

NORTHWEST WEATHER & AVALANCHE CENTER

2001-2002 ANNUAL REPORT-JUNE 2002



Report Prepared by Mark Moore, Garth Ferber and Kenny Kramer

A partnership between the USDA Forest Service, Washington State Department of Transportation, Washington State Parks and Recreation Commission, Washington State Snowpark and Snowmobile Programs, National Weather Service, National Park Service, Pacific Northwest Ski Area Association, British Columbia Ministry of Highways, Friends of the Avalanche Center and others



Cover Photo credits:

Shuksan Arm Knob Avalanche—natural 3-5 meter slab that released around noon on 2-14-99 and claimed two lives. Photo taken from within the ski area toward Shuksan Arm Ridge and the convex roll where the slide release occurred. Shuksan Arm Chair #8 (Hemispheres Chair) is in the foreground of the picture, with Rumble Gully just over the ridge beyond the chair. A possible cornice collapse which may have been involved in the release is along the ridge to the upper right of the fracture line. Note the many secondary (some relatively large) fracture lines triggered by the main release in the upper center of photo. The Shuksan Arm ridgeline lies in the wilderness right to left at top of the photo, with Mt Shuksan off camera to the left. The traverse track that is commonly used by skiers and snowboarders to access terrain within the Mt Baker Wilderness runs diagonally from right to left just below the rock cliff in the middle right of the photo. The old fracture line just below the ridgeline in the upper right rear of the photo was released through control about 3 weeks earlier to protect rescuers when a smaller avalanche caught and killed a snowboarder lower in the gully. *Photo by Mark Moore.*

NWAC 2002 Annual Report

TABLE OF CONTENTS

TABLE OF CONTENTS	3
LIST OF FIGURES AND TABLES.....	5
FIGURES.....	5
TABLES.....	5
SUMMARY AND MISSION STATEMENT.....	6
MISSION—	6
SUMMARY—.....	7
<i>Administration</i>	7
<i>Funding</i>	7
<i>Housing & Location</i>	7
<i>Staff</i>	7
DIRECT PROGRAM BENEFITS—	8
<i>Avalanche Accidents and Public Snow Safety</i>	8
<i>Highway and Ski Area Maintenance and Snow Safety</i>	8
<i>Education</i>	8
<i>Applied Research</i>	9
<i>Field Data</i>	9
WEATHER AND AVALANCHES.....	10
LATE OCTOBER AND NOVEMBER.....	10
DECEMBER.....	10
JANUARY.....	12
FEBRUARY.....	15
MARCH.....	17
APRIL.....	20
MAY.....	22
AVALANCHE ACCIDENTS	26
CLIMATE.....	29
GENERAL—.....	29
<i>NRCS SNOW PACK SUMMARY—early June</i>	34
DECEMBER.....	34
JANUARY.....	35
FEBRUARY.....	35
MARCH.....	35
APRIL.....	36
MAY.....	36
FIELD.....	37
THE EARLY SEASON—OCTOBER-DECEMBER.....	37
MID-SEASON.....	38
<i>Snoqualmie Pass</i>	38
<i>Mt Hood Meadows</i>	38
<i>Mission Ridge</i>	39
<i>Timberline</i>	39

<i>Crystal Mountain</i>	39
<i>Tumwater</i>	40
<i>Hurricane Ridge</i>	40
<i>Mazama</i>	40
<i>Washington Pass</i>	40
<i>Stevens Pass</i>	40
LATE SEASON	40
<i>Miscellaneous</i>	40
OFFICE	42
NWAC PRODUCT DISSEMINATION AND WEB SITE	43
TRAINING	45
PUBLIC RELATIONS/EDUCATION	46
FUNDING	50
APPENDIX	53
NWAC AND AVALANCHE RELATED ARTICLES	53

List of Figures and Tables

Figures

FIGURE 1. FORKS (QUILLAYUTE), WA FREEZING LEVELS AND STEVENS PASS, WA PRECIPITATION FOR DECEMBER, 2001	11
FIGURE 2. FORKS (QUILLAYUTE), WA FREEZING LEVELS AND STEVENS PASS, WA PRECIPITATION FOR JANUARY, 2002	13
FIGURE 3. FORKS (QUILLAYUTE), WA FREEZING LEVELS AND STEVENS PASS, WA PRECIPITATION FOR FEBRUARY, 2002	16
FIGURE 4. FORKS (QUILLAYUTE), WA FREEZING LEVELS AND STEVENS PASS, WA PRECIPITATION FOR MARCH, 2002	18
FIGURE 5. FORKS (QUILLAYUTE), WA FREEZING LEVELS AND STEVENS PASS, WA PRECIPITATION FOR APRIL, 2002	21
FIGURE 6. NUMBER OF DAYS/MONTH WITH WARNINGS OR SPECIAL STATEMENTS--1973-2002.....	23
FIGURE 7. TOTAL NUMBER OF DAYS/YEAR WITH WARNINGS OR SPECIAL STATEMENTS	23
FIGURE 8. FORKS (QUILLAYUTE), WA FREEZING LEVELS AND STEVENS PASS, WA PRECIPITATION FOR MAY, 2002.....	24
FIGURE 9. US AVALANCHE FATALITIES BY YEAR AND 5-YEAR MOVING AVERAGE	26
FIGURE 10. 2001/02 US AVALANCHE FATALITIES BY CATEGORY	27
FIGURE 11. 2001/02 US AVALANCHE FATALITIES BY STATE	28
FIGURE 12. SNOWDEPTH DATA FROM MT BAKER, WA FOR 2000/01 AND 2001/02 VERSUS CLIMATOLOGICAL AVERAGE DEPTH	29
FIGURE 13. SNOWDEPTH DATA FROM STEVENS PASS, WA FOR 2000/01 AND 2001/02 VERSUS CLIMATOLOGICAL AVERAGE DEPTH.....	30
FIGURE 14. SNOWDEPTH DATA FROM SNOQUALMIE PASS, WA FOR 2000/01 AND 2001/02 VERSUS CLIMATOLOGICAL AVERAGE DEPTH.....	30
FIGURE 15. SNOWDEPTH DATA FROM PARADISE ON MT RAINIER, WA FOR 2000/01 AND 2001/02 VERSUS CLIMATOLOGICAL AVERAGE DEPTH	31
FIGURE 16. SNOWDEPTH DATA FROM MT HOOD, OR FOR 2000/01 AND 2001/02 VERSUS CLIMATOLOGICAL AVERAGE DEPTH	31
FIGURE 17. SNOQUALMIE PASS ACCUMULATIVE SNOWFALL BY YEAR—1949/50 TO 2001/02 (DATA THROUGH 4/04/02).....	32
FIGURE 18. SEASONAL PRECIPITATION FOR STEVENS PASS, WA--OCT-MAY, 1973-2002.....	33
FIGURE 19. MONTHLY PRECIPITATION FOR STEVENS PASS, WA--2001/02 VERSUS AVERAGE.....	33
FIGURE 20. NWAC WEB SITE HISTORY FROM 9/30/96 TO 6/9/2002—WEEKLY SITE ACCESSES (x1000).....	43
FIGURE 21. ANNUAL PHONE CALLS TO AVALANCHE AND WEATHER HOT-LINE RECORDERS (1991-2002).....	44
FIGURE 22. 2001/02 HITS ON NWAC WEATHER AND AVALANCHE PRODUCTS	44
FIGURE 23. 2001/02 NWAC FORECAST ACCESSES VIA THE WEB	45
FIGURE 24. NWAC ANNUAL COOPERATOR FUNDING--PIE CHART FOR 2002 (FUNDING SHOWN INCLUDES ALL MAJOR COOPERATOR CONTRIBUTIONS, INCLUDING PNSAA)	51
FIGURE 25. NWAC ANNUAL EXPENSES--2002 PIE CHART	51

Tables

TABLE 1. US AVALANCHE FATALITIES BY ACTIVITY CATEGORY	27
TABLE 2. US AVALANCHE FATALITIES BY MONTH--1997-2002	28
TABLE 3. NWAC PRESENTATIONS AND INTERVIEWS 2001/2002	47
TABLE 4. NWAC TOTAL PROGRAM COSTS FOR 2002--DIRECT + INDIRECT CONTRIBUTIONS	52

Northwest Weather & Avalanche Center 2001/02 Annual Report

NWAC Program administered by USDA-Forest Service
with cooperative funding and support from:

- Washington State Department of Transportation
 - National Weather Service
 - National Park Service
- Washington State Parks and Recreation Commission (including Snowmobile and Snowpark Programs)
 - Pacific Northwest Ski Area Association
 - Friends of the Avalanche Center
- BC Ministry of Highways and Transportation
 - and other private organizations

Report prepared June 2002 by Mark Moore, Garth Ferber and Kenny Kramer

SUMMARY AND MISSION STATEMENT

Northwest Weather and Avalanche Center

Mission—

The Northwest Weather and Avalanche Center (NWAC) promotes safety by helping reduce the impacts of avalanches and adverse mountain weather on recreation, industry and transportation in Washington, Oregon and southern British Columbia through data collection, forecasting and education.

To achieve this mission, the NW Avalanche Center:

- assists a variety of snow safety and snow maintenance programs by providing and analyzing useful weather snow and avalanche data, and by producing and distributing a variety of mountain weather and avalanche forecast products.
- assists back country travelers by providing current information on snowpack structure and avalanche danger, and by forecasting expected changes in snow and avalanche conditions.

The professional mountain meteorologists and avalanche specialists at NWAC are on duty from September through June, issuing twice daily forecasts from about mid-November through mid-April and special statements as warranted in the early Fall and mid-late Spring.

Summary—

Administration

Since its inception, the NWAC has been administered by the US Department of Agriculture-Forest Service.

Funding

The Avalanche Center is cooperatively funded by a variety of federal, state and private agencies. Important cooperators include the Washington State Department of Transportation, Washington State Parks and Recreation Commission (Snowmobile and Snowpark Programs), National Weather Service, National Park Service, Pacific Northwest Ski Areas Association, British Columbia Ministry of Highways and Transportation, and others.

During it's research phase of operation in 1976-78, the Avalanche Center annual operating costs were ~\$81,500, and these costs were shared by WSDOT and The Federal Highway Administration. This provided short summary weather forecasts for three major mountain passes and a short avalanche forecast for about 4 months/year.

In Fiscal Year (FY) 2000, annual operating costs were ~\$245,000, for FY2001 ~\$247,000, and for FY2002 ~ \$238,000, with decreased funding levels expected for FY2003. However, the program now provides detailed twice daily meso-scale weather and avalanche forecasts for all the Washington Cascades and Olympics, and northern Oregon Cascades—or together for an area larger than Switzerland. These forecasts are routinely available for 6 months/year, with spot forecasts prepared for the southern BC Cascades and Crater Lake area in Oregon as needed for 8 months/year. NWAC forecasters also prepare daily weather forecasts for WSDOT avalanche control and maintenance personnel for higher pass closure and opening operations in the early fall and mid-late spring. The program also **manages the most comprehensive real-time mountain weather data network in the US.**

The total of Direct (actual revenues received) and Indirect (in-kind) contributions for the Avalanche Center in were ~\$348,825 in FY98, ~\$378,275 in FY99, ~399,000 in FY2000, ~\$405,000 for FY2001, and ~\$399,000 in FY02.

The Colorado Avalanche Information Center (CAIC) also provides forecasts and avalanche control / recommendations for the Colorado Department of Transportation (CDOT) for a series of mountain passes. CDOT support of the CAIC program for FY2001 totaled nearly ~\$270,000 (FY02 figures not yet available).

Housing & Location

The NWAC is housed at the National Weather Service Forecast Office in Seattle, Washington, at the Western Regional Headquarters of NOAA at Sandpoint. The National Weather Service provides in-kind contributions of office space, computer, weather and satellite data access, and dissemination services and has also contributed periodic capital equipment (weather sensors).

Staff

To help minimize cooperator costs, three professional avalanche/weather forecasters are employed for 9-10 months/year, with a fourth forecaster intermittently available for spot forecasting during the winter months. Non-forecast season duties include planning and maintenance of the data network and related services (including web site development), program administration, education, cooperation with program cooperators, and data application of new weather and avalanche technology to meet program goals.

Direct Program Benefits—

Avalanche Accidents and Public Snow Safety

Soaring back country usage during the last 30 years (cross country skiing and then snowmobilers and snowboarders) has produced **an annual average avalanche fatality toll in the United States that has risen from 5-10/year in the early 1970's to approximately 28 deaths/year** (5-yr moving average), with 32 fatalities recorded in 1998-99, and 33 in 2000-01— both unfortunate modern-day records (since 1950). This trend toward increased numbers of avalanche fatalities nationwide continued in 2001-02 with 32 fatalities reported through early June, 2002.

However, **in the Northwest the fatality toll has and has been declining slightly and now stands at an average of ~2/year** (5-yr total of 11 fatalities for Washington and Oregon from 1997/98-2001/02).

It is believed that avalanche education and forecasts have resulted in a significant reduction in both avalanche accidents and resulting rescue efforts and costs, hence stabilizing or reducing the number of avalanche fatalities despite major increases in winter back country use and recreation.

There are many documented instances where travelers canceled trips or rescheduled timing or locations of planned trips based on forecast information.

There is also significant documented evidence of popular public response to the program—the NWAC Avalanche Forecast Hotlines now log between 10 and 15,000 phone calls annually, with about **1.6 million hits** on NWAC avalanche and mountain weather products via the web during the past year (2001/2002).

Highway and Ski Area Maintenance and Snow Safety

Washington State Department of Transportation claims considerable annual savings through usage of the program.

WSDOT estimated that the **program saved the state approximately \$180,000 in 1977/78 and over \$330,000 in 1986/87 in direct maintenance costs, lower closure times and reduced public impact. More recently, a 1997 WSDOT study indicated that Puget Sound area businesses lose a total of \$485,000 per hour of pass closure (for Snoqualmie Pass only), with an estimated \$750,000/hour of lost revenues in 2001** (economist study, Seattle PI, December 2001). This means that a total of about 16 million dollars is lost by local area businesses for every day of I-90 pass closure (other concurrent pass closures would increase this figure). Such a figure underscores the economic importance of a reliable and accurate avalanche and mountain weather forecasting program. These figures do not include the increased safety margin for highway travelers owing to a more effective and responsive avalanche control and highway maintenance program.

The ski industry (PNSAA and NW ski schools) claim significant benefits in daily area operation, school and work planning, lift operations, and snow safety programs.

Forest Service personnel also allege more efficient maintenance and grooming of popular cross country and snowmobile trails as a direct result of NWAC forecasts.

Education

NWAC forecast staff present a variety of avalanche, weather and snow safety seminars which educate the public and cooperators. During the last 5 years, over 10,000 people have attended

avalanche and weather presentations by forecast staff and Friends of the Avalanche Center associates.

Applied Research

Forecast staff constantly tries to apply and advance state-of-the-art techniques in weather and avalanche science. To meet this goal forecasters attend a variety of training sessions or workshops.

Forecasters have also been instrumental in aiding advances in weather sensors and automated weather sensing techniques, as well as contributing significantly to methodology for avalanche and weather forecast dissemination.

To share these techniques and help expand avalanche and/or weather awareness, forecasters give a variety of presentations at International Snow Science Workshops, the National Avalanche School, and other weather and snow seminars.

Field Data

The NWAC plans, develops, installs and maintains the most comprehensive data network of its kind in the United States. A network of 24 remote automated weather stations (most consisting of at least two or more sub-stations) telemeter hourly precipitation, snowdepth, temperature, wind and relative humidity data to the NWAC. Data from these stations is automatically linked to the NWAC web site in order to provide both the public (skiers, snowboarders, hikers, climbers and other recreationists) and cooperators enhanced access to real-time weather and avalanche-related data. The NWAC utilizes the mountain weather data to support more accurate forecasts, and cooperators utilize the information for planning, maintenance and avalanche control purposes.

WEATHER AND AVALANCHES

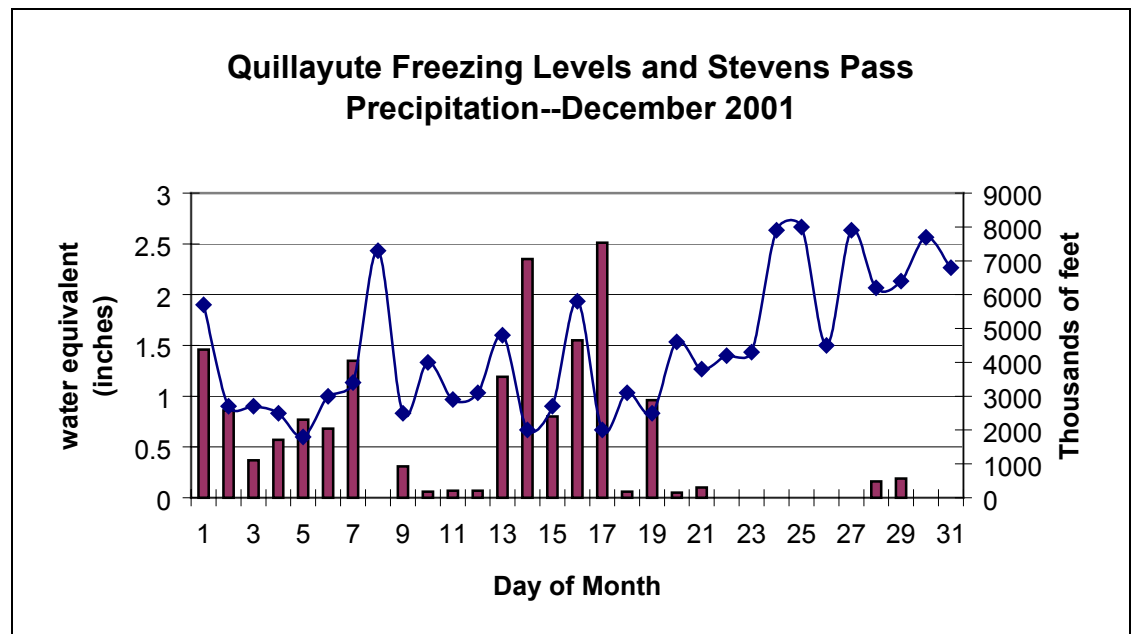
Late October and November

The Northwest received an initial round of snow in late October, but the amounts were only enough for some early backcountry skiing in areas having a smooth underlying ground surface such as grassy meadows on Green Mountain! Then, a broad flat upper ridge prevailed and shunted most significant moisture northward, bringing generally dry and relatively mild conditions for much of early-mid November. This helped melt much of the earlier October snow pack and helped prevent significant faceting of the shallow snow. Finally the ridge broke down in mid-late November and allowed an increasingly strong storm track to develop across the Northwest, a storm track that aimed at the west coast and continued relatively constantly until mid-December. While initially the freezing levels remained above the lower passes, several major storms arrived in mid-late November that began to increase the snow depths above 4 to 5000 feet and produce an increase in the avalanche danger. While not starting regular daily forecasting yet, the NWAC issued several special statements (on the 21st and 22nd) over the long Thanksgiving Day weekend as the avalanche potential gradually increased at mid and higher elevations and began to bury terrain and vegetative anchors. While lower elevation snow pack still remained relatively thin below about 4000 feet (less than 20 inches at Stevens Pass), enough snowfall accumulated at higher elevations that Mt Hood Meadows ski area opened on the 24th, with Crystal Mountain and Mt Baker quickly following on the 25th of November. Also, on the 24th of November a very lucky snowboarder survived a 5-6 minute total avalanche burial near Paradise on Mt. Rainier—a relatively small slide that he triggered and which swept him into a creek drainage and associated terrain trap. While he had a transceiver, his partner had left his beacon back in the car. Fortunately a small dime-sized part of his snowboard binding protruded from the snow and was observed by his friend, who was able to probe and dig him out in time. His amazing recounting of this incident can be found on the NWAC web site at http://www.nwac.noaa.gov/PVC_11_24_01-9_lives.htm and is recounted in the Appendix. As larger and more vigorous storms began to arrive during the last week of November, the Avalanche Center issued daily special statements before commencing regular daily operation on Wednesday, November 28th.

December

A very strong zonal westerly flow rotating around a deep upper low in the northern Gulf of Alaska then directed a series of strong weather systems over the Northwest from late November through mid-December. As freezing levels remained consistently low from the 28th of November through the morning of December 7th, heavy snow accumulations were reported throughout the region and most snow packs doubled their depth during this time (also see the precipitation and freezing levels shown in Figure 1 below). Cumulative snowfalls for the 10-day period 11/28-12/7/01 ranged from a low of about 60 inches to over 120 inches, or an average of 6-12 inches/day every day. Several weak layers developed in the snow pack from variations in wind speeds and temperatures during and in between storms, and this produced several significant avalanche events. On December 1st, an out of bounds skier was hit by a soft slab but not buried at Mt Hood Meadows. Then on December 2, lots of direct action natural and triggered very soft slabs were reported, along with some isolated deeper slides released with explosives. At Mt Baker, several 4 to 5 ft slabs released on Hemispheres and “The Elbow”—with these slides reaching down to the crust formed during the warming and heavy rain early in the Thanksgiving Day weekend. And Mission Ridge reported 3 foot soft slabs released from ski cuts, some running sympathetically and most running full path and full width on Saturday Dec 1st. One slide path released as a patroller—who was still over 100 feet away—approached it!!

Figure 1. Forks (Quillayute), WA Freezing levels and Stevens Pass, WA precipitation for December, 2001



On the 5th of December, Mt Hood Meadows and Timberline received 32 inches of snowfall in 24 hrs. The result—issuance of the first avalanche warning of the season and lots of natural avalanches, as well as a significant number of controlled soft slabs from skis and explosives. Most slides involved only the most recently deposited snow and most of these ran on a weak layer about 1 foot down in the snow pack. However, lots of deep unconsolidated snow remained in the backcountry and forecasters continued to be wary of the potential for larger slides releasing to the old Thanksgiving crust. Fortunately though, significant snow pack settlement and the lack of large loading events with high freezing levels and rain confined most avalanche activity to the most recently deposited snow and prevented all but isolated slide releases from reaching the old crust. While the majority of avalanche events were direct action and storm related, near Alpental ski area several steep avalanche paths overlying smooth rock faces released to the ground producing 5-6 ft fractures. Also, on an east facing steep slope in White River Canyon between Mt Hood Meadows and Timberline, the Meadows snow safety director reported what appeared to be a 20+ ft fracture line and associated debris just below a cornice.

