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AVALANCHE CONTROL
SITE PLANNING
AVALANCHE ZONING
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EXPLOSIVES TRAINING
TECHNICAL WITNESS

Avalanche Hazard Study
The City of Ketchum, Idaho

September 1977

Prepared for: Mr. Russell Pinto
Planning Department
City of Ketchum, Idaho

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Several portions of the City of Ketchum are regularly threatened by snow avalanche hazard. Some of these areas are otherwise attractive for homesites or for commercial uses. Some of the threatened areas are already occupied by homes, and some of the homes have suffered avalanche effects, ranging from mild damage to total destruction.

The objective of this study and report is to delineate, as accurately as is possible within the limits of the avalanche art, avalanche hazard zones that lie along the north side of Warm Springs Canyon within the City Limits; and avalanche hazard zones on the west slope of Dollar Mountain, within the City Limits. Avalanche Hazard Zones are shown on the accompanying Avalanche Zone Map (AZM).

The field portion of this study was conducted during the period 28-29 September, 1977. Avalanche observations and data accumulated over the years by Forest Service personnel of the Ketchum Ranger District and data accumulated by Mr. Phil Puchner for the City, as well as the writer's own findings and data accumulated in earlier studies of nearby avalanche sites, materially aided in swift conclusion of this study.

Preliminary Considerations

Formulation of an avalanche zoning plan must be based on several key factors, primarily: terrain configurations, vegetative cover, and weather phenomena, avalanches, and other natural occurrences experienced at the site. Studies and research necessary to evaluation of these key factors include:

Terrain analysis

Slope gradient, orientation, and vertical relief, and surface features such as smoothness or ruggedness, the presence of large boulders, outcrops, gullies, and ridges.

Analysis of vegetation

Vegetative types, distribution, and relative ages. Damaged vegetation is frequently the most important indicator of avalanche activity, both size and frequency.

Observation and analysis of avalanche debris distribution

Debris broken from trees by passing avalanches is used as one guide in the estimation of destructive power, limits of the hazard zones, and frequency of occurrence.

Historical data: snow, weather, and avalanche occurrences

Study of weather records, as available. Frequently applicable records are not available. In these cases, inference must be drawn from other historical sources.
Study of photographs may yield valuable information as to snow deposition patterns and avalanche occurrence.
Study of avalanche records. Formal records rarely exist, thus many sources of this information must be explored: newspapers, long-term residents, journals, and public agencies of various types are all potential sources. Information from

> these sources must be noted and evaluated for accuracy, relevance, and as possible indications of other events that may have gone unnoticed and unrecorded.

Correlation of the key factors allows a subjective assignment of avalanche hazard zones within a study area, according to the estimated frequency, destructive power, and limits of expected avalanche occurrences.

The Swiss Avalanche Classification System is used in this report for designation of the hazard zones. Table 1 shows the criteria used. It should be noted, however, that the primary difference between the Red and Blue Zones used in the Swiss system is the estimated frequency of occurrence of avalanche forces. The reader should note that equal forces are to be expected in both zones, but on different levels of frequency.

Discussion

Philosophy of Avalanche Zoning

The following selected quotations from the avalanche literature are included here to illustrate for the City the manner in which avalanche zoning has been undertaken in other parts of the United States and in other countries.

From The Avalanche Zoning Plan, a Swiss publication by Hans Frutiger describing the concept and description of the avalanche zones:

> An avalanche zone can generally be subdivided into three sections: a starting zone, a track, and a runout-damage zone. Since the building authorities need to know only the conditions of the inhabited areas and potential construction sites, which are mostly located in the runout zone, the starting zone and the track are ordinarily not included in zone planning. However, workers compiling

the avalanche zoning map must also judge the starting zone and the track. It is from the characteristics of these areas that the size, runout distance, and frequency of expected slides can be estimated.

