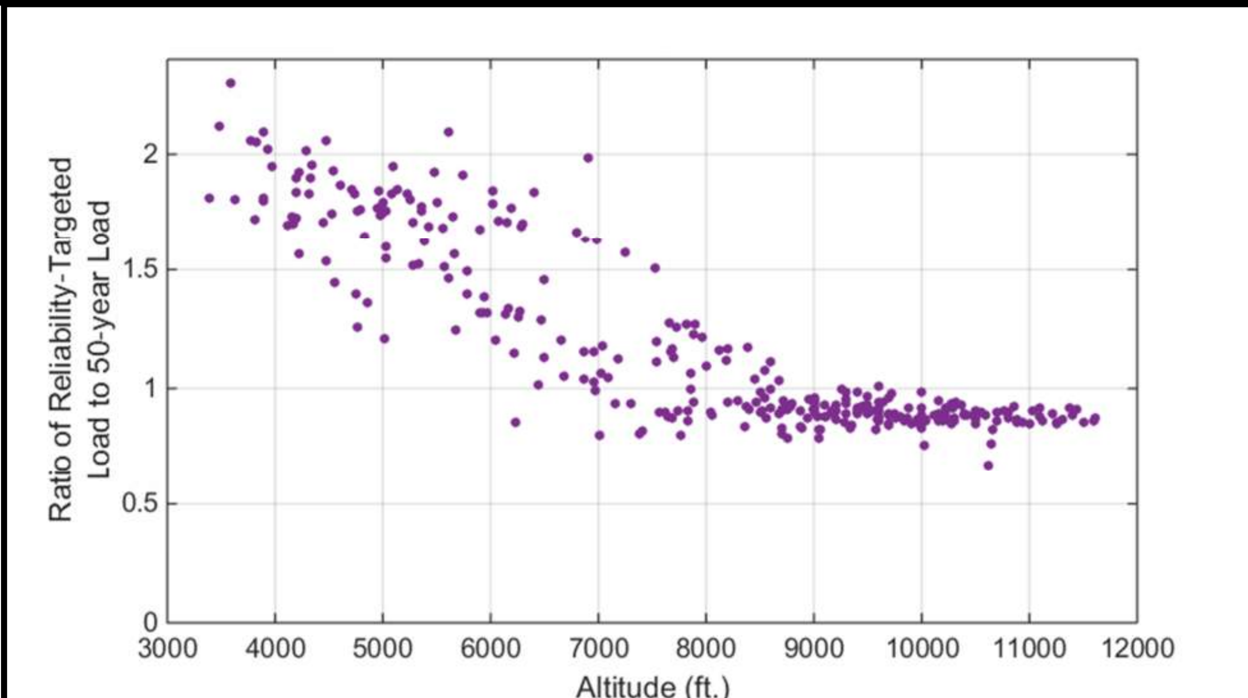
2016

Colorado Design Snow Loads



Prepared by the Structural Engineers Association of Colorado (SEAC) Snow Load Committee

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Structural Engineers Association of Colorado

Prepared By

The SEAC Snow Load Committee

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Executive Summary

The Structural Engineers Association of Colorado (SEAC) has developed new ground snow loads recommended for use in structural design in Colorado. The recommended loads are based on a suite of over 300 snow sites in the state of Colorado for which data have been assembled from historical records of ground snow loads and depth. Philosophically, these loads represent a transition from a uniform hazard approach to a uniform risk approach for determining design snow loads. Previous design snow loads, including those in the 2007 SEAC report, are based on a uniform hazard, *i.e.* the design value at a site is taken as the snow load that occurs, on average, once every 50 years (in other words, the mean recurrence interval is 50 years). However, due to the large variations in climate throughout Colorado, new studies conducted by this committee have shown that using the 50-year load as the basis for design does not provide uniform protection against the risk of roof failure. In particular, at sites on the plains, roof design based on the 50-year ground snow load may not achieve the reliability levels targeted by the national standard for loads, *ASCE/SEI 7*, meaning that the probability of failure may be higher than expected. The converse is true in mountainous regions, where the reliability achieved when the 50-year load is used in design may actually be greater than required by *ASCE 7*. These patterns stem from differences in snowfall and accumulation throughout the state. In the mountains, snow builds up over the course of the winter, producing large ground snow loads, but fairly low variability in the loads from year to year. Snow loads on the plains tend to be dependent on large single-storm events and are highly variable from year to year.

The computation of loads for a target probability of failure results in loads appropriate for strength-based structural design. However, for convenience of use with *ASCE 7*, the loads presented in this report have been divided by the load factor (1.6) prescribed for snow loads in the *ASCE 7*. Thus, the loads are also appropriate for use with allowable stress design methods and for serviceability checks.

Compared to the 2007 recommended loads, there have been small decreases in design loads in the mountains (approximately 10 percent), and increases in recommended design loads on the plains (approximately 50 percent to100 percent). The increased design loads on the plains are consistent with historic and current practice, where design roof loads of 20 to 30 psf have typically been used instead of the 50-year values. A number of other improvements have been made. First, the new analysis utilizes approximately seven additional years of weather data generated since the development of the 2007 map. Second, improved relationships for snow depth and snow weight have been used. Third, a method of using all the data for large regions of the state to better predict rare events has been incorporated. Finally, the snow loads have been correlated with the altitude of the site and maps have been produced that provide parameters to compute the ground snow load given the altitude of the site. The mapping process introduces a geographic smoothing, or averaging, on top of the reliability-targeted loads, which reduces some of the "noise" inherent in the historical records. The recommended design loads are those determined from the mapping process.

This report documents: (a) new mapped values, including comparison to previously used values, (b) snow load and depth data used in the development of the maps, and (c) probabilistic approaches used to evaluate roof reliability and conduct spatial smoothing. The report also provides recommendations for use of these loads with *ASCE 7* and for future improvements.

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Part 1. Recommended Design Snow Loads

1.1. Introduction and Motivation

This report documents the basis for and motivation behind the 2015 SEAC design snow load recommendations, as well as the methods by which they are developed. The new snow load map is based on a detailed statistical analysis that aims to achieve uniform resistance against snow loads throughout the state of Colorado.

1.1.1. The Need for Revised Design Snow Load Recommendations and a New Map

The design snow loads described in this report revise the existing maps for Colorado in a number of ways. First, it incorporates new snow data not available in previous analyses. Second, the new map smooths design values between nearby sites, eliminating large jumps between adjacent communities, and provides updated guidance on the determination of snow loads as a function of altitude that is based on the unique climatological conditions in our state.

Finally, and most importantly, the new map revises design snow loads to ensure that the risk of roof failure due to snow loading, or, alternatively, the structural safety and reliability for snow loading, are consistent across the state. This report quantifies safety in terms of the reliability index (or safety index) β, which is inversely related to the probability of failure; a higher safety index corresponds to lower probability of failure. The national standard for loads, *ASCE/SEI7* (hereafter *ASCE 7*), targets a safety index of 3.0 (0.13 percent probability of failure in 50 years) for failure mechanisms that are not sudden and do not lead to widespread progression in ordinary occupancy (Risk Category II) buildings under snow loads[1]. Previously, designing roofs for a 50-year snow load was assumed to satisfy these criteria, but analyses show that a 50-year load is conservative in some areas of Colorado and non-conservative in others. The SEAC 2007 design snow load recommendations, which are based on a uniform hazard of a 50-year mean recurrence interval (MRI) snow load, produce safety indices ranging from approximately $\beta = 2$ on the plains (2.3 percent probability of failure in 50 years) to $\beta = 3.5$ in the mountains (0.02 percent probability of failure in 50 years) for ordinary occupancy buildings. The probability of failure is higher on the plains because of the larger variability in annual maximum snow loads on the plains as compared to the mountains, where snowfall and accumulation are more consistent from year to year. The large variability in annual maximum snow loads means that plains sites are more likely to experience loads that are significantly greater than their 50-year loads during the life of the structure, causing roof failures. These discrepancies in safety and building performance across the state of Colorado are in need of resolution.

1.1.2. Objective of New Reliability-Based Design Snow Loads

The objective of the new snow load recommendations is to achieve uniform safety for snow loading across the state of Colorado. The target safety objective of a reliability index of $\beta = 3$ is appropriate for these recommendations; material design standards address "failure limit states

[1] The target of $\beta = 3.0$ is found in Table C3.1.3.1a of *ASCE 7-10*. These targets will be moved to the body of the standard in future editions.

that are sudden or lead to wide-spread progression of damage through resistance factors and other provisions." *ASCE 7* targets other safety levels for different Risk Categories and includes load adjustment factors for other Risk Categories, and this report includes recommendations to modify those adjusting factors to achieve consistent reliability targets. The design loads recommended in this report are developed to achieve the target safety objective, an approach that is fundamentally different than current practice, which is to design for a uniform hazard (*e.g.* a 50-year snow load). As a result, the recommended design ground snow loads are decreased in the mountains and increased on the plains of Colorado to meet the uniform safety objective. The concept of targeting a consistent safety or reliability rather than consistent hazard is not new to the Structural Engineering profession. For example, Ellingwood and Tekie (1999) address the need to target uniform reliability with regard to wind loading and the *ASCE 7*-10 Maximum Considered Earthquake (MCE) values are risk-based rather than hazard-based (Luco et al. 2007).

1.2. Recommended Design Snow Loads for Colorado

1.2.1. Basis for Use

The recommended design ground snow loads provided in this report are intended to be used with the *ASCE 7* procedures for structural design. As such, they provide design ground snow loads which must then be converted to roof snow loads according to the *ASCE 7* procedures, with appropriate treatment of exposure to wind, thermal properties of the roof, roof slope, unbalanced snow loads, drifting, and risk categories. For convenience, the recommended loads are provided in both map and tabular form. It is the responsibility of the engineer to check with the local authority having jurisdiction to verify code-required design snow loads before using these recommendations. This report is a recommendation, not a building code.

1.2.2. Design Snow Loads

Tabulated Design Values

The recommended design ground snow loads are tabulated for many locations in the state of Colorado, see Table 1.1. Many communities in relatively flat areas are covered by entries in the table defining portions of counties, suburban areas, or the Eastern Plains. These values may be used to compute design loads at nearby sites, *i.e.* those sites that are (a) within five miles, (b) within 1000 ft. of altitude, and (c) not separated by a mountain ridge from the tabulated location, according to the procedures described below. If a site is not near enough to the tabulated site to use these adjustments, the mapped design values should be used (described below).

In most parts of the state (except for locations east of the Rocky Mountains and below 6500 ft. altitude), if the site of interest is higher altitude than a nearby tabulated site, the design ground snow load should be adjusted from the tabulated values using Equation 1.1.

$$p_{g,site} = p_{g,tabulated} * \left(\frac{A_{site}}{A_{tabulated}}\right)^3 \qquad 1.1,$$

where $p_{g,site}$ and $p_{g,tabulated}$ are the design ground snow load at the building site and at the tabulated location, respectively, and A_{site} and $A_{tabulated}$ are the altitudes of the building site and the tabulated location in thousands of ft., respectively. If the site of interest is lower in altitude than the tabulated location, the tabulated load may be used without modification. Many communities extend over land with greatly varying altitudes, so it is important to compare the altitude of the site with the tabulated altitude.

For locations East of the Rocky Mountains and below 6500 ft. altitude, the tabulated loads may be used without modification for sites lower in altitude than the tabulated location and also up to 250 ft. higher in altitude than the tabulated location. Otherwise, refer to Equation 1.2 in the section entitled *Mapped Design Values* to determine the design ground snow load.

The development of the design snow load values is described in detail in Part 2 of this report.

Table 1.1a Tabulated design ground snow loads (p_g) for the state of Colorado (Cities/Towns)

City/Town	County	Latitude (deg)	Longitude (deg)	Altitude (ft)	Design Ground Snow Load (pg) (psf)*
Aguilar	Las Animas	37.40	-104.65	6390	**55**
Air Force Academy	El Paso	39.01	-104.89	7000	**55**
Alamosa	Alamosa	37.47	-105.87	7540	25
Allenspark	Boulder	40.19	-105.53	8500	70
Alma	Park	39.28	-106.06	10360	65
Antonito	Conejos	37.08	-106.01	7890	40
Arapaho ski area base	Summit	39.64	-105.87	10850	125
Arvada	Jefferson	39.80	-105.09	5350	40
Aspen	Pitkin	39.19	-106.82	7890	75
Aurora	Adams	39.73	-104.83	5400	40
Avon	Eagle	39.63	-106.52	7430	60
Bailey	Park	39.41	-105.47	7740	**80**
Basalt	Eagle	39.37	-107.03	6610	55
Battlement Mesa	Mesa	39.44	-108.03	5490	35
Bayfield	La Plata	37.23	-107.60	6900	55
Beaver Creek	Eagle	39.60	-106.52	8080	75
Bellvue	Larimer	40.63	-105.17	5130	**40**
Beulah	Pueblo	38.08	-104.99	6380	**55**
Black Forest	El Paso	39.01	104.70	7370	65
Black Hawk	Gilpin	39.80	-105.49	8540	*85*
Blue River	Summit	39.38	-106.05	10500	90
Boulder	Boulder	40.01	-105.27	5330	40
Branson	Las Animas	37.02	-103.88	6270	**55**
Breckenridge	Summit	39.50	-106.04	9600	80
Brighton	Adams	39.99	-104.82	4980	35
Broomfield	Broomfield	39.92	-105.09	5390	40
Buena Vista	Chaffee	38.84	-106.13	7960	**35**
Canon City	Fremont	38.44	-105.24	5350	*35*
Carbondale	Garfield	39.40	-107.21	6170	50
Cascade	El Paso	38.90	-104.97	7380	**60**
Castle Pines	Douglas	39.47	-104.89	6370	50
Castle Rock	Douglas	39.37	-104.86	6220	45
Cedaredge	Delta	38.90	-107.93	6230	*35*
Centennial	Arapahoe	39.58	-104.88	5830	*40*
Central City	Gilpin	39.80	-105.51	8510	85
Cimarron Hills	El Paso	38.86	-104.70	6450	*45*
Coal Creek Canyon	Boulder	39.92	-105.40	8600	105
Collbran	Mesa	39.24	-107.96	5980	**45**

Table 1.1a Tabulated design ground snow loads (p_g) for the state of Colorado (Cities/Towns)

City/Town	County	Latitude (deg)	Longitude (deg)	Altitude (ft)	Design Ground Snow Load (pg) (psf)*
Colorado Springs (downtown)	El Paso	38.83	-104.82	6010	45
Colorado Springs (Chapel HIlls)	El Paso	38.95	-104.79	6500	50
Commerce City	Adams	39.81	-104.93	5160	35
Conifer	Jefferson	39.52	-105.31	8280	100
Copper Mountain ski area base	Summit	39.51	-106.14	9700	80
Cortez	Montezuma	37.35	-108.59	6190	*30*
Craig	Moffat	40.52	-107.55	6200	*30*
Crawford	Delta	38.70	-107.61	6560	45
Creede	Mineral	37.85	-106.93	8800	65
Crested Butte	Gunnison	38.87	-106.98	8910	**125**
Crestone	Saguache	38.00	-105.70	7930	35
Cripple Creek	Teller	38.75	-105.18	9490	70
De Beque	Mesa	39.33	-108.22	4950	**30**
Del Norte	Rio Grande	37.68	-106.35	7880	30
Denver	Denver	39.74	-104.98	5280	*35*
Dillon	Summit	39.63	-106.04	9110	*65*
Dinosaur	Moffat	40.24	-109.01	5920	35
Dolores	Montezuma	37.47	-108.50	6940	**55**
Dotsero	Eagle	39.65	-107.07	6150	40
Dove Creek	Dolores	37.77	-108.91	6840	45
Durango	La Plata	37.28	-107.88	6530	**55**
Durango Mountain ski area base	La Plata	37.63	-107.81	9000	**125**
Eagle	Eagle	39.66	-106.83	6600	45
Edwards	Eagle	39.64	-106.59	7220	55
El Jebel	Eagle	39.40	-107.09	6480	50
Elbert	Elbert	39.22	-104.54	6720	**55**
Empire	Clear Creek	39.76	-105.68	8620	60
Estes Park	Larimer	40.38	-105.52	7520	**65**
Evergreen	Jefferson	39.63	-105.32	7050	**70**
Fairplay	Park	39.22	-106.00	9950	55
Fort Carson (HQ)	El Paso	38.74	-104.79	5800	*40*
Fort Collins	Larimer	40.59	-105.08	5000	35
Fort Garland	Costilla	37.43	-105.43	7940	25
Fort Morgan	Morgan	40.25	-103.80	4330	30
Fountain	El Paso	38.68	-104.70	5550	*35*

Table 1.1a Tabulated design ground snow loads (p_g) for the state of Colorado (Cities/Towns)

City/Town	*County*	*Latitude (deg)*	*Longitude (deg)*	*Altitude (ft)*	*Design Ground Snow Load (pg) (psf)**
Franktown	Douglas	39.39	-104.75	6160	45
Fraser	Grand	39.94	-105.82	8580	75
Frisco	Summit	39.57	-106.10	9080	65
Genesee	Jefferson	39.70	-105.27	7650	80
Georgetown	Clear Creek	39.71	-105.70	8520	60
Gleneagle	El Paso	39.05	-104.83	6930	**55**
Glenwood Springs	Garfield	39.55	-107.32	5760	40
Granby	Grand	40.09	-105.94	7980	55
Grand Junction	Mesa	39.06	-108.55	4590	25
Grand Lake	Grand	40.25	-105.82	8390	70
Greeley	Weld	40.42	-104.71	4680	30
Green Mountain Falls	Teller	38.93	-105.02	7760	**70**
Gunnison	Gunnison	38.55	-106.93	7700	*45*
Gypsum	Eagle	39.65	-106.95	6310	40
Hartsel	Park	39.02	-105.80	8870	35
Hayden	Routt	40.50	-107.26	6350	**55**
Highlands Ranch	Douglas	39.54	-104.97	5900	45
Hot Sulphur Springs	Grand	40.07	-106.10	7730	45
Howard	Fremont	38.45	-105.84	6720	**40**
Idaho Springs	Clear Creek	39.74	-105.51	7530	60
Ignacio	La Plata	37.12	-107.63	6450	45
Keystone ski area base	Summit	39.60	-105.95	9170	70
Kremmling	Grand	40.06	-106.39	7310	40
La Junta	Otero	37.99	-103.54	4080	30
La Veta	Huerfano	37.51	-105.01	7040	50
Lake City	Hinsdale	38.03	-107.32	8660	55
Lakewood	Jefferson	39.70	-105.08	5520	40
Lamar	Prowers	38.09	-102.62	3620	30
Larkspur	Douglas	39.23	-104.89	6730	55
Leadville	Lake	39.25	-106.29	10160	*75*
Littleton	Arapahoe	39.61	-105.02	5350	40
Livermore	Larimer	40.79	-105.22	5900	45
Longmont	Boulder	40.17	-105.10	4980	35
Loveland	Larimer	40.40	-105.07	4980	35
Loveland ski area base	Clear Creek	39.68	-105.90	10850	125
Lyons	Boulder	40.22	-105.27	5370	40
Mancos	Montezuma	37.34	-108.29	7030	*45*
Manitou Springs	El Paso	38.86	-104.92	6360	50

Table 1.1a Tabulated design ground snow loads (p_g) for the state of Colorado (Cities/Towns)

City/Town	*County*	*Latitude (deg)*	*Longitude (deg)*	*Altitude (ft)*	*Design Ground Snow Load (pg) (psf)**
Marble	Gunnison	39.07	-107.19	7990	90
Meeker	Rio Blanco	40.04	-107.91	6240	40
Mesa	Mesa	39.17	-108.14	5640	**35**
Mesa Verde	Montezuma	37.15	-108.52	6770	**50**
Minturn	Eagle	39.59	-106.43	7860	70
Monarch ski area base	Chaffee	38.51	-106.33	10800	135
Monte Vista	Rio Grande	37.58	-106.15	7660	25
Montezuma	Summit	39.58	-105.87	10310	105
Montrose	Montrose	38.48	-107.88	5810	25
Monument	El Paso	39.09	-104.87	6980	**60**
Mount Crested Butte ski area base	Gunnison	38.90	-106.97	9900	155
Mountain Village	San Miguel	37.93	-107.86	9600	120
Nederland	Boulder	39.96	-105.51	8230	70
Newcastle	Garfield	39.57	-107.54	5600	35
Norwood	San Miguel	38.13	-108.29	7010	*35*
Nucla	Montrose	38.27	-108.55	5790	25
Oak Creek	Routt	40.28	-106.96	7430	70
Ophir	San Miguel	37.86	-107.83	9700	125
Ouray	Ouray	38.02	-107.67	7790	**65**
Pagosa Springs	Archuleta	37.27	-107.01	7130	75
Palmer Lake	El Paso	39.11	-104.91	7300	65
Paonia	Delta	38.87	-107.59	5680	35
Parker	Douglas	39.52	-104.76	5870	45
Pitkin	Gunnison	38.61	-106.52	9220	**105**
Poncha Springs	Chaffee	38.51	-106.08	7470	45
Ponderosa Park	Elbert	39.40	-104.64	6680	55
Pueblo	Pueblo	38.25	-104.61	4690	30
Pueblo West	Pueblo	38.33	-104.74	4960	35
Rangely	Rio Blanco	40.09	-108.80	5230	**35**
Red Cliff	Eagle	39.51	-106.37	8750	85
Rico	Dolores	37.69	-108.03	8830	*100*
Ridgway	Ouray	38.15	-107.76	7050	*40*
Rifle	Garfield	39.53	-107.78	5350	**40**
Roxborough Park	Douglas	39.46	-105.08	6000	45
Rye	Pueblo	37.92	-104.93	6800	60
Salida	Chaffee	38.53	-106.00	7080	**45**
San Luis	Costilla	37.20	-105.42	7980	30
Sawpit	San Miguel	37.99	-108.00	7590	55

Table 1.1a Tabulated design ground snow loads (p_g) for the state of Colorado (Cities/Towns)

City/Town	*County*	*Latitude (deg)*	*Longitude (deg)*	*Altitude (ft)*	*Design Ground Snow Load (pg) (psf)**
Security-Widefield	El Paso	38.74	-104.72	5800	*40*
Sedalia	Douglas	39.44	-104.96	5840	**50**
Silt	Garfield	39.55	-107.66	5460	35
Silver Cliff	Custer	38.14	-105.45	7990	55
Silver Plume	Clear Creek	39.70	-105.73	9100	70
Silverthorne	Summit	39.63	-106.07	8760	**65**
Silverton	San Juan	37.81	-107.66	9310	*105*
Snowmass Village	Pitkin	39.21	-106.94	8210	90
South Fork	Rio Grande	37.67	-106.64	8210	70
Steamboat Springs	Routt	40.48	-106.83	6730	**85**
Sterling	Logan	40.63	-103.21	3940	30
Telluride	San Miguel	37.94	-107.81	8790	*75*
The Pinery	Douglas	39.44	104.74	6250	50
Thornton	Adams	39.87	-104.97	5350	40
Trinidad	Las Animas	37.17	-104.50	6030	45
Vail	Eagle	39.64	-106.37	8190	**90**
Vail, Mid- Mountain	Eagle	39.61	-106.37	10300	**175**
Victor	Teller	38.71	-105.14	9710	80
Walden	Jackson	40.73	-106.28	8100	*45*
Walsenburg	Huerfano	37.62	-104.78	6170	45
Ward	Boulder	40.07	-105.51	9150	*75*
Westcliffe	Custer	38.13	-105.47	7870	50
Westminster	Adams	39.84	-105.04	5380	40
Winter Park	Grand	39.89	-105.76	9050	**100**
Wolf Creek ski area base	Mineral	37.47	-106.79	10650	295
Woodland Park	Teller	38.99	-105.06	8480	85
Woodmore	El Paso	39.11	-104.85	7240	**65**
Yampa	Routt	40.15	-106.91	7880	*60*

**Tabulated loads must be adjusted by Equation 1.1 where site altitude is greater than the tabulated altitude*

Table 1.1b Tabulated design ground snow loads (p_g) for the state of Colorado (groups of communities)

Groups of Communities	*Design Ground Snow Load (pg) (psf)**
Communities east of Interstate Highway 25 and not otherwise tabulated	
- below 4750 feet	30
- 4750 feet or above, but below 5250 feet	35
- 5250 feet or above, but below 5750 feet	40
- 5750 feet or above, but below 6250 feet	45
- 6250 feet or above, but below 6500 feet	50
Denver suburban communities	
- in Adams County, more than 1 mile west of S. Platte River	40
- in Adams County, more than 2 miles east of S. Platte River	40
- in Adams County, elsewhere	35
- in Arapahoe County, except east of Tower Road	40
- in Broomfield County	40
- in Douglas County, within 3 miles of Arapahoe County	45
- in Jefferson County more than 1 mile east of foothills	40
Boulder County Communities not otherwise tabulated	
- more than 1 mile east of foothills and north of Baseline Rd	35
- more than 1 mile east of foothills and south of Baseline Rd	40
Conejos County Communities not otherwise tabulated	
- below 7700 feet	25
Costilla County Communities not otherwise tabulated	
- below 7800 feet	25
Delta County Communities not otherwise tabulated	
- below 5500 feet	25
Fremont County Communities not otherwise tabulated	
- below 5400 feet	35
Larimer County Communities not otherwise tabulated	
- more than 1 mile east of foothills and south of Co. Rd 66	35
Mesa County Communities not otherwise tabulated	
- below 5000 feet	25
Montrose County Communities not otherwise tabulated	
- below 5500 feet	25
Pueblo County Communities not otherwise tabulated	
- below 4750 feet	30
Saguache County Communities not otherwise tabulated	
- below 7800 feet	25
Weld County Communities not otherwise tabulated	
- West of Interstate Highway 25	35
- East of Interstate Highway 25	refer to the general rules above

**Tabulated loads must be adjusted by Equation 1.1 where site altitude is greater than the tabulated altitude*

Mapped Design Values

In addition to the tabulated design ground snow loads, this report also provides a parameter map for determining design ground snow loads, which is included at the end of this section.

In this map, the state is divided into three regions: (1) east of the Rocky Mountains below 6500 ft. altitude, (2) the eastern slopes of the Rocky Mountains above 6500 ft., and (3) the remainder of the state.

East of the Rockies, below 6500 ft. altitude (*i.e.* the first region), Equation 1.2 should be used to compute the ground snow loads:

$$p_{g,site} = max[10A_{site} - 15\ ,30] \qquad 1.2,$$

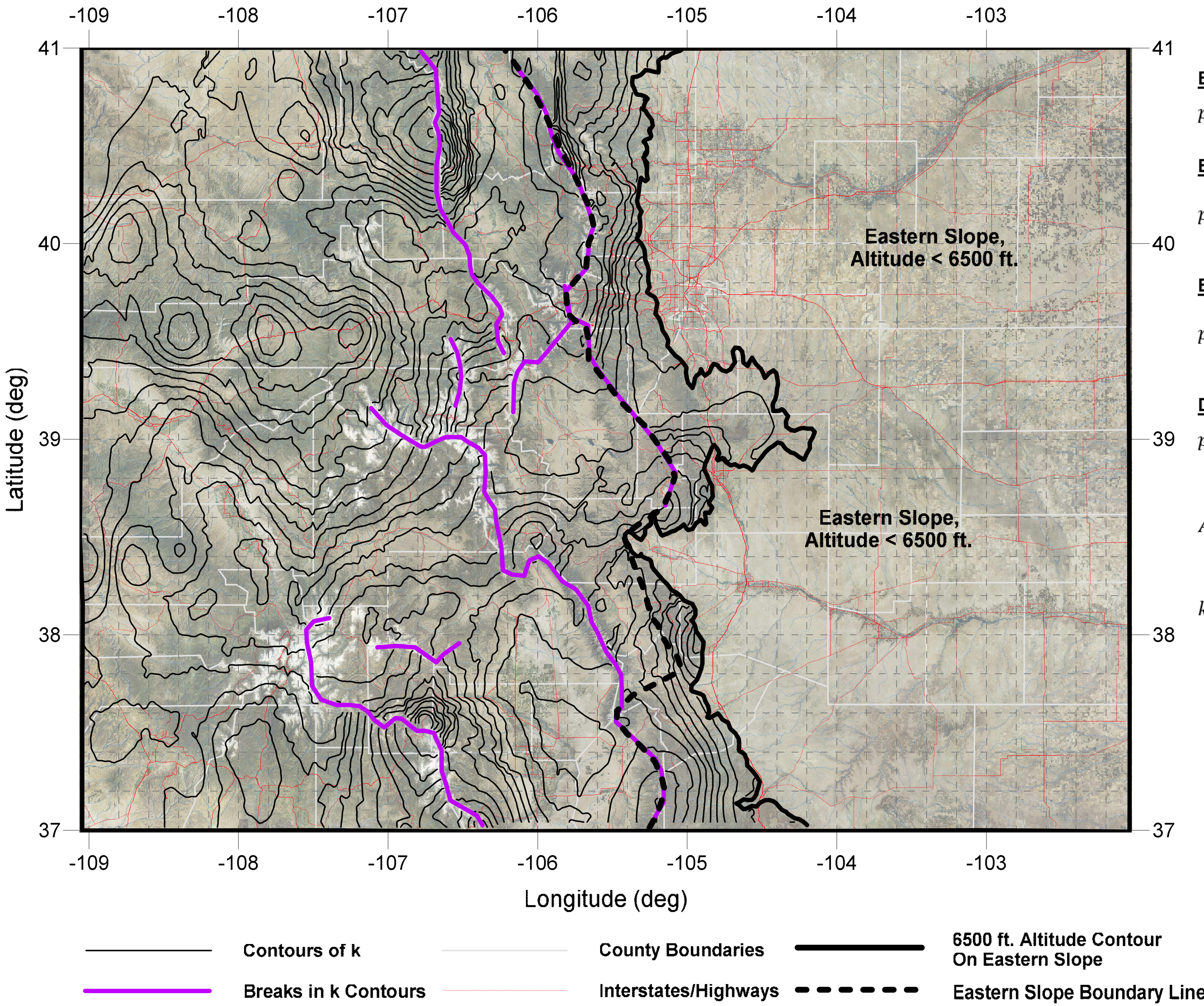
In the second and third regions, a parameter *K* is mapped for determining design ground snow loads. Design ground snow loads are determined based on *K* by Equation 1.3:

$$p_{g,site} = max\left[\frac{K_{site}}{100} * A_{site}^3, MIN\right] \qquad 1.3,$$

where $p_{g,site}$ is the design ground snow load and A_{site} is the altitude of the building site in thousands of feet. MIN is 50 psf for the eastern slopes of the Rocky Mountains above 6500 ft. (*i.e.* region 2) and 25 psf for areas not on the eastern slope. Equation 1.3 is only applicable below 11,500 ft. altitude, where contours of the parameter *K* are mapped. For sites between contours *K* should be interpolated between the nearby contours. When determining the value of *K* from the map, it is important to note that the map is partitioned along mountain ridges, where the contour lines for the parameter K are interrupted. Therefore, when interpolating between contours on the map for the value of *K* at a location, treat such discontinuities as a boundary and extrapolate from contours on the same side of the ridge. Many, but not all, of these discontinuities are locations above 11,500 ft. The detailed development of these equations and the parameter map is discussed in Part 2 of this report.

Mapped vs. Tabulated Design Values

Most of the tabulated loads are determined directly from the parameter map and then rounded to the nearest 5 psf. However, there are locations where the tabulated value is different than the rounded value from the map. These differences occur where analysis of local snow data yields results significantly different than the spatial averaging required to construct the map. Higher values are shown in **bold** type and smaller values are shown in *italic* type. Spatial averaging was allowed to control on the Eastern Plains, but local data was given extra weight in the mountainous areas. For sites where the tabulated load is more conservative than the load determined from the parameter map, the tabulated load (**bold** type) takes precedence over the load from the parameter map. Rounding to the nearest 5 psf is not mandatory, and at locations not governed by the **bold**faced type in the table, values computed from the map may be used.



Eastern Slope, Altitude < 6500 ft.:

$p_g = max(10A - 15{,}30)$

Eastern Slope, Altitude ≥ 6500 ft.:

$p_g = max\left(\frac{k}{100}A^3, 50\right)$

Elsewhere:

$p_g = max\left(\frac{k}{100}A^3, 25\right)$

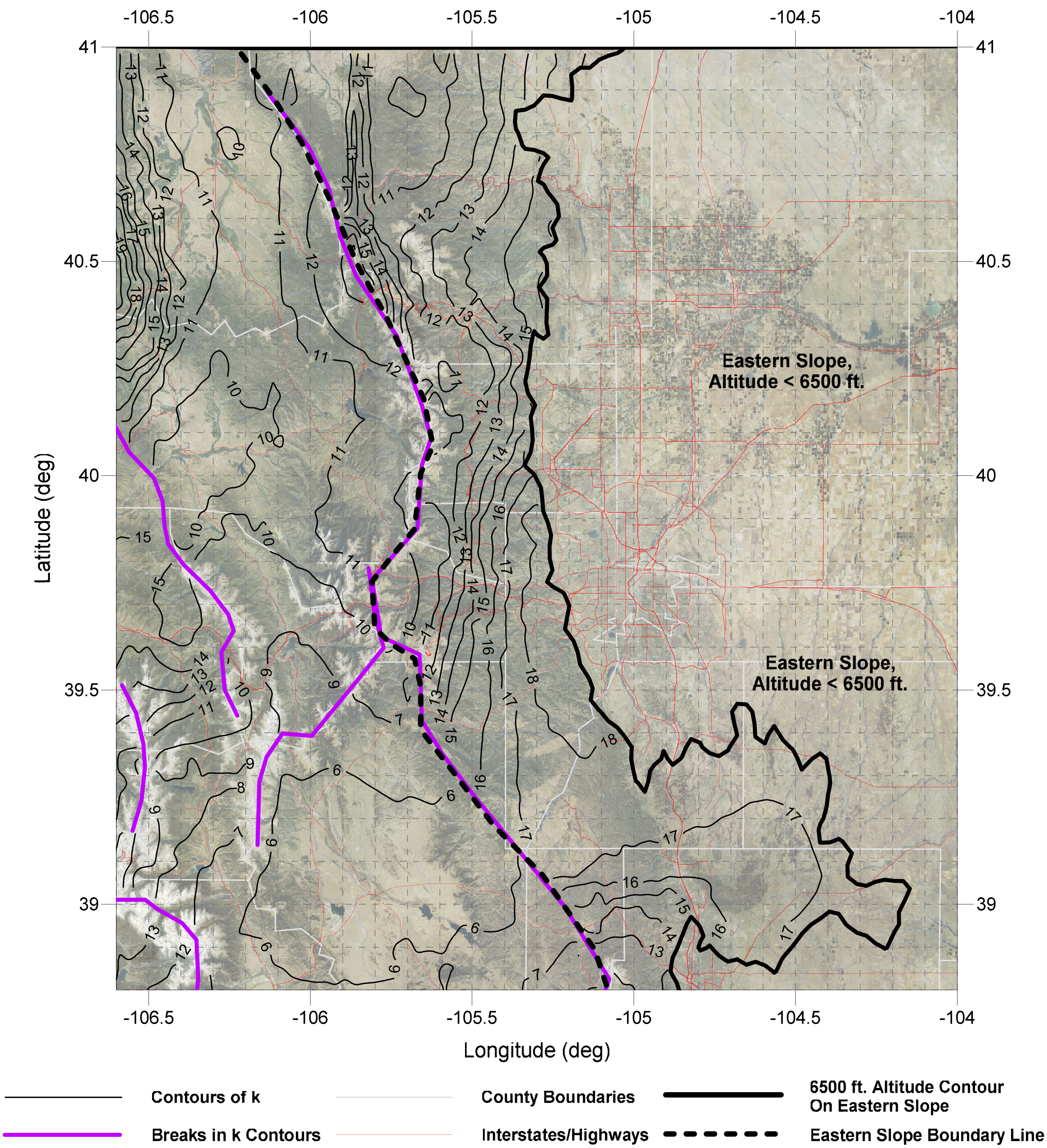
Definitions:

p_g = Ground snow load (psf)

A = Altitude (thousands of ft.)

k = Parameter value from contour map

Figure 1.1a: Overview Map



Eastern Slope, Altitude < 6500 ft.:

$$p_g = max(10A - 15, 30)$$

Eastern Slope, Altitude ≥ 6500 ft.:

$$p_g = max\left(\frac{k}{100}A^3, 50\right)$$

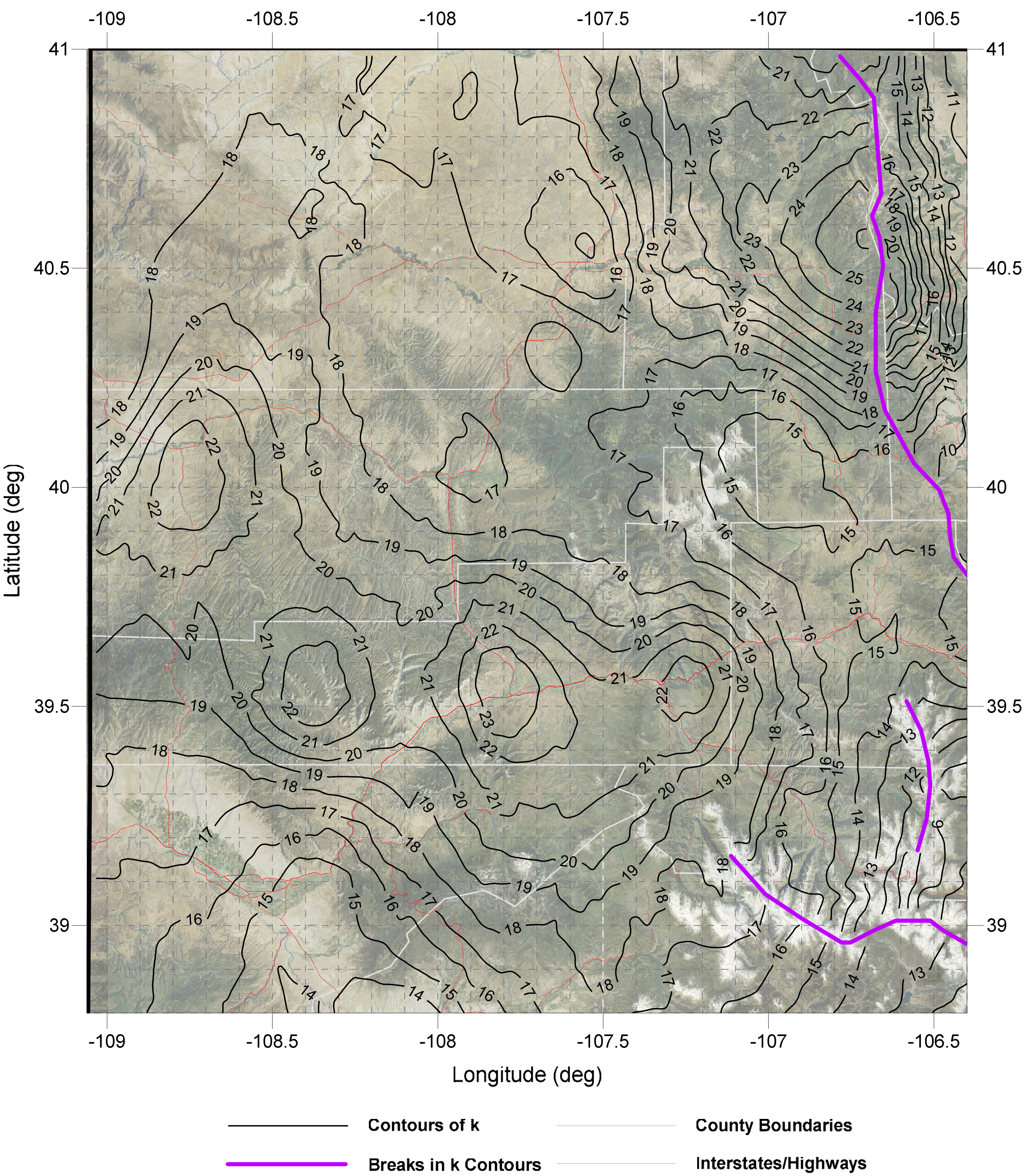
Elsewhere:

$$p_g = max\left(\frac{k}{100}A^3, 25\right)$$

Definitions:

p_g = Ground snow load (psf), A = Altitude (thousands of ft.), k = Parameter value from contour map

Figure 1.1b: North Central Colorado Parameter Map for Determining Ground Snow Loads



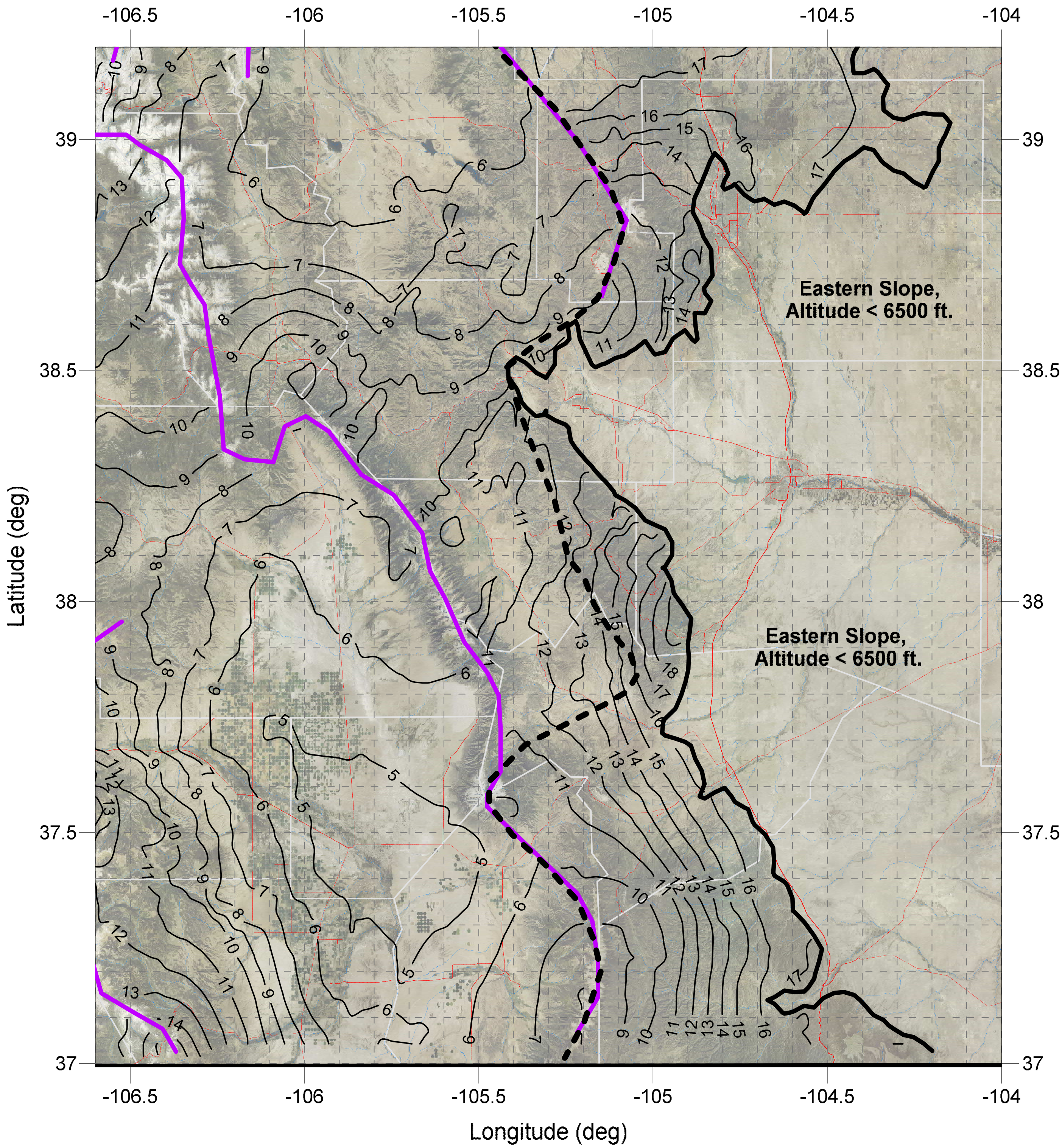
Equation for ground snow load:

$$p_g = max\left(\frac{k}{100}A^3, 25\right)$$

Definitions:

p_g = Ground snow load (psf), k = Parameter value from contour map, A = Altitude (thousands of ft.)

