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 2003 through the September 2004 water year. Figure 7 denotes the monthly accumulation of the Columbia Basin snowpack for Water Year 2004 expressed as a percent of normal peak snowpack. Figure 8 denotes the accumulated precipitation in inches for the Water 2004 at primary Columbia River basins. Figure 9 is a map of the Pacific Northwest monthly temperature departures from normal for the month of December 2003.

After a very warm and dry summer, fall 2003 opened on a cooler note, with October and November precipitation above normal in Canada and across northern Idaho and western Washington. All other areas carried on the theme of the summer, with below normal precipitation amounts. For October through November, precipitation was 92 percent of normal at Columbia above Grand Coulee, 60 percent of normal at the Snake River above Ice Harbor, and 83 percent of normal at Columbia above The Dalles. A continental airmass entered the region mainly late in October, bringing colder than normal temperatures, and drier conditions in northern regions. This pattern held through November, producing many low temperature records, some of which occurred in several spots west of the Cascades. Although not a record, Spokane registered -22.8 degC (–9 degF) on 22 November 2003. For the lead fall months, regional temperatures departed +6.8 degC (+3.7 degF). Warmer weather was on the way, though, as the storm track changed into December, bringing more maritime air to the region, and consequently wetter weather.

Most of December was wetter-than-normal as this maritime, westerly flow brought in frequent fronts. The core of the storm track ran across the U.S. part of the basin, rather than in Canada. As such, precipitation was 131 percent of normal at the Snake River above Ice Harbor, 98 percent of normal at Columbia above The Dalles, but 73 percent of normal at Columbia above Grand Coulee. While much of the month was mild, another cold,

continental airmass moved south into the region later in the month. It combined with the antecedent moist flow to bring snow into the Willamette Valley, the north Oregon Coast, and through western Washington. Thus began a turn toward a very cold start to winter, even though the mild part of the month was sufficient to skew December's regional departures to +5.2 degC (+2.9 degF).

The cold airmass of December opened up 2004 with arctic air that further dropped regional temperatures. Snow remained on the ground for several days in Portland and Seattle, and an ice storm plagued Portland. The pattern shifted about mid-January through its end. This change brought warmer and wetter weather, with several daily precipitation records: 45 mm (1.76 inches) at Olympia, 65 mm 2.59 inches) at Astoria, and 41 mm (1.63 inches) at Seattle. Overall precipitation was 106 percent of normal at Columbia above Grand Coulee, 104 percent of normal at the Snake River above Ice Harbor, and 101 percent of normal at Columbia above The Dalles. January's regional temperature departures were -0.2 degC (-0.1 degF), but were not indicative of the mean swing from -8.8 degC (–4.9 degF) to +9.5 degC (+5.3 degF), brought about by the weather pattern change. The cold air of January settled in deeply over southern Idaho through to the Great Basin, and resulted in much below normal temperatures for February, thanks to strong temperature inversions. High pressure, that caused these inversions, resulted in below normal precipitation for the southern and Canadian basins in February. Most of the rain and snow fell about mid month, due to a series of cold fronts in a westerly flow targeted over mainly the central regions, containing the Clearwater, Lower Granite, and Lower Snake districts.

The fronts brought the monthly precipitation to only 54 percent of normal at the Columbia above Grand Coulee, 95 percent of normal at the Snake River above Ice Harbor, and 72 percent of normal at Columbia above The Dalles. Temperature departures were -1.8 degC (-1.0 degF), with mean departures ranging from -13.5degC (–7.5 degF) to +8.1 degC (+4.5 degF). The higher sun angle of late February through early March easily broke the temperature inversions, and combined with the development of a high-pressure area in the upper air, resulted in warmer-than-normal temperatures for March. The upper level high was effective in detouring and/or weakening fronts as they moved inland. March precipitation was therefore below average, registering 83 percent of normal at Columbia above Grand Coulee, 40 percent of normal at the Snake River above Ice Harbor, and 94 percent of normal at Columbia above The Dalles. The monthly, regional temperature departure reflected the upper air pattern: +7.2 degC (+4.0 degF), with record high temperatures at several locations. Some daily readings were all-time March records, such as 26 degC (78 degF) at Missoula on the 30th. At the same time that the high developed over a large part of the western U.S., a very strong low developed east of the Rockies. Although this pattern broke somewhat in April, and more so in May, it returned toward summer, and held for most of that season. In April a few strong fronts dented the upper high, and precipitation crept close to normal.

April precipitation was 77 percent of normal at Columbia above Grand Coulee, 70 percent of normal at the Snake River above Ice Harbor, and 72 percent of normal at Columbia above The Dalles. The effective precipitation occurred mainly in mid-month, with drier conditions prevailing at it's start and close. Regional temperatures departed +5.2 degC (+2.9 degF), with another set of daily record readings, notably 24 degC (75 degF) on the 30th at Astoria. Wetter, yet continued mild, weather came in May, as at least two upper level low pressure troughs moved through the region, further caving in the once-established upper high. Warmer-than-normal offshore water temperatures likely helped keep nighttime minima above normal. This, coupled with the onshore flow brought about by these transient upper troughs, resulted in quite a bit of cloud cover and precipitation. May was a boost to streamflows, with its precipitation at 124 percent of normal at Columbia above Grand Coulee, 145 percent of normal at the Snake River above Ice Harbor, and 140 percent of normal at Columbia above The Dalles. A daily rainfall record was set at Spokane on the 21st, with 56 mm (2.19 inches).

