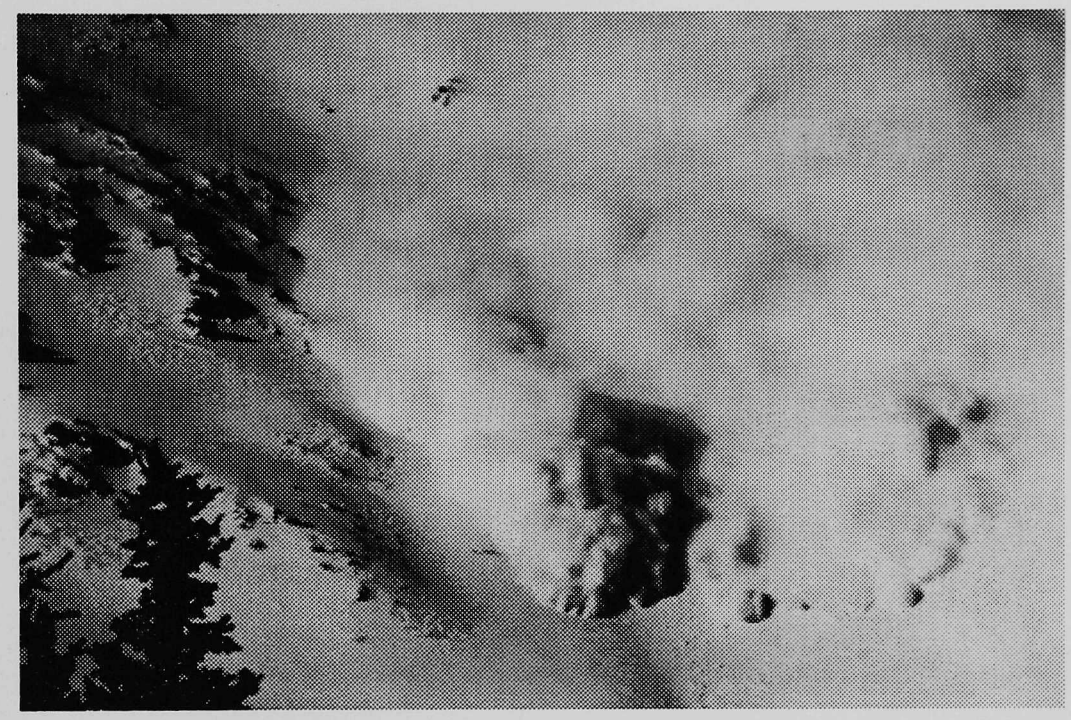
Snow & Avalanche



Annual Report 1996-97

Colorado Avalanche Information Center

Colorado Geological Survey • Department of Natural Resources

Cover: A large avalanche on December 19, 1996, in Peak 7 Bowl, Breckenridge, released by avalauncher and photographed by ski patroller Matthew Krane.

Colorado Avalanche Information Center

Annual Report 1996-97

July 1997

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STATE OF COLORADO

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Director's Statement

To our sponsors and patrons:

The Colorado Avalanche Information Center has completed its 14th year of operation, and we are doing very well, thank you. In this year-end statement, I want to highlight four measures of our success.

First, we are succeeding well in our mission of avalanche safety for Coloradoans, via our program of forecasting and education. It was a blue-ribbon year, for it was the first winter since 1968-69 without an avalanche death, and only the third winter in the last 40 without a fatality. This was attributable to a wonderfully stable snowpack much of the winter, but let's also give credit to the CAIC forecasters for doing a good job and to the recreationists who called the hotlines and practiced good travel techniques in the backcountry. As a further measure of our success, our hotline calls and bulletin board hits showed an increase despite a large number of low-danger days.

Second, the CAIC went on-line on February 15, with the debut of our Internet home page. This will grow in importance as an efficient way to get information to the public, but with 6,400 hits on our forecast page, we were already averaging almost 100 a day. Special thanks go to Dale Atkins for creating this web site.

Third, CAIC authors Nick Logan and Dale Atkins finished their long-awaited book, *The Snowy Torrents.* This is a very important and popular book on avalanche accidents that should enjoy wide readership and generate strong sales for the Colorado Geological Survey publications for years to come.

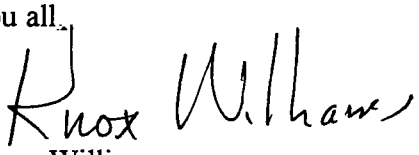
Fourth, our ever-changing funding landscape presents new challenges each year, and we continue to be innovative and compete successfully for the cash funding that keeps the CAIC alive and well. A few items appearing in the Funding and Budget section of this report deserve special mention:

- The CAIC lost a friend with the saddening death of Jim Hackett. His wife, Jan, kindly designated the CAIC as the recipient of donations made to the Jim Hackett Memorial Fund.
- Friends in Summit County, with a large push from Copper Mountain Patrol Director Chuck Tolton, made it possible that a portion of fines collected from violators of the Skier Safety Act be donated to the CAIC. This appears as an entry called Summit

County District Court, and promises to be a recurring source of funding for the CAIC. We're not sure how we feel about this, but we can certainly use the money.

- We successfully launched our grassroots campaign called Friends of the CAIC, which raised almost $15,000. We hope to increase this funding with an ever-growing and stable group of friends making a small annual donation. Perks include *The Beacon: A Newsletter for Friends of the CAIC* and receiving our daily forecast by e-mail.

As always, I want to thank all our sponsors who make our mission of avalanche safety possible. And I want to thank my staff of forecasters for the professionalism and expertise they bring to the job everyday. Dale Atkins, Andy Gleason, Denny Hogan, Rob Hunker, Nick Logan, Lee Metzger, Mark Mueller, Dan Tobin, and Scott Toepfer – thank you all.



Knox Williams
Director

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Executive Summary

Mission: The Colorado Avalanche Information Center promotes safety by reducing the impact of avalanches on recreation, industry, and transportation in the State through a program of forecasting and education.

Administration: The Center is a program of the Colorado Geological Survey of the Department of Natural Resources.

Funding: The Center is totally funded by grants and donations. In FY 96-97, total revenues were $356,588, compared to $326,483 last year. This year the Center began its Friends of the CAIC, a grass roots funding campaign to support forecasting for backcountry users.

Housing: The main office of the Avalanche Center is at the National Weather Service in Denver. Offices for CDOT operations are located in Silverton, Pagosa Springs, Marble, and the Eisenhower Tunnel.

Staff: Total staff was 10. Four forecasters shared the duties of a 7-day work week during the winter season at the main office in Denver. Two forecasters were the Silverton office, two at the Eisenhower Tunnel, one at Pagosa Springs, and one at Marble. Personnel at the four mountain offices provide specific training and forecasting for CDOT.

Avalanche events of 1996-97: The mountain snowpack in Colorado was the strongest and safest in decades. A total of 1,700 avalanches was reported to the Center (15% below normal.) Avalanche Warnings were posted on 24 days (9 below normal.) There were no avalanche deaths, for the first time since the winter of 1968-69. Property damage was 10% of normal.

Hotlines, bulletin board, home page, and radio broadcasts: The public made 87,092 calls to the seven CAIC hotlines this winter (up 2% from last year), 32,537 calls to the TravelBank Systems bulletin board (also up 2%), and 6,400 hits to our home page forecast. Additionally, 11 mountain radio stations broadcast our hotline messages daily.

Media contacts: As the State's spokes-agency for avalanche matters, we received or initiated 150 contacts with broadcast and print media.

Public education: We presented 84 avalanche seminars to 3,796 people.

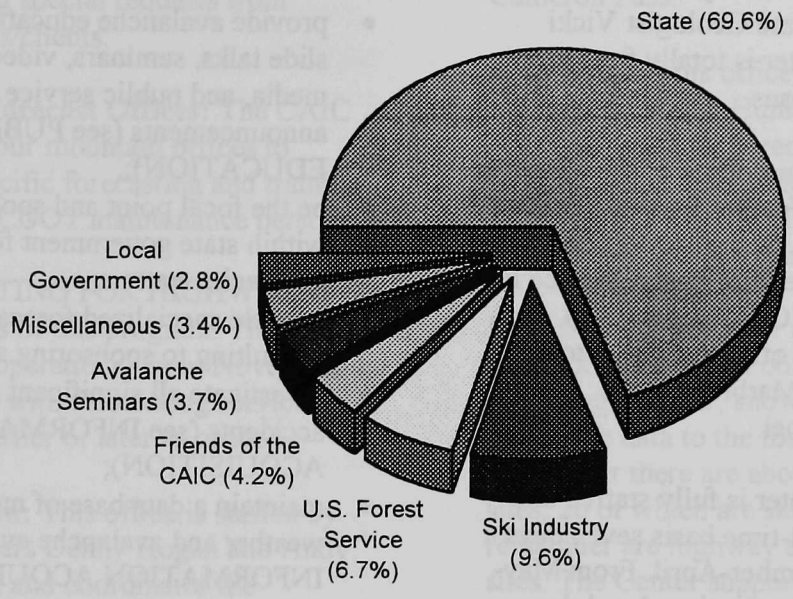
Publications: Big news was the completion of the fourth volume of The Snowy Torrents published by the Colorado Geological Survey. The 265 page book on American avalanche accidents from 1980 to 1986 describes 146 incidents. Center personnel also co-authored Avalanche Rescue Techniques and published several publications in international conference proceedings and popular magazines.

Funding and Budget

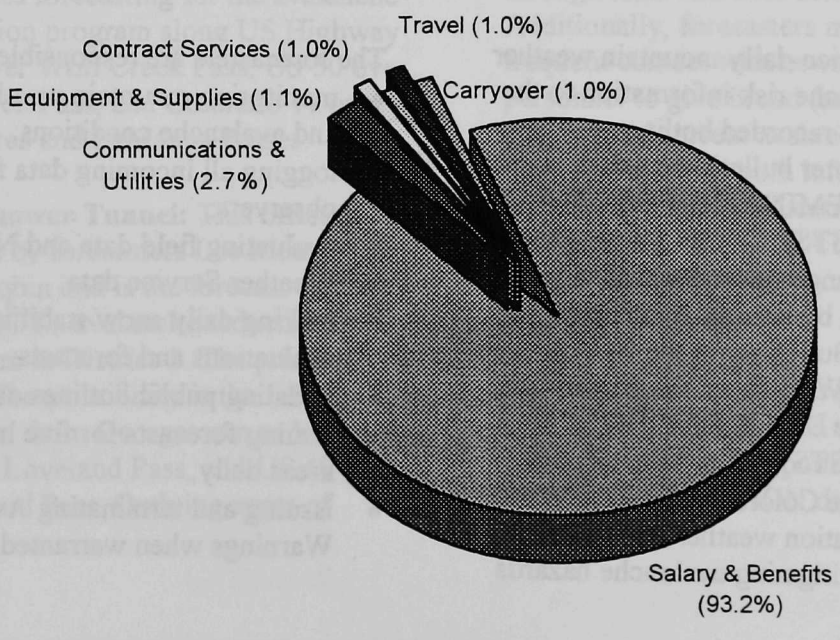
Colorado Avalanche Information Center is totally funded by grants and donations. For FY 1996-97, funding of $356,588 came from the sponsors listed below.