If the starting zone is uniform, chances are that the slide is released over the full extent of the zone, which results in a large avalanche. If it is separated by rock outcroppings, forest patches and ridges, small slides will frequently release, but the resulting avalanches will be small and harmless. Slopes with an inclination of 60% [32°] or more can generally be considered avalanche starting zones; however, a slide will break loose only under certain weather conditions. The most important factor which is necessary to release an avalanche is heavy snowfall. A large amount of snowfall will result in new snow avalanches that can be dangerous for inhabited areas. Under conditions of heavy snowfall, the rapidly increasing new snow layer cannot settle and stabilize enough to bond with the old layer of snow or the ground below it, so that after a given amount of time the new snow layer will slide off as an avalanche. Steep slopes with approximately 30 cm [12"] of new snowfall represent a local slide danger. If the snowfall accumulates to about 50 cm [20"], the expected avalanches will be larger, but if it accumulates to about 70 cm [28"], avalanches release in areas that seldom experience them. An important factor in judging avalanche areas are slopes with an inclination of between 55% and 60% [29° and 32°]. Such slopes do not release immediately under heavy snowfall, allowing for exceptionally large avalanches, as was demonstrated in the winter of 1950/51.

Along with the new snow avalanches which usually occur in mid-winter and which are composed of dry and light snow, spring and ground avalanches should be mentioned. Their release is effected by warm and clear weather and by strong solar radiation or by the "Föhn" [Chinook Wind], all factors which cause the entire meltwater-saturated snow layer to slide along the ground. The wet and heavy snow moves relatively slow and generally follows a well-known slide path. Ground avalanches are especially important to transportation and communication links, such as railroads and highways.

On slopes and in gullies with an inclination of about 30% [17°], avalanches will not ordinarily stop in their downward movement. Slopes with such angles must still be counted as part of the track. The average inclination for most avalanche paths that extend for a long distance is between 40% and 70% [22° and 35°]. The direction and run out distance of an avalanche in the area of deposit is determined by the form, direction, and slope of the lower area of the track. According to their type and by the corresponding shape of the track, avalanches can be thrown out of their path and can follow totally different directions. In one instance, it could be observed that the advanced fronts of ground avalanches and dust avalanches (a snow-air mixture) were deposited 400 m apart, even though they released from the same zone. The different dynamics of two types of avalanches result in a much larger area of deposition than is observed with only one type of avalanche. The possibility of building on alluvial fans below the mouth of gullies must often be considered. Avalanches are channeled in the gullies and enter, at the beginning of the outrun, a relatively flat and wide terrain. Retardation often begins at the gully mouth. The outrun distance of large avalanches is long, despite the small inclination of the slope. At inclinations of 10% to 15% [6° to 8°], outrun distances of 500 m to 1000 m [1500' to 3000'] are observed. On a steep and irregular track, dry snow avalanches develop into powder avalanches of respectable size. The resulting impact can lead to destruction at places which cannot be reached by the sliding snow. In narrow valleys, the air blast can reach far up the opposite slopes.

As a result of unusual weather conditions, avalanches can occur at places where it was never considered possible. A combination of low temperature and intense snowfall can lead to an unusually loose snow layer that can even release in forested areas. Mountain forests in general and especially larch forests show thin open stands which are not able to prevent the starting of avalanches. The avalanches from January 10-12, 1954, which especially affected the Grosse Walsertal in Austria are a case in point. Schilcher said following the event: "From the southern and partially from the northern valley slopes of the Grosse Walsertal, loose snow and dust avalanches of all sizes spread over 50% of the total area. The release areas existed along the length of the valley and were scattered in a southwesterly direction at any height between 800 m and 1850 m [2600' and 6000'] and were located in open country as well as in forests." Such possibilities must be strongly considered, since sunny ridges located under steep mountain forests make ideal locations for summer houses.