The regional temperature departure was close to normal, at +0.5 degC (+0.3 degF), with some chilly readings in western Montana helping to skew the values. The upper air high that weakened from its March strength, regained footing in June, although not of the caliber from June of 2003. Nonetheless, the strengthening of the ridge, and the locking-in of low pressure, once again, east of the Rockies signaled a turn toward warmer and drier weather, especially mid to late in the month. As such, June precipitation was 79 percent of normal at Columbia

above Grand Coulee, 97 percent of normal at the Snake River above Ice Harbor, and 92 percent of normal at Columbia above The Dalles. A strong and wet thunderstorm pattern resulted in these higher values for the Snake River above Ice Harbor. Some studies have shown that with warmer-than-normal water temperatures in the eastern Gulf of Alaska, the Pacific Northwest often experiences an above normal warm-season of severe weather, containing strong storms. These patterns are often characterized by above normal temperatures, in part again held up due to warmer minimum temperatures. For June, regional temperatures departed +2.7 degC (+1.5 degF). Summer began warm, extending through its first full month of July, with only a temporary low-pressure trough bringing another round of strong and wet thunderstorms to the same regions as that in June.

As a result, July precipitation was greatest, relative to normal, above Ice Harbor at the Snake River, with 96 percent of normal. At Columbia above Grand Coulee, it totaled 77 percent of normal, and 76 percent of normal at Columbia above The Dalles. Along with the frequent thunderstorms and severe weather, the biggest story of July was the warmth, resulting in record high temperatures. These included readings for the 23rd: 36 degC (96 degF) at Astoria and 39 degC (103 degF) at Portland. Overall, the Basin's temperatures departed +5.4 degC (+3.0 degF), with continued above normal overnight readings, and a general increase in relative humidity readings. The pattern remained largely unchanged through much of August, until the onset of the first few Atlantic hurricanes, and an active west Pacific typhoon cycle set the stage for a wet turnaround later in August.

A burst of precipitation occurred between the 20th and 28th of August, elevating totals to above normal, and causing rises in streamflows. In a normally very dry month in most sectors, the resultant breakdown was impressive: 195 percent of normal at Columbia above Grand Coulee, 192 percent of normal at Snake above Ice Harbor, and 204 percent of normal at Columbia above The Dalles. August had many record precipitation events, within a nine-day period. Some of these included 27mm (1.07 inches) at Missoula, and 13 mm (0.51 inches) at Yakima. August regional temperatures departed +3.8 degC (+2.1 degF), but cooler conditions were on the way, as this shift in the weather pattern led to the development of an upper level low-pressure trough close to the Pacific Northwest to open September. In September, temperatures departed roughly -3.6 degC (–2.0 degF), and regional precipitation ran near to slightly above normal, especially after storms in the first five days of the month.

2. Snowpack

The Columbia Basin snowpack was 66 percent of average on May 1! This compares to 85 percent of average on April 1 and 89 percent of last year. The overall snowpack is at 63 percent of the average peak accumulation, compared to 84 percent last year. Hot and dry characterizes the weather pattern we have been in over the last two months. Most of the basin has received very little precipitation during March and April. And to top that off, the snowmelt started early over much of the basin; a result of much above normal temperatures. As a result, much of the mountain snowpack declined in record proportions. The Snake has been especially hard hit by the hot, dry weather. While there have been some modest rises in the streamflow levels, most streams and rivers are below median levels. With poor remaining snowpacks, expected Spring and Summer runoff could be very low. Not a basin was spared from the onslaught of hot and dry weather. The basin snowpack above Castlegar declined from 87 percent to 71 percent of average. The basin snowpack above Grand Coulee declined from 85 percent to 70 percent of average. And worst of all... the Snake snowpack plunged from 84 percent of average on April 1 to 60 percent of average on May 1.

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 2004, 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 2004, 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. Mean monthly 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 2004 were near or below normal for most of the index sites. The Snake River Basin index sites continued with the fourth straight year of below normal streamflow. The index station with the highest mean annual discharge, in percent of normal, was the John Day River at Service Creek, Oregon with 90%, and the lowest was the Snake River at Weiser, Idaho, with 56%.

Below normal streamflows were reported at 7 out of 10 index gages for October. By January, 9 out of 10 index gages in the Columbia River Basin were reporting below normal flows. Snowpack in the basin was at or above normal levels at the end of February but an earlier than normal snowmelt eroded the snowpack in April and May. Mean monthly streamflows for April were at or above normal for 6 out of 10 index gages, with the notable exception of the 2 index gages in the Snake River Basin, where streamflow was less than 42% of normal for the month. A wet May helped maintain streamflows, which were already showing signs of being below normal due in part to the early snowmelt. Mean monthly streamflows in July were below normal for most of the index sites, but greater than normal precipitation in late summer boosted streamflow levels throughout the Columbia River Basin. By September, the mean monthlies were at or above normal for most of the index gages.

Tables 6, 7, 8, 9, and 10 show additional comparisons of WY 2004 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

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.