II. HYDROMETEOROLOGY

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. Meteorology

Water Year 97 was preceded by a pleasant summer across the Columbia Basin the result of an upper atmosphere pressure ridge along the west coast that dominated the weather patterns. This warm and generally dry weather gradually faded away as the ridge gave way to occasional minor weather disturbances which brought scattered showers to the region. This weather pattern continued until mid-October when a low pressure system stalled in the Gulf of Alaska, sending a series of storms into the Northwest, and beginning the snow accumulation season. Seasonal weather continued through mid-November when the first major storm of the water year moved through the Northwest. During November 18-19, a strong and very wet airmass tracked through the region producing two-day total rainfall amounts of between 10 and 14 inches at a few sites in southwestern Oregon, more than 6 inches covered large sections of western Oregon and the southern Cascades, and more than 2 inches across much of northern Idaho, northern and western Oregon, and southwestern Washington. As the rainfall slackened during the days following the storm peak, the moist airmass began mixing with significantly cooler Arctic air that had infiltrated the basin, resulting in some heavy snowfall at middle and upper elevations in the mountain and scattered ice pellets and freezing rain in northeastern Washington and northern Idaho. Moderate but steady precipitation continued until Christmas when heavy rainfall again visited the region as a weather pattern, with its moisture source in the central equatorial Pacific, sent a series of warm and wet storm systems into the Northwest that lasted through New Years Day. The warm and wet winds of this Pineapple Express reacted with the heavy snowpack to generate a pronounced snowmelt, mostly from low elevation snowpacks, which, together with the rainfall, produced widespread flooding in Washington, Oregon, and Idaho. Light to moderate precipitation returned in early January and continued intermittently through March.

On April 1, the snowmelt season began with little low elevation snow; the snowpack that existed prior to the New Years floods was never fully replaced in the western drainages. During April the region near the Continental Divide suffered from very cold weather as a Yukon airmass swept into western Montana where it collided with marine air to produce record snowfall at both Missoula and Kalispell. Other parts of the Northwest continued to be subjected to scattered showers for the rest of the month which continuing into early May. Late April weather was accented by two unusual storms: the remnants of typhoon Esa and the remnants of tropical storm Jimmy, which produced record daily rainfall at many stations. By May 8, a strong high pressure ridge developed, drawing warm air into the region, resulting in rapid snowmelt and flooding in the Clark Fork, Yaak, Fisher, Pend Oreille, Spokane, Tonasket, Yakima and Snake basins. By the last week of the month the high pressure system was replaced by westerly flow that produced rain showers throughout the basin. June saw a continuation of the unsettled weather except for a warm spell in the upper Snake basin which produced major snowmelt-driven flooding near mid-month. During early July, a deep, persistent, and unseasonable upper atmospheric low pressure system established itself in the Gulf of Alaska which set up a west-southwesterly flow

Table 1

MONTHLY PRECIPITATION TOTALS BY SUB-BASIN -- WY 97

(With Percentages of Normal)

SUB-BASINS	UNITS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Columbia ab Grand Coulee	**in.**	**2.48**	**3.69**	**4.95**	**3.23**	**1.44**	**3.15**	**1.72**	**2.16**	**2.72**	**2.42**	**1.29**	**2.77**
	%	140	135	160	107	69	176	108	102	116	151	77	161
Snake R ab Ice Harbor	**in.**	**1.24**	**2.52**	**5.29**	**3.26**	**0.90**	**1.43**	**1.80**	**1.41**	**1.69**	**1.89**	**0.98**	**1.31**
	%	104	130	261	156	58	89	126	82	105	233	102	113
Columbia ab The Dalles	**in.**	**2.14**	**3.53**	**5.88**	**3.68**	**1.52**	**2.89**	**1.95**	**1.76**	**2.03**	**2.08**	**0.99**	**2.10**
	%	130	129	195	124	72	153	122	96	112	191	80	150
Columbia ab Castlegar	**in.**	**3.35**	**3.68**	**4.88**	**5.02**	**2.23**	**4.19**	**2.02**	**2.02**	**3.26**	**4.34**	**1.64**	**4.88**
	%	123	101	113	119	76	180	105	93	118	177	69	204
Kootenai	**in.**	**2.78**	**4.23**	**5.57**	**3.27**	**1.01**	**3.86**	**1.71**	**2.11**	**2.67**	**2.11**	**0.96**	**3.44**
	%	159	146	172	107	50	226	106	103	112	125	58	197
Clark Fork	**in.**	**0.97**	**2.74**	**5.23**	**2.21**	**1.07**	**1.60**	**1.51**	**2.18**	**2.49**	**1.81**	**1.00**	**1.13**
	%	88	170	284	108	80	123	122	112	128	174	76	87
Flathead	**in.**	**2.36**	**3.99**	**5.47**	**2.44**	**1.80**	**3.03**	**1.60**	**2.69**	**3.11**	**1.27**	**1.84**	**2.24**
	%	148	171	220	97	98	180	102	112	118	89	117	125
Pend Oreille-Spokane	**in.**	**4.05**	**5.48**	**7.25**	**3.72**	**3.00**	**4.34**	**3.07**	**2.61**	**1.99**	**2.26**	**0.94**	**2.26**
	%	196	139	181	93	101	159	144	117	98	222	70	145
Northeast Washington	**in.**	**2.56**	**3.16**	**3.98**	**2.48**	**1.17**	**2.17**	**1.74**	**2.71**	**2.51**	**1.76**	**1.02**	**2.67**
	%	223	138	161	133	77	144	129	146	147	164	84	290
Okanogan	**in.**	**1.66**	**2.17**	**3.51**	**1.86**	**0.74**	**1.21**	**0.96**	**1.72**	**2.57**	**2.11**	**0.67**	**2.64**
	%	187	139	168	106	59	117	97	133	187	209	58	264
E Slope Wash Cascades	**in.**	**4.75**	**7.08**	**13.00**	**8.43**	**3.62**	**8.85**	**2.93**	**1.37**	**1.65**	**1.16**	**0.63**	**3.21**
	%	178	119	183	120	78	260	139	94	135	176	65	221
Central Washington	**in.**	**1.36**	**1.74**	**3.67**	**1.42**	**0.73**	**1.05**	**0.69**	**0.68**	**0.65**	**0.50**	**0.30**	**0.60**
	%	247	140	266	139	92	138	110	98	116	171	72	135
Upper Snake	**in.**	**1.15**	**2.67**	**5.97**	**3.78**	**1.63**	**1.87**	**1.85**	**2.70**	**2.33**	**2.66**	**1.88**	**1.87**
	%	79	132	284	164	93	115	115	124	116	208	137	115
Snake River Plain	**in.**	**0.72**	**1.52**	**3.34**	**1.99**	**0.21**	**0.55**	**1.10**	**0.90**	**1.47**	**1.00**	**0.72**	**1.39**
	%	89	128	309	185	25	54	107	68	133	169	102	164
Owyhee-Malheur	**in.**	**0.89**	**1.26**	**3.41**	**2.77**	**0.20**	**0.44**	**1.24**	**0.92**	**1.25**	**0.94**	**0.20**	**0.60**
	%	116	93	257	227	21	41	136	78	112	199	32	94
Salmon-Boise-Payette	**in.**	**1.51**	**3.29**	**7.68**	**3.96**	**0.93**	**1.38**	**1.86**	**0.94**	**1.65**	**1.55**	**0.95**	**1.23**
	%	114	131	289	145	48	72	123	60	106	224	113	107
Burnt-Grande Ronde	**in.**	**1.44**	**2.58**	**4.45**	**2.22**	**0.77**	**1.00**	**2.11**	**0.97**	**1.25**	**1.97**	**0.33**	**0.89**
	%	131	134	221	114	57	71	171	65	88	298	36	97
Clearwater	**in.**	**2.88**	**4.32**	**7.23**	**5.09**	**2.86**	**4.80**	**4.42**	**2.19**	**1.99**	**3.72**	**1.26**	**2.42**
	%	133	132	200	130	100	162	169	78	80	332	95	129
Southeast Washington	**in.**	**2.63**	**3.61**	**5.33**	**2.70**	**1.64**	**2.37**	**2.45**	**1.65**	**0.91**	**1.21**	**0.23**	**0.97**
	%	204	170	191	171	157	152	154	149	143	145	140	138
Upper John Day	**in.**	**1.31**	**2.41**	**3.57**	**2.24**	**0.62**	**0.81**	**1.88**	**0.75**	**1.24**	**1.74**	**0.11**	**0.79**
	%	125	128	189	134	51	60	161	52	97	280	13	99
Umatilla-Lwr John Day	**in.**	**1.82**	**3.50**	**3.45**	**1.85**	**1.30**	**2.17**	**2.31**	**0.87**	**1.65**	**0.86**	**0.22**	**1.00**
	%	160	162	165	94	88	141	163	66	153	187	31	123
Upr Deschutes-Crooked	**in.**	**0.99**	**3.78**	**5.68**	**2.42**	**0.86**	**0.65**	**1.42**	**0.65**	**1.27**	**1.16**	**0.51**	**1.00**
	%	102	172	248	115	60	49	165	70	137	226	76	156
Hood-Lower Deschutes	**in.**	**3.50**	**7.58**	**10.47**	**5.03**	**2.36**	**3.67**	**2.90**	**1.09**	**1.27**	**0.59**	**0.83**	**1.35**
	%	180	174	215	109	73	133	147	76	115	144	109	109
NW Slope Wash Cascades	**in.**	**12.22**	**14.03**	**16.69**	**16.34**	**9.57**	**18.88**	**8.24**	**4.87**	**6.31**	**3.81**	**1.37**	**7.64**
	%	166	113	129	122	98	220	133	109	184	193	57	175
SW Slope Wash Cascades	**in.**	**9.36**	**12.29**	**20.08**	**12.89**	**6.94**	**13.70**	**6.93**	**4.29**	**4.18**	**1.94**	**2.12**	**5.91**
	%	173	119	183	116	85	195	139	123	147	153	114	183
Willamette	**in.**	**8.13**	**14.13**	**21.27**	**10.54**	**4.69**	**9.88**	**5.92**	**3.19**	**2.72**	**0.97**	**1.50**	**3.99**
	%	193	153	222	118	69	153	138	102	133	131	125	175
Rogue-Umpqua	**in.**	**4.47**	**7.99**	**16.76**	**7.04**	**2.63**	**3.47**	**3.15**	**1.62**	**2.13**	**0.22**	**1.25**	**2.04**
	%	167	130	276	132	64	86	130	96	239	62	165	166
Klamath	**in.**	**1.49**	**3.37**	**8.56**	**4.10**	**1.37**	**0.96**	**1.83**	**0.59**	**1.18**	**0.80**	**0.85**	**1.17**
	%	109	122	282	158	73	50	181	60	138	199	129	167
Lake County-Goose Lk	**in.**	**0.94**	**1.79**	**3.15**	**2.90**	**1.14**	**0.46**	**1.27**	**0.71**	**1.01**	**0.71**	**0.15**	**0.54**
	%	98	113	192	200	110	39	128	59	87	166	24	87
Harney Basin	**in.**	**0.86**	**1.55**	**2.87**	**2.61**	**0.41**	**0.34**	**2.04**	**1.60**	**0.86**	**0.93**	**0.27**	**0.49**
	%	98	102	184	207	42	29	240	143	88	207	39	73

Table 2

ACCUMULATED MONTHLY PRECIPITATION TOTALS BY SUB-BASINS -- WY 97

(With Percentages of Normal)

