Snow and Avalanche

Colorado Avalanche Information Center

INFORMATION SERIES 53

Annual Report 1998-99

Colorado
Geological Survey
Department of Natural Resources
Denver, Colorado
1999

Cover: CAIC forecasters Nick Logan and Cathy Fraser inspect the remote weather station near Loveland Pass. Photo by Halsted Morris.

INFORMATION SERIES 53

COLORADO AVALANCHE INFORMATION CENTER

Annual Report 1998-99

August 1999

Bill Owens, Governor, State of Colorado
Greg E. Walcher, Director, Department of Natural Resources
Vicki Cowart, State Geologist, Colorado Geological Survey
Denver, Colorado
1999

Director's Report

To our sponsors and patrons:

We avalanche forecasters had a tough time finding a rhythm last winter, since an undercurrent of schizophrenia seemed to dominate the weather pattern. Trapped somewhere between El Nino and La Nina, the winter gyrated month-to-month from extremely dry to very snowy. By the time winter ended in early May, it had proved to be a rather docile avalanche season. Seasonal snowfall, number of avalanches, days of high danger, days with avalanche warnings, accidents, and avalanche damage were all below normal.

It was impossible, however, for the forecasters to relax, because a persistent weak layer lurked at the bottom of the snow cover and carried with it the threat of disaster. Our fears came true on February 6 when an avalanche tragedy claimed the lives of three young men. It was the worst avalanche accident in Colorado in 11 years, and it helped push the seasonal toll to six, which is right at the 10-year average. You can read all about it inside.

The year also brought a noteworthy highlight and a character-building lowlight. On the positive side, more people got our daily forecasts than ever before. When we totaled our hotline calls, web-site hits, and e-mailings, the number topped 220,000. That's 60,000 more than last year, and is a good measure of the public use—and success—of our forecast program.

On the downside, our revenue stream of donations dried up a bit (because of the light snowfall). As a result the Center ran out of money before the end of April and was forced to close early, for the first time in 16 years. (Forecasting for highways was unaffected because of continued strong funding from CDOT.)

Looking to the future, I feel this funding shortfall was a one-time bump in an otherwise successful year in promoting avalanche safety. My optimism stems from (1) using last year as a learning process to strengthen our fundraising and control costs to avert future headaches, and (2) having secured funding next year from the Severance Tax Fund. This will greatly help us to reach our forecasting and educational goals and will stabilize our funding in the immediate future.

The CAIC has completed its 16th year of operation, and we continue to grow (as needed) to meet our clients needs and to meet the demand for our services. 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 they bring to the job everyday. Nick Logan, Dale Atkins, Scott Toepfer, Mark Mueller, Lee Metzger, Rob Hunker, Andy Gleason, Doug Lewis, and Cathy Fraser—thank you all. It's a pleasure to work with you.

Knox Williams

Knox Williams
Director

TABLE OF CONTENTS

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 98–99, total revenues were $365,499, compared to $375,511 in recurring revenues last year.

Housing: The main office of the Avalanche Center is at the National Weather Service Forecast Office, which in May 1999 moved from Denver to Boulder. Offices for CDOT operations are located in Silverton, Pagosa Springs, Carbondale, and the Eisenhower Tunnel.

Staff: Total staff was 10. Four forecasters shared the duties of a 7-day workweek 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 Carbondale. Personnel at the four mountain offices provide specific training and forecasting for CDOT.

Avalanche events of 1998–99: This was a transition year, with the weather pattern making a change from El Niño to La Niña. Overall it produced a storm track that was north of Colorado so that snowfall that was slightly below normal for Colorado's Northern Mountains, below normal in the Central Mountains, and far below normal in the Southern Mountains—although heavy April snows boosted the percentages for all mountains. The mountain snowpack was shallower than normal almost all winter. A total of 2,048 avalanches was reported to the Center (5 percent below the average of 2,166). There were few large storms and few extensive avalanche cycles. Avalanche Warnings were posted on 19 days (14 below normal). There were six avalanche deaths (normal). Property damage was virtually nil at $2,000 (far below normal).

Dissemination of forecasts via hotlines, Internet, e-mail, and radio broadcasts: The public made 62,868 calls to the CAIC hotlines this winter, a number that is well below past years for reasons discussed in Section VII of this report. However, we sent 45,000 forecasts via e-mail to Friends of the CAIC, and there were 104,600 hits on our web site forecast page. That is a total of more than 212,000 sendings of our forecast messages. Additionally, 11 mountain radio stations broadcast our hotline messages daily.

Media contacts: As Colorado's spokes-agency for avalanche matters, we received or initiated 198 contacts with broadcast and print media.

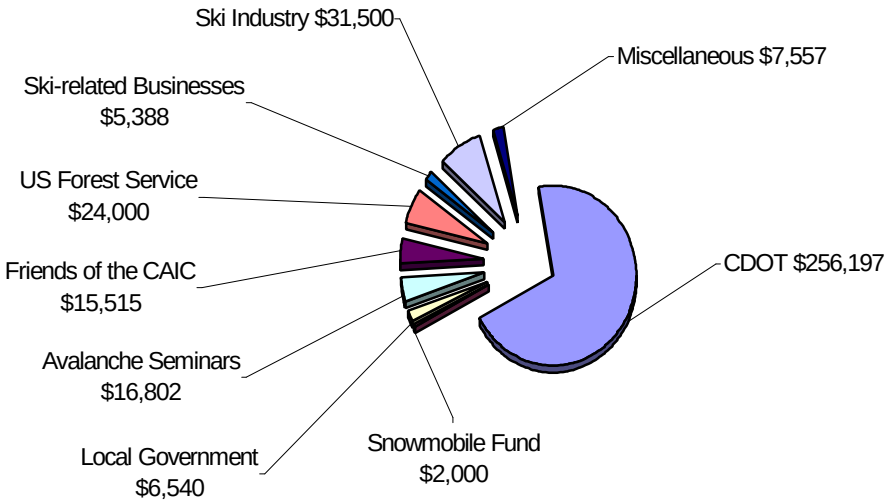
Public education: We presented 68 avalanche seminars to 3,226 people.

Funding and Budget

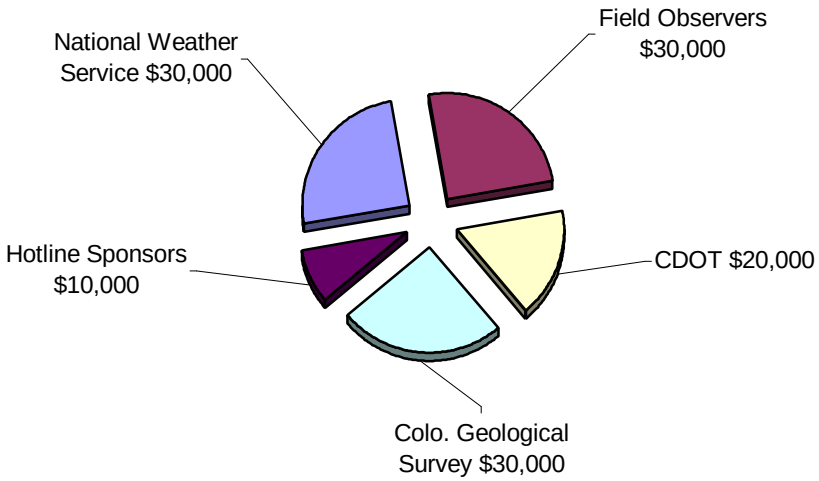
For FY 1998–99, funding from donation-s, grants, and contracts came from the sponsors and clients listed below. Estimated in-kind support is also shown.

State	**$258,197**
CDOT contract for services	234,197
CDOT grant	22,000
Parks, Snowmobile Fund	2,000
Federal	**$24,000**
US Forest Service	24,000
Local Government	**$6,540**
Summit County District Court	3,290
Summit County Government	1,500
Town of Frisco	1,000
Town of Dillon	500
Town of Silverthorne	250
Ski Resorts	**$31,500**
Colorado Ski Country USA	20,000
Vail Associates	2,000
Aspen Skiing Company	1,500
Breckenridge	1,500
Winter Park	1,500
Steamboat	1,500
Arapahoe Basin	1,000
Copper Mountain	1,000
Keystone	1,000
Monarch	300
Crested Butte	200
Friends of the CAIC	**$15,515**
Avalanche Seminars	**$16,802**
Colorado Mountain Club	3,600
Colorado Snowmobile Assoc.	3,189
Summit Huts	1,375
Silverton Avalanche School	1,350
Summit County Rescue	1,000
Newt Wheatley Foundation	900
Summit County Pro Course	600
Steamboat Ski Haus	583
Mountain Rescue - Aspen	500
Ft. Collins Mountain Shop	500
Pikes Peak Alpine School	475
International Alpine School	400
Rocky Mt. Ski Instructors	400
American Avalanche Institute	300
Colorado Outward Bound School	300
Vail Associates	270
Hi Country Snowmobiles	240
COR Adventures	210
Arapahoe Library	200
Salida Ranger District	150
Buena Vista Snowmobile Club	100
Crested Butte S&R	100
Summit Schools	60
Ski-related Businesses	**$5,388**
People Productions	1,189
REI	1,000
Mountain Chalet	950
Braun Huts	500
Tenth Mountain Huts	500
Rescue Technology	500
Fort Lewis Outdoor Pursuits	300
Brian Mountain Nordic	225
Great Pacific/Patagonia	224
Miscellaneous	**$7,557**
Interest earned	6,357
Ascent Entertainment	1,000
Unapix	100
Jeff Clement Memorial Fund	100
Total	**$365,499**
Estimated In-kind Support	**$120,000**
Colorado Geological Survey	30,000
National Weather Service	30,000
Field observations	30,000
CDOT	20,000
Hotline sponsors	10,000
Grand Total	**$485,499**

Where the Money Came From



Estimated In-kind Support



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 CAIC central office is with the National Weather Service, which recently moved to Boulder. For CDOT forecasting operations, the Center maintains offices in Silverton, Pagosa Springs, Carbondale, and the Eisenhower Tunnel.

