Natural Disaster Survey Report

DISASTROUS FLOODS FROM THE SEVERE WINTER STORMS IN CALIFORNIA, NEVADA, WASHINGTON, OREGON, AND IDAHO

December 1996 - January 1997

Prepared by
Western Region Headquarters

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service, Silver Spring, Maryland

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Preface

A joint Western Region (WR)/National Storm Survey Team was assembled following the major winter storms of December 25, 1996, through January 5, 1997, which struck California, Nevada, Washington, Oregon, and Idaho, producing high winds, ice storms, and significant precipitation that resulted in record flooding and numerous mudslides. The survey team was formed to review the operations and effectiveness of products and services of the Next Generation Weather Radar (NEXRAD) Weather Service Forecast Offices (NWSFOs) and NEXRAD Weather Service Offices (NWSOs) in Boise, Seattle, Portland, Medford, Eureka, Sacramento, Monterey, Reno, and the River Forecast Centers (RFCs) in Sacramento and Portland prior to and during the event. The primary focus of the survey was the flood event associated with the storms.

In order to cover the large area effected in a timely manner, the survey team was divided into three groups with a leader for each group. The survey was conducted during the periods of January 13-16 and January 20-24, 1997.

The flood survey team consisted of Robert Tibi, Chief, WR Hydrologic Services Division (HSD) (team leader); Gregg Rishel, Deputy Chief, WR HSD (group leader); Andrea Bair, Hydrologist, WR HSD; Dave Toronto, Warning Coordination Meteorologist (WCM), NWSFO Salt Lake City; Glenn Austin, Deputy Chief, Office of Hydrology, Hydrologic Operations Division; Dave Bright, Science and Operations Officer (SOO), NWSO Tucson (group leader); James Henderson, Deputy Director, Aviation Weather Center; and Andy Bryant, Service Hydrologist (SH), NWSO Tucson.

The survey team split into three groups: Group A, led by Gregg Rishel, visited California-Nevada RFC (CNRFC), NWSO Sacramento, NWSFO Monterey, Northwest RFC (NWRFC), NWSFO Portland, NWSFO Seattle, and the associated emergency management offices; Group B, led by Bob Tibi, visited NWSOs Eureka and Medford; and Group C, led by Dave Bright, visited NWSFOs Boise and Reno and the associated emergency management offices.

The storm survey team wishes to express its appreciation to the staffs of the National Weather Service (NWS) field offices at Sacramento, Monterey, Portland, Seattle, Eureka, Medford, Boise, and Reno for their cooperation and support, for scheduling meetings and interviews for team members, and for preparing and providing data and summaries for the survey team.

Robert S. Winokur
Acting Assistant Administrator
for Weather Services

October 1997

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Abbreviations and Acronyms

AFOS	Automation of Field Operations and Services
ALERT	Automated Local Evaluation in Real-Time
AM	Area Manager
ASOS	Automated Surface Observation System
AVN	Aviation Forecast Model
AWIPS	Advanced Weather Interactive Processing System
BDS	Bureau of Disaster Services
CBRFC	Colorado Basin River Forecast Center
CDEC	California Data Exchange Center
CDWR	California Department of Water Resources
CFS	Cubic Feet Per Second
CNRFC	California-Nevada River Forecast Center
COE	U.S. Army Corps of Engineers
DAPM	Data Acquisition Program Manager
DCP	Data Collection Platform
DWOPER	Operational Dynamic Wave Routing Model
EAS	Emergency Alert System
EM	Emergency Manager
EMWIN	Emergency Managers Weather Information Network
EOC	Emergency Operations Center
FAA	Federal Aviation Administration
FLDWAV	Flood Wave Forecasting Model
FLS	Flood Statement
FLW	Flood Warning
GARP	GEMPAK Analysis Rendering Package
GEMPAK	General Meteorological Package
GOES	Geostationary Operational Environmental Satellite
HADS	Hydrometeorological Automated Data System
HAS	Hydrometeorological Analysis and Support
HMT	Hydrometeorological Technician
HPC	Heavy Precipitation Center
HRL	Hydrologic Research Laboratory
HSA	Hydrologic Service Area
HSD	Hydrological Services Division
HSM	Hydrologic Services Manual
IFP	Interactive Forecast Procedure
IWIN	Interactive Weather Information Network
LARC	Limited Automatic Remote Collector
LSR	Local Storm Report
MB	Millibar
METAR	Aviation Routine Weather Report

MIC	Meteorologist in Charge
MM5	Mesoscale Meteorological Model Version 5
MOU	Memorandum of Understanding
MRF	Medium Range Forecast Model
MSD	Meteorological Services Division
MSL	Mean Sea Level
NCEP	National Centers for Environmental Prediction
NEXRAD	Next Generation Weather Radar (WSR-88D)
NOAA	National Oceanic and Atmospheric Administration
NOHRSC	National Operational Hydrologic Remote Sensing Center
NOWCAST	Short Term Forecast
NWR	NOAA Weather Radio
NWRFC	Northwest River Forecast Center
NWS	National Weather Service
NWSFO	NEXRAD Weather Service Forecast Office
NWSO	NEXRAD Weather Service Office
NWSRFS	National Weather Service River Forecasting System
OES	Office of Emergency Services
PIL	Product Identifier List
QPF	Quantitative Precipitation Forecast
QPS	Quantitative Precipitation Support
PST	Pacific Standard Time
RAMSDIS	Ramm Advanced Meteorological Satellite Demonstration and Interpretation System
RFC	River Forecast Center
ROML	Regional Operations Manual Letter
RVF	River Forecast Guidance
SAME	Specific Area Message Encoder
SDM	Station Duty Manual
SH	Service Hydrologist
SHEF	Standardized Hydrologic Exchange Format
SNOTEL	Snow Telemetry
SOO	Science and Operations Officer
SPS	Special Weather Statement
SRWARN	Southern Region Warning Program
SSARR	Streamflow Simulation And River Routing Model
SSD	Scientific Services Division
SSMI	Special Satellite Microwave Imagery
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
UTC	Coordinated Universal Time
VAD	Velocity Azimuth Display
WCM	Warning Coordination Meteorologist
WFO	Weather Forecast Office
WHFS	WFO Hydrologic Forecasting System

WR	Western Region
WRH	Western Region Headquarters
WSR-88D	Weather Surveillance Radar-1988 Doppler

Executive Summary

A series of powerful Pacific Ocean disturbances of tropical origin, following an unusually wet autumn, brought a deluge of severe winter weather, high winds, and associated flooding to a widespread portion of the western United States over the Christmas/New Year's period. Several bouts of heavy rain combined with snow melt resulted in excessive runoff that produced severe flooding across a five-state area. Record flooding was recorded in the north and central parts of California, western Nevada, and southwestern Idaho. Major flooding was recorded in Washington and Oregon. In addition to flooding, the storms brought high winds and caused numerous mud and rock slides. A total of 84 counties in the five-state area were declared Federal disaster areas: 45 counties in California, 5 in Nevada, 14 in Washington, 7 in Oregon, and 13 in Idaho. Thirteen persons lost their lives due to flooding and flood-related accidents/ incidents: 10 in California, 2 in Nevada, and 1 in Oregon. An additional five persons were killed when a small plane crashed in Idaho during evacuations, and one person was killed in Oregon due to an accident related to icy roadways. Storm damages were extensive to homes, businesses, agriculture, and infrastructure, with damage estimates exceeding several billion dollars. The hardest hit areas were California with over $2 billion in estimated damages and western Nevada with over $1 billion in estimated damages.

The classic ingredients for severe wintertime flooding in the West are a heavy snowpack over nearly saturated or frozen ground, followed by a rapid warming and a heavy rainfall event. These conditions occurred in late December 1996 through early January 1997 over north and central California, western Nevada, Washington, Oregon, and southwestern Idaho. The period of heaviest rainfall accompanied by snowmelt occurred over the five-state area from December 24, 1996 (Christmas Eve), through January 3, 1997. Rainfall totals of 18 to 33 inches were recorded in the orographically favored areas, and large areas of 6 to 12 inches were recorded elsewhere throughout the affected region. This rain fell on already saturated soils from a very wet autumn and early winter. Precipitation totals for the period from October 1, 1996, through early January 1997, were as high as 60 inches in parts of California and eastern Nevada, western Oregon, and western Washington, and over 24 inches in parts of Idaho. In addition to the heavy precipitation, a rapid warm-up accompanied the late December and early January storms, adding significant runoff from snowmelt to the flood-producing storm runoff. Flooding began on Christmas with most rivers reaching crest by January 5.

The warning and forecast services provided by NWS offices in California, Oregon, Washington, Nevada, and Idaho during this event were judged to have been excellent. NWS services were characterized by early recognition and notification of the potential for flooding followed by accurate and timely warnings, forecasts, and updates throughout the event. Flood Potential Outlooks were issued days before the onset of the flood-producing precipitation, and lead times for warnings for flooding on the mainstem rivers were generally several days. The NWS received many accolades from the media and the emergency services community. All people and agencies interviewed by the survey team expressed their gratitude for the NWS's services prior to and during the event; only positive comments were heard. In addition, it was the

survey team's finding that dissemination of information throughout the event between the NWS offices and the state and local agencies was outstanding. A tribute to their professionalism, the staffs of the affected NWS offices worked many long and arduous shifts over a holiday period to ensure that the NWS provided the best service possible to the public, media, emergency managers (EMs), and users of hydrologic information.

In order to produce an effective survey report in a timely manner for such a widespread event, the survey team visited the NWS offices that had primary responsibility for issuing warnings and forecasts for the areas that experienced the greatest impact from the flooding. These offices included NWSFO Boise, NWSFO Seattle, NWSFO Portland, the NWRFC, NWSO Medford, NWSO Eureka, NWSO Sacramento, the CNRFC, NWSFO Monterey, and NWSFO Reno. Other offices involved but not visited included NWSO Spokane, NWSO Pendleton, NWSO Hanford, and NWSO Missoula. Information from these offices was included in the discussions with the Area Managers (AMs) for the applicable states that were visited. The storm survey report is structured in the following way: an overall summary of the meteorology and hydrology of the event, an individual chapter for each NWS office visited, and appendices of specific stage and crest information for each Hydrologic Service Area (HSA). The individual chapters for the NWS offices contain a general overview of the event as it affected that office's warning and forecast area, a discussion of selected areas reviewed by the survey team at each location, and a listing of findings and recommendations for areas where enhancements to services may be made. The findings and recommendations are divided into primary findings and recommendations, defined as those areas that can be implemented in a relatively "short" time, and supplemental findings and recommendations, defined as items that either require no action or are of a "longer" term nature. Contacts with external offices and agencies (media, emergency services, etc.) as well as their associated NWS office also are summarized.

In summary, the NWS provided excellent warning and forecast services during this event characterized by early recognition, accurate and timely warnings and forecasts, and frequent updates. As a means to highlight the strengths of the warning and forecast program and to identify areas where enhancements to services are possible, findings and recommendations for each area are contained in separate sections with each chapter for each NWS office visited.

The NWS acknowledges the contributions of the many Federal (U.S. Geological Survey [USGS], U.S. Army Corps of Engineers [COE], U.S. Bureau of Reclamation [USBR], etc.), state (California Department of Water Resources [CDWR], Nevada Division of Water Planning, etc.) and local (Automated Local Evaluation in Real-Time [ALERT] operators, Flood Control Districts, Emergency Management Services, etc.) cooperators which, in partnership, work together with the NWS to collect and use the most up to date hydrometeorological data to support the flood warning and forecast programs.

Principal among the many agencies that the NWS works with is the USGS which furnishes continuous information of river stage and discharge and provides ratings and rating revisions to the NWS. The COE and the CDWR function as joint forecast partners with the NWRFC and CNRFC, respectively, during flood events, and the many local ALERT operators provide real-time data and hydrologic information used by the NWS's RFCs and offices (NWSFOs and

NWSOs) with hydrologic service area responsibilities to assess and predict hydrologic events. The contributions, cooperation, and coordination with these agencies was invaluable during this event.

Hydrometeorological Description of the Event

Flooding at the end of 1996 and early in 1997 was the result of a series of powerful weather systems which followed an unusually wet autumn season. Christmas Eve marked a transition from cooler polar flow to warm, moist southwesterly flow across the western United States. Embedded within this subtropical flow was a series of low pressure systems. Each system was progressively stronger, culminating with the parent low moving into northern and central California on January 1, 1997. Washington, Oregon, Idaho, California, and Nevada were all dramatically impacted by these systems.

ANTECEDENT CONDITIONS

Mid-November to Mid-December 1996

During the period from mid-November to mid-December 1996, many areas received above-normal precipitation, greatly increasing the snowpack over mid and high elevations. An unusually strong jet stream was positioned over Oregon, northern California, and southern Idaho. At lower levels, southwesterly flow brought abundant moisture into the region from the subtropics. The strong jet stream helped a series of storms containing abundant moisture invade the western United States. Western Oregon and the Sierra Nevada received copious amounts of precipitation, while Washington, Idaho, northern California, and the rest of Oregon also received above-normal amounts of precipitation from these storms.

December 14-23, 1996

Early in the 10-day period of December 14-23, 1996, a high amplitude ridge located over the northern Pacific dominated the weather pattern. Tropical moisture from the previous period was cut off as the polar jet influenced the weather pattern in the West. Strong northwest flow moved southward into the western United States. Colder Canadian air kept temperatures below normal throughout much of the region, even at lower elevations. By mid-December, both mid and high elevation snowpacks were well above normal in many locations. Lower elevation snowpack increased as well. Boise, Idaho, received the second highest 24-hour snow accumulation on record when a heavy snowstorm moved through the state on December 19. The Sierra Nevada and Cascades also experienced heavy snow events during this 10-day period.

METEOROLOGICAL DISCUSSION

Christmas Eve was the beginning of a transition from the cold, northerly flow characterizing the previous 10-day period, to a much warmer period influenced by southwesterly flow. As early as December 24, the Medium Range Forecast (MRF) model began to indicate a major change to a wet, potential flood situation commencing on December 29. For the next few days, the MRF would consistently forecast a synoptic pattern reminiscent of previously devastating flooding situations.

The large-scale circulation pattern consisted of a well-defined, closed high pressure center at the mid and upper levels of the atmosphere located over western Alaska. The polar jet stream was forced to the south of the blocking high, enabling it to merge with the subtropical jet. This consolidation created a strong low-latitude jet stream, south of the mean ridge, positioned near Hawaii. Abundant moisture was supplied to the flow due to a combination of moisture from the tropics and the remnants of Typhoon "Fran." This long fetch of moist subtropical flow extended from the eastern Pacific well into the western United States. A series of three major cyclonic storm systems were embedded within this flow. Each wave was progressively stronger and each moved progressively further to the south. As each low pressure center approached the West Coast, the surface pressure gradient tightened producing strong southerly surface winds. Several areas, especially along the coast, experienced damaging gale force or stronger winds. Warm temperatures, during the day and at night, produced unseasonably high freezing levels (between 8,000 and 11,000 feet).

The first two low pressure centers produced moderate to heavy rains and damaging winds but were both weaker than the models had been forecasting. Models forecast these two storms to pass further south than where they actually verified. On New Year's Day, the third and most intense short wave trough was pushing onto the West Coast. This third system was handled very well by the models both in timing and intensity. This slow moving system was loaded with moisture and warmer temperatures and produced gale force and stronger winds as well as widespread heavy precipitation. Maximum jet stream winds associated with this system were near 170 knots. Moderate to heavy rain fell on top of an already ripe snowpack, which resulted in incredible amounts of runoff. Many rivers were already swollen and reservoirs were nearing their storage capacity from runoff from previous rainfall and snowmelt. The combination of large volumes of runoff and rivers already near or above flood stage created the perfect scenario for a devastating flooding event.

In the northern part of the region, warm air associated with the subtropical connection moved over cooler air trapped at lower levels, resulting in perfect conditions for freezing rain and heavy wet snow. This was the case when Washington and Oregon experienced damaging freezing rain and heavy wet snow during the latter part of December. These conditions lasted until December 30, when most precipitation turned to moderate and heavy rain. Heavy wet snow caused millions of dollars worth of damage to various structures in Washington.

Overall, model guidance for this event was quite good. At least 5 days prior to the first wave pushing onto the coast, the MRF was forecasting a major change to an extremely wet pattern. By December 28, short-term regional model forecasts began to confirm the MRF's synoptic analysis. The third storm, on New Year's Day, was handled the best by the models in terms of location, timing, and intensity. The 29 km MESO-ETA provided good quantitative precipitation forecast (QPF) guidance for the 30-hour period from 0000 Coordinated Universal Time (UTC) on January 1 to 0900 UTC on January 2, 1997. For example, between 13 and 15 inches of snow fell in the Sierras north of Lake Tahoe, with the MESO-ETA forecasting nearly 10 inches. QPF guidance from the National Centers for Environmental Prediction (NCEP) tended to overestimate precipitation in many locations, especially during the first two storms. Many forecasters felt that the Rhea orographic precipitation model, a local model, provided better QPF guidance for the entire event. This model, with a 5 km resolution terrain, proficiently handled both the intensity and distribution of the precipitation.

Stronger polar air moved in on January 3, 1997, allowing the subtropical jet to weaken considerably and temperatures around the region to cool. With ridging taking place over the western United States, precipitation decreased in amounts and intensity. Freezing levels returned to normal wintertime levels and rain turned to snow in many locations. This pattern change ended the meteorological portion of the event, although flooding continued in some areas into mid-January.

SUMMARY OF PRECIPITATION

Precipitation during the period December 26, 1996, to January 3, 1997, was a major factor in the flooding which occurred across large portions of five Western States. Most of the precipitation during this period fell in the form of rain over much of the region due to unseasonably warm temperatures. In northern parts of the region, frozen precipitation fell during the first half of the period in question. Much of this frozen precipitation melted in the latter half of the period contributing to the excessive runoff.

Idaho

Rainfall in Idaho was lower than many other areas which were affected by severe flooding. Rainfall totals for the December 26, 1996-January 3, 1997, period were generally in the 2- to 6-inch range. However, runoff from this rainfall was quite high due to wet soils and extensive snowmelt. A snowstorm on December 21 deposited nearly a foot of snow in the valleys of southwestern and central Idaho and as much as 3 feet in the mountains. A significant portion of this snow melted during the December 26, 1996, to January 3, 1997, period.

Washington

Rainfall totals in Washington during the December 26, 1996, to January 3, 1997, period were much heavier west of the Cascade Mountains than to the east. About 2 inches of rain fell east of the Cascades during the period. In addition, this area also experienced significant snowmelt. West of the Cascades, precipitation was significantly influenced by topography. In addition, the northwest half of Washington received snowfall during the first half of the period. Liquid equivalents for the period December 26, 1996, to January 3, 1997, ranged from 6 to 12 inches in western Washington. The heaviest amounts occurred on the west slopes of the Cascade Mountains.

Oregon

In Oregon, the heaviest precipitation in late December 1996 through early January 1997 fell along the Coast Range and on the west slopes of the Cascade Mountains. As was the case in Washington, precipitation amounts were lower on the east side of the Cascades. Liquid equivalents for the period ranged from 2 to 6 inches east of the Cascades and from 6 to 18 inches west of the Cascades. A few locations in the Coast Range received as much as 8 inches in a single 24-hour period.

California

Most of the precipitation in California fell in the northern half of the state, with only light amounts recorded in the southern half. Throughout California, much of the precipitation fell as rain except at elevations above 8,000 to 10,000 feet.

In northern California, precipitation totals varied widely as amounts at any given location were heavily influenced by topography. Precipitation in the Central Valley during the period December 26, 1996, to January 3, 1997, ranged from 1 to 5 inches. Amounts in the Coast Range for the same period were generally 6 to 12 inches, with some areas receiving up to 18 inches. Precipitation in the Sierra Nevada Mountains generally ranged from 6 inches at the lower elevations to over 24 inches in the orographically favored areas. Precipitation amounts in the 6- to 18-inch range occurred on the east side of the Sierra Nevada Mountains in California.

Individual locations in the orographically favored areas of the Sierra Nevada recorded very impressive precipitation totals. Rainfall amounts of 10 to 12 inches in a single 24-hour period were reported at several locations in the Feather and upper Sacramento River systems. Storm totals for a few locations in these same drainages for the period December 26, 1996, to January 3, 1997, ranged from 24 to 40 inches.

Nevada

Heavy precipitation in Nevada during late December 1996 and early January 1997 was confined to the extreme western part of the state where rainfall totals ranged from 2 to 12 inches. Reno, Nevada, reported nearly 7 inches of rain in a 24-hour period ending on January 1, 1997. Runoff from the heavy rainfall on the eastern side of the Sierra Nevada in California was a significant factor in the flood experienced in western Nevada during this event.

HYDROLOGICAL DISCUSSION

Widespread flooding occurred over large portions of five Western States from late December 1996 through early January 1997. This flooding resulted from excessive runoff caused by a combination of heavy rainfall, snowmelt from all but the highest elevations, and antecedent conditions consisting of above normal streamflows and very wet soils.

Record flooding occurred in California, Nevada, and Idaho. In California, the hardest hit areas included the rivers and tributaries of the Russian, Napa, Sacramento, and San Joaquin Rivers. The Walker, Carson, and Truckee Rivers and their tributaries in Nevada and California all experienced extensive flooding. The flooding on the Truckee River at Reno, Nevada, was the worst in almost 50 years. In Idaho, the worst flooding was along the Weiser and Payette Rivers.

Idaho

Flooding in Idaho during late December 1996 and early January 1997 was primarily confined to the central and southwestern portions of the state. This was the area which received the most precipitation and warmest temperatures during this time period.

The Weiser River rose rapidly on December 29 in response to runoff from rain and snowmelt. At the town of Weiser, the Weiser River exceeded flood stage on the afternoon of December 29. By the morning of December 30, the Weiser River had crested along its length and had begun to fall. Rain began again in the region, and by the afternoon of December 30, the Weiser River had once again begun to rise.

Rain and snowmelt continued on December 31, resulting in rapid rises on the Weiser and Payette Rivers. The Weiser River remained above flood stage at Weiser and rose to flood stage at Cambridge early on December 31. By the afternoon of December 31, the Payette River at Emmett was above flood stage as well.

Runoff from rainfall and snowmelt resulted in rises continuing into the New Year. Small stream flooding was widespread in southwest and central Idaho on January 1, 1997. Also on January 1, the Snake River at Weiser exceeded flood stage as did the South Fork of the Clearwater river near Stiles. By late on January 1, the Weiser River at Cambridge crested but not before reaching a new record stage of 14.26 feet (old record was 13.9 feet). The crest on the Weiser River at Weiser occurred on January 2 at a new record height of approximate 16.5 feet (old record 16.0 feet). The crest on the Payette River at Emmett also occurred on January 2. The crest was 32,300 cubic feet per second (cfs), just below the record of 32,700 cfs. The Snake River crested at Weiser on January 3 at a level 2.5 feet above flood stage.

Washington

Heavy rainfall and low-level snowmelt produced widespread flooding in much of western Washington beginning in late December 1996. The heavy precipitation then moved east of the

Cascades, resulting in flooding in southeastern Washington during the first few days of January 1997.

The Deschutes River exceeded flood stage on December 29, the first river in western Washington to do so in this event. Over the next 2 days, most of the rivers in western Washington (except for those in the extreme northwest part of the state) exceeded flood stage. Extensive small stream and urban flooding occurred throughout western Washington at this time as well.

Widespread flooding on small creeks and streams occurred in southeastern Washington during the first few days of the New Year. Several rivers also flooded in this area as well, including the Walla Walla River, the Touchet River, the Klickitat River, Hangman Creek, and the Palouse River.

Major flooding occurred along the Skookumchuck, Skokomish, and Chehalis Rivers in western Washington during this event. In southeastern Washington, flooding was most significant along the Touchet River and Hangman Creek. Hangman Creek at Spokane crested at a new record level of 14.9 feet on January 1. The flooding on other rivers in Washington was minor to moderate, affecting low-lying areas, secondary roads, agricultural lands, and a few residences.