Federal	***$24,000***
U.S. Forest Service	24,000
State	***$250,000***
Colo. Dept of Transportation	248,000
Colo. Div of Parks, Snowmobile	2,000
Local Government	***$10,007***
Summit County District Court	4,307
Eagle County	2,000
Summit County	1,500
Town of Frisco	1,000
Town of Dillon	500
Town of Silverthorne	500
Town of Vail	200
Ski Industry	***$34,300***
Colorado Ski Country USA	20,000
Aspen Skiing Company	4,000
Keystone/Breckenridge/A Basin	3,000
Vail Associates	2,000
Winter Park Recreational Assoc.	1,500
Steamboat Ski Corporation	1,000
Copper Mountain	1,000
Telluride Ski Corporation	1,000
Breckenridge Pro Patrol	500
Crested Butte Pro Patrol	300
Friends of the CAIC	***$14,976***
Avalanche Seminars	***$13,076***
Colorado Mountain Club	3,275
REI	1,800
Newt Wheatley Memorial Found.	900
Vail Associates	900
Mountain Chalet, Colorado Springs	850
Mountain Rescue - Aspen	800
Ski Haus, Steamboat	601
Pikes Peak Alpine School	600
Summit County Prof. Aval. School	600
Summit County Rescue	600
Silverton Avalanche School	500
Colo. School of Mines	300
Hidden Treasure Yurt	300
Metro State College	250
Rocky Mountain Ski Instructors	225
Flanagan's Ski Rental, Winter Park	200
Colorado Outward Bound	175
Buena Vista Snowmobile Club	125
Cheyenne Ski Club	75
Miscellaneous	***$10,104***
Summit Foundation	2,600
A Basin Enduro	1,600
Jim Hackett Memorial Fund	1,385
Sales of videos and slide sets	1,219
Ascent Entertainment	1,000
Alfred Braun Hut System	500
Climax Molybdenum Co.	500
Tenth Mountain Hut Association	500
Alpine Rescue Team	250
Fort Lewis College	250
International Alpine School	200
Ethan Morris Gell Memorial Fund	125
Crested Butte Search & Rescue	100
Total	**$356,588**

REVENUES
$356,588



EXPENDITURES
$356,588



Operations

Administration: The CAIC is a program of the Geological Survey under the directorship of State Geologist Vicki Cowart. The Center is totally funded by grants and donations.

Housing: The main office of the Center is at the National Weather Service Forecast Office in Denver. Secondary office space is provided by the U.S. Forest Service in Fort Collins. For CDOT operations, the Center maintains offices in Silverton, Pagosa Springs, Marble, and the Eisenhower Tunnel.

Season: The Center is fully staffed and operates on a full-time basis seven days a week from November-April. From May-October, the Center is closed and three staff members work part-time providing only administrative and other necessary services.

Purposes: The purposes of the Center are to:

- monitor the changing weather, snow cover, and avalanche conditions in the Colorado mountains (see Data Sites below);
- provide twice-daily mountain weather and avalanche risk information to the public, via recorded hotline messages and computer bulletin-board messages (see DISSEMINATION OF FORECASTS);
- warn of dangerous avalanche conditions by issuing Avalanche Warning Bulletins via the NOAA Colorado Weatherwire and news media (see DISSEMINATION OF FORECASTS);
- provide the Colorado Department of Transportation weather and snowpack data for mitigating avalanche hazards along mountain highways (see FORECASTING FOR HIGHWAYS);
- provide avalanche education through slide talks, seminars, videos, news media, and public service announcements (see PUBLIC EDUCATION);
- be the focal point and spokes-agency within state government for all avalanche matters;
- provide specialized forecasts and consulting to sponsoring agencies;
- investigate all significant avalanche accidents (see INFORMATION ACQUISITION);
- maintain a data base of mountain weather and avalanche events (see INFORMATION ACQUISITION).

Staffing and Duties at the Main Office: Personnel for the 1996-97 season were Knox Williams (Director), Nick Logan (Associate Director), Dale Atkins, and Scott Toepfer. Collectively, this staff has more than 90 years of snow and avalanche experience. The Center was manned daily from 5 am to 3 pm, from opening day on November 9 until closing on May 1.

The forecasters are responsible for:

- monitoring mountain weather, snow, and avalanche conditions;
- logging all incoming data from observers;
- evaluating field data and National Weather Service data;
- making daily snow stability evaluations and forecasts;
- updating public hotlines daily;
- issuing forecasts for five highway areas daily;
- issuing and terminating Avalanche Warnings when warranted;

- initiating or responding to calls from the news media;
- handling special requests from sponsors/clients.

Highway Forecast Offices: The CAIC maintains four mountain offices to provide specific forecasting and training services to CDOT maintenance personnel.

FORECASTING FOR HIGHWAYS gives details of this program. These offices are operational from November 1 to April 30, with forecasting services available earlier or later as needed.

- **Silverton:** This office is staffed by forecasters Denny Hogan and Andy Gleason and coordinates the forecasting for the avalanche reduction program for CDOT along US Highway 550 from Coal Bank Hill to Red Mountain Pass, Colorado Highway 145 over Lizard Head Pass, and Colorado Highway 110.

- **Pagosa Springs:** This office is staffed by forecaster Mark Mueller and provides forecasting for the avalanche reduction program along US Highway 160 over Wolf Creek Pass, US 50 over Monarch Pass, and Colorado 17 over Cumbres and LaManga Passes.

- **Eisenhower Tunnel:** This office is staffed by forecasters Lee Metzger and Dan Tobin and is the forecast center for CDOT's avalanche reduction program in District 1. The primary area of responsibility is the I-70 corridor from Georgetown to Vail, US 6 over Loveland Pass, and US 40 over Berthoud Pass. Outlying areas of responsibility are Colorado 82 over Independence Pass and Colorado 14 over Cameron Pass.

- **Marble:** This office is staffed by forecaster Rob Hunker and is responsible for forecasting for Colorado 133 over McClure Pass, Colorado 139 over Douglas Pass, and Colorado 65 on Grand Mesa.

Data Sites: The Center maintains a network of mountain observation sites for providing weather, snowpack, and avalanche data to the forecast office. Altogether there are about 33 manned sites, 20 of which are ski areas and the remainder are highway and backcountry sites. The Center supports a contract observer at Gothic. The Highway Forecast Offices maintain and access data from remote weather stations, and also use the NRCS Snotel sites.

Education: One mission of the Center is to provide avalanche education opportunities to citizens, tourists, and avalanche practitioners. We do this through talks and field seminars. Additionally, forecasters maintain frequent contact with news media personnel to give broad (and accurate) coverage of current avalanche conditions. Such news stories both inform and enhance avalanche education with the public. PUBLIC EDUCATION details our efforts toward public education and safety.

Publications: The Center publishes avalanche-related articles and produces videos as need and opportunity arise. PUBLIC EDUCATION details this year's publications

Weather and Avalanche Synopsis

The winter of 1996-97 provided avalanche workers an interesting dichotomy. In terms of snow and avalanches the winter 1996-97 was just as remarkable as it was unremarkable. This winter continued the recent remarkable trend of abundant snows in the Colorado Mountains. However, unlike previous winters when heavy snows typically resulted in numerous avalanches and accidents, the winter of 1996-97 was unremarkable. Unremarkable were the number of avalanches: below average, and the number of accidents: about average; however, from the undistinguished statistics one truly remarkable statistic emerges: no fatalities! This marked the first winter since 1968-69 that Colorado was free of avalanche deaths. The surprising lack of avalanche activity and fatalities was more a function of when the snow fell rather than how much fell.

From November through January copious snowfalls produced a strong and stable snowpack that was abnormal by Colorado standards: it possessed very little depth hoar. In February the light snowfalls added little additional mass to the snowpack; however, the fair weather created near-surface weaknesses that could have caused significant future avalanche problems.

February's mild weather resulted in surface hoar and strong temperature gradients near the surface that produced faceted sugar snow in the upper layers of the snowpack. With the formation of significant weak layers near the surface the snowpack was poised for a significant avalanche cycle, if March turned snowy.

To the relief, and disappointment, of avalanche workers, big March snows failed to appear and so, too, did any expected avalanche cycle. During

March high pressure dominated the entire southwestern United States. In Colorado mild and warm conditions transformed the near-surface weaknesses and shallow new snow layers into strong and stable snow layers. Even with the arrival of April's heavy snows, the snowpack was devoid of weak layers and produced few avalanches and accidents. The timing of the abundant snows resulted in one of the strongest and most stable Colorado snowpacks in decades.

For the 1996-97 season snowfall was above normal in the Northern, Central and Southern Mountains[1]. The number of reported avalanches and the number of days with Avalanche Warnings were below normal. As we mentioned above, there were no avalanche deaths, but the number of people injured was up slightly. Property damage and losses were minor.

Snowfall

Table 1 shows monthly and seasonal snowfalls for all sites that regularly reported data to the Avalanche Center this year.

[1] The geographical regions called Northern, Central, and Southern Mountains of Colorado are used extensively in this report. The Northern Mountains extend from the Wyoming border to a line from Denver to Hoosier Pass (just south of Breckenridge) to Glenwood Springs, as the southern boundary. This boundary roughly follows the I-70 corridor but dips south in the area of Breckenridge to include the Ten Mile Range. The Central Mountains extend south from the Denver-Hoosier Pass-Glenwood Springs line to a southern boundary line from Pueblo to Montrose. The Southern Mountains lie between this Pueblo-Montrose line and the New Mexico border.

Abundant snows blanketed all the Colorado Mountains beginning in mid-October and continued through January. Monthly snowfall totals were typically 100-200+% of normal.

February saw the infamous split-flow pattern form in the storm track. Though snows continued to fall over the Southern Mountains, in the Central and Northern Mountains drier conditions prevailed.

March was an exceptionally dry month as the storm track moved to the north of Colorado. The Southern Mountains experienced one of the driest winter months on record. Snowfall was only 9-17% of normal.

In April the storm track roared back over the mountains and resulted in stormy weather and above-normal snowfalls for all mountain areas.

Spring finally returned in May, but the exceptionally strong snowpack only yielded minor wet-avalanche cycles as the snow slowly melted.