From the Technical Supplement to Geophysical Hazards Investigation for the City and Borough of Juneau, Alaska:

> Red Zone: On red zones buildings are not permitted. This rule does not apply to buildings which can neither be damaged nor destroyed by avalanches and the use of which does not bring avalanche hazards on persons or animals. The risk of damage to real value should not exceed reasonable proportions. These are matters of insurance techniques.
>
> Blue Zone: In the blue zone buildings are permitted provided that precautionary measures be taken. These might refer to:
>
> --the kind of building
> --its arrangement and its proportions
> --its stability and strength
>
> Domestic buildings are also permitted insofar as they do not raise the risk by inducing heavy traffic or gatherings of people. This would be the case especially with schools, restaurants, and so forth.
>
> During periods of avalanche hazard, the local avalanche service takes preventive measures like closures and evacuations to prevent at least the loss of lives in case of avalanche occurrence.
>
> White Zone: In the white zone no restrictive regulations regarding snow avalanches exist.

The above quotation is included here as an example of zoning implementation and regulations elsewhere.

Calculation of destructive avalanche probabilities and estimation of return intervals of avalanches at a given site is best accomplished by comparison of snow accumulation data and known avalanche events. Such comparisons require accurate, correlated observations over an extended period of time. These observations do not exist for the study area. Consequently, in this report, the estimated exposure of the various portions of the study area to avalanche hazards is based primarily on: terrain configurations, vegetative cover, area-wide weather data, and observed snow distribution patterns; and secondarily on the sites' avalanche history and debris distribution.

TABLE 1

TABULATION OF SNOW AVALANCHE ZONE CRITERIA

Zone	Zone Characterized As:	Return Period	Damage will Result to Structures not Capable of Withstanding the Wind/ Snow Pressures Listed Below	Probability of Occurrence
White No Hazard	Free of Avalanche Hazard	None	20 lb/ft^2 wind pressure (= approx. 70 mph wind)	
Blue Potential Hazard	Avalanches Occur Seldom But May Be Powerful	More than 90 yrs. or	More than 600 lb/ft^2 snow pressure (= More than 350 mph wind)	less than 1% per year
		More than 30 yrs. or	200-600 lb/ft^2 snow pressure (= approx. 220-350 mph wind)	less than 3% per year
		Less than 30 yrs.	20-200 lb/ft^2 snow pressure (= approx. 70-220 mph wind)	more than 3% per year
Red High Hazard	Frequent and Powerful Avalanches	Less than 30 yrs. or	200-600 lb/ft^2 snow pressure (= approx. 220-350 mph wind)	more than 3% per year
		Less than 90 yrs.	More than 600 lb/ft^2 snow pressure (= More than 350 mph wind)	more than 1% per year

Source: Geophysical Hazards Investigation for the City and Borough of Juneau, Alaska
A Summary Report 1972

In analysis of the Avalanche Zone Map and of Table 1, it is important to consider that, while estimates of return intervals of avalanches are given, the year or years in which return will occur cannot be predicted. For example: A site for which a thirty-year return interval is given has an estimated one in thirty probability of being struck each year, and this probability does not change when the event occurs. Thus, a site that was struck in 1977 cannot assume immunity in 1978.

Fast-moving avalanches often travel, on a level runout zone, on the order of two-thirds the measured vertical fall of the avalanche and still retain destructive force. In isolated conditions, avalanches have been known to travel even farther, on level ground, than the total number of vertical feet they fell on the slope above. Thus, avalanches that attain great momentum can be expected to affect additional existing structures at Warm Springs from time to time. Further, where historical records show frequent avalanche activity, as at Creek Slide, the likelihood of a large avalanche in any given winter is distinct.

Where the moving snow is confined by terrain features such as gully walls, again as at Creek Slide, avalanches retain their momentum and destructive capability for greater distances in the runout zones than do avalanches that fall on open unconfined slopes. For this reason, Creek Slide will slide much farther than adjacent open slope avalanches.

Wherever fast-moving avalanches fall for great distances, e.g., circa 1,000' vertical, wind-blast effects can be expected. These effects are often seen well beyond the actual deposition zone of snow and other debris. Wind-blast is known to demolish wood-frame structures occasionally and has even been known to lift a heavy dump-truck from a roadway alongside a slide-path and deposit it in the ravine below the road. Wind-blast is not well understood by avalanche workers; some current literature estimates maximum wind-blast forces at ±100 pounds per square foot (psf), but recorded structural damage and observed effects on trees imply much greater forces. In this report, wind-blast effects are included in the zones shown on the AZM.