Most of the rivers in Washington crested during the period December 30, 1996, and January 2, 1997. Flooding continued on several rivers in Washington until January 4 or 5.

Oregon

Much of the state of Oregon was affected by the flooding event of late December 1996 and early January 1997. The levels of rivers and streams was high in late December due to a series of previous precipitation events. These precipitation events also had resulted in a deep snowpack in the mountains of Oregon and raised soil moisture levels in the lower elevations. This set the stage for an extreme runoff event as rain and higher temperatures moved into the state beginning on Christmas Day.

Flooding began on the coastal rivers and streams on December 26. These rivers and streams began to recede by the following day. Renewed rises occurred on December 28, when rain again moved into the region. By December 29, runoff from rainfall and snowmelt was producing rises on rivers and streams throughout Oregon, including the area east of the Cascade Mountains. Flooding of small streams and urban areas became more widespread during this time as well.

More rain moved into the region late on December 30 and continued into December 31. Freezing levels remained high, resulting in continued flooding problems throughout the state. By December 31, major flooding was occurring along the Tualatin River. Major flooding occurred along the Rogue, Sprague, and Williamson Rivers on January 1. Bear Creek reached near record flows on January 1 as well, resulting in considerable damage. Elsewhere in the state, flooding problems were moderate in many areas with minor problems in a few areas.

Water levels began to recede on small creeks and streams on January 1, with crests on the river occurring during the period January 1-3. Most locations fell below flood stage by Monday, January 6, although flooding continued at a few locations until Thursday, January 9.

California

Northern and central California were strongly affected by flooding during this event. Precipitation in November and much of December 1996 resulted in high water levels, significant snowpacks, and wet soils. With these antecedent conditions, the region was primed for a significant runoff event when heavy rain and warm temperatures were experienced in late December 1996.

Rainfall kept river levels high in northern California during the period December 25-28. During this same period, many reservoirs in northern and central California were increasing releases to regain storage capacity. These releases served to keep river levels high downstream but below flood stage levels.

A rain event on December 28 and 29 produced additional rises on rivers in northern California. This rainfall produced some urban and small stream flooding problems, however, no river flooding occurred. Another storm system moved into northwestern California on Monday, December 30. Rain from this system produced a very rapid runoff response.

Flooding began on rivers in northern California late on December 30. By December 31, flooding was occurring on the Klamath, Eel, Russian, and Sacramento Rivers and many of their tributaries. Another storm system began to affect northern California late on December 31. This system was the strongest yet and contained warmer air which moved freezing levels to high elevations, resulting in significant snowmelt.

Major flooding was occurring on most major rivers and their tributaries in northern and central California by New Year's Day. The most significant flooding at this time occurred on the Eel, Russian, Napa, and Sacramento River systems. By late on January 1, these river systems began to crest. Record crests occurred at locations on the Sacramento and Russian Rivers. Inflows to Shasta and Oroville Dams reached record levels as well. Flooding began on the slower responding San Joaquin River system on January 1.

The rivers in northern California and in the Napa and Russian River Basins were falling by January 2, as were water levels in the upper Sacramento River Basin. Recession was slow, given lingering rainfall and snowmelt. The Cosumnes River in central California was at record levels at this time, and other locations in the San Joaquin River Basin were still rising. The upper Merced River rose to extremely high stages in Yosemite National Park, causing widespread damage and isolating park visitors and employees.

Crests on the Sacramento River were over by January 3, although flooding persisted until January 5. The flooding on the Napa, Russian, and other northern California rivers had ended by

January 3. Rivers in the San Joaquin River Basin crested from January 3-6. Flooding persisted at a few locations in the San Joaquin Basin until January 12.

Levee failures contributed much of the flood damage in central California during this event. In the Project Flood Control Systems of the Sacramento and San Joaquin Rivers, approximately 61 separate levee failures were reported during this event. Many more unreported breaks occurred on private levee systems in this region. Many of the levee failures occurred at or after peak stages.

A large levee break occurred on January 2 on the Feather River at Arbota, just downstream of the confluence of the Yuba River. This failure resulted in three deaths and millions of dollars in damages. A major break occurred on the Sutter Bypass of the Sacramento River on January 4. This break threatened the town of Meridian with inundation. A serious slump occurred on the Tisdale Bypass on January 4 as well. This threatened residents in southwestern Sutter County until it was repaired about a week later.

In the San Joaquin River Basin, multiple levee failures occurred in the vicinity of Vernalis, flooding rural agricultural lands. These failures began to occur on January 5 and continued over the next several days. Several levee failures occurred on the Stanislaus River just upstream of the confluence with the San Joaquin River on January 5. These breaks resulted in the inundation of the Wetherbe Lake area, including several trailer parks. A number of levee breaks also occurred along the Cosumnes River on January 2-3. These breaks resulted in flooding on the towns of Whilton and Rancho Murietta. Several highways were also inundated by waters flowing through these breaks.

Nevada

Flooding during this event in Nevada was limited to the rivers and streams draining the east slopes of the Sierra Nevada. Storms prior to December 26 deposited heavy snow on the east sides of the Sierra Nevada Mountains at all elevations. Melt from this snowpack combined with rainfall in late December 1996 and early January 1997 to produce catastrophic flooding on the Walker, Carson, and Truckee River systems.

Warm temperatures began to produce snowmelt on December 26. This snowmelt, along with light precipitation continued into the next day. Runoff began to cause urban and small stream flooding on December 27. Over the next several days, freezing levels continued to rise and precipitation increased in intensity. By December 29, rapid snowmelt was occurring in the valleys of western Nevada and in the lower elevations of the east slopes of the Sierra Nevada. Urban and small stream flooding became more widespread and rises began on the Walker, Carson, and Truckee River systems.

Freezing levels remained high through January 1, producing continuous snowmelt. Heavy rain fell in the region from late December 30, 1996, through much of January 1, 1997, as well. By early New Year's Day, flooding was occurring throughout the region. The flooding rapidly increased in magnitude and areal extent. By late January 1, many locations along the Walker, Carson, and Truckee Rivers and their tributaries were experiencing major flooding.

The Truckee River crested at Reno, Nevada, on January 2 but not before closing down much of the city. Transportation in and out of Reno came to a virtual stop as flood waters closed railroad lines, the airport, and Interstate 80. Flood waters reached the bottom of the jetways at Reno International Airport. Air and rail transportation were shut down for over 36 hours, while a portion of Interstate 80 was closed for almost 48 hours. The Truckee River at Reno fell below flood stage very late on January 2.

Crests also began to occur on the Carson and Walker Rivers on January 2. Crests continued for the next couple of days as the peak runoff moved downstream. Water levels began to fall below flood stage levels late on January 2, however, recession was slow and flooding continued at a few locations in the region until mid-January.

Record water levels occurred at almost every forecast point on the Walker and Carson Rivers during this event. On the Truckee River, record levels occurred at about half of the forecast points. Flooding in much of the eastern Sierra Nevada and western Nevada, including the city of Reno, was the worse seen in almost 50 years.

Office Summaries

NWSFO BOISE, IDAHO

Event Overview

Starting around the middle of November 1996, Idaho experienced frequent heavy snow and ice storms. These severe winter storms not only produced extensive damage (e.g., collapsed roofs, road closures) but deposited the heavy snowpack which eventually contributed to record flooding. Significant flooding commenced in the Boise HSA on December 29, 1996, and lasted through the first week of January 1997.

The particular winter storm event immediately preceding the flood began on December 19, when cold air allowed snow to accumulate to the valley floors over much of Idaho. Boise received 10 inches of snow on December 19, which is the second heaviest 24-hour accumulation on record. These storms produced power outages, road closures, and the isolation of several small towns. By Christmas, the high and low elevation snowpack was well above normal. On December 27, the National Guard was convened to assist in the snow removal in Bonner, Shoshone, and Boise Counties.

Rapid warming began to develop on Christmas Eve as wet weather systems originating from the subtropics moved into the region. This unseasonably warm and moist weather pattern produced freezing levels as high as 10,000 feet mean sea level (MSL) on January 1. The combination of rapid day and night snowmelt (at both low and high elevations), well above normal temperatures, and days of moderate rain produced significant runoff in the basins of southwestern Idaho.

River flooding and mudslides developed rapidly in southwestern Idaho starting on Sunday, December 29. The most significant flooding occurred on the Payette and Weiser Rivers, which both crested on January 2. The Snake River also flooded and contributed to the flood problems occurring on the Weiser and Payette Rivers by creating backwater on these two rivers. The Snake River crested on January 3. Minor flooding also occurred on the Boise River during this period. Thirteen counties in Idaho were declared disaster areas.

Northern Idaho avoided significant flooding, primarily due to slightly lower freezing levels and less rainfall. However, northern Idaho experienced significant damage and isolation during the 4 to 6 weeks of severe winter weather preceding the flooding in southern Idaho.

Disaster Survey Focus Areas

Overall HSA Operations During a Record Flood Event

The HSA at NWSFO Boise extends from extreme eastern Oregon through much of southern Idaho. Flooding occurred throughout much of the HSA, with the most significant flooding occurring on the Payette and Weiser Rivers. There are several river forecast points in southern Idaho, including one on the Payette River and two on the Weiser River.

No one was surprised that flooding occurred; however, the rapid onset and extreme magnitude of the flooding were not expected. NWSFO Boise added a dedicated hydrologic shift from 4 p.m. MST on January 1 through 4 p.m. MST, January 2, 1997. Additionally, a staff person remained at the Bureau of Disaster Services (BDS) from 4 p.m. MST, January 1, through 4 p.m. MST, January 2.

Coordination Activities with Emergency Managers: Preparations and Operations

Coordination with county emergency personnel varied from county to county. The variation was obviously the result of interest and/or workload of the particular county EM. Efforts to educate and train county EMs was and is ongoing in the Boise office. As recently as September 1996, a Southwest Idaho Emergency Managers' meeting was held in McCall, Idaho. This was attended by WCM Carl Weinbrecht and Senior SH Mary Mellema.

For the most part, these groups had nothing but high praise for the NWS, including their preparation, forecasts, coordination, and support during the storm event.

QPF Activities

NWSFO Boise issues routine QPFs at 12 UTC for six points in southwest Idaho. These QPFs cover the next 24 hours in 6-hour increments. Updates are issued through coordination with the RFC and may be initiated by the Boise forecaster or the Hydrometeorological Analysis and Support (HAS) forecaster at the NWRFC. The six QPF points for southwest Idaho are: Boise, Burley, McCall, Pocatello, Burns, and Rome.

Coordination and Support from NWRFC

The NWS NWRFC in Portland, Oregon, is staffed with hydrologists and HAS forecasters who provide support to NWS forecast offices in the Pacific Northwest. For southern Idaho, the NWRFC uses the Streamflow Simulation And River Routing (SSARR) model to simulate rainfall runoff based on observed and forecast precipitation. Model-based forecasts are generated for several river forecast points. These forecasts serve as guidance to the NWSFO Boise staff which issues river statements and flood watches and warnings to the public. The improved National Weather Service River Forecasting System (NWSRFS) modeling system is scheduled to be operational over Boise's HSA by early 1999.

The Boise SH and other staff stated that the support from the NWRFC was excellent and very helpful during this flood event. The NWRFC operated 24 hours a day during the event, and guidance products were issued frequently, as often as every 6 hours. The NWRFC hydrologists spent significant time on the phone with NWSFO Boise discussing the model output and river forecasts. Overall, the RFC was attentive to the hydrologic support needs at NWSFO Boise.

Data Availability and Needs Including HYDROMET Support

Data availability is a continuing problem for most of the western United States, and NWSFO Boise's area of service is no exception. Most of the gages and associated equipment in place functioned well during the flood, except for the Limited Automatic Remote Collectors (LARCs) at river gages. Many LARCs were either damaged by flood waters in the gage houses, or telephone lines were broken by floating debris severing connection to the LARC. It should be noted that the majority of the river gage data and rating information used by the NWS is provided by the USGS. The contributions, cooperation, and coordination with the USGS was invaluable during this event.

A lack of information on the low-elevation snowpack impaired NWSFO Boise's ability to assess the threat of major flooding. Snow Telemetry (SNOTEL) sites are fairly numerous at elevations above 6,000 feet, but only spotter information is available below this level.

NWSFO Boise recently installed the HYDROMET 4.0 software on their HYDROMET computer. The software functioned well ingesting and displaying data in various ways. However, the lack of Alarm functionality in the HYDROMET 4.0 package sometimes made it difficult for forecasters on duty to stay on top of rapidly rising river flows.

Role of New Technologies

NWSFO Boise is part of a risk reduction to determine the usefulness of the Interactive Computer Worded Forecast software developed by the Techniques Development Laboratory. This system allows the forecaster to manipulate grids and matrices rather than typing textually based forecasts. Additional systems in the Boise office include access to gridded data and digital satellite data. The Weather Forecast Office (WFO) Hydrologic Forecasting System (WHFS) hydrologic package was installed but not operational during the flood event.

Primary Findings and Recommendations

Finding NWSFO Boise forecasters indicated that coordination calls were often very time-consuming. Most of the forecasters surveyed did not use the "BLAST-UP" system and disliked multiple-office conference calls, feeling that input was not as candid as person-to-person calls.

Recommendation Although coordination is vital to improve the quality of NWS public products, procedures should be reviewed to streamline the time requirements. It is recommended that a routine conference call be evaluated in an effort to streamline office coordination. Managers and forecasters should promote candid, yet tactful, discussion between forecasters on these conference calls.

Finding John Cline, Director of the BDS, was seriously concerned with the decentralization of responsibility resulting from the NWS modernization. His concerns centered on two issues: (1) coordination, and (2) the future ability of the NWS to honor their Memorandum of Understanding (MOU) and dedicate a person to staff the Emergency Operations Center (EOC). His group does not have the time to deal with two, three, or even four individual NWS offices in order to receive weather support during an emergency. Additionally, Mr. Cline expressed concern that during Stage II staffing, the relationship with NWSFO Boise will be degraded due to reduced NWS staff.

Recommendation The NWS should identify the one office in each state to be responsible for briefing state emergency officials. This designated "state office" should be responsible for acquiring the guidance, forecasts, and briefings provided by the appropriate NWS offices.

Recommendation The Meteorologist in Charge (MIC) and staff at Boise should do a post assessment to determine if tools could help reduce the requirement of dedicated human staffing by the NWS at the Idaho BDS EOC during the event. The Emergency Managers Weather Information Network (EMWIN), the Boise Internet home page, and the National Oceanic and Atmospheric Administration (NOAA) Weather Radio (NWR) should be available to the EOC and could provide a means of "self-briefing" by state officials.

Finding The extra hydrology and EOC staffing by NWSFO Boise stretched the staff resources of the office. However, no Hydrometeorological Technicians (HMTs) were called in to work extra shifts during the event, and overall there appears to be a reluctance by NWSFO Boise to integrate the HMT staff into the hydrology program.

Recommendation The hydrology program is a vital office function that is the responsibility of every employee of the office. The MIC, SOO, and SH should work with the operational staff to ensure that everyone is fully aware of the program, fully trained, and has the ability to handle critical flood-related duties.

Finding During the flood event, the state of Idaho participated in a conference call briefing from NCEP which seemed heavily biased toward flooding west of the Cascade and Sierra Nevada Mountains. Some of the forecast information presented during this briefing conflicted with the locally produced forecasts.

Recommendation Before briefing non-NWS officials, NCEP should consult with NWS field offices or review locally produced products to ensure that their briefing does not conflict with official forecasts and non-routine products issued by local NWS offices.

Summary of Damages, Deaths, Injuries, and Major Impacts

* All information contained in this section is preliminary and is based on estimates available at the time the report was written.

Rivers That Flooded:

Weiser
Snake
Payette

Rivers That Exceeded Record Level:

Weiser River at Cambridge and Weiser

Counties in Boise's HSA Declared Disaster Areas:

Gem County, ID
Washington County, ID
Clearwater County, ID
Payette County, ID
Latah County, ID
Bonner County, ID
Boise County, ID
Adams County, ID
Idaho County, ID
Valley County, ID
Elmore County, ID
Boundary County, ID
Shoshone County, ID

(Declarations were at the Federal and state levels.)

Major Impacts:

— No deaths were attributed to the flooding in Idaho.
— Many road closures due to high water and mudslides.
— Many small communities were isolated due to road closures.
— Major damage in towns of Weiser, Emmett, Payette, Cambridge, and Council, among others.
— Damage estimates for Idaho approach $25 million: $18 million to public property and $7 million to private property.

Estimated Damage in Dollars by County:

None available at time of report.

Supplementary Findings and Recommendations

Finding The NWS staff provided excellent service to the many Federal, state, county, and local agencies involved in water management and emergency services, along with the television, radio, and newspaper media. All had very positive comments about their interaction with NWSFO Boise during survey team interviews.

Finding NWSFO Boise keeps all necessary phone numbers in one file that is available on paper and on an operations-area computer. This file is updated at least once a month and provides quick access to names and phone numbers. This is more efficient than keeping phone numbers in various locations, such as the Station Duty Manual (SDM), Hydrologic Services Manual (HSM), operations-area Rolodex files, etc.

Recommendation Field offices should ensure that all phone numbers necessary to operations are located in one place, both on computer and in paper form. Procedures should be in place to update this phone list on a regular basis.

Finding The SH has coordinated several training efforts to ensure the NWSFO Boise staff is equipped to perform hydrologic duties during a flood event. Flood operations comprised a major portion of the fall 1996 office preparedness drill.

Finding The NWSFO Boise WCM has hosted several media workshops. The unanimous opinion of the local media and the Boise office is that these workshops are very valuable for improving the government-private meteorologist partnership.

Recommendation All NWS offices should investigate similar workshops to train and meet the local media.

Finding A three-way conference call between NWSFO Boise, NWSO Missoula, and NWSO Spokane revealed that these offices worked well together during this event.

Recommendation An employee exchange program between coordinating offices should be considered. This will allow the opportunity to understand other office's operations and improve coordination.

Finding EMs from Washington and Payette Counties, where the majority of the flooding occurred, were interviewed. The Washington County EM was very aware of the services NWSFO Boise provided and worked very closely with the Boise staff. On the other hand, the Payette County EM was unaware of the services provided by the NWS. This EM had been on the job less than a year and had no telephone numbers for the NWS office. He was unaware that the NWS office was staffed 24 hours a day. This individual did not attend the training session for EMs held by the NWS in September 1996. Furthermore, the BDS Area Field Officer never informed the NWS that Payette County had a new EM.

Recommendation The survey team recognizes the difficulty involved in coordinating with some local emergency officials, particularly those who may not recognize the importance of NWS support until after disaster strikes. Nevertheless, the NWS must ensure that a minimum level of contact is maintained with these officials on a routine basis.

Finding NWSFO Boise and the Idaho BDS established an MOU in 1996 to promote interaction between these two agencies during a weather disaster. During the height of this event, a member of the NWSFO Boise staff provided in-person support to the BDS. The BDS officials expressed their gratitude for the job well done by the NWSFO Boise staff.

Recommendation All WR field offices should ensure that state emergency management agencies are aware of the services the NWS can provide. Operating procedures should be established at NWSFO Boise regarding the placement of "on-site" representatives to avoid staffing problems at the NWS office.

Finding The NCEP/Heavy Precipitation Center (HPC) QPFs are not routinely reviewed at the Boise office. It was felt by the forecasters who were interviewed that the HPC did not always fully understand the various flow patterns that caused significant precipitation across the Snake River Valley. Yet, the HPC QPFs for the late December and early January storms did reasonably well and appeared to form a good first guess at the magnitude of the event.

Recommendation Significant improvement has been made by the HPC on QPFs, particularly during heavy precipitation events. NWSFO Boise should re-evaluate the usefulness of HPC guidance. Additionally, all NWS offices should document events where the HPC QPF guidance does not cover events well and provide this feedback to the HPC.

Recommendation The HPC should work with Boise (as well as other WR offices and the WR Scientific Services Division [SSD]) to present seminar(s) to the WR, detailing the methods HPC uses for determining QPFs in the mountainous west. A seminar (or teletraining session) would be an ideal medium to allow forecasters to evaluate HPC techniques and provide feedback.

Recommendation NWSFO Boise should implement the Mountain Mapper program in its operations. Using this program to generate QPFs will standardize this operation throughout the WR.

Finding The town of Payette on the Payette River has a reliable, telemetered stream gage but is not an official forecast point. Forecasts for this location would be helpful to emergency officials.

Recommendation The Boise SH and NWRFC should coordinate to develop a new forecast point for the Payette River near Payette, especially when the NWSRFS models are implemented for the Middle Snake Basin.

Finding NWSFO Boise receives Geostationary Operational Environmental Satellite (GOES) data through the Hydrometeorological Automated Data System (HADS). During this flood event, data was not available for several locations due to a problem with the HADS data transmission. The Boise SH contacted the HADS staff, which was very helpful with trying to resolve the problem, even on the New Year's holiday. NWSFO Boise was able to connect into the Bureau of Reclamation's system using HYDROMET 4.0 to retrieve GOES data; however this procedure became tedious at times.

Recommendation HADS is the official means of disseminating GOES data within the NWS. The Office of Hydrology has taken to ensure the reliability of this system during flood events.

Finding A key cause of the record flooding was the pre-event, low-elevation snowpack in southern Idaho. NWSFO Boise had limited quantitative snow data at elevations below 6,000 feet, receiving only irregular spotter reports of snow depth, water equivalent, and melt. Estimates of snow cover and water equivalent produced by the National Operational Hydrologic Remote Sensing Center (NOHRSC) are not available until early January of each year. Thus, only limited snow data for low elevations was available during this event.

Recommendation The NOHRSC should examine the possibility of producing its products earlier each winter. The NWSFO Boise should recruit and train some reliable spotters at elevation ranges not covered by SNOTEL gages to systematically measure snow and water equivalent and report this information at regular intervals (e.g., once or twice a day) to the Boise office.

Finding Discussion with the EMs revealed the need for more gages at several locations. For example, the Washington county EM said he frequently used the "stick-in-the-mud method" to determine river level changes and rates of change.

Recommendation The MIC and SH should work with the USGS and local officials to determine where gages on smaller creeks and drainage basins would prove useful in future events. Automated gages or inexpensive staff gages should be provided and installed where feasible.

Finding The NWSFO Boise Internet home page was extremely useful during the heavy snow and flood events in Idaho. The home page was used by other agencies, the general public, and even Boise staff on business outside of the office. Although the home page is not officially "operational," it was relied on heavily.

Recommendation Although Internet home pages are not an operational system for the dissemination of NWS warnings and forecasts, their popularity suggests that each NWS office maintaining a home page should ensure that it is operating with current data. Home pages must be identified as provisional data with disclaimers indicating such.

Finding The WHFS had been recently installed at NWSFO Boise but was not used during this flood event for several critical reasons.

(1) The LARC-telemetered data was only available on WHFS through the Centralized Automatic Data Acquisition System that only comes in every 6 hours. Much more frequent data was needed to keep track of the rises on the Weiser River.

(2) The NWRFC forecasts are not Standardized Hydrologic Exchange Format (SHEF)-coded for the state of Idaho. SHEF-coded forecasts

are necessary for ingest into the River Product Formatter within WHFS.

Recommendations WHFS limitations, such as the ingesting of LARC-telemetered data and RFC forecast products, should be addressed so that the WHFS can be effectively used in NWS operations.

Finding It was found that the nationally supported Interactive Weather Information Network (IWIN) did not always contain the latest flood warnings during the flood event. Both the NWS and customers indicated that the NWS Boise home page and the Internet were key sources of information during the flood event.

Recommendation Ensure that the IWIN system is indeed operational 24 hours a day.

NWSFO SEATTLE, WASHINGTON

Event Overview

Western Washington was affected by three systems which moved across the region in succession during the period of December 25, 1996, through January 1, 1997. These systems combined to produce high winds, heavy rain, freezing rain, and heavy snow across the region. The inclement weather resulted in widespread damages across the area.

