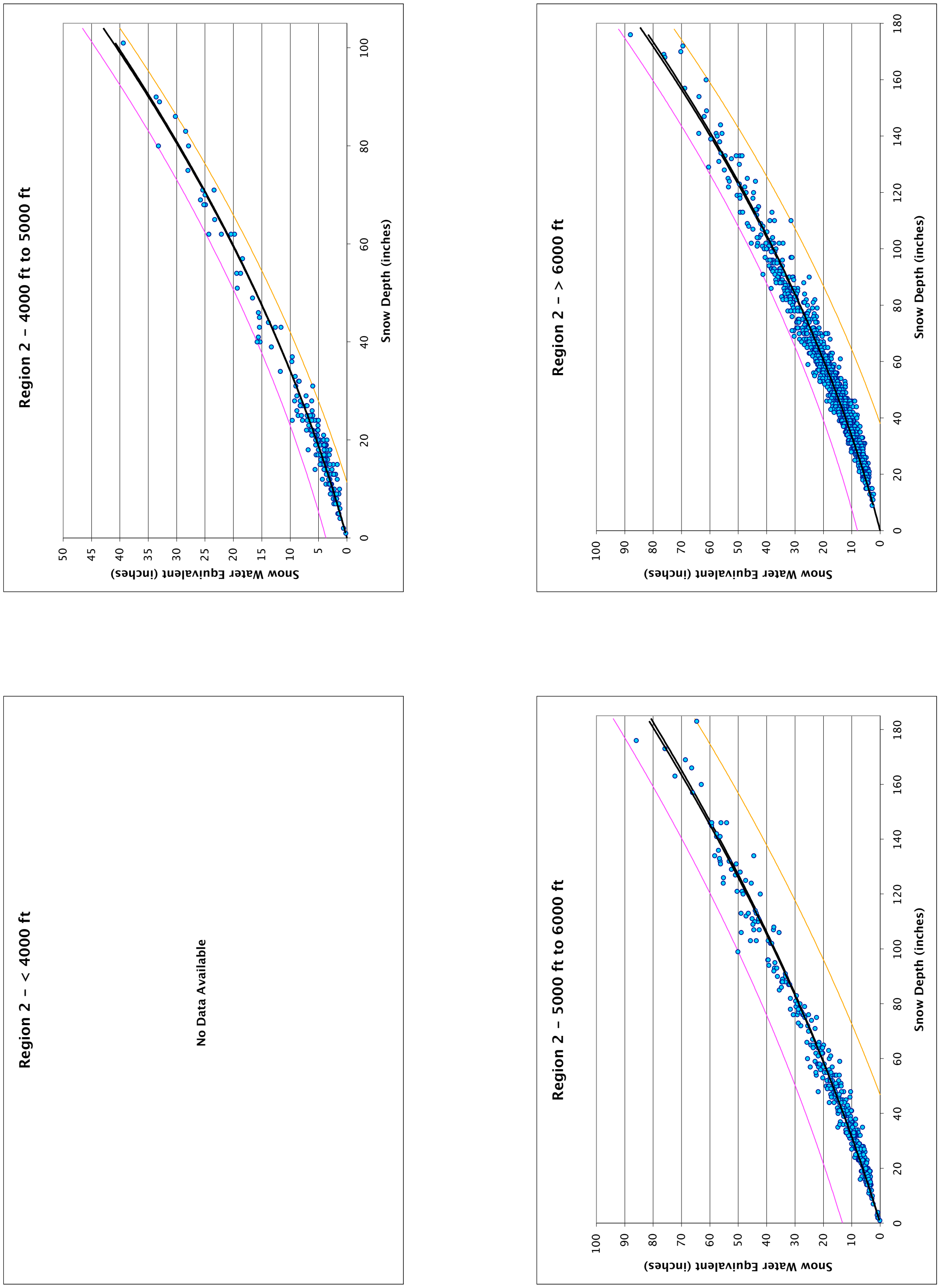

Figure B.2: Snow depth/Snow water equivalent relationships for Region 2

