II. HYDROMETEOROLOGY

OBSERVATIONS: Weather Snowpack SWSI Streamflow Flood Events
FORECASTS: Runoff Volume Long Range Peaks Daily Streamflows

A. OBSERVATIONS

With the Pacific Northwest's highly diverse hydrologic conditions, both areally and seasonally, information on weather, snowpacks, and streamflows played a pivotal role in the effective operation of the dams and reservoirs to meet the needs of the region's people, industry, and natural resources. This chapter summarizes these conditions, first generally in describing the overall conditions throughout the year and then some unique conditions that had a pronounced effect on the region. The chapter concludes with summaries of forecasts and peak streamflow conditions.

1. Weather

The Pacific Northwest has the most diverse weather conditions of any region of the nation, varying from the arid conditions in the shadows of the Olympic and Cascade mountains to very wet rainforest along the Pacific coast to dry areas that are subject to occasional cold outbreaks of winter continental weather in the Rocky Mountains along the Continental Divide. The normal seasonal variations are just as dramatic with the coastal areas and Cascade Mountains receiving their maximum precipitation in the winter months while the eastern basins, with more steppe and continental climates, have their maximum precipitation in early summer. To best consider all these seasonal and areal variations, the following weather discussion will reference departures of temperatures and precipitation from normals rather than observed values. Monthly sub-basin precipitation is shown in Table 1 and Table 2, basin temperature in Table 3, and a graphic display of daily temperatures and precipitation for selected basins are shown in Charts 1-4 in Appendix D, and a map of the annual precipitation in the Columbia drainage, Figure 6.

The cumulative precipitation indices in the three major basins of the Columbia drainage, the Columbia Basin above Grand Coulee, Snake Basin above Ice Harbor, and the Columbia Basin above The Dalles, in addition to the Willamette Basin which joins the Columbia below The Dalles, Figure 7, shows that the excess precipitation in November, December, and February and the dry spring kept the year-end totals near normal. Figure 8, the history of these indices for WY 77-99, shows the near normal totals of the three main Columbia basins and somewhat higher in the Willamette Basin.

The water year began with minor but fairly frequent storm systems that moved from the Gulf of Alaska into the region. This pattern was interrupted twice in the month (October 5-7 and 19-24) when high pressure ridges diverted the storm track into southern Alaska and northern British Columbia and brought warm dry airmass with it. The cooler weather, that returned at months end, managed to keep the October's average basin temperature slightly below normal (-0.6°F) while the warm days kept the precipitation below normal (70%).

November's storm tracks came from a more southerly direction, *i.e.*, over warmer moisture source, resulting in more precipitation and warmer temperatures. The average basin temperature was above normal (+3.5°F) with average daily station temperature departures ranging from 0.2°F below normal to 6.5°F above normal. Frequent storm systems dominated most of the basin producing periods of heavy, flood producing rainfall during the period November 20-27 over western Washington and western Oregon and heavy snowfall in the Cascades and the Rockies. The total monthly precipitation was 113% and 108% of normal in the upper Columbia and Snake basins, respectively, resulting in rapidly increasing snowpacks. Monthly precipitation ranged from more than 200% of normal in southwestern Oregon to 185% in the upper Deschutes of central Oregon, and 184% in the Clark Fork of western Montana to the only sub-basin with below normal precipitation (86%), the Snake River Plain in south-central Idaho.