A cold front moved southward across Washington State on December 25, allowing cold air to settle over the lowland areas. Early on December 26, warm moist air from the south began to overrun this cold air. The result was a mixture of snow and freezing rain north of the front, while rain fell south of the front. This precipitation continued through most of December 27. Snowfall from this event was as high as 16 inches in extreme northwest Washington. Heavy accumulations of glaze occurred to the south and east of Seattle during this event, resulting in widespread power outages and damage to trees and shrubs.

Hard on the heels of the first system, the second moved toward the region from the southwest on December 28. Warm moist air once again moved northward across the region producing 6 to 14 inches of heavy wet snow to the north and locally heavy rain to the south. As the frontal system moved north on December 29, snow changed to rain and surface temperatures climbed into the 40s. This resulted in rapid snowmelt and increasing runoff. Flooded roadways and structure collapses followed this change in precipitation type and warming temperatures.

The last of the three systems moved into the region on December 31. This system was warm enough that most of the precipitation was in the form of rain. This rainfall was locally heavy. The system also produced high winds, especially in coastal areas. The locally heavy rainfall combined with the ongoing snowmelt resulted in major flooding along several rivers in western Washington. Widespread urban and small stream flooding also occurred, along with numerous mudslides and other significant erosion. Along the coast, the combination of runoff, high tides, and 25-foot swells produced by the high winds resulted in significant coastal flooding and erosion. The rainfall from this last event began to diminish on January 1, bringing a gradual end to the entire event.

Disaster Survey Focus Areas

NWSFO/NWRFC Interactions

Coordination calls between NWSFO Seattle and the NWRFC occurred several times each day during the event. The frequency of calls was highest when the precipitation was the heaviest and rivers were rising rapidly. The NWSFO forecaster preparing the Quantitative Precipitation Support (QPS) and the HAS forecaster at the RFC discussed the QPS prior to each issuance of this product. The staffer working the hydrology desk at the NWSFO discussed river forecasts with the hydrologic forecasters at the NWRFC.

River forecast guidance was discussed every RFC forecast cycle prior to the rivers cresting. At other times, this coordination occurred once or twice a day. The NWRFC was very receptive to requests for updated guidance and assistance. Overall, NWSFO Seattle felt that the relationship with the NWRFC was markedly better than prior events. Improvements in forecast guidance turnaround time and content from the NWRFC were a big help to the NWSFO in fulfilling their hydrologic mission during this period.

Data Collection and Quality Control

NWSFO Seattle experienced several data problems during this event. Data problems included a temporary outage of Data Collection Platform (DCP) data, loss of power at Automated Surface Observation System (ASOS) sites resulting in lost data, and the loss of a couple of USGS gages and LARCs due to inundation. None of these outages were crippling, although they did have some impact on the operations of the office.

Spotter reports were invaluable during the heavy snow, freezing rain, and heavy rainfall portions of the event. The reports from the spotters assisted the forecasters in pinpointing where and when the change over to another precipitation type occurred. The number of calls from spotters has increased markedly to the point where answering spotter calls has become a workload issue.

NWSFO Seattle is currently quality controlling reports from ASOS sites. Quality control efforts for other data is hindered by the unavailability of tools to handle the large quantity of data efficiently. In addition, current workload of the operational staff prohibits manually handling data quality control.

Staffing and Backup Procedures

NWSFO Seattle was able to adequately staff the office during this event despite a significant number of the office staff being unavailable due to illness and annual leave. The heavy snow and street flooding in the Seattle area created problems for the staff getting to and from the office. Despite these problems, the office was able to cover the hydrology desk adequately during the event. The SH provided the base coverage for this with forecasters covering the other times. Staffing never reached a point where backup procedures were needed, however, the office management recognized if the number of available people had been much lower, backup would have been required for some programs.

QPS Activities, Weather Surveillance Radar-1988 Doppler (WSR-88D) Data, and Use of NCEP Guidance

The public forecaster at NWSFO Seattle usually handled the creation of the QPS product. Currently, the office is generating 3-day forecasts of precipitation (in 6-hour increments), freezing levels, and maximum/minimum temperature. The times these products are issued are important to NWSFO Seattle as any change in times would conflict with the issuance of other products.

Model output and guidance from NCEP's HPC was used as a first guess of the forecasted precipitation. Reflectivity data from the WSR-88D was used to locate areas of the heaviest precipitation in the Day 1 QPS forecasts. WSR-88D data was also very useful in the forecasting of the timing of change-over of precipitation type. WSR-88D velocity products were very useful in verifying model projections of winds and in the decision process on issuing high wind watches and warnings.

Statewide Coordination Issues

The state of Washington Emergency Management Agency has requested that they have a single point of contact within the NWS in the state. During this event, NWSFO Seattle handled this role. Various members of the Seattle staff performed this task, including the MIC, Deputy MIC, WCM, SH, and lead forecaster. Coordination during this event was handled by telephone and the use of the Internet home page, however, in-person briefings have been used in the past and likely will be used again. The single point of contact will require that all NWS offices which have responsibility within the state to closely coordinate with each other to ensure consistent messages are conveyed to the state.

Public Product Format and County Flood Level Terminology

The format of public hydrology products used by NWSFO Seattle is the result of surveys the office has conducted. These surveys included state agencies, county EMs, and the media. The consensus of these surveys was that products should be in a tabular format. The format is designed to group information by universal generic codes. This enables the state of Washington to route parts of the product to EMs in affected counties.

Many counties in the state of Washington have identified various flood levels for the rivers in their jurisdiction. These levels, usually designated by a number, indicate the degree of flooding and the type of response needed for a given event. NWSFO Seattle refers the expected crest for a location to the corresponding county flood level in their statements to assist county and local officials. NWSFO Seattle has received considerable positive feedback regarding this practice.

NWSFO Support for NWSO Spokane

NWSO Spokane was able to handle this event without the assistance of NWSFO Seattle. The event was much less widespread in Spokane's area of responsibility. The AM at Seattle and the MIC at Spokane discussed the event afterwards and concluded that the training Spokane had received was adequate to handle the event that Spokane experienced.

Integration of Hydrology as a Station Program

NWSFO Seattle utilized a large percent of the staff in handling the hydrology program during this event. Forecasters, interns, and HMTs were involved in handling the event in addition to the SH. During the most hydrologically active portion of the event, there was a person dedicated to the hydrology program during the day and swing shifts. The duty forecasters handled the hydrology duties when a designated person was unavailable.

Freezing Rain, Heavy Snow, and High Wind Event

These events were well handled by NWSFO Seattle. Lead times on heavy snow, freezing rain, and high wind events were excellent. In many cases, watches were issued with more than 24 hours lead time, and most warnings had lead times of 6 hours or more. Data from buoys was limited during this event, which had a negative impact on the lead times of heavy surf advisories. The Seattle office was quite innovative in utilizing all of the available technology to stay ahead of the event as it developed. This was a major reason for the excellent lead times provided by NWS products.

Many of the watches, warnings, and statements issued by NWSFO Seattle were very specific during the period of inclement weather. The office pinpointed areas of heavy snow and high wind with good accuracy, and they even issued a statement warning of potential structural collapses due to heavy loads from snow and rain.

Primary Findings and Recommendations

Finding How data quality control should be performed and by whom is unclear at NWSFO Seattle and other field offices. Tools and training to perform this function are also lacking at this time. Due to the present situation, data quality control is less robust than it could be at this and other offices. NWSFO Seattle suggested that Mountain Mapper will provide a tool for some data quality control.

Recommendation The Western Region Headquarters (WRH) needs to establish guidelines on how data quality control is to be performed and what HSA office responsibilities are for data quality control. In addition, tools and training related to data quality control need to be provided to the field offices so they can perform this function. The WRH also needs to push the implementation of Mountain Mapper at all field offices in the region.

Finding Currently, verification for the first 24 hours is provided for QPS products. The lack of verification information for the periods beyond 24 hours hinders improvement of skill in producing this product.

Recommendation The NWRFC should develop procedures to provide verification information for periods beyond 24 hours to QPS generating offices. This verification should include statistics on precipitation, freezing levels, and maximum/minimum temperature forecasts.

Finding Several ASOS sites in Seattle's area experienced power failures during this event. This resulted in a loss of "real-time" data from these sensors which hindered operations.

Recommendation Sources of backup power should be obtained for ASOS sites.

Finding The need for HSA service backup was not a significant issue during this event, however, HSA backup procedures are minimal at this time.

Recommendation The WRH and the HSAs need to examine the existing HSA service backup procedures and formulate and adopt procedures as needed to provide for adequate HSA service backup.

Finding Emergency management for the state of Washington has expressed the desire for a single point of contact from the NWS. This will create a coordination issue among NWS offices serving a given state.

Recommendation Operating procedures and plans must be formulated and adopted to ensure that adequate coordination between offices continues in the NWS. A single office in each state should be designated as the NWS point of contact for state EMs.

Finding NWSFO Seattle has created a format for their hydrologic products which enables the state of Washington to route a portion of the product to affected counties. This system is well liked by the emergency management community. In order for this system to continue to function as designed, all offices issuing hydrologic products for the state of Washington will have to conform to this product format.

Recommendation The HSD should establish policies governing product format to ensure that systems, such as those found in the state of Washington, continue to function after all the HSA transfers are complete.

Finding The levee systems within the HSA are not well documented. The lack of readily available knowledge on levee systems could be a problem in future events.

Recommendation The NWSFO should devote some resources to obtaining additional information on the location, structural status, and potential inundation areas related to levee systems in their HSA.

Summary of Damages, Deaths, Injuries, and Major Impacts

* All information in this section is preliminary and is based on estimate available at the time the report was written.

Rivers That Flooded:

Lewis	Cowlitz
Naselle	Willapa
Chehalis	Skookumchuck
Satsop	Skokomish
Deschutes	White
Cedar	Snoqualmie
Snohomish	Walla Walla
Klickitat	

(No rivers exceeded record levels in Seattle's HSA.)

Counties in Seattle's HSA Declared Disaster Areas:

San Juan County, WA	Island County, WA
Kitsap County, WA	Clallam County, WA
Jefferson County, WA	Mason County, WA
Grays Harbor County, WA	Thurston County, WA
Lewis County, WA	Pierce County, WA
King County, WA	Snohomish County, WA
Skagit County, WA	Whatcom County, WA

(Declarations were at the Federal and state levels.)

Major Impacts:

— No deaths were reported in the state of Washington during this event.
— Numerous road closures occurred due to high water and mudslides.
— A number of homes were destroyed, damaged, or rendered unsafe due to mudslides.
— Heavy snow and ice caused numerous power outages, especially in the Seattle/Tacoma area.
— Heavy snow and ice also caused widespread damage to landscaping and trees.
— A number of structures collapsed due to snow/rain load, including warehouses and boat shelters.
— Residential and commercial areas of Chehalis and Centralia were significantly impacted by flooding.
— Approximately two dozen homes were evacuated in Mason County due to flooding of the Skokomish River.
— Damage estimated at $315 million in the state of Washington.

Estimates of Damage in Dollars by County:

None available at time of report.

Supplementary Findings and Recommendations

Finding

NWSFO Seattle did an excellent job in handling the events of late December 1996 and early January 1997.

Finding

Interaction and coordination with the NWRFC was improved during this event compared to previous events.

Finding

NWSO Spokane handled this event internally without assistance from the NWSFO Seattle. The MICs from both offices discussed the event afterwards and agreed that training has been adequate for the HSA hand-over.

Finding

Several of the NWSFO Seattle staff were involved in this event. The office has made good strides in integrating the hydrology program as an office function.

Finding

NWSFO Seattle provided excellent service on the freezing rain, heavy snow, and high wind events. The lead times on these products were excellent. The response of the EMs and utilities was quite good. The response by the public on the statements warning of roof collapses was not as great, even though most roof collapses occurred well after these statements were issued. This was especially evident at the marinas.

Finding

NWSFO Seattle staff was quite innovative in utilizing various technologies to forecast the meteorological event. An example of this was to use the Mesoscale Meteorological Model Version 5 (MM5) output to confirm a change from snow to freezing rain when the WSR-88D data suggested bright banding was occurring.

NWSFO PORTLAND, OREGON

Event Overview

A series of weather events impacted Oregon during the period from December 15, 1996, through January 2, 1997. These weather events produced snow and ice, heavy rain, and high wind during this period. The result was widespread flooding as well as damage from snow, ice, and wind.

Heavy snows fell in the mountains of Oregon on December 19-20. This was followed by more snow in the mountains and rain in the lowlands on December 21-22. Temperatures and snow levels began to rise on December 23. Showers occurred on December 23, and by the next day rainfall increased in intensity and areal coverage.

On December 25, snow levels in the Cascades rose to 8,000 feet. Cold air moved into the Columbia River Basin from the north, resulting in significant freezing rain and snow in the Columbia Gorge and the city of Portland. Most of the rest of Oregon received additional rain during this event. The coastal rivers and smaller tributary streams in northern Oregon began to reach flood stage on December 25 as well.

By December 26, moderate to heavy rain continued over Oregon, except for the Columbia Gorge where freezing rain and snow continued. Strong surface pressure gradients produced high winds along the Oregon coast. Some of the larger tributary streams began to flood. This system exited the area on December 27. However, another system was poised to move into the region. A flood potential outlook was issued early on December 27. Later in the day, watches were issued for a variety of expected weather, including high wind, winter storm, and flooding. The flood watches highlighted the already high river flows and signaled that significant flooding was possible.

Rain began to fall in southwestern Oregon on December 28 and moved northward during the day. Some snow fell in the Willamette Valley, and shallow cold air was again trapped near the Columbia Gorge, resulting in the second freezing rain event in 3 days. Coastal rivers began to rise again in response to the rainfall. Rain continued on December 29, with very heavy amounts occurring in the Coast Range. Freezing rain, sleet, and snow continued to fall near the Columbia River. Southwest flow aloft increased, resulting in rising freezing levels in the mountains and very strong surface winds, especially along the coast. Rivers throughout the region were rising, with many approaching flood stage levels.

Rainfall subsided somewhat on December 30, but another system moved into the region producing heavy rain on December 31. Freezing levels remained high, resulting in increased snowmelt which added to the runoff problems. Strong wind accompanied this system, especially in coastal areas. By late on December 31, flooding was occurring throughout the region, with major flooding occurring on the Tualatin River.

Bands of rainfall replaced the heavy steady rain on January 1. Showery rains continued on January 2-3. Crests began on the smaller rivers and tributaries in western Oregon late on New Year's Day. The mainstem rivers crested on the January 2-3, as did the rivers and streams in eastern Oregon.

Disaster Survey Focus Areas

NWSFO/NWRFC Interactions

Coordination between the NWSFO and the NWRFC went very well during this event. In general, the coordination was improved over past flood events. The primary areas of coordination between the two offices were the QPS and the river forecast guidance. The QPS coordination was largely done by the forecasters preparing the QPS and the RFC HAS forecasters. The person working the "hydrology desk" and the RFC hydrologist coordinated the river forecasts. Weather briefings held by the offices are attended by personnel from both offices with interactions common.

QPS coordination worked quite well. The requests from the RFC for QPS updates were handled as quickly as the NWSFO workload allowed. Discussions between the offices to assist the HAS forecasters in preparing long-term QPS products were common and well coordinated.

Coordination of the RFC river forecast guidance went well, especially in the area of requests for forecast updates for basins calibrated in the NWSRFS model. NWSFO Portland and the NWRFC have identified some areas where river forecast guidance is less than ideal, such as time required for updates and forecast details. Both offices are working towards making improvements in these areas.

Data Collection and Quality Control

Data from the LARCs were extremely important during this event. Data from DCPs were received reliably via HADS throughout the event. HYDROMET was heavily utilized during this event to call LARCs and display data. The NWSFO is working with the NWRFC to run their HYDROMET computers as redundant systems, so in the case of a computer failure one system can backup the other.

Current data quality control efforts in the NWSFO emphasize ASOS and Aviation Routine Weather Report (METAR) codes. Efforts are also underway to utilize some HYDROMET graphical displays being developed by the Colorado Basin River Forecast Center (CBRFC) to quality control automated precipitation gages. It is hoped that this program will be functional within the next few months. The current workload (NWR and telephone calls) of the HMTs during flood events prevents them from performing extensive quality control work at these times.

Numbering of Products and Changes to Formats

Flood-related products were numbered during this event by NWSFO Portland. The numbering of products may be confusing when multiple offices in the same state are issuing flood products in different sequences. NWSFO Portland will evaluate the use of numbering on hydrologic products for future events.

The format of the hydrology products issued by the NWSFO was changed for this event at the request of the media and the EMs. The current format is similar to that used by NWSFO Seattle. This will help with transition when NWSFO Portland assumes responsibility from NWSFO Seattle for several counties in southwestern Washington.

Integration of Hydrology as a Station Program

The NWSFO has been reasonably successful in integrating the hydrology program as a station function. The HMTs perform the routine daily hydrology duties. Generally, the lead forecasters generate the QPS products as part of their shift duties. The lead forecasters also handle minor flood-event products as part of their shift duties. The hydrology duties for significant flood events are handled by the SH, if available, or by calling in additional forecasters. The telephone workload during flood events is heavy, and everyone on shift pitches in to handle this task.

QPS Activities, WSR-88D Data, and Use of NCEP Guidance

The generation of the QPS product is routinely done once a day by the lead forecasters. The QPS product contains forecasts of precipitation, freezing levels, and maximum/minimum temperatures for approximately 20 locations. All forecasts are for 3 days and the precipitation forecasts are broken into 6-hour increments. QPS products are currently updated on requests from the RFC or whenever the NWSFO desires updated guidance from the RFC. The NWSFO is considering establishing guidelines for monitoring rainfall and comparing it with current QPS. This scrutiny would then be the basis for updating QPS if needed.

NCEP guidance is heavily utilized by the forecasters in generating the first 24 hours of QPS. Satellite data is very helpful for this time period as well. Data from the WSR-88D is used in a qualitative manner for this same time frame to locate the areas of heaviest precipitation. Model guidance is the primary input to the Day 2 and 3 QPS products.

Statewide Coordination Issues

NWSFO Portland has found that in this and other events the state coordination is not a big issue in Oregon. State agencies seem to have enough understanding of the NWS structure to contact the NWS office responsible for a given area and/or event. Furthermore, most of the response activities in Oregon are handled by the county emergency management offices which are in close contact with the NWS office which serves them.

NWSFO Support for NWSO Medford

NWSFO Portland and NWSO Medford coordinated closely in this event, especially concerning QPS. NWSFO Portland's perception was that NWSO Medford was very well prepared to handle this event. NWSO Medford prepared all hydrologic products, except flash flood watches, for their HSA. The flash flood watches were coordinated with NWSFO Portland which issued the products. NWSFO Portland expressed concern that they would have had real difficulty handling this event if NWSO Medford had not already assumed HSA responsibilities for its area.

NWSFO Support for NWSO Pendleton

Much of the significant flooding during this event was in the area which will become NWSO Pendleton's HSA. Several of the staff members at NWSO Pendleton are well versed in the hydrology program. These staff members prepared hydrologic products as work files and sent them to NWSFO Portland for dissemination. There was considerable coordination between the two offices concerning hydrologic products during the event.

There are several subject areas which need to be completed before NWSO Pendleton can assume full HSA duties, including the documentation of river forecast points, installation of HYDROMET, and training of the entire staff on hydrologic operations and issues.

Freezing Rain, Heavy Snow, and High Wind Event

NWSFO Portland was able to provide good lead time on high wind watches and warnings for coastal Oregon during this event. The WSR-88D Velocity Azimuth Display (VAD) wind profiles were very useful in issuing the high wind warnings. The high wind watches were based largely on surface analysis, 850 millibar (mb) analysis and model guidance, which was good for this part of the event.

The first freezing rain episode was not well handled by the models. The forecasters recognized the possibility of freezing rain if storm development deviated from model solutions and mentioned the possibility in discussions. However, the public forecasts did not deviate significantly from model guidance and did not contain any mention of freezing rain. The second freezing rain episode was recognized early by the models and forecasters. Watches for freezing rain were issued well in advance of the second event for the affected areas.

Primary Findings and Recommendations

Finding HYDROMET was heavily utilized during this event. HYDROMET 4.0 remains in testing mode due to the need for some improvements. NWSFO Portland has worked with CBRFC to provide means of plotting data, forecasts, and hydrographs using HYDROMET 4.0.

Recommendation Plotting capabilities for HYDROMET 4.0 developed at CBRFC should be documented and sent to other WR sites. Development work on alarm features and group dialing that were available in "old" HYDROMET should be given top priority so they can be utilized in the field as soon as possible.

Finding SHEF coding of precipitation products from the Federal Aviation Administration (FAA) ASOS sites would be beneficial. Currently, this information must be SHEF encoded by hand.

Recommendation The WR and Weather Service Headquarters should investigate the possibility of having the FAA ASOS sites produce SHEF-encoded precipitation products.

Finding NWSFO Portland has identified several locations where telemetry is needed to expedite data availability.

Recommendation NWSFO Portland should request such telemetry through normal WR channels.

Finding NWSFO Portland needs to address the information requirements of customers on rivers which are not under flood warnings.

Recommendation In addition to local efforts underway on a solution to this problem, the HSD should canvass other WR offices to see how they are handling this problem and if any of these methods could be used at NWSFO Portland.

Finding There is a lack of detailed knowledge of the levee systems within the HSA, including the area to be handed over to NWSO Pendleton in the near future. This lack of knowledge could be a problem in future events.

Recommendation The NWSFO should devote some resources to obtaining additional information on the location, structural status, and potential inundation areas related to levee systems in their HSA.

Finding NWSFO Portland coordinated Flash Flood Watches with NWSO Medford during this event. Since these watches were based largely on forecast rainfall, this was not a problem. However, coordination of Flash Flood Watches for short-fused events, such as dam breaks and levee failures, could result in significantly reduced lead times.

Recommendation The WRH should consider assigning Flash Flood Watch responsibilities for short-fused events, i.e., potential dam breaks, levee failure, etc., to all offices (NWSFOs and NWSOs) with HSA responsibility.

Summary of Damages, Deaths, Injuries, and Major Impacts

* All information contained in this section is preliminary and based on estimates available at time report was written.

Rivers That Flooded:

Nehalem	Wilson
Nestucca	Siletz
Alsea	McKenzie
Mohawk	Marys
Luckiamute	S. Yamhill
Pudding	Molalla
Tualatin	Umatilla
Clackamas	Johnson Creek
Columbia	Grande Ronde

Willamette (includes Middle and Center Forks)
Santiam (includes North and South)

(No rivers exceeded record flood levels in Portland's HSA.)

Counties in Portland's HSA Declared Disaster Areas:

Clackamas County, OR
Columbia County, OR
Wallowa County , OR
The city of Keizer in Marion County, OR

(Declarations were at the Federal and state levels.)

Major Impacts:

— Two deaths related to the event were reported in Portland's HSA.
  — A backhoe operator was killed when the machine he was operating slid into the water as he attempted to remove ice from a creek in Multnomah State Park.
  — A man was killed when he was struck by a car and knocked off of an icy overpass in Portland.
— Approximately 400 people were sheltered as a result of evacuations.
— Numerous road closures resulted from flooding and mudslides.
— The town of Tualatin experienced flooding of the downtown and residential areas.
— Most roads in the vicinity of Tualatin were closed by high water.
— A levee failed on Sauvies Island in the Columbia River resulting in the inundation of farmland.
— The ice storms which affected Portland and the Columbia River Gorge resulted in numerous power outages and travel problems.

— Interstate 84 in the Columbia Gorge was closed for 4 days due to snow, ice, and mudslides. Reportedly, there were eight different mudslides which affected I-84.
— Portland International Airport was closed for over 4 hours during one of these power outages.
— Over 6,000 people lost power in Seaside, Oregon, during the New Year's Day wind storm.

Estimated Damage in Dollars by County:

None available at time of report.

Supplementary Findings and Recommendations

Finding The hydrology program was performed by the entire NWSFO staff during this event, with at least one individual designated as the "hydro" person on each shift.

Finding Events such as this require a great deal of extra staffing in order to handle the extra product issuance and telephone workload.

Finding NWSFO Portland has emphasized outreach to the user community. This included a workshop conducted with the NWRFC for EMs, the media, and public officials last fall.