Storms briefly let up for a day or so around the 7th of December when a brief upper ridge followed the large upper trough that had brought sustained heavy snowfall. However, the break was very brief and a gradually increasing west-northwesterly flow began to move back over the area on the 8th. This flow brought significant amounts of relatively low density snow at low freezing levels on the 9th through the 11th before a brief break and then a gradual shift toward rising freezing levels and further heavy precipitation occurred on the 13th and 14th—again see Figure 1. This brought a substantial increase in the avalanche danger with the second avalanche warning of the season issued on the 13th. Only a slight decrease in the danger occurred on the 14th as temperatures lowered and heavy precipitation became more showery. But then all of this recent new snowfall—now totaling from 150 to over 200 inches in some areas since late November—was loaded by very heavy rain or snow over the weekend of the 15th and 16th of December. Some areas received from 3 to over 5 inches of rain, with from 20 to 40 inches of additional snowfall at higher elevations. With this much loading combined with strong winds and rising freezing levels, a high to extreme danger developed mid-late on the 15th through the 16th with a major avalanche cycle reported. Widespread natural avalanching was reported in most locations later on the 15th and 16th, with both a ski patroller and a customer caught in separate avalanche accidents on the 15th at Crystal Mountain.

The last strong storm of the month moved across the area on the 18th, bringing an additional 10-20 inches of snow. While the following upper low tracked slowly across Oregon and northern California later on the 19th and 20th of December, return flow around the low brought relatively light snowfall but strong east to southeast winds. This helped to maintain considerable danger with 1 to 2 ft slabs being reported by several ski areas and back country observers. Field reports indicated that several weak layers had developed within the storm snow from the 18th along with a weaker bond of new snow to the old crust above about 5 to 6000 feet. Finally moderate to strong upper ridging built over the region on the 21st and 22nd, and this combined with a split in the westerlies just offshore diverted and weakened much of the incoming storm energy. While relatively light snowfall occurred on the 22nd, and this mostly in the south, strong ridge top winds were able to erode much of the loose surface snow deposited earlier in the week, producing an increasing danger from wind transport alone.

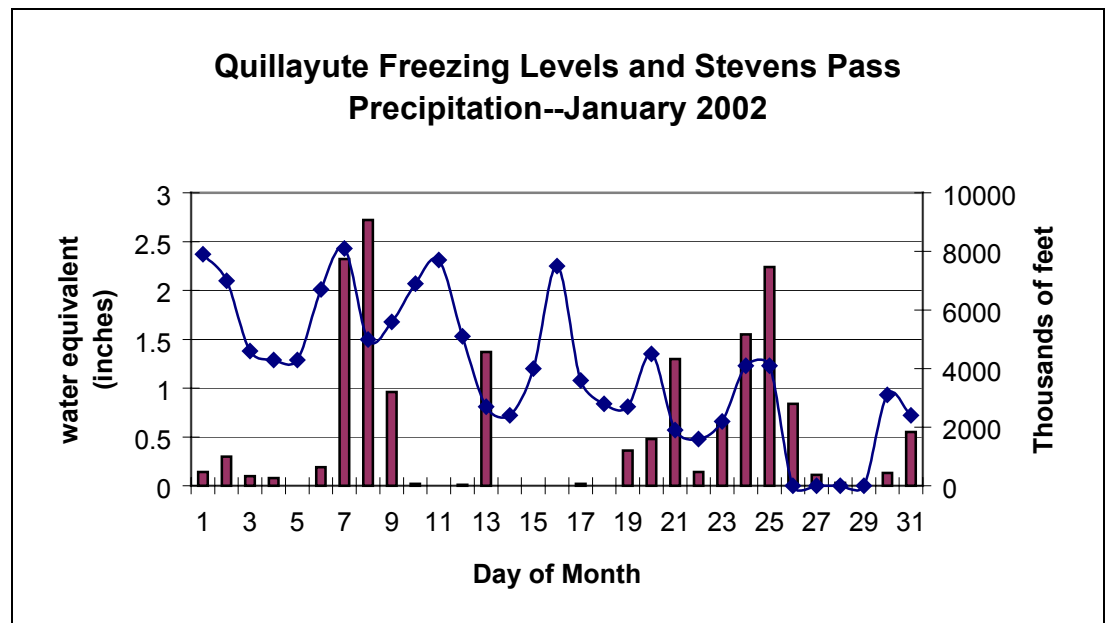
Snowfall totals for the 8 Dec to 19 Dec period ranged from about 45 inches (Crystal Mountain) to 115 inches (Paradise) for an average of about 4 to 10 inches a day for the 11-day period.

Further strengthening upper ridging and a modified omega block remained relatively stationary over the area from the 23rd-28th with only minor disturbances penetrating the slowly retreating block on the 27th. This brought generally fair skies along with slow warming aloft and gradual settlement of the heavy snowfall from earlier in the month. However, a cool easterly surface flow at lower elevations combined with widespread low clouds along the Cascade east slopes began to facet and weaken some of the upper part of the snow pack as well as the entire snow pack where depths remained shallow, such as along the Cascade east slopes and exposed ridges. Also some wind transport near the passes and along higher ridges near the crest allowed for development of some small but sensitive wind slabs—some of which formed over previous surface hoar. In areas not exposed to either the winds or the low clouds, widespread surface hoar developed—some reaching 2-3 cm in size. Near the passes and in areas affected by the winds, more sporadic and intermittent surface hoar was reported. However, overall the weakening of the snow pack and the development of surface hoar both helped to set the stage for significant increases in the avalanche danger when heavier new snowfall returned. Some warming aloft and further clear skies due to continued west coast ridge remained through December 30th, maintaining a moderate danger above about 4000 feet and a low danger below that. A slight weakening of the ridge was expected to allow a return to some weak weather systems into the New Year, however the main ridge position looked rather entrenched along the west coast in late December.

January

Minor storms and snowfall arrived during the first few days of January, with some periods of mild temperatures mainly west of the crest. However, near the Cascade passes, some cold easterly winds occurred as colder Columbia Basin air was drawn over the crest as pressures lowered to the west on the 5th and 6th of January. This gave a mix of crusts and intervening low density layers, with some freezing rain crusts near the passes. About 3-7 inches of snowfall was added to this mix of new snow and interspersed crusts on the night of January 5th. However on the 6th and 7th of January, a very strong west to southwest flow streamed over the top of flat upper ridging over or just east of the Cascades. This brought heavy rainfall for almost 48 hours in the Olympics and north-central Washington Cascades near and west of the crest with these areas receiving from 4 to 8 inches of rain (slightly lesser amounts were received in the southern Washington Cascades, with generally lighter amounts along the Cascade east slopes and “only” 1-2 inches of rain in the Mt Hood area). The freezing level rise and locally heavy precipitation that occurred near and west of the Cascade crest at this time is depicted graphically in Figure 2. This rainfall brought some of the worst western Washington flooding since 1998, and brought down some of the recent snow as well. The debris and fracture lines from some large wet loose and isolated web slab slides were subsequently observed in the back country, with some slides running down to very low angle terrain and stacking 10-20 feet of debris (these seen just east of Stevens Pass) on 10 degree slopes.

Figure 2. Forks (Quillayute), WA Freezing levels and Stevens Pass, WA precipitation for January, 2002



Following the heavy rainfall, some rather minor new snow accumulations were reported on the 8th and 9th of January, but a relatively good bond of new snow to the old crust was reported as rain changed slowly to snow. With lowering temperatures and winds during the snowfall, the increased danger from the new snowfall was rather limited. Finally a healthy non-splitting trough produced the first significant *snowfall* of the New Year over the weekend of the 12th and 13th. This snowfall ranged from 6 to over 16 inches, was accompanied by strong west winds and lowering freezing levels, and the bond of the new snow to the old refreezing or refrozen crust was rather poor, except at the lowest elevations. As a result several avalanche accidents were reported with both ski patrollers and the public taking short but no doubt memorable rides with snow pillows in very low locations lying adjacent to areas that had been heavily scoured and stabilized by the strong winds. Fortunately no one was injured and lost equipment was the only result.

Strongly rebuilding upper ridging offshore during the week of January 14th-18th produced a cool, dry northerly flow over the region. This resulted in generally fair cold weather in most areas early in the week, with a weak disturbance producing some very light snowfall mid-week followed by more clearing skies later in the week. Along with generally light winds, conditions were ideal for surface hoar, weak sun crusts on south-facing slopes and lots of near surface faceting of the snow over the old crust from early January. This set the stage for a significant increase in the danger over the weekend of January 19-20th when a series of strong upper troughs moved into the region in a generally cool west-northwesterly upper flow. Multiple layers of buried surface hoar, smooth sun and rain crusts and an abundance of faceted and low-density snow over the crust all contributed to the subsequent increase in the danger.

The expected danger increase was highlighted in the avalanche forecast some four to five days in advance as the forecast models proved very reliable during this period of very strong westerly flow. During the five-day period from the 18th through the 22nd most Cascade west slope areas and the Olympics received some 45 to 65 inches of snow with Mt Hood receiving some 80 inches of new snowfall! Unfortunately, not everyone heeded the message of greatly increased instability and danger with the new snow loading an abundance of weak layers over the early January crust. Numerous avalanche accidents occurred over the long Martin Luther King Holiday weekend, especially on Sunday and Monday, the 20th and 21st. Three separate incidents occurred in the Stevens Pass backcountry Monday with several injuries and nine people in two parties caught and either fully or partially buried along with minor to moderate injuries, including a possible broken arm and leg. Near Crystal Mountain a veteran pro patroller was caught and taken for a long ride by an unexpected 1-2 ft

slab after doing control on the slope—fortunately only lost equipment was reported with minor injuries and a very sore body the next morning. Further to the south, en route to help find and rescue a party of two that had triggered and been caught by avalanches, a party of four backcountry patrollers were caught Sunday at Crater Lake National Park in southern Oregon with one would-be rescuer buried head first to his waist and another buried 5 to 6 feet for 30 to 40 minutes before being found alive by avalanche beacon. It is amazing and very fortunate that all of the avalanche victims survived. But the accidents and the unstable snow pack structure were certainly a BIG eye and mind opener for many, and all of this helped to underscore the first annual Washington State Avalanche Awareness Week, proclaimed by Governor Gary Locke from January 21st through the 27th of 2002.

With a deep upper low moving out of the Gulf of Alaska on the 23rd and 24th, a strong front was followed by moderate to heavy orographic winds. This produced significantly more heavy snow, strong ridge top winds, and slightly rising freezing levels on Thursday and Friday, the 24th and 25th. With the additional loading—now totaling from 6 to over 10 feet over the early January crust—natural and human triggered slides became increasingly likely once again, and the Avalanche Center issued Avalanche Warnings for three consecutive days from the 24th-26th, the first with a high to extreme danger. While some settlement limited the depth of most avalanches to the most recently deposited snow, some isolated 4 to 6 ft slabs continued to release down to the faceted snow or surface hoar lying over the early January crust. In most of the above accidents, surface hoar, a sun crust, low density low wind deposited snow (from breaks between storms) or faceted snow above the crust was involved.

The deep upper and associated surface low continued to slowly track southward along the coast Sunday and Monday, the 27th and 28th. This brought further lowering freezing levels and some light to moderate snowfall along with very light winds. Although this produced a relatively stable density profile in the upper part (6-12 inches) of the snow pack, forecasts and forecasters continued to worry about the lingering more deeply buried weak layers as well as the old crust. In fact, several statements issued during this time stressed this continuing concern (from the 01/27/02 forecast):

“While lowering temperatures and gradually diminishing winds during the past few days have produced a slightly more stable density profile in the upper 6 to 12 inches of the snow pack, significant concern remains for slides releasing on one or more of the more deeply buried weak layers....”

The lure of fluffy champagne surface snow, an overall decrease in showers and some partial clearing Sunday with further clearing Monday should not blind travelers from the continuing avalanche danger that lurks beneath the placid snow surface. Travelers are strongly urged to perform normal safety and stability tests of the snow pack and continue to make safe route selections. Several skiers and boarders have been very lucky during the past week of high danger and these accidents illustrate the need for always applying safe travel techniques and for continually assessing snow pack stability.”

As the lows moved southward late on the 27th and the 28th of January, moderate to heavy showers slowly decreased to light to moderate followed by clearing skies and increasingly cold temperatures in the northerly flow behind the low and associated cold air drainage from an arctic high that plunged southward along the east slopes of the Rockies. This colder and clear weather allowed very slow and limited stabilization of the snow pack while promoting continued faceting and weakening of the snow pack near the old crust or other strong density variations in the upper part of the snow pack. The clearing also allowed for increasing surface hoar to form, thus setting another great stage for a potential dramatic and rapid increase in the danger with the next snowfall. The large amount of new snowfall throughout much of January also brought the climatological snowdepth from near average on the 15th to much above average by the 1st of February (from ~110 to 170% of normal), as can be seen from the figures in the Climate section later in this report.

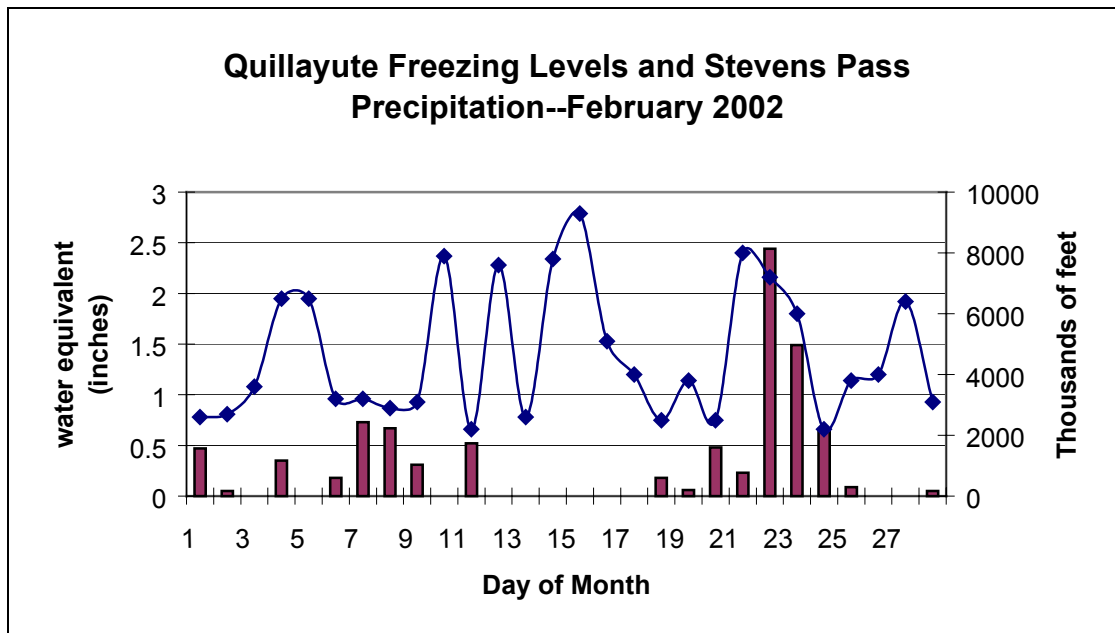
February

The new snowfall arrived with vigor during several minor storms in early February and more significantly with a deep and broad upper trough that moved over the region from the 6th-8th. The first storm series brought 12-16 inches of relatively low density snow at relatively low freezing levels, but was accompanied by moderate winds. Falling over buried surface hoar and/or very low density snow this resulted in a general increase in the danger with natural and human triggered slide releases probable. Fortunately most slides that were reported involved only the most recently deposited snow. The broad upper trough that followed brought new snowfall ranging up to 30-40 inches from February 6-8th along with significant west to southwest winds. This brought several days of sustained heavy loading to an already weak snow pack structure in the upper layers, and the ensuing instability resulted in several near misses. On the 8th at Hurricane Ridge on a heavily loaded northeast facing slope, a snowboarder triggered an 18-inch slab that carried him about 300 ft vertical through trees and into a road cut—all at about the 5200 ft level. Then on the 9th near Crystal Mountain, three separate avalanche incidents were reported involving skiers and snowboarders, all triggering recent storm snow with slabs from 1-2 feet running quickly on weak storm layers deposited during showers earlier in the week. It is interesting to note that the snowboarder reported triggering the slab from the bottom while post holing up a steep NE exposure near Three-Way Peak—such a trigger would indicate a very weak layer and very cohesive slab, with considerable stored elastic energy. Fortunately once again either no or only minor injuries were reported. However, all of the continued loading—now totaling over 100 inches in some areas since the early January crust and nearby surface hoar was buried—apparently continued to stress the old weaknesses near the crust, for on the 8th and 9th two large and widely separated explosive controlled slides occurred. The first was a 10-15 ft fracture on a NE exposure slope in the Hemispheres above the top of the Mt Baker-Shuksan Arm Chair at about 6000 feet, and the other was a 6 ft slab near Kemper's shoulder, a NE loading slope at approximately the same elevation near Crystal Mountain. Both indicated the continuing potential for large isolated slides to the old early January crust. The avalanche forecast issued on the 10th continued to discuss this layer as a possibility for deeper releases, but mainly for larger groups of snowmobilers...

“While it is unlikely that the weight of single skiers or snowboarders would be able to release such large slabs, these could be triggered by snowmobilers or groups of snowmobilers and hence extreme caution is advised when highmarking steeper heavily wind loaded terrain. Otherwise, most snow pack instability should be confined to most recent slabs from either storms last week or recent wind loading and a considerable avalanche danger remains on lee slopes near higher ridgelines in the Olympics, Mt Hood area and the Washington Cascades near and west of the crest...”

While increasing snow pack settlement on the 9th and 10th helped to begin decreasing the danger from the recent heavy snow loading, a fast moving and windy disturbance moving across the area late on the 10th produced increasing light to moderate snow and further wind slabs in most areas, as ridge top winds gusted to 70-80 mph in a variety of locations.

Figure 3. Forks (Quillayute), WA Freezing levels and Stevens Pass, WA precipitation for February, 2002



Then, could it be??? A Mid-Winter's Break?? Yes! Following the fast moving disturbance on the 10th, extended forecast models indicated an increasing ridge was expected to dominate Northwest weather for much of the next week. And in fact a large west coast upper ridge dominated the weather from Monday February 11th through Friday the 15th. (this lack of precipitation and generally higher freezing levels is shown graphically in Figure 3) above. With no precipitation, clear skies and gradual warming through the five-day period, the snow pack saw significant settlement and strengthening. While mountain temperatures reached into the mid 40's in many areas with increasingly strong sunshine, some wet loose slides were reported on south slopes both near Crystal Mountain and around Stevens Pass. No other avalanche activity was reported during this period, with the exception of the Mt Baker Wilderness area adjacent to the ski area, where helicopter bombing on Thursday February 14th produced several large avalanches with crowns of 9 to over 12 feet! These slides were triggered by large amounts of ANFO (250 pounds), and ran from the northeasterly starting zone just below the Shuksan Arm Ridge through Rumble Gully and down to near the valley floor, about 2000 ft vertical. (The Forest Service allowed explosive control of the Shuksan Arm Ridge within the Mt Baker Wilderness Area because of the perceived avalanche danger to the lower terminal of Chair #8.)

As the upper ridge grudgingly moved eastward on the 16th of February, a weak and split upper trough slowly moved over the region over the weekend of the 16th and 17th. Associated mainly light snow buried sporadic surface hoar and near surface faceted snow, helping to set the stage for a more significant increase in the danger with future heavier snowfall that was forecast to arrive the next week. Unfortunately if you're thinking avalanches or fortunately if you're not, reality did not follow the forecast models and only minor snowfall amounts arrived during much of the early-mid part of the week (the 18th-20th), bringing the weekly snowfall totals to a meager 4 to 12 inches or so. However, the lower density snow or surface hoar did get buried and set the stage for some sensitive slide releases when the really heavier precipitation arrived late on the 20th through the 22nd. However, this precipitation arrived with significantly higher freezing levels with snow or freezing rain changing mostly to heavy rain—at least in the Olympics and north-central Washington Cascades on Thursday morning, the 21st. Even though only relatively small amounts of recent snow had accumulated over either the wind hardened surface or the melt-freeze crust that had developed during the week of mostly fair and gradually warmer weather from the 11th-15th, warming and rain has a tendency to

weaken, load or loosen even the most stable of surfaces. Hence, an avalanche watch was issued on the morning of the 20th, and a warning on the morning of the 21st, both well warranted as numerous slides were reported on the 21st, starting out as relatively sensitive wind slabs and ending up the day as wet loose or wet slabs. Also as a result of this warming and rainfall, both Stevens and Snoqualmie Passes reported avalanches releasing to or crossing the highway on both the 21st and 22nd. Both passes experienced several hours of closure as a result, the most notable being approximately a four to five hour closure on Stevens Pass on the morning of the 22nd after avalanche control with the tank produced significant avalanche debris on the highway. According to one of the avalanche control team, the observed slide was one of the largest at Old Faithful #3 during the past 10 years, and the large 2-3 ft wet slab deposited some 20 feet of snow on the highway over all four lanes for 100+ feet of highway length before some of the debris flowed over the 8-10 ft high road cut and descended on to the valley floor. Other reports indicated some isolated natural slides with several reports of very large climax avalanches, several in the Snoqualmie Pass vicinity (one on shot #8 in the Alpentel ski area—about a 4-8 ft slab, and one to the east of Snoqualmie Pass near Mt. Catherine that produced from 15-20+ feet of debris plus timber that apparently ran to near the ground), and another just south of Stevens Pass near Mt. Josephine. Subsequent fracture line analysis of the Mt Josephine slide indicated that the avalanche started as a 6-8 inch which then triggered a larger 1.5+ meter slide that ran to the early January crust. This slide released about 2 PM on the 22nd, about 1.5 hours before another large natural slide released on Old Faithful #6 above US 2 just west of the Stevens Pass summit. While the path had been controlled by artillery (the tank) earlier that morning, the wet slab was apparently not yet ready to release, and even though most precipitation had stopped by mid-afternoon, the warm air temperatures continued the melt and produced an estimated 2-3 ft fracture. The ensuing avalanche hit the highway and lifted a vehicle up and over the roadside snowberm/Jersey rail and tumbled it down the embankment. The car was totaled but fortunately early reports indicate only minor injuries resulted from the incident.