SUB-BASINS	UNITS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Columbia abv Grand Coulee	**in.**	**2.48**	**6.17**	**11.12**	**14.35**	**15.79**	**18.94**	**20.66**	**22.82**	**25.54**	**27.96**	**29.25**	**32.02**
	%	140	137	146	135	124	130	128	125	124	126	122	125
Snake abv Ice Harbor	**in.**	**1.24**	**3.76**	**9.05**	**12.31**	**13.21**	**14.64**	**16.44**	**17.84**	**19.53**	**21.42**	**22.40**	**23.71**
	%	104	120	175	170	150	141	139	132	129	134	132	131
Columbia abv The Dalles	**in.**	**2.14**	**5.66**	**11.54**	**15.22**	**16.75**	**19.63**	**21.58**	**23.34**	**25.36**	**27.44**	**28.43**	**30.53**
	%	130	130	156	147	135	137	135	131	130	133	130	131
Columbia abv Castlegar	**in.**	**3.35**	**7.02**	**11.91**	**16.92**	**19.15**	**23.35**	**25.37**	**27.39**	**30.65**	**34.99**	**36.63**	**41.51**
	%	123	110	111	114	107	116	115	113	113	119	115	121
Kootenai	**in.**	**2.78**	**7.00**	**12.57**	**15.84**	**16.85**	**20.71**	**22.42**	**24.53**	**27.20**	**29.31**	**30.27**	**33.70**
	%	159	151	160	145	130	141	138	134	131	131	126	131
Clark Fork	**in.**	**0.97**	**3.71**	**8.94**	**11.15**	**12.21**	**13.81**	**15.32**	**17.50**	**20.00**	**21.81**	**22.81**	**23.94**
	%	88	137	196	169	154	150	147	141	139	142	136	133
Flathead	**in.**	**2.36**	**6.35**	**11.83**	**14.27**	**16.07**	**19.10**	**20.69**	**23.38**	**26.50**	**27.77**	**29.61**	**31.85**
	%	148	162	184	160	149	154	148	142	139	136	134	134
Pend Oreille-Spokane	**in.**	**4.05**	**9.53**	**16.78**	**20.50**	**23.50**	**27.84**	**30.92**	**33.53**	**35.52**	**37.78**	**38.72**	**40.98**
	%	196	159	168	146	138	141	141	139	136	139	136	136
Northeast Washington	**in.**	**2.56**	**5.72**	**9.70**	**12.18**	**13.35**	**15.52**	**17.26**	**19.97**	**22.48**	**24.24**	**25.26**	**27.92**
	%	223	167	164	157	144	144	142	143	143	145	140	148
Okanogan	**in.**	**1.66**	**3.84**	**7.34**	**9.20**	**9.94**	**11.16**	**12.11**	**13.84**	**16.41**	**18.52**	**19.19**	**21.83**
	%	187	156	161	146	132	130	126	127	134	139	133	141
E Slope Wash Cascades	**in.**	**4.75**	**11.82**	**24.82**	**33.25**	**36.87**	**45.72**	**48.65**	**50.02**	**51.67**	**52.83**	**53.45**	**56.66**
	%	178	137	158	146	135	148	148	146	145	146	144	147
Central Washington	**in.**	**1.36**	**3.10**	**6.77**	**8.19**	**8.92**	**9.97**	**10.67**	**11.34**	**11.99**	**12.49**	**12.79**	**13.38**
	%	247	173	214	196	179	173	167	160	157	158	153	152
Upper Snake	**in.**	**1.15**	**3.82**	**9.79**	**13.58**	**15.20**	**17.07**	**18.93**	**21.62**	**23.95**	**26.61**	**28.49**	**30.36**
	%	79	109	175	172	158	151	147	144	140	145	145	142
Snake River Plain	**in.**	**0.72**	**2.25**	**5.59**	**7.58**	**7.79**	**8.35**	**9.45**	**10.35**	**11.83**	**12.82**	**13.55**	**14.94**
	%	89	112	181	182	155	138	134	123	124	127	125	128
Owyhee-Malheur	**in.**	**0.89**	**2.15**	**5.57**	**8.33**	**8.53**	**8.97**	**10.21**	**11.13**	**12.38**	**13.32**	**13.51**	**14.12**
	%	116	101	161	178	152	134	134	127	125	129	123	122
Salmon-Boise-Payette	**in.**	**1.51**	**4.80**	**12.47**	**16.43**	**17.36**	**18.73**	**20.59**	**21.53**	**23.18**	**24.73**	**25.68**	**26.91**
	%	114	125	192	178	155	143	141	133	131	134	133	132
Burnt Grande Ronde	**in**	**1.44**	**4.02**	**8.47**	**10.69**	**11.46**	**12.46**	**14.56**	**15.53**	**16.78**	**18.75**	**19.07**	**19.97**
	%	131	133	168	153	137	128	133	125	121	129	124	122
Clearwater	**in.**	**2.88**	**7.19**	**14.43**	**19.51**	**22.37**	**27.17**	**31.60**	**33.79**	**35.77**	**39.49**	**40.75**	**43.17**
	%	133	132	159	150	141	144	148	140	134	142	140	139
Southeast Washington	**in.**	**2.63**	**6.24**	**11.57**	**14.28**	**15.92**	**18.29**	**20.75**	**22.39**	**23.30**	**24.51**	**24.74**	**25.71**
	%	204	170	191	171	157	152	154	149	143	145	140	138
Upper John Day	**in.**	**1.31**	**3.73**	**7.30**	**9.54**	**10.16**	**10.96**	**12.85**	**13.60**	**14.84**	**16.57**	**16.69**	**17.48**
	%	125	127	151	147	132	121	126	117	115	122	116	115
Umatilla-Lower John Day	**in.**	**1.82**	**5.32**	**8.77**	**10.62**	**11.92**	**14.08**	**16.39**	**17.26**	**18.91**	**19.77**	**19.99**	**20.98**
	%	160	161	163	144	135	136	139	132	133	135	130	130
Upper Deschutes-Crooked	**in.**	**0.99**	**4.77**	**10.44**	**12.86**	**13.72**	**14.37**	**15.79**	**16.44**	**17.71**	**18.87**	**19.38**	**20.39**
	%	102	150	191	170	152	139	141	136	136	139	136	137
Hood-Lower Deschutes	**in.**	**3.50**	**11.08**	**21.54**	**26.58**	**28.94**	**32.61**	**35.51**	**36.60**	**37.87**	**38.46**	**39.29**	**40.63**
	%	180	176	193	168	152	150	149	145	144	144	143	142
NW Slope Wash Cascades	**in.**	**12.22**	**26.25**	**42.94**	**59.29**	**68.85**	**87.73**	**95.97**	**100.84**	**107.15**	**110.96**	**112.34**	**119.98**
	%	166	133	131	128	123	136	136	134	136	138	135	137
SW Slope Wash Cascades	**in.**	**9.36**	**21.65**	**41.73**	**54.62**	**61.56**	**75.26**	**82.19**	**86.48**	**90.66**	**92.60**	**94.72**	**100.63**
	%	173	138	156	145	134	142	142	141	141	141	141	142
Willamette	**in.**	**8.13**	**22.26**	**43.53**	**54.08**	**58.76**	**68.65**	**74.57**	**77.75**	**80.47**	**81.44**	**82.94**	**86.93**
	%	193	165	189	169	151	152	151	148	147	147	146	148
Rogue-Umpqua	**in.**	**4.47**	**12.46**	**29.22**	**36.27**	**38.90**	**42.37**	**45.51**	**47.13**	**49.26**	**49.49**	**50.74**	**52.78**
	%	167	141	196	179	160	149	148	145	147	147	147	148
Klamath	**in.**	**1.49**	**4.86**	**13.43**	**17.53**	**18.90**	**19.86**	**21.69**	**22.28**	**23.46**	**24.26**	**25.12**	**26.29**
	%	109	118	187	179	162	146	149	143	143	144	144	145
Lake County-Goose Lake	**in.**	**0.94**	**2.73**	**5.88**	**8.78**	**9.92**	**10.38**	**11.65**	**12.37**	**13.38**	**14.09**	**14.24**	**14.77**
	%	98	107	141	156	149	133	132	123	120	121	116	115
Harney Basin	**in.**	**0.86**	**2.41**	**5.28**	**7.89**	**8.30**	**8.64**	**10.68**	**12.28**	**13.14**	**14.07**	**14.34**	**14.83**
	%	98	100	133	151	134	117	130	132	128	131	125	122

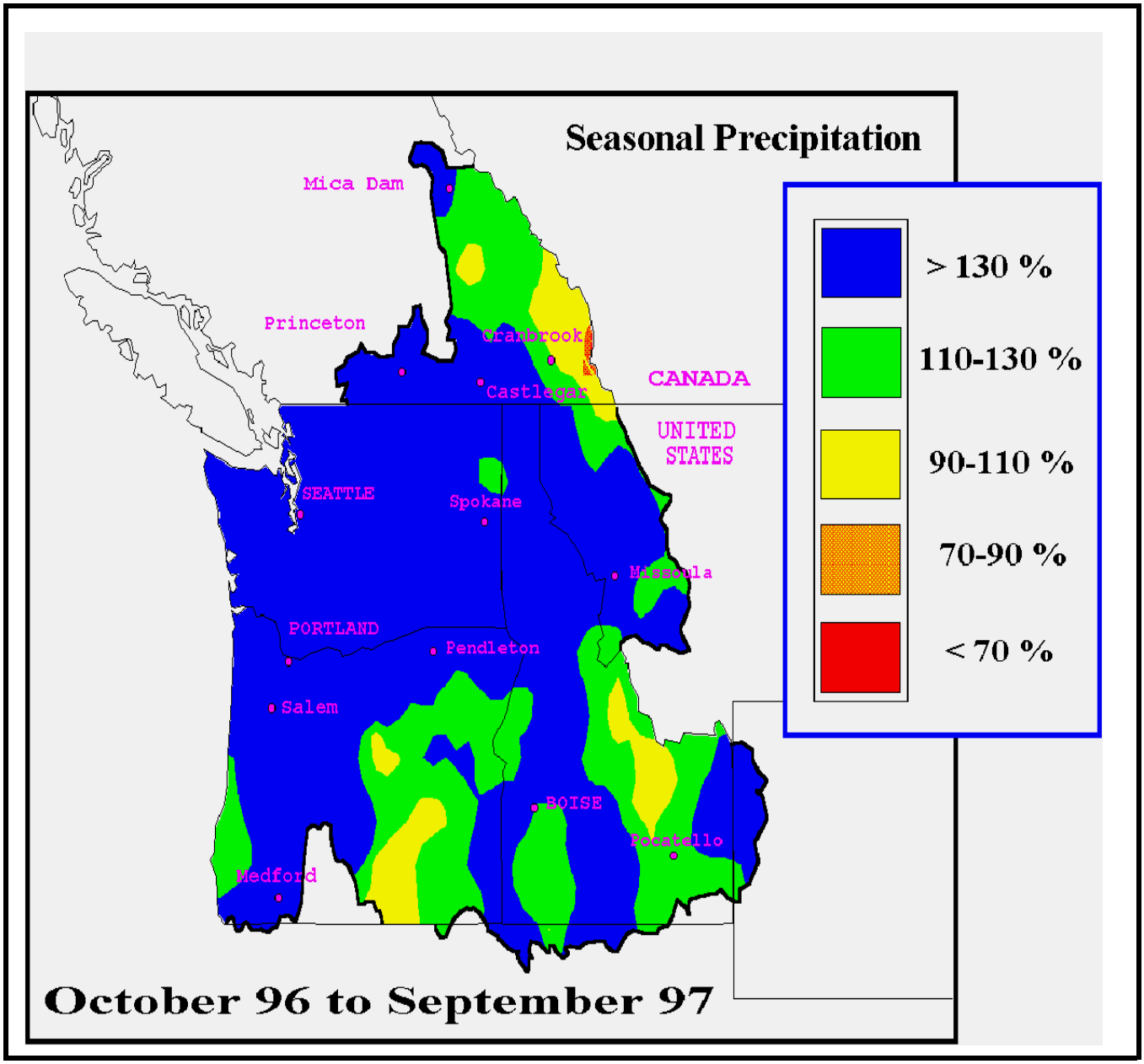

Figure 6. **ANNUAL (WATER YEAR) PRECIPITATION MAP**

into the Northwest, producing not only heavy westside rainfall and new daily records at Astoria and Seattle, but also unusual summer flooding in the Skagit Basin of northern Puget Sound. By mid-July summer finally arrived when a broad pressure ridge established itself over the Northwest producing dry weather and moderate temperatures over much of the region. August was warm and dry except for the 20th and 21st when the remnants of eastern Pacific hurricane Ignacio moved northward along the coastline from California and drenched the coastal basins of Washington and Oregon with up to two inches of rainfall. September was warm and very wet, with Astoria setting a new monthly rainfall record and Eugene being the third wettest on record. An unseasonable low pressure system established itself near the Aleutians, sending warm moist air into the northwest. With only a brief respite near the 12th showers and unstable weather continued through the end of the water year. After mid-month the remnant of yet another hurricane, Linda, brought heavy rains to the westside basins and unstable weather conditions which produced showers and funnel clouds in the region.