Finding NWSFO Portland has utilized a number of innovative methods in disseminating its products, including cooperative efforts with the media and Internet Web site, in an effort to reach more users and reduce the telephone workload in the office.

Finding Hydrologic training is important both on station and to NWSO Pendleton which will get the HSA responsibilities in the near future. The Hydrologic Services Course is needed to help with this training.

Recommendation The Office of Hydrology should issue the new Hydrological Services Course as soon as possible.

Finding River forecast guidance from the RFC needs to contain: time river will reach flood stage, time and height of the crest, and time river will recede below flood stage.

Finding At times, more timely updates were needed from the RFC. Both offices are aware of the factors affecting more frequent updates and are working on solutions to current bottlenecks in the process.

Finding NWSFO Portland identified a need for more frequent updates of stage data during events and has established a procedure to provide updated stage data to customers on an hourly basis.

Finding NWSO Pendleton provided draft forms of most of the hydrologic products for the rivers on the east side of the Cascades during this event. This was a great help to the staff of NWSFO Portland.

Finding NWSFO Portland must expand information on its forecast points, especially in the area of potential damages and impacts.

Finding During last two significant flood events, the RFC forecast guidance for the Mohawk River has been quite high. The RFC is aware of this and is investigating a solution. The RFC is currently utilizing the SSARR model and NWSRFS on this river. During the last event, NWSRFS provided better guidance values.

NORTHWEST RFC

Event Overview

The Pacific Northwest experienced a wet period from mid-November through mid-December 1996. Heavy snows were the rule over all but the lower elevations during this period. Rain fell in the lower terrain, resulting in wet soil conditions and high streamflows. This weather set the stage for the flooding experienced in the NWRFC's area of responsibility in late December 1996 and early January 1997.

In Oregon, rainfall during the period December 21-25 produced rises to flood stage levels on coastal rivers and tributary streams. More rain on December 26 aggravated this situation and resulted in flooding on a number of the larger tributary rivers. After a brief break, rain began again on December 28, resulting in rises on the coastal rivers once again. Heavy rainfall on December 29 produced rising levels on rivers and streams throughout the state with widespread flooding. Runoff from rainfall and snowmelt continued through December 31. The smaller rivers and streams began to crest on January 1, with other crests following over the next couple of days.

Much of the precipitation in Washington was snow or freezing rain until late December. Warm air finally replaced the cold air on December 29, resulting in street and small stream flooding in western Washington. In addition, runoff was sufficient to result in major flooding along the Chehalis and Skookumchuck Rivers and minor to moderate flooding on four other rivers in western Washington. Heavy rain on December 31 resulted in flooding on a number of rivers throughout the state of Washington. This round of flooding was generally minor and started on January 1. Rivers were above flood stage for 1 to 5 days during this event.

Most of the precipitation in Idaho was in the form of snow until December 24, when warmer air moved into the area. Moderate rainfall during the next week combined with snowmelt at low and high elevations to produce a significant runoff event. Small stream flooding began on December 27, and by December 29 flooding was occurring on a number of rivers. Flooding continued on most rivers in southwestern and central Idaho on January 2-3. Record flooding was reported at a number of locations along the Weiser and Payette Rivers during this event.

Disaster Survey Focus Areas

NWSRFS Performance, Interactive Forecast Procedure (IFP), and Desired Enhancements

The NWSRFS was used operationally to forecast river levels in western Washington and Oregon during this event. In general, the forecasts provided by the NWSRFS were quite good. The NWSRFS provides more flexibility regarding times when updates can be run and allows forecasters to focus on specific forecast points rather than entire basins. The quality of data being used in NWSRFS is critical to obtaining good output. The NWRFC devoted considerable time during this event performing quality control on the input data.

The NWRFC made extensive use of IFP during this event. In general, this system worked well. Some enhancements to IFP are necessary in order for this system to meet forecasters' needs and improve forecast generation time. The NWRFC has sent a list of proposed enhancements to the Office of Hydrology. This list prioritizes areas critical to NWRFC's operations.

Use of QPS, WSR-88D Data, and NCEP Guidance in RFC Operations

The NWRFC was provided QPS by the NWSFOs at least once a day during the event. These products included 3-day forecasts for precipitation, freezing levels, and maximum/minimum temperatures. The precipitation forecasts were provided in 6-hour amounts for each day. All of this data is necessary in order for the RFC to provide accurate forecast guidance to the HSA offices.

The NWRFC has received requests from cooperators for river forecast guidance beyond 3 days. Ideally, such guidance should be based on QPF beyond the next 3-day period. Meeting the request for river forecast guidance beyond 3 days is both a workload issue and an issue on the scientific capability to produce QPS and river guidance beyond 3 days. Further examination of these issues will be necessary.

The HAS forecasters at the NWRFC utilized WSR-88D reflectivity data in a qualitative manner during this event to identify areas of heavy rainfall. Satellite data was extremely useful in identifying areas where heavy precipitation was likely to occur. Guidance from NCEP was used to adjust QPS precipitation and freezing level forecasts.

HAS Activities

The NWRFC HAS forecasters provided QPS and liaison support to the RFC hydrologic staff during the event. The HAS forecasters handled all QPS issues for the NWRFC. These efforts included coordinating the QPS forecasts generated by the other NWS offices and ensured that QPS was included in all the RFC model runs. The HAS forecasters also used observed precipitation data to verify QPS forecasts. The HAS forecasters worked numerous shifts during the event and provided invaluable hydrometeorological support to the RFC staff.

Much of the HAS forecasters' time was devoted to manipulating the QPS products. This process will be standardized once all offices are using Mountain Mapper to generate their QPS products. Mountain Mapper will allow the HAS forecasters to mosaic the QPS products automatically. The NWRFC plans to move forward in implementing this process throughout their area.

RFC/NWSFO/NWSO Coordination

Coordination among the NWS offices generally went well during this event. The NWRFC has held a number of workshops with the HSAs they support. These sessions have provided a basis for understanding between the offices and have alleviated some of the misconceptions which existed about other offices. One of the highlights of the coordination between the RFC and other NWS offices was in the area of QPS. The NWRFC noted that there was vast improvement in coordination over past events.

The NWRFC expressed concerns about data quality. Obviously, the quality of the data used in the hydrologic models is directly related to the quality of the river guidance produced by the RFC. Since the HSA offices have a vested interest in the quality of the RFC guidance, they should be concerned with data quality as well. The NWRFC currently performs quality checks on all data used in the hydrologic models. This is a time-consuming but necessary task. The HSA offices should become involved in data quality control as well. Both offices performing data quality control would provide two levels of checks on data quality lessening the chances of "bad" data being used.

Modeling of Levee Failures

The NWRFC recognizes the need for having some procedures for dealing with levee failures. Efforts are planned to model levee breaches to predict inundation and effects of river flow. This project will require the assistance of the HSA offices in gathering information on the levee systems which exist in the region.

Primary Findings and Recommendations

Finding The NWRFC has found it necessary to perform extensive quality control of data prior to running the forecast models. This task is time consuming and often slows the forecast process, delaying forecast guidance issuance to the HSAs. The NWRFC is not staffed to handle ALL data quality control in its area.

Finding There is a lack of tools available to the HSAs and to the RFC to automate quality control.

Recommendation The HSD must work with the HSAs and RFCs to make data quality control a "team effort" and a high priority function. Efforts must be made to determine what tools have been developed at various offices to provide data quality control to see if they can be applied at other offices.

Finding The conversion to METAR from Surface Airways Observation reports has caused problems for the NWRFC in utilizing precipitation data from the "first order" stations which don't automatically send a SHEF-encoded message. The fact that zero precipitation is not reported is also a problem.

Recommendation The WRH should request that all METAR reports include precipitation (including times of zero precipitation). Also, a request should be made to require that all METAR sites provide a SHEF-encoded product.

Finding QPS (forecast of precipitation, temperatures, and freezing levels) is an extremely important component of river forecasting in the NWRFC's area. The process requires significant efforts in the office generating the QPS and in the RFC. Coordination between these offices is paramount to providing good quality QPS to the forecast model, and the HAS functions act as the point for this coordination. During this event, the HAS function worked very well.

Finding Standardization of the QPS product generation utilizing a tool, such as Mountain Mapper, is highly desirable.

Recommendation The WRH should move forward on the implementation of Mountain Mapper at all field offices.

Finding NWRFC experience is that QPS quality improves with practice, use of local expertise, and acceptance as a high-priority product.

Recommendation Offices not currently generating QPS should begin to practice as soon as possible to learn techniques and how to fit this function into a work schedule as a high priority product.

Finding The NWRFC was largely satisfied with coordination with other NWS offices and cooperating agencies. Difficulties were few and usually due to a lack of understanding of the river forecast process (including the time needed for data quality control).

Recommendation The NWRFC should continue to provide outreach to the weather offices it serves. The WRH/HSD must continue to work with the AMs and MICs to integrate the hydrology program as a station function to facilitate coordination with the RFCs.

Finding In basins where NWSRFS has been implemented, the NWRFC is currently issuing forecast guidance every day for all forecast points. Data for locations not in flood are not always being transmitted to the user community. There were a number of requests for this type of information during this flood event.

Recommendation The HSD should examine current policy and amend it as necessary to ensure that information on all river forecast points is included in products issued by the HSAs during flood events.

Finding The NWRFC has requested some enhancements to NWSRFS and specifically to IFP. An example of an enhancement request is that the MODVIEWER needs to be modified to streamline the ability to look at specific Tulsa plots. Many of these enhancements need a higher priority than currently exists within the Office of Hydrology.

Recommendation The Office of Hydrology should consider raising the priorities of certain enhancements which have been requested by the NWRFC.

Summary of Damages, Deaths, Injuries, and Major Impacts

Damage summaries are contained in the individual summaries for the individual HSAs served by this RFC.

Supplementary Findings and Recommendations

Finding The NWRFC has been doing self assessments after every flood event. These self assessments have been useful in pinpointing areas for improvement.

Finding The NWRFC's transition from SSARR model to NWSRFS is progressing, and the staff is doing a good job transitioning to NWSRFS.

Finding The NWSRFS calibration has proven to be very resource intensive both in terms of personnel and development time. The NWRFC has brought in SHs to assist with calibration efforts. This practice has provided the SHs with valuable experience with the calibrations and operational needs of NWSRFS.

Finding The NWSRFS, where it has been implemented, has proven to be an improvement over the SSARR model in allowing the forecasters to focus on problem areas and provide quicker turnaround of forecasts than in the past.

Finding The NWRFC/NWSFO Portland office is located in the flood plain and is vulnerable to rapid inundation in the event of a levee failure.

Recommendation The WRH and the Portland offices should work together to ensure that adequate backup procedures are in place and have been tested.

NWSO MEDFORD, OREGON

Event Overview

The day after Christmas (1996), a weather system with a tropical moisture connection had set up bringing more rain to an already wet southern Oregon and northern California. Both November and early December had been quite wet with a few bouts of minor flooding. This system would be the beginning of the second and most dramatic round of flooding in NWSO Medford's HSA. The numerical models advertised copious amount of precipitation with a series of systems moving in from the Pacific. This, in combination with an extensive snowpack in the mountains of southern Oregon, northern California, and eastern Oregon, prompted flood watches across the entire HSA. The first round of rain was on December 26, which brought moderate rises to most rivers in southern Oregon and northern California west of the Cascade Mountains. An interesting aspect of this series of storms was that they continued to add additional snow to the higher elevations. Warm air advection ahead of and associated with each successive system continued to gradually raise freezing levels across the area. Another rain event occurred on December 28 and 29. Freezing levels again rose with this system allowing rain to fall on top of the already existing snowpack. Rivers rose again to higher levels than with the previous rain since runoff from the December 26 event was still occurring. The second rain event did not produce any flooding, but river stages were at significant levels.

The forecast models indicated that more heavy rain was still in store for the region. Along with more significant rainfall, forecasts called for freezing levels to continue to rise. On December 30, the forecasted rain began. As expected, there was also a significant rise in the freezing levels. The South Fork of the Couquille River at Myrtle Point reached flood stage and the Rogue River at Dodge Bridge briefly reached flood stage with this rain event. Along with the heavy rains, some of the snow in the higher elevations began to melt, enhancing the storm runoff. Most damage from flooding at this point was associated with small streams and tributaries and was primarily urban in nature, such as ponding due to blocked and overwhelmed drainage systems. The rain along with the warmer temperatures were making for a wetter snowpack throughout the HSA.

By New Year's Day (1997), light rains continued to fall over most of Oregon and northern and central California. Rivers had already peaked from the previous rain and were in recession, but runoff was still occurring in all basins. River stages remained at significantly high levels and reservoirs continued to fill at accelerated rates. The last and heaviest of the rains were forecast to arrive New Year's Eve and New Year's Day. The Applegate Reservoir was beginning to fill at a rapid rate due to runoff from the rain and melting snow. Small streams and creeks were causing numerous problems throughout the area. By late afternoon on New Year's Eve, temperatures across southern Oregon were in the low 60s, with freezing levels above 10,000 feet. The warm temperatures and forecasted heavy rain in combination with the still significant snowpack in the higher elevations would set the stage for the New Year's Flood of 1997.

By New Year's Day, copious amounts of rain had fallen over all of southern Oregon and northern California. This, in combination with the rapidly melting snow, drove rivers and streams well above flood levels across all of NWSO Medford's HSA. The Applegate Reservoir filled and was now forced to release water from the spillway. This was the first operational spill ever from the Applegate Reservoir. The Lost Creek Reservoir was able to store the bulk of the water coming down from the Rogue River headwaters. Flood stages were significantly exceeded downstream from Shady Cove, Oregon, and damage was very much evident in these areas. Even with the dam in place, the tremendous runoff from the tributaries brought the Rogue River well above flood stages. The two biggest contributors to the Rogue River flows below Dodge Bridge near Eagle Point, Oregon, were Little Butte Creek and Bear Creek. Bear Creek at Medford, Oregon, reached near record flows with this storm, and damage was widespread in Jackson and Josephine Counties. Most notably would be the commons district in downtown Ashland, Oregon, and the Applegate Valley. Areas east of the Cascade Mountains did not escape the wrath either. Lake County had extensive flooding due to snowmelt and rains. The Sprague and Williamson Rivers in Klamath County also spilled out of their banks and caused significant flooding problems. In northern California, there was widespread flooding in the Scott River Basin, the Sacramento headwaters, and the mainstem of the Klamath River.

Disaster Survey Focus Areas

Overall HSA Operations at an Office with "New" HSA Responsibilities

NWSO Medford assumed HSA responsibilities on October 2, 1996. A SH was assigned to the NWSO in May 1995. The station has put together an excellent hydrology program. The HSM, along with several other reference documents, describes the HSA and HSA responsibilities in a clear, concise manner. Other supporting references include maps of the HSA highlighting the rivers, forecast points, and gage locations. In addition, the SH developed a manual for each basin which allows the forecasters to have quick, easy access to information for their area of concern. All forecast and HMT staff have been trained in hydrologic operations and are adequately prepared to handle a hydrologic event. Several minor flood events had occurred since the HSA responsibility was assumed, and all were handled well which helped prepare the staff for this major event.

Overall, the hydrologic services provided during this event were excellent. Warnings and forecasts were issued well before the onset of flooding. A flood watch was issued for southwestern Oregon and Siskiyou County in Northern California at 4 p.m. Pacific Standard Time (PST) on December 27. Small stream flooding began on December 31, followed by flooding on the larger rivers. River flooding began to crest beginning on January 1. Lead times for most basins were 5 days or greater.

Data Collection and Dissemination

The primary data collection tool was the HYDROMET system. The office has the HYDROMET 4.0 software loaded and running. This proved to be a valuable resource for both data collection and data display. Although the HYDROMET system was of great value during this event, several needed enhancements were identified. Specifically, the dialing routine needs to be upgraded and additional memory is needed for Medford's system. In addition, other programmatic enhancements to the software, such as alarm/alert feature, documentation, etc., would be desirable (these have been enumerated in other portions of the report). Currently, the SH spends about 70 percent of his developmental time maintaining HYDROMET.

Gages within the HSA functioned throughout the event with no major failures. However, several areas were identified where additional gaging is needed and would have been helpful during the event. Areas where additional gaging could have helped include the Illinois River near Agness and on the Coquille River. In addition, several locations within the HSA have non-telemetered gages available which could be upgraded. The NWSO should investigate the feasibility for upgrading the data collection network through the addition of gages, cooperative observers, and telemetry.

NWSO Medford/RFC(s) Interactions

NWSO Medford's HSA includes portions of southwest Oregon and northern California and is serviced by both the CNRFC and the NWRFC. Although both RFCs were very responsive to the NWSO's needs during the event, the coordination efforts would be reduced if a single RFC were responsible for the Klamath Basin. Since the reach of the Klamath Basin in Oregon is not modeled by the NWRFC, the entire basin responsibility would be better served by the CNRFC.

Support from the RFCs was excellent. Both RFCs issued frequent forecasts and updates. The NWRFC issued 6 hourly updates to their forecasts and transmitted hydrographs to the NWSO. Additional forecast points may be needed in the Klamath Basin. The NWSO should identify and coordinate these needs with the appropriate RFC. In addition, the RFCs should investigate the feasibility of modeling Scott, Shasta, and Indian Creek. Gaging is available in these flood-prone areas. The NWSRFS, used by both RFCs, worked well during the event. The Coquille and Umpqua Basins were recently calibrated for NWSRFS (previously they were forecast using the COE SSARR model). Ratings for the Coquille need to be updated.

Integration of Hydrology as a Station Program

NWSO Medford is another good example of the integration of hydrology as a station program. Generally, the hydrologic functions are assigned to the aviation meteorologist. During the event, the aviation forecasters handled the event along with help from the HMTs. Additional staff was called in on overtime to support this event. The SH functioned as the program manager and consultant for HSA operations as well as filling in on operational shifts, both hydrologic and meteorologic.

During this event, the hydrologic warnings and forecasts were primarily issued by the meteorologic forecast staff. The HMTs wrote some of the public products and were responsible for the data collection and quality control. Staffing was adequate throughout the event.

Coordination and Preparedness Activities

Statewide coordination during the event was provided by NWSFOs Monterey and Portland. NWSFO Portland spoke for activities in Oregon, and NWSFO Monterey spoke for statewide activities in California through a forecaster assigned to the state Office of Emergency Services (OES). In general, this worked well in Oregon. However, NWSO Medford was not aware that another office was speaking for a portion of their HSA in California. As indicated in other portions of this report, operating procedures on statewide coordination need to be developed and implemented in the WR.

Another area of minor concern regarding coordination was that offices in Oregon and California use different formats for their hydrologic products. This can lead to difficulty for an office like Medford where the HSA responsibility spans more than one state. Preparation of summaries is more time consuming since some products may need reformatting. Also, some users may have to deal with products from several offices which are in different formats which could lead to confusion. The WRH should investigate the need for common product formats. In addition to differing product formats, there was also some confusion over which Automation of Field Operations and Services (AFOS) product headers to use for various situations. Streamlining of AFOS Product Identifier Lists (PILs) and product headers is currently underway and should resolve this issue.

Preparedness was at a high level. All staff members had been given hydrologic training and hydrology was a part of the station drills. In addition, much work has been done with users of NWSO Medford's hydrology products to coordinate the HSA responsibilities and requirements. During this event, numerous contacts were made to the counties to update EMs and action agencies. During most of the calls, a successful exchange of information left the county and the NWSO much better informed. The only area where response was minimal was in Modoc County, California. During these exchanges, it was identified that the flood stage at Applegate on the Applegate River needed to be adjusted to a lower level.

The local TV weathercasters did an excellent job of passing NWS information to the public. Scott Lewis, TV meteorologist on local Channel 12, stated that he had the highest regards for the NWSO staff, and that they had been extremely helpful to him and Channel 12 during the event.

Primary Findings and Recommendations

Finding The HYDROMET system proved to be a valuable tool for data collection and display. However, some system and software upgrades are needed.

Recommendation The CNRFC should make enhancement to the HYDROMET 4.0 software to add alarm/alert capabilities, upgrade the dialing routine, and add programmatic enhancements described in other sections of this report. In addition, clear user instructions and additional documentation is needed. Additional memory should be obtained for the NWSO Medford system.

Finding Additional gaging and telemetry needs were identified in Medford's HSA. Specifically, gaging is needed on the Illinois River near Agness, Oregon, and telemetry is needed on the Coquille River.

Recommendation NWSO Medford should work with the USGS and the counties to determine the feasibility of expanding the gaging network and adding telemetry to existing gages.

Finding The Klamath River flows through portions of Oregon and northern California. Forecast responsibility is currently split between the NWRFC and the CNRFC. Forecast and coordination activities would be more efficient if one RFC handled the entire Klamath Basin.

Recommendation Responsibility for the Klamath River Basin in Oregon should be transferred from the NWRFC to the CNRFC resulting in a single RFC having responsibility for the entire Klamath River Basin.

Finding It was identified that additional forecast points are desired on the Klamath River. In addition, several flood-prone areas on the Scott, Shasta, and Indian Creek are gaged but not modeled. Also, ratings on the Coquille River need to be updated.

Recommendation The NWSO SH needs to work with the RFCs to identify forecast points needed on the Klamath and to determine the feasibility for having these and the other areas listed above modeled. The SH should work with the appropriate agency to obtain updated ratings for the Coquille River. These should be sent to the RFC.

Finding During the event, it was determined that the flood stage at Applegate on the Applegate River needed to be adjusted to a lower level.

Recommendation The SH should work with the county OES and the RFC to determine the correct flood stage for Applegate. A request to change the flood stage should be submitted to the WRH/HSD.

Finding At times, the NWSO Medford staff was confused on which product header to use in a given situation.

Recommendation The WR/HSD should review hydrologic products, streamline where possible, and issue clear guidance on the use of each product. SHs should provide training on products so that all staff members are familiar with hydrology product usage.

Finding Statewide coordination is being performed by a single office in each state, but at times NWSO Medford was not aware of the coordination efforts in

California or the content of information being passed for their HSA. In addition, differing product formats in California and Oregon make coordination more difficult.

Recommendation The WRH should develop and implement a policy on statewide coordination activities and responsibilities. The WR/HSD should develop a common format for hydrology products.

Summary of Damages, Deaths, Injuries, and Major Impacts

* All information in this section is preliminary and based on estimates available at the time the report was written.

Rivers That Flooded:

Rogue	Applegate
Bear Creek	Sprague
Klamath	Williamson

Coquille (includes mainstem and South Fork)
Umpqua (includes mainstem and South Fork)

(No rivers exceeded record levels in Medford's HSA.)

Counties in Medford's HSA Declared Disaster Areas:

Jackson County, OR	Josephine County, OR
Lake County, OR	Klamath County, OR

(Declarations were at the Federal and state levels.)

Major Impacts:

— No deaths were attributed to the flood throughout southwestern Oregon and northeastern California. While some injuries were reported, no details are available.

— The town of Ashland suffered greatly, since the fresh water and sewage systems were rendered unsafe because of the flooding. A mudslide took out the road that led to the sewage treatment plant and caused the release of raw sewage. The sewage went into Bear Creek. Portable toilets and outlets for fresh water were placed around the town. Many of the downtown businesses were destroyed by the flood waters. The integrity of some of the structures in the Ashland Plaza, which date back to the late 1800s, are now in question. Some Ashland streets were severely damaged.

— Over 500 mobile homes were evacuated throughout the Rogue Valley. Many, if not most, were in the Bear Creek drainage. Many may not be salvageable.

— Many homes throughout the HSA near the affected creeks and rivers were evacuated and/or damaged due to the high water. Many people were stranded because of roads and bridges being washed away or damaged severely. In the small town of Lake Creek, about 20 miles southeast of Medford, a half dozen residents were cut off for several days when a wooden bridge to their homes was washed away. The neighbors strung a cable across the creek and passed food and water to the stranded families.

— Homes along 7 miles of the Rogue River were evacuated. An extreme amount of water overflowed the neighboring areas of the confluence of the Applegate and the Rogue River west of the city of Grants Pass. A mudslide closed Interstate 5 near the town of Dunsmuir in southern Siskiyou County. Many people were stranded on both sides of the slide until it was cleared several days later.