Figure 1.1c: Northwest Colorado Parameter Map for Determining Ground Snow Loads



Contours of k
Breaks in k Contours
County Boundaries
Interstates/Highways
6500 ft. Altitude Contour On Eastern Slope
Eastern Slope Boundary Line

<u>Eastern Slope, Altitude < 6500 ft.:</u>

$$p_g = max(10A - 15, 30)$$

<u>Eastern Slope, Altitude ≥ 6500 ft.:</u>

$$p_g = max\left(\frac{k}{100}A^3, 50\right)$$

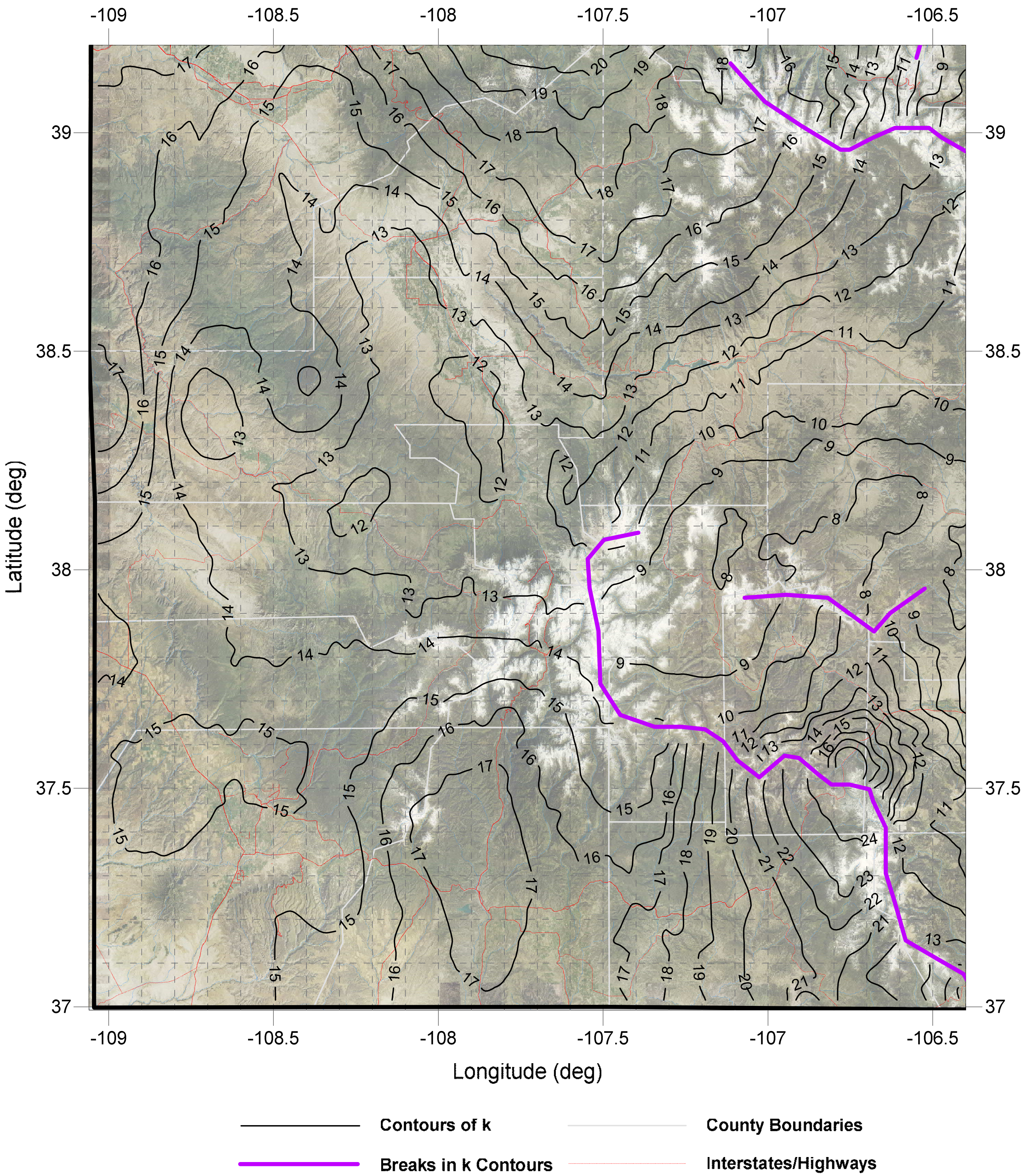
<u>Elsewhere:</u>

$$p_g = max\left(\frac{k}{100}A^3, 25\right)$$

<u>Definitions:</u>

p_g = Ground snow load (psf), A = Altitude (thousands of ft.), k = Parameter value from contour map

Figure 1.1d: South Central Colorado Parameter Map for Determining Ground Snow Loads



Equation for ground snow load:

$$p_g = max\left(\frac{k}{100}A^3, 25\right)$$

Definitions:

p_g = Ground snow load (psf), k = Parameter value from contour map, A = Altitude (thousands of ft.)

 Figure 1.1e: Southwest Colorado Parameter Map for Determining Ground Snow Loads

1.2.3. Additional Recommendations

Loads for Use in Serviceability Checks

Roof snow loads that are determined from the design ground snow loads in this study are considered sufficient for checking serviceability limit states. However, it should be noted that given the focus on safety (strength) in development of these loads, the loads may have some limitations for serviceability checks. Appendix 4 addresses serviceability loads in more detail.

Structures Assigned to Higher Risk Categories

ASCE 7 requires snow load importance factors of $I_s = 1.1$ and $I_s = 1.2$ for Risk Category III and IV buildings, respectively. However, the increases in safety provided by these safety factors is not consistent throughout Colorado, even when they are applied to reliability-targeted design snow loads. *ASCE 7* states that Risk Category III and IV buildings are intended to have safety indices of $\beta = 3.25$ and $\beta = 3.5$, respectively (ASCE 2010). A study of snow load importance factors that is described in Appendix A4.3 shows that the *ASCE 7* importance factors are non-conservative at low altitude locations and slightly conservative at high altitude locations in Colorado. This trends occur because distributions of annual maximum snow loads at low altitude sites (such as sites on the plains) tend to have longer/heavier tails. As are result, larger increases in the design loads are required at low altitude sites to increase safety against snow-induced failure than for high elevation sites where snow loading is less variable from year to year.

Therefore, the committee recommends that the snow loading importance factor (I_s) be computed by Equation 1.4 for Risk Category IV buildings. For Risk Category III buildings, I_s should be taken as the average of Equation 1.4 and the value 1.0. No change is recommended for the importance factors for Risk Category I and II buildings.

$$I_s = 1.15 \leq 1.66 - 0.056 * A \leq 1.4 \qquad 1.4,$$

where A is the site altitude in thousands of feet. Development of Equation 1.4 is documented in Appendix A4.3.

Drifting on Plains and Other High Exposure Areas

The ASCE 7 recommendation for snow drift loads are derived from data obtained across a wide range of climates. More extreme drifts are known to occur where prolonged and strong winds are typical, and studies are currently underway to attempt to quantify this effect. This type of behavior has been observed on the plains of Colorado, as well as sites above timberline. The committee does not have enough information to make a quantitative recommendation, but does make a general recommendation that engineers consider maximum roof drift widths greater than the maximum roof drift widths specified in ASCE 7 for buildings with roof steps that are located on exposed sites on the plains. This phenomenon occurs because large snow storms in those regions are often accompanied by long duration winds (on the order of days) oriented in a consistent direction. If the wind direction is perpendicular to the roof step, a large snow drift will form. Designing for snow drift widths beyond what is required in ASCE 7 is ultimately at the discretion of the engineer and the authority having jurisdiction.

Sites Above Timberline

This report does not recommend design ground snow loads for sites above timberline (or approximately 11,500 ft. of altitude[2]), first because there are few historical snow data records for locations above timberline, and, second, the relation between ground and roof loads[3] is likely very different at locations above timberline due to the extreme wind exposure. Therefore, flat roof loads may well be smaller than recommended in *ASCE 7*, and drift profiles are likely more extreme (*i.e.*, the length of the drift for a given height of drift will be larger than recommended in *ASCE 7*). Snow loads for structures at such sites should be based on knowledge of the local climate and the judgment of the engineer and the authority having jurisdiction.

1.3. Future Work

The 2015 SEAC design ground snow load recommendations represent the best estimate of reliability-targeted ground snow loads for the state of Colorado, given the tools and resources currently available to the SEAC Snow Load Committee. However, there remain ways in which the SEAC Snow Load Committee believes that these recommendations may be improved in the future. The mapping process has introduced a significant amount of averaging of locally large and small loads. Further improvement may be possible by accounting for topographic slope aspect (*i.e*. direction) and inclination at mountain sites (DePaolo 2013). While accounting for local topography is currently infeasible for a study of this scale, it likely will be feasible within the foreseeable future, as additional data and analysis tools become available.

In addition to improving the recommendations for design snow loads, there are other improvements that may be needed for snow design procedures more generally. Two areas of possible improvement are the criteria for calculated snow drift loads on roofs with steps, ridges, or valleys and the snow load duration factor for wood construction. Current snow drifting criteria and duration factors are based on data sets that neither come from, nor are consistent with, snow loading that is observed in portions of the state of Colorado. Therefore, Colorado-specific analyses of snow drifting and load duration are important topics for future study.

1.4. Acknowledgments

The committee gratefully acknowledges Dick Cunningham for his extensive efforts in getting this new edition of the SEAC snow loads started, Mike DePaolo for his innovative studies and new techniques for classifying and determining ground snow loads, Bruce Ellingwood for his counsel and advice on statistical analysis, and Derek Kozak and Dania Hussain for their work on reliability assessment of buildings under snow loads. In addition, drafts of this report have been reviewed by the members of SEAC and related experts in the fields of study; their review comments are gratefully acknowledged.

[2] Timberline is defined as 11,500 ft. altitude in this study, although the precise altitude varies across the state.
[3] The ground to roof snow load conversion for the reliability assessments is discussed in Part 2 and in Appendix 2

Part 2. Development of 2015 Design Snow Loads for Colorado

The goal of the newly proposed ground snow load design values is to achieve consistent structural safety against snow-induced roof failure throughout the state of Colorado. Experience with snow loads in Colorado indicates that the use of a 50-year mean recurrence interval load as the specified nominal load on the ground, along with a snow load factor of 1.6 (LRFD) or a constant safety factor (ASD), will not satisfy the basic safety objective in significant populated areas of the state and may be unnecessarily costly in other areas. Therefore, the recommended design ground snow loads are computed so that roof structures designed in accordance with *ASCE 7* will have a safety index (β) of 3 with respect to snow loading. Consequently, the recommended ground snow loads are not necessarily 50-year or 30-year loads, as with previous editions, but are instead calibrated to achieve a target safety (β=3). The mean recurrence intervals of the recommended ground snow loads range between 20 and 300 years.

The target safety index of 3 is for relatively benign[4] structural failures in ordinary Risk Category buildings (Risk Category II). Target safety indices for buildings belonging to risk categories I, III, and IV, are 2.5, 3.25, and 3.5, respectively (ASCE 2010). Adjustments in snow loads to achieve the different reliability targets for different Risk Category buildings are achieved through snow load importance factors that are associated with each Risk Category in *ASCE 7*. As recommended in Section 1.2.3, the snow load importance factors for non-Risk Category II buildings should be adjusted to meet the desired safety objectives. The basis for these adjusted importance factors is described in Appendix 4.

The procedures for determining the proposed design ground snow loads are outlined as follows: (1) Data acquisition and processing; (2) Reliability analysis; (3) Mapping of reliability based ground snow loads.

2.1. Data acquisition and processing

2.1.1. Data Sources

The recommended design ground snow loads in this report are based on historical records of annual maximum ground snow at 603 snow recording stations throughout the state of Colorado.[5] The historical records are obtained from four sources: Snow Course stations (NRCS 2015), SNOTEL (*i.e.* SNOwpack TELemetry) stations (NRCS 2015), National Weather Service (NWS) cooperative observer (CO-OP) stations (WRCC 2015), and first order NWS stations. Appendix 5 tabulates summary statistics for all of the snow stations in this study.

Snow Course Stations

Snow Course stations consist of a series of ten locations along a course (typically about a half mile long) at which a trained observer measures snow depth (inches) and weight in inches or water (*i.e.* snow water equivalent, "SWE") on a monthly basis (NRCS 2015). The measurements

[4] "Relatively benign" means a failure limit state that gives warning (generally, meaning the failure is ductile) and does not precipitate a widespread failure vertically or horizontally. It is the intent of ASCE 7 that adjustments in safety for other types of limit states are accomplished through resistance factors in material design standards.
[5] These stations are distinctly different from the town/city locations listed in Table 1.1 of the report.

are obtained by plunging an aluminum pipe through the snow pack to the ground and measuring the depth of snow around the outside of the tube and weight of the snow that is trapped inside it. The average depth and weight for the ten locations is reported. Snow Course stations are primarily located in mountainous areas above 8,500 ft. altitude in the state of Colorado. Data from 177 Snow Course stations are collected from the Natural Resources Conservations Service (NRCS) website for this study.

SNOTEL Stations

SNOTELs are automated stations that measure the weight of snow (SWE) via a fluid-filled pillow that senses pressure from the snow on top of it (NRCS 2015). The data are electronically transmitted to a central repository. SNOTEL stations are often located in remote mountainous areas where accessibility is limited, and they have replaced a number of Snow Course stations over the years. Many SNOTEL stations also have sensors to measure snow depth. Data from 117 SNOTEL stations are collected from the NRCS website for this study.

NWS CO-OP Stations

NWS CO-OP stations (referred to hereafter as "NWS" stations) record snow depth on a daily basis (NWS 2015). However, snow weight is not recorded. For the purposes of this study, the depth measurements at these stations are converted to snow weights, using the relationships developed in Appendix 1. Data from 303 NWS stations are collected from the Western Regional Climate Center (WRCC 2015).

First Order NWS Stations

There are six "First Order" stations in the state of Colorado: Alamosa San Luis Valley Regional Airport, Colorado Springs Municipal Airport, Denver-Stapleton, Fort Collins, Grand Junction Walker, and Pueblo Memorial Airport. These are NWS stations that report depth of snow on a daily basis, but have historically reported daily snow weight (*i.e.* SWE) as well. For the six First Order stations, the average number of snow years is 66 and the average number of years with SWE data is 28.

2.1.2. Initial Data Processing

Data collected from the 603 stations are consolidated to create 463 historical records. The consolidated records are referred to as "snow sites." Snow sites are created by combining data records from stations very near to each other for which snow accumulation patterns are expected to be the same or very similar. Snow sites with less than 30 years of historical data are eliminated from the basic analysis, because these records are considered to be insufficient for the statistical analysis. There are 327 snow sites that have 30 or more years of data. An additional 60 sites with 18 to 29 years of data are used in some areas to inform the mapping process.

Combining Nearby Stations to Make Snow Sites

Data from nearby stations are combined so that longer records of annual maximum snow data are available. The combinations of stations often result from newer stations that have replaced older stations in nearly identical locations (*e.g.,* a SNOTEL station that replaces a Snow Course

Station). In some cases, the locations of the different stations that are combined to make a snow site are different, but they are close enough that no substantial difference in snow accumulation patterns is expected between them. Similar combinations of stations are already present in the NWS data that is collected for this study. In particular, it is common for many NWS stations to have had two to five locations over their lifetime, but only one continuous data record is reported. The easily available data does not always make clear when a NWS station has changed location, and at some stations (*e.g.* Pueblo) the NWS did not combine the record as the station moved.

The following criteria are implemented to determine if snow stations are in close enough proximity for their records to be combined: (1) plains stations (east of the Front Range and below 5,000 ft. altitude) within approximately twelve miles and 500 ft. altitude of each other, (2) stations above 6,000 ft. altitude within approximately two miles and 300 ft. altitude of each other, and (3) any other stations within approximately five miles and 300 ft. altitude of each other. These criteria are based on observations of snow recordings at adjacent stations and the judgment of the SEAC Snow Load Committee.

When a snow site consists of multiple stations that have data for the same year, direct weight measurements are given priority over snow weights that are converted from depth measurements. If there are multiple stations with the same data type in a given year (*i.e.,* all having direct weight measurements or all having depth measurements that are converted to weights), then the maximum annual snow weight for that year is taken as the maximum from all of the contributing stations.

2.2. Methodology to Compute Reliability-Targeted Ground Snow Loads

Reliability analyses are performed for each snow site to determine the design ground snow load that will result in a safety index of $\beta = 3$ for roof snow loading on a test building designed according to *ASCE 7*. The test structure is a simply supported, uniformly loaded steel roof girder with lateral support that is controlled by flexure, which meets the definition of "relatively benign" failure. The safety index β is computed through Monte Carlo simulation (Fishman 2006).

2.2.1. Test Structure Design

Reliability analyses are performed for a test structure[6], which is a 30 ft. wide-flange steel roof girder with 30 ft. of tributary width and 15 psf design dead load (D), including self-weight. Design roof snow loads (S) are computed per *ASCE 7* as 0.7 times the design ground snow load[7], with all other factors of the *ASCE 7* method (exposure, thermal, importance, and slope) set equal to 1.0, implying that the test structure is part of a roof of a heated building situated in a suburban exposure with a partially exposed roof. The LRFD ultimate design load (U, Equation 2.1) and a

[6] The authors conducted sensitivity studies showing that the reliability analysis results are insensitive to the roof geometry and other design assumptions.
[7] The 0.7 factor increases to 1.0 as the ground snow load decreases from 28.6 psf to 20 psf, in accordance with the minimum snow load provisions of *ASCE 7*.

strength reduction factor of 0.9 are used to determine the necessary plastic section modulus for design. Serviceability and non-flexure limit states are not considered in the test structure design.

$$U = 1.2D + 1.6S \tag{2.1}$$

2.2.2. Reliability Analysis Overview

For each computation of β, 10 million Monte Carlo simulations of maximum annual snow load are conducted.[8] A direct analytical approach to computing the reliability was not appropriate because of the multiple sources of uncertainty to consider in the reliability calculations.

Each simulation generates a random realization of demand on the roof and a random realization of the capacity of the roof, considering uncertainties in these quantities as described in more detail below. These values are compared to determine if the test structure fails in a given realization. The total number of failures divided by the total number of simulations is the expected annual rate of failure (λ). The probability of failure for a 50-year time period ($P_{f,50}$) is then computed by the Poisson distribution in Equation 2.2 and converted to a reliability index β by Equation 2.3:

$$P_{f,50} = 1 - \exp(-50\lambda) \approx 50\lambda \tag{2.2}$$

$$\beta = \Phi^{-1}(1 - P_{f,50}) \tag{2.3},$$

where Φ^{-1} is the inverse standard normal cumulative distribution function. The β defined by *ASCE 7* is based on a 50-year service life of the structure.

2.2.3. Uncertain Demand Variables

The roof demand is the sum of snow load demand and dead load demand. Snow load demand is a product of two random variables: the annual maximum ground snow load and the ratio of roof snow load to ground snow load.

Annual Maximum Ground Snow Load

Each Monte Carlo simulation generates a random annual maximum ground snow load from a probability distribution of annual maximum ground snow loads for the site of interest. The lognormal distribution is used to model annual maximum snow loads at every site. At each site, the process for fitting the distribution emphasizes the upper tail, which is crucial for the reliability analysis. The central tendency of the distribution is determined directly from data at the site of interest. However, the historical record is too short to confidently predict the rare events that cause failure from the data available at any one site. Therefore, the shape of the upper tail is determined by combining data from 20 or more snow sites that are similar to the site of

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[8] If the theoretical value of the safety index is β = 3.0, it can be shown by constructing a confidence interval with a binomial distribution that β computed from 10 million Monte Carlo simulations will be within ± 0.03 of the true theoretical value approximately 90% of the time.

interest and fitting a shared tail shape. Appendix 3 gives a detailed explanation of the process for fitting the annual maximum snow load probability distributions at each site.

Ratio of Roof Snow Load to Ground Snow Load

Annual maximum ground snow loads are converted to roof snow loads by a ground to roof conversion factor (*GR*), which represents the ratio of roof snow load to ground snow load.[9] The expected value of *GR* decreases as ground snow load increases, therefore it is a function of the simulated ground snow load ($p_{g,sim}$). *GR* is modeled by a lognormal distribution with median and logarithmic standard deviation described by Equations 2.4 and 2.5, respectively:

$$GR_{Median} = 0.50 * \exp\left(-0.034 * p_{g,sim}\right) + 0.4 \qquad 2.4$$

$$\sigma_{GR} = \min(.007 * p_{g,sim} + 0.1\,, 0.33) \qquad 2.5$$

Equations 2.4 and 2.5 are developed in Appendix 2.

Roof Dead Load Demand

The roof dead load demand is modeled by a normal distribution with a mean value of 1.05 times the design dead load and COV of 0.1. This model is adopted from Ellingwood *et al.* (1982).

2.2.4. Uncertain Capacity Variables

The capacity of the test structure is a product of the steel yield strength and plastic section modulus. The yield strength of the steel is modeled as 1.1 times the nominal yield strength of 50 ksi with a logarithmic standard deviation of 0.09, which is within the range of strength values for rolled steel sections subjected to bending (*e.g.* as reported by a number of sources, Kennedy and Gad Aly 1980, Bartlett *et al.* 2003, Schmidt and Bartlett 2002). The plastic section modulus follows a normal distribution with a mean of 1.05 times the design plastic section modulus and COV of 0.05 (Galambos and Ravindra, 1978; Lind, 1977). The 5 percent increase in section modulus accounts for the average increase in section size that occurs when discrete steel sections are selected (~3 percent) for design and for variability in compact section properties (~2 percent).

2.2.5. Example Reliability Assessments

Sample results for three snow sites, Copper Mountain, Denver-Stapleton, and Yampa, are shown in this section (Figure 2.1 - Figure 2.6). These sites are selected for illustration to demonstrate key differences between mountain sites with high annual snowfall, non-mountain sites with sporadic snow fall, and intermediate snowfall sites. At high altitude mountain sites like Copper Mountain[10], where the altitude is 10,550 ft., it is common for the reliability-targeted ground snow load (*i.e.,* the design ground snow to achieve β=3) to be on the order of 10 percent lower than the 50 year ground snow load (Figure 2.1). For lower altitude non-mountain sites, such as Denver-Stapleton, it is common that the reliability-targeted design ground snow load is on the order of

[9] For statistical analysis, we use our best estimate for the ground to roof conversion, which should not be confused with the ground to roof conversion factor of 0.7 that is used for the design step.
[10] Note that the Copper Mountain altitude that is cited here is for the recording station on the slope of the mountain and not at the population center that is reported in Table 1.1.

75 percent higher than the 50-year ground snow load (Figure 2.3). Yampa is an example of a snow site where the reliability-targeted ground snow load and the 50-year ground snow load are approximately equivalent (Figure 2.5).

The reason that mountain sites such as Copper Mountain tend to have reliability-targeted loads that are lower than their 50-year loads is because the distribution of annual maximum snow loads have relatively light upper tails (*e.g.* Figure 2.2); this means that loads significantly larger than their 50-year load are extremely rare, so the 50-year load times the 1.6 factor is too conservative for design. For example, the 50-year load for the Copper Mountain site is 110 psf and the logarithmic standard deviation that describes the tail of the distribution is approximately 0.20; therefore, an ultimate design load of 1.6 times the 50-year load (176 psf) has a mean recurrence interval of approximately 146,000 years, which is extremely rare.. A design ground snow load of 98 psf, 11 percent lower than the 50-year load, results in β=3 at the Copper Mountain snow site. The new design point (1.6 times 98 psf = 157 psf) has a mean recurrence interval of approximately 13,000 years.

The opposite is true for sites like Denver-Stapleton. High variability of annual maximum snow loads at these sites results in heavy-tailed ground snow load distributions (*e.g.* Figure 2.4), which means that loads significantly higher than the 50-year load are much less rare at these sites. For example, the 50-year load at Denver-Stapleton is approximately 20 psf and the logarithmic standard deviation that describes the upper tail shape of the distribution is 0.75. A design point of 1.6 times the 50-year load (32 psf) has a mean recurrence interval of 265 years and has actually been observed in Denver within the last 100 years. A design point with such a short mean recurrence interval is inadequate for the desired structural safety, which is why design ground snow loads at heavy-tailed snow sites need to be significantly larger than their 50-year values. A design ground snow load of 34 psf, 70 percent higher than the 50-year load, results in β=3 at the Denver-Stapleton snow site. The new design point (1.6 times 34 psf = 54 psf) has a mean recurrence interval of approximately 2,700 years. This design ground snow load results in a design flat roof snow load of 25 psf, which is consistent with local practice.

A third location, Yampa (Figure 2.5 and Figure 2.6), is an example of a site whose annual maximum ground snow load distribution has a shape that is consistent with the assumptions for determining the *ASCE 7* snow load factor of 1.6 for factoring 50-year snow loads. As seen in Figure 2.5, the design ground snow load that leads to β=3.0 is 46 psf, which is very near the 50-year load of 47 psf. The design point (1.6 x 46 = 74 psf) has a mean recurrence interval of approximately 6,700 years.

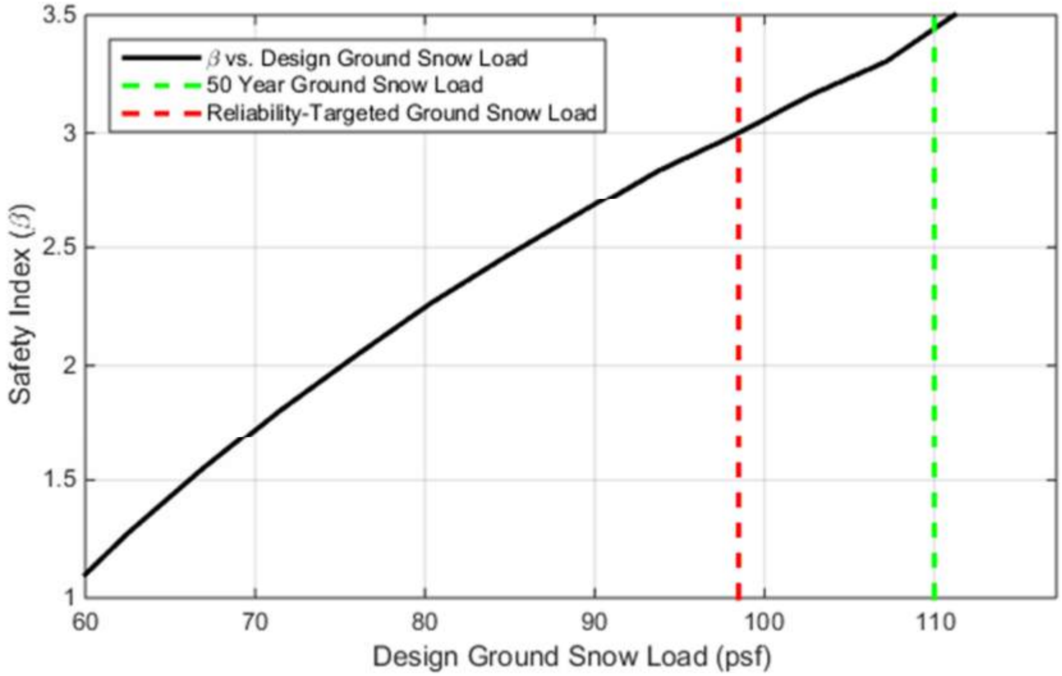

Figure 2.1. Reliability analysis results for the Copper Mountain snow site (altitude=10550 ft.). The reliability-targeted design ground snow load is approximately 98 psf, which is 11 percent lower than the 50-year load of approximately 110 psf.

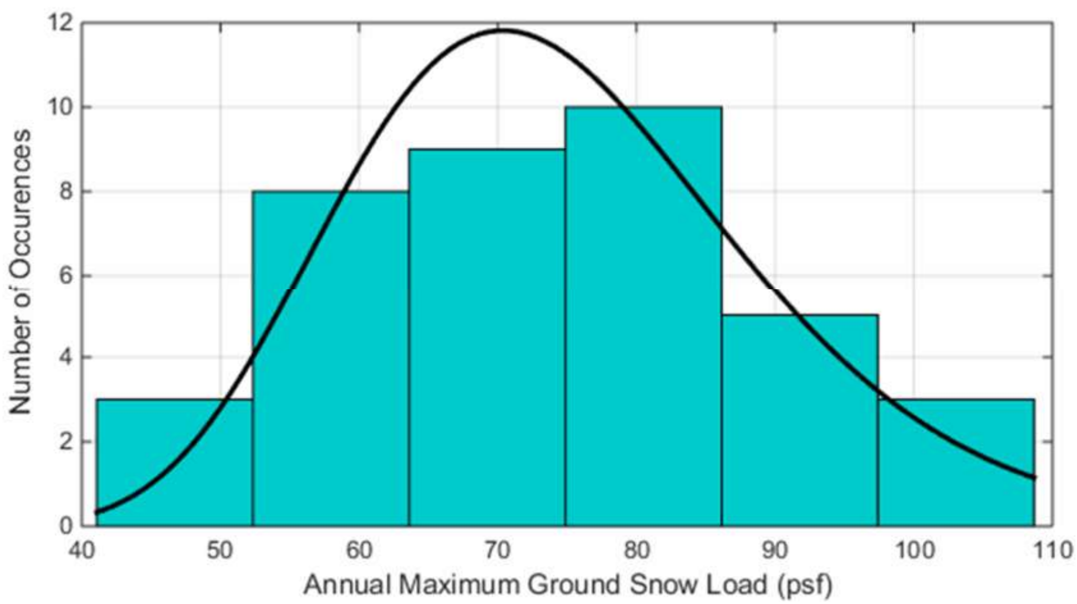

Figure 2.2. Histogram of historical maximum annual ground snow loads at the Copper Mountain snow site (altitude=10550 ft.). The fitted Lognormal Probability Density Function scaled to match the scale of the histogram is overlain. The parameters of the distribution are: median=73 psf and logarithmic standard deviation=0.20.

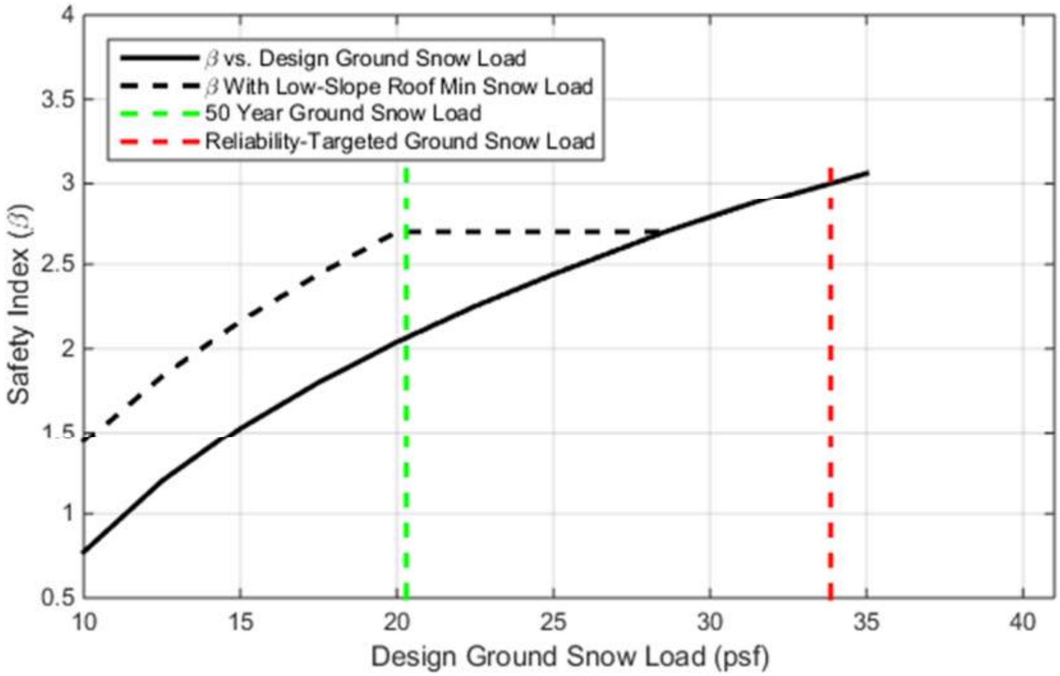

Figure 2.3. Reliability analysis results for the Denver-Stapleton snow site (altitude=5290 ft.). The reliability-targeted design ground snow load is approximately 34 psf, which is 70 percent higher than the 50-year load of approximately 20 psf.

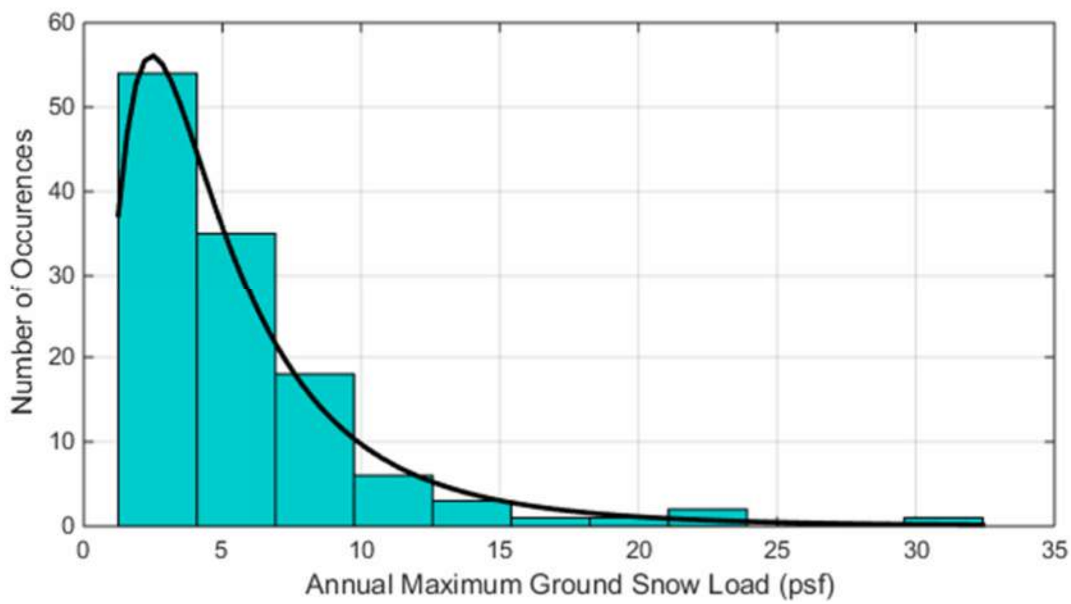

Figure 2.4. Histogram of maximum annual historical ground snow loads at the Denver-Stapleton snow site (altitude=5290 ft.). The fitted Lognormal Probability Density Function scaled to match the scale of the histogram is overlain. The parameters of the distribution are: median=4.3 psf and logarithmic standard deviation=0.75.

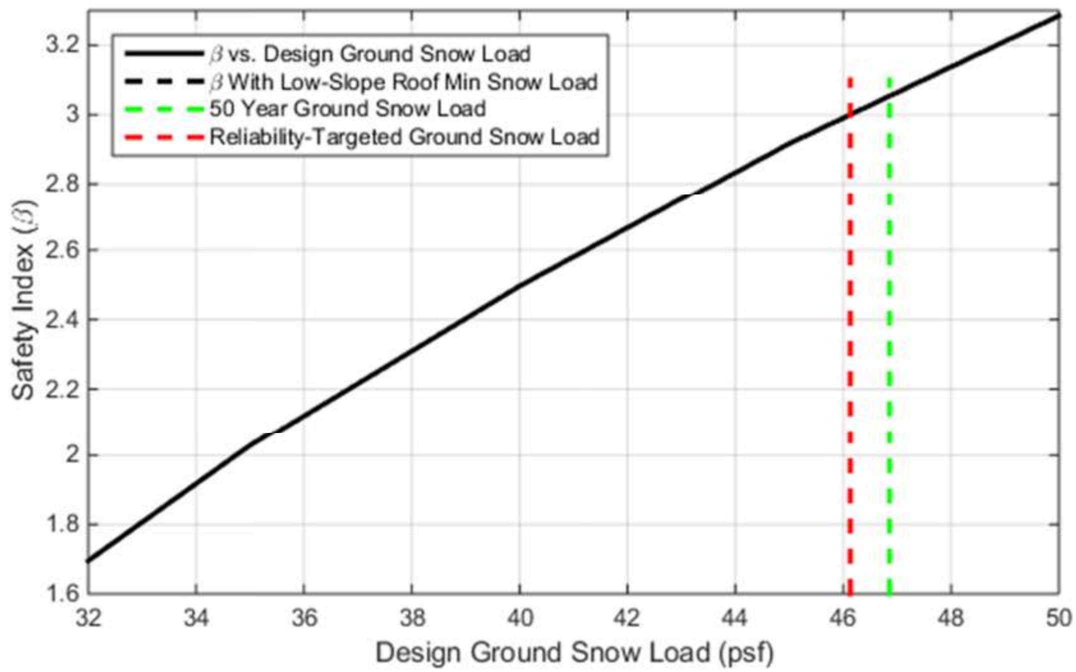

Figure 2.5. Reliability analysis results for the Yampa snow site (altitude=7860 ft.). The reliability-targeted design ground snow of 46 psf is very similar to the 50-year load of approximately 47 psf.

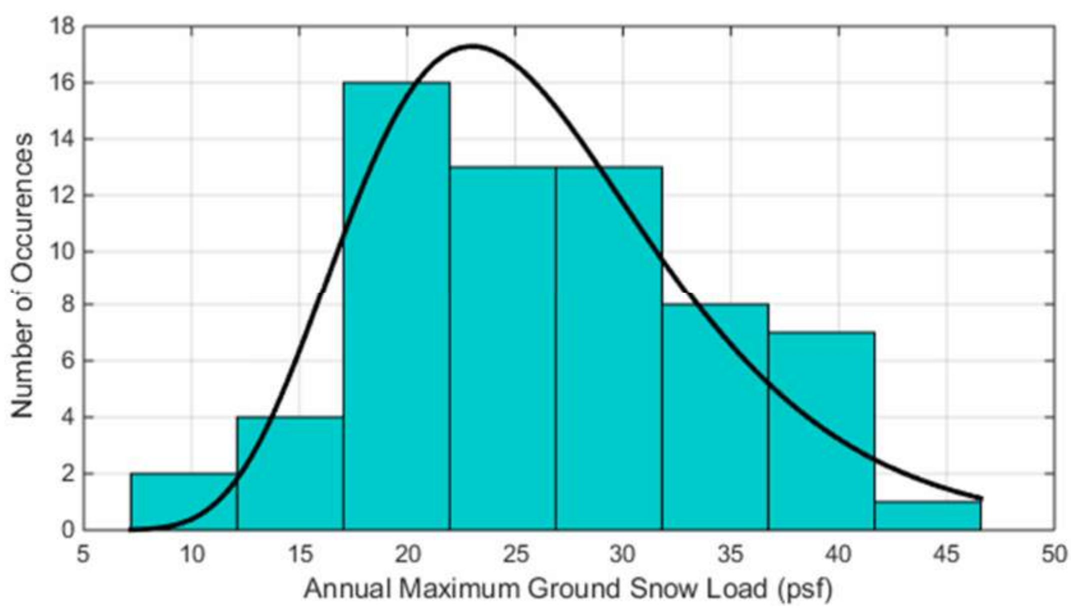

Figure 2.6. Histogram of historical maximum annual ground snow loads at the Yampa snow site (altitude=7860 ft.). The fitted Lognormal Probability Density Function scaled to match the scale of the histogram is overlain. The parameters of the distribution are: median=25 psf and logarithmic standard deviation=0.30.

2.3. Mapping Reliability-Targeted Ground Snow Loads

2.3.1. Overview

Reliability-targeted design ground snow loads for the state of Colorado are communicated via a map and accompanying set of equations (see Section 1.2.2). The proposed map and equations are intended to be used in conjunction with *ASCE 7*. Use of the map and equations requires knowledge of the location (latitude and longitude) and altitude of a potential building site.

The eastern portion of the state sees little change in design ground snow loads with location. Therefore, the discussion in this section mostly focuses on the remainder of the state where altitude and snow loading are both highly variable.

West of the 6500 ft. altitude contour on the eastern slope of the Rockies, a parameter K is mapped. The parameter K is combined with altitude to compute the design ground snow load,

$$p_g = max\left[\frac{K}{100} * A^3, MIN\right] \qquad 2.6,$$

where p_g is the design ground snow load at a building location in psf, A is altitude in thousands of feet, K is a parameter determined from the proposed map, and MIN is 50 psf on the eastern slope of the Rockies and 25 psf elsewhere. Mapped values of K provide a cleaner, simpler map than if we mapped p_g directly, due to big changes in altitude in some parts of the state. Equation 2.6 applies at altitudes below 11,500 ft. wherever values of K are given on the map. Areas above 11,500 ft. require expert judgment and/or site-specific analysis to determine their ground snow loads, as described in Section 1.2.3.