This westerly flow of storms continued through mid December producing basin-wide temperatures that were near normal, although mean station temperatures varied from -0.2°F to +6.5°F from normal. Then the Gulf of Alaska low pressure system was displaced by a short-lived but strong upper air ridge which brought a cold Arctic airmass across the region, producing temperatures as low as -20°F at Missoula on December 20 and single-digit temperatures in the Portland area. After four days the Gulf low began to reestablished itself and sent a warm mid-latitude storm, loaded with subtropical moisture, into the Northwest. This, on the days following Christmas, was the strongest westside storm of the year and extended from southern Oregon to northern Puget Sound dropping as much as 10 inches of rainfall in two days and setting new daily rainfall records for December 27 at four weather stations and producing peak annual flows in westside basins. Snowmelt from the storm's warm temperatures and rains extended into eastern Washington and Oregon where flooding occurred on many small low elevation streams while high elevation snowpacks continued to increase. Despite the Arctic air outbreak the average monthly temperature for the basin was above normal (0.67°F) with the mean monthly temperatures at individuals stations varying from -5.2°F to +7.5°F from normal. Precipitation was above normal in the Columbia Basin above Grand Coulee (128%), normal (100%) in the Snake Basin, and 120% in the basin above The Dalles; the greatest amount was 166% in the East Slopes Washington Cascades and the lowest was 59% in the Owyhee/Malheur of southeastern Oregon.

Several minor Gulf weather disturbances, with trajectories over cooler water moved across the basin until mid January bringing moderate to sometimes heavy rains to coastal areas and heavy snows to both the Cascades and eastern portions of the Columbia Basin. Then the storm trajectory became more zonal and, for the remainder of the month, ushered numerous storms (approximately one every third day) into the Northwest, producing warmer temperatures and moderate to heavy coastal and valley rains on the westside of the Cascades and heavy snow in the Cascades and eastside upper elevation basins. Average temperature for the basin was well above normal (5.2°F) and precipitation was greatest in the Snake Basin (116%), normal above Grand Coulee (101%), and slightly above normal (107%) in the basin above The Dalles.

The number of Pacific storms entering the Northwest increased during February, producing virtually endless precipitation and accompanied by slightly above normal temperatures, focusing the brunt of their energy across the western basins and occasionally into central basins producing significant valley rain and mountain snow accumulation across most of the basin. West of the Continental Divide active warm fronts resulted in occasional rain-on-snow events that resulted in low elevation snowmelt runoff while at higher elevation snow packs continued to build. February was the wettest month of the year with all the sub-basins reporting more than 100% of normal and four sub-basins reporting more than 200% of normal while the "driest" sub-basin reported 111%. Average basin-wide temperatures were +1.7°F from normal although the individual stations varied from -7.2°F to +7.1°F.

Weakening storms, with lingering showers, continued their assault during March although snow accumulation was less than normal which resulted in a snow volume decrease in almost all basins. The exception was the Willamette and southwest Oregon sub-basins which received the brunt of the storms and where snow accumulated at greater than normal rates, but volume still decreased due to less than normal monthly precipitation. In the latter half of March a brief hot spell started the snowmelt process across eastern Oregon, south-central Idaho, and into southwestern Montana, with the most pronounced flow increase found in western Idaho's Weiser River basin and in the low elevation snowpack in southeastern Oregon's Owyhee Valley. Meanwhile, the snowpack across the remainder of the region were still significantly above normal. The average basin monthly temperature was slightly above normal (+0.5°F) while the monthly precipitation was below normal in all but sub-basins and ranged from 46% in central Oregon to 104% in the Columbia basin above Castlegar, British Columbia.

With zonal flow similar to that of early March, April began with frequent storms accompanied by cold showers which produced more valley rain and low elevation mountain snowfall with occasional moderate precipitation which reached into the Blue Mountains, Idaho, western Montana, and Wyoming. After mid month moist Pacific air masses from central California moved northward into Idaho, western Wyoming, and western Montana. This advection of warm dry air resulted in noticeable mid to late April snowmelt-induced increases in streamflows, from the Snake Basin in Oregon and Idaho to the upper Columbia and Kootenay basins. However, despite this erosion of mid-elevation snowpack, more widespread high elevation snow accumulation occurred in both early and late April. Monthly precipitation averaged about two-thirds of normal in all three major sub basins of the Columbia. The mid month cold snap outbreak dominated the average monthly temperature for the basin was above normal (-1.5°F) while the station average temperatures ranged from +0.8°F to -5.1°F. Average basin precipitation was below normal in the Columbia above Grand Coulee (53%), the basin above The Dalles (62%), and (74%) in the Snake Basin; with the highest (near normal) in the middle and lower Snake Plain.