— Just trying to navigate around the area was difficult due to the multitude of mudslides and the backup of water on the roads. A survey of the local area by plane 2 days after the flood showed that many roads were still impacted by high water.

Estimated Damage In Dollars by County:

Lake County, OR	$6.3 million
Jackson County, OR	$50.5 million
Josephine County, OR	$10.0 million
Clackamas County, OR	No figures available
Klamath County, OR	$393,000.00
Siskiyou County, CA	No figures available
Modoc County, CA	$2.0 million

Supplemental Findings and Recommendations

Finding The NWSO staff did an excellent job during this event. Hydrologic warnings and forecasts were accurate and timely. Frequent updates were issued throughout the event to keep the public, media, and EMs informed. Early recognition of the event resulted in lead times of 5 days or more for most of the rivers in the HSA.

Finding The hydrology program at NWSO Medford is well integrated as a station function. All forecasters and HMTs have been trained in hydrology and HSA operations and are very capable. The SH has done an outstanding job in spinning-up a "new" HSA program.

Recommendation Spin-up checklists used by the NWSO Medford SH to establish the Medford program should be made available to other spin-up sites as a reference/guide for developing new station hydrology programs.

Finding The EMWIN system did not have local hydrology data, and no products were available under the "Hydrology" menu.

Recommendation The WRH/Meteorological Services Division (MSD) needs to look into this and take any necessary actions to ensure that hydrology data and products are available on EMWIN.

Finding Snow cover data and water equivalent information from the NOHRSC are not available until January.

Recommendation The NOHRSC needs to investigate the feasibility of having their products available earlier in the winter season.

NWSO EUREKA, CALIFORNIA

Event Overview

Early December weather for the northern California coast was dominated by an extensive southwest flow of warm, moist air. This flow of tropical air was more extensive than the commonly known "Pineapple Express" and could be traced back as far as southeast Asia. This flow continuously drove weather systems onto the coast resulting in almost continuous rain during the early portion of the month. This persistent rainfall raised soil moisture levels and began the "set-up" for the significant runoff and flooding that was to begin later in the month. By mid-December, a high pressure ridge had built over the area putting northern California under a cooler, northerly flow and cutting off the influx of moisture to the region. However, this reprieve from the rain which dominated the early portion of the month only lasted about a week. Shortly before Christmas (1996), the next regime of wet weather set up. Again, the dominant pattern was a southwest flow of warm, moist air of tropical origin though not as deep or extensive as that of early December.

The return of the southwesterly flow of warm, moist air brought several bouts of rain which fell on the already very wet soils. The result was significant flooding over much of California, including NWSO Eureka's HSA, in late December and early January. The southwesterly flow was the result of strong high pressure over the southwest United States combined with an incoming low pressure trough from the Gulf of Alaska. As the moisture thrust onshore, orographics played a role in enhancing the development of heavy rain over most of northwest California. Heavy rain began falling in Eureka's HSA on December 30, causing many creeks and smaller rivers to rise above bankful stages that night. By December 31, the larger Smith, Mad, Van Duzan, Eel, and Klamath Rivers rose to levels well above flood stages with most cresting on January 1, 1997. All roads into northwest California were blocked by either flooding, landslides, or downed trees for a time. Record flooding was measured on Redwood Creek at Orick.

The flooding caused one fatality in Trinity County and extensive damage throughout the HSA. The areas hardest hit by the flooding were the towns of Klamath and Stafford. Klamath is located on the Klamath River in Del Norte County where Highway 101 crosses the river. Numerous homes and businesses were damaged or destroyed in an area between the main highway and the river. The town of Klamath Glen, located just upriver from Klamath, was spared damage by a levee constructed after the 1964 floods. The levee did suffer a small breech but held throughout the event. Stafford, located 4 ½ miles southeast of Rio Dell along Highway 101 and the Eel River, was virtually wiped out by a mudslide.

By January 2, the high pressure over the Southwest began to break down as the low in the Gulf of Alaska moved toward the California coast. The flow of moisture shifted southward and the area of hydrologic impact became central and southern California. For the northern areas of the state, cooler, drier air moved in and the rain subsided. Gradually, a high pressure ridge built over the eastern Pacific. The resultant cool, northwesterly flow into Eureka's HSA brought a reprieve from the rain, and all rivers in the HSA receded to lower levels. The North Coast was dry for the better part of the following 2 weeks.

Disaster Survey Focus Areas

Overall HSA Operations and Service Evaluation

Overall HSA operations at NWSO Eureka were handled primarily by the meteorological forecasters and HMT staffs throughout the event. The SH had just arrived on station and functioned primarily in an advisory capacity. All staff at the NWSO was trained in hydrology by the previous SH and were fully capable of handling the station's hydrologic responsibilities. Warning and forecast services provided by the NWSO Eureka staff for this event were excellent and were characterized by early recognition followed by timely and accurate warnings and forecasts for the hydrologic situation. An editorial in the *Eureka Times-Standard* (the local newspaper) from Sunday, January 5, 1997, stated, "To their credit, the region's disaster response agencies worked most efficiently throughout the crisis. Significant advance warnings kept North Coast residents abreast of the mounting weather threat. Frequent, timely updates on river and road conditions were dispensed to North Coast media and rapidly turned around for the public's benefit."

The potential for flooding within Eureka's HSA was recognized several days before the onset of the heavy rains. A flood potential outlook, which included northern California, was issued by NWSFO Monterey on December 26 at 6 p.m. PST, and a special weather statement (SPS) was issued by NWSO Eureka for their warning and forecast area at 4 a.m. PST on December 27. Both products highlighted the coming storm and the potential for significant flooding. The heavy rain began falling on December 30, and mainstem flooding began on December 31, 5 days after the first public notification of the impending event. Numerous warnings and statements were issued during the event, and lead times ranged from a minimum of 2 hours up to as much as 14 hours from the time of warning to the time the river location exceeded flood stage. Lead times to time of crest ranged from 4 hours to 24 hours.

Preparedness and Training Activities

The entire NWSO staff had been trained by the station's previous SH on hydrologic operations and responsibilities and were well prepared to handle a flood event. Hydrologic manuals were readily available which provided the necessary instructions on the HSA operations as well as descriptions of rivers, flood-prone areas, gage locations, and impacts of various flood levels. In addition, up-to-date E-19s were available for all river forecast points. In addition to these resources, the WCM had prepared a river product formatter that facilitated the composition of flood products to include forecast information and impact statements. This proved to be a valuable time saver.

Discussions with the on-site CDWR representative revealed that a significant amount of field work and coordination was done by the CDWR and NWSO staff in the area. These efforts resulted in a high level of knowledge of HSA operations and a high level of preparedness. The "new" SH should continue to work with the CDWR representative to learn the HSA and continue to enhance the NWSO staff's hydrologic knowledge and expertise.

Dissemination and Coordination

As indicated above, products were disseminated in a timely fashion with frequent updates to keep the public informed on the developing and changing situation. An internal area of confusion during the event was the selection of the appropriate AFOS PIL to use for various warning situations (small streams, urban areas, flash flood, river flood, etc.). In addition, there were questions on watch responsibility under various conditions. For example, the NWSFO had flash flood watch responsibility (a county warning area activity), but the NWSO had the responsibility for watches for HSA activities (rivers). The confusion on watch/warning responsibilities will be largely eliminated with the demise of the area management concept. A streamlining of hydrologic product headers and AFOS PILs should resolve the remainder of the internal confusion on products.

Another area of confusion was the terminology used in products from the RFC and the CDWR. Specifically, some forecast products jointly issued by the CNRFC and the CDWR contained "rise to" forecasts. These products do not provide a crest forecast but can imply a crest due to their wording and thus can be misleading to the users. In addition, the CDWR uses "warning" stages to indicate levels below flood stage where actions or notifications are required by the CDWR or OES personnel. This terminology is often confused with the NWS warning terminology used to indicate above flood stage levels. Actions need to be taken to eliminate confusing terminology in CDWR and NWS products.

Statewide coordination during the event was provided by NWSFO Monterey. The NWSFO assigned a forecaster to work in the state OES office. In addition, NWSFO Monterey issued the first product for the event, a flood potential outlook, for all of central and northern California. While these were positive activities which were beneficial to both the public and the emergency management community, they did raise some concerns. Specifically, the NWSOs were not always aware of what was being briefed for their areas of responsibility. Also, the forecaster at the OES was not always aware of the NWSO's intent to update a product. Additional planning and policies are needed to ensure that proper coordination is done on a statewide level and to ensure that all offices are aware of activities which involve their county warning area and the HSA.

Integration of Hydrology as a Station Program

As mentioned previously, the entire NWSO staff is trained in hydrology and HSA operations and was involved with the program during the event. The SH, although new on-site, was available for assistance. However, the forecast and HMT staffs were the primary persons preparing the warnings and forecasts handling data collection and product dissemination, coordinating with the RFC and CDWR, and handling inquires from the public and the media. This event was an excellent demonstration of the concept of hydrology as a station program.

Data Collection and Quality Control

Overall, data availability in the HSA was adequate, and all gages and telemetry functioned throughout the event with no major failures. However, several areas exist where network enhancements are needed. There is a lack of information on the level of the Trinity River in Trinity County, the site of the only fatality in NWSO Eureka's HSA during this event. There are several gages along the reach of the river, but none are telemetered. Both the sheriff's office and the county OES have expressed concern over this lack of information. The addition of telemetry to these gages should be investigated. Also, additional precipitation gages are needed in the upper Eel River Basin and the upper reaches of the Trinity River Basin.

The HYDROMET system was used for data collection during the event. In addition to the data collection capabilities, the data display capabilities proved to be very beneficial to the forecast staff. However, some enhancements to the HYDROMET 4.0 software could make this system more user friendly and of greater value during flood operations. Areas where enhancements are needed include the addition of an alarm/alert capability (a feature in the "old" software load), clearer user instructions, and better documentation.

NWSO/RFC Interactions and Coordination

Interactions and coordination between the NWSO and the CNRFC went very well during this event. Coordination primarily took place between the NWSO meteorologists and the RFC HAS forecasters. Although the NWSFO was providing QPF information to the RFC for Northern California, the NWSO staff provided QPF input as well. The NWSO was using the Mountain Mapper software provided by the CNRFC to produce QPF information. The NWSO had been using this software for some time to produce practice QPFs twice daily and was very familiar with it.

The RFC was receptive to requests for assistance from the NWSO and provided timely and accurate forecast information for Eureka's HSA. It was obvious that there was a good working relationship between the RFC, NWSO Eureka, and the CDWR staff at Eureka.

Primary Findings and Recommendations

Finding At times, the NWSO staff was confused on which product header to use in a given situation. Also, there was some confusion over which office had responsibility for watches under various situations.

Recommendation The WR/HSD should review hydrologic products, streamline where possible, and issue clear guidance to field offices on the use of each product and which office(s) have responsibility for issuance of each product type(s). SHs should provide training on products and responsibilities so that all staff members are familiar with hydrology product usage and responsibilities for watch products.

Finding Statewide coordination was being provided by NWSFO Monterey via a forecaster at the OES. In addition, NWSO Sacramento also spoke for the state through a hydrologist assigned to the State/Federal Flood Center. At times, all offices in the state were not aware of the content of these activities. In addition, those doing the statewide coordination were not always aware of plans for updates at individual offices. The state OES expressed a desire to receive information for the state from a single source.

Recommendation The WR/HSD and MSD should develop a policy on statewide coordination for both hydrologic and meteorologic products. In addition, a single office in each state should be responsible for issuing summaries to statewide emergency management agencies.

Finding Terminology used in CNRFC and CDWR products was at times confusing and misleading. Specifically, the terms "rise to" in RFC forecasts and "warning stage" in RFC and CDWR products were often misunderstood by the public.

Recommendation The CNRFC should avoid use of "rise to" in their forecasts. Forecasts should contain either a crest forecast or terminology to indicate a river trend when crests are not yet available (such as, the river stage is forecast to rise to XX stage and continue to rise). In addition, the WCM should work with the CDWR to see if an alternative can be found for "warning stage" terminology.

Finding Although several river gages are located along the Trinity River in Trinity County, no information is available due to a lack of telemetry. In addition, additional precipitation information is needed in the upper Eel River Basin and the upper reaches of the Trinity River Basin.

Recommendation The NWSO should investigate the feasibility of installing telemetry on the available gages in the Trinity River Basin. In addition, the NWSO should access the feasibility of expanding the precipitation network through the addition of gages and/or cooperative observers.

Finding The HYDROMET system was used as the primary data collection and display tool for the forecast staff. Some enhancements to the HYDROMET 4.0 software are needed to support operations and to make the system more user friendly.

Recommendation The CNRFC should add an alarm/alert feature to the HYDROMET 4.0 software and provide clear user instructions and documentation.

Summary of Damages, Deaths, Injuries, and Major Impacts

* All information in this section is preliminary and based on estimates available at the time the report was written.

Rivers That Flooded:

Klamath	Mad
Van Duzen	Eel

Rivers That Exceeded Record Levels:

Redwood Creek at Orick

Counties in Declared Disaster Areas in Eureka's HSA:

Del Norte County, CA	Humbolt County, CA
Mendocino County, CA	Trinity County, CA

(Declarations were at the Federal and state levels.)

Major Impacts:

— One fatality in Trinity County. An individual tried to cross a flooded creek in a vehicle. The individual was able to get out of his car but was swept down the creek and drowned.
— Road closures temporarily cut off many land transportation routes. Approximately 70 homes and numerous businesses were damaged or destroyed on the lower Klamath River.
— Homes near Stafford in central Humbolt County were destroyed by mudslides.

Estimated Damage in Dollars by County:

Del Norte	$5-7 million ($3.8 million in town of Klamath)
Humbolt	$24.3 million
Mendocino	$20 million
Trinity	No figures available at time of report

Supplemental Findings and Recommendations

Finding The NWSO Eureka staff provided excellent warning and forecast services throughout the event. The services were characterized by early recognition of the flood potential and timely and accurate warnings and forecasts throughout the event.

Finding Staff integration in the hydrology program worked very well. The concept of hydrology as a station program was well demonstrated at NWSO Eureka.

Finding The WCM at NWSO Eureka developed a personal computer-based product formatter for river products which included forecasts, crest information, and impact statements. This program saved valuable time during the event and helped the staff issue warnings and statements to the public much quicker. In addition, the software provided a quick resource to the forecast staff on impacts at various stages.

Recommendation The impact information in this program should become part of the data base used to support the river product formatter in WHFS when the Advanced Weather Interactive Processing System (AWIPS) is delivered to NWSO Eureka. In the meantime, this product formatter should be used by the NWSO and shared with other offices for their use.

NWSO SACRAMENTO, CALIFORNIA

Event Overview

A series of three rain events affected the NWSO Sacramento HSA in late December 1996 and early January 1997. The first occurred on December 26, when 1 ½ to 3 inches of rain fell. The heaviest of this rainfall occurred in the Feather River Basin in the northern part of the HSA. This precipitation raised soil moisture levels and set the stage for significant runoff from the subsequent events.

The second precipitation event occurred on December 29-30. This event was very orographic in nature with rainfall amounts of an inch or so at valley locations and up to 8 inches reported at some locations in the mountains of northern California. This event produced significant rises on the headwaters on the rivers in the HSA, especially in the northern portion of the HSA.

The last event of the series was by far the strongest. This event was very strongly terrain dependent and was warmer than the previous events with freezing levels rising to 10,000 feet. This storm moved into the area New Year's Eve (1996), and by New Year's Day morning, heavy rainfall was occurring throughout northern California. Rainfall amounts from this event were very high with amounts in the 6- to 10-inch range common.

Rainfall totals for all three events ranged from 3.7 inches in Sacramento to 42.2 inches at Buck's Lake in the Feather River Basin. A number of locations in the higher terrain reported rainfall totals in excess of 24 inches.

Water levels at many locations on the Feather, American, Yuba, and upper Sacramento Rivers exceeded flood stage on New Year's Day. This flooding resulted in the closure of a number of highways including US 50. Flooding became more widespread on January 1, as flooding began in the San Joaquin River Basin. Levee failures also began to occur in the Sacramento River Basin adding to the flooding problems. Road closures became more numerous, and by late on January 2 virtually all roads connecting northern California to Nevada and Oregon were closed.

The significant rain had ended in the region by January 3. High water levels and levee failures continued for a number of days afterward. Most locations in the Sacramento Basin crested by late on January 3, while crests at most locations in the San Joaquin Basin occurred on January 4-5. Record crests occurred at a number of locations in the Sacramento and San Joaquin Basins.

Disaster Survey Focus Areas

HSA Operations at a Spin-up Office with New HSA Responsibilities

HSA operations at NWSO Sacramento were handled by the forecast staff during this event. Both the meteorologists and HMTs were involved in the hydrology program. The SH worked in the Federal-State Flood Center during the event but was available to the office staff for consultation. The training program at Sacramento had adequately prepared the staff to handle the event, and manuals and other materials were available for reference. A few areas needing improvement were identified from this event, and plans have already been made to deal with them (see findings and recommendations).

NWSO Sacramento Interactions with the CDWR

The interactions between the NWSO and the CDWR was largely handled by the SH. As mentioned above, the SH worked in the Flood Center during the event. Duties handled by the SH in this role included: media interviews, warning calls to EMs, liaison to the CNRFC and the EMs, interpretation of NWS products, and provision of information to the NWSO staff on the developing situation (i.e., levee breaches). The attaching of a NWS employee to the Flood Center during a significant hydrologic event was mutually beneficial. There is a question of whether anyone on the NWSO Sacramento staff besides the SH could handle this duty. This is a concern both of the survey team and those of the NWSO Sacramento staff who were interviewed.

Staffing Issues at a Spin-up Office During a Major Flood Event

NWSO Sacramento had adequate staff available to handle all office duties during this event. This included assigning the SH to work in the Federal-State Flood Center. At least one extra person was brought in on overtime during the day and swing shifts to handle the bulk of the hydrology program duties. While doing their own after-event assessment, the office management team acknowledged the need for an extra person on the midnight shift during the height of the flooding. Staff resources were available to cover this period, and in future events it is likely the staff on the midnight shift would be augmented as well.

Support for NWSO Hanford

NWSO Sacramento coordinated with NWSO Hanford several times each day during the event. Routinely scheduled coordination calls used to discuss the meteorological situation and QPF were made between the meteorologists at both offices. In addition, numerous coordination contacts occurred between the Hanford office and the Flood Center to pass information concerning levee problems, reservoir inflows and outflows, etc. This data exchange enabled NWSO Hanford to issue statements on the event and handle media briefings, even though they have not yet assumed HSA responsibilities. Their involvement in the event helped to lessen the workload of NWSO Sacramento.

NWSO Sacramento/CNRFC Interactions

Interaction and coordination between NWSO Sacramento and the CNRFC went very well during this event. While most of the coordination on river forecasts was handled by the SH, the meteorologists and HMTs were also involved. The meteorologists worked with the HAS forecasters on QPF updates and whomever was covering the hydrology program often contacted the RFC. The CNRFC and NWSO Sacramento have obviously placed a high priority on developing a good working relationship.

Integration of Hydrology as a Station Program at NWSO Sacramento

As mentioned previously, the entire staff of NWSO Sacramento was involved with the hydrology program during this event. The SH was available for consultation, but the rest of the staff prepared and disseminated the hydrologic products, handled inquiries from the public and the media, and relayed information to the Flood Center and to the CNRFC.

NWSO Sacramento Training and Preparedness Activities

The WCM and the SH have visited many of the county EMs in NWSO Sacramento's HSA. A representative of the CDWR accompanied them on many of these visits. In addition, media workshops have been held which included hydrology products as part of the program. Special emphasis has been placed on performing outreach, including hydrology, in the Redding, California, area.

Primary Findings and Recommendations

Finding NWSO Sacramento issued Flash Flood Watches during this event for potential levee breaches in their HSA. These watches were necessary to adequately inform the public of a dangerous situation. The staff of NWSO Sacramento did not have an "adequate comfort level" on whose office the watch responsibility fell for this situation as described in the WR Regional Operations Manual Letters (ROMLs).

Recommendation The MSD and HSD in WRH must review the ROMLs on watch dissemination and ensure that all field offices are clear on which office the watch responsibility falls, especially for situations such as potential levee failures.

Finding At times, the NWSO Sacramento staff was confused on which product header to use in a given situation.

Recommendation The HSD should review hydrologic products, streamline where possible, and issue clear guidance to field offices on the use of each product. SHs should provide training on products so that all staff members are familiar with hydrology product usage.

Finding

Placing the SH in the Federal-State Flood Center during the event worked well without adversely affecting the ability of the office to adequately staff for the event. There is concern on how this role would be filled in the absence of the SH and how adequately the role of such a liaison is defined.

Recommendation

The role of the individual placed in the Federal-State Flood Center needs to be more clearly defined. The role of this individual could easily be expanded to speaking for the NWS for the entire state. Coordination plans should be implemented to ensure that information is exchanged between this individual and all NWS offices. The WRH should ensure that the MOU between the NWS and the CDWR adequately covers this function.

Finding

The hydrologic program at NWSO Sacramento is new and must develop further to augment and enhance the established programs of the CDWR and CNRFC. The office has made strides in this area by issuing a large number of products during the recent event which were directed at the public and media.

Recommendation

NWSO Sacramento should continue their efforts to provide value-added information in their hydrologic products. Their efforts to add information (i.e., impact statements) to their hydrology products should be a high priority.

Finding

NWSO Sacramento provided a valuable service by highlighting levee failures and potential levee failures in products it issued during the flood event. These products would have been even more useful if detailed information concerning levees and the impacts of levee failures was available to the NWSO staff.

Recommendation

NWSO Sacramento should attempt to obtain detailed information concerning levee failures and incorporate this information into station hydrologic reference materials.

Summary of Damages, Deaths, Injuries, and Major Impacts

* All information in this section is preliminary and based on estimates available at the time the report was written.

Rivers That Flooded:

- Sacramento
- Yolo Bypass
- American
- Merced
- Stanislaus
- Cosumnes
- Cache Creek
- Feather
- San Joaquin
- Tuolumne
- Mokelumne

Rivers That Exceeded Record Levels:

- Sacramento River at Hamilton City, Colusa, and Fremont Weir
- Feather River at Yuba City and Nicolaus
- Cosumnes River at Michigan Bar
- Eastside Bypass at El Nido
- Tuolumne River at Modesto

Counties in Declared Disaster Areas in Sacramento's HSA:

- Shasta County, CA
- Glenn County, CA
- Plumas County, CA
- Colusa County, CA
- Yuba County, CA
- Nevada County, CA
- Yolo County, CA
- El Dorado County, CA
- Solano County, CA
- Amador County, CA
- Stanislaus County, CA
- Merced County, CA
- Madera County, Ca
- Kings County, CA
- Kern County, CA
- Tehama County, CA
- Butte County, CA
- Lake County, CA
- Sutter County, CA
- Sierra County, CA
- Placer County, CA
- Sacramento County, CA
- Alpine County, CA
- San Joaquin County, CA
- Calaveras County, CA
- Tuolumne County, CA
- Mariposa County, CA
- Fresno County, CA
- Tulare County, CA

(Declarations were at the Federal and state levels.)

Major Impacts:

- Seven deaths occurred within the HSA during this event. The fatalities occurred when people attempted to drive across flooded roadways or were caught in flood waters due to levee breaks.
  - Two deaths occurred in Mariposa County: one victim tried to drive across a flooded bridge and the other was a drowning victim found in the Merced River.
  - One death occurred in Sacramento County. Victim was found drowned in a vehicle in a normally dry ditch along Highway 99 near the Cosumnes River.
  - One death occurred in Shasta County. Victim was found drowned in vehicle in Burney Creek.
  - Three deaths occurred in Yuba County. Victims all drowned as a result of levee failure on Feather River at Arboga.
- Over 100,000 people were evacuated during the course of the event.
- Most of the evacuations were related to levees, either actual failures or the potential for failure.
- Flood waters resulted in the stranding of a number of tourists and workers and caused extensive damage in Yosemite National Park.
- Hundreds of roadways were closed, including parts of all the major highways in the region (I-5, I-80, US 50, and US 99).
- Damage estimates in the HSA are approaching $1.7 billion.