2.3.2. Importance of Correlations of Snow Loads with Altitude

Correlations of design ground snow loads with altitude are a vital part of the mapping process, because they provide a means for estimating snow loading at locations between snow sites where historical snow data are available. This section illustrates by example that a contour map of design ground snow loads is susceptible to severe misrepresentations of snow loading at intermediate locations if it does not account for their altitudes.

Consider the two-dimensional graphic of an example region in Figure 2.7. The reliability-targeted snow loads at the snow sites with data available (blue triangles) are 30 psf, 80 psf, and 40 psf, from left to right. Suppose that one is interested in determining the design ground snow loads at the intermediate sites marked by the two red stars. A contour map constructed from the calculated design ground snow loads would interpolate between the known points, predicting design ground snow loads of 55 psf and 60 psf at the base of the mountain and the top of the mountain, respectively. Both of those estimations are inaccurate. The most obvious problem in this example is that the site at the top of the mountain (9500 ft. altitude) would have a ground snow load 25 percent lower than the site that is part way up the mountain (8300 ft. altitude). Therefore, the option of generating a state-wide contour map of design ground snow loads from the 327 discrete snow sites, without explicitly accounting for altitude, is ruled out.

Now let us reconsider the same two intermediate sites in Figure 2.7, but account for their altitudes. Using the proposed mapping approach, one can determine that the value of the parameter K in Equation 2.6 is approximately 14 for the example region. This K value is based on the neighboring snow sites where snow data are available (blue triangles). Substituting the altitudes of the two intermediate sites into Equation 2.6 produces design ground snow loads of 32 psf at the base of the mountain and 120 psf at the top. This is expected to be a more accurate representation of the ground snow loading at the intermediate sites, because it follows a trend that is observed at sites where data are available, *i.e.* design ground snow loads at sites in the same general area are approximately proportional to altitude cubed. Therefore, mapping the parameter K for Equation 2.6 is a more effective method for determining ground snow loads than contours of ground snow loads that simply interpolate the load between snow sites.

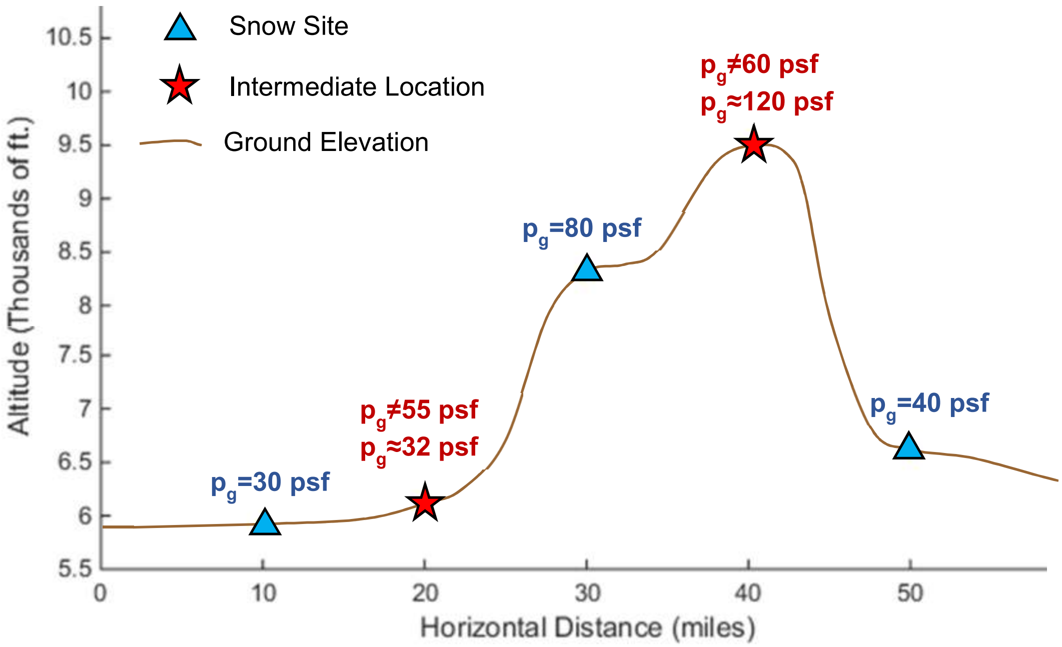

Figure 2.7. Two dimensional elevation view of three snow sites (blue triangles) and two intermediate sites (red stars). Design ground snow loads (p_g) at the intermediate sites are estimated by interpolation between the snow sites with and without consideration of their altitudes. Estimates not accounting for altitude are p_g≠XX psf, and estimates that account for altitude are p_g≈XX psf.

2.3.3. Correlations of Snow Loads with Altitude

The proposed map takes advantage of correlations between design snow loads and altitude. The form of Equation 2.6, which relates altitude to design snow loads at locations west of the plains through the parameter K was determined through a sensitivity study. This sensitivity study divided the state into a number of sub-regions, showing that variations in reliability-targeted ground snow loads at sites near to each other are approximately proportional to altitude cubed. As an example, altitudes and reliability-targeted ground snow loads for sites from two sub-regions in Southwestern Colorado are shown in Figure 2.8. The best-fit power curves show that reliability-targeted loads are proportional to altitude to the powers 3.0 and 3.3, respectively. For simplicity, the mapping equation (Equation 2.6) assumes that design snow loads vary with altitude cubed (a power of 3.0) throughout the state, so that only one parameter, *i.e.* K, needs to be mapped.

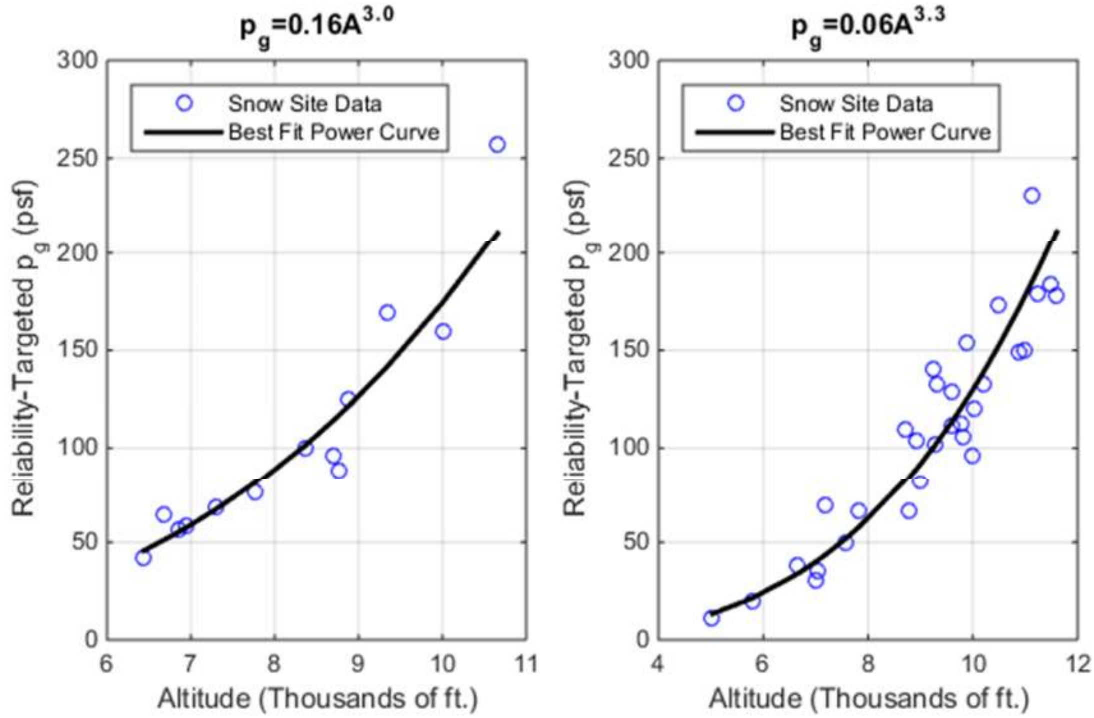

Figure 2.8. Reliability-targeted design ground snow loads for two example sub-regions that are located in the western portion of the state (left) and the southwestern portion of the state (right).

2.3.4. Methods for Mapping the Parameter *K*

The proposed map provides values of *K* to be used throughout much of the state. Contours of the parameter *K* are mapped in Surfer (Golden Software 2015) using a method called, "inverse distance to power." The mapping process is performed by completing the following steps:

1) Compute the theoretical value of the map parameter *K* at each snow site (327 locations) by rearranging Equation 2.6 and plugging in the altitude and reliability-targeted design ground snow load.
2) Establish "Fault Lines," which are lines of allowed discontinuity in the contour plot, using expert judgment and local knowledge. These are mostly at mountain ridges that separate areas with different snow accumulation patterns.
3) Establish a grid of approximately 50,000 points across the state, located at approximately 1.5 mile intervals, which provide the basis for the map.
4) For a grid point of interest, Surfer searches for the nearest 12 neighboring snow sites without crossing fault lines.
5) A weighted average of the parameter *K* is computed for the grid point from the identified 12 neighboring snow sites. The contribution of each snow site to the weighted average is inversely proportional to its distance from the point of interest to the power 2.0.
6) Steps 4 and 5 are repeated for every grid point in the state of Colorado and contours of *K* are interpolated from the values at the grid points.

2.3.5. Expert Judgment

The final stage of the mapping process is to refine the map by expert judgment. Primarily, this involves: (1) manually smoothing the contours of the parameter K where knowledge of the local climate and geography indicate that it should have little fluctuation, and (2) allowing the values of K to fluctuate more than the mapping algorithm originally allowed in regions where snow loads are known to fluctuate significantly across a small distance. The final refinements of the map have little influence on its predictions of design ground snow loads at the majority of the snow sites. However, notable changes in the contours due to manual edits do occur in a few places. In regions near Aspen and Vail, manual edits increase the mapped values by approximately 15 percent to bring the load that the map predicts up to a value that is comparable to the reliability assessment for those towns. This occurs because other nearby sites have less snow, so the original smoothing of the map forced Vail and Aspen snow load values lower than they should be.

2.3.6. Evaluation of the Proposed Snow Map

The snow map is evaluated by comparing the map predictions of design ground snow loads to those computed directly by the reliability analysis. Figure 2.9 shows these comparisons, broken down by general regions of the state (for specific information about the four general regions, refer to Figure A3.15 in Appendix 3). For each region, design ground snow loads from the map are plotted against the design ground snow loads that are computed with reliability analysis. Data points above the 45 degree lines (blue lines) are conservative, because the load from the map is higher than the load computed from reliability analysis. Data points below the 45 degree lines are non-conservative, because the load from the map is lower than the computed load. The scatter in the plots reveals that a significant amount of aleatory uncertainty (noise) is smoothed out by the mapping process. In other words, sites with unusually large loads tend to have mapped loads lower than their loads from the reliability analysis, and vice versa for snow sites where no large snow loads have been observed.

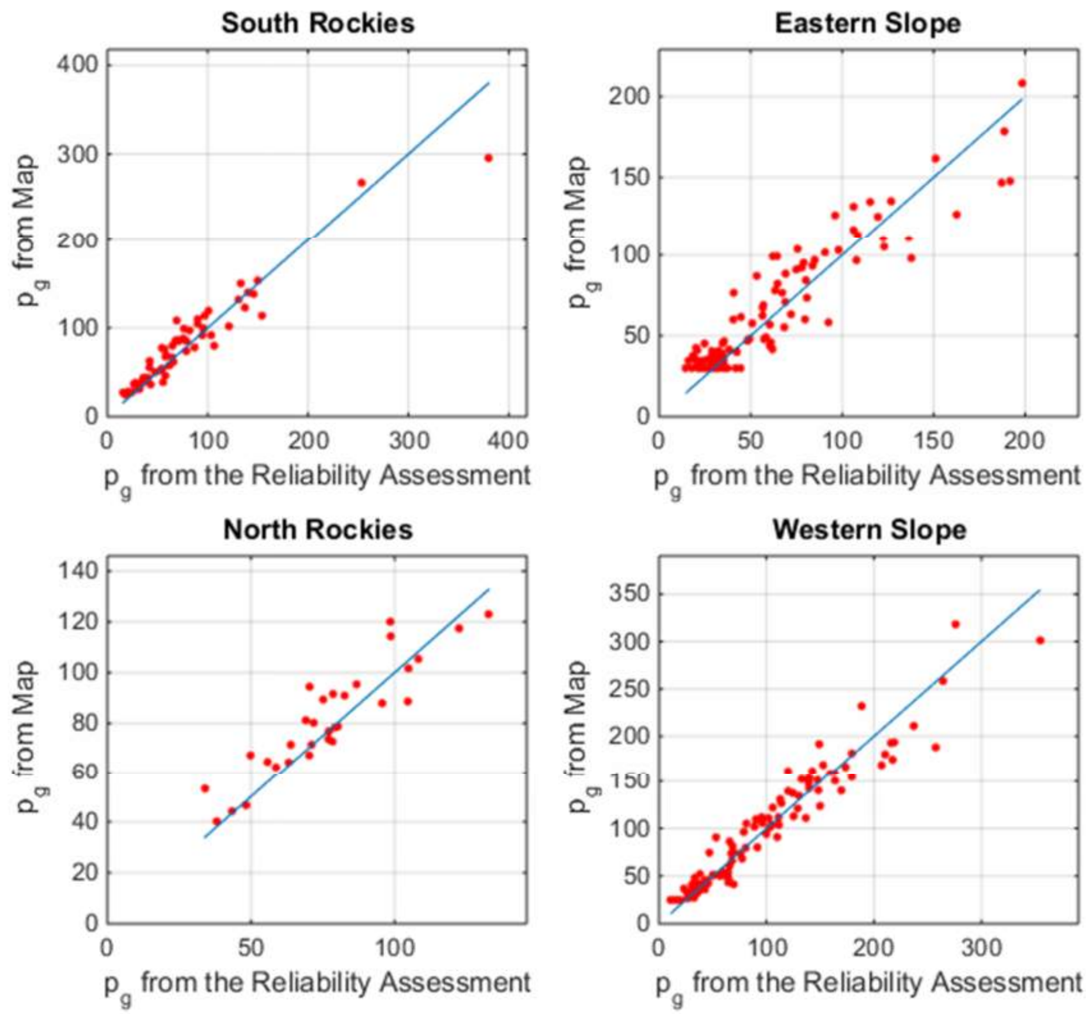

Figure 2.9. Design ground snow loads from the map, plotted against design ground snow loads that are computed directly from reliability analysis for the four main regions of the state of Colorado. Each plot has a blue 45 degree line to indicate what a perfect match would be.

2.4. Comparisons of 2015 Recommended Loads with Previous Provisions

2.4.1. Comparison of Reliability-Targeted Design Ground Snow Loads to 50-year Ground Snow Loads

The differences between the reliability-targeted ground snow loads and the 50-year ground snow loads for the 327 snow sites that are used in this study are expressed as a ratio in Figure 2.10. The reliability-targeted loads are approximately equal to the 50-year loads at sites located at 8000-8500 ft. altitude. At lower altitude sites, where distributions of annual maximum snow loads are heavily skewed and tend to have heavy upper tails, the reliability-targeted design ground snow loads are larger than the 50-year loads. The typical ratio of reliability-targeted loads to 50-year loads increases from approximately 1.0 to 2.0 as altitude decreases from 8000 ft. to

3500 ft.[11] At mountainous sites above 8500 ft. altitude, the reliability-targeted ground snow loads are approximately 90 percent of the 50-year loads.

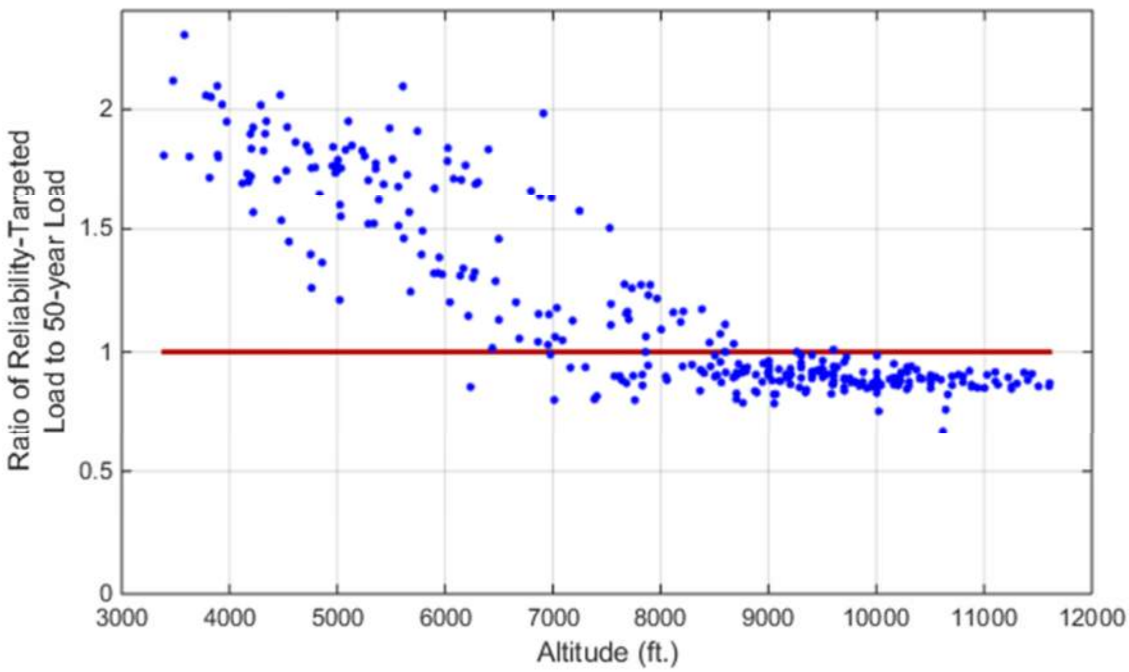

Figure 2.10. Ratio of the computed reliability-targeted design ground snow load (for β=3) to the 50-year ground snow load at the 327 snow sites in Colorado.

2.4.2. Comparison with Prior SEAC Recommendations

SEAC has recommended design snow loads twice before: SEAC (1971) and SEAC (2007). A comparison of the 297 tabulated locations are provided in Appendix 6. Additionally, comparisons of mapped and tabulated loads are shown for 17 example locations in Table 2.1. The basis of the 1971 recommendations was a 30-year roof load. Since the 1971 version gives roof loads directly, they are divided by a ground-to-roof conversion factor of 0.7 to be comparable to design ground snow loads that are used with modern editions of *ASCE 7.* The basis of the 2007 edition was 50-year ground snow loads.

In addition to a having a different basis for determining design snow loading, the two older editions of the SEAC snow load recommendations utilize different methods of mapping those loads. The 2007 snow load map shows contours of design ground snow loads, but it does not do any spatial smoothing of those loads before generating the contours, nor does it fully account for altitude. The 1971 version maps a parameter that must be combined with a site's altitude to compute the design snow load. This approach is similar to the proposed mapping method that is

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[11] This indicates that a large number of snow-induced failures should have been observed on the plains over the course of the last century. That is not the case, however, because it has been common practice to design for roof snow loads of 20 psf – 30 psf on the plains, despite the 50-year load being much lower.

used in the 2015 recommendations, except that the parameter is determined by region rather than from a contour map.

Lastly, more data are available now than were available at the time that previous editions of the SEAC snow map were produced. However, we note that differences due to increases in available data are less significant than the differences that are due to changes in the basis for computing the design snow load values and the methods by which they are mapped.

General conclusions about the differences in recommended design snow loads between the three editions of the snow map are made by comparing example design ground snow load values in Table 2.1. The 2015 map tends to provide loads that are slightly lower than the 1971 map at most locations. It also recommends loads that are lower than the 2007 map at high altitude locations, but the loads are higher than the 2007 map at low altitude locations.

In addition to producing reliability-targeted design snow loads instead of hazard-targeted design snow loads, a significant advantage of the 2015 snow load map over the 2007 map is its capability to predict snow loading at locations where recorded snow data are not available, as discussed in Section 2.3.2. Consider, for example, the cases of Carbondale and Colorado Springs in Table 2.1. Carbondale and Colorado Springs are both similar to the hypothetical example site at the foot of the mountain in Figure 2.7. Carbondale is situated between the Glenwood Springs snow site (similar in altitude) and the Aspen snow site (much higher altitude). Colorado Springs is situated between the Colorado Springs Municipal Airport snow site (similar altitude) and the Ruxton Park snow site (much higher altitude). The 2007 snow load map assigned snow loads at Carbondale and Colorado Springs that are between the snow loads at their neighboring sites, even though they should actually be nearly the same as the neighboring snow site that has similar altitude. As a result, the 2007 map overestimated the Carbondale and Colorado Springs snow loads by about 40 psf, because the snow loads are interpolated between neighboring snow sites without fully accounting for their altitudes. In the case of Colorado Springs, the 2007 map shows that the load increases from 20 psf at the airport to 70 psf at downtown over a distance of only six miles with less than 300 ft. of altitude gain. The 2015 edition of the SEAC snow map significantly reduces this source of mapping error.

Table 2.1 Design ground snow loads (p_g) at 17 example locations in Colorado

City/Town	*Lat. (deg.)*	*Lon. (deg.)*	*Alt. (ft.)*	*1971 Map (Converted to p_g)*	*1971 Tabulated (Converted to p_g)*	*2007 Map*	*2007 Tabulated*	*2015 Map*	*2015 Tabulated*
Aspen	39.19	-106.82	7890	99	107	105	105	75	75
Boulder	40.01	-105.27	5330	45	43	28	25	38	40
Carbondale	39.40	-107.21	6170	50	57	90	90	49	50
Colorado Springs (downtown)	38.83	-104.82	6010	46	43	70	20	45	45
Colorado Springs Municipal Airport	38.81	-104.68	6150	48	NA	20	20	46	NA

City/Town	Lat. (deg.)	Lon. (deg.)	Alt. (ft.)	1971 Map (Converted to p_g)	1971 Tabulated (Converted to p_g)	2007 Map	2007 Tabulated	2015 Map	2015 Tabulated
Cripple Creek	38.75	-105.18	9490	69	57	35	35	72	70
Denver	39.74	-104.98	5280	44	43	20	30	38	35
Estes Park	40.43	-105.52	7520	52	57	50	45	59	65
Fort Collins	40.59	-105.08	5000	37	43	20	20	35	35
Glenwood Springs	39.55	-107.32	5760	55	57	30	30	43	40
Lamar	38.09	-102.62	3620	29	29	25	30	30	30
Rangely	40.09	-108.80	5230	30	29	20	20	32	35
Silverton	37.81	-107.66	9310	125	129	150	140	112	105
Snowmass Village	39.21	-106.94	8210	110	NA	165	165	87	90
Steamboat Springs	40.48	-106.83	6730	107	107	100	100	75	85
Vail	39.64	-106.37	8190	109	107	170	145	84	90
Vail Mid-Mountain	39.61	-106.37	10300	197	NA	210	210	170	175

*Where the tabulated load for the 2007 edition differs from the map load, the tabulated load is listed second.

2.5. Conclusions

For the first time, a map of reliability-consistent design ground snow loads has been developed for the state of Colorado. The development of this map was in response to a recognition that the current LRFD design load factor for snow loads (i.e. 1.6), when applied to a ground snow load that has a 50-year mean recurrence interval, does not lead to consistent safety against snow-induced collapse across the state of Colorado. The committee believes that inconsistent reliability is not a Colorado-specific issue, and this study is an example of one solution to that problem.

The new reliability-targeted design ground snow loads target a safety index of β=3.0, which is the stated safety objective of the *ASCE 7* for relatively benign structural failures in ordinary Risk Category buildings (Risk Category II). The new loads are on the order of 50 to 100 percent larger than the 50-year loads in the plains and approximately 10 percent lower than the 50-year loads at high elevation locations. Although the increases of design ground snow loads for the plains seem large, they result in roof snow loads that are consistent with current and historic design practice in that portion of the state, which is to design roofs for 20 to 30 psf of snow load.

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Appendix 1. Development of Conversions between Snow Depth and Snow Weight

A1.1. Introduction

Direct measurements of snow weight, reported in the form of snow water equivalent, are used for determining annual maximum snow weights whenever possible. However, the majority of NWS stations do not report snow weight measurements, so weight must be estimated from depth. This appendix describes the process for obtaining the relationships between annual maximum snow depth and annual maximum snow weight that are used to estimate annual maximum ground snow loads at NWS stations for the state of Colorado.

A1.2. Compacted Snow and Settled Snow

For the purpose of developing depth-to-weight relationships for ground snow in Colorado, snow is classified as “compacted” or “settled” (SEAC 2007). Compacted snow generally occurs at mountain sites and is a result of multi-storm accumulation (*i.e.* the snow does not melt off completely between snow storms). Compacted snow tends to be relatively dense, due to multiple layers of snow from a series of snowstorms condensing the snow layers beneath them over time. Sites with altitude greater than 8500 ft. are considered to be compacted snow sites in this study. The 8500 ft. criterion for compacted snow is based on the judgment of the SEAC Snow Load Committee and is grounded in the observation that most Snow Course stations (*i.e.* stations intended to gauge winter snow pack for estimating spring run-off and therefore located where season-long accumulation is expected to occur) are located at altitudes of 8500 ft. and higher.

Settled snow sites are at lower altitudes and are characterized by ground snow that tends to melt off between snowstorms. The annual maximum snow loads at settled snow sites are often the result of only one storm and snow at these sites is generally less dense because there is less time for it to consolidate. This study considers settled snow sites in the state of Colorado to be those located east of the Rocky Mountains with altitude less than 6500 ft. and those located in or west of the Rocky Mountains with altitude less than 5500 ft. The criteria for settled snow sites are based on the judgment and experience of the SEAC Snow Load Committee. The upper limit altitude for settled snow sites is lower in the Rocky Mountains and western portion of Colorado than in the eastern part of the state, because snow in mountain valleys tends to persist longer without melting than snow in the eastern portion of the state at similar altitudes.

Separate depth-to-weight relationships are employed for compacted and settled snow sites, because compacted snow is generally denser than settled snow. There is also a large portion of the state of Colorado that does not meet the criteria for compacted or settled snow; snow sites in these areas are termed “intermediate” snow sites. This study considers intermediate snow sites as a hybrid combination of settled and compacted snow. Conversions of snow depth to snow weight for the three snow types (compacted, settled, and intermediate) are presented in the sections that follow.

A1.3. Compacted Snow Sites

To examine the relationship between snow depth and weight at compacted snow sites, annual maximum snow depth and annual maximum snow weight data from all Snow Course sites are plotted on Figure A1.1; only years for which depth and weight data are both available are used.

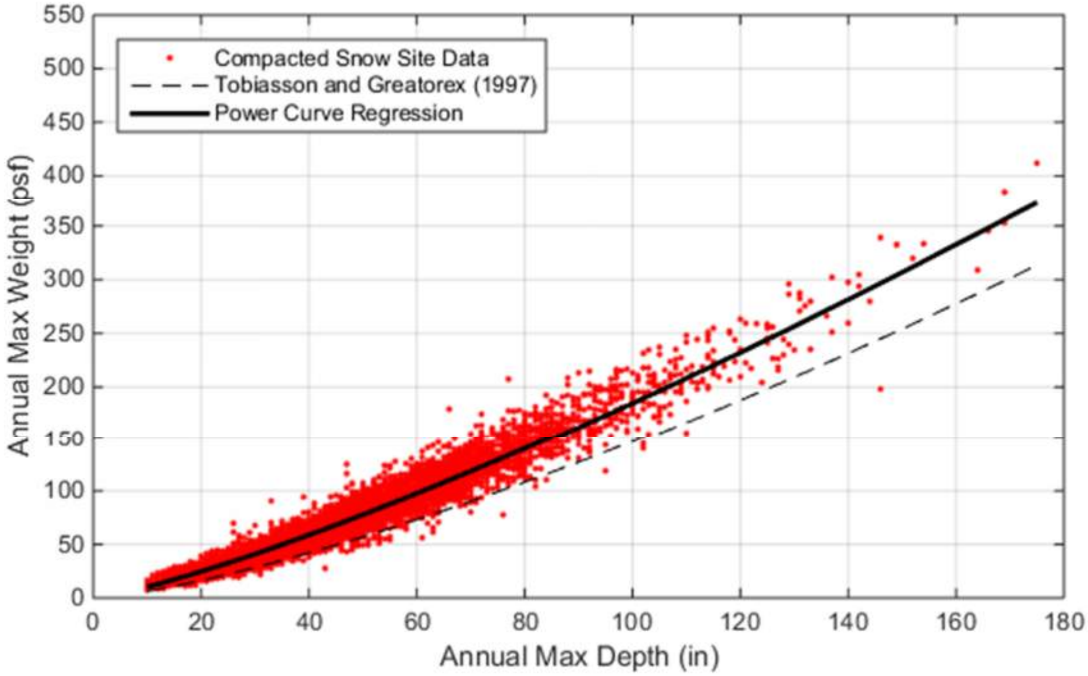

Figure A1.1 Annual maximum snow weight vs. annual maximum snow depth for compacted snow sites in the state of Colorado.

Two possible depth-to-weight relationships are shown on Figure A1.1: (1) a power curve developed by Tobiason and Greatorex (1997), and (2) a power curve fitted to the Colorado specific data. The Tobiasson and Greatorex (1997) relationship and the power curve fitted to the Colorado snow course data are described by Equations A1.1 and A1.2, respectively.

$$w = 0.279 * d^{1.36} \quad \text{A1.1}$$

$$w = 0.584 * d^{1.25} \quad \text{A1.2}$$

where w is snow weight or load in psf and d is snow depth in inches.

Examination of Figure A1.1 shows that the power curve that is fitted specifically to the Colorado compacted snow data predicts snow weight better than the Tobiasson and Greatorex relationship, which underestimates density at compacted snow sites. This is reasonable because their relationship was not developed for high altitude sites where compacted snow conditions are expected. Therefore, annual maximum depth data are converted to annual maximum weights by Equation A1.2 at compacted snow sites where only snow depth data are available.

A1.4. Settled Snow Sites

An analysis of settled snow sites is shown in Figure A1.2. There are fewer stations at settled snow sites that report both depth and weight data, so the data set for fitting a Colorado-specific depth-to-weight relationship for settled snow is small in comparison to the data set available for fitting a compacted snow relationship (125 data points vs. 6,524 data points, respectively).

Visual inspection of Figure A1.2 reveals that a power curve relationship fitted to Colorado data is very similar to the Tobiasson and Greatorex (1997) relationship up to a snow depth of about 12 inches. Beyond 12 inches, there is very little data available to calibrate a Colorado-specific relationship. We note that the Tobiasson and Greatorex (1997) equation was fitted to data from first order NWS stations across the United States, many of which are be expected to be settled snow sites. Therefore, since the Tobiasson and Greatorex relationship fits the Colorado settled snow data well at depths below 12 inches (where significant data are available), it is not unreasonable to assume that it also predicts the depth-to-weight relationship at depths greater than 12 inches as well[12]. Therefore, the Tobiasson and Greatorex (1997) equation (Equation A1.1) is selected for use at settled snow sites.

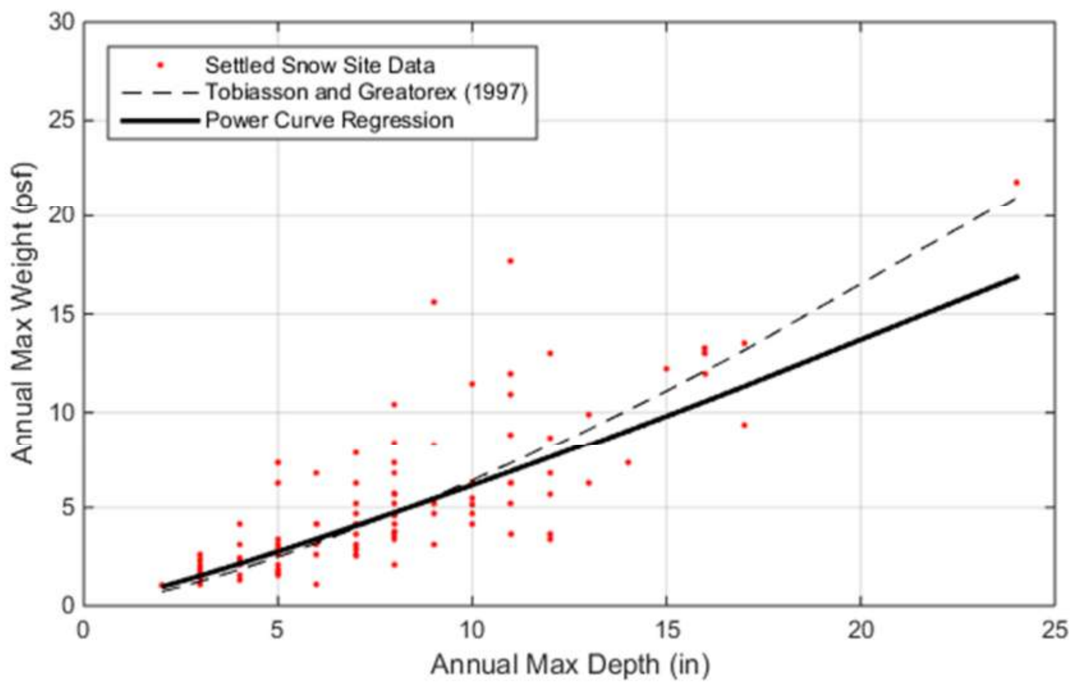

Figure A1.2 Annual maximum snow weight vs. annual maximum snow depth for settled snow sites in the state of Colorado.

A1.5. Intermediate Snow Sites

Intermediate snow sites are those that are neither classified as compacted or settled. There is insufficient data from stations at altitudes between 6500 ft. and 8500 ft. in the state of Colorado that report both depth and weight to fit a model to intermediate site data directly.

As an alternative, the depth-to-weight conversion at intermediate snow sites is computed by linearly interpolating (based on altitude) between the compacted and settled depth-to-weight conversions. Given the absence of data in the state of Colorado to either reject or verify an

[12] A fundamental difference, however, is that the Tobiasson and Greatorex relationship was fitted to 50-year maxima of snow depth and weight, rather than annual maxima. This difference does not appear to bias the predictions for Colorado settled snow data.

approach for determining snow weights at intermediate snow sites, the SEAC Snow Load Committee considers the interpolation approach to be a rational solution for those locations.

A1.6. Treatment of Uncertainty/Variability in the Depth-to-Weight Conversions

The depth-to-weight conversions are uncertain, as evidenced by the scatter of the recorded data points about the theoretical relationships in Figure A1.1 and Figure A1.2. Therefore, statistical analyses were performed to determine if and how to deal with the additional uncertainty that comes from having depth rather than weight data at some sites. These analyses led to a conclusion that unbiased estimations of the annual maximum ground snow load distribution shapes, and ultimately the safety index beta, are possible when annual maximum snow depths are converted directly to weight without consideration of the additional variability of the depth-to-weight conversions.

The analyses conducted to investigate the variability in the depth-to-weight conversions are presented in Figure A1.3. Figure A1.3 compares statistics of annual maximum weight data that are computed from two kinds of weight data: (1) weights computed indirectly from depth measurements by depth-to-weight conversions (*i.e.* “converted” weight data) and (2) weight data that are measured. For this comparison, only the 133 snow sites having both depth and weight recordings are used. For each site, the ratio of four statistics that describe the annual maximum weights are compared: mean, coefficient of variation, 50-year load (weight), and the design snow load to produce a safety index of 3. On average, the ratio of the statistic computed from converted weight data to that computed from recorded weight data is approximately 1.0, although it varies from site to site as shown in Figure A1.3. First, we observe that our estimates of those statistics are unbiased on average. Since our goal is to produce our best estimates of the design loads that will result in a safety index of 3, annual maximum depth measurements are converted directly to annual maximum weights, without incorporating the uncertainty of the conversions, since this is shown to be an unbiased approach. However, our confidence in the annual maximum weight statistics that are determined from converted weight data is lower than if actual snow weights had been measured. This additional source of uncertainty is not considered in the analysis.

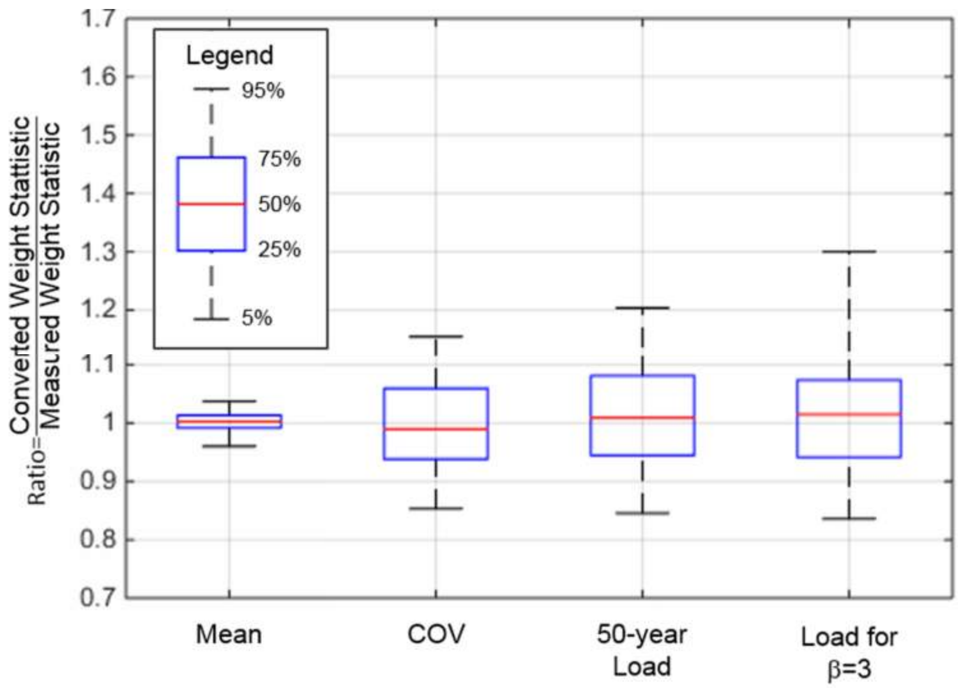

Figure A1.3 Boxplots, showing the 5th, 25th, 50th, 75th, and 95th percentiles of the ratio of statistics computed from converted weights to statistics computed from measured weights, for 133 sites.

A1.7. Works Cited

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Appendix 2. Development of Ground to Roof Weight Conversion for Monte Carlo Simulation

A2.1. Introduction

This appendix describes the development of a probabilistic model to convert ground snow weights to roof snow weights (hereafter referred to as "*GR*"). This is **not** the ground to roof conversion for design (*i.e.* 0.7 in *ASCE 7*-10); it is a ground to roof conversion for computing the reliability of roof structures subjected to given ground snow loads. Therefore, the objective is to develop a mathematical model that computes the expected roof snow load and its variability, given a ground snow load, as accurately and precisely as possible. The resulting roof snow load represents the estimate of the snow load that is on the roof at the time of the annual maximum ground snow load.

Probabilistic models for determining roof snow loads based on ground snow loads have been developed in the past, notably Ellingwood and O'Rourke (1985). Based on the data available at the time, they determined that the ratio of roof snow load to ground snow load (*i.e. GR*) is approximately lognormally distributed with a median of 0.47 and logarithmic standard deviation of 0.42. Additional data has been collected since Ellingwood and O'Rourke published their results in 1985, so this study uses a new data set to make a more refined *GR* model.

A2.2. Roof and Ground Snow Loads Data Set

The data set for constructing the *GR* model (see Figure A2.1) was collected by Høibø (1988, 1989) and reported by Thiis and O'Rourke (2015). The data set consists of approximately 870 simultaneous measurements of balanced roof snow load and ground snow load. The measurements were taken over a span of 20 years (1966 to 1986), primarily for buildings with low-slope (<45°), unheated, rough (not slippery) roofs in southern Norway. This constitutes a larger data set than was previously available, including a wide variation in ground snow loads at which the measurements were made. The data is shown in Figure A2.1. For completeness, the we note that the Thiis and O'Rourke (2015) data represents the ratio of roof snow load to ground snow load occurring at an instant in time, rather than the ratio of annual maximum roof snow load to annual maximum ground snow load, which may not occur simultaneously. Data for comparing the annual maxima is not currently available, so the available data are used with the expectation that differences between the two ratios are relatively small.

As shown in Figure A2.1, there is significant variability in *GR,* but there is also an apparent downward trend such that the *GR* is smaller for higher roof loads. This occurs because large ground snow loads are often the result of snow accumulating over time, and roof snow weight tends to decrease more quickly with time than does ground snow weight, due to factors such as wind removal, melting, and sublimation.

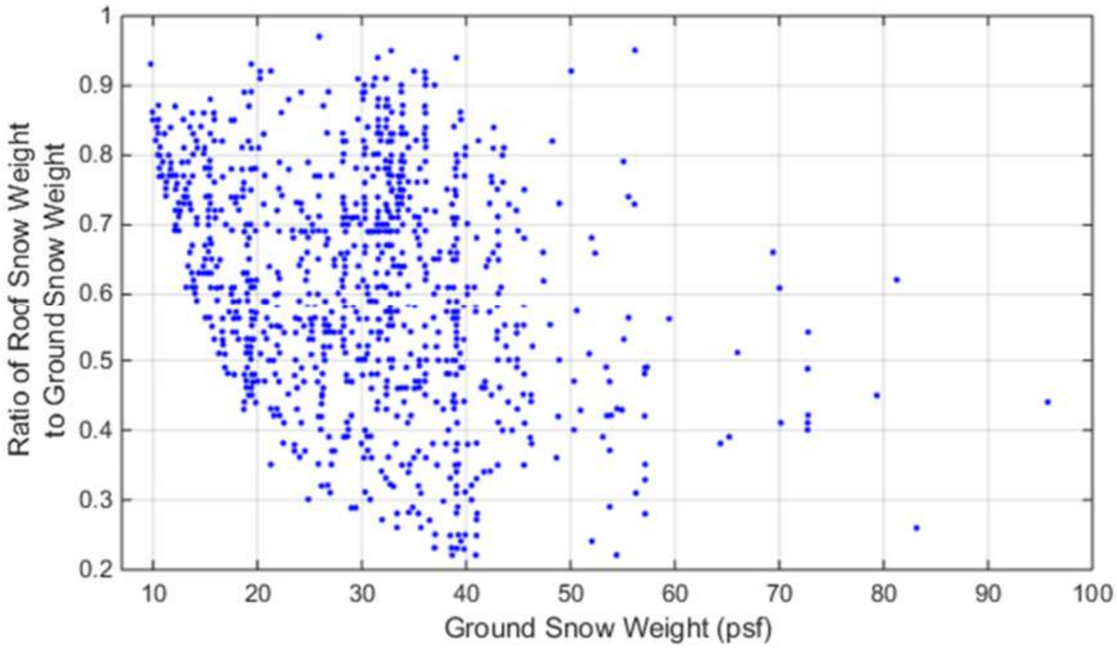

Figure A2.1 Ratios of measured roof load to measured ground snow load. Data collected by Høibø (1988, 1989) and obtained from Thiis and O'Rourke (2015).