Overall, below normal temperatures (-2.7°F) and precipitation (70%-95% in the three major basins) prevailed in the interior basin during May while near to above normal precipitation occurred west of the Cascades. May began with more of April: a series of Gulf of Alaska storms dominating the region which resulted from a broad trough of low pressure aloft with moist unstable air circulating at the surface. This pattern brought more rain to the valleys and more snow to the mountains. The monthly temperature over the region averaged below normal. On May 17, warm southwest flow began to infiltrate the basin so that by late May a high pressure ridge became dominant over the basin, producing above normal temperatures on the east side of the Cascades, helping to spur the main runoff in the Snake River basin. Flood stages were reached in the upper Snake area as well as along the Imnaha River of eastern Oregon. Elsewhere, moderate streamflow rises were experienced in the Upper Columbia, Pend Oreille, East Kootenay, Spokane, and Okanogan basins.

June weather was dominated by an unseasonably low latitude jet stream in the Gulf of Alaska which sent cold and wet storms into the Pacific Northwest. This pattern of zonal flow was briefly interrupted in mid month by a short lived but high amplitude pressure ridge over the entire region which brought with it a warm air mass giving another boost to the snowmelt process. Late in the month the Gulf low reestablished itself, bringing significant rain to the western and northeastern portions of the basin. Seasonal river flow peaks occurred mid June in the Kootenay and Upper Columbia basins. Average basin temperatures were 2.5°F below normal and monthly precipitation averaged near normal (95% to 107%) in the three major sub basins.

During July the Northwest experienced cooler and drier than normal conditions, with the exception of areas west of the Cascades and portions of southern Canada which received most of the basin's July rainfall. The month began with showery cool weather in much of the northern portion of the basin and by mid month the main jet stream retreated northward to southern Canada and the basin began to experience some ridging with the main trough staying off the Oregon coast through the end of the month. This upper air flow pattern brought moisture from the south into eastern Idaho and western Montana. Basin temperatures for the month averaged below normal (-2.5°F). July precipitation was 88% and 74% of normal in the basin above Grand Coulee and The Dalles, respectively, and only 32% of normal in the Snake Basin.

Early in August an upper level trough developed off the California coast, producing a southwest flow with weather disturbances initiated showers and thunderstorms. In mid month the high pressure ridge built over the region, pushing the jet stream to the north, producing dry warm weather across most of the basin. At month's end a low brought unseasonable cool temperatures and unsettled conditions. On the whole the month proved to be pleasant with temperatures slightly below normal (-0.5°F although one station was -7.8°F) and rainfall ranging from normal (101%) in the Snake Basin to above normal in the upper Columbia (131%) and above The Dalles (122%).

The cooler weather from the end of August continued into the first part of September and then was followed with a warm period until near month's end when the cooler weather returned. On the whole the month proved to be pleasant with temperatures slightly above normal (-0.5°F although one station was -8.1°F). September rainfall ranged from zero inches in much of the Snake Basin to 65% in parts of the basin in British Columbia. The basins above Grand Coulee, Ice Harbor, and The Dalles were 47%, 23%, and 34%, respectively.

2. Snowpack

Snowpack measurements begin with the first snowfall at SNOTEL sites. These early season snowpack, however, are highly variable and not representative of the peak values so this report begins with the January 1 readings. Two points of reference are to compare the observed snowpack to the long-term normal snowpack. First is to compare the observed value to the normal for that date. Second is to compare the observed snowpack to the normal peak annual snowpack which usually occurs near April 1 as seen in Figure 9.

The snowpack season started off very high in January and never fell below normal. The 174% of normal for New Year's Day was attained by well above average snowpacks in every major sub-basin. The sub-basins with typically the highest volume runoff, the Kootenay, Pend Oreille, and Canadian Columbia, started off over 120%, while the lowest snowpack in the Columbia drainage was the upper Snake in Wyoming, at 107%.