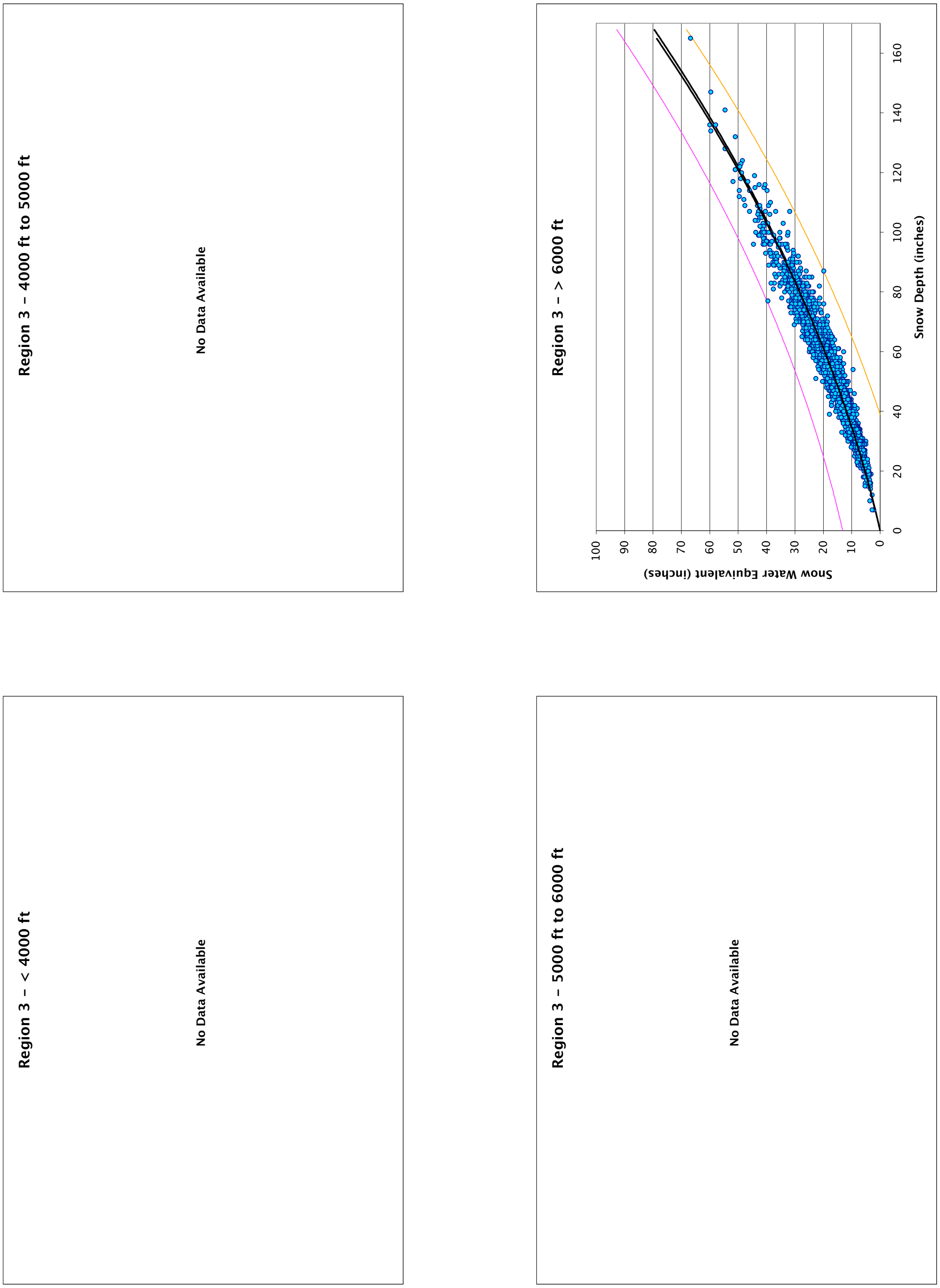

Figure B.3: Snow depth/Snow water equivalent relationships for Region 3

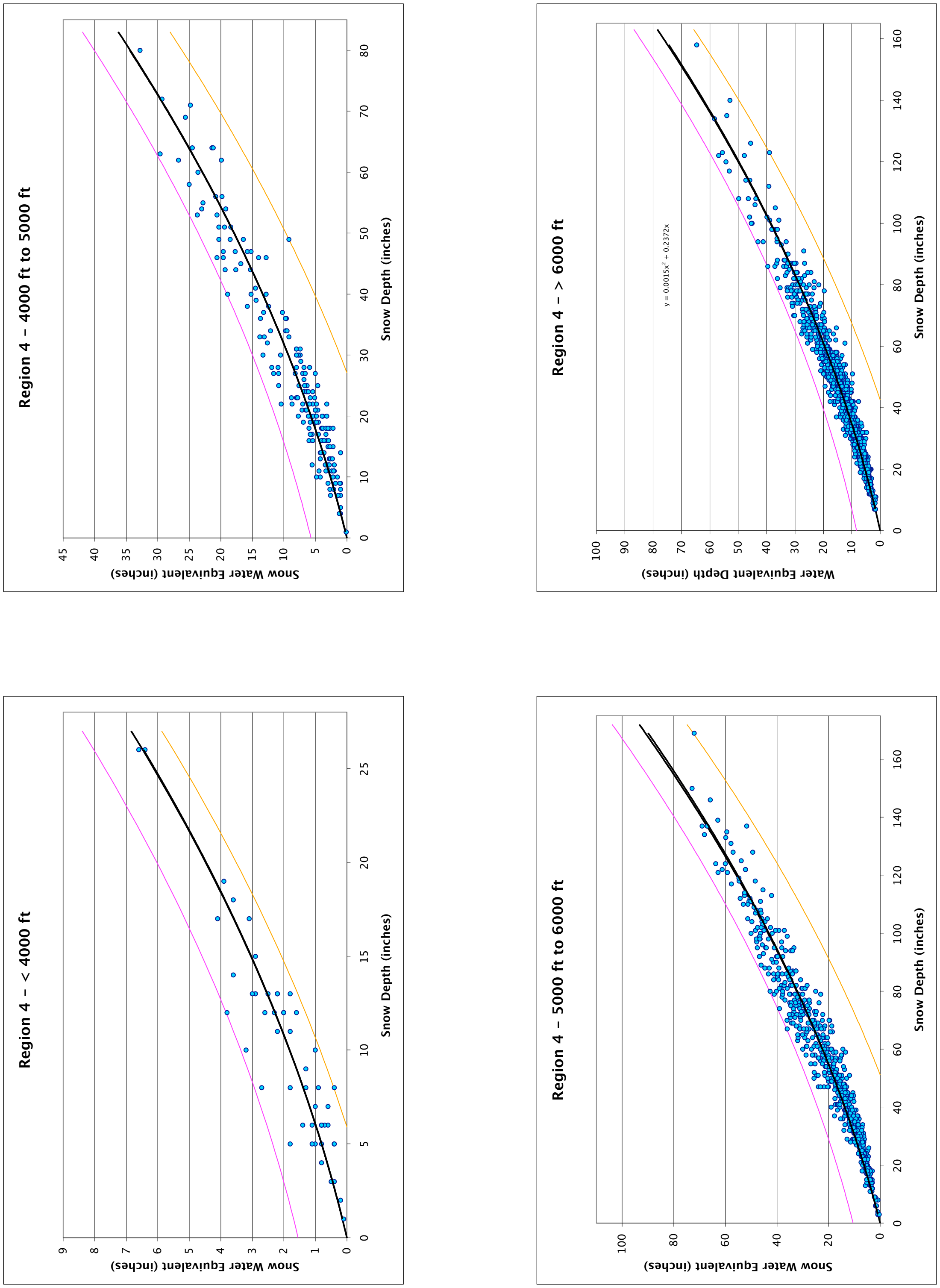