A2.3. Fitting the Probabilistic Model

For this report, we fit a new model for *GR* to the data presented in Figure A2.1. Following Ellingwood and O'Rourke (1985), the *GR* is assumed to be lognormally distributed. However, the proposed model also accounts for the downward trend in *GR* as ground snow weight increases (see Figure A2.1).

For use in Monte Carlo simulation analysis, it is ideal that the *GR* model have an analytical form to aid fast simulation of large sets of random variables. However, the nature of the data does not lend itself well to fitting an analytical function directly to it; specifically, it is not homoscedastic and it is not linearized through a simple transformation (*e.g.* a log transformation). Consequently, the *GR* model is fit to the data in two steps: a nonparametric model is fit to the data in step one, and that model is used to inform an analytical model that is developed in step 2.

A2.3.1. Step 1: Non-parametric Characterization of the Ground-to-Roof Snow Weight Conversion

The median and logarithmic standard deviation of *GR* are quantified at 25 different ground snow weights by local polynomial regression (Fan and Gijbels 1996). The results of the local polynomial regression are shown in Figure A2.2. As the ground snow weight increases, *GR* decreases.

The local polynomial regression is a moving weighted regression of the natural log of *GR* vs. ground snow weight. For each of the 25 selected ground snow weights, a weighted linear regression is performed using the closest 20 percent of the data points (distances between data points are measured by the difference in ground snow weight) to determine the median and logarithmic standard deviation of *GR* at each ground snow weight of interest. To investigate the sensitivity of the number of data points used in the local polynomial regression, we repeated the local polynomial regression using the closest 50 percent of the data points rather than 20 percent. There are only very minor changes in the fitted curve, increasing the estimate of logarithmic standard deviation by about 0.01 and producing a smoothing effect on *GR* at snow weights less than 40 psf. These calculations are used to determine the moving median and log standard deviation in Figure A2.2.

A2.3.2. Step 2: Fitting the Analytical Ground-to-Roof Snow Weight Conversion Model

An analytical model of GR is fitted to match the results of the local polynomial regression analysis. The GR model relates the ground snow load to the median *GR* and its logarithmic standard deviation, as shown by Equations A2.1 and A2.2.

$$GR_{Median} = 0.50 * \exp\left(-0.034 * p_g\right) + 0.4 \qquad \text{A2.1}$$

$$\sigma_{GR} = \min(.007 * p_g + 0.1\,, 0.33) \qquad \text{A2.2}$$

where P_g is the ground snow weight in psf and σ_{GR} is the logarithmic standard deviation of *GR*. The analytical *GR* model, plus and minus one logarithmic standard deviation, is shown with solid and dashed black lines in Figure A2.2, and the model for the logarithmic standard deviation of *GR* is also shown in Figure A2.3.

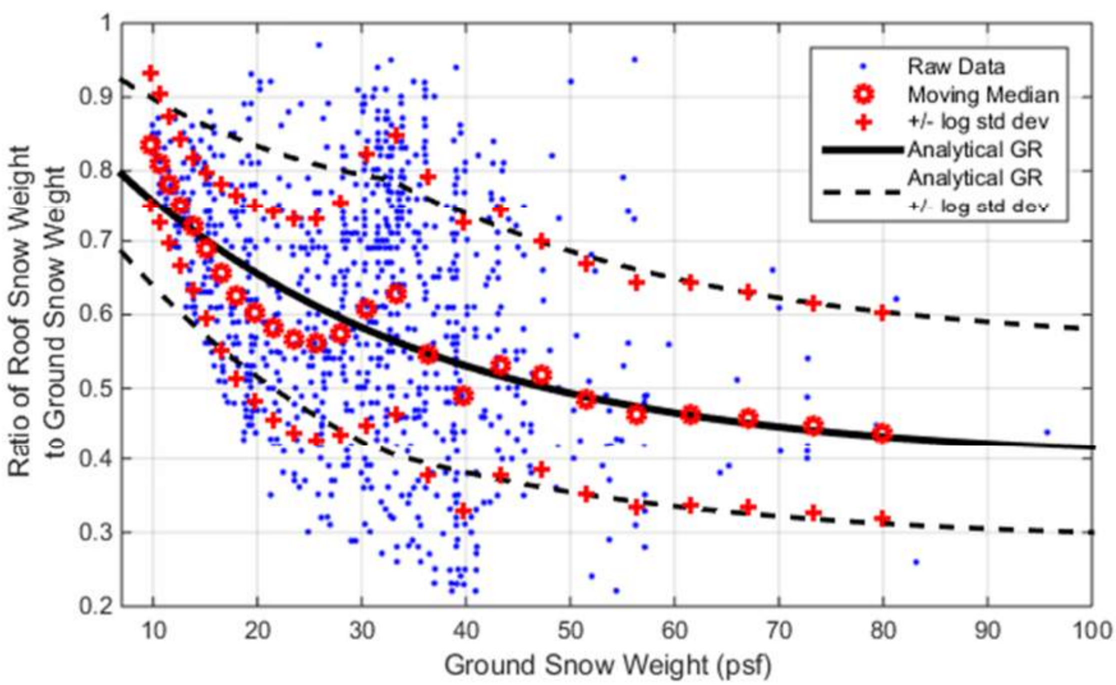

Figure A2.2 Local polynomial (*i.e.* moving median) and analytical approximations of *GR*, with the ratio of roof snow weight to ground snow weight for the recorded data underlain. Raw data was collected by Høibø (1988, 1989) and obtained from Thiis and O'Rourke (2015).

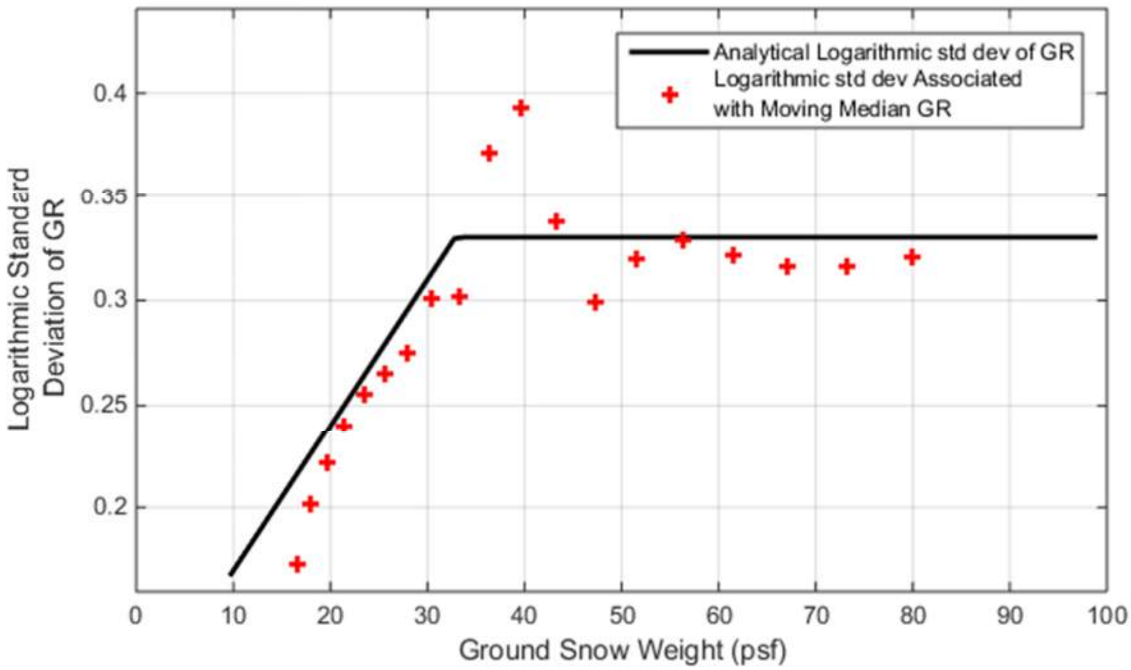

Figure A2.3 Logarithmic standard deviation of *GR* computed by local polynomial regression and by the analytical model.

A2.4. Discussion and Limitations

The analytical model of *GR* closely agrees, on average, with the moving median *GR* (which is estimated with local polynomial regression) for ground snow weights greater than 25 psf. Ground snow weights greater than 25 psf are the primary focus for fitting the *GR* model, because the proposed minimum design ground snow load in Colorado is 25 psf. Since the corresponding LRFD design point for a 25 psf ground snow load is 1.6 x 25 = 40 psf, failures are not are expected to occur when the weight of snow on the ground is less than 25 psf[13]. Deviations of the moving median from the analytical function at ground snow weights greater than 25 psf are due to local fluctuations of the data that the committee believes are random and not systematic; the proposed analytical function smooths those fluctuations. There are, however, three limitations of the GR model that may impact the reliability analysis results.

The first limitation of the *GR* model is that there is insufficient data beyond ground snow weights of approximately 80 psf. Due to a lack of knowledge about *GR* beyond 80 psf, the function that is selected to model *GR* has an asymptote of 0.4, which is nearly reached at a ground snow load of 80 psf. The SEAC Snow Load Committee hypothesizes that the median *GR* should decrease below 0.4 at ground snow weights greater than those in the data set. However, without *GR* data to confirm the hypothesis, we are compelled to constrain the *GR* model to a median value of 0.4

[13] A sensitivity study showed that ground snow loads less than 25 psf would account for approximately 0%-1% of roof failures in buildings designed for ground snow loads of 25 psf, assuming there are no design or construction defects.

or above. This assumption is conservative, since it leads to higher *GRs* than are probably realistic for large ground snow loads.

The second limitation is that the data used to fit the *GR* model was obtained from unheated roofs with slopes up to 45° having a variety of exposures (Thiis and O'Rourke 2015), whereas the reliability analyses in this study that utilize the *GR* model consider only flat roofs with normal thermal conditions and exposure. Since the surfaces of the roofs represented by the data set were primarily rough (non-slippery), it is unlikely that roof slope significantly affects the *GR* data. However, it is highly likely that the recorded *GR*s are biased high (*i.e.* conservative), since the data is mostly coming from unheated roofs, where snow melting occurs more slowly. In addition, we note that the variety of exposure types and thermal conditions increases the scatter of the data. As a result, the logarithmic standard deviation of the *GR* model is most certainly overestimated, which adds to the conservatism of the model. Corrections could be made to the *GR* model to account for roof thermal conditions and exposure, but the necessary information to do so is not currently available.

The third limitation is that, if the *GR* model is used to simulate random values of *GR* in a Monte Carlo reliability analysis, it is possible to get GR greater than 1.0, particularly at lower ground snow loads. Physically, $GR > 1$ in the reliability assessment implies that the annual maximum roof snow weight is greater than the annual maximum ground snow weight. The committee acknowledges that there are circumstances under which the roof snow weight may be larger than the ground snow weight (such as a roof that is colder than the ground and accumulates snow more quickly), but it is unlikely that the difference between them is large. Therefore, for simulation purposes, GR values are capped at 1.25; this upper bound is based on the judgment and experience of the SEAC Snow Load Committee, and the committee expects that it is conservative.

A2.5. Conclusions

An analytical model to predict the median and logarithmic standard deviation of the ground to roof snow weight conversion factor (*GR*) is fit to a Norwegian data set that consists of simultaneous measurements of roof snow weight and ground snow weight. The use of this new data set allows us to quantify *GR* as a function of the ground snow load. This change reduces the median GR at large loads (>80 psf) to approximately 0.4, rather than the 0.47 used in older models. In addition, this change reduces the error term (*i.e.* the logarithmic standard deviation) from 0.42 to 0.33. Nonetheless, the predictions of median *GR* and its logarithmic standard deviation are conservatively high due to limitations of the model and of the data set to which it is fit, particularly at large snow loads. Without additional data, there is not a statistically defensible way to either quantify or eliminate these biases. Despite this conservatism, the use of the new GR model reduces the estimates of roof loads compared to the previously used Ellingwood model, thus improving the reliability assessed at all Colorado sites.

A2.6. Works Cited

Ellingwood, B., & O'Rourke, M. (1985). Probabilistic models of snow loads on structures. *Structural safety*, 2(4), 291-299.

Fan, J., & Gijbels, I. (1996). Local polynomial modeling and its applications: Monographs on statistics and applied probability 66 (Vol. 66). CRC Press.

Thiis, T., & O'Rourke, M. (2015). "A model for snow loading on gable roofs." *Journal of Structural Engineering*, In Press.

Appendix 3. Determining Probability Distributions for Snow Sites

A3.1. Introduction

Probability density functions are used to represent the distributions of annual maximum ground snow loads at snow sites. Previous studies (*e.g.* Ellingwood and Redfield 1983, SEAC 2007) have used probability distributions to determine characteristic loads for a given return period interval, *e.g.* a snow weight with a mean recurrence of 50 years. In this study, the role of the annual maximum snow weight probability distributions is distinctly different than that of previous studies in that the distributions are intended to be used for reliability analyses, rather than to predict a single characteristic snow load. Therefore, the distributions of annual maximum snow loads in this study should be representative of the true annual maximum snow load distribution over the entire region of the distribution *that impacts the structural reliability analysis*, not just the 50-year load.

Probability density functions that represent annual maximum ground snow loads at a given site are computed in two stages. First, a distribution is fit specifically to the annual maximum snow weight data at each individual site ("site-specific" distribution fitting). Next, the upper tail of the distribution is adjusted to account for information from snow data at similar sites. This appendix describes the site-specific tail-fitting approach that is used, as well as the method for adjusting the distribution upper tails to account for observations at similar snow sites.

A3.2. Site-Specific Distribution Fitting

A3.2.1. Background

Distributions of annual maximum ground snow loads in the United States have been predominantly modeled by the Lognormal distribution, which was recommended by Ellingwood and Redfield (1983), who studied annual maximum snow loads in the Northeast quadrant of the United States. However, when fitted to snow data in many locations on the plains and lower foothills of Colorado, the lognormal distribution fitted to the entire historical record is insufficient for modeling rare loads, because its tail dies off too quickly. As an example, the 50-year load at Denver-Stapleton using 121 years of data from 1893 to 2013 is 20.4 psf when a Type II Extreme Value (Hereafter "Type II") distribution is fitted to the data, versus 17.1 psf when a Lognormal distribution is fitted to the data. In this case, the Type II is a better fit based on a number of goodness-of-fit statistical tests. For this reason, the SEAC Snow Load Committee, in developing its 2007 snow load recommendations for Colorado (SEAC 2007), explored a variety of distributions for modeling annual maximum ground snow loads: Normal, 3-parameter Lognormal, 3-parameter Gamma, 3-parameter Loggamma, Frechet Type II Extreme Value, and Gumbel Type 1 Extreme Value.

A3.2.2. Tail-Fitting Approach

This study takes a different approach to modeling probability distributions of annual maximum ground snow loads. Rather than consider a variety of possible distributions, the lognormal distribution is used, but it is fitted only to the upper tail of the data, as in Ellingwood (1981). This approach, hereafter referred to as “tail-fitting,” ensures that the site-specific distribution is fitted to the portion of the data set that is important for determining rare loads.

Tail fitting is performed by the following steps:

1. Rank order the annual maximum ground snow data.
2. Plot the rank-ordered data on probability paper.
3. Fit a least-squares linear regression line to the top 33 percent of the data.

An example of the tail-fitting technique applied to the same Denver-Stapleton data is shown in Figure A3.1. Figure A3.1 shows that the tail-fit distribution captures the tail behavior well, whereas the upper tail of the recorded data is thicker than what is predicted by a lognormal distribution fitted to the entire data set. For comparison, the 50-year load according to the tail-fit Lognormal distribution is 20.5 psf, versus 17.1 psf for the Lognormal fitted to all of the data and 20.4 psf for the Type II distribution (which is the best fit distribution if the data are fit to the entire data set). We note also that the tail-fit distribution often does not match the observed data for low snow loads, but low snow loads are not important for the reliability assessment, because they do not cause failures.

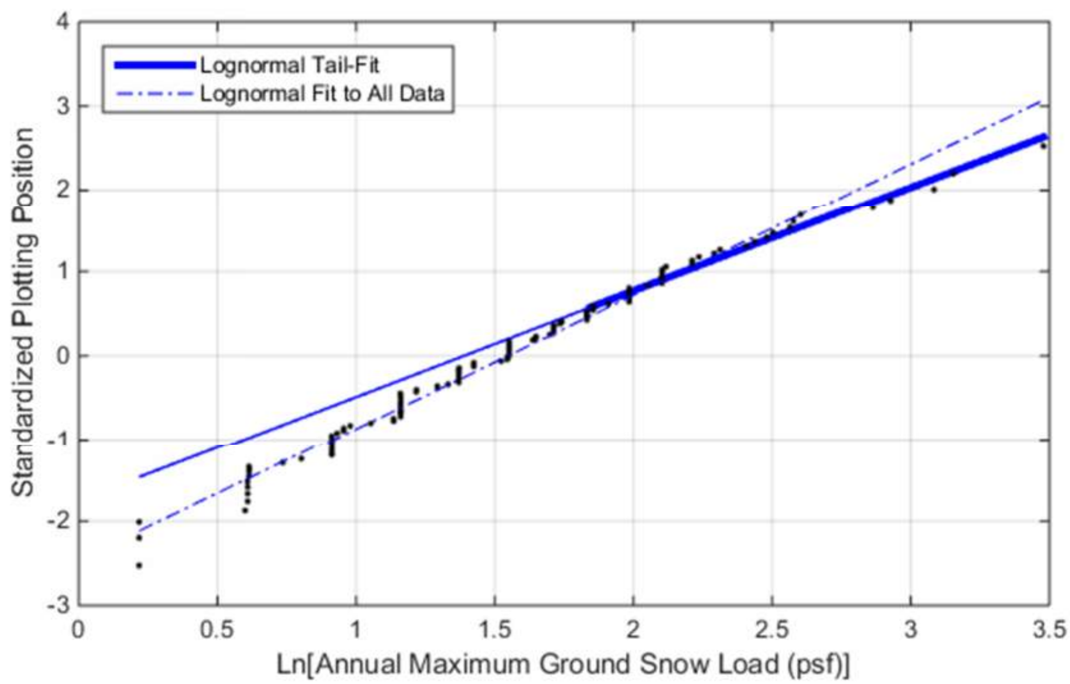

Figure A3.1 Probability plot of a tail-fit lognormal distribution for the Denver-Stapleton data alongside a lognormal distribution fitted to the entire data set. The thickened part of the solid line represents the range over which the tail-fitted distribution was fitted (*i.e.* upper 33 percent of the data points).

A3.2.3. Limitations of the Site-Specific Tail-Fitting Approach

For most sites in Colorado, the lognormal tail-fitting technique works well for predicting extreme loads with recurrence intervals up to about 50 years. However, extrapolating the distribution to predict rare loads whose recurrence intervals are much greater than the length of the data time-series (*i.e.* greater than approximately 50 years for most snow sites) should be done cautiously, because the extrapolations will only be correct if the true distribution of the data is Lognormal. As an illustration, four tail-fits are performed on the Denver-Stapleton data using the Normal, Lognormal, Gamma, and Loggamma distributions, in addition to a Type II distribution fit to the entire data set. These distributions are overlaid on a histogram of the original data in Figure A3.2, as well as Lognormal probability plots in Figure A3.3. The Loggamma and Type II distributions are the best-fitting distributions according to several goodness-of-fit statistical tests. However, with the exception of the Normal distribution (which bears no resemblance to the Denver-Stapleton data whatsoever), each of the distributions are similar over the portion of the data set to which they are fitted (*i.e.* the top 33 percent). The 50, 100, 500, and 1000 year loads for the four tail-fitted distributions are reported in Table A3.1. Table A3.1 shows that the tail-fit distributions agree fairly well for time-intervals within the span of the data set (121 years in the case of Denver-Stapleton), but deviate substantially beyond it; this trend can be observed visually in Figure A3.3.

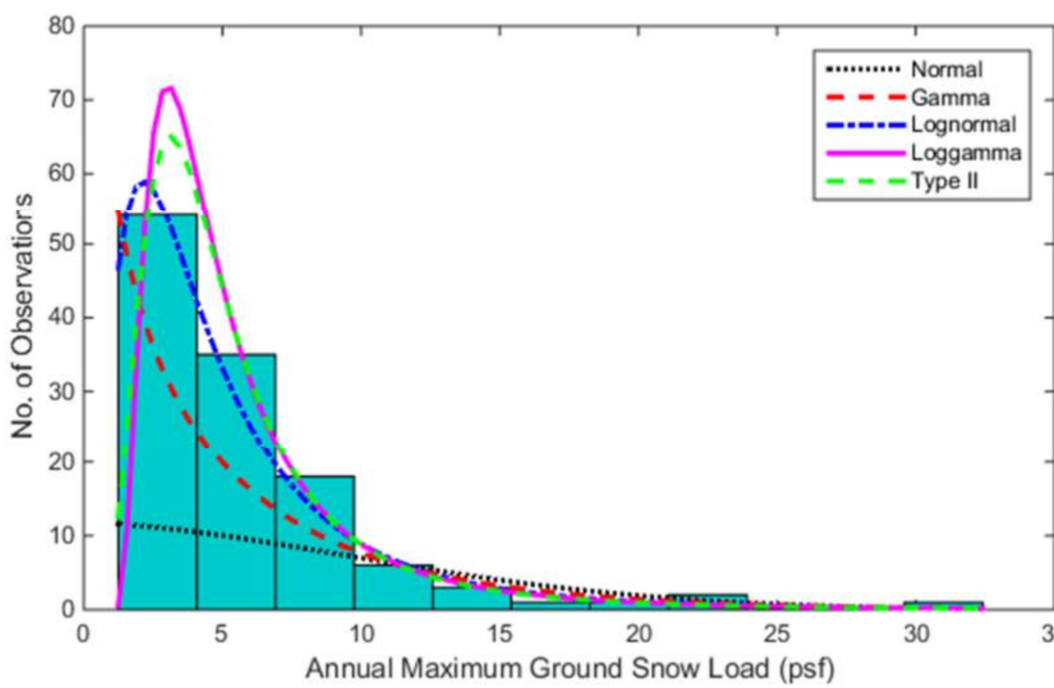

Figure A3.2 Histogram of the Denver-Stapleton annual maximum snow loads with four different tail-fit distributions overlaid, in addition to a Type II distribution fitted to the entire data set.

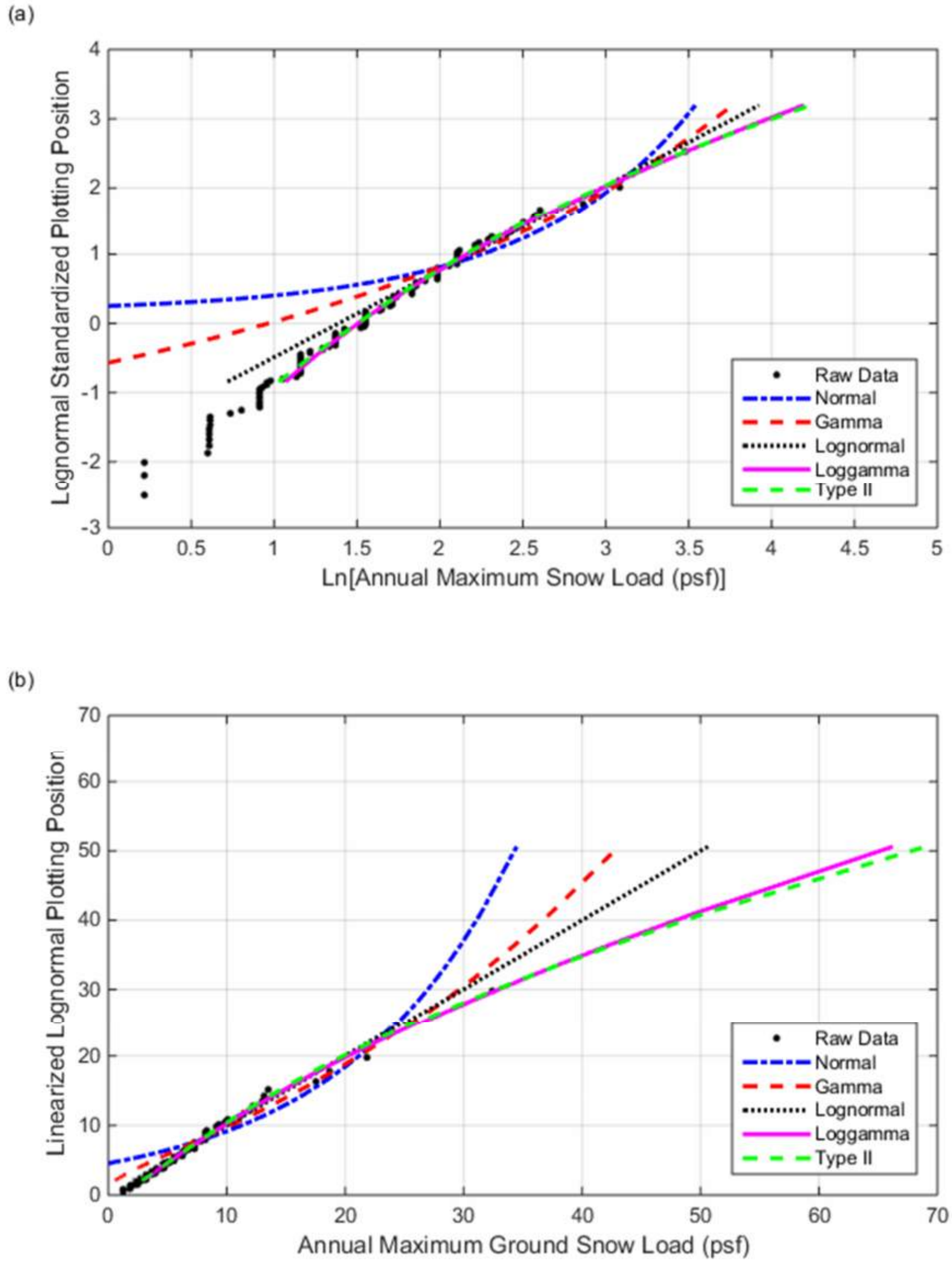

Figure A3.3 Denver-Stapleton annual maximum snow weights plotted on (a) a Lognormal probability plot and (b) a linearized lognormal probability plot. The results of tail-fit distributions, in addition to a Type II distribution that is fitted to the entire data set, are overlaid.

Table A3.1 Ground snow loads predicted by four tail-fitted distributions and the Type II distribution for Denver-Stapleton

Mean Recurrence Interval	Tail-fitted Distribution				Type II
	Normal	Gamma	Lognormal	Loggamma	
50 yrs	21.5 psf	21.6 psf	20.5 psf	20.8 psf	20.4 psf
100 yrs	24.6 psf	26.0 psf	25.4 psf	26.8 psf	26.5 psf
500 yrs	30.9 psf	36.3 psf	39.4 psf	46.9 psf	47.6 psf
1000 yrs	33.3 psf	40.8 psf	46.6 psf	59.0 psf	60.8 psf

Therefore, it is concluded that Lognormal tail-fit distributions are satisfactory for predicting rare loads with up to approximately 50-year recurrence intervals, but they may be unsatisfactory for predicting extremely rare loads (*e.g.* 500 or 1000 year loads) unless the data are actually lognormally distributed in the far tail. In this study, Lognormal tail-fit distributions are used to predict 20-year loads at each site, which is needed in the later analysis.

If the true underlying distribution of the data were known, then a simple solution for predicting extreme loads would be to use the true distribution, rather than a lognormal distribution. However, determining the true underlying distribution of annual maximum snow loads at a site is not as simple as selecting the distribution that fits the data best. There are two reasons for this assertion. The first is that randomness of the data can result in the selection of a best-fit distribution that is not the true underlying distribution. For example, a sensitivity study showed that random 50-year data sets generated from a Lognormal distribution with logarithmic standard deviation of 0.6 are identified as being Type II distributions (*i.e.* best fit by a Type II) more often than they are identified as Lognormal. This misidentification occurs partly because the Type II distribution has three parameters and is therefore more adaptable to intricacies of a particular dataset, even when those intricacies are random and not actually real properties of the true underlying distribution. In this example, fitting a Type II distribution to data whose true parent distribution is not Type II is relatively inconsequential for predicting loads with mean recurrence intervals near or within the span of the data, but it results in large disparities at extremely large loads, similar to the disparities shown among the various distributions in Figure A3.3 and Table A3.1.

The second reason that determining snow load distributions based only site-specific analyses is not practical is because data records at individual sites are not long enough to verify whether a best-fit distribution for the 30 to100 years of recorded data is still applicable for loads as rare as 500-1000 years. It may be that the extreme upper tails are described by distributions that are different than those that describe the bulk of the data below the extreme upper tail, or it may be that they do not follow any particular probability density function at all. If each snow site is analyzed in isolation, these problems are difficult to overcome. However, further insight about the true shapes of the distribution tails over the range that is critical for the reliability assessment is achieved by accounting for observations at several similar snow sites collectively, as described in the following sections.

A3.3. Distribution Tail Shapes Informed by Multiple Snow Sites

Additional information about the upper tail shapes is obtained by combining data from similar snow sites. The essence of the procedure is to determine the magnitude of the snow loads in the distribution tail with a site-specific analysis, but determine the shape of the tail by considering the combined data from a number of stations whose distribution tails are expected to have similar shapes. Grouping, or "clustering" of snow sites in Colorado with similar properties to obtain information about their distribution shapes is suggested by DePaolo (2013).

To explain, we start with a simple case, wherein several snow sites are assumed to have the same underlying distribution, in terms of the mean as well as the shape of the upper tail of the distribution. This assumption may be valid for the eastern plains of Colorado, for example, where there are not big variations in climate from site to site. For this case, the procedure is as simple as combining the data from multiple stations to create one large data set. A collection of 20 snow sites having 50 years of annual maximum snow data per site, for example, could be combined to make a single station with 20x50=1000 data points. In this example, a distribution fit to the enlarged data set can allow a better prediction of rare loads having up to a 1000-year mean recurrence interval without extrapolation. If all of the contributing snow sites are expected to have the same distribution shape and magnitude, then the enlarged data set provides a better estimation of that distribution.

Combining data from multiple sites to obtain and enlarged data record assumes that the snow data from the different sites are statistically independent. However, sites in a common region are often affected by the same storm and, as a result, the annual maxima at different sites are likely to be correlated. Some of this correlation is eliminated by combining nearby snow sites into single stations before fitting the distributions. However the correlation is not entirely eliminated, so its potential impact on the resulting fitted distributions was determined by a sensitivity study. To test the impact of correlation between annual maximum snow loads, random sets of historical snow data were sampled from a known distribution, with and without correlation between them. The correlated data sets had correlation coefficients between them of 0.6, which is based on the correlation coefficient between the Denver and Boulder historical snow records. The distribution fitting methods that are explained in this appendix were applied to the simulated data. The results showed that correlations between snow sites reduces the confidence in the fitted distribution parameters, because the impacts of correlations among data are similar to the impact of reducing the size of the data set. However, the presence of correlations did not bias the estimates of the distribution parameters significantly (less than 5% bias was introduced by the correlation).

For the case where the magnitudes of the annual maximum snow weight distributions are expected to vary among snow sites, the process of combining the data to make a single enlarged data set is described by the following steps, which are illustrated in Figure A3.4 - Figure A3.7:

1. Select a group of snow sites whose distribution shapes are expected to be similar to that of the site of interest (see Section A3.3.2).
2. For each site, determine the 20-year load using a site-specific tail-fit lognormal distribution (refer to Section A3.2.2).
3. Scale each site's historical record so that the 20-year load is equal to the average 20-year load for all of the sites in the group.
4. Combine all of the scaled data into an enlarged data set.

5. Fit a lognormal distribution to the top 10 percent of the enlarged data set, using the tail-fitting method described in Section A3.2.2. The smaller (10 percent) fraction of the tail, as compared to the 33 percent used in the site-specific approach, is permissible because there are far more data points in the enlarged data set.
6. Apply a correction to the logarithmic standard deviation of the fitted distribution to account for systematic biases that are introduced by the scaling process (see Section A3.3.1).
7. For the site of interest, re-scale the distribution from Steps 5 and 6 to the 20-year snow load at that site from Step 2.

The distributions resulting from this procedure match the 20-year load at each site, but have upper tails whose shapes are informed by a number of sites whose upper tail behaviors are expected to be similar. Therefore, they maintain a site-specific scale, or magnitude, but a regionally-informed tail shape. This process is referred to as "clustered station distribution fitting" for the remainder of this appendix, because clusters of sites are used for determining distribution tail shapes.

This procedure is different than fitting a distribution to the data at one site without considering adjacent and similar sites in another significant way. Considering one site at a time, it is not unusual to discard the largest recorded value as an outlier based on statistical tests. Combined normalized data from several similar sites results in such data points not being discarded, because they represent the truly rare event for the group of sites.

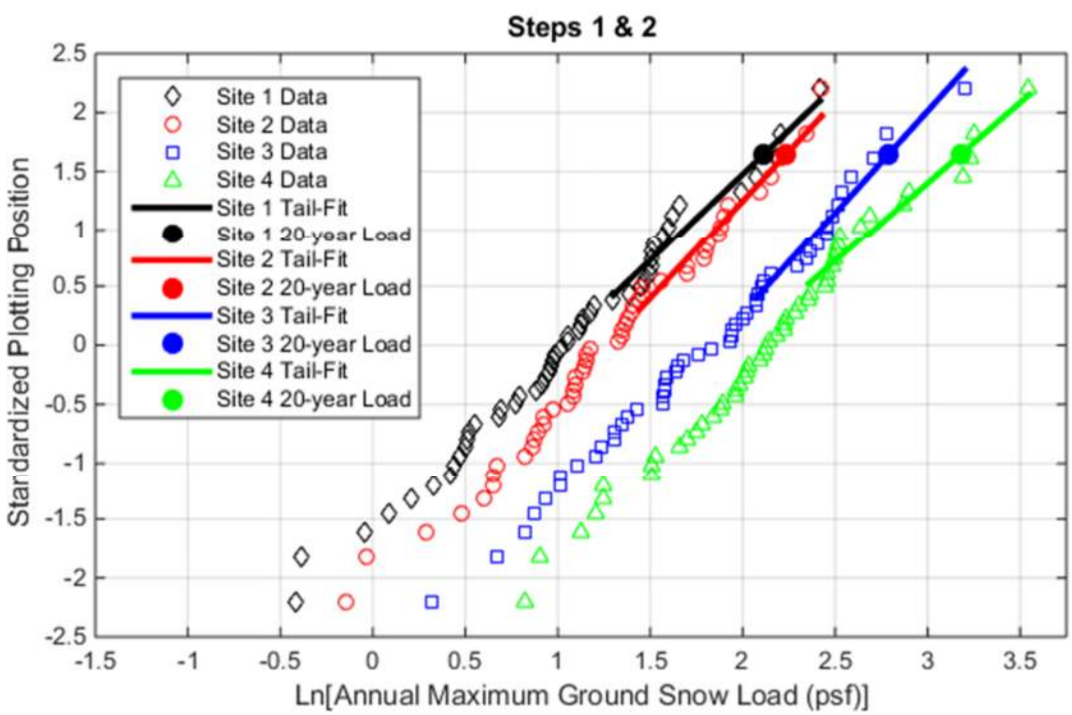

Figure A3.4 Illustration of Steps 1-2 of the cluster station distribution fitting procedure, for four hypothetical sites (noting that a minimum of 20 sites are used for the actual procedure). At this stage, tail-fit distributions have been developed at each site and their 20-year loads have been determined. Historical records for each hypothetical site are generated from lognormal distributions having σ=0.6, but different median values.

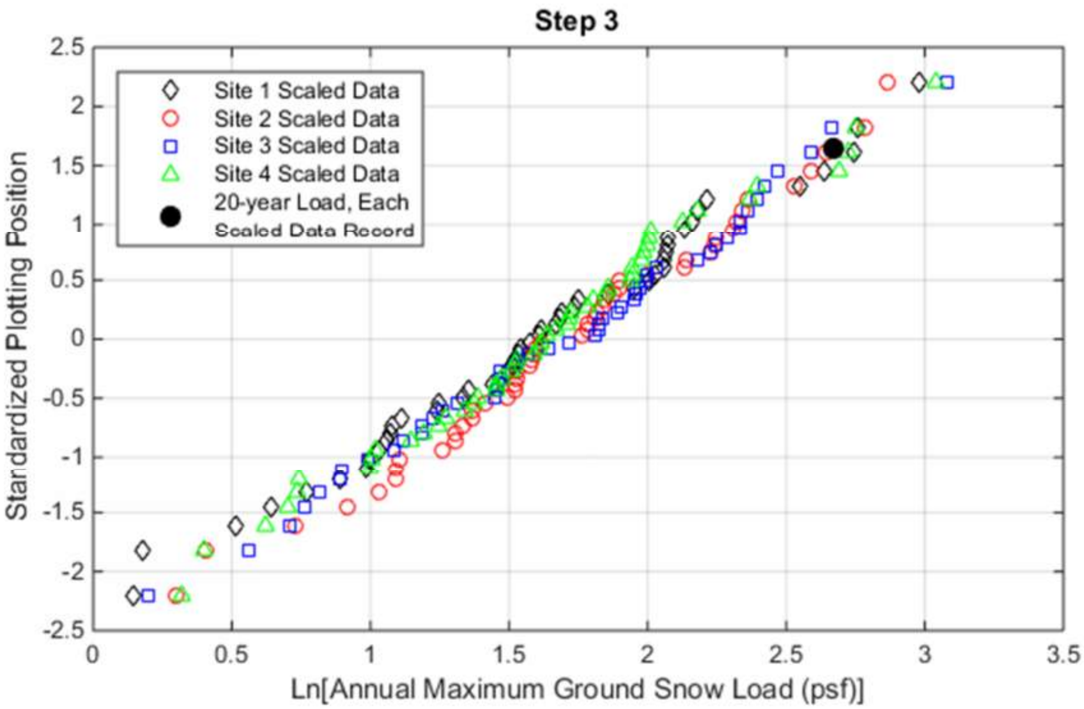

Figure A3.5 Illustration of Step 3 of the cluster station distribution fitting procedure. Data from each site are scaled to have a common 20-year load.

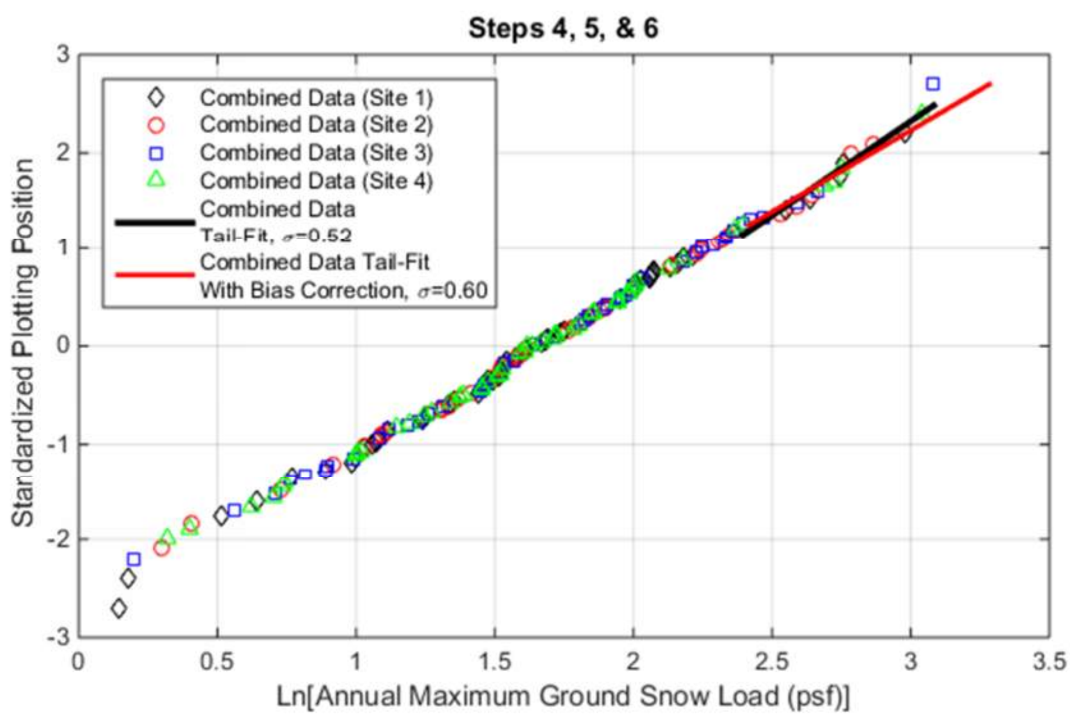

Figure A3.6 Illustration of Steps 4-6 of the cluster station distribution fitting procedure. The scaled data are combined to make a single data set. The plot shows the data in their new rank-ordered plotting positions. A

lognormal distribution is fitted to the top 10 percent of the enlarged data set and then corrected to account for bias that is systematically introduced.

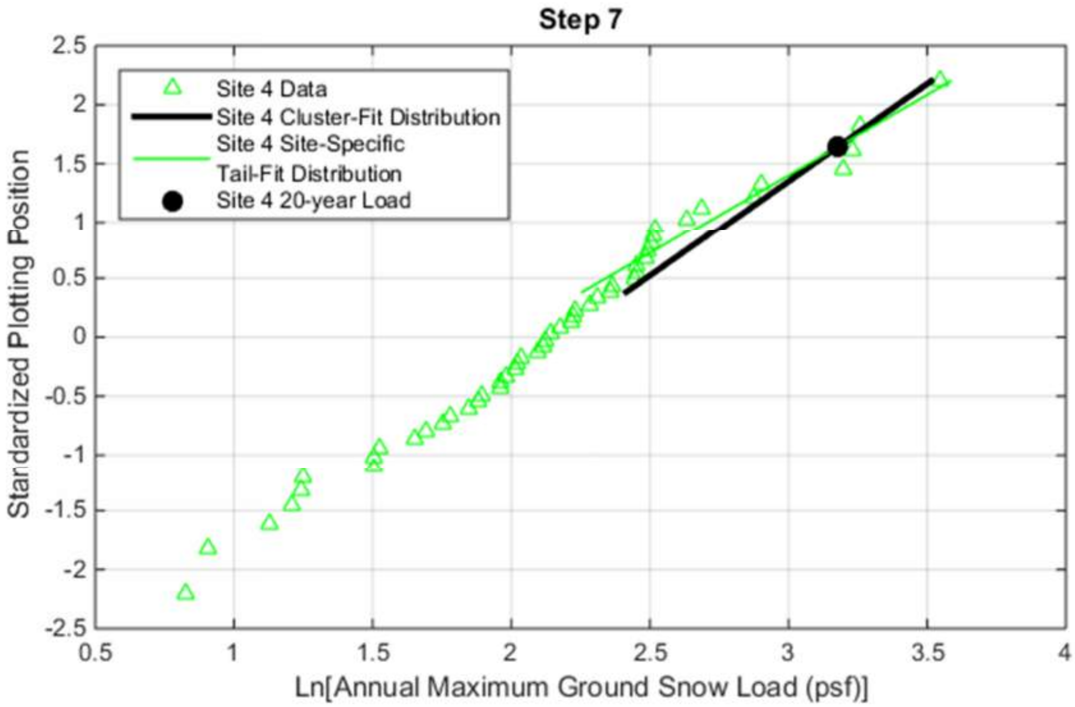

Figure A3.7 Illustration of Step 7 of the cluster station distribution fitting procedure for the case where the site of interest is Site 4. The cluster-fit distribution is scaled so that its 20-year load matches the 20-year load that is determined for Site 4 by a site-specific tail-fit distribution.