Following the heavy rainfall of the 20-22nd, freezing levels slowly lowered on the 23rd along with light to moderate snowfall that helped to briefly cover and soften what could develop into a very nasty and smooth sliding surface, either with or without new snow. Unfortunately, strong northwest winds on the 23rd continued into early on the 24th and eroded much of the new snowfall from windward slopes, scouring exposed slopes down to the strengthening crust while creating some sensitive wind slabs on lee slopes. These slabs began to settle during several days of relatively clear and cold weather that followed on the 26th and 27th. However, a weak upper disturbance dropped southward in the generally northerly flow around a strengthening offshore ridge and dropped several inches of snow to most areas late on the 27th and early on the 28th. Unfortunately this new snow did little to ease the danger from the hard crust (from slips on the very firm surface) with most of its effect being to bury some recently developing surface hoar and along with some strong winds, create some additional shallow but rather sensitive wind slabs.

March

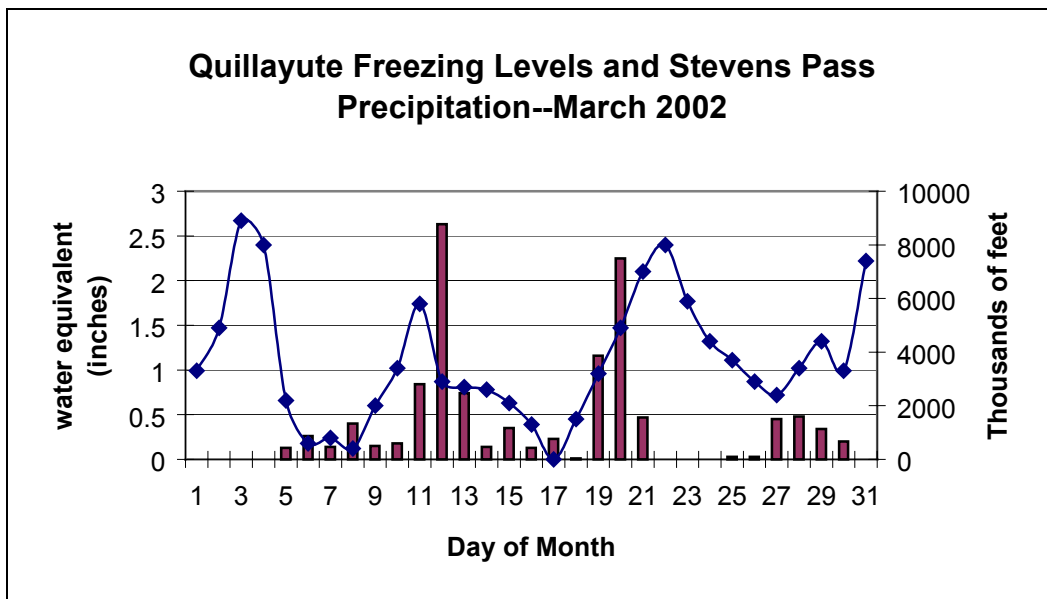
With the exception of some high clouds at times later on the 28th of February through the 2nd of March, mostly fair weather with increasingly strong sunshine dominated Northwest weather for several days. The sunshine helped develop an increasing surface crust on the recent small amounts of new snow while helping to gradually strengthen the snow after refreezing overnight. Unfortunately, the clear skies and relatively low freezing levels allowed air temperatures to plummet overnight into the low to upper teens in many areas, and this resulted in considerable faceting of snow near the recent crust from the heavy rain and very warm temperatures of late February. Along with increasing surface hoar either on this strong crust or over the sun crust, and the temperature gradient weakened bond of new snow to the crust in places that had not been scoured by winds, the stage was set for a significant increase when more significant amounts of new snow arrived.

Fortunately for stability, some warm air moved over the area March 3rd. Along with strong sunshine much of the surface hoar was destroyed. However, more hoar frost developed overnight on the 3rd and along with the crusts already in place, a significant increase in the danger was likely whenever sufficient snow arrived. Finally on the 4th and 5th of March a strong upper trough moved over and

flattened the ridge before digging southward along the BC coast and retrograding the ridge westward late on the 4th. This situation brought some modified arctic air southward and the associated strong westerly flow around the closed low converged with a warmer westerly flow moving under the offshore block to focus increasing moderate snowfall over the region (especially over the southern part) later on the 5th through the 7th, with heaviest amounts in the south Cascades and Mt Hood area. Along with very low freezing levels and some strong winds, the new snow did not bond well to the old rain or sun crust, and with areas of surface hoar buried as well, some rather sensitive but mostly shallow slabs were reported releasing on the crust on the morning of the 6th, especially in the Mt Hood area. According to the patrol director, some slides were releasing as the slope was approached. A second slightly stronger weather system moved along the southern BC coast and over the area on the 7th, bringing further light to moderate snowfall and increased winds, along with a significant amount of lowland snow. Several more weak to moderate storms moved over the region on the 8th and 9th, bringing further light to moderate amounts of snowfall at continued relatively low but slightly rising freezing levels and generally increasing winds, with new snowfall over the crust ranging from about a foot to over three feet. This generally worsening weather began to develop some increasingly sensitive 1 to 2 ft wind slabs by the 9th and 10th, producing an increasing number of skier and snowboarder triggered slides, most reaching the old late February crust. While most slides released were less than 12 to 14 inches, some isolated slabs of 2 ft + released from heavily wind loaded terrain. Also on the 10th, a skier triggered and was injured by a significant wind slab near Chair Peak in the Alpental valley in the early afternoon while another skier triggered a 12-18 inch slab on nearby Granite Mountain, fortunately surviving a 30-45 minute and 5 ft deep burial by some miraculous air holes—see the accident report at http://www.nwac.noaa.gov/Granite_Mtn_03_10_02.htm)

March continued to increase in storm ferocity on the 11th (see Figure 4 below) when a vigorous storm and associated deep upper trough rotated out of the parent low and moved over the area. The accompanying warming and very strong winds early-mid day on the 11th made for much more cohesive and slab-like surface snow—now able to propagate fractures over relatively long distances. As a result, NWAC issued an avalanche watch on the 10th for the expected heavy loading. The watch also highlighted the developing considerable danger on the 10th that caught several skiers and snowboarders in small to medium slides.

Figure 4. Forks (Quillayute), WA Freezing levels and Stevens Pass, WA precipitation for March, 2002



The heavy snow and slab layers overloaded the low density snow on many slopes, with a high quality sliding surface provided by the hard snow. Widespread natural and triggered avalanches generally up to 2-3 feet on varied steeper aspects were seen on the 10th and 11th, with rain or mixed rain and snow

reaching to about the 4000-4500 ft level in most areas. The high instability created a close call on Granite Mountain near Snoqualmie Pass on 10 March when a climber was buried for 20+ minutes after a 1500-foot ride down the mountainside. Strong west winds gradually decreased while heavy snowfall continued on the 12th and 13th with a cooling trend and another 1-2 feet of snowfall. Several 1-2 ft triggered avalanches were reported from Stevens Pass, Snoqualmie, Crystal Mountain and Mt Hood Meadows. These triggered slab avalanches were between 4000 to 6500 feet on 35-40 degree northwest to northeast aspects. Snow safety personnel report that some were very easily triggered. As the associated deep upper low slowly moved south-southeastward along the west coast from the 12th-15th, a gradually increasing amount of very low density snow accumulated along the very light winds at very low snow levels. Extremely good powder delighted hordes of winter recreation seekers with screams of ecstasy reported in many areas. Following quickly on the heels of the deep upper low another moderate short wave tracked over the region on the weekend of the 16th and 17th, producing another 1-2 feet of snow at further low and lowering freezing levels and bringing some lowland snow to western Washington. This most recent storm brought the snow totals since the Monday (the 11th) warm-up to some 2-5+ feet with over 5-9 feet now accumulated since the late February rain crust was formed. And all of this new snow was very susceptible to a dramatic increase in the danger if loaded by large amounts of high-density snow. Of course the month that had come in like gangbusters refused to leave quietly, and the westerlies—which flowed over and under an offshore rex block—merged again just offshore early on the morning of the 18th and compressed an increasing strong west to northwesterly flow over the region. A front imbedded in this strong flow moved quickly over the area on the afternoon and evening of the 18th as the northern branch of westerlies pushed the front through to the southeast. But then the old frontal boundary was quickly pushed back northward on the 19th as a southern branch ridge formed just offshore. This stalled the front over the south-central Cascades early on the 19th and over the north-central Cascades later on the 19th through early on the 20th, producing copious amounts of relatively high density snow and increasing winds. The expected gradually larger and increasingly unstable wind slabs prompted issuance of an avalanche watch on the 18th with avalanche warnings for generally high danger on the 19th and 20th as some 2-4 feet of new higher density snow accumulated over the lower density snow from the previous week along with a sporadically produced layer of surface hoar. Field reports indicated a very sensitive snow pack with sympathetic slides releases, remotely triggered avalanches and a host of avalanches and avalanche incidents. Several snowmobilers were caught in a slide near Stampede Pass and a vehicle was hit by a sluff near Stevens Pass. As snowfall rates reached upward to 2-4 inches/hour on the afternoon and evening of the 19th, WSDOT avalanche control crews on I-90 and US-2 could not keep up with the high loading rates and increasing numbers of natural avalanches hitting both passes, prompting closures for both passes in the afternoon of the 19th through mid-day or early afternoon on the 20th. The \$660,000-800,000/hour of lost revenue by the state (for both Stevens and Snoqualmie Passes—with Stevens Pass receiving approximately 1/5 of the traffic on Snoqualmie Pass) was probably worth it since no deaths or serious injuries resulted. Nevertheless, avalanche debris to the highways reached from 10 to nearly 40 feet deep (on Stevens Pass), with some slides releasing further than they have in years. Also a Cadillac that initially ran into and got stuck in a small slide west of the Stevens Pass summit was quickly evacuated due to the high avalanche danger. Unfortunately the vehicle was later consumed and significantly compressed by some 30+ feet of debris from a very large subsequently controlled slide.

While a significant decrease from the heavy snowfall rates on the 20th allowed for a slight stabilizing trend in the danger on the 21st and 22nd, moderate to strong winds both at the ridge top level and near the passes kept a considerable danger going on many wind loaded slopes...mainly west facing slopes. Generally light amounts of new snow and increasing snow pack settlement of from 6 to almost 20 inches by the 24th allowed for further stabilization of the recent large amounts of relatively low density snow over the weekend of the 23rd and 24th. Also rising freezing levels and increasingly strong early spring sunshine helped to develop an increasing surface crust and further decrease the danger while producing a "*most excellent*" breakable trap crust and associated marginal ski and snowboard conditions on many sun exposed and lower elevation slopes. Despite the overall decrease in the danger, some small wet loose slides released both in the back country and near the highway, with several slides just reaching inside lanes at both Stevens and Snoqualmie Passes. Fortunately, these relatively small deposits were avoided by traffic until they could be cleared by maintenance, and

subsequent avalanche control helped to further stabilize the potentially wet loose snow pack.

A cool but mostly cloudy west-northwesterly flow moved over the area Monday and Tuesday, the 25th and 26th, as several storms passed by mostly to the north across south-central BC. While very light snowfall was reported, in general this cooler weather helped to solidify the near surface crust while also allowing for further settlement of the heavy snowfall that had been received during much of mid-late March. Although another moderate frontal system moved mainly across BC late Tuesday and early Wednesday, and yet another late Wednesday as a stronger jetstream carried relatively strong southern parts of the storms across north-central Washington. Moderate to heavy snowfall resulted from about Snoqualmie Pass northward with from 8-12 inches reported along with strong ridge top winds of 50 to over 100 mph. This produced very sensitive wind slabs lying over either some lighter snow from earlier in the week or the melt-freeze crust from the previous weekend. These storms produced not only a very strong north to south and west to east gradient in snowfall, but also a marked contrast in snow pack stability between the northern and southern parts of the avalanche forecast areas. Only light amounts of new snow occurred from the 27th–30th and these mainly in the north. This allowed for further slow settlement and stabilization of the recent northern snowfall while a significant rise in freezing levels and partly to mostly sunny skies in the southern Cascades and Mt Hood area produced the first forecast of generally low danger below 7000 feet since early in the winter—even though this was mainly for overnight and early morning conditions.

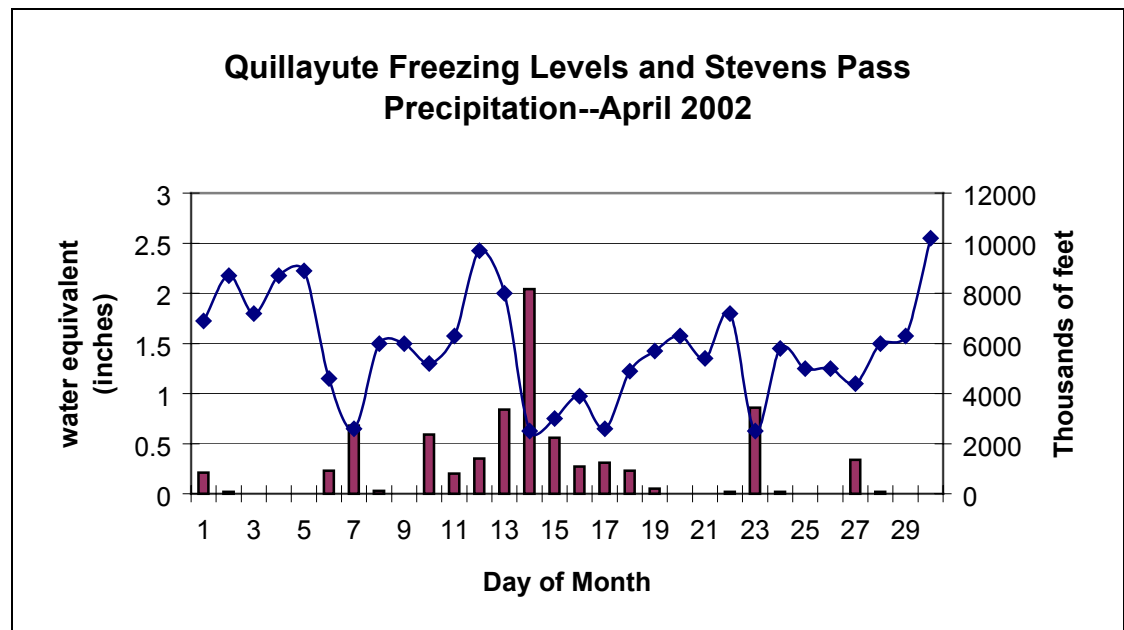
Finally mid-late on the 31st a moderate front moved southward across the region as the northern and southern branches of the westerlies split about a 1000 miles offshore and then merged just off the coast with a strong jet stream across BC shearing a moderate trough over north-central Washington. This produced light to moderate amounts of snowfall in the north-central Cascades and little or no snowfall in the south, where mostly low avalanche danger persisted. However, moderate winds produced some shallow wind slabs and some cornice formation, which became a little more of a concern in early April when rising freezing levels and some actual spring clearing finally arrived. Several days of mostly fair weather and rising daytime temperatures in early April (from about the 1st-4th) helped to weaken the small amounts of new snow over an old crust and produced some small wet loose slides along with some minor cornice falls during the heat of the later morning and afternoons. However, increasing crust formation overnight and further snowpack settlement helped eliminate immediate concern for instability remaining within most of the March snowfall, putting forecast operation in a more spring-like mode, at least for the time being.

April

The first week in April continued to be, surprisingly enough, almost spring-like, with clearing skies and warming temperatures through the 5th bringing good cheer to all who had endured a rather long winter. The generally higher freezing levels and lack of early spring precipitation shows up well on Figure 5 below. This weather also allowed for further settlement and stabilization of late March snowfall and an increasing surface crust to form. While some small wet loose slides were reported along with collapse of small cornices during daytime warming, these were generally isolated as the clear skies and dry atmosphere allowed for significant radiation loss from the snow surface and relatively limited melt. Nevertheless a generally low danger continued in most areas overnight and during early morning hours with only a slight increase in the danger during daytime heating. However, this all began to change as merging flow around a big split in the Gulf of Alaska began to send gradually strengthening weather disturbances over the region beginning late on the 5th and continuing through the 11th. Fortunately or unfortunately, depending on how you want to look at it, freezing levels during these storms ranged from 4 to 6000 feet, and were initially concentrated across the northern Washington Cascades. Along with some breaks between storms, significant daytime warming and the increasingly strong spring sunshine, considerable melt and weakening of near surface snow occurred, with the melt water percolating into the snow pack and weakening and lubricating gradually deeper layers in some areas. This produced mostly moderate to considerable danger throughout much of the week as significant wet loose slides were observed at lower elevations, along with some slab or wet slab slides at higher elevations that received new wet snow. However, some climax slides released to the ground on the 10th and 11th, mainly on slopes having a smooth underlying ground surface.

Did this mean that the second coming of spring was on its way? Well, not really as a strong frontal system moved over the region late on the 12th through the 13-14th weekend. Initially the associated warm front brought heavy rain at high freezing levels, with 24-hour amounts ranging from 1.5 to 2.5 inches. This caused at least a few cornice collapses or wet snow avalanches. A cornice collapse on Cowboy Ridge at Stevens Pass Ski Area caused a 2-6 foot step fracture to a mid winter crust, with an average of 5-6 feet but up to 15-20 feet of avalanche debris near the Tye Mill run. Another climax avalanche occurred in Clarke Canyon near the Mt Hood Meadows Ski area. Snow levels fell dramatically following the front, and about 1-2 feet of orographic snowfall fell at Hurricane Ridge and in the Washington Cascades from about Snoqualmie north on 14 and 15 April. This probably helped slab layers build on some lee slopes. One of these layers was triggered on the northeast side of the King at Crystal Mountain on 17 April, during relatively warm afternoon temperatures. More mostly light snow fell that week. By the end of the week, a couple of days of dry weather and warmer afternoon temperatures had begun to cause a transition to spring conditions.

Figure 5. Forks (Quillayute), WA Freezing levels and Stevens Pass, WA precipitation for April, 2002



A sure sign of spring came as the Chinook Pass WSDOT avalanche and maintenance crews set to work on April 18. The first round of avalanche control resulted in a huge avalanche, with an explosively triggered 7-10 foot deep by 600-ft wide slab avalanche on the south slopes of Knob 1, a major ridgeline just east of the summit. Most other slides in other areas were much smaller, with only skier triggered surface wet snow avalanches. Although skies cleared some on the 19th and 20th as weak upper ridging moved over the area, the ridge moved out of a generally cool west-northwesterly flow and hence only slightly rising freezing levels resulted, with recent new snow slowly melting and settling in place for the most part. Also variable mid and high clouds persisted in places along with a weak onshore flow that produced partly cloudy skies and areas of low clouds near and west of the Cascade crest. While some wet loose and isolated wet slabs resulted most areas reported gradually settling and stabilizing surface snow with an increasingly strong surface crust developing during the late night and early morning hours. This trend toward a more normal spring-like snow pack and associated diurnal changes in stability allowed the NWAC to close daily operation on Sunday, the 21st of April—also the time of closure for Crystal Mountain (with a brief reopening expected later in May at least for a few weekends).

Despite the end of normal daily forecasting on the 21st of April, NWAC staff continued to provide mountain weather forecasts for WSDOT at Chinook, Cayuse and Washington Passes. Staff also continued to monitor the snow pack for potential issuance of special avalanche statements in the advent of unusually severe avalanche conditions. Although communication with the WSDOT avalanche crew on Washington Pass was intermittent during the spring, weather data, forecast and snowpack information exchanges became daily or more often occurrences (Monday-Thursday) with the Chinook/Cayuse Pass operation.

Winter was slow to relinquish its grip on Washington as several minor storms brought 6-10 inches of new snowfall to the north-central Washington Cascades on the 22nd and early on the 23rd before giving way to weak upper ridging later on the 23rd and 24th. This snow fell down to the 2500-3000 ft level, but was mostly confined to areas from about Snoqualmie Pass northward.

Following the weak ridging, another minor trough sheared eastward across southern BC, dragging some light showers with it into northern Washington late on the 24th and early on the 25th. As strong upper ridging built into the Gulf of Alaska, disturbances in the northerly flow along the BC coast allowed a stronger upper trough to carve out over the eastern Pacific and then move southward over the area late on the 25th through the 27th. This spread increasing light to moderate snow spreading southward at relatively low freezing levels along the Cascade west slopes. Subsequent return flow around the closed upper low spread increasing snowfall to the Cascade east slopes as well, with new snowfall amounts ranging up to 8-12 inches at Mission Ridge, Chinook Pass and near Crystal Mountain on the 26th and 27th, with generally smaller amounts of 2-6 inches in most other areas. Fortunately, a drier but relatively cool northwesterly flow followed the low on the 28th-30th, thus allowing for much of the snowfall to slowly stabilize in place—a common occurrence during many Northwest springs and not requiring any special avalanche statements. Nevertheless, the new snow was still warmed by increasingly strong mid-late spring sunshine and a significant number of wet loose and isolated wet slabs were reported by the avalanche crew on Chinook Pass during the week of April 29th-May 3rd. With afternoon temperatures reaching to the upper 40's to low 50's, the new snow became quite wet and weak during the late morning and afternoon.

May

A late season winter storm cycle came in early May. Increasing westerly flow combined with increasing showers in the circulation around the low to spread increasing snowfall southward over the weekend of the 4th and 5th, with some 12-20 inches of new snow in the north Cascades, followed by further moderate to heavy snow showers in most areas near and west of the Cascade crest through the 6th. Along with very low freezing levels and strong winds, this prompted the issuance of a series of special avalanche statements between the 3rd and the 10th of May. This increase in May special statements shows up well in the Monthly Warnings Figure following, which was in general characterized by an overall decrease in numbers of warnings or special statements for the year—most notably in February. Perhaps the trend toward an overall decrease in warnings shown in Figure 7 can be attributed in part to the introduction of the 5 danger levels in the US during the late 1990's (in the Northwest during the 1996/97 winter), rather than the previous 4 that had been in effect through much of the period from 1970 through the mid-late 1990's. This allowed forecasters to forecast a significant increase in avalanche danger (up to considerable where natural avalanches are possible and human triggered slabs probable) without posting an avalanche warning for a particular geographical zone.