During January, most sub-basins saw minor drops in percent of normal, except for the Columbia above Arrow Lakes which increased 11% to 133%. This sub-basin, which accounts for 24% of the snowpack index above The Dalles, remained high, with 86% of the normal peak snowpack accumulation already on the ground by early February. All sub-basins were still above 100%, with the Snake Headwaters the lowest (108%). Winter continued through February with every sub-basin except those in Canada increasing, with the greatest snowpacks being Washington's Yakima at 182%, the North Cascades at 160% followed by the Snake Headwaters with a 127%. The lowest snowpacks were found in the minimally contributing small sub-basins on the south side of the Snake Basin in Idaho, at about 100%. The overall snowpack index on March 1 was 121% of the normal peak accumulation. The increases in snowpacks was small during March, except in British Columbia, so that the overall index on the date of its normal peak was 132%. The snowpacks in the Cascades in Washington remained the highest, ranging from 176% in the Yakima to160% for the North Cascades, followed by the Deschutes in Oregon (169%), and in Idaho, the Clearwater at 133%, the Salmon at 124%, and the Boise/Payette at 119% on April1 (Figure 10).

With the possibility of high snowmelt runoff attention was turned to the rate of snowmelt. With the cool April weather stalling the snowmelt the May 1 overall snowpack index remained high at 131% of the normal peak, including the Washington Cascades which had snowpacks near 200%. The North Cascades set a new May record going back to 1955 with 207% while the lowest snowpack was 117% in the Salmon Basin in Idaho. May weather, although cooler than normal, was warm enough to produce snowmelt at a steady but moderate rate, thus avoiding a rapid runoff and over-bank flows in most rivers.

3. Surface Water Supply Index - SWSI

Category-score numerical methods have been developed to indicate the status of the overall surface water supply. The Surface Water Supply Index (SWSI) was developed by the NRCS and has been applied, with slight variations, in portions of the Pacific Northwest. Thus far, the SWSI has only been applied to basins in Oregon, Idaho, and Montana; but only the Oregon values are computed monthly. These indices include consideration of the status of the surface waters and reservoir contents of the basin, along with precipitation, snow, temperature, and other parameters. The index has a range of +4.1 (very ample supply of water) through 0.0 (normal supply), to -4.1 (very inadequate supply).

This water year saw nearly all Oregon basins start with near or above normal water supply (Table 4). The exceptions were the North Coast (-1.1). The water supply generally decreased during the year. (The Klamath, Lake County, and Harney areas do not contribute to the Columbia drainage or have flood control reservoirs and therefore are not germane to this report).

The effects of the water supply on the regulation of the specific reservoir projects are discussed in Chapter III, the effects on power generation, irrigation, recreation, fisheries, and other activities are discussed, by activity, in Chapter IV.

4. Streamflow

Streamflows in the Pacific Northwest were measured at approximately 900 gaging stations. To condense these data, gages at 14 index locations, on both uncontrolled streams and controlled streams, were used to summarize the flows throughout the region. The gages with upstream reservoir storage had their discharges adjusted for the amount of storage. Mean monthly discharges for each of these index stations, as expressed as a percentage of their 1961-90 normal discharges, are shown in Table 5 and Table 6. Flood peaks will be discussed in Section 6 below.

This was the fifth year in a row in which the average discharge of the index stations was "above normal." The station with the highest annual discharge, in percent of normal, was at the Chehalis River at Grand Mound, with

160%, and the lowest, for the second year in a row, was at the MF Flathead River near West Glacier with 96%.