A3.3.1. Accounting for Systematic Biases in the Distributions that are Fitted to the Clustered Data Sets

Sources of Bias in the Distributions that are Fitted to the Clustered Data Sets

In scaling the data from several snow sites to create a clustered data set, a systematic bias is introduced. The bias is a result of data sets with large rare loads tending to be scaled down, because their calculated 20-year loads tend to be higher than those of sites that have not experienced large rare loads; this leads to a systematic reduction of large rare loads in the clustered data sets. This section explains, by example, the origin of that bias and is followed by an explanation of how it is corrected.

Let us consider the data shown in Figure A3.8. The data represent two hypothetical sites, each having the same parent distribution, *i.e.* following the same lognormal distribution with the same mean and standard deviations, but with unique sets of random data representing their historical records. In their 50 years of record, Site 1 has not experienced any significantly rare loads, but Site 2 has. The largest loads at Sites 1 and 2 are 13.3 psf and 21 psf, respectively, which correspond to mean recurrence intervals of 29 years and 199 years, according to the theoretical parent distribution. As a result, the distributions that are fit to the two site's data predict 20-year loads of 11.3 psf and 14.0 psf, in comparison to the theoretical 20-year load of 12 psf.

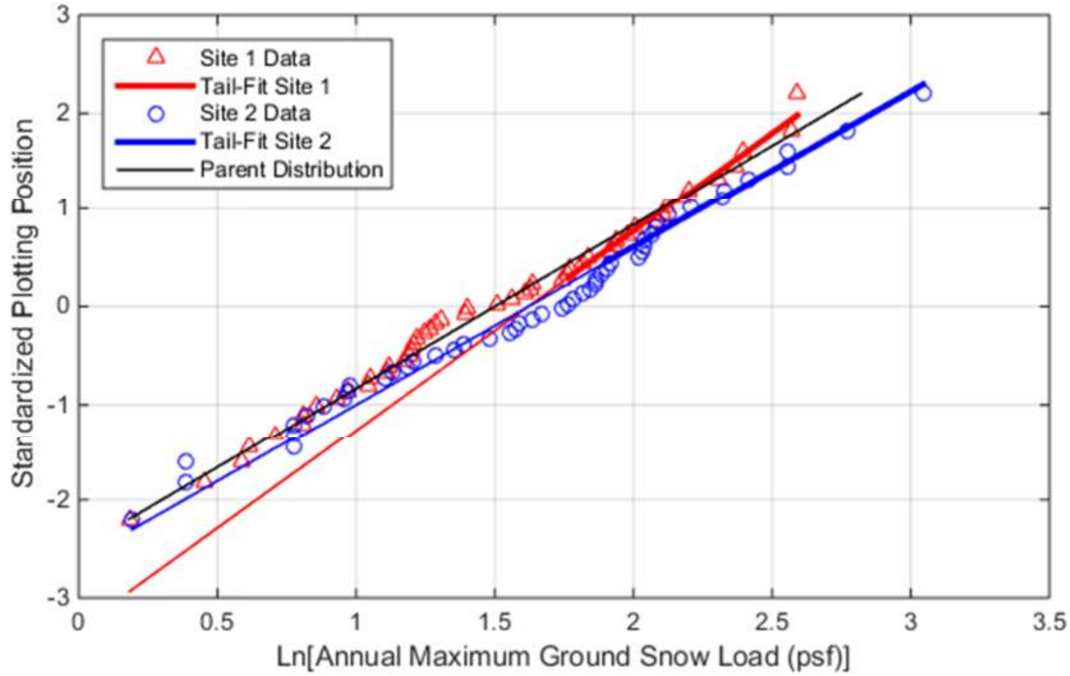

Figure A3.8 Two randomly generated data sets, each coming from the same theoretical parent distribution (black line, Lognormal with Mu=1.5 and Sigma=0.6). A site-specific tail-fit Lognormal distribution is fit to each site; the parameters are Mu=1.62, Sigma=0.49 and Mu=1.62, Sigma=0.62 for sites 1 and 2 respectively. The thickened portion of the lines represent the range over which the tail-fitted distributions are fitted.

The data from Sites 1 and 2 are combined to make a clustered data set, according to the clustered station distribution fitting procedure described in Section A3.3. Each data set is scaled so that its 20-year load is equal to the average of the two (12.7 psf); the necessary scale factors for Sites 1 and 2 are 1.12 and 0.9, respectively. The top 10 percent of the clustered, scaled data set is shown with the solid symbols in Figure A3.9. Accompanying it on the same figure is the same subset of the data, but with no scaling.

Comparing the two distributions in Figure A3.9 shows that scaling the data before combining it tends to reduce the logarithmic standard deviation (*i.e.* the shape parameter) of the distribution that that is fitted to it. That is because rare loads (*e.g.* the largest load in Site 2 of the example) tend to raise the 20-year load that is computed at a given site, thus reducing the scale factor applied to sites with those data, and diminishing their impact on the distribution tail. In this example, the unscaled combined data set has a logarithmic standard deviation of 0.6, which is equal to that of the parent distribution. However, the scaled combined data set has logarithmic standard deviation of 0.52, which is an underestimation of the true logarithmic standard deviation. For groups of sites in which the shape and scale of the distribution are expected to be the same, this problem could be circumvented by combining their data without performing any scaling. However, with the exception of possibly the eastern plains, the groups of snow sites that are formed are expected to vary in scale, so scaling must occur before combining them to make an enlarged station.

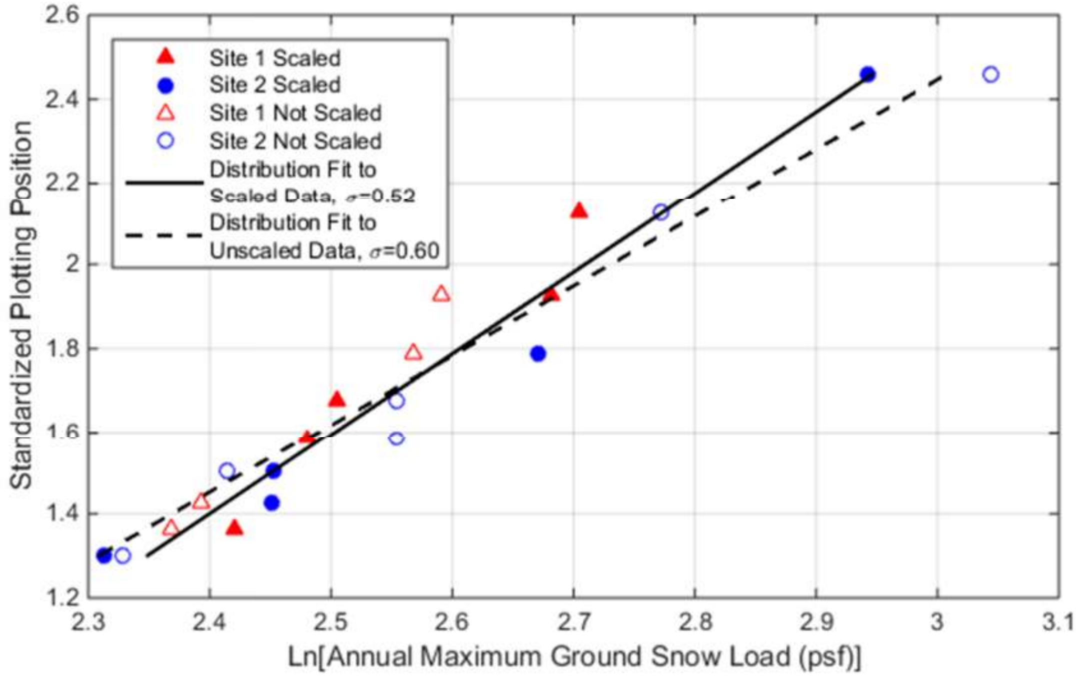

Figure A3.9 Lognormal probability plot of the top 10 percent of data points for the enlarged example data set, with and without scaling of the Site 1 and Site 2 data.

Correcting the Systematic Bias Introduced by the Scaling Method

The shapes (*i.e.* the logarithmic standard deviation, σ) that are obtained by the clustered station distribution fitting approach are corrected by Equations A3.1 and A3.2.

$$\sigma_{Corrected} = 1.16 * \sigma_{Clustered\ Data} \quad \text{A3.1}$$

$$\sigma_{Corrected} = 0.97 * \sigma_{Clustered\ Data} + 0.03 \quad \text{A3.2}$$

Equation A3.1 is applicable for groups of snow sites where the parent distribution is expected to be Lognormal. Equation A3.2 is applicable for groups of snow sites where the parent distribution is expected to be Normal or Gamma.

Selection of either Equation A3.1 or A3.1 requires knowledge of the parent distribution family. The likely parent distribution for a given group of stations is strongly related to the shape of a lognormal distribution that is tail-fitted to their combined (scaled) data. Groups of snow sites with larger logarithmic standard deviation terms are often fit better by more heavy tailed distributions (*i.e.* Lognormal and sometimes even Loggamma). Based on sensitivity studies conducted by the SEAC Snow Load Committee, groups of sites with uncorrected logarithmic standard deviations greater than 0.6 are assumed to have parent distributions that are Lognormal, so they are corrected with Equation A3.1. Those with logarithmic standard deviations less than 0.3 are assumed to have parent distributions that are Normal or Gamma, so they are corrected with Equation A3.2. If the uncorrected logarithmic standard deviation is between 0.3 and 0.6, then the underlying parent distribution is assumed to be thinner-tailed than lognormal, but thicker-tailed than Gamma and Normal; in such cases the correction is computed by a weighted average of Equations A3.1 and A3.2, where the weights are proportional to the uncorrected logarithmic standard deviation, relative to the threshold values of 0.3 and 0.6.

Development and Validation of the Distribution Shape Corrections

Equations A3.1 and A3.2 are calibrated for the range distributions observed at Colorado snow sites, and may not be accurate for other regions. A series of sensitivity studies showed that these corrections are unbiased for the purpose of estimating safety indices in the range of 2.0-3.5 at sites with parent distributions that are Normal, Gamma, or Lognormal, and having coefficients of variation ranging from 0.2 to 1.4. Some of the details of the validation and sensitivity studies are provided here.

The sufficiency of the Equations A3.1 and A3.2 for correcting distribution shapes (*i.e.* logarithmic standard deviation, σ) for the clustered station distribution fitting method are tested, starting with Equation A3.1. Recall that Equation A3.1 is intended to correct the distribution shape that is determined from a clustered data set when the parent distributions of the individual stations are assumed to be Lognormal. Therefore, it is tested by applying the correction to data that is randomly generated from a Lognormal distribution. One-thousand sets of data are generated from a lognormal distribution, each set containing 50 data points to represent a 50-year historical record. Then, the clustered station distribution fitting approach is applied to the simulated data to compute a distribution shape. The shape of the fitted distribution is compared to the shape of the true underlying (parent) distribution by comparing their logarithmic standard deviations. The results of several of these tests are shown in Figure A3.10, demonstrating that Equation A3.1 is effective for correcting bias in the distribution shape that is introduced by the clustered station distribution fitting method.

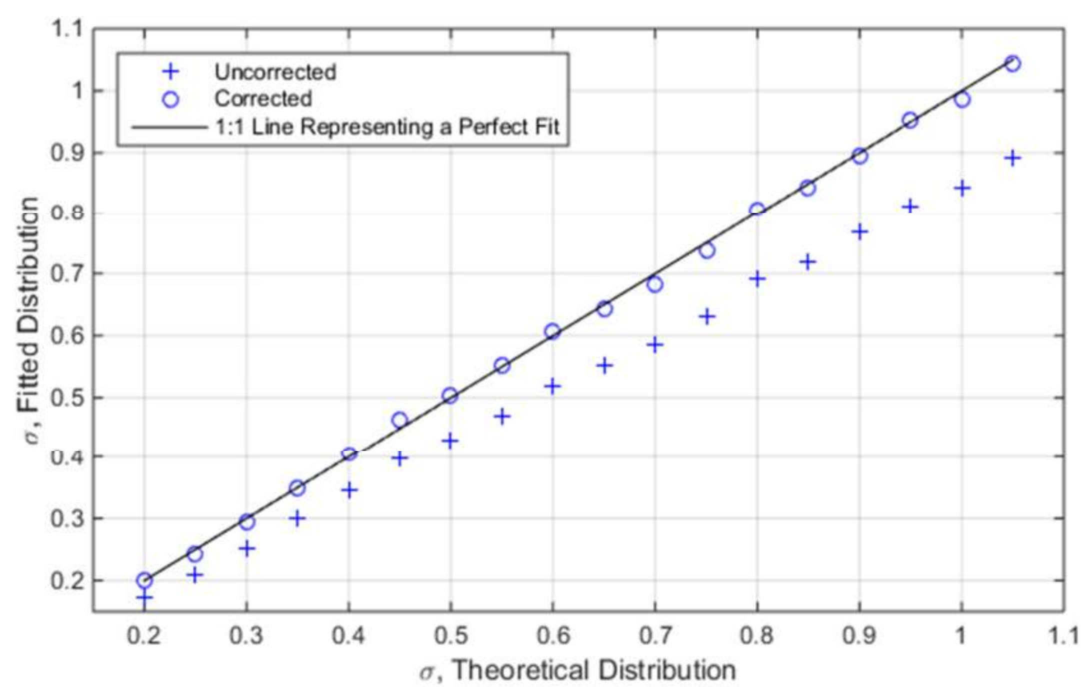

Figure A3.10 Logarithmic standard deviation (σ) obtained by scaling and grouping 1000 sets of data and performing a lognormal tail-fit on the top 10 percent of the combined data set. Each set is composed of 50 data points generated from a lognormal distribution. The process is repeated for theoretical distributions having σ ranging from 0.2 to 1.05, which corresponds to COV of 0.4 to 1.4. The correction (Equation A1.1) removes the bias in σ that is introduced by the cluster station distribution fitting method.

Testing Equation A3.2 for correcting the clustered station distribution fitting approach when it is used to model Gamma or Normal distributed data is less straightforward, because there is no direct comparison of parameters. Therefore, the correction for Normal and Gamma distributed data is tested by comparing reliability analysis results from distributions fitted to randomly generated historical records to reliability analysis results for the theoretical distributions from which the random historical records were generated. As with the previous tests, 1,000 data sets, each containing 50 data points, are generated from a theoretical distribution; then, a lognormal distribution is fitted to the clustered data set by the clustered station distribution fitting method. Reliability analyses performed with the theoretical distributions and with the fitted distributions are compared in Figure A3.11 through Figure A3.14. These comparisons show that the correction equation (Equation A3.2) corrects the shape of the distribution tail well enough to compute reliability-consistent design ground snow loads (*i.e.* the design ground snow load that would result in a reliability index of 3.0) that are nearly indistinguishable from those that are computed from the true theoretical parent distribution. These reliability results demonstrate that the corrected distributions approximate well the theoretical distributions over the portion of the distribution upper tails that is critical for the reliability assessment.

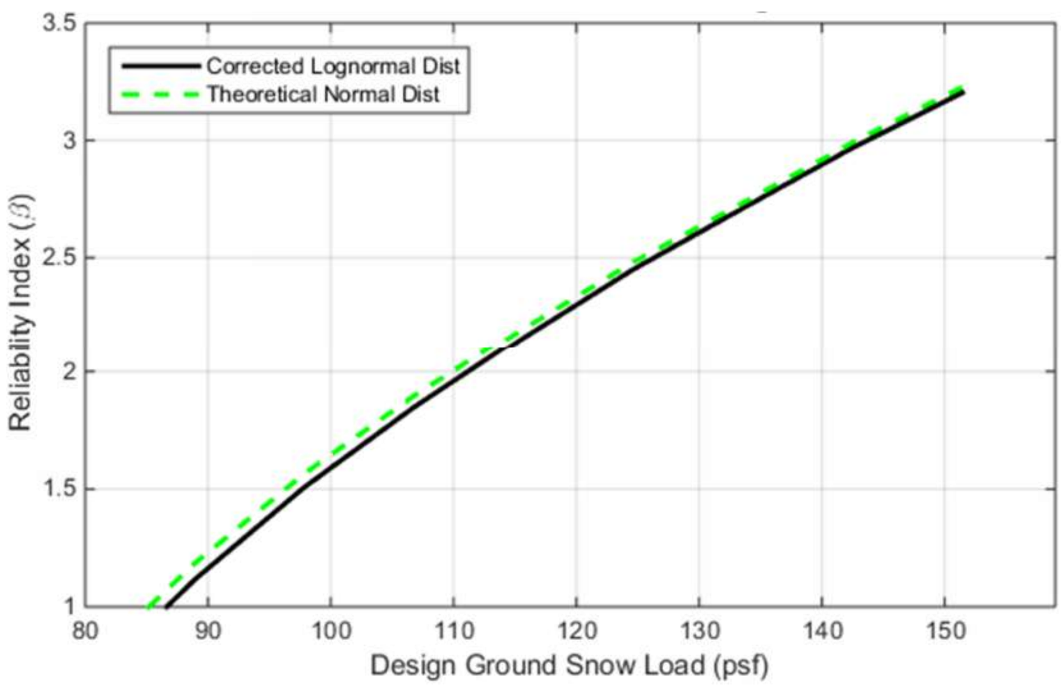

Figure A3.11 Reliability analysis results for a corrected Lognormal distribution that is fitted to data that are generated from a Normal distribution with mean 100 psf and COV 0.3. Annual maximum ground snow load distributions of this shape and scale are common at altitudes above 8,000 ft. in Colorado.

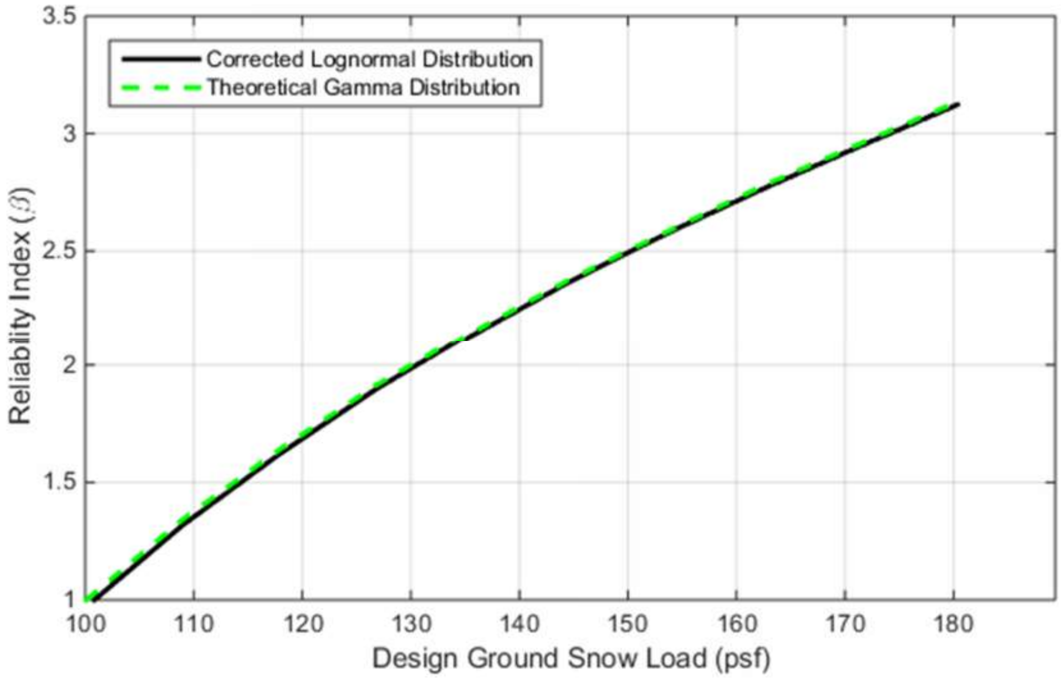

Figure A3.12 Reliability analysis results for a corrected Lognormal distribution that is fit to data that are generated from a Gamma distribution with parameters k=15 and theta=8 (*i.e.* mean=120 psf and COV=0.26). Annual maximum ground snow load distributions of this shape and scale are common at altitudes above 8,000 ft. in Colorado.

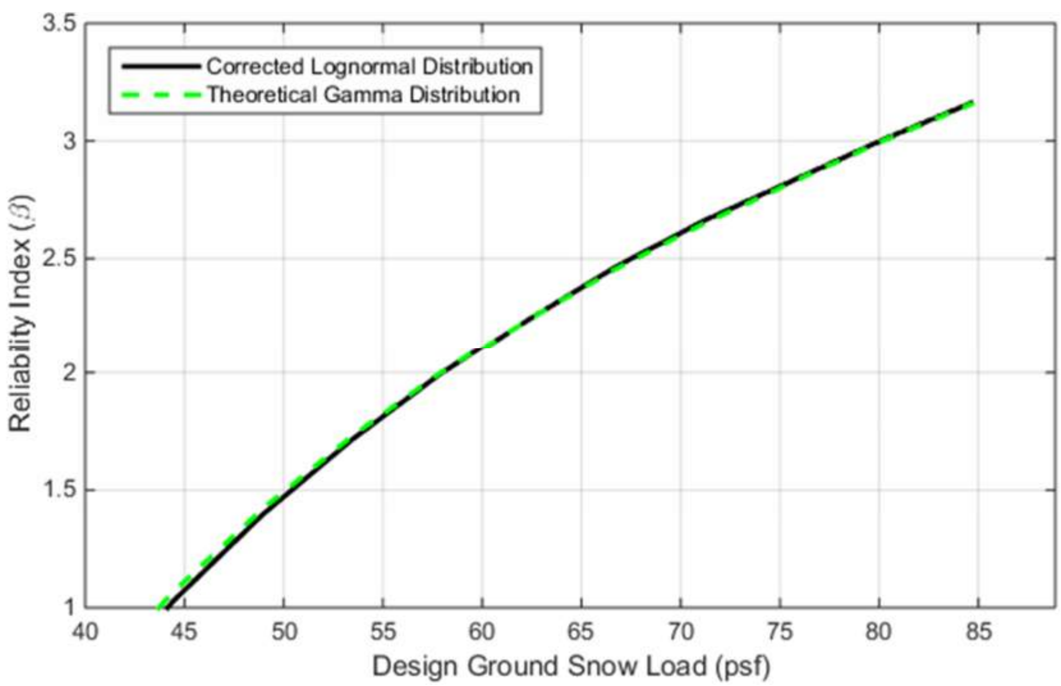

Figure A3.13 Reliability analysis results for a corrected Lognormal distribution that is fit to data that are generated from a Gamma distribution with parameters k=6 and theta=7 (*i.e.* mean=42 psf and COV=0.4). Annual maximum ground snow load distributions of this shape and scale are common at altitudes between 6,500 ft. and 8,500 ft. in Colorado.

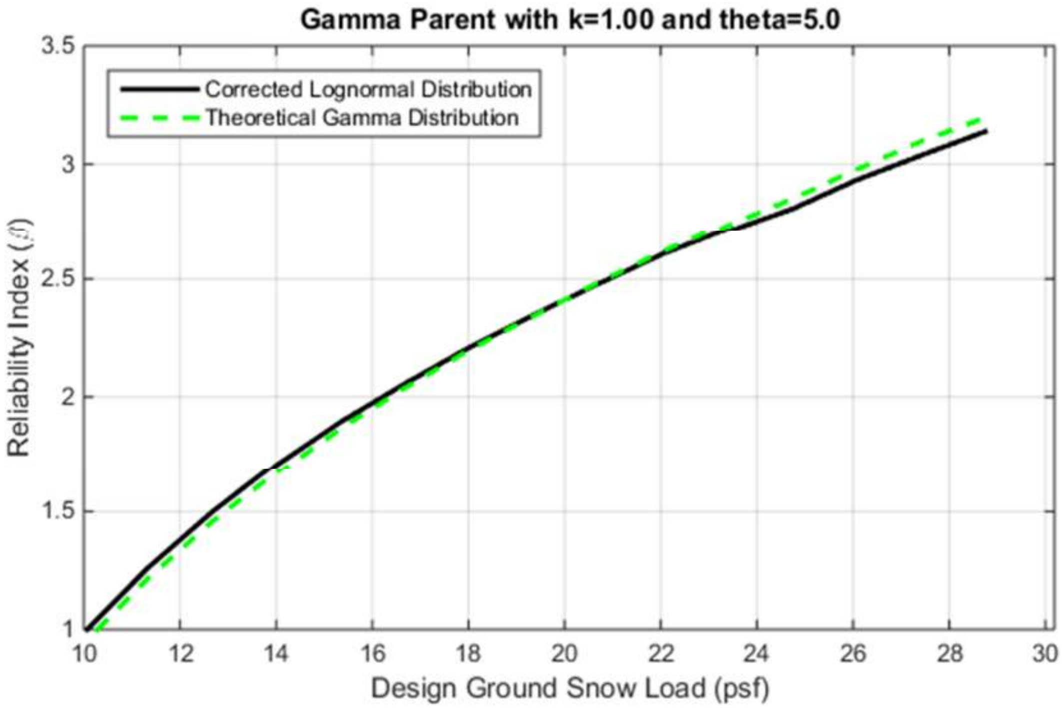

Figure A3.14 Reliability analysis results for a corrected Lognormal distribution that is fit to data that are generated from a Gamma distribution with parameters k=1 and theta=5 (*i.e.* mean=5 psf and COV=1.0). Annual maximum ground snow load distributions of this shape and scale are common at altitudes below 6,500 ft., however the expected parent distributions at such sites are often Lognormal, not Gamma.

A3.3.2. Approach for Clustering Sites with Similar Distribution Shapes

To carry out the proposed distribution fitting method, it is necessary to determine groups or clusters of snow stations whose upper tails are expected to be similarly shaped prior to applying the cluster station distribution fitting method. The assembly of snow sites into clusters is performed in two stages: (1) stations are divided into coarse regions for which different snow distribution characteristics are expected, based on climatic and macro-topographical features, and (2) for each site, a minimum of 20 additional sites from the same topographic region with similar altitudes are clustered with it.

For the purpose of examining annual maximum snow load distribution properties on a regional basis, the COV is taken as a proxy for the distribution shape. Distributions with heavy upper tails tend to have larger COV, as compared to distributions with light upper tails. Another proxy for distribution shape, skewness, is not discussed, but additional studies by the committee show that trends in skewness and COV are very similar, and that skewness and COV are strongly correlated for Colorado snow sites (correlation coefficient = 0.8).

Division of Snow Sites into Topographic Regions

Initially, snow stations are divided into six regions, shown in Figure A3.15: (1) the eastern slope (*i.e.* Front Range and eastward), (2) the western slope of the Rocky Mountains, (3) the northern Rocky Mountains, (4) the east-central Rocky Mountains, (5) the southwest Rocky Mountains, and (6) the San Luis Valley. The initial division into these topographic regions is based on a combination of expert judgment and k-means cluster analysis. The concept of clustering snow sites into groups to characterize their distributions of annual maximum snow loading is not new (*e.g.* DePaolo 2013).

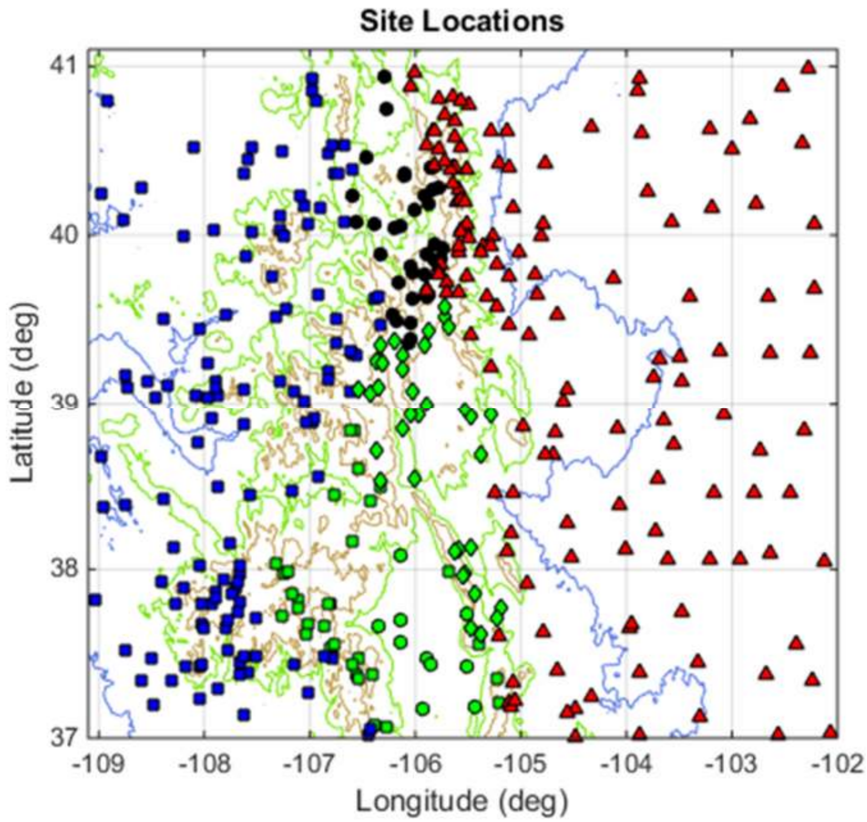

Figure A3.15 Map of sites by topographic region assignment. The base map has blue, green, and brown altitude contours at 5,500 t., 8,500 ft., and 10,500 ft., respectively. Eastern slope sites are red triangles, western slope sites are blue Squares, northern Rockies sites are black circles, east-central Rockies sites are green diamonds, southwest Rockies sites are green squares, and San Luis Valley sites are green circles. The latter three, represented by green markers, were eventually combined into one topographic region.

Analysis of the historical annual maximum snow loads in these regions shows that the proxy for distribution shape, COV, is correlated with altitude and topographic region. For example, Figure A3.16 shows the trends in COV with altitude for sites within the western slope and eastern slope topographic regions. COV decreases with altitude for both regions, but the trend is somewhat different for each of them. There is little distinction in the trends of COV with altitude among the east central Rocky Mountains, southwest Rocky Mountains, and San Luis Valley sites (*i.e.* all of the snow sites plotted in green in Figure A3.15) so these are combined into one topographic region for analysis. The remaining three topographic regions are considered separately, so a total of four topographic regions are used.

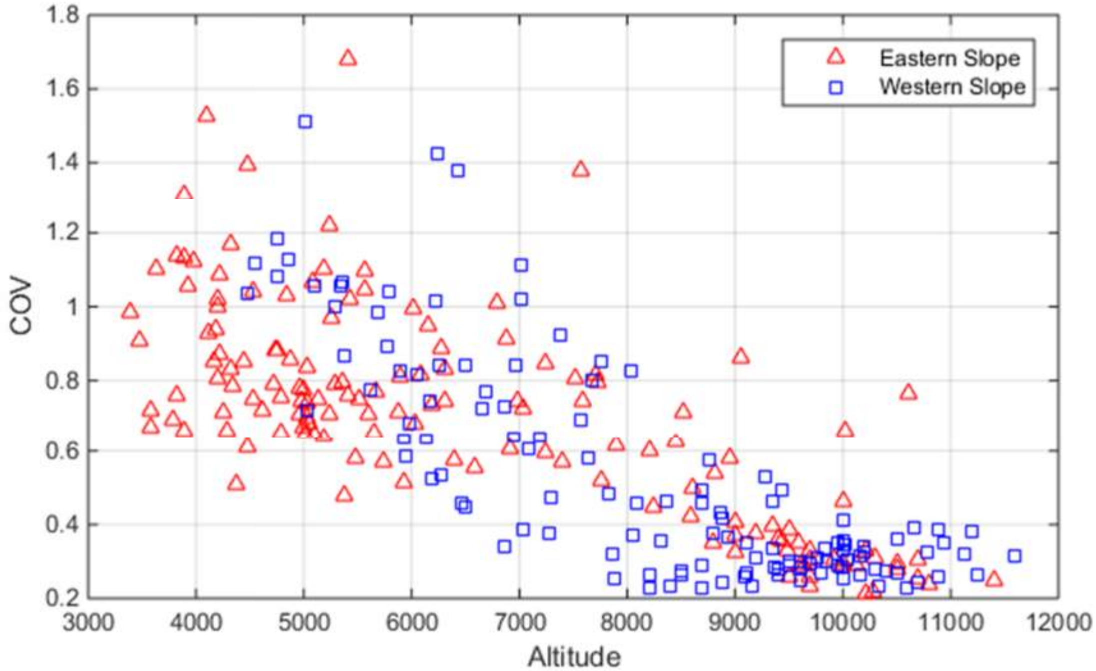

Figure A3.16 Comparison of COV and altitude for annual maximum snow weight data in two topographic regions: Eastern Slope (red triangles) and Western Slope (blue squares).

Cluster Analysis

Clusters of snow sites for performing the clustered station distribution fitting method at each site are formed by selecting all snow sites that are: (a) within the same topographic region as the site of interest and (b) within 1000 ft. altitude of the site of interest. If a cluster contains less than 20 snow sites, the altitude criterion is relaxed until a minimum of 20 snow sites are included. This approach implies that each site is grouped with its 20 (or more) most similar sites on the basis of region and altitude. This cluster is used in determining the shape of the tail for the site of interest, as described in Section A3.2.2.

A3.4. Discussion and Conclusions

This Appendix describes the method for determining probability distributions for annual maximum ground snow loads, "cluster station distribution fitting". The method emphasizes the portion of the distribution that is critical for reliability analysis, the extreme upper tail. The resulting distributions are constructed to match the 20-year load at each snow site that is determined from a site-specific analysis, but have an extreme upper-tail that is informed by a broader group of snow stations whose distribution shapes are expected to be similar to the site of interest. Clusters of stations whose distribution shapes are expected to be similar are determined by a combination of topographic region and altitude.

The method computes 20-year loads at each site from a Lognormal distribution that is fit to the upper 33 percent of the site data. The shape of the distribution at each site is determined by combining data from a minimum of 20 stations to make an enlarged data set and fitting a lognormal distribution to the top 10 percent of its data. This appendix shows that estimating the upper tail distribution shape this way and applying a calibrated correction factor leads to unbiased predictions of the reliability index β. Annual maximum snow load distributions at all of the snow sites are determined by the cluster station distribution method.

A3.5. Works Cited

DePaolo, M. (2013). *A Proposal for a Unified Process to Improve Probabilistic Ground Snow Loads in the United States using SNODAS Modeled Weather Station Data.* M.S. Thesis, University of Colorado Boulder.

Ellingwood, B. (1981). "Wind and snow load statistics for probabilistic design." *Journal of the Structural Division*, 107(7), 1345-1350.

Ellingwood, B., & Redfield, R. (1983). "Ground snow loads for structural design." *Journal of Structural Engineering*, 109(4), 950-964.

SEAC, 2007. *Colorado Ground Snow Loads.* Prepared by the SEAC Snow Load Committee.

Appendix 4. Recommendations for Serviceability Loads and Importance Factors

A4.1. Introduction

This Appendix addresses serviceability loads and importance factors for snow load design in the state of Colorado. The newly proposed design ground snow loads, for the first time, target consistent reliability against structural failure rather than a consistent hazard, resulting in design ground snow loads with mean recurrence intervals on the order of 20 years to 300 years. Serviceability checks for snow loads are generally performed for loads with a 50-year mean recurrence interval (MRI) hazard.

In addition, the large range of mean recurrence intervals of the design ground snow loads raises the following question: will snow load importance factors (I_s) for Risk Category III and IV lead to uniform increases in structural reliability across all sites in the state of Colorado?

A4.2. Serviceability Loads

Serviceability checks for snow loads on roofs have traditionally been performed with the 50-year snow load. **Error! Reference source not found.** shows that the ratio of 50-year loads to reliability-targeted loads (referred to as $r_{service}$) varies from about 0.5 to 1.3 for Colorado snow sites and is correlated with altitude. The empirical relationship for $r_{service}$ in **Error! Reference source not found.** is defined by Equation A4.1.

$$r_{service} = 0.55 \leq .13 * A - 0.06 \leq 1.15 \qquad \text{A4.1,}$$

where A is the altitude of a site in thousands of feet.

Given the approximations involved in the statistical analysis and especially the mapping, the SEAC Snow Load Committee believes that the reliability targeted loads are sufficient for serviceability checks in most structures. For sensitive structures at high altitudes, the $r_{service}$ could be used to increase the reliability-targeted load to a 50-year load. If $r_{service}$ values less than 1.0 are used at lower altitudes, the SEAC Snow Load Committee recommends that the ground snow load for serviceability not be taken less than 25 psf.

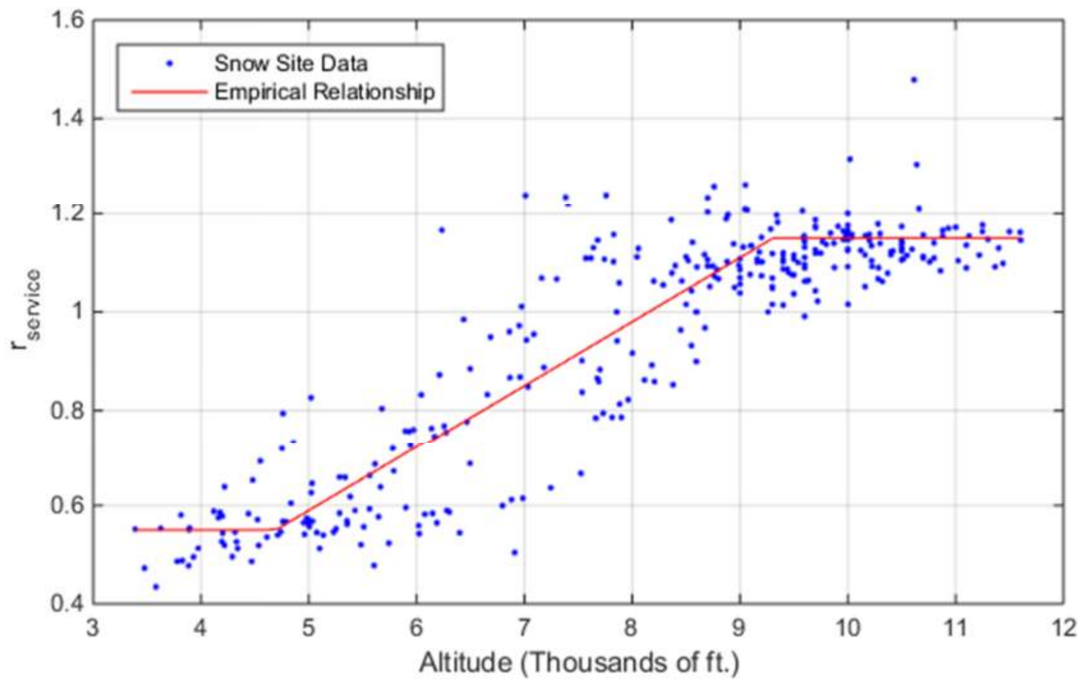

Figure A4.1. Relationship between the ratios of 50-year ground snow loads to reliability-based loads ($r_{service}$) for each site plotted against altitude for Colorado snow sites.

A4.3. Snow Load Importance Factors

This section shows that uniform importance factors of 1.2 for Risk Category IV buildings and 1.1 for Risk Category III buildings do not achieve the target safety indices for these higher Risk Category buildings, so an alternative model is proposed. Figure A4.2 shows the required I_s to achieve safety indices of β=3.5 (*i.e.* the intended reliability for importance category IV buildings) at the Colorado snow sites. The results indicate that the *ASCE 7* I_s of 1.2 for Risk Category IV buildings is non-conservative at low altitudes in the state of Colorado and conservative at high altitudes. A higher I_s is needed at low altitude sites because their annual maximum snow loads are characterized by heavy-tailed distributions, which results in a larger increase in load being necessary to increase β from 3.0 to the desired safety level (*i.e.* 3.5 for risk

Category IV and 3.25 for Risk Category III).

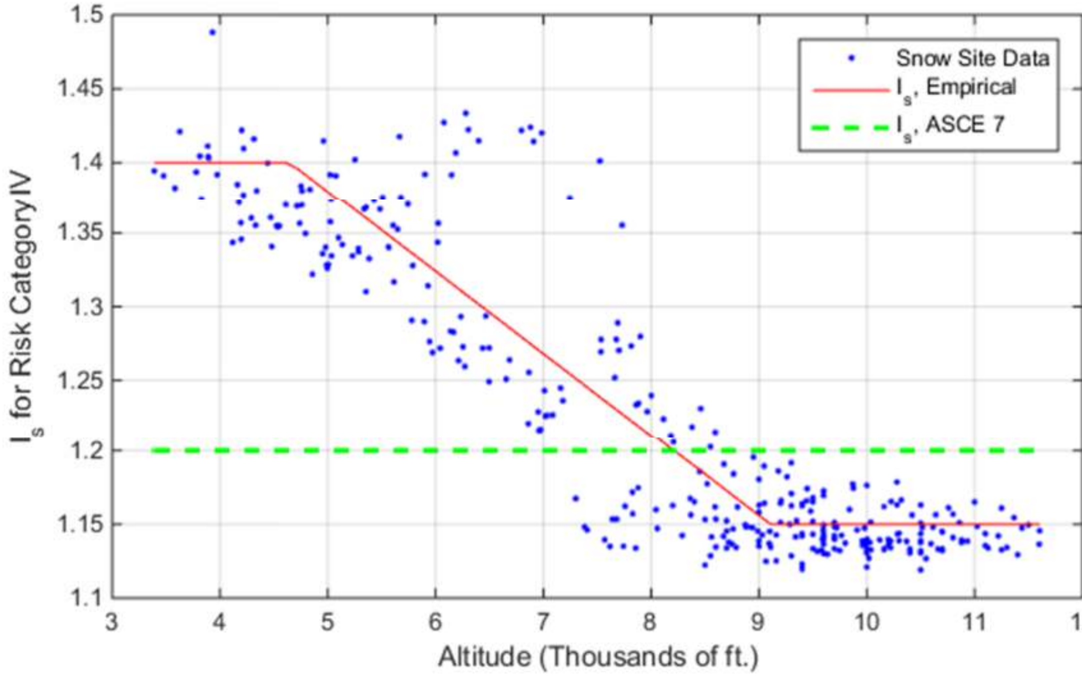

Figure A4.2. Importance factors to achieve a safety index of b=3.5 at Colorado snow sites.

