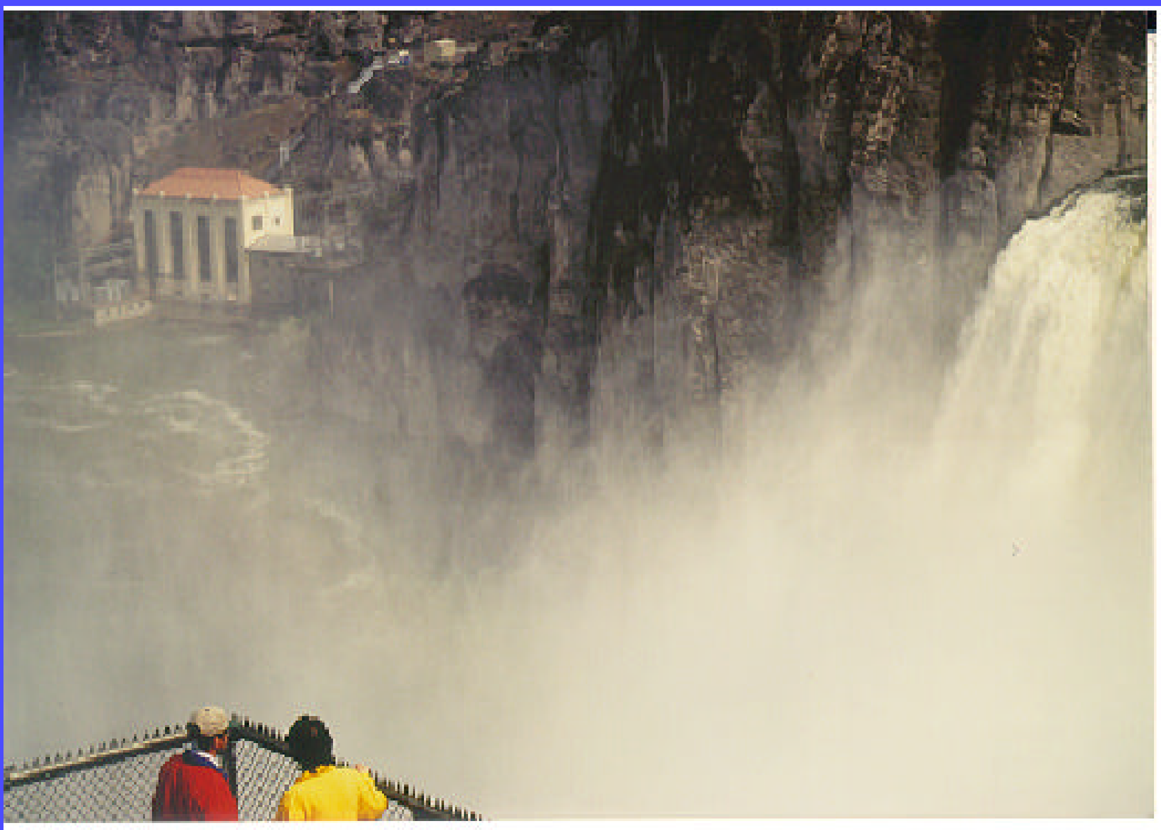
COLUMBIA RIVER
WATER MANAGEMENT REPORT
Water Year 1997



Columbia River Water Management Group
April 1998

COLUMBIA RIVER WATER MANAGEMENT GROUP

I. Purpose.

The Columbia River Water Management Group will act as a committee to consider problems relating to operation and management of water control facilities. Upon review and discussion of the problems the group will make tentative recommendations for consideration of the individual agencies having primary responsibilities in these areas. Particular emphasis will be placed on coordination of river system operations including the efficient operation of the hydrometeorological system required for each operation. The basic objective of the group is to facilitate agreement among the agencies in the interest of more effective and efficient public service in the use of water resources of the Pacific Northwest.

II. Composition.

The Columbia River Water Management Group will be composed of the representatives of the States and of the Federal agencies involved in the operation and management of water control facilities or forecasting of streamflows related to water management activities in the Columbia River basin and contiguous areas in western Washington and Oregon. Each State and member agency will designate an official representative, together with an alternate, who will be delegated to set forth his agency's position on problems related to water management and river regulation. It is envisioned that these representatives will be supervisory personnel who are actively directing or allied with water management problems. Meetings would be open to representatives of other public and private organizations concerned with the activities of the group.

The Chairman of the Group will be from one of the three U.S. Federal Project operating agencies, namely, Bonneville Power Administration, Bureau of Reclamation, and the Corps of Engineers and this position will rotate annually. The Group normally will meet monthly throughout the year, or at such other intervals of time at the discretion of the Chairman. The permanent secretary will be provided by the Corps of Engineers, or as mutually agreed among the three Federal operating agencies.

III. Functions.

1. Coordinate seasonal program for system and project operations and the resolution of operational problems.

2. Prepare an annual report of significant water management events and such special reports as warranted.

3. Coordinate compilation of project operation data and water-use requirements, both at the reservoir sites and at downstream locations, for common use by all operating agencies.

4. Coordinate and perform as required the development of seasonal runoff forecasting procedures for Columbia River and tributaries, and coordinate the use of such forecasts by operating agencies.

5. Explore adequacy and propriety of short and medium range streamflow forecasts, and coordinate the use of such forecasts by operating agencies.

6. Coordinate the maintenance and expansion of the existing cooperative hydrometeorological reporting network for the Columbia River basin, including automation of reporting, communication requirements, and data bank facilities required for project operation.

7. Such other functions as are mutually agreeable among the operating agencies.

Revised January 14, 1972

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PREFACE

There are several things the editorial staff feels will help the readers understand this report. First, the material in this report was prepared by many Federal and State agencies as well as other non-governmental organizations. These contributions were of varying sizes and subjects, and were edited only to have a consistent format, thus maintaining the original author's style and intent. The also contain the numeric values calculated at their agency, which in some cases may differ slightly from those of other agencies due to calculation procedures. Minor differences were not resolved.

Second, there is a difference in spelling the names of some of the rivers, depending upon the spelling preference in the country. The proper spelling are consistent with the location being discussed. Example of these differences include:

United States	Canada
Kootenai River	Kootenay River
Okanogan River	Okanagan River
Pend Oreille River	Pend d'Oreille River

Third, is the inclusion of equivalent metric units. The inclusion of metric values is limited to the introduction and historical portions of this report with the one exception: water quality data, including water temperatures, which is measured and reported in metric units. Regarding the other hydrologic and meteorologic data, the agencies that collect and distribute these data do so in English units, *i.e.*, feet, inches, acre-feet, degrees Fahrenheit, etc, and are published as such in this report. Standard SI unit conversions are used in this report.

Fourth, all pool, reservoir, and lake surface levels are expressed in elevation, i.e., feet above mean sea level. Streamgage heights, on the other hand, are expressed in feet above a datum specific to each individual gage.

Unless otherwise noted, a standard 30-year period (1961-90) is used to compute means for hydrologic data. (In Canada this is computed on a calendar year basis whereas in the United States a water year period is used.) These mathematical means will be referred to as "normals" with arithmetic means of other time periods referred to as "averages." Except for temperatures all departures from normals are expressed in percent of the normal value.

Finally, this is a report on water management activities that pertain to the operation of dams and reservoirs. Other water-related activities, for example, dredging of coastal harbors and their associated, water quality studies, as well as adjudication of groundwater rights, are not project operations activities and, therefore, are not included in this report.

Copies of some of the back issues of this report, dating back to 1971, are still available. Copies may be obtained by contacting the Secretary to the Columbia River Water Management Group listed inside the back cover of this report. As time permits these publications will be added to the CRWMG web site.

SUMMARY

THE 1997 WATER YEAR IN REVIEW

Water year 1997 proved to be an unusually wet time in the Pacific Northwest. At the end of the second month all 27 primary sub-basins had normal or greater than normal seasonal precipitation, a status that remained throughout the year. The Upper John Day sub-basin was the driest with 115% of normal rainfall and Central Washington was the wettest with 152%. Of the 324 sub-basin-months of precipitation 43 sub-basin-months, or 13%, had less than 75% of normal rainfall, while 54% had more than 125% of normal rainfall, and 12% had more than 200% of normal, with the maximum monthly precipitation of 332% of normal observed in the Clearwater basin of central Idaho.

The Columbia Basin average snowpack was significantly greater than observed in the last 10 years. The April 1 snowpacks was 137% of normal at the beginning of the snowmelt season. Washington state generally had the greatest snowpack with the Yakima basin peaking at 215% of normal. Most of the snowpacks melted at a moderate rate and produce no over bank flows.

The streamflows produced by the heavy rains and abundant snowpacks produced some new record runoff volumes, but few new instantaneous peak flows. The new records were associated with the storms and floods of November, January, February, and March plus the wet summer months of August and September.

Three winter and one summer flood events occurred this year. The first winter flood was in November and resulted in a new record peak stage on Johnson Creek near Milwaukie although much of northwestern Oregon was inundated by this short but intense storm. The second event occurred after New Years Day, effecting northern Oregon, southern Washington, and central Idaho. Although flooding was common over much of the region west of the Cascades New peak flow records were set in the Weiser Basin in central Idaho and Hangman Creek near Spokane, Washington. The March event centered mainly in southwestern Washington and set new peak flow records on the Naselle, Satsop, Skokomish, and Cedar rivers. The affects of this storm were also felt near Spokane where the Little Spokane River broke its previous record peak flood stage by 1.5 ft.

The well above normal basin-wide snowpacks presented a potential for major flooding in the Columbia Basin, if spring and summer temperatures were to be above normal for an extended period. However, temperatures remained cool for the most part so the snowmelt was orderly and extended, presenting a long runoff by with few significant flood peaks. The exception was in the upper Snake Basin where a brief hot spell in June produced flooding from the Idaho-Wyoming border to central Idaho.

Good runoff volume forecasting proved to be a benefit in the reservoir operation. Most flood control reservoirs were effectively drafted to store the impending runoff. The observed January-July runoff volume was 159.0 maf, 150% of normal, exceeding the record years of 1972 and 1974.

The operation of flood control reservoirs was as expected for the volume of runoff. From April 7 through August 31 storage in Grand Coulee, Libby, Hungry Horse, and Dworshak was used to augment flows at McNary and Lower Granite, in accordance with National Marine Fisheries Service's Biological Opinion for meeting target flows for salmon out-migration. Libby flow augmentation was also made for sturgeon spawning in the Kootenai River near Bonners Ferry, Idaho. Albeni Falls is in a three year study of an higher minimum winter pool elevation to evaluate this operations effects on resident fish spawning. Dworshak drawdown began in July to get to the reservoir surface down to the 1500-foot level for grouting of cracks in the structure.

The high volume of runoff, together with lower than expected power demands, due to warmer temperatures in the southwest, provided more water to be spilled in addition to that requested by the fisheries agencies to maintain an in-river migration of juvenile salmon from their spawning areas to the ocean. Total dissolved gas values exceeded 120% for up to 68 days on the lower Snake River and for 71 days on the lower Columbia River. Peak TDG levels were in excess of 130%.

This year's hatchery releases were 10 million less than normal and 13 million less than last year. Juveniles collected were 19% greater than in 1996 but due to the BiOp 131% more were returned to the river for instream migration. Total fish transported this year was approximately the same at 1996 and 60% of the 1995.

Most returning adust salmon species showed increases over the previous year's counts, with only fall chinook and steelhead counts were lower at Ice Harbor and McNary. Counts of returning spring chinook doubled from 1996 at Bonneville, tripled their return at McNary, and increased by five-fold at Ice Harbor while coho and sockeye both increased at Ice Harbor.

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I. INTRODUCTION

A. PURPOSE

This document reports on the operation of reservoirs and associated water management activities in the Columbia River Basin and the Pacific Northwest during Water Year 1997 (October 1996 through September 1997). It is prepared by the Columbia River Water Management Group (CRWMG), an interagency coordination group composed of representatives from federal and state agencies in the Pacific Northwest. (See inside the front cover for the charter and inside the back cover for agency representatives). Because the management of the Columbia River is a multi-faceted effort involving the resources of several agencies and the support of many others, this report reflects the collective input of as many as 15 different agencies. The 1997 report represents the 27th "Blue Book" published since the CRWMG initiated publication of the report in 1971. (Smaller reports were made for 15 years proceeding the 1971 report.) The history of the CRWMG and its predecessor organization, the Columbia Basin Interagency Committee (CBIAC), is contained in Chapter V.

This report is a record of the activities surrounding the regulation of the major reservoirs in the Columbia Basin and other river drainages in the Northwest. It includes a description of the weather, the forecasts of runoff, project operation data, plots and descriptions of reservoir regulation, and summary statistics on the accomplishments associated with the system operations. In addition, this report contains a brief summary of Group meetings and planning and regulatory activities undertaken during the water year by state and federal members of the CRWMG.

This report contains nine chapters and four appendices. They describe the weather and hydrology (Chapter II), reservoir operation (Chapter III), flood control events, power generation, fisheries management, and other water resource related activities (Chapters IV to VIII), and a chapter (IX) with acknowledgments. Appendices A, B, and C contain static information on definitions, abbreviations, and pertinent data on the major dams, powerhouses, and reservoirs in the Northwest. Appendix D contains graphic displays of the annual weather, project operation, and streamflow.

B. BASIN DESCRIPTION

This report discusses the water resources of the Pacific Northwest, which includes those in the Columbia River basin and its tributaries, plus the coastal streams of Washington and Oregon (Figure 1). It includes all the state of Washington, most of Oregon and Idaho, western Montana, southeastern British Columbia, and portions of Wyoming, Nevada. Utah, and California. The Columbia Basin itself covers 670,800 sq km (259,000 sq mi) and the coastal drainages of Oregon and Washington, including Puget Sound, cover 96,089 sq km (37,100 sq mi), for a total area of 766,900 sq km (296,100 sq mi).

The dominate physiographic features of the Northwest are the Pacific Ocean, the mountain ranges and the Columbia River Basin. The Pacific Ocean affects the region because it is the source of all moisture entering the region. The landmass is traversed by three major mountain ranges, the Coast Range, the Cascade Range, and the Rocky Mountains, crossing the region in a roughly north-south direction. As storms are driven across the Northwest by the prevailing westerly winds, the mountains force the removal of moisture from the airmass, as indicated by the higher rainfall west of the mountains than in east-side valleys. The Coast Range (excluding the Olympic Mountains), with a few peaks that extend over 915 m (3000 ft), generally lie within 30 km (20 mi) of the Pacific Ocean. The Olympic Mountains also lie adjacent to the Pacific Ocean, but have a different geological history, have peaks over 2130 m (7000 ft). The 100 km (62 mi) wide Puget

Sound/Willamette Valley trench, which extends from British Columbia to southern Oregon, separates the Coastal/Olympic and Cascade mountain ranges. The Cascades, a volcanic range with several peaks over 3050 m (10,000 ft), has an average crest elevation near 1830 m (6000 ft). East of the Cascade Range is the Columbia River Basin that drains the remainder of the Northwest. It is bordered on the east by the Continental Divide and the Rocky Mountains, on the south by the low divide into the Great Basins of Utah and Nevada, and on the north by the Monashee (a range within the Rockies) and Cascade mountains in British Columbia.

The Columbia River is the largest river in the Pacific Northwest and, with a length of 1953 km (1214 mi), is the 15th longest in North America. From its source at Columbia Lake at an elevation of 809 m (2650 ft) in Canada's Selkirk Mountains it first flows northwestward through eastern British Columbia, then turns southward toward the United States. It crosses the US-Canadian border north of Spokane, Washington, then flows southward across central Washington where it is joined by the Snake River, which drains southeastern Washington, eastern Oregon and southern Idaho. The Columbia then turns westward, forming the border between Washington and Oregon, flows through the Columbia River Gorge through the Cascade Mountains and on to its mouth at the Pacific Ocean near Astoria, Oregon.

The Columbia ranks sixth in North America in terms of runoff after the Mississippi, MacKenzie, St Lawrence, Nelson, and Yukon rivers and is ranked 32nd among rivers of the world in area drained. The major tributaries to the Columbia are the Kootenai and Flathead/Pend Oreille rivers which drain southeastern British Columbia, western Montana, and northern Idaho, the Snake River which drains western Wyoming, most of Idaho, eastern Oregon and southeastern Washington, and the Willamette River of western Oregon (Figure 2). There ten large drainages in the coastal basin of Washington, including Puget Sound (Figure 3), and four on the Oregon coast (Figure 4).

The climate of the region ranges from continental arid in parts of the Columbia Basin interior to alpine in the Coast and Cascade mountains to maritime rainforest in coastal areas. In parts of eastern Washington, eastern Oregon, and the Snake River basin an average of less than 200 mm (8 in.) of precipitation occurs annually. In contrast, some the coastal mountain rain forests receive more than 5100 mm (200 in.) of annual precipitation.

C. WATER RESOURCE DEVELOPMENT

Before the river systems of the Northwest were developed, the water resources mainly provided habitat for fish and wildlife, with people living along the shoreline to use the available food sources and to use the rivers for transportation. However, with the growth of both settlement and industry, the rivers have been developed for additional uses to meet the needs of the region: energy production, water supply, recreation, and flood control.

The first navigation locks constructed in the region were those on the Willamette River at Oregon City in 1873, which allowed navigation around the Willamette Falls, and in 1876 on the Columbia River two miles upstream of the present day location of Bonneville Dam, which allowed navigation around the treacherous cascades. The Willamette Locks are still in operation while the Cascade Locks were no longer needed when the construction of Bonneville Dam and Locks provided slack-water navigation up to The Dalles, Oregon. The lock walls, without the gates, can still be seen in the park at Cascades Locks, Oregon.

Hydroelectric development in the Northwest began in the late 1880's when electric "dynamos", now called generators, were installed on the Spokane River in Spokane, on the Willamette River at Oregon City, and on the Snoqualmie River at Snoqualmie Falls, east of Seattle. Harnessing the energy of the mainstem Columbia River did not begin until the Chelan County PUD #1 completed the construction of Rock Island Dam near Wenatchee in 1932, followed closely by the construction of Grand Coulee and Bonneville dams in the late 1930's. Bonneville was constructed with state-of-the-art fish ladders to assist the passage of returning salmon.

There were two other main periods of federal dam construction in the basin. The first was in the 1950's when Hungry Horse, Chief Joseph, The Dalles, McNary, Albeni Falls, and Ice Harbor dams were built, and the second was in the mid-1970's when the Columbia River Treaty projects (Libby, Mica, Duncan, and Keenleyside), Dworshak, and three lower Snake projects (Lower Granite, Little Goose, Lower Monumental) were built. Most of the construction of public utility and privately owned dams was also during these periods.

The river resource development responded to the region's population that had grown from approximately 2.8 million in 1933 to more than eight million today. Storage projects on the Columbia and lower Snake basins contain more than 53 billion cubic meters (43 million af) of usable flood control space and were authorized primarily for flood control, hydroelectric energy generation, irrigation, and navigation. Other uses include fish and wildlife enhancement, recreation, low-flow augmentation, and both municipal and industrial water supply. Figure 5 is a schematic drawing of the interrelationship of the operation of the projects in the Northwest. It also includes some of the key streamgages whose data are used in regulating the many reservoirs in the region.

D. TYPES OF RESERVOIR PROJECTS

Many so-called "reservoir" projects are actually "run-of-river," or "pondage" projects that have little or no storage capacity in comparison to their streamflow. Since these projects cannot store streamflow they generate electric energy with the water as it flows past the project. Bonneville, The Dalles, and McNary on the lower Columbia, the projects on the mid-Columbia (Priest Rapids to Chief Joseph), and Ice Harbor to Lower Granite on the lower Snake River are examples of pondage projects.

Some projects are designed specifically for daily reregulating of outflows from an upstream project. Big Cliff and Dexter Reservoirs in the Willamette Basin are examples of this type of reservoir, because they regulate and smooth out the peaking discharges caused by fluctuations in power generation at Detroit and Lookout Point dams, respectively, while their own outflows remain relatively constant.

A true storage reservoir is one that generally fills and drafts on an annual cycle. Some are "annual" storage reservoirs which are drafted to the minimum conservation pool and yet refill every year. Foster, Pend Oreille Lake, and Kootenay Lake are examples of annual reservoirs. Other storage reservoirs are "cyclic" because they may not refill each year. The amount of drawdown of cyclic reservoirs is based on volume inflow forecasts. Dworshak, Libby, Hungry Horse, Mica, Keenleyside, and Duncan dams are examples of cyclic reservoirs.

Another feature of storage reservoirs is the existence of at-site power generating facilities. Arrow and Duncan dams, for example, do not have at-site generation but yet have significant power benefits because water released from them can be timed to passes through many powerhouses downstream at times of peak power demands.

E. ANNUAL REGULATION CYCLE

There are two different regulation cycles for storage reservoirs in the Northwest. In the Northwest interior, where springtime snowmelt is the main source of river flows in the Columbia River, water is released from reservoirs during the cold winter period to generate electricity to meet the higher power demands and to prepare the reservoirs to store the snowmelt of the next spring and summer. In years with large snowfalls, flood control requirements may require additional drafting before snowmelt begins. The reservoirs are then filled during the snowmelt period, April through August, retaining the stored water for the next cycle and achieving flood control objectives in the process. After filling, the reservoirs generally remain as full as possible until the end of the summer recreation season, then they are lowered again to repeat the cycle of power generation and drafting for the next summer's flood control.

West of the Cascade Mountains, where much of the winter precipitation falls as rain, the regulation is quite different. During the late summer and fall, reservoirs are lowered (drafted) to provide flood control space for possible winter rain-produced floods. Winter drafting of reservoir below set flood control limits, even for electric power generation, may reduce the chances of spring refill for summer use as flow augmentation and recreation. If winter flood control operation is required, the stored water is released as soon as possible after the flood to regain storage space for controlling subsequent floods. Most of the reservoirs west of the Cascades begin seasonal refilling during February in proportion to the decreasing magnitude and possibility of flooding. This operation continues until the reservoirs finally reach their maximum level which is normally during late May. The reservoirs are usually held as full as possible during the summer for recreational use, although some downstream water uses may require some reservoir drafting. Drawdown must begin in the fall so that by November or early December there is sufficient storage space for winter flood control.

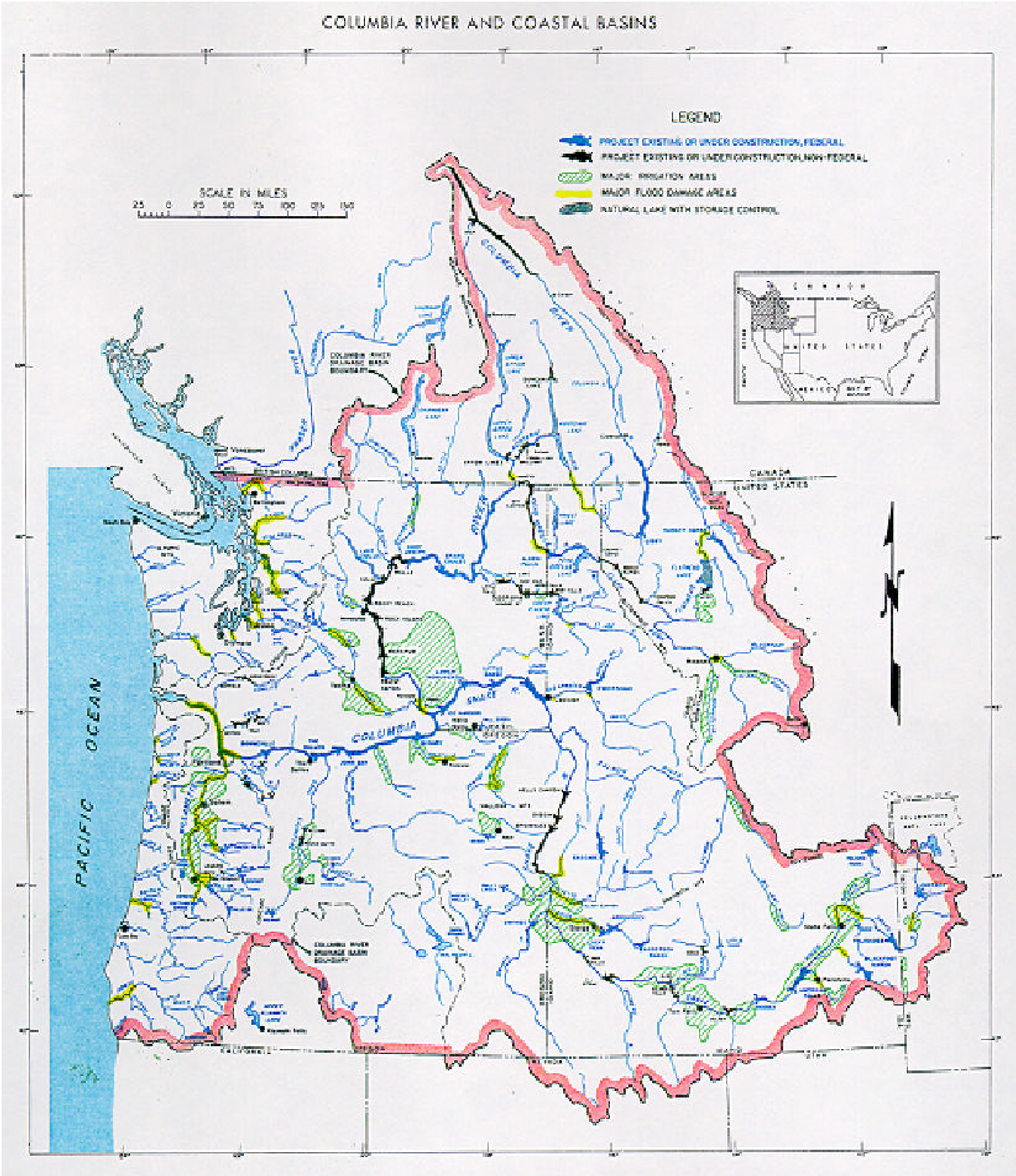

Figure 1. **COLUMBIA RIVER AND COASTAL BASINS MAP**

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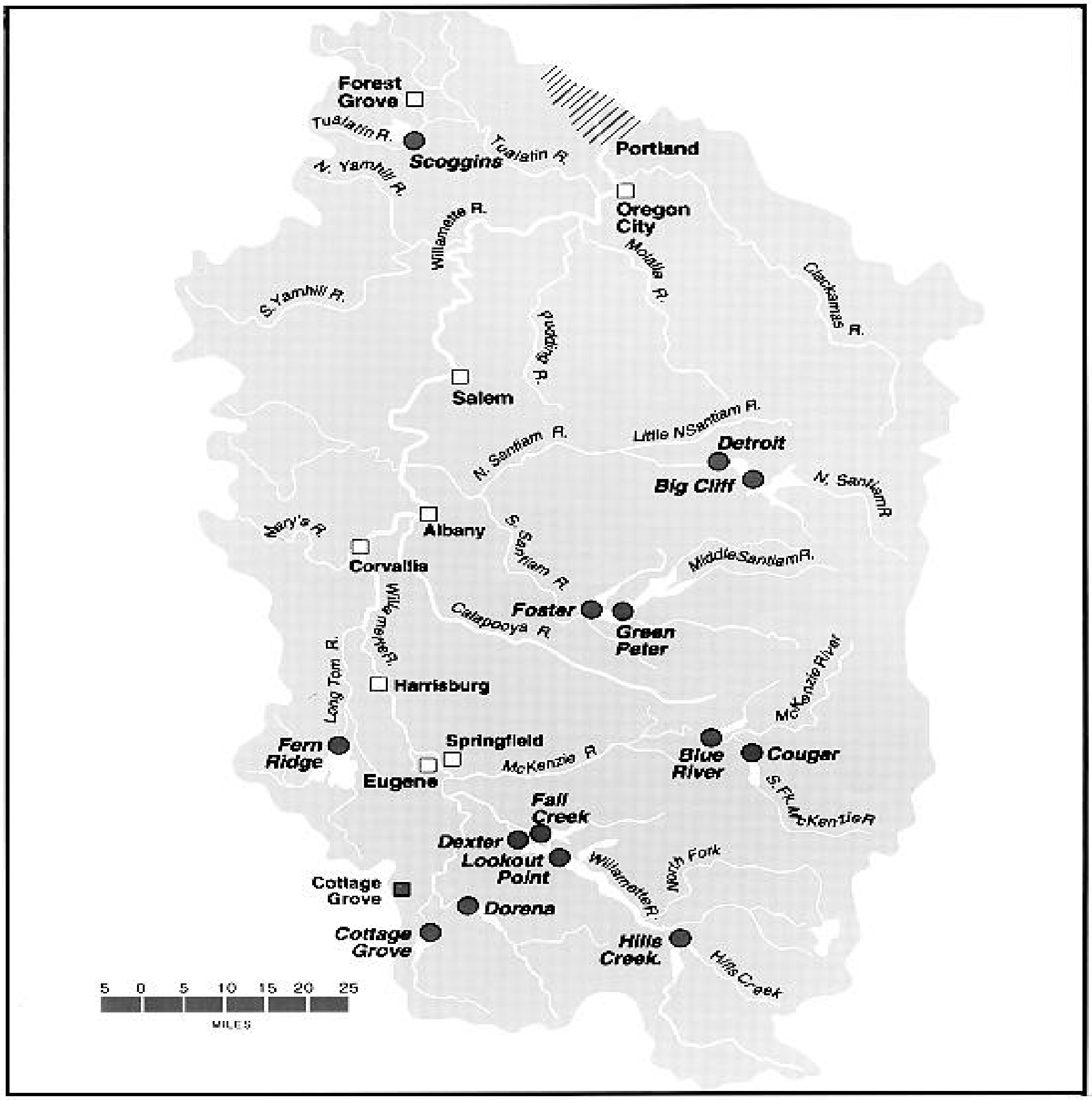

Figure 2. **WILLAMETTE RIVER BASIN MAP**

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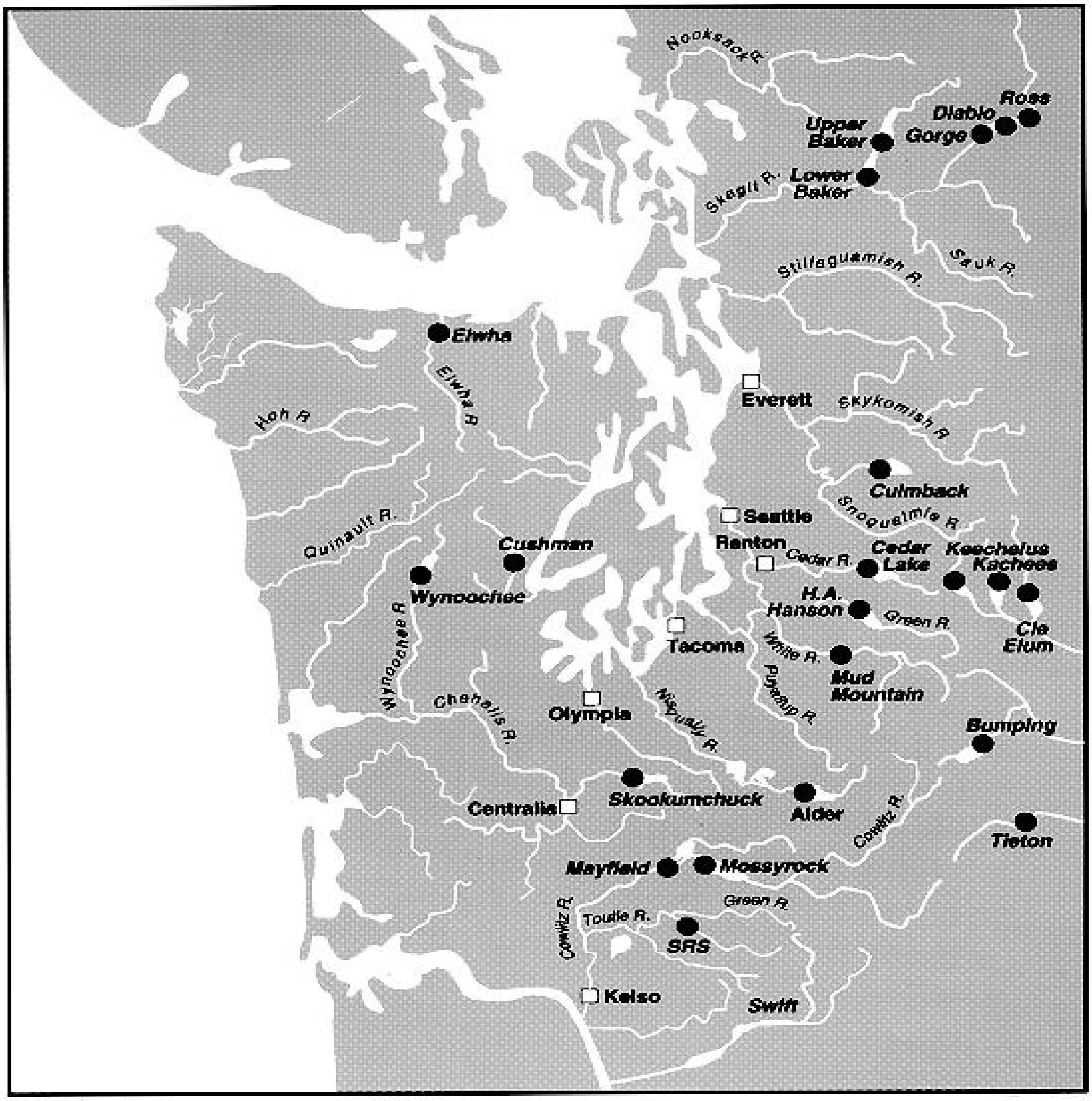