The water year began with normal or below streamflows at most of the index stations. The flows in the Wilson and Skykomish rivers were so low that normal October rainfall, which caused large flow increases, still left the rivers with below normal average monthly flows. The high water events in late November in northwest Oregon, southwest Washington, and southern Puget Sound, produced large flow and increasing the average discharges for these gages to the well above their normal range. Smaller flow increases occurred in west-central Idaho and eastern Washington as the weakening storms traversed the basin. The drainage with the lowest discharge was the MF Flathead River with an average of 43% of normal discharge after the first two months of the water year. December experienced several more high water events in the westside basins with the post-Christmas event producing the peak annual discharge on many westside rivers and again causing large increases in the average discharges for December. The West Glacier gage continued to have the lowest average monthly discharge (71%). January discharges remained fairly constant in response to a month of weather that was free of intense storms although moderate storms after mid month and again near month's end, did result in some minor highwater in western Washington. February also had fairly constant streamflows until late in the month when another intense storm traversed the basin producing high but not necessarily overbank flows. These moderate storms penetrated the Cascade barrier to produce some high water events in eastern Washington from Pullman northward to Spokane. These events were sufficient to maintain the average monthly discharges at their "above normal" status.

The shift from rain-generated runoff to snowmelt generated runoff began in March as short unseasonably warm spells penetrated the eastern basins. The above normal flows at westside gages actually decreases from the previous month while the eastside gages showed significant increases. During April a late season isolated storm in western Montana gave a significant boost to the West Glacier gage while discharges at other eastside gages remained relatively unchanged. May experienced not only typical seasonal warming but also several brief hot spells which triggered snowmelt that produced the annual peak discharges in the basins east of the Cascades near month's end and in early June in the basins on the west slopes of the Rockies. Following these peaks, the rivers were in recession through the end of the water year.

The year ended with the Chehalis, Wilson, and Umpqua rivers on the westside having the largest average annual discharges, 160%, 156%, and 146%, respectively, and the John Day River and the Snake River at Weiser, had annual discharges averaging 129% and 127%, respectively. The Columbia River at The Dalles, the combined flow of the upper Columbia and the Snake River, had 120% of normal while the Willamette Basin had 134%.

Tables 7, 8, 9, and 10 show additional comparisons of WY-99 modified streamflows and runoff with historical flows. These modified flows, which reduce the streamflow data to a common state of hydrologic development, use a long term average (LTA) of 1928-89. These tables show that although in the four key basins the mean monthly discharges varied from 69% to 168% of their LTA there were no record breaking extremes, either high or low.

5. Flood Events

This water year there were numerous periods when above-flood stage flows occurred in the Northwest, albeit mostly on small uncontrolled streams and rivers. The information given here is covers only the larger events and is preliminary and subject to change. More detailed information on these storms will be found in the web site http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms and in Chapter III on project operation.

a. WINTER FLOODS. Twelve flood events (Table 11) occurred during the winter, with most occurring from the Cascades westward, although several extended into central Oregon and far eastern Washington. These floods were the aftermath of a series of wet frontal systems that provided sufficient rainfall to induce high river flows. The first storm system arrived on November 21 and produced above flood flows on streams in the Coquille, Umpqua, and Siletz basins of southwest Oregon and into the Chehalis, Deschutes, Skokomish, and Snohomish basins of western Washington. On November 25-26 another storm, with daily rainfall of 3.06 inches and 2.82 inches in Olympia, pushed at least eight rivers in northwest Oregon and five in southwest Washington over their flood stages. Many rivers in western Washington recorded their peak annual discharge from this event. The next storm system arrived on December 1 produced moderate flooding from the Coquille basin on southern Oregon coast, northward to the Wilson River at Tillamook and eastward into the Willamette valley.