The relationship between altitude and I_s for Risk Category IV buildings is approximated by the empirical equation,

$$I_s = 1.15 \leq 1.66 - 0.056 * A \leq 1.4 \qquad \text{A4.2,}$$

where A is the altitude of a site in thousands of feet.

The performance of the empirical equation for computing I_s for Risk Category IV buildings (Equation A4.2) is compared to the performance of Risk Category IV buildings designed for a constant snow importance factor of 1.2, as in *ASCE 7.* Calculations of the safety index β at each snow site for the design load factored by I_s are displayed in Figure A4.3 and Figure A4.4. By visual inspection, a constant I_s of 1.2 is conservatively biased for sites with altitudes above 8000 ft. and non-conservatively biased for sites with altitudes below 7500 ft. in the state of Colorado (Figure A4.3). However, when I_s is computed with Equation A4.2, the biases are removed (Figure A4.4).

Therefore, the SEAC Snow Load Committee recommends that I_s be determined by Equation A4.2 for Risk Category IV buildings in Colorado. For Risk Category III buildings, I_s should be the average of 1.0 and Equation A4.2.

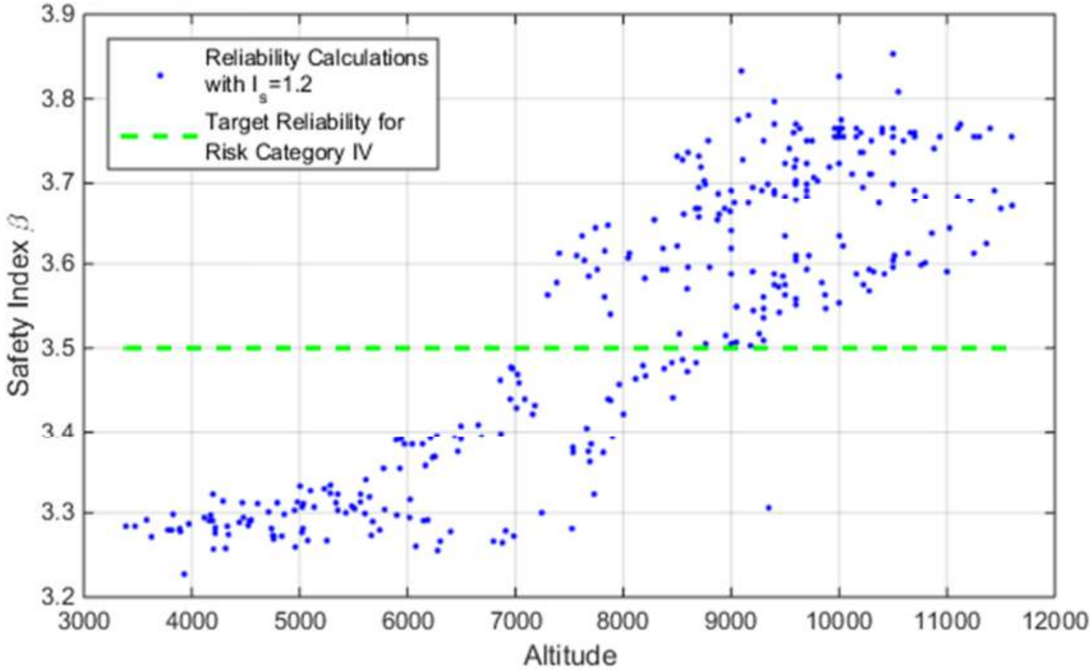

Figure A4.3. Calculations of the safety index β for each snow site, using I_s=1.2.

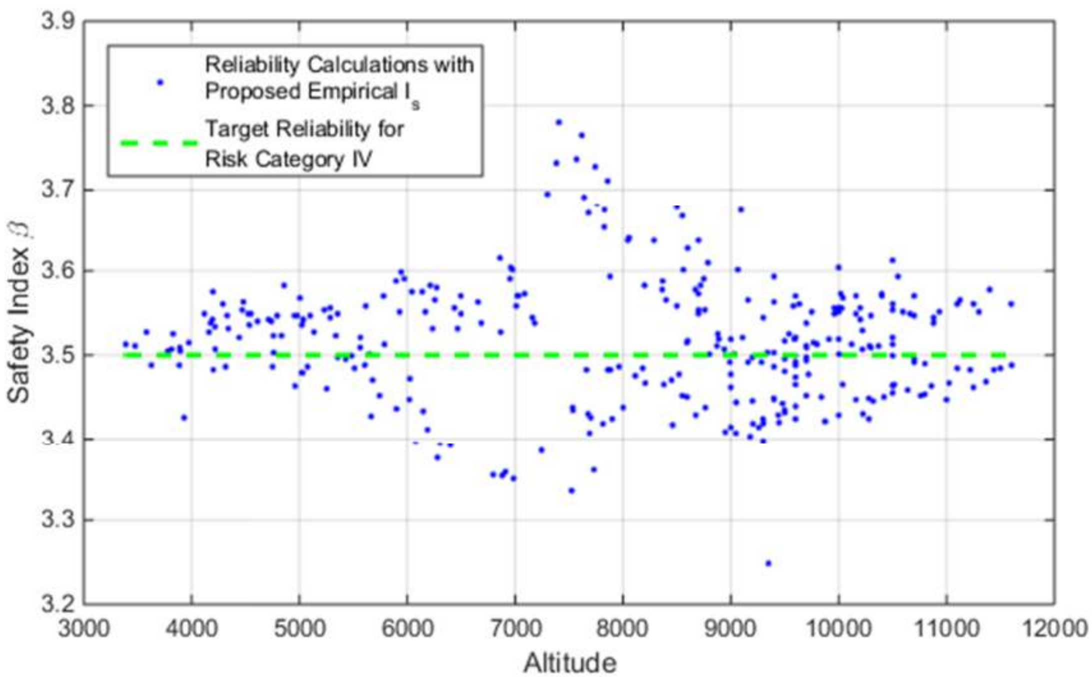

Figure A4.4. Calculations of the safety index β for each snow site, using I_s from Equation A4.2.

Appendix 5. Tabulated Data Summary

A5.1. Introduction

Raw station data and assembled snow site data are summarized in this appendix. The summary statistics in this appendix are for annual maximum ground snow loads. Reliability-based ground snow loads for each assembled snow site are also reported. We note, however, that the reliability-targeted ground snow loads are different than those reported in Table 1.1 primarily because the altitudes of the assembled stations are different that the altitudes of the population centers reported in Table 1.1 and spatial averaging (smoothing) of the design ground snow loads is not yet applied. Snow load values in this appendix should not be used for design.

The raw data come from four types of snow recording stations: first-order National Weather Service (NWS) stations, CO-OP NWS stations, snow courses, and SNOTEL (short for SNOwpack TELemetry) stations. Descriptions of each station type are available in Section 2.1.1. In the raw data summary, first order NWS stations are denoted “First Order,” NWS Co-op stations are denoted “NWS,” snow courses are denoted “SNOW,” and SNOTEL stations are denoted “SNTL.”

The assembled snow site data are the result of combining snow stations that are either at the same location or very near each other. For example, many snow courses have been replaced by SNOTEL stations at the same location; these are combined to make one snow site. The procedure for combining snow stations to assemble the snow sites is described in Section 2.1.2. When tabulating the assembled site data, only the station name with the longest data record is reported (in most cases, the stations from which a snow site is assembled have the same name). Recorded snow weights are reported as snow water equivalents (SWE), which is the height in inches of an equivalent (weight) column of water. Each inch of SWE is approximately 5.2 psf.

A5.2. Raw Data Summary

Table A5.1 Raw data summary

Station Name	*ID*	*Type*	*Lat (deg)*	*Lon (deg)*	*Alt (ft.)*	*Num Snow Yrs*	*Yrs with Depth*	*Max Depth (in)*	*Yrs with SWE*	*Max SWE (in)*
ALAMOSA SAN LUIS VALLEY REGIONAL AIRPORT	2	First Order	37.44	-105.86	7534	53	53	18	39	3.1
COLORADO SPRINGS MUNICIPAL AIRPORT	3	First Order	38.81	-104.69	6182	65	65	20	16	2.5
DENVER-STAPLETON	1	First Order	39.76	-104.87	5286	121	121	33	43	4.2
FORT COLLINS	4	First Order	40.62	-105.13	5004	65	65	23	3	3.0
GRAND JUNCTION WALKER	5	First Order	39.13	-108.54	4858	51	51	16	34	3.4
PUEBLO MEMORIAL AIRPORT	6	First Order	38.29	-104.50	4720	41	41	24	31	1.4
AGUILAR	50102	NWS	37.40	-104.65	6400	32	32	29	0	NA
AKRON 1 N	50114	NWS	40.17	-103.22	4663	48	48	28	0	NA
AKRON 4 E	50109	NWS	40.15	-103.14	4540	35	35	18	0	NA
ALAMOSA	50125	NWS	37.47	-105.88	7536	81	81	18	0	NA

Table A5.1 Raw data summary

Station Name	ID	Type	Lat (deg)	Lon (deg)	Alt (ft.)	Num Snow Yrs	Yrs with Depth	Max Depth (in)	Yrs with SWE	Max SWE (in)
ALLENSPARK 1 NW	50183	NWS	40.20	-105.55	8540	11	11	38	0	NA
ALLENSPARK LODGE	50183	NWS	40.20	-105.53	8450	32	32	38	0	NA
ALTENBERN	50214	NWS	39.50	-108.38	5678	65	65	54	0	NA
AMES	50228	NWS	37.87	-107.88	8700	38	38	78	0	NA
AMY	50242	NWS	38.88	-103.65	5243	26	26	24	0	NA
ANTERO RSVR	50263	NWS	38.99	-105.89	8920	52	52	25	0	NA
ARAPAHOE	50304	NWS	38.85	-102.18	4020	22	22	17	0	NA
AROYA 6 NE	50343	NWS	38.92	-103.08	4793	24	24	6	0	NA
ARRIBA	50348	NWS	39.29	-103.25	5242	17	17	18	0	NA
ASPEN	50370	NWS	39.20	-106.83	8045	77	77	60	0	NA
AYER RCH	50437	NWS	39.02	-104.60	7234	26	26	24	0	NA
AYER RCH	50437	NWS	39.02	-104.60	7234	22	22	24	0	NA
BAILEY	50454	NWS	39.40	-105.48	7730	60	60	45	0	NA
BLANCA	50776	NWS	37.42	-105.52	7815	59	59	13	0	NA
BLOOM	50784	NWS	37.68	-103.95	4484	23	23	36	0	NA
BLUE MESA LAKE	50797	NWS	38.47	-107.17	7568	45	45	40	0	NA
BOND	50810	NWS	39.88	-106.68	6706	16	16	17	0	NA
BONHAM RSVR	50825	NWS	39.10	-107.90	9852	26	26	98	0	NA
BONNY LAKE	50834	NWS	39.63	-102.18	3701	58	58	24	0	NA
BOULDER	50848	NWS	39.99	-105.27	5484	63	63	27	0	NA
BRANDON	50895	NWS	38.45	-102.45	3931	39	39	10	0	NA
BRANSON	50898	NWS	37.02	-103.88	6280	32	32	33	0	NA
BRECKENRIDGE	50909	NWS	39.49	-106.04	9580	48	48	56	0	NA
BRIGGSDALE	50945	NWS	40.64	-104.33	4834	40	40	19	0	NA
BRIGHTON	50950	NWS	39.99	-104.82	4980	40	40	18	0	NA
BROWNS PARK REFUGE	51017	NWS	40.80	-108.92	5354	30	30	16	0	NA
BUCKHORN MTN 1 E	51060	NWS	40.62	-105.29	7400	25	25	37	0	NA
BUENA VISTA	51071	NWS	38.83	-106.13	7963	113	113	22	0	NA
BURLINGTON	51121	NWS	39.30	-102.26	4197	115	115	27	0	NA
BUTLER RCH	51157	NWS	38.03	-104.47	4852	25	25	21	0	NA
BYERS 5 ENE	51179	NWS	39.74	-104.13	5100	82	82	24	0	NA
CABIN CREEK	51186	NWS	39.66	-105.71	10020	43	43	65	0	NA
CAMPO 7 S	51268	NWS	37.02	-102.56	4118	54	54	16	0	NA
CANON CITY	51294	NWS	38.45	-105.24	5355	111	111	25	0	NA
CASCADE	51384	NWS	37.67	-107.80	8855	9	9	82	0	NA
CASTLE ROCK	51401	NWS	39.41	-104.91	6186	46	46	44	0	NA
CEDAREDGE	51440	NWS	38.90	-107.93	6213	104	104	35	0	NA
CENTER 4 SSW	51458	NWS	37.70	-106.14	7676	58	58	18	0	NA
CHEESMAN	51528	NWS	39.22	-105.28	6880	111	111	44	0	NA

Table A5.1 Raw data summary

Station Name	ID	Type	Lat (deg)	Lon (deg)	Alt (ft.)	Num Snow Yrs	Yrs with Depth	Max Depth (in)	Yrs with SWE	Max SWE (in)
CHERAW 1 N	51539	NWS	38.11	-103.51	4147	19	19	14	0	NA
CHERRY CREEK DAM	51547	NWS	39.65	-104.85	5647	50	50	28	0	NA
CHEYENNE WELLS	51564	NWS	38.82	-102.36	4250	67	67	15	0	NA
CIMARRON	51609	NWS	38.44	-107.56	7010	46	46	46	0	NA
CLIMAX	51660	NWS	39.37	-106.19	11294	63	63	81	0	NA
COAL CREEK CANYON	51681	NWS	39.90	-105.38	8950	19	19	56	0	NA
COCHETOPA CREEK	51713	NWS	38.45	-106.76	8002	65	65	38	0	NA
COLLBRAN	51741	NWS	39.24	-107.97	6043	44	44	33	0	NA
COLORADO NM	51772	NWS	39.10	-108.73	5779	66	66	30	0	NA
CORTEZ	51886	NWS	37.34	-108.59	6167	76	76	21	0	NA
CRAIG	51928	NWS	40.52	-107.55	6255	75	75	21	0	NA
CRAIG 4 SW	51932	NWS	40.45	-107.59	6496	36	36	22	0	NA
CRESTED BUTTE	51959	NWS	38.87	-106.98	8865	99	99	120	0	NA
CRESTONE 1 SE	51964	NWS	37.98	-105.68	8115	31	31	26	0	NA
CRIPPLE CREEK	51973	NWS	38.75	-105.18	9541	6	6	14	0	NA
CUMBRES	52048	NWS	37.02	-106.45	10026	18	18	136	0	NA
DEL NORTE	52184	NWS	37.67	-106.35	7884	58	58	19	0	NA
DELHI	52178	NWS	37.63	-104.02	5092	25	25	20	0	NA
DELTA	52192	NWS	38.75	-108.07	5031	38	38	9	0	NA
DILLON 1 E	52281	NWS	39.63	-106.04	9065	68	68	43	0	NA
DINOSAUR NATL MONUMNT	52286	NWS	40.24	-108.97	5972	46	46	23	0	NA
DOHERTY RCH	52312	NWS	37.38	-103.88	5135	32	32	18	0	NA
DOLORES	52326	NWS	37.47	-108.50	6953	56	56	43	0	NA
DURANGO	52432	NWS	37.29	-107.87	6665	63	63	39	0	NA
DURANGO WATER RESOURCE	52441	NWS	37.29	-107.86	6750	21	21	39	0	NA
EADS 2 S	52446	NWS	38.45	-102.78	4217	72	72	14	0	NA
EAGLE FAA AP	52454	NWS	39.65	-106.92	6497	52	52	32	0	NA
EASTONVILLE 1 NNW	52494	NWS	39.08	-104.57	7245	57	57	36	0	NA
EDGEWATER	52557	NWS	39.75	-105.08	5453	50	50	18	0	NA
ELBERT	52593	NWS	39.22	-104.55	6766	11	11	20	0	NA
ELECTRA LAKE	52624	NWS	37.55	-107.80	8406	14	14	57	0	NA
ESTES PARK	52759	NWS	40.38	-105.52	7524	93	93	42	0	NA
EVERGREEN	52790	NWS	39.64	-105.32	6985	41	41	42	0	NA
EVERSOLL RCH	52803	NWS	37.03	-102.07	3583	23	23	12	0	NA
FAIRPLAY	52814	NWS	39.23	-106.00	10007	14	14	23	0	NA
FLAGLER 2 NW	52932	NWS	39.32	-103.08	4980	64	64	19	0	NA
FLEMING 1 W	52944	NWS	40.68	-102.83	4290	76	76	18	0	NA
FLORISSANT FOSSIL BED	52965	NWS	38.91	-105.29	8379	35	35	24	0	NA

Table A5.1 Raw data summary

Station Name	*ID*	*Type*	*Lat (deg)*	*Lon (deg)*	*Alt (ft.)*	*Num Snow Yrs*	*Yrs with Depth*	*Max Depth (in)*	*Yrs with SWE*	*Max SWE (in)*
FORDER 8 S	52997	NWS	38.55	-103.68	4749	30	30	14	0	NA
FOUNTAIN	53063	NWS	38.68	-104.70	5565	46	46	25	0	NA
FOUNTAIN 6 NNE	53068	NWS	38.78	-104.62	5965	12	12	25	0	NA
FOWLER 1 SE	53079	NWS	38.12	-104.01	4330	69	69	17	0	NA
FRASER	53113	NWS	39.94	-105.82	8560	86	86	59	0	NA
FRUITA 1 W	53146	NWS	39.17	-108.75	4480	65	65	18	0	NA
FT CARSON	53002	NWS	38.68	-104.77	5869	22	22	16	0	NA
FT COLLINS	53005	NWS	40.61	-105.13	5004	65	65	23	0	NA
FT LEWIS	53016	NWS	37.23	-108.05	7640	63	63	49	0	NA
FT LUPTON 2 SE	53027	NWS	4NA7	-104.78	5023	64	64	30	0	NA
FT MORGAN	53038	NWS	40.26	-103.81	4340	57	57	14	0	NA
GARDNER	53222	NWS	37.77	-105.18	6974	32	32	30	0	NA
GATEWAY 1 SE	53246	NWS	38.67	-108.97	4550	64	64	15	0	NA
GENOA	53258	NWS	39.28	-103.50	5606	69	69	14	0	NA
GEORGETOWN	53261	NWS	39.72	-105.70	8520	50	50	46	0	NA
GLENDEVEY	53340	NWS	40.80	-105.88	8274	9	9	46	0	NA
GLENWOOD SPGS #2	53359	NWS	39.52	-107.32	5895	62	62	30	0	NA
GORE PASS RCH	53423	NWS	40.15	-106.47	7605	6	6	18	0	NA
GRAND JUNCTION 6 ESE	53489	NWS	39.04	-108.47	4760	49	49	14	0	NA
GRAND JUNCTION WALKER	53488	NWS	39.13	-108.54	4858	114	114	18	0	NA
GRAND LAKE 1 NW	53496	NWS	40.27	-105.83	8720	65	65	56	0	NA
GRAND LAKE 6 SSW	53500	NWS	40.18	-105.87	8288	47	47	38	0	NA
GRAND VALLEY	53508	NWS	39.45	-108.05	5092	16	16	26	0	NA
GRANT	53530	NWS	39.46	-105.68	8675	50	50	36	0	NA
GREAT SAND DUNES NM	53541	NWS	37.73	-105.51	8183	59	59	24	0	NA
GREELEY	53546	NWS	40.42	-104.68	4652	19	19	18	0	NA
GREELEY UNC	53553	NWS	40.40	-104.70	4715	46	46	20	0	NA
GREEN MTN DAM	53592	NWS	39.88	-106.33	7743	64	64	38	0	NA
GROSS RSVR	53629	NWS	39.94	-105.35	6910	35	35	43	0	NA
GUFFEY 10 SE	53656	NWS	38.68	-105.38	8595	55	55	26	0	NA
GUNNISON 1 N	53662	NWS	38.55	-106.92	7680	58	58	38	0	NA
HAMILTON	53738	NWS	40.37	-107.62	6234	44	44	39	0	NA
HARMON RCH	53783	NWS	37.48	-102.68	4544	11	11	10	0	NA
HARTSEL	53811	NWS	39.03	-105.80	8875	16	16	22	0	NA
HASWELL	53828	NWS	38.45	-103.16	4525	62	62	22	0	NA
HAWTHORNE	53850	NWS	39.93	-105.28	5925	27	27	29	0	NA
HAYDEN	53867	NWS	40.49	-107.25	6467	66	66	43	0	NA
HERMIT 7 ESE	53951	NWS	37.77	-107.11	9048	58	58	46	0	NA

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Station Name	ID	Type	Lat (deg)	Lon (deg)	Alt (ft.)	Num Snow Yrs	Yrs with Depth	Max Depth (in)	Yrs with SWE	Max SWE (in)
HIGBEE 2 SW	53982	NWS	37.75	-103.47	4252	8	8	6	0	NA
HOHNHOLZ RCH	54054	NWS	40.97	-106.00	7760	28	28	26	0	NA
HOLLY	54076	NWS	38.05	-102.12	3390	61	61	22	0	NA
HOLYOKE	54082	NWS	40.55	-102.34	3780	64	64	20	0	NA
HOT SULPHUR SPGS 2 SW	54129	NWS	4NA5	-106.13	7605	21	21	48	0	NA
HOURGLASS RSVR	54135	NWS	40.58	-105.63	9520	25	25	62	0	NA
HUGO	54172	NWS	39.13	-103.47	5030	24	24	11	0	NA
IDAHO SPRINGS	54234	NWS	39.75	-105.52	7566	19	19	36	0	NA
IDALIA 4 NNE	54242	NWS	39.75	-102.27	3969	52	52	13	0	NA
IGNACIO 1 N	54250	NWS	37.13	-107.63	6437	42	42	32	0	NA
INDEPENDENCE PASS 5 SW	54270	NWS	39.08	-106.62	10558	19	19	96	0	NA
INTER CANYON	54293	NWS	39.57	-105.22	7040	29	29	57	0	NA
JOES 2 SE	54380	NWS	39.63	-102.65	4251	29	29	18	0	NA
JOHN MARTIN DAM	54388	NWS	38.06	-102.93	3814	66	66	22	0	NA
JONES PASS 2 E	54397	NWS	39.77	-105.85	10328	12	12	63	0	NA
JULESBURG	54413	NWS	40.99	-102.27	3469	90	90	25	0	NA
KARVAL	54444	NWS	38.74	-103.54	5075	58	58	18	0	NA
KASSLER	54452	NWS	39.49	-105.10	5586	65	65	38	0	NA
KAUFFMAN 4 SSE	54460	NWS	40.85	-103.90	5253	34	34	14	0	NA
KIM 10 SSE	54546	NWS	37.12	-103.30	5300	25	25	30	0	NA
KIM 15 NNE	54538	NWS	37.45	-103.32	5190	25	25	43	0	NA
KIOWA 4 SW	54585	NWS	39.30	-104.52	6555	10	10	19	0	NA
KIOWA 5 SE	54584	NWS	39.28	-104.43	6355	7	7	12	0	NA
KIT CARSON 6 SE	54603	NWS	38.70	-102.73	4202	65	65	17	0	NA
KREMMLING	54664	NWS	4NA6	-106.38	7406	43	43	36	0	NA
LA JUNTA 20 S	54726	NWS	37.75	-103.48	4210	31	31	31	0	NA
LA JUNTA 4 NNE	54720	NWS	38.05	-103.52	4194	52	52	21	0	NA
LA VETA	54865	NWS	37.50	-105.00	7034	8	8	27	0	NA
LAKE CITY	54734	NWS	38.04	-107.32	8764	57	57	46	0	NA
LAKE GEORGE 8 SW	54742	NWS	38.91	-105.47	8550	53	53	32	0	NA
LAKE MORAINE	54750	NWS	38.82	-104.98	10273	15	15	57	0	NA
LAKEWOOD	54762	NWS	39.75	-105.12	5640	51	51	38	0	NA
LAMAR	54770	NWS	38.09	-102.63	3627	118	118	36	0	NA
LAS ANIMAS	54834	NWS	38.06	-103.22	3890	67	67	30	0	NA
LEADVILLE	54884	NWS	39.25	-106.30	10131	32	32	54	0	NA
LEADVILLE 2 SW	54885	NWS	39.23	-106.32	9938	30	30	30	0	NA
LEMON DAM	54934	NWS	37.38	-107.66	8363	31	31	62	0	NA
LEROY 5 WSW	54945	NWS	40.51	-103.00	4470	65	65	24	0	NA

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Station Name	ID	Type	Lat (deg)	Lon (deg)	Alt (ft.)	Num Snow Yrs	Yrs with Depth	Max Depth (in)	Yrs with SWE	Max SWE (in)
LIME 3 SE	55001	NWS	38.12	-104.58	4905	17	17	19	0	NA
LIMON	55017	NWS	39.27	-103.68	5368	23	23	8	0	NA
LIMON 10 SSW	55015	NWS	39.15	-103.77	5564	52	52	31	0	NA
LIMON WSMO	55018	NWS	39.18	-103.70	5562	23	23	18	0	NA
LINDON 4 S	55025	NWS	39.68	-103.42	4890	25	25	14	0	NA
LITTLE HILLS	55048	NWS	4NA0	-108.20	6139	43	43	30	0	NA
LITTLETON	55056	NWS	39.62	-105.02	5340	14	14	33	0	NA
LONGMONT 2 ESE	55116	NWS	40.17	-105.07	4953	55	55	16	0	NA
LOVELAND NCWCD	55236	NWS	40.40	-105.11	5040	21	21	20	0	NA
MANASSA	55322	NWS	37.17	-105.94	7690	58	58	13	0	NA
MANCOS	55327	NWS	37.34	-108.30	6960	50	50	28	0	NA
MARVINE	55408	NWS	4NA2	-107.54	7283	25	25	61	0	NA
MARVINE RCH	55414	NWS	4NA3	-107.46	7800	10	10	62	0	NA
MASSADONA 3 E	55422	NWS	40.28	-108.60	6185	22	22	24	0	NA
MAYBELL	55446	NWS	40.52	-108.09	5944	46	46	29	0	NA
MEEKER	55484	NWS	4NA3	-107.90	6236	43	43	21	0	NA
MEEKER #2	55487	NWS	4NA3	-107.92	6351	20	20	30	0	NA
MEREDITH	55507	NWS	39.37	-106.75	7826	42	42	57	0	NA
MESA LAKES RESORT	55520	NWS	39.05	-108.08	9806	8	8	98	0	NA
MESA VERDE NP	55531	NWS	37.20	-108.49	7087	65	65	39	0	NA
MONTE VISTA	55706	NWS	37.57	-106.14	7662	63	63	18	0	NA
MONTROSE #2	55722	NWS	38.49	-107.88	5789	60	60	18	0	NA
MONTROSE 1	55717	NWS	38.48	-107.88	5785	25	25	20	0	NA
MONUMENT	55734	NWS	39.10	-104.87	7079	14	14	26	0	NA
MONUMENT 2 WSW	55730	NWS	39.08	-104.92	7346	15	15	30	0	NA
MT EVANS RSCH STN	55797	NWS	39.65	-105.60	10630	16	16	104	0	NA
NEDERLAND 2 NNE	55878	NWS	39.98	-105.50	8240	18	18	32	0	NA
NEW RAYMER	55922	NWS	40.60	-103.85	4793	38	38	19	0	NA
NEW RAYMER 21 N	55934	NWS	40.93	-103.87	5180	26	26	20	0	NA
NORTH LAKE	55990	NWS	37.22	-105.05	8806	27	27	24	0	NA
NORTHDALE	55970	NWS	37.82	-109.03	6655	52	52	29	0	NA
NORTHGLENN	55984	NWS	39.90	-105.01	5407	29	29	22	0	NA
NORWOOD	56012	NWS	38.13	-108.28	7019	51	51	28	0	NA
NUNN	56023	NWS	40.71	-104.78	5196	17	17	12	0	NA
OLATHE	56081	NWS	38.62	-107.98	5364	7	7	14	0	NA
ORDWAY 2 ENE	56131	NWS	38.22	-103.72	4315	62	62	18	0	NA
ORDWAY 21 N	56136	NWS	38.53	-103.71	4767	33	33	15	0	NA
OTIS 11 NE	56192	NWS	40.27	-102.84	4229	38	38	12	0	NA
OURAY	56203	NWS	38.02	-107.67	7828	58	58	49	0	NA

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Station Name	ID	Type	Lat (deg)	Lon (deg)	Alt (ft.)	Num Snow Yrs	Yrs with Depth	Max Depth (in)	Yrs with SWE	Max SWE (in)
OVID	56225	NWS	40.96	-102.38	3533	11	11	10	0	NA
PAGOSA SPRINGS	56258	NWS	37.27	-107.02	7181	49	49	46	0	NA
PALISADE	56266	NWS	39.11	-108.35	4751	62	62	12	0	NA
PALISADE LAKES 6 SSE	56271	NWS	37.43	-107.15	8094	20	20	58	0	NA
PALMER LAKE	56280	NWS	39.12	-104.92	7273	10	10	36	0	NA
PAONIA	56306	NWS	38.86	-107.58	5851	9	9	11	0	NA
PAONIA 1 SW	56306	NWS	38.85	-107.62	5576	56	56	26	0	NA
PARACHUTE	56311	NWS	39.45	-108.05	5090	8	8	20	0	NA
PARADOX 1 E	56315	NWS	38.37	-108.95	5282	26	26	20	0	NA
PARADOX 1 W	56318	NWS	38.38	-108.98	5530	18	18	23	0	NA
PARKER 6 E	56326	NWS	39.52	-104.65	6304	50	50	36	0	NA
PARSHALL 10 SSE	56342	NWS	39.92	-106.12	8274	8	8	75	0	NA
PENROSE	56410	NWS	38.45	-105.07	5413	22	22	5	0	NA
PERRY PARK	56430	NWS	39.26	-104.97	6326	7	7	0	0	NA
PITKIN	56513	NWS	38.60	-106.53	9199	27	27	70	0	NA
PLACERVILLE	56520	NWS	38.02	-108.05	7383	59	59	45	0	NA
PLATORO	56559	NWS	37.35	-106.53	9834	6	6	72	0	NA
PUEBLO 6 SSW	56767	NWS	38.18	-104.65	4915	12	12	10	0	NA
PUEBLO ARMY DEPOT	56763	NWS	38.31	-104.35	4682	17	17	16	0	NA
PUEBLO CITY RSVR	56743	NWS	38.28	-104.65	4692	20	20	12	0	NA
PUEBLO FIRE STN #2	56748	NWS	38.27	-104.60	4705	6	6	4	0	NA
PUEBLO RSVR	56765	NWS	38.26	-104.72	4855	38	38	15	0	NA
PUEBLO WB AP	56738	NWS	38.23	-104.63	4806	7	7	11	0	NA
PUEBLO WSO AP	56740	NWS	38.28	-104.50	4671	59	59	12	0	NA
PYRAMID	56797	NWS	40.23	-107.09	8030	23	23	50	0	NA
RALSTON RSVR	56816	NWS	39.83	-105.24	5900	35	35	38	0	NA
RAND	56820	NWS	40.43	-106.17	8630	10	10	26	0	NA
RANGELY 1 E	56832	NWS	4NA9	-108.77	5285	63	63	27	0	NA
RED FEATHER LAKES 2 SE	56925	NWS	40.79	-105.56	8207	34	34	26	0	NA
RED WING 1 WSW	56977	NWS	37.72	-105.32	7900	15	15	0	0	NA
REDSTONE 4 W	56970	NWS	39.20	-107.30	8066	12	12	59	0	NA
RICO	57017	NWS	37.69	-108.03	8821	53	53	89	0	NA
RIDGWAY	57020	NWS	38.15	-107.76	7034	31	31	25	0	NA
RIFLE	57031	NWS	39.53	-107.79	5337	79	79	40	0	NA
RIO GRANDE RSVR	57050	NWS	37.73	-107.27	9686	23	23	59	0	NA
ROCKY FORD 2 SE	57167	NWS	38.04	-103.69	4170	65	65	19	0	NA
RUSH	57287	NWS	38.83	-104.08	6020	54	54	23	0	NA
RUSTIC 9 WSW	57296	NWS	40.71	-105.71	7700	20	20	36	0	NA
RUXTON PARK	57309	NWS	38.84	-104.97	9050	46	46	49	0	NA

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RYE	57315	NWS	37.92	-104.93	6796	32	32	36	0	NA
SAGUACHE	57337	NWS	38.08	-106.14	7701	59	59	23	0	NA
SALIDA	57370	NWS	38.53	-106.02	7160	48	48	42	0	NA
SALIDA 3 W	57371	NWS	38.53	-106.05	7488	11	11	30	0	NA
SAN LUIS 1 E	57430	NWS	37.18	-105.43	8060	24	24	8	0	NA
SARGENTS	57460	NWS	38.40	-106.42	8460	40	40	37	0	NA
SARGENTS 6W	57461	NWS	38.40	-106.50	8136	10	10	55	0	NA
SEDALIA 4 SSE	57510	NWS	39.40	-104.95	5975	49	49	28	0	NA
SEDGWICK	57513	NWS	40.94	-102.52	3584	19	19	14	0	NA
SEDGWICK 5 S	57515	NWS	40.86	-102.52	3990	55	55	24	0	NA
SHAW 2 E	57557	NWS	39.55	-103.35	5181	13	13	18	0	NA
SHEEP MTN	57572	NWS	37.72	-105.24	7754	26	26	29	0	NA
SHOSHONE	57618	NWS	39.57	-107.23	5930	60	60	39	0	NA
SILVERTON	57656	NWS	37.81	-107.66	9285	92	92	70	0	NA
SOUTH PLATTE	57816	NWS	39.41	-105.18	6156	10	10	7	0	NA
SPICER	57848	NWS	40.46	-106.46	8368	52	52	49	0	NA
SPRINGFIELD	57862	NWS	37.40	-102.61	4408	29	29	13	0	NA
SPRINGFIELD 7 WSW	57866	NWS	37.37	-102.75	4622	46	46	21	0	NA
SPRINGFIELD 8 S	57867	NWS	37.28	-102.62	4505	15	15	8	0	NA
SQUAW MTN	57881	NWS	39.68	-105.50	11509	13	13	49	0	NA
STATE TURKEY EXP FAR	57928	NWS	37.22	-107.27	6663	11	11	34	0	NA
STEAMBOAT SPRINGS	57936	NWS	40.49	-106.82	6865	94	94	61	0	NA
STERLING	57950	NWS	40.63	-103.21	3974	58	58	18	0	NA
STONINGTON	57992	NWS	37.30	-102.19	3816	48	48	12	0	NA
STRATTON	58008	NWS	39.30	-102.59	4401	55	55	28	0	NA
STRONTIA SPRINGS DAM	58022	NWS	39.43	-105.12	5840	29	29	39	0	NA
SUGARLOAF RSVR	58064	NWS	39.25	-106.37	9871	60	60	66	0	NA
TACOMA	58154	NWS	37.52	-107.78	7300	38	38	54	0	NA
TACONY 10 SE	58157	NWS	38.38	-104.07	4960	56	56	11	0	NA
TAYLOR PARK	58184	NWS	38.82	-106.61	9179	48	48	72	0	NA
TELLURIDE	58204	NWS	37.95	-107.82	8775	75	75	64	0	NA
TIMPAS 13 SW	58290	NWS	37.67	-103.92	4831	15	15	16	0	NA
TRINIDAD	58429	NWS	37.18	-104.49	6030	61	61	31	0	NA
TRINIDAD FAA AP	58434	NWS	37.25	-104.33	5742	53	53	16	0	NA
TRINIDAD LAKE	58436	NWS	37.15	-104.56	6310	23	23	20	0	NA
TRINIDAD RIVER	58431	NWS	37.17	-104.51	6002	16	16	0	0	NA
TROUT LAKE	58454	NWS	37.83	-107.88	9707	16	16	79	0	NA
TROY 1 SE	58468	NWS	37.13	-103.30	5514	37	37	18	0	NA

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Station Name	*ID*	*Type*	*Lat (deg)*	*Lon (deg)*	*Alt (ft.)*	*Num Snow Yrs*	*Yrs with Depth*	*Max Depth (in)*	*Yrs with SWE*	*Max SWE (in)*
TWIN LAKES RESERVOIR	58501	NWS	39.09	-106.35	9205	59	59	38	0	NA
TWO BUTTES	58510	NWS	37.56	-102.39	4090	20	20	11	0	NA
URAVAN	58560	NWS	38.38	-108.74	5021	50	50	10	0	NA
UTLEYVILLE	58574	NWS	37.27	-103.03	5003	8	8	6	0	NA
VAIL	58575	NWS	39.64	-106.35	8304	27	27	67	0	NA
VALLECITO DAM	58582	NWS	37.38	-107.58	7758	61	61	53	0	NA
VICTOR	58649	NWS	38.72	-105.15	9708	7	7	24	0	NA
VONA	58722	NWS	39.30	-102.73	4505	34	34	18	0	NA
WAGON WHEEL GAP 3 N	58742	NWS	37.80	-106.83	8507	22	22	32	0	NA
WALDEN	58756	NWS	40.74	-106.28	8056	64	64	33	0	NA
WALSENBURG	58781	NWS	37.63	-104.79	6188	64	64	30	0	NA
WALSH 1 W	58793	NWS	37.38	-102.30	3978	46	46	28	0	NA
WATERDALE	58839	NWS	40.43	-105.21	5230	65	65	24	0	NA
WESTCLIFFE	58931	NWS	38.13	-105.47	7860	65	65	34	0	NA
WETMORE 2 S	58986	NWS	38.22	-105.10	6585	19	19	28	0	NA
WETMORE 9 S	58990	NWS	38.13	-105.08	7365	6	6	24	0	NA
WHEAT RIDGE	58994	NWS	39.78	-105.12	5394	33	33	26	0	NA
WIGGINS 7 SW	59025	NWS	40.15	-104.18	4715	11	11	11	0	NA
WILLIAMS FORK DAM	59096	NWS	4NA4	-106.20	7618	31	31	34	0	NA
WINDSOR	59147	NWS	40.47	-104.90	4743	34	34	14	0	NA
WINTER PARK	59175	NWS	39.87	-105.76	9108	65	65	75	0	NA
WOLF CREEK PASS 1 E	59181	NWS	37.48	-106.78	10640	35	35	251	0	NA
WOLF CREEK PASS 4 W	59183	NWS	37.48	-106.87	9436	21	21	196	0	NA
WOODROW 6 NNE	59213	NWS	4NA8	-103.57	4374	20	20	12	0	NA
WOOTTON RCH	59216	NWS	37.00	-104.48	7582	23	23	30	0	NA
WRAY	59243	NWS	4NA6	-102.22	3582	90	90	16	0	NA
YAMPA	59265	NWS	40.16	-106.91	7857	64	64	35	0	NA
YELLOW JACKET 2 W	59275	NWS	37.52	-108.75	6860	40	40	36	0	NA
YUMA	59295	NWS	40.12	-102.72	4140	58	58	30	0	NA
YUMA 10 NW	59297	NWS	40.21	-102.81	4110	24	24	16	0	NA
ALEXANDER LAKE	07K03	SNOW	39.03	-107.97	10160	53	53	109	53	38.9
ANTERO	05L05	SNOW	38.92	-105.97	9300	45	45	39	45	7.1
ANTERO RESERVOIR	05L06	SNOW	39.00	-105.88	9000	29	29	26	29	5.3
APISHAPA	05M07	SNOW	37.33	-105.07	10000	27	27	62	27	17.4
ARROW	05K06	SNOW	39.92	-105.77	9680	52	52	67	52	26.1
BALTIMORE	05K23	SNOW	39.90	-105.58	8800	52	52	55	52	16.2
BEAR RIVER	07J03	SNOW	4NA7	-107.02	9100	28	28	54	28	17.2
BENNETT CREEK	05J33	SNOW	40.67	-105.62	9200	47	47	48	47	13.4