Figure B.4: Snow depth/Snow water equivalent relationships for Region 4

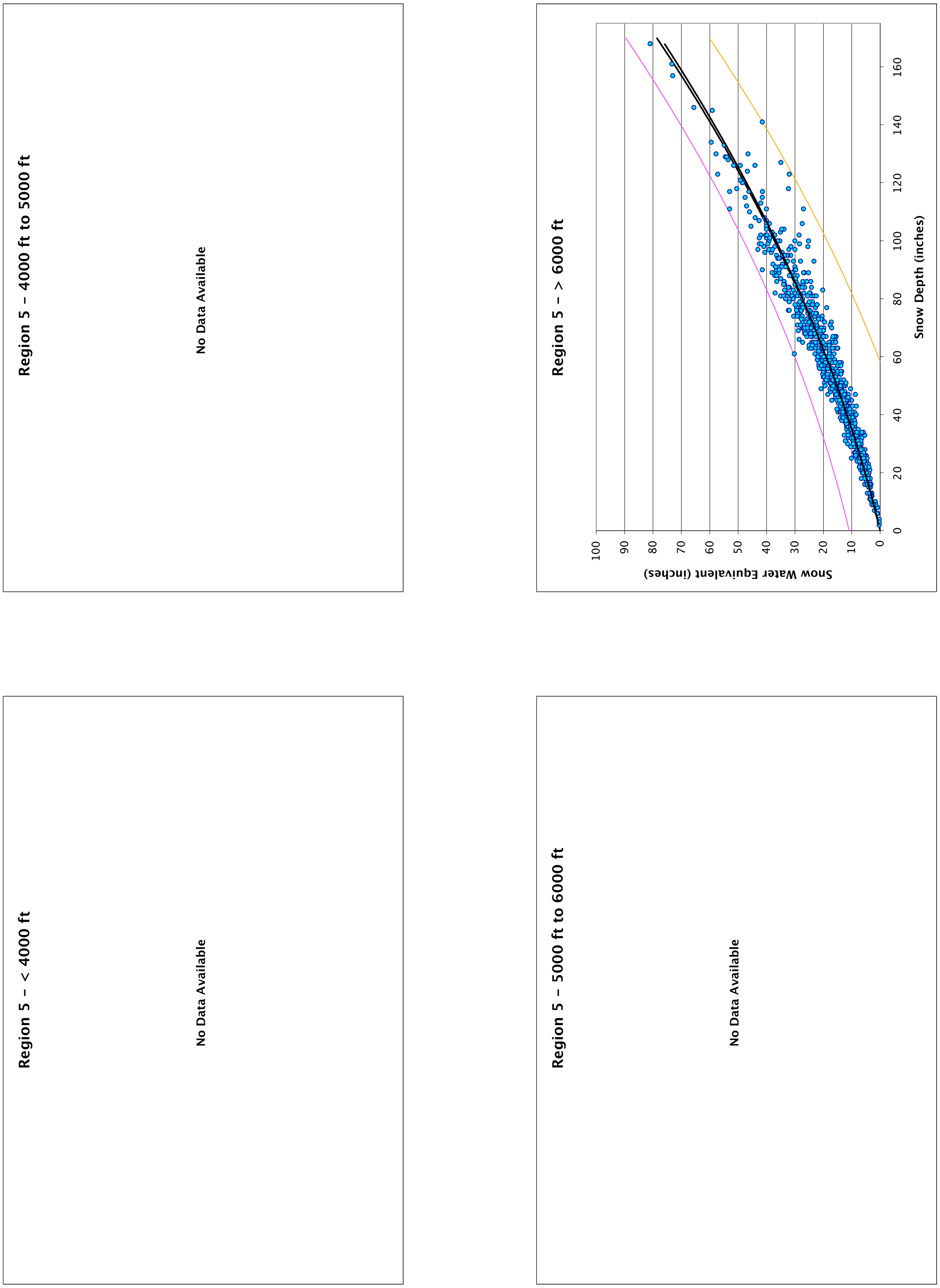

Figure B.5: Snow depth/Snow water equivalent relationships for Region 5

Figure B.6: Snow depth/Snow water equivalent relationships for Region 6