Figure 6. Number of days/month with warnings or special statements--1973-2002

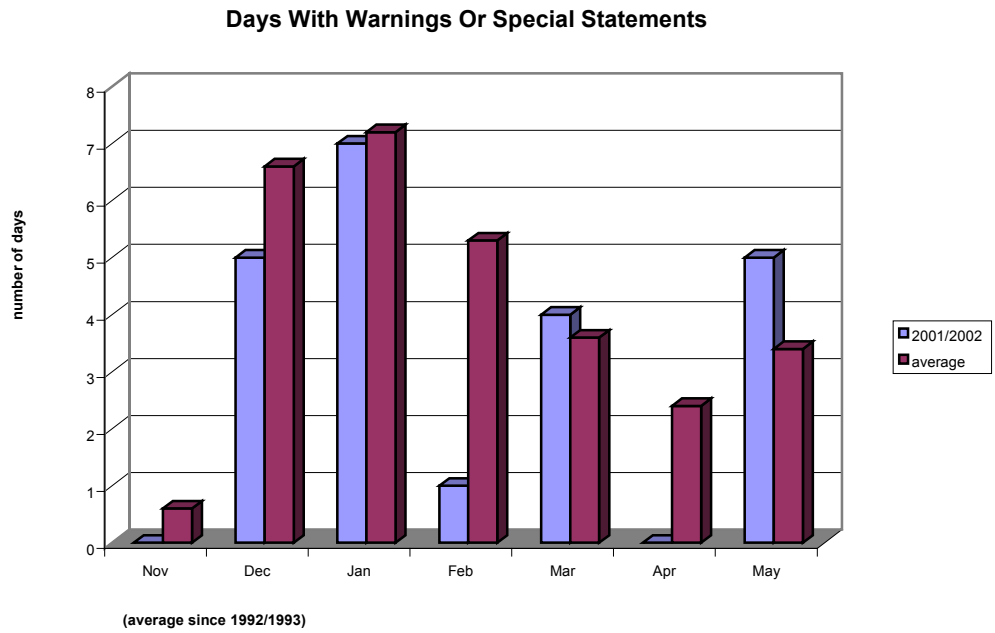
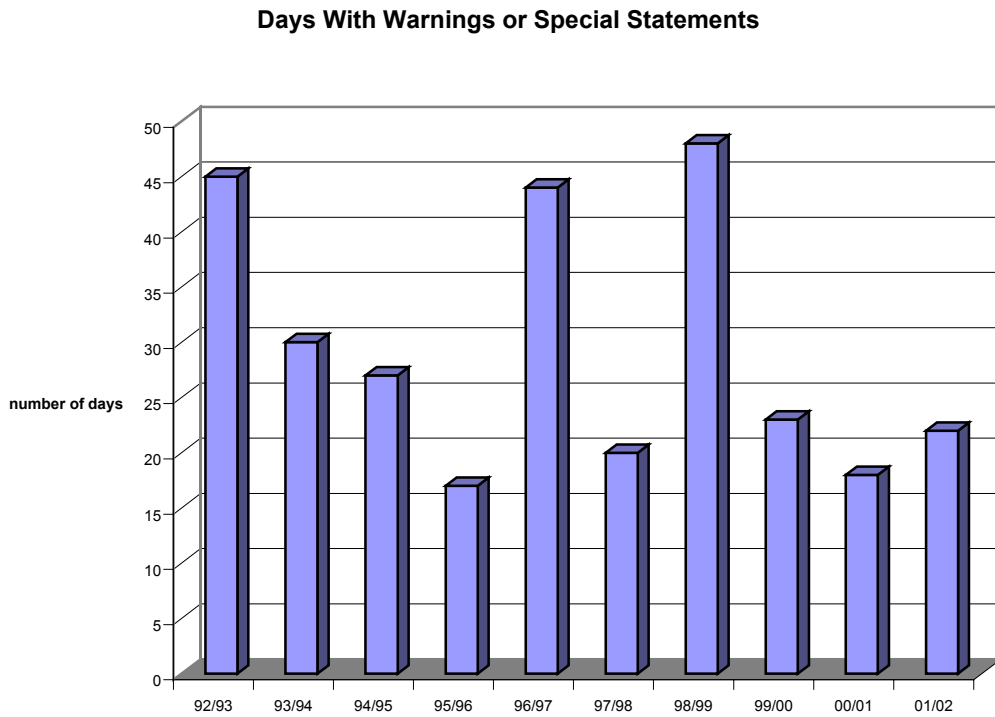
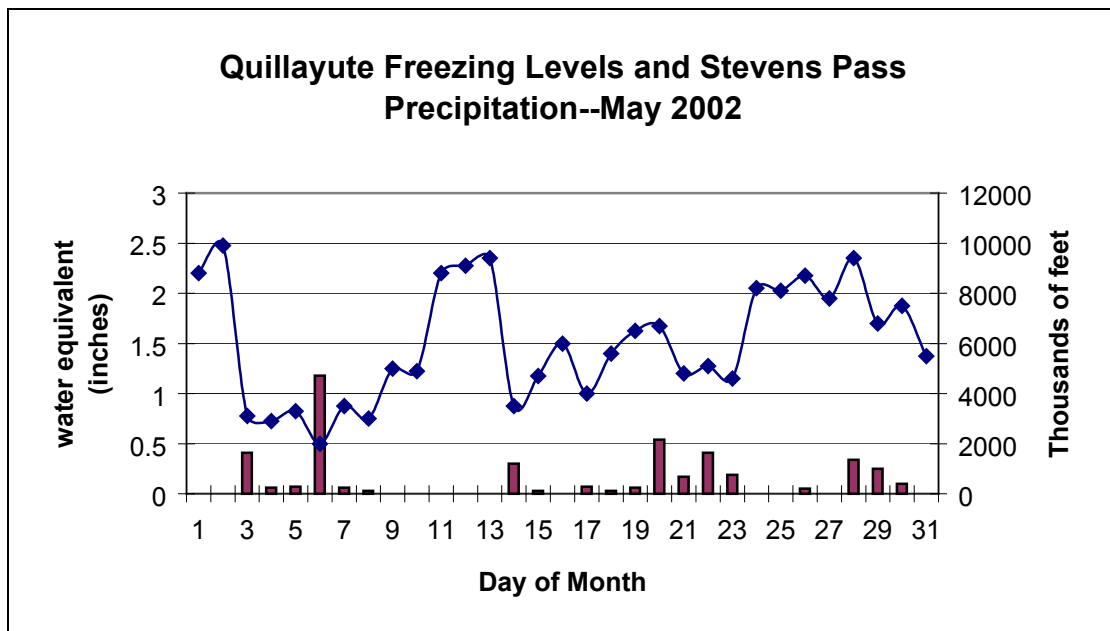


Figure 7. Total number of days/year with warnings or special statements



Although Figure 8 below shows relatively minor precipitation accumulations near Stevens Pass in early May, other areas received significantly more and combined with the relatively low freezing levels, this resulted in snowfall to most locations along with generally increased avalanche activity. Some small 12 inch soft slab avalanches that ran several hundred feet were triggered by late season backcountry skiers at Stevens Pass. One skier was briefly caught but managed to stay on the hill as the snow flowed around him and on down the hill. Also during the first few days of May the WSDOT came under increasing pressure to open Washington Pass. However, several large cornices threatened the highway and the arrival of the storms delayed the opening until the 7th. The long wave ridge remained well anchored at about 150 degrees west and a generally cool northwesterly flow prevailed over Washington and northern Oregon, bringing generally low freezing levels and showery weather with most days bringing at least a few inches of snow to the Cascade west slopes and the Olympics. A final moderate upper low arrived mid-late week (the 8th-10th) to continue a generally cool showery week, helping to minimize the threat of any large wet spring avalanches and confining most instability to mainly surface wet loose or wet slabs involving the most recently deposited snow.

Figure 8. Forks (Quillayute), WA Freezing levels and Stevens Pass, WA precipitation for May, 2002



Cool weather generally continued for most of the remainder of May except for a brief dry clear period from about the 10th to the 14th. Overall the generally cool weather from mid-late May helped to gradually stabilize snow and minimize the threat of spring avalanches. A warmer period with some precipitation came at the end of May as several weak upper disturbances passed through the area in a weak to moderate southwesterly flow. In areas with a shallower snow cover, percolation channels allowed rainfall to rather quickly drain from the snow pack, such as was reported from Chinook Pass. But a large avalanche in the Liberty Bell #3 chute also closed Washington at about 5 pm on Memorial Day—possibly triggered by one of the collapsing cornices that forecasters had been concerned about earlier. This avalanche covered Highway 20 with 20-30 feet of snow for a distance of 80-100 feet. It is very fortunate that no cars were buried since there was a lot of traffic that day across the pass.

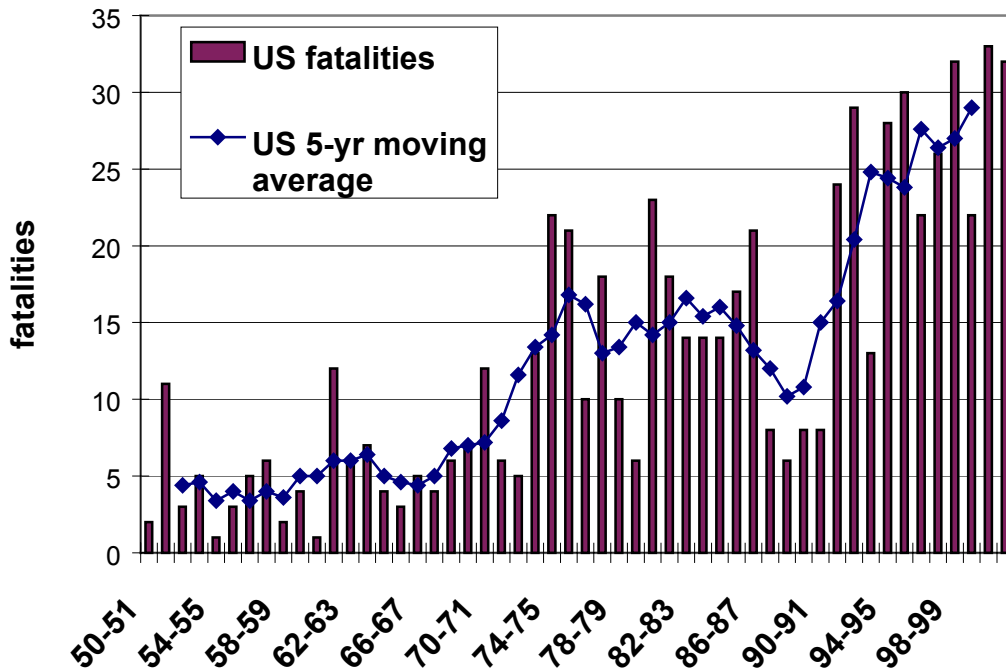
Several late season climbing accidents unfortunately occurred on Mt Baker, Mt Rainier, and Mt Hood at the end of May, with a lot of news media attention. Although none of the accidents were caused by avalanches, they all were related to either adverse mountain weather conditions, marginal snow pack conditions or possible problems with equipment, route selection or travel techniques. This should remind climbers of the value of acting in accordance to the information in mountain weather forecasts,

and to always be aware of surface snow conditions and their relationship to other climbing parties, should problems develop. The most serious example of a weather related problem occurred on the north side of Mt Rainier in the last few days of May. A group of 4 climbers set out to climb Liberty Ridge on 25 May and slowly made their way up the mountain despite deteriorating weather. But high winds and snow near the summit on the night of May 28th apparently destroyed their tents, and caused them to become hypothermic and disoriented. Three of the climbers died while a 4th was able to make his way down the mountain to report in incident This unfortunate accident seems to demonstrate the need for enhanced mountain weather forecasting efforts by NWAC in the spring; an option that is being examined by the National Park Service and US Forest Service.

AVALANCHE ACCIDENTS

After a relatively slow start in December and January, avalanche accidents and fatalities nationwide really began to hit their more normal full stride (the 5-year moving average is now over 27 deaths/year) in February and March. By the end of March, total US fatalities reached 32 (one below the current modern-day—post 1950—record of 33, as shown in Figure 9 below), with 43 fatalities in North America as a whole. Fortunately, the rapid increase in fatal avalanche accidents recorded in February and March in North America stopped in April and May, with several further accidents but no fatalities. In the Northwest, a series of miracle rescues involving extremely fortunate people occurred in the winter of 2001/02—with lots of accidents reported but no fatalities through the end of May (yes—we’re knocking on wood and hoping the zero trend continues!). While not all avalanche involvements are written up or reported, many of the narratives and descriptions of a significant number of events are still shown on the NWAC web site (for both this last and other years) at <http://www.nwac.noaa.gov/nw04000.htm#US%20&%20NW%20Accident%20Charts%20%20%20Up%20dated>. Nationwide, the breakdown of fatalities by activity category is shown in Figure 10 below and on the NWAC web site at http://www.nwac.noaa.gov/19982002_avi_fatal_by_activity.htm. The avalanche fatality breakdown by state is also shown below in Figure 11 and on the web site at http://www.nwac.noaa.gov/19852000_aval_fatal_by_state.htm. Through May of 2002, Montana and Alaska lead the US fatality count with 9 and 8 avalanche related deaths, respectively, with Colorado at 6, Utah at 5, Wyoming at 2, and Idaho and California with 1 each.

Figure 9. US Avalanche Fatalities by year and 5-year moving average



Meanwhile, as Figure 10 below shows, snowmobilers continue to lead convincingly in terms of activity category, accounting for over 50% of the US deaths this year (16 of 32) and over 42% during the past

5 years (60 of 142)—see Table 1. As mentioned in earlier reports and as is typically reflected in the thoughts of most avalanche professionals, the dramatic increase in fatality share among snowmobilers is probably due to a combination of factors—most probably from the great increase in the power of snow machines combined with the increasing desire of riders to engage in high marking without adequate knowledge of the snow stability, their impact on this stability, or the weather trends that might be affecting this snow stability.

Figure 10. 2001/02 US Avalanche Fatalities by Category

2001/02 US Avalanche Fatalities by Activity Category
32 total thru 4/29/02--Data courtesy NWAC, CAIC and WAN

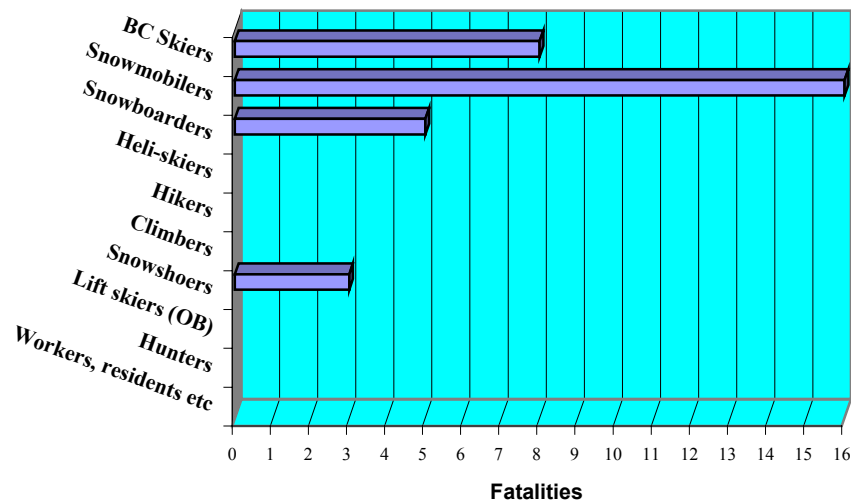


Table 1. US Avalanche Fatalities by Activity Category

1997/98	1998/99	1999/00	2000/01	2001/02	Total	Percent of Total	Activity Category
2	3	9	10	8	84	23.40%	BC Skiers
14	10	5	15	16	96	26.74%	Snowmobilers
4	12	1	2	5	37	10.31%	Snowboarders
0	0	0	0	0	0	0.00%	Heli-skiers
2	1	0	3		6	1.67%	Hikers
2	1	0	2		51	14.21%	Climbers
1	1	1	1	3	7	1.95%	Snowshoers
1	1	4			30	8.36%	Lift skiers (OB)
					5		Lift skiers (in bounds)
					4		Patrollers
0	1	0			21	5.85%	Hunters/misc recreation
0	2	2			18	5.01%	Workers, residents etc
26	32	22	33	32	359		Total

Since the winter of 1985/86, Washington and Oregon have accounted for 26 avalanche fatalities, or approximately 1.6 deaths/year (WA--1.2/yr and OR--.4/yr together), with the most recent 5 years producing a Northwest average of 2.2/yr (11 fatalities since 1997/98) and the past 10 years 2.0/yr (20 fatalities since 1992/93). The high snowmobile user areas of Montana and Alaska have experienced the greatest increase in recent fatal avalanche accidents. Meanwhile the notoriously weak Colorado snow pack has kept avalanche accidents high there and the highly changeable weather regime in Utah (exhibiting both continental and maritime weather) combined with increased numbers of users seeking out deep powder have produced a general increase in avalanche fatalities in Utah. Overall,

the drive toward an extreme experience, whether it is via snowmobile, ski, snowboard or other (climber, etc) has probably also contributed to the general increase in US avalanche fatalities.

Figure 11. 2001/02 US Avalanche Fatalities by State

UNITED STATES AVALANCHE FATALITIES by STATE																					
1985-1986 to 2001/2002 (To June 1, 2002)																					
STATE	Winter Season																	16 Years			
	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02	Total	Average	STATE	
CO	4	11	5	4	4	6	9	12	1	9	7	1	6	6	8	4	6	103	6.1	CO	
AK	0	6	2	0	1	1	2	7	2	6	8	4	3	12	5	4	8	71	4.2	AK	
UT	5	2	0	0	1	0	5	3	1	5	2	6	2	5	2	6	5	50	2.9	UT	
MT	2	1	0	0	1	0	1	1	6	3	3	1	7	2	2	7	9	46	2.7	MT	
WY	2	0	0	0	0	0	2	1	1	1	3	2	1	2	0	7	2	24	1.4	WY	
WA	2	0	1	0	0	0	2	0	0	1	0	5	2	3	1	3	0	20	1.2	WA	
ID	0	1	0	0	0	0	0	2	0	0	3	3	3	0	2	0	1	15	0.9	ID	
CA	2	0	0	0	1	0	2	1	0	2	0	0	1	1	0	2	1	13	0.8	CA	
OR	0	0	0	1	0	0	0	1	2	0	0	0	1	1	0	0	0	6	0.4	OR	
NH	0	0	0	0	0	1	0	0	0	0	3	0	0	0	1	0	0	5	0.3	NH	
NV	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0.1	NV	
NY	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	2	0.1	NY	
AZ	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.1	AZ	
NM	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.1	NM	
TOTAL	17	21	8	6	8	8	24	29	13	28	30	22	26	32	22	33	32	359	21.1	TOTAL	

While it is evident from the following chart that the wintertime period from November through March produces the greatest number of avalanche fatalities in the US, this is certainly not the only time to practice avalanche awareness as a relatively large and unfortunate number of accidents and fatalities occur outside the core winter period. In fact, avalanche fatalities have occurred in every month of the year, and May often shows up with an increase in accidents as avalanche awareness sometimes lags or dwindles as the minds of recreationists wander to other sports or activities even while their present state places them clearly in the path of potential avalanche danger.

Table 2. US Avalanche Fatalities by Month--1997-2002

US Avalanche Fatalities by Month--1997-2002							
Month	1997/98	1998/99	1999/2000	2000/01	2001/02	Total	
November		2	2	1	1	2	8
December		1	1	4	10	4	20
January		14	9	7	2	7	39
February		2	7	4	9	6	28
March		2	6	4	5	13	30
April		3	6	2	6		17
May		1	1				2
June		1					1
Total		26	32	22	33	32	145

CLIMATE

General—

As the climate records and the climatological snow depth graphs below indicate, the winter in 2002 was very good in terms of snowfall with above average to well above average snowdepths reported for almost all areas. It is especially evident from the snowdepth graphs that most of the snow came in a series of waves—with heaviest accumulation shown in late November and early December, in early-mid January, and again in early-mid March.