For the seasonal trend, note in Table 1 the percent-of-normal totals for December-March. All sites but Red Mountain Pass received above-normal snows ranging from 110-133%. Red Mountain Pass still received a respectable 86% of normal. Also note that only a few sites have long-term snowfall records for the 6 months of

Table 1. 1996-97 Snowfall (inches)

	Nov	Dec	Jan	Feb	Mar	Apr	Total Dec-Mar	% of Normal	Total Nov-Apr	% of Normal
Northern Mountains										
Arapahoe Basin	51	108	56	24	25	65	213	102%	329	
Bear Lake (RMNP)	38	91	68	30	23	86	212	129%	336	137%
Beaver Creek	69	102	79	47	42		270	120%		
Berthoud Pass	57	90	67	39	44	100	240	116%	397	126%
Breckenridge	53	103	72	35	38	77	248	122%	378	
Copper Mountain		91	78	41	32	69	242	132%		
Eldora	32	82	64	40	28		214			
Keystone	39	89	63	28	30	66	210		315	
Steamboat	53	98	116	33	23	55	270	110%	378	
Vail	64	112	107	52	27	72	298	113%	434	
Winter Park	55	110	68	42	44	76	264	103%	395	108%
Central Mountains										
Aspen Highlands	47	76	65	28	33	58	202	117%	307	
Aspen Mountain		80	64	44	35		223	133%		
Crested Butte		103	84	25	14		226	133%		
Gothic	65	136	113	40	26	84	315	129%	464	134%
Monarch	42	86	86	40	8		220	114%		
Southern Mountains										
Purgatory		54	95	51	5		205	110%		
Red Mountain Pass	73	62	58	50	11	69	181	86%	323	
Telluride		58	77	60	9		204	108%		
Wolf Creek	79	37	146	94	7		284	107%		

November-April. Abundant snows in November and April helped boost seasonal totals for all four sites.

Avalanches

This winter a total of 1,700 avalanches were reported to the Avalanche Center from November to early May. This number is 15% below normal. Table 2 shows the monthly distribution of these events.

November was an active avalanche month (160, as shown in Table 2). Though there was little depth-hoar development abundant snows resulted in numerous direct-action avalanches. The trend of numerous direct-action avalanches continued in December and January. Deep instabilities were not a problem so avalanches tended to be small to medium sized rather than large and destructive.

Historically February is a big avalanche month; however, this February left avalanche workers disappointed. During the 1990s the previous six Februarys each averaged about 850 reported avalanches. This trend ended in February 1997 when light snows and few weak layers resulted in few (250) avalanches.

By March warm temperatures and lack of precipitation wiped out any significant weak layers, so the resulting snowpack was again strong and stable. Relatively few avalanches were reported. In April winter-like weather returned, and again the strong snowpack allowed relatively few avalanches. Only at the lower elevations did the snowpack struggle to melt, but at higher elevations the snowpack grew deeper. It was May before the snowpack started to melt away, and in the absence of weak layers there was no significant wet-avalanche cycle.

Avalanche Danger and Warnings

Table 2 shows the danger ratings (low, moderate, moderate-high, high, extreme) for the Northern, Central, and Southern Mountains on a days-per-month basis. The table also shows avalanche counts, accidents, and warning periods by month.

The 24 Avalanche Warning days were well under the long-term average of 33 days. (A warning day is one on which the danger was rated high or extreme and an Avalanche Warning was issued.)

Table 5 shows the impact of avalanches this season on Colorado mountain highways. It lists the number of natural and controlled avalanches reaching roadways.

Avalanche Accidents

The last part of Table 2 lists a monthly breakdown of avalanches involving people and property in 1996-97, while Table 3 compares these same statistics with long-term averages. The totals between the Tables 2 and 3 differ because Table 3 lists all accidents reported this winter.

Table 4 includes two additional incidents that occurred in May. In the absence of any large and destructive avalanche cycles, very little property was damaged. Property damages were estimated at $11,000, about 10% of normal.

Figure 1 represents a 14-year look at avalanche accidents. Shown here are the number of people caught in avalanches and killed for each winter.

Figure 1. Colorado Avalanche Victims by Winter

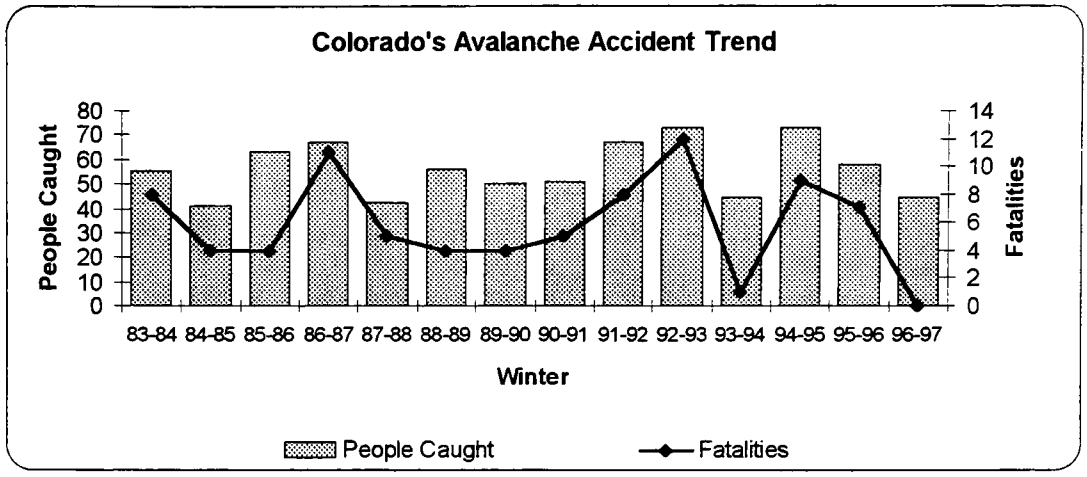


Table 2. 1996-97 Summary of Avalanches, Hazard Days, and Accidents

	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
Avalanches reported	160	547	378	250	210	141	14	**1700**
Days with 1 or more slab avalanches	21	29	22	20	19	19	5	**135**
Avalanche warning periods	0	4	2	1	0	0	0	**7**
Days with warning in effect	0	13	9	1	1	0	0	**24**
NORTHERN MOUNTAINS								
Days with hazard rated ...								
LOW	4	0	3	16	11	10		**44**
MODERATE	13	3	16	12	12	16		**72**
MODERATE-HIGH	2	18	7	0	6	1		**34**
HIGH	3	10	5	0	2	0		**20**
EXTREME	0	0	0	0	0	0		**0**
CENTRAL MOUNTAINS								
Days with hazard rated ...								
LOW	6	0	3	17	11	10		**47**
MODERATE	12	10	16	11	12	16		**77**
MODERATE-HIGH	3	13	9	0	7	1		**33**
HIGH	1	8	3	0	1	0		**13**
EXTREME	0	0	0	0	0	0		**0**
SOUTHERN MOUNTAINS								
Days with hazard rated ...								
LOW	6	0	7	20	14	13		**60**
MODERATE	12	15	12	7	11	13		**70**
MODERATE-HIGH	3	15	9	0	6	1		**34**
HIGH	1	1	3	1	0	0		**6**
EXTREME	0	0	0	0	0	0		**0**
AVALANCHE ACCIDENTS	4	16	3	7	4	5	2	**41**
People caught	4	17	5	7	5	4	2	**44**
People partly buried	0	3	0	1	3	0	1	**8**
People buried	1	0	0	0	0	0	0	**1**
People injured	1	2	1	0	1	1	0	**6**
People killed	0	0	0	0	0	0	0	**0**
Vehicles caught	0	1	1	0	0	2	0	**4**

Table 3. Colorado avalanche accidents grouped by month, 1996-97

Date	Location	Details
11/2	Loveland Pass	1 bc snowboarder caught
11/9	Berthoud Pass (old ski area)	1 bc snowboarder caught
11/9	Berthoud Pass (old ski area)	1 bc skier caught
11/15	Wolf Creek	1 ski patroller caught and buried
11/18	Crested Butte	1 ski patroller caught
11/19	Loveland Pass	1 bc snowboarder caught and partly buried
11/19	Loveland Pass	1 bc snowboarder caught
12/3	Loveland Pass	1 bc skier caught
12/5	Red Mountain Pass	1 car and motorist caught
12/6	Arapahoe Basin	1 ski patroller caught
12/6	Breckenridge	1 out-of-bounds lift skier caught
12/6	Crested Butte	2 ski patrollers caught (post control release)
12/7	La Manga Pass	1 bc snowboarder caught
12/7	Wolf Creek Pass	1 bc skier caught
12/14	Searle Pass (near Copper Mtn.)	1 snowmobiler caught, machine totaled ($4,000)
12/16	Breckenridge	1 ski patroller caught and injured (minor)
12/18	Telluride	1 bc skier caught and partly buried
12/18	Loveland Basin	1 out building destroyed ($2,000)
12/27	Gore Range (near Vail)	1 snowshoer caught and partly buried
12/29	St. Elmo	2 snowshoers caught, 1 partly buried and injured (serious)
1/10	Vail Pass	1 van caught and 3 motorists caught
1/15	Arapahoe Basin	1 ski patroller caught and injured (minor)
1/24	Loveland Pass	1 bc snowboarder caught
2/7	Aspen Mountain	1 bc skier caught
2/9	Vail Pass, Black Lake	1 bc snowboarder caught
2/16	Loveland Pass	1 bc skier caught and partly buried
2/22	Breckenridge	2 ski patrollers caught
2/27	Cameron Pass	1 bc skier caught
3/1	Loveland Basin	1 out-of-bounds skier caught
3/8	Tenderfoot Mtn. (Summit Cty.)	1 snowmobiler caught
3/11	Aspen Highlands	1 bc snowboarder caught, partly buried and injured (serious)
3/27	Willow Pass (near Clark)	2 children caught and partly buried (roof avalanche)
4/22	Red Mountain Pass	1 motorist caught, 1 car damaged ($5,000)
4/22	Breckenridge	1 lift skier caught
4/23	Keystone	1 out-of-bounds snowboarder caught
4/24	Loveland Basin	1 ski patroller caught
5/1	Berthoud Pass	1 bc snowboarder caught, partly buried
5/15	Loveland Pass	1 bc skier caught

Table 4. Colorado avalanche victims

Category	Total 1996-97	Average (26 winters)	Difference
People caught	**44**	42	+2
People partly buried	**8**	11	-3
People totally buried	**1**	8	-7
People injured	**6**	4	+2
People killed	**0**	5	-5

Table 5. Avalanches reaching Colorado Highways, 1996-97 (does not include bank-slips)

Forecast Office	Inclusive Highways	Natural Avalanches	Triggered Avalanches	Totai
Silverton	U.S. 550 Ouray to Coal Bank Pass; U.S. 145 Lizard Head Pass; County Rd. 110	41	34	**75**
Eisenhower Tunnel	U.S. 40 Berthoud Pass; U.S. 6 Loveland Pass; I-70 Georgetown to Vail	16	72	**88**
Pagosa Springs	U.S. 160 Wolf Creek Pass; U.S. 50 Monarch Pass; S.H. 17 Cumbres and La Manga passes	84	8	**92**
Marble	S.H. 133 McClure Pass; S.H. 139 Douglas Pass; S.H. 65 Grand Mesa; S.H. 24 Tennessee Pass; S.H. 91 Fremont Pass; S.H. 82 Independence Pass, Shale Bluffs, Snowmass Canyon; I-70 Glenwood Canyon	15	23	**38**

Detailed Winter Summary

The following narrative contains monthly weather information, avalanche events and other highlights of the 1996-97 winter season. Information found in the section FORECASTING for HIGHWAYS augments this narrative.