Estimated Damage in Dollars by County:

Fresno County	$4.2 million
Kern County	$0.1 million
Kings County	$50.3 million
Madera County	$7.1 million
Mariposa County	$8.5 million
Merced County	$9 million
Sequoia National Park	$0.2 million
Tulare County	$6.6 million
Yosemite National Park	$178 million

(Figures for other counties are not available at this time.)

Supplemental Findings and Recommendations

Finding Staff integration in the hydrology program worked very well. The SH worked in the Federal-State Flood Center during most of the event.

Finding NWSO Sacramento has used a team approach to community outreach which paid dividends during this event.

Finding Generally, the office was adequately staffed for this event, although at times the overnight period could have been aided with additional staff. Staff was available to fill this void.

Recommendation The office should prepare a plan to adequately staff all shifts during a major hydrologic event.

Finding The Specific Area Message Encoder (SAME) and the new Emergency Alert System (EAS) programs were implemented on January 1, right in the middle of this event. EAS was activated using the SAME unit on a number of occasions. A problem was identified in using this system. The instructions indicate that the NWR tone alert be transmitted within the SAME alert for EAS. This causes a problem for the media who do not want this tone included in the SAME activation.

Recommendation The WRH/MSD should examine this problem and issue new instructions to alleviate this problem.

CALIFORNIA-NEVADA RFC

Event Overview

Heavy precipitation began on December 25, 1996, in extreme northwestern California. On December 26, the heavy rainfall spread over most of northern California. The heavy rainfall continued on December 27-28. Rainfall totals during this period ranged as high as 6 inches. By the morning of December 29, most rivers and streams in northern California were within bank but rising rapidly.

Very heavy rainfall continued in northern California on December 29-31. This wave of precipitation was accompanied by rising snow levels in the Sierras. Significant rainfall also spread to the east of the Sierras during this period. Rainfall during this 3-day period ranged over a foot in some of the higher terrain of northern and central California. Major rises on rivers and streams in northern California continued with flooding occurring throughout the region. Significant rises also occurred on the rivers and streams on the east slopes of the Sierra with flooding expected there as well.

The heavy rains continued on December 31, 1996, and January 1, 1997, with rainfall beginning to taper off on January 2. The heaviest rainfall during this period was in central California where up to a foot of rain fell. Most of the rivers in northern California crested on the January 1-2 and began to recede by January 3. The crests on most of the rivers and streams east of the Sierras occurred on January 2-3. A number of levee failures occurred in central California during this time period. These levee failures produced significant property damage in a number of areas.

River levels receded slowly following the crests, and lower reaches of the larger rivers remained above flood stage for days and in some cases weeks following the crests.

Disaster Survey Focus Areas

Federal/State Interactions

The CNRFC worked closely with the CDWR during this event. CDWR engineers worked along with CNRFC forecasters to produce the river forecast guidance during much of the event. Once the river forecast guidance had been prepared, it was distributed via AFOS, the California Data Exchange Center (CDEC), and hand carried to the Federal-State Flood Center.

The relationship between the NWS and the CDWR is evolving in response to NWS restructuring. While the CNRFC will continue to have a very close relationship with the CDWR, the role of the HSAs hopefully will expand over time. This expansion will likely occur in the area of service to the media and less sophisticated users of NWS hydrologic products.

Coordination with the U.S. Bureau of Reclamation (USBR), the COE, etc., on Reservoir Operations and Inflow Forecasting

Coordination with the USBR was first rate. The CNRFC supplies inflow forecasts in 6-hour time steps out to 72 hours. On several occasions, reservoir inflow guidance was provided out to 5 days. These forecasts were updated routinely twice a day during the event. Additional updated inflow forecasts were made at the request of the USBR. The accuracy of these inflow forecasts was critical to the CNRFC's ability to supply good forecast guidance for locations downstream of the reservoirs. The CNRFC hopes to eventually integrate the coordination with the USBR into the forecast process using NWSRFS.

The CNRFC also coordinated closely with the COE. The COE has recently requested forecasts for additional points that affect their projects. The CNRFC will be reviewing this request and working toward improved forecast service to the COE.

There are a number of non-federally operated reservoirs and water control projects in the San Joaquin River Basin. Data exchange and coordination with these projects is not on par with the federally operated projects. Often the CNRFC must react to the actions of these projects rather than being a part of the decision-making process. These projects individually are rather small, but their cumulative effects can be quite large. CDWR also has had difficulty in coordinating with these projects. Coordination and cooperation with these projects increased dramatically during the runoff event.

Use of QPF, WSR-88D Data, and NCEP Guidance in RFC Operations

Forecasts of precipitation (QPF) are an integral part of the river forecast process at the CNRFC. These forecasts currently originate from NWSFOs Monterey and Reno. At the present time, the QPF from these offices is for the next 24 hours in 6-hour time steps and is updated twice a day during periods of potentially heavy precipitation. The RFC HAS forecasters assimilate the QPF into the RFC models. This process requires that the first period of the QPF be manipulated to fit developing conditions. In addition, QPF for Days 2 and 3 are generated by the HAS forecasters. QPF for 3 days is needed to provide accurate inflow forecasts for the flood control projects in the region. The HAS forecasters spent a great deal of time coordinating QPF with the generating offices during this event.

Data from the WSR-88D radar was used qualitatively by the HAS forecasters to adjust the first period of the QPF product. The NCEP HPC guidance was also used in a qualitative manner during this event. The NCEP model output (specifically the prognostic grid-point soundings) is used as input to the local orographic model used to produce a first estimate of QPF. This guidance was automatically generated and provided support to the NWS office generating the QPF products.

HAS Activities

The HAS forecaster workload was heavily weighted toward QPF issues during this event. The HAS forecasters made adjustments to the QPF generated by the NWSFOs as required by developing conditions. This procedure was necessary in order for the CNRFC to make hydrologic model runs at times significantly before or after the receipt of QPF guidance from the NWSFOs. The HAS forecasters also produced QPF for Days 2 and 3 in support of inflow forecasts for flood reservoirs. All significant adjustments to the NWSFO-issued QPF were coordinated with that office prior to being used in the hydrologic model runs.

The role of the HAS forecasters during this event is seen by the CNRFC as a necessary interim step in the development of a comprehensive QPF program. The CNRFC would eventually like to see all the HSAs providing QPF for 3 days in 6-hour time steps every 6 hours during potential flooding events. Until all of the offices are prepared to provide this data, the HAS unit will be required to fill in the gaps. Once all of the offices are providing QPF in the above mentioned manner, the HAS forecasters will have more time to perform data quality control and other functions related to the hydrologic model process.

The HAS forecasters provided coordination support to the joint NWS-CDWR briefings and coordinated with the USBR and the COE.

NWSRFS Performance and Transition Progress

Rainfall-runoff modeling for all of CNRFC's basins are performed within the NWSRFS. The routings in the Sacramento and San Joaquin Rivers are currently performed outside of the NWSRFS. These routings are very complicated; time and additional technique development will be required to handle these within the NWSRFS. The CNRFC is actively involved in calibrating the Flood Wave Forecasting (FLDWAV) model to handle the routings of the Sacramento River. Modeling of the San Joaquin mainstem forecast points within the NWSRFS will be evaluated this summer.

Overall, the forecast guidance provided by the NWSRFS was very good. A number of basins require adjustments to the calibration based on performance during these events. The adjustments are basically minor and in reality are part of the calibration process. The snow model worked well in this event and handled the rain-on-snow adequately.

The CNRFC has identified a number of areas which will need to be refined to obtain maximum efficiency from the NWSRFS. These areas include: new methods for quality control of data, improvements to IFP to allow more flexibility, a fix to the hourly discharge display routine, and improvement to the method for QPF adjustment. The CNRFC is working on some of these problems internally and in conjunction with the Hydrologic Research Laboratory (HRL) on the others.

Modeling of Levee Failures

The CNRFC plans to investigate the use of FLDWAV to handle levee breeches. The big hurdle to this effort will be obtaining cross sectional information on areas behind the levees that will define the areas that would be inundated in the event of a failure. It will take a big effort to obtain this type of data.

The COE has a program which has the capability of simulating levee failure. This program has been calibrated on the Feather, American, and upper Sacramento Rivers. Work is underway on the lower Sacramento River. This program is not set up to run in an operational mode; it is strictly a "what if" or post-event model. Furthermore, it would not be readily integrated into NWSRFS, and there is a question of how it could be used in the future when the NWS is issuing probabilistic forecasts and using dynamic models.

Operational Dynamic Wave Routing (DWOPER) versus FLDWAV

Early CNRFC investigation into the use of DWOPER to handle the routings on the Sacramento determined that it will not work very well. It does appear that FLDWAV, with some refinements, will be able to handle this task. The CNRFC has committed 2.5 person's development time to the effort of calibrating the Sacramento River in FLDWAV. Calibration will be in stages: low flow, high flow within levees, and flow overtopping levees.

The HRL has provided a great deal of support to the CNRFC in their FLDWAV calibration efforts and has pledged to continue this support. One area which must be addressed by the HRL is that FLDWAV must be integrated into NWSRFS before CNRFC proceeds beyond the low and high within levee calibration efforts. The CNRFC estimates it will have completed this portion of the calibration by October 1997. The HRL plans to integrate FLDWAV into NWSRFS by late spring 1997.

RFC/NWSFO/NWSO Coordination

Coordination with the HSA offices during this event went well from the CNRFC's viewpoint. There was a great deal of coordination between the HAS forecasters and the NWSFOs/NWSOs concerning QPF through scheduled and adhoc conference calls. These discussions were invaluable to the HAS unit in refining the QPF used in the RFC models. A significant amount of coordination concerning river forecast guidance and updates to such guidance also took place during this event. There were a few instances where the coordination could have been better. These instances have already been discussed and resolved by the CNRFC and the affected office.

Primary Findings and Recommendations

Finding The QPF was critical during this event. Incorporating QPF into the hydrologic model and coordination with the offices generating QPF is time consuming and cumbersome at times.

Recommendation The implementation of Mountain Mapper into the QPF process will alleviate many of the incorporation problems. The WRH should proceed with the implementation of this program as soon as possible. If staffing levels permit, QPF generating offices should update QPF every 6 hours during periods of heavy rainfall.

Finding The QPF out to 3 days is needed by the CNRFC. The Day 2 and 3 QPFs are currently being generated by the HAS forecasters.

Recommendation The QPF generating offices should explore the possibility of generating 3-day QPFs.

Finding At present, there is no formal verification of QPF guidance.

Recommendation The CNRFC should implement a QPF verification scheme to provide feedback to the QPF generating offices.

Finding Data availability was very good throughout the event. There are several areas which could be improved, including improving automated quality control of data and the lack of reliable data at non-federal flood control projects.

Recommendation The CNRFC should explore means to improve in-house quality control of automated data. The RFC and the HSA offices should work with other agencies to improve data availability from the non-federal flood control projects.

Finding The river forecast guidance (RVF) issued by the CNRFC currently goes to CDEC at the same time it is sent to other NWS offices. This guidance is intended for water management and sophisticated emergency management agencies. Subsequent flood warning products (FLW, FLS) that include call to action and specific impact statements issued by the HSA offices are sent to the CDEC and through the traditional dissemination systems to less sophisticated users.

Recommendation The CNRFC must continue to ensure that adjustments to RVF products based on HSA comments are made quickly. NWS offices, including the CNRFC, should continue to refine, enhance, and optimize collaborative dissemination of flood warning information.

Finding Coordination with other NWS offices went well during this event. The RFC was responsive to requests for updates from the HSA offices.

Recommendation The RFC should continue to work closely with the HSA offices and ensure they are familiar with established procedures for obtaining updated forecast guidance.

Summary of Damages, Deaths, Injuries, and Major Impacts

Damage summaries are contained in the individual summaries for the individual HSAs served by this RFC.

Supplementary Findings and Recommendations

Finding The CNRFC needs 3-day QPF input into the hydrologic models in order to provide the best possible 3-day inflow forecasts for flood control projects.

Recommendation The NCEP should explore the possibility of issuing a Day 3 QPF product. Such a product would assist in the generation of the Day 3 QPF needed for forecasting reservoir inflows.

Finding The CNRFC is currently running a local orographic model to assist in QPF generation. This model requires certain data (i.e., the 1000 mb Aviation Forecast Model [AVN] gridded data and the MRF gridded data) which is currently unavailable over the WR wide area network.

Recommendation The CNRFC and SSD at the WRH should work together to ensure that all data needed for the local orographic model are available when needed.

Finding The HAS function at CNRFC worked extremely well during the event.

Finding The NWSRFS worked well during the event without significant problems. Simulations were generally very good, even though flows above rating tables and record flows were experienced at a number of locations.

Finding The 6-hour time step currently used in NWSRFS modeling does not handle all locations in the CNRFC's area well. There is a need for a shorter time step.

Recommendation The implementation of the 1-hour discharge display in NWSRFS would improve this situation. The CNRFC should explore development of procedures using shorter time steps. These locations may be good candidates for WHFS Site Specific when it is deployed.

Finding The CNRFC is currently devoting significant resources to the development of FLDWAV in their forecasting procedures for the Sacramento River. This is a long-term project. Support for this effort from the HRL has been excellent.

Recommendation The CNRFC should continue their efforts to incorporate FLDWAV into their procedures. The HSD should ensure that the HRL continues to support this effort and that the schedule for incorporating FLDWAV into NWSRFS does not slip. The HRL must be willing to make necessary enhancements to FLDWAV (i.e., network capability) for this effort to succeed.

NWSFO MONTEREY, CALIFORNIA

Event Overview

A series of three rain events affected northern and central California in late December 1996-early January 1997. The first of these occurred on December 26 and affected the area north of NWSFO Monterey's area of responsibility. Precipitation from this event served to raise soil moisture levels and set the stage for significant runoff from the subsequent precipitation events.

The second precipitation occurred on December 29-30. This event was very orographic in nature with rainfall amounts of a inch or so at valley locations and up to 8 inches reported at some locations in the mountains of northern California. This event produced significant rises on the rivers in the northern portion of Monterey's HSA.

The last event of the series was by far the strongest. This event was strongly terrain dependent and was warmer than the previous events with freezing levels rising to 10,000 feet. Precipitation moved into the area New Year's Eve, and by New Year's Day morning, heavy rainfall was occurring throughout northern California. Rainfall from this event was very high with amounts in the 6- to 10-inch range common. This precipitation event was accompanied by high winds and heavy surf along the central California coast.

Small stream and flash flooding began in the HSA on December 30. The most significant flooding occurred on January 1-2, 1997, in conjunction with the last wave of precipitation. Flooding was extensive in the northern portion of the HSA with the Russian and Napa Rivers and their tributaries being the hardest hit. Crests occurred throughout the HSA by January 2.

Most of the damage from high winds and heavy surf occurred late on December 31, 1996, or early on January 1, 1997, when the last wave came onshore.

Disaster Survey Focus Areas

Preparedness and Training Activities

NWSFO Monterey has put significant efforts into hydrologic training for the entire staff. Training includes presentations by the SH as well as staff from the CNRFC. Drills on various parts of the hydrology program are conducted periodically, with the most recent held last fall. The drills cover areas such as where to find information and people to contact in specific instances. This training has improved the ability of the staff to handle hydrologic events.

There has been an emphasis on community outreach within Monterey's area of responsibility. This outreach has been an office endeavor, involving the WCM, SH, MIC, and others. The outreach paid good dividends during this event as many EMs began to make plans based on the issuance of flood potential statements and public information statements which were issued well in advance of the actual event. This was especially important since this event occurred during a period when many people travel or are otherwise unavailable. The NWSFO Monterey staff recognized this and advertised the possibility of problems well in advance, giving managers additional planning and organization time.

NWSFO/CNRFC Interactions

Interactions between the Monterey office and the CNRFC were in two general areas. One was coordinating the QPF product generated at Monterey and the other was coordinating the river forecast guidance issued by the CNRFC. Extensive coordination occurred in both areas.

Coordination between the Monterey staff and the CNRFC HAS forecasters took place several times each day. This coordination centered on the QPF product Monterey was producing twice each day in support of the RFC river forecasting efforts and QPF updates prepared by the HAS forecasters. River forecast guidance was coordinated as needed by the Monterey staff member issuing the hydrology product. Several Monterey staff members remarked that the interactions and coordination with the CNRFC were vastly improved over past flood events.

Statewide Coordination Issues

NWSFO Monterey sent a staff member to the San Francisco County OES office and then to the OES Region II office in Oakland, California, during this event. This individual provided interpretation of NWS products to the EMs and conducted numerous media interviews during this tour of duty. The individual was able to access NWS products from the "state circuit" and Internet home pages to use in briefing OES officials. NWS-OES conference calls were held twice daily. These conference calls were open to all NWS offices.

QPF Activities, WSR-88D Data, and Use of NCEP Guidance

The QPF products were generated by NWSFO Monterey twice a day during the event. The procedure to do this is quite time consuming, often taking several hours to complete this task. Much of the time is involved with running and adjusting local orographic models which are based on NCEP model output. The current QPF procedures use "rainy day ratios" to compute amounts. The NWSFO also ran Mountain Mapper during this event. The graphical output from Mountain Mapper was placed on the office's home page where it drew a wide audience, especially among the EMs.

The NWSFO forecasters expressed some concern about their QPF efforts. First of all, it was felt that the RFC was often not using the QPF the NWSFO generates. This lead to the feeling by some of the NWSFO staff that the CNRFC HAS forecasters should be doing QPF on their own. Clearly, there is room for improvement in the coordination of QPF between the NWSFO and CNRFC. The NWSFO also feels that the implementation of Mountain Mapper should proceed posthaste. This would allow the opportunity to test Mountain Mapper prior to next fall's rainy season. The implementation of Mountain Mapper will streamline the procedure for generating QPF and provide some feedback to the QPF forecaster.

The model guidance was critical in the early assessment of the event and the ability to provide flood outlooks and other statements with significant lead times. The medium and long range models advertised the potential for heavy rain and high winds well in advance of the event. The WSR-88D reflectivity data were utilized along with ALERT data to accurately assess areas of very heavy rainfall and allowed flash flood warnings to be tailored for these areas. Data from the radar and NCEP guidance were used only in a qualitative manner in preparing QPF during this event. The WSR-88D VAD wind data and data from available wind profilers, especially the one on the Farallon Islands, were critical to issuance of timely high wind watches and warnings.

Performance of HYDROMET

NWSFO Monterey used the old version of HYDROMET operationally during this flood event. This system performed flawlessly throughout the event. HYDROMET is the "heart and soul" of the hydrology program at NWSFO Monterey, since it is the primary tool used to monitor precipitation and river stages. The HYDROMET 4.0 system was partially functional during the event; it was used to collect ALERT data. Testing of the HYDROMET 4.0 system has revealed several shortcomings which will have to be corrected before it can replace the old HYDROMET system. These shortcomings include the lack of an alarm feature and the inability to perform group dial ups of LARC gages.

Availability of Data and Use of ALERT Data

The most useful hydrologic data came from the LARC gage network and the ALERT gage network. Data from these networks were the most reliable and timely means available to NWSFO Monterey to determine rainfall rates and monitor river stages during the event. NWSFO Monterey has found that the ALERT gage network is the best tool for flash flood product issuance. This was the first event since two new ALERT repeaters were installed. These repeaters provided access to a number of ALERT gages which were previously unavailable to the Monterey office.

Several different tools and data sets were used by the forecasters during this event. GARP (GEMPAK [General Meteorological Package] Analysis Rendering Package) allowed the forecasters to overlay digital satellite imagery with gridded data and observation. Image averaging on the Ramm Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS) was helpful in pinpointing areas of heavy precipitation. Satellite and radar data were used to track precipitation movement and train echos. Radar precipitation estimates were not accurate (which had been the case in past events as well). SSMI (Special Satellite Microwave Imagery) data was very useful in determining where the highest precipitable water and rainfall rates were in the storms when they were over the ocean or just offshore.

OES Coordination and Briefings

"BLAST-UP" coordination calls were made to county OES directors on December 26 and 27 to alert them of potential weather problems beginning on the weekend. On December 28, twice daily conference calls were begun between NWSFO Monterey and the California OES. OES offices involved with these calls included three Regional Operation Centers and the OES Coastal Region Office. These scheduled conference calls continued through January 5, 1997. NWSOs Sacramento, Hanford, Eureka, NWSFO Oxnard, and the CNRFC also participated in many of these conference calls.

On December 29 and 30, a forecaster from NWSFO Monterey was detached to the OES Emergency Operations Center in San Francisco where he provided weather briefings and media interviews. This individual moved to the OES Region II office in Oakland on December 31 to provide better support for the widespread flooding which was expected. The San Francisco OES office was first selected to ensure preparation and media attention for the holiday (New Year's) and because the OES Regional Office had not yet been fully activated. Due to staff shortages at NWSFO Monterey, the liaison at OES Region II Headquarters was limited to one day. Having a liaison at this location for at least one more day would have been valuable.

Integration of Hydrology as a Station Program

Hydrologic products were issued by a number of members of the NWSFO Monterey staff during the course of this event. While the SH worked long hours, so did the rest of the available NWSFO staff. Hydrologic training conducted at NWSFO Monterey during the past couple of years has prepared the staff to handle the hydrology program. Good progress is being made in this area.

High Wind Event

Medium to long range model guidance pointed toward high winds in advance of the flooding event. Model guidance predicted a tighter gradient than occurred during a high wind event on December 12. This guidance was the primary reason for the issuance of a high wind watch more than 24 hours in advance of the event. The wind profiler and WSR-88D VAD wind data were used for the decision to upgrade to a high wind warning. Lead times on the high wind warnings were generally 5 or 6 hours.

The Bay Area often has the most problems with high winds. However, this is an area which is not covered well by the available equipment. It is too far from the radar for VAD winds to be of much use, and there is no wind profiler in this area. While this lack of data was not a significant problem in this event, it has been a problem during other events which were not as well handled by the models.

Primary Findings and Recommendations

Finding An NWS employee was placed in the San Francisco County OES and then to the Region II OES office. This paid dividends in NWS relations with these agencies and provided the opportunity for increased media attention for the NWS. These benefits were maximized by having the individual at the OES regional office. Many state agencies have expressed the desire for a single point of contact with the NWS. An individual placed at a regional or state office becomes this point of contact by default.

Recommendation Plans need to be developed and adopted in each state establishing procedures for having a single point of contact between the NWS and state agencies. These plans should include instructions to ensure that adequate coordination occurs between all affected NWS offices and the point of contact. These plans should be part of the SDM at every office with responsibility within a given state.

Finding In future events where multiple counties are affected, there may be competition for an "on-site" NWS representative in county emergency operation centers.

Recommendation NWSFO Monterey should establish clear operating procedures regarding the placement of "on-site" representatives to avoid staffing problems and perceived favoritism for certain counties.

Finding NWSFO Monterey prepared QPF guidance via the "rainy day ratio" method during this event. They also experimented with using Mountain Mapper. The utilization of all available data and model guidance (i.e., SSMI satellite data, GARP data, Lawrence Livermore model, local orographic models, etc.) is needed to produce the best quality QPF guidance. QPF generation was a very labor-intensive exercise.

Recommendation The use of Mountain Mapper for QPF generation will standardize this procedure and should streamline the process. The implementation of Mountain Mapper for the production of QPF should proceed at all levels without delay. The workload of producing QPF could be further reduced by transferring QPF duties to the spin-up offices.

Finding The lack of feedback on the QPF from the RFC hinders the evaluation of the development of QPF.

Recommendation The CNRFC should implement a method of supplying verification statistics to the QPF offices as soon as possible.

Finding The number and variety of watches, warnings, and advisories issued during this event was quite large. Keeping track of all of the current products was an arduous task.

Recommendation The WRH should examine methods to reduce the workload of monitoring and documenting current watch, warning, and advisory products.