The storm that produced the most severe flooding this year began on Christmas Day with heavy rains falling on a low elevation snowpack and frozen ground that extended from the central Oregon coast eastward to the Cascades and northward to the southern edge of Puget Sound. The lowlands had 2-5 inches of rainfall and the coastal mountains had 6-10 inches by December 28. The Wilson River at Tillamook crest of 19.6 ft was a 50-year storm that was higher than the previous record high flood of February 1996. Many highways throughout northwest Oregon were closed due to slides and washouts, especially along the coast and in Coastal Mountain range. More than 30 houses were destroyed from Alsea and Siletz rivers on the coast to Corvallis and Scio in the Willamette Valley. This event produced the annual peak discharges on rivers in this area. The effects of this storm also extended east of the Cascades with field flooding near Umatilla and with rainfall, snowmelt, and ice jam flooding in Lostine in northeastern Oregon. In Washington the warm rains produced rapid snowmelt and ice jams that caused small stream flooding in the Cashmere valley, Yakima valley, and other eastside Cascade basins as well as in the Palouse of southeastern Washington where downtown Pullman floods resulted from heavy rains, snowmelt, and ice jams. Of these, only the Yakima valley projects have flood control storage, but they were above the runoff producing lowlands.

In western Washington Howard A. Hanson Dam stored roughly 70 ft of flood flow, reducing the inflow peak of 12,010 cfs to 7,200 cfs, Mud Mountain stored roughly 271 ft, reducing inflow peak from 10,520 cfs to 8,220 cfs, and the Mossyrock/Mayfield Project (a Section 7 project) stored roughly 70 ft, reducing the inflow peak from 36,220 cfs to 17,710 cfs. Other Washington project basins were not in the storm center's trajectory and had no significant impact on streamflow.

The Willamette projects were affected by all three November-December storms, with the post Christmas event being the most significant. This storm filled the Corps and other flood control reservoirs to 20 to 50% of their flood control storage and reduced flows by up to 50%. The mainstem Willamette gages exceed flood stages at Harrisburg, Albany, and Salem, with a flow reduction of 6.7 ft at the Salem gage. The tributaries that exceeded their flood stages included the Mohawk, Luckiamute, Marys, Santiam, Tualatin, and Clackamas. This storm provided most of the flood control benefits for the year.

More storms, but with less areal coverage and lesser intensity, occurred on the Oregon coast on January 23, February 6-7, and February 16-18. Each of these rain storms was centered on the southern Oregon coast that raising the Coquille and other rivers above their flood stages. The last of these storms was accompanied by severe winds and coincided with the occurrence of high tides that made the crossing of the Columbia River bar at Astoria so dangerous, even for very large sea-going commercial vessels, that the US Coast Guard closed the bar to all navigation for 102 hours. On February 24-25 eastern Washington was again visited by heavy rains, warm temperatures, and abundant snowmelt which pushed the SF Palouse River in Pullman, the Little Spokane River near Dartford, Hangman Creek and other small streams near Spokane, out of their banks. Still another series of storms struck the Northwest beginning on February 27 accompanied by heavy rains that raised the discharges above flood stage on the Rogue and Coquille rivers followed by Wilson and other northwest Oregon rivers. This storm also affected the Little Spokane River which crested at 6.9 ft at Dartford, Washington on March 31.

b. SPRING FLOODS Spring snowmelt flooding was limited to areas in Idaho, eastern Oregon, and eastern Washington and involved mostly small rivers and streams (Table 12). On May 17 an upper air pressure ridge began building over the Columbia Basin bringing a warmer airmass that accelerated the snowmelt to produce the annual peak flows in late May and early June. Flood stages were reached in the Snake, Clark Fork and Kootenai drainages. Areas flooded in the Snake basin were the perennial flood area of the Henrys Fork near Rexburg, on the Weiser and Imnaha rivers of the middle Snake, and the Snake River at Anatone (the only gage on these rivers with upstream flood control storage). In western Montana the Yaak, Bitterroot, and St Regis rivers also exceeded their flood stages with minor flooding.

June weather was basically cold and wet except for a brief interruption in mid month when a warm air mass traversed the basin and gave another boost to the final snowmelt event of the year. This melt episode removed the last of the snowpack, mostly at higher elevations in the upper Snake basin.