November

November started with 1 to 3 feet of snow on the ground above treeline in all mountain areas. This snow came from a large storm that hit the mountains on October 25-29. The East Riverside path on highway 550 ran 3,200 vertical feet and over the snow shed on October 29, the earliest ever recorded. A small cycle of avalanches–24 total–occurred from October 29 to November 5.

As the Avalanche Center started its season on November 9, high pressure dominated the western United States. A slow-moving system moved into Colorado on the 14th and brought snow through the 19th. Some storm amounts were Beaver Creek, 24", Vail, 25", Wolf Creek, 27", Steamboat and Gothic, 29", and Red Mountain Pass, 33". Winds during this storm were light until the 19th when the subtropical jet moved north into Wyoming. Gusts to 119 miles per hour were reported along the Front Range. Still, only a few ski areas were open, but this storm allowed for a great base to develop, introducing what would be a very poor season for the ski repair business. It also brought the first significant avalanche cycle of November. This storm started cold and warmed as it ended, the atypical upside-down storm. There were 51 slides reported, 40 of which were in the Northern Mountains.

This was followed by a short-lived period of high pressure as the next storm moved onto the California coast. This next storm struck the Southern Mountains of Colorado on the 23rd with a southwest flow. 12" of new snow fell on Coal Bank Pass, 10" at Molas and Steamboat, and 9.5" at Snowmass. This was a quick-hitting system, which was followed by another weak system that kept light snow falling in all mountain areas through the 26th. Only minor avalanches were noted on the 25th - 27th. A deep trough developed over the Great Basin at this time, but the main energy tracked well to the south of Colorado. The next storm in the series dove south as well and also practiced the hit and run routine, leaving Wolf Creek Pass with 14" of new snow for the last 2 days of the month.

November snowfall was above normal for all mountain areas. In the Northern Mountains, Bear Lake in Rocky Mountain National Park got 96% of normal; A Basin and Breckenridge, 110%; and Berthoud Pass, 118%; in the Central Mountains, Monarch, 100%; Aspen Highlands, 112%; and Gothic, 123%; in the Southern Mountains, Wolf Creek, 135%; and Red Mountain Pass, 155%.

Seven avalanche incidents were reported, resulting in seven people caught and one injured. The injury was a broken leg sustained by a backcountry snowboarder on Berthoud Pass on November 9.

December

The last storm of November carried into December and brought a few inches of new snow to the Northern and Central Mountains on the morning of the 1st. The big story, though, was high winds along the Continental Divide, with gusts to 60 mph. The first night of December brought a very brief respite from new snow, but the

next in a long line of storms was poised to hit all mountain areas. These storms brought snow and strong winds every day through the 8th, with only brief breaks in the action. Some snow totals for this time frame were: A Basin, 38"; Berthoud Pass, 34"; Vail, 29"; Gothic, 36.5" (20" of which was reported on the 6th); and Telluride, 17.5". Wind gusts to 105 miles per hour were recorded along the Front Range on the 4th.

This storm brought the first Avalanche Warning of the season, which ran from December 5-9 and covered all mountain areas. Scattered avalanche releases were noted on the 1st and continued through the 5th. Then activity increased significantly beginning on the 6th. There were 352 avalanches reported during this storm cycle, one of the most active cycles for the entire 1996-97 season.

No sooner had this system ended when clouds from the next system were already rolling into the northwest corner of the state on the 9th. This would be the start of a phenomenal stretch of moist zonal flow into Colorado and would bring a continuing flow of small storms –good for light snowfall at most mountain sites every day until December 30. Colorado ski areas, therefore, had bountiful snows for the Christmas crowds.

The month of December would end with clear skies and very warm conditions, a welcome sight after nearly 28 days of clouds and snow. Avalanche activity was widespread during this storm period. We issued Avalanche Warnings three times during this period of sustained snowfall–the 12th-13th, 16th-19th, and 21st-22nd.

A total of 547 avalanches were reported during December, although far more ran but were not reported as visibility remained very limited for almost the entire month. There were 13 avalanche incidents reported to the Center, resulting in 14 people caught and two injured. An outbuilding at Loveland Basin was destroyed on the 18th ($2,000 loss).

December snowfall was heavy. In the Northern Mountains, all sites recorded 145-185% of normal, though Copper Mountain got 200%, Breckenridge, 210%, and Bear Lake, 265%. In the Central Mountains, all sites got 200-250% of normal. In the Southern Mountains, the range was 115-155%, except somehow Wolf Creek got skipped and wound up with only 64% of normal. The heavy snows of November and December produced a deep snowpack without significant weak layers in the middle and lower portions of the snow cover. This would be the foundation of one of the strongest and safest snow covers in many decades in the Colorado mountains.

January

High pressure that began at the end December produced 2 more days of sunshine and very warm temperatures. On January 2, down-sloping winds brought record temperatures to the eastern plains. Colorado Springs reached 73°, and Pueblo soared to 81° before a slow-moving system inched its way into Colorado on January 3. Instead of snow, this storm started with rain at elevations as high as 11,000 feet before changing to snow: quite unusual for a mid-winter-Colorado storm. Snow totals from the 4th-6th ranged from 6-15". Avalanches were reported daily from

the 2nd - 5th. Most were small, but a few were classed as size 3. On the night of the 6th the edge of the storm just nipped the east San Juans and Wolf Creek Pass, leaving 12" by morning. This produced 15 small avalanches from the San Juans. This storm began with a strong jet (for example, gusts to 78 mph at Snowmass on the 3rd), but winds quickly died off to allow for little increase in avalanche hazard, a pattern that would dominate for the rest of the winter.

The storm track quickly regained focus on the 9th and set up with a long fetch of moisture stretching from British Columbia to Colorado. It was a pattern that would favor the North and Central Mountains with snow from the 9th-14th, but on the 12th the storm would drop further south and bring heavy snow to the Southern Mountains. Overall this storm brought some of the heaviest snows of the winter: From the 9th-15th, Vail picked up 63" and Steamboat got 80", while from the 12th-15th, Purgatory got 61" and Wolf Creek, 80". This storm cycle caused forecasters to hoist our fifth Avalanche Warning of the season, which was in effect from January 10-15. There were 197 avalanches reported, the majority coming from the Southern Mountains.

High pressure dominated Colorado's weather for the next 5 days, bringing weather more like March than January. Light snow returned on the 21st and continued until the 23rd, with generally 3-8" of snow being reported. More moisture and more snow swept in on the 24th and brought snows daily to most mountain sites through the 28th. Gothic got the most with 39", which prompted an Avalanche Warning to be issued for the West Elk Mountains on January 26-28.

For the third month in a row, snowfall was well above normal. In the Northern Mountains, all sites were 120-160% of normal, though Bear Lake got 173%. In the Central Mountains, all sites were 180-190% of normal. In the Southern Mountains, Red Mountain Pass got 115%; Telluride, 170%; Wolf Creek, 218%; and Purgatory, 228%.

The total number of avalanches reported--378--was well below normal, and only three avalanche accidents were reported in January, despite the copious snowfalls. The snowpack was bombproof beneath the new snow layers of each storm, meaning that only surface avalanches were possible. Backcountry skiers and snowboarders were beginning to realize this was one of the few winters when they could ski avalanche paths in mid-winter with little risk, and they were doing it.

February

The dry weather that began at the end of January lasted only until February 2 as an upper-level low pressure system moved into the state. This was the first of a one-two punch of storms to hit Colorado over the next 6 days. Snow began in the North and Central Mountains of Colorado on the afternoon of the 2nd and continued on and off through the 6th. Some representative storm totals were Steamboat, 17", Winter Park, 14", Vail, 30", Aspen Mountain, 21", and Gothic, 18". The second part of the storm brought 12" of new snow to Telluride on the morning of the 7th, and 13" to Red Mountain Pass. Scattered, small, and mostly insignificant avalanches were reported daily from the 3rd-7th.

A split flow weather pattern then developed by the 8th and left Colorado high and dry until the night of the 11th when only 1-2" of new snow fell in the Northern Mountains with the passage of a weak storm system. This weak system brought a northwest wind flow that kept light snow showers in the North and Central Mountains until the 15th. Snowfall of 2-6" fell in the Northern Mountains on the 15th and was accompanied by strong winds. This resulted in 44 small avalanches being reported on the 15th-17th.

Very light snows fell in all mountain areas on the 18th-20th, followed by heavier snows on the morning of the 21st when Winter Park reported 11.5", Berthoud Pass, 10", and Breckenridge and Beaver Creek, 9". Only seven small slides resulted from this snowfall. From the 24th-26th, light snows fell daily, and then a burst of heavier snow came on the 27th-28th. Steamboat added another 12" of snow from the 19th till the 28th, and Gothic added 20" during the same period. The Southern Mountains, however, fared much better: Wolf Creek totaled 62.5" of snow from the 18th-28th, including 18" of new snow on the morning of the 28th. Coal Bank Pass got 22" that same morning, and Purgatory, 19". This prompted an Avalanche Warning being issued for the Southern Mountains early on the 28th; it was dropped on March 1.

From the 24th-27th, a smattering of small avalanches was reported daily from all mountain areas, for a total of 74 for those 4 days. On the 28th, 56 avalanches were reported from the Southern Mountains. Overall, though, February was a fairly quiet month for slide activity, with only 250 avalanches being reported. Only seven avalanche incidents involving people were reported to the Center, with seven people caught and only one person partially buried. Snowfall amounts were below normal in the Northern and Central Mountains and above normal in the Southern. In the Northern, snowfall ranged from 59-89% of normal (though Copper Mountain got 100%); in the Central, 60-84% (though Aspen Mountain, 102%); and in the Southern, Red Mountain Pass, 97%; Purgatory, 105%; Telluride, 131%; and Wolf Creek, 142%.

March

March came in stormy, but actually more like a kitten than a lion. On the 1st, 2-7" of new snow was reported from all mountain sites, although Molas Pass reported 22". This was followed by dry weather on the 2nd and a return to snow and strong winds on the 3rd. A trace to 5" fell in the Northern and Central Mountains, and winds along the Front Range and 10 Mile Range gusted to near 70 mph. This snowy pattern would continue until the 5th. with 10-12" around Summit County, Vail and Berthoud Pass; 10-14" in the Aspen area; and only a trace in Silverton. These snows led to 81 avalanches that were reported on the 1st-6th.