Table A5.1 Raw data summary

Station Name	ID	Type	Lat (deg)	Lon (deg)	Alt (ft.)	Num Snow Yrs	Yrs with Depth	Max Depth (in)	Yrs with SWE	Max SWE (in)
BERTHOUD FALLS	05K13	SNOW	39.78	-105.78	10500	62	62	72	62	23.2
BERTHOUD PASS	05K03	SNOW	39.83	-105.75	9700	77	77	85	77	30.3
BERTHOUD SUMMIT	05K14	SNOW	39.80	-105.78	11300	41	41	92	41	34.8
BIG MEADOWS	06M25	SNOW	37.53	-106.80	9260	44	44	92	44	26.1
BIG SOUTH	05J03	SNOW	40.62	-105.82	8600	75	75	31	75	7.9
BIGELOW DIVIDE	05L03	SNOW	38.10	-105.13	9350	29	29	58	29	14.8
BISON RESERVOIR	05L08	SNOW	38.77	-105.10	10220	15	15	31	15	8.6
BLUE RIVER	06K21	SNOW	39.38	-106.05	10500	56	56	54	56	16.2
BOULDER FALLS	05J25	SNOW	4NA2	-105.57	10000	60	60	74	60	22.9
BOURBON	05M05	SNOW	37.18	-105.10	9600	35	35	54	35	13.0
BROWN CABIN	05M04	SNOW	37.55	-105.40	9600	46	46	54	46	15.7
BURRO MOUNTAIN	07K02	SNOW	39.88	-107.60	9400	72	72	82	72	29.5
BUTTE	06L11	SNOW	38.90	-106.95	10160	25	25	85	25	25.3
BUTTERHILL	06J37	SNOW	40.93	-106.98	7880	34	34	62	34	20.2
CAMERON PASS	05J01	SNOW	40.52	-105.57	10285	76	76	107	76	40.9
CASCADE	07M05	SNOW	37.65	-107.80	8840	51	51	83	51	27.5
CHAMBERS LAKE	05J02	SNOW	40.62	-105.83	9000	76	76	51	76	15.4
COCHETOPA PASS	06L06	SNOW	38.17	-106.60	10000	64	64	38	64	10.5
COLUMBINE DITCH	06K47	SNOW	39.38	-106.25	11576	5	5	84	5	25.4
COLUMBINE LODGE	06J03	SNOW	40.40	-106.60	9160	63	63	99	63	34.9
COLUMBINE PASS	08L02	SNOW	38.42	-108.38	9140	7	7	90	7	28.6
COMO	05K25	SNOW	39.35	-105.92	10370	46	46	45	46	13.5
COPELAND LAKE	05J18	SNOW	40.20	-105.57	8600	43	43	40	43	11.8
CORRAL CREEK	06J17	SNOW	40.15	-106.15	9700	17	17	58	17	18.0
CRESTED BUTTE	07L01	SNOW	38.88	-107.00	8920	74	74	79	74	26.7
CROSHO	07J04	SNOW	40.17	-107.05	9100	2	2	51	2	17.6
CUCHARAS CREEK	05M12	SNOW	37.33	-105.08	9700	38	38	68	38	16.5
CULEBRA	05M03	SNOW	37.22	-105.20	10500	53	53	65	53	24.1
CUMBRES PASS	06M07	SNOW	37.02	-106.45	10020	54	54	104	54	41.0
CUMBRES TRESTLE	06M22	SNOW	37.02	-106.45	10020	19	19	126	19	47.5
DEADMAN HILL	05J06	SNOW	40.80	-105.77	10220	64	64	73	64	26.6
DEER RIDGE	05J17	SNOW	40.40	-105.63	9000	64	64	35	64	10.4
DRY LAKE	06J01	SNOW	40.53	-106.78	8400	51	51	88	51	31.3
ELEVEN MILE	05L07	SNOW	38.95	-105.53	8590	29	29	13	29	3.1
ELK RIVER #2	06J15	SNOW	40.85	-106.97	8700	51	51	79	51	27.1
ELKHORN	06J36	SNOW	40.98	-106.92	8475	11	11	92	11	41.3
EMPIRE	05K10	SNOW	39.77	-105.78	9600	51	51	44	51	14.1
EMPIRE #2	05K29	SNOW	39.77	-105.78	9680	40	40	44	40	12.1
EWING UPPER	06K48	SNOW	39.37	-106.28	11270	5	5	68	5	20.8

Table A5.1 Raw data summary

Station Name	ID	Type	Lat (deg)	Lon (deg)	Alt (ft.)	Num Snow Yrs	Yrs with Depth	Max Depth (in)	Yrs with SWE	Max SWE (in)
FOUR MILE PARK	06K07	SNOW	39.07	-106.43	9700	61	61	48	61	11.8
FREMONT PASS	06K08	SNOW	39.38	-106.20	11400	59	59	76	59	27.7
GENEVA PARK	05K11	SNOW	39.52	-105.72	9600	64	64	35	64	8.0
GLEN MAR RANCH	06K20	SNOW	39.82	-106.05	8750	53	53	55	53	15.7
GORE PASS	06J11	SNOW	4NA8	-106.55	9400	58	58	54	58	16.0
GRANBY	05J16	SNOW	40.15	-106.00	8600	64	64	45	64	14.8
GRAND LAKE	05J19	SNOW	40.27	-105.83	8600	44	44	54	44	16.1
GRAYBACK	06M21	SNOW	37.47	-106.53	11600	40	40	81	40	26.5
GRIZZLY PEAK	05K09	SNOW	39.65	-105.87	11100	48	48	83	48	29.5
GROUNDHOG	08M03	SNOW	37.80	-108.27	8940	35	35	61	35	22.4
HAGERMAN TUNNEL	06K42	SNOW	39.25	-106.50	11150	15	15	92	15	37.0
HAHN'S PEAK	06J14	SNOW	40.80	-106.93	8200	23	23	66	23	22.3
HERMIT LAKE	05L04	SNOW	38.10	-105.63	10400	18	18	50	18	18.0
HIDDEN VALLEY	05J13	SNOW	40.40	-105.65	9480	72	72	64	72	17.8
HIWAY	06M19	SNOW	37.47	-106.78	10750	34	34	120	34	48.1
HOOSIER PASS	06K01	SNOW	39.37	-106.07	11400	53	53	66	53	20.4
HORSESHOE MOUNTAIN	06K35	SNOW	39.20	-106.13	11220	46	46	61	46	17.7
HOURGLASS LAKE	05J11	SNOW	40.58	-105.63	9360	73	73	52	73	18.1
HUERFANO	05M15	SNOW	37.65	-105.47	10080	19	19	55	19	15.8
IDARADO	07M27	SNOW	37.93	-107.67	9800	12	12	67	12	22.8
INDEPENDENCE PASS	06K04	SNOW	39.07	-106.62	10600	76	76	83	76	27.4
IRONTON PARK	07M06	SNOW	37.97	-107.67	9600	75	75	79	75	28.1
IVANHOE	06K10	SNOW	39.28	-106.55	10400	52	52	86	52	27.4
JEFFERSON CREEK	05K08	SNOW	39.43	-105.87	10280	53	53	53	53	15.5
JOE WRIGHT	05J37	SNOW	40.53	-105.88	10120	23	23	102	23	39.9
JONES PASS	05K21	SNOW	39.77	-105.90	10400	56	56	78	56	26.8
KEYSTONE	07L04	SNOW	38.87	-107.03	9960	49	49	97	49	35.7
KILN	06K30	SNOW	39.32	-106.62	9600	24	24	59	24	17.9
LA MANGA	06M11	SNOW	37.08	-106.38	10120	28	28	114	28	48.3
LA PLATA	08M04	SNOW	37.42	-108.05	9340	39	39	108	39	41.9
LA VETA PASS	05M01	SNOW	37.60	-105.20	9440	74	74	57	74	18.3
LAKE CITY	07M08	SNOW	37.98	-107.25	10160	64	64	48	64	14.7
LAKE HUMPHREY	06M15	SNOW	37.67	-106.87	9000	49	49	71	49	17.8
LAKE IRENE	05J10	SNOW	40.42	-105.82	10700	58	58	90	58	41.0
LAPLAND	05K07	SNOW	39.89	-105.89	9300	73	73	62	73	18.8
LEFT HAND	05J44	SNOW	4NA8	-105.53	9900	3	3	46	3	14.8
LEMON RESERVOIR	07M23	SNOW	37.45	-107.67	8700	44	44	67	44	22.9
LEMON RESERVOIR #2	07M24	SNOW	37.45	-107.65	10000	11	11	80	11	28.1
LIFT	06K27	SNOW	39.15	-106.82	11250	32	32	103	32	33.0

Table A5.1 Raw data summary

Station Name	ID	Type	Lat (deg)	Lon (deg)	Alt (ft.)	Num Snow Yrs	Yrs with Depth	Max Depth (in)	Yrs with SWE	Max SWE (in)
LIZARD HEAD	07M03	SNOW	37.80	-107.93	10200	49	49	83	49	30.4
LIZARD HEAD PASS	07M29	SNOW	37.80	-107.93	10200	11	11	79	11	24.4
LONE CONE	08M07	SNOW	37.90	-108.20	9600	28	28	75	28	25.0
LONG DRAW RESERVOIR	05J27	SNOW	40.51	-105.77	9980	29	29	71	29	22.7
LONGS PEAK	05J22	SNOW	40.27	-105.58	10500	62	62	72	62	20.9
LOSTMAN	06K49	SNOW	39.12	-106.62	10626	5	5	78	5	23.7
LOVE LAKE	07M10	SNOW	37.67	-107.02	10000	48	48	73	48	21.7
LOVELAND PASS	05K05	SNOW	39.68	-105.90	10800	55	55	71	55	26.9
LYNX PASS	06J06	SNOW	4NA8	-106.67	8880	54	54	65	54	19.2
MANCOS T-DOWN	08M02	SNOW	37.43	-108.17	10000	32	32	101	32	37.6
MC CLURE PASS	07K09	SNOW	39.13	-107.28	9500	40	40	74	40	27.0
MC INTYRE	05J15	SNOW	40.78	-105.93	9100	11	11	50	11	16.3
MC KENZIE GULCH	06K28	SNOW	39.50	-106.75	8500	51	51	44	51	9.7
MESA LAKES	08K04	SNOW	39.05	-108.08	10000	63	63	91	63	32.8
MIDDLE CREEK	07M21	SNOW	37.62	-107.03	11250	12	12	111	12	42.2
MIDDLE FORK CAMPGROUND	06K12	SNOW	39.78	-106.02	9000	77	77	55	77	17.6
MILNER PASS	05J24	SNOW	40.40	-105.83	9750	57	57	68	57	21.8
MINERAL CREEK	07M14	SNOW	37.85	-107.73	10040	39	39	79	39	24.9
MOLAS LAKE	07M12	SNOW	37.75	-107.68	10500	49	49	82	49	31.2
MONARCH OFFSHOOT	06L09	SNOW	38.52	-106.33	10500	68	27	72	68	26.8
MONARCH PASS	06L04	SNOW	38.52	-106.33	10500	49	49	80	49	30.9
MOSQUITO CREEK	06K34	SNOW	39.28	-106.13	10980	46	46	58	46	16.2
NAST LAKE	06K06	SNOW	39.30	-106.60	8700	71	71	50	71	13.2
NORTH INLET GRAND LAKE	05J09	SNOW	40.28	-105.77	9000	74	74	50	74	17.9
NORTH LOST TRAIL	07K01	SNOW	39.07	-107.15	9200	55	55	71	55	27.1
NORTH MOUNTAIN	08M09	SNOW	37.93	-108.40	9360	19	19	80	19	29.6
NORTHGATE	06J07	SNOW	40.93	-106.28	8550	43	43	40	43	10.5
OPHIR LOOP	07M18	SNOW	37.92	-107.83	11320	15	15	76	15	24.6
PANDO	06K19	SNOW	39.47	-106.33	9500	38	38	51	38	15.7
PARK CONE	06L02	SNOW	38.82	-106.58	9600	73	73	67	73	22.4
PARK RESERVOIR	07K06	SNOW	39.05	-107.88	9960	51	51	119	51	46.9
PARK VIEW	06J02	SNOW	40.37	-106.10	9160	77	77	54	77	14.6
PASS CREEK	06M18	SNOW	37.55	-106.77	9300	32	32	76	32	27.2
PHANTOM VALLEY	05J04	SNOW	40.40	-105.85	9030	51	51	61	51	19.0
PINE CREEK	05J31	SNOW	40.77	-105.50	7900	39	39	29	39	6.8
PINOS MILL	06M24	SNOW	37.05	-106.42	10000	44	44	146	44	41.0
PLATORO	06M09	SNOW	37.35	-106.55	9880	61	61	90	61	34.6

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Station Name	ID	Type	Lat (deg)	Lon (deg)	Alt (ft.)	Num Snow Yrs	Yrs with Depth	Max Depth (in)	Yrs with SWE	Max SWE (in)
POOL TABLE MOUNTAIN	06M14	SNOW	37.80	-106.80	9840	64	64	57	64	15.6
PORCUPINE	07M20	SNOW	37.85	-107.17	10280	62	62	73	62	22.9
PORPHYRY CREEK	06L03	SNOW	38.48	-106.33	10760	59	59	85	59	30.4
RABBIT EARS	06J09	SNOW	40.37	-106.73	9400	49	48	110	49	41.9
RANCH CREEK	05K18	SNOW	39.93	-105.73	9400	56	56	62	56	22.3
RED FEATHER	05J20	SNOW	40.82	-105.65	9000	57	57	43	57	14.7
RED MOUNTAIN PASS	07M15	SNOW	37.88	-107.70	11020	39	39	125	39	49.0
RICO	08M05	SNOW	37.67	-108.03	8700	54	54	60	54	20.4
RIO BLANCO	07J01	SNOW	4NA3	-107.28	8500	71	71	64	71	24.1
RIVER SPRINGS	06M05	SNOW	37.07	-106.27	9300	53	53	55	53	19.8
ROACH	06J12	SNOW	40.87	-106.05	9700	46	46	87	46	31.1
SAINT ELMO	06L05	SNOW	38.70	-106.37	10400	47	46	70	47	22.0
SANTA MARIA	07M17	SNOW	37.82	-107.12	9600	74	74	46	74	13.4
SAWTOOTH	05J45	SNOW	40.13	-105.58	9740	11	11	90	11	3NA
SHRINE PASS	06K09	SNOW	39.53	-106.22	10700	71	71	79	71	27.9
SILVER LAKES	06M04	SNOW	37.38	-106.40	9500	75	75	49	75	15.0
SNAKE RIVER	05K16	SNOW	39.63	-105.90	10000	62	62	56	62	16.0
SOUTH COLONY	05M13	SNOW	37.97	-105.55	11140	21	21	98	21	38.8
SPRUCE CREEK	05L10	SNOW	38.22	-105.68	10940	11	11	68	11	17.6
SPUD MOUNTAIN	07M11	SNOW	37.70	-107.78	10660	42	42	121	42	49.9
SUMMIT RANCH	06K14	SNOW	39.72	-106.17	9400	34	34	52	34	15.3
SUMMITILLE (DISC.)	06M06	SNOW	37.43	-106.60	11500	36	36	100	36	37.5
SUNDANCE	05K22	SNOW	39.57	-105.73	11100	33	33	55	33	15.3
TELLURIDE	07M02	SNOW	37.93	-107.80	8800	74	74	52	74	13.8
TENNESSEE PASS	06K02	SNOW	39.35	-106.33	10200	55	55	62	55	19.1
TENNESSEE PASS #2	06K25	SNOW	39.35	-106.35	10280	26	26	60	26	18.2
TOWER	06J29	SNOW	40.53	-106.68	10500	24	24	175	24	79.2
TRICKLE DIVIDE	07K05	SNOW	39.13	-107.90	10000	47	47	126	47	49.2
TRINCHERA	05M08	SNOW	37.35	-105.23	10860	33	33	62	33	15.6
TROUT CREEK PASS	06L12	SNOW	38.92	-106.05	9720	39	39	36	39	9.3
TROUT LAKE	07M09	SNOW	37.83	-107.88	9780	35	35	73	35	24.2
TROUT LAKE #2	07M28	SNOW	37.83	-107.88	9780	30	30	69	30	21.2
TWIN LAKES TUNNEL	06K03	SNOW	39.08	-106.53	10450	75	75	60	75	18.8
TWO MILE	05J26	SNOW	40.38	-105.67	10500	41	41	80	41	25.8
UNIVERSITY CAMP	05J08	SNOW	4NA3	-105.57	10300	61	61	97	61	38.8
UPPER RIO GRANDE	07M16	SNOW	37.72	-107.27	9400	62	62	73	62	21.6
UPPER SAN JUAN	06M03	SNOW	37.48	-106.83	10200	61	61	142	61	58.6
UTE CREEK	05M17	SNOW	37.62	-105.37	10650	17	17	62	17	19.6
UTE PASS	06K41	SNOW	39.82	-106.10	9550	13	13	62	13	19.3

Table A5.1 Raw data summary

Station Name	ID	Type	Lat (deg)	Lon (deg)	Alt (ft.)	Num Snow Yrs	Yrs with Depth	Max Depth (in)	Yrs with SWE	Max SWE (in)
VALLECITO	07M31	SNOW	37.48	-107.50	10880	12	12	84	12	28.2
VASQUEZ	05K19	SNOW	39.85	-105.82	9600	56	56	72	56	24.3
WARD	05J21	SNOW	4NA7	-105.52	9500	62	62	50	62	12.8
WESTCLIFFE	05L02	SNOW	38.12	-105.58	9400	47	47	53	47	13.2
WESTON	06K26	SNOW	39.07	-106.02	9300	30	30	48	30	8.6
WHISKEY CREEK	05M14	SNOW	37.22	-105.12	10220	8	8	51	8	15.4
WILD BASIN	05J05	SNOW	40.20	-105.60	9600	76	76	69	76	24.5
WILLOW CREEK PASS	06J05	SNOW	40.35	-106.10	9540	72	72	69	72	20.6
WILLOW PARK	05J40	SNOW	40.43	-105.73	10700	9	9	84	9	31.0
WINFIELD MIDDLE	06K50	SNOW	38.98	-106.45	10340	4	4	42	4	12.1
WOLF CREEK PASS	06M01	SNOW	37.47	-106.78	10320	50	50	131	50	55.3
WOLF CREEK SUMMIT	06M17	SNOW	37.48	-106.80	11000	39	39	137	39	58.1
WURTZ LOWER	06K51	SNOW	39.39	-106.36	10690	5	5	70	5	22.6
WURTZ MIDDLE	06K52	SNOW	39.41	-106.37	10436	5	5	80	5	26.8
YAMPA VIEW	06J10	SNOW	40.37	-106.77	8200	62	61	71	62	24.5
APISHAPA	05M07S	SNTL	37.33	-105.07	10000	55	0	NA	55	15.7
ARAPAHO RIDGE	06J08S	SNTL	40.35	-106.38	10960	13	0	NA	13	29.4
ARROW PILLOW	05K06S	SNTL	39.92	-105.75	9680	62	0	NA	62	24.8
BEAR LAKE	05J39S	SNTL	40.31	-105.64	9500	37	0	NA	37	27.3
BEAR RIVER	07J03S	SNTL	4NA6	-107.01	9080	11	0	NA	11	14.2
BEARTOWN	07M32S	SNTL	37.71	-107.51	11600	33	0	NA	33	37.2
BEAVER CK VILLAGE	06K45S	SNTL	39.60	-106.51	8500	12	0	NA	12	14.9
BERTHOUD SUMMIT	05K14S	SNTL	39.80	-105.78	11300	55	0	NA	55	29.2
BISON LAKE	07K12S	SNTL	39.76	-107.36	10880	30	0	NA	30	43.3
BLACK MESA	08M12S	SNTL	37.79	-108.18	11580	3	0	NA	3	20.1
BLACK MOUNTAIN	05J28S	SNTL	40.89	-105.66	8920	5	0	NA	5	12.6
BRUMLEY	06K40S	SNTL	39.09	-106.54	10600	55	0	NA	55	16.8
BUCKSKIN JOE	06K16S	SNTL	39.30	-106.11	11150	16	0	NA	16	12.3
BUFFALO PARK	06J18S	SNTL	40.23	-106.60	9240	20	0	NA	20	21.4
BURRO MOUNTAIN	07K02S	SNTL	39.88	-107.60	9400	80	0	NA	80	33.1
BUTTE	06L11S	SNTL	38.89	-106.95	10160	55	0	NA	55	24.7
CASCADE	07M05S	SNTL	37.65	-107.81	8880	77	0	NA	77	30.7
CASCADE #2	07M35S	SNTL	37.66	-107.80	8920	25	0	NA	25	25.3
CATHEDRAL BLUFFS PILLOW	08K02S	SNTL	39.88	-108.60	8500	8	0	NA	8	26.9
CHAPMAN TUNNEL	06K46S	SNTL	39.26	-106.63	10110	8	0	NA	8	21.4
COCHETOPA PASS	06L06S	SNTL	38.16	-106.60	10020	11	0	NA	11	5.8
COLUMBINE	06J03S	SNTL	40.39	-106.60	9160	80	0	NA	80	37.9
COLUMBINE PASS	08L02S	SNTL	38.42	-108.38	9400	29	0	NA	29	33.5
COLUMBUS BASIN	08M10S	SNTL	37.44	-108.02	10785	21	0	NA	21	42.3

Table A5.1 Raw data summary

Station Name	ID	Type	Lat (deg)	Lon (deg)	Alt (ft.)	Num Snow Yrs	Yrs with Depth	Max Depth (in)	Yrs with SWE	Max SWE (in)
COPELAND LAKE	05J18S	SNTL	40.21	-105.57	8600	35	0	NA	35	9.0
COPPER MOUNTAIN	06K24S	SNTL	39.49	-106.17	10550	38	0	NA	38	20.9
CROSHO	07J04S	SNTL	40.17	-107.06	9100	29	0	NA	29	19.3
CULEBRA #2	05M03S	SNTL	37.21	-105.20	10500	55	0	NA	55	19.3
CUMBRES TRESTLE	06M22S	SNTL	37.02	-106.45	10040	55	0	NA	55	50.9
DEADMAN HILL	05J06S	SNTL	40.81	-105.77	10220	78	0	NA	78	25.2
DRY LAKE	06J01S	SNTL	40.53	-106.78	8400	77	0	NA	77	35.3
ECHO LAKE	05K27S	SNTL	39.66	-105.59	10600	17	0	NA	17	12.5
EL DIENTE PEAK	08M06S	SNTL	37.79	-108.02	10000	29	0	NA	29	25.2
ELK RIVER	06J15S	SNTL	40.85	-106.97	8700	77	0	NA	77	30.4
ELLIOT RIDGE	06K29S	SNTL	39.86	-106.42	10520	6	0	NA	6	23.1
FOOL CREEK	05K30S	SNTL	39.87	-105.87	11150	4	0	NA	4	25.0
FREMONT PASS	06K08S	SNTL	39.38	-106.20	11400	77	0	NA	77	27.5
GLEN COVE	05L11S	SNTL	38.88	-105.07	11460	11	0	NA	11	9.5
GRAYBACK	06M21S	SNTL	37.47	-106.54	11620	11	0	NA	11	25.6
GRIZZLY PEAK	05K09S	SNTL	39.65	-105.87	11100	55	0	NA	55	28.8
HAGERMAN TUNNEL PILLOW	06K42S	SNTL	39.25	-106.50	11150	6	0	NA	6	42.9
HAYDEN PASS	05L12S	SNTL	38.29	-105.85	10720	8	0	NA	8	21.0
HIGH LONESOME	05J45S	SNTL	4NA4	-105.75	10620	2	0	NA	2	24.8
HOOSIER PASS	06K01S	SNTL	39.36	-106.06	11400	77	0	NA	77	22.0
HOURGLASS LAKE	05J11S	SNTL	40.58	-105.63	9380	7	0	NA	7	14.6
IDARADO	07M27S	SNTL	37.93	-107.68	9800	37	0	NA	37	23.0
INDEPENDENCE PASS	06K04S	SNTL	39.08	-106.61	10600	80	0	NA	80	26.9
IVANHOE	06K10S	SNTL	39.29	-106.55	10400	70	0	NA	70	21.7
JACKWHACKER GULCH	05K26S	SNTL	39.57	-105.80	10960	17	0	NA	17	15.7
JOE WRIGHT	05J37S	SNTL	40.53	-105.89	10120	49	0	NA	49	33.3
JONES PASS	05K21S	SNTL	39.76	-105.91	10400	16	0	NA	16	20.5
KILN	06K30S	SNTL	39.32	-106.61	9600	49	0	NA	49	19.5
LAKE ELDORA	05J41S	SNTL	39.94	-105.59	9700	37	0	NA	37	23.9
LAKE IRENE	05J10S	SNTL	40.41	-105.82	10700	78	0	NA	78	41.1
LILY POND	06M23S	SNTL	37.38	-106.55	11000	64	0	NA	64	36.6
LIZARD HEAD PASS	07M29S	SNTL	37.80	-107.92	10200	55	0	NA	55	28.1
LONE CONE	08M07S	SNTL	37.89	-108.20	9600	55	0	NA	55	27.7
LONG DRAW RESV	05J27S	SNTL	40.51	-105.77	9980	6	0	NA	6	23.0
LOST DOG	06J38S	SNTL	40.82	-106.75	9320	17	0	NA	17	35.8
LOVELAND BASIN	05K05S	SNTL	39.67	-105.90	11400	23	0	NA	23	28.7
LYNX PASS	06J06S	SNTL	4NA8	-106.67	8880	80	0	NA	80	20.8
MANCOS	08M02S	SNTL	37.43	-108.17	10000	36	0	NA	36	34.5
MC CLURE PASS	07K09S	SNTL	39.13	-107.29	9500	55	0	NA	55	28.5

Table A5.1 Raw data summary

Station Name	ID	Type	Lat (deg)	Lon (deg)	Alt (ft.)	Num Snow Yrs	Yrs with Depth	Max Depth (in)	Yrs with SWE	Max SWE (in)
MCCOY PARK	06K44S	SNTL	39.60	-106.54	9480	13	0	NA	13	17.4
MEDANO PASS	05M16S	SNTL	37.85	-105.44	9649	20	0	NA	20	10.3
MESA LAKES	08K04S	SNTL	39.06	-108.06	10000	29	0	NA	29	28.9
MICHIGAN CREEK	05K28S	SNTL	39.44	-105.91	10600	17	0	NA	17	15.3
MIDDLE CREEK	07M21S	SNTL	37.62	-107.03	11250	37	0	NA	37	38.3
MIDDLE FORK CAMP	06K12S	SNTL	39.80	-106.03	8940	14	0	NA	14	14.5
MINERAL CREEK	07M14S	SNTL	37.85	-107.73	10040	55	0	NA	55	28.9
MOLAS LAKE	07M12S	SNTL	37.75	-107.69	10500	65	0	NA	65	46.5
MOON PASS	06M26S	SNTL	37.97	-106.56	11140	7	0	NA	7	7.9
NAST LAKE	06K06S	SNTL	39.30	-106.61	8700	77	0	NA	77	14.2
NAVAL OILSHALE PILLOW	07K10S	SNTL	39.60	-107.95	8800	10	0	NA	10	32.7
NEVER SUMMER	06J27S	SNTL	40.40	-105.96	10280	13	0	NA	13	33.3
NIWOT	05J42S	SNTL	4NA4	-105.54	9910	77	0	NA	77	24.8
NORTH LOST TRAIL	07K01S	SNTL	39.08	-107.14	9200	80	0	NA	80	35.6
OVERLAND RES.	07K14S	SNTL	39.09	-107.63	9840	26	0	NA	26	21.1
PARK CONE	06L02S	SNTL	38.82	-106.59	9600	79	0	NA	79	22.8
PARK RESERVOIR	07K06S	SNTL	39.05	-107.87	9960	55	0	NA	55	46.9
PHANTOM VALLEY	05J04S	SNTL	40.40	-105.85	9030	80	0	NA	80	17.7
PORPHYRY CREEK	06L03S	SNTL	38.49	-106.34	10760	76	0	NA	76	27.7
RABBIT EARS	06J09S	SNTL	40.37	-106.74	9400	62	0	NA	62	44.4
RAWAH	06J20S	SNTL	40.71	-106.01	9020	13	0	NA	13	16.7
RED MOUNTAIN PASS	07M33S	SNTL	37.89	-107.71	11200	55	0	NA	55	43.5
RIPPLE CREEK	07J05S	SNTL	40.11	-107.29	10340	29	0	NA	29	38.6
ROACH	06J12S	SNTL	40.88	-106.05	9700	76	0	NA	76	26.9
ROUGH AND TUMBLE	06K43S	SNTL	39.03	-106.08	10360	17	0	NA	17	10.4
SAINT ELMO	06L05S	SNTL	38.70	-106.37	10540	8	0	NA	8	14.3
SARGENTS MESA	06L13S	SNTL	38.29	-106.37	11530	7	0	NA	7	11.1
SCHOFIELD PASS	07K11S	SNTL	39.02	-107.05	10700	30	0	NA	30	48.8
SCOTCH CREEK	08M08S	SNTL	37.65	-108.01	9100	29	0	NA	29	21.2
SHARKSTOOTH	08M04S	SNTL	37.50	-108.11	10720	11	0	NA	11	29.5
SLUMGULLION	07M30S	SNTL	37.99	-107.20	11440	37	0	NA	37	18.6
SOUTH COLONY	05M13S	SNTL	37.97	-105.54	10800	37	0	NA	37	30.8
SPUD MOUNTAIN	07M11S	SNTL	37.70	-107.78	10660	64	0	NA	64	61.6
STILLWATER CREEK	05J12S	SNTL	40.23	-105.92	8720	67	0	NA	67	12.8
STUMP LAKES	07M34S	SNTL	37.48	-107.63	11200	29	0	NA	29	34.7
SUMMIT RANCH	06K14S	SNTL	39.72	-106.16	9400	35	0	NA	35	17.5
TOWER	06J29S	SNTL	40.54	-106.68	10500	50	0	NA	50	71.1
TRAPPER LAKE	07K13S	SNTL	4NA0	-107.24	9700	30	0	NA	30	31.9
TRINCHERA	05M08S	SNTL	37.35	-105.23	10860	49	0	NA	49	15.2

Table A5.1 Raw data summary

Station Name	ID	Type	Lat (deg)	Lon (deg)	Alt (ft.)	Num Snow Yrs	Yrs with Depth	Max Depth (in)	Yrs with SWE	Max SWE (in)
UNIVERSITY CAMP	05J08S	SNTL	4NA3	-105.58	10300	78	0	NA	78	36.4
UPPER RIO GRANDE	07M16S	SNTL	37.72	-107.26	9400	55	0	NA	55	17.4
UPPER SAN JUAN	06M03S	SNTL	37.49	-106.84	10200	78	0	NA	78	60.1
UPPER TAYLOR	06L14S	SNTL	38.99	-106.75	10640	6	0	NA	6	21.2
UTE CREEK	05M17S	SNTL	37.61	-105.37	10650	15	0	NA	15	20.3
VAIL MOUNTAIN	06K39S	SNTL	39.62	-106.38	10300	38	0	NA	38	30.6
VALLECITO	07M31S	SNTL	37.49	-107.51	10880	35	0	NA	35	32.3
WAGER GULCH	07M37S	SNTL	37.88	-107.36	11100	4	0	NA	4	9.9
WEMINUCHE CREEK	07M36S	SNTL	37.52	-107.32	10740	5	0	NA	5	15.2
WHISKEY CK	05M14S	SNTL	37.21	-105.12	10220	55	0	NA	55	18.9
WILD BASIN	05J05S	SNTL	40.20	-105.60	9560	10	0	NA	10	21.3
WILLOW CREEK PASS	06J05S	SNTL	40.35	-106.09	9540	78	0	NA	78	2NA
WILLOW PARK	05J40S	SNTL	40.43	-105.73	10700	38	0	NA	38	29.6
WOLF CREEK SUMMIT	06M17S	SNTL	37.48	-106.80	11000	55	0	NA	55	64.0
ZIRKEL	06J19S	SNTL	40.79	-106.60	9340	12	0	NA	12	42.2

A5.3. Assembled Snow Site Data Summary

Statistical data that is computed for each snow site is tabulated in this section. Snow sites with fewer than 18 years of historical data are not used in this study. Snow sites with 18-29 years are not used directly for generating the snow map, but information at some of these sites is used indirectly to inform various decisions relating to the snow map. Many of the snow sites have the same or similar names as city/town locations that are tabulated in other sections of this report (*e.g.* Table 1.1). However, their tabulated snow loads may differ somewhat. That is for two reasons: (1) the altitude at the city/town is different than the altitude of the snow site location, (2) the design snow load is increased or decreased from the computed value based on information at other nearby locations (*i.e.* fluctuations in snow loads are smoothed by the snow map and reflected in Table 1.1). The snow load values in this appendix ***should not*** be used for design.

Table A5.2 Assembled snow site data

Site Name	Lat (deg)	Long (deg)	Alt (ft)	Num Yrs	Mean Annual Max Ground Snow Load (psf)	Max Ground Snow Load (psf)	50-year Ground Snow Load (psf)	Reliability-Based Ground Snow Load
AGUILAR	37.4	-104.65	6400	32	11.2	27	32	58
Akron 1 N	40.16	-103.19	4611	65	5.7	26	19	36
Alamosa	37.47	-105.88	7536	81	4.9	19	16	19
ALAMOSA SAN LUIS VALLEY REGIONAL AIRPORT	37.44	-105.86	7534	53	4.1	16	16	18
ALEXANDER LAKE	39.03	-107.97	10160	53	132.5	202	200	180

Table A5.2 Assembled snow site data

Site Name	Lat (deg)	Long (deg)	Alt (ft)	Num Yrs	Mean Annual Max Ground Snow Load (psf)	Max Ground Snow Load (psf)	50-year Ground Snow Load (psf)	Reliability-Based Ground Snow Load
Allenspark Lodge	40.2	-105.53	8450	32	20.7	55	55	57
ALTENBERN	39.5	-108.38	5678	65	11.9	65	56	69
Ames	37.87	-107.88	8700	38	58.3	135	136	110
Amy	38.88	-103.65	5243	26	3.5	21	23	32
Antero	38.92	-105.97	9300	45	14.2	37	40	39
Antero RSVR	39	-105.89	8949	53	7.7	31	29	28
Apishapa	37.33	-105.07	10000	55	42.6	90	95	79
Arapaho Ridge	40.35	-106.38	10960	13	106.6	153	NA	NA
AROYA 6 NE	38.92	-103.08	4793	24	1.2	3	5	8
ARROW PILLOW	39.92	-105.75	9588	75	74.2	136	124	108
ASPEN	39.2	-106.83	8045	77	46.4	94	89	80
AYER RCH	39.02	-104.6	7234	26	8.3	25	47	59
BAILEY	39.4	-105.48	7730	60	17.1	63	64	81
Baltimore	39.9	-105.58	8800	52	39.4	84	74	69
Bear Lake	40.31	-105.64	9500	37	89.6	142	153	138
Bear River	40.07	-107.02	9094	31	58	89	87	81
Beartown	37.71	-107.51	11600	33	117	193	207	178
Beaver Ck Village	39.6	-106.51	8500	12	58.4	77	NA	NA
Bennett Creek	40.67	-105.62	9200	47	37.7	70	74	69
Berthoud Falls	39.78	-105.78	10500	62	73.6	121	120	106
Berthoud Pass	39.83	-105.75	9700	77	90	158	139	123
Berthoud Summit	39.8	-105.78	11300	65	106	181	170	148
Big Meadows	37.53	-106.8	9260	44	75.9	136	140	140
Big South	40.62	-105.82	8600	75	17.8	41	41	41
BIGELOW DIVIDE	38.1	-105.13	9350	29	43.2	77	83	76
Bison Lake	39.76	-107.36	10880	30	130.6	225	218	189
BISON RESERVOIR	38.77	-105.1	10220	15	23.1	45	NA	NA
Black Mesa	37.79	-108.18	11580	3	91.5	105	NA	NA
Black Mountain	40.89	-105.66	8920	5	50.8	66	NA	NA
Blanca	37.42	-105.52	7815	59	5.4	13	14	18
BLOOM	37.68	-103.95	4484	22	7.1	36	65	79
BLUE MESA LAKE	38.47	-107.17	7568	45	18.6	54	56	50
Blue River	39.38	-106.05	10500	56	46.1	84	81	71
Bond	39.88	-106.68	6706	16	5.6	16	NA	NA
BONHAM RSVR	39.1	-107.9	9852	26	126.5	180	188	172
BONNY LAKE	39.69	-102.22	3828	62	4.6	21	16	33
BOULDER	39.99	-105.27	5484	63	8.3	25	22	43
Boulder Falls	40.02	-105.57	10000	60	72.1	119	122	106

Table A5.2 Assembled snow site data

Site Name	Lat (deg)	Long (deg)	Alt (ft)	Num Yrs	Mean Annual Max Ground Snow Load (psf)	Max Ground Snow Load (psf)	50-year Ground Snow Load (psf)	Reliability-Based Ground Snow Load
BOURBON	37.18	-105.1	9600	35	42.4	68	67	63
Brandon	38.45	-102.45	3931	39	1.5	6	7	15
BRANSON	37.02	-103.88	6280	32	7.7	32	34	57
BRECKENRIDGE	39.49	-106.04	9580	48	39.6	89	97	80
BRIGGSDALE	40.64	-104.33	4834	40	2.6	15	13	21
BRIGHTON	39.99	-104.82	4980	40	4.9	14	18	31
Brown Cabin	37.55	-105.4	9600	46	38.9	82	83	76
BROWNS PARK REFUGE	40.8	-108.92	5354	30	3.5	12	15	26
BUCKHORN MTN 1 E	40.62	-105.29	7400	25	20.3	45	51	76
Buena Vista	38.83	-106.13	7963	113	8.6	26	25	30
Buffalo Park	40.23	-106.6	9240	20	68.5	111	123	105
Burlington	39.3	-102.26	4197	115	3.8	25	17	30
Burro Mountain	39.88	-107.6	9400	80	100.5	172	154	139
Butler RCH	38.07	-104.51	4873	28	4.6	18	19	33
Butte	38.89	-106.95	10160	55	79.9	132	139	120
Butterhill	40.93	-106.98	7880	34	69.4	105	111	105
Byers 5 ENE	39.74	-104.13	5100	82	6.1	21	17	34
CABIN CREEK	39.66	-105.71	10020	43	27.1	108	85	64
Cameron Pass	40.52	-105.57	10285	76	147.5	213	209	192
CAMPO 7 S	37.02	-102.56	4118	54	3	12	15	25
CANON CITY	38.45	-105.24	5355	111	4.7	22	17	30
Cascade	37.65	-107.8	8872	77	70.9	160	149	125
CATHEDRAL BLUFFS PILLOW	39.88	-108.6	8500	8	105	140	NA	NA
Cedaredge	38.9	-107.93	6213	104	6.6	39	29	34
CENTER 4 SSW	37.7	-106.14	7676	58	4.6	20	16	18
Chambers Lake	40.62	-105.83	9000	76	44.2	80	80	75
Chapman Tunnel	39.26	-106.63	10110	8	68.6	111	NA	NA
CHEESMAN	39.22	-105.28	6880	111	8.8	51	37	60
CHERRY CREEK DAM	39.65	-104.85	5647	50	6.8	26	22	38
CHEYENNE WELLS	38.83	-102.32	4193	67	3.6	13	14	26
CIMARRON	38.44	-107.56	7010	46	12.1	61	77	62
COAL CREEK CANYON	39.9	-105.38	8950	19	40.6	89	108	93
COCHETOPA CREEK	38.45	-106.76	8002	65	16.5	52	50	55
Cochetopa Pass	38.17	-106.6	10003	67	30.5	55	55	54
COLLBRAN	39.24	-107.97	6043	44	9.3	35	38	46
Colorado NM	39.1	-108.73	5779	66	5.2	30	22	30
COLORADO SPRINGS MUNICIPAL AIRPORT	38.81	-104.68	6148	65	4.6	22	21	36

Table A5.2 Assembled snow site data

Site Name	Lat (deg)	Long (deg)	Alt (ft)	Num Yrs	Mean Annual Max Ground Snow Load (psf)	Max Ground Snow Load (psf)	50-year Ground Snow Load (psf)	Reliability-Based Ground Snow Load
Columbine	40.39	-106.6	9160	80	131.3	197	199	179
Columbine Ditch	39.38	-106.25	11576	5	88.8	132	NA	NA
Columbine Pass	38.42	-108.38	9349	32	92.5	174	177	150
Columbus Basin	37.44	-108.02	10785	21	124.4	220	258	209
Como	39.35	-105.92	10370	46	33.7	70	62	58
Copeland Lake	40.2	-105.57	8593	67	28.4	61	57	57
Copper Mountain	39.49	-106.17	10550	38	73.7	109	110	99
Corral Creek	40.15	-106.15	9700	17	65.7	94	NA	NA
Cortez	37.34	-108.59	6167	76	5.5	19	19	26
CRAIG	40.52	-107.55	6255	75	4.6	20	18	23
CRAIG 4 SW	40.45	-107.59	6496	36	10.8	22	23	33
CRESTED BUTTE	38.88	-106.99	8889	104	78.2	232	164	137
CRESTONE 1 SE	37.98	-105.68	8115	31	13.4	33	37	43
CRIPPLE CREEK	38.75	-105.18	9541	6	7.3	16	NA	NA
Crosho	40.17	-107.06	9100	30	63.5	100	108	96
Cucharas Creek	37.33	-105.08	9700	38	49.1	86	94	80
Culebra #2	37.21	-105.2	10500	76	63.1	125	117	103
Cumbres Trestle	37.02	-106.45	10028	97	140.7	271	251	217
Deadman Hill	40.81	-105.77	10220	78	93.4	138	135	123
Deer Ridge	40.4	-105.63	9000	64	28.3	54	55	53
DEL NORTE	37.67	-106.35	7884	58	7.1	22	21	26
DELHI	37.65	-103.98	4994	40	4.8	16	16	28
Delta	38.75	-108.07	5031	38	2.1	6	7	11
DENVER-STAPLETON	39.76	-104.87	5286	121	5.8	32	20	35
Dillon 1 E	39.63	-106.04	9065	68	21	64	60	50
DINOSAUR NATL MONUMNT	40.24	-108.97	5972	46	7.5	21	25	33
DOHERTY RCH	37.38	-103.88	5135	32	4.2	14	15	28
DOLORES	37.47	-108.5	6953	56	18	55	56	58
Dry Lake	40.53	-106.78	8400	77	117.2	184	179	164
Durango	37.29	-107.87	6686	63	15.3	47	61	64
EADS 2 S	38.45	-102.78	4217	72	2.8	10	11	22
EAGLE FAA AP	39.65	-106.92	6497	52	9.8	36	40	45
EASTONVILLE 1 NNW	39.08	-104.57	7245	57	13.3	42	36	57
Echo Lake	39.66	-105.59	10615	32	64.8	194	277	187
El Diente Peak	37.79	-108.02	10000	29	73.6	131	141	118
ELBERT	39.22	-104.55	6766	11	8.3	18	NA	NA
ELECTRA LAKE	37.55	-107.8	8406	14	49.8	91	NA	NA