The water year ended as one on the wettest on record with new annual precipitation records set at Portland, Astoria, Salem, and Eugene plus many other sites basin-wide. Virtually all of Washington, plus western Oregon,

had in excess of 140% of its normal annual precipitation, northern Idaho and western Montana had in excess of 130%, and from Oregon's closed basin eastward to the Continental Divide, and eastern British Columbia had in excess of 120% of normal precipitation. Annual precipitation was 125% of normal for the Columbia Basin above Grand Coulee, 132% for the Snake Basin above Ice Harbor Dam, 131% for the Columbia Basin above The Dalles, 147% for the Willamette Basin, and 136% for the northwest slopes of the Washington Cascades.

2. Climatology

The 30-station average monthly basin temperature, compared to the 1961-90 normal, varied from a low of 2.3°F below normal during November to a high of 2.6°F above normal in May. The coldest average monmthly stations temperatures were in the Upper Columbia Basin during November and December when station average monthly temperatures were as low as 16.5°F and 14.4°F below normal, respectively. The warmest average monthly stations temperatures were in the coastal basins during December (5.8°F above normal) and during June in the Upper Snake Basin (6.4°F above normal), triggering the snowmelt season. May was also the warmest month basin-wide. June averaged only 1.9°F above normal in the Upper Snake and still produced record floods. The remainder of the Columbia Basin remained at or below normal temperatures and had a slow steady runoff from the abundant snowpack.

Table 1 shows how monthly precipitation varied, in each sub-basin. Table 2 shows how the precipitation accumulated during the year. Figure 6 shows a geograph-

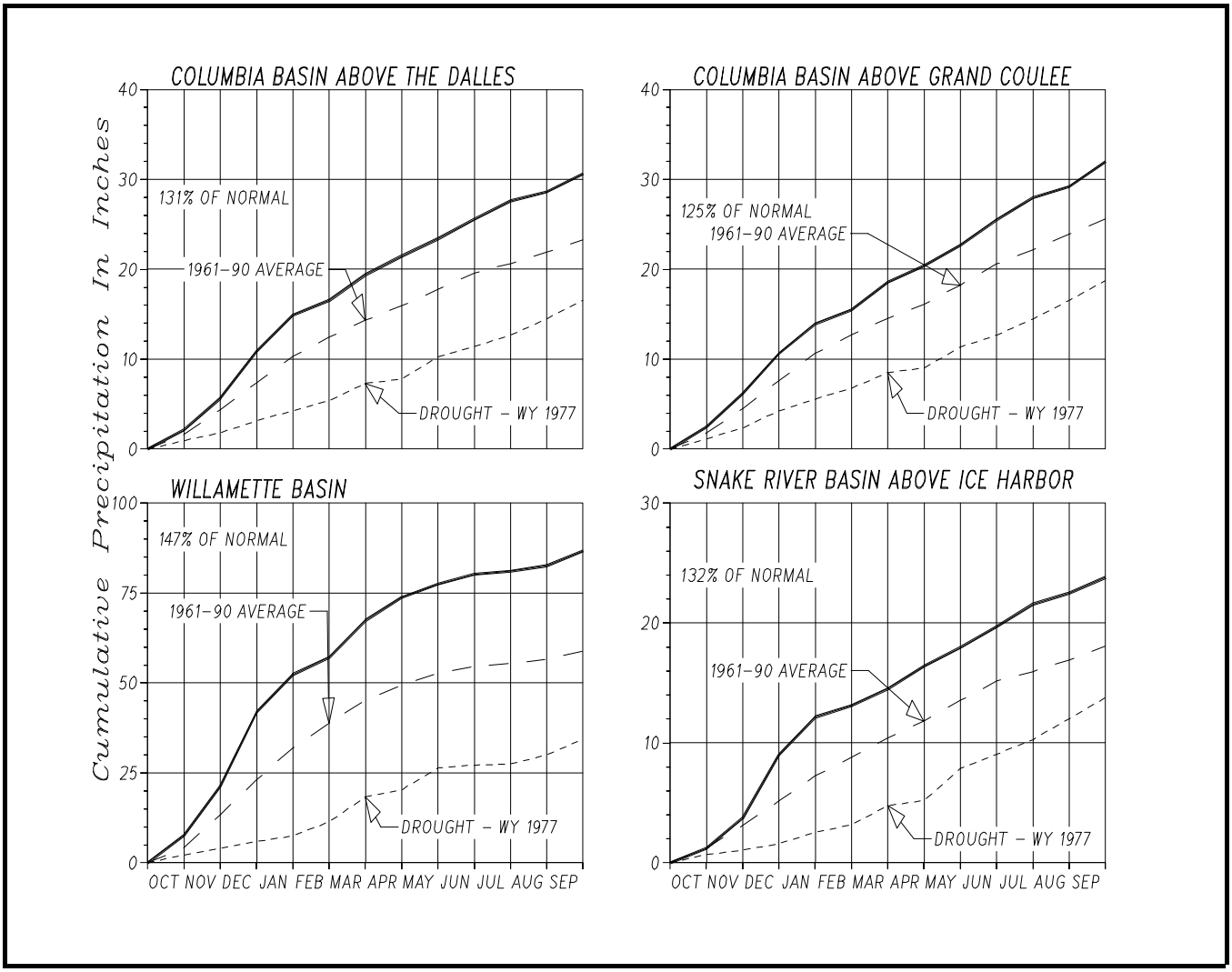

Figure 7. **ACCUMULATED MONTHLY DIVISION PRECIPITATION**

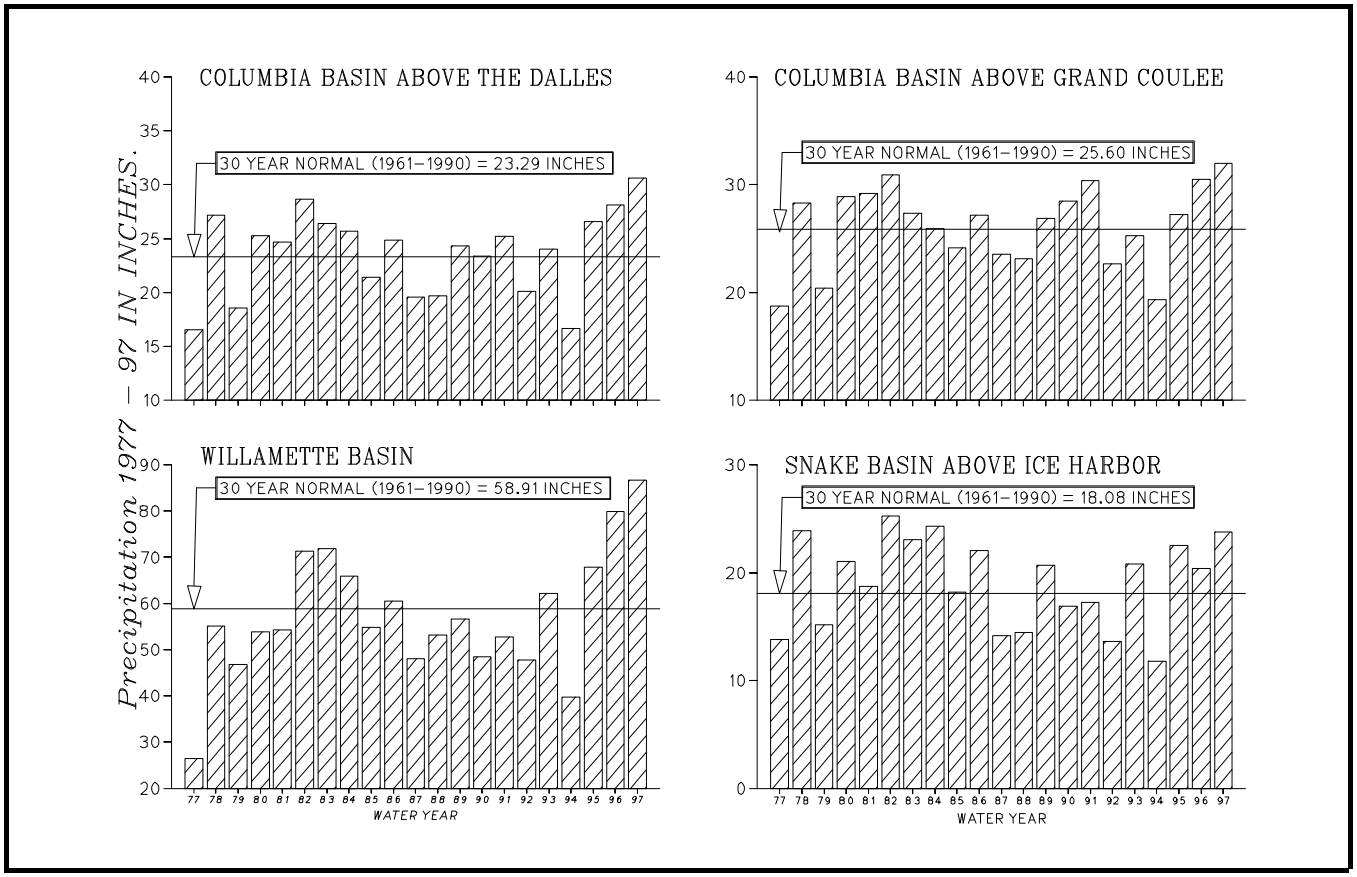

Figure 8. **DIVISION WATER YEAR PRECIPITATION, 1977-97**

ical distribution of the year's precipitation as a percent of normal **(also see Appendix D, Charts 1-4)**.

The cumulative precipitation indices in the four major basins of the Columbia drainage, Figure 7, shows the fall and summer precipitation affecting the annual precipitation totals. Figure 8, the history of these indices for WY 77-97, show that in the Columbia Basin the last years have been significantly above normal, and in the Willamette Basin the last two years with their major rain-produced floods have been well above normal.

3. Snowpack

The Columbia Basin average snowpack was, generally, significantly greater than what had been the case for more than ten years and well above normal (Figure 9).

On January 1 the snowpack, with every sub-basin reporting over 100% of normal snow water content, averaged 170% of normal, breaking a 30-year record by exceeding the previous snowpack record maximum by seven percentage points. The sub-basins which generally contribute 71% of the runoff of the Columbia River at The Dalles have snowpack greater than 180% of normal, and of these, the sub-basins which generally contribute 18% of the runoff at The Dalles have snowpacks over 200%. Prior to 1995, the last year with every sub-basin over 100% was 1985, the year with the highest snowpack in the past 30 years was 1965, which had similar percentages in most sub-basins, but had less in the major contributing basins of the Kootenai, Pend Oreille, and Clearwater. The Canadian snowpack, at 106%, was the lowest percentage in the Columbia Basin, although only 10 sites in the Upper Columbia were available prior to February 1, when a full complement of Canadian snow measurements typically begin. The overall snowpack index (SPI), the average basin snow water content expressed as a percentage of the 30-year normal April 1 average basin snow water content (typically 44%), was 75% on January 1.

