# SNOW LOAD ANALYSIS AND RECREATIONAL USES OF SNOW DATA



By

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## Introduction

Architects, engineers, and building officials have long needed a method of estimating the weight of snow that may accumulate on a building roof or structure. With this information they can determine the strength requirements necessary to prevent collapse of a structure or unacceptable strain.

Also, in recent years winter recreation has grown to an extremely large business throughout the western United States. Many ski areas have been built, and many more are in the planning stage. The same snow data that have provided a reliable tool for forecasting streamflow, as well as providing information on snow loads, are important in evaluating winter recreation site potential.

## Snow Load Procedure

### Oregon--Design Method

The Soil Conservation Service and the Structural Engineers Association of Oregon cooperated on a publication, "Snow Load Analysis for Oregon", issued in June 1971, that gives the expected snow loads for Oregon and a procedure for using these loads in the design of buildings.

The Association did the research to find a method of applying estimated snow loads to building design. The research showed that the Uniform Building Code of Canada 1/ contained the most rational and useful method of design. The Canadians have done extensive work in comparing ground snow loads to loads found on roofs and structures. Various shapes of roofs and buildings, exposure, etc., have been investigated. They derived a method to apply this information and basic ground snow load data to the design of buildings. Permission was secured from the National Research Council of Canada to recommend their method for use in Oregon and to reproduce their coefficients and explanations in the "Snow Load Analysis for Oregon" publication.

The value and need for the Oregon snow load publication is best described by Jerry Estoup, chairman of the Structural Engineers Snow Load Committee. He says, "Every time a structural engineer begins the design of a new project--a building, a bridge, or whatever--he must decide what loads are appropriately applied to the structure. Generally accepted regional building codes give required floor, wind, and seismic loads but usually state that snow loads should be in accordance with local regulations. In large metropolitan areas engineers usually know the accepted snow loads. However, for remote areas, areas of high elevation, and other comparable situations, the proper values are seldom known. Sometimes it is possible to ascertain the required loads by telephoning authorities in the area. However, the engineer may find that the required loads are not established, or he can't locate anyone who has the information he needs. When this happens, the only alternative is to attempt to establish a snow load by independent research. This often becomes a laborious task requiring additional searches for information. After available information is assembled, the task of justifying the loads derived may become an additional burden on the engineer. He may finally be required to compile the information used, together with his analysis and conclusions, and present the work to the local authorities for review. Contrast the preceding procedure with the ability to turn to the appropriate graph in the booklet (Snow Load Analysis for Oregon) and read off the appropriate load. Justification of the loads to the authorities will probably consist of nothing more than quoting the source. As an additional bonus, a rational and appropriate method of design, especially fitted to the form taken by the snow load data, is handily contained within the booklet. The savings in time and energy possible make the booklet a valuable design tool for any structural engineer."

Charles Bartl, chief building inspector of Clackamas County, Oregon, has indicated to us that he is very pleased with this publication, and he has attempted to endorse its Oregon adoption as a design handbook for agencies responsible for codes and approvals. He says, "It is far too seldom that this type of information is available for design agencies."

"Snow Load Analysis for Oregon" is a practical publication serving a definite need of architects, engineers, and building officials.

Oregon--Snow Values

Previous work has been done by Thom 2/ in presenting expected snowpack on the ground in pounds per square foot on a very general basis (a map of the United States). The map he produced was not localized enough to be of value to the Oregon Structural Engineers Association. The 25-year return interval values indicated by Thom range from a minimum of 5 pounds to a maximum of 20 pounds per square foot for the entire state of Oregon. The Association was already recommending a minimum of 25 pounds per foot$^2$ for the valley areas of the state that receive the least amount of snow, and it needed additional information for the mountainous and high desert areas that cover large portions of the state.

In order to localize the data as was done by Brown 3/ in Nevada, and make it as useful as possible, it was felt that snow measurements for countysize areas should be analysed and presented so the extreme snow accumulation variations that exist in Oregon, as shown in Summary of Snow Survey Measurements for Oregon 4/, would be readily noticeable.