Snow creep is another effect that should be considered when building on or immediately beneath snow slopes. Creep is similar to a glacial action, is constantly occurring in all snow on any slope, except perhaps when the temperature falls to below -40°F. Creep occurs in all snow on an inclined plane; the rapidity of the creep depends on the slope angle, snow depth, temperature, water content of the snow, and ground surface features. Creep is simply snow settlement, but on an inclined surface. It is a massive, nearly incalculable force, is capable of pushing in the walls of unheated structures or of bending steel towers if conditions are correct. Creep is more of a factor in deep snow country such as the Sierra or the Cascades than in the Ketchum area, but it can exert great forces at selected locations anywhere. Unheated structures in creep zones can be designed and constructed to be creep resistant in much the same manner that they can be designed to be avalanche resistant, but the potential forces are great and the cost of resisting those forces is substantial.

Weather

Ketchum is under the general influence of continental climatic factors. Snow packs are generally relatively shallow; winter temperatures are generally cold. Structural instability within the snowpack is normal, is expected each year. Occasional warm Pacific storms intrude upon the area, bringing intense snowfalls or rain. At least one intense storm that deposits heavy amounts of snow in a short period of time can be expected each year.

These weather and snow conditions lead to a high incidence of avalanches that involve many layers within the snowpack, and may involve the entire snowpack. Such avalanches can be widespread, can run for long distances, and can be very destructive. At least one cycle of destructive avalanches should be expected in Ketchum each year.

Avalanche History

Warm Springs Canyon

The history of avalanche activity in Warm Springs Canyon is moderately long and is, at least in selected circles, well known. The number of observed avalanches, together with terrain, vegetative and weather factors characteristic of the site, are sufficient to verify frequent avalanche hazard to the canyon floor. Numerous avalanches are observed on the upper and lower slopes annually. Many of these reach the slope-canyon transition; a small percentage of them travel farther. The largest avalanche path (Creek Slide) is known to have slid to Warm Springs Creek in circa. 1922. The same slidepath reached to within 200' of the main road in December 1971 on the same date that the Vorlase house on Huffman Drive was demolished by an avalanche that came from the west side of Division Gully. The east end of Sage Road was covered by avalanche snow in January and March 1974, and again in February 1975. Another avalanche, herein called the Duplex Lot Slide, slid to the main road through Warm Springs Subdivision, 4th Addition, in 1974, through the area occupied on the dates of the study by a sign advertising duplex lots for sale. Finally, City records show that a man was killed by an avalanche in Heidelberg Divide (see AZM) on an unrecorded date.

West Slope of Dollar Mountain

Informal short-term observations of this area reveal that avalanches occur regularly on the slope above Trail Creek. At least three of the avalanches observed just north of the City limits in the past six years are known to have reached the irrigation ditch just east of the Creek. None of these recorded avalanches intruded upon occupied land; thus no damage to structures here has been recorded. In December 1971 an avalanche within the City limits descended from elevation 6,220' to 5,860' just to the northeast of the Maricich House. This slide did not reach the ditch or the trees that grow along the ditch. As at Warm Springs, these observations, together with physical factors at the site sufficiently verify the avalanche threat to the slope and to a portion of the alluvial plain below.

Description

Warm Springs Canyon

The northern slope of Warm Springs Canyon rises abruptly from the nearly level canyon floor at elevation 5,860' to an un-named summit at just over 7,600'. Two prominent shoulders, or ridges, extend south and east from this summit. The south shoulder descends more or less gradually to the canyon floor, with a final steep drop-off of some 240' at a quarry just above the main road. The east shoulder's descent is interrupted by a saddle and a brief rise to point 6,944', whence it descends again to the floor at Heidelberg Divide. East of the Divide another small hill rises abruptly to elevation 6,360'.