Figure 3. **WESTERN WASHINGTON MAP**

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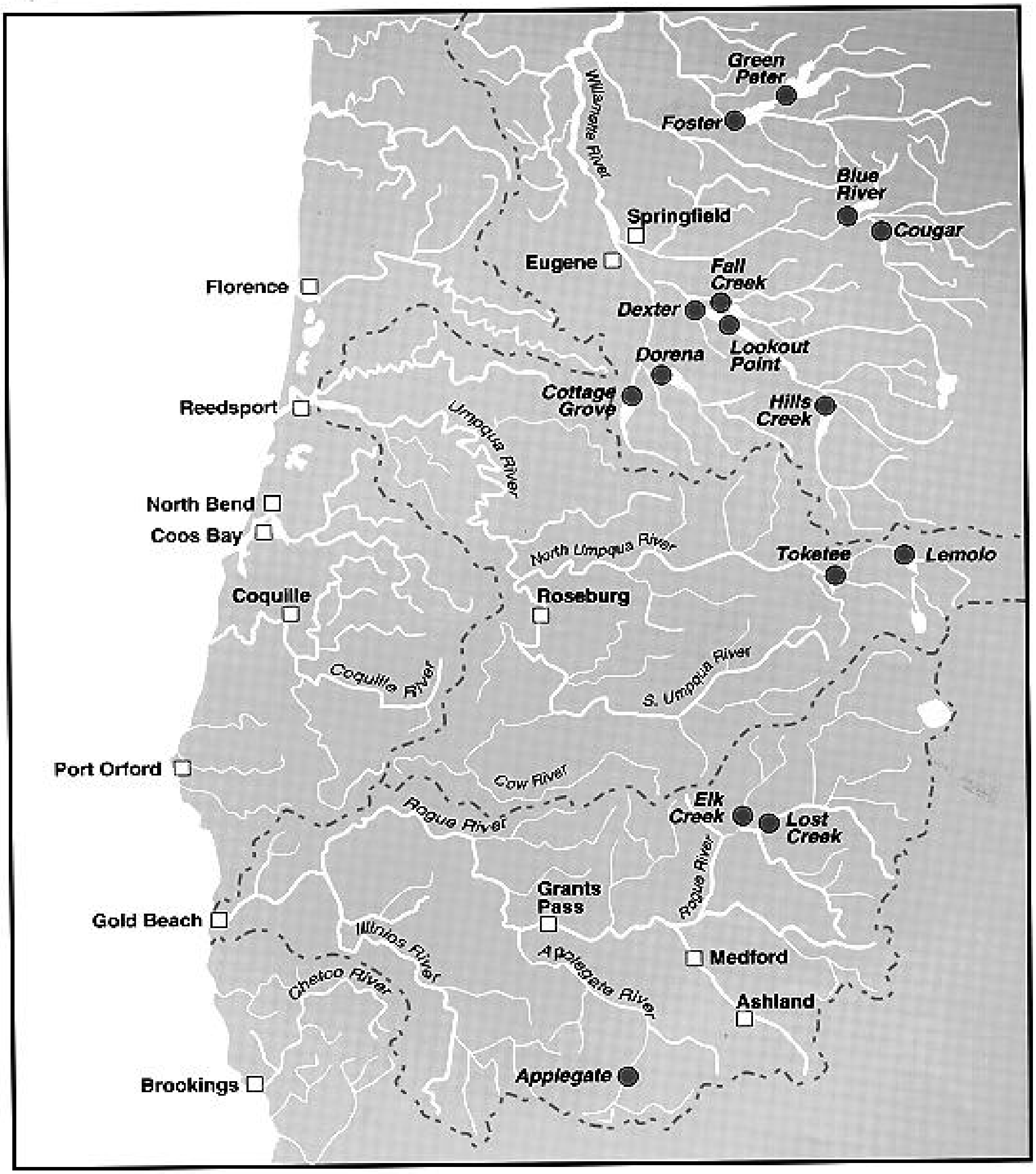

Figure 4. **SOUTHERN OREGON COASTAL BASINS MAP**

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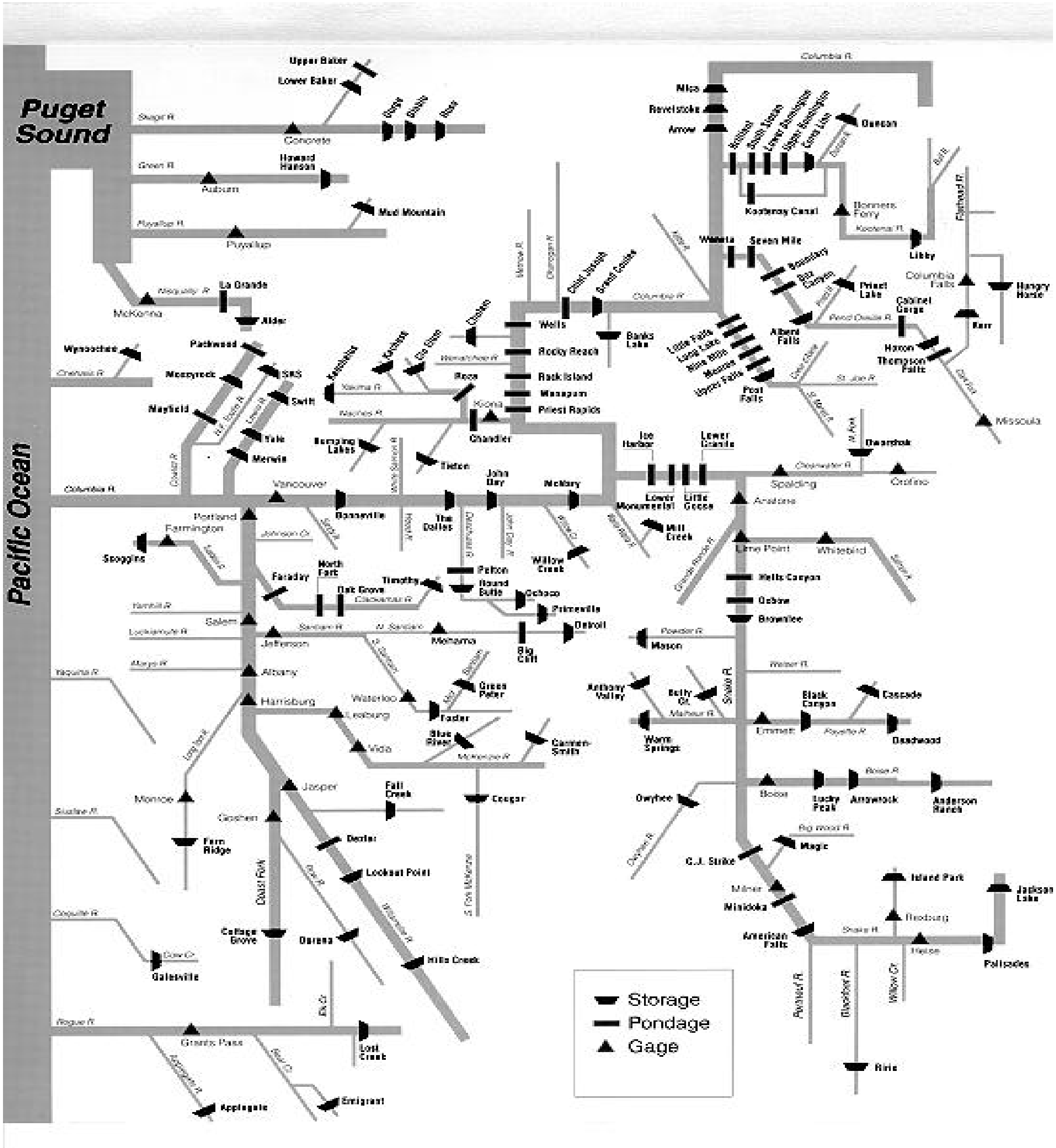

Figure 5. **PACIFIC NORTHWEST RESERVOIR SYSTEM SCHEMATIC**

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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

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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

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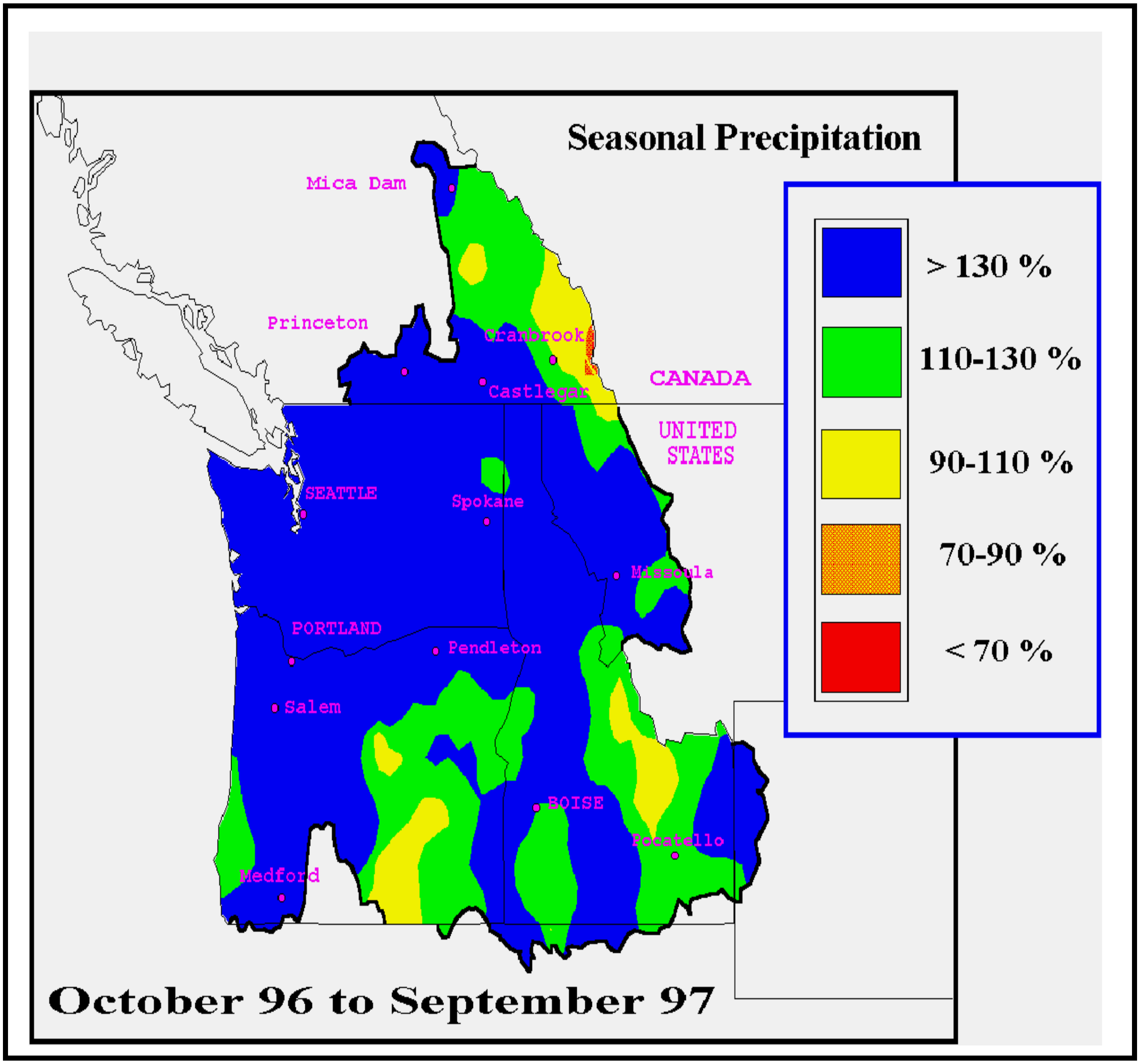

Figure 6. **ANNUAL (WATER YEAR) PRECIPITATION MAP**

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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 monthly 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-

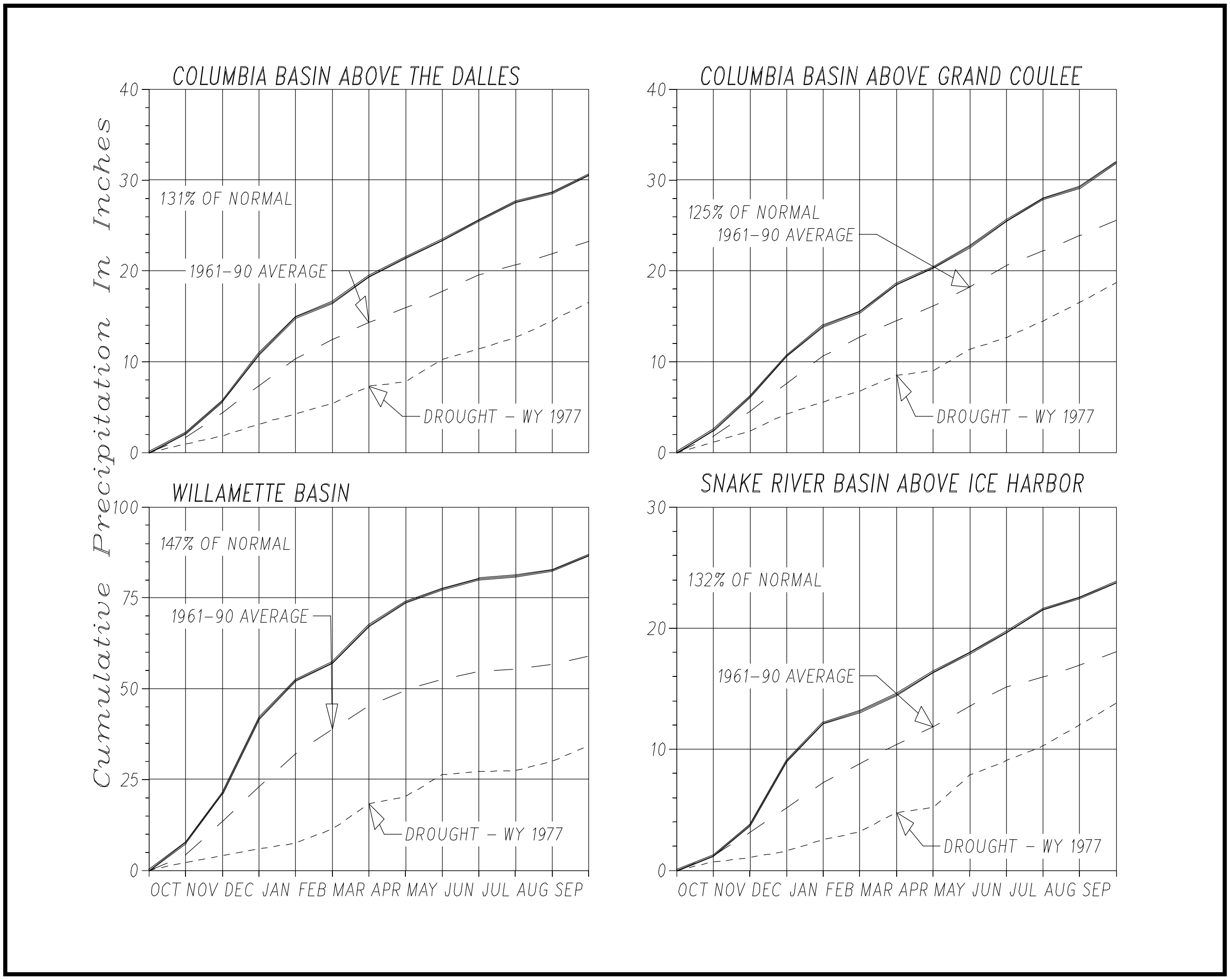

Figure 7. **ACCUMULATED MONTHLY DIVISION PRECIPITATION**

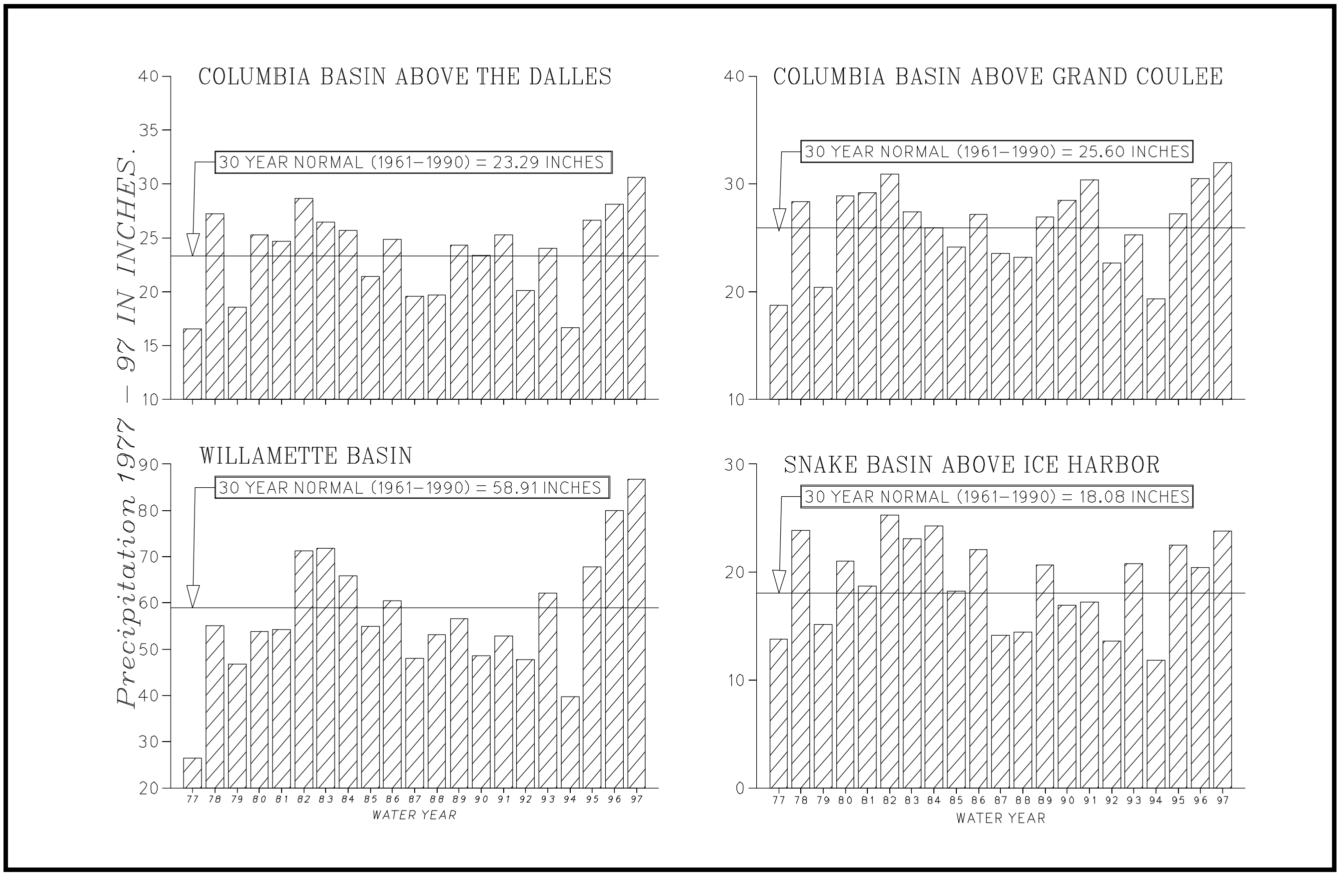

Figure 8. **DIVISION WATER YEAR PRECIPITATION, 1977-97**

ical distribution of the year's precipitation as a percent of normal.

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

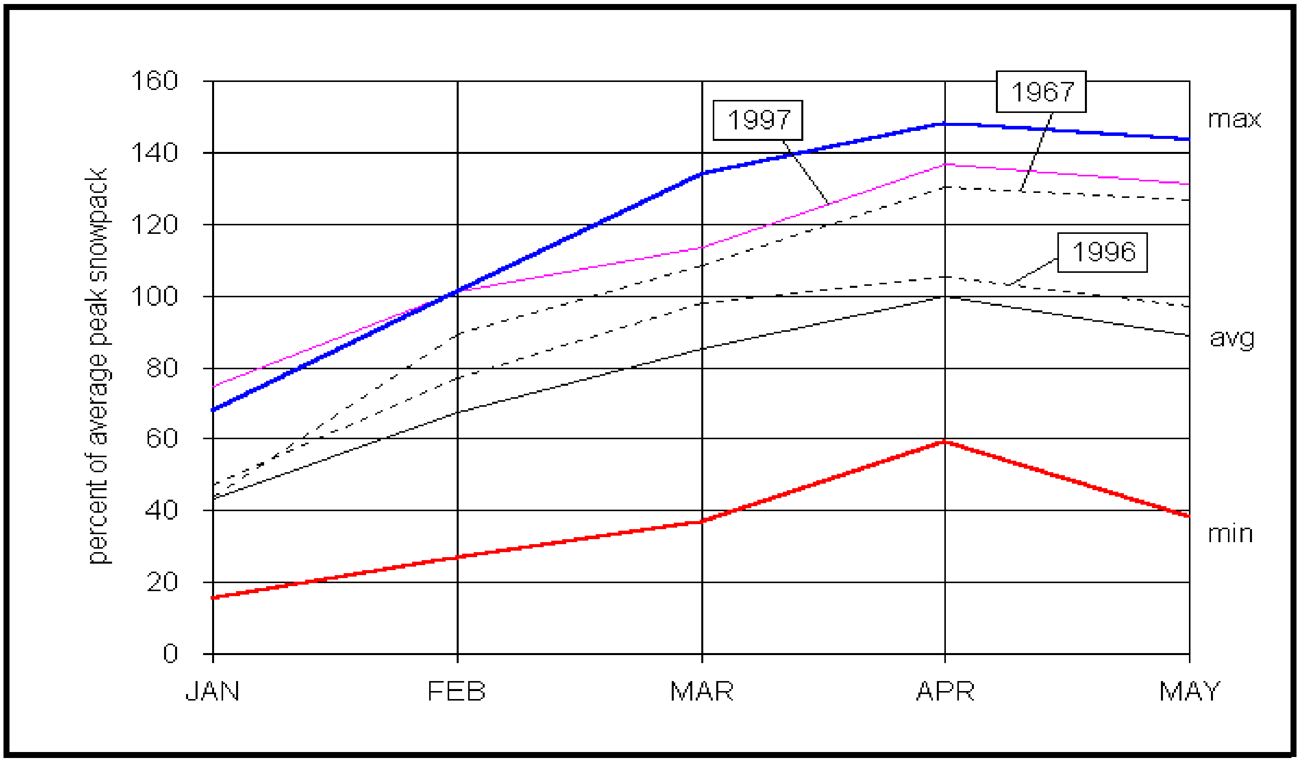

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Figure 9. **COLUMBIA BASIN AVERAGE SNOWPACK**

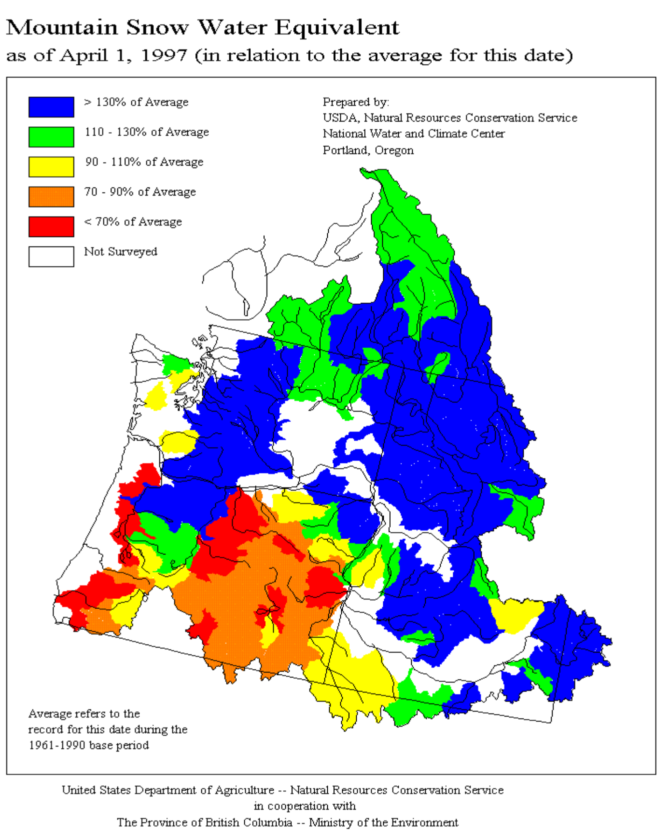

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Figure 10. **MOUNTAIN SNOW WATER CONTENT MAP, APRIL 1**

gained 13% to 119% of normal by February 1. Thes snowpacks were still the lowest in the basin, with the nex lowest, being the small mid-Columbia drainages in north eastern Oregon and southeastern Washington, which wer 120% of their normal snowpack. The best in the basin wa the Lower Snake (upstream of the Clearwater) at 210% an the Yakima at 204%, which were the only sub-basin remaining above 200%. Although January had hig streamflows across the basin, many lower elevation drainages were not affected by the New Year's Day storn and kept their snowpack, including Camas Creek in centra Idaho and the Owyhee River in southeastern Oregon Overall, the Columbia SPI was 101%, equaling the previ ous 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%, an several that contribute most significantly to the flow at Th Dalles remain well above normal, including the Pen Oreille at 145%, Spokane at 146%, Clearwater at 147% and Salmon at 146%. This is the first year since 1982 tha all sub-basins have been over 100% on March 1. Mean while the Canadian snowpacks remained relative low at jus above normal, which prevents the overall Columbi snowpack from approaching the record levels of 1972, a it had on January 1 and February 1. Oregon's John Da Basin had the lowest snowpack in the basin with 103% while a few miles north Washington's

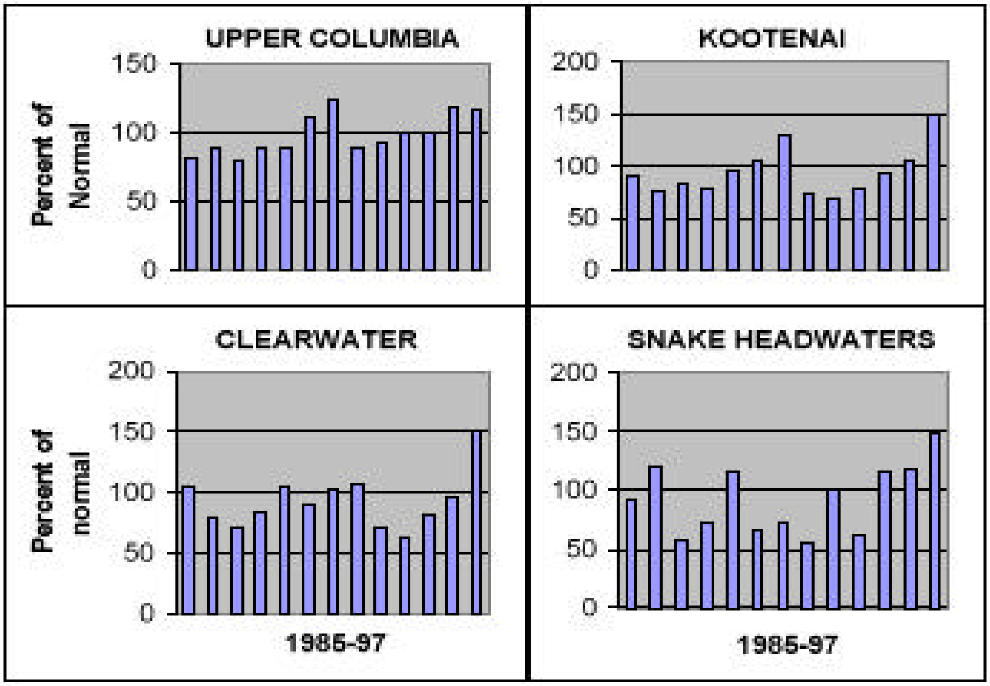

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Figure 11. **SNOW WATER CONTENT AT KEY SITES**

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

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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

Back

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.

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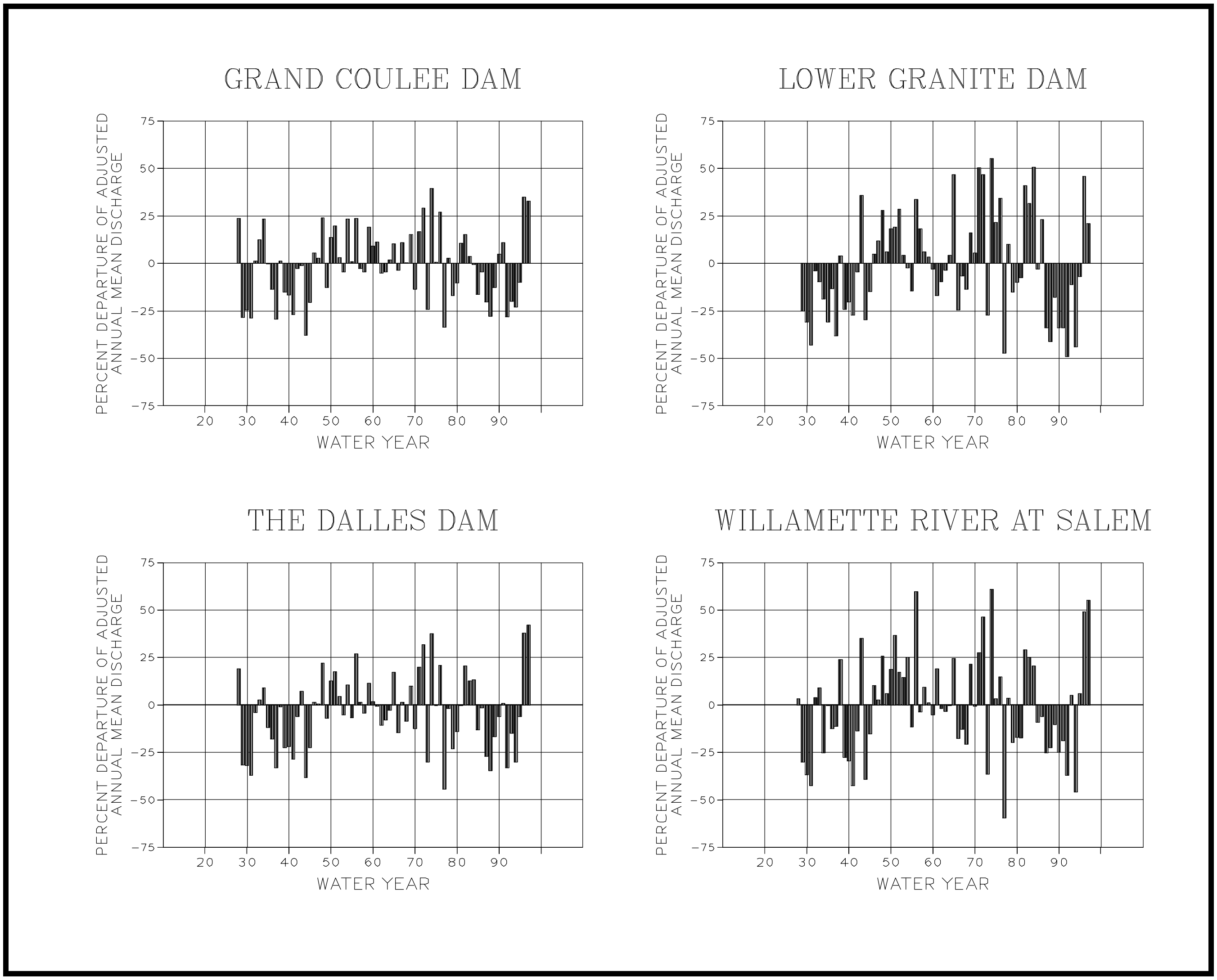

Figure 12. **FOUR BASIN DISCHARGE - DEPARTURE FROM 1928-90 AVERAGE**

(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 use a long term average (LTA) of 1928-89, were reduced to a common period.

The Columbia River at Grand Coulee, Table 6, set a new maximum April-July runoff volume record. Although January, March, and May average discharges were 150% or more of their LTA, they were still below their record peak monthly averages. Despite the heavy

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	**50,370**	**101**	49,770
Nov	92,400	1996	22,160	1930	**43,460**	**95**	45,510
Dec	114,100	1934	21,980	1931	**40,690**	**97**	41,880
Jan	112,100	1974	14,550	1930	**57,150**	**150**	38,010
Feb	102,100	1996	17,940	1936	**48,830**	**118**	41,360
Mar	121,800	1972	24,990	1937	**92,830**	**177**	52,480
Apr	249,300	1934	51,450	1929	**161,550**	**138**	117,400
May	419,800	1957	159,500	1977	**409,560**	**152**	269,600
Jun	521,500	1974	184,000	1941	**445,720**	**140**	318,000
Jul	339,200	1954	106,000	1977	**242,670**	**127**	190,800
Aug	189,600	1976	70,010	1987	**115,490**	**114**	101,500
Sep	112,000	1976	45,250	1987	**86,900**	**137**	63,600
Annual	157,400	1974	69,900	1944	**150,048**	**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	**20,119**	**124**	16,220
Jan-Jul	91,200	1974	36,110	1944	**88,173**	**142**	62,100
Apr-Jul	76,180	1974	31,800	1944	**76,239**	**141**	54,220
Apr-Aug	84,170	1974	36,780	1944	**83,340**	**138**	60,460
Apr-Sep	88,540	1974	40,320	1944	**88,511**	**138**	64,250
Annual	114,000	1974	50,700	1944	**108,630**	**135**	80,450

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

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snowpacks in British Columbia, northern Idaho, and western Montana, the spring and summer mean monthly discharge did not approach their previous records.

On the Snake River at Lower Granite, Table 7, January with 254% LTA set a new record of maximum mean monthly discharge. This record resulted from the New Year's flood that reached into the Snake Basin producing unusual winter flooding. Even the record peak floods in June did not produce enough volume to approach the mean monthly discharge of the 1974 record. The record annual flows was supplied in part by the spent tropical storms that traverses the Northwest.

On the Columbia River at The Dalles, Table 8, May with its 160% LTA set a new record for maximum mean monthly discharge while January, with 201% LTA, was well below the January 1974 record. The November and December monthly runoffs and the annual discharge/runoff were near their respective records.

On the Willamette River at Salem, Table 9, despite their twice-LTA discharges November and December,

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	**21,730**	**86**	25,170
Nov	46,600	1996	17,640	1932	**28,200**	**98**	28,830
Dec	72,500	1996	16,870	1936	**39,910**	**120**	33,250
Jan	75,400	1974	15,780	1937	**87,330**	**254**	34,360
Feb	105,100	1996	17,840	1932	**82,020**	**208**	39,350
Mar	134,000	1972	21,470	1977	**98,000**	**196**	50,030
Apr	162,800	1943	36,880	1977	**120,330**	**146**	82,540
May	206,100	1971	48,900	1977	**197,650**	**163**	121,200
Jun	241,100	1974	31,910	1934	**178,910**	**163**	110,000
Jul	85,970	1975	15,480	1931	**58,030**	**144**	40,340
Aug	32,280	1984	11,840	1931	**28,620**	**132**	21,650
Sep	32,740	1965	14,410	1931	**30,540**	**136**	22,400
Annual	**81,239**	**1997**	27,390	1977	**80,837**	**159**	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	**21,419**	**169**	12,700
Jan-Jul	47,860	1974	12,840	1977	**49,478**	**172**	28,780
Apr-Jul	35,680	1974	8,636	1977	**33,527**	**157**	21,390
Apr-Aug	37,450	1974	9,530	1977	**35,287**	**155**	22,720
Apr-Sep	38,850	1974	10,590	1977	**37,104**	**154**	24,050
Annual	58,130	1974	19,830	1977	**58,523**	**159**	36,730

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

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did not meet their previous records. However, an excess of late summer rainfall was produced by a plethora of nearly spent hurricanes, typhoons, and extra tropical storms that found their way into the Northwest.