By February 1, several sub-basin's snowpacks had decreased on the order of 35% from last month's readings, including the Pend Oreille, North Cascades, Snake Headwaters, Boise, and Clearwater. All sub-basins, however, remained well above normal with the Pend Oreille at 160% and the Snake Headwaters at 186%. While the snowpacks in the United States were decreasing in percentage of normal, the Upper Columbia in Canada

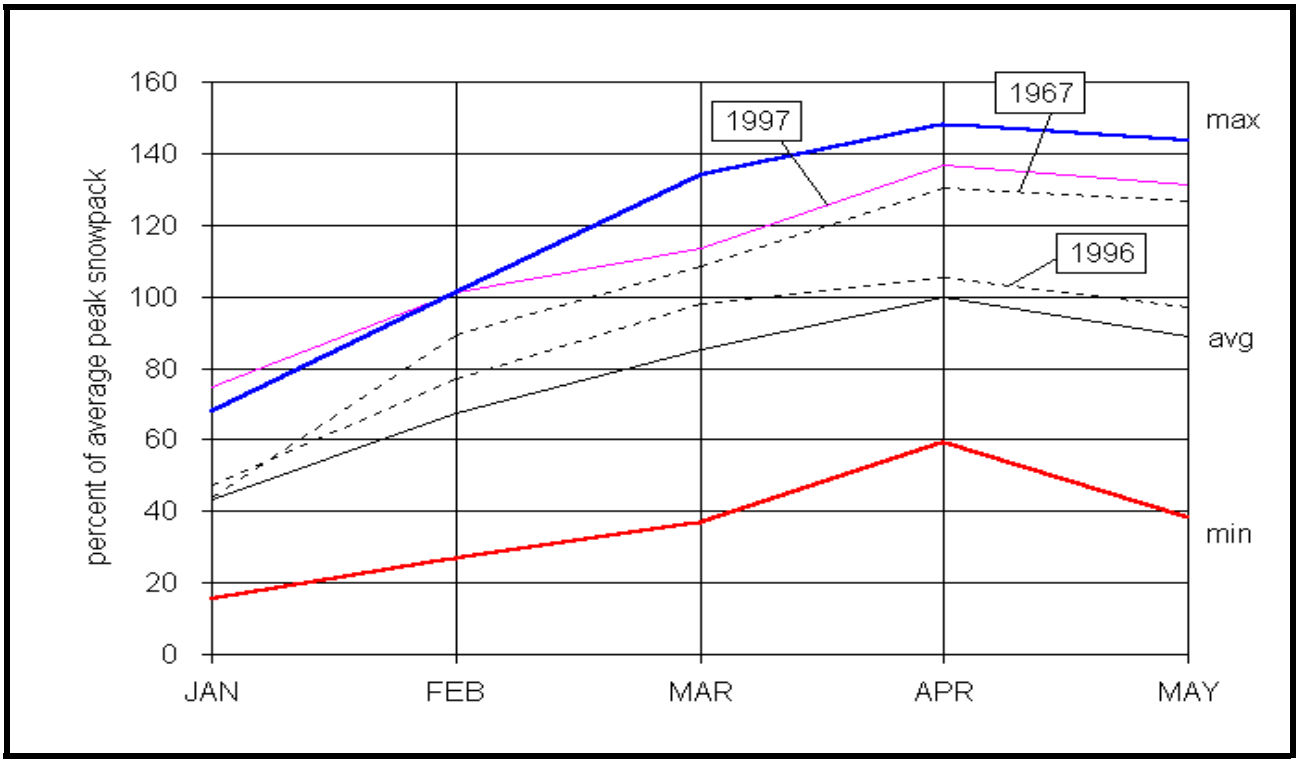

Figure 9. **COLUMBIA BASIN AVERAGE SNOWPACK**

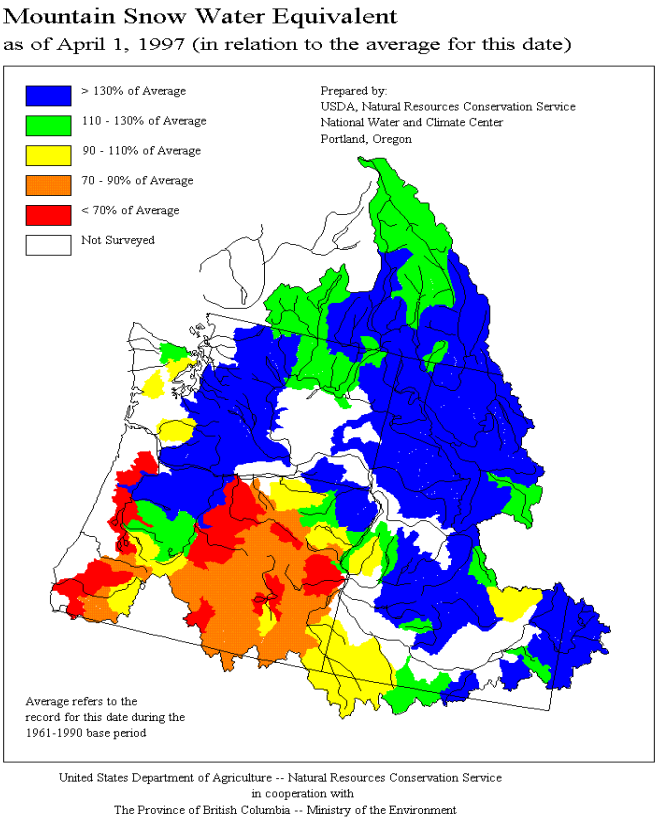

Figure 10. **MOUNTAIN SNOW WATER CONTENT MAP, APRIL 1**

gained 13% to 119% of normal by February 1. These snowpacks were still the lowest in the basin, with the next lowest, being the small mid-Columbia drainages in northeastern Oregon and southeastern Washington, which were 120% of their normal snowpack. The best in the basin was the Lower Snake (upstream of the Clearwater) at 210% and the Yakima at 204%, which were the only sub-basins remaining above 200%. Although January had high streamflows across the basin, many lower elevations drainages were not affected by the New Year's Day storm and kept their snowpack, including Camas Creek in central Idaho and the Owyhee River in southeastern Oregon. Overall, the Columbia SPI was 101%, equaling the previous maximum from 1972.

Large decreases in snowpack percentages, 15%-30%, occurred all across the Columbia Basin during February, yet on March 1, all sub-basins remain above 100%, and several that contribute most significantly to the flow at The Dalles remain well above normal, including the Pend Oreille at 145%, Spokane at 146%, Clearwater at 147%, and Salmon at 146%. This is the first year since 1982 that all sub-basins have been over 100% on March 1. Meanwhile the Canadian snowpacks remained relative low at just above normal, which prevents the overall Columbia snowpack from approaching the record levels of 1972, as it had on January 1 and February 1. Oregon's John Day Basin had the lowest snowpack in the basin with 103% while a few miles north Washington's

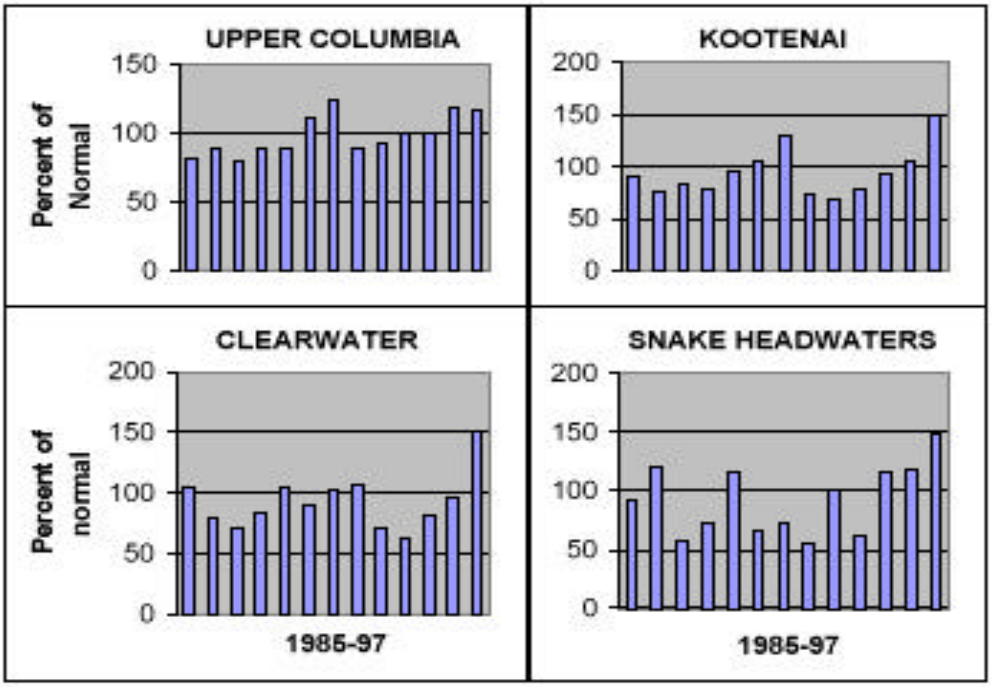

Figure 11. **SNOW WATER CONTENT AT KEY SITES**

Yakima Basin was the highest in the basin, with 178%, down 26% from February 1. The Idaho snowpack remained well above normal all season with the Boise drainage at 147%, followed by 165% to 175% in the Big Wood, Little Wood, Big Lost, and Henrys Fork. South of the Snake River near record snowpacks remained which were similar to 1984 when Oakley and Salmon Falls reservoirs received high snowmelt runoff and filled quickly requiring emergency action to prevent overfilling. The overall Columbia Basin SPI above The Dalles this month was 114% of its normal April peak in April and 133% of normal for March 1.

Snowpacks in the northern half of the Columbia Basin increased during March while those to the south decreased, resulting in April 1 snowpacks in the Clearwater increasing by 4% to 151%, the Salmon decreasing 8% to 138%, and the Canadian snowpack and the US Northern Cascades both increasing 11%, the largest increases during the month. Washington, in general, had the highest snowpack, with the Yakima at 177% on normal and the North Cascades at 152% while the Boise-Payette area and the Snake Headwater snowpacks both decreased 10% to 15%, but remained well above normal with 130% and 149%, respectively. The lower elevation snowpacks, including Camas Creek and the Owyhee, started melting at a moderate pace during the month. Declines in the snowpack percentage across the region were small enough to leave the overall snowpack still well above normal at 137%. This was the third highest April snowpack since 1960, with 1972 and 1974 being higher with the 1967 snowpack being similar but slightly lower. March snowmelt in the low elevation John Day Basin reduced the April 1 snowpack to below normal with a decrease of 36% to 67% of normal and the Deschutes the second lowest at 107%. The April 1 Columbia Basin SPI was 137% (Figure 10).

Even as warmer April weather infiltrated the basin and the snowmelt area gradually expanded from lower elevation basins to include those at higher elevations. By May 1 a number of sites had not yet recorded their maxima snowpacks for the year. In typical fashion for above normal snowpacks, the decreases in the water content and SPI were slower than for normal snowpacks because of the greater volume of snow to ripen and saturate, *ie*, with a greater amount of snow a greater amount of heat energy was need to melt it. While the Canadian snowpacks remained constant throughout April at 117%, every other sub-basin of the Columbia increased

Table 3

OREGON SURFACE WATER SUPPLY INDEX (SWSI)
on first of month, by divisions

Basin	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
N Coast	1.0	0.9	1.3	1.5	1.6	0.9	0.5	0.5	-0.3	0.3	1.1	1.4
S Coast	1.2	0.9	1.2	1.7	1.8	1.5	1.1	0.8	0.2	0.1	0.7	0.8
Willamette	0.7	0.4	0.6	1.1	1.4	1.8	2.0	1.8	1.2	1.3	2.0	1.7
Rogue/Umpqua	3.0	2.6	2.5	2.4	2.3	1.9	1.6	1.6	1.4	1.8	2.5	3.0
Upper Deschutes	1.7	1.5	2.0	2.4	2.6	2.5	2.3	2.2	1.8	1.9	2.4	2.8
Lower Deschutes	-0.2	0.0	0.7	1.4	1.8	2.1	2.1	2.4	2.2	2.4	2.8	2.6
Upper John Day	-0.1	-0.1	0.5	1.4	2.1	2.3	1.7	1.8	1.0	0.6	1.2	1.1
Lower John Day	0.6	0.8	1.4	1.9	2.0	1.9	1.6	1.3	0.6	0.4	0.6	0.5
Owyhee	0.5	-0.0	0.2	0.5	1.1	1.2	1.6	2.0	1.8	1.5	1.6	1.6
Malheur	0.6	0.2	0.5	1.3	1.8	2.1	1.9	1.8	1.4	0.8	0.8	1.0
GR/ Powder/Burnt	0.0	0.1	0.4	0.9	1.6	2.0	2.0	2.4	2.0	1.6	1.8	1.5
Harney	0.2	-0.3	-0.6	0.2	1.0	0.9	0.6	0.7	0.1	-0.8	-0.2	0.1
Lake County	1.1	0.9	0.5	0.8	1.5	1.8	1.4	1.8	0.8	0.1	0.1	0.1
Klamath	-0.5	-0.9	-0.8	0.2	1.1	1.5	1.4	1.8	0.9	0.3	0.1	0.2

Note: A SWSI value of 0.0 represents normal water supply; -4.1 indicates extreme drought; +4.1 indicates very wet conditions

Table 4

STREAMFLOWS AS PERCENT OF MONTHLY NORMAL

RIVER	STATION	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
JOHN DAY	Service Creek	101	**144**	**313**	**316**	**189**	**157**	**147**	111	**73**	90	104	**132**
WILSON	Tillamook	**168**	101	**177**	110	85	**173**	110	91	94	96	**70**	**336**
UMPQUA	Elkton	**163**	**205**	**302**	**134**	101	106	92	95	89	**125**	**125**	**146**
COLUMBIA	The Dalles [1]	101	98	**121**	**193**	**152**	**164**	107	**165**	**141**	**131**	114	**138**
WILLAMETTE	Salem [1]	**188**	**216**	**244**	**140**	108	**153**	113	102	98	**141**	**146**	**162**
CHEHALIS	Grand Mound	**128**	100	**179**	**158**	102	**190**	**126**	**145**	**180**	**180**	**152**	**212**
SKYKOMISH	Gold Bar	**176**	116	**65**	**152**	**120**	**207**	**146**	**167**	**145**	**172**	**113**	**177**
SPOKANE	Spokane [1]	114	101	106	**221**	**122**	**163**	**149**	**189**	**160**	**186**	**170**	**155**
SNAKE	Heise [1]	107	119	**132**	**147**	96	**150**	**141**	**200**	**186**	**127**	**151**	**124**
SNAKE	Weiser	82	91	**123**	**229**	**226**	**199**	**158**	**150**	**210**	**154**	**144**	**141**
SALMON	White Bird	96	**133**	**138**	**248**	**129**	**154**	**164**	**188**	**145**	119	**137**	**122**
CLEARWATER	Spalding [1]	85	89	87	**193**	**153**	**170**	**153**	**176**	**143**	**168**	**162**	**138**
CLARK FORK	St Regis	88	88	89	**143**	101	**148**	**152**	**211**	**168**	**143**	**133**	**107**
MF FLATHEAD	W Glacier	92	**60**	**73**	**144**	89	**138**	96	**334**	**134**	113	**122**	113

[1] Adjusted for upstream storage. **Bold** numbers are outside the "normal" range of 80% to 120%.