Season: From November–April, the Center is fully staffed and operates on a full-time basis seven days a week. 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 mountain weather and avalanche risk information to the public, via recorded hotline messages and via the Internet and e-mail (see Section VII, Dissemination of Hazard Forecasts);
- warn of dangerous avalanche conditions by issuing Avalanche Warning Bulletins via the NOAA Colorado Weatherwire and news media (see Section VII, Dissemination of Hazard Forecasts);
- provide the Colorado Department of Transportation weather and snowpack data for reducing avalanche hazards along mountain highways (see Section IX, Forecasting for Colorado's Highways);
- provide avalanche education through slide talks, seminars, videos, publications, and media contacts (see Section VIII, Public Education);
- be the focal point and spokes-agency in state government for all avalanche matters;
- provide specialized forecasts and consulting to sponsoring agencies;
- investigate all significant avalanche accidents (see Section VI, Data Acquisition);

Staffing and Duties at the Main Office: Personnel for the 1998–99 season were Knox Williams (Director), Nick Logan (Associate Director), Dale Atkins, and Scott Toepfer. Collectively, this staff has about 100 years of snow and avalanche experience. The Center was staffed daily from 5 am to 3 pm, from opening day on November 6, 1998 until closing on April 12, 1999.

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. Section IX 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 Andy Gleason and Doug Lewis, and coordinates the forecasting for the avalanche reduction program for CDOT along US 550 from Coal Bank Hill to Red Mountain Pass, Colorado 145 over Lizard Head Pass, and Colorado 110 along Cement Creek.
- **Pagosa Springs:** This office is staffed by forecaster Mark Mueller and provides forecasting for the avalanche reduction program along US 160 over Wolf Creek Pass, US 50 over Monarch Pass, and Colorado 17 over Cumbres and La Manga Passes.
- **Eisenhower Tunnel:** This office is staffed by forecasters Lee Metzger and Cathy Fraser 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.
- **Western Slope:** This office is in Carbondale and is staffed by forecaster Rob Hunker. It 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. Section VIII, 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. Section VIII, Public Education, details this year's publications.

Friends Association: The grassroots support group called "Friends of the CAIC" totaled 545 members in 1998–99. For an annual donation of $25 or more, the Friends receive three issues of *The Beacon* newsletter and receive the morning forecast via e-mail.

Weather and Avalanche Synopsis

In the fall of 1998 a sibling rivalry developed in the Pacific Ocean with the visit of La Niña. (Unusually cold ocean temperatures in the equatorial Pacific, compared to her petulant brother El Niño.) In theory the colder ocean supports a more northwesterly storm track favoring the Pacific Northwest and hopefully a snowier winter for Colorado. Indeed all-time, record-setting snows fell over the Pacific Northwest, but by the time storms reached Colorado little extra moisture was left. By the end of this winter the Colorado snowfall and avalanche statistics would tell of an average winter; however, more importantly one should look at the highs and lows that created this season's average numbers.

Though not as well known as her mighty brother, two previous La Niñas had appeared in recent years. In 1988–89 and then again in 1995–96. Though snowfall patterns and amounts varied dramatically during the three recent La Niñas a common theme was revealed. All three winters exhibited a nasty split personality of drought and deluge.

This winter seasonal snowfall ranged from near to above normal in the Northern Mountains to near normal to well below normal in the Central and Southern Mountains[1]. The number of reported avalanches was about normal; however, the number of avalanche warning periods and days were below normal. Avalanche deaths were right on the long-term average, and property damage was negligible.

Snowfall

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

The winter in the San Juans started in earnest in October and abundant snows continued to fall through November, while most areas in the Central and Northern Mountains were left out. By the end of November the storm track split apart as generally dry and windy conditions persisted through much of December.

December was an especially dry month with many sites reporting less then 24 in. of snowfall. A desiccated Crested Butte got only 9 in.! Conditions turned around in January when an active northwesterly storm track brought snow to all mountain areas. Many sites reported 80+ in. of snowfall. Though January snowfalls were not nearly as impressive as in 1996, three sites in January, 1999, amassed more than 100 in. of snow.

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.

In February the storm track retreated northward and only its southern edge nipped Colorado. Its retreat blocked any incursion of cold arctic air into Colorado, but also carried the bulk of storms' energies to the north of our state leaving the Colorado mountains, warm, windy and unsettled. Snowfall favored the Northern and Central Mountains.

Mild weather conditions persisted through March as high pressure dominated all mountain areas. Only a few feeble, winter-like storms interrupted the fair, spring-like weather. By the end of March it seemed old-man winter was done for the season. Water managers across the state spoke of drought conditions as the snow-water equivalent of the winter's snowpack fell to 65 percent of average. The San Juan Mountains were the driest with only 46 percent of average.

Just when thoughts were turning to an early summer, winter returned in vengeance in April. All mountain areas received abundant snows and bitter cold temperatures. Many sites from Red Mountain Pass to Loveland Pass saw huge increases in the snowpack depths and snow water equivalents during April. The deluge of snow continued into early May. Some of the season's heaviest snows fell in the first week of May. The mountain snowpack reached it deepest depths about three weeks later than average; the fear of drought was erased as the snow water-equivalents soared state wide to 105 percent of average.

For the season trend, note in Table 1 the percent-of-normal totals for December–March. Most sites in the Northern and Central Mountains received near normal to slightly above normal snowfall. Vail, Crested Butte, and Monarch were the have-nots with snowfall ranging from 76 percent to 64 percent of normal. All sites in the Southern Mountains were below normal. Both Purgatory and Wolf Creek got less than one-half of their normal snowfall. Only a few sites have long-term snowfall records for the 6 months of November–April. In the Northern Mountains the dry November was offset by the wet April and the percent-of-normal changed very little. In the Central and Southern Mountain the April snows significantly boosted the seasonal average.

Both Purgatory and Wolf Creek got less than one-half of their normal snowfall.

Though most sites escaped drought-like conditions the Grand Mesa had one of its driest winters ever. Powderhorn reported a slight 100 in. from November through March. (For comparison this 5-month period was the second driest ever for the Grand Junction region, only surpassing 1976–77 by 0.10 in. of water.)

Avalanches

This winter a total of 2,048 avalanches was reported to the Center from November to April. This number is 5 percent below the average of 2,166. Table 2 shows the monthly distribution of these events.

November and December produced relatively few avalanches (121 and 172), mainly because of little slab formation from the meager early-season snows in the Northern and Central Mountains. Deep October snows in the Southern Mountains created a strong early-season snowpack. Though avalanches were not falling the snowpack grew weaker by the

day. The mild and dry weather conditions promoted significant depth-hoar and upper-level faceted-grain formation. A tenuous snow cover developed and this set the stage for a shattering of the snowpack when January's heavy snows arrived. A record number of avalanches was reported this January (1,169, as shown in Table 2). With little weakness left in the snowpack February produced relatively few avalanches.

Thaw instability and wet avalanches were limited to a warm-up in March. Such a warm-up is early for spring avalanches as the snowpack remains cool. Some shallow wet-snow avalanches occurred, but the mild and warm conditions only consolidated the snowpack creating a strong and stable snowpack, and only 109 avalanches were reported. Winter's return in April caused 187 avalanches, but most events involved only new snow. Cold temperatures inhibited the usual wet-slab avalanches. In the absence of any significant weak layers the snowpack slowly melted away in May and June.

Avalanche Danger and Warnings

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

The 19 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.)

Avalanche Accidents

The last part of Table 2 lists a monthly breakdown of avalanches involving people and property in 1998–99, while Figure 2 compares these same statistics by decade. During the winter of 1998–99 the number of people caught (61) was only slightly below the 1990s average of 64. The 18 people partly buried were significantly more than the 1990s average of 13. The eight buried were less than the decade average of 11. The numbers injured and killed matched the 1990s average of six each. Only one property site was struck and damages were estimated at $2,000.

Table 3 lists all avalanche accidents reported this winter. The fatal accidents are italicized. Avalanche Center personnel try to investigate all fatal accidents (see Section VI). It is remarkable to note the grouping of accidents by month. Avalanche accidents started early with the season's first snows, but as the storms abated in December so too did the number of accidents. Heavy snows on a weak snow snowpack created dangerous conditions in January and a huge number of accidents were reported. By February weak layers had been removed and few accidents were reported. March was another quiet month for avalanches and accidents, but with the arrival of April's snows came avalanches and accidents.

Figure 1 represents a 16-year look at the number of people caught and killed in avalanches each winter. Figure 2 shows the accident trend over the last 3 decades.