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

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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	**87,110**	**100**	87,340
Nov	167,500	1996	50,110	1930	**88,380**	**98**	90,260
Dec	223,000	1996	51,320	1931	**113,570**	**120**	94,810
Jan	222,700	1974	39,160	1937	**186,850**	**201**	92,930
Feb	279,000	1996	51,160	1937	**172,030**	**164**	105,100
Mar	316,900	1972	59,130	1977	**235,720**	**184**	127,900
Apr	400,200	1943	108,000	1929	**334,500**	**148**	225,500
May	**669,400**	**1957**	221,000	1977	**681,480**	**160**	425,100
Jun	841,300	1974	248,500	1977	**694,490**	**147**	473,200
Jul	428,100	1954	122,000	1977	**330,910**	**125**	256,300
Aug	228,800	1976	95,190	1987	**157,270**	**115**	137,200
Sep	150,600	1959	67,950	1988	**133,150**	**137**	97,150
Annual	268,600	1974	108,600	1977	**268,233**	**145**	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	**67,186**	**186**	36,030
Jan-Jul	156,900	1974	53,810	1977	**139,310**	**135**	102,900
Apr-Jul	124,100	1974	43,060	1977	**102,198**	**122**	83,470
Apr-Aug	134,600	1974	49,580	1977	**111,080**	**121**	91,910
Apr-Sep	140,400	1974	54,250	1977	**116,609**	**119**	97,690
Annual	194,400	1974	78,610	1977	**194,191**	**145**	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	**12,490**	**165**	7,542
Nov	71,400	1974	3,160	1937	**56,500**	**222**	25,450
Dec	128,300	1965	5,300	1977	**114,960**	**260**	44,190
Jan	94,300	1953	6,090	1977	**67,960**	**146**	46,700
Feb	101,300	1996	6,340	1977	**46,400**	**107**	43,320
Mar	79,080	1972	11,130	1941	**55,390**	**152**	36,360
Apr	63,410	1937	10,820	1941	**31,810**	**105**	30,210
May	39,920	1963	10,160	1987	**21,990**	**98**	22,410
Jun	36,760	1933	4,518	1992	**13,040**	**92**	14,090
Jul	12,290	1983	2,490	1940	**8,340**	**139**	5,988
Aug	5,970	1968	1,911	1967	**5,720**	**149**	3,830
Sep	7,556	1978	2,467	1987	**6,760**	**167**	4,050
Annual	38,170	1974	9,593	1977	**36,802**	**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	**19,503**	**159**	12,228
Jan-Jul	18,210	1972	5,561	1977	**17,587**	**148**	11,915
Apr-Jul	8,011	1937	2,253	1987	**5,539**	**126**	4,382
Apr-Aug	8,294	1937	2,435	1987	**5,807**	**126**	4,618
Apr-Sep	8,540	1937	2,582	1987	**6,069**	**125**	4,859
Annual	27,630	1974	6,945	1977	**26,644**	**156**	17,087

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

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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

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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

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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	Carnation	54.0	58.0	1/2	56.5		11/24/90	60.7	65.2
Snohomish	Snohomish	25.0	29.0	1/3	25.1				
Cedar	Renton	12.0	12.4	1/2	12.7		11/24/90	17.13	10.6
Skokomish	Potlatch	15.5		1/1	16.7		12/20/94	17.47	
Deschutes	Rainier	12.0		12/30	14.3		1/9/90	17.01	9.6
Skookumchuck	Centralia	85.0		12/30	70.2				
Grand Mound	Grand Mound	13.3		12/30	17.3		2/9/96	19.98	74.8
Satsop	Satsop	34.0	38.0	1/1	34.5		1/22/35	38.9	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	12.0	14.5	**1/1**		**22.8**	12/22/55	13.9	10.1
	Weiser	9.0		**1/1**		**34.5**	3/25/93	11.96	21.7

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

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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	Carnation	54.0	58.0	1/2	56.5		11/24/90	60.7	65.2
Snohomish	Snohomish	25.0	29.0	1/3	25.1				
Cedar	Renton	12.0	12.4	1/2	12.7		11/24/90	17.13	10.6
Skokomish	Potlatch	15.5		1/1	16.7		12/20/94	17.47	
Deschutes	Rainier	12.0		12/30	14.3		1/9/90	17.01	9.6
Satsop	Satsop	34.0	38.0	**3/19**	**38.87**	**63.6**	12/20/94	37.28	50.6
Wynoochee	abv Black Cr	19.0		3/19	20.21	25.6R	1/19/68	20.54	25.5
Quinault	Quinault Lk			3/19		46.4	11/4/95	20.51	50.2
Willapa	Willapa	21.0		3/19	24.54	12.1	12/20/94	27.28	14.8
Naselle	Naselle			**3/18**	**19.17**	**12**	11/24/90	18.45	11.3
Little 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

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JUNE FLOOD PEAKS - IDAHO

RIVER	GAGE	DAMAGE STAGE		OBSERVED PEAK			PREVIOUS RECORD		
		ZERO	MAJOR	DATE	STAGE	DISCH	DATE	STAGE	DISCH
Snake	Flagg Ranch			6/5		14.5	6/5/96	10.75	15.0
	Moran			6/11		12.1	6/12/18	10.41	15.1
	Irwin			**6/19**		**40.4**	6/4-6/56	13.31	31.8
	Heise	21 **		6/13		43.5	5/19/27	16.0	60.0
Henrys Fork	St Anthony	7.0		5/30		10.6	5/16/84	8.62	13.2
	Rexburg	9.0		6/12		13.6	5/17/84	12.05	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**

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Table 16

FORECAST AND OBSERVED RUNOFF (kaf)

STREAM	STATION	FORECAST PERIOD	30-YR NORMAL	FORECAST JAN 1	FORECAST APR 1	OBS RUNOFF	FCST ERR (%) JAN 1	FCST ERR (%) 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 Apr-Sep	6,396 6,772	7,160 7,580	7,700 8,090	8,055 8,348	14 18	6 4
COLUMBIA	Birchbank	Apr-Sep	43,800	48,700	51,900	54,619	+14	+6
SF FLATHEAD	Hungry Horse Inflow	Jan-Jul Apr-Jul Apr-Sep	2,269 2,051 2,184	2,970 2,690 2,860	3,200 2,940 3,130	3,291 3,027 3,208	14 16 16	4 4 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 Apr-Aug	63,280 60,940	76,800 74,000	82,000 78,300	88,170 83,340	18 10	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 Apr-Jul	3,548 2,700	5,230 3,980	5,600 4,300	5,935 4,637	20 24	9 12
CLEARWATER	Spalding	Apr-Jul	7,618	11,000	11,800	12,203	16	5
SNAKE	Lower Granite	Jan-Jul Apr-Aug	29,740 23,000	45,400 35,000	48,300 34,800	49,478 35,290	14 1	4 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 Apr-Aug	105,900 93,250	138,000 121,000	149,000 125,000	159,000 133,133	13 09	9 06

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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 co-ordination 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)	
			Low	High		Low	High		Date
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.

III. RESERVOIR REGULATION

The reservoir system in the Northwest is made up of Federal, municipal, public, and privately owned dams. Regardless of ownership major hydroelectric projects are operated in accordance with the Pacific Northwest Coordinating Agreement. This agreement coordinates the seasonal operation of the system member's projects for the best use of their collective reservoir storage. This and some of the other agreements that affect project operation are briefly discussed in Chapter VI. In this chapter, however, the regulation of the system as a unit is described followed by the regulation of the operation of individual projects in downstream order and chronologically from the beginning of the operational year.

The members of the coordinated system of reservoirs are listed in Appendix A. Daily project operations are shown on charts in Appendix D. Charts 5-30 show the storage and streamflow hydrographs from July 1, 1996 through September 30, 1997, for major storage projects, Charts 31-56 present the annual hydrographs for flood storage projects, hydrographs of the spring freshet are shown in Charts 57-79, Chart 80 shows The Dalles discharge hydrograph for regulated and unregulated conditions, Charts 81-84 are the Willamette Basin's control point hydrographs, Charts 85-88 are the reservoir hydrographs for other Section 7 projects, and Charts 89-92 are summary hydrographs for the four key stations. Table 21 is the monthly rule curves and observed reservoir elevations for the major storage projects.

A. SYSTEM OPERATION

The operating year began with the coordinated reservoir system officially filling to 99.5% of storage capacity on July 31, 1996. As a result, first year firm energy load carrying capability (FELCC) was adopted for the 1997-98 operating year. Because of persistent high flows, the system generally operated to Operating Rule Curves (ORC) or flood control for the entire year. The system storage energy reached 99.1% of full on Jule 31, 1997, and the system adopted the first-year FELCC for the 1997-98 PNCA (Pacific Northwest Coordinating Agreement) Final Regulation study.

The January 1, 1997 water supply forecast was for The Dalles was 138.0 maf for the January-July period, or 130% of normal. Subsequent forecasts through April reflected an increasing trend, with the April forecast being 141% of normal. During April through July, above normal precipitation turned the forecasts upward with the June showing runoff forecast volumes of 159.0 maf, 150% of normal.

In April, the system was on the Energy Content Curve, with Grand Coulee, Libby, Hungry Horse, and Dworshak at or above their April 15 flood control elevations. During the April 7 - August 31 flow augmentation period, these projects were used to augment flows at Lower Granite and McNary. In accordance with the National Marine Fisheries Service's Biological Opinion, these projects were regulated in an attempt to meet Lower Granite suggested target flows that are listed in Chapter IV, Section G.

Daily flood control regulations were required during January at Libby, Grand Coulee, Dworshak and the Snake River projects. This year's observed peak flow at The Dalles was 570.7 kcfs on June 17 with a corresponding unregulated peak of 896.0 kcfs on June 15. The observed winter peak flow at The Dalles was 321.5 kcfs on January 5 with a corresponding unregulated peak of 398.0 kcfs on January 3. Last year's observed peak was 462.2 kcfs. The system reached 47% of its full energy capacity in the Actual Energy Regulation (AER) on July 31, 1997, resulting in first-year FELCC being adopted for the 1997-98 operating year. The observed refill was near 90% of capacity, providing some reservoir operating storage above the proportional draft level going into the new operating year.

Table 19

MONTHLY OBSERVED RESERVOIR ELEVATIONS AND RULE CURVES

	1996						1997						
PROJECT	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MA	APR 15	APR 30	MAY	JUN	JUL
MICA													
OBS	2475.4	2471.3	2462.1	2443.3	2427.3	2410.5	2402.5	2390.7	2384.2	2383.7	2406.4	2406.4	2448.1
MRC	2469.8	2469.8	2467.9	2467.9	2467.9	2466.0	2464.3	2462.4	2462.4	2462.4	2465.9	2467.3	2469.8
BECC	2469.8	2469.8	2469.7	2467.0	2460.1	2452.6	2442.7	2431.7	2426.1	2421.1	2425.3	2449.5	2469.8
CRC1	2469.8	2469.8	2459.8	2443.6	2427.0	2408.8	2396.5	2386.3	2382.3	2379.2	2387.4	2414.9	2444.0
CRC2		There is no CRC2 because the 1995-96 Final Regulation was a one year critical period.											
CRC3	2455.9	2459.2	2457.7	2451.5	2438.8	2426.7	2409.9	2393.8	2393.8	2393.8	2393.8	2393.8	2415.2
ARROW													
OBS	1437.6	1428.4	1421.9	1422.1	1418.1	1407.7	1343.8	1389.5	1393.7	1397.6	1419.8	1419.8	1437.5
MRC	1444.0	1444.0	1442.1	1442.1	1436.2	1434.1	1432.1	1429.8	1430.2	1431.0	1439.2	1444.0	1444.0
BECC	1441.1	1435.9	1431.5	1422.8	1421.6	1398.0	1390.1	1402.3	1403.2	1406.2	1418.7	1436.8	1444.0
CRC1	1441.1	1435.9	1431.5	1422.8	1421.6	1398.0	1384.2	1384.4	1387.6	1390.4	1401.4	1430.1	1442.1
CRC2			There is no CRC2 because the 1995-96 Final Regulation was a one year critical period.										
CRC3	1438.4	1437.6	1436.7	1428.6	1419.2	1407.4	1391.5	1381.4	1377.9	1378.7	1378.7	1390.1	1408.8
DUNCAN													
OBS	1892.1	1883.7	1880.6	1872.6	1857.4	1837.5	1808.9	1797.6	1799.9	1796.8	1834.5	1834.5	1879.7
MRC	1892.0	1892.0	1892.0	1892.0	1868.6	1853.0	1838.0	1838.0	1839.2	1841.3	1854.4	1873.7	1892.0
BECC	1890.8	1887.6	1877.5	1867.5	1852.2	1842.2	1835.8	1836.5	1837.7	1837.7	1854.7	1876.7	1892.0
CRC1	1890.8	1887.6	1877.5	1867.5	1852.2	1842.2	1814.2	1806.7	1796.5	1795.0	1818.8	1853.5	1876.4
CRC2			There is no CRC2 because the 1995-96 Final Regulation was a one year critical period.										
CRC3	1833.7	1843.4	1852.0	1856.0	1840.3	1829.0	1823.1	1806.8	1807.0	1796.9	1795.2	1823.2	1853.8
LIBBY													
OBS	2452.3	2448.7	2439.3	2425.2	2402.1	2370.3	2339.3	2339.7	2337.7	2343.8	2399.5	2442.1	2453.3
MRC	2459.0	2459.0	2459.0	2448.0	2411.0	2419.5	2427.9	2432.1	2433.1	2435.0	2443.9	2459.0	2459.0
BECC	2439.0	2432.4	2430.9	2428.4	2411.0	2406.9	2403.6	2400.5	2399.6	2399.5	2424.2	2449.9	2459.0
CRC1	2439.0	2432.4	2430.9	2428.4	2411.0	2406.9	2403.6	2400.3	2399.1	2397.2	2413.3	2416.0	2427.9
CRC2			There is no CRC2 because the 1995-96 Final Regulation was a one year critical period.										
CRC3	2442.4	2439.6	2428.6	2427.1	2412.4	2365.4	2330.9	2324.9	2316.4	2308.6	2301.2	2346.1	2375.9
HUNGRY HORSE													
OBS	3543.2	3537.7	3531.9	3528.4	3511.1	3488.8	3468.2	3449.1	3434.5	3442.0	3516.7	3553.4	3559.8
MRC	3560.0	3560.0	3555.7	3555.7	3555.7	3547.6	3540.0	3531.0	3526.7	3522.3	3544.1	3560.0	3560.0
BECC	3540.1	3535.1	3529.1	3522.7	3515.5	3507.3	3501.1	3498.2	3502.2	3508.2	3542.8	3556.9	3560.0
CRC1	3540.1	3535.1	3529.1	3522.7	3515.5	3507.3	3499.8	3491.0	3488.6	3494.0	3529.6	3552.7	3558.3
CRC2			There is no CRC2 because the 1995-96 Final Regulation was a one year critical period.										
CRC3	3470.6	3456.7	3429.2	3424.2	3419.0	3402.4	3390.2	3381.2	3358.1	3367.9	3358.1	3436.1	3449.8
KERR													
OBS	2892.8	2892.3	2891.9	2888.9	2887.6	2887.5	2885.9	2885.4	2885.7	2887.1	2891.5	2891.5	2892.8
MRC	2893.0	2893.0	2893.0	2893.0	2893.0	2893.0	2893.0	2893.0	2883.0	2890.0	2890.0	2893.0	2893.0
BECC	2893.0	2892.5	2892.8	2891.2	2888.1	2885.3	2883.5	2883.0	2883.0	2883.1	2890.0	2893.0	2893.0
CRC1	2893.0	2892.5	2892.8	2891.2	2888.1	2885.3	2883.5	2883.0	2883.0	2883.1	2890.0	2893.0	2893.0
CRC2			There is no CRC2 because the 1995-96 Final Regulation was a one year critical period.										
CRC3	2893.0	2893.0	2893.0	2891.9	2890.9	2889.6	2887.2	2885.0	2883.7	2883.3	2884.6	2890.0	2893.0
ALBENI FALLS													
OBS	2062.2	2060.2	2055.4	2055.3	2055.6	2055.6	2056.0	2055.3	2055.3	2057.6	2064.8	2061.8	2062.4
MRC	2062.5	2062.5	2060.0	2056.0	2056.0	2060.0	2060.0	2056.0	2056.0	2056.0	2062.5	2062.5	2062.5
BECC	2062.5	2060.0	2055.0	2055.0	2055.0	2055.0	2055.0	2055.0	2055.5	2056.0	2057.0	2062.5	2062.5
CRC1	2062.5	2060.0	2055.0	2055.0	2055.0	2055.0	2055.0	2055.0	2055.5	2056.0	2057.0	2062.5	2062.5
CRC2		There is no CRC2 because the 1995-96 Final Regulation was a one year critical period.											
CRC3	2062.0	2062.0	2060.0	2054.0	2051.0	2051.0	2051.0	2051.0	2051.0	2051.0	2054.0	2057.0	2062.0
GRAND COULEE													
OBS	1280.3	1281.7	1284.7	1284.8	1274.2	1263.0	1243.2	1288.7	1219.6	1210.9	1251.7	1284.1	1287.5
MRC	1290.0	1290.0	1290.0	1290.0	1290.0	1290.0	1288.7	1282.2	1281.0	1281.0	1288.2	1290.0	1290.0
BECC	1280.1	1285.0	1287.2	1286.0	1281.0	1287.4	1290.0	1283.1	1277.9	1280.1	1280.1	1280.1	1290.0
CRC1	1280.1	1285.0	1287.2	1286.0	1281.0	1287.4	1290.0	1283.1	1277.9	1280.1	1280.1	1280.1	1280.1
CRC2		There is no CRC2 because the 1995-96 Final Regulation was a one year critical period.											
CRC3	1288.1	1288.1	1288.1	1288.1	1290.0	1287.2	1283.6	1270.8	1247.2	1248.6	1248.1	1255.0	1285.2
DWORSHAK													
OBS	1535.6	1519.5	1520.0	1523.2	1531.4	1519.4	1488.6	1466.4	1448.2	1455.2	1556.6	1598.6	1563.7
MRC	1600.0	1587.7	1581.9	1568.9	1558.2	1555.5	1558.2	1570.2	1581.2	1571.3	1592.9	1600.0	1600.0
BECC	1517.8	1515.3	1512.1	1508.7	1506.6	1502.4	1499.5	1508.6	1530.3	1545.5	1591.4	1599.8	1600.0
CRC1	1517.8	1515.3	1512.1	1508.7	1506.6	1502.4	1499.5	1502.2	1511.3	1520.1	1541.0	1530.7	1520.1
CRC2		There is no CRC2 because the 1995-96 Final Regulation was a one year critical period.											
CRC3	1563.7	1563.1	1562.4	1563.3	1565.3	1558.2	1559.8	1562.2	1576.7	1589.0	1582.8	1586.5	1596.1

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B. PROJECT OPERATION

The operation of the individual projects is discussed in downstream order, beginning at the headwaters of the Columbia River. Operation of each project is generally discussed chronologically beginning in the summer or early fall of the preceding water year. Exceptions will be noted by including the calendar year. The locations of these projects are shown on the maps in Chapter I, pages 3 through 6.

1. Mica Project

Kinbasket Lake was formed by the construction of Mica Dam near the Big Bend on the upper Columbia River in east-central British Columbia. The project is part of the Columbia River Treaty between the United States and Canada and is owned by BC Hydro and Power Authority (BCH or BC Hydro) and is operated primarily for power and flood control. This year's operation is graphically shown on Charts 5 and 57.

The Mica reservoir (Kinbasket Lake) surface elevation on July 31, 1996 was 2470.4 ft, 4.6 ft below full pool level. The reservoir continued to fill in August, reaching its peak elevation for the year, 2475.4 ft, on September 1 and remained above 2460.0 ft until early November. Mica Treaty storage, expressed in volume and not reservoir level, was 6.657 maf (3356 ksfd or 95% of full) on July 31, 1996. Mica Treaty storage continued to refill during August, reaching a maximum of 7.00 maf (3529 ksfd or 100% of full) on August 12. Actual Mica discharges were fairly high throughout the summer, and the Mica Treaty flex reached 829 kaf (418 ksfd) on August 31. Mica powerhouse discharges during November and December averaged about 37 kcfs and 29 kcfs, respectively, as the reservoir drafted to 2427.2 ft by December 31 at which time Treaty storage was 4.25 maf (2142.7 ksfd).

In January, the inflows decreased to 1.0 kcfs or less and then gradually increased between February and mid-April before the start of spring freshet, Non-Treaty Storage reached 75% of the full amount. Mica powerhouse discharges for January averaged around 26.4 kcfs which continued to decrease over the winter season. The reservoir drafted to 2401.1 ft by February 28, with Treaty Storage at 2.00 maf (1007.1 ksfd) and Mica Treaty flex at 647 kaf (326 ksfd) on that date. The BC Hydro NTSA (non-Treaty storage allocation) remained unchanged at 1688 kaf (851 ksfd) in February and March. Mica Reservoir continued to draft during March and April, reaching its lowest level for the year at 2383.6 ft on April 25, which was 21 ft lower than the previous year's low. Mica Treaty Storage reached a minimum of 0.11 maf (or 56 ksfd), on April 30 with Mica flex storage reaching 50 kaf (25 ksfd).

Powerhouse discharge in April was about 15 kcfs, dropping to an average of about 3 to 3.5 kcfs in May and June when the corresponding plant generation was less than 10% of plant capacity. With the start of the spring freshet in early May, Mica discharges were reduced and the reservoir refilled quickly. At the end of May, the Mica Treaty flex storage had been increased to 165 maf (83 ksfd). Treaty discharge was 10 kcfs for May and June, allowing Treaty storage to refill to 6.62 maf (3336.9 ksfd or 94% of full) by July 31. Local inflows were the highest in June and July averaging about 66 kcfs and 59 kcfs respectively. Actual Mica discharges during July averaged 20 kcfs, resulting in the Mica Treaty flex storage of 59 kaf (29 ksfd) by the end of July as the reservoir refilled to 2471.1 ft. The powerhouse discharge increased to 21 kcfs with plant generation at about 45% of plant capacity in July.

The reservoir level remained within a foot of full pool between August 8 and 19 before receding. Treaty storage reached its maximum allowed volume at 7.00 maf (3529 ksfd) on August 12. The inflows decreased to less than 30 kcfs by mid-September.

The peak daily inflow was 95.44 kcfs on June 17, with a corresponding outflow of 3.5 kcfs, the maximum daily outflow was 38.79 kcfs on July 24.

2. Revelstoke Project

The Revelstoke project, located on the Columbia River between Mica Dam and Arrow Lakes, is owned by BC Hydro and is operated primarily for power generation. This year's operation is graphically shown on Chart 6.

During this operating year the Revelstoke project was basically operated as a run-of-river plant, maintaining the reservoir within 4.8 ft of its normal full pool level of 1880.0 ft. During the spring freshet, June through August, the reservoir level was operated as low as 1875.4 ft to allow control of high local inflows.

3. Keenleyside Project (Arrow Reservoir)

Keenleyside Dam was constructed as part of the Columbia River Treaty between the United States and Canada and is owned and operated by BC Hydro for flood control and downstream power generation; it has no on-site hydropower facilities. The reservoir controlled by Keenleyside Dam consists of two tandem natural lakes, Upper and Lower Arrow Lakes, on the Columbia River in southeastern British Columbia. During normal operation, the land area between the lakes is flooded, creating a single lake. This year's operation is graphically shown on Charts 7 and 58.

Arrow Lakes reached a maximum level on July 10, 1996, 1442.6 ft and then drafted slightly to 1442.4 ft by July 3 at which time the Arrow Treaty storage account was full at 7.10 maf. Then it was drafted slowly to 1428.4 ft by the end of September followed by discharges averaging 55 kcfs in October, 50 kcfs in November, and 45 kcfs in December, drafting the reservoir to 1418.1 ft by December 31, when the Arrow Treaty storage at 4.9 maf (2447 ksfd, or 68% of full).

In early January, BC Hydro requested that Arrow outflows be selectively reduced below Treaty requests to keep river levels at acceptable and maintainable levels during whitefish spawning and later emergence. BPA agreed to this under terms of the Non-Power Uses Agreement and so the treaty requests were reduced with a total of 400 kaf (202 ksfd) held back. This storage was later returned and the Canadian Treaty Storage returned to the Treaty Storage Regulation (TSR) levels. Arrow Lakes continued to draft during the January-March period when the local inflows ranged between 5.0 to 5.8 kcfs.

Arrow Reservoir reached its lowest level for the year, 1389.5 ft, on March 31, at the same time Arrow Treaty Storage reached its minimum at 0.78 maf (392 ksfd or 11% of full). During April, Arrow discharge was kept between 15-20 kcfs in an attempt to insure that rainbow trout would not spawn high on the river banks that might be out of the water if river flows decrease. Several trout redds, which were de-watered, were kept wetted for a limited time using a pump and sprinkler system. From April through June, Arrow was operated under the terms of two Operating Committee agreements: ***Operation of Treaty Storage for Enhancement of Whitefish Spawning for January 1 through April 30, 1997***, and ***Operation of Treaty Storage for Enhancement of Trout Spawning for March 1 through July 31, 1997***. These agreements allowed the Arrow project flows to be maintained and avoid dewatering rainbow trout redds. With the low discharge throughout April and most of May, and start of spring freshet in mid-May when high inflows occurred, the Arrow Reservoir level rose to 1397.6 ft by April 30 and to 1419.8 ft by May 31 and continued to fill in June due to higher inflows. With the start of the spring freshet, increasing discharges from the Kootenay River created a backwater effect on the Norns Creek Fan, a prime spawning location for rainbow trout. Discharge from Arrow was held at 20 kcfs for the first three weeks of May and gradually increased throughout June, raising the pool to 1437.4 ft by June 30. Except for a few days near the end of June, Arrow Lake slightly exceeded the Treaty flood control curve levels during June and early July.

Arrow discharge was increased substantially in July as Arrow Treaty Storage neared full and the reservoir reached its highest level for the year, 1444.1 ft on July 31, slightly above full pool elevation of 1444.0 ft. The Arrow discharge peaked for the summer at 94.6 kcfs on July 17 and the Arrow Treaty storage content continued to fill and reached full (7.1 maf) on July 31. With the increased project discharges in late July and August, Arrow Lakes drafted to approximately 1439.0 ft by the end of August. To minimize spill at the Canadian Kootenay River plants and maintain Lake Koocanusa (Libby Reservoir) water levels in Canada for resident fish and recreation, the Canadian and US Entities agreed to a Libby-Arrow water transfer (swap) for late summer. Under the agreement, Libby release was reduced by a total of 377 kaf (190 ksfd) through August and instead, an equal amount of water was released from Arrow. This water, effectively stored in Libby, will be returned to Arrow in the October to December period as part of the agreement.

The peak daily inflow was 121.5 kcfs on July 9, with a corresponding outflow of 60.0 kcfs while the unregulated peak inflow was 214.5 kcfs on May 31 and the maximum daily outflow was 94.6 kcfs on July 18.

4. Libby Project (Lake Koocanusa)

Lake Koocanusa and Libby Dam, on the Kootenai River in northwest Montana, were constructed as part of the Columbia River Treaty with Canada and are operated by the Corps of Engineers for power, flood control, and recreational benefits. The lake extends from the dam near Libby, 60 river miles to the international border and another 30 miles (at full pool) into British Columbia. This year's operation is graphically shown on Charts 8 and 59.

Lake Koocanusa started the operating year full, at 2459.0 ft, 2.4 higher than last year. The first 12 days of August saw Libby releasing 24 kcfs which was then reduced to 12-14 kcfs for the remainder of the month because of high water difficulties near Bonners Ferry. Libby did not release its full BiOp volume allocation due to the Arrow Libby swap of nearly 377 kaf (190 ksfd), which was delivered from Arrow Lakes instead. September outflows were 8-12 kcfs for an on-going Montana Fish, Wildlife & Parks fishery study. The observed pool level on September 30 was 2448.7 ft, while the assured energy refill (AER) level was 2432.3 ft. During October, Libby was used for weekly load shaping: weekend (Thursdays through Sundays) flows were 8 kcfs and the weekday flows were 14.5 kcfs. By October 21 weekly load following stopped and the project released 14.5 kcfs for nearly the rest of the month drafting the reservoir nine feet to 2439.26 ft on October 31. Libby operated for power, fish monitoring studies, and flood control in November and was drafted about 14 feet and then maintained full load (20 kcfs on four units, one unit was out of service due to a forced outage) for the whole month of December. The exception was for four days over the Christmas holiday when power loads were down and a fish monitoring study was conducted requiring 4 kcfs. The project was drafted to 2402.13 ft by the end of December, which is 8.87 ft below the Upper Rule Curve, to try to eliminate possible spill in January to get down to anticipated low flood control elevations.

On January 1 and February 1, the runoff volume forecasts required the project was operated for flood control by using all four available units at their maximum capacity for both months. On March 1 the runoff volume forecast was reduced so outflows in March were reduced from 18 kcfs to 7 kcfs weekly average. Between March 17-21 and April 1-10, flat flows of 4.0 kcfs and 6.0 kcfs, respectively, were maintained to meet flood control/refill needs as well as accommodate the State of Idaho's request to facilitate rainbow trout spawning. Project releases in April and May of 8.7 kcfs and 13 kcfs, respectively, considered flood control needs as well as temporary refill to provide higher flows for both sturgeon in June and salmon in August.

The US Fish and Wildlife Service requested three flow pulsing operations, up to full powerhouse capacity, to enhance sturgeon spawning above Bonners Ferry where the hard river bottom is more conducive to sturgeon egg survival. These pulses were requested to take place when the water temperature at Bonners Ferry reached 10°C, 12°C, and 14°C. The first pulse was sent on June 5-19 and the second pulse on June 24-28. The third pulse was not sent due to fear of filling/spilling the reservoir in June. However, heavy June rain caused several "natural pulses" for the sturgeon.

Throughout July the temperature and rainfall remained below normal, resulting in the water supply forecast under estimating the actual runoff. By July 16 the outflow was ramped down to 10 kcfs causing the reservoir to rise to near 2453 ft (6 ft from full) by the end of the month. Libby continued this discharge until the Libby/Arrow swap (see Chapter IV, Section H) was initiated on August 13 when the outflow was increased to 14.5 kcfs with a total of 377 kaf (190 ksfd) swapped (stored in Libby while an equal amount was released from Arrow). The maximum reservoir level reached was 2454.82 ft on August 12 and by the end of August it was 2450.12 ft, less than 10 ft from full. September outflows were weekly shaped for power production: higher flows during the week and lower flows during the weekend. This weekly operation, in lieu of daily shaped flows, was to help improve the general health of the river. The pool on September 30 was 2447.38 ft while the proportional draft point (PDP) level was 2441.3 ft.

The peak daily inflow during the water year was 80.3 kcfs on June 2, with a corresponding outflow of 12.0 kcfs. Maximum daily outflow was 28.0 kcfs on several days in June.

5. Kootenai River at Bonners Ferry

The Kootenai River at Bonners Ferry, Idaho, a major control point for the flood control operation of Libby Dam, is located 82 miles downstream of Libby Dam. Its stages are affected by both river flow and by backwater from Kootenay Lake. This year's operation is graphically shown on Chart 60.

The peak regulated stage was 1764.4 ft on May 17 while Libby was releasing 4.0 kcfs and the unregulated peak stage would have been 1779.9 ft, well above the 1766.5 ft bankfull stage.

6. Duncan Project

Duncan Dam and Lake on the Duncan River, a tributary to Kootenay Lake in southeastern British Columbia, was constructed as part of the Columbia River Treaty between the United States and Canada. The project is owned and operated by BC Hydro and, although it has no on-site power-generating facilities, it is operated for downstream power generation and for flood control. This year's operation is graphically shown on Charts 9 and 61.

Duncan Reservoir level was 1882.2 ft (slightly above full) on July 31, 1996 and passed inflow during August; then during September its discharged was increased to an average of 5.5 kcfs to maintain both the Kootenay Lake levels and outflows. Project discharge was reduced to an average of 3.5 kcfs in October and remained at that level for most of November and decreasing to 2 kcfs in first half of December. Higher discharges between mid-December and February were necessary to again support Kootenay Lake levels and flows. Duncan Reservoir was at 1857.4 ft (58% of full) on December 31. These operations contributed to Duncan reservoir levels remaining at or below the flood control curve in this operating year. During January, project discharge increased to about 6 kcfs which continued the reservoir drafting throughout February and into mid-March to meet Kootenay Lake IJC levels. Duncan reservoir exceeded its Treaty flood control curve slightly near the end of February and then continued to draft another 6 ft below the flood control curve between March and May 1. The reservoir reached its lowest level for the year at 1796.6 ft (2.2 ft above empty) on May 1 when project discharge was reduced to minimum, 100 cfs, to begin refilling the reservoir. The reservoir reached 1834.4 ft on May 31 and 1879.7 ft on June 30. Duncan remained on minimum discharge until July 4 when discharge was increased to slow the rate of reservoir refill. Duncan Reservoir reached 1892.0 ft, full pool, on July 15 and exceeded it by 0.1 ft on July 30. Duncan passed inflow during August to maintain the reservoir near full pool and on September 1 discharge was increased to start drafting the reservoir and to fill Kootenay Lake.

The peak daily inflow was 23.8 kcfs on July 8 with a corresponding outflow of 7.0 cfs and the maximum daily outflow was 14.1 kcfs on July 17.

7. Kootenay Lake

Kootenay Lake is a large natural lake on the Kootenay River in southeastern British Columbia which has most of its inflow regulated by Libby and Duncan dams. The seasonal regulation of the lake level is governed by rules established by the International Joint Commission (IJC) as agreed upon by the United States and Canada. Outflow from the lake is discharged through a series of instream powerhouses and/or diverted to the offstream Kootenay Canal Plant before it joins the Columbia River below Brilliant Dam near Castlegar, British Columbia. Although Corra Linn Dam, the project immediately downstream from the lake, controls the lake level, a constriction in the river channel at Grohman Narrows, between the lake and the dam, limits the maximum project outflow both during periods of high flows and when the lake approaches its minimum level. This year's operation is graphically shown on Charts 10 and 62.

The level of Kootenay Lake at Queens Bay was 1746.4 ft on July 31, 1996, while the level at Nelson, BC, was below the summer IJC operating level of 1743.32 ft. Discharges were adjusted to pass inflow during August through December then, beginning in January and continuing to mid-March, Kootenay Lake was drafted to avoid violating the IJC order, lowering the lake level to a low of 1739.7 ft on March 19. The lake then started to fill with the local inflows into Kootenay Lake peaking on March 23 at 53.9 kcfs. At this time the discharge was about 26 kcfs causing the lake exceeded the IJC level by up to one foot between March 20 and April 1. This was not a Treaty violation, however because the exceedence was due to extraordinarily high natural inflow conditions which are allowable under the 1938 IJC Order on Kootenay Lake. The outflow from Duncan was reduced to its minimum to lower the Kootenay Lake level to the IJC limit. The lake remained below the IJC levels for the remainder of the water year.

Mainstem inflows to Kootenay Lake increased starting mid-April filling the lake to its peak level for the year, 1752.9 ft, on June 12 where it remained until June 16, before starting to draft. With receding runoff in late June and reduced Libby discharge in July, Kootenay Lake drafted. The Nelson gage dropped below the IJC summer level of 1743.32 ft on August 12 after which lake discharges were adjusted to keep the Nelson gage below the IJC level until the end of August, reaching its lowest level for the year, 1743.6 ft, on September 1. During September, due to late occurrences of heavy rainfall, lake discharges were adjusted to gradually refill the reservoir and on September 30, the lake was at 1744.42 ft.