The linear relationship of elevation to snow accumulation has been noted and discussed previously by Schaerer 5/, Garstka 6/, Hannaford 7/, and Seligman 8/. Their work shows this relationship on an individual mountain and watershed basis. It was felt, however, that the relationship would still prevail on a multiwatershed area such as a county.

Oregon--Results

Maximum recorded weights of snow on the ground as determined from measurements taken by the Soil Conservation Service, Oregon State University, and the State Engineer of Oregon, were taken for various county areas in the state (Fig. 1) and plotted against elevation (Fig. 2). These maximum values were derived from monthly measurements taken during the snow seasons from 1940 to 1969. This interval of years was selected because most snow courses in the state had a period of record at least this long. At a few snow course locations where the period of record was short, the data were statistically extrapolated, as is often done when insufficient observations are available. All maximum values were then compared to the results of the Log Pearson Type III frequency analysis at the 3 percent level of significance with very good correlation (Fig. 3).

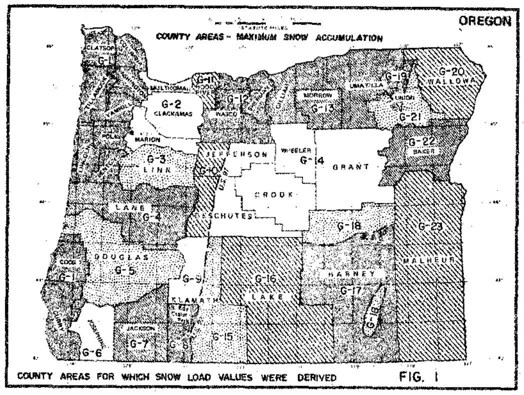
In most cases the plotted points (psf vs. elevation) show very small deviations from the curve. However, occasionally there are large deviations due to local orographic effects, exposure, etc., which are noted (Fig. 3). When applying the snow load values to structures, the designer needs to adjust the graphical data for local effects, safety, and lifespan considerations.

Nevada--Snow Values

In Washoe County, Nevada, snow load values have been included in the county building code 3/. This is fitting especially in western states because most building is governed or inspected on a countywide basis. The tables included in the Washoe County Building Code compare the elevation within the county to the snow (roof live) loads in pounds per square foot. "Roof live" snow loads were determined as a percentage of ground snow loads. (Example: Table 1 - Excerpt from Washoe County Building Codes).

Most localities find that the county codes are satisfactory and economically feasible. However, many areas in the west have considerable variance in the annual snowpack at similar elevations within a countysize area. If one of these more highly variable areas has considerable construction activity, it will be advantageous and justifiable to increase the detail of the county snow load criteria. This can be handled in several ways. One is by delineating an area within a county and providing snow load criteria applicable to the area.

The Lake Tahoe area of California and Nevada is a special area that has had considerable development during the recent years. Many problems caused by the increase in population are very difficult to solve. The problems are complicated legally by having portions of five counties in two states.



COUNTY AREAS FOR WHICH SNOW LOAD VALUES WERE DERIVED FIG. 1

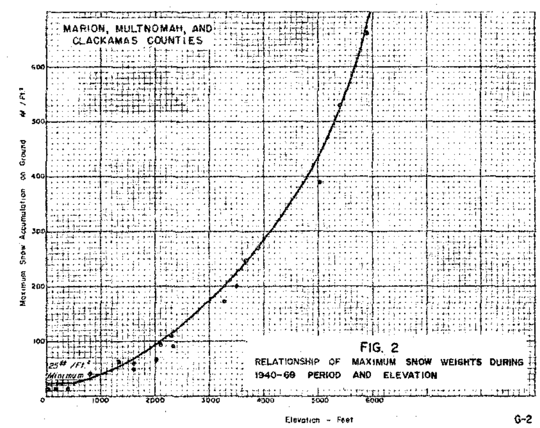


FIG. 2
RELATIONSHIP OF MAXIMUM SNOW WEIGHTS DURING 1940-69 PERIOD AND ELEVATION

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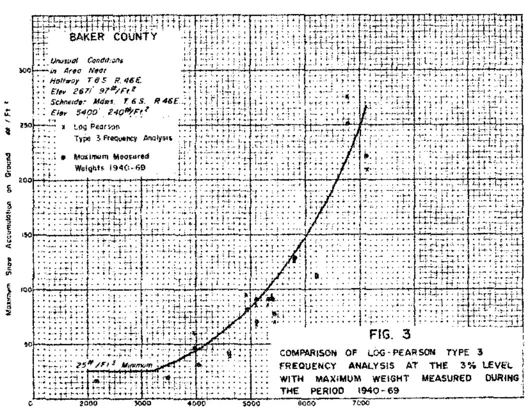