Table 5

MEAN ANNUAL DISCHARGES

RIVER STATION	ANNUAL		JAN-JUL		APR-JUL		APR-SEP	
	DISCH [1]	% [2]	DISCH [1]	% [2]	DISCH [1]	% [2]	DISCH [1]	% [2]
Columbia R bl Mica*	22.48	110	25.73	111	38.90	110	41.37	111
Columbia R bl Arrow*	48.25	114	58.05	116	80.85	117	92.71	115
Kootenay R at Ft Steele	5.90	95	7.84	96	10.09	96	12.65	96
Kootenai R bl Libby*	13.82	121	19.16	126	23.00	125	29.94	123
Duncan R bl Duncan*	4.22	117	5.04	116	7.36	118	8.20	119
Kootenay R at Corra Linn*	36.99	132	52.16	137	61.10	134	79.88	133
Columbia R at Birchbank*	89.60	123	117.43	127	150.48	127	184.02	125
Clark Fork ab Missoula	4.66	148	6.77	159	7.42	164	10.10	160
Clark Fork at St Regis	11.72	156	17.52	168	19.12	174	26.56	169
MF Flathead R nr W Glacier	3.69	127	5.62	133	6.50	133	9.02	132
SF Flathead R nr Columbia Falls*	5.05	139	7.83	145	8.84	148	12.51	147
Flathead R nr Polson*	16.07	138	24.44	144	27.70	147	38.77	145
Clark Fork nr Plains*	29.88	149	44.69	156	49.97	160	69.01	158
Pend Oreille R at Newport*	38.23	146	58.31	157	63.30	163	88.71	160
Spokane R nr Post Falls*	10.55	160	16.20	167	13.39	170	19.10	170
Columbia R bl Grand Coulee*	150.05	133	209.69	139	243.85	140	315.06	137
Okanogan R nr Tonasket	5.16	181	7.28	181	8.35	179	10.82	187
Wenatchee R at Peshastin	4.28	146	6.21	145	6.63	147	9.03	147
Columbia R bl Priest Rapids*	176.20	140	244.95	148	282.08	147	364.54	145
Yakima R at Cle Elum*	3.06	143	4.45	162	4.07	164	5.62	162
Yakima R nr Parker*	7.46	148	10.84	174	9.65	178	13.25	176
Snake R nr Heise*	11.60	159	16.13	169	18.78	174	24.76	168
Boise R nr Boise*	4.92	173	7.44	178	6.83	164	9.64	161
Payette R nr Horseshoe Bend*	5.25	177	7.66	196	5.62	159	7.79	145
Snake R at Hells Canyon*	34.07	165	45.77	186	34.23	167	42.25	163
Salmon R at White Bird	17.96	154	26.24	160	28.22	158	38.87	155
Grande Ronde R at Troy	5.09	174	7.68	181	5.87	166	8.34	162
Clearwater R at Orofino*	13.51	149	21.30	156	21.14	155	30.28	154
NF Clearwater R bl Dworshak*	9.06	158	14.11	167	13.40	172	19.16	169
Clearwater R at Spalding*	24.03	155	37.67	163	35.29	160	50.43	159
Snake R bl Lower Granite*	80.84	155	117.67	166	102.22	155	138.55	152
Columbia R at The Dalles*	268.23	142	378.13	150	388.61	146	510.21	143
McKenzie R nr Vida*	6.08	148	6.17	130	3.89	118	4.68	119
N Santiam R nr Mehama*	5.08	149	5.06	129	2.60	110	3.31	114
S Santiam R at Waterloo*	4.47	148	4.08	118	1.52	93	2.05	96
Willamette R at Salem*	36.80	155	34.95	124	14.57	108	18.74	113
Rogue R at Raygold*	5.16	168	5.27	130	2.76	115	3.38	115
Cowlitz R at Castle Rock*	13.02	139	16.05	143	8.87	121	11.65	121
Skagit R nr Concrete*	19.51	128	24.80	138	23.45	134	29.43	130

[1] Average discharge in kcfs. [2] Percent of 1961-90 normal. * Adjusted for upstream storage.

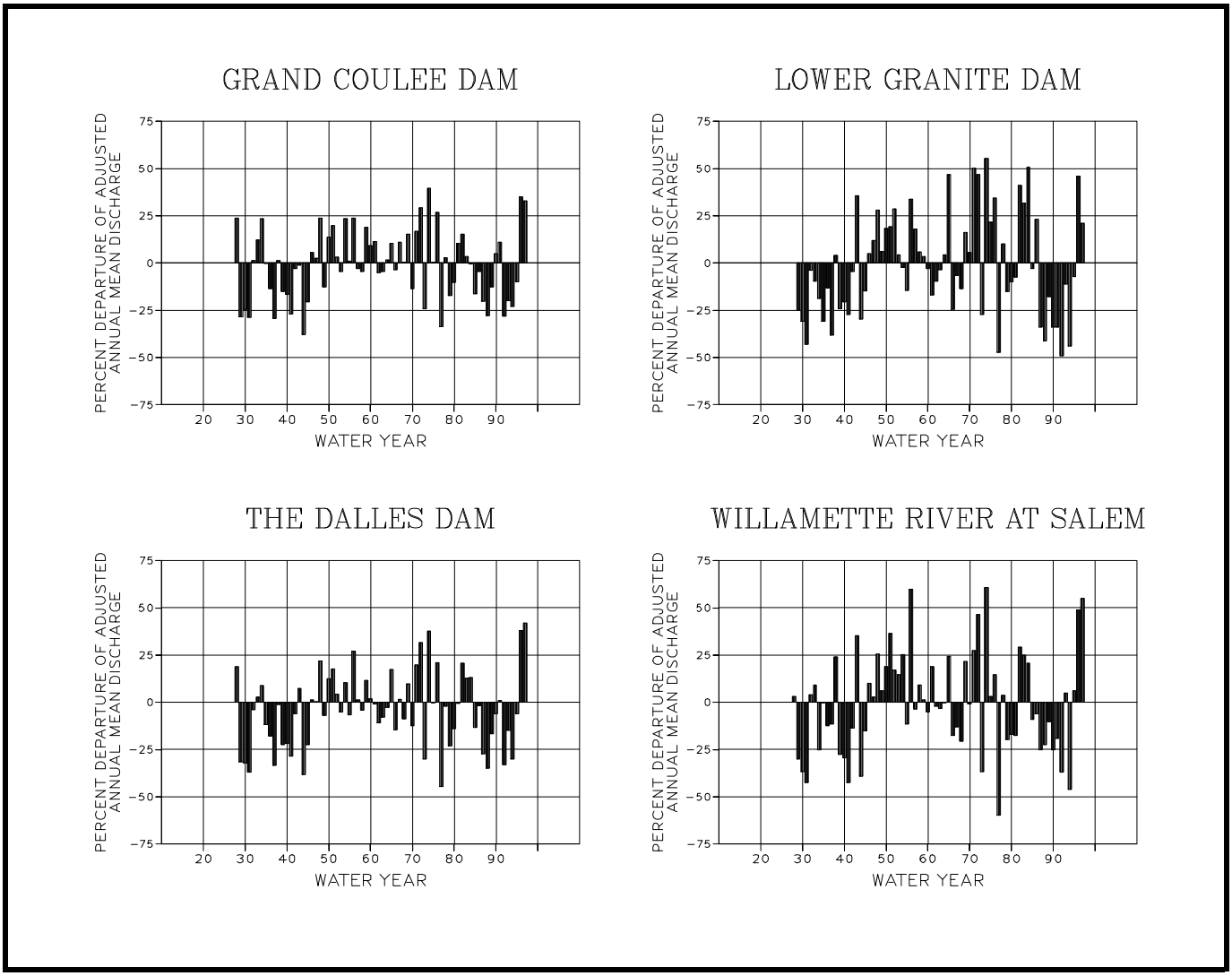

Figure 12. **FOUR BASIN DISCHARGE - DEPARTURE FROM 1928-90 AVERAGE**

(except the John Day Basin). Washington continues with the highest percentages with the Yakima up 38% to 215% for May 1, by far the highest in that basin since SNOTEL was installed sixteen years ago, the previous high was 153% in 1983, the North Cascades was at 80% (the highest May 1 snowpack since 1961, higher than both the 1972 and 1974). In Idaho, the Clearwater snowpack was 167%, the second highest in 43 years exceeded only by 1972 (173%). Every US sub-basin north of the Clearwater was over 150%; the Kootenai at 153% was surpassed in the last 37 years only by the 1972 (160%) and 1974 (163%) and in Idaho the 130% to 140% snowpacks, although high, were not records. The Snake headwaters with 167%, however, had the second highest May 1 snowpack in 38 years and Oregon was well above normal in spots (Mt Hood and the Wallowa Mountains). The overall SPI for the month was 131% (Figure 11).

By June 1 all the low elevation snowpacks had melted and middle and upper elevation snowpacks were melting at moderate rate but not producing significant overbank flows. The exception was in he Upper Snake Basin were a brief hot spell accelerated the snowmelt and causing flooding in the basin above Milner Dam.

4. Surface Water Supply Index

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 includes 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 a general increase in the SWSI in Oregon (Table 3). Nearly all basins started the year with near normal water supply. The exceptions were the Rogue/Umpqua (3.0) which was on the high or wet side. The largest changes occurred in the northern half of eastern Oregon from as low as -0.1 (normal) to 2.4 (moderately wet). (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.

5. 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 4.

This was a wet year had streamflows averaging 154% of normal, a 10% increase over last years average. The highest average monthly flow was on the MF Flathead River near West Glacier, MT, which had 176%, up 37%, and the Snake River at Weiser, ID, at 165%, up 40%. The lowest mean annual flow was on the Wilson River in northwestern Oregon with 129%, down 32% from that of last year with its record floods.

The water year began with normal or below streamflow throughout the region. Above normal rains in the western basins during the latter three weeks of October resulted in significant rises in flows to above normal west of the Cascades. With no significant storm penetration into the eastern basins there was little change in flows. November streamflows mirrored those of October except in southwestern Oregon where unseasonably heavy rainfall after mid-month resulted in average monthly streamflow increasing by 300% and 400% over those of October. Heavy rains in early and late December in western Oregon again produced high discharges; with peak flows records being set on Bear Creek in Medford, and in the Klamath Basin of southern Oregon. These higher flows on New Years Day were augmented by snowmelt mainly from low elevation basins, occurred in virtually all of the Northwest except for the basins in eastern Idaho and western Montana. Streamflows during January generally decreased from their New Years Day peaks except in the far eastern basins which peaked later in January. February and March flows generally receded toward normal due to cooler temperatures that put most of the precipitation into the snowpacks and reduced streamflows. During March, in the Puget Sound area and northern Columbia basin's rivers responded to three weeks of steady precipitation by increased flows while the southern basins had decreasing streamflows and a building of the abundant snowpack. April streamflows remained above normal with little response to the slowly increasing temperatures. May, despite its well below temperatures and heavy mid month precipitation basin-wide, managed to produce major increases in streamflows in eastern headwater basins with the Clark Fork at St Regis and the MF Flathead River near West Glacier producing new peak flow records. With the cool spring the snowmelt runoff remained snow and steady, avoiding the potentially disastrous peaks that might have occurred had a long warm weather spell accompanied the heavy snowpack. The Upper Snake Basin near mid-June proved to be another exception with its brief but warm spell that produced record peak flows from the headwaters to Milner, ID. July, August and September flows, although above normal, continued to decline from their peaks in May and June. Rare summer high water in some river in western Washington and Oregon were the response to remnants of unusual Pacific hurricanes and typhoons that traversed the Northwest (Table 5).