There was a change this year in methodology for calculating the IJC levels. The past interpretation had been that the regulated inflows (equal to or less than the natural flows) into Kootenay Lake should be used for the calculation of the IJC level. An interpretation on the IJC order was requested from the Board of Control by the US Army Corps of Engineers. The Board ruled that the natural (unregulated) flows are to be used in the calculation.

8. Columbia River at Birchbank

The Columbia River at Birchbank, British Columbia, includes the effects of regulation of all the Columbia River Treaty Projects. Its flow is regulated by the use of storage in Kinbasket, Arrow, Koocanusa, Duncan, and Kootenay Lakes. This is the portion of the Grand Coulee inflow contributed by the Columbia and Kootenay rivers. The Flathead/Pend Oreille River enters the Columbia downstream of the Birchbank gage. This year's operation is graphically shown on Chart 63.

The unregulated daily peak flow at Birchbank was 313.96 kcfs on June 18 and the observed peak was 160.24 kcfs on July 16. Thus, the Treaty storage reduced the Columbia discharge well below the 225 kcfs level of discharge for bankfull and flood stage.

9. Hungry Horse Project

Hungry Horse, a Section 7 Project on the South Fork Flathead River near Kalispell, Montana, is owned and operated by the Bureau of Reclamation for flood control, power, recreation, and fisheries. This year's operation is graphically shown on Charts 11 and 64.

On October 1, 1996, the lake was at 3537.9 ft after its peak of 3560.69 ft on July 31, drafting for downstream fish migration. The reservoir began mandatory drafting in October with a target level (BECC) of 3515.0 ft by January 1. Because of early snow accumulation, reservoir releases were increased to between 6000 cfs and 8000 cfs on December 10 to provide a constant winter drawdown schedule. By April 20 the reservoir had been pre-drafted 130 ft to 3430.51 ft, the May 1 flood control target. At this time releases were reduced for about six weeks to put in place a protective relaying system between the units and new transformers. Due to the high potential for flooding the spillway flashboards were removed. During the refill period releases were not provided through the outlet works so the total dissolved gas standard would not be exceeded. The reservoir inflow increased quickly after May 1 filling the reservoir to its maximum of 3559.82 ft on July 31. Releases were provided for ESA operations during August, following the official TMT weekly forecasts. The reservoir was drafted 20 ft to 3540.00 ft by September 22 and by September 30 the reservoir drafted to 3537.50 ft. A kokanee spawning flow of at least 3500 cfs was provided at Columbia Falls throughout the entire year.

The peak inflow of 41.9 kcfs occurred on May 17 and the maximum outflow was 12.7 kcfs on June 22.

10. Flathead R at Columbia Falls

Discharges on the Flathead River at Columbia Falls gage record the combined flows of the North, Middle and South forks of the Flathead River. The flows on the North and Middle forks are uncontrolled and those of the South Fork are regulated by Hungry Horse Dam. This year's operation is graphically shown on Chart 65.

Greater than normal rainfall in June triggered snowmelt which resulted in the year's peak stage of 15.5 ft, or 59.9 kcfs, on May 17 at the time Hungry Horse outflow was 300 cfs. The unregulated peak was 101.6 kcfs on the same day.

11. Kerr Project (Flathead Lake)

Flathead Lake is a natural lake, the level of which is controlled by Kerr Dam which is owned by Montana Power Company and is licensed to be operated for power, flood control, and recreation. Spring refill of Flathead Lake is coordinated with the Corps of Engineers' Reservoir Control Center to control flooding of the agricultural lowlands between Kalispell and Flathead Lake. This area is prone to flooding if the lake reaches its full level, 2893.0 ft, coincident with the river flow being above 45 kcfs. This year's operation is graphically shown on Charts 12 and 66.

In late October Flathead Lake began a gradual draft from near full pool, which lasted throughout the autumn and winter months, for power production and spring flood control, reaching its minimum level for the year, 2884.81 ft on March 20. Refilling was slow until late April when inflows began increasing rapidly. The heavy rains of mid-May caused concern about overfilling the lake which greatly increased project discharges during late May and part of June.

The observed lake gage at Somers crested at 2893.0 ft on July 11 (unregulated 2895.6 ft on June 7 - a reduction of 2.6 ft), and the project outflow near Polson peaked at 52.2 kcfs on June 15 (unregulated 74.8 kcfs on June 7).

The peak seasonal inflow was 59.9 kcfs on May 16, the unregulated peak inflow was 101.6 kcfs on May 17, and the peak lake level was 2892.99 ft on August 11.

12. Albeni Falls Project (Pend Oreille Lake)

Pend Oreille Lake is a natural lake, whose outflow and lake level are controlled by constrictions in the outlet channel and by Albeni Falls Dam, a Corps project that is operated for flood control, power, and recreation. The dam is located 29 miles downstream of Pend Oreille Lake on the Pend Oreille River. Although the dam controls the lake level, the river channel between the lake and the dam limits the project outflow during both high flow periods and when the lake is near its minimum level. Inflow to Albeni Falls Dam is affected by the regulation of upstream impoundments, namely Hungry Horse and Flathead Lake (Kerr Dam) on a seasonal basis, and by two Washington Water Power projects, Noxon Rapids and Cabinet Gorge, on a daily basis. This year's operation is graphically shown on Charts 13 and 67.

The annual autumn drawdown of Pend Oreille Lake began immediately after Labor Day, drafting to 2060.0 ft on October 3. The lake continued drafting with discharge averaging 18.9 kcfs in October and 17.3 kcfs in November. This was the second year of a three year fish habitat study to test if cleaner gravels at higher lake levels are more conducive to spawning of kokanee salmon in Lake Pend Oreille. Normally, 2051.0 ft is the minimum winter lake elevation but in this study, the minimum elevation was 2055.0 ft. The study is a Fish and Wildlife measure adopted by the Northwest Power Planning Council and conducted by the Idaho Department of Fish and Game. At the end of October and November, the lake was at 2055.4 ft and 2055.3 ft, respectively. The minimum level, 2055.0 ft, was established for January through March. The maximum flood control rule curve elevations for January, February, and March were 2060.0 ft, 2060.0 ft and 2056.0 ft, respectively. The project stayed at or below these levels through March. In April, the project reached 2057.57 ft, which exceeded its maximum flood control rule curve by 1.57 ft. The project continued to fill during the spring runoff in May and June even though on April 21 the project went to free flow (no generation, all spill), which continued through June 24, to get a maximum amount of water out of the lake (the generating units can only operate if there is at least 8 ft of head). Project discharges averaged 42.5 kcfs, 100.7 kcfs, and 116.2 kcfs in April, May, and June, respectively. By June 24 the project had drafted to 2061.96 ft, 0.04 ft below its maximum flood control rule curve. Between June 24 and September 7 the lake was maintained between 2062.0 ft and 2062.5 ft.

The observed lake inflow peaked at 152.7 kcfs (unregulated 170.8 kcfs on May 31), the lake gage at Hope crested at 2065.7 ft on June 4 (unregulated 2068.3 ft on June 8 - a reduction of 2.6 ft), and the project outflow peaked at 138.2 kcfs on June 5 (unregulated 159.4 kcfs on June 8).

13. Grand Coulee Project

Grand Coulee is owned by the Bureau of Reclamation and operated for flood control (under Section 7 of the 1944 Flood Control Act), power, irrigation, recreation, fisheries, and navigation. This year's operation is graphically shown on Charts 14 and 68.

Because of high runoff volume forecasts this winter he operational objective for the Columbia River was to provide enough flood control space and still meet the Biological Opinion (BiOp) flows. The early runoff allowed target flows to be met until late August. Releases were made in July and August to meet Endangered Species Act (ESA) target flow requirements of 260 kcfs for April 20-June 30 and 200 kcfs for July 1-August 31 with Grand Coulee drafting to 1280.0 ft.

On October 1, Grand Coulee Reservoir, Franklin D Roosevelt (FDR) Lake was at 1282.5 ft and was operated above 1270.0 ft through late January. The lake was drafted for flood control to its low for the year at 1208.6 ft on May 4. The reservoir refilled to 1289.9 ft by July 20. FDR continued operations of flow augmentation, normal water budget, and ESA requirements until the end of August. The lowest level reached for operations was 1279.8 ft on August 30. The reservoir filled to 1285.0 ft on September 30 and the maximum daily outflow was 295 kcfs on June 22.

14. Mid-Columbia PUD Projects

Five run-of-river projects located on the mid-Columbia River in central Washington are operated by three separate Public Utility Districts (PUD's) primarily for power, flood control, fishery, and recreation. The five projects, in downstream order, are Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids and the three Public Utility Districts are those of Douglas, Chelan, and Grant counties. Although the projects are operated by these PUD's, 14 utilities, in addition to the three PUD's, split ownership of the generation output of these plants. Article 34 of the Federal Energy Regulatory Commission licenses for these projects states that some flood control space be provided, as instructed by the Corps, to replace lost valley storage under certain flood potential conditions but was not required this year. The operation of these projects is summarized in the flow of the Columbia River at Priest Rapids, Washington as shown on Chart 89.

Numerous special operations occurred at these projects to assist in the downstream passage of juvenile anadromous fish during the 1997 outmigration, including FERC-required spill. These include: during autumn, a coordinated effort was carried out to operate Priest Rapids to encourage fish to spawn at lower levels in the Vernita Bar area; from mid-October to late November (the primary spawning period), daytime flows were held as low as possible in an attempt to reduce the subsequent minimum flow necessary to protect redds until emergence of fry in early spring. The protection level was established at 65.0 kcfs.

The unregulated peak flow at Priest Rapids was 599 kcfs on June 6, and the observed peak was 414.9 kcfs on June 12.

15. Yakima Project

The five storage reservoirs in the Yakima Basin in Eastern Washington were operated by Reclamation for irrigation, fish and wildlife enhancement, flood control, power generation, and recreation. This year's operation is graphically shown on Charts 31 and 32.

Yakima Project flood control operations started in mid-February, with the bypassing of inflow to maintain flood control space from the reservoir system, and continued into early July. The heavy runoff held Yakima River at Parker flows at or above 10.0 kcfs from mid-March to mid-June, but caused no major flooding in the Yakima River System. Yakima Project successfully maintained a balance between the very high runoff forecast, maximum flood control space and maximizing storage in July for irrigation and carryover storage.

The system reached maximum storage for the year on July 6 at 1,068 kaf, and was placed on storage control on July 21. Bumping Reservoir was allowed to surcharge and pass flow over the spillway for instream outflows while repair work was completed on the outlet tunnel and channel. From mid-July until the end of irrigation season the runoff in the Yakima River Basin continued to be above normal. All entitlement water users received a full water supply, but due to the above normal rainfall the water users required only 82% (2.15 maf) of entitlement water to meet their needs. The Project storage on September 30 was 585.0 kaf, 159% of normal.

With the excellent total water supply available, the Yakima Basin was regulated to provide target flows of 600 cfs for Yakima River at Parker, and 600 cfs for Yakima River at Prosser. These flows are required by law in "TITLE XII -- YAKIMA RIVER BASIN WATER ENHANCEMENT PROJECT", Section 1205.

The Yakima reservoirs were operated to enhance both fish spawning conditions during September to mid-October and incubation/rearing conditions from mid-October through March 23. The bypassing of reservoir inflows to maintain flood space requirements or power rights supported incubation/rearing level flows for the rest of the season. Incubation/rearing releases from reservoirs included 9.6 kaf from Keechelus, 40.4 kaf from Cle Elum, 0.9 kaf from Bumping Lake and 4.5 kaf from Rimrock.

Both fish spawning enhancements,"Mini-Flip-Flop" and "Flip-Flop" operations were executed in the Yakima River Basin. The "Mini-Flip-Flop" operation required increasing outflows from Kachess Reservoir and decreasing outflows from Keechelus Reservoir to supply the demands in the Easton reach of the upper Yakima River. This provided for low spawning flows in the Yakima River above Lake Easton. The incubation/rearing level flows required during the winter were then supported by releases from Keechelus Reservoir. The "Mini-Flip-Flop" operation was implemented during the week of August 25-29.

The Yakima River to Naches River, "Flip-Flop" operation was executed for the 17th consecutive year. It involved drawing storage from Keechelus, Kachess, and

Cle Elum reservoirs to meet all Yakima River diversions in June, July, August and the first few days of September. During these months Rimrock and Bumping reservoirs were used only to meet the Naches and Tieton river diversions. In September, when low stages of river flows were required in the Yakima River from Easton to the mouth of the Teanaway River, the Yakima River reservoirs were set to meet only the spawning flow levels. Also, up to 400 cfs was routed around that reach via the Kittitas Canal. The Yakima system below the confluence of the Naches River, as well as the Naches and Tieton diversions, were met with releases from Tieton and Bumping reservoirs. These flows were provided, under a 1980 court order, for spring Chinook salmon. The "flip-flop" operation, implemented during the period September 2-10, provided a longer more environmentally friendly ramping down of flow levels in the upper Yakima River.

Spawning flows were set at 60 cfs on the Yakima River near Crystal Springs, 200 cfs on the Yakima River below Easton Dam, and 200 cfs on the Cle Elum River below the reservoir. Due to the high carryover in reservoir storage and well above normal October inflows, which at this time required the bypass of inflows through the reservoir system, incubation/rearing flow levels have not been established at this time.

16. Jackson - Palisades Project

Active storage in the Jackson/Palisades System includes 847 kaf in Jackson Lake and 1.20 maf in Palisades Reservoir, a Section 7 project, for a combined total of 2.047 maf. This system was operated as a multipurpose unit for flood control, irrigation, recreation, fish and wildlife, and power production. Discharge from Jackson Lake is measured on the Snake River at Moran, Wyoming, and discharge from Palisades Reservoir is measured on the Snake River near Irwin, Idaho. This year's operation is graphically shown on Charts 33, 34, 69 and 70.

Flood control releases of 1500 cfs from Jackson Lake Dam began in early February and were gradually increased in mid-March from 1,500 cfs to 3,500 cfs on March 22. This release was held until Jackson Lake Reservoir reached a maximum flood control space of 427.0 kaf on May 5 (27.0 kaf above the maximum space called for by rule curves). In early June, Jackson Lake filled rapidly reaching a maximum content of 874, kaf on June 11 and resulting in the maximum release of 11.7 kcfs on June 12. On June 7 Jackson Lake filled into 1.06 ft of surcharge as outflows were gradually decreased to 7,000 cfs until June 28, when Jackson Lake came out of surcharge. In the Jackson area, flood control levies had to be repaired and reinforced during the peak of the runoff to prevent breaches in the levies.

Flood control releases to make space in Palisades Reservoir began in mid-January, reached 13.0 kcfs on February 28 where they remained until April 8 when they were reduced to 9.0 kcfs. The reduced outflow was required as the reservoir approached empty to prevent the formation of a dangerous vortex near the intake structure. As freshet inflow increased, releases were increased to 17.0 kcfs by May 7. During the rest of May releases were adjusted to keep the Snake River near Shelley at or near flood stage. During the last week in May and the first two weeks in June above normal rainfall added to the rapidly melting snow, raising the Palisades inflow to its peak of 58.5 kcfs. As the reservoir approached its maximum capacity in the second week in June Palisades outflows were increased quickly to its peak for the year of 40,290 cfs on June 20. This was the highest release since closure of Palisades Dam in 1957 and greatly exceeded the previous record of 25.3 kcfs in June 1974. Palisades Reservoir filled on June 13 and by June 20, 0.9 ft of surcharge was used to limit the peak outflow. Widespread flooding occurred downstream of Palisades Dam as the levies breached near the towns of Roberts and Menan, resulting in their evacuation. Damages included water inside of homes, loss of farm crops, some farm land destroyed, and major structural damage to bridges and canal diversion facilities. By July 1 releases were reduced to 22.0 kcfs.

After the above normal runoff in 1996, contents in Jackson Lake and Palisades reservoirs totaled 1,543 kaf on October 1. Storage increased steadily through the first half of the winter until flood control rule curves dictated that flood control space be evacuated. Drafting began on January 10 and freshet storage began on May 6. Maximum system content was 2,079 kaf on June 20 and the September 30 content was 1,746 kaf, 523 kaf above normal.

The unregulated peak flow at the Heise gage was 56.1 kcfs on June 6, and the observed peak flow was 40.3 kcfs on June 20. Flood regulation curves were designed to maintain flows at Heise at or below 20.0 kcfs, and flood stage is at 24.5 kcfs.

17. Ririe Project

Ririe Reservoir is a Section 7 project on Willow Creek in eastern Idaho that is owned and operated by the Bureau of Reclamation for the joint uses of irrigation, flood control, recreation, and fish and wildlife. Its active capacity of 90.5 kaf includes exclusive flood control space of 10.0 kaf. This year's operation is graphically shown on Chart 35.

The peak daily inflow was 2,307 cfs on April 29 and the maximum release was 1,670 cfs on May 8th. The maximum active reservoir content was 83.1 kaf on May 18, 2,537 af into the exclusive flood control space. Storage at the end of the water year was 62.4 kaf, 78% of capacity.

18. American Falls Project

American Falls Dam is a Section 7 project on the Snake River near Pocatello, Idaho, that has an active capacity of 1,673,000 af and is operated primarily for irrigation, power, and flood control. During the irrigation season American Falls Reservoir is operated to meet irrigation needs in the Snake Basin downstream from American Falls Dam. The Snake River near Shelley gage, approximately 73 miles upstream from the dam, is the control point for flood regulation in American Falls Reservoir and for irrigation releases from upstream reservoirs. Milner Dam, located 74.0 river miles below American Falls, serves as a headworks for irrigation diversion in the middle Snake River plain. In normal years only minimum flows pass Milner with the remainder of the flow diverted for irrigation. This year's operation is graphically shown on Charts 36, 37, 38 and 71.

Project releases in the fall gradually decreased throughout October reaching 2.0 kcfs by the end of the month. The release was reduced to 1.0 kcfs on November 13 and remained there until December 4 when outflow was gradually increased, eventually reaching 20.0 kcfs on February 25. Above normal precipitation fell in November, December, and January requiring drafting for flood control space in American Falls Reservoir. Project outflow was maintained at 20.0 kcfs until April 11, which provided 606 kaf of flood control space, then releases were gradually decreased to 14,500 cfs by April 22. Heavy snowmelt runoff from the Henrys Fork during May combined with large releases from Palisades Dam and low irrigation demand caused American Falls Reservoir to fill rapidly, reaching full capacity on June 3 while releasing 24.0 kcfs. Inflows continued to rise as heavy rainfall persisted in the basin, and flood flows were released from Palisades Dam, until American Falls Dam was releasing the maximum mean daily discharge for the year of 46.0 kcfs on June 24, the highest measured flow since 1918. After the flood peak passed, releases were cut rapidly until the second week in July when they equaled normal irrigation deliveries.

Maximum storage at American Falls during the year was 1,705.7 kaf on June 19 while the reservoir contents on September 30 was 956.7 kaf, 434.0 kaf above normal.

19. Little Wood Project

Although it was originally constructed by Little Wood Irrigation District for exclusive irrigation use, the Little Wood Dam and Reservoir, on the Little Wood River in central Idaho, has been designated as a Section 7 project since its enlargement by the Bureau of Reclamation, to an active capacity of 30.0 kaf, is now operated also for flood control. The Little Wood River at Carey streamgage, approximately 3 miles downstream from the dam, is the control point for reservoir operations. This year's operation is graphically shown on Chart 39.

The reservoir filled gradually from mid November in response to heavy rains and was followed by the extraordinarily heavy New Year's Day rainfall that produced the annual peak flow of 1.30 kcfs and raised the pool to 90% of capacity. Flood control space was evacuated following the peak and through the end of February with a discharge of 300 cfs and was maintained in March and most of April by passing inflow. The reservoir started filling from the spring freshet in mid-April, filled by May 30, and remaining full until June 30. Maximum reservoir content was 30,495 af on June 5 and the storage at the end of September was 9,760 af, 3,300 af above normal.

Maximum mean daily springtime inflow was 1,271 cfs on April 21 and peak mean daily discharge at the Carey gage was 916 cfs on June 11.

20. Owyhee Project

Owyhee Reservoir has an active capacity of 715 kaf and, although it was constructed by Reclamation as a single-purpose irrigation reservoir, it can provide significant incidental flood protection along the lower Owyhee River and along the Snake River from Nyssa to Weiser. Most of the largest floods from this basin result from winter rains on snowpack over frozen ground. This year's operation is graphically shown on Chart 40.

The peak mean daily inflow was 31,590 cfs on January 3 and the peak daily outflow was 4,154 cfs on February 7. The spring peak inflow was 9,740 kcfs on March 21. The reservoir reached a maximum content of 722 kaf on May 16 and the storage at the end of September was 432 kaf, 121% of normal.

21. Boise Project

The Boise Project, Arrowrock Division, is a three-reservoir system composed of Anderson Ranch, Arrowrock, and Lucky Peak reservoirs with a combined total active storage capacity of 974 kaf. Anderson Ranch and Arrowrock, Section 7 projects, are operated by Reclamation while Lucky Peak is a Corps project that is regulated in close cooperation with the two projects that are upstream. A powerhouse was retrofitted to Lucky Peak by Seattle City Light. This system is operated as a multipurpose unit for flood control, fish and wildlife, power production, recreation, and irrigation. The Boise River at Glenwood Bridge streamgage is the control point for the flood control operation of the system. This year's operation is graphically shown on Charts 41 and 72.

Releases from Anderson Ranch Reservoir were maintained at 600 cfs through October and reduced to the winter minimum release of 300 cfs on November 4 and held at that level until December 26 when they were increased to 600 cfs. In mid January the release was increased to 1,600 cfs and further increased later in the month reaching a total discharge of 3,000 cfs by January 28. The Anderson Ranch release was maintained at 3,000 cfs until mid April when it was reduced to 2,600 cfs and in mid May it was increased to 3,000 cfs and held at that rate until early June. As the reservoir filled the release was gradually increased, reaching a maximum discharge of 5,586 cfs on June 13. The release was subsequently reduced to 1,600 cfs by July 7 and maintained at that rate until August 6 when the release was reduced to 600 cfs, the summer minimum release rate, and was maintained at that rate through the balance of the water year.

The flow of the Boise River below Lucky Peak Reservoir was set at 240 cfs at the end of the irrigation season, and maintained at that level until flood control releases were initiated on December 26. Extremely heavy rains and warm temperatures prevailed in the Boise Basin from mid-December through early January resulting in extremely high runoff on January 1 and 2. The mean daily inflow into the Boise River reservoirs on January 2 exceeded 24,000 cfs with the estimated instantaneous peak inflow of approximately 29,000 cfs. The reservoir system contained the runoff and prevented severe flooding along the Boise River. On January 10 the release from Lucky Peak Reservoir was increased to 6,500 cfs, the flood control target flow and then, due to continued heavy precipitation and record level runoff forecasts, the release was increased to 7,000 cfs, flood stage, on January 31. The flow of the Boise River at Glenwood Bridge was maintained at or near flood stage from then until early May while the maximum release from Lucky Peak Reservoir was 9,766 cfs on April 20. (The difference between Lucky Peak releases and flow at the Glenwood Bridge gaging station is diverted for irrigation, primarily by the New York Canal, upstream of Boise.) The spring freshet peak daily inflow was approximately 22.0 kcfs on May 17, with an outflow of 8.0 kcfs. Flood control releases continued until June 29 when the freshet was over. The flow of the Boise River was maintained at or below flood stage throughout the runoff period and the reservoir system was filled to 99.1% of capacity by early July. Between mid-July and late August 40 kaf was released from Boise River reservoirs for salmon flow augmentation.

Content in the three reservoir system on September 30 was 564 kaf, 134% of normal.

22. Malheur Project

Beulah (Agency Valley Dam) and Warm Springs Reservoirs were originally constructed and operated as single-purpose irrigation reservoirs. Since the construction of Bully Creek Reservoir in 1962, all three of these Section 7 reservoirs are operated for multipurpose benefits and have a combined active capacity of 281 kaf. The Malheur River is similar to the Owyhee River in that the major floods are usually caused by rain on frozen and snow-covered ground. The Malheur River at the Vale, Oregon, streamgage is the control point for flood control operation of the reservoirs, with the primary goal of limiting flows to 8,000 cfs. This year's operation is graphically shown on Charts 43, 44, and 45.

Flood control operations in the Malheur Basin prevented serious flooding during the January 2 flood event. The downstream flow briefly exceeded 8,000 cfs with reports of some minor flooding of low-lying farmland between Vale and Ontario, Oregon. Without the reservoirs, the estimated instantaneous flow would have been in the 16,000 cfs range.

Warm Springs Reservoir reached a maximum storage volume of 188 kaf on May 19 and drafting to 89 kaf by the end of water year. End of year carryover storage in Beulah Reservoir was 23 kaf. Bully Creek Reservoir reached a maximum storage volume of 30 kaf on April 14 and ended the year with carryover storage volume of 11 kaf.

23. Payette Project

The Payette River reservoir storage system includes Cascade and Deadwood reservoirs which have a combined total active storage capacity of 815 kaf. These reservoirs were originally constructed by Reclamation for irrigation and power purposes, but now are also operated informally for incidental flood control. The control point for flood control operation of these projects is the Payette River near Horseshoe Bend streamgage at river mile 60.8. A second key streamgage is the Payette River near Emmett at river mile 38.4. Approximately 65% of the drainage basin above Horseshoe Bend is unregulated. This year's operation is graphically shown on Charts 42 and 73.

From mid October through early December the release from Cascade Reservoir was maintained at the minimum release rate of 200 cfs, the natural flow water right of the Idaho Power Co powerplant at Cascade Reservoir. On December 5 project releases were increased to 1,000 cfs to draft the reservoir for snowmelt runoff flood control and were generally maintained between 1500 cfs and 3800 cfs until late June. On four occasions these flows were reduced to the minimum of 200 cfs to minimize downstream flows during extremely high runoff periods in early January, early February, in mid April, and in mid May. Severe flooding affected the Payette Basin in early January when daily inflow into Cascade Reservoir peaked at 11,262 cfs on January 1. The peak flow of the Payette River near Emmett was estimated at about 33,000 cfs on January 2 (flood stage is 16,000 cfs at Emmett) with an unregulated peak flow on January 2 at Emmett of about 45,000 cfs. Water stored upstream at Cascade and Deadwood reservoirs and Payette Lake reduced the flood peak by about 12,000 cfs. No significant flooding occurred in the Payette basin except for the high flows of early January. Cascade Reservoir filled on July 1 and was maintained at full pool through July 11. As the reservoir began to draft in mid-July the release rate was set at 1,500 cfs to provide for delivery of water for irrigation and salmon flow augmentation. Releases gradually decreased after Labor Day, reaching 700 cfs by the end of the water year.

The release from Deadwood Reservoir was maintained at the winter minimum release rate of 50 cfs from the beginning of the water year until early December when flood control releases were initiated, increasing outflows to 100 cfs and subsequently increased to 200 cfs on December 11 but were mostly in the range of 300 to 800 cfs. Flood control releases continued until June 8 when the reservoir filled. As in the case of Cascade Reservoir, the Deadwood release was reduced to the 50 cfs minimum to minimize downstream flow during high runoff periods in early January, early February, and mid April and mid May with the maximum release for flood control evacuation, 1,280 cfs, occurred on February 18. The peak inflow into Deadwood Reservoir was 2,826 cfs on May 17. Subsequent to filling the maximum flow from Deadwood was 1,437 cfs on June 15.

A total of 155 kaf was obligated for release for salmon flow augmentation. About 109 kaf was released from Cascade and Deadwood reservoirs between mid-July and September 2. The remaining 46 kaf is to be released between late November and January 1998. Some of the water released from Cascade Reservoir for this purpose is water conveyed downstream from Payette Lake.

Carryover in Cascade Reservoir on September 30 was 507 kaf, 129% of normal while Deadwood Reservoir carried over 120 kaf, or 200% of normal.

24. Snake R at Weiser

Snake River at Weiser flows are highly regulated by upstream irrigation diversions and reservoir storage operations previously discussed in this chapter. These operations normally results in a fairly smooth hydrograph at Weiser. This year's operation is graphically shown on Charts 46 and 74.

A major rain on snow event in late December and early January established the peak flow for the year. The computed unregulated peak flow at Weiser was 154.6 kcfs on January 2 and the observed peak was 81.8 kcfs on January 3, which is just shy of the record flow of 83.8 kcfs established in 1952, and third highest since record keeping began in 1910. (Peak flow in 1921 was also slightly higher.) Operation of the Boise, Payette, and Owyhee Projects were responsible for an approximate 50% flow reduction at the Weiser gage during the January flood. The spring freshet peak observed flow was 60.5 kcfs of June 17 and the unregulated peak was 122 kcfs on May 19.

25. Powder Project

Phillips Lake is formed by Mason Dam on the Powder River in eastern Oregon that is owned by Reclamation and is operated by the Baker Valley Irrigation District as a multipurpose project with 17 kaf for exclusive flood control, 21 kaf for joint use, and 52.5 kaf for active conservation use, for a total active capacity of 90.5 kaf. The control point for flood control regulation is the Powder River at Baker streamgage, which should be controlled to 500 cfs, if possible. This year's operation is graphically shown on Chart 88.

High flows in early January affected the basin as elsewhere in the region. The peak flow of the Powder River at Baker City was 554 cfs on January 1. Storage of high inflows in Phillips Reservoir substantially reduced downstream flooding as the peak mean daily inflow on January 1 was 1073 cfs with a release rate of only 11 cfs. Releases for snowmelt runoff from Phillips Reservoir were initiated on January 21 and continued through early July. The maximum release for flood control was in the range of 480 to 490 cfs and were maintained from May 17 through June 2.

Phillips Reservoir reached a maximum storage volume of 84.3 kaf on May 21, which was 93% of its total active capacity. The end of the year storage content in the reservoir was 47.1 kaf, 52% of its total active capacity.

26. Brownlee Project

The Brownlee, Oxbow, and Hells Canyon dam complex is owned and operated by Idaho Power Company (IPC). These tandem projects on the Snake River on the border between Oregon and Idaho are operated in accordance with a single license issued by the Federal Energy Regulatory Commission which requires operation for flood control and navigation, in addition to power. Specifically, this license requires that Brownlee, the only one of the three projects with significant storage, provide a minimum of 500 kaf of flood control space by March 1 in years of normal or greater forecast water supply at Brownlee and The Dalles. The license does, however, have a provision for a partial waiver of this requirement in dry years or for increased space in wet years. The license also requires adequate navigation depths be maintained below Hells Canyon Dam. Spring refill of Brownlee is coordinated with the Corps of Engineers Reservoir Control Center for flood control. This year's operation is graphically shown on Charts 15 and 75.

Brownlee began the water year at 2045.3 ft after a July-September draft to help meet NMFS target flows for juvenile fish migration at Lower Granite Dam. The lake was then drafted to 2032.5 ft by October 19 to create space in the reservoir so a portion of the inflow could be stored while discharge from Hells Canyon could be maintained near between 9.5 and 12 kcfs to encourage fall chinook salmon to spawn at a low levels in the downstream channel between late October and December 9. The goal was that the lake be full near the end of the spawning operation. This goal was met, as by December 15 when the pool had filled to 2076.4 ft (2077.0 ft is full pool). The Hells Canyon discharge was then maintained above 12.5 kcfs until fry emergence in the spring. At the request of IPC the Corps, after consultation with NMFS, waived the navigation requirement of maintaining 13 kcfs at Lime Point, near Anatone, through April 15.

(During this period the New Year's peak inflow came at the time of this full pool. This was the peak flow, 81 kcfs for the year and was passed without any storing.)

Based on the forecast at Brownlee and The Dalles the Corps notified IPC that 750 kaf of flood control storage space was required at Brownlee (surface elevation of 1976.0 ft) by April 30. Throughout the forecast period, the flood storage requirement remained at 750 ft and by April 30 the reservoir was drafted to 1982.75 ft. The project continued to draft for flood control to a low of 1976.37 ft on May 2. Increasing inflows from the beginning of the spring runoff refilled Brownlee reservoir to 2076.44 ft on June 28.

The State of Idaho developed a plan (which was approved by the Technical Management Team) to start drafting Brownlee on July 24 to meet the 237 kaf augmentation volume required per the Biological Opinion (See Chapter IV, Section G). The outflow was about 20 kcfs in order to keep Oxbow from spilling (because of unit outage). This outflow was held constant from July 24 to September 14 when Brownlee releases were increased to about 30 kcfs for the last two weeks in September in order to make room for the large amount of upper Snake water that had runoff in the summer and was not used by irrigators. Brownlee was drafted to 2070.5 ft by July 31, to 2051.8 ft by August 31 and 2022.6 ft by September 30.

The regulated peak spring inflow was 63.3 kcfs on June 16 and the unregulated peak inflow was 133.5 kcfs on May 17. Maximum daily outflow was 65.6 kcfs on April 28.

27. Dworshak Project

Dworshak Lake and Dam are located on the North Fork Clearwater River near Orofino in west central Idaho. This project was constructed and is operated by the Corps of Engineers for power, flood control, fishery, navigation and recreation. This year's operation is graphically shown on Charts 16 and 76.

Dworshak, at 1519.53 ft on October 1, was filled to 1531.4 ft by the end of December, which was below the Upper Rule Curve level of 1558.0 ft. Based on the current flood control rule curves, Dworshak was to be at minimum pool (1445.0 ft) to provide 2.00 maf of flood control space by March 31. The high runoff volume forecast first issued on January 1 continued throughout the spring so the project was drafted to empty on April 3 and had to spill starting April 16 to pass inflow and stay empty. (The New Year's Day storm did not extend into the NF Clearwater River.) Starting on April 22 the project, releasing 25 kcfs (channel capacity), started to fill involuntarily because of the high flows. The project maintained 25 kcfs outflow through May 10, filling to 1452.7 ft. To alleviate flooding problems in Orofino (backwater affect from the Clearwater River), project releases were reduced to 1.3 kcfs between May 15 and 19. Between late May and early June, flows were managed with the target of refill towards the end of June but not filling too quickly to maintain flood control protection downstream until the freshet was over. The project filled on July 3. The State of Idaho issued a dissolved gas waiver allowing the project to voluntarily reach dissolved gas levels up to 120% between July 15 and August 15 so the project could stay full longer before starting to draft for the grouting contract to slow down leakage of the dam. The project stayed within 1-foot of full (1599.0 ft to 1600.0 ft) until July 16 when the outflows were increased to 22 kcfs, where they remained through August 15 and were gradually ramped down by the end of August until the target pool level of 1500.0 ft was reached. The project passed inflow through the rest of the water year as the grouting work progressed. (The grouting work was completed December 15, 1997.)

The peak daily inflow was 48.8 kcfs on May 15, while outflow at the time was 1.3 kcfs. The peak daily outflow was 25.1 kcfs which was maintained April 21 through May 9.

28. Clearwater River at Spalding

The streamgage on the Clearwater River at Spalding in west-central Idaho measures the portion of the inflow to Lower Granite Dam that originates in the Clearwater River Basin. It is also used as a flood control point in the operation of Dworshak Dam. This year's operation is graphically shown on Chart 77.

The observed peak flow at Spalding this year was 80.7 kcfs on May 16 when Dworshak was releasing 1.0 kcfs. The unregulated peak flow during the flood season was 127.5 kcfs on May 16, well above the flow at flood stage of 111.6 kcfs.