Finding The staff of NWSFO Monterey provided extraordinary service to the emergency management community prior to and during this event. The early notification of the potential for a significant event allowed the EMs to prepare staffing and resources even though the event occurred over a holiday.

Finding Coordination between the CNRFC and NWSFO Monterey was improved over past events. Coordination calls between the two offices occurred several times a day concerning QPF. Coordination with the CNRFC concerning river forecasts was most satisfactory from NWSFO Monterey's viewpoint.

Summary of Damages, Deaths, Injuries, and Major Impacts

* All information in this section is preliminary and based on estimates available at the time the report was written.

Rivers That Flooded:

Napa	Russian
Redwood Creek	Castro Valley Creek
Pescadero Creek	San Lorenzo Creek
Soquel Creek	Corralitos Creek
Big Sur	San Antonio

(No rivers exceeded record levels in Monterey's HSA.)

Counties in Declared Disaster Areas in Monterey's HSA:

Sonoma County, CA	Napa County, CA
Marin County, CA	Contra Costa County, CA
San Francisco County, CA	Alameda County, CA
Santa Cruz County, CA	Santa Clara County, CA
San Mateo County, CA	San Benito County, CA
Kings County, CA	Tulare County, CA

(Declarations were at the Federal and state levels.)

Major Impacts:

— Two deaths occurred within the HSA during this event.
— The two deaths occurred in Sonoma County. No details are available at this time.
— Extensive damage to homes, businesses, agriculture, and infrastructure due to flooding, especially along the Napa and Russian Rivers.
— Heavy surf resulted in some damage along the central California coast.

— In the Guerneville area along the Russian River, over 3,000 people were evacuated, with 6,000 more advised to evacuate.
— Evacuations also occurred along the Napa and Pajaro Rivers.
— Numerous primary and secondary roads were closed due to high water and mudslides.

Estimated Damage in Dollars by County:

No damage figures by county are available.

Supplementary Findings and Recommendations

Finding The Monterey office was innovative in obtaining and utilizing new data sources and technologies in handling this event. To utilize these data sets and technologies, the office must employ numerous computer systems. The office must increase staffing during events to fully utilize the new data sets and technologies. Extensive use of overtime hours were used during this event by NWSFO Monterey to cover shifts to ensure that the public was properly warned. There is concern among the office management that future staffing levels may not allow full utilization of all the available data and technology.

Finding The high wind event was well handled by NWSFO Monterey. Model guidance provided means of providing long lead time watches for this event. The WSR-88D VAD wind data and wind profilers provided data needed to issue warnings with good lead time. The wind profiler on the Farallon Islands was especially valuable. Wind data availability in the Bay area is lacking. This area is not well covered by the WSR-88D VAD winds, and no wind profiler data is available in the Bay area.

Recommendation The WRH should investigate a wind profiler for the Bay area.

Finding The NWSFO staff was well prepared to handle the hydrologic event and all staff participated in this portion of the office activities.

Recommendation The NWSFO should continue its hydrologic training program to ensure that the staff is always prepared for hydrologic events.

Finding HYDROMET performed well during the event. HYDROMET 4.0 was used only to collect ALERT data. The conversion to HYDROMET 4.0 will be accomplished once it has been tested to ensure that it will provide all necessary functions handled now by the "old" HYDROMET system.

Recommendation The WRH should ensure that HYDROMET 4.0 maintains all of the functionality of the "old" HYDROMET. This will require some enhancements to the current build of HYDROMET 4.0.

Finding ALERT data was paramount to handling the hydrologic event. The WSR-88D and RAMSDIS data was extremely valuable in pinpointing the location of the heaviest rainfall. The LARC data was heavily utilized for flood forecasting. There are several locations on the Napa and Russian Rivers where river gage telemetry is needed.

Recommendation The WRH should take steps to ensure that a telephone line is installed at Guerneville on the Russian River so the LARC installation can be completed. NWSFO Monterey should ensure that the data from the ALERT gages to be installed on the Napa River is received as soon as it is available.

NWSFO RENO, NEVADA

Event Overview

Precipitation since the start of the 1997 water year (October 1996) through the middle of December 1996 was well above normal across much of NWSFO Reno's county warning area. The two previous water years were both above normal; consequently, the storage reservoirs in the area, including Lake Tahoe, were near capacity.

On the first day of winter (December 21, 1996), a major winter storm struck the Sierra and western Nevada. Cold air associated with a deep trough in the Gulf of Alaska combined with significant Pacific moisture to produce very heavy snowfall. By December 23, the valleys of extreme western Nevada had received 1 to 2 feet of snow, with 4 to 12 feet accumulating in the Sierra Mountains.

Conditions began to warm on December 26-27 as a Pacific storm brought generally light precipitation to the area. The snow level rose to 6,500 feet MSL, and minor urban and small stream flooding occurred around Lake Tahoe and western Nevada. Freezing levels continued to gradually rise, and precipitation intensity gradually increased during the next few days. On December 29, heavier rainfall amounts occurred over the area as the snow level rose to 7,500 feet MSL. A strong southwesterly flow also initiated a period of high wind events. Rapid snowmelt in the valleys of western Nevada as well as the lower elevations of the eastern Sierra produced saturated soils and heavy runoff. Localized areas of urban and small stream flooding, as well as rising levels on the Truckee, Carson, and Walker Rivers, were common. Conditions also had become ideal for mud and rock slides.

Periods of rain, sometimes heavy, and high freezing levels then continued, reaching a maximum on December 31, 1996, and January 1, 1997. Moisture from the remnants of Typhoon Fran was brought toward the Pacific coast as a warm, tropical fetch of moisture developed from near Hawaii. By New Year's Day, freezing levels peaked at 10,700 feet MSL, along with moderate to heavy rainfall and very strong winds.

The NWSFO Reno office issued a Flood Potential Outlook on December 27 and updated this Outlook on December 28 and 29. The first Flood Warning was issued on December 29 for the Truckee River below Reno. Numerous updates and additional warnings were issued over the next several days as hydrometeorolgical conditions worsened and a major flood event developed. Most locations on the Carson, Walker, and Truckee Rivers crested on January 2, with several sites exceeding the "100-year flood." As the Truckee River crested, the city of Reno became isolated due to flooding of highways, the railroad, and at the airport.

Disaster Survey Focus Areas

RFC/NWSFO Interactions and Frequency of Updates

The CNRFC issues river forecasts and guidance to the Reno office. The two offices enjoyed a good working relationship during the event. HAS forecasters at the RFC coordinated closely with forecasters at the NWSFO to blend and produce QPFs. The NWSFO provided QPFs daily at 12 UTC which were used as input to the river forecast model. The QPF and river forecast products can be generated at other times.

Preparedness and Training for River and Flash Flood Events

Numerous seminars on hydrologic subjects have been held for the NWSFO Reno staff. These seminars have covered basic hydrology, RFC operations and procedures, and use of HYDROMET. A detailed reference manual covering the hydrology program of NWSFO Reno is readily available to the staff for reference. The WCM and the SH have conducted considerable user community outreach, explaining NWS products and services.

High Wind Event and Heavy Mountain Snow

Extensive flooding caused the most damage and gained the most attention during this event, but very heavy snow preceded the flooding. High winds also occurred throughout the event. NWSFO Reno was not only consumed with hydrological problems associated with the flooding, but meteorological demands on the staff were very high. Snowfall on the order of several feet blanketed the mountains prior to the warm rain, and wind gusting over 100 mph occurred in the mountains.

Overall HSA Operations During a Record Flood Event and the Integration of Hydrology as a Station Program

NWSFO Reno provided excellent hydrologic services during this event. A flood potential statement was issued 2 days prior to the onset of any flooding. The office provided close coordination with the media and the emergency management community. This coordination drew praise from many EMs and sources within the media. Several forecasters performed hydrologic services in addition to the SH and the hydro focal point.

NWS Coordination Activities

Coordination between NWSFO Reno and NWSFO Monterey worked quite well throughout this event. The Reno office was included in all "BLAST-UP" calls initiated by the Monterey office. This allowed for close coordination on weather warnings, snow levels, and QPFs. The other weather offices in the state of Nevada, NWSOs Elko and Las Vegas, were not affected by this event to any great extent.

Customer Coordination Activities Including Public Dissemination and User Response

Coordination with county emergency personnel is made more difficult for the Reno office since they serve all or parts of nine counties in California as well as eight counties in Nevada. Coordination with county personnel varied from county to county. Efforts to educate and train county EMs was and is ongoing in the Reno office.

The EMs surveyed after the event had nothing but high praise for the NWS, including their preparation, forecasts, coordination, and support during the storm event. A number of EMs were not surveyed due to inclement weather during the site visit.

QPF Activities

NWSFO Reno issues routine QPFs at 12 UTC for two points in eastern California: Woodfords and Truckee, California. These points coincide with RFC forecast points along the Truckee and Carson Rivers. The QPFs cover the next 24 hours in 6-hour increments. QPF forecasts are often coordinated with the RFC HAS forecasters. Updates to QPF can be initiated by the NWSFO staff or requested by the RFC.

HSA Operations for a River Event in a HSA Primarily Focused on Flash Floods

The common perception is that the main hydrologic problems in the Reno HSA are associated with flash floods and not river floods. However, this is the third year in a row in which river flooding has occurred in the area, and the third instance of major flooding in the past 11 years. The NWSFO Reno staff has had a number of seminars regarding river flooding, and a manual on procedures for handling river flood events is available for reference.

Hydrologic Documentation and Procedures for a River Event

The "Operational Hydrology Manual for Mainstem Rivers" covers the procedures for handling a river flood event in NWSFO Reno's HSA. This document has been prepared by the SH utilizing extensive input from the forecaster staff. In addition to this document, the SDM contains a section on river flooding. A manual also has been prepared on the use of HYDROMET.

Data Availability and Communications

Data availability is a continuing problem for most of the western United States, and NWSFO Reno's area of service is no exception. In fact, the data available across the Reno county warning area is particularly sparse, and more automated equipment is needed. In addition to the data shortage, problems exist with the telephone connection to the NWR that serves the Reno metropolitan area.

Role of New Technologies

New technologies, i.e., N-AWIPS and RAMSDIS, available to the NWSFO Reno forecasters enabled them to better analyze and predict meteorological situations during this event. Precipitation estimates from the WSR-88D near Reno are typically poor during winter events. However, when freezing levels rose to above 10,000 feet during this event, precipitation estimates were quite reasonable. These estimates enabled the Reno forecasters to pinpoint heavy rainfall in a portion of the Truckee River Basin not protected by flood control reservoirs. This information helped the forecasters to realize the flood threat early in the event.

Primary Findings and Recommendations

Finding D. Rishel and S. Staggs from the CNRFC presented a seminar to the staff covering the RFC models in December 1995. SH Gary Barbato has presented seminars covering the basics of hydrology and use of HYDROMET.

Recommendation The MIC, SH, and SOO should ensure that ALL operational meteorologists (and HMTs) have a basic working knowledge of the river models, including the significance of QPF.

Finding The Southern Region Warning Program (SRWARN) doesn't allow automatic composition of warnings if a zone crosses state boundaries. The product must be edited on AFOS prior to transmission which is very time consuming and can also introduce coding errors.

Recommendation Better software (e.g., a WordPerfect macro and/or an update to SRWARN) should be developed that handles coding of products across state boundaries.

Finding NWSFO Reno issues short term forecasts (i.e., nowcasts) routinely 4 times a day. Station policy requires these nowcasts to be updated every 2 hours during changing weather conditions. The nowcasts issued during this event were typically up to date and issued in accordance with station policy. However, many of the HMTs and the Data Acquisition Program Manager (DAPM) indicated that they believed the product was too much of a time burden and did not present any new information. In many cases during this event, the nowcasts were simply a copy of the zone forecast.

Recommendation The MIC and management team must establish the local nowcast policy in accordance with workload and time constraints. The nowcasts should continue to be issued in the current manner, however, continued training needs to be accomplished to make the nowcasts useful to the user community.

Finding

The HMTs contributed greatly to the successful operations during the event. However, they had only limited involvement in actual hydrology operations. The HMTs seemed comfortable with retrieving data from the HYDROMET computer but often would pass along requests for data or river forecast information to the SH or the hydro focal point.

Recommendation

The MIC, SOO, SH, and DAPM need to ensure that all HMTs are fully trained in the flood-related operations at NWSFO Reno, including the use of HYDROMET 4.0 software and the composition of flood products.

Finding

Forecasters at NWSFO Reno felt that coordination went very well with NWSFO Monterey. The two NWSFOs have worked out a scheme where NWSFO Reno is included in the NWSFO Monterey "BLAST-UP" coordination calls for California offices.

Finding

NWSFO Reno installed the HYDROMET 4.0 system during fall 1996. During the flood event, HYDROMET 4.0 was still lacking features that were available in the "old" version of HYDROMET that greatly helped forecasters to recognize possible flood threats. These included the alarm functionality, streamflow simulation models, access to AFOS products, and preparation of AFOS river and precipitation data summaries.

Recommendation

NWSFO Reno needs to complete the installation and setup of the various components of HYDROMET 4.0 as soon as possible.

Recommendation

Enhancements and documentation updates are needed to HYDROMET 4.0. The CNRFC should address these needs as soon as possible.

Summary of Damages, Deaths, Injuries, and Major Impacts

* All information in this section is preliminary and based on estimates available at the time the report was written.

Rivers That Flooded:

- Walker (including East and West)
- Carson (including East and West Forks)
- Truckee
- Galena Creek
- Steamboat Creek

Rivers That Exceeded Record Levels:

East Walker near Bridgeport, CA
West Walker near Coleville, CA, and Wellington, NV
Walker River at Yerington, NV, and near Schurz, NV
East Fork Carson River near Markleeville, CA, and near Gardnerville, NV
West Fork Carson River near Woodsford, CA
Carson River near Carson City, NV, and Fort Churchill, NV
Truckee River at Tahoe City, CA, near Truckee, CA, at Sparks, NV, at Vista, NV, below Tracy, NV, and near Nixon, NV
Galena Creek near Washoe City, NV

Counties in Declared Disaster Areas in Reno's HSA:

Lassen County, CA	Plumas County, CA
Sierra County, CA	Nevada County, CA
Placer County, CA	El Dorado County, CA
Alpine County, CA	Mono County, CA
Washoe County, NV	Storey County, NV
Carson City County, NV	Lyon County, NV
Douglas County, NV	Churchill County, NV

(Declarations were at the Federal and state levels.)

Major Impacts:

— Two deaths occurred within the HSA during this event.
  — A man retrieving belongings from a flooded business in Sparks (Washoe County), NV, was drowned when he drove onto a washed out roadway and was swept into the Truckee River.
  — An emergency worker operating heavy equipment along the East Fork of the Carson River in Douglas County was drowned when the levee he was working on eroded into the river.
— Fifty people sustained flood-related injuries during this event in Nevada. Four of these injuries required hospitalization. One person was injured in California during the flooding.
— Damage estimates range between $500 million and $1 billion, with $10-15 million damage at the Reno airport alone!
— Reno-Tahoe International Airport was closed for over 36 hours due to flooding.
— Significant infrastructure damage, i.e., many levee and dikes damaged or destroyed, numerous bridges damaged or destroyed, a number of roadways severely damaged (including Interstate 80).
— Extensive damage to private property throughout the region. Hundreds of businesses and homes have been damaged or destroyed.

Estimated Damage in Dollars by County:

Alpine County, CA	$5.89 million
El Dorado County, CA	$62.5 million
Lassen County, CA	$1.5 million
Mono County, CA	$78.4 million
Nevada County, CA	$28.9 million
Placer County, CA	$7.7 million
Plumas County, CA	$91.2 million
Sierra County, CA	$27.6 million
Carson City County, NV	$6.4 million
Churchill County, NV	$0.03 million
Douglas County, NV	$0.5 million
Lyon County, NV	$1.8 million
Storey County, NV	$0.5 million
Washoe County, NV	$8.2 million

(Note that the estimates for the Nevada counties do not contain figures from private businesses or individuals.)

Supplementary Findings and Recommendations

Finding Updates to QPFs are permitted at any time, and the CNRFC will rerun the river forecast models if an updated QPF is received.

Finding The NWSFO Reno office and the CNRFC enjoyed a good working relationship during the flood event.

Finding A potentially significant update to the QPF was discussed between NWSFO Reno and the CNRFC via telephone but never transmitted. The river model was not rerun based on this QPF, although the Reno staff was under the impression it had been.

Recommendation NWSFO Reno and the CNRFC should establish well defined procedures for updating QPF and river forecasts.

Finding Interviews with several media personnel and EMs revealed a considerable amount of praise for the services provided by the NWS during this flood event.

Finding All new meteorologists at the Reno office must complete a 10-page hydrologic drill. This drill is a general overview of hydrology and hydrologic operations at NWSFO Reno and acquaints the newcomer to references necessary for hydrologic operations. Additionally, the winter 1995 drill covered QPF forecasting and monitoring.

Finding One of the media interviewed revealed that if SH Gary Barbato or assistant Steve Goldstein was not the person he was coordinating with, then the services were much slower. The staff appears to have received hydrologic training, but their proficiency was not sharp as the SH or the focal point.

Recommendation The SH and hydro focal point at NWSFO Reno should continue their fine preparedness activities, working to ensure everyone can retrieve the information requested by customers in an expedient manner.

Finding There were few Local Storm Reports (LSRs) (for both wind and snow) issued during the event. The LSRs are a quick and easy way to share information with NWS customers and provide a data base for post-analysis verification studies.

Recommendation The MIC and WCM should ensure that the LSR policy is clearly stated in the SDM and that all operational staff are aware that this is a means of disseminating severe weather reports.

Finding The NWR broadcast length reached 13 minutes several times during the storm event. This long broadcast occurred even after several products, including the nowcast, had been eliminated from the broadcast.

Recommendation The Reno management team needs to consider additional methods of shortening the NWR cycle, particularly during periods of significant weather.

Finding After being informed of an impending major precipitation event, Reno Cooperative Program Manager, Bert Soileau, came off of annual leave (on December 30, 1996) and called every cooperative weather observer in his area, especially those with Fischer/Porter gages. He briefed them on upcoming weather conditions and asked them to dump and recharge their gages. He also went to Truckee and Mt. Rose rain gages and dumped and recharged these two telemetered gages. This ensured that all Fischer/ Porter gages in the Reno area of responsibility were working and had a maximum capacity for precipitation measurement.

Recommendation Mr. Soileau is to be commended for his excellent forethought and action. All offices should ensure that their data network is operational prior to a big event.

Finding The Reno hydrology focal point and other forecasters worked with the SH to develop a more user-friendly hydrology manual. This manual was heavily utilized during the flood and contributed to the integration of hydrology as a station program.

Finding The survey team interviewed members of the media and various county and city EMs. The media had high praise for the Reno office and its activities prior to and during the flood. EMs from all of the counties affected by the floods were in contact with NWSFO Reno during the event.

Finding During the event, the MIC made a decision that all information given to the media would be handled by the MIC, WCM, or SH. This led to some confusion at one point where information going to the media differed from the official products being issued by the office.

Recommendation While it is commendable and recommended that media workload be lifted from operational forecasters during severe weather events, care should be taken to ensure that official NWS products and media information are the same.

Finding Several product dissemination problems were identified during this event. One of the problems involved the lack of the ability to route products using universal generic codes. Another was that NWS products were not being transferred from local dispatch centers to local emergency operation centers.

Recommendation The MIC and WCM should work with the appropriate agencies to rectify the communication problems.

Finding The Reno NWR transmitter on Slide Mountain ceased to function due to telephone line failure during the event. A new transmitter installed on Virginia Peak has the capability of broadcasting into some portions of the Reno/Sparks area. This information was broadcast when the Virginia Peak transmitter went on air.

Recommendation The communication link between NWSFO Reno and Slide Mountain should be upgraded to a microwave link to better ensure broadcast reliability. NWSFO Reno should routinely advertise on both the Slide Mountain and the Virginia Peak NWRs that the program material is interchangeable in case of a transmitter failure.

Finding Forecasters at NWSFO Reno utilize guidance from NCEP, computer derived QPFs, and forecasts from the NWSFO Monterey in assembling their local QPFs. A review of the QPFs issued by NWSFO Reno showed they did quite well during the overall flooding period. The NCEP QPFs tended to focus too much on the western-facing slopes and didn't bring enough precipitation to the eastern drainages.

Recommendation The HPC should examine their forecasting procedures to ensure they do not have a western Sierra bias.

Finding Although flash flooding occurs more frequently than mainstem river flooding in NWSFO Reno's HSA, the area has experienced significant flood events in recent years. The survey team found the SH and the office staff to be well prepared to address a mainstem river flood event.

Finding The runoff models used by the CNRFC did not accurately forecast the flows for most of the rivers in Reno's HSA. The models generally underforecasted flows prior to the flooding, and then overforecasted flows after flooding began.

Recommendation The Reno SH and the hydrologists at the CNRFC need to look closely at the model performance during the flood event, focusing on response to observed and forecasted precipitation and snowmelt. Model improvements should be identified and implemented.

Finding NWSFO Reno stated that the CNRFC was not able to issue updated RVFs often enough to meet user needs. This created confusion for the forecasters since the station hydrology manual implies that river forecasts cannot be updated without input from the CNRFC.

Recommendation NWSFO Reno and the CNRFC should work together to establish procedures to ensure that adequate river forecast updates are available to meet user needs.

Finding NWSFO Reno is trying to change the perception that the main hydrologic problem in Nevada is flash flooding, especially in the northern part of the state. A larger percentage of the population within the HSA is subject to river flooding than subject to flash flooding. The Reno staff understands that river flooding is a significant hydrologic problem in their HSA.

Finding NWSFO Reno has a very useful hydrology manual for mainstem river flooding that was developed by the SH in coordination with many of the forecasters in the Reno office. The manual includes detailed sections on hydrologic product issuances, coordination with the CNRFC, and information on each of the river basins in Reno's HSA.

Finding Most of the automated station data is available in HYDROMET, but it is difficult to display these meteorological data in HYDROMET.

Recommendation Improve HYDROMET's ability to plot and analyze meteorological data.

Appendices

Flood Stage Reports

NWS FORM E-3 U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL WEATHER SERVICE	HYDROLOGIC SERVICE AREA: **NWSFO Boise, ID**
FLOOD STAGE REPORT	REPORT FOR: **MONTH:** January **YEAR:** 1997

RIVER AND STATION	FLOOD STAGE (feet)	ABOVE FLOOD STAGES (dates)		CREST	
		From	To	STAGE (feet)	DATE
Weiser River near Cambridge	12.0	12/31/96	1/5/97	14.3*	1/1/97 flow unknown
Weiser River near Weiser	9.5	12/29/96	1/5/97	17.2	½/97 34,500 cfs
Payette River near Emmett	16k cfs	12/31/96	1/5/97	32.3k cfs	½/97
Snake River near Weiser	12.0	1/1/97	1/4/97	14.5	1/3/97 83,925 cfs

All data unofficial. USGS will publish official records.

* - Some flow on the Weiser River near Cambridge went around levee behind gage, hence gage height at crest is not indicative of total flow. Had all flow been contained in river channel stage and flow at crest would have been higher than reported here.