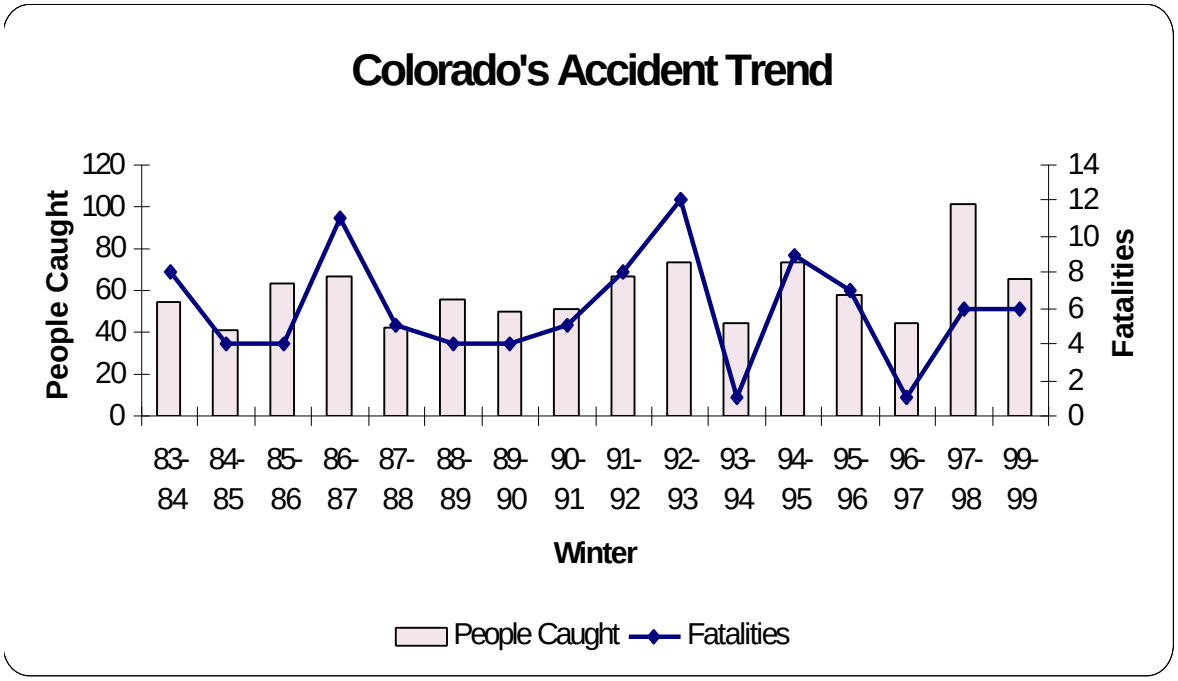


Figure 1. Colorado's Accident Trend

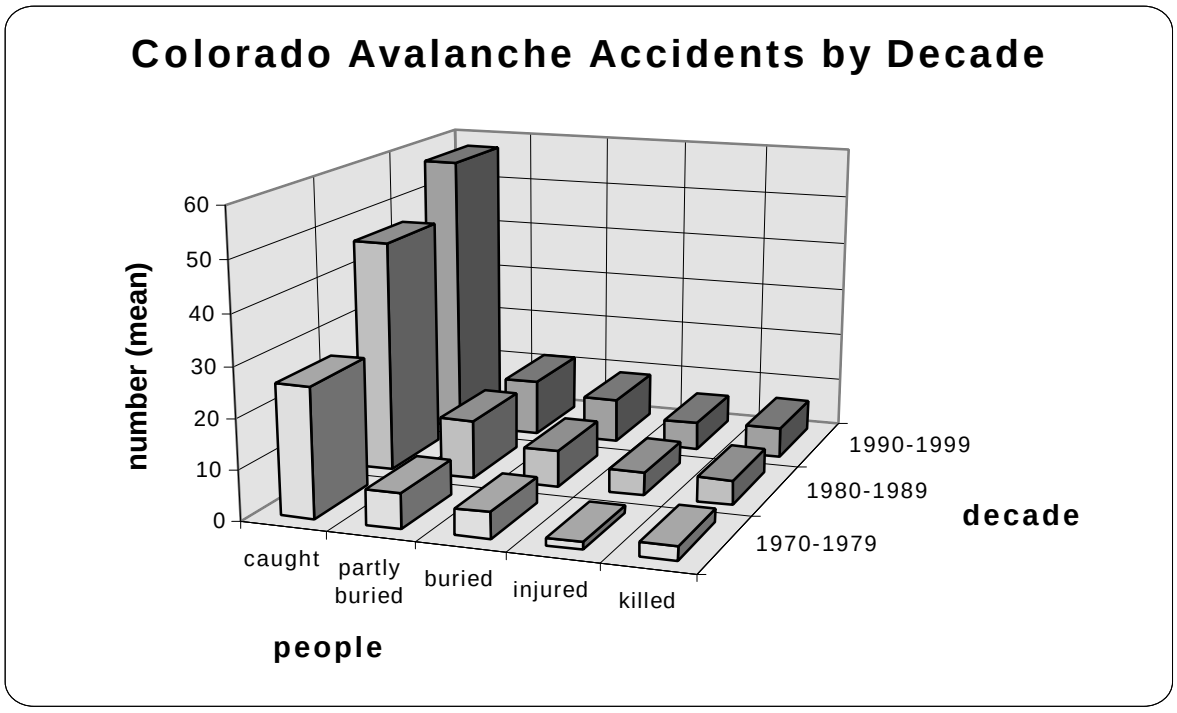


Figure 2. Colorado Avalanche Accidents by Decade

Table 1. 1998–99 Snowfall in Inches

	Nov	Dec	Jan	Feb	Mar	Apr	Total Dec-Mar	% of Normal	Total Nov-Apr	% of Normal
Northern Mountains										
Arapahoe Basin	25	27	88	49	28	66	192	102	283	97
Bear Lake (RMNP)	18	37	70	26	17	70	150	91	238	97
Beaver Creek	42	21	84	49	39		193	85		
Berthoud Pass*	46	38	111	60	51	79	260*		385*	
Breckenridge	16	25	84	62	25	56	196	98	268	
Copper Mountain	10	21	95	56	32	52	204	110	266	
Eldora	17	30	68	21	27		146			
Keystone	18	25	80	37	19	45	161		224	
Loveland Basin	30	36	135	59	33	91	263	115	384	113
Steamboat		46	96	65	25		232	95		
Vail	43	18	101	48	31	68	198	76	309	
Winter Park	33	28	99	55	44		226	88		
*new study plot, no correlation to past										
Central Mountains										
Aspen Highlands										
Aspen Mountain		30	58	43	30		161	94		
Aspen Snowmass	56	19	57	50	37		163			
Crested Butte	48	9	66	35	18		128	76		
Gothic	58	12	97	54	32	83	195	80	336	98
Irwin Lodge	51	24	95	54	29	60	202		313	
McClure Pass	37	24	44	33	16	32	117		186	
Monarch	19	15	58	24	27		124	64		
Powderhorn	22	22	18	28	10		78			
Sunlight		25	46	48	22		141			
Southern Mountains										
Purgatory	54	20	35	23	10	61	88	47	203	
Red Mountain Pass	47	19	67	30	19	80	135	65	262	88
Telluride	53	22	63	26	24		135	71		
Wolf Creek	56	40	41	26	13	74**	120	45		
**from April 1-4										

Table 2. 1998–99 Summary of Avalanches, Hazard Days, and Accidents

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	TOTAL
Avalanches reported		121	172	1169	210	109	187	80	**2048**
Days with 1 or more slab avalanches		16	18	29	21	15	20	7	**126**
Avalanche warning periods		1	0	3	1	0	1	0	**6**
Days with warning in effect		2	0	11	2	0	4	0	**19**
NORTHERN MOUNTAINS									
Days with hazard rated ...									
LOW		7	21	0	0	10	3		**41**
MODERATE		16	4	10	22	21	8		**81**
CONSIDERABLE		1	4	14	4	0	0		**23**
HIGH		0	2	6	2	0	0		**10**
EXTREME		0	0	1	0	0	0		**1**
CENTRAL MOUNTAINS									
Days with hazard rated ...									
LOW		7	21	0	0	14	0		**42**
MODERATE		17	8	17	23	17	11		**93**
CONSIDERABLE		0	0	9	5	0	0		**14**
HIGH		0	2	2	0	0	0		**4**
EXTREME		0	0	3	0	0	0		**3**
SOUTHERN MOUNTAINS									
Days with hazard rated ...									
LOW		8	18	0	4	17	0		**47**
MODERATE		13	11	20	19	13	7		**83**
CONSIDERABLE		2	0	6	5	0	1		**14**
HIGH		1	2	3	0	1	3		**10**
EXTREME		0	0	2	0	0	0		**2**
AVALANCHE ACCIDENTS	1	3	3	23	4	2	13	2	**51**
People caught	1	3	3	30	7	2	14	1	**61**
People partly buried	1	1	1	8	2	2	3	0	**18**
People buried	0	0	0	3	3	0	2	0	**8**
People injured	0	0	1	3	0	1	1	0	**6**
People killed	0	0	0	2	3	0	1	0	**6**
Vehicles caught	0	0	0	2	0	0	0	0	**2**
Property sites damaged	0	0	0	2	0	0	0	1	**1**

Table 3. Colorado Avalanche Accidents by Month, 1998-99 (italics indicate fatal accident)

Date	Location	Details
10/29	Montezuma Basin (Aspen)	1 backcountry skier caught and partly buried
11/8	Telluride	1 backcountry skier caught, partly buried and injured
11/14	North Star Mtn. (Hoosier Pass)	1 snowshoer caught
11/20	Loveland Pass	1 backcountry skier caught
12/21	Breckenridge	1 snowmaker caught
12/29	Arapahoe Basin	1 out-of-area skier caught
12/31	Beaver Creek	1 ski patroller caught and partly buried
1/1	Monarch Pass	1 snowmobiler caught
1/6	Anthracite Range (Kebler Pass)	1 backcountry skier caught and injured
1/6	Vail	2 snowboarders caught
1/9	Eisenhower Tunnel (West side)	2 backcountry skiers caught, 2 dogs caught, 1 dog buried and killed
1/9	Berthoud Pass	1 backcountry skier caught
1/10	Berthoud Pass	1 ski patroller caught and partly buried
1/11	East Vail Chutes	1 backcountry skier caught and buried (fingers out)
1/12	Francie's Cabin	2 backcountry skiers caught
1/17	Monarch Pass	1 worker caught, 1 snowplow caught
1/17	East Vail Chutes	1 backcountry skier caught
1/19	Aspen Mountain	2 out-of-area lift skiers caught and partly buried
1/19	Crested Butte	1 ski patroller caught
1/20	Vail	2 backcountry skiers caught and partly buried, 1 injured
1/20	Aspen Mountain	1 backcountry skier caught
1/21	Lizard Head Pass	1 snowplow caught
1/22	*Aspen Highlands*	*2 out-of-area skiers caught, 1 buried and killed*
1/22	Vail	1 ski patroller caught, partly buried and injured
1/22	Crested Butte	1 ski patroller caught and partly buried
1/23	Loveland	1 ski patroller caught
1/25	Sunlight	1 ski patroller and 1 ski instructor caught
1/30	*Grand Mesa*	*1 snowmobiler caught, buried and killed*
1/30	Markely Hut (Elk Mtns.)	2 snowboarders caught
1/31	Irwin (Kebler Pass)	1 snowcat skier caught and partly buried
2/6	*Cumberland Pass*	*2 backcountry skiers and 1 snowmobiler caught, buried and killed. 1 backcountry skier caught & partly buried*
2/18	Grand Mesa	1 backcountry skier caught
2/20	Monarch	1 ski patroller caught and partly buried
2/24	Aspen Highlands	1 out-of-bounds snowboarder caught