29. Lower Snake Projects

Lower Granite, Little Goose, Lower Monumental, and Ice Harbor are run-of-river projects on the lower portion of the Snake River in southeastern Washington. Lower Granite and Little Goose have 5-foot forebay operating ranges, and Lower Monumental and Ice Harbor have 3-foot ranges. All four projects are operated by the Corps of Engineers for navigation, hydropower, fishery, and recreation. This year's operation is graphically shown on Charts 78 and 90.

During the summer the projects were operated at minimum operating pool (MOP) with the intent to increase water velocities to aid downstream juvenile fish migration.

Lower Monumental and Little Goose projects operated in their top foot operating ranges October 1 through December 31 to enhance adult fish ladder access. Ice Harbor operated slightly below its top foot through December 31 to provide as good fish ladder conditions as possible (for upstream adult fish migration) and also provide reservoir space to protect workers who were installing flip lips in the tailrace. Lower Granite operated between 734.0 ft and 735.0 ft from October 1 through November 15 which was as low as possible for juvenile fish migration yet high enough for navigation restrictions. On November 15 Lower Granite operation range was increased to 734.0 ft to 738.0 ft, and was operated to maintain Lewiston below 738.0 ft if flows were low and below 737.0 ft if flows were above 50.0 kcfs for flood control. Lower Granite was drafted to 729.9 ft on January 1 because of the high inflow forecast and then began to have problems with barges that had drafts great than 14 ft which were unable to travel over the upstream lock sill. Also, undermining of the Lewiston levees was a concern.

Starting on April 9, all projects were drafted to MOP or MOP-plus-one-foot for juvenile fish migration, as required by the Biological Opinion. Required night time spill was initiated at Lower Granite, Little Goose, Ice Harbor, and Lower Monumental on April 10. Ice Harbor was spilling around the clock due to decreased powerhouse flow capacity because of out-of-service generator units. Fish transportation by both truck and barge were also initiated in April. Spill occurred at all the Lower Snake projects during most of April, May and June. Navigation companies had problems navigating barges at Ice Harbor because of the river currents caused by the newly installed flip lips. In May, various spill patterns were tested to learn which combination of flows and spillway gates had the least the impact on navigation. Lower Monumental and Little Goose refilled in early September and operated in their top foot of their operating range through the month of September to enhance adult fish ladder access. The flip lip contractor returned to work at Ice Harbor in September and the project operated slightly below its top foot through the rest of the month for both adult fish migration and contractor safety.

The regulated peak flow into Lower Granite was 225.3 kcfs on May 17 and the unregulated peak was 357.9 kcfs on May 17.

30. Mill Creek Project

Mill Creek Dam and Bennington Lake is a Corps of project in the Mill Creek basin, east of Walla Walla, Washington. This off-stream project receives high flows that were diverted from Mill Creek for flood control. The reservoir's active storage capacity of 8,200 af was used for flood control and recreation. This year's operation is graphically shown on Chart 47.

From October 1 through December 31 Bennington Lake's level ranged between 1195.0 ft and 1194.5 ft. During January two major flood control operations were required, each followed quickly by drafting the pool to prepare for possible subsequent flood control operations. The first, on January 1, was caused by storms in late December that filled Bennington Lake to a peak of 1211.7 ft. The second flood operation on January 31, was caused by storms in late January that filled the pool from 1207.8 ft to a peak of 1212.1 ft on February 1. Seepage and evaporation losses caused drawdown of Bennington Lake to conservation pool level of 1205.0 ft by April 14 and to 1193.8 ft by September 30; streamflows were not sufficient to maintain the pool at 1205.0 ft.

31. Willow Creek Project

Willow Creek Dam at river mile 52.4, together with the City of Heppner Flood Warning System, constitutes the Corps of Engineers flood protection provided for the urban reach of Willow Creek through the city and immediately north of Heppner in north-central Oregon. The dam is a 154 ft high roller-compacted concrete structure with an unregulated spillway. The 14,091 af of storage space below the ungated spillway crest, 2113.5 ft, is allocated to flood control, irrigation, and minimum flow maintenance. The lake is held at 2063.0 ft in the winter and 2076.5 ft in the summer to provide for flood control. This year's operation is graphically shown on Chart 48.

There were small two flood control regulation events this water year, both occurred in January and had inflows in the 400 cfs range and each followed quickly by drafting the pool to prepare for possible subsequent flood control operations. The early January storm filled the pool to 2075.5 ft and the late January event filled the pool to 2073.0 ft. Maximum summer operation pool of 2076.5 ft occurred in early June. The water year ended, and also the water conservation season, with a pool level consistent with the scheduled water control regulation curves. Pool drawdown does not occur until the next water year, starting after Columbus Day each October.

32. John Day Project

Lake Umatilla is the reservoir behind John Day Dam on the Columbia River that straddles the Oregon-Washington border and is operated by the Corps primarily for power, flood control, and navigation. The lake has approximately 500 kaf of active storage in its full operating range, 257-268 ft. Historically, the Corps generally operated the lake in the range of 260.0-265.0 ft from November through the spring runoff. Following the spring runoff, and continuing until mid-October, the pool is normally operated in its top 3 ft, 265.0-268.0 ft. However, in recent years the lake has been operated at lower levels in an attempt to improve juvenile fish passage through the reservoir with lower surface levels and faster water velocities. In addition, the lake may be drafted to as low as 257.0 ft for flood control and power. This year's operation is graphically shown on Chart 17.

The official range of John Day Dam forebay operation is 260.0 to 265.0 ft beginning November 1. Normally a limit of 263.5 to 265.0 ft exists on Wednesdays, weekends and holidays for water fowl hunting between mid-October to mid-January. At the end of December, the forebay was drafted to between 257.0 ft and 260.0 ft. Between mid-January through April, a contractor started working in the tailrace to install flip lips on 18 of the 20 spill bays. This work involved hard-hat diving that required work barges and crane to remain in the tailrace area for the work period. There was also a no spill objective a majority of the time for the worker's safety and impact on work schedule. Normally the pool is operated above a minimum of 262.5 ft for the benefit of the Irrigon and Umatilla Hatcheries and irrigators. The project was drafted below 262.0 ft on two different occasions for flood control for Portland-Vancouver Harbor: during December 27 - January 1 and January 31 – February 2. Also, April 24 through June 25 John Day was operated for flood control for Portland-Vancouver Harbor as well as for irrigators. Initially, the forebay was maintained below 262.0 ft. Then, when the high flows started, John Day project releases were controlled to maintain Initial Control Flow Conditions at The Dalles (flows not to exceed 530 kcfs) for flood control in the Portland area. The project was regulated to a delicate balance to maintain flood control space for Portland yet allow the forebay to occasionally fill above 262.0 ft to allow the irrigators to water their crops.

Between July and August the pool was operated according to NMFS Biological Opinion requirements and irrigation needs. In September the flip lip contractor started working again, requiring a no spill condition 6 days/week. Because of the low water conditions, there was no problem providing no spill.

33. Upper Deschutes Project

This multiple reservoir system is composed of Prineville and Ochoco reservoirs on the Crooked River, both Section 7 projects, and Crane Prairie, Wickiup, Crescent Lake, and Haystack reservoirs on the Deschutes River. Including Haystack, which is an offstream reregulating reservoir, there is a combined total active storage capacity of 559 kaf. This year's operation is graphically shown on Charts 49 and 50.

Crescent Lake storage at the beginning of the water year was 38.7 kaf. Storage peaked for the season at 86.1 kaf on July 9, which is essentially full. This was the highest reservoir level since 1976. Carryover storage at the end of the year was 71.7 kaf. The maximum combined Wickiup and Crane Prairie storage of 250.8 kaf was reached on April 30. Combined storage at the end of the year was 176.2 kaf.

Prineville Reservoir entered the water year with a carryover of 102 kaf, 106% of normal. Winter flood control space was maintained by releasing a stream resource maintenance flow of approximately 80 cfs until early December, when higher flood control releases began to be necessary. Peak storage of 158.7 kaf, 104% of active capacity, was reached on April 24. The maximum inflow was approximately 6.73 kcfs on January 1; maximum release was 2.96 kcfs on January 3. The reservoir had a storage of 90 kaf, 94% of normal at the end of September.

Ochoco Reservoir entered the water year with a carryover of 18.9 kaf. The outlets were closed following irrigation season and all inflow was stored until late December, when flood control releases were required. The New Year's Day storm nearly filled the reservoir and forced releases to be turned up to maximum outlet works capacity of approximately 420 cfs. Discharges continued at peak capacity until February 17 in order to draft the reservoir back down to its flood control rule curve requirement. Discharges from late February through early April ranged from 15 cfs to 300 cfs to keep the reservoir at or near its rule curve requirements. Peak discharge was 423 cfs on January 7, and peak inflow was about 2.13 kcfs on January 1. The reservoir filled by early April and remained nearly full through most of June when releases began for irrigation; the peak storage of 44.7 kaf occurred on April 23. Irrigation demand drafted the reservoir during the summer to 25.5 kaf by the end of September.

34. Chief Joseph, McNary, The Dalles, and Bonneville Projects

These run-of-river projects are operated by the Corps for hydropower, navigation, irrigation, recreation, and fisheries. Chief Joseph is located on mid-Columbia River in central Washington. McNary, The Dalles, and Bonneville are on the lower Columbia River, straddling the Oregon-Washington border. Several special operations occur each year at these projects to meet special requirements for power production, navigation, recreation, fishery, and construction activities. This year's operation is graphically shown on Charts 80 and 91.

McNary Dam had Biological Opinion flow requirements that varied throughout the spring summer (see Chapter IV, Section G, Fishery Operations). Also continuing at McNary this year was the unloading of ten decommissioned defueled submarine reactor compartments at the Hanford Reservation, one during March and the other nine in September and October 1997, necessitating special operation of the water level behind McNary Dam and the Priest Rapids discharges to allow barge docking at the Port of Benton slip. Also, special operations at McNary for national level competitive boat races, shoreline weed control, boat ramp construction, habitat island maintenance, waterfowl nesting, and waterfowl hunting occurred throughout the year. At times, these requests conflicted with each other, requiring special coordination.

Spill for juvenile fish passage occurred at McNary, John Day, The Dalles, and Bonneville during the spring and summer. Spill levels were set in accordance with the Corps' Fish Passage Plan for 1997. See Section g, Fishery Operations for additional information.

The peak winter flood regulated flow at The Dalles was 321.5 kcfs on January 5 and the peak unregulated flow was 398.0 kcfs on January 3. The unregulated peak snowmelt flow at The Dalles was 896.0 kcfs on June 7 and was controlled to a peak of 570.7 kcfs on June 15.

35. Columbia River at Vancouver

The Columbia River Basin reservoir system was operated for flood control once during the winter of 1996-97. Most of the flood contribution came from the Willamette River and lower Columbia River tributaries. Treaty projects' outflows were not reduced to alleviate flooding conditions in the Portland-Vancouver harbor during this high water event because there was sufficient storage available in Grand Coulee to achieve flood control objectives.

The observed peak stage at Vancouver, which was the result of an unusual winter rain/snowmelt flood, was 22.1 ft, 6.1 ft over flood stage, on January 2 and the unregulated peak stage for this event was 23.9 ft on January 4. As a comparison, in 1964, the flood crest was 27.7 ft and in February 1996, 27.2 ft was reached. The all time record is 31 ft in 1948. Bankfull at Vancouver is 16 ft and a major flood is at a stage of 26 ft.

The spring snowmelt runoff peak flood stage at Vancouver was exceeded for much of May and June. Significant flood control was provided by the Treaty projects. The observed peak stage at Vancouver, was 19.0 ft on June 4 and the unregulated stage was 28.4 ft on June 8. Please see Chart 79.

36. Willamette Basin Projects

There are 25 dams in the Willamette Valley of western Oregon. The Corps operates 11 storage and two reregulating reservoirs; Reclamation operates one storage project, Scoggins Dam, a Section 7 project; and the remaining 11 are single-purpose, hydroelectric plants operated by public and private utilities. The federal projects are:

Hydroelectric		Non-power
Storage	**Reregulation**	**Storage only**
Hills Creek	Big Cliff	Fall Creek
Lookout Point	Dexter	Cottage Grove
Cougar		Dorena
Green Peter		Blue River
Foster		Fern Ridge
Detroit		Scoggins

These projects are operated for flood control, hydropower (where applicable), irrigation, fishery habitat, and recreation. Since these federal projects are operated as a system to control the flow of the Willamette River, their operation will be discussed as a unit. WY 97's operation is graphically shown on Charts 18-28, 81,82,83,84, and 92.

a. CORPS PROJECTS The Willamette reservoirs operated by the Corps were about full at the beginning of the summer of 1996. Summertime rainfall was above normal, so augmentation of the mainstem flows was achieved by the normal releases from the projects as outlined in the summer augmentation plan developed in May 1996.

The summer low flow augmentation meeting was not held in May because of the above average water year. The augmentation plan was drafted and sent to the State and Federal agencies that have an interest in the Willamette flows and only minor comments were returned for inclusion in the overall plan. The following minimum flows, in cfs, for the mainstem Willamette were adopted:

Location	June	July	August	September
Albany	4,500	4,500	5,000	5,000
Salem	6,000	6,000	6,500	7,000

During the summer of 1996 precipitation was near normal so additional augmentation was not required to maintain mainstem flows. The releases from the projects were increased for local requirements for fish or other environmental concerns of the Oregon Department of Fish and Wildlife (ODFW). The flow from Lookout Point was increased in July to 2500 cfs, Cougar was increased to full load on both units in August, Fall Creek releases were between 200 cfs and 500 cfs through Labor Day, which drafted the lake 10 ft. The release was then increased to 1200 cfs to draft the lake to 710.0 ft. Heavy precipitation during October, November, and December allowed the project to be below 710.0 ft for 26 days and releases below 500 cfs for only 19 days, which are the goals for safe fish passage.

From October through April a series of storms passed throughout the valley, with rainfall averaging from 110% to 300% of normal, preventing about half of the projects from reaching minimum flood control pool. The largest runoff occurred with storms that started on December 20, reaching a peak on December 25 and 26 with 6.8 inches reported at Cougar Dam for that 48 hour period. The Willamette projects were drafting from the storm that started on the December 20th, and were about 9% full on December 24. By January 4th the system was about 69% full with the projects on the McKenzie and the Santiam Rivers receiving the blunt of the storm. The river stage at Salem reached a maximum of almost 29 ft on January 3. By comparison the February 1996 river stage at Salem peaked at 35 ft. Stream levels at control points are shown in the following table.

Location	Obs'd Stage	Bankfull Stage	Flood Stage	Major Stage
Jasper	***9.9***		10.0	15.0
Goshen	***11.8***		13.0	16.0
Eugene	***19.5***		23.0	29.0
Vida	***16.3***	6.0	11.0	14.0
Harrisburg	***12.8***	10.3	14.0	17.0
Monroe	***8.7***	9.0	9.0	
Waterloo	***9.8***	9.9	12.0	18.0
Mehama	***8.8***	11.0	13.5	
Jefferson	***14.4***	12.8	15.0	20.0
Salem	***29.0***	21.4	28.0	33.0

The projects were all back to the rule curve by the middle to the end of January and continued to fill on schedule during the refill period February through May. All the projects completed filling on schedule except for Cottage Grove, which filled to a foot and a half of the conservation pool. A summer augmentation plan was sent to interested parties in May, and because the summer runoff was forecast to be at or above normal for the June-September period no meeting was held. July through October continued to have above normal inflows and so additional augmentation of the main stem was not required. The releases from the projects were increased to meet minimum flows downstream and requirements of the Oregon DFW.

b. RECLAMATION PROJECT. Henry Hagg Lake was formed by Scoggins Dam on Scoggins Creek, tributary to the Tualatin River near Forest Grove, Oregon. The reservoir has an active capacity of 53.64 kaf and is operated for flood control, irrigation, municipal supply, fish and wildlife, recreation, and water quality. The inflow occurs mostly from winter rain storms. The year's operation was generally according to flood control regulations and is graphically shown on Chart 85.

Henry Hagg Lake storage, at the beginning of the water year, was 26 kaf, 48% of capacity and 100% of normal. The reservoir was further drafted during the fall to meet late season irrigation demand and provide water quality flows downstream on the Tualatin River, reaching its lowest storage for the year of 23.4 kaf on November 12. Storage began to accumulate when the discharge was reduced to the project minimums beginning in mid November and reached the flood control rule curve by early December, when a high water event forced storage above the curve. Releases up to about 1,250 cfs were required in mid December to draft the reservoir towards its rule curve requirement. This flood space evacuation was nearly completed when a significant flood event occurred in late December and early January. Peak inflows were captured by the reservoir during the event, forcing it to essentially fill by January 2. Significant releases were not required from the reservoir until after the downstream flows had peaked and were in recession. The gage height at the Tualatin River near Dilley flood control point peaked for the year at about 17.9 ft on January 2. The year's highest peak mean daily inflow to the reservoir occurred on December 31 at 2,007 cfs (peak hourly inflow was much higher), and peak discharge of 1,660 cfs was measured on January 3. The reservoir was drafted to its rule curve on January 15, which it essentially followed until it refilled in early May and remained full until draft began in early July.

Storage at the end of the water year was 24.4 kaf, 46% of capacity and 94% of normal. Inflow during the water year was 129.8 kaf, 142% of normal.

37. Western Washington Projects

a. HOWARD A. HANSON DAM.

Howard A. Hanson Dam, on the Green River at river mile 64.5, is a flood control and conservation storage project. The project provides winter flood protection primarily for the lower Green-Duwamish River valley between the cities of Auburn and Seattle. In the spring, over 24 kaf is stored to augment low flows for fisheries in late summer and fall. The City of Tacoma operates a major M&I water supply diversion dam and pipeline 3.5 miles downstream from Hanson Dam. The year's operation is graphically shown on Chart 51.

The project began the year with the pool at 1110.6 ft, 5.5 ft below the 98% rule curve and on December 4 it reached the normal minimum flood control level of 1070.0 ft. This pool level provides a few feet for water quality control, yet the reservoir is essentially empty. The project was not operated for flood control this year.

However, seismic retrofit work on the intake tower and walkway columns required additional regulation to maintain a pool at less than 1140.0 ft although the pool did reach a winter peak of 1127.6 ft on February 16.

Beginning in early April, and continuing through September, the Corps, the city of Tacoma Water Department, the Muckleshoot Indian Tribe, and Federal and state resource agencies coordinated project refill operation, continuing a policy initiated in 1988. Due to an unusually large snowpack, refill of the reservoir was delayed to reduce the possibility of passing high inflows after the reservoir was full. Refill was initiated by capturing a constant 400 cfs (800 af/day) on May 6 at a pool of 1185.0 ft. On May 22, the capture rate was increased to insure the reservoir filled to the conservation level of 1141.0 ft by June 1. Draft of the reservoir began on August 21 to augment flows for downstream fisheries.

Peak streamflows reached 9,430 cfs on March 20 at the Green River near Auburn streamgage, well below the authorized 12.0 kcfs control flow, the unregulated streamflows was 11.9 kcfs at the Auburn gage, and the greatest release from the dam was 7,395 cfs.

b. <u>MUD MOUNTAIN DAM</u> Mud Mountain Dam, on the White River at river mile 29.6, is a single-purpose, flood control project which is normally empty except during flood control operation, project maintenance, and occasional regulation for downstream needs. The year's operation was generally according to flood control regulations and is graphically shown on Chart 52.

In January, flood control regulation by Mud Mountain Dam limited the discharge at Puyallup to a maximum of 23.46 kcfs. Without this regulation, the Puyallup gage would have reached approximately 28.2 kcfs. On January 1 the inflow peaked at approximately 12.0 kcfs while the peak pool elevation occurred on January 8 at 1062.72 ft. In addition to this normal flood control operations, special dam regulation occurred on three occasions; the first during the week of December 16 when Puget Sound Energy required flows of 2,000 cfs to test modifications to their diversion structure below Mud Mountain. Second, from January 10 to February 6 when Northwest Pipeline requested flows of 2,500 cfs to 3,500 cfs for streambed reconstruction. Erosion of the bank had exposed a high pressure gas transmission line. Third, in July and August, inspection and repair of the outlet tunnels required detailed gate operations.

c. <u>WYNOOCHEE DAM</u> Wynoochee Dam, on the Wynoochee River at river mile 51.8, provides flood control for the lower Wynoochee Valley, water supply for the city of Aberdeen's diversion at river mile 8.1, fishery enhancement, recreation, and irrigation benefits. On July 26, 1995 the project ownership was transferred from the city of Aberdeen to the city of Tacoma. However, the Corps' role in the flood control operation of the project remains unchanged while Tacoma is responsible for all non-flood reservoir regulation duties. The year's operation was generally according to flood control regulations and is graphically shown on Chart 53.

The Corps assumed flood control operation of the Wynoochee Dam Project on four occasions. The last storm on March 18 proved to be a 100 year event in the lower basin with more than 21 inches of precipitation felling over a three day period. The Spillway Gate Regulation Curve, used to balance the remaining storage volume with the observed inflow was used for the first time, although the spillway was not used.

The observed peak flow for the Wynoochee River above Black Creek gage, the control point, was 25.6 kcfs on March 19 where the zero damage flow is 18,000 cfs. Preliminary damage estimates were in excess of 1 million dollars. Unregulated, the flow would have reached 37.0 kcfs which meant flood control operations at the dam lowered the downstream stage by approximately 3.0 ft.

c. <u>LAKE WASHINGTON SHIP CANAL AND HIRAM M. CHITTENDEN LOCKS PROJECT</u> The Chittenden Locks project controls the level of both Lake Union and Lake Washington, and provides a navigation channel between these lakes and Puget Sound. Project facilities include a large and small lock, spillway gates, fish ladder, smolt slide, saltwater drain, and a special saltwater barrier at the upstream end of the large lock. The saltwater drain and barrier are designed to reduce and control saltwater intrusion into the fresh water lakes.

Lake Washington began the water year at 20.9 ft, and gradually drafted to 20.0 ft by December 1 to provide shoreline protection against wind and wave action. Throughout the winter, the Locks were operated to optimize fish passage and limit salt water intrusion into Lake Union. The spring refill began February 16, but was interrupted on March 20 in preparation of a series smolt passage tests. The objective of the tests was to quantify the passage of juvenile salmon through the locks when no discharge was occurring over the spillways. To prepare for the shutdown of the spillways during this high flow period, it was necessary to hold the elevation of Lake Washington at 21.1 ft. After a series of fill and spill operations for the smolt passage tests, Lake Washington reached the normal conservation pool of 21.85 ft on June 18, and continued to fill to a maximum of 21.95 ft on June 25. Release of the storage and draft of the lake began on 24 June. The lake continued to draft until the end of the year and dropped to 20.9 ft by 30 September. Lake Washington was held within the normal operating range of 20.0 ft to 22.0 ft the entire year.

e. <u>ROSS PROJECT</u> Ross Dam, located on the Skagit River at mile 105.2, is owned and operated by the

City of Seattle, Department of Lighting (Seattle City Light). The FERC license for the Dam states that evacuation of flood control storage must begin by October 1 and be completed by December 1 to provide storage of 120.0 kaf above the pool elevation of 1,592.1 ft. The storage space must remain available until at least March 15 of the following year. The FERC license also gives the Corps limited authority to specify project regulation during a flood emergency. During a flood event, when the unregulated or natural flow in the Skagit River near the town of Concrete is forecast to exceed the major damage level of 90.0 kcfs, the Corps can specify operation of the project. Under this flood control operation, Seattle City Light is permitted to release full powerhouse capacity from Ross provided the flow is reregulated by the two downstream projects, Diablo and Gorge, to a maximum outflow of 5,000 cfs. The year's operation was generally according to flood control regulations and is graphically shown on Chart 54.

Two storm events raised flooding concerns in the Skagit River Basin this water year. On March 19 a rain on snow caused the forecast flow at Concrete to exceed 90.0 kcfs. Fortunately, storage of inflow and less than predicted precipitation resulted in observed flows less than 90.0 kcfs. On July 9 a 30- to 40-year precipitation event caused minor flooding when the flow rose to 91.4 kcfs at Concrete. This relatively rare summer flood event heightened flood concerns because Ross Reservoir was only 0.35 ft below the summer conservation pool level of 1602.5 ft. Although flows from unregulated areas of the basin below the dam rose quickly, inflow to the dam remained below 20.0 kcfs. The maximum storm discharge from the project was 13.33 kcfs and the pool peaked at 1602.47 ft.

f. <u>UPPER BAKER PROJECT</u> Upper Baker Dam is located near Concrete, Washington at river mile 9.3 on the Baker River, a tributary of the Skagit River. The two dam hydroelectric project is owned and operated by Puget Sound Energy (PSE) formally Puget Sound Power & Light Company. The FERC license for Upper Baker Dam requires 16 kaf of flood control storage space to be provided by November 1 for replacement of natural valley storage eliminated by the project. An additional 58.0 kaf of flood control storage is provided by November 15 in accordance with congressional legislation and an agreement between PSE and the Federal government for reimbursement of power losses due to operation of the additional storage for flood control. When necessary, flood control storage is managed by the Corps from November 1 through March 1 each year. As with Ross Dam, the Corps can specify operation of Upper Baker Dam when the unregulated or natural flow in the Skagit River near the town of Concrete is forecast to exceed 90.0 kcfs. Under flood control operation, PSE is required to maintain a release of 5,000 cfs from Upper Baker Dam. The year's operation was generally according to flood control regulations and is graphically shown on Chart 55.

In March, PSE stored most of the flow in the Baker River which assisted in keeping the flow of the Skagit River at Concrete below 90.0 kcfs. At the time, PSE's maintenance and construction work on Lower Baker Dam allowed spill only at night. The timing of the event was such that the Corps flood control operations were minimal. In July, Upper Baker Reservoir was 0.65 ft from the normal summer conservation pool elevation of 724.0 ft. Inflow peaked at approximately 20.0 kcfs and the pool rose to a maximum of 723.75 ft. The maximum discharge was 18.9 cfs.

g. <u>MOSSYROCK & MAYFIELD DAMS</u> Mossyrock and Mayfield dams are tandem projects on the Cowlitz River that are owned and operated by Tacoma City Light for hydroelectric power generation and flood control. Their FERC license gives the Corps limited authority to specify project regulation during a flood emergency. The flood control plan for Mossyrock is to provide a maximum of 360 kaf of flood control storage between 778.5-745.5 ft during December and January, with a gradual drawdown from full pool beginning October 1 and gradual refilling to full pool between February 1 and June 1. Storage space of 21 kaf assigned to Mayfield may be substituted at any time for an equal amount in Mossyrock. The year's operation was generally according to flood control regulations and is graphically shown on Chart 56.

During November and December, lake elevations were held some 8 to 12 ft below the water control curves evacuation schedule, possibly because of the very high inflows which had occurred last fall. The most significant flood control operation occurred during the flood event of January 1-5 with a peak inflow of 45.0 kcfs. The maximum lake level of 764.5 ft occurred on January 4 and the maximum outflow from Mayfield Dam was 25.0 kcfs on January 9. During February through May, the lake was filled to 8 to 12 ft below the authorized project filling schedule. Storage and water releases during the conservation release season were typical of previous years.

h. <u>SEDIMENT RETENTION STRUCTURE</u> The Sediment Retention Structure (SRS) is a Corps project on the North Fork Toutle River in southwestern Washington designed to trap Mount St. Helens volcanic sediment by slowing the river flow. The dam was design with six rows of outlet pipes which allow the water to pass through the SRS and into the outlet channel. The rows of outlets are successively blocked and closed as the sediment deposited in the pool continues to increase. From November 1987 through September 1996, sediment deposits have resulted in closing of the lowest three rows of outlets.

In March 1997 the fourth row outlets were closed and in September the fifth row was closed. Currently, the project has trapped 56.4 mcy of sediment; that 22% of the 258 mcy design capacity. The maximum pool was 927.9 ft on March 4.

38. Oregon Coastal Projects

Out of the 11 dams in the Rogue River Basin of southwestern Oregon, two are operated by the Corps, seven by Reclamation, and two by a private utility. Only the Corps projects, one of the Reclamation projects, and a county owned project are operated for flood control. The Corps reservoirs, Lost Creek and Applegate, with a combined active storage of 390 kaf, are operated for flood control, irrigation, fish and wildlife enhancement, municipal and industrial water supply, water quality, recreation and power (at Lost Creek only). Elk Creek Dam is a partially completed Corps project on Elk Creek, a tributary to the Rogue, five miles below Lost Creek. Reclamation's Emigrant Lake has 39 kaf of storage and is operated for flood control, irrigation, and recreation. Galesville Dam is owned by the Douglas County. The latter two projects are operated under Corps direction, when needed, for flood control.

a. LOST CREEK DAM. The lake level at the beginning of the water year was being held at constant because of anadromous fish needs downstream of the dam. Consequently, by late October, the pool level was approximately 8 ft encroached into flood control space. Following the major spawning period, the pool level was drafted to its minimum pool level by mid-November. The project experienced high runoff and major flooding through the entire major flood season (November, December, and January). There were three progressively greater flood events: the first was in late November, the second in early December, and the third in late December/early January was the largest event. The third flood event was a major flood event that started on the last day of December and lasted through January 6. The heavy tropical precipitation was related to an eastern shift of enhanced tropical convection associated with a phenomenon called the Madden-Julian Oscillation across the western tropical Pacific. Precipitation at Bigelow Camp, Rogue River was 15.5 inches between December 27 and January 2. Peak inflow to Lost Creek Lake was 26,000 cfs. Preliminary computations indicate that the last December/early January event was approximately a 20-year event in the upper Rogue. The lake filled to 1868 ft, within 4 ft of the maximum pool elevation. On January 5, a regulating outlet hatch failed, consequently water releases to keep the pool from filling needed to be released from the spillway. This was the first spillway discharge event in the history of the project. Project releases were up to 16,000 cfs for three days, 7,500 cfs of which were over the spillway. Flows at the nearest control point 20 miles downstream, Dodge Bridge, were held at flood stage of 10 ft. The regulating outlet hatch was repaired following the flood. Stage reductions at Dodge Bridge (the first downstream control point) was estimated to be 3.3 ft, 2.7 ft at Raygold, and 4.2 ft at the major damage control point of Grants Pass. There were no significant water resources issues for the rest of the water year. The reservoir elevation at the end of the water year were again focused on meeting anadromous fish needs downstream of the project. Flood damages prevented this year for the Rogue River Basin (Lost Creek and Applegate Dams) was $30 M.

b. APPLEGATE DAM. The lake began the water year 5 ft below its Water Control Diagram minimum pool elevation of 1889.0 ft. Like Lost Creek, the project experienced three incrementally larger flood events during the major flood season. Peak inflow to Applegate Lake was approximately 26,000 cfs (similar to Lost Creek Dam). Preliminary computations indicate that the late December/early January flood event was approximately a 40-year event upstream of the dam, and an 80-year event in the middle of the Applegate River Basin. The New Year's Day flood was within 0.5 ft of reaching the Applegate Lake full pool elevation of 1987.0 ft, including a special regulation curve operation in effect. Project releases reached approximately 16.0 kcfs, 12.0 kcfs of which was spillway use. Use of the regulating outlet during spillway discharge caused significant erosion of the stilling basin area. Flood stage at the downstream control point was exceeded. Observed stages near the community of Applegate were 16.8 ft; flood stage is 13.0 ft. Stage reduction was estimated at 5.8 ft. The reservoir operation for the rest of the water year focused on meeting anadromous fish needs and other project purposes such as recreation. There were no significant water resources issues for the rest of the water year. Flood damages prevented for the Rogue River Basin (Lost Creek and Applegate Dams) was $30 million.

c. ELK CREEK DAM. The storage area behind the partially-completed Elk Creek Dam is dry except for involuntary storage during high water periods.

d. GALESVILLE DAM The lake was operated according to its rule curve and its operations were in compliance with flood control regulations. The lake filled to the flood control curve in April. The year's operation is graphically shown on Chart 86.

The lake was operated according to the authorized water control diagram. Operations were in compliance with flood control regulations. Significant flood control operations were carried out on December 8, and January 1-5. The maximum reservoir level was 1883.1 ft on January 2, with minor flow over the freeflow spillway crest, resulting from sustained the high inflow of 3,000 cfs caused by high runoffs of rainfall plus snow melt. The lake was filled between February 1 and May 1 in accordance with its water control diagram. However, the lake was held 11 ft below its normal Maximum Conservation Pool elevation throughout the conservation release season, due to cavitation problems, which were limiting the project's maximum outlet releases.

e. <u>EMIGRANT DAM</u>. The lake was operated by Reclamation in accordance with the authorized rule curve as graphically shown on Chart 87.

The lake was filled between January 1 and May 1, in accordance with the project rule curve. Minor flood control operations occurred on December 15 and January 20, with the highest lake levels during these events being 2218.4 ft and 2222.6 ft, respectively. Full pool is at 2251.3 ft.

Twin Falls Project. Note the roof access to the turbine-generator unit. Access road to the second (new) powerhouse is in the lower left. Vortex in center of afterbay leads to drain under roadway to river. Work is underway to shore up the windows in preparation for the upcoming peak river discharges.

Twin Falls New Powerhouse. Remaining falls of the original Twin Falls from surface deck of powerhouse. Note roof access to turbine-generator unit.

IV. FUNCTIONAL ACCOMPLISHMENTS

The hydrologic conditions and the reservoir regulation described in the preceding two chapters have produced significant effects on many aspects of life in the Pacific Northwest. These effects are discussed and quantified within the following benefit categories: flood control, energy generation, irrigation, navigation, recreation, water quality, and fishery operation. These discussions are not intended to be thorough or complete but are cursory and contain only the salient features. For more information contact either the appropriate agency whose Water Management Group members are listed inside the back cover of this report or contact the Water Management Group officers, also listed inside the back cover.

A. FLOOD DAMAGES

The effect of reservoir regulation on downstream river flow is determined by routing (the calculation of travel time, diversions, etc) and comparing regulated and unregulated (*ie* natural or pre-project) flows. The flood damages given in Table 20 are for selected sites associated with reservoir flood control operation and show both the observed flows and damages and the unregulated flows (those that would have been observed without the flood control dams) and the damages prevented (the additional damages that would have occurred without the flood control reservoir operation). The reduction in the river stage or flow that resulted from the reservoir regulation was used to index the value of damages prevented. This year both the observed and prevented damages in northwestern Oregon were difficult to determine because of the multiple floods that occurred in the same locations and the damages from the earlier floods that were still unrepaired at the time of the subsequent flood events.

The flood damage prevented by reservoir operation in the Northwest was $4,290,956,000. Damages prevented in the Willamette Basin constituted 91% of this total and nearly 9% of the total was in the Snake Basin and one-third of the latter in the Boise sub-basin. The high damage prevention in Idaho was due to above normal spring precipitation and short warm spells causing slow snowmelt of a near record snowpack in the upper and middle Snake River Basin. Some of the damages prevented in the Upper Snake Basin result from new development in the flood plain near Jackson, Wyoming.