Tables 6-9 show an additional comparison of WY 97 modified streamflows and runoff with historical flows. These modified flows, which were developed for hydrosystem studies, were reduced to a common period.

The Columbia River at Grand Coulee, Table 6, set four new maximum mean monthly discharge records, November and January-March. The November and February floods broke the record average monthly discharge records set in WY 96. Despite the heavy snow-

Table 6

MODIFIED DISCHARGE AND RUNOFF [1]
COLUMBIA RIVER AT GRAND COULEE, WASHINGTON

MONTH	MEAN MONTHLY MODIFIED STREAMFLOWS (cfs)						
	MAXIMUM		MINIMUM		WY 97		1928-89 AVERAGE
	Discharge	WY	Discharge	WY	Discharge	% of Avg	
Oct	95,170	1960	23,630	1987	**94,300**	**198**	49,770
Nov	**93,880**	**1997**	22,160	1930	**93,880**	**206**	45,510
Dec	114,100	1934	21,980	1931	**110,670**	**264**	41,880
Jan	**141,610**	**1997**	14,550	1930	**141,610**	**373**	38,010
Feb	**137,430**	**1997**	17,940	1936	**137,430**	**332**	41,360
Mar	**129,230**	**1997**	24,990	1937	**129,230**	**249**	52,480
Apr	249,300	1934	51,450	1929	**152,660**	**137**	117,400
May	419,800	1957	159,500	1977	**218,320**	**83**	269,600
Jun	521,500	1974	184,000	1941	**258,050**	**83**	318,000
Jul	339,200	1954	106,000	1977	**169,220**	**92**	190,800
Aug	189,600	1976	70,010	1987	**135,280**	**143**	101,500
Sep	112,000	1976	45,250	1987	**97,440**	**164**	63,600
Annual	157,400	1974	69,900	1944	**144,819**	**135**	111,100

MONTH	MODIFIED RUNOFF ACCUMULATION (kaf)						
	MAXIMUM		MINIMUM		WY 97		1928-89 AVERAGE
	Runoff	WY	Runoff	WY	Runoff	% of Avg	
Oct-Mar	31,240	1934	8,290	1937	**16,220**	**185**	16,220
Jan-Jul	91,200	1974	36,110	1944	**62,100**	**161**	62,100
Apr-Jul	76,180	1974	31,800	1944	**54,220**	**124**	54,220
Apr-Aug	84,170	1974	36,780	1944	**60,640**	**123**	60,460
Apr-Sep	88,540	1974	40,320	1944	**61,250**	**122**	64,250
Annual	114,000	1974	50,700	1944	**80,450**	**135**	80,450

[1] Modified streamflows, 1990 Level of Irrigation, 1928-89.

packs in British Columbia, northern Idaho, and western Montana, the spring and summer mean monthly discharge did not come close to equaling their previous records.

On the Snake River at Lower Granite, Table 7, three months set new records of maximum mean monthly discharge: January, August and September. The January record was set with the flow supplied by the New Year's flood that reached into parts of the Snake Basin. Even the record peak floods in June did not produce enough volume to approach the mean monthly discharge of the 1974 record. The record flows of August and September were supplied in part by the spent tropical storms that traverses the Northwest.

On the Columbia River at The Dalles, Table 8, one month set a new record for maximum mean monthly discharge: January, which eclipsed the January 1974 record by 22%.

On the Willamette River at Salem, Table 9, two months set new records of maximum mean monthly discharge: August and September. These new flows ex-

Table 7

MODIFIED DISCHARGE AND RUNOFF [1]
SNAKE RIVER AT LOWER GRANITE, WASHINGTON

MONTH	MEAN MONTHLY MODIFIED STREAMFLOWS (cfs)						
	MAXIMUM		MINIMUM		WY 97		1928-89 AVERAGE
	Discharge	WY	Discharge	WY	Discharge	% of Avg	
Oct	45,400	1960	16,630	1932	**22,050**	**88**	25,170
Nov	46,600	1996	17,640	1932	**21,810**	**76**	28,830
Dec	72,500	1996	16,870	1936	**36,850**	**111**	33,250
Jan	**92,050**	**1997**	15,780	1937	**92,050**	**268**	34,360
Feb	105,100	1996	17,840	1932	**92,300**	**235**	39,350
Mar	134,000	1972	21,470	1977	**108,230**	**216**	50,030
Apr	162,800	1943	36,880	1977	**121,970**	**148**	82,540
May	206,100	1971	48,900	1977	**169,030**	**139**	121,200
Jun	241,100	1974	31,910	1934	**161,280**	**147**	110,000
Jul	85,970	1975	15,480	1931	**68,890**	**171**	40,340
Aug	**46,140**	**1997**	11,840	1931	**46,140**	**213**	21,650
Sep	**35,490**	**1997**	14,410	1931	**35,490**	**158**	22,400
Annual	**81,239**	**1997**	27,390	1977	**81,239**	**160**	50,730

MONTH	MODIFIED RUNOFF ACCUMULATION (kaf)						
	MAXIMUM		MINIMUM		WY 97		1928-89 AVERAGE
	Runoff	WY	Runoff	WY	Runoff	% of Avg	
Oct-Mar	23,200	1996	6,913	1937	**12,760**	**182**	12,700
Jan-Jul	47,860	1974	12,840	1977	**26,362**	**161**	28,780
Apr-Jul	35,680	1974	8,636	1977	**21,390**	**131**	21,390
Apr-Aug	37,450	1974	9,530	1977	**22,722**	**130**	22,720
Apr-Sep	38,850	1974	10,590	1977	**24,056**	**128**	24,050
Annual	58,130	1974	19,830	1977	**36,816**	**160**	36,730

[1] Modified streamflows, 1990 Level of Irrigation, 1928-89

ceeded their previous record with assistance from the excess rainfall produced by a plethora of spent hurricanes, typhoons, and extra tropical storms that found their way into the Northwest during the summer.

6. Flood Events

Winter Season November weather was punctuated by the wettest short-term rainfall in history at many locations. Corvallis Water Bureau exceeded last year's record by 20%, Roseburg exceeded its 30-year record by 33%, and Madras exceeded its record set in 1995 by 80%. Flooding occurred widely in western and central Oregon with the rivers rising exceptionally fast, due to the intense rainfall. However, the storm was short lived and the rivers, many of which exceeded their flood stage, crested quickly with only Johnson Creek reaching a new record stages (Table 10).

Late December into early January a series of warm, moist storms brought flooding to Oregon, Eastern Washington, and Idaho. Rainfall amounts exceeded 8

Table 8

MODIFIED DISCHARGE AND RUNOFF [1]
COLUMBIA RIVER AT THE DALLES, OREGON

MONTH	MEAN MONTHLY MODIFIED STREAMFLOWS (cfs)						
	MAXIMUM		MINIMUM		WY 97		1928-89 Average
	Discharge	WY	Discharge	WY	Discharge	% of Avg	
Oct	165,800	1960	54,650	1988	**129,020**	**99**	87,340
Nov	167,500	1996	50,110	1930	**134,110**	**98**	90,260
Dec	223,000	1996	51,320	1931	**186,090**	**120**	94,810
Jan	**274,950**	1997	39,160	1937	**274,950**	**201**	92,930
Feb	279,000	1996	51,160	1937	**268,930**	**164**	105,100
Mar	316,900	1972	59,130	1977	**282,380**	**178**	127,900
Apr	400,200	1943	108,000	1929	**326,830**	**105**	225,500
May	669,400	1957	221,000	1977	**457,960**	**161**	425,100
Jun	841,300	1974	248,500	1977	**318,890**	**147**	473,200
Jul	428,100	1954	122,000	1977	**266,830**	**132**	256,300
Aug	228,800	1976	95,190	1987	**194,530**	**115**	137,200
Sep	150,600	1959	67,950	1988	**148,610**	**138**	97,150
Annual	268,600	1974	108,600	1977	**249,170**	**141**	184,600

MONTH	MODIFIED RUNOFF ACCUMULATION (kaf)						
	MAXIMUM		MINIMUM		WY 97		1928-89 Average
	Runoff	WY	Runoff	WY	Runoff	% of Avg	
Oct-Mar	67,200	1996	19,640	1937	**36,195**	**146**	36,030
Jan-Jul	156,900	1974	53,810	1977	**87,338**	**176**	102,900
Apr-Jul	124,100	1974	43,060	1977	**83,473**	**142**	83,470
Apr-Aug	134,600	1974	49,580	1977	**91,909**	**139**	91,910
Apr-Sep	140,400	1974	54,250	1977	**97,690**	**139**	97,690
Annual	194,400	1974	78,610	1977	**133,885**	**141**	133,700

[1] Modified streamflows, 1990 Level of Irrigation, 1928-89

inches in 24-hours at some of the wetter spots in Oregon, with many other sites receiving 2-4 inches in 24-hours. In addition, areas east of the Cascades had a considerable low elevation snowpack which melted to augmented the rain driven flood peak.

Most streams in Western Oregon flooded during this period (Table 11). In the Willamette streams generally crested 1 to 3 ft above flood stage with some damage to low lying homes along many rivers. In Southwestern Oregon, streams crested 2 to 6 ft above flood stage. Reservoir flood control storage lowered river stages by more than 6 ft at some sites in the upper Willamette Basin and by 4 ft in the lower basin. Rogue River stages were reduced by one to six feet by flood control storage in Lost Creek and Applegate reservoirs. Generally only minor damage occurred to dwellings in the flood plain, with the exception of severe flooding on Bear Creek near Medford where flood damages which reportedly exceeded $60

Table 9

MODIFIED DISCHARGE AND RUNOFF [1]
WILLAMETTE RIVER AT SALEM, OREGON

MONTH	MEAN MONTHLY MODIFIED STREAMFLOWS (cfs)						
	MAXIMUM		MINIMUM		WY 97		1928-89 Average
	Discharge	WY	Discharge	WY	Discharge	% of Avg	
Oct	32,130	1948	2,530	1988	**19,160**	**165**	7,542
Nov	71,400	1974	3,160	1937	**57,910**	**226**	25,450
Dec	128,300	1965	5,300	1977	**105,320**	**260**	44,190
Jan	94,300	1953	6,090	1977	**79,850**	**141**	46,700
Feb	101,300	1996	6,340	1977	**40,000**	**109**	43,320
Mar	79,080	1972	11,130	1941	**46,120**	**151**	36,360
Apr	63,410	1937	10,820	1941	**25,560**	**106**	30,210
May	39,920	1963	10,160	1987	**19,970**	**100**	22,410
Jun	36,760	1933	4,518	1992	**13,020**	**92**	14,090
Jul	12,290	1983	2,490	1940	**9,940**	**139**	5,988
Aug	**9,080**	**1997**	1,911	1967	**9,080**	**151**	3,830
Sep	**12,720**	**1997**	2,467	1987	**12,720**	**171**	4,050
Annual	38,170	1974	9,593	1977	**36,636**	**156**	23,585

MONTH	MODIFIED RUNOFF ACCUMULATION (kaf)						
	MAXIMUM		MINIMUM		WY 97		1928-89 Average
	Runoff	WY	Runoff	WY	Runoff	% of Avg	
Oct-Mar	21,200	1956	3,151	1977	**12,411**	**174**	12,228
Jan-Jul	18,210	1972	5,561	1977	**11,768**	**127**	11,915
Apr-Jul	8,011	1937	2,253	1987	**4,423**	**104**	4,382
Apr-Aug	8,294	1937	2,435	1987	**4,646**	**106**	4,618
Apr-Sep	8,540	1937	2,582	1987	**4,881**	**109**	4,859
Annual	27,630	1974	6,945	1977	**17,292**	**156**	17,087

[1] Modified streamflows, 1990 Level of Irrigation, 1928-89.

million.