Figure 12. Snowdepth data from Mt Baker, WA for 2000/01 and 2001/02 versus climatological average depth

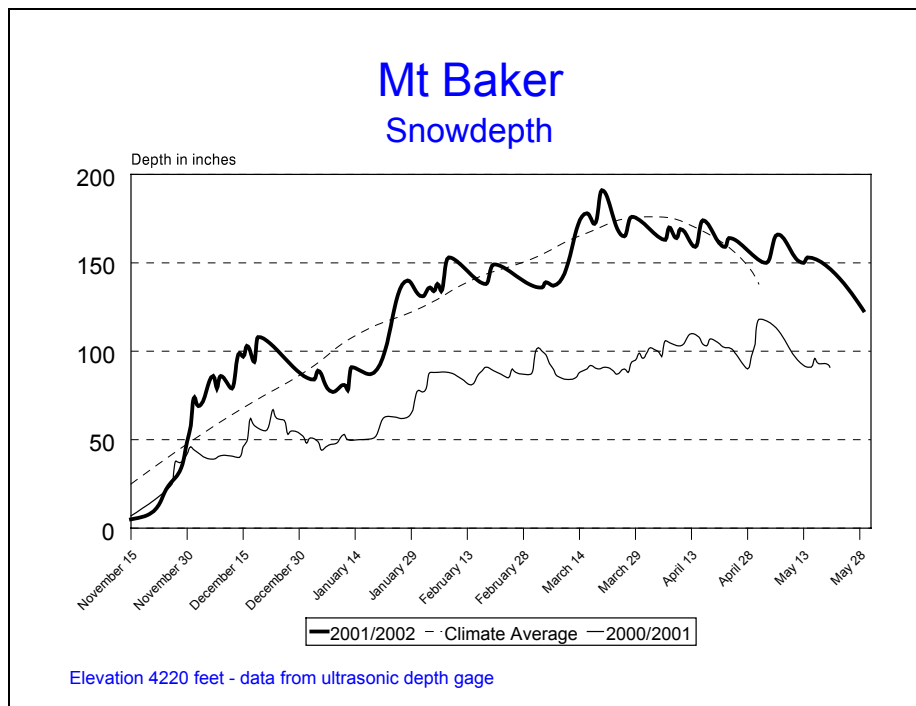


Figure 13. Snowdepth data from Stevens Pass, WA for 2000/01 and 2001/02 versus climatological average depth

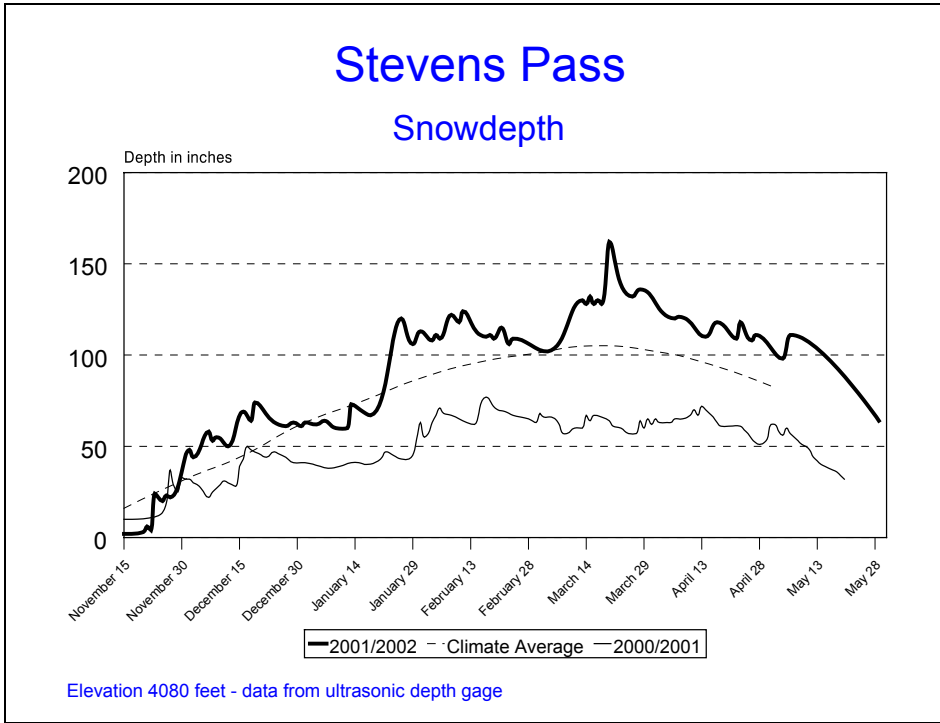


Figure 14. Snowdepth data from Snoqualmie Pass, WA for 2000/01 and 2001/02 versus climatological average depth

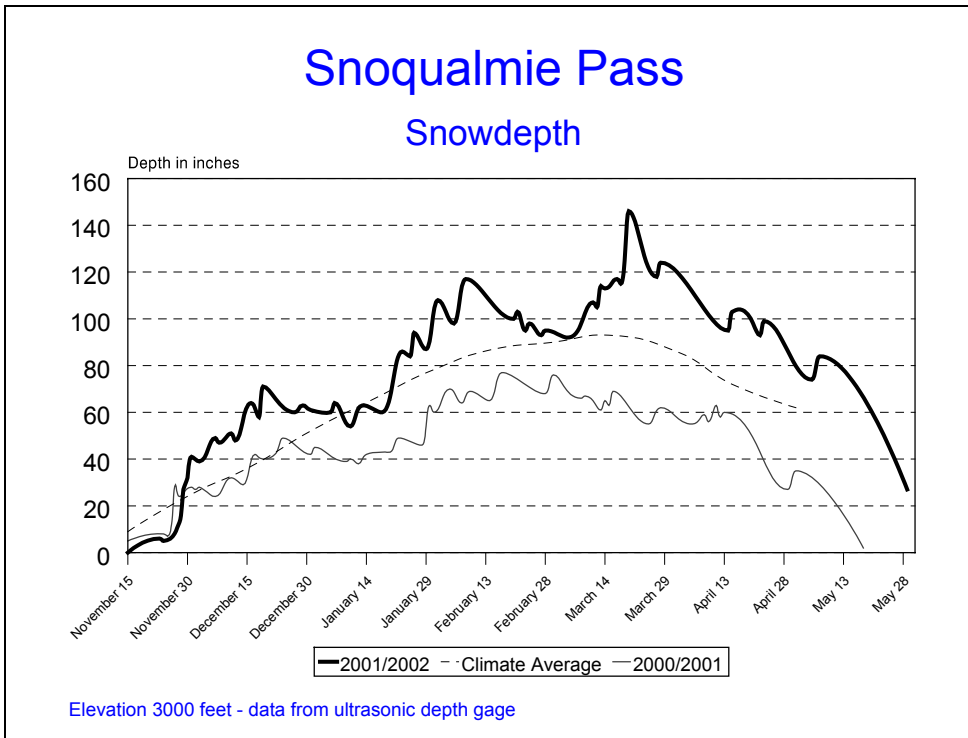


Figure 15. Snowdepth data from Paradise on Mt Rainier, WA for 2000/01 and 2001/02 versus climatological average depth

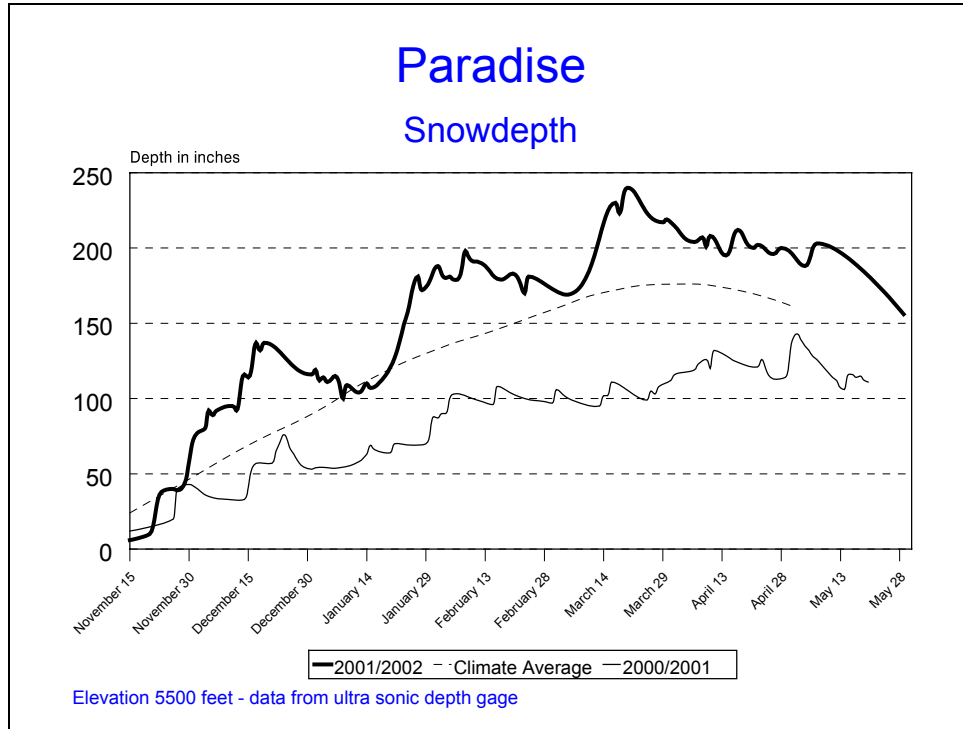
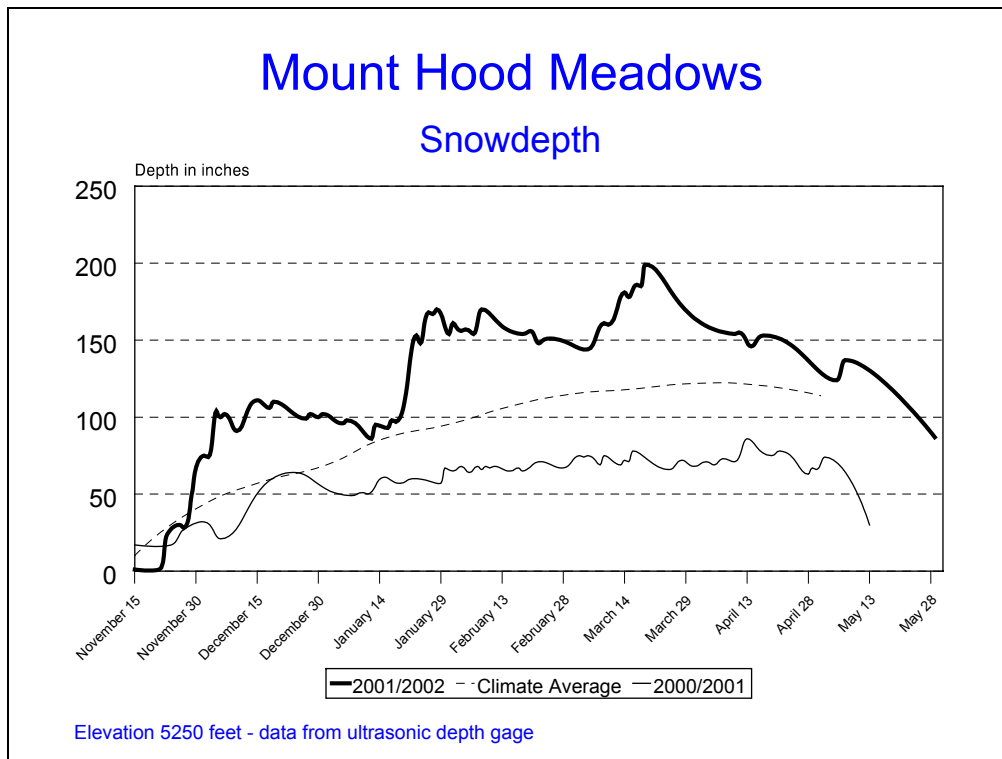


Figure 16. Snowdepth data from Mt Hood, OR for 2000/01 and 2001/02 versus climatological average depth



The data from Figure 17 below suggests that while not a record setting winter for the Snoqualmie Pass area, the winter snowfall was above average, perhaps in the upper 1/3 of all winters since 1949/50. And Figure 18 indicates that for Stevens Pass total water equivalent received was in the upper ~20% of all winters since 1973.

Figure 17. Snoqualmie Pass accumulative snowfall by year—1949/50 to 2001/02 (data through 4/04/02)

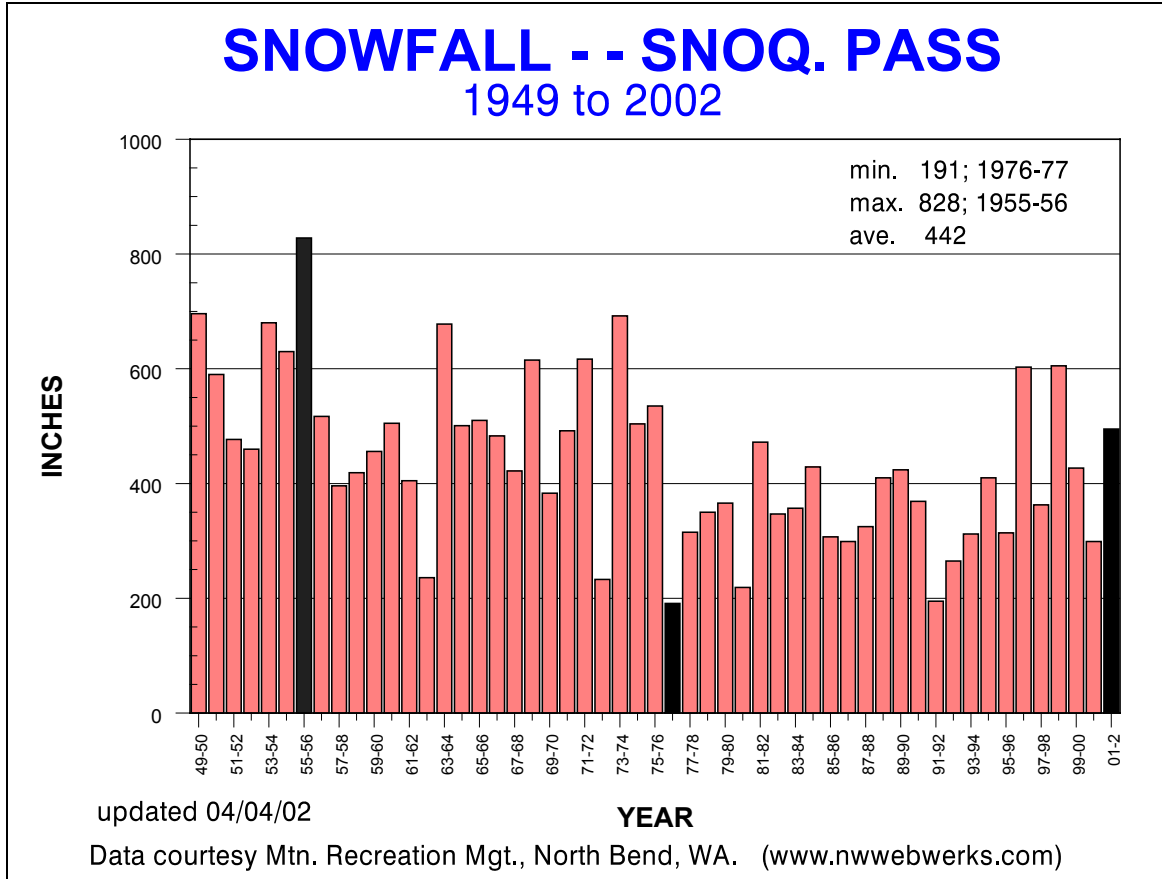
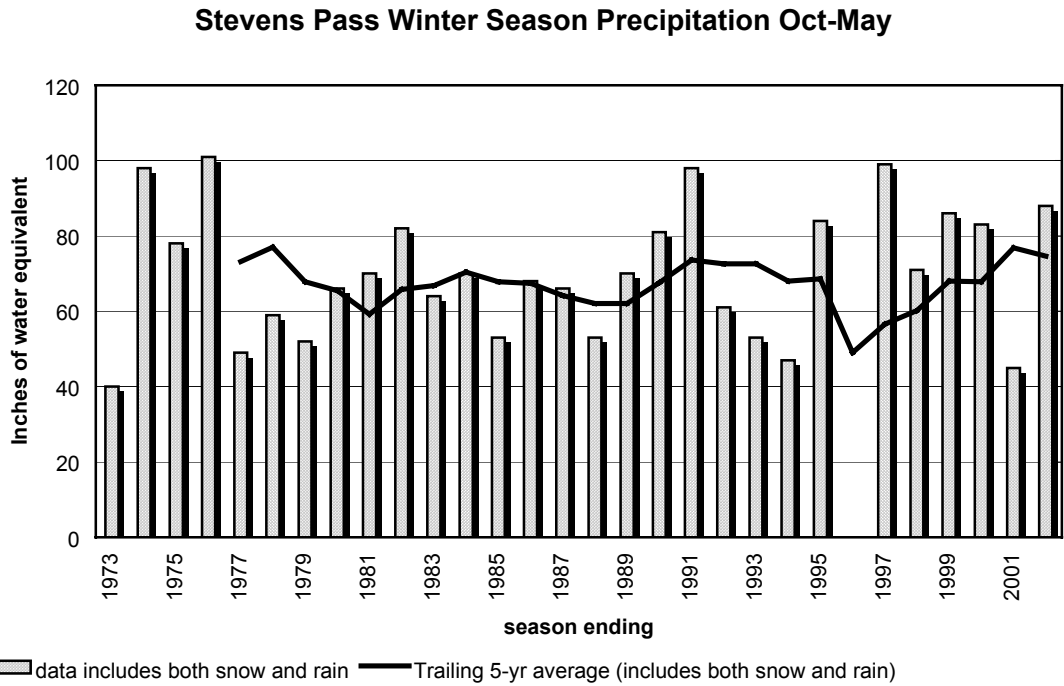
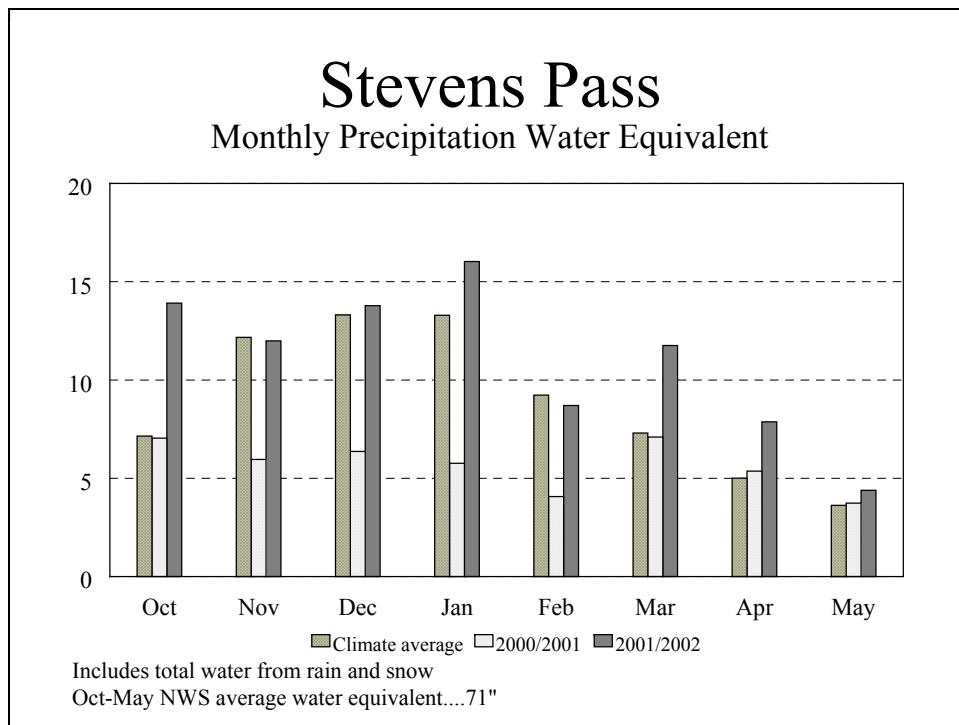


Figure 18. Seasonal precipitation for Stevens Pass, WA--Oct-May, 1973-2002



Monthly precipitation figures for Stevens Pass, WA (see Figure 19 below) also show that for most of last winter, the monthly water equivalent of snow and rain ranged above average—and thankfully the precipitation was considerably above that recorded during the mini-drought year of 2000/01.

Figure 19. Monthly precipitation for Stevens Pass, WA--2001/02 versus average



Natural Resources Conservation Service snow pack data also reflected that these rather robust but not record setting numbers continued into late spring, with Basin wide averages running from about 115 to 140% of normal as of early May, 2002 (for water equivalent contained in the snow pack). Later season data by the Natural Resources Conservation Service in June corroborated the generally above normal snowdepth shown for most late season months in the NWAC snowdepth data and charts. On June 1st, the NRCS report for Washington stated that:

NRCS SNOW PACK SUMMARY—early June

The June 1 statewide SNOTEL readings were above average at 172%. Approximately 20 of 56 SNOTEL sites had reported complete melt-out by June 1. Readings in the Cedar River Basin reported the highest at 534% of average. Westside averages from SNOTEL and June 1 snow surveys included the North Puget Sound river basins with 133% of average, the Central Puget river basins with 268% and the Lewis-Cowlitz basins with 184% of average. Snowpack along the east slopes of the Cascade Mountains included the Yakima and the Wenatchee areas with 160%. Snowpack in the Spokane River Basin was at 188% and the Walla Walla River Basin had 77% of average. Maximum snow water content in Washington was at Paradise Park SNOTEL near Mount Rainer, with water content of 84.6 inches. This site normally has 61.6 inches of water content on June 1.

Fortunately, the snowfall was sufficient to lure record setting numbers of skiers and snowboarders to most Northwest ski areas, with record setting “skier visits” reported from several areas. Following are semi-monthly climatological snowdepth reports for key mountain weather sites.