The Willamette Basin damages prevented were attributed to three rainstorms: mid November, New Year's, and the beginning of February. On the mainstem Willamette River flow reductions were 45-63% during the November event, and 30-36% during the other two events. The fact that no observed damages are listed for the Willamette Basin may be deceptive because of the unrepaired damages from the February 1996 record flood that still existing at the time of the November event. However, the operation of the Willamette Basin flood control projects the damages prevented totaled $3,912,321,000.

Table 21 is a tabulation of damages prevented by major flood control projects in the Columbia Basin for the period since 1948 through 1997. Damages prevented for the lower Columbia and for the entire basin represent the damage for the cost and development of the year of occurrence. At today's cost and development level, the amounts in past years would be much larger. The damage prevented by control of winter floods on tributary streams is not shown.

B. ELECTRIC ENERGY

Power operations in this report reference two major

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Table 20

SUMMARY OF FLOOD DAMAGE OBSERVED AND PREVENTED
Columbia River and Tributaries

		UNREGULATED [1]			OBSERVED			CALCULATED DAMAGES $1000	
POINT	RIVER	Flow (kcfs)	Stage (ft)	Date	Flow (kcfs)	Stage (ft)	Date	Obs'vd	Prev'd [2]
Bonners Ferry, ID	Kootenai		79.9	May 18		64.4	May 17	0	58,268
Columbia Falls, MT	Flathead	101.6		May 17	59.9		May 17	3,953	20,067
Hope, ID	Pend Oreille		2068.3	Jun 8		2062.7	Jun 4	1,060	2,332
Newport, WA	Pend Oreille	159.4		Jun 8	138.2		Jun 5	5,512	12,296
Cle Elum, WA	Yakima	13.9		May 14	7.9		Jun 1	0	257
Parker, WA	Yakima	38.6		May 15	19.0		May 15	800	9,056
Flat Creek, WY	Snake	36.1		Jun 5	29.9		Jun 11	85	18,136
Heise, ID	Snake	58.5		Jun 11	42.5		Jun 14	0	1,678
Shelly, ID	Snake	72.9		Jun 7	47.6		Jun 16	6,692	45,900
Carey, ID	Little Wood	1.3		Jan 2	.92		Jun 11	532	102
Boise, ID	Boise	22.0		May 18	7.2		Mar 22	0	120,528
Owyhee, OR	Owyhee	31.6		Jan 3	4.2		Jan 9	0	2,707
Emmett, ID	Payette	27.3		May 18	18.8		Jan 3	0	1,898
Weiser, ID	Snake	154.6		Jan 3	81.8		Jun 3	0	29,733
Spalding, ID	Clearwater	127.5		May 17	80.7		May 17	0	2,099
Lower Granite, WA	Snake	357.9		May 17	225.3		May 18	0	5,244
The Dalles, OR[3]	Columbia	897.9		Jun 7	570.7		Jun 15		
Vancouver, WA	Columbia		28.4	Jun 8		21.6	Jan 3	0[4]	48,334
					COLUMBIA BASIN SUBTOTAL			63,014	378,635
Salem, OR	Willamette	272.2		Nov 21	167.0		Jan 2	0[4]	3,912,321
							GRAND TOTAL	63,014	4,290,956

[1] In the Columbia River Basin, flows are those which would have resulted without regulation by Mica, Libby, Duncan, Arrow Lakes, Hungry Horse, Flathead, Noxon Rapids, Pend Oreille, Grand Coulee, Chelan, Jackson Lake, Palisades, American Falls, Dworshak, run-of-river projects, Grand Coulee pumping, and major irrigation diversions in the Snake and Yakima River Basins.

In the Willamette and western Washington Basins, flows are those which would have resulted without regulation by Hills Creek, Lookout Point, Falls Creek, Cottage Grove, Dorena, Fern Ridge, Blue River, Cougar, Detroit, Green Peter, Foster, Howard Hanson, Mud Mountain, Wynoochee, and Mossyrock Projects.

[2] Damages prevented are those prevented by reservoirs and diversions noted above. Additional damages prevented by levees and channel improvements are not included in the prevented amounts. Observed damages in uncontrolled tributaries are not included.

[3] Damages are included in the Vancouver, WA values.

[4] Observed damages from the November 1996 flood were not determined because of overlapping damages from the February 1996 flood that in many cases were not repaired prior to the November event.

entities: the Coordinated System and the Federal Columbia River Power System (FCRPS). The former includes most of the generating facilities, hydro and thermal, in the Pacific Northwest, including the FCRPS projects, which are Federally owned (Appendix A). There are three major operational thermal plants in the Northwest. Each of these plants contribute a portion of their output, through contractual arrangements or Federal financing, to the Federal System. The nuclear plant is Washington Public Power Supply System nuclear power plant #2 (WNP-2). The fossil fuel plants are Centralia and Boardman. Although participants of the Coordinated System operate their own reservoirs, the power system is operated as a one-owner system to optimize both energy

Table 21

EFFECT OF RESERVOIR REGULATION ON FLOOD PEAKS AND DAMAGES
Columbia River Basin

Water Year	Max Annual Mean Daily Peak[1] The Dalles (kcfs)		Damages Prevented ($1 million)		Water Year	Max Annual Mean Daily Peak[1] The Dalles (kcfs)		Damages Prevented ($1 million)	
	Unreg	Obsrv	Lwr Col[2]	Col Bsn[3]		Unreg	Obsrv	Lwr Col[2]	Col Bsn[3]
1948	1010	1010	*	*	1976	637	419	15.65	43.08
1949	660	624	0.67	*	1977	276	183	0.00	0.00
1950	823	744	9.80	*	1978	565	313	6.00	30.61[4]
					1979	482	306	1.50	4.65
1951	672	602	0.80	*	1980	544	341	5.16	15.26[R]
1952	579	561	0.34	*					
1953	672	612	1.18	*	1981	579	436	10.91	45.26[R]
1954	590	560	0.26	*	1982	759	422	15.22	78.62
1955	614	551	0.62	*	1983	732	400	18.48	131.00[R]
					1984	628	376	10.71	107.29
1956	940	823	25.00	37.67	1985	550	274	10.45	23.46
1957	820	705	6.60	11.11					
1958	735	593	3.55	7.83	1986	719	388[R]	0.24[R]	72.06[R]
1959	642	555	0.88	2.6	1987	439	284	0.00	9.09
1960	493	470	0.08	0.58	1988	342	236	0.00	2.74
					1989	512	312	6.30	37.10
1961	789	699	6.50	7.7	1990	511	372	1.66	15.75
1962	503	460	0.09	1.79					
1963	481	437	0.03	0.65	1991	568	348	2.64	101.16
1964	764	662	7.60	22.91	1992	328	232	0.00	0.71
1965	669	520	1.44	7.18	1993	602	382[R]	0.00[R]	81.37
					1994	381	224	0.00	11.74
1966	455	396	0.00	0.43	1995	552	296	0.03	61.54
1967	781	622	14.21	20.80					
1968	533	404	0.26	1.07	1996	719	456	4.32[R]	227.03[R]
1969	628	449	2.61	5.51	1997	898	571	48.33	378.64
1970	634	429	1.16	6.34					
1971	740	557	8.49	25.76					
1972	1053	618	213.10	260.49					
1973	402	221	0.00	0.52					
1974	1010	590	239.73	306.36					
1975	669	423	9.41	40.97					

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[1] Observed discharges are preliminary values calculated from project data. [2] Damages are for the Columbia River below McNary Dam. [Dollar values are for the year of the flood. Willamette excluded.] [3] Totals are damages prevented by major projects above The Dalles during the spring and summer runoff. Damages prevented in Canada and/or by levees and channel improvements are not included. [4] Damages are based on the flood of December 1977. [R] Revised

Table 22

END OF MONTH ENERGY STORAGE - thousand MWh

MONTH	COORDINATED SYSTEM			CANADIAN TREATY		
	ORC/PDP	Actual	Difference	ORC/PDP	Actual	Difference
Aug 96	58.5	58.8	0.3	22.5	22.2	-0.3
Sep 96	55.6	55.4	-0.2	21.8	20.8	-1.0
Oct 96	53.0	51.8	-1.2	20.5	19.4	-1.1
Nov 96	49.3	47.4	-1.8	18.2	17.4	-0.8
Dec 96	43.1	40.7	-2.4	15.0	14.4	-0.6
Jan 97	27.9	29.5	1.6	7.8	8.3	0.5
Feb 97	17.1	19.5	2.4	3.3	4.2	0.9
Mar 97	12.7	15.1	2.4	1.0	2.1	1.1
Apr 97	13.6	16.1	2.5	0.3	2.8	2.5
May 97	38.2	39.9	1.7	6.7	8.5	1.8
Jun 97	58.1	57.5	-0.6	17.8	17.7	-0.1
Jul 97	62.0	62.0	0.0	22.0	22.0	0.0
Aug 97	58.5	57.8	0.7	22.5	21.9	-0.6
Sep 97	55.7	56.2	0.5	21.6	21.4	-0.2

Table 23

SOURCES OF BPA ENERGY

SOURCE	AMOUNT (MWh)	PERCENT
COE*	69,768,247	66.2
USBR*	27,194,094	25.8
THERMAL	6,838,779	6.5
MISC.	1,535,279	1.5
TOTAL	105,336,399	100.0

* Hydroelectric energy

production and management of the other water resources in the Pacific Northwest.

1. Generation

The Coordinated System storage level at the beginning of the 1996-97 operating year was 99.5% full which resulted in the System adopting first year Firm Energy Load Carrying Capability (FELCC) from the critical period studies. Due to above average streamflows throughout the year, the system generally operated to the Operating Rule Curve (ORC) or flood control for the entire period, producing large amounts of surplus energy. The system storage energy reached 99.1% full on July 31,1997, and the System adopted the FELCC from the 1997-98 PNCA Final Regulation study. Table 22 shows the status of energy stored in the Coordinated System at the end of each month in the 1996-97 operating year compared with the ORC or Proportional Draft Point (PDP) where applicable. Normal full Coordinated System reservoir energy content is approximately 63,700 MW-mo.

Table 23 shows the breakdown of Federal generation between the Corps, Reclamation, thermal, and miscellaneous energy sources. Also tabulated are the percentage changes over the operating year. The Corps' portion changed by 0.7% and Reclamation's by -3.0%.

Thermal generation decreased by +12.7% while miscellaneous generation changed by -4.3%. Of the Federal energy marketed by BPA, the Corps continues to generate two-thirds of the total and Reclamation continues to generate one-fourth.

Table 24

HISTORICAL POWER PURCHASES
in millions of dollars

YEAR	BUY	YEAR	BUY
FY97	$39	FY90	$11
FY96	$55	FY89	$93
FY95	$155	FY88	$20
FY94	$207	FY87	$3
FY93	$216	FY86	$1
FY92	$137	FY85	$10
FY91	$21		

Note: Purchases do not include storage costs.

2. Marketing

Fiscal year 1997 was a record year for bulk power sales. The fact that it was one of the highest water years in the historic record, coupled with a reduction in firm loads produced substantial surplus energy during the water year. Even during the fall and winter months streamflows were high enough to support large surplus secondary energy sales throughout the period. Table 24 lists FY 97 purchases in relation to those for the past 12 years. The FY 97 purchases were kept to a minimum due to above normal precipitation and streamflows. Table 25 specifically shows the continuous sale of surplus and nonfirm energy that picked up in the fall and continued through the spring.

Table 25

ENERGY PURCHASES AND SALES BY MONTHS
(MegaWatt-hours)

Mo/ Yr	Purchases	TO NORTHWEST UTILITIES		TO SOUTHWEST UTILITIES	
		Nonfirm	Surplus Firm	Nonfirm	Surplus Firm
Aug 96					
Sep					
Oct	231	257	1678	243	1041
Nov	279	59	1236	64	868
Dec	198	75	2440	47	1127
Jan 97	160	1042	2828	288	1159
Feb	318	1150	2949	481	898
Mar	291	644	3523	841	1421
Apr	443	179	3304	402	1904
May	311	265	3178	562	2106
Jun	96	358	3145	258	2533
Jul	334	233	2700	200	3028
Aug	*184*	*63*	*2024*	*60*	*3019*
Sep	*251*	*17*	*1745*	*5*	*1763*
TOTAL	3096	4342	30,750	3451	20,867

*Includes scheduled and non-scheduled utilities. Data in *italica* are preliminary

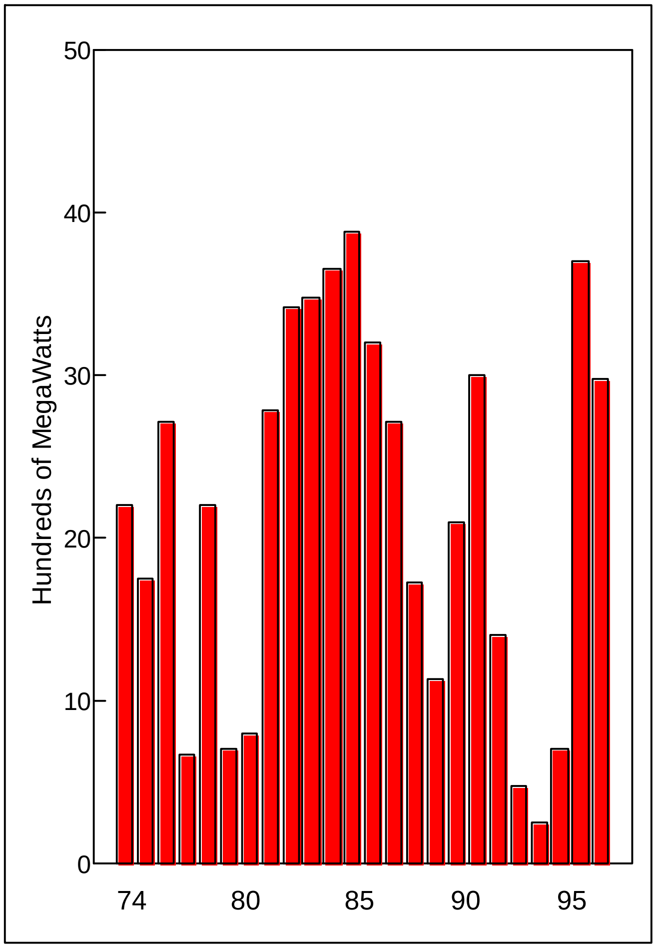

Figure 13. **1996-97 CAPACITY OF THE NW-SW INTERTIE IN MW**

This was a year of adjustment for BPA as the Transmission and Power Businesses were functionally split into two organizations in accordance with the FERC rulings. By mid March 1997, the Power Business Line was consolidated all at one location in Portland, and the Transmission Business Line was consolidated and located at the Dittmer Control Center in Vancouver, Washington.

3. Northwest-Southwest Intertie

Much of the year was spent reviewing combined Operational Transfer Capacity of the California-Oregon Intertie and the Pacific DC Intertie as a result of the July and August 1997 outages. Figure 13 displays the fluctuation in the total capacity available over the fiscal year. Frequently, the sum of the individual capacities of the AC and DC lines were restricted by the combined transfer limits set by the Western States Coordinating Council. In real time operation, the reductions in the capacity ratings led to more frequent problems with unscheduled flow (also known as loop flow) throughout the summer and fall. Unscheduled flow is governed by the law of physics that causes power from a given source to flow over all possible paths to its destination. To allow for unscheduled flow, further reductions in the rated capacity of the Intertie were necessary, calling for widespread reduction of southbound energy deliveries.

4. Industry Changes

Sweeping changes in the West Coast energy market began in late 1997 with the signing of California Law AB1890, calling for deregulation of California's investor-owned electric utilities (IOUs), and opening the state's

Table 26

FERC LICENSE ACTIVITY BY STATE

ACTION	WA	OR	ID	MT	WY	TOTAL
Licenses	60	24	45	8	3	140
License Applications	20	2	2	0	0	24
Exemptions	19	22	66	4	1	112
Exemption Applications	0	1	0	0	0	2
TOTALS	99	48	113	12	4	276

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$21 billion electricity market to competition. In 1997, the California Independent System Operation (ISO) and Power Exchange (PX) were created, marking the beginning of this new era. BPA planned to meet these new market challenges by working to certify as an ISO scheduling coordinator and to certify as a PX participant to market surplus energy in California. The development of new electronic trading, scheduling, account tracking and settlement tools with these emerging market entities was also initiated in 1997. BPA will transition from conducting a five days per week prescheduling of energy and transmission to prescheduling seven days per week. Energy trading and transmission acquisition functions are expected to move to a 7-day per week, 24-hour per day basis within the next year to keep pace with industry changes as they unfold.

5. Energy Licensing and Regulation

As of the end of the water year, the Federal Energy River Regulatory Commission (FERC) had a total of 140 outstanding licenses and 112 exemptions in the Columbia River Water Management Group area, which FERC's Portland Regional Office staff inspects for compliance with its dam safety program and other terms and conditions of project authorization. Also, 24 applications for license or exemptions involving new hydropower capacity were pending within the area. In all, the Commission has 276 projects under its supervision in the area, consisting of either outstanding licenses, exemptions issued, or applications for license. Table 26 is a breakdown of these categories by state.

Construction inspections were conducted at 23 projects at which construction was underway during the reporting period. New generating capacity under construction represents approximately 10 MW of energy that is now or will be marketed by either BPA, licensed utilities, or directly used by the hydropower developer.

C. IRRIGATION

Irrigation service from Bureau of Reclamation projects was available to an estimated 2,870,000 acres. Of that total, actual irrigation deliveries were made to approximately 2,735,000 acres. The water came from 52 reservoirs with an active capacity of about 10,090 kaf. This does not include 8,214 kaf of storage in Franklin D. Roosevelt Lake (behind Grand Coulee Dam) and Hungry Horse Reservoir in western Montana. Record high deliveries were made to farms in 1970 and 1974.

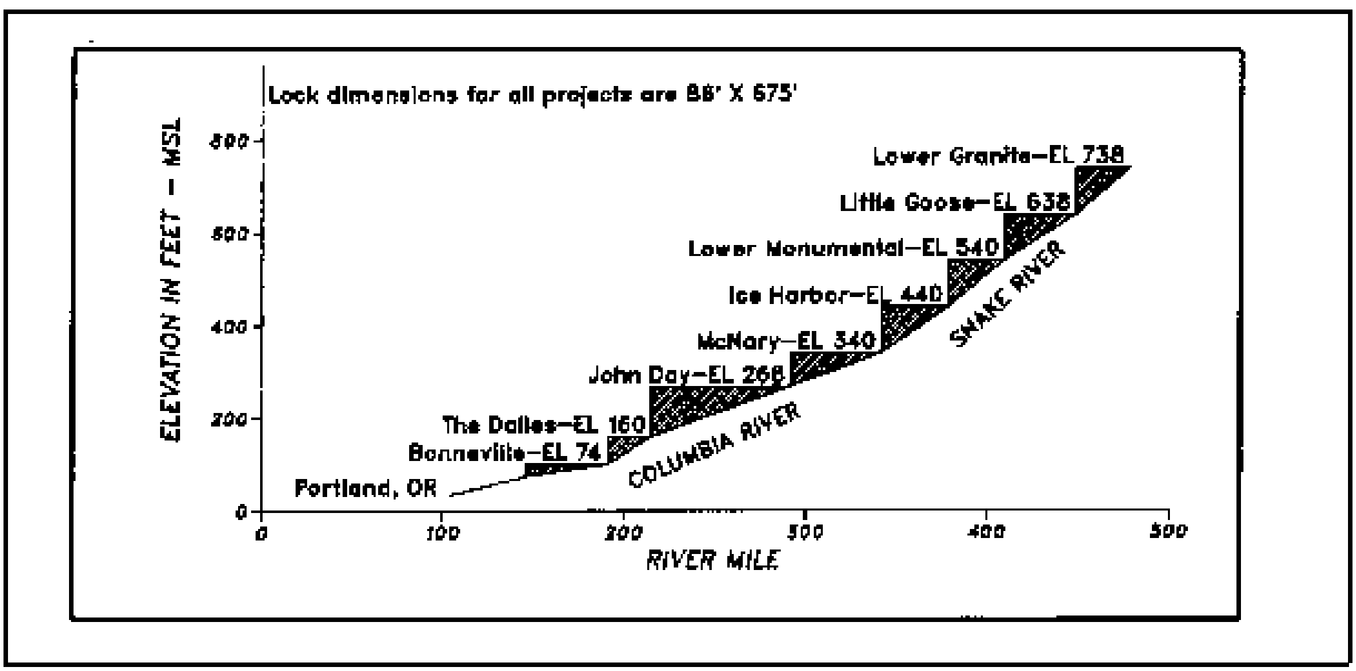

Figure 14. **PROFILE OF LOWER COLUMBIA AND SNAKE RIVERS**

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D. NAVIGATION

The Corps of Engineers operates navigation locks on three waterways in the Pacific Northwest: the Columbia-Snake River Inland Waterway in Washington and Oregon, the Willamette Falls Lock in western Oregon, and the Lake Washington Ship Canal in Seattle. The Columbia-Snake River Inland Waterway, Figure 14, extends 465 river miles from the Pacific Ocean to Lewiston, Idaho. The waterway has the capability of providing safe passage for ocean-going vessels up to Vancouver, Washington, and Portland, and for shallow-draft tugs, barges, log rafts, and recreation boats to Lewiston.

Navigation on the Columbia River from Portland to Pasco, Washington, is made possible by four locks that elevate the river from 8 ft mean sea level (msl) below Bonneville Dam 42 miles east of Portland to 340 ft msl in McNary Reservoir. This latter pool extends to Pasco on the Columbia and to Ice Harbor Dam on the Snake River. Navigation on the Snake River from its confluence with the Columbia near Pasco, to Lewiston, is made possible by four locks which elevate the river from 340 ft at Ice Harbor Dam to 738 ft in the Lower Granite reservoir. The nominal dimensions of all locks are 86 ft wide and 675 ft long. All the locks were closed simultaneously during March for annual maintenance.

Navigational flow requirements on the Columbia and Snake rivers were met by streamflows and pool levels determined from other project requirements. Cargo was generally transported without any special operational requirements, although occasionally some unusual navigation requirements demand special regulation. However, these special requirements did not generally alter the Columbia River regulation enough to have a significant effect on other project purposes.

The special project operations were necessary to meet navigational requirements during this year had to do with vessel groundings, emergency operation at projects, and for transportation and off loading of decommissioned defueled submarine nuclear reactor cores at Hanford, Washington. The latter special operations were required at both upstream and downstream projects to hold the McNary pool at a constant elevation during the several hours required to off load the reactor cores.

Commercial cargo through the Columbia-Snake locks consist chiefly of gasoline, jet fuel and kerosene, diesel fuel, fertilizers, grain, and logs. More cargo, mostly grains, was hauled down river than was hauled upstream. March tonnages were less than other months on the Snake and lower Columbia due to the annual closure for maintenance. The Willamette Falls Lock Project, located on the Willamette River at Oregon City, transports vessels and cargo around the 40-foot high Willamette Falls. This lock, with four locking chambers, is used mainly by sand and gravel barges and by wood products shippers. Efforts to rebuild the locks with a single chamber have never been funded.

The Lake Washington Ship Canal Project provides ship access between the saltwater of Puget Sound and the freshwater of Salmon Bay, Lake Union, and Lake Washington. The major cargo through the locks was sand, gravel, and wood products. However, because of its proximity to the heart of Seattle the majority of its lockages were for pleasure craft, especially in the summer. A large portion of the Seattle commercial fishing fleet, consisting of trawlers and gillnetters, is moored in Salmon Bay, immediately above the locks. During the commercial fishing season these vessels are major users of the locks. Tour boats and government vessels, especially NOAA vessels based on Lake Washington, and Coast Guard vessels moored above the locks, also use the locks.

E. RECREATION

Although many agencies provide recreational facilities, the only agencies to also have project operational activities are the Corps of Engineers and the Bureau of Reclamation. These operational activities include not only those activities for which the projects were authorized but also those ancillary activities which benefit the public without adversely impacting the authorized operations. The added benefits include maintaining some reservoirs within certain elevation ranges throughout the recreation season while at other projects it may be regulating downstream discharges for the activities. Recreational activities include boating, fishing, sailing, hunting, rafting, wind surfing, hydroplane racing, and cross channel swimming. In some cases, the reservoirs are maintained at high elevations during the camping and picnicking season for aesthetic reasons.

Historically, the Corps and Reclamation use different methods to count visitation-days and consequently they could not be directly compared. Now both agencies will be using the visitor-hour/visitor-day method. The difference in the two systems used in the past was that a recreation-day equaled a visit by one person to an area for all of or any part of a 24-hour day; whereas a visitor-hour equated to actual time spent on an area. Twelve visitor-hours equals one visitor day.

1. Corps of Engineers

Recreation use at Corps administered water resource projects was an estimated 9.0 million 12-hour visitor-days, or 110 million visitor-hours. Although the continuing drought conditions in the Northwest affected the use of certain recreation facilities and reduced water surface area, visitation to Corps projects was nearly the same as last year.

The high volume of runoff this year at Libby assured a full pool that increased recreational usage of the lake and tourist facilities. A high runoff volume also occurred at Dworshak but the early drawdown for the grouting contract limited the water contact recreation.

The total capital investment in recreation development is over $45 million which generates significant benefits each year. Three Corps projects exceeded half-million visitor-days of use and one project, Bonneville Dam, exceeded 1 million visitor-days.

Sightseeing continues to be the leading recreation activity. Facilities such as visitor centers, overlooks, and interpretive facilities are provided to accommodate this use. Swimming, boating, fishing, and general day use activities are other recreational opportunities sought by visitors to Corps projects. Wind surfing, particularly on the Columbia River projects, has become a highly visible activity over the past several years.

2. Bureau of Reclamation

Reclamation reservoirs provide water-based recreation opportunities unique to the surrounding areas in some of the more arid portions of the region. Reclamation's Pacific Northwest (PN) Region has 79 recreation areas on 66 reservoirs, providing 395,000 acres of water surface and 2,400 miles of shoreline. Reclamation works cooperatively with state, county, irrigation districts, and federal agencies, as well as private concessionaires in developing and managing many of the recreation areas at Reclamation reservoirs. Recreation facilities include 6,250 campsites in 148 campgrounds; 150 picnic areas; 39 swimming beaches, and 196 boat launch ramps. Recreation facilities are evaluated in terms of visitor safety and accessibility and improved as needed.

This recreation season was successful for water dependent recreation activities. Visitor data has not been measured for the past three years. Given the excellent water conditions it is assumed that recreation use remained at the 10.5 million 12-hour visitor day level as reported in 1992.

The Title 28 Program provides a 50% cost share with non-Federal management partners for construction of new recreation facilities or rehabilitation of existing facilities. The PN Region received $1,148,000 for 19 new or ongoing recreation and fish and wildlife projects in Idaho, Oregon, and Washington. These projects improved accessibility and visitor safety, increased facility capacity, enhanced recreation opportunities, and fish and wildlife benefits.

! Reclamation cost shared, with Washington County, Oregon, to construct a group picnic pavilion and make site improvements at Henry Hagg Lake (Scoggins Dam).

! Reclamation cost shared with Bonneville County, Idaho, at Ririe Reservoir to upgrade Juniper Campground and Blacktail Park. Improvements included expanding parking facilities to provide safe turn-around areas for boaters, installing a water and sewer system and electric power to 50 camp spurs.

! Reclamation cost shared with the Yakima Indian Nation to move an existing high-voltage power line away from fish acclimation ponds, installation of gravity-flow water supply and additional fish rearing pond.

The PN Region continued to support the Catch A Special Thrill (C.A.S.T.) program through three events. The children invited range in age from 7-16 years old and have a variety of physical or developmental disabilities or in some cases, a terminal illness. The Snake River Area Office sponsored its 5th annual C.A.S.T. event at Black Canyon Park on September 13th; Upper Columbia Area Office sponsored its 6th annual C.A.S.T. event at Steamboat Rock State Park in eastern Washington on August 16th; and the Lower Columbia Area Office sponsored its 2nd annual event at Henry Hagg Lake west of Portland, Oregon on September 7th.

Reclamation issued a final Environmental Assessment and Finding of No Significant impact for the Scattered Tracts Resource Management Plan (RMP) which addresses Reclamation's future management of almost 90,000 acres within the Columbia Basin in Washington. The RMP was developed through a process of public and agency involvement as required by the National Environmental Policy Act. This process was initiated in April 1992 and continued throughout the planning process. The preferred alternative proposes the disposal of 11,687 acres of publicly held lands within the Columbia Basin. In addition to 31,891 acres retained for project purposes, 37,467 acres will be retained for various resource values, and 8,474 acres placed in a Aland trust@ for potential future development.

F. WATER QUALITY

Project operations-related water quality activities were conducted by the Corps of Engineers and the Bureau of Reclamation. Activities included checking for compliance with applicable federal and state water quality standards and regulations and determining the affects on stream productivity, especially related to anadromous fish. The majority of these activities were carried out during the juvenile fish migration season.

1. Dissolved Gas

The Columbia/Snake River Total Dissolved Gas Monitoring Program is an annual continuing activity since 1984 with the primary objective to collect real-time dissolved gas and water temperature data for use in reservoir regulation. This data is collected as a priority during the anadromous fish migration season (April-August) and as a second priority outside of the endangered species migration period. The collecting and transmitting of real-time dissolved gas and water temperature data was the responsibility of the individual Corps Districts, Reclamation, and other participating agencies. The Corps' Division staff continued to coordinate the system-wide monitoring program and prepare periodic reports. All data were ultimately stored in the Division's Water Quality Master computer file.

This year's program operated from mid-April through mid September for most stations. A total of 39 instrument sites were in operation, at various reservoir forebay and tailwater locations as shown in Figure 15. As requested by EPA and the state environmental qualities offices, year-round monitoring also occurred at several key locations, including International Boundary, Dworshak (tailwater), Lower Granite (forebay and tailwater), Ice Harbor (forebay and tailwater), McNary (two forebay stations and one tailwater station), Bonneville (forebay), and at Warrendale, Oregon.

All the data collection instruments were fully automated but used different methods for transmitting data. Most instruments were connected to individual data collection platforms that were programmed to collect data hourly and to transmit them every four hours via GOES telemetry. Instruments operated by the Corps' Walla Walla District were programmed to transmit hourly data directly to the District office via radio transmission and phone lines, and then to the Division via phone lines.

Figure 15. **LOCATION OF DISSOLVED GAS MONITORING STATIONS**

Data transmission from some of the PUD instruments was manually entered and sent via the Columbia Basin Telecommunications (CBT) system.

This data, along with pertinent reservoir and flow information, were posted on the Columbia River Operational Hydromet Management System (CROHMS) data base and displayed both on the Technical Management and the Portland District home pages. It was routinely used as a real-time basis for adjusting project spill in an attempt to control total dissolved gas levels to the state standards.

As was the case in the previous three years, NMFS required that spill be implemented at lower Columbia and lower Snake rivers mainstem dams to achieve an 80% fish passage efficiency (FPE). This requirement continued to be subjected to the State standards for total dissolved gas of 110%. At NMFS's request Idaho, Oregon, and Washington temporarily increased their TDG limits to 115% in the reservoir forebays and 120% in the tailwater areas in several installments (Table 27). The well above average runoff, combined with lack of energy market, triggered involuntary spill at a much greater level than that required in the BiOp during April, May and June. Average weekly flows at Lower Granite exceeded 160 kcfs during most of the April - June period. At McNary, average weekly flows were greater than 450 kcfs from late April through June, with peak runoff occurring in mid-June.

The resultant total dissolved gas exceeded 130% below several dams for extended periods during April through June, a situation similar to that of 1996. Tailrace areas that were most seriously affected were below Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, and Bonneville (down to Kalama, Washingotn). This year, the number of days with total dissolved gas levels above 120% ranged from 60 at Lower Granite to 135 days at Ice Harbor (the most downstream of the Snake River dams) and from 42 days at Wauna Mills, Oregon, to 84 days at McNary. In the summer, the above-120% conditions persisted for a few days in July below McNary and Bonneville (Skamania, Washington). In the headwater areas, Dworshak released close to the maximum downstream channel capacity of 25 kcfs (including a spill of up to about 13 kcfs) during late April-early May and during July-August.

Average monthly and maximum instantaneous forebay dissolved gas were generally higher than those recorded in 1996 because of the higher runoff and spill, and also stayed at those high levels for longer periods. Most of the levels exceeding 130% saturation generally occurred at the same locations as last year.

2. Water Temperature

Monitoring of water temperature conditions throughout the Columbia and Snake river mainstem's was conducted in parallel to dissolved gas monitoring. Water

Table 27

GRANTING OF WAIVERS TO WATER QUALITY STANDARDS

GRANTOR	DATE GRANTED	PERIOD COVERED	PURPOSE
Oregon	Feb 28	Mar 3-23	Hatchery release
Washington	Feb 28	March 3-23	Hatchery release
Nez Perce Tribe	April 8	April 10 - August 30	Fish migration
Idaho	April 15	April 15 - June 1	Fish migration
Oregon	April 18	April 18 - August 31	Fish migration
Idaho	June 18	June 18 - July 15	Dworshak grouting
Idaho	July 24	August 18 - 31	Fish migration
Oregon	August 1	August 1 - 31	Emergency
Washington	August 8	August 1 - 31	Emergency

temperature measurements were taken at the same depth (about 15 ft) as the total dissolved gas sensors. In addition to surface water temperature, project personnel also collected water temperature data in the powerhouse scroll-cases on a daily basis. In some cases, water temperatures from the adult fishway collection system were also reported.

Water temperatures, which reflect air temperatures and streamflows, were generally slightly higher than in 1996 for most of the April-August period for the mid-Columbia, Snake and lower Columbia Rivers. The exception was the slightly lower water temperatures in April on the Snake and lower Columbia rivers.

A detailed report on the Dissolved Gas (and Water Temperature) Monitoring activities is prepared annually by the Corps.

3. Other Water Quality Activities

a. Reclamation. The primary emphasis of Reclamation water quality activities is to identify problems associated with management of operating projects and to develop appropriate corrective strategies.

! A water quality modeling study at Cascade Reservoir on the NF Payette River was completed. The two-dimensional BETTER model developed by the Tennessee Valley Authority, was used to evaluate in-reservoir management options, including selective withdrawal, a minimum pool for water quality protection, re-aeration, and bank stabilization. Reclamation worked closely with the city of McCall and others to help eliminate discharge of municipal waste water into the NF Payette River, and initiated implementation of storm water management measures. A monitoring program was also initiated to evaluate the effectiveness of constructed wetlands in reducing phosphorus loading associated with irrigation return flows to the reservoir.

! A series of outlet works release tests at Grand Coulee, to measure the effects of operation of the outlet works on downstream TDG, was completed. The outlet works, comprised of two tiers of 20 conduits each, discharge onto the downstream face of the spillway, and use a roller bucket dissipater. Test results indicated that upper and lower outlet works produced the same percent increase in TDG in the tailrace, and that the lowest TDG increases occurred when upper and lower level outlet works were operated in an over/under combination.