Table 3. Continued…

Date	Location	Details
3/9	Beaver Creek	1 out-of-bounds snowboarder caught and partly buried
3/21	Engineer Mtn. (S. San Juans)	1 climber caught, partly buried, and injured (fractured ankle)
4/4	Gore Range	1 backcountry skier caught
4/5	Red Mountain Pass	1 backcountry skier caught
4/6	Garrett Pk. (Aspen)	2 backcountry skiers caught, 1 partly buried
4/6	St. Mary's Glacier	1 backcountry skier caught, and buried (found by voice)
4/6	Marble	1 backcountry skier caught and partly buried
4/7	*Ophir*	*1 backcountry skier caught, buried and killed*
4/7	Mt. Whetstone	1 backcountry skier caught
4/15	Loveland	1 ski patroller caught
4/16	Keystone	1 ski patroller caught and injured
4/17	Breckenridge	1 ski patroller caught
4/17	Breckenridge	1 ski patroller caught (separate incidents)
4/26	Breckenridge	1 ski patroller caught
4/30	Guanella Pass	1 backcountry snowboarder caught
5/6	Telluride	1 power line damaged
5/22	St. Mary's Glacier	1 backcountry skier caught

Detailed Winter Summary

October

The winter of 1998–99 began as a holdover from last year's El Niño pattern. Even though the Pacific Ocean had reversed its temperatures by cooling dramatically and officially becoming a La Niña episode, the atmosphere had not yet coupled with the colder ocean temperatures. Therefore, winter began in Colorado with a parade of southern storms, as would be expected in an El Niño winter. October snowfall was significant in the San Juan Mountains, but our study plots were not yet operational, so measurements are not available. However, the snow depth at Wolf Creek Ski Area by November 1 was already 48 in. Compare this to the depth at several other sites: Steamboat, 10 in.; Beaver Creek, 14 in.; Winter Park, 5 in.; Bear Lake, 6 in.; Snowmass, 13 in.; and Gothic, 2 in.

November

The first 2 weeks of November brought continued moderate snows to the Southern Mountains: Wolf Creek got 47 in. in these 2 weeks, 22 in. of which fell on the 8th and 9th. This brought the first avalanche warning of the season on the 9th–10th, which covered the San Juan Mountains. Sixteen avalanches were reported from the warning area on the 9th; they were primarily confined to the new snow but some fractures were 4–7 ft deep. Snowfall for these 2 weeks was generally less in the Northern and Central Mountains. For example, Beaver Creek got 25 in.; Gothic, on the other hand, reported 48 in.

This storm cycle was followed by several days of high pressure and warming temperatures. On the 18th a weak short wave traversed the North and Central Mountains. In 3 days, it brought only 5.5 in. of new snow to Winter Park and 10 in. to Steamboat. There was no new snow in the southern portion of the state. Following this weak system, high pressure and temperatures in the 40s to low 50s shrunk the snowpack, especially on south and west aspects, until the 28th. Then the next storm brought only scant new snow to the North and Central Mountains, while the Southern Mountains reported a good dose of new with 13 in falling at Purgatory by the 29th and 7 in. at Wolf Creek Pass. A split flow pattern began to set up as November came to a close.

Monthly snowfall at most sites was well below normal, especially in the North and Central Mountains. A Basin, Bear Lake, Winter Park, and Monarch all received 45–52 percent of normal, while in the Southern Mountains, Wolf Creek got 92 percnet and Red Mountain Pass, 100 percent. Gothic, with 112 percent, was the only site above normal. In all 62 avalanches were recorded in the Northern Mountains, 11 in the Central Mountains and 48 in the San Juans. Two backcountry skiers and one snowshoer were caught in slides for the month. It was a quiet start for the 1998–99 season.

December

Colorado waited patiently for the first storm of the month to materialize. By the 4th light snow began to fall in the Southern Mountains and at Steamboat. It would snow over all Colorado mountains for the next 7 days as a slow-moving trough broke down the wall of high pressure, at least temporarily. Steamboat benefited from a much-needed 22 in. during this cycle, whereas Purgatory could only squeeze out 10 in.

The snowpack in the Southern Mountains was consolidating well; but on the other hand a shallow snowpack coupled with the long cold nights of December were taking a toll on the strength of the snow in the North and Central Mountains. The winter was setting up to be a typical continental winter—lots of depth hoar.

… a typical continental winter—lots of depth hoar.

An arctic airmass dropped out of Canada to start the second half of December. The coldest air stayed east of the Continental Divide on the 19th. This arctic airmass allowed the jet stream to set up over the Front Range, bringing cold wind-chill temperatures but also some much anticipated snow. Wind gusts to 84 mph were reported from Summit County on the 20th, while wind-chill temperatures to -50 were reported from many sites early on the 20th. Only light snows fell in the North and Central Mountains on the 19th–20th. Then on the morning of the 21st after a brief, beneficial wind shift to the southwest, Wolf Creek Pass reported 15 in. new and Coal Bank Pass, 21 in.

Beginning Christmas Day a weak series of storms coming in on a northwest jet stream enhanced snowfall through the 30th. Loveland Basin got 22 in. of snow in the last week of December, and Steamboat, 20 in. However, Gothic in the Central Mountains was teased with only 2 in. for the same period, with Wolf Creek Pass seeing no new snow at all, a good example of a northerly wind flow shutting off precipitation in the San Juans. This new snow in the Northern Mountains brought a flurry of shallow avalanche activity, as the snowpack foundation was quite weak.

December snowfall was decidedly below normal. Snowfall in the Northern Mountains ranged from 28–69 percent of normal; in the Central Mountains, 21–77 percent; and in the Southern Mountains, 43–67 percent. Only Bear Lake on the east side of the Continental Divide managed to beat par with 109 percent of normal. There were 103 avalanches reported from the Northern, 43 from the Central, and only 26 from the Southern Mountains. No warnings were issued for the month and only three people were caught in slides. November and December had been fairly kind to Colorado's backcountry users.

January

The new year began with continued snows in the Colorado mountains. A persistent high pressure ridge had developed over California, which put Colorado under strong northwest wind flow. This pattern brought a continuous string of storms into the North and Central

Mountains for January. New snow would be reported from at least one site every day from January 1–28. Additionally January would be an exceptionally windy month, and many observers would comment on the amount of wind. The peak gust would be 122 mph that was recorded at the Mt. Abrams weather site on Red Mountain Pass on the 26th.

The first storm of January, however, favored the Southern and Central Mountains. New Years Day saw 5 in. of new snow in Silverton, 6 in. in Gothic, but only 1–2 in. in the Summit County area. The first 6 days of January brought continuous light snow to the Northern Mountains. Vail got 36 in. and Steamboat, 31 in. during this time, with persistent winds that caused blowing snow. We issued an avalanche advisory for the Northern Mountains on the 4th which became a full-fledged warning on the 5th–7th. The stress had arrived that would cause failure in the very weak snowpack.

The stress had arrived that would cause failure in the very weak snowpack.

Light snows fell daily at most sites from the 7th–15th, and then a strong short wave moved in on the 16th. This brought sustained snowfall until the 25th in the North and Central Mountains. During this time, Steamboat got 52 in.; Winter Park, 38 in.; A Basin, 49 in.; Breckenridge, 50 in.; Vail, 37 in.; Aspen Mountain, 34 in.; and Gothic, 73 in. On the 3 days of the 20th-22nd, Telluride recorded 33 in. We issued an avalanche advisory on the 16th and this became a warning on the 18th which lasted until the 24th. More than 600 avalanches were reported during this episode, as well as the first avalanche death of the season which occurred on the 22nd when an out-of-area skier died near Aspen Highlands. A second avalanche death occurred on the 30th when a snowmobiler died on Grand Mesa.

…the first avalanche death of the season…

Snowfall was above normal for almost all mountain sites. In the Northern Mountains, it varied from 133–205 percent, and in the Central Mountains was 120–160 percent of normal. In the San Juans, Telluride got 136 percent and Red Mountain Pass, 132 percent, while Wolf Creek managed but 61 percent of normal. In all there were 23 avalanche incidents in January, with 30 people caught, and 2 killed. A rough month for avalanches, with 348 avalanches reported in the Northern, 401 in the Central, and 420 in the Southern Mountains. More than half of the winter's avalanches fell in January.

February

A weak system moved over the mountains the first night of February and brought only light snowfall but terrific winds to the Front Range. Winds gusted to 106 mph on the ridge above Winter Park on the morning of the 3rd. Many trees blew down along Berthoud Pass.

High pressure brought fair weather on the 4th but then a digging trough brought snow on the 5th. Wolf Creek saw 13.5 in. in 2 days, and then as winds became more northwesterly, other areas of

…the worst avalanche accident in years…

the state began to see snow as well. The northerly wind flow kept the North and Central Mountains in light snow through the 8th. It was on the 6th when the worst avalanche accident in 11 years struck on Cumberland Pass in the southern Sawatch Range. Three young men were killed in a large avalanche while skiing and snowmobiling on the steep, leeward, south side of the pass. (The last worst occurred on January 10, 1988 that killed three skiers near Pearl Pass.)