CLIMATOLOGICAL SNOWDEPTH INFORMATION
 NORTHWEST WEATHER AND AVALANCHE CENTER
 ISSUED THROUGH NATIONAL WEATHER SERVICE SEATTLE

December

DATA IN INCHES, -99 DENOTES MISSING DATA

1 December 2001

	CURRENT DEPTH	CLIMATE AVERAGE	PER CENT OF NORMAL	LAST YEAR	THRU 2000 MAX/YEAR	THRU 2000 MIN/YEAR
MT BAKER	58	49	118	38	140/1948	1/1939
STEVENS	37	32	116	30	67/1942	0/1941
SNOQUALMIE	44	25	176	25	84/1955	1/1969
STAMPEDE	41	31	132	26	93/1945	0/1976
PARADISE	68	48	142	42	125/1994	1/1976
WHITE PASS	30	20	150	12	53/1984	1/1999
MT HOOD	60	42	143	32	113/1984	10/1995

15 December 2001

	CURRENT DEPTH	CLIMATE AVERAGE	PER CENT OF NORMAL	LAST YEAR	THRU 2000 MAX/YEAR	THRU 2000 MIN/YEAR
MT BAKER	104	68	153	41	168/1948	16/1976
STEVENS	66	44	150	38	80/1973	5/1976
SNOQUALMIE	61	36	169	35	116/1948	0/1976
STAMPEDE	-99	44	-99	32	119/1948	9/1976
PARADISE	114	68	168	41	170/1948	4/1976
WHITE PASS	42	31	135	21	73/1996	2/1989
MT HOOD	110	57	193	47	118/1984	8/1989

January

1 January 2002

	CURRENT DEPTH	CLIMATE AVERAGE	PER CENT OF NORMAL	LAST YEAR	THRU 2001 MAX/YEAR	THRU 2001 MIN/YEAR
MT BAKER	98	88	111	48	190/1949	1/1928
STEVENS	63	62	102	41	117/1956	10/1981
SNOQUALMIE	64	53	121	46	136/1949	0/1981
STAMPEDE	62	59	105	-99	132/1949	0/1981
PARADISE	114	91	125	54	163/1969	20/1977
WHITE PASS	40	35	114	26	84/1997	4/1990
MT HOOD	101	69	146	54	145/1985	6/1981

15 January 2002

	CURRENT DEPTH	CLIMATE AVERAGE	PER CENT OF NORMAL	LAST YEAR	THRU 2001 MAX/YEAR	THRU 2001 MIN/YEAR
MT BAKER	88	109	81	50	180/1971	15/1981
STEVENS	70	73	96	41	146/1969	6/1981
SNOQUALMIE	62	65	95	44	123/1969	0/1981
STAMPEDE	54	73	74	38	179/1972	0/1981
PARADISE	107	112	96	69	216/1969	31/1981
WHITE PASS	37	45	82	37	80/2000	0/1981
MT HOOD	94	86	109	61	144/1989	0/1981

February

1 February 2002

	CURRENT DEPTH	CLIMATE AVERAGE	PER CENT OF NORMAL	LAST YEAR	THRU 2001 MAX/YEAR	THRU 2001 MIN/YEAR
MT BAKER	131	124	106	77	234/1933	17/1981
STEVENS	113	87	130	55	152/1964	10/1981
SNOQUALMIE	108	79	137	59	154/1964	8/1977
STAMPEDE	118	88	134	57	228/1946	2/1977
PARADISE	188	132	142	90	240/1969	27/1977
WHITE PASS	86	51	169	40	88/1997	0/1977
MT HOOD	161	96	168	66	156/1982	15/1981

15 February 2002

	CURRENT DEPTH	CLIMATE AVERAGE	PER CENT OF NORMAL	LAST YEAR	THRU 2001 MAX/YEAR	THRU 2001 MIN/YEAR
MT BAKER	154	140	110	93	244/1999	24/1977
STEVENS	116	95	122	67	166/1956	16/1977
SNOQUALMIE	106	87	122	66	168/1949	4/1977
STAMPEDE	118	93	127	62	202/1949	0/1977
PARADISE	184	145	127	96	264/1972	24/1977
WHITE PASS	78	55	142	41	100/1999	0/1977
MT HOOD	157	107	147	65	162/1999	27/1981

March

1 March 2002

	CURRENT DEPTH	CLIMATE AVERAGE	PER CENT OF NORMAL	LAST YEAR	THRU 2001 MAX/YEAR	THRU 2001 MIN/YEAR
MT BAKER	153	151	101	87	296/1999	48/1981
STEVENS	105	100	105	63	196/1956	30/1981
SNOQUALMIE	94	90	104	66	198/1956	20/1981
STAMPEDE	106	101	105	60	195/1969	21/1981
PARADISE	177	158	112	98	276/1999	67/1977
WHITE PASS	60	57	105	39	115/1999	11/1977
MT HOOD	147	115	128	67	199/1999	38/1981

15 March 2002

	CURRENT DEPTH	CLIMATE AVERAGE	PER CENT OF NORMAL	LAST YEAR	THRU 2001 MAX/YEAR	THRU 2001 MIN/YEAR
MT BAKER	191	165	116	90	305/1999	44/1981
STEVENS	135	104	130	64	200/1956	26/1981
SNOQUALMIE	114	93	123	60	195/1956	10/1957
STAMPEDE	-99	104	-99	60	216/1964	13/1981
PARADISE	224	170	132	102	357/1956	72/1981
WHITE PASS	86	56	154	32	132/1997	8/1981
MT HOOD	178	118	151	71	188/1999	33/1981

April

1 April 2002

	CURRENT DEPTH	CLIMATE AVERAGE	PER CENT OF NORMAL	LAST YEAR	THRU 2001 MAX/YEAR	THRU 2001 MIN/YEAR
MT BAKER	186	175	106	99	311/1999	72/1934
STEVENS	132	101	131	65	192/1956	24/1941
SNOQUALMIE	112	86	130	54	170/1956	2/1992
STAMPEDE	134	101	133	59	183/1956	17/1992
PARADISE	220	175	126	116	327/1956	66/1941
WHITE PASS	76	53	143	24	110/1997	0/1992
MT HOOD	167	122	137	68	199/1999	55/1992

15 April 2002

	CURRENT DEPTH	CLIMATE AVERAGE	PER CENT OF NORMAL	LAST YEAR	THRU 2001 MAX/YEAR	THRU 2001 MIN/YEAR
MT BAKER	168	168	100	109	290/1999	56/1934
STEVENS	117	94	124	68	170/1956	17/1941
SNOQUALMIE	100	72	139	58	153/1974	0/1992
STAMPEDE	-99	100	-99	-99	216/1964	9/1992
PARADISE	200	173	116	127	302/1972	68/1934
WHITE PASS	55	44	125	24	95/1997	0/1992
MT HOOD	146	121	121	82	190/1982	54/1992

May

1 May 2002

MT BAKER	153	137	112	126	270/1999	20/1934
STEVENS	102	83	123	62	141/1964	36/1942
SNOQUALMIE	79	62	127	35	131/1974	0/1992
STAMPEDE	-99	82	-99	-99	176/1964	1/1992
PARADISE	191	160	119	140	295/1972	36/1941
WHITE PASS	30	25	120	-99	70/1999	0/1996
MT HOOD	131	114	115	71	162/1997	70/1994

FIELD**The Early Season—October-December**

With significant numbers of unhappy experiences dealing with long line run related problems and radio telemetered sites, major field work commenced at Mt Hood, Stevens Pass and Chinook Pass this fall, along with normal troubleshooting and maintenance of the remaining sites. In the Mt Hood area, the problems with long line runs were best addressed by adding new dataloggers and modems at both ends of the long line run, so that only phone lines would be required to endure the problems associated with the long lines (problems such as induced AC, shorts, grounding differentials, etc). Hence new stations were installed at the base of Mt Hood Ski Bowl, at the top of the Magic Mile chairlift at Timberline Ski area, at the top of the Pucci Chair at Timberline, and at the top of the Blue Chair at Mt Hood Meadows. This allowed for most weather sensors to be installed immediately adjacent to the loggers, eliminating all but minor line problems. Although these new weather stations required significant programming of new data loggers and the NWAC office programs for decoding and formatting the data for display on the web site, the decreased maintenance problems with the sites should be well worth all the effort involved.

While some minor glitches developed (and were resolved) in these new systems, thus far this year most are operating admirably and have greatly alleviated previous problems with the sensors and data loggers. Unfortunately, such additions or replacements have required considerable capital equipment purchases—it is hoped that the equipment will enjoy a long and trouble-free life as owing to an anticipated slowly dwindling budget, replacements for these may be along time in coming. Station by station descriptions of major work follows:

Government Camp—Mt Hood Ski Bowl – by working with the ski area patrol and mountain managers, new Rohn 45G towers were installed at the base of the ski area, with a surplus 25G tower installed for snow depth only at the top of Tom, Dick and Harry mountain. The ski area also provided an extra phone line and this allowed for reliable precipitation and temperature from the base, as well as for more reliable temperature and winds from mountain top along with a new hourly total snow depth.

Timberline Ski Area – with the excellent assistance of the ski area (who ran new power, phone and telemetry lines and helped with installation of a new Rohn 45G tower) a new base station was added at the 6000 ft level just adjacent to the top of the Pucci Chairlift. Electrically heated precipitation, air temperature, relative humidity, wind speed and wind direction, total and 24-hour snow depths were all added to this station, which is now much more reliable and should really help both forecasting efforts and on-site maintenance efforts for this area. We also relocated the old base logger to a new logger location at the top of the Mile Chair (7000 feet) along with a new modem and new heated wind speed and direction. This change eliminated all of the long land line problems that have intermittently plagued the site for several years.

Mt Hood Meadows – a new upper station (data logger, junction box, phone modem) was added to the top of the Blue Chair to mitigate continuing problems with long line runs up the chair to both temperature and wind sensors at the 6600 ft level. Additionally, land lines were rerouted for all sensors to accommodate the change, and the ski area worked closely with NWAC staff to help with the modification, as well as providing a new phone line necessary for the modifications to the weather systems. A continuing problem with the precipitation gage readout from the base data logger was finally resolved in December with a swapped data logger and modification of the data logger program.

Stevens Pass Ski Area – NWAC staff cooperated with the WSDOT avalanche control crew and ski area patrol personnel to install and troubleshoot a new weather station at the top of the Brooks Chair, and for maintenance and troubleshooting of the temperature, precipitation & snowdepth site at the top

of the Skyline Chair. The Brooks site required a new datalogger, modem and heated wind system—all of which were installed with the idea that they would ultimately replace the aging weather data system in the Grace Lakes area. The Grace Lakes site was one of the first sites to be installed by NWAC staff and WSDOT crews back in the mid-late 1970's, and an increasing number of the land lines and towers have broken, requiring a significant amount of time and cost to repair and/or replace each year. If agreement can be reached between WSDOT avalanche crews and NWAC, it is hoped that much of the remote Grace Lakes Weather Station can be pulled over the summer and replaced with data from the generally more reliable Brooks/Tye/Skyline and Daisy system that has been developed within the ski area. Although there is a possibility that the land line telemetry cable could be replaced with an RF link to the wind site station only—the old AC power cable continues to be a concern. All parties agree that the old 480-volt power cable may be becoming more of a liability than it's worth and should probably be removed.

Chinook Pass – new radio telemetry system was purchased, installed and tested by NWAC staff during the late summer and early fall; once it was shown to work a new snowdepth sensor was installed the Pass site in the fall. To get the radio system fully functional required not only new radios but also reorientation of the directional antennas almost 90 degrees away from direct line of sight—a technique that is sometimes used when topography interrupts the signal and allows for bounce of the signal off nearby ridges to achieve a connection between the base station and the remote.

General—Other less labor intensive data network maintenance visits included installation of new air temperature/relative humidity sensors at White Pass (ski area) and Snoqualmie Pass (DOT site); new snow depth sensors at Alpental (ski area), Stevens Pass (ski area), Stevens Pass (DOT) and White Pass (ski area); and new wind sensors at White Pass (ski area) and Mt Hood Meadows; new data loggers at Paradise (NPS) and Mt Hood Meadows (ski area). Several trips were also required to check and clean precipitation gage wiring, orifices and funnels and to replace RV battery backups for AC and other sites.

While forecasters kept relatively close contact with the snow pack with at least weekly trips to a variety of sites throughout the Olympics, Washington Cascades and northern Oregon Cascades, instrumentation problems at remote weather stations also constituted a significant portion of the field time. In many instances, field trips were necessitated by instrumentation repair that fortunately also involved some time devoted to snowpits, stability analysis and shear tests. However it is always amazing how much time is often required for supposedly simple instrumentation fixes. In any case, a summary of significant instrumentation problems encountered from January-March follows.

Mid-Season

Snoqualmie Pass

The Alpental precipitation gage started showing intermittent readings in late December and early January. With the help of the WSDOT Snoqualmie Pass avalanche crew, the gage was removed and the problem identified and fixed in late January. The problem—bad base heaters—apparently resulting from power surges; unfortunately the cost of repair was almost ½ the price of a new gage—or about \$1,250. Later in February, the snow depth sensor at Alpental ceased working (unknown reason). Once again the WSDOT avalanche crew were able to help and installed a replacement sensor that is now working well.

Mt Hood Meadows

After a prior early season fix and a few weeks of reasonable readings, significant problems redeveloped and continued with the Mt Hood Meadows precipitation gage and phone lines in January, along with a series of power outages that required intermittent reprogramming of the base station datalogger. However, the phone line problem and precipitation gage ultimately required a site visit to fix. Garth and Mark replaced the precipitation gage in late January along with an ailing base station RV battery. The combined fix seemed to eliminate most previous problems with the

precipitation readings and access to the station. However, intermittent precipitation problems that continued in early February indicate that the land lines between the data logger and the gage should be replaced next summer, and this will be done in conjunction with replacement and upgrading of the old tower at the base study plot, and perhaps replacement of an old wind tower near the top of the Blue Chair. Also, intermittent access problems continue with the upper Mt Hood Meadows data logger—a problem that appears to be linked to the phone system switch at the area, since it only develops overnight through early morning when the switch is not staffed. However, the switch has been checked and the mountain manager remains unconvinced that the switch is the problem. Forecasters plan to manually monitor early morning access of the station in the weeks ahead to try to determine what the problem might be.

Mission Ridge

Wind system heating problems and power problems reared their ugly heads at Mission Ridge in late January. Fortunately remote programming of the site was possible, and quick fixes of the data telemetry resulted.

Timberline

During the heavy snowfall several stations were unable to reliably clear the 24-hour depth sensors on a daily basis. This resulted in bad data as snow moved toward and over the top of several depth sensors. Fortunately most began to reliably work again after snow safety personnel reached the sites and dug them out. Unfortunately, the very heavy snowfall and increasingly large snow depths threatened to overwhelm several 20-24 ft towers that were erected for precipitation and snow depth measurements. While a mid-winter trip to Timberline in late January prevented imminent burial and destruction of the sensors at Timberline Lodge by raising the tower another 10 feet (insertion of an extra 10 ft section in the middle of the tower), future summer or early fall maintenance may involve replacement and raising of several other towers another 10 feet or so to prevent potential future burial during heavy snow years.

Crystal Mountain

The weather station datalogger at mountaintop stopped answering the automated data scheduler phone calls in mid-late March. This outage not only was a loss of wind and temperature data from the top of Crystal Mountain, but also cut off access to the Chinook Pass weather system that uses the Crystal Mountain top data logger as the base station for the RF link. Forecasters attempted to remotely fix the problem, but even with electrical help from the ski area were unable to do so. Hence Garth and Mark scheduled a quick instrumentation/snow pack trip to the site in late March—arriving with heavy packs of tools, replacement modems and loggers. After checking all regulated DC chargers and the RV battery, it was determined that a lack of power was most likely the culprit, as once the battery was properly charged, both the mountain top site and the Chinook Pass site began to happily discharge data. However, the RV battery was installed in the fall of 2000, and is now scheduled for replacement. Also the trickle chargers had become unplugged behind a coffee maker—apparently coffee was more important than weather in the early morning hours.

During this site visit, Mark also reprogrammed an analog output module for the ski area so that the patrol or upper lift operators can have direct real-time readout of both wind speed and direction on an existing Esterline-Angus chart recorder. Power surge problems within the land lines going down the mountain had taken out one of the analog channels, but fortunately the program could be rewritten around the bad output channel.

Also in January the Crystal Mountain ski area—urged on by the ski patrol and director Paul Baugher—purchased a new 45G Rohn tower, as well as data logger, phone modem, telephone line, logger enclosure, power supplies and two snow depth sensors. After excavating a large hole to the ground (through the 10+ ft snow cover), the patrol then proceeded to temporarily install the tower and sensors at the upper Green Valley study plot. Mark wrote the program for the logger and after the ski area finished installation, downloaded the program to the logger. Eureka—the site has since worked

almost flawlessly, and is providing both NWAC and the ski area useful snow pack and weather data from an important upper elevation area.

Tumwater

The Tumwater station stopped working in mid-late March. Subsequent investigations indicate that the phone modem may have problems since the modem is not answering. Hopefully WSDOT avalanche crews will be able to look at the problem and advise forecasters of possible fixes, although it appears that it may be a simple power problem. If the modem does not have power, then the phone line just rings and rings.

Hurricane Ridge

Intermittent phone line outages for the newly installed CR10X data logger site at Hurricane Ridge have fortunately been resolved by a reset of the phone line (a microwave system) by the NPS radio technicians at Park HQ in Port Angeles. However, a lack of measured precipitation from the site in late March indicates that the precipitation gage may not be heating—hopefully it is just a tripped breaker or unplugged power cord, but possibly one or more of the internal heaters may be malfunctioning—a common problem in this type of gage that may get power surges in remote locations. NPS personnel have been contacted and will hopefully be able to fix or at least help pinpoint the problem.

Mazama

With the great help of Jim Gregg, a Freestone Inn consultant and old Arrowhead Corporation employee, several problems with a heated precipitation gage and snowdepth gage outages at the Mazama weather site were handled remotely.

Washington Pass

This station was originally installed back in the late 1980's and is in need of a significant overhaul. With the direction commonly reading north no matter what the real direction is, the wind sensor needs to be replaced. However, this sensor lies on top of a 60-ft old style 25G Rohn tower and it may be difficult to properly replace it (against regulations) without constructing a new larger and FS approved 45G tower. Other problems with the site include a needed replacement of a Judd snow depth sensor and a better and longer lasting propane heated precipitation gage. Such replacements will be difficult if future funding limits capital equipment procurement. Plans are to talk with the WSDOT-Stevens Pass avalanche crew to consider changes to the site or potential alternative locations.

Stevens Pass

Precipitation gage readings of no water equivalent on March 28 and 29th seem to point a finger at a lack of power and no heating for the ski area gage. Ski area personnel have been contacted and will advise forecasters of potential problems.

Problems continued with the precipitation gage in early April, as either the heater stopped functioning or another problem surfaced with the tipping bucket mechanism (the back plate of a circuit board next to the bucket has often become corroded and shorts across the board, rendering the precipitation tips useless as no current flows with a tip). This potential problem will be investigated.

Late season

Miscellaneous

Late season problems cropped up at several stations in May, including problems with the snow depth sensors at Hurricane Ridge and Washington Pass, air temperature/relative humidity sensors at Hurricane ridge, and potential precipitation gage problems at Mt Baker. All of these sensor outages

will be addressed in the summer or early fall, as staff schedule and funding allow. Highest priority items for the summer and early fall include:

- replacement of sensor towers at Mt Hood Meadows (both upper and lower),
- removal of the old Grace Lakes weather system near Stevens Pass,
- requesting permission from the Olympic NPS to install a new more reliable and more accurate precipitation and snow depth tower to the west of the existing area,
- conversion of the Mt Baker site(s) from satellite and meteor burst telemetry to more reliable and easier to program microwave telephone links
- more complete installation of the Green Valley study plot tower—placing a taller base and tower in concrete and leveling
- install replacement temperature controller boxes for Timberline wind systems—both are 240 volt systems and the upper site experienced significant riming problems on the wind direction side during the latter half of the year

OFFICE

Much of the early Fall was taken up by programming of both new and old weather stations as the NWAC began to take the jump from an old DOS-based Quick Basic formatting and datalogger scheduling & programming system to a newer and hopefully more stable and reliable Windows system. This transition—which has been underway during the past 6-9 months—is expected to take place gradually over the latter part of this winter and early next spring, and should be integrated wholly into the normal forecasting operation by next winter. Once the transition has occurred, it should allow transfer of all of the automated scheduling, data interrogation and data dissemination duties from an old WSDOT contributed computer to a newer and faster IBM system. Eventually this should also allow for automatic preparation and dissemination of graphical weather plots for both forecaster usage and for those public or other users that desire and utilize a more visual approach to remote weather station data.

Office time during the fall was also taken up with migration of forecasting duties to a new IBM computer received last spring from the Forest Service, as well as trying to streamline and enhance data reception, data and forecast dissemination, and forecast procedures. Other work involved Mark's preparation of slides, Powerpoint presentations, and other lecture/workshop aids for teaching duties at the 17th biannual National Avalanche School (<http://www.avalancheschool.org/index.asp>) in late October thru early November in the Canyons Resort of Utah. Also both Kenny and Garth needed time to learn and prepare for any changes in the National Weather Service computer graphics that we rely on regularly for forecast preparation, and to prepare for other talks and avalanche awareness presentations during the upcoming winter. Mark also responded to several requests for paper reviews and to a request by the Canadian National Science and Engineering Research Council for an updated review of the Industrial Research Chair in Snow and Avalanche Science at the University of British Columbia—a task that he became initially involved with four years ago along with several Canadian and other scientists when the Snow and Avalanche IRC was initially proposed and subsequently funded.

During this time of forecasting preparation, Kenny researched and subsequently procured some PDA's (personal desk assistants—small handhelds) that forecasters hoped to be able to take with them in the field for programming dataloggers, rather than the bulkier laptop that has been used previously. After creating new directories, loading a new PC Connect program from Campbell Scientific designed for just such a mission, and synching the data and program files between the office computer and the PDA (a Sony Clie), Kenny and Garth successfully tested the new programming and troubleshooting link on a field trip to White Pass in late October. Finally, after additional instrumentation work and with Garth taking the lead in other pre-forecasting office preparation work (programming forecast dissemination scripts or batch files as well as freezing level logs and forecast archiving routines), winter began arriving in late November. After over a week of intermittent and then continuous special avalanche statements issued by NWAC from November 21st-27th, full regular daily operation began on November 28th, 2001.

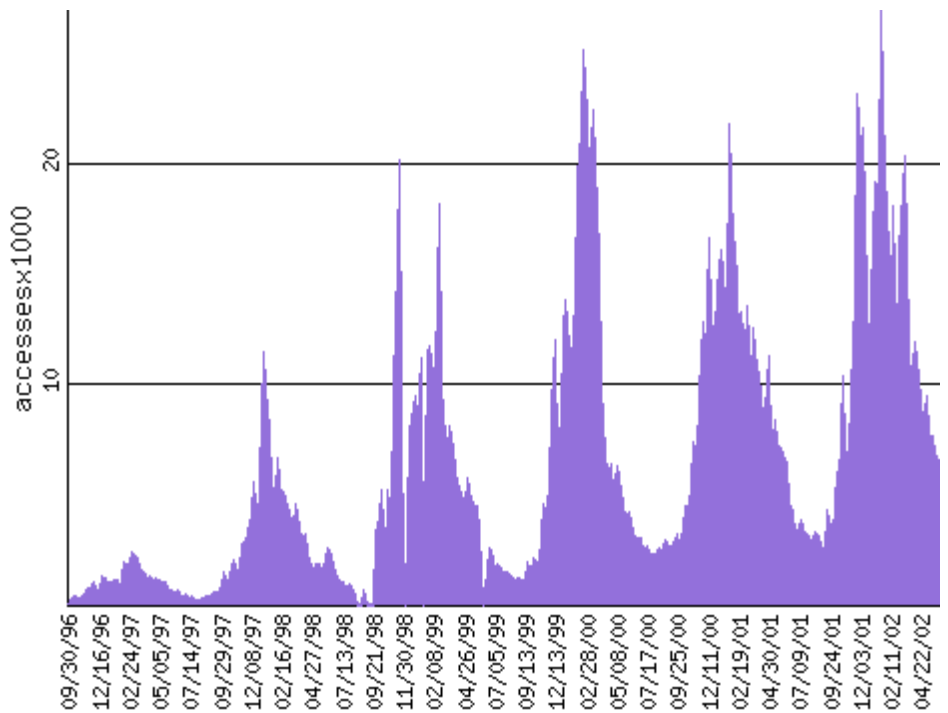
With continued modernization of the National Weather Service, one of the newer components at the Avalanche Center this past year has been a graphical PC workstation that can help supplement the AWIPS (Advanced Weather Interactive Processing System) displays that have now been the forecaster mainstay for viewing graphical forecast products over the past several years. However, as NWAC and the Forest Service were not able to procure such a workstation directly (not available on the mandatory contract and national review and approval of such a procurement was unlikely), the Friends of the Avalanche Center showed their support for the Center by donating the necessary workstation. The workstation arrived in late February and is being worked on now by National Weather Service technicians who hope to have all of the software and LAN cable installed, as well as necessary IP addresses by mid-April. Having easier direct access to the forecast models and satellite data within the NWAC forecast cubicle while composing the forecasts and talking with cooperators should make for much better information sharing.