! The Burnt River Basin Water Temperature Modeling Study was initiated to develop a water temperature plan for the Burnt River basin. Stream temperature models will be used to simulate the instream cooling that result from riparian shading, existing reservoir storage, irrigation return flows, and other appropriate management practices are being considered in development of a temperature management plan.

! The joint water quality data gathering and modeling with the University of Idaho in the Middle Snake River area between Minidoka Dam and King Hill continued to provide baseline information on water quality and irrigation returns to the river for use in nutrient management planning, and evaluating impacts of the salmon migration flow augmentation program on threatened and endangered snail populations in the Snake River.

! Reclamation participated in multi-agency development of water quality management plans for the lower Boise and Payette rivers including a screening of potential irrigation waste water treatment and reuse sites, and the scoping of a demonstration reuse project.

! Injection wells near Minidoka, used for disposal of most irrigation return flows and storm water runoff, are subject to Idaho's increasingly stringent regulations for the quality of injected water. To eliminate the possibility of contamination of domestic wells, and due to EPA's designation of the Snake Plain Aquifer as a Asole source of drinking water@ under the Federal Safe Drinking Water Act, an alternative means of disposing of drainwater and stormwater, without use of injection wells, was implement.

! The reservoir water quality surveillance program focused on reservoirs suppling small projects in eastern Oregon provided chemical, physical, and biological data needed to manage water quality in Reclamation reservoirs and downstream releases. Information is stored on the EPA's STORET data base.

! Long-term water quality monitoring of irrigation supplies and returns continued on the Boise, Columbia Basin, Minidoka, and Yakima projects. Additional data was gathered for assessment of nonpoint source irrigation impacts in the Owyhee, Malheur, Powder, and Burnt basins.

b. Corps of Engineers

Portland District activities included the following:

! Flow and water temperature targets were again met for the Lost Creek and Applegate projects in the Rogue Basin resulting in very good spring and summer conditions for juvenile and adult migration. Routine water quality monitoring for nutrients and limnological parameters continued at both projects.

! In the Willamette Basin, at Cottage Grove Lake, water was sampled for mercury content to study the relationship between reservoir operations and mercury concentrations in the fish. There was also significant monitoring at Detroit Lake for turbidity because of the turbidity issues raised following the 1996 flood. At the City of Salem's request, the District drafted the pool to 25 ft below minimum power pool in an effort to reduce downstream turbidity. In other studies the volunteer water quality monitoring program continued at Fern Ridge reservoir; temperature monitors were placed in streams below Hills Creek to collect data for modeling the river, and routine surface-to-bottom profiling of reservoirs for limnological parameters continued during the spring and summer at all projects.

At Willow Creek Lake routine nutrient, methane, hydrogen sulfide and other limnological data were collected and other water quality studies with less impact on reservoir operation continued at numerous locations.

Seattle District activities included the following:

! Control of saltwater intrusion continued at the Hiram M. Chittenden Locks with the district monitoring saltwater intrusion into the ship canal using a series of real-time water quality sensors at six upstream stations enabling a quick response to slight increases in salinity before the salt water wedge reached Lake Washington. Various combinations of spill and saltwater drain openings were evaluated to study the efficiencies of saltwater control techniques. Mini-flushing, a low water use technique that removes saltwater from the lock chamber before it enters the ship canal, was not used this year due to concerns of fishery agencies

! A two-dimensional water quality model, CEQUAL-W2 developed by the Waterways Experiment Station (WES), was used to examine the effects of changes in Chittenden Locks operations on saltwater intrusion into the Lake Washington Ship Canal.

! The district is involved in continuing negotiations with the City of Seattle concerning a new set of instream flows for the Cedar River, a tributary of Lake Washington that supplies most of the inflow to the lake. These negotiations, which are part of a Habitat Conservation Plan (HCP), includes representatives from the Corps, National Marine Fisheries Service, and US Fish and Wildlife Service as well as state agencies and an Indian tribe.

! The district continued to monitor water quality at Wynoochee Dam, now owned by the City of Tacoma.

! At Howard A. Hanson Dam water quality studies continued on the possible impacts of increased summer conservation storage, selective withdrawals and downstream turbidity, while at Mud Mountain Dam sediment deposits in the reservoir and downstream turbidity continued to be evaluated.

Flood control at Libby Dam, with consideration also given to benefit for endangered Kootenai River white sturgeon and Snake River salmon stocks, dominated operations at Libby Dam. Numerous sturgeon eggs were found in the Kootenai River below Kootenai Falls, and one larval sturgeon was detected as a result of this operation.

Walla Walla Many water quality studies were conducted to support the Lower Snake River Juvenile Salmon Migration Feasibility Study (LSRFS). Individual studies included:

! Primary Productivity Study, to develop a model of the reservoir system macro and micro-habitat needed to assess the current carrying capacity.

! Sediment studies, to find the locations of the greatest percentage of fine material and to establish sediment particle distribution ranges for other studies.

! Baseline limnological study, a continuation of the same study initiated three years ago.

The District also conducted several normal O&M water quality programs as detailed below.

! At Lucky Peak Reservoir, water samples were collected for analysis and Hydrolab profiles were taken.

! At Mill Creek and Bennington Lake, water samples and limnological readings were taken and were analyzed for nutrients and chlorophyll a.

! At Dworshak regular water quality data collection continued on inflow streams, in the reservoir and in the river below the dam.

Temperature data was also collected from Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Reservoirs; the North Fork of the Clearwater, the Middle Fork of the Clearwater, and downstream of their confluence.

The WES team supporting DGAS continued to conduct extensive field research activities both prior to and during the fish passage spill season on the lower Columbia and lower Snake rivers as part of the Phase II Field Sampling Effort For the Gas Abatement Study (DGAS). Field sampling was conducted at Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, Bonneville, and the tidal pool. Spillway TDG performance was studied at McNary and Bonneville under a wide range of operational conditions.

G. FISHERY OPERATIONS

Fishery operations were implemented in accordance with the Corps' Fish Passage Plan (FPP), which describes the manner in which the Corps' mainstem projects on the lower Snake and Columbia River will operate throughout the year to provide safe fish passage. This was in compliance with National Marine Fisheries Service (NMFS) Biological Opinion (BiOp) which contains other measures, including flow augmentation in the Columbia River,

Table 28

PROPOSED SPILL SCHEDULE FOR JUVENILE FISH PASSAGE
(daily averages)

		LWG	LGS	LMN	IHR	MCN	JDA	TDA	BON
Spring	*% Spill*	*80*	*80*	*81*	*27*	*50*	*33*	*64*	*100*
	Time of day	18-0600	18-0600	18-0600	00-2400	18-0600	18-0600	00-2400	00-2400
Summer	% Spill	*0*	*0*	*0*	*70*	*0*	*86*	*64*	*100*
	Time of day				00-2400		18-0600	00-2400	00-2400

* Bonneville daytime spills are limited to 75 kcfs to minimize adult salmon fall back and up to the 120% of spill capacity during the night.

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Table 29

TARGET FLOWS FOR JUVENILE FISH PASSAGE

Week Ending	Lower Granite			McNary		
	Seasonal Target	Weekly Target	Actual Flow	Seasonal Target	Weekly Target	Actual Flow
4/6						
4/13	57.14	57.14	**84.93**	0.00	0.00	**251.94**
4/20	100.00	100.00	**108.46**	37.14	37.14	**263.40**
4/27	100.00	100.00	**172.07**	260.00	260.00	**395.17**
5/4	100.00	100.00	**160.57**	260.00	260.00	**426. 14**
5/11	100.00	100.00	**150.87**	260.00	260.00	**391.29**
5/18	100.00	100.00	**201.99**	260.00	260.00	**475.54**
5/25	100.00	100.00	**181.91**	260.00	260.00	**490.87**
6/1	100.00	100.00	**154.16**	260.00	260.00	**463.81**
6/8	100.00	100.00	**182.41**	260.00	260.00	**511.59**
6/15	100.00	100.00	**182.37**	260.00	260.00	**536.63**
6/22	87.14	87.14	**172.06**	260.00	260.00	**506.66**
6/29	55.00	55.00	**114.23**	260.00	260.00	**394.39**
7/6	55.00	55.00	**94.67**	208.57	208.57	**301.86**
7/13	55.00	55.00	**67.01**	200.00	200.00	**275.26**
7/20	55.00	55.00	**63.13**	200.00	200.00	**292.80**
7/27	55.00	55.00	**60.99**	200.00	200.00	**261.39**
8/3	55.00	55.00	**58.16**	200.00	200.00	**208.47**
8/10	55.00	55.00	53.23	200.00	200.00	**213.06**
8/17	55.00	55.00	48.74	200.00	200.00	**200.06**
8/24	55.00	55.00	41.90	200.00	200.00	**200.33**
8/31	55.00	55.00	36.23	200.00	200.00	185.51

Bold Actual Flows met or exceeded target flows. All flows in kcfs.

Table 30

ACTUAL SPILL OPERATIONS FOR JUVENILE FISH PASSAGE

	LWG	LGS	LMN	IHR	MCN	JDA	TDA	BON
Spring								
Avg Outflow (kcfs)	162.53	156.63	168.12	161.72	454.83	478.50	463.47	462.07
Spill Days	72	72	72	72	72	72	72	72
Avg Spill (kcfs)	58.96	60.22	64.53	92.89	289.41	161.47	298.38	254.07
% Spill	36.3	38.4	38.4	57.4	63.6	33.7	64.4	55.0
Spill days> 120%	50	49	57	68	71	68	48	70
Summer								
Avg Outflow (kcfs)	66.32	65.39	70.19	72.34	136.51	239.39	230.70	240.09
Spill Days	37	13	18	72	62	62	62	62
Avg Spill (kcfs)	4.5	3.53	3.87	40.62	77.88	46.1	146.82	100.32
% Spill	6.8	5.47	5.5	56.2	32.9	19.3	63.6	41.8
Spill days> 120%	3	1	3	13	0	1	0	4

Average daily spill in kcfs.

additional 427 kaf from the upper Snake River, in-season water management process, and operating the lower Snake River reservoirs at minimum operating pool (MOP) and John Day reservoir to the minimum level needed for irrigation pumping. In-season management of river operations was again provided by the Technical Management Team (TMT) while dispute resolution and policy guidance was provided by the Implementation Team (IT) and Executive Committee (EC) which are made up of representatives from the Corps, Reclamation, BPA, NMFS, USFWS, ODFW, WDFW, and IDFG. The State of Montana and CRITFC withdrew from the process.

1. Actual Operation.

This year's well above normal runoff resulted in high levels of spill that created very high total dissolved gas (TDG) levels throughout the Columbia River system. These conditions raised several issues concerning spill and means of minimizing TDG, as well as other reservoir operations, flood control, use of storage for flow augmentation, including juvenile fish transportation and operation of collector projects, lower Snake River reservoir operation at greater than MOP, and for auxiliary water supply problems in the Bonneville Second Powerhouse adult fish passage facilities.

2. Spill for Fish.

The BiOp prescribed a spilling schedule, Table 28, and target flows, Table 29, at lower Snake and Columbia river projects that would provide a target fish passage efficiency (FPE) of 80% or more. This spill requirement was divided into spring and summer periods with the spring spill for the lower Snake River projects to run from April 10 to June 20 and the summer spill from June 21 to August 31. For the lower Columbia River projects spring spill ran from April 20 to June 30 and summer spill from July 1 to August 31. The spill requirements are shown in the table below. For most of the year, the TDG spill caps dictated the amount spilled.

As shown in Table 30, during the spring season the average daily spill ranged from 58 kcfs to 93 kcfs (36% to 57% of the daily flow average) at lower Snake River dams, and from 161 to 298 kcfs (34% to 63% of the daily flow average) at lower Columbia River dams. All these dams showed 72 days of spill in the spring. During the summer season, the average daily spill range was 4 to 41 kcfs (5 to 56% of daily average) for lower Snake River dams and 46 to 147 kcfs (19% to 64% of daily average) for lower Columbia River dams. Ice Harbor spilled continuously because of reduced hydraulic capacity; but the lower Columbia River dams spilled only for 62 days in summer. The Dalles spilled the most water for the year, followed by McNary and Bonneville.

3. Juvenile Fish Runs.

Salmonids are hatched either in hatcheries or in the river (called wild fish) where they grow until their time for migration to the ocean. In some case, selected hatchery fry are placed in the river to grow in a natural setting before they beginning their natural migrating to the ocean. Some species begin their migration in the year of their hatching while others winter in the river before beginning their odyssey to the ocean.

During this travel time the juveniles are subject to many perils from predation from other fish and birds, spill at dams that can cause dissolved gas disease, physical injuries that may occur during dam passage, stress, diseases, and other problems. Depending upon the location in the basin of the hatcheries or redds the young fish will have to traverse up to nine dams on their out-migration. To help mitigate these dangers an alternate method of transportation has been developed for the juveniles. Specially designed barges and tanker trucks transport the young fish past the dams where they are released back into the river downstream of Bonneville Dam. This reduces their travel mortality rate for most species while maintain their biological timing for arrival at the ocean.

a. HATCHERY RELEASES. Hatchery fish released into the Columbia basin streams and rivers totaled approximately 66.7 million juvenile salmon, 10

Table 31

SUMMARY OF FISH DISPOSITION AT COLLECTOR DAMS

	CHINOOK		STEELHEAD	COHO	SOCKEYE	TOTAL
	Yearlings	**Subyearlings**				
LWR GRANITE						
Collected	281,665	89,608	7,322,641	1,377	3,453	4,698,744
Bypassed	1,194	1,628	107,969	29	0	110,820
Trucked	**6,809**	**85,826**	**152,336**	**439**	**1,172**	**246,582**
Barged	**269,279**	**998**	**4,026,161**	**926**	**2,162**	**4,299,526**
Total Transported	**276,088**	**86,824**	**4,178,497**	**1,365**	**3,334**	**4,546,108**
LITTLE GOOSE						
Collected	195,250	60231	1,947,986	33	1,397	2,204,897
Bypassed	104,294	222	1,439,194	0	255	1,543,965
Trucked	**2,541**	**56,413**	**23,014**	**30**	**335**	**82,333**
Barged	**81,316**	**87**	**413,223**	**0**	**625**	**495,251**
Total Transported	**83,857**	**56,500**	**436,237**	**30**	**960**	**577,584**
LWR MON'TAL						
Collected	233,530	18,712	1,672,846	290	2,278	1,927,656
Bypassed	114,519	189	1,081,123	90	934	1,196,855
Trucked	**1,562**	**18,130**	**14,081**	**108**	**916**	**34,797**
Barged	**117,186**	**2**	**577,315**	**92**	**387**	**694,982**
Total Transported	**118,748**	**18,132**	**591,396**	**200**	**1,303**	**729,779**
McNARY						
Collected	458,677	5,522,578	481,281	110,150	84,460	6,657,146
Bypassed	430,186	259,731	454,380	760,737	67,149	1,288,183
Trucked	**25,790**	**3,317,703**	**25,489**	**32,469**	**14,130**	**3,415,581**
Barged	**385**	**1,827,055**	**882**	**598**	**2,201**	**1,831,121**
Total Transported	**26,175**	**5,144,758**	**26,371**	**33,067**	**16,331**	**5,246,702**
TOTAL						
Collected	1,169,122	5,691,129	8,424,754	111,850	91,588	15,488,443
Bypassed	650,193	261,770	3,082,666	76,856	68,338	4,139,823
Trucked	**36,702**	3,478,072	**214,920**	**33,046**	**16,553**	**3,779,293**
Barged	**468,166**	1,828,142	**5,017,581**	**1,616**	**5,375**	**7,320,880**
Total Transported	**504,868**	5,306,214	**5,232,501**	**34,662**	**21,928**	**11,100,173**

These accumulated totals are from the tables listed on the internet through 10/3/1997 million less than normal and 13 million less than last year. The release of summer chinook from hatcheries on the Snake were less than normal and the spring chinook was also below normal. The release of steelhead was near normal. Limited returns from previous years reduced the number of fish returning to the hatchery for spawning.

b. COLLECTION OF JUVENILES Lower Granite, Little Goose, Lower Monumental, and McNary dams are Acollector dams@ that are equipped with submersible traveling screens, bypass facilities, and raceways capable of holding large number of fish for later transport past the dams. Operation of the fish collection facilities at Lower Granite, Little Goose, and Lower Monumental continued through October. The facilities at McNary were scheduled to operate as long as fish were present and passing the project and while conditions permitted.

It should be noted in the onset that the number of juveniles collected, bypassed, or transported is not a good indicator of the size of the juvenile fish run. Collection efficiency, spill rate and timing, and other factors all play key rolls in juvenile passage.

With the high flows this year the fish managers decided to let more of the juveniles migrate in the river, despite the higher TDG values. Although the total juveniles collected was 19% greater than in 1996 the number of fish bypassed back to the river increased by 131%. The actual counts of fish collected and bypassed is summarized in Table 31.

c. TRANSPORTATION. Barge transportation of fish on the lower Snake and Columbia rivers began in 1977 replacing most of the truck transportation, which had begun several years earlier. Transportation was initiated to reduce juvenile mortality resulting from passage through powerhouse turbines and project reservoirs. Juveniles are transported from upstream collector projects to a location downstream of Bonneville, the most

Table 32

JUVENILE FISH TRANSPORT BY PROJECT, 1978-97

YEAR	LOWER GRANITE	LITTLE GOOSE	LOWER MONUMENTAL	McNARY	TOTAL
1978	1,980,600	997,285		82,211	3,059,906
1979	2.367,446	1,453,615		1,247,120	5,068,181
1980	3,830,747	2,282,987		1,740,545	7,854,279
1981	2,730,866	1,464,991		4,112.993	8,308,850
1982	1,851,616	1,234,110		3,003,853	6,089,579
1983	2,368,049	868,937		4,326,013	7,562,999
1984	2,046,020	2,274,307		4,708,632	9,028,959
1985	4,459,438	2,008,980		8,321,649	14,790,067
1986	4,683,260	2,050,130		6,760,421	13,493,811
1987	5,470,751	1,910,026		9,655,789	17,036,566
1988	7,504,860	1,708,401		10,820,592	20,033,853
1989	6,703,360	2,310,458		6,364,143	15,377,971
1990	9,336,878	2,319,978		9,789,733	21,446,589
1991	8,420,639	2,245,587		4,808,476	15,474,702
1992	6,766,364	1,777,940		8,997,836	17,542,140
1993	7,577,782	1,325,364	955,195	5,205,420	15,063,761
1994	6,839,755	1,453,818	1,410,024	5,750,590	15,456,181
1995	9,058,442	2,400,917	1,657,567	5,435,658	18,552,584
1996	5,136,914	1,879,029	1,264,057	2,907,322	11,187,340
1997	4,546,108	557,584	729,779	5,246,702	11,100,173

Note: Lower Monumental began counting transport in 1993.

Back

downstream dam.

This year the juvenile transport season began oi March and ended in October at Lower Granite, Little Goose, and Lower Monumental. Collection facilities at McNary remained in operation as long as juvenile fish continued to arrive at the project or until the facilities had to be closed for safety. In general trucking was limited to periods when daily collection was less than 20,000 fish per day. The total count of juveniles listed by transport mode and project is given in Table 32.

The total number of fish transported by barge and truck remained virtually the same as last year, although the numbers from the Snake collector projects were lower than last year they were higher at McNary on the Columbia River. The highest count was in 1990 while 1995 was third highest.

4. Adult Runs

Adult fish counts were obtained at twelve of the thirteen mainstream Columbia and Snake river dams that have fish passage facilities. Although many species were counted (Table 33) only the salmonid races and species counts at three major dams are reported, with their 10-year averages and with the counts of the past five years. The difference between the McNary and Ice Harbor counts is an index to the mid-Columbia return.

Most species showed increases over the previous year's counts, with only fall chinook and steelhead counts at Ice Harbor and McNary lower than in 1996. Returning spring chinook doubles their 1996 count at Bonneville, tripled the return at McNary and increased more than five-fold at Ice Harbor. Summer chinook responded similarly with increases of 66% at Bonneville, 45% at McNary and 132% at Ice Harbor. The counts of fall chinook and steelhead were mixed with 7.5% increases for both at Bonneville while both species counts decreased at McNary and Ice Harbor: 7.5% and 15.5% at McNary and 17% and 21% at Ice Harbor. The big winners, however, were the coho and sockeye at Ice Harbor which increased from 10 to 64 and one to 16, respectively.

H. SPECIAL OPERATIONS

1. Vernita Bar

As in the past, flows were provided at Vernita Bar to

Table 33

YEARLY ADULT FISH COUNTS

BONNEVILLE	**1997**	**1996**	**1995**	**1994**	**1993**	**1992**	**10-Year Average**	**Last Higher Year**
Spring Chinook	**115,034**	56,433	9,846	20,566	112,172	90,582	73,322	'86
Summer Chinook	**29,863**	17,989	15,325	19,531	23,616	19,245	25,463	'89
Fall Chinook	**238,314**	221,524	164,686	203,353	141,622	146,104	229,449	'89
Coho	**24,423**	18,455	12,009	22,894	11,457	16,553	21,659	'91
Steelhead	**251,384**	234,040	230,258	161,978	187,972	312,833	234,183	'92
Sockeye	**46,927**	29,037	8,719	12,678	80,178	84,998	58,150	'93
McNARY								
Spring Chinook	**57,236**	17,683	5,572	9,007	59,556	50,504	35,756	'93
Summer Chinook	**22,351**	15,406	13,200	14,313	20,374	14,414	19,093	'89
Fall Chinook	79,412	81,562	92,443	105,568	63,428	70,688	91,324	'96
Coho	**2,482**	1,842	997	1,735	460	1,804	1,121	'89
Steelhead	118,866	140,749	127,065	94,427	93,280	203,341	102,578	'96
Sockeye	**37,560**	28,584	8,320	10,601	66,484	68,732	46,041	'93
ICE HARBOR								
Spring Chinook	**40,352**	7,466	1,719	3,472	24,935	26,114	17,953	pre '84
Summer Chinook	**9,318**	4,018	903	1,003	6,919	4,378	4,797	pre '84
Fall Chinook	3,908	4,699	5,204	3,133	3,141	5,531	3,990	'96
Coho	**64**	10	4	1	1	0	0	pre '84
Steelhead	84,311	107,099	90,573	51,704	73,101	160,637	64,121	'96
Sockeye	**16**	1	3	0	18	30	11	'93

NOTES: 1. Adult and jack counts for chinook and coho are combined. 2. Data source: Fish Passage Center internet publications. 3.Data is preliminary. **4. Bold** typeface shows increase over 1995.

encourage fall chinook spawning at low elevations in the channel as required by agreement between Grant County PUD and the Federal Energy Regulatory Commission. During mid-October through late November, daytime discharges at Priest Rapids were kept below 50 kcfs as much as possible to minimize redd building above that level on Vernita Bar. This was accomplished by reverse load factoring at the project, with reduced power generation during daylight hours and higher generation at night to pass the daily average inflow.

2. Libby Arrow Swap.

The Canadian and United States entities of the Columbia River Treaty Operation Committee entered into an agreement to store and release water in Libby and Arrow reservoirs in an optimal manner. They agreed to store water in Libby during August 1-31, 1997 and return water to Arrow between September 1, 1997 and January 16, 1998. This arrangement was desirable to the United States because instead of releasing salmon augmentation water (as required by the Biological Opinion) from Libby in August, the water was released in the fall and winter months and the Libby reservoir could remain high for summer recreation. This arrangement was desirable to Canada for two reasons. The first one being that Libby Reservoir backs up into Canada, and a higher Libby reservoir in August means better summer recreation in Canada also. The second reason is because Arrow Lakes released more water than normal in August, releases in the fall/winter period were lower than normal. Lower fall/winter flows were preferred because this encouraged whitefish to spawn at lower levels and the eggs would be more likely to stay submerged/safe until they hatched.

The amount of water swapped between Libby and Arrow reservoirs was about 380 kaf (190 ksfd). This resulted in Libby being drafted to 2450.12 ft at the end of August instead of 2439.0 ft as called for in the Biological Opinion.

Near **Thousand Springs Powerhouse**. Ron Abramovich, NRCS, explains how artificial wetlands, with selected nutrient-hungry vegetation, are being used to upgrade the quality of the used irrigation flow being returned to the river.

Thousand Springs Powerhouse. Within easy walking distance of the Thousand Springs powerhouse is the snail in-field work site for endangered mollusca. Five species of mollusca (snails) found in this area have been listed under the ESA as either threatened or endangered. Approval for up grading of Thousand Springs hinges on the outcome of this study.

V. COLUMBIA RIVER WATER MANAGEMENT GROUP

A. MEETINGS

The Columbia River Water Management Group met every month, except August. At each meeting, agency representatives reported briefly on various events which occurred during the preceding month in their respective areas of water management interest: weather and flood summaries and runoff forecasts by the NWS-River Forecast Center; streamflow by the US Geological Survey; snow accumulation/melt by the US Natural Resources Conservation Service; energy usage and outlook by the Bonneville Power Administration; water supply in irrigation reservoirs by the Bureau of Reclamation; flood control operations and reservoir regulation by Reclamation and the Corps of Engineers; water quality by the EPA, Corps, and other agencies; fisheries by the Corps, National Marine Fisheries Service and other agencies; project licensing by the Federal Energy Regulatory Commission; state activities by the member states; and additional comments by other organizations present. The Hydromet Data, Water Quality, and Forecast Committees, and the Depletions Task Force, also reported on their water management activities.

1. Meeting Summary

The following are highlights of significant items discussed or reported at the CRWMG meetings, not discussed elsewhere in this report.

! The need to update the 30-year averages on five or 10 year intervals, or extending the normal period to 35 or more years was discussed. Some of the unresolved issues include: are there any specific time periods, such as the inter-decadal oscillation, that might bias the normals, availability of software, availability of personnel familiar with the software and procedures, workload requirements, cost sharing, the availability of newer, more accurate correlation factors to estimate missing data, the time period recommended by the World Meteorological Organization, etc.

! In lieu of allowing access to hydrologic data and reports in a finite data base the Corps, and other agencies are releasing their data via their Internet web site.

! Agency budget cutbacks are forcing a reduction in the data collection network necessary for the management of the water resources of the Northwest. Most station cuts come long after budgets are set making it difficult for another agency to assume the funding of a discontinued gage. All agreed that the number of gages is at its minimum, and that a maximum warning time of the discontinuing the operation of a gage should have maximum advanced notice for other agencies to react.

! A post doctoral staff member of the University of Washington Department of Atmospheric Sciences has begun a major effort to study the effects of El Niño on the weather of the Northwest. One presentation has already been made to the Portland area water managers.

! The April forecast meeting was held in the conference area of the new Water Resources Center in Vancouver, Washington. This education center, on the bank of the Columbia River, contains displays that emphasize the importance of water in people's lives and is a popular tour spot for school science classes.

2. Snake River Plain Tour

The Water Management Group traveled to southern Idaho to visit sites in the middle Snake River plain that are important to the operation of the Columbia River water resource. The sites visited included, investigations of the ESA listed endangered snails, irrigation diversion facilities, irrigation return flow treatment, new powerhouse and river diversion construction, commercial farming of trout and other fish, and record-high river flows on the upper Snake River and tributaries.

Upper Malad, the first project visited, is an Idaho Power project located at river-mile 1.0 on the Malad River between Bliss and Hagerman, Idaho. It was constructed in 1949, has a single 9.0 MW unit, and a hydraulic capacity of 800 cfs, the turbine, with a 124-ft head, is fed by a flume that is filled, roughly one mile upstream from the powerhouse, at a diversion dam on the Malad River and a smaller flume catching all the runoff from a small spring below the diversion dam. Typically, nearly all the water from the river is diverted through the powerhouse, but this year, with the near record discharges, approximately 2500 cfs was flowing in the river and 800 cfs in the flume. The narrow canyon through the columnar basalt made this flow an awesome cataract.

The inflow to Thousand Springs powerhouse, an Idaho Power project located on the Snake River about 10 river miles above the mouth of the Malad River, is provided by the springs that flow from the basalt cliffs and is collected in a half-mile long flume. The powerhouse, with a total hydraulic capacity of 560 cfs, has three units that with a 182-ft head produces a total output of 8.0 MW.

Within walking distance of Thousand Springs is the site of the study of the Mid-Snake Macro-invertebrate Study of five species of ESA-listed molluscs: Utah Valvata, Bliss Rapids, Banbury Springs Lanx, Idaho Springsnail, and the Snake River Physa snails. The study, designed to update the distribution data of endangered and threatened snails, and to describe their principle habitat associations, is investigating at the life-history of the snails and is looking for additional colonies outside this known habitat area.

The Clear Springs Fish Research Center is part of a multi-unit commercial enterprise that breeds, grows, harvests, and markets rainbow trout. The outlying Clear Springs units are all located within 15 miles of the Center because their only water supply from the springs in the basalt cliffs. Although Clear Springs has also studied the commercial rearing of salmon and sturgeon, the limited water supply from the springs means reduction in trout production to accommodate production of the other fish. The research Center contains laboratories for water quality, virology, genetics, biologics, nutrition, pathology and specific pathogenic infections. Spawning of brood stock in controlled by adjusting the light exposure to provide harvestable stock all year round rather than just in the spring. The brood stock are spawned only once a year and are used for only one or two spawns although they could be used for three to six years. The object of shorter spawning life is to incorporate the latest genetic improvements in the brood stock. There is some reuse of the water before it is treated and returned to the river.

The Cedar Draw Water Quality Research and Demonstration Project, operated by the Twin Falls Canal Company (TFCC), was designed to use an abandoned fish hatchery to remove sediment and nutrients from the irrigation flow being returned to the river. The hatchery raceways with their slow flows removes sediment and the fish rearing ponds with islands of bull rushes or other nutrient-hungry plants remove the nutrients. This facility removes 80% of the sediment and a Alarge@ percentage of the nutrients.

TFCC is also encouraging their customers to switch to overhead sprinklers, rather than ditch irrigation, to reduce erosion, and therefore, the cost of sediment removal. Unfortunately, beans, a major crop of the region, do not respond well to overhead irrigation. Currently, TFCC is spending 22% of their budget on water quality improvement of the return flow.

Milner Dam is a jointly owned project that diverts water into three separate irrigation canals as well as to the Milner powerhouses. On the south side of the Snake River the Twin Falls Canal receives 8 kcfs with 5 kcfs going into the 58 MW, two-units powerhouse, a mile downstream from the dam, and 3 kcfs flow into the irrigation system. On the north side of the river the Northside Canal withdraws 2.0 kcfs and the Gooding Canal withdraws another 800 cfs. In 1992 construction was completed on a new control structure and small generating unit at Milner Dam. The original spillway, built in 1914, is now blocked with a fuse plug, for emergency use only, while the new structure with five radial drum gates controls the forebay level as well as canal inflow. This small hydro unit has a hydraulic capacity of 200 cfs, an output of 830 KW, and, when the Milner spillway is not in use, provides minimum flows between the dam and the downstream powerhouse.

The Twin Falls project on the Snake River above the city of Twin Falls, added a new powerhouse in 1995 to complement the unit built in 1935. The intake for the first powerhouse was built into the saddle dam in the south channel of the Twin Falls thereby eliminating the Atwin@ of the scenic falls and forcing all spill over the north falls. The intake for the second powerhouse was built adjacent to the first penstock in the south falls saddle dam. The old powerhouse generates 8.4 MW with a hydraulic capacity of 960 cfs while the Kaplan unit in the powerhouse generates 44.4 MW with 4.0 kcfs hydraulic capacity.

Shoshone Falls, three river miles below the Twin Falls project, diverts 950 cfs into a three-unit powerhouse to generate 12.5 MW at a head of 205 ft. At the time of this visit there was approximately 21 kcfs going over the falls, which are 52 ft higher than Niagara Falls.

3. Hydromet Data Committee

The Hydromet Data Committee (HDC) is a standing committee of the Columbia River Water Management Group that handles matters pertaining to hydrometeorological data. The work of this committee is directed mainly toward the coordination and development of the automated Columbia River Operational Hydromet Management System (CROHMS). To date, the major emphasis has been getting data into the CROHMS data bank facility and in the development of viewer-oriented data files for users of CROHMS data. Although emphasis will continue on entering data into the CROHMS data bank facility, a new emphasis is being applied to data transfers between computers, primarily in computer retrieval of data from the CROHMS data bank facility.

Tour group. (L-R) Dusica Jevremovic (FPC), Chan Modini (COE), Dala Walton (USBR), Russ Morrow (COE), Lisa von der Heydt (BPA), Ed Kim (COE), Ed Hubbard (USGS), Tim Brewer (IPC), Ted Day (USBR), Ron Abramovich (NRCS). Not shown Roger Ross (COE). The raceways of this former fish hatchery are now sediment settling ponds for the irrigation return flow before the water is gravity drained to nutrient-leaching ponds with their special vegetation. The final step is gravity flow back into the river.

Cedar Draw Research Project. Irrigation return flow enters the raceways, now settling ponds, from the supply manifold, then to the rearing ponds (background upper right) where high nutrient-using plants consume the chemicals before the water is released back into the river. This is an energy efficient continuous gravity system.

Thousand Springs Powerplant with collection flume and untapped springs to left of penstock. These springs are the outlet of the Lost River which disappears underground into the lava beds 100 miles to the northeast near Arco, Idaho. Note unique architectural style of powerhouse.

UpperMalad Powerplant flume diversion dam. River flow greater than the flume and powerhouse capacity is diverted back into the river channel. Both canal; overflow section and diversion dam gates are used to bypass excess flow. Note irrigation return flow coming off cliff.

Upper Malad Powerplant. Penstock leads from flume to powerhouse. Typically all the river flow is diverted into the powerhouse flume. At this time the river flow exceeds flume capacity by and estimated 3000 cfs. Flow in the Lower Malad flume is partially controlled by diversion structure.

MilnerDam spillway discharge. Four of the five spillway gates are being used to pass the river flow in excess of the capacity of the three irrigation canals (Gooding, Northside, and Southside canals) the and two powerhouses (at-site and downstream powerhouses) that are fed by this project.

MilnerDam stilling basin sill and downstream river section with the old spillway in the background. The at-site powerplant, which typically provides required minimum instream flow in the one mile down to the powerhouse, is in lower right of picture. The project is currently spilling about 17.5 kcfs.

Control structure on southside canal (one mile below Milner) controls both the flow into the downstream powerhouse, which is located just upstream and to the left of this structure, and the irrigation flow in the canal.

Milner Downstream Powerhouse. The Southside canal carries 8500 cfs from the Milner pool to feed the south side canal irrigators and the Milner downstream powerhouse, which has a capacity of 5.5 kcfs and 58.5 MW from the two units. Powerhouse inflow is controlled by the structure pictured above.

Committee activities this year consisted of coordinating activities between the various agencies, working on a station priority listing, discussing better methods of data distribution, and how to computer generate new hydromet station maps.

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4. Depletions Task Force

The Depletions Task Force did not meet this year due to other work priority.

5. Water Quality Committee

The Columbia River Water Management Group-Water Quality Committee (CRWMG-WQC) established in January 1994, has evolved into an organization that has progressed beyond dealing just with operational water quality topics and therefore is no longer directly associated with the CRWMG.