On the 9th a brief, one-day ridge of high pressure brought clear skies to Colorado. This was quickly replaced by a digging trough that hit the San Juans with the first push of new snow on the 10th. All mountains would eventually prosper from this 2-day storm, although Powderhorn on Grand Mesa was especially happy with 17 in. of new snow. Wolf Creek got 12 in. plus wind gusts to 91 mph. Beaver Creek did the best for the Northern Mountains with 7 in. new and wind gusts into the 80s.

Fair weather dominated on the 12th–14th, then a series of fast-moving storms attacked Colorado from the 15th–23rd. Once again the new snow was accompanied by high winds during this cycle. Gusts to 109 mph were reported along the Highway 550 corridor. Breckenridge recorded 53 in. of new snow; Gothic, 30 in.; and in the Southern Mountains Telluride could only scrape up 9 in. during the cycle.

High pressure and gradually warming temperatures gradually stabilized the snowpack before the next storm moved in on the 26th. This storm was weak and could only manage light snow for the Northern Mountains, where 6 in. fell at Steamboat and 2–5 in. at other areas. February ran out under this high-pressure ridge.

February snowfall was highly variable, but with prevailing northwest flow, it favored the Northern Mountains and diminished rapidly toward the south and east. In the Northern Mountains, Breckenridge and Copper Mountain got 137 percent of normal; Steamboat, 115 percent; A Basin, 109 percent; Winter Park, 96 percent; Vail, 83 percent; and Bear Lake on the east side of the Continental Divide, only 55 percent. In the Central Mountains, Aspen got 100 percent; Crested Butte and Gothic, 83 percent; and Monarch, 50 percent. In the San Juans, Red Mountain Pass got 60 percent; Telluride, 56 percent; Purgatory, 47 percent; and Wolf Creek, 40 percent. Only 80 avalanches were reported in the Northern Mountains despite the snow and strong winds, 93 in the Central Mountains, and a measly 37 in the San Juans. There were only four incidents reported statewide in February, but one of those took three lives, which brings to mind an Ed LaChapelle quote, "Never trust a continental snowpack."

There were only four incidents reported statewide in February, but one of those took three lives…

March

A weak storm system crossed the Northern Mountains on the 2nd and brought 2–8 in. of snow there, and only trace–1 in. to the Central Mountains. The next storm on the 5th-6th brought 5–11 in. to the Northern, 7–13 in. to the Central, and 0–2 in. to the Southern Mountains. Widespread light snow fell on the 8th-10th with 6-12 in. being typical

accumulations. Then a fourth system on the 12th–13th brought 3–10 in. to all mountain areas. This storm cycle produced little wind, an uncommon occurrence for the winter so far.

Beginning on the 14th, high pressure and exceptionally warm temperatures, into the 50s and 60s put a stranglehold on the Colorado Rockies for the next 13 days. The warm weather pattern allowed strong settlement and strengthening of the snowpack throughout the state and solidified a strong bridge over the weak foundation that had formed early in the season. The only snow that fell in the mountains during this period of high pressure was 6 in.at Monarch on the 24th, a result of a southeast upslope.

On the 27th cold air aloft moved over Colorado and created an unstable atmosphere and snow showers, which brought 7 in. to Vail and 6 in. to Gothic. Strong winds again visited the higher peaks with gusts into the 70s and 80s being reported from the North and Central Mountains. The month would end under high pressure as the next storm stalled off the west coast.

It was an exceptionally dry March. Snowfall was 40–63 percent of normal in the Northern, 44–57 percent in the Central, and a paltry 17–40 percent in the Southern Mountains. Not surprisingly, it was also a quiet month for avalanches: only 33 in the Northern, 46 in the Central, and 30 in the Southern Mountains. No avalanche warnings or advisories were issued and only two incidents happened that caught one climber and one snowboarder.

April

April would make up for the quiet month of March as a constant barrage of strong winds, cold temperatures and heavy snow would blanket the state in a numbing return to winter. It began on the 1st as a strong storm came into Colorado from the southwest and finally ended late on the 5th. Wolf Creek had suffered through one of its driest ski seasons ever and closed for the season on April 4. But from the 1st–4th, 74 in. of snow fell at Wolf Creek, while 50 in. fell at Purgatory on the 1st–5th. The heavy snows prompted our final avalanche warning of the season, which was issued for the San Juans on the 2nd–5th. Snowfall from this storm was much less in the Central and Northern Mountains and ranged from 12–18 in.

A short-lived ridge of high pressure covered the state on the 6th and 7th, and it was on the 7th that the final avalanche fatality of the season occurred when a back-country skier died in a large slide that he triggered near Ophir. This avalanche was a direct result of the heavy snows that had fallen a few days earlier in the San Juans.

…the final avalanche fatality of the season…

On the 8th a storm came out of the Gulf of Alaska but brought more cold air than snow. Temperatures plummeted into the single digits and wind chill factors dropped well below zero. It took awhile for the warm March temperatures to be driven out by the cold Arctic air. Spring at the high elevations can have a difficult time wrestling winter out of the way.

The third system of the month moved quickly into the mountains on the 10th, but only lasted for 2 days and brought light snows of 6–9 in. to the North and Central Mountains, and the southern mountains virtually being shut out, as Telluride saw only 2 in. The next system plowed into the state on the 14th and brought significant snow (11–17 in.) to the Northern Mountains until the 16th. Wind chill factors on both the 15th and 16th were frigid at –50 to –60 degrees, some of the coldest temperatures of the season. It was a harsh close to our forecasting season, as the Avalanche Center ceased issuing public forecasts on April 18. The early closing date was forced because of lack of funding.

Wind chill factors … -50 to -60 degrees, some of the coldest temperatures of the season.

But winter was far from over. The Avalanche Center remained open to support avalanche forecasting along Colorado's highways. Another spring storm brought widespread snows on the 22nd–25th. Red Mountain got 24 in.; Gothic, 25 in.; and A Basin, 15 in. The last 5 days of April brought additional light snows to most mountain areas.

Few of our observing sites recorded data all month, but among those that did, it was a month of above-normal snowfall: Copper Mountain, 104 percent; A Basin, 117 percent; Bear Lake, 167 percent; Gothic, 176 percent; and Red Mountain Pass, 192 percent. With all the new snow and wind, 13 avalanche accidents were reported, which resulted in 14 people caught and 1 killed.

May

A final strong storm came out of the southwest and struck the San Juans on May 1 and continued until the 5th. This storm dropped 51 in. of snow on Red Mountain Pass and produced a rare May avalanche cycle. A final interesting note: The snows of April and May were enough to bring the snowpack in the San Juans from about 50 percent of normal to 90–100 percent of normal. In the Northern and Central Mountains, the boost from the late-season snows was not quite so dramatic, but still significant.

…enough to bring the snowpack in the San Juans from about 50 percent of normal to 90–100 percent of normal.

Data Acquisition

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.

Snowmobile observer network: New this season the Center, in cooperation with the Colorado Snowmobile Association, established a volunteer observer network. Trained by Center staff, 35 recreational snowmobilers take a few snow and avalanche observations during the course of their usual riding activities. Their observations are then e-mailed or faxed to the Center. This new network supplies the Center with information and data from many distant mountain areas and has created a partnership unique in the avalanche industry.

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, and radiosonde data are all available from the new, state-of-the-art AWIPS 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 (www.avalanche.org) 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, search and

rescue teams, 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.

Dissemination of Hazard Forecasts

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.

Public Hotlines

Data from some 35 field-observation sites are used to prepare forecasts for eight hotlines 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 in Summit County. The Alpineer in Crested Butte also hosted a hotline this winter.

This winter a total of 62,868 calls was placed to the hotlines. The following table breaks down the call counts by location. The hotlines in Aspen, Vail and Crested Butte do not have counters.

Location	Phone #	Number of calls
Denver	303-275-5360	16,762
Ft. Collins	970-482-0457	4,760
Colo. Springs	719-520-0020	5,061
Summit County	970-668-0600	18,536
Durango	970-247-8187	17,749
Aspen	970-827-5687	N/A
Vail	970-920-1664	N/A
Crested Butte	970-641-7161	N/A

E-mail to "Friends," Observers and Forecasters

Our grassroots support organization, "Friends of the CAIC," is comprised of some 545 members. For a contribution of $25 or more, "Friends" with e-mail receive a daily mountain weather forecast and snowpack evaluation. CAIC observers and highway forecasters also get the forecast via e-mail. We have found this to be an effective and efficient way to distribute CAIC's regular updates. "Friends" also use e-mail to communicate address changes, make suggestions, and report avalanche occurrences and accident information to the CAIC. Approximately 45,000 forecasts were sent via e-mail to our Friends.

Web Site

The Center's own web site (www.caic.state.co.us) consists of 20+ different pages with a text information, pictures, and links that can be used by backcountry travelers, students and snow workers. The most popular page is the daily-forecast page. It received 104,600 contacts by the end of May.

Figure 3 below shows CAIC's total product dissemination growth from all outlets. Note how hotline use declined when the forecast became readily available through home computers. CAIC's Web site has become very popular in a short time and an increasing number of people are now getting the daily forecast via e-mail through our "Friends of the CAIC" program.