In Eastern Oregon serious flooding occurred on the lower Grande Ronde near Troy, and on the Imnaha River. Flood damages were reportedly near $4 million. Minor flooding took place on the Umatilla, John Day, and Deschutes rivers.

Central Idaho was hardest hit by this storm, especially on the Weiser and Payette River drainages. In these basins, an extensive low elevation snowpack was subjected to warm temperatures and heavy rain that produced severe to record level flooding on the Weiser River. At the town of Weiser, the river crested at 16.5 ft, one-half foot above the previous flood-of-record. On the Payette River serious flooding occurred on the lower Payette from Horseshoe Bend to the mouth. Levees were washed out near Payette, causing widespread flooding. The 32.3 kcfs peak on the Payette River at Emmett, which was just under the previous peak of record,

Table 10

NOVEMBER FLOOD PEAKS - OREGON

RIVER	GAGE	DAMAGE STAGE		OBSERVED			PREVIOUS RECORD		
		ZERO	MAJOR	DATE	STAGE	DISCH	DATE	STAGE	DISCH
Willamette	Harrisburg	14.0	17.0	11/19	15.53	80.0	12/-/1861	20.5	
Clackamas	Estacada	10.0		11/19	21.9		12/22/64	28.36	86.9
Johnson Creek	Sycamore	11.0		**11/19**	**15.38**	**3.02**	12/22/64	14.68	2.62
	Milwaukie	27.4		11/19	30.08	2.15	2/8/96	30.27	2.17
Marys	Philomath	20.0		11/19	18.7		1/15/74	20.91	
Luckiamute	Suver	27.0		11/19	29.7		12/22/64	34.52	32.9
Alsea	Tidewater	18.0		11/19	22.26	28.2	12/22/64	27.44	41.8
Siletz	Siletz	16.0		11/19	18.7		11/20/21	31.6	40.8
South Umpqua	Brockway	26.0		11/19	24.7		12/23/64	34.28	125
Bear Creek	Medford			11/19	5.73	1.01	12/22/62	10.04	14.5
Rogue	Grants Pass	20.0	24.5	11/19	10.87	22.8	12/23/64	35.15	152
	Agness	17.0		11/19	14.56	42.3	12/23/64	68.03	290
Deschutes	Madras			11/20	3.99	7.01	7/16/83	7.7	22.5

Bold new record

produced flood damages estimated near $25 million. The mainstem Snake River, both at Weiser and Anatone, also exceeded flood stage, but damage was minor.

The storm also affected Washington rivers and those east of the Cascades (Table 12). Many rivers in western Washington rose above their flood stage but at most sites the flooding was minor. The Chehalis rose to more than 4.0 ft over its flood stage while the Deschutes and Snoqualmie rivers crested at more than two feet over their flood stages. In Eastern Washington the Klickitat and Walla Walla rivers and Hangman Creek exceeded flood stage. Along the lower Walla Walla River some homes were evacuated and some county roads were under water. On Hangmen Creek the crest of 14.9 ft, which was a new peak of record, substantially damaged both houses and golf courses on the lower part of the creek.

In March another extremely intense storm hit a small area on the Olympic Peninsula in Washington (Table 13). The observed crest on the Skokomish River near Potlatch was the highest level in recorded history. During the storm up to 14 inches of rain fell in headwaters areas of the Wynoochee River, with headwaters adjacent to the Skokomish River, causing the gage at Montesano to exceeded flood stage for the first time since Wynoochee Dam was built. The Cedar River, even with informal flood control at upstream water supply projects, managed to exceed major flood stage. The unregulated Satsop River eclipsed its old all time peak stage by more than 1.5 ft as did the Naselle River. The Little Spokane River in eastern Washington also set a new peak stage nearly 1.0 ft greater than the old record.

Spring Floods During the winter record snowpacks accumulated in most areas of the Columbia Basin from fall and winter precipitation that averaged greater than 130% of normal for all areas except the Columbia Basin in Canada. The autumn and early winter rainfall recharged the soil moisture before colder temperatures moved into the region and snow began accumulating. These precursor conditions, high soil moisture, frozen ground, and heavy snowpacks, portended possible serious flooding in Idaho, Montana, and portions of eastern Oregon and eastern Washington.

Most spring peaks flows occurred during a period of hot spell in May. The exception was the upper Snake and upper Salmon rivers where a combination of snowmelt and heavy rainfall produced a flood peak in early June. In Montana new record peak flows were recorded on the Stillwater River near Kalispell and on the Clark Fork at St Regis (Table 14). The potential for record peak flows on the Flathead River and the upper Clark Fork was mitigated by cooler-than-normal temperatures from mid-May through June which retarded snowmelt rates.

Table 11

DECEMBER-JANUARY FLOOD PEAKS - OREGON

RIVER	GAGE	DAMAGE STAGE		OBSERVED PEAK			REDUCTION	
		ZERO	MAJOR	DATE	STAGE	DISCH	STAGE	DISCH
MF Willamette	Jasper	10.0		12/25	10.1	23.4	4.5	35.5
CF Willamette	Goshen	13.0		12/31	13.2	15.5	1.4	4.0
Willamette	Eugene	23.0	29.0	12/31	20.0	39.0	6.6	36.5
	Harrisburg	14.0	17.0	12/31	13.5	65.8	5.7	65.8
	Albany	25.0	32.0	1/2	27.3	96.2	5.4	59.5
	Salem	28.0	33.0	1/2	29.4	162.8	4.8	69.3
	Oregon City	14.0	17.0	1/2	16.3	263.1	1.0	33.6
	Portland	18.0	25.0	1/3	23.5	306.0		
McKenzie	Vida	11.0	14.0	12/31	7.8	21.1	4.4	19.6
Long Tom	Monroe			12/29	8.9	6.52	2.6	7.58
N Santiam	Mehama	11.0	13.5	12/26	8.9	18.9	2.8	19.3
S Santiam	Waterloo	12.0		12/29	10.3	19.3	7.2	30.8
Santiam	Jefferson	15.0	20.0	12/26	17.0	62.2	4.0	49.5
S Yamhill	McMinnville	50.0		12/30	55.2	28		
Tualatin	Dilley	17.0		12/30	17.95	3.3		
	West Linn	13.5		1/2	16.3	21		
Johnson	Milwaukie	27.4		1/1	29.35	1.7		
Wilson	Tillamook	13.0		12/29	13.9	17		
Nehalem	Foss	14.0		12/31	19.1	35		
Grande Ronde	Troy	10.0		1/1	12.15	38		
Imnaha	Imnaha	4.2		1/1	10.3	7.5		
Warm Springs	Kahneeta H S	4.2		1/1	9.6	8.7		
John Day	Service Cr			1/1	16.5	35		
Deschutes	Moody	8.0		1/1	9.0			
Lost Creek Lake	Outflow			1/10		16.9e		
Rogue	Dodge Bridge	10.0	10.0	1/1	10.23e	26.8	3.3	24.2
	Central Point			1/1	17.10e	69.99	2.7	22.91
	Grants Pass	20.0	24.5	1/1	25.55e	85.8	4.2	23.2
	Agness	17.0		1/2	51.19e	241.0	6.2	26.0
Applegate Lake	Outflow			1/1		15.8e		
Applegate	Applegate	13.0		1/1	16.76e	29.56	5.9	14.94
	Wilderville			1/1	16.52e	52.2	1.1	13.2

e = estimated

Table 12

DECEMBER - JANUARY FLOOD PEAKS - WASHINGTON & IDAHO

RIVER	GAGE	DAMAGE STAGE		OBSERVED PEAK			PREVIOUS RECORD		
		ZERO	MAJOR	DATE	STAGE	DISCH	DATE	STAGE	DISCH
Nooksack	Ferndale	12.0	15.1	12/31		25.4*	11/10/90	23.56	57.0
Snoqualmie Snohomish	Carnation Snohomish	54.0 25.0	58.0 29.0	1/2 1/3	56.5 25.1		11/24/90	60.7	65.2
Cedar	Renton	12.0	12.4	1/2	12.7		11/24/90	17.13	10.6
Skokomish Deschutes	Potlatch Rainier	15.5 12.0		1/1 12/30	16.7 14.3		12/20/94 1/9/90	17.47 17.01	 9.6
Skookumchuck Grand Mound Satsop	Centralia Grand Mound Satsop	85.0 13.3 34.0	 38.0	12/30 12/30 1/1	70.2 17.3 34.5		 2/9/96 1/22/35	 19.98 38.9	 74.8 46.6
Willapa	Willapa	21.0		1/1	21.9		12/20/94	27.28	14.8
Hangman	Spokane	11.0		**1/1**	**15.4**	**25.8**	2/3/63	13.35	20.6
St Joe	Calder	13.0	16.0	12/31	13.9	24.0*	12/23/33		53.0
Payette	Banks			1/1		19.1			
Weiser	Cambridge Weiser	12.0 9.0	14.5	**1/1** **1/1**		**22.8** **34.5**	12/22/55 3/25/93	13.9 11.96	10.1 21.7

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* Ice jam affected stage. **Bold** new record

In Washington, the lower Pend Oreille and Spokane rivers were the only ones to approach a peak of record during the spring runoff. The peak of 29.0 ft at Spokane exceeded all but the 1894 record peak. The Pend Oreille River at Newport had a peak flow of 138.3 kcfs, also was exceeded only by the 1894 record spring peak. Substantial damage was done on the Pend Oreille River in the reach from Newport down to Box Canyon Dam. Some levees failed and hundreds of homes had to be evacuated. An estimated total of $3 million damage was done to homes, road, bridges, and business during the flood.

In Idaho, several record flood peaks were observed on the upper Snake during the June rain-on-snow event. Peak flows at Heise, Blackfoot, and Milner were exceeded only by the 1894 flood peaks. The peak flow on the Henrys Fork near Rexburg was the third highest of record. Severe flooding took place on the Snake River from Heise to Milner. Hundreds of homes were flooded, state and interstate highways submerged, and numerous irrigation works were damaged during the flood. The peak flow of 17.1 kcfs on the Salmon River at Salmon, was just under the record flow of 17.7 kcfs set in 1974.

Record snowpacks at high-elevation in the Boise and Payette basins did not produce record spring peaks, probably because much of their low- to mid-elevation snow was lost during the January flood event and not replaced.

In Oregon, only the Grande Ronde and the Imnaha rivers experienced flooding during the spring season. On the lower Columbia peak stages were controlled to near 19 ft at Vancouver, three feet above flood stage, producing only minor lowland flooding.

Table 13

MARCH FLOOD PEAKS - WASHINGTON & IDAHO

RIVER	GAGE	DAMAGE STAGE		OBSERVED PEAK			PREVIOUS RECORD		
		ZERO	MAJOR	DATE	STAGE	DISCH	DATE	STAGE	DISCH
Nooksack	Ferndale	12.0	15.1	12/31		25.4*	11/10/90	23.56	57.0
Snoqualmie Snohomish	Carnation Snohomish	54.0 25.0	58.0 29.0	1/2 1/3	56.5 25.1		11/24/90	60.7	65.2
Cedar	Renton	12.0	12.4	1/2	12.7		11/24/90	17.13	10.6
Skokomish Deschutes	Potlatch Rainier	15.5 12.0		1/1 12/30	16.7 14.3		12/20/94 1/9/90	17.47 17.01	 9.6
Satsop Wynoochee	Satsop abv Black Cr	34.0 19.0	38.0	**3/19** 3/19	**38.87** 20.21	**63.6** 25.6R	12/20/94 1/19/68	37.28 20.54	50.6 25.5
Quinault Willapa Naselle	Quinault Lk Willapa Naselle	 21.0 	 	3/19 3/19 **3/18**	 24.54 **19.17**	46.4 12.1 **12**	11/4/95 12/20/94 11/24/90	20.51 27.28 18.45	50.2 14.8 11.3
Ltl Spokane	Dartford			**3/21**	**8.24**	**4.12**	2/17/70	7.29	3.17

. * Ice jam affected stage. **Bold** new record R = regulated

Table 14

JUNE FLOOD PEAKS - IDAHO

RIVER	GAGE	DAMAGE STAGE		OBSERVED PEAK			PREVIOUS RECORD		
		ZERO	MAJOR	DATE	STAGE	DISCH	DATE	STAGE	DISCH
Snake	Flagg Ranch Moran Irwin Heise	 21 **	 	6/5 6/11 **6/19** 6/13	 	14.5 12.1 **40.4** 43.5	6/5/96 6/12/18 6/4-6/56 5/19/27	10.75 10.41 13.31 16.0	15.0 15.1 31.8 60.0
Henrys Fork	St Anthony Rexburg	7.0 9.0		5/30 6/12		10.6 13.6	5/16/84 5/17/84	8.62 12.05	13.2 16.4
Willow	blw Tex Cr			**5/9**		**2.42**	4/23/86	5.76	1.49
Snake	Shelley	12.0	12.5	**6/17**		**47.8**	6/17/18	16.97	47.2
Portneuf	Pocatello	8.0	11.0	5/20		1.3	2/24/62	11.35	2.99
Snake	Milner			**6/22**		**30.8**	7/4/27	20.83	26.0

. * Ice jam affected stage. **Bold** new record R = regulated ** discharge in kcfs

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 minimize 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, the upper Snake River Basin in 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.