6. Forecast Committee

In their 1992 Fish and Wildlife Program, the Northwest Power Planning Council tasked Bonneville, Reclamation, and the Corps to "fund a review of the current runoff forecasting system, including (1) the potential for accuracy improvements of volume forecasts; (2) the potential for forecasting the shape of runoff; (3) the benefits of expanding telemetered snow monitoring system; and (4) resolution of the institutional barriers for the installation of hydrologic measurement sites in the existing and proposed wilderness areas." To ensure adequate incorporation of all responsible agencies, this review was to be carried out under the auspices of the CRWMG. In early 1992, the CRWMG authorized the Forecast Committee with multiple agency representation, to proceed with responding to the Council's request. The Garen forecast procedures were selected for the official procedure for forecasting Dworshak snowmelt runoff inflow. Effort will not be directed towards improving the Libby runoff forecasting procedure.

B. STATE ACTIVITIES

1. Oregon

With help from the Oregon legislature, work on the backlog of water right applications was completed on schedule and within budget and staff are now able to stay current with new. Completion was timely because of the enormous workload and concentration of resources currently being directed at the Oregon Plan for saving threatened or endangered fish.

Recently Oregon avoided a federal listing for coho on the coast by developing a plan that concentrates much of the state natural resources budget toward coho recovery. Efforts are now underway to extend the plan to steelhead which will extend aerial coverage in the Oregon Plan to most tributaries of the Columbia River.

Work is in progress on two major groundwater studies. The first is an investigation of the groundwater in the Deschutes Basin that covers an area that extending from Billy Chinook Reservoir to the divide above La Pine, Oregon, and should be completed around January 1998. The second study investigates the Willamette Basin and is two years from completion. Both studies are jointly funded between the Oregon Water Resources Department (OWRD) and the US Geological Survey. Additional investigations are scheduled to begin this fall in the South Coast and Klamath basins.

VI. TREATY, AGREEMENTS, AND ACTIVITIES

A. COLUMBIA RIVER TREATY

The Columbia River Treaty between the Unites States and Canada, formally adopted on September 16, 1964, provided for the construction and operation of Mica, Arrow, and Duncan dams in Canada, and Libby Dam in the United States. Under the Treaty, each nation has designated an operating entity. The Canadian entity is British Columbia Hydro and Power Authority, while the United States entity consists jointly of the Bonneville Power Administration and the North Pacific Division, Corps of Engineers. The entities have, in turn, appointed representatives to two committees, the Operating Committee and Hydrometeorological Committee, which are charged with carrying out the operating arrangements necessary to implement the Treaty.

Each year, the Operating Committee meets bi-monthly to coordinate the details of the operation of the Treaty projects and to prepare plans for future year's operations. The committee prepared four reports which are issued each year. This year the reports were: "The Assured Operation Plan (AOP) for Operating Year 2001-2002"; "Determination of Downstream Benefits Resulting from Canadian Storage for Operating Year 2001-2002"; "Detailed Operating Plan for Operating Year 1996-1997"; and "Annual Report on Operation of Treaty Projects." The operating plans are based on system analysis studies conducted by the Operating Committee.

The Hydrometeorological Committee meets twice each year to coordinate the collection and exchange of hydromet and operational data between the entities, and to coordinate runoff volume forecasts and forecasting procedure development. Each year the Committee reviews their publication of the hydrometeorological stations used for treaty operational studies.

B. PACIFIC NORTHWEST COORDINATION AGREEMENT

Operation of system storage for power generation during the 1996-1997 operating year was governed by the Pacific Northwest Coordination Agreement (PNCA). This is an agreement among the major generating utilities of the Pacific Northwest which provides for planned electric power operation during the operating year. The PNCA also provides for the use of Columbia River Treaty storage at downstream plants. Execution of the agreement began in August 1964 and will terminate on June 30, 2003.

The agreement provides for procedures for establishing system operating criteria for each succeeding operating year. The PNCA operating year begins on August 1 and concludes on July 31 of each year. Development of the annual operating plan begins in February and should be completed in September of every year. Studies made during the development of the annual operating plan determine the

- system firm load carrying capability (FLCC),
- energy exchanges,
- schedule of levels that each storage reservoir should follow in order to assure meeting FLCC,
- determine headwater benefits, and
- establishes rights and obligations of each party for use of stored water at headwater projects.

During realtime operations, studies are made at least twice monthly to update the system's operation and draft rights as they change with new streamflow forecasts. The semi-monthly performance of the Actual Energy Regulation (AER) meets system FLCC, recomputes the end-of-month storage level of each reservoir, and updates the rights and obligations of each party.

C. SYSTEM OPERATIONS REVIEW

Several studies, agreements, and activities have been undertaken in response to additional demands on Columbia River system operations for varied and often conflicting uses such as power production, flood control, navigation, recreation, fisheries, irrigation , and environmental quality. Of particular interest is the need to adjust system operation to respond to the listing of salmon, steelhead and sturgeon species in the Columbia Basin under the Endangered Species Act (ESA). Three salmon species have been listed under ESA by the National Marine Fisheries Service (NMFS): the Snake River sockeye salmon (endangered listing of November 20, 1991), the Snake River fall chinook salmon (threatened listing of April 22, 1992), and the Snake River spring/summer chinook salmon (threaten listing of April 22, 1992 reclassified to endangered listing of August 18, 1994). The United States Fish and Wildlife Service (USFWS) listed the Kootenai River white sturgeon as an endangered species in September 1994.

Recently steelhead have been listed under ESA, but specific actions have not yet been defined to address recovery actions. The ESA listings for steelhead are the Upper Columbia River steelhead (endangered listing of October 17, 1997) and Snake River steelhead (threatened listing of October 17, 1997). The ESA listings were followed by numerous litigations, court findings, and agency studies, and agency decisions. The following briefly describes some of the major ongoing activities and key recent actions, all of which have, or will, influence the operation of Columbia River system.

The Columbia River System Operation Review (SOR) was a five year study undertaken as a joint effort of the Corps of Engineers, the Bureau of Reclamation, and the Bonneville Power Administration. The study focus was on the operation of 14 Federal Columbia River system hydropower projects. A main goal for this study was to develop a system operating strategy and regional forum for allowing interested parties, other than the Federal agencies, a long-term role in system planning. Another goal was to undertake the necessary studies to address the approaching expiration of the Pacific Northwest Coordination Agreement (PNCA) and the Canadian Entitlement Allocation Agreement (CEAA). The SOR provided the background studies for decisions on renewal of these agreements.

The continued decline of salmon runs in the Columbia basin surfaced the need to examine ways to improve survival of salmon and other species. Columbia River salmon and sturgeon survival evolved as the major focus of the SOR when certain Snake River salmon species and the Kootenai River white sturgeon were listed as endangered or threatened species under the ESA. With the ESA listings, the National Marine Fisheries Service (NMFS) became a key player in the SOR. The study not only served as a vehicle to examine possible changes in the operation of the Columbia system, but it also provided an avenue to develop, evaluate, and implement recovery actions under ESA. The outcome of the report was an Environmental Impact Statement which covered the draft salmon and sturgeon recovery actions and the renewal of the regional power agreements.

The final EIS was published in November 1995 and consisted of a Main report and twenty technical appendices. The EIS covered four decision areas: (1) a long term system operation strategy for the Columbia-Snake system, (2) a process for involving regional interests in the review and recommendation process, (3) a renewal process for the regional power coordination process (Pacific Northwest Coordination Agreement), and (4) a course of action for the Canadian Entitlement Allocation Agreement. The final analysis evaluated in detail seven separate system operating strategies which included a wide range of possibilities; from operating the system to optimize power generation, to an operation that would severely reduce power generation to enhance salmon and sturgeon survival. The strategies that would most impact hydropower production included lowering several reservoirs to a Anatural river elevation@, or operating the reservoirs to maximize flow augmentation during the downstream migration of salmon. The flow augmentation plans would drastically reduce the power pool storage and flexibility during the peak load winter months. The agencies' Preferred Alternative represented the operation of the 14 Federal dams as recommended by the National Marine Fisheries Service and the US Fish and Wildlife Service in their Biological Opinions to support the recovery of ESA listed species. On February 20, 1997 the Corps issued a Record of Decision (ROD) to implement the preferred alternative (the Reasonable and Prudent Alternative (RPA)) and to respond to the NMFS Biological Opinion.

D. CANADIAN ENTITLEMENT ALLOCATION EXTENSION

On April 29, 1997, five Canadian Entitlement Allocation Extension Agreement (CEAEA) were executed between the BPA and each of the five public utility district-owned dams on the mid-Columbia River. The five mid-Columbia projects are Priest Rapids, Wanapum, Wells, Rock Island and Rocky Reach. The CEAA was executed in 1964 and describes the distribution of power benefits gained in the United States from the Canadian storage provided by the Columbia River Treaty. The CEAEA will begin to replace the CEAA in 1998 when the first portion of the Canadian Entitlement is returned to Canada.

E. SYSTEM CONFIGURATION STUDY

The System Configuration Study (SCS) was initiated by the Corps of Engineers in 1991 to evaluate technical, environmental, and economic effects of potential modifications of Federal dams and reservoirs on the Snake and Columbia Rivers with the goal of improving survival rates for anadromous salmoides migrating down river.

Phase I completed in June 1995, was a reconnaissance level screening of 22 alternatives to improve passage, possible upstream water storage sites for augmentation flows, annual drawdowns of the four Lower Snake River projects and John Day, and collection facilities upstream of Lower Granite Dam. The study narrowed the list of options to be considered in greater detail to three possible drawdown options.

Phase II (Ongoing) has developed into a major program containing many separate and specific studies. The Lower Snake River Juvenile Salmon Migration Feasibility Study was initiated in 1994 to evaluate the potential modifications to the four lower Snake River dams in order to increase the survival of juvenile salmon and steelhead that migrate through the project areas. An Interim Status Report issued in December 1996 reduced options for further study to: (1) Existing conditions as directed by the 1995 BiOp, (2) Removing sections or all of the four Snake River dams to permanently drain the reservoirs to operate as a Anatural river,@ and (3) System improvements including surface bypass collection, fish guidance improvements, turbine improvements, gas abatement measures, and possible operational changes (*ie*, augmentation and spill). The Corps is currently conducting the Feasibility Study to examine the biological, engineering, economic, and social effects associated with the three options and will recommend a course of action in a draft report and environmental impact statement in April 1999.

Shoshone Falls. Under typical June flows only the minimum required instream flows are passed over the falls and the remainder diverted by the diversion into the powerhouse below the falls (see the cover photo).

Archer Highway bridge across the Snake River between Ririe and Rexburg, Idaho.

Snake River flooding of private residence near Blackfoot, Idaho.

VII. OPERATING PLAN FOR 1997-98

Each year the regulation of the Columbia River Basin reservoir system is unique in many details but similar in seasonal characteristics. While most of this annual report describes the unique features of the past year's operation, this chapter briefly describes the general operating plan for the coming water year for major reservoirs.

A. GUIDELINES AND RULE CURVES

Seasonal operational guidelines were established either on a permanent basis in preconstruction documents or were developed, based on studies of historical stream flows that were adjusted for current conditions. These guidelines for the major reservoirs are given in Table 34. They were established on a continuing basis and are not changed each year, whereas other guidelines are recomputed annually or seasonally to meet varying conditions. These operating guidelines, or "rule curves," give a schedule of reservoir elevations that are desirable and provide guidance in meeting project functions: to assure adequate space is available for flood control, to assure adequate water to meet electric power demands by using storage and natural flow efficiently, and also to reasonably assure reservoir refill. The guidelines shown do not reflect special regulations under the ESA for fisheries.

The PNCA provides that prior to the start of each operating year (from August 1 through July 31), a reservoir operating and storage schedule be developed to provide the optimum firm energy load carrying capability (FELCC) for each reservoir in the coordinated system. System regulation studies are to define reservoir elevations as critical rule curves (CRC) on a monthly basis to ensure that adequate firm energy will be available from the coordinated system if there is a recurrence of any critical flow conditions.

Assured Refill Curves (ARC), consisting of monthly reservoir elevations, are also determined to limit reservoir drafts for secondary energy and guide the refill of reservoirs. These curves provide a high degree of assurance that a reservoir will refill by the end of the operating year. In some cases, refill target elevations are recomputed each month during the refill season based on the latest snowpack and precipitation measurements, and these are called variable energy content curves (VECC).

Each individual reservoir has several sets of curves. A listing of either monthly upper rule curve or flood control rule curve elevations, monthly critical rule curve elevations, and monthly base energy content curve elevations is given for some major reservoirs in Table 35. The values in this table indicate a range of mid-month and month-end elevations which are used as a guide in regulated individual reservoirs, as well as the total reservoir system. Obviously, operations must be flexible and deviations must be made from exact planned elevations to provide for changes in weather, inflows, load demands, plant outages, usual general seasonal considerations, and changing social priorities.

B. SPECIAL REGULATIONS UNDER ESA

Under the Endangered Species Act (ESA) two biological opinions were prepared, one for the white sturgeon and the other for Snake River salmon. The sturgeon biological opinion focuses on Libby's operation and attempts to replicate the pre-project spring runoff flow regimen. On the other hand, the biological opinion for salmon focuses on increasing spring and summer flow to assist juvenile downstream migration. To accomplish this, flow targets for the lower Columbia River at McNary Dam and the Snake River at Lower Granite Dam were developed, based on the forecasted runoff volume. Spring flow targets at McNary range from 220 to 260 kcfs, and the summer target is 200 kcfs. While at Lower Granite, spring flow targets range from 85 to 100 kcfs, and in the spring range from 50 to 55 kcfs.

Libby operates under the sturgeon and salmon biological opinion which requires the project to be on minimum flow unless flood control evacuation requires a higher release. However, modifications have been made to project operations because the IJC order or flood control requirements cannot be violated. The special ESA operational guidelines are:

- April 15-30: Increase discharge to attain a flow of 15 kcfs at Bonners Ferry.
- May 1-19: Maintain a flow of 15 kcfs at Bonners Ferry.
- May 20-June 30: Increase discharge to support a flow of 35 kcfs at Bonners Ferry, without spilling.
- July 1-21: Decrease discharge to maintain a flow of 11 kcfs at Bonners Ferry.
- July 22-31: Decrease project discharge to four kcfs minimum flow.
- August 1-31: Increase project discharge to support McNary flow target, without spilling, if the reservoir is above 2439 ft.

The salmon biological opinion operation at Hungry Horse Dam requires the project to be at its flood control level on April 20 and draft to support the McNary flow target in August. Minimum elevation the reservoir would be drafted to, in order to support the flow target, is to between 3550 ft and 3540 ft, for August 15 and August 31, respectively.

There is a three-year test operation at Albeni Falls which is intended to maintain the reservoir at 2055 ft during the winter through April 29. The test operation will be concluded in April 1999.

Grand Coulee salmon biological opinion operation requires the reservoir to be at flood control elevation on April 20 and support McNary flow target through August 31. A reservoir draft limit of 1280 ft was used to support target flows.

To support the salmon biological opinion, Dworshak was operated on minimum flow unless a higher release is required for flood control evacuation and supported Lower Granite target flows through August 31. The reservoir augmented target flows down to 1520 ft while not exceeding a discharge of 14.0 kcfs.

Lower Malad flume entrance. The entrance to the Lower Malad powerhouse flume is located in the Upper Malad afterbay. The flow into the flume is controlled by a flume gate and the river gate structure. Note that the flume gate is closed (powerplant is out of service), diverting the water back into the river. US 30 bridge is in the background.

Table 34

PROJECT SEASONAL OPERATIONAL GUIDELINES

	LIBBY	DUNCAN	KOOTENAY LK	MICA	ARROW	HUNGRY HRS	
JL	Complete filling and hold full as long as	Complete filling and hold full as long as .	Hold Lake elev in accordance with IJC.	Complete filling and hold full as long as	Complete filling and hold full as	Complete filling and hold full as long as	JL
AU	possible subject to ESA operation.	possible		possible.	long as possible.	possible subject to ESA operation.	AU
SE	Optional draft.	Optional draft.	Fill to normal full and hold as streamflows	Optional draft.	Optional draft.	Optional draft. limited by ESA.	SE
OC			permit.		Optional draft.		OC
NO	Mandatory draft.				Optional draft.		NO
DE		Mandatory draft.			Mandatory draft.		DE
JA	Draft for flood control or on minimum	Draft for flood control a/o pwr requirements	Draft Lake in accordance with IJC Order.	Draft for flood control a/o power requirements	Draft for f/c a/o power requirements	Draft for flood control or on minimum	JA
FE	flow	is dependent upon volume inflow forecasts.		is dependent upon volume inflow forecasts.	is dependent upon volume inflow fcst.	flow.	FE
MR		Fill as required for flood control or					MR
AP	ESA sturgeon and salmon operation.	assured refill.	Operate in accordance with IJC Order. Lake	Fill as required for flood control or assured refill.	Fill as required for flood control or		AP
MY			on free flow once spring runoff begins.		assured refill.	ESA salmon operation.	MY
JU							JU

	ALBENI FALLS	GRAND COULEE	BROWNLEE	DWORSHAK	JOHN DAY	WILLAMETTE	
JL	Complete filling and hold full as long as	Complete filling and hold full as long as	Complete filling and hold full as long as	Complete filling and hold full as long as	Generally hold pool in a 3-ft operating	Reservoirs kept as full as possible, but	JL
AU	possible.	possible subject to ESA operation.	possible.	possible subject to ESA operation.	range elevation 265-268 ft.	meeting minimum flow is primary.	AU
SE	Optional draft.	Reservoir generally operated in top five ft.	Optional draft.	Mandatory draft.		Mandatory draft for winter flood control	SE
OC	Mandatory draft.			Mandatory draft limited to 1.3 kcfs over inflow.		regulation.	OC
NO				Mandatory draft.	Generally hold pool between 263-265		NO
DE	Hold reservoir near level.	Optional draft limited by ESA.		Optional draft.	ft. Flood control may require draft to	Operate to control winter floods.	DE
JA	Refill permitted to 2060 ft but must be at	Draft for flood control or on minimum flow.		Draft for flood control or on minimum flow.	257 ft and filled to 268 ft.		JA
FE	or below 2056 ft by Mar 30.		Req at or below elev 2077 ft by Feb 29.			Generally fill from snowmelt & rainfall	FE
MR	Draft not permitted below Dec 1 level.		Var flood cntl draft based on vol inflow.			runoff.	MR
AP	Must to be at or abv 2054 ft by April 30.		Regulate as required by runoff conditions.				AP
MY	Fill as required for flood control.	ESA salmon operation.	Fill as required for flood control or	ESA salmon operation.		Hold near full for summer recreation.	MY
JU	Normally try to fill by mid- June.		assured refill.				JU

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Table 35

1997-98 MONTHLY OPERATING PLAN RESERVOIR RULE CURVES

PROJECT		1997							1998					
	JUL	AUG 15	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR 15	APR	MAY	JUN
MICA			Normal full pool 2475.0 ft					Minimum pool 2320.0 ft						
MRC		2469.8	2469.8	2469.8	2467.9	2467.9	2467.9	FCRC	FCRC	FCRC	FCRC	FCRC		
ECC	2469.8	2469.7	2469.8	2469.8	2469.8	2469.8	2469.8	2463.4	2453.9	2441.3	2435.6	2430.5	2432.5	2452.6
CRC1	2452.0	2465.3	2466.2	2462.8	2458.0	2448.6	2437.8	2414.7	2403.2	2397.3	2394.5	2395.1	2394.6	2422.9
CRC2	2439.6	2469.5	2469.8	2469.8	2466.0	2455.2	2440.4	2419.7	2406.6	2393.8	2389.9	2388.1	2395.8	2422.1
CRC3	2430.4	2458.8	2462.2	2461.5	2456.8	2447.5	2436.9	2414.5	2397.5	2395.5	2396.1	2394.4	2394.1	2414.1
CRC4	2393.8	2431.6	2431.5	2425.4	2416.5	2403.3	2393.9	2394.1	2393.8	2393.8	2393.8	2393.8	2393.8	2393.8
ARROW			Normal full pool 1444.0 ft					Minimum pool 1377.9 ft						
MRC		1444.0	1444.0	1444.0	1442.1	1442.1	1436.2	FCRC	FCRC	FCRC		FCRC		
ECC	1444.0	1444.0	1444.0	1443.3	1441.9	1439.7	1430.0	1412.6	1400.9	1406.6	1407.8	1409.5	1423.1	1439.1
CRC1	1435.7	1441.7	1441.2	1440.3	1435.8	1426.9	1414.1	1395.5	1382.4	1382.6	1380.1	1386.2	1392.8	1418.3
CRC2	1444.0	1440.7	1439.4	1436.2	1429.3	1423.8	1413.1	1391.5	1377.9	1383.6	1384.1	1385.5	1391.4	1421.9
CRC3	1415.5	1439.4	1438.6	1439.0	1434.8	1425.7	1412.0	1397.8	1380.2	1381.7	1381.0	1380.2	1392.9	1404.1
CRC4	1377.9	1416.1	1411.7	1411.1	1406.8	1404.5	1396.2	1386.2	1377.9	1377.9	1377.9	1377.9	1377.9	1377.9
DUNCAN			Normal full pool 1892.0 ft					Minimum pool 1794.2 ft						
MRC		1892.0	1892.0	1892.0	1892.0	1892.0	1868.6	FCRC	FCRC	FCRC	FCRC	FCRC		
ECC	1892.0	1892.0	1892.0	1890.5	1884.7	1868.4	1856.9	1838.9	1833.6	1838.8	1839.8	1837.7	1850.7	1843.0
CRC1	1824.1	1874.4	1867.2	1853.7	1826.5	1799.0	1798.7	1796.6	1797.6	1795.4	1798.2	1794.4	1794.2	1831.8
CRC2	1845.4	1881.4	1872.4	1861.3	1834.7	1806.9	1801.2	1797.5	1796.4	1795.4	1797.1	1794.4	1794.2	1836.0
CRC3	1819.1	1816.1	1823.2	1824.2	1796.9	1796.8	1796.4	1796.8	1796.6	1796.0	1797.3	1795.2	1807.2	1830.2
CRC4	1794.2	1805.0	1795.7	1794.8	1794.6	1794.2	1794.2	1794.2	1794.2	1794.2	1794.2	1794.2	1794.2	1794.2
LIBBY			Normal full pool 2459.0 ft					Minimum pool 2287.0 ft						
MRC		2459.0	2459.0	2459.0	2459.0	2448.0	2411.0	FCRC	FCRC	FCRC	FCRC	FCRC		
ECC		2459.0	2459.0	2447.0	2443.2	2430.9	2424.2	2421.7	2419.0	2416.3	2415.5	2413.8	2433.7	2456.5
CRC1	2442.7	2454.0	2453.4	2443.7	2435.2	2405.3	2368.7	2359.1	2356.1	2352.3	2355.7	2367.7	2400.4	2423.5
CRC2	2427.8	2438.3	2439.0	2433.6	2430.3	2419.7	2411.0	2406.9	2403.5	2400.2	2398.9	2397.0	2413.2	2415.9
CRC3	2400.6	2456.5	2453.9	2445.4	2445.2	2426.0	2390.3	2363.9	2331.3	2301.9	2300.2	2300.0	2345.2	2387.0
CRC4	2287.0	2396.4	2397.3	2378.4	2373.8	2366.8	2362.9	2303.6	2287.0	2287.0	2287.0	2287.0	2287.0	2287.0
HUNGRY HORSE			Normal full pool 3560.0 ft					Minimum pool 3336.0 ft						
MRC		3560.0	3560.0	3560.0	3560.0	3560.0	3560.0	FCRC	FCRC					
ECC	3560.0	3560.0	3560.0	3560.0	3560.0	3560.0	3559.7	3555.1	3551.8	3548.4	3545.0	3535.3	3552.1	3560.0
CRC1	3476.1	3552.8	3544.2	3517.8	3496.1	3484.7	3455.6	3401.9	3390.1	3369.7	3392.6	3424.0	3468.1	3468.9
CRC2	3558.1	3550.0	3540.1	3535.1	3529.1	3522.7	3515.5	3507.3	3499.5	3490.7	3488.3	3493.7	3529.3	3552.5
CRC3	3443.6	3526.6	3517.0	3488.7	3468.6	3460.7	3428.8	3390.2	3380.0	3358.1	3358.1	3358.1	3436.1	3453.7
CRC4	3336.0	3446.2	3439.5	3432.5	3423.9	3413.4	3390.8	3340.9	3336.0	3336.0	3336.0	3336.0	3336.0	3336.0
FLATHEAD LAKE			Normal full pool 2893.0 ft					Minimum pool 2883.0 ft						
MRC		2893.0	2893.0	2893.0	2893.0	2893.0	2893.0							
ECC	2892.7	2893.0	2893.0	2893.0	2892.4	2889.7	2889.0	2887.1	2885.2	2883.6	2884.8	2884.8	2890.0	2893.0
CRC1	2893.0	2893.0	2893.0	2893.0	2892.2	2890.1	2889.3	2889.3	2886.0	2883.9	2884.0	2886.2	2890.0	2893.0
CRC2	2893.0	2893.0	2893.0	2892.4	2891.9	2889.0	2886.9	2885.4	2884.2	2883.0	2883.0	2883.1	2890.0	2893.0
CRC3	2893.0	2893.0	2893.0	2893.0	2891.9	2890.9	2889.6	2888.2	2885.0	2883.7	2883.7	2884.4	2890.0	2893.0
CRC4	2883.0	2892.7	2892.7	2892.7	2891.0	2887.9	2885.3	2884.2	2883.0	2883.0	2883.0	2883.0	2883.0	2883.0
ALBENI FALLS			Normal full pool 2062.5 ft					Minimum pool 2049.7 ft						
MRC		2062.5	2062.5	2062.5	2060.0	2056.0	2056.0	FCRC	FCRC	FCRC				
ECC	2062.0	2062.5	2062.5	2060.0	2054.0	2051.0	2051.0	2051.0	2051.0	2051.0	2054.0	2057.0	2062.0	2062.0
CRC1	2062.0	2062.0	2062.0	2060.0	2054.0	2051.0	2051.0	2051.0	2051.0	2051.0	2051.0	2054.0	2057.0	2062.0
CRC2	2062.5	2062.5	2062.5	2060.0	2054.0	2051.0	2051.0	2051.0	2051.0	2051.0	2054.2	2056.0	2057.0	2062.5
CRC3	2062.0	2062.0	2062.0	2060.0	2054.0	2051.0	2051.0	2051.0	2051.0	2051.0	2051.0	2054.0	2057.0	2062.0
CRC4	2049.7	2062.0	2062.0	2060.0	2054.0	2051.0	2051.0	2051.0	2049.7	2049.7	2049.7	2049.7	2049.7	2049.7
GRAND COULEE			Normal full pool 1290.0 ft					Minimum pool 1208.0 ft						
MRC		1290.0	1290.0	1290.0	1290.0	1290.0	1290.0	FCRC	FCRC	FCRC		FCRC		
ECC	1290.0	1290.0	1290.0	1288.3	1288.3	1288.3	1288.1	1289.3	1289.9	1269.0	1281.4	1282.4	1245.6	1285.1
CRC1	1290.0	1289.9	1288.0	1288.0	1288.0	1289.7	1288.1	1280.6	1274.3	1245.6	1253.0	1267.3	1265.5	1290.0
CRC2	1280.1	1280.1	1280.1	1282.3	1284.1	1285.1	1279.3	1288.8	1289.9	1283.1	1278.4	1280.1	1283.1	1282.1
CRC3	1289.6	1290.0	1289.8	1289.2	1288.4	1288.2	1288.4	1290.0	1290.0	1265.9	1264.9	1257.8	1261.7	1289.8
CRC4	1208.0	1289.3	1290.0	1290.0	1289.2	1283.3	1259.1	1241.3	1208.0	1208.0	1208.0	1208.0	1208.0	1208.0
DWORSHAK			Normal full pool 1600.0 ft					Minimum pool 1445.0 ft						
MRC		1600.0	1600.0	1587.7	1581.9	1568.9	1558.2	FCRC	FCRC	FCRC	FCRC			
ECC	1600.0	1569.7	1569.9	1569.4	1570.6	1568.9	1558.2	1556.8	1556.1	1562.9	1577.5	1588.9	1593.2	1600.0
CRC1	1563.9	1574.6	1574.4	1573.5	1573.2	1568.9	1558.2	1556.9	1562.0	1573.7	1578.4	1584.2	1575.8	1589.5
CRC2	1532.8	1519.9	1519.3	1518.2	1516.4	1514.6	1514.1	1511.6	1510.2	1514.1	1523.2	1523.6	1552.7	1560.5
CRC3	1598.3	1592.0	1591.6	1586.0	1581.9	1568.9	1558.2	1559.8	1562.2	1576.7	1589.0	1583.1	1587.6	1597.1
CRC4	1445.0	1588.1	1587.1	1583.5	1580.0	1568.9	1538.9	1494.4	1445.0	1445.0	1445.0	1445.0	1445.0	1445.0

VIII. MAJOR CONSTRUCTION AT PROJECTS

There are many construction projects at dams, pumping stations, diversion works, fish screens, and other facilities that all play their part in the management of the water resources of the Pacific Northwest. This chapter, by necessity, summarizes those construction projects that are associated with dams that have flood control, major power generation, irrigation supply, fisheries, or water supply, both Federally and non-Federally owned. It includes project construction for up rating of generators, repair of flood damages, and for safety of dams.

A. FEDERAL PROJECTS

1. Chief Joseph Pumping Plant

Construction is underway to install fishscreen intake manifold for the pumping plant and an air burst cleaning system at Reclamation's East Unit River Pumping Plant of their Chief Joseph Project. The contract is for $421,777 was awarded on September 1997 for intake fishscreen modifications.

2. Ochoco Dam

Reclamation is completing work required on the spillway modification contract for installation of a flowmeter, steel pipe, and electrical conduit, constructing inspection well and irrigation diversion structures, and repairing cracks in the stilling basin. This safety of dams contract was awarded on August 1997 for $300,880.

3. Salmon Lake Dam

Construction has been completed by Reclamation on a test section of 44 stone columns at the downstream toe of Salmon Lake Dam in the Okanogan Basin that were installed to investigate the effectiveness of stone columns as a ground improvement method for liquefaction remediation and treatment design by comparing foundation strengths before and after stone column installation. This safety of dams contract for the test section was awarded on June 1997 for $388,634.

4. McKay Dam

Construction, by Reclamation, to place a filter and drain system and install a toe drain and outfall system at the downstream base of the dam, and to install instrumentation on the upstream face of the dam, is approximately 50% complete. This contract for $1,159,334 was awarded on August 1997.

5. Mud Mountain Dam

The final phase of the reconstruction of Mud Mountain Dam has been completed and the final acceptance of the hydraulic gate operation for the new intake structure was signed in the fall of 1996. Since then several problems have arisen so some work continues. The warranty remains in effect through one year of trouble-free operation of the hydraulic gates.

B. NON-FEDERAL PROJECTS

1. Frog Lake Dam, Oak Grove Project

Portland General Electric Company's (PGE) Frog Lake Dam is located in an area of ancient landslide terrain along the north side of the Clackamas River. A 70-foot-high, 2,200-foot-long embankment forms the west and north sides of the 530-acre-foot reservoir. The Frog Lake Slide (FLS) represents a reactivated portion of this terrain. The reactivated head scarp of the FLS, located between the inlet and outlet structures, was identified by divers in 1990. The FLS is about 3,000 feet wide, at least 250 feet deep, and extends about 5,000 feet downslope to the Clackamas River. In September 1996, PGE indicated that the reservoir would be reduced to about 144 af by constructing a cofferdam in an east-west direction across the reservoir, and proposed removing the western portion of Frog Lake Dam and constructing a new embankment in its place. Final plans and specifications for the project were submitted by PGE March 28, 1997 letter. Construction was authorized and commenced on July 14, 1997, and was completed on November 10, 1997 at the cost of $1,485,000.

2. Faraday Forebay, North Fork Project

The 32.5-foot-high Faraday forebay embankment forms the 500 af forebay for the Faraday Powerhouse of PGE's project on the North Fork of the Clackamas River. The powerhouse was flooded in February 1996 and all five indoor generating units and auxiliary equipment inside the plant was damaged. Clean up work started immediately following the flood. PGE contracted with two private firms for the repair of the units including generator rewinding and rotor repair. Unit No. 4 was replaced and became operational on July 31, 1997. The other four units were placed on-line on November 26, 1996. The repair cost, including clean up work, was $1,700,000.

3. Nisqually River

The Nisqually River Project (Alder and La Grande dams), licensed to the City of Tacoma, is located in central part of western Washington, on the west slope of Mount Rainier, approximately 30 miles southwest of Tacoma, Washington. Alder Dam, a 285-foot-high arch structure, impounds Alder Lake, a 241.2 kaf reservoir. La Grande Dam, a 192-foot-high arch structure, impounds La Grande Lake, a 3,015 af reregulating reservoir. On February 8, 1996, a flood of record occurred (approximately 44,000 cfs), causing severe damage to the Alder spillway plunge pool and flooding the La Grande Powerhouse. The plunge pool is not structurally contiguous with the dam or spillway, and repairs primarily consisted of replacing the lost and eroded concrete. Many of the electrical facilities were damaged at the La Grande Powerhouse, including all five generators. The four older generators were rewound and placed back into service by September 1996 and the repairs of the fifth generator was completed on January 14, 1997. The cost was approximately $1,600,000 for the powerhouse (lost generation not included), $21,000 for road repair, and $600,000 for the repair of Alder spillway plunge pool, for $2,221,000.

4. South Fork Tolt River

In January 1996 the City of Seattle completed the installation a new 16.8 MW powerplant at its existing Tolt water supply dam on the SF Tolt River. The existing project includes a 200-foot-high zoned earthfill dam, and an 882 af regulating basin with two saddle dams. A new contract to make seismic upgrades to the project included strengthening of the regulating basin's south dike and the main dam's intake and spillway tower, along with the access footbridge. The work to modify the intake and spillway tower structures is scheduled to be completed in May 1998 at an approximate cost of $8.94 million.

5. McNary Dam

Northern Wasco County People's Utility District (NWCPUD) was issued a license by September 30, 1991 Commission Order to construct a powerplant at the Army Corps of Engineer's McNary Dam, located at River Mile 292 on the Columbia River. The power project is located between the navigation lock and the project spillway, on the Auxiliary Water Supply System to the Washington Shore Fishway of McNary Dam. The project includes an intake structure with water supply conduits; a powerhouse with a single vertical turbine-generator rated at 9.69 MW; a turbine bypass facility; a diffuser water supply pool; horizontal weir/orifice flow control facilities for providing water to the diffusion chambers; about 1800 ft of transmission lines; and electrical interconnections. The proposed turbine/ generator installation will use the existing auxiliary water supply conduits and distribute flow from the turbine discharge to the diffusers, and then to the fishway. An April 2, 1996 FERC Order approved transfer of the license to include Public Utility District No. 1 of Klickitat County as co-licensee with NWCPUD. The project was completed in September 1997 and commercial on-line generation began November 3. Total cost was approximately $26,390,000.

6. Rocky Reach Dam

The Rocky Reach