Another item of interest is the overall increase in email into the Avalanche Center, both in terms of field snow pack and avalanche information, and requests for data or forecasts. In addition to forecasting, instrumentation and field snow pack analysis, and administration of the Avalanche Center, NWAC staff respond to literally hundreds of emails that include avalanche and weather-related questions as well as requests for past data and forecasts. While litigation related requests must be written and go through proper FOIA (Freedom of Information Act) channels, forecasters try to respond to other non-litigation related data requests in a timely fashion and check emails to the Avalanche Center on a regular basis.

NWAC Product Dissemination and Web Site

Meanwhile, access of NWAC forecast and data products continues to expand dramatically, especially on the web site (www.nwac.noaa.gov). By late May, the web site registered over a 45% increase in data hits and accesses above the previous record setting year of 2000/01 (about 1.1 million hits were recorded in 2000/01). Historical weekly web site visits of the NWAC web site since its inception in 1996 are shown below.

Figure 20. NWAC Web Site history from 9/30/96 to 6/9/2002—Weekly site accesses (x1000)



However, many users of NWAC products bypass the NWAC web site and go directly to the files that are stored on the NOAA-NWS server. Also, a variety of other web sites download the products and then store them for display and dissemination locally. Since NWAC has no way of knowing dissemination totals through these and other means, the contact figures below represent the lower end of user accesses. In any case, as of June 1st, **total direct data and forecast accesses for the past season (October 1-June 2, 2002 or 8 months) reached 1.6 million hits**, along with nearly 500,000 accesses of NWAC web site pages. Access data for both seasonal forecast hits and combined data and forecast hits are shown in Figures 21-23 below. As signs of rapidly changing times, it is interesting to note that while the avalanche forecast hotline phone numbers (503-303-2448 in Portland and 206-526-6677 in Seattle) are still active and continue to receive about 10-15,000 calls/year (Figure 21 below), accesses of these same forecasts on the web site (Figure 23) are averaging **over 17,000 hits per week**. It is hoped that the this greatly increased forecast dissemination—as well as of the hourly mountain weather data—are all helping users to make wiser

and safer decisions about trip planning and general travel in the back country.

Figure 21. Annual Phone Calls to Avalanche and Weather Hot-line Recorders (1991-2002)

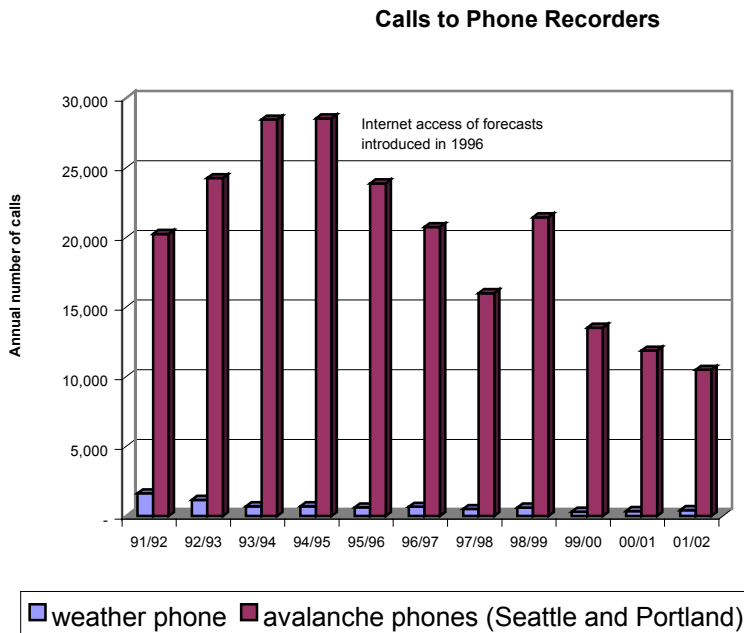


Figure 22. 2001/02 hits on NWAC weather and avalanche products

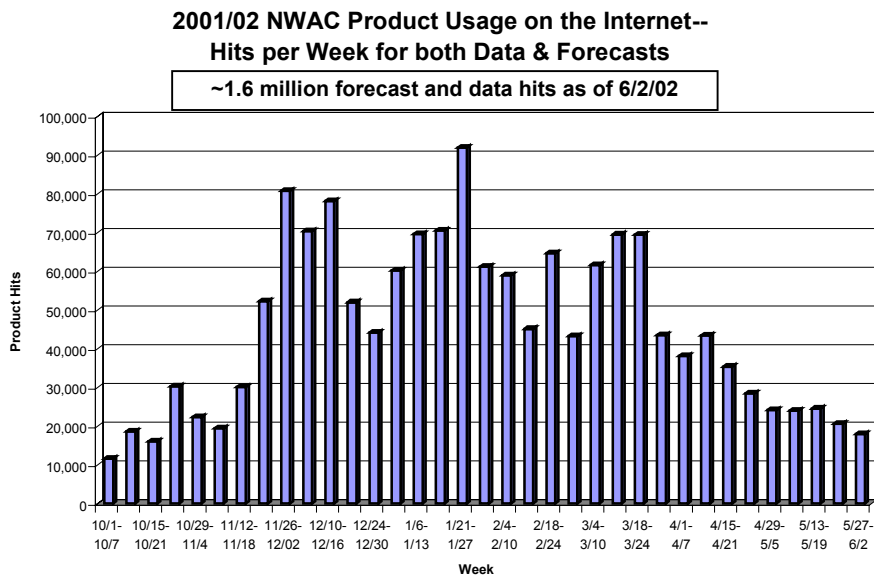
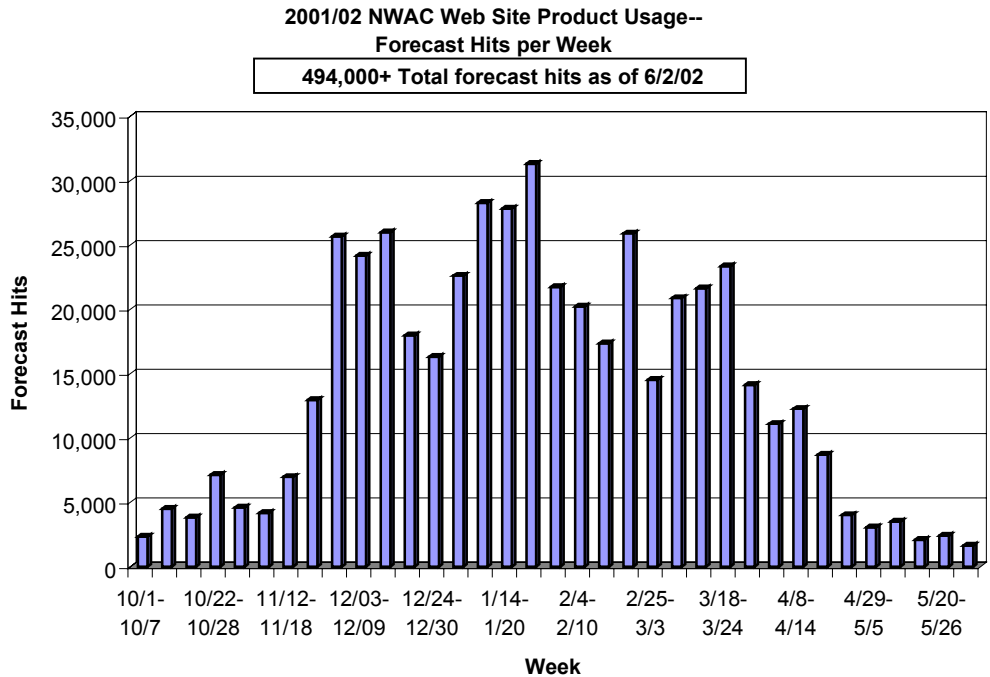


Figure 23. 2001/02 NWAC forecast accesses via the web



TRAINING

Thanks to Dr. Sue Ferguson of the Forest Service’s Pacific Northwest Fire Research Lab—PNW-FERA—NWAC forecasters were invited to attend a three-day training on the primary field datalogger and software used for the remote mountain weather data network and a variety of other data networks utilized by both avalanche and fire weather programs in the Northwest. This training involved specifics and usage of the Campbell Scientific dataloggers as well as related software and instrumentation and was held at the PNW offices in Seattle. Due to forecast scheduling, Kenny and Mark were only able to attend the final advanced topic day, but much was learned and shared and it is hoped that this additional training will pay big dividends in data accuracy and reliability as well as post analysis and display.

As time and staffing schedules allow, NWAC forecasters also self-study a variety of weather and avalanche related topics during the course of the year. While these are largely seat-of-the-pants efforts, they do result in forecasters staying near the state-of-the-art for weather and related science. More comprehensive and structured training is anticipated in the near future when the National Weather Service integrates the IFPS (Interactive Forecast Preparation System) into its operational schedule over the next year or so. It is hoped that NWAC staff can utilize the IFPS to output some graphical products to support and augment (ultimately a phased replacement) the text-based products that have been the mainstay of the program since its inception.

PUBLIC RELATIONS/EDUCATION

As education is one of the primary missions of the NWAC, and the Forest Service (through the National Avalanche Center) in conjunction with the NSAA (National Ski Areas Association) and NSP (National Ski Patrol) help to fund and administer the biannual National Avalanche School (NAS), Mark represented the NWAC as one of the school's primary instructors. The school features 20-25 top avalanche educators from around the US, and is considered one of the top avalanche training programs in the country. During most years, some 2-300 students attend the school which has been offered in such locations as Copper Mountain, CO, Reno, NV, Incline Village, NV, and now the Canyons, UT. The 6-day classroom session is followed by a 3-day field session held at various locations around the US in January or February. Prior to the school, Mark attended a 2-day Regional Avalanche Center Meeting and Professional Development Seminar co-hosted by the Forest Service's National Avalanche Center and Snow Basin, UT.

The Mountaineers group of Washington, in cooperation with the Friends of the Avalanche Center (FOAC), presented a Back Country Expo on November 17th. The event offered awareness talks on snow, avalanches, climbing and other winter recreation along with vendor displays from a variety of winter recreation concerns. Mark and Larry Donovan from the Mt Baker-Snoqualmie National Forest Supervisor's Office attended and staffed an NWAC and Forest Service booth, respectively, and Mark presented a talk on snow stability tests and techniques.

In addition to strong educational efforts by FOAC staff (notably Roland Emetaz and Ken White)—who continued to give avalanche presentations to a variety of user groups—the FOAC also offered several fund raisers to help increase awareness of and funding for the Avalanche Center in late November and early December. Cooperating with Teton Gravity Research, who supplied the film *The Mind Addiction*, FOAC presented several showings as benefits for FOAC. Unfortunately the initial showing was beset by a power problem when an accident brought down all the power for a sizeable area in north Seattle, including the film venue at REI. This necessitated a rain check with the first showing rescheduled for most attendees in later in December. However a small but hardy group persisted despite the power outage and braved the elements and cool temperatures for an intimate outside showing of the film via TV-VCR hookup from an emergency REI generator. At subsequent more favorable conditions (indoor with power) some 2-400 attended the event and this helped raise extra dollars for FOAC educational efforts and support of the Center. Forecasters from the Avalanche Center attended all but one of the showings, and talked briefly about the Center, the winter ahead and the need to remain avalanche aware.

Garth took a trip to Crater Lake in southern Oregon on December 7th-9th, helping the NPS with an instrumentation site that NWAC helps maintain, looking at the snow pack, and presenting a day-long training to rangers and the Crater Lake Nordic Patrol. While outside of the normal daily coverage area for NWAC forecasts, NWAC does issue special avalanche statements for the Crater Lake area after consultation with NPS rangers, and together with other National Parks like Mt Rainier and Olympics, Crater Lake provides significant funding for NWAC operation. Then Garth journeyed to Hurricane Ridge in the Olympics on the 8th and 9th of January, both for instrumentation fixes at the remote weather station in Olympic National Park and for an evening avalanche awareness talk for the public and park personnel. While the talk response was good with the 40 or so attending enjoying and learning, the instrumentation fix was more complex and involved substantial phone line problems that continued intermittently for some time.

Meanwhile later in the month on the 23rd of January, Mark went to Paradise and Mt Rainier National Park for an all-day awareness and snow pack stability session with park personnel, including maintenance staff, park rangers and search and rescue folks. Some 30 folks attended and learned probably more than they wanted about snow pack, snowpits and mountain weather. Fortunately, the information gathered during the field session was not only very instructive for the students (lots of

highly unstable snow that fractured easily and cleanly for illustration purposes) but also was helpful for preparing the forecasts for high to extreme danger the following day. The late January increase in avalanche danger came at a fortuitous time, as Governor Gary Locke (at the behest of the FOAC) proclaimed the first annual Washington State Avalanche Awareness Week from January 21st-27th, 2002. This is part of an effort to hopefully promote a national avalanche awareness week to help emphasize the growing concern over the high avalanche fatality toll throughout the US.

During the early part of February, the rash of NW avalanche incidents combined with several large avalanche fatality accidents in British Columbia (three local BC skiers killed) and Montana (four snowmobilers killed in one avalanche) prompted an increased news media response and NWAC forecasters experienced a considerable increase in interviews in late January through early February. In fact, a KATU TV crew from Portland met Garth and Mark at Timberline Lodge on Mt Hood for extensive interviews on the 29th of January. While the forecasters erected a new tower section and raised all of the sensors an extra 10 feet (the depth at the time was 207 inches with only a 22 ft/260-inch tower installed) to prevent future burial, the cameraman and reporter conducted a running interview from the base of the tower. Unfortunately, the weather was rather marginal (strong winds, cold temperatures and intermittent snow), and the reporter had not dressed completely for the occasion. By the end of an hour's shoot she was rapidly losing feeling in her fingers and appeared almost hypothermic. Garth and Mark urged the reporter to conclude the interview and go get some hot chocolate, a recommendation that was happily followed. Fortunately later she seemed quite normal and no worse for the exposure.

At the request of the Stevens Pass professional ski patrol, Mark gave a short mountain weather talk to about 20 pro patrollers on the 25th of February, then toured around the Stevens Pass vicinity to check out the slides that occurred during the heavy rainfall from the previous week. Then it was off to Mt St Helens where Mark joined with Roland Emetaz (previous liaison and one of the Founding Fathers of the NWAC) to give a snow stability session to 20 or so members of the Volcano Mountain Rescue group on the 3rd of March. Finally late in March Mark presented a requested talk on "*Snow Physics*" to an interested group of 25-30 high school seniors at a Nathan Hale High School physics class in north Seattle.

Of course the prolonged highway pass closures in March also produced a lot of news media interest, both regionally and nationally, and forecasters gave several live and taped interviews for both radio and TV. On the evening of the 19th of March, Mark gave a live interview regarding the high avalanche danger and the pass closures to Cable News Network, while Garth engaged in several live radio interviews on the morning of the 20th.

Educational efforts continued well into the spring, as Mark gave avalanche awareness and mountain weather talks to the National Park Service rangers and maintenance personnel at Mt Rainier in mid-May, and to a Snow Ecology class at Evergreen State College in late May. For the season (as shown in the table below) the combined efforts of the NWAC staff and FOAC educators reached over 2,600 interested people.

Table 3. NWAC Presentations and Interviews 2001/2002

Date	Organization	#	Location	Speaker
Oct 24 Moore	Regional Aval Center Mtg	60	Snow Basin UT	
Oct 25 Moore	Regional Aval Center Mtg	60	Snow Basin UT	
Oct 29	National Avalanche School	200	Park City UT	Moore
Oct 30	National Avalanche School	200	Park City UT	Moore
Oct 29-Nov 2	National Avalanche School	125	Park City UT	Moore
Nov 8	FOAC Fundraiser REI	25	Seattle	Ferber
Nov 17	Seattle Mtn'eers BC Expo	60	Seattle	Moore

Date	Organization	#	Location	Speaker
Nov 17	Seattle Mtn'eers BC Expo	55	Seattle	White
Nov 30	FOAC Fundraiser	150	Seattle	Moore
Nov 30	KOMO – Interview		Seattle Metro	Ferber
Dec 3	Tacoma Mtn'eers	60	Tacoma	Emetaz
Dec 4	Everett Mtn'eers	42	Everett	White
Dec 8	Crater Lake NP	40	Crater Lake	Ferber
Dec 12	Seattle Mtn'eers Snowshoe	80	Seattle	White
Jan 3	Wa State Ski Touring Assoc	100		White
Jan 5-6	NAI – Basic	70	Crystal	Moore
Jan 8	Oregon Nordic Club	85	Portland	Emetaz
Jan 15	Olympia Mtn'eers	40	Olympia	Emetaz
Jan 16-17	NAI	80	Crystal Mtn	Moore
Jan 23	Mt Rainier NP	30	Paradise	Moore
Jan 25	NW Cable News – Interview		Seattle Metro	Ferber
Jan 25	KING 5 News – Interview		Seattle Metro	Ferber
Jan 26	Mountain Madness - Field	20	Blewett Pass	Ferber
Jan 29	KATU-TV – Interview		Portland Metro	Moore
Jan 29	REI – Store	50	Tualitin	Emetaz
Jan 30	BSA – Mt Baker Council	85	Everett	White
Feb 2	Mountain Madness - Field	20	Blewett Pass	Kramer
Feb 2-3	NAI – Advanced	110	Crystal Mtn	Moore
Feb 4	Volcano Mtn Rescue	30	Yacoli	Emetaz
Feb 7	Everett Mtn'eers - Nordic	32	Everett	White
Feb 11	BSA – Troop #120	20	Everett	White
Feb 14	KING 5 TV News – Interview		Seattle Metro	Kramer
Feb 16	Wa State Snowmobile Assoc	50	Okanagan	White
Mar 3	Volcano Mtn Rescue	10	Cougar	Moore
Mar 3	Volcano Mtn Rescue	10	Cougar	Emetaz
Mar 13	Tacoma Mtn'eers - Climbing	80	Tacoma	Emetaz
Mar 18-19	NW Forecasters Mtg	15	Crystal	Ferber/Kramer
Mar 19	Cable News NW TV- Interview		Northwest	Moore
Mar 19	Nathan Hale HS	40	Seattle	Moore
Mar 26	Tacoma Mtn'eers - Scramble	60	Tacoma	Emetaz
Mar 27	Vancouver Snowmobilers		20 Vancouver	Emetaz
Mar 28	Patagonia – Store	70	Portland	Emetaz
Mar 29	Ski Rally Mtg REI	90	Seattle	Ferber
April 5	Whatcom Co & Glacier Riders Snowmobile Club	31	Bellingham	White
April 8	BSA – Troop	20	Mercer Is	White
April 9	Fire Weather Workshop	25	Seattle	Ferber
April 11	Everett Mtn'eers - Scramble	50	Everett	White
April 30	Everett Mtn'eers - Climbing	54	Everett	White
May 6	Evergreen St College	25	Olympia	Moore
May 20	Mt Rainier NP	25	Paradise	Moore
May 30	KOMO TV- Interview		Seattle Metro	Ferber
June 2	Whatcom Co & Glacier Riders Snowmobile Club	31	Bellingham	White
June 20	Seattle Mtn Rescue	20	Seattle	Kramer

Approximate Total

2600 +

Note that the above list of educational opportunities and public information contacts do not include extensive interviews for a variety of print publications including the Seattle PI, Seattle Times, Tacoma News Tribune, USA Today, and others.

In addition to the FOAC events presented earlier in the education section above, the Friends of the Avalanche Center (www.avalanchenw.org) orchestrated several other interesting and beneficial events in support of the NWAC during the year. *SnowBash 2002*, held in early January, was a gathering of back country snow aficionados held at the Fremont Unconventional Center in Seattle partly as a celebration of the great early season snows, and partly as a fund raiser and a good way to locally increase avalanche awareness. The event featured a great variety of door prizes donated by local and other vendors as well as co-hosting of the event by Rich Marriott, the KING-5 television celebrity, and a short talk on avalanche awareness by Mark Moore. Some 400+ happy skiers, snowboarders and other winter recreationists reveled in the party-like atmosphere while a local DJ spun a variety of tunes, and the FOAC organizers kept beverage containers full to the brim. Overall the *Snowbash 2002* party brought in several thousand dollars to help meet the FOAC mission of enhancing avalanche education and increasing the level of awareness about the Avalanche Center, as well as donating equipment as needed.

Along with corporate sponsors REI and Lifelink, FOAC also helped host the first annual Northwest Randonee Rally—a significant ski race benefit. The event consisted of several aggressive and challenging Randonee Ski Rally courses near the Alpental Ski Area on Sunday, March 31st, with some 70+ racers signing up for the apparently internationally sanctioned event. FOAC president Bruce Greenstein was instrumental in organizing and setting up the event, with strong support from several FOAC board members and the Alpental Professional Ski Patrol. From early reports, the blend of both local and international racers seemed to like the course and were generally pleased that the storm front held off until Sunday night, after the race was finished and the celebration had begun.