FIG. 3
COMPARISON OF LOG-PEARSON TYPE 3 FREQUENCY ANALYSIS AT THE 3% LEVEL WITH MAXIMUM WEIGHT MEASURED DURING THE PERIOD 1940-69

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Because of pressing ecological problems, the Lake Tahoe Regional Planning Agency was formed. This agency requested the Soil Conservation Service to supply snow load data to be used in determining building design and other factors such as road and parking lot snow removal, etc. Since considerable development is contemplated, it was necessary to provide snow load information on a detailed basis.

Nevada--Results

Lake Tahoe is located at 6,229 feet elevation in the Sierra Nevada Range. The mountain range has peaks in excess of 10,000 feet around the lake. The majority of the winter's storms are Pacific maritime. The orographic effect of the Sierra Nevada causes the western side of the Tahoe Basin to have a much deeper snowpack than the eastern side, which is in a rain shadow area. The Tahoe Basin also receives heavier snowfall in the north than in the south, primarily due to an orographic effect. Because of these physical factors, a map was prepared delineating the snow zone boundaries as they change markedly from east to west and north to south. For study purposes the watershed was divided into four sections: northeast, northwest, southeast, and southwest (Fig. 4).

In each of these areas, snow courses were selected at various elevations. All past records from these snow courses were analyzed, using the Log Pearson type III frequency analysis. Snow depths having a probability of .04 in any one year (4 percent chance), or 1 out of 25 years, were developed from selected snow courses (Fig. 5). These data were converted to pounds per square foot and plotted versus elevation (Fig. 6). Note the difference in the slopes of the lines for the separate areas. This shows graphically the variation between the areas in the Lake Tahoe Basin. For example, snow load construction criteria for a home built at 7,000 feet in the northwest portion of the basin would be 400 pounds per square foot, while at the same elevation is the southeast portion it would be slightly less than 150 pounds per square foot. This makes separating these areas necessary and illustrates the economic value to the public.

To present this data a map of the area with isolines indicating the various snow load zones was produced 9/. For each 25 to 50 pounds per square foot difference, separate isoline delineations were plotted. This map is within limits of accuracy accepted and easily understood by building contractors, county commissioners, etc.

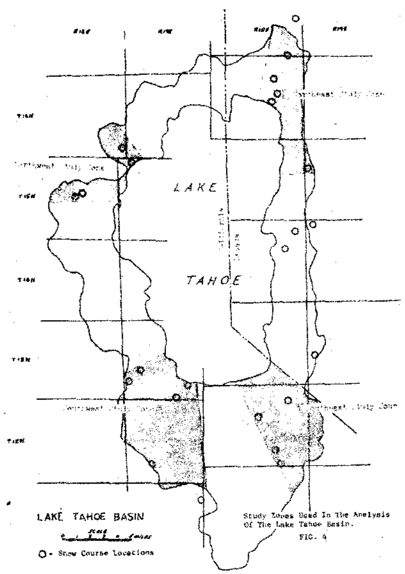
In any deep snow zone area that is having or expects considerable urban development, there is a definite need for this type of snow load data. If basic data are not available from existing snow courses, short term snow courses throughout the elevation range could be established. After a few years of record, these short term courses could be correlated to other similar courses in the region with longer periods of record, and be used to determine snow loads with reasonable limits. Example: If a long term snow course shows 40 percent of its maximum record on the date of sampling, the new snow course located at a similar elevation would show about 40 percent of its maximum load on the same date. This data can then be expanded to form the sectors for developing the snow load criteria. The existing snow courses have been installed primarily for the prediction of streamflow runoff, and they may not be located in places that will yield the best information for analysing snow loads on buildings and structures. In areas where building officials feel that snow course data are inadequate, additional short term snow course sites may be established. The information obtained can then be used to adjust the recommended values.