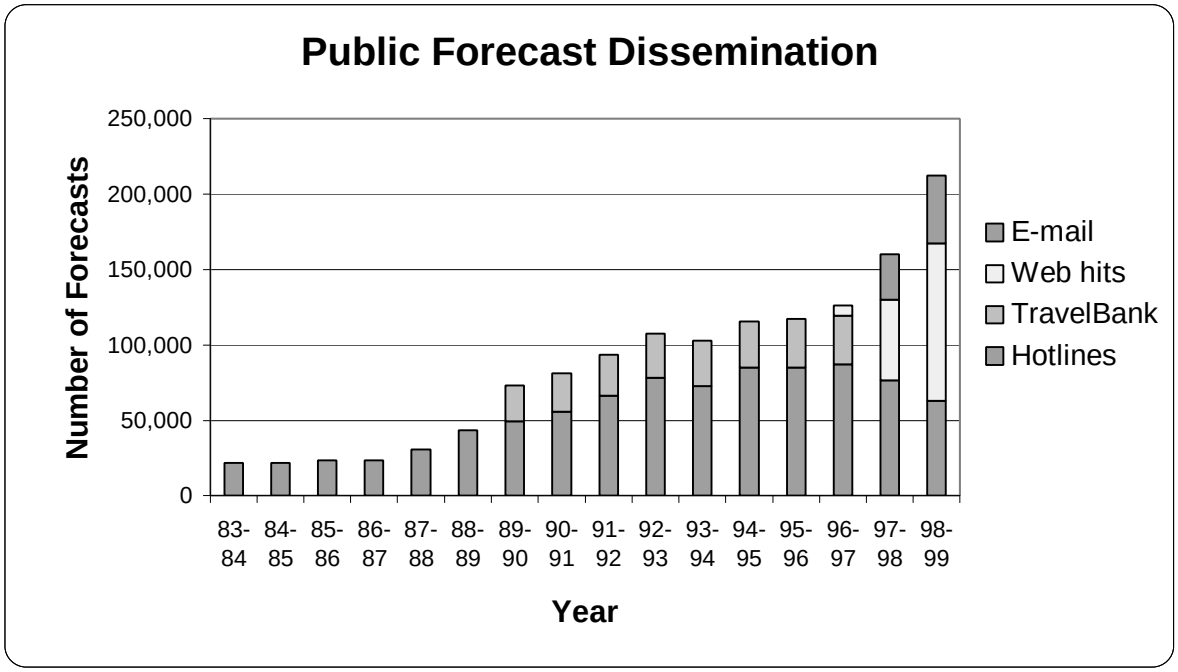


Figure 3. Public Forecast Dissemination

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 long distance telephone calls to an avalanche hotline would be inconvenient and costly. While some stations broadcast our message daily, others have been most helpful by broadcasting Avalanche Warnings and Special Avalanche Advisories when necessary. Some stations conveying these bulletins include public radio KVNF-FM in Paonia, KOTO in Telluride, KVMT in Vail, KFMU in Steamboat, and KYSL-FM in Frisco.

NOAA Colorado Weatherwire

During times when the avalanche danger is rated high or extreme, CAIC forecasters issue Avalanche Warning bulletins twice daily until the danger subsides and an Avalanche Warning Termination Bulletin is dispensed. Special Avalanche Advisories are issued when the avalanche danger could increase significantly if a storm forecast verifies. These bulletins are transmitted to the news media via the National Oceanic and Atmospheric Administration (NOAA) Weatherwire. Six separate warning periods covered 19 days and four, 1-day Special Advisories were issued this winter.

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. This winter the Center made 198 contacts with the media. For reasons of timeliness, the daily forecast is not issued through the printed media. However, it is not uncommon for the media to follow up on avalanche warnings, special advisories and accidents.

Public Education

A prime responsibility 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 Courses

This season courses began on September 14. By the time the last talk was given on April 26, the Center staff had spoken on 68 different occasions to some 3,226 people.

The courses vary from 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 13 winters of avalanche education are displayed in Figure 4 below.

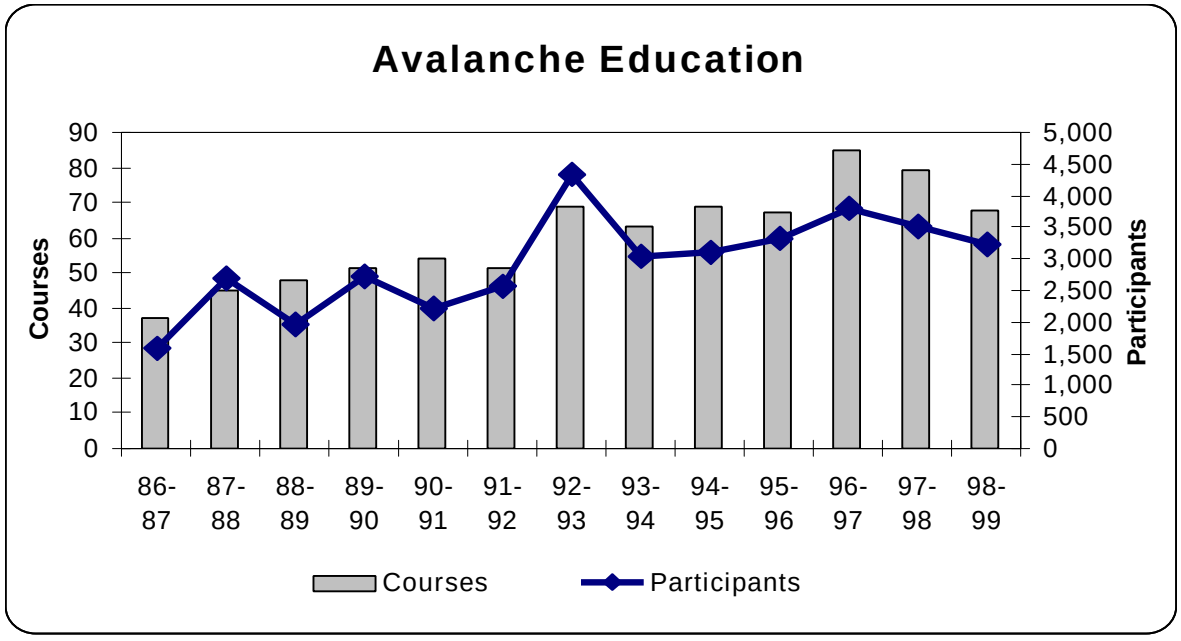


Figure 4. Avalanche Courses and Participants

Table 4 lists all courses taught by CAIC staff in 1998–99. The scope and content varied from a 1-hour overview to 2- or 3-day courses covering mountain meteorology, avalanche terrain recognition, the Colorado snowpack, methods of safe winter travel, and survival and rescue techniques. Students this winter included backcountry enthusiasts, professional ski patrollers, search and rescue volunteers, law enforcement officers, members of ski and snowmobile clubs, the Colorado Mountain Club, USFS, and CDOT.

Table 4. Avalanche Talks and Seminars, 1998–99

Date	Personnel	Group	Participants
9/14	D Atkins	CMC, Leadership Training	29
10/10–11	Williams/Logan	Colorado Snowmobile Exposition, Denver	200
10/21	D Atkins	Mountain Miser, Englewood	84
10/29	D Atkins	General Awareness, Boulder	30
10/31	K Williams	ISSW, Sun River, OR	450
11/2	Atkins/Metzger/ Fraser	CDOT, Hidden Valley	24
11/4	S Toepfer	General Awareness, Englewood	25
11/14	D Hogan	Buena Vista Snowdrifters, Buena Vista	78
11/15	S Toepfer	Cross Country Ski School, Vail	25
11/18	D Atkins	Alpine Rescue Team, Evergreen	23
11/19	S Toepfer	General Awareness, Crested Butte	100
11/19	D Hogan	S&R & snowmobile club, Salida	42
11/21	S Toepfer	Castlewood Library, Englewood	15
11/23	N Logan	Summit Co. Awareness, Breckenridge	210
11/23	S Toepfer	Summit County High School	20
11/23	S Toepfer	General Awareness, Vail Public Library	120
12/1	K Williams	General Awareness, Ft. Collins	70
12/4–5	Atkins/Logan/ Toepfer	Colorado S&R Board, Summit Co.	120
12/8	Atkins/Metzger/ Fraser	CDOT, Hidden Valley	32
12/9	N Logan	Mountain Chalet, Colo. Spgs.	65
12/11–12	S Toepfer	Babes in the Backcountry, Francie's Cabin	8
12/12–13	S Toepfer	Beacon Clinic, Francie's Cabin	14
12/20	Logan/Atkins	CMC instructors, Arapahoe Basin	18
1/4	N Logan	Breckenridge pro patrol, Breckenridge	14
1/6	D Atkins	Alpine Rescue Team, Evergreen	32
1/6–7	Toepfer/Hunker	Colorado Snowmobile Association	26
1/8–9	N Logan	Mountain Rescue Aspen	120
1/8–10	Toepfer/Hogan	Telluride pro patrol	42
1/10	A Gleason	Silverton Snowmobile Club	14
1/11	D Louis	Silverton High School	10
1/12	N Logan	Breckenridge Elementary School	30
1/12–13	S Toepfer	Colorado Outdoor Education	60
1/13	A Gleason	Silverton High School	10
1/13	Gleason/Lewis	General Awareness, Silverton	8
1/15–16	N Logan	Ski Haus, Steamboat, Rabbit Ears Pass	80
1/16	Gleason/Lewis	Boy Scouts, Durango/Silverton	23
1/16–17	Williams/Hogan	Newt Wheatley, Vail	14
1/19–20	Toepfer/Hogan	Colorado Snowmobile Association	25