Table A5.2 Assembled snow site data

Site Name	Lat (deg)	Long (deg)	Alt (ft)	Num Yrs	Mean Annual Max Ground Snow Load (psf)	Max Ground Snow Load (psf)	50-year Ground Snow Load (psf)	Reliability-Based Ground Snow Load
Eleven Mile	38.95	-105.53	8590	29	3.6	16	20	20
Elk River	40.85	-106.97	8700	77	102.3	158	155	140
ELKHORN	40.98	-106.92	8475	11	135.8	215	NA	NA
Elliot Ridge	39.86	-106.42	10520	6	86.1	120	NA	NA
EMPIRE	39.77	-105.78	9635	64	43.7	73	69	65
ESTES PARK	40.38	-105.52	7524	93	12.7	57	45	68
EVERGREEN	39.64	-105.32	6985	41	11.7	49	44	72
EVERSOLL RCH	37.03	-102.07	3583	23	2.9	8	10	22
Ewing Upper	39.37	-106.28	11270	5	73.4	108	NA	NA
FAIRPLAY	39.23	-106	10007	14	14.1	29	NA	NA
FLAGLER 2 NW	39.31	-103.12	5035	73	4.4	15	16	29
FLEMING 1 W	40.68	-102.83	4290	76	5.2	14	16	32
FLORISSANT FOSSIL BED	38.91	-105.29	8379	35	10.3	30	29	34
Fool Creek	39.87	-105.87	11150	4	89.8	130	NA	NA
FORT COLLINS	40.61	-105.13	5004	65	6	20	19	34
FOUNTAIN	38.68	-104.7	5565	46	4.2	22	22	33
FOUR MILE PARK	39.07	-106.43	9700	61	29.1	61	61	58
FOWLER 1 SE	38.12	-104.01	4330	69	3.2	13	12	24
FRASER	39.94	-105.82	8560	86	40.8	95	88	77
Fremont Pass	39.38	-106.2	11367	77	96.2	144	140	128
Fruita 1 W	39.17	-108.75	4480	65	2.6	14	11	17
FT CARSON	38.68	-104.77	5869	22	3.8	12	13	23
FT LEWIS	37.23	-108.05	7640	63	28.9	70	76	67
Ft Lupton 2 SE	40.07	-104.78	5023	64	5.6	28	22	35
FT MORGAN	40.26	-103.81	4340	57	2.9	10	11	22
Gardner	37.77	-105.18	6974	32	8.7	31	40	40
GATEWAY 1 SE	38.67	-108.97	4550	64	2.2	11	11	16
Geneva Park	39.52	-105.72	9600	64	21	42	42	42
GENOA	39.28	-103.5	5606	68	3.6	10	10	21
GEORGETOWN	39.72	-105.7	8520	50	13.6	70	45	41
Glen Cove	38.88	-105.07	11460	11	24.1	49	NA	NA
GLEN MAR RANCH	39.82	-106.05	8750	53	46.7	82	77	70
Glendevey	40.8	-105.88	8274	9	37.5	69	NA	NA
Glenwood SPGS #2	39.52	-107.32	5895	62	9.4	30	33	43
Gore Pass	40.08	-106.55	9400	58	55	83	87	79
Gore Pass RCH	40.15	-106.47	7605	6	8.1	19	NA	NA
Granby	40.15	-106	8600	64	39.5	77	69	63
Grand Junction 6 ESE	39.04	-108.47	4760	49	1.7	10	11	13

Table A5.2 Assembled snow site data

Site Name	Lat (deg)	Long (deg)	Alt (ft)	Num Yrs	Mean Annual Max Ground Snow Load (psf)	Max Ground Snow Load (psf)	50-year Ground Snow Load (psf)	Reliability-Based Ground Snow Load
Grand Junction Walker	39.13	-108.54	4858	114	2.7	18	14	19
Grand Lake 1 NW	40.27	-105.83	8671	65	48.1	85	86	77
Grand Lake 6 SSW	40.18	-105.87	8288	47	24.6	54	62	59
Grand Valley	39.45	-108.05	5091	24	6.1	23	32	42
Grant	39.46	-105.68	8675	50	21.6	51	56	58
Grayback	37.47	-106.53	11604	43	81.8	138	150	131
Great Sand Dunes NM	37.73	-105.51	8183	59	8.5	30	29	32
Greeley UNC	40.43	-104.77	4712	65	4.9	16	17	32
Green MTN Dam	39.88	-106.33	7743	64	21.3	51	53	48
Grizzly Peak	39.65	-105.87	11100	74	100	153	158	139
Gross RSVR	39.94	-105.35	6910	35	18.7	50	47	93
Groundhog	37.8	-108.27	8940	35	64.1	116	118	103
Guffey 10 SE	38.68	-105.38	8595	55	11.4	34	32	36
Gunnison 1 N	38.55	-106.92	7680	58	12.4	51	44	38
Hagerman Tunnel	39.25	-106.5	11150	17	141.2	223	NA	NA
HAHN'S PEAK	40.8	-106.93	8200	23	74.9	116	122	111
Hamilton	40.37	-107.62	6234	44	8	45	75	64
Hartsel	39.03	-105.8	8875	16	11	28	NA	NA
Haswell	38.45	-103.16	4525	62	3	19	14	24
Hawthorne	39.93	-105.28	5925	27	11.4	27	31	53
Hayden	40.49	-107.25	6467	66	22.2	52	50	64
Hayden Pass	38.29	-105.85	10720	8	74	109	NA	NA
Hermit 7 ESE	37.77	-107.11	9048	58	18.2	70	78	64
HERMIT LAKE	38.1	-105.63	10400	18	51.2	94	104	90
Hidden Valley	40.4	-105.65	9480	72	55.6	93	98	91
High Lonesome	40.04	-105.75	10620	2	98.3	129	NA	NA
Hohnholz RCH	40.97	-106	7760	28	14.9	32	39	56
Holly	38.05	-102.12	3390	61	3.5	19	16	29
Holyoke	40.55	-102.34	3780	64	4.4	16	15	30
Hoosier Pass	39.36	-106.06	11400	79	75.4	114	116	103
Horseshoe Mountain	39.2	-106.13	11220	46	57.2	92	95	85
HOT SULPHUR SPGS 2 SW	40.05	-106.13	7605	21	14	68	73	53
Hourglass Lake	40.58	-105.63	9399	76	44	94	82	76
HUERFANO	37.65	-105.47	10080	19	58.5	82	89	89
Hugo	39.13	-103.47	5030	24	3.1	7	9	19
Idaho Springs	39.75	-105.52	7566	19	7.3	47	56	63
Idarado	37.93	-107.68	9800	37	73.3	120	120	106

Table A5.2 Assembled snow site data

Site Name	Lat (deg)	Long (deg)	Alt (ft)	Num Yrs	Mean Annual Max Ground Snow Load (psf)	Max Ground Snow Load (psf)	50-year Ground Snow Load (psf)	Reliability-Based Ground Snow Load
Ignacio 1 N	37.13	-107.63	6437	42	6.2	35	42	42
Independence Pass	39.08	-106.62	10595	80	93.5	142	141	125
Inter Canyon	39.57	-105.22	7040	29	26.7	74	95	148
Ironton Park	37.97	-107.67	9600	75	74.3	146	127	111
Ivanhoe	39.29	-106.55	10400	70	94.2	142	146	130
Jackwhacker Gulch	39.57	-105.8	10960	17	56.1	82	NA	NA
JEFFERSON CREEK	39.43	-105.87	10280	53	50.8	81	84	79
Joe Wright	40.53	-105.89	10120	49	128.5	207	212	189
Joes 2 SE	39.63	-102.65	4251	29	5.2	14	18	34
John Martin Dam	38.06	-102.93	3814	66	3.3	19	18	32
Jones Pass	39.77	-105.9	10400	59	91.5	139	137	122
Jones Pass 2 E	39.77	-105.85	10328	12	70	104	NA	NA
Julesburg	40.98	-102.28	3476	90	4	22	14	29
Karval	38.74	-103.54	5075	58	2.5	14	11	20
Kassler	39.47	-105.1	5665	65	10.8	41	40	62
Kauffman 4 SSE	40.85	-103.9	5253	34	2.4	10	10	18
Keystone	38.87	-107.03	9960	49	104.6	186	190	163
Kiln	39.32	-106.61	9600	49	64.9	101	99	90
Kim 15 NNE	37.45	-103.32	5190	25	8.8	46	51	69
Kiowa 4 SW	39.3	-104.52	6555	10	7.8	16	NA	NA
Kiowa 5 SE	39.28	-104.43	6355	7	3.1	8	NA	NA
Kit Carson 6 SE	38.7	-102.73	4202	65	2.2	13	10	18
Kremmling	40.06	-106.38	7406	43	12.3	46	46	38
La Junta 20 S	37.75	-103.48	4219	39	5.4	30	28	45
LA MANGA	37.08	-106.38	10120	28	114.4	251	240	212
La Plata	37.42	-108.05	9340	39	92.4	218	203	170
La Veta	37.5	-105	7034	8	13	28	NA	NA
La Veta Pass	37.6	-105.2	9440	74	50	95	92	85
Lake City	37.98	-107.25	10160	64	39.9	76	71	68
Lake City	38.04	-107.32	8764	57	22.6	70	66	62
Lake Eldora	39.94	-105.59	9700	37	62.7	124	116	98
Lake George 8 SW	38.91	-105.47	8550	53	10.8	44	33	35
LAKE HUMPHREY	37.67	-106.87	9000	49	37.2	93	87	82
Lake Irene	40.41	-105.82	10700	78	140.3	214	221	198
Lake Moraine	38.82	-104.98	10273	15	29.3	91	NA	NA
Lakewood	39.76	-105.11	5510	101	7.2	39	24	42
Lamar	38.09	-102.63	3627	118	4.5	36	20	36
Lapland	39.89	-105.89	9300	73	54.1	98	92	83

Table A5.2 Assembled snow site data

Site Name	Lat (deg)	Long (deg)	Alt (ft)	Num Yrs	Mean Annual Max Ground Snow Load (psf)	Max Ground Snow Load (psf)	50-year Ground Snow Load (psf)	Reliability-Based Ground Snow Load
Las Animas	38.06	-103.22	3890	67	3.4	28	18	32
Leadville	39.24	-106.31	10037	62	28.1	85	75	65
Left Hand	40.08	-105.53	9900	3	60.8	77	NA	NA
Lemon Dam	37.38	-107.66	8363	31	50.9	100	118	100
Lemon Reservoir	37.45	-107.67	8700	44	50	119	116	96
LEMON RESERVOIR #2	37.45	-107.65	10000	11	68.2	146	NA	NA
Leroy 5 WSW	40.51	-103	4470	65	5.3	21	15	30
LIFT	39.15	-106.82	11250	32	106.7	172	177	153
Lily Pond	37.38	-106.55	11000	64	82.8	190	176	150
Limon	39.27	-103.68	5368	23	2.4	5	6	13
Limon 10 SSW	39.16	-103.75	5563	75	4	30	17	29
Lindon 4 S	39.64	-103.39	4990	30	3.8	14	14	25
Little Hills	40	-108.2	6139	43	9.6	31	30	39
Littleton	39.62	-105.02	5340	14	11.2	32	NA	NA
Lizard Head Pass	37.8	-107.93	10200	75	88.7	158	154	133
Lone Cone	37.89	-108.2	9600	55	89.3	144	143	129
Long Draw Reservoir	40.51	-105.77	9980	31	77.5	120	132	115
Longmont 2 ESE	40.17	-105.07	4953	55	3.6	12	14	24
Longs Peak	40.27	-105.58	10500	62	64.5	109	110	96
Lost Dog	40.82	-106.75	9320	17	120.4	186	NA	NA
Lostman	39.12	-106.62	10626	5	85.9	123	NA	NA
Love Lake	37.67	-107.02	10000	48	52.8	113	104	96
Loveland Basin	39.67	-105.9	11400	23	97.3	149	158	140
Loveland NCWCD	40.4	-105.11	5040	21	5.1	16	19	32
LOVELAND PASS	39.68	-105.9	10800	55	87.2	140	133	120
Lynx Pass	40.08	-106.67	8880	80	67.8	108	104	94
Manassa	37.17	-105.94	7690	58	3.8	13	14	16
Mancos	37.34	-108.3	6960	50	8.5	32	29	33
Mancos	37.43	-108.17	10000	36	94.9	196	187	159
Marvine	40.02	-107.54	7283	25	44.5	89	93	86
MARVINE RCH	40.03	-107.46	7800	10	50.4	96	NA	NA
Massadona 3 E	40.28	-108.6	6185	22	12.4	23	25	38
Maybell	40.52	-108.09	5944	46	9.9	29	27	37
Mc Clure Pass	39.13	-107.29	9500	66	94	148	156	140
Mc Intyre	40.78	-105.93	9100	11	66.2	85	NA	NA
Mc Kenzie Gulch	39.5	-106.75	8500	51	34.2	50	54	53
Mccoy Park	39.6	-106.54	9480	13	70.2	90	NA	NA
Medano Pass	37.85	-105.44	9649	20	33.2	54	66	63

Table A5.2 Assembled snow site data

Site Name	Lat (deg)	Long (deg)	Alt (ft)	Num Yrs	Mean Annual Max Ground Snow Load (psf)	Max Ground Snow Load (psf)	50-year Ground Snow Load (psf)	Reliability-Based Ground Snow Load
Meeker	40.03	-107.91	6272	63	10.3	32	28	37
Meredith	39.37	-106.75	7826	42	38.8	86	85	77
Mesa Lakes	39.05	-108.07	9984	79	98.5	171	165	143
Mesa Verde NP	37.2	-108.49	7087	65	18.7	49	57	59
Michigan Creek	39.44	-105.91	10600	17	53.7	80	NA	NA
Middle Creek	37.62	-107.03	11250	37	105.4	219	210	179
Middle Fork Campground	39.78	-106.02	8991	80	54.9	92	86	78
Milner Pass	40.4	-105.83	9750	57	68.9	113	110	98
Mineral Creek	37.85	-107.73	10040	65	80.7	150	139	120
Molas Lake	37.75	-107.69	10500	65	110.4	242	204	174
Monarch Offshoot	38.52	-106.33	10500	68	92	161	152	137
Monte Vista	37.57	-106.14	7662	63	6.4	20	19	24
Montrose #2	38.49	-107.88	5788	60	3.1	17	13	20
Monument	39.1	-104.87	7079	14	7.8	27	NA	NA
Monument 2 WSW	39.08	-104.92	7346	15	13.4	34	NA	NA
Moon Pass	37.97	-106.56	11140	7	30.5	41	NA	NA
Mosquito Creek	39.29	-106.12	11024	49	51	84	87	79
Nast Lake	39.3	-106.61	8700	77	44.2	74	75	68
NAVAL OILSHALE PILLOW	39.6	-107.95	8800	10	114.1	170	NA	NA
Nederland 2 NNE	39.98	-105.5	8240	18	20.7	43	51	55
Never Summer	40.4	-105.96	10280	13	98.4	173	NA	NA
New Raymer	40.6	-103.85	4793	38	4.4	15	16	28
New Raymer 21 N	40.93	-103.87	5180	26	5.1	16	17	31
Niwot	40.04	-105.54	9910	77	71.3	129	127	109
North Inlet Grand Lake	40.28	-105.77	9000	74	46.8	93	83	75
North Lake	37.22	-105.05	8806	27	12.1	31	30	30
North Lost Trail	39.07	-107.14	9200	80	97.2	185	171	148
North Mountain	37.93	-108.4	9360	19	93	154	170	146
Northdale	37.82	-109.03	6655	52	9.6	32	32	38
NORTHGATE	40.93	-106.28	8550	43	34.5	55	58	56
Northglenn	39.9	-105.01	5407	29	5.8	19	23	39
Norwood	38.13	-108.28	7019	51	6.3	32	29	31
Nunn	40.71	-104.78	5196	17	4	8	NA	NA
Olathe	38.62	-107.98	5364	7	3.3	10	NA	NA
OPHIR LOOP	37.92	-107.83	11320	15	91.1	128	NA	NA
Ordway 2 ENE	38.22	-103.72	4315	62	2.1	14	10	18
Ordway 21 N	38.54	-103.7	4759	63	2.7	11	12	21

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Site Name	Lat (deg)	Long (deg)	Alt (ft)	Num Yrs	Mean Annual Max Ground Snow Load (psf)	Max Ground Snow Load (psf)	50-year Ground Snow Load (psf)	Reliability-Based Ground Snow Load
Ouray	38.02	-107.67	7828	58	29.9	71	76	66
Overland Res.	39.09	-107.63	9840	26	64.9	110	136	111
Pagosa Springs	37.27	-107.02	7181	49	23.8	62	61	69
Palisade	39.11	-108.35	4751	62	1.7	8	8	12
Palisade Lakes 6 SSE	37.43	-107.15	8094	20	48.4	90	103	92
Palmer Lake	39.12	-104.92	7273	10	19.3	42	NA	NA
PANDO	39.47	-106.33	9500	38	52.7	82	88	79
Paonia 1 SW	38.85	-107.62	5614	65	6.4	24	24	34
Paradox 1 E	38.37	-108.96	5383	44	5.1	20	20	32
Park Cone	38.82	-106.59	9600	79	57.1	119	103	97
Park Reservoir	39.05	-107.88	9960	76	146.2	244	241	210
Park View	40.37	-106.1	9160	77	50.3	76	79	72
Parker 6 E	39.52	-104.65	6304	50	7.2	36	29	49
Parshall 10 SSE	39.92	-106.12	8274	8	29.6	127	NA	NA
PASS CREEK	37.55	-106.77	9300	32	69.3	141	139	133
Penrose	38.45	-105.07	5413	22	0.5	2	3	5
Perry Park	39.26	-104.97	6326	7	0	0	NA	NA
Phantom Valley	40.4	-105.85	9030	80	55.4	99	98	87
PINE CREEK	40.77	-105.5	7900	39	13.8	35	40	51
Pinos Mill	37.05	-106.42	10000	44	130.4	213	241	207
Pitkin	38.6	-106.53	9199	27	56.8	118	118	111
Placerville	38.02	-108.05	7383	59	14.5	61	64	51
Platoro	37.35	-106.55	9876	61	83.6	180	168	154
Pool Table Mountain	37.8	-106.8	9840	64	30.4	81	80	69
Porcupine	37.85	-107.17	10280	62	49.8	119	112	95
Porphyry Creek	38.49	-106.34	10760	76	91.3	158	144	131
Pueblo WSO AP	38.27	-104.56	4739	66	3.3	21	12	22
Pyramid	40.23	-107.09	8030	23	29.4	74	79	71
Rabbit Ears	40.37	-106.74	9400	65	150.3	231	245	219
Ralston RSVR	39.83	-105.24	5900	35	10.2	39	36	61
Rand	40.43	-106.17	8630	10	18.4	34	NA	NA
Rangely 1 E	40.09	-108.77	5285	63	5.2	25	24	37
Rawah	40.71	-106.01	9020	13	55.3	87	NA	NA
Red Feather	40.82	-105.65	9000	57	39.5	76	73	67
Red Feather Lakes 2 SE	40.79	-105.56	8207	34	16.1	33	38	45
Red Mountain Pass	37.89	-107.71	11125	65	152.9	255	267	231
Red Wing 1 WSW	37.72	-105.32	7900	15	0	0	NA	NA
Redstone 4 W	39.2	-107.3	8066	12	43	92	NA	NA

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Site Name	Lat (deg)	Long (deg)	Alt (ft)	Num Yrs	Mean Annual Max Ground Snow Load (psf)	Max Ground Snow Load (psf)	50-year Ground Snow Load (psf)	Reliability-Based Ground Snow Load
RICO	37.68	-108.03	8760	63	42.6	144	112	89
Ridgway	38.15	-107.76	7034	31	13	28	30	36
Rifle	39.53	-107.79	5337	79	6.4	42	28	43
Rio Blanco	40.03	-107.28	8500	71	77.8	125	124	112
Ripple Creek	40.11	-107.29	10340	29	128.8	201	209	181
RIVER SPRINGS	37.07	-106.27	9300	53	35.6	103	82	76
Roach	40.87	-106.05	9700	76	98.5	162	153	136
Rocky Ford 2 SE	38.05	-103.6	4176	68	4	18	18	31
Rough And Tumble	39.03	-106.08	10360	17	32.4	54	NA	NA
Rush	38.83	-104.08	6020	54	3.2	20	14	25
Rustic 9 WSW	40.71	-105.71	7700	20	13.6	47	55	70
Ruxton Park	38.84	-104.97	9050	46	25.5	76	99	78
Rye	37.92	-104.93	6796	32	10.2	39	48	80
Saguache	38.08	-106.14	7701	59	4.8	27	18	21
Saint Elmo	38.7	-106.37	10420	50	64.9	114	113	101
Salida	38.53	-106.02	7160	48	12.6	55	59	56
Salida 3 W	38.53	-106.05	7488	11	11.7	37	NA	NA
San Luis 1 E	37.18	-105.43	8060	24	3.8	7	10	13
Santa Maria	37.82	-107.12	9600	74	24.8	70	62	57
Sargents	38.4	-106.42	8460	40	14.2	53	70	66
Sargents 6W	38.4	-106.5	8136	10	39.6	85	NA	NA
Sargents Mesa	38.29	-106.37	11530	7	46.5	58	NA	NA
Sawtooth	40.13	-105.58	9740	11	103.3	156	NA	NA
Schofield Pass	39.02	-107.05	10700	30	174.1	254	263	237
Scotch Creek	37.65	-108.01	9100	29	60.6	110	127	104
Sedalia 4 SSE	39.41	-104.93	6077	54	10	48	36	61
Sedgwick 5 S	40.88	-102.52	3886	65	6.6	21	20	42
Sharkstooth	37.5	-108.11	10720	11	97.1	153	NA	NA
Sheep MTN	37.72	-105.24	7754	26	12.9	35	45	49
Shoshone	39.57	-107.23	5930	60	17.4	43	49	65
Shrine Pass	39.53	-106.22	10700	71	101.9	145	147	133
Silver Lakes	37.38	-106.4	9500	75	34.4	78	72	70
Silverton	37.81	-107.66	9285	92	55.7	118	119	102
Slumgullion	37.99	-107.2	11440	37	69.4	97	103	94
Snake River	39.63	-105.9	10000	62	42.8	83	79	70
South Colony	37.97	-105.54	10800	37	95	160	166	146
SOUTH COLONY	37.97	-105.55	11140	21	125.3	202	222	193
South Platte	39.41	-105.18	6156	10	0.8	4	NA	NA

Table A5.2 Assembled snow site data

Site Name	Lat (deg)	Long (deg)	Alt (ft)	Num Yrs	Mean Annual Max Ground Snow Load (psf)	Max Ground Snow Load (psf)	50-year Ground Snow Load (psf)	Reliability-Based Ground Snow Load
Spicer	40.46	-106.46	8368	52	33.3	75	75	69
Springfield 7 WSW	37.38	-102.68	4535	54	4.1	18	14	27
SPRUCE CREEK	38.22	-105.68	10940	11	58.3	92	NA	NA
Spud Mountain	37.7	-107.78	10660	64	152	320	311	258
Squaw MTN	39.68	-105.5	11509	13	43.4	76	NA	NA
STATE TURKEY EXP FAR	37.22	-107.27	6663	11	11.8	39	NA	NA
Steamboat Springs	40.49	-106.82	6865	94	43.4	86	79	92
Sterling	40.63	-103.21	3974	58	2.9	14	14	27
Stillwater Creek	40.23	-105.92	8720	67	43	67	67	64
Stonington	37.34	-102.24	3895	64	3.5	26	17	30
Stratton	39.3	-102.65	4441	59	5.3	26	22	37
Stump Lakes	37.48	-107.63	11200	29	91	180	207	163
Sugarloaf RSVR	39.25	-106.37	9871	60	53.2	110	121	106
Summit Ranch	39.72	-106.16	9400	63	51.7	91	89	79
SUMMITILLE (DISC.)	37.43	-106.6	11500	36	112	195	213	184
Sundance	39.57	-105.73	11100	33	51.4	80	83	76
Tacoma	37.52	-107.78	7300	38	32.1	77	72	68
Tacony 10 SE	38.38	-104.07	4960	56	2.5	7	9	16
Taylor Park	38.82	-106.61	9179	48	41.5	122	136	121
Telluride	37.94	-107.81	8788	96	39.7	72	71	66
TENNESSEE PASS	39.35	-106.34	10226	73	57.3	99	98	90
Tower	40.54	-106.68	10500	50	250.4	412	402	355
Trapper Lake	40	-107.24	9700	30	95	166	173	148
TRICKLE DIVIDE	39.13	-107.9	10000	47	159.4	256	243	216
Trinchera	37.35	-105.23	10860	49	52.4	81	85	79
Trinidad	37.18	-104.49	6024	61	6.1	30	19	35
Trinidad FAA AP	37.25	-104.33	5742	53	3.8	12	11	20
Trinidad Lake	37.15	-104.56	6310	23	6	16	21	40
Trout Creek Pass	38.92	-106.05	9720	39	26.4	48	54	53
TROUT LAKE	37.83	-107.88	9766	64	74.7	126	129	113
Troy 1 SE	37.13	-103.3	5428	62	4.5	28	20	34
Twin Lakes Reservoir	39.09	-106.35	9205	59	13	55	46	42
Twin Lakes Tunnel	39.08	-106.53	10513	78	59.7	98	100	90
Two Buttes	37.56	-102.39	4090	20	1.3	7	10	17
TWO MILE	40.38	-105.67	10500	41	89.5	134	142	127
University Camp	40.03	-105.58	10300	78	107	202	188	163
UPPER RIO GRANDE	37.72	-107.26	9447	78	42.1	112	94	87
Upper San Juan	37.49	-106.84	10200	78	171.9	313	303	264

Table A5.2 Assembled snow site data

Site Name	Lat (deg)	Long (deg)	Alt (ft)	Num Yrs	Mean Annual Max Ground Snow Load (psf)	Max Ground Snow Load (psf)	50-year Ground Snow Load (psf)	Reliability-Based Ground Snow Load
Upper Taylor	38.99	-106.75	10640	6	68.8	110	NA	NA
Uravan	38.38	-108.74	5021	50	1.2	6	9	11
Ute Creek	37.62	-105.37	10650	20	60.9	106	127	109
UTE PASS	39.82	-106.1	9550	13	62.1	100	NA	NA
Utleyville	37.27	-103.03	5003	8	1.7	3	NA	NA
Vail	39.64	-106.35	8304	27	55.1	110	109	94
Vail Mountain	39.62	-106.38	10300	38	106.2	159	174	153
Vallecito	37.49	-107.51	10880	35	92	168	174	149
Vallecito Dam	37.38	-107.58	7758	61	26.1	78	94	76
Vasquez	39.85	-105.82	9600	56	75.7	126	119	105
Victor	38.72	-105.15	9708	7	14.3	31	NA	NA
Wager Gulch	37.88	-107.36	11100	4	39.7	51	NA	NA
Wagon Wheel Gap 3 N	37.8	-106.83	8507	22	18	44	63	64
Walden	40.74	-106.28	8056	64	12.1	44	38	34
Walsenburg	37.63	-104.79	6188	64	7.5	28	27	48
Ward	40.07	-105.52	9500	62	34.2	67	67	62
Waterdale	40.43	-105.21	5230	65	5.8	21	19	34
Weminuche Creek	37.52	-107.32	10740	5	73.7	79	NA	NA
Westcliffe	38.13	-105.47	7860	65	13.9	45	45	48
WESTCLIFFE	38.12	-105.58	9400	47	40.1	69	72	71
Weston	39.07	-106.02	9300	30	18.4	45	41	41
Wetmore 2 S	38.22	-105.1	6585	19	10.3	26	33	55
Wetmore 9 S	38.13	-105.08	7365	6	20.9	25	NA	NA
Whiskey Ck	37.21	-105.12	10220	55	54	98	95	84
Wiggins 7 SW	40.15	-104.18	4715	11	2.5	7	NA	NA
Wild Basin	40.2	-105.6	9595	79	68.5	127	124	108
Williams Fork Dam	40.04	-106.2	7618	31	19.6	44	48	43
Willow Creek Pass	40.35	-106.09	9540	78	72	107	105	96
Willow Park	40.43	-105.73	10700	38	96.8	161	175	151
Winfield Middle	38.98	-106.45	10340	4	43.9	63	NA	NA
Winter Park	39.87	-105.76	9108	65	73.6	129	119	105
WOLF CREEK PASS	37.47	-106.78	10320	50	160.1	288	269	253
Wolf Creek Pass 1 E	37.48	-106.78	10640	35	160.8	583	496	380
Wolf Creek Pass 4 W	37.48	-106.87	9436	21	167.9	428	447	344
Wolf Creek Summit	37.48	-106.8	10934	65	173.7	333	323	276
Woodrow 6 NNE	40.08	-103.57	4374	20	3.4	8	9	20
Wootton RCH	37	-104.48	7582	23	11.8	35	42	65
Wray	40.06	-102.22	3582	90	3.4	12	11	25

Table A5.2 Assembled snow site data

Site Name	*Lat (deg)*	*Long (deg)*	*Alt (ft)*	*Num Yrs*	*Mean Annual Max Ground Snow Load (psf)*	*Max Ground Snow Load (psf)*	*50-year Ground Snow Load (psf)*	*Reliability-Based Ground Snow Load*
Wurtz Middle	39.4	-106.37	10563	5	94.8	139	NA	NA
Yampa	40.16	-106.91	7857	64	26	47	47	47
Yampa View	40.37	-106.77	8200	62	82	127	121	114
Yellow Jacket 2 W	37.52	-108.75	6860	40	16.3	43	54	57
Yuma	40.19	-102.78	4162	65	5.1	28	20	35
Zirkel	40.79	-106.6	9340	12	150.7	219	NA	NA

Appendix 6. Comparison of 2015 Design Ground Snow Loads to Previous Editions

Table A6.1 Comparison of 2015 design ground snow loads to previous editions

City/Town	County	Latitude (deg)	Longitude (deg)	Altitude (ft.)	2015 Tabulated P_g (psf)	2007 Tabulated P_g (psf)	Difference from 2015	1971 Tabulated Flat Roof Snow Load (psf)	1971 Tabulated Flat Roof Snow Load Converted to Equivelent P_g (psf)	Difference from 2015
Aguilar	Las Animas	37.40	-104.65	6390	55	20	-64%	40	57	4%
Air Force Academy	El Paso	39.01	-104.89	7000	55	45	-18%			
Alamosa	Alamosa	37.47	-105.87	7540	25	20	-20%	20	29	14%
Alma	Park	39.28	-106.06	10360	65	140	115%			
Antonito	Conejos	37.08	-106.01	7890	40	20	-50%	20	29	-29%
Arvada	Jefferson	39.80	-105.09	5350	40	30	-25%			
Aspen	Pitkin	39.19	-106.82	7890	75	105	40%	75	107	43%
Aurora	Adams	39.73	-104.83	5400	40	30	-25%			
Avon	Eagle	39.63	-106.52	7430	60	120	100%			
Bailey	Park	39.41	-105.47	7740	80	65	-19%			
Basalt	Eagle	39.37	-107.03	6610	55	120	118%			
Bayfield	La Plata	37.23	-107.60	6900	55	55	0%			
Beaver Creek	Eagle	39.60	-106.52	8080	75	120	60%			
Bellvue	Larimer	40.63	-105.17	5130	40	35	-13%			
Black Hawk	Gilpin	39.80	-105.49	8540	85	40	-53%			
Blue River	Summit	39.38	-106.05	10500	90	70	-22%			
Boulder	Boulder	40.01	-105.27	5330	40	25	-38%	30	43	7%
Branson	Las Animas	37.02	-103.88	6270	55	20	-64%			
Breckenridge	Summit	39.50	-106.04	9600	80	110	38%	65	93	16%
Brighton	Adams	39.99	-104.82	4980	35	20	-43%			
Broomfield	Broomfield	39.92	-105.09	5390	40	20	-50%			
Buena Vista	Chaffee	38.84	-106.13	7960	35	20	-43%	40	57	63%
Canon City	Fremont	38.44	-105.24	5350	35	20	-43%	30	43	22%
Carbondale	Garfield	39.40	-107.21	6170	50	90	80%	40	57	14%
Cascade	El Paso	38.90	-104.97	7380	60	80	33%			
Castle Rock	Douglas	39.37	-104.86	6220	45	30	-33%	40	57	27%
Cedaredge	Delta	38.90	-107.93	6230	35	30	-14%	35	50	43%
Centennial	Arapahoe	39.58	-104.88	5830	40	30	-25%			
Central City	Gilpin	39.80	-105.51	8510	85	40	-53%	50	71	-16%

Table A6.1 Comparison of 2015 design ground snow loads to previous editions

City/Town	County	Latitude (deg)	Longitude (deg)	Altitude (ft.)	2015 Tabulated P_g (psf)	2007 Tabulated P_g (psf)	Difference from 2015	1971 Tabulated Flat Roof Snow Load (psf)	1971 Tabulated Flat Roof Snow Load Converted to Equivelent P_g (psf)	Difference from 2015
Collbran	Mesa	39.24	-107.96	5980	45	55	22%			
Commerce City	Adams	39.81	-104.93	5160	35	25	-29%			
Conifer	Jefferson	39.52	-105.31	8280	100	70	-30%			
Cortez	Montezuma	37.35	-108.59	6190	30	20	-33%	25	36	19%
Craig	Moffat	40.52	-107.55	6200	30	55	83%	35	50	67%
Crawford	Delta	38.70	-107.61	6560	45	20	-56%			
Creede	Mineral	37.85	-106.93	8800	65	55	-15%	65	93	43%
Crested Butte	Gunnison	38.87	-106.98	8910	125	100	-20%	100	143	14%
Crestone	Saguache	38.00	-105.70	7930	35	30	-14%			
Cripple Creek	Teller	38.75	-105.18	9490	70	35	-50%	40	57	-18%
De Beque	Mesa	39.33	-108.22	4950	30	65	117%			
Del Norte	Rio Grande	37.68	-106.35	7880	30	20	-33%	20	29	-5%
Denver	Denver	39.74	-104.98	5280	35	30	-14%	30	43	22%
Dillon	Summit	39.63	-106.04	9110	65	65	0%	50	71	10%
Dinosaur	Moffat	40.24	-109.01	5920	35	30	-14%			
Dolores	Montezuma	37.47	-108.50	6940	55	85	55%	40	57	4%
Dove Creek	Dolores	37.77	-108.91	6840	45	50	11%	25	36	-21%
Durango	La Plata	37.28	-107.88	6530	55	60	9%	40	57	4%
Eagle	Eagle	39.66	-106.83	6600	45	55	22%	40	57	27%
Edwards	Eagle	39.64	-106.59	7220	55	100	82%			
Elbert	Elbert	39.22	-104.54	6720	55	20	-64%			
Empire	Clear Creek	39.76	-105.68	8620	60	80	33%			
Estes Park	Larimer	40.43	-105.52	7520	65	45	-31%	40	57	-12%
Evergreen	Jefferson	39.63	-105.32	7050	70	45	-36%	40	57	-18%
Fairplay	Park	39.22	-106.00	9950	55	95	73%	50	71	30%
Fort Collins	Larimer	40.59	-105.08	5000	35	20	-43%	30	43	22%
Fort Garland	Costilla	37.43	-105.43	7940	25	40	60%			
Fort Morgan	Morgan	40.25	-103.80	4330	30	20	-33%	25	36	19%
Fountain	El Paso	38.68	-104.70	5550	35	20	-43%			
Franktown	Douglas	39.39	-104.75	6160	45	25	-44%			
Fraser	Grand	39.94	-105.82	8580	75	105	40%	65	93	24%
Frisco	Summit	39.57	-106.10	9080	65	100	54%			
Georgetown	Clear Creek	39.71	-105.70	8520	60	65	8%	75	107	79%

Table A6.1 Comparison of 2015 design ground snow loads to previous editions

City/Town	*County*	*Latitude (deg)*	*Longitude (deg)*	*Altitude (ft.)*	*2015 Tabulated P_g (psf)*	*2007 Tabulated P_g (psf)*	*Difference from 2015*	*1971 Tabulated Flat Roof Snow Load (psf)*	*1971 Tabulated Flat Roof Snow Load Converted to Equivelent P_g (psf)*	*Difference from 2015*
Glenwood Springs	Garfield	39.55	-107.32	5760	40	30	-25%	40	57	43%
Granby	Grand	40.09	-105.94	7980	55	65	18%			
Grand Junction	Mesa	39.06	-108.55	4590	25	20	-20%	20	29	14%
Grand Lake	Grand	40.25	-105.82	8390	70	80	14%	65	93	33%
Greeley	Weld	40.42	-104.71	4680	30	30	0%	30	43	43%
Green Mountain Falls	Teller	38.93	-105.02	7760	70	65	-7%			
Gunnison	Gunnison	38.55	-106.93	7700	45	40	-11%	50	71	59%
Gypsum	Eagle	39.65	-106.95	6310	40	45	13%			
Hartsel	Park	39.02	-105.80	8870	35	20	-43%	30	43	22%
Hayden	Routt	40.50	-107.26	6350	55	70	27%	50	71	30%
Highlands Ranch	Douglas	39.54	-104.97	5900	45	30	-33%			
Hot Sulphur Springs	Grand	40.07	-106.10	7730	45	90	100%			
Howard	Fremont	38.45	-105.84	6720	40	25	-38%			
Idaho Springs	Clear Creek	39.74	-105.51	7530	60	55	-8%	50	71	19%
Ignacio	La Plata	37.12	-107.63	6450	45	30	-33%	40	57	27%
Kremmling	Grand	40.06	-106.39	7310	40	75	88%	50	71	79%
La Junta	Otero	37.99	-103.54	4080	30	20	-33%	25	36	19%
La Veta	Huerfano	37.51	-105.01	7040	50	90	80%	50	71	43%
Lake City	Hinsdale	38.03	-107.32	8660	55	70	27%	65	93	69%
Lakewood	Jefferson	39.70	-105.08	5520	40	35	-13%			
Lamar	Prowers	38.09	-102.62	3620	30	30	0%	20	29	-5%
Larkspur	Douglas	39.23	-104.89	6730	55	35	-36%			
Leadville	Lake	39.25	-106.29	10160	75	115	53%	80	114	52%
Littleton	Arapahoe	39.61	-105.02	5350	40	40	0%			
Livermore	Larimer	40.79	-105.22	5900	45	35	-22%			
Longmont	Boulder	40.17	-105.10	4980	35	20	-43%			
Loveland	Larimer	40.40	-105.07	4980	35	20	-43%			
Lyons	Boulder	40.22	-105.27	5370	40	20	-50%	30	43	7%
Mancos	Montezuma	37.34	-108.29	7030	45	30	-33%	50	71	59%
Manitou Springs	El Paso	38.86	-104.92	6360	50	100	100%			
Marble	Gunnison	39.07	-107.19	7990	90	155	72%			
Meeker	Rio Blanco	40.04	-107.91	6240	40	20	-50%	30	43	7%

Table A6.1 Comparison of 2015 design ground snow loads to previous editions

City/Town	County	Latitude (deg)	Longitude (deg)	Altitude (ft.)	2015 Tabulated P_g (psf)	2007 Tabulated P_g (psf)	Difference from 2015	1971 Tabulated Flat Roof Snow Load (psf)	1971 Tabulated Flat Roof Snow Load Converted to Equivelent P_g (psf)	Difference from 2015
Mesa	Mesa	39.17	-108.14	5640	35	120	243%			
Mesa Verde	Montezuma	37.15	-108.52	6770	50	60	20%	50	71	43%
Minturn	Eagle	39.59	-106.43	7860	70	170	143%			
Monte Vista	Rio Grande	37.58	-106.15	7660	25	20	-20%	20	29	14%
Montezuma	Summit	39.58	-105.87	10310	105	80	-24%			
Montrose	Montrose	38.48	-107.88	5810	25	30	20%	25	36	43%
Monument	El Paso	39.09	-104.87	6980	60	45	-25%			
Nederland	Boulder	39.96	-105.51	8230	70	40	-43%	50	71	2%
Newcastle	Garfield	39.57	-107.54	5600	35	40	14%			
Norwood	San Miguel	38.13	-108.29	7010	35	25	-29%	30	43	22%
Nucla	Montrose	38.27	-108.55	5790	25	75	200%			
Oak Creek	Routt	40.28	-106.96	7430	70	85	21%			
Ophir	San Miguel	37.86	-107.83	9700	125	170	36%			
Ouray	Ouray	38.02	-107.67	7790	65	50	-23%	50	71	10%
Pagosa Springs	Archuleta	37.27	-107.01	7130	75	100	33%	65	93	24%
Palmer Lake	El Paso	39.11	-104.91	7300	65	45	-31%	40	57	-12%
Paonia	Delta	38.87	-107.59	5680	35	20	-43%	25	36	2%
Parker	Douglas	39.52	-104.76	5870	45	30	-33%			
Pitkin	Gunnison	38.61	-106.52	9220	105	105	0%			
Poncha Springs	Chaffee	38.51	-106.08	7470	45	70	56%			
Pueblo	Pueblo	38.25	-104.61	4690	30	20	-33%	25	36	19%
Rangely	Rio Blanco	40.09	-108.80	5230	35	20	-43%	20	29	-18%
Red Cliff	Eagle	39.65	-106.37	8750	85	110	29%			
Rico	Dolores	37.69	-108.03	8830	100	145	45%			
Ridgway	Ouray	38.15	-107.76	7050	40	20	-50%			
Rifle	Garfield	39.53	-107.78	5350	40	20	-50%	30	43	7%
Rye	Pueblo	37.92	-104.93	6800	60	35	-42%			
Salida	Chaffee	38.53	-106.00	7080	45	50	11%	40	57	27%
San Luis	Costilla	37.20	-105.42	7980	30	20	-33%			
Sawpit	San Miguel	37.99	-108.00	7590	55	85	55%			
Sedalia	Douglas	39.44	-104.96	5840	50	30	-40%			
Silt	Garfield	39.55	-107.66	5460	35	30	-14%			
Silver Cliff	Custer	38.14	-105.45	7990	55	35	-36%			
Silver Plume	Clear Creek	39.70	-105.73	9100	70	65	-7%			

Table A6.1 Comparison of 2015 design ground snow loads to previous editions

City/Town	County	Latitude (deg)	Longitude (deg)	Altitude (ft.)	2015 Tabulated $P_{g\ (psf)}$	2007 Tabulated P_g (psf)	Difference from 2015	1971 Tabulated Flat Roof Snow Load (psf)	1971 Tabulated Flat Roof Snow Load Converted to Equivelent $P_{g\ (psf)}$	Difference from 2015
Silverthorne	Summit	39.63	-106.07	8760	65	70	8%			
Silverton	San Juan	37.81	-107.66	9310	105	140	33%	90	129	22%
Snowmass Village	Pitkin	39.21	-106.94	8210	90	165	83%			
South Fork	Rio Grande	37.67	-106.64	8210	70	55	-21%			
Steamboat Springs	Routt	40.48	-106.83	6730	85	100	18%	75	107	26%
Sterling	Logan	40.63	-103.21	3940	30	20	-33%	20	29	-5%
Telluride	San Miguel	37.94	-107.81	8790	75	100	33%	75	107	43%
Thornton	Adams	39.87	-104.97	5350	40	25	-38%			
Trinidad	Las Animas	37.17	-104.50	6030	45	35	-22%	40	57	27%
Victor	Teller	38.71	-105.14	9710	80	40	-50%			
Walden	Jackson	40.73	-106.28	8100	45	50	11%	50	71	59%
Walsenburg	Huerfano	37.62	-104.78	6170	45	25	-44%	35	50	11%
Ward	Boulder	40.07	-105.51	9150	75	75	0%			
Westcliffe	Custer	38.13	-105.47	7870	50	35	-30%	40	57	14%
Westminster	Adams	39.84	-105.04	5380	40	25	-38%			
Winter Park	Grand	39.89	-105.76	9050	100	140	40%	100	143	43%
Woodland Park	Teller	38.99	-105.06	8480	85	50	-41%			
Yampa	Routt	40.15	-106.91	7880	60	50	-17%	50	71	19%