II. HYDROMETEOROLOGY

A. OBSERVATIONS

With the Pacific Northwest's highly diverse hydrologic conditions, both areally and seasonally, information on weather, snow packs, 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 Figure 6 is a map of the annual precipitation in the Columbia drainage. Figure 6 shows accumulated precipitation across the Columbia Basin during the October 2002 through the September 2003 water year. Figure 7 denotes the monthly accumulation of the Columbia Basin snowpack for Water Year 2003 expressed as a percent of normal peak snowpack. Figure 8 denotes the accumulated precipitation in inches for the Water 2003 at primary Columbia River basins. Figure 9 is a map of the Pacific Northwest monthly temperature departures from normal for the month of December 2002.

The 2003 WY, which began in October 2002, was cooler than normal temperature and below average precipitation. A ridge of high pressure off the Pacific Northwest coast was the dominant weather feature through much of October. Any weather disturbances that managed to break through this blocking ridge were weak and dropped only light precipitation across the region. Many low temperature records were broken on the 30th and 31st as cold arctic air mass plunged south into the U.S. from Canada. Precipitation in October was 30 percent of normal (1971-2000) at the Columbia River above Grand Coulee, 44 percent of normal at the Snake River above Ice Harbor, and 33 percent at the Columbia River above The Dalles. October 2002 was cooler than average as well. For the 31-station temperature index for the Pacific Northwest, regional temperature departed -1.8 degrees Celsius (-3.2 degrees Fahrenheit) from normal relative to the 1971-2000 normals. Mean temperature departures ranged from -3.6 to -0.1 degrees Celsius
(-6.5 to -0.1 degrees Fahrenheit).

Although the second week of November brought a series of Pacific storms, high pressure was the dominant weather feature most of the month, resulting in well below normal precipitation across the region. November precipitation was: 64 percent of normal (1971-2000) at the Columbia River above Grand Coulee, 55 percent of normal at the Snake River above Ice Harbor, and 57 percent at the Columbia River above The Dalles. The

accumulated WY (October through November) precipitation was: 51 percent of normal (1971-2000) at the Columbia River above Grand Coulee, 51 percent of normal at the Snake River above Ice Harbor, and 49 percent at the Columbia River above The Dalles. The regional temperature index for the Pacific Northwest departed +0.7 degrees Celsius (+1.2 degrees Fahrenheit) from normal in November.

December 2002 was a continuation of seasonal warm weather. December precipitation was: 93 percent of normal at the Columbia River above Grand Coulee, 101 percent of normal at the Snake River above Ice Harbor, and 102 percent at the Columbia River above The Dalles. The warm weather was characterized by a Pacific Northwest temperature departure of +2.9 degrees Celsius (+5.2 degrees Fahrenheit) from normal, and mean temperature departures ranging from +0.9 to +4.1 degrees Celsius (+1.7 to +7.3 degrees Fahrenheit).

January temperatures continued to be warm. January 2003 was the second warmest January on record for several cities, including Seattle, WA and Pocatello, ID. Early in the month the main storm track occasionally dipped south of the U.S.-Canadian border. This brought above normal precipitation to far northern tier basins, but left the rest of the region drier than normal. Late in the month, heavier precipitation fell across most areas as storm systems with access to tropical moisture moved into the Pacific Northwest. January precipitation was: 101 percent of normal at the Columbia River above Grand Coulee, 120 percent of normal at the Snake River above Ice Harbor, and 116 percent at the Columbia River above The Dalles. The seasonal precipitation accumulation increased slightly to: 76 percent of normal at the Columbia River above Grand Coulee, 86 percent of normal at the Snake River above Ice Harbor, and 83 percent at the Columbia River above The Dalles. There were daily precipitation records established in January including 18.3 mm (0.72 inches) at Boise, ID on the 27th, 21.8 mm (0.86 inches) at Portland, OR, 11.4 mm (0.45 inches) (tie) at Yakima, WA and 14.0 mm (0.55 inches) at the Pendleton, OR Airport on the 30th.

The 31-station temperature index for the Pacific Northwest departed +4.1 degrees Celsius (+7.3 degrees Fahrenheit) from normal in January, where mean temperature departures ranged from +2.4 to +5.9 degrees Celsius (+4.4 to +10.6 degrees Fahrenheit). New high temperature records tied or broken on the Pacific Northwest coastal areas and inland such as: 15.0 degrees Celsius (59 degrees Fahrenheit) (tie) at Portland, OR on the 4th, 13.9 degrees Celsius (57 degrees Fahrenheit) at Sea-Tac Airport on the 6th, 8.9 degrees Celsius (48 degrees Fahrenheit) at Missoula, MT on the 25th, 11.7 degrees Celsius (53 degrees Fahrenheit) at Pocatello, ID on the 27th, and 15.6 degrees Celsius (60 degrees Fahrenheit) at Pocatello, ID on the 31st. There were no new low temperature records tied or broken in January.