Table 15

UNREGULATED RUNOFF VOLUME FORECASTS
(Thousand Acre-Feet)

FORECAST DATE	MICA	ARROW	LIBBY	DUNCAN	GRAND COULEE
	Feb-Sep	Feb-Sep	Jan-Jul	Feb-Sep	Jan-Jul
Jan 1	13,500	27,100	7160	2340	76,800
Feb 1	14,400	28,800	7420	2610	79,700
Mar 1	14,100	29,000	7050	2470	77700
Apr 1	14,900	30,000	7700	2520	82,000
May 1	15,100	30,400	7760	2570	83,300
Jun 1	15,300	30,900	8210	2610	89,400
Obs	**14,245**	**30,736**	**8055**	**2748**	**88,170**
FORECAST DATE	**HUNGRY HORSE**	**YAKIMA PARKER**	**DWORSHAK**	**LOWER GRANITE**	**THE DALLES**
	Jan-Jul	Apr-Sep	Jan-Jul	Jan-Jul	Jan-Jul
Jan 1	2970	2990	5230	45,400	138,000
Feb 1	3020	3010	5260	49,100	145,000
Mar 1	3030	2790	5200	48,000	142,000
Apr 1	3200	3050	5600	48,300	149,000
May 1	3210	3190	5840	50,600	153,000
Jun 1	3760	3180	5780	49,400	159,000
Obs	**3291**	**3504**	**5935**	**49,478**	**159,000**

Table 16

FORECAST AND OBSERVED RUNOFF (kaf)

STREAM	STATION	FORECAST PERIOD	30-YR NORMAL	FORECAST		OBS RUNOFF	FCST ERR (%)	
				JAN 1	APR 1		JAN 1	APR 1
COLUMBIA	Mica Inflow	Feb-Sep	13,170	13,500	14,900	14,245	+9	-1
	Duncan Inflow	Feb-Sep	2,319	2,340	2,520	2748	+18	+10
KOOTENAI	Libby Inflow	Jan-Jul	6,396	7,160	7,700	8,055	14	6
		Apr-Sep	6,772	7,580	8,090	8,348	18	4
COLUMBIA	Birchbank	Apr-Sep	43,800	48,700	51,900	54,619	+14	+6
SF FLATHEAD	Hungry Horse Inflow	Jan-Jul	2,269	2,970	3,200	3,291	14	4
		Apr-Jul	2,051	2,690	2,940	3,027	16	4
		Apr-Sep	2,184	2,860	3,130	3,208	16	4
FLATHEAD	Flathead Inflow	Apr-Sep	6,926	9,120	10,000	10,055	13	1
PEND OREILLE	Pend Oreille Inf	Apr-Sep	14,370	19,900	2,100	22,977	21	14
SPOKANE	Spokane	Apr-Sep	2,864	4,390	4,820	4,860	16	1
COLUMBIA	Grand Coulee Inflow	Jan-Jul	63,280	76,800	82,000	88,170	18	10
		Apr-Aug	60,940	74,000	78,300	83,340	10	6
OKANOGAN	Tonasket	Apr-Sep	1,623	2,150	2,400	3,032	54	39
METHOW	Pateros	Apr-Sep	941	1,180	1,410	1,417	25	1
WENATCHEE	Peshastin	Apr-Sep	1,636	2,160	2,420	2405	15	-1
COLUMBIA	Priest Rapids	Apr-Sep	70,410	86,800	92,900	96,518	14	5
YAKIMA	Parker	Apr-Sep	1,994	2,990	3,050	3,504	26	23
SNAKE	Moran	Apr-Jul	781	1,060	1,170	1,413	45	31
	Heise	Apr-Jul	3,451	4,860	5,090	5,992	33	26
BOISE	Boise	Apr-Jul	1,421	2,590	2,540	2,332	-18	-15
PAYETTE	Emmett	Apr-Jul	1,186	2,480	2,290	1,885	-50	-34
SNAKE	Weiser	Apr-Jul	5,465	9,580	8,750	9,208	-7	8
SALMON	White Bird	Apr-Jul	5,955	9,470	8,800	9,405	-1	10
GRANDE RONDE	Troy	Apr-Jul	1,214	1,960	1,400	2,018	5	50
NF CLEARWATER	Dworshak	Jan-Jul	3,548	5,230	5,600	5,935	20	9
		Apr-Jul	2,700	3,980	4,300	4,637	24	12
CLEARWATER	Spalding	Apr-Jul	7,618	11,000	11,800	12,203	16	5
SNAKE	Lower Granite	Jan-Jul	29,740	45,400	48,300	49,478	14	4
		Apr-Aug	23,000	35,000	34,800	35,290	1	2
JOHN DAY	Service Creek	Apr-Sep	821	1,370	1,150	943	-52	-25
DESCHUTES	Moody	Apr-Sep	1,902	2,460	2,310	2,269	-10	-2
COLUMBIA	The Dalles	Jan-Jul	105,900	138,000	149,000	159,000	13	9
		Apr-Aug	93,250	121,000	125,000	133,133	45	31

1. Runoff Volumes

The monthly forecasts for ten key sites (Table 15) show that the initial January 1 forecasts were modified as the season progressed to reflect how the precipitation, temperature, snowpack, and discharge depart from their normals. Water supply volume forecasts on January 1, Table 16, indicated above normal runoff was expected in all basins because of the initial hydrologic conditions were above normal for all basins. This water supply picture continued to increase through April 1, as the rainfall continued above normal in the Columbia and Snake basins. This two month weather regime increased the volume runoff forecasts by as much as 20% in some sub-basins, specifically on the upper Columbia River and parts of the Pend Oreille River system. This table also shows the forecast errors for each basin.

Table 17

MONTHLY FORECASTS VS. ACTUAL RUNOFF
COLUMBIA RIVER ABOVE THE DALLES

YEAR	JANUARY-JULY RUNOFF VOLUME (kaf)						
	FORECAST ISSUE DATE						OBSERVED
	JAN 1	FEB 1	MAR 1	APR 1	MAY 1	JUN 1	
1970	82,500	99,500	93,400	94,300	95,100	--	**95,700**
1971	110,900	129,500	126,000	134,000	133,000	135,000	**137,500**
1972	110,100	128,000	138,700	146,100	146,000	146,000	**151,700**
1973	93,100	90,500	84,700	83,000	80,400	78,700	**71,200**
1974	123,000	140,000	146,000	149,000	147,000	147,000	**156,300**
1975	96,100	106,200	114,700	116,700	115,200	113,000	**112,400**
1976	113,000	116,000	121,000	124,000	124,000	124,000	**122,800**
1977	75,700	62,200	55,900	58,100	53,800	57,400	**53,800**
1978	120,000	114,000	108,000	101,000	104,000	105,000	**105,600**
1979	88,000	78,600	93,000	87,300	89,900	89,700	**83,100**
1980	88,900	88,900	88,900	89,700	90,600	97,700	**95,800**
1981	106,000	84,700	84,500	81,900	83,200	95,900	**103,500**
1982	110,000	120,000	126,000	130,000	131,000	128,000	**129,900**
1983	110,000	108,000	113,000	121,000	121,000	119,000	**118,700**
1984	113,000	103,000	97,600	102,000	107,000	114,000	**119,000**
1985	131,000	109,000	105,000	98,600	98,600	100,000	**87,700**
1986	96,800	93,300	103,300	106,000	108,000	108,000	**108,300**
1987	88,900	81,900	78,000	80,000	76,700	75,800	**76,500**
1988	79,200	74,800	72,700	74,000	76,100	75,000	**72,700**
1989	101,100	102,000	94,200	99,500	98,600	96,900	**90,600**
1990	86,500	101,000	104,000	96,000	96,000	99,500	**99,700**
1991	116,000	110,000	107,000	106,000	106,000	104,000	**107,000**
1992	92,600	89,100	83,300	71,200	71,200	67,800	**70,400**
1993	92,600	86,500	77,300	76,600	81,900	86,100	**88,000**
1994	79,700	76,300	78,100	73,200	75,500	74,600	**75,000**
1995	101,000	99,600	94,300	99,600	99,600	97,900	**117,100**
1996	116,000	122,000	130,000	126,000	134,000	141,000	**139,300**
1997	138,000	145,000	142,000	149,000	153,000	159,000	**159,000**

Table 17 shows the history of forecasting the January-July runoff of the Columbia River at The Dalles for the period 1970-97. 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 the models. This year's observed January-July runoff was 159 maf, exceeding both the notable volumes of 1972 and 1974.

2. Long-Range Peaks

Spring peak-flow forecasts, expressed as a range of stages or flows, are a product of volume forecasts with model simulations of daily forecasts which provide adjustments to these long-range predictions and were expressed so there was a probability that 25% of peak discharges may occur above the higher limit, and a 25% probability of the peak occurring below the lower limit. The verification of this year's forecasts for key stations in Table 18 shows that most of the observed peaks fell above the expected range. This reflects the period of moderate rain and reduced the need for irrigation diversions and thereby increasing in-river flows for May and June.

3. Daily Streamflows

The forecasts of operational streamflow were prepared by the NWRFC. The three operating agencies, Reclamation, Bonneville, and the Corps, used these stream flow forecasts in their day-to-day reservoir project operation and energy operation. Close and constant coordination was required between these agencies and the NWRFC because project operation 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.

Table 18

FORECAST AND OBSERVED PEAK FLOW AND STAGES
FORECAST ISSUED APRIL 1

RIVER	STATION	FLOOD STAGE (ft)	PEAK REGULATED STAGE			PEAK REGULATED FLOW			
			Forecast (ft)		Obs'd[1] Stage (ft)	Forecast (kcfs)		Obs'd Flow (kcfs)	Date
			Low	High		Low	High		
Flathead	Columbia Falls	13.0	14.0	16.4	15.3	52.0	71.9	61.6	5/17
Clark Fork	ab Missoula	11.0	11.0	13.8	12.6	21.5	31.3	26.5	5/18
	St Regis	19.0	19.2	20.8	20.3	60.9	73.5	68.2	5/18
Pend Oreille	Newport	106. [1]				120.2	140.2	138.3	6/05
Spokane	Spokane	27.0	27.6	28.8	29.0	34.8	40.8	44.7	5/20
Okanogan	Tonasket	15.0	16.4	18.4	17.8	23.8	30.2	27.8	5/18
Wenatchee	Peshastin	13.0	12.0	13.8	12.3	21.0	26.8	21.5	5/17
Columbia	Priest Rapids	422. [1]	29.4	32.0		346.4	406.4	414.9	6/12
Yakima	Parker	10.0	9.8	11.2	10.3	19.4	25.4	19.7	5/15
Henrys Fork	Rexburg	9.0	10.8	11.4	11.1	12.4	14.8	13.2	5/26
Payette	Emmett	16.0 [1]	11.8	14.4	18.2	20.0	27.7	100.5	4/21
Salmon	White Bird	32.0	32.2	34.6	32.2	101.8	122.5	84.0	5/18
Clearwater	Spalding	18.0	15.6	18.6	15.6	85.7	119.5	230.0	5/17
Snake	Lower Granite	325. [1]				264.0	342.1		5/18
Columbia	The Dalles					537.1	617.1	563.2	6/03
	Vancouver	16.0	16.6	23.2	19.1				6/04
Willamette	Portland	18.0	16.1	22.7	18.6				6/04

Peak forecasts predict the range of the 67% chance (1-sigma about the median) of occurrence. Abnormal weather during the critical melt period may cause the peak to be outside the indicated range. Source NW RFC. [1] Discharge in kcfs.