Average canyon-to-crest slope gradients are nearly uniform at 31° throughout most of the area, with some variation to a low gradient of 26° and to a high of 33°. With minor variations, the vertical profile of all the slopes is nearly uniform. Horizontal profile of the mountainside is broken by numerous shallow draws, by several prominent dry creeks, by a deep ravine (called Division Gully in this report) just west of point 6,944', and by Heidelberg Divide, which, geologically, could probably be called a water-gap between

Adams Gulch and Warm Springs Canyon.

The slopes themselves are almost entirely smooth, with few rugosities that would impede snow movement. The general aspect of the slopes is south to southeast.

Vegetative cover is almost exclusively low brush. Isolated clumps of conifers appear high on the slope near the un-named summit, and a small grove of aspens exists some 150' above the western portion of Sage Road.

Study of winter photographs of the area shows slopes smoothed by the snow cover. Cornices appear on the west sides of several of the creeks and draws, as well as on the east-facing slopes that fall into Heidelberg Divide and into the ravine east of the easternmost small hill (point 6,360').

West Slope of Dollar Mountain

Terrain here consists of a north-south running ridge at the western foot of Dollar Mountain, the smooth west-facing slopes below the ridge, and a gently sloping alluvial plain at the foot of the slopes. The plain is only some 100-150' in width from the irrigation ditch to the plain-slope transition. Slope gradient on the plain is 7-10° for most of its width, with a narrow nearly-level section just east of the ditch. Elevation of the plain varies from 5,840' at the ditch to about 5,860' at the transition. Slopes rise abruptly from the plain to the ridge crest, which varies here from a high point of 6,300' to a prominent rock hump (elevation 5,960') at the south end of the ridge. Slope gradients are generally in the 29-32° range on all of the west-facing portions of the subject area, with a short 35° pitch below the rock hump. A short south-facing 35° slope lies just south of an outcrop at elevation 6,080'.

Evaluation

Warm Springs Canyon

With the exception of a small 26° area above the western part of Sage Road and the old gray-fenced swimming pool near the western City limit, virtually all of the mountainside above the Canyon lies in the range of steepness known to produce frequent avalanches. Vegetative or terrain features that would tend to inhibit snow movement are non-existent. Thus, all that is required is an appropriate snow condition for any portion of the mountain, with the exception mentioned above, to avalanche. The vast majority of avalanches here will halt on the slope or at the slope-canyon transition; some will travel greater or lesser distances beyond the transition toward the creek. Avalanches will occur most frequently where terrain features and/or slope aspect favor heaviest snow depositions. These factors generally favor the Creek Slidepath and slopes adjacent including the Duplex Lot Slide. History bears out this observation.

Where the slopes are very long and steep, as above the eastern part of Sage Road, at Creek Slide, and just west and east of Division Gully, avalanches may involve very large quantities of snow and may travel great distances with destructive force. It is worth noting here, however, that avalanches need not be particularly large nor fall great distances in order to be destructive: The avalanche that destroyed the Vorlase house fell only an estimated 400-450' and involved an estimated 12" deep layer of snow. This was not a large avalanche by any standard, yet it was sufficient to demolish a wood-frame structure that stood at the slope-canyon transition.

Only a few semi-protected sites exist in the transition zone along the length of the study area: None is safe under severe avalanche conditions.

Avalanches that occur at the quarry at the west end of the study zone will usually halt at the transition, but may occasionally reach and block the road.

Avalanches will occur on the west, south, and east-facing slopes of the small hill (point 6,360') just east of the Heidelberg Divide. These avalanches, due to their short vertical fall, will usually halt at the transition; those avalanches that travel beyond the transition will carry little destructive force but may knock over and bury people. Avalanches fall into Heidelberg Divide from both east and west, occasionally covering the entire width of the Divide.