Winter Recreation Areas

Nevada

The Soil Conservation Service offices in Montana and Nevada have recently published statewide maps indicating areas within the states having adequate snowfall for ski areas and similar winter recreation sites 11/.

Snowpack criteria for winter recreation developments are dictated somewhat by local needs. The direction and aspect of ski runs, amount of slope, grooming, typical wind drifting, etc., determine each area's snowpack needs. According to ski area operators in Montana, 2 inches of snow-water equivalent, which is the same as 12 to 18 inches of new snow or 4 to 6 inches of packed snow, is the average minimum necessary for skiable snow conditions. It is also important that a ski area be in operation by mid-December at least 18 years out of 20. A closing date is not critical because most skiers do not ski after Easter regardless of snow conditions.



Study Zones Used In The Analysis Of The Lake Tahoe Basin.
FIG. 4

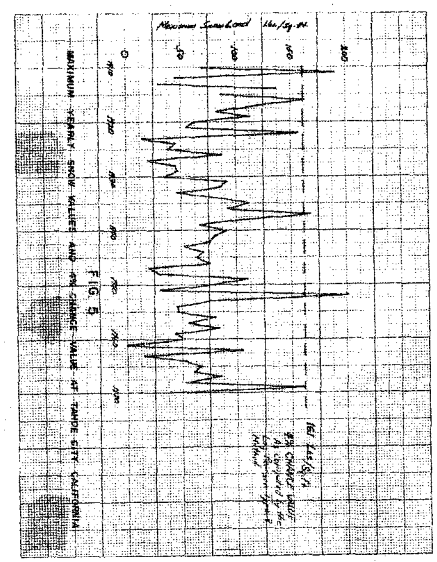


FIG. 5
MAXIMUM YEARLY SNOW VALUES AND 4% CHANGE VALUE AT TAHOE CITY CALIFORNIA

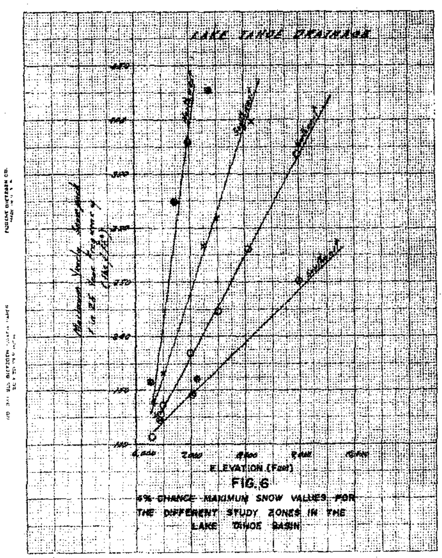


FIG. 6
4% CHANGE MAXIMUM SNOW VALUES FOR THE DIFFERENT STUDY ZONES IN THE LAKE TAHOE BASIN

In Nevada many snow courses are measured on January 1, but there are very few December 1 measurements available. Using what were available, average December snowpack increments were estimated. One-half of the December increment for each snow course was subtracted from its respective January 1 value to arrive at an adjusted December 15 reading. Studies of past years' snow pillow data (1955-1972) revealed that snow buildup in the area is fairly uniform throughout December. With the limited data available (7 years) we felt it was reasonable to split the December increment in half. These assumed December 15 snow-water content readings were then analysed using the Log Pearson type III analysis.

All the areas in the state meeting the criteria of 2 inches of snow-water equivalent in 18 out of 20 years were delineated. A statewide map, indicating adequate snowfall for ski areas and other winter recreation area use in Nevada, was then prepared 12/.

When a specific site is being contemplated for a winter recreation area, it is desirable to install a few short term snow courses for snowpack evaluation of the area. The short term records collected while the proposed area is in the feasibility study period can be compared directly with long term data, thereby giving the short term snow courses more reliability and more meaning. This additional snow course information allows people to develop winter recreation facilities based on data that should improve their chances of having adequate snow.

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12/ Nevada Areas with Adequate Snowfall for Winter Recreation - Prepared by the U. S. Department of Agriculture, Soil Conservation Service, Snow Survey and Water Supply Forecast Unit, Reno, Nevada

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