B. FORECASTS

River forecasts are prepared primarily by the Northwest River Forecast Center (NWRFC) under an agreement between the NWRFC, the Corps, and Bonneville and are fully coordinated with the Bureau of Reclamation. Under this Columbia River Forecasting Service (CRFS) agreement all major projects are assumed to be operated based on coordinated forecasts. This minimizes unanticipated project operations due to the use of different flow forecasts. This agreement sets three main goals: (1) pool certain resources of the three participating agencies within the region; (2) avoid duplication of forecasts; and (3) increase the overall efficiency of operation. These forecasts are released monthly about the tenth of each month between January and June and are based on the basin hydrologic conditions on the first of each month plus normal weather assumed throughout the remainder of the forecast period.

In addition to these CRFS forecasts, the NWRFC also prepared forecasts which are distributed through the state NWS offices for public warning, for rivers in areas that were not affected by project regulations.

For forecast points located below flood control projects, outflow schedules are provided by the operating agency before the downstream flood warning is issued. The forecast area includes all of Oregon, Washington, Idaho, western Montana, western Wyoming, and the Columbia Basin portion of British Columbia. Distribution of all these forecasts was through CROHMS, by the Columbia Basin Telecommunications system (CBT), and the National Weather Service (NWS) web page (www.nwrfc.noaa.gov). The NWS AFOS system is used to transmit the forecasts to the state hydrologist offices in Seattle, Portland, Medford, Boise, Missoula, Pendleton, Pocatello, and Spokane for public release.

1. Runoff Volumes

Water supply volume forecasts issued on January 1, Table 13, indicated slightly above normal runoff could be expected from most sub-basin. Above average runoff was forecast for streams draining from the Cascades in eastern Washington. Forecasts remained nearly unchanged on February 1 and then increased on March 1 from 10 to 30% in most areas. The sharpest increases in volume were on the Snake River. After March 1 the volumes decreased slightly so that by April 1, the character of the 1998-99 snow accumulation was clear; with record snow at high elevations in most areas. However, warm temperatures throughout the winter and early spring prevented any snow accumulations at low levels and kept most mid elevation snow accumulations near their normal amounts. Tables 14 displays the monthly forecasts at key sites and their verification.

The seasonal volume forecast issued January 1 were under-forecast for the Snake and Lower Columbia drainages and over-forecast in western Montana. The January 1 errors were as high as 30% in some Lower Columbia and Snake River basins, but errors generally ranged from 5-15% basin wide. The volume forecast errors on April 1 ranged from 5-15% in all areas.

Table 15 shows the history of forecasts of the January-July runoff of the Columbia River at The Dalles for the period 1970-99. These are the actual forecasts made each year and do not include the effects of improvements in forecast models or changes in the amount and quality of data used in models. WY-99 adjusted runoff for the Dalles was 124.1 maf. A caveat for this table lists the actual historic forecasts that were made at the time and do not include corrections or adjustments for improvements in forecast models, changes in the quality of data, number of data stations used or their locations that have occurred in recent years.

2. Long-Range Peaks

Spring peak flow forecasts, expressed as a range of stages or flows, are a product of volume forecasts with model simulation of daily forecasts which provide adjustments to these long-range predictions. The forecast peak stage or flow are expressed so there was a probability that 16% of peak drainage may occur above the higher limit and a 16% probability of the peak occurring below the lower limit. A comparison of this year's forecast and observed peaks for key sites is shown in Table 16. Most Peaks fell within the expected ranges. The Spokane and several other rivers fell below the expected range reflecting the non-existent low level snowpack and only on average mid level snowpack in the area.

3. Daily Streamflows

The forecasts of operational streamflow were prepared by the NWRFC. The three operating agencies, Reclamation, Bonneville, and the Corps, used these streamflow forecasts in their day-to-day reservoir project operation and energy production. Close and constant coordination was required between these agencies and the NWRFC because project operations were dependent upon forecasts and the forecasts must take into consideration the project operation. The results of water resource uses of these forecasts are described in the following two chapters of this report.