Following this snowy period, high pressure developed with a vengeance until the 14th (though some light snow fell in the Northern Mountains on the 9th.) Mid-mountain temperatures well into the 50's were reported from many sites. The warm weather contributed to some small wet-loose avalanches on the 11th-17th, but mostly it created a very solid snowpack for the rest of the month. On the 15th, the next system tried to move into Colorado but ran up against this strong high pressure system. This limited the amount of precipitation that would fell. The Northern Mountains were the only beneficiaries and

received only a trace to 9". Another fast-moving system brought 1-3" to the Northern Mountains on the night of the 17th and fair skies were quick to follow. High pressure would become the dominate feature for the rest of the month, with only weak systems bringing light snow on the 23rd-24th and again on the 28th-29th. Widespread, but small, wet avalanches fell on the 18th-22nd as daytime temperatures warmed into the 40's and 50's. March ended under clear skies and warm temperatures, and more wet avalanches fell on the 30th-31st.

March was a dry and dusty month, with some record minimum snowfalls being recorded, especially in the Southern Mountains. Purgatory, Red Mountain Pass, Telluride, and Wolf Creek all set records with snowfalls of only 9-17% of normal. In the Central Mountains, Monarch set a low-snowfall record with only 15% of normal, while all other sites came in with 35-66%. In the Northern Mountains, all sites had 39-76% of normal.

The month of March saw four avalanche incidents with five people being caught, only one of whom was injured in a backcountry slide near Aspen Highlands.

April

After the unseasonably warm and dry March, observers were unprepared for the return to winter that April would bring. An almost constant barrage of storms would hurl into the high country for the next 30 days. It began with a powerful closed low over the Great Basin that sent three short waves into the Colorado mountains from the 1st-13th. On the 1st-3rd, Steamboat got 8"; Aspen Mountain, 12"; Gothic, 13"; and Telluride, 14". On the 4th-6th, Steamboat got 26"; Winter Park, 22"; Telluride, 27"; and Red Mountain Pass, 21". On the 8th-13th, Steamboat again got 26"; Telluride, 14"; and Wolf Creek, 24".

The storm snow bonded well with the stable snowpack underneath, so that avalanches were not large nor numerous. Still, Red Mountain Pass reported 10 slides on the 5th, and 12 fell on the 5th-7th in Summit County and around Loveland Pass. Telluride counted 8 slides on the 8th-9th.

Many ski areas began to close after the middle of the month, so data became confined mainly to the North and Central Mountains. Another storm passed over northeast Colorado on the 15th and brought only a trace to ½" of snow to the Northern Mountains, followed by one of the few periods of sunshine for the state in April, which lasted into the 20th. But winter was not about to let go just yet. A series of storms could be seen on the satellite images, stacked up well out into the Pacific. New snow would fall almost every day for the rest of the month. Berthoud Pass got 20" on the 21st-22nd, which resulted in 22 avalanches in the Berthoud and Loveland areas on the 21st-23rd.

The biggest whopper brought upslope snows to the Front Range and foothills west of Boulder where up to 4' of snow fell on the 24th and 25th. Again, 22 avalanches were reported in the Front Range.

April snowfall totals were far above normal. Bear Lake got 204%; Winter Park, 180%; Berthoud Pass, 174%; and Gothic, 174%. A total of 141 avalanches was reported, and avalanche incidents

were mostly minor with four people being caught. On the 22nd a motorist was injured when snow and icicles hit his car, causing damage of $5,000.

Daily Weather, Snowpack, and Avalanche Data

The Avalanche Center relies on incoming data to make accurate assessments of current avalanche stability, and to make mountain weather and avalanche hazard forecasts. There are two main sources of these data–the Colorado observer network and the National Weather Service.

Colorado observer network: The Center has established a network of about 33 manned observation sites in the Colorado mountains. Twenty-one of the sites are developed ski areas, from which snow safety personnel report current weather, snowpack, and avalanche data. The remaining sites are highway, heli-ski, and backcountry sites, from which volunteers or contract observers report to the Center.

Remote weather net: The Center has established a network of remote high elevation weather stations. The seven stations are located on Mt. Abrams, Red Mountain, Lizard Head, Wolf Creek, Loveland, Berthoud and McClure Passes. Forecasters can access stations via computer modem giving forecasters real-time data any time during the day or night. Forecasters can also access similar stations located at several ski areas.

National Weather Service: Avalanche Center personnel have access to all products and expertise of the NWS staff. Computerized weather maps, satellite photos and imagery, radar data, radiosonde data are all available from the new, state-of-the-art WFO Advanced workstations. Also available are information from manned and remote weather stations, and written analyses and forecasts. Additionally, discussions with NWS forecasters in interpreting data and products are an immense help.

Westwide Avalanche Network

As a cooperative member in the Westwide Avalanche Network the Colorado Avalanche Information Center serves as a repository for avalanche accident data for the United States. Information on avalanche accidents is stored in a data base at the Center and are used by Center personnel on a real-time basis and also for later analysis. Trends in avalanche accidents, relationships between survival and burial times and depths, and types of rescues are essential information to be passed on to snow scientists and the public. Lectures, field seminars, media contacts, and publications by Center personnel are some of the methods for disseminating this information.

Additionally, the Center responds to about 30 requests a year for raw or tabulated data. These requests come from the ski industry, the Forest Service, universities, snow researchers, consultants, and lawyers.

Accident Investigation

Avalanche Center personnel try to investigate all significant avalanche accidents and fatal accidents. This winter the Center staff visited several accident sites. Information obtained from field data, witnesses, survivors, and rescuers is used for current stability evaluation and for future educational purposes.

The Colorado Avalanche Information Center provides vital information to the public, specialized audiences, and sponsors. Following are the means by which the Center disperses information on mountain weather, avalanche, and snowpack conditions.

Hotlines

Incoming data from about 33 field-observation sites are continually assimilated to prepare forecasts for seven recorded message systems located in Colorado. People can call for three types of information: an up-to-date mountain weather forecast, a current snow condition report, and an avalanche hazard evaluation. Phone sponsors include the USFS in Denver, Aspen and Minturn; the Mountain Shop in Ft. Collins; the Mountain Chalet in Colorado Springs; Pine Needle Mountaineering in Durango and the Summit County Rescue Group for Summit County.

This winter a total of 87,092 calls (Figure 2) were placed to the hotlines, up 2% from last season. Usage fluctuates yearly due to local snow and avalanche conditions. The following shows this winter's activity for each hotline and the percent of change from the previous winter. The significant increase in the Fort Collins hotline was likely to the due the fact that early season calls to the Denver hotline were transferred to Fort Collins. The Denver hotline was not operational until mid December resulting in a significant drop in its usage numbers.

Radio Broadcasts

The Avalanche Center continues to enjoy a large listening audience through dedicated radio stations in mountain communities. This is especially beneficial to regions where a long distance telephone call to one of the hotlines would be inconvenient and costly. Eleven stations carry our message. While some stations broadcast our message daily, others have been most helpful by transmitting Avalanche Warnings or Special Avalanche Advisories when necessary. Some of the stations conveying our bulletins are public radio station KVNF-FM in Paonia, station KOTO in Telluride, and KYSL-FM in Frisco.

NOAA Colorado Weatherwire

During times when the avalanche hazard is rated high or extreme, CAIC forecasters issue Avalanche Warning bulletins twice daily until the hazard subsides. At that time an Avalanche Warning Termination Bulletin is dispensed. Special Avalanche Advisories are issued when the avalanche danger could increase significantly if a storm forecast verifies.

Location	Phone	Number of calls	% change
Denver	(303) 275-5360	14,770	-27%
Ft. Collins	(970) 482-0457	16,777	+97%
Colo. Springs	(719) 520-0020	7,742	-33%
Summit County	(970) 668-0600	22,637	+1%
Vail	(970) 827-5687	2,900	+21%
Aspen	(970) 920-1664	3,247	+23%
Durango	(970) 247-8187	19,019	+7%

These bulletins are transmitted to the news media via the National Oceanic and Atmospheric Administration (NOAA) Weatherwire.

News Media

Throughout the winter avalanche-related incidents draw the public's, and therefore the media's, attention. These events usually involve people, property, highways, or anomalous mountain weather conditions. When this occurs, CAIC forecasters are obligated to respond to, and sometimes initiate contacts. Television, radio, newspaper, and magazine reporters from Colorado, other states and other countries are provided accurate information for broad news coverage. There were 150 inquiries in 1996-97.

TravelBank Systems

For the eighth year, "TravelBank Systems" provided a computer bulletin board outlet for the Avalanche Center's daily forecasts. Located in Denver, this system can be accessed from anywhere in the United States through (303) 671-7669. In addition to individuals, travel agents, travel and recreation organizations and other agencies utilize the service. Response remains exceptional with 32,537 contacts this season. Use of this system has increased gradually each winter and was up 2% from last year.

Web Site

In mid February the Center entered cyberspace with its own web site (http://www.netway.net/caic). The web site consists of more than 12 different pages with a variety of information and links that can be used by backcountry travelers and snow workers. The most popular page is the daily-forecast page; it had received 6,400 hits by the end of the season. Use of the web site grew dramatically: by late April the daily forecast page was averaging about 100 hits per day.

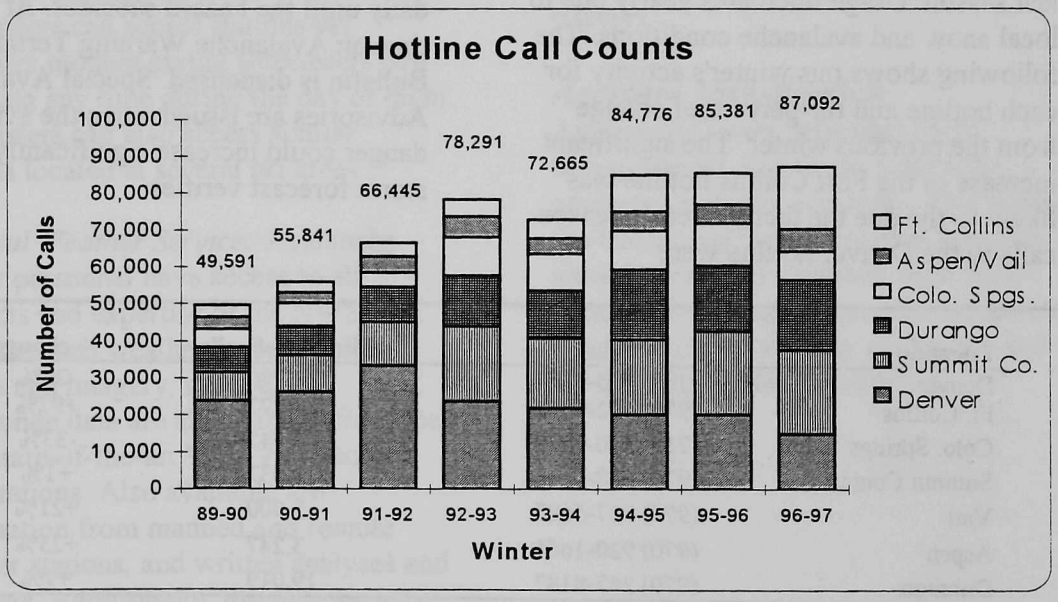


Figure 2. Hotline Use by Winter and Location

A prime obligation of the Avalanche Center is to provide education about avalanches. Education is key to reducing avalanche accidents. Our education objective is achieved through the following means:

avalanche education are displayed in Figure 3 below.