FUNDING

As in many years during the recent past, NWAC is continuing to experience considerable fiscal pressure on maintaining normal operation. Although past records indicate that since FY1993 funding of the program has increased less than inflation, the demands for better and more comprehensive forecasts and data have not diminished. An expanded and more reliable remote weather data network has been developed to help support these increased forecast needs, with NWAC utilizing the best available sensors to make the data and resultant forecasts more reliable than ever. An enhanced network of automated 24-hour and total snow depth sensors has been employed to help both forecasters and cooperators, with updated hourly data being available on the web site more reliably than ever before. Graphical capabilities to both forecast and data products are being developed whenever time and funding allow, with avalanche accident information and statistics updated regularly on the web site. On the education front, NWAC staff continue to educate as much as possible—see the Education section—and spend considerable time developing and enhancing a variety of educational avalanche and weather related presentations for the public and cooperators. Despite the overall efforts which have stabilized and perhaps decreased the numbers of avalanche related accidents and fatalities in the Northwest—see the Accidents section above—a lack of funding seems to be a perennial problem.

To help address this issue, the Forest Service and NWAC staff are engaged in a number of efforts with cooperators to help reduce or eliminate expected shortages in both the short and long term. These efforts include proposals that utilize fee-demo dollars for enhanced forecasting services and data network support requests for Title II funding sources (and Title III in cooperation with non-profit programs). Although the extent of such potential support is unknown at this time, cooperators and the NWAC are optimistic that at least some additional funding can be found to help lessen the impact of anticipated future shortages. In one of several bright spots, to aid the plight of the Avalanche Center, the Pacific Northwest Ski Area Association (PNSAA) has already committed to increased levels of support over the next two years—with their annual donations increasing by \$2,500/year through FY04 (\$10,000/year in FY02 to \$15,000/year in FY04—a 50% increase). And during a special early edition annual cooperator meeting in late April, the National Weather Service offered some instrumentation support of approximately \$5,000 (if their budget remains stable) and FOAC offered several thousand dollars to help with instrumentation at selected weather stations. The following pie charts (Figures 24 and 25) show rather simply the expected income and expenditures of the NWAC for the current fiscal year (FY2002—October 2001 through September 2002).

Figure 24. NWAC Annual Cooperator Funding--Pie chart for 2002 (Funding shown includes all major cooperator contributions, including PNSAA)

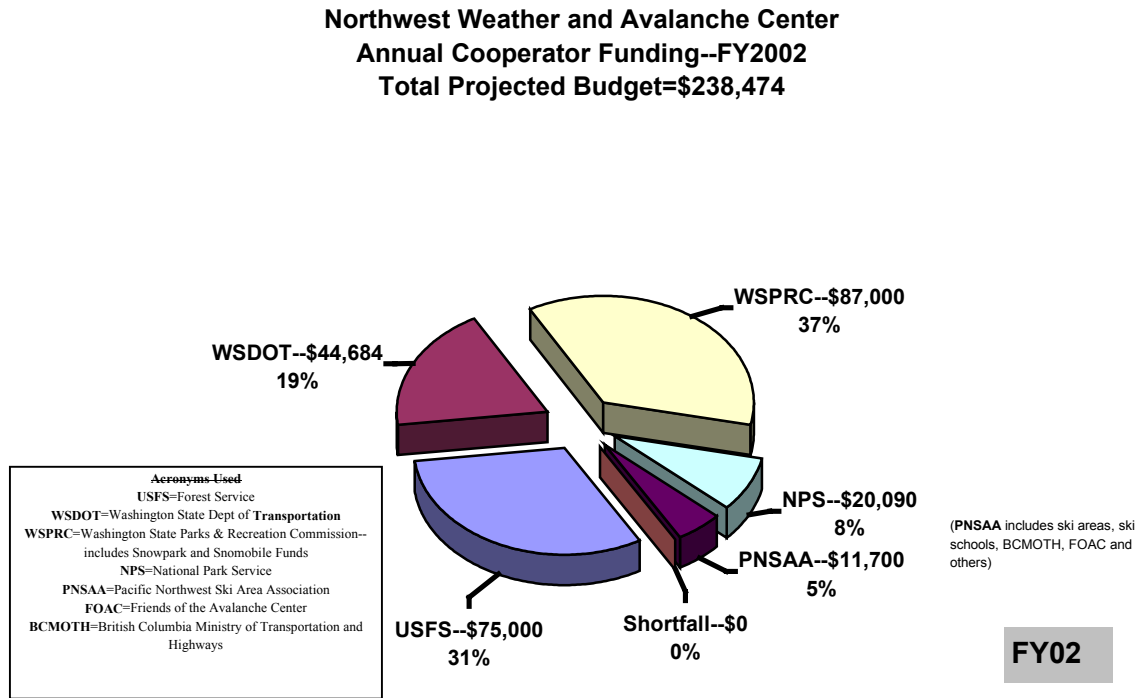
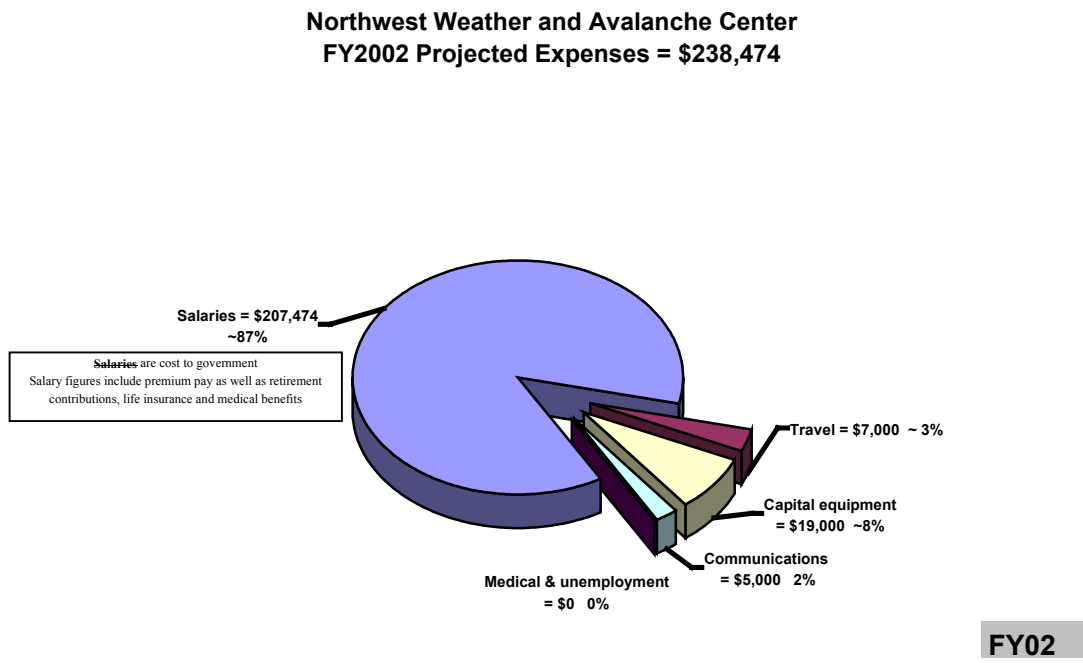


Figure 25. NWAC Annual Expenses--2002 Pie Chart




The NWAC is able to succeed by a large number of primary and other cooperators who support the center's operation through direct dollar contributions. However, other very important in-kind support is often overlooked but is nonetheless critical for continued success. These indirect contributions are shown in Table 4, which outlines the total direct and indirect contributions by a variety of supporters. Both direct and indirect contributions are necessary to allow the Avalanche Center to succeed, as is obvious from the rather large amount of indirect dollars and in-kind support that shows in contributions from such cooperators as the National Weather Service. The National Weather Service Forecast Office in Seattle, WA contributes a generous amount of office space and office services (including network routers, printers, electronic technicians, T-1 web access, forecast consoles, dissemination circuits, etc), as well as access to and availability of the expertise of operational forecasters along with a wide range of weather products including satellite and radar imagery, forecast model maps and other output, and observational data. Certainly the Avalanche Center would not be what it is today if not for the combined efforts of a lot of agencies and individuals involved.

Table 4. NWAC Total Program Costs for 2002--Direct + Indirect Contributions

Cooperator	Contribution Type	Amount/year (Approximate \$)
USDA-Forest Service	Administrative Overhead (~30% of direct contribution)	\$26,265
Washington Department of Transportation	Observations and instrumentation support	\$19,040
National Park Service	Observations and instrumentation support	\$4,710
National Weather Service	Weather product access (~\$37,950/yr), office costs (~\$3,800/yr), equipment maintenance (~\$12,016/yr)	\$55,380
NWS, USFS, WSDOT	Peripheral support equipment; e.g., communication and display equipment to duplicate NWS receipt of weather data (1-time cost)	\$50,540
PNSAA	Observations, phone lines, power for instrumentation, lift access, electrician assistance	\$6,320
Total Indirect Support		~\$158,490
Total Direct Support		\$238,474
Total Direct + Indirect = Total Program Costs (approximate cost to reproduce program in private sector)		~\$396,964

APPENDIX

NWAC and Avalanche Related Articles

 P-I.com

 Northwest

In avalanche country, thinnest of defenses hangs tough

Poorly funded warning system relies on a coterie of experts able to improvise

Thursday, December 27, 2001

By [TOM PAULSON](#)
SEATTLE POST-INTELLIGENCER REPORTER

SNOQUALMIE PASS -- An empty salsa jar, a Schmitz beer can, bubble gum and a surplus Army tank are among the tools used by a small, poorly funded network of winter backcountry experts to protect against avalanches in the Cascades.

This in a region that has been home to the pioneers of American avalanche science and that holds the record for the nation's largest death toll, 96, in a single slide.

Avalanches kill more people in Washington than any other natural hazard -- claiming two or three lives every year.

With the snow levels already at 120 percent to 140 percent of normal, the recent stretch of sunshine and cold nights likely will increase avalanche risk by creating frost layers that weaken the structure of the snowpack.

AVALANCHE BASICS

For a quick introduction to how avalanches form and how to avoid them, see [our illustrated poster](#) (130K Acrobat PDF).

 Image

Avalanches also cost money. Economists estimate that for every hour Interstate 90 is closed, businesses lose about \$750,000 because of stalled shipping, lost perishables, rerouting costs and the like. In 1996-97, Snoqualmie Pass was closed for more than seven days due to avalanches, a \$130 million loss for businesses.

Yet avalanche defense in this region largely depends on a small group of skiers, snow scientists and other backcountry experts who labor at this important task by improvising on shoestring budgets and working other jobs to pay the bills.

"We're barely able to keep everything running," said Craig Wilbour, avalanche-control chief at the pass for the state Department of Transportation.

On Wilbour's desk in a small office at the pass is a computer, its screen displaying the kinds of real-time data he needs to accurately assess avalanche risk at any given moment -- wind, precipitation, snowpack, temperature and solar radiation.

The high-tech look of the data on the screen gives no hint that one of the graph lines -- detailing ongoing changes in solar radiation -- comes from a La Victoria salsa jar.

Solar detectors typically cost about \$1,000, money that would come out of Wilbour's annual budget of about \$200,000 for his three-man seasonal crew.

So Wilbour, who grew up in a mining town and learned early in life how to make do with less, instead bought some cheap solar cells and transistors at RadioShack, soldered them together with wires and placed them in the salsa jar.

"It works fine," he said with a shrug.

The salsa solar solution is not an aberration for the region.

In British Columbia, California and throughout much of Europe, avalanche control is often done using remote controlled propane gas "exploders" to test dangerous snow.

The use of these "fixed exploders" came from research done at the University of Washington, funded by the Washington and Colorado state transportation departments.

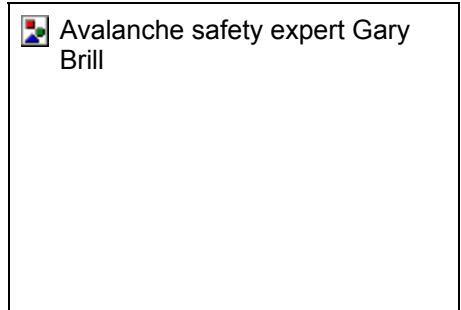
But at Stevens Pass, the DOT uses a donated Vietnam-era tank to fire shells at the riskiest slopes, a daunting task when the clouds roll in and obscure the targets. Wilbour's team uses the more routine recoilless rifle.

"For some reason, it's always been very difficult to get funding for avalanche work," said Mark Moore, director of the Northwest Weather and Avalanche Center, located at the National Weather Service office in Seattle.

Moore, one of the nation's leading avalanche experts, and his colleagues maintain and operate 21 remote weather stations monitoring avalanche and mountain weather conditions in Washington, Oregon and British Columbia to produce the most comprehensive avalanche information database in the nation.

The center also depends on snowpack information from ski patrollers, knowledgeable backcountry skiers and people like Wilbour.

In addition to real-time avalanche monitoring, the center's data are often used by scientists who study snow and ice.



Avalanche safety expert Gary Brill, center, looks at the reading on KING-5 weather expert Jeff Renner's transceiver during a class on how to find an avalanche victim. *Meryl Schenker / Seattle Post-Intelligencer*
[Click for larger photo](#)

Reports from the Northwest avalanche center are a regular feature at scientific conferences such as the International Snow Science Workshop, where academics and practical snow managers like Wilbour meet to compare notes.

"We're the only place in the U.S. that has dedicated avalanche and mountain weather forecasts," said Paul Baugher, ski patrol director at Crystal Mountain.

"We rely on these guys, and they rely on us. We just hope the center can stay solvent."

Housed in the weather service building, administered by the U.S. Forest Service, the Northwest avalanche center receives about \$240,000 a year from varied sources: the DOT; state and national park services; the weather service; local ski resorts; and the B.C. Ministry of Highways and Transportation.

But it's barely enough to get by, forcing Moore and his colleagues to work other jobs.

They can only spare so much time hiking out to check on their remote weather stations. On one occasion, they discovered a magnet had fallen off a precipitation gauge. They used chewing gum to reattach it.

"It worked flawlessly for three months," Moore said. Another time, a ski patroller at Crystal used a Schmitz beer can to fix a rain gauge.

Despite that patchwork maintenance, the center is still widely regarded as one of the nation's leading centers for avalanche and mountain weather forecasting. It was launched 25 years ago by former UW snow scientist Ed LaChapelle -- a man many consider the "father of American avalanche science."

In 1976, because of LaChapelle's groundbreaking research improving avalanche forecasting, state transportation officials funded the start of the Northwest avalanche center.

Moore and Rich Marriott, now a KING-5 television meteorologist, were LaChapelle's graduate students then. At about the same time, Wilbour (then a ski patroller at Alpentel) was asked by state officials to create a more proactive system for protecting I-90 from slides.

The link between science and the center continues to this day.

"A lot of the research now is in the area of snow physics; the mechanics," Moore said.

He and Wilbour have worked with Howard Conway, the UW's leading expert on avalanches. One project led by Conway -- who is now in Antarctica -- showed that Cascade avalanches were not taking place according to standard theory.

When it rains on snow, the standard theory of avalanche science went, the water would percolate down to a hard layer in the snowpack, where it would, over time, lubricate the layer and, eventually, allow for a slab avalanche.

"But we were getting avalanches at the first raindrop," Wilbour said. "Obviously, this was happening before the water could percolate down into a snow layer."

Conway, Wilbour, Moore and others in the local avalanche community worked to come up with new methods for predicting avalanche hazard that better fit the soggy Cascades -- and better fit the needs for keeping roads open and the backcountry safe.

One motivation is to make sure history doesn't repeat itself. Washington holds the distinction of having had the worst avalanche disaster in American history, and one of the worst transportation disasters. In 1910, 96 people were killed when two trains that had stopped on the west side of Stevens Pass were hit by massive avalanches.

It's clear that avalanches should rank high on the list of natural hazards in the Pacific Northwest, but those who struggle on a shoestring to protect against this threat every winter say they are now looking at even greater funding cuts.

"A lot of people think the avalanche center is a luxury," Moore said. "They don't understand that it's at the core of a community of people who perform a critical service."

P-I reporter Tom Paulson can be reached at 206-448-8318 or tompaulson@seattlepi.com. The following Avalanche Basics figure is reproduced from the Paulson article. Copyright 2001 Seattle Post-Intelligencer, reprinted with permission.

Seattle Post-Intelligencer

AVALANCHE BASICS

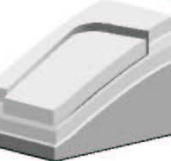
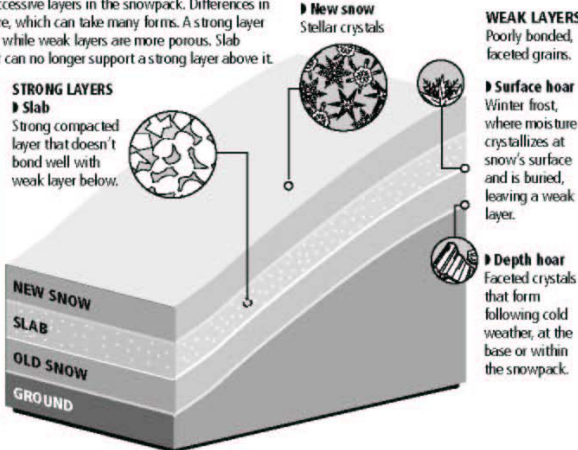
Winter snowfall brings with it an increased likelihood of avalanches, especially slab avalanches which are the most common in our area. Snow type, weather and terrain are all factors in slab avalanche conditions. Knowing these conditions and recognizing danger signs can greatly improve your chances of avoiding an avalanche.

AVALANCHE CONDITIONS

Over time, snow and wind create successive layers in the snowpack. Differences in layers depend on the snow's structure, which can take many forms. A strong layer consists of densely compacted snow while weak layers are more porous. Slab avalanches occur when a weak layer can no longer support a strong layer above it.



ALASKA MOUNTAIN SAFETY CENTER INC.
In this thin cross-section of snowpack, backlit by the sun, light comes through the weaker, less dense layers.



2. Once the slab is loose, gravity pulls it downhill at speeds sometimes exceeding 100 mph. The avalanche won't stop until it reaches a runout zone, usually a slope of less than 20 degrees.



Slab avalanche
1. Many factors can contribute to a slab breaking loose and sliding down a slope. A slab can be less than 1 inch to 35 feet deep, and a few yards to more than a mile wide.

SNOW FACTORS

Storms
Types especially prone to slab formation

- Columns
- Needles
- Spatial dendrites

Weak bonding
These forms are less likely to be found in slabs. Their shapes make a more porous, weaker layer.

- Plates
- Stellar crystals

Snow metamorphism
Snow crystals constantly change. In cold weather, grains can grow and become more faceted in a process known as kinetic growth. In warmer temperatures, grains become more rounded and settle quickly.

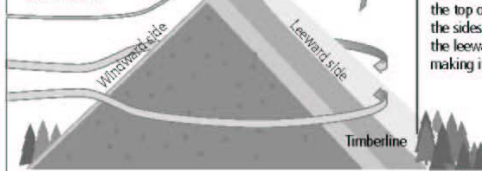
- Rounded grains**
Form strong, well-bonded, cohesive layers.
- Faceted grains**
Large angular grains form, usually near the crust. Found in cold, shadowed areas. The low density and porosity make for a weak, collapsible layer.
- Wet grains/melt-freeze**
Freeze is strong but crust can become bed surface for avalanches.
Melt causes rapid weakening as water becomes lubricant.

Source: Alaska Mountain Safety Center, Colorado Avalanche Information Center, "Snow Sense" by Jill Fredston and Doug Fesler

WEATHER FACTORS

- Storms**
Most natural avalanches happen during or shortly after a storm.
- Wind**
As the snow blows, grains become more rounded and can form heavy slab layers.
Strong winds can blow snow off the windward side onto the leeward side, where it settles. Rapid wind-loading can lead to avalanches.
Cornices can form at the peak, and this overhanging snow can be very unstable.
- Cold weather**
If a weak layer is formed, cold weather can keep it weak by not allowing the snow grains to round and make stronger bonds. For this reason shaded areas are usually weaker than sunny areas.
- Warm weather**
Moderate warming can strengthen the snowpack, while too much warmth can weaken the snow by melting grains and lubricating the bonds between them.

Wind can keep snow from piling up on the windward side, making it safer than the leeward side.



Unsafe area
Snow blown over the top or around the sides can load the leeward side, making it unsafe.

TERRAIN FACTORS

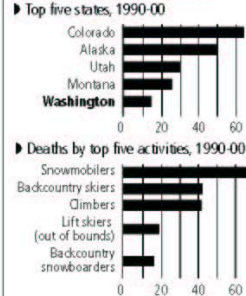
Slope angle
Slab avalanches usually start on angles between 30° and 45°

Anchors
Ledges and groups of boulders and trees anchor snow until they are covered up. Anchored areas can hold snow on slopes above until the weight of the snow is too great. Anchors can also be starting points for avalanches, since gravity will be pulling a slab down while the anchor holds the snow above in place.

Poor anchors
Most avalanches start above the timberline, where there are few anchors.
Ground covered by grass and rock slabs doesn't hold snow in place.

Unsafe area

U.S. avalanche fatalities



Danger signs

Most victims of an avalanche are the ones who triggered it, ignoring many obvious signs. Here are a few:

- Previous avalanche activity**
The most obvious sign of a dangerous area is previous avalanche activity.
- Vegetation**
Swaths of open slope between forested areas.
Damaged trees (esp. on uphill side).
"Disaster species," such as alders, willows, dwarf birch and cottonwoods.
Marked difference in heights of trees.
- Sounds**
Hollow sounds indicate a weak layer under a more dense layer.
"Whumphing" noises are the sound of weak layers collapsing.

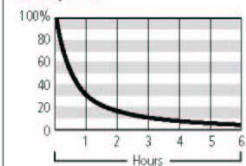
- Shooting cracks**
Indicate snow is cohesive enough to break off in slabs.
- Recent wind loading**
Snow drifts on one side of trees.
Cornices.
Drifting patterns on surface.

Rescue Gear

- Beacon to send and receive signals to find person under the snow.
- Retractable pole or convertible ski poles for probing the snow to find victims.
- Shovel to dig through the heavy snow that can set like concrete.

Survival odds

Survival chances of a person buried in snow by hour.



For more information see
www.avalanche.org
www.nwac.noaa.gov

DAVID BADPERS/SEATTLE POST-INTELLIGENCER