Table 4. Continued

Date	Personnel	Group	Participants
1/19,21,23	Logan/Williams	Colorado Mtn. Club, Golden, Jones Pass	47
1/20	D Atkins	Rocky Mtn. Rescue Group, Boulder	68
1/20	A Gleason	Prescott College Students, Red Mtn. Pass	10
1/20,24	K Williams	Mountain Shop, Ft Collins	28
1/22–24	Toepfer/Gleason/ Lewis	Silverton Avalanche School	80
1/26	S Toepfer	DU Snowboard Club, Denver	50
1/28	N Logan	General Awareness, Salida	15
1/29–31	Gleason/Lewis	Silverton Avalanche School	80
2/1,3,6	Atkins/Williams	Colorado Mtn. Club, Golden, Jones Pass	45
2/2–3	Toepfer/Logan	Summit Pro Patrol Course, Copper Mtn	20
2/3–4	D Atkins	Natl. Outdoor Leadership Sch., Driggs, ID	16
2/4	S Toepfer	Battle Mountain High School, Eagle-Vail	25
2/5-–7	D Hogan	Silverton Avalanche School	49
2/6	N Logan	Summit Snowmobile Club, Frisco	15
2/9	S Toepfer	Patagonia Staff	6
2/10–13	D Atkins	Estin Hut	12
2/11	K Williams	Diamond Peak Ski Patrol	25
2/11	S Toepfer	Arapahoe Library	12
2/13–15	S Toepfer	Alaska Mountain Safety Center, Alaska	30
2/18	D Atkins	Skyline High School, Longmont	41
2/22–23	D Hogan	Newt Wheatley, Vail	7
2/22–24	N Logan	PSIA, Copper Mtn. & Francie's Cabin	10
2/23	D Atkins	CDOT	18
2/25–27	S Toepfer	Babes in the Backcountry, Francie's Cabin	30
3/1,3,6	Atkins/Williams	Colorado Mtn. Club, Golden, Jones Pass	40
3/12	K Williams	Denver Gyro Club	16
3/13–14	S Toepfer	Pikes Peak Alpine School	8
3/18	D Atkins	National Ski Patrol, Loveland S.A.	42
3/19–21	S Toepfer	Babes in the Backcountry, Francie’s Cabin	20
4/26	D Atkins	Colorado Mtn. Club, Golden, Jones Pass	51
		68 Courses Total	**3,226**

To teach these courses, CAIC forecasters invested 471 hours in teaching, 87.5 hours in preparation, and 172.5 hours driving to the sites of the courses.

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 search and rescue teams who conduct organized avalanche search and rescue missions.

Avalanche Slide Sets

For the 12th winter the Center has made available slide sets of avalanche accident statistics in the U.S. Updated every two years, these 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. They logged field data, studied weather maps and satellite photos, made the decisions necessary for a daily weather and avalanche hazard forecast, wrote the forecast, and read it into the hotlines. The intent was to give field observers the experience of actually being the forecaster. Seven people accepted the challenge and became a "forecaster for a day."

Publications

Center personnel worked on several projects for publication this year. Both Scott Toepfer and Dale Atkins had articles in *The Avalanche Review*—a publication of the American Association of Avalanche Professionals—and also in *Backcountry Magazine*. Additionally, the Center produces three issues of *The Beacon*, a newsletter for Friends of the CAIC.

Web Site

The Center's web page (www.caic.state.co.us) provides avalanche and mountain weather information useful to the novices and the experts alike. In addition to the popular daily forecast page Internet surfers can get information, pictures and graphics on all sorts of avalanche and weather related topics. Dale Atkins is the creator of the CAIC web site.

Professional Conferences

All the Center's staff attended the 1998 International Snow Science Workshop held this year in Sun River, Oregon. Knox Williams presented a paper on avalanche forecasting in North America, and Nick Logan presented a poster on mountain weather forecasting and Andy Gleason presented a poster on snow stability tests. Technical papers by all three were published in the proceedings. A paper written by Atkins on U.S. avalanche accidents was presented at the 1998 International Alpine Rescue Commission's (IKAR) annual meeting in Austria.

Forecasting for Colorado's Highways

Introduction

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. Now six CAIC avalanche forecasters are based in Silverton, Pagosa Springs, Carbondale and the Eisenhower Tunnel. They prepare daily stability evaluations, provide recommendations for avalanche reduction and road closures, maintain weather and avalanche records and conduct avalanche training for highway personnel. CDOT provides the funds necessary to run this program.

Table 5 shows the impact of avalanches this season on Colorado Mountain highways. It lists the number of natural and explosive-triggered avalanches reaching roadways. Read further to learn more about the operation and winter's events for each forecast region.

Table 5. Avalanches reaching Colorado Highways, 1998–99 (does not include bank-slips)

Forecast Office	Inclusive Highways	Natural Avalanches	Triggered Avalanches	*Total*
Silverton	US 550 Ouray to Coal Bank Pass; US 145 Lizard Head Pass; Colo. 110 (Silverton to Gladstone)	111	79	***190***
Eisenhower Tunnel	US 40 Berthoud Pass; US 6 Loveland Pass; I-70 Georgetown to Vail Colo. 82 Independence Pass	8	32	***40***
Pagosa Springs	US 160 Wolf Creek Pass; US 50 Monarch Pass; Colo. 17 Cumbres and La Manga passes	8	1	***9***
Western Slope	Colo. 133 McClure Pass; Colo. 139 Douglas Pass; Colo. 65 Grand Mesa; Colo. 24 Tennessee Pass; Colo. 82 Shale Bluffs, Snowmass Canyon; I-70 Glenwood Canyon	3	11	***14***
			Total	***253***

CDOT/Silverton Forecast Office

The Silverton Forecast Office has completed its seventh winter monitoring and forecasting avalanches for some 97 slide paths along the US 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 Andy Gleason and Doug Lewis prepared daily evaluations to keep CDOT apprised of avalanche conditions in their region.

Weather: This winter came in like a lion, was a lamb most of the season, and went out like a lion. Early snow in October and November required avalanche control in early November. Mid winter was mostly mild except for an avalanche cycle in late January. Spring was very mild during March, with the annual wet slide cycle about one month early. Late spring was more like winter for the San Juans. They received up to 100 in. of snow during April and another 50 in. in early May. By late March the snowpack for the San Juans was dangerously low, averaging below 50 percent of normal at Snotel sites. But with April and May's snowfall, the averages rebounded to normal and above.

Here are some of the highlights. October and early November had a significant amount of snowfall (75 in.) which seemed to be a harbinger of a very snowy winter. December, however, had little snow and allowed the snow on the ground to become faceted. January brought near-normal snow and a significant avalanche cycle. Also in January a wind gust that reached 122 mph was recorded on Mt. Abrams. This was the strongest gust since wind sensors were installed in 1993. February was characterized by strong winds and warm temperatures. A few days of above freezing temperatures at mountain top levels helped to stabilize the snowpack. March had the lowest snowfall amounts on record. Only 8.5 in. of snow fell on Coal Bank Pass and 19 in. on Red Mountain Pass. Many avalanche paths melted out during March and the spring wet avalanche cycle was about one month earlier than usual. The season seemed like it was over until April brought near-record amounts of snow. There was over 100 in. of new snow on Coal Bank Pass. Snow began falling on April 22 and did not let up for more than an 18 hour period until May 5th . With 16 straight days of snowfall the snowpack went from averages of 40 to 60 percent of average to normal and above. Between May 1st and May 5th snow totals with amount of water equivalents in inches were: Red Mountain Pass, 51/3.95; Monument 40.5/3.85, Molas Pass, 27/3.0; Coal Bank Pass 30.5/3.1. This significant volume of snow created an avalanche cycle that forced closure of Red Mountain Pass twice.

The following table shows the total snowfall and water equivalent for selected study plots.

Season Snow and Water Equivalent in Inches

Station	Total Snow	Water Equivalent	Comments
Red Mountain Pass	340.5	32.85	116% of normal at seasons end*
Molas Pass	269.5	29.15	182% of normal at seasons end*
Coal Bank Pass	307.5	34.4	139% of normal at seasons end*
Monument/Idarado	208.5	19.45	202% of normal at seasons end*

* All data based upon Snotel yearly averages on 5-11-99

Avalanche: With early fall snow in November the snowpack started out with a stable base. These first snows were wet and heavy which prevented the entire snowpack from becoming faceted during December's clear and dry spells. Near surface facet layers, formed in December and early January, became the weak layers for the avalanche cycle in the third week of January. Wind loading contributed to some large slides during this cycle.

A significant storm event occurred on March 12th when a very localized storm brought snow at a rate of more than 2 inches per hour to the Uncompahgre Gorge on the north side of Red Mountain Pass. This area received 18 in. of snow in about 9 hours whereas other regions got only 2–6 in. of snow in the same period. This was the result of a wrap-round, closed low pressure system which affected only the north side of the San Juans. There was an avalanche cycle in the gorge but nowhere else.

The snows of April were mostly wet and heavy and bonded well to the old snow surface. In many cases the snow fell on bare paths and bonded well to the ground. There was relatively little avalanching during April compared to the amount of snow that fell. All avalanches were direct action avalanches with little or no propagation into the lower, basal layers of the snowpack. May's avalanche cycles were also direct action with all slides confined to surface layers. Total length of avalanche debris at center line due to natural and artificial avalanches was 955 feet. Depth at center line ranged form 1 foot to 10 feet and averaged about 4 feet.

Avalanche control missions were carried out 15 times this season. Molas, Coal Bank and Lizard Head passes had one each, the rest were on Red Mountain Pass. Thirteen missions were conducted with the avalauncher, two with the Howitzer and one training mission was done with the helicopter. Red Mountain Pass was closed for a total of 110 hours (4.6 days); Molas and Coal Bank passes, 17.25 hours; Lizard Head Pass, 5.5 hours.

More than 140 natural and triggered avalanches were tallied that did not hit the road. Those that did reach the road collectively put a large volume of snow on the centerline, which is shown below.

Highway	Debris on Centerline (depth/length)
Red Mtn Pass	2–10 ft x 6,940 ft
Molas/Coal Bank	11 naturals hit road, 3 triggered hit road for 2–5 ft x 708 ft
Lizard Head Pass	3 naturals hit road for 2–5 ft x 200 ft
CO 110, Gladstone	1–4 ft x 550 ft

Other: The forecasters presented several avalanche training courses and seminars in the region. In all, they spent more than 70 hours teaching 446 CDOT and public participants. They conducted six newspaper interviews and one interview for television.

CDOT/Pagosa Springs Forecast Office

The Pagosa Springs Forecast Office is located in the CDOT maintenance barn and staffed by Mark Mueller. The office completed its sixth winter of operation this spring. The forecast region includes US 160, Wolf Creek Pass; US 50, Monarch Pass; and Colorado 17, Cumbres and La Manga passes.