Table 6 lists all courses taught in 1996-97. The scope and content varied from a 1-hour overview to 2- or 3-day courses

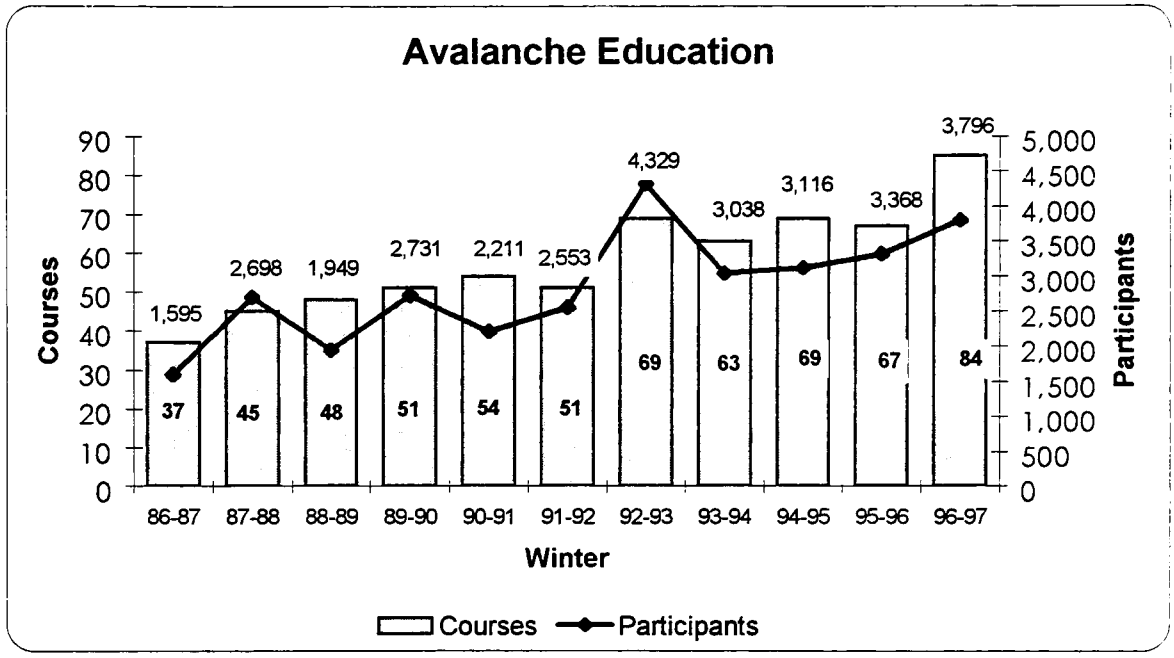


Figure 3. Avalanche Courses by Winter

Avalanche Awareness Talks and Field Seminars

This season, avalanche education began on November 2. By the time the last talk was given on May 18, the Center staff had spoken on 84 different occasions to some 3,796 people.

Participants attended 1-hour seminars to multi-day field exercises. Through our agreement with the Colorado Department of Transportation, CDOT winter maintenance personnel received training in avalanche awareness and rescue, safety precautions, and avalanche reporting techniques. Comparisons of 10 winters of

covering mountain meteorology, avalanche terrain recognition, the Colorado snowpack, methods of safe winter travel, and survival and rescue techniques. The students' included backcountry enthusiasts, professional ski patrollers, search & rescue volunteers, and members of law enforcement, ski and snowmobile clubs, Colorado Mountain Club members, USFS, and CDOT.

To teach these courses, CAIC forecasters invested 406 hours in teaching, 110 hours in preparation, and 165 hours driving to and from the courses.

Avalanche Cards and Brochures

The Colorado Avalanche Information Center distributes wallet-size avalanche cards with the hotline numbers and brochures explaining the "what's, where's, and why's" of avalanches. We distribute these at lectures and seminars, and include them in return letters of correspondence with the public.

Avalanche Rescue Videos

Two avalanche rescue training videos produced by the Center continue to be well received and widely distributed across North America. Avalanche Rescue Beacons: A Race Against Time (1995) demonstrates the proper use of rescue beacons and small-party avalanche rescue for groups in the backcountry equipped with and without beacons. Avalanche Rescue: Not a Second to Waste (1992) is geared toward ski patrols and mountain search and rescue teams who conduct organized avalanche search and rescue missions.

Avalanche Slide Sets

For the tenth winter the Center has made available slide-sets of avalanche accident statistics in the U.S. Updated every two years the computer-generated images provide high-quality visual aids to enhance talks and seminars and have been used by avalanche educators throughout the U.S.

Forecaster for a Day

The Center offered to its field observers the opportunity to spend a full 10-hour day at the Center and perform the duties of the forecaster (under the supervision of the forecaster.) They were to log field data, study weather maps and satellite photos, make the decisions necessary for a daily weather and avalanche hazard forecast, write that forecast, and read it into the hotlines. The intent was to give field observers the experience of actually being the forecaster. Ten people accepted the challenge and became a "forecaster for a day."

Publications

Big news was the completion of the fourth volume of The Snowy Torrents written by Nick Logan and Dale Atkins and published by the Colorado Geological Survey. The 265 page book on American avalanche accidents from 1980 to 1986 describes 146 incidents.

Center personnel also worked on several other publications this year: (1) Knox Williams presented a paper at a meeting in Davos (see below) to be published in the proceedings; (2) Dale Atkins co-authored another book Avalanche Rescue Techniques recently published by the National Ski Patrol. Atkins also had multiple articles in The Avalanche Review—a publication of the American Association of Avalanche Professionals, Back Country and the Ski Patroller magazines. He was published in the 1996 ISSW proceedings, and lastly he was a co-author on poster presentation at the 1997 Rocky Mountain Conference on Emergency Medicine.

Conferences

Atkins started off the conference season in September with a presentation at the International Alpine Rescue Commission's annual meeting in Poland.

All the Center's staff attended the 1996 International Snow Science Workshop held at Banff, British Columbia, Canada

in October. Atkins presented a poster "Loveland Basin Avalanche, February 1996" and he was also a co-author on another presentation "The New Westwide Avalanche Network." Some 478 snow and avalanche scientists and practitioners attended from the U.S. and 14 foreign countries.

In November Knox Williams was an invited presenter at the International Snow Symposium and 60th Anniversary of SFISAR conference in Davos, Switzerland. He presented a paper entitled "An Overview of Avalanche Forecasting in North America."

In February Atkins was an invited presenter at the Wilderness Medical Society's annual winter conference in Steamboat Springs.

Table 6. Avalanche Courses, 1996-97

Date	Personnel	Group	Participants
9/18-21	D. Atkins	IKAR, Karpac, Poland	42
11/2	D. Atkins	Alpine Rescue Team, Evergreen	22
11/6	S. Toepfer	R.E.I., Denver	40
11/7	DA, NL, LM, RH	CDOT, Hidden Valley	38
11/20-23	K. Williams	SFISAR, Davos, Switzerland	200
11/12	N. Logan	Buena Vista Snowdrifters, Buena Vista	76
11/13	D. Atkins	Neptune Mountaineering, Boulder	83
11/14	N. Logan	Summit Co. Awareness, Breckenridge	230
11/19	DA, NL, LM, DT	CDOT, Silverthorne	30
11/20	D. Hogan, A. Gleason	public awareness, Silverton	25
11/21	S. Toepfer	Vail x-country ski school, Vail	30
11/25	S. Toepfer	Crested Butte S&R, Crested Butte	200
11/25-26	D. Hogan, A. Gleason	CDOT, Silverton	45
12/2	S. Toepfer	public awareness, Vail	100
12/3	K. Williams	Mountain Shop, Ft. Collins	80
12/3	D. Atkins	Colorado Outward Bound, Leadville	13
12/4	DA, NL, LM, DT	CDOT, Hidden Valley	6
12/4	D. Atkins	Neptune Mountaineering, Boulder	62
12/7-8	ST, DA, NL	Summit Co. S&R, Breckenridge/Webster Pass	110
12/9	DA, DT	CDOT, Hidden Valley	32
12/9	D. Hogan, A. Gleason	CDOT, Silverton	28
12/10	M. Mueller	CDOT, Alamosa	13
12/11	M. Mueller	public awareness, Pagosa Springs	10
12/11	N. Logan	Mountain Chalet, Colorado Springs	80
12/11	D. Hogan, A. Gleason	Silverton public school, Silverton	55
12/12-13	S. Toepfer	Newt Wheatly Memorial, Vail	10
12/14-15	S. Toepfer	beacon clinic, Francie's Cabin, near Breckenridge	20
12/18	D. Atkins	Alpine Rescue Team, Evergreen	7
12/18	K. Williams	public awareness, Winter Park	40
12/18	D. Hogan, A. Gleason	public awareness, Silverton	11
1/4-5	S. Toepfer	Pikes Peak Alpine School, Pikes Peak	12
1/7	M. Mueller	Pagosa Springs Outdoor Club, Pagosa Springs	36
1/7, 9, 11	K. Williams, N. Logan	Colorado Mountain Club, Golden/Jones Pass	28
1/9	S. Toepfer	University of New Hampshire	14