NWS FORM E-3 **U.S. DEPARTMENT OF COMMERCE**
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

HYDROLOGIC SERVICE AREA:

NWSFO Seattle, WA

REPORT

FOR:

FLOOD STAGE REPORT

MONTH: December YEAR: 1996

RIVER AND STATION	FLOOD STAGE (feet)	ABOVE FLOOD STAGES (dates)		CREST	
		From	To	STAGE	DATE (feet)
Lewis River at Woodland	21.0	½/97	½/97	21.0	½/97
Cowlitz River at Randle	18.0	1/1/97	½/97	18.5	1/1/97
Cowlitz River at Castle Rock	23.0	12/29/96	12/29/96	23.3	12/29/96
Cowlitz River at Kelso	20.0	1/1/97	1/4/97	22.3	1/3/97
Naselle River near Naselle *	15.5	12/31/96	12/31/96	15.5	12/31/96
Willapa River near Willapa *	21.0	12/31/96	1/1/97	22.1	1/1/97
Chehalis River at Centralia	65.0	12/30/96	1/3/97	70.2	12/30/96
Chehalis River near Grand Mound *	13.3	12/30/96	1/5/97	17.5	12/30/96
Skookumchuck River at Centralia	85.0	12/30/96	12/31/96	86.2	12/30/96
Satsop River near Satsop	34.0	1/1/97	1/1/97	34.5	1/1/97
Skokomish River near Potlatch	15.5	12/30/96	1/3/97	16.8	1/1/97
Deschutes River near Rainier *	12.0	12/29/96	12/30/96	14.3	12/29/96
White River below Mud Mountain Dam **	8,000	12/30/96	12/30/96	8,200	12/30/96
Cedar River at Renton	12.0	12/31/96	1/5/97	12.8	½/97
Snoqualmie River near Carnation	54.0	1/1/97	1/3/97	56.5	½/97
Snohomish River at Snohomish	25.0	1/1/97	1/3/97	25.4	½/97
Walla Walla River near Touchet	13.0	12/31/96	½/97	17.1	1/1/97
Klickitat River near Pitt	9.0	1/1/97	1/4/97	12.4	½/97

* These are sites where we are working with local officials to establish a flood stage.

** Flood stage and crest are expressed as discharge values (cfs).

All data unofficial. USGS will publish official records.

NWS FORM E-3 (5-71) (PRES. BY WSOM E-41)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

HYDROLOGIC SERVICE AREA (HSA)
Portland, OR

[Hydrologic Service Area]
REPORT FOR :
MONTH DEC YEAR 1996

FLOOD STAGE REPORT

RIVER AND STATION	FLOOD STAGE *(Feet)*	ABOVE FLOOD STAGES *(Dates)* FROM	TO	CREST STAGE *(Feet)*	CREST DATE (LOCAL TIME)
Nehalem nr Foss	14			12.78	12/05
		12/29	1/3	18.73	12/31 2345
Wilson nr Tillamook	13			11.76	12/05
		12/29	12/30	13.92	12/29 2200
Nestucca nr Beaver	18			10.27	12/05
Siletz at Siletz	16			14.45	12/05
				12.52	12/08
		12/26	12/27	18.32	12/26 1415
Alsea nr Tidewater	18			15.89	12/05
				14.51	12/08
		1/1	1/1	18.19	1/1 0415
MF Willamette at Jasper	10*			9.97	12/17
CF Willamette nr Goshen	13*			11.68	12/05
				12.07	12/14
		12/31	12/31	13.20	12/31 0655
		1/1	1/1	13.06	1/1 0855
Willamette at Eugene	23			19.15	½ 1201
McKenzie nr Vida	11			6.51	1/1 0900
Mohawk nr Springfield	15	12/25	12/27	17.3	12/26 0700
Willamette at Harrisburg	14			13.34	12/31 1900
Marys nr Philomath	20			18.44	1/1 0000
Willamette at Corvallis	20	12/31	1/3	21.63	1/1 1300
Willamette at Albany	25	12/31	1/3	27.25	½ 0500
S Santiam at Waterloo	12*			10.30	12/29 2000

N Santiam at Mehama	11*			9.36 8.70	12/05 1/1	 0315
Santiam at Jefferson	15	 12/30	 12/30	14.22 14.86 15.70	12/08 1/1 12/30	 1000 0400
Luckiamute nr Suver	27	12/08 12/29	12/09 1/3	28.00 29.03	12/09 12/30	 0430
Willamette at Salem	28	 1/1	 1/3	26.63 29.28	12/09 ½	 1745
S Yamhill at McMinnville	50	 12/30	 1/3	43.69 46.84 55.06 55.01	12/07 12/09 12/30 1/1	 1300 1900
Pudding at Aurora	22	12/27	1/6	26.67	1/3	0800
Molalla nr Canby	13			12.50	12/25	1800
Tualatin nr Dilley	17	12/25	1/9	18.06	12/30	0300
Tualatin at Farmington	32	 12/30	 1/6	31.42 34.81	12/10 1/1	 2200
Tualatin at West Linn	13.5	12/31	1/6	16.37	½	1600
Oregon City Locks-Upper	14	12/27	1/5	16.46	½	2300
Oregon City Locks-Lower	27	12/09 12/27	12/09 1/6	27.20 36.28	12/09 ½	 2200
Clackamas at Estacada	10	12/05 1/1	12/05 1/3	10.08 12.19	12/05 1/1	 0600
Johnson Creek at Sycamore	11	12/08 12/30	12/08 1/1	11.95 12.06	12/08 1/1	 0130
Willamette at Portland	18	12/31	1/6	22.54	1/3	0700
Columbia at Vancouver	16	12/31	1/7	22.55	1/3	0500
Columbia at St Helens	17	1/1	1/5	19.78	1/3	0400
Columbia at Longview	12	12/31	1/7	15.84	½	1030
Grande Ronde nr LaGrande	10	1/1	1/1	10.40	1/1	1200
Grande Ronde at Troy	10	1/1	½	12.69	1/1	1345
Umatilla at Pendleton	8	1/1	½	9.51	1/1	1628
John Day nr John Day * = Unofficial Flood Stage	8	1/1	½	8.84	½	0100

NWS FORM E-3
(5-71)
(PRES. BY WSOM E-41)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

HYDROLOGIC SERVICE AREA (HSA)
Medford, Oregon

FLOOD STAGE REPORT

REPORT FOR :
MONTH **December**
YEAR **1996**

RIVER AND STATION	FLOOD STAGE *(Feet)*	ABOVE FLOOD STAGES *(Dates)* FROM	TO	CREST STAGE *(Feet)*	DATE
S. Fork Coquille River At Myrtle Point, Oregon	38.0	12/8/96 12/31/96	12/10/96 1/1/97	42.5 38.6	12/8/96 12/31/96
Coquille River At Coquille, Oregon	21.0	12/8/96	12/11/96	22.4	12/9/96
S. Umpqua River At Winston (Brockway), Oregon	26.0	12/8/96	12/9/96	28.4	12/8/96
S. Umpqua River At Roseburg, Oregon	22.0	12/8/96	12/9/96	26.3	12/9/96
Umpqua River Near Elkton, Oregon	33.0	12/8/96	12/9/96	39.4	12/9/96
Rogue River Near Eagle Point, Oregon (At Dodge Bridge)	10.0	12/30/96	12/30/96	10.0	12/30/96
Rogue River Near Central Point, Oregon (Below Gold Ray Dam)	12.0	12/8/96 12/31/96	12/9/96 12/31/96	12.4 13.0	12/8/96 12/31/96

NWS FORM E-3 (5-71) (PRES. BY WSOM E-41)	U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL WEATHER SERVICE	HYDROLOGIC SERVICE AREA (HSA) **Medford, Oregon**
	FLOOD STAGE REPORT	REPORT FOR : MONTH **January** YEAR **1997**

RIVER AND STATION	FLOOD STAGE *(Feet)*	ABOVE FLOOD STAGES *(Dates)*		CREST	
		FROM	TO	STAGE *(Feet)*	DATE
S. Fork Coquille River At Myrtle Point, Oregon	38.0			39.6	1/1/97
Coquille River At Coquille, Oregon	21.0			21.1	1/1/97
Rogue River Near Eagle Point, Oregon (At Dodge Bridge)	10.0			10.2	1/1/97
Rogue River Near Central Point, Oregon (Below Gold Ray Dam)	12.0			17.2	1/1/97
Bear Cr. Medford, Oregon	None			13.6	1/1/97
Rogue River At Grants Pass, Oregon	20.0			25.5	1/1/97
Applegate River Near Applegate, Oregon	13.0			17.9	1/1/97
Rogue River At Agness, Oregon	None			39.7	½/97
S. Umpqua At Roseburg, Oregon	22.0			22.2	1/1/97
Umpqua River Near Elkton, Oregon	33.0			33.1	1/1/97
Klamath River Below Iron Gate Dam	None			13.1	1/1/97
Sprague River Near Beatty, Oregon	None			11.25	½/97
Williamson River Below Chiloquin, Oregon	None			10.8	1/5/97

NWS FORM E-3 (5-71) (PRES. BY WSOM E-41)	U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL WEATHER SERVICE	HYDROLOGIC SERVICE AREA (HSA) **EUREKA, CA**
	FLOOD STAGE REPORT	REPORT FOR : MONTH: **JANUARY** YEAR: **1997**

RIVER AND STATION	FLOOD STAGE *(Feet)*	ABOVE FLOOD STAGES *(Dates)*		CREST	
		FROM	TO	STAGE *(Feet)*	DATE
KLAMATH RIVER AT TURWAR	34.0	12/31	1/3	45.22	1/1
KLAMATH RIVER AT ORLEANS	38.0	1/1**	1/3	38.23*	1/3
EEL RIVER NEAR SCOTIA	51.0	1/1	½	54.97	1/1
EEL RIVER AT FERNBRIDGE	20.0	12/30	½	25.22	1/1
EEL RIVER AT MIRANDA	33.0	1/1	1/1	33.64	1/1
MAD RIVER AT ARCATA	22.0	1/1	½	25.46	1/1
VAN DUZEN RIVER NR BRIDGEVILLE	17.0	1/1	1/1	17.91	1/1

**Date estimated from event data - gauge malfunction

*Highest stage recorded after repairs

NWS FORM E-3 **U.S. DEPARTMENT OF COMMERCE**
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

HYDROLOGIC SERVICE AREA:
Sacramento, CA

REPORT FOR:
MONTH: December YEAR: 1996

FLOOD STAGE REPORT

RIVER AND STATION	FLOOD STAGE (feet)	ABOVE FLOOD STAGES (dates)		CREST	
		From	To	STAGE (feet)	DATE
Sacramento River Bend Bridge	27.0	12/31/96 0700	12/31/96 1500	28.52	12/31/96 0900
Red Bluff	23.0	12/31/96 0600	12/31/96 1830	24.39	12/31/96 1130
Tehama Bridge	213.0	12/29/96	Remained abv FS for the rest of the month. River peak occurred in January 1997		
Vina Woodson Bridge	183.0	12/31/97	Remained abv FS for the rest of the month. River peak occurred in January 1997		
Hamilton City	148.0	12/31/97	Remained abv FS for the rest of the month. River peak occurred in January 1997		
Ord Ferry	114 LB	12/31/97	Remained abv FS for the rest of the month. River peak occurred in January 1997		

WS FORM E-3
(5-71)
(PRES.BY WSOM E-41)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

HYDROLOGIC SERVICE AREA: Sacramento, CA

FLOOD STAGE REPORT

REPORT FOR: Month: January Year: 1997

RIVER AND STATION	FLOOD STAGE *(Feet)*	ABOVE FLOOD STAGES (Dates)		CREST	
		FROM	TO	STAGE *(Feet)*	DATE
<u>SACRAMENTO RIVER</u>					
Bend Bridge	27.0	1/1/97 0600	1/2/97 1300	30.58	1/1/97 1100 hrs
Tehama Bridge	213.0	12/29/86 1800	1/7/97 0400	221.24	1/1/97 1900
		1/22/97 1400	1/27/97 0800	217.85	1/25/97 1600
Vina Woodson Bridge	183.0	12/31/97 0001	1/5/97 2000	189.56	1/1/97 2000
		1/25/97 1115	1/26/97 1630	184.59	1/25/97 1815
Hamilton City	148.0	12/31/96 1700	1/3/97 1100	150.92	1/2/97 0300
Ord Ferry	114.0	12/31/96 0500	1/6/97 1700	118.66	1/2/97 0500
		1/25/97 2200	1/27/97 1300	115.68	1/26/97 1400
Fremont Weir	40.8	1/2/97 0800	1/3/97 0300	42.47	1/2/97 0200
Verona	41.3	1/2/97 1500	1/3/97 0400	42.09	1/2/97 2200
<u>CACHE CREEK</u>					
Rumsey Bridge	14.0	1/1/97 0300	1/1/97 0900	18.06	1/1/97 0500
<u>YOLO BYPASS</u>					
Lisbon	26.2	1/2/97 1800	1/5/97 0700	27.18	1/3/97 0400

WS FORM E-3
(5-71)
(PRES.BY WSOM E-41)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

FLOOD STAGE REPORT

HYDROLOGIC SERVICE AREA: Sacramento, CA

REPORT FOR: Month: January Year: 1997

RIVER AND STATION	FLOOD STAGE (Feet)	ABOVE FLOOD STAGES (Dates) FROM	TO	CREST STAGE (Feet)	CREST DATE
SAN JOAQUIN RIVER					
Vernalis	29.0	1/4/97 0600	1/12/97 1200	33.85	1/5/97 0300
		1/27/97 2045	*	29.52	1/27/97
	*Stages fluctuated just above flood stage into February 1997.				
EASTSIDE BYPASS					
El Nido	19.0	Channel capacity is much reduced from design capacity due to massive amounts of siltation from previous floods. Current stages do not reflect flows from previous floods. Stages at El Nido fluctuated near flood stage from 1/2/97 - 0600 hrs into February 1997.			
	19.0			19.87	1/6/97 1600
				20.75	1/27/97 0930
MERCED RIVER					
Modesto	55.0	1/3/97 0001	1/12/97 1800	70.92	1/4/97 0500
		1/26/97 0600	1/27/97	55.63	1/27/97 1030
MOKELUMNE RIVER					
Bensons Ferry	18.0	1/2/97 1645	1/4/97 1330	21.32	1/3/97 1315
COSUMNES RIVER					
Michigan Bar	12.0	1/1/97 1330	1/3/97 0715	18.31	1/2/97 1115

WS FORM E-3	U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL WEATHER SERVICE	RIVER DISTRICT OFFICE: NWSFO Monterey HSA
FLOOD STAGE REPORT		REPORT FOR: **MONTH** January **YEAR** 1997

RIVER AND STATION	STAGE (FEET)	ABOVE FLOOD STAGES (DATES) FROM:	TO:	CREST STAGE (FEET)	CREST DATE
Following are crests which occurred on non-mainstem rivers in the MTR HSA during January, 1997. All flood stages are unofficial. All data is subject to revision by the USGS. Times are in PST.					
Sonoma County:					
Petaluma R @ Corona	24.0			24.9 25.2	1845 22nd 0945 25th
Petaluma R @ Payran	10.0			11.3 11.1	1715 22nd 0815 25th
Napa County:					
Redwood Ck @ Forrest	9.5			9.8	1715 22nd
Redwood Ck @ Mt Veeder	8.0			8.7 11.1	0615 1st 1645 22nd
Napa Ck @ Hwy 29	12.0			15.2 16.3 13.0	0615 1st 1730 22nd 0745 25th
Alameda County:					
Castro Valley Ck	7.0			8.3	0630 2nd 1,284 cfs
San Mateo County:					
Pescadero Ck	12.0			13.5	1500 1st 3,676 cfs

WS FORM E-3

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RIVER DISTRICT OFFICE:

NWSFO Monterey HSA

FLOOD STAGE REPORT

REPORT FOR:
MONTH January
YEAR 1997

RIVER AND STATION	STAGE (FEET)	ABOVE FLOOD STAGES (DATES) FROM:	TO:	CREST STAGE (FEET)	CREST DATE
Following are crests which occurred on non-mainstem rivers in the MTR HSA during January, 1997. All flood stages are unofficial. All data is subject to revision by the USGS. Times are in PST.					
Santa Cruz County:					
San Lorenzo R	14.0			17.1	1815 1st 9486 cfs
Soquel Ck	14.5			15.1	1700 1st
Corralitos Ck	11.5			12.6	1930 1st 3676 cfs
				13.0	1000 2nd 3847 cfs
Santa Clara County:					
Coyote Ck @ Madrone	10.0			10.8	1730 26th
Coyote Ck @ Edenvale	10.0			12.1	2300 26th
Monterey County:					
Big Sur R	10.0			10.6	2045 1st 5034 cfs
San Antonio R	10.0			11.7	2050 1st 9080 cfs
Following are crests which occurred on mainstem river points in the MTR HSA during January, 1997. The times are in PST. Data is subject to revision by the USGS.					
Napa River...					
nr St Helena	13.0	0230 1st	1830 1st	17.7	1930 1st 13,100 cfs
nr Napa	25.0	0645 1st	0045 2nd	28.1	1700 1st 26,750 cfs
Russian River...					
nr Healdsburg	19.0	1800 Dec 31st	0745 2nd	24.7	0745 1st 65,930 cfs
nr Guerneville	32.0	1130 Dec 31st	1445 3rd	45.0	0015 2nd 82,120 cfs

NWS FORM E-3 U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL WEATHER SERVICE	HYDROLOGIC SERVICE AREA: **RENO, NEVADA**
FLOOD STAGE REPORT	REPORT FOR: **JANUARY 1997; PAGE 1**

RIVER AND STATION	FLOOD STAGE (feet)	ABOVE FLOOD STAGE (date/time) From (All times are PST)	To	***JANUARY 1997 CRESTS*** STAGE (feet)	DATE/TIME (All times PST)
East Walker River					
nr Bridgeport CA	5.5*	1/1 1000	1/10 0700	6.73 1810 cfs ***New Record Stage/Flow***	1/4 1015
West Walker River					
below Little Walker River nr Coleville CA	5.5*	1/1 1900	1/3 1800	10.06 11,700 cfs ***USGS est >100 yr flood*** ***New Record Stage/Flow***	½ 1500
near Coleville, CA ***(Gage Destroyed 1/2 @ ~1540 PST)***	7.0	1/1 2015	1/3 E2000	E12.0 E>12,000 cfs ***USGS est >100 yr flood*** ***New Record Stage/Flow***	1/2 E1800
at Hoye Bridge nr Wellington NV ***(Gage Completely Submerged During Flood Crest)***	8.0*	1/3 E0200	1/5 E0300	E13.6 E5,800 cfs ***USGS est >100 yr flood*** ***New Record Stage/Flow***	1/3 E2100
Mainstem Walker River					
at Yerington NV	11.3*	1/3 0200	1/12 1800	14.47 Flow Unknown ***New Record Stage***	1/4 1600
near Wabuska, NV	9.7*	1/3 0700	1/17 1000	10.89 2580 cfs ***USGS est <50 yr flood***	1/6 0615
below Weber Reservoir nr Schurz NV	8.3*	1/9 0300	1/12 0100	8.76 2600 cfs ***New Record Stage/Flow***	1/9 1400
East Fork Carson River					
below Markleeville Ck nr Markleeville CA	7.0*	1/1 0700	1/3 1100	11.78 21,000 cfs ***USGS est >100 yr flood*** ***New Record Stage/Flow***	½ 1530

NWS FORM E-3 **U.S. DEPARTMENT OF COMMERCE** NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL WEATHER SERVICE	HYDROLOGIC SERVICE AREA: **RENO, NEVADA**
FLOOD STAGE REPORT	REPORT FOR: **JANUARY 1997; CONTINUED** **PAGE 2**

RIVER AND STATION	FLOOD STAGE (ft)	ABOVE FLOOD STAGE (date/time) From (All times are PST)	To	***JANUARY 1997 CRESTS*** STAGE (feet)	DATE/TIME (All times PST)
nr Gardnerville NV ***(Gage Destroyed 1/2 @ 1530 PST)***	7.0	1/1 1030	1/3 E1800	E12.8 E20,000 cfs ***USGS est***	1/2 E2100 ***>100 yr flood***
				New Record Stage/Flow	
		1/25 E1300	1/25 E2200	E7.1 E6500cfs	1/25 E1600
West Fork Carson River nr Woodfords CA ***(New Channel Cut-Flow Diverted Away From Gage Sometime on 1/2/97)***	6.0	1/1 1400	E1/3 E0900	E>11.0 E8,000 cfs ***USGS est***	1/2 E1000 ***>100 yr flood***
				New Record Stage/Flow	
Mainstem Carson River nr Carson City NV	10.0	1/2 0900	1/4 2200	18.40 27,500 cfs ***USGS est***	1/3 0545 ***~100 yr flood***
				New Record Stage	
nr Fort Churchill NV ***(Gage Destroyed 1/3 @ 1000 PST)***	10.0*	1/3 E0600	E1/6 E1200	E15.2 E25,000 cfs ***USGS est***	1/3 E2100 ***>100 yr flood***
				New Record Stage/Flow	
Lahontan Reservoir nr Fallon NV	4163.4*	1/6 0300	1/14 2000	4163.83	1/7-8
Truckee River Lake Tahoe at Tahoe City CA	6229.1	1/2 1200	1/16 0400	6229.39**&**	1/5 0800
&: Highest Lake Tahoe Elevation Since July 17, 1917; First Time Legal Limit (6229.1) Exceeded Since Truckee River Agreement of 1935.					
		1/23 0600	2/3 0600	6229.34	1/26 0800
at Tahoe City CA	8.5*	12/16 0800	12/19 1100	8.51 2003 cfs	12/16-18
		12/22 0800	???? Still at 8.86' on 2/21/97	9.55 2666 cfs	1/2 0800
				New Record Stage/Flow	

NWS FORM E-3 U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

HYDROLOGIC SERVICE AREA:

RENO, NEVADA

REPORT FOR: **JANUARY 1997; CONTINUED**

PAGE 3

FLOOD STAGE REPORT

RIVER AND STATION	FLOOD STAGE (ft)	ABOVE FLOOD STAGE (date/time) From (All times are PST)	To	***JANUARY 1997 CRESTS*** STAGE (feet)	DATE/TIME (All times PST)
nr Truckee CA ***Telemetry Inoperative or Unreliable During Most of Flood Event***	4.5*	12/26 E2200	???? Still at 4.6' on 2/21/97	9.97 11,900 cfs ***USGS est***	1/2 0115 ***>100 yr flood***
				New Record Stage/Flow	
at Farad CA	11.0	1/1 1100	1/2 1645	13.17 15,000 cfs ***USGS est***	1/2 0445 ***<50 yr flood***
at Reno NV	12.0	1/1 1030	1/2 2215	14.91 18,000 cfs ***USGS est***	1/2 0800 ***<50 yr flood***
at Sparks NV ***Phone Lines Washed Out 1/1 @ 1800; Restored 1/5 @ 1845***	11.5*	1/1 0200	1/16 1315 cfs	E>17.5 E>19,000	1/2 E1000
				New Record Stage/Flow	
Galena Ck at Galena SP nr Washoe City NV ***ALERT Telemetry Inoperative or Unreliable During New Years Flood; Inoperative During Small Stream Flooding 1/24-25***	2.2*	1/1 E0800	1/2 E1345	E5.3 Flow Unknown	½ 0500
				New Record Stage/Flow	
Steamboat Ck at Steamboat NV	4.5*	1/1 0900	1/3 0900	5.7 1605 cfs	½ 0630
Some Missing Data During New Years Flood Event (Alert Telemetry)		1/25 0900	1/25 1415	4.81 850 cfs	1/25 1000
Truckee River at Vista NV	14.0*	12/29 1800	1/16 1400	24.04 flow unknown	½ 2050
				New Record Stage/Flow	
		1/25 1045	1/26 2015	15.54 E9000 cfs	1/25 1645

NWS FORM E-3 U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL WEATHER SERVICE	HYDROLOGIC SERVICE AREA: RENO, NEVADA
FLOOD STAGE REPORT	REPORT FOR: **JANUARY 1997; CONTINUED** **PAGE 4**

RIVER AND STATION	FLOOD STAGE (ft)	ABOVE FLOOD STAGE (date/time) From (All times are PST)	To	***JANUARY 1997 CRESTS*** STAGE (feet)	DATE/TIME (All times PST)
below Tracy NV ***Gage Destroyed 1/2 @ 2130 PST***	10.0*	1/1 0815	E1/16 E2000	Unknown ***New Record Stage/Flow***	1/3 E0500
		E1/25 E1300	E1/26 2300	E10.4 E8900cfs	E1/25 1900
nr Nixon NV	10.0*	1/1 1700	1/16 2200	16.08 22,000 cfs ***USGS est >50 yr flood*** ***New Record Stage/Flow***	1/3 1100
		1/25 2300	1/27 0400	10.17 8725cfs	1/26 2200