West Slope of Dollar Mountain

Avalanches may originate as high as elevation 6,220' in the northernmost of the slides here. One, and possibly two, starting zones are at 6,080', just north of the outcrop. Snow will doubtless slide from the rock hump at the lower end of the ridge; these slides may involve deep layers of snow, but will not gain sufficient momentum to travel beyond the plain-slope transition. Avalanches from the northernmost of the slides will generally halt at the transition, but will, on rare occasion, travel beyond the ditch with destructive force. Slides from the other starting zones will not penetrate beyond the ditch with destructive force, but will probably reach and damage the small corral that is situated just north of a small shack and east of the ditch. The short 35° south-facing slope at elevation 6,080' will doubtless slide from time to time but the snow will halt after a maximum of 100' of travel at a transition to leveling ground at elevation 5,980'.

Defense Methods

Numerous methods are available for combating or alleviating avalanche hazards. The most effective and most economic method is to locate buildings properly--out of the avalanche zones. Failing that, buildings can be protected by detached structures of various types; or they can be protected by appropriate design and construction of the structure itself. General criteria for structures designed to withstand avalanche forces include:

1. No building should present an impact surface perpendicular to the avalanche slope. Each building should be designed and placed so that only a corner and continuous walls face the avalanche.
2. Windows facing the avalanche should have shutters as impact-resistant as the wall in which the window is placed. There should be no large windows facing the avalanche.
3. There should be no roof overhang over walls facing the avalanche. Vertical forces associated with avalanche impacts may be sufficient to lift the roof off the wall if there is an overhang.
4. Each building should be capable of withstanding horizontal avalanche impact forces expectable at the given site. These forces will vary with the types of avalanche expected, with the character of the avalanche path affecting the site, and with the location of the building. Several examples: Buildings located in the slope-canyon transition on Huffman Drive would receive much greater forces than buildings located some 100' beyond, on the south side of Simpson Drive. Buildings located in the runout zones of the larger slidepaths, such as the Creek Slide or the Duplex Lot Slide, can be expected to receive greater forces than those at either Huffman or Simpson Drive.

It is not possible, within reasonable economic limits, to specify structural impact-resistant factors in this report that would assure immunity to all potential avalanche forces for all buildings that may be constructed in Warm Springs Canyon. Due to the variables mentioned in the preceding paragraph, each building site should be studied and evaluated, followed by structural design tailored to that specific site.

Where houses are located in the immediate slope transition, or worse yet, if they are placed in an excavation into the hillside, avalanching snow may impact on the roof of the structure. In such situations both roof and supporting walls will be subject to enormous vertical and dynamic impact and load factors.

Minimum structural standards can be stated that will provide substantial avalanche protection under most avalanche conditions that will be experienced in Warm Springs Canyon, not including the Red Zone of Creek Slide:*

1. Structures sited within 50' of the slope-canyon transition should be capable of withstanding horizontal impact forces of 1600 psf from ground level to 13' above grade.
2. Structures sited 50-100' from the transition should be capable of withstanding horizontal impact forces of 1,000 psf from ground level to 10' above grade, and 600 psf from the 10' level to 13' above grade.
3. Structures sited more than 100' from the transition and within the avalanche zones should be capable of withstanding horizontal impact forces of 800 psf from ground level to 10' above grade, and 400 psf from the 10' level to 13' above grade.

Basis for the above standards:

Assumptions are: 4-7' snowpack at building, avalanche travels on this surface; flowing snow in avalanche is 4-6' deep when it reaches building; greatest impact forces will occur in the lower levels of the flowing snow.

NOTE: It is not considered economically feasible to construct wood-frame structures which will withstand snow pressures of more than 200 psf. The above standards imply reinforced concrete structures

* Structures sited in the Red Zone of Creek Slide may be subject to as much as 3,000 psf horizontal pressure to the 15' level, to as much as 300 psf vertical roof load, and to as much as 450 psf frictional loading, on the roof, produced by moving snow. If structures must be sited here, the protection system must be carefully devised and will be extremely expensive if it is to be effective.

to the 13' level, or to the roof if the roof level is lower than 13'. If the roof level is lower than 13', roof loading factors for structures in the Red Zone of Creek Slide apply.

Buildings sited in Red and Blue Zones at the west slope of Dollar Mountain will, if they adhere to the general criteria and minimum standards stated above, be avalanche-proof.

Respectfully submitted,

Norman A. Wilson