Public Education

Date	Personnel	Group	Participants
1/9-10	S. Toepfer	Snowboard Society, Vail	50
1/10	D. Hogan	Prescott College, Silverton	7
1/10-11	N. Logan	Mountain Rescue Aspen, Aspen	110
1/14	K. Williams	National Ski Patrol Patch, Ft. Collins	30
1/15	L. Metzger	Breckenridge Elementary, Breckenridge	16
1/15	D. Atkins	Neptune Mountaineering, Boulder	54
1/15	D. Hogan, A. Gleason	public awareness, Silverton	21
1/15-17	K. Williams	PSIA, Leadville	15
1/17-18	K. Williams	Newt Wheatly Memorial, Vail	15
1/17-19	ST, DH, AG	Telluride Avalanche School, Telluride	40
1/18	A. Gleason	Ouray Ice Festival, Ouray	75
1/24-26	D. Atkins	Avalanche & Weather Workshop, Lindley Hut (near Aspen)	12
1/24-26	S Toepfer, A Gleason	Silverton Avalanche School Level I, Silverton	80
1/25	K. Williams	Discovery Center, Ft. Collins	10
1/27-30	K. Williams	REI, Denver	34
1/29	L. Metzger	CDOT	15
1/29-30	N. Logan	Vail Ski School, Vail	18
1/30	M. Mueller	CDOT, Poncha Springs	10
1/31, 2/1-2	A. Gleason	Silverton Avalanche School Level I, Silverton	90
2/1	D. Tobin	Taos Ski Patrol, Taos, NM	24
2/4	L. Metzger	Breckenridge Elementary, Breckenridge	16
2/4	D. Atkins	Wilderness Medical Society, Steamboat	380
2/4	D. Atkins	Wilderness Medical Society workshops	140
2/5-6	N. Logan	Ski Haus, Steamboat Springs	60
2/5, 8	S. Toepfer	Metro State, Denver	12
2/6	K. Williams	Cheyenne Ski Club, Cheyenne, WY	70
2/7-8	D. Atkins	Larimer Co. Search & Rescue, Estes Park	22
2/7-9	D. Hogan, A. Gleason	Silverton Avalanche School Level II, Silverton	49
2/10	R. Hunker	CDOT Patrol 15	4
2/12	D. Atkins	Loveland Ski Patrol, Loveland Ski Area	14
2/12	A. Gleason	public field course, Silverton	2
2/14-15	S. Toepfer, N. Logan	Colorado School of Mines, Golden/Jones Pass	40
2/15	R. Hunker	Carbondale Search & Rescue, Carbondale	6
2/18, 20, 22	K. Williams, N. Logan	Colorado Mountain Club, Golden/Jones Pass	37
2/19-20	ST, DA, NL	Summit Co. Pro Course, Breckenridge/Loveland	40
2/24-25	S. Toepfer	backcountry course, Hidden Treasure Yurt	8
2/24, 27	K. Williams	REI, Denver	35
2/27-28	S. Toepfer, N. Logan	Vail Ski School, Vail	40
3/1-2	D. Atkins	Pikes Peak Alpine School, Pikes Peak	14
3/2	D. Hogan	Guides Course, Red Mountain Pass	24
3/2, 4-5	S. Toepfer	Babes in the Backcountry, Francie's Cabin	21
3/3, 5, 8	KW, DA, ST	Colorado Mountain Club, Golden/Jones Pass	28
3/6	D. Hogan	CDOT, Cascade	4
3/7	S. Toepfer, D. Tobin	Newt Wheatly Memorial, Vail	12
3/9	D. Hogan, A. Gleason	D & S Railroad	4
3/22	D. Tobin	National Ski Patrol, Berthoud Pass	20
4/17-18	R. Hunker	CDOT, Independence Pass	13
4/23	D. Atkins	Alpine Rescue Team, Evergreen	34
5/5	D. Atkins	Colorado Mountain Club-Basic Mtn. Sch., Golden	58
5/18	D. Atkins	Colorado SAR Conference, Granby	35
		84 Courses **Total**	**3,796**

Six CAIC avalanche forecasters work closely with the Colorado Department of Transportation (CDOT). Based in Silverton, Pagosa Springs, Marble and the Eisenhower Tunnel, they prepare daily stability evaluations and provide recommendations for avalanche reduction and road closures. In 1992, Silverton was chosen for the location of the first CAIC-CDOT avalanche forecast office. Following a successful trial run under heavy winter conditions, the Statewide Avalanche Reduction Plan officially took effect on October 1, 1993. CDOT provides the funds necessary to operate this program.

CDOT / Silverton Avalanche Program

The Silverton Forecast Office has completed its fifth winter watching some 97 slide paths along the US Highway 550 corridor from Coal Bank Pass north to Ouray. Additionally, this office is responsible for avalanche forecasts along Colorado 145, Lizard Head Pass. Colorado 110 (Silverton to Gladstone) is also inspected for avalanche activity and snowfall accumulations.

The forecasters work closely with plow drivers who contribute valuable storm data and slide observations to help formulate the forecasts. Training, including procedures for avalanche rescue and personal safety, is provided to CDOT workers and others. This winter Lead Forecaster Denny Hogan and Andy Gleason prepared daily evaluations to keep CDOT apprised of avalanche conditions in their region.

Winter Synopsis

The season started out with a bang when 45 inches of snow fell at the end of October. On October 29, an avalanche pulled out of the East Riverside path and overran the snow shed protecting US 550. It deposited some 10 feet of snow in the Uncompahgre Gorge below. This was the earliest that the East Riverside is known to have run to this magnitude.

December had record snows and warm temperatures early in the month. This led to deep snowpack stability, which persisted throughout the winter. January and February saw typical large snows but few avalanches that reached the highway due to the unusually strong snowpack. A non-scientific poll of locals showed that this was one of the most stable snowpacks in 15-20 years. March had record low snowfalls with only 2 inches recorded on Highway 550 south of Silverton. Warm temperatures in March led to an early wet avalanche cycle on the 18th. Due to the lack of depth hoar in the lower snowpack, the size of the wet slides was small and limited to the surface layers. April was the second snowiest month. Winter did not want to quit and the abundant fresh snow that fell brought 30-year averages up to 130-150% of normal by the end of the season.

Weather Highlights

Strong winds blew down power lines in December. There were few "San Juaners," large storms that specifically target the San Juan Mountains, but one such storm struck in January. It left 60 inches of fresh snow with 5.1 inches of water equivalent on Coal Bank Pass. While this was one of the biggest snowfalls, the number and size of the avalanches it produced was

relatively small due to the strong lower snowpack.

Snowfall was measured at Coal Bank Pass, Molas Pass, Red Mountain Pass, Monument (East Riverside), Lizard Head Pass, and Gladstone sites. Remote weather stations located on Red Mountain #3 (above Red Mountain Pass at 12,890'), on Mt. Abrams north of Red Mountain Pass, and near the summit of Lizard Head Pass measured wind, temperature and relative humidity. These weather stations are invaluable to avalanche forecasting, especially during storm periods and when roads are closed with no access to the snow study plots. National Resource Conservation Service (NRCS) Snotel sites along the corridors were also accessed for data. The following is a record of this winter's snowfall and water equivalent measured along U.S. Highway 550.

Snowpack Highlights

Sintered depth hoar in the lower snowpack was the highlight of the season. Depth hoar formed in early November with typical cold temperatures and a shallow snowpack. But a warming trend in early December melted and re-froze the lower 50cm of the snowpack making it strong and stable. It remained this way throughout the winter with virtually no avalanches running to the ground.

Graupel layers comprised of soft, round pellets in mid-pack provided the weakness for avalanche cycles in January but were not a problem after that. Most of the avalanches this winter were class-3 or smaller, with only four class-4's and no class-5's (largest relative to path size) avalanches. Most of the slides released in the upper new snow layers because of the strong, deeper snowpack near the ground.

Road Closures

To help to formulate the daily forecast, direct observations were made of the avalanche paths adjacent to the highways and all observations were recorded on CDOT's computerized recording system, *C-Dot*. This winter avalanches covered Highway 550 a total of 5,810 feet along the centerline, 5-12 feet deep; Highway 145, 200 feet in length, 4-6 feet deep; and Colorado 110, 220 linear feet, 4-6 feet deep.

There were 10 road closures on Red Mountain Pass totaling 257 hours, or 10.7 days. These occurred on December 6-7, 26 hours; December 21, 1.5 hours; December 22-23, 39 hours; January 12-16, 96 hours; January 24, 2 hours; January 25-27, 47 hours; February 24-25, 24 hours; February 28, 7 hours; March 1, 2 hours; and April 4 for 13 hours. Highway 550 south of Silverton to Coal Bank Pass was closed from January 12-16 for 82 hours. See Table 5, Avalanches Reaching Colorado Highways, for more details.

Study Plot Location	Total Snow (inches)	Water Equivalent (inches)	Snotel % of Average (as of 5-14-97)
Red Mountain Pass	334.5	38.10	143
Monument	238.5	23.05	228 (Idarado)
Coal Bank Pass	357.0	36.05	146
Molas Pass	263.5	27.20	168
Gladstone	239.5	25.00	n.a.

Accidents
Only one accident occurred this year. On April 21 at 5:10 p.m., the Mother Cline released a small, wet slide that damaged the roof and windows of a car when a large chunk of ice was dislodged by the slide. The driver and only occupant of the vehicle sustained minor injuries from flying glass.

Research/Internship
In an effort to refine the art of avalanche forecasting along the highways, Andy Gleason continued his research comparing the results from Rutschblock and Shredblock tests of snowpack stability. Following a third winter of tests in 1998, a formal paper will be presented on the subject at the ISSW.

An intern from Colorado State University helped the forecasters collect snowpit data this season. Joe Stock lived in Silverton from January to April and conducted field studies for his Masters research project on near-surface faceted snow. His contribution of much-needed snowpack data was an asset to the program.

CDOT / Eisenhower Tunnel Avalanche Program

This was the fourth season of operation for the Eisenhower Tunnel Forecast Office located at the west end of the tunnel. The office is also the center for CDOT communications during the winter. Lead Forecaster Lee Metzger and Dan Tobin provided daily avalanche hazard evaluations plus recommendations for avalanche control or road closures when necessary. The scope of this office includes US 40 Berthoud Pass, US 6 Loveland Pass and I-70 from Silverplume to Vail.

Avalanche hazard evaluations are compiled every morning and faxed to area maintenance shops and CDOT offices. These include an avalanche condition rating based on snowfall and weather data, path observations, slide activity and a daily weather forecast from the Avalanche Center in Denver. Also included is a summary of the weather forecast and recommendations for avalanche reduction or road closures.

Frequent contacts with highway maintenance personnel provide useful information on snow and weather observations. Avalanche training sessions are offered to CDOT personnel that focus on avalanche characteristics, case histories, problem solving scenarios, the CDOT Avalanche Rescue Plan and hands-on training with rescue equipment.

Weather Summary
Two Campbell Scientific remote weather stations were installed in October to record wind speed and direction, temperatures and relative humidity. The data is accessed by computer modem and radio telemetry. One system is located just above the Seven Sisters avalanche paths on Loveland Pass at 11,900'. The other sits on the Continental Divide above Berthoud Pass at 11,850'. The information provided by these weather instruments is critical to forecasting avalanches along the highways.

Snowfall and weather data were gathered from six study plots located at the Eisenhower Tunnel, Berthoud Pass, Loveland Pass and Vail Pass. Each site measures cumulative snowfall, storm

totals, 24-hour accumulation and snow water content. Most sites are checked daily, others periodically and during storms. The snowfall data for each site this winter is shown on the following page.

The winter of 1996-97 was well above average for snowfall along the Front Range but fell short of the record season last winter. Snowfall was above average every month except February and March. The 397 inches recorded on Berthoud Pass was well above the 46-year average of 312 inches. It was a common feeling among the plow drivers that this winter was colder and windier than usual along the Continental Divide.

Avalanche Summary

Avalanche reduction missions were necessary throughout the winter. Explosive charges were delivered in the avalanche paths via avalauncher, helicopter, 105mm recoilless rifle and howitzer, and by hand. These missions were conducted 30 times on Loveland Pass, 14 on Berthoud Pass and 16 times along I-70 using some 3,553 pounds of explosives.

Loveland Pass was closed 17 times and Vail Pass twice due to avalanche conditions. This does not include spot closures for avalanche reduction. December and January were the busiest months for avalanche activity. In December, 108 slides recorded, including six large avalanches; January saw 66 avalanches with three large events.

In addition, backcountry use by recreationists is heavy along Berthoud and Loveland passes where skiers and snowboarders sometimes trigger slides that reach the highway. Fortunately, this did not occur this winter. People, however, did trigger 26 slides in the backcountry near Berthoud Pass and nine avalanches near Loveland and Vail passes. More than 130 natural avalanches were also observed.

Despite these numbers, only one incident occurred. On January 10, a natural slide released from The Narrows path on Vail Pass at 11:30 in the morning. It caught and partially buried one vehicle. The small avalanche caused very little damage to the van and the occupants were unscathed.

The type of avalanche activity and length of centerline covered on Berthoud, Loveland and Vail passes are shown below.

Type	Ava-lanches	On road	C/L covered
Natural release	72	18	1-6' x 700'
Artificial release	222	77	1-10' x 4,155'
Total	**294**	**95**	**1-10' x 4,855'**

This season was snowy, cold and windy. Snow that fell in early winter developed into a strong and stable snowpack in the basal layers. This is atypical for the Front Range of Colorado where it is normal to find weak, cohesionless depth hoar near the ground. Weak layers formed only in the upper snowpack in January and February which confined avalanche activity to shallow slabs in the new snow layers. Consequently, the number of large, long-running slides reaching the highways was reduced.

Study Plot Location	Nov	Dec	Jan	Feb	Mar	Apr	Total	Max Depth
Eisenhower Tunnel	41	87	70	22	26	63	**309**	76 on 2/3
Berthoud Pass, Q-12	57	90	67	40	44	100	**397**	92 on 4/30
Berthoud Pass, Q-13	59	101	73	43	45	102	**422**	105 on 4/30
Loveland Pass east	49	97	67	25	24	65	**327**	83 on 4/25
Loveland Pass west	44	95	55	22	25	63	**303**	64 on 4/25
Vail Pass	37	90	72	26	19	24	**267**	76 on 2/7

CDOT / Pagosa Springs Avalanche Program

The Pagosa Springs Forecast Office, located in the CDOT maintenance barn and staffed by Mark Mueller, completed its fourth winter of operation this spring.

Daily forecasts were issued from November 15 to April 25. The forecast region includes US 160, Wolf Creek Pass; US 50, Monarch Pass; and Colorado 17, Cumbres and La Manga passes.

Weather Summary

Following near-drought conditions last season, snowfall was slightly above average this winter. But it did not come evenly. Most of the snow fell from November into February with mostly dry conditions after that. January was the snowiest month and March the driest. The maximum snow depth at Wolf Creek Pass reached 123 inches on February 28. The following shows the radical distribution of monthly snowfall amounts at the summit of 10,880-foot Wolf Creek Pass.

November	December	January	February	March	April	Total
74	35	128	86	2	51	**376"**

In addition to measuring new snow depth, a sample is weighed to determine its water content. This tells the forecaster how much actual weight (and increased stress) has been added to the snowpack. On the following page are monthly water equivalents for sites in the forecast area.

Avalanche Summary

Avalanche activity revolved around four storm cycles: On December 6-7, little snow fell but it was effectively re-distributed by the wind onto a fragile surface hoar layer. Size-3 slides (moderate for the size of the avalanche path) were easily triggered. One ski touring party triggered seven avalanches and two of the people took short rides. Snowmobile-triggered slides were observed at Cumbres Pass.

Avalanche control 2 days later was unsuccessful in releasing additional slides at Wolf Creek Pass. This storm also triggered the most serious avalanche activity of the winter along Monarch Pass.

On January 5-6, high intensity snowfall overnight triggered numerous small slabs. Wolf Creek Pass was closed overnight due to the avalanche danger and morning observations revealed sluffing in all avalanche paths. Avalanche control that afternoon released two small slides. The highway was reopened after an 11-hour closure.

Forecasting for Highways

From January 11-15, a well-developed storm formed in the Great Basin and pummeled the San Juan Mountains for 4 days. It was a large storm but not of historic proportions. Over 100 inches of snow was recorded at the summit highway camp. Alberta and Alberta's Cousin released with explosives in one of the biggest slides there in recent memory. The slide roared down over the snow shed and into the creek below. Broken trees 25-35 years old were found in the debris. The Camp slide almost reached the highway, which was another uncommon event.

Some 1,743 linear feet of highway was buried under avalanche debris and the road was reopened after a 74-hour closure. The avalauncher at Cumbres Pass was put to good use during this storm, releasing a medium size slide at the Railroad Bank, the largest occurrence of the season.

The storm on February 27-28 saw high snowfall intensities and increasing snow density forced a closure of the pass. The Pit ran across the road which is uncommon for this path. Avalanches covered 1,420 feet of roadway. It was reopened after 27 hours.

Thirty-five significant avalanches hit Wolf Creek Pass this winter. These slides covered a total of 3,299 feet of the highway with an average depth of 4 feet. The maximum depth of debris on the road was 12 feet at Stud Muffin, which can accumulate from several slides down the same track.

The table on the following page shows avalanches hitting US 160 along Wolf Creek Pass.

Other avalanche activity that threatened but did not reach the road are shown in the table on the following page.

Summary

Four winters of forecasting along Wolf Creek Pass has become quite valuable in understanding avalanche formation and release specific to this area. This year a thorough investigation of all available weather and avalanche data about the pass was initiated which will produce better avalanche hazard forecasts in the future. Additionally, access to the Internet and Snotel data provided two more tools for this office to use for gathering weather data and other pertinent information about outlying forecast areas the office is responsible for.

Site	Nov	Dec	Jan	Feb	Mar	Apr	Total	% of normal
Wolf Creek Pass	9.72"	4.46"	10.75"	6.86"	0.22"	6.49"	38.53"	n.a.
Wolf Creek Snotel	9.3"	5.1"	10.4"	6.8"	0.2"	5.8"	37.6"	115%
Cumbres Pass Snotel	6.2"	4.7"	10.8"	4.4"	0.3"	4.8"	31.2"	140%
Monarch Pass Snotel	2.5"	5.4"	5.5"	1.8"	0.4"	3.8"	19.4"	115%

Size	Trigger					Total
	Natural	Explosive	Avalauncher	Other*	Cornice**	
1	16	0	2	0	4	**22**
2	61	10	0	1	9	**81**
3	27	0	0	0	3	**30**
4	3	3	0	0	0	**6**
5	0	0	0	0	0	**0**
Total	**107**	**13**	**2**	**1**	**16**	**139**

* slides triggered during snow removal

** slides triggered by the forecaster to assess snow stability

CDOT / Marble Avalanche Program

This marked the third winter of operation for the Marble Avalanche Forecast Office which was the fourth CAIC branch office established to forecast for mountain highways. The office, staffed by Rob Hunker, is based at the fire station in the small town of Marble. Avalanche forecasting is provided to Region III, Maintenance Section 2 of CDOT including seven highways in the Central Mountains. The forecast is disseminated to 17 stations within the CDOT/CAIC organization. A total of 53 avalanche hazard advisories were issued from October 29 to April 19.

Colorado 133 over McClure Pass near Marble is the primary area of responsibility in this forecast region. This two-lane pass is a vital link for commuters between Paonia and the Carbondale/ Aspen areas. All of the avalanche danger lies on the east side of the pass with some 20 paths in less than 2 miles. This area is unique in two ways. First, its lower elevation well below timberline has overall warmer weather with associated affects on the snowpack, including occasional rain. And second, portions of the Chair Mountain subdivision lie in the runout zones of the two largest avalanche paths in the group. This precludes most artificial avalanche reduction efforts.

The forecast office closely monitors avalanche potential on Colorado 139, Douglas Pass; Colorado 65 on Grand Mesa; Colorado 82 at Snowmass Canyon and the Shale Bluffs area near Aspen. Other areas include Colorado 82 at Twin Lakes on the east side of Independence Pass; US 24 at Battle Mountain and Tennessee Pass, and Colorado 91 Fremont Pass.

Snow study plots are maintained along each highway and a remote weather station is situated at the top of Lone Tree Bowl which threatens McClure Pass. Subdivision homeowners below the bowl provide housing and electricity for the base station that is linked via radio telemetry to the sensors near the rim of the bowl. CDOT Weather Scans also provided data to collectively help determine the avalanche potential above the highways.

Weather Synopsis

Early snowfall in October and continued above-average snow during November, December and January produced a stronger than normal snowpack. As a result, very few avalanches ran this season.

On February 1, McClure Pass had received 196 inches of new snow with a water content of 16.2 inches since November 1st. Also, two significant rain events came on November 22 and January 3. February and March were dry and warm with only 3.7 inches of water equivalent combined. The first 11 days of April saw winter conditions prevail and a total of 3.35 inches of water accumulated up until the 23rd. Snow depth at the McClure Snotel site on April 23 was 38 inches and 137% of average, with total precipitation (water equivalent) at 130% of average. After March 1, warm temperatures and little new snow allowed the snowpack to remain strong and cohesive. Total snowfall at McClure Pass reached 291 inches with a water equivalent of 24.2 inches. Grand Mesa saw 28.3 inches of water this winter.

Avalanche Synopsis

The greatest potential for avalanche hazard on McClure Pass came early this year with a major wet avalanche cycle the first week of January. Luckily, the rain and snow ended just before the critical point for occurrence. Rain and rain crusts played a major role in a complicated, layered snowpack during the first 3 months of the season. Rain can be a major contributing factor toward snowpack instability at McClure Pass and close inspections were made December through mid-February to determine bonding characteristics between layers.

No avalanches crossed Colorado 133 on the pass during the season and only three small slides contacted the road during a wet cycle in March. McClure Pass was closed once during the season for 2 hours to conduct stability tests with explosives. Colorado 65 on Grand Mesa was closed nine times for avalanche reduction and each time medium-size slides covered the road. Colorado 139 over Douglas Pass was closed for 20 hours January 13-14 because of two small avalanches that crossed the road in the Headwall area. US 24 at Battle Mountain experienced wet avalanche cycles in March and April put snow on the road but did not close it. There were no closures on Colorado 82 (Twin Lakes, Snowmass Canyon and Shale Bluffs), Colorado 91 (Fremont Pass) or I-70 (Glenwood Canyon). Avalanches reaching highways monitored by this office are shown below.

Highway	Natural	Triggered
Colorado 133, McClure Pass	3	0
Colorado 65, Grand Mesa	5	23
Colorado 139, Douglas Pass	2	0
Colorado 91 Fremont Pass	1	0
US 24, Battle Mountain	4	0