Weather: This winter was dry except for two wet months, October and April, that were like bookends at the beginning and end. October data is included in this year's snowfall and precipitation report because it was wetter than normal and set the stage for the winter. At Wolf Creek and Cumbres passes wet, dense snowfall in October and early November became a very strong layer. This would prevent any avalanches from running on the ground. After mid-November snowfall became rare, a trend that would continue until April. By the time a moisture-laden storm brought 5–7 ft of snow in early April, the mild, mid-winter weather had decreased the potential for even large avalanches to effect the highways.

As the season drew to a close, the study plot at the CDOT facilities just east of the summit of Wolf Creek Pass established an April snowfall record. By April 26th, 113 in. of snow had fallen during the month. The previous record was 100 in. established in 1968. (Weather records go back to the late 1950s at this site.) The following tables show monthly statistics from the forecaster's study plot at the summit of the pass.

Monthly Snowfall at Wolf Creek Pass (10,880 Ft) in Inches

Oct [1]	Nov	Dec	Jan	Feb	Mar	Apr [2]	Total
61	54	31	35	21	11	82	296

1. This is a conservative estimated snowfall total. Observations in October were made regularly but not daily.
2. Total snowfall to April 28th.

Snow Water Equivalent in Inches

Site	*Month*								*Percent of Normal*
	Oct	Nov	Dec	Jan	Feb	Mar	Apr [1]	Total	
Wolf Creek Pass	M [2]	8.4	2.5	3.5	2.6	1.1	6.4	24.5	
Wolf Creek Snotel	11	6.5	3.1	3.4	2.9	1.6	9.2	37.7	95
Upper San Juan Snotel	11	6.6	3.4	3.7	2.6	0.9	8.6	37.3	108
Cumbres Snotel	6	6.2	0.8	2.8	1.5	1.8	6.3	25.5	102
Monarch Snotel	4.1	1.8	0.6	3.5	1.2	1.8	2.6	16.2	84

1. April data to April 28th.
2. Daily precipitation observations began 11/1.

It was a very windy spring. On April 9th a record gust of 96 mph was documented at the anemometer site above the pass at 11,780 ft. This is the instrument's 5th season at this location.

Avalanche: Slide activity was very limited this winter. No avalanches effected Wolf Creek, Cumbres or La Manga passes. This was due to a stronger than normal snowpack and not enough mid-winter snowfall to significantly stress the snowpack. Fragile snow layers existed throughout the winter but by the time the long awaited storm arrived in April it was a matter of too-little-too-late. Road closures were not necessary for general avalanche danger but short traffic delays (3 hours total) for control missions occurred on January 21st and April 5th on Wolf Creek Pass.

On Monarch Pass, with colder temperatures and less early season snowfall, the snowpack was weaker. Only small avalanches on Big Slide, and numerous other bank slides, effected the road. A storm that dumped 60 in. of new snow in late January caused the only significant avalanche cycle of the season. A small avalanche on Big Slide struck a snowplow but there were no injuries and damage was minor. Following this large storm, avalanche control was

necessary on January 22nd to ensure an adequate margin of safety. Traffic was delayed only 1 hour.

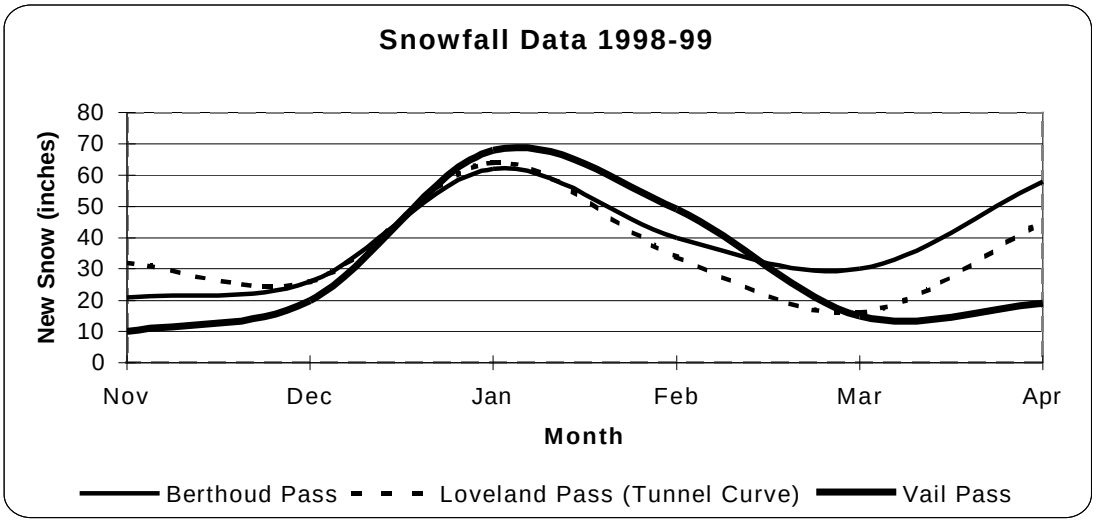
Other: Mild weather and a slow avalanche season allowed continued investigation into historical weather and avalanche data from Wolf Creek Pass. A paper, "A Brief Avalanche History of Wolf Creek Pass," has been developed from this research. Some 158 participants, both public and CDOT, received avalanche training from this office during the winter.

CDOT/Eisenhower Tunnel Forecast Office

This was the sixth season of operation for this office. Lead forecaster Lee Metzger and coworker Cathy Fraser staffed the office which is housed in the CDOT engineers building (Road Control) at the west portal of the Eisenhower Tunnel.

The forecast area covers CDOT Region 1. This includes US 40, Berthoud Pass; US 6, Loveland Pass and Interstate 70 from Georgetown to Vail. Cameron and Independence passes are monitored when required. Snowfall and weather data are gathered daily from snow study plots located at Road Control, Berthoud Pass, Loveland Pass, Vail Pass and the highway shop near Arapahoe Basin. All data are stored in the computer and monthly summaries are distributed to CDOT shops, highway supervisors and the CAIC.

Weather: This season was generally uneventful. The early-season snowpack quickly turned to depth hoar, setting the stage for a potentially dangerous avalanche season. But that was not the outcome. While some storms did bring avalanche activity, many did not increase the danger appreciably. The graph below shows the roller coaster ride of monthly snowfall amounts this winter.



Monthly Snowfall from Selected Sites

Avalanche: The only avalanche "incident" to involve the highway was on February 23rd when a skier triggered a slide in the Seven Sisters on Loveland Pass. The avalanche closed the road from 2:30 pm to 3:46 pm. Skiers had also triggered previous slides but none had reached the road. There was a close call near the west end of the Eisenhower Tunnel when, on January 9th, two skiers and two dogs were caught in a slide they triggered. The skiers and one dog escaped, one dog was never found.

The snowpack began turning isothermal by the end of March. Mild temperature gradients lingered only in isolated pockets on northerly aspects. However, late spring snows and warmer temperatures contributed to wet-snow avalanches. This threat persisted and forecasting continued well into May. See Table 5, "Avalanches Reaching Colorado Highways," below for more information.)

Other: More than 100 people, both CDOT and public, participated in avalanche classes taught through this office.

CDOT/Western Slope Forecast Office

The Western Slope Avalanche Forecast Office, based in Carbondale, provides avalanche forecasting services to Region III, Maintenance Section 2, for four highways in the Central Mountains. Colorado 133 over McClure Pass near Marble is the primary area of responsibility. Additional forecasting is provided for Colorado 139 at Douglas Pass, Colorado 65 on Grand Mesa, and US 24 at Battle Mountain. Forecaster, Rob Hunker issued 33 Avalanche Hazard Advisories to CDOT from November 6th to April 2nd.

Weather: Normal precipitation for October and half of November was followed by a dry December and first half of January. There were only three storms this season with a duration of 4 days or longer. The first came in early November, the second in late January and the third in early April. None of these were considered major in the context of creating significant avalanche danger for the highways. By March 31st, snowfall and precipitation averages on McClure Pass had decreased to a low of 75 percent and 50 percent of average respectively. This year will be remembered as mild with very little snowfall, but windy. Wind speeds were above average both during snowfall periods and during fair weather. The following is a breakdown of monthly snowfall totals on McClure Pass.

Nov	Dec	Jan	Feb	Mar	Apr	**Total**
37 in.	24 in.	44.5 in.	32.5 in.	16 in.	32 in.	**186 in.**

The high water content of the October and November snows, combined with warm air temperatures, created a strong early season snowpack. However, this quickly reverted to kinetic grain growth in December and early January with dry and cold air conditions. By the end of January a typical Colorado snowpack existed that consisted of a weak, faceted basal layer covered by a stiff slab, just waiting for a larger load to cause widespread avalanches.

Avalanche: The first and only road closure in Region 3 occurred on Grand Mesa on January 21st. Three natural avalanches reached the highway and a subsequent explosive control mission put 11 more slides onto the road. This was a very unusual winter for Grand Mesa because it is normally closed from 5 to 9 times per season for avalanche control work. In fact, this was a very unusual winter for the other areas as well. On McClure, Douglas and Battle Mountain passes no avalanches reached the road, nor was there a wet avalanche cycle this spring.

Drought conditions prevailed during February and March and the snowpack began to melt out. Thus, the avalanche season was short with little avalanche activity. It ended by late March. A summary of road closures and avalanches reaching the roads is shown below.

Highway	Natural avalanches	Triggered avalanches	Road closures
CO 133, McClure Pass	0	0	0
CO 65, Grand Mesa	3	11	1
CO 139, Douglas Pass	0	0	0
US 24, Battle Mountain	0	0	0

Other: This office investigated the backcountry avalanche fatalities at Grand Mesa on January 30th and Cumberland Pass on February 6th. Rob's write-up on the Cumberland Pass accident can be found in this season's last copy of *The Beacon*, Vol. 3, No. 3.