Early in February the subtropical jet remained positioned across the Southern U.S. leaving the Pacific Northwest under the influence of high pressure and drier than normal weather. The polar jet moved farther south late in the month, allowing a series of frontal systems to bring periods of light to moderate precipitation to the region. February precipitation was: 54 percent of normal at the Columbia River above Grand Coulee, 89 percent of normal at the Snake River above Ice Harbor, and 69 percent at the Columbia River above The Dalles. The seasonal accumulation for the WY remained well below average at the primary indices: 73 percent of normal above Grand Coulee, 87 percent at the Snake River above Ice Harbor, and 80 percent at The Dalles. The temperature index departed slightly above normal.

The month of March 2003 began dry and became wet as the month progressed. A wetter weather regime dominated through the latter part of the month as a ridge of high pressure in the Gulf of Alaska weakened and flow at upper levels became more zonal. Moderate to heavy precipitation events were experienced on the 6th-8th, 12th-14th, and 21st-22nd of March. The change is characterized by the monthly precipitation summary, where: Grand Coulee was 200 percent of normal, The Snake River at Ice Harbor was 134 percent of normal, and The Dalles 175 percent in March. This influenced the seasonal precipitation accumulations October through March: 89 percent of normal above Grand Coulee, 94 percent of normal above Ice Harbor, and 93 percent above The Dalles. The temperature index for the Pacific Northwest departed +0.8 degrees Celsius (+1.5 degrees Fahrenheit) from normal in March.

April remained wet, but cool. April precipitation was: 123 percent of normal above Grand Coulee, 143 percent of normal above Ice Harbor, and 130 percent above The Dalles. The month of April caused additional positive influence to the seasonal precipitation accumulations which were: 92 percent of normal above Grand Coulee, 100 percent of normal above Ice Harbor, and 97 percent above The Dalles. A daily precipitation record was broken in April at Yakima, WA when it received 16.3 mm (0.64 inches) of rain on the 26th. The 31-station temperature index for the Pacific Northwest departed -0.2 degrees Celsius (-0.3 degrees Fahrenheit) from normal relative to the 1971-2000 normals. Mean temperature departures ranged from -1.7 to +1.9 degrees Celsius (-3.0 to +3.4 degrees Fahrenheit).

During the month of May, the region returned to drier and warmer than normal conditions. May precipitation was: 82 percent, 94 percent, and 85 percent of normal at Grand Coulee, Ice Harbor and The Dalles, respectively. The dry conditions in May caused a return to below average seasonal accumulations in the basin: 91 percent of normal (1971-2000) at the Columbia River above Grand Coulee, 99 percent of normal at the Snake River above Ice Harbor, and 95 percent of normal at the Columbia River above The Dalles. The temperature index was near normal with departure of only -0.1 degrees Celsius (-0.1 degrees Fahrenheit) from normal, where mean temperature departures ranged from -1.4 to +1.7 degrees Celsius (-2.5 to +3.0 degrees Fahrenheit). High temperature records broken in May included 31.7 degrees Celsius (89 degrees Fahrenheit) at Pocatello, ID and 36.1 degrees Celsius (97 degrees Fahrenheit) (tie) at Boise, ID on the 24th, 36.1 degrees Celsius (97 degrees Fahrenheit) at Pocatello, ID and 37.2 degrees Celsius (99 degrees Fahrenheit) (tie) at Boise, ID on the 28th, and 35.0 degrees Celsius (95 degrees Fahrenheit) at Boise, ID (tie) and 35.6 degrees Celsius (96 degrees Fahrenheit) at Pocatello, ID on the 29th. Low temperature records broken in May included -0.6 degrees Celsius (31 degrees Fahrenheit) at Pendleton, OR on the 7th, 0.0 degrees Celsius (32 degrees Fahrenheit) at Pendleton, OR on the 8th; 4.4 degrees Celsius (40 degrees Fahrenheit) at Seattle, WA on the 16th; -3.9 degrees Celsius (25 degrees Fahrenheit) at Kalispell, MT and -1.7 degrees Celsius (29 degrees Fahrenheit) at Yakima, WA on the 17th; 2.8 degrees Celsius (37 degrees Fahrenheit) at Seattle, WA, and 3.3 degrees Celsius (38 degrees Fahrenheit) at Portland, OR on the 18th; -5.0 degrees Celsius (23 degrees Fahrenheit) at Pocatello, ID, -0.6 degrees Celsius (31 degrees Fahrenheit) at Pendleton, OR, 0.0 degrees Celsius (32 degrees Fahrenheit) at Spokane, WA, and 4.4 degrees Celsius (40 degrees Fahrenheit) at Portland, OR on the 19th; and -5.0 degrees Celsius (23 degrees Fahrenheit) at Pocatello, ID on the 20th. Seasonal snowpack accumulation at the Columbia River above The Dalles is shown in Chart 2. Seasonal below average precipitation has resulted in below average snowpack.

The month of June kept the region in a dry warm weather pattern. June was drier than May with precipitation of: 69 percent of normal above Grand Coulee, 38 percent of normal above Ice Harbor, and 50 percent above The Dalles. This again brought the seasonal average precipitation accumulations down to: 88 percent above Grand Coulee, 93 percent above Ice Harbor, and 91 percent above The Dalles. The dry conditions were accentuated by new record low precipitation for the entire month at Pendleton, OR and Yakima, WA where only a trace of precipitation fell. The warm conditions were quantified by a temperature index departure of +1.2 degrees Celsius (+2.2 degrees Fahrenheit) from normal in June. Some high temperature records in June were 32.8 degrees Celsius (91 degrees Fahrenheit) on the 4th and 35.6 degrees Celsius (96 degrees Fahrenheit) on the 5th at Portland, OR, and 34.4 degrees Celsius (94 degrees Fahrenheit) (tie) at Pendleton, OR on the 7th.

July was very dry. July precipitation was: 18 percent of normal (1971-2000) at the Columbia River above Grand Coulee, 36 percent of normal at the Snake River above Ice Harbor, and 20 percent of normal at the Columbia River above The Dalles. This further reduced the seasonal accumulated precipitation to: 83 percent of normal (1971-2000) at the Columbia River above Grand Coulee, 90 percent of normal at the Snake River above Ice Harbor, and 87 percent of normal at the Columbia River above The Dalles. July temperature departures remained above normal at +2.7 degrees Celsius (+4.9 degrees Fahrenheit).

August continued very dry and warm. The precipitation was only 32 percent, 107 percent and 56 percent of normal at Grand Coulee, Ice harbor and The Dalles, respectively. Although Ice Harbor precipitation was 107 percent of normal, normal precipitation is only 21.8 mm (0.86 inches) during August. Seasonal precipitation from

October 2002 through August 2003 continued below average across the basin at: 79 percent of normal above Grand Coulee, 91 percent of normal above Ice Harbor, and 85 percent above The Dalles. The 31-station temperature index for the Pacific Northwest departed +1.7 degrees Celsius (+3.0 degrees Fahrenheit) from normal relative to the 1971-2000 normals. Mean temperature departures ranged from -0.2 to +3.7 degrees Celsius (-0.3 to +6.7 degrees Fahrenheit). High temperature records tied or broken in August included 37.2 degrees Celsius (99 degrees Fahrenheit) at Kalispell, MT and 37.8 degrees Celsius (100 degrees Fahrenheit) at Pocatello, ID on the 10th, and 37.2 degrees Celsius (99 degrees Fahrenheit) at Pocatello, ID on the 13th.

In September, the upper level high held for at least part of the month, but the storm track punched inland temporarily. This allowed a series of fronts to bring some precipitation into portions of the basin. Precipitation was 92 percent of normal at the Columbia River above Grand Coulee and 83 percent of normal at the Columbia River above The Dalles. September was a warm month, with record high temperatures at Portland of 35 degrees Celsius (95 degrees Fahrenheit) and Pendleton of 37.8 degrees Celsius (100 degrees Fahrenheit). The 31-station temperature index for the Basin departed +1.3 degrees Celsius (+2.3 degrees Fahrenheit).

2. Snowpack

The 2003 Columbia Basin snowpack started out very low on the first of January. The snow conditions were below last year's nearly average snowpack and reminiscent of 2001, which produced record and near record minimums over the basin. This makes two low years out of the last three.

The Columbia Basin snowpack index increased to 78 percent of average on February 1, compared to 70.6 percent of average on January 1, and 109.8 percent last year. January experienced above average precipitation
over much of the northern portion of the basin. However, that was countered by very dry conditions over the southern portion.

The Columbia Basin snowpack index decreased to 74 percent on March 1, compared to 78 percent on February 1 and 107 percent last year. The March 1 snowpack index for the Columbia Basin above The Dalles was down 2 percent from February 1. In general, basin snowpack percent of seasonal averages declined in the U.S., reflecting a dry second half of February. In summary, the March 1 Columbia Basin snowpack index above Castlegar was 119 percent of average, above Grand Coulee was 113 percent, the Snake was at 93 percent, and above The Dalles, it was 107 percent of average.

The Columbia Basin snowpack above The Dalles increased to 86 percent of average on April 1, compared to 74 percent on March 1. The snowpack above Castlegar increased to 83 percent, up 11 percent from March 1. The snowpack above Grand Coulee increased to 85 percent, up 13 percent from March 1. The Snake River snowpack above Ice Harbor increased to 94 percent, up 14 percent from March 1.

Essentially, the Columbia Basin snowpack above The Dalles remained unchanged from last month. The Columbia snowpack now stands at 89 percent of average. The snowpacks in the Columbia sub-basins also increased slightly. The snowpack above Castlegar is at 87 percent, above Grande Coulee at 88 percent and above Ice Harbor at 98 percent. The percent of peak index at The Dalles decreased from 86 percent to 84 percent of average.

For information about snowpack measurements including that needed to develop the Oregon Surface Water Supply Index or SWSI for Table 4, see the NRCS National Water & Climate Center web site at http://www.or.nrcs.usda.gov/snow/watersupply/swsi.html .

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).

For monthly information about the Oregon SWSI for the years 1997 to 2003, see the web site at: http://www.or.nrcs.usda.gov/snow/watersupply/swsi.html. For pertinent information about the Idaho SWSI for water year 2003, see the web site at: http://www.id.nrcs.usda.gov/snow/watersupply . (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 this information, data from 10 index gages, on both uncontrolled and controlled streams, were used to summarize the flows throughout the region. Data from all gages are reported with observed flows and are not adjusted for the amount of storage. Monthly mean discharges for each of these index stations, expressed as a percentage of their 1971-2000 normal discharges, are shown in Table 5 . Flood peaks will be discussed in Section 5.

The annual mean streamflows throughout the Columbia River Basin for WY 2003 were near or below normal for most of the index sites. The Snake River Basin index sites continued with the third straight year of below normal streamflow. The index station with the highest mean annual discharge, in percent of normal, was the Clearwater River at Spalding, Idaho, with 96%, and the lowest was the Snake River at Weiser, Idaho, with 60%.

Below normal streamflows were reported at 8 out of 10 index gages for October. By December all 10 index gages in the Columbia River Basin were reporting below normal flows. Snowpack remained sparse through the end of February for most of the basin. A wet and cool March and April improved the snowpack and streamflow in the eastern part of the basin but remained far below normal for most of Oregon and southern Idaho. Monthly mean streamflows for April were at or above normal for 8 out of 10 index gages with the notable exception of the 2 index gages in the Snake River Basin, which were less than 45% of normal for the month. Late spring and summer precipitation were below normal for most of the Columbia River Basin. Streamflows tapered off from their normal ranges, and by September the monthly means were below normal for most of the index gages.

Tables 6, 7, 8, 9, and 10 show additional comparisons of WY 2003 observed streamflows and runoff with historical flows. The Snake River at Anatone had a record low November and December mean observed streamflow for the period of record.

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 that 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 (http://www.nws.noaa.gov/forecasts.html). 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 both January 1 and April 1, Table 13, indicated near normal runoff conditions could be expected from most sub-basins. Slightly above average runoff was forecast for streams draining from the Rocky Mountains into the upper Columbia River Basin, and below average runoff was forecast for the lower Snake River basin. Tables 14 displays the monthly forecasts at key sites and their verification. Table 15 shows the history of forecasts of the January-July runoff of the Columbia River at The Dalles for the period 1970-2003. 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-2000 adjusted runoff for the Dalles was 98.0 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.

For information about water supply streamflow products posted by NRCS, National Water & Climate Center, see the NRCS web site at http://www.wcc.nrcs.usda.gov/water/w_qnty.html. Products for this web site include streamflow color graphics maps and forecast probability charts.

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 that 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.

3. Daily Streamflows

The forecasts of operational streamflow were prepared by the NWRFC. The three operating agencies, Bureau of Reclamation, Bonneville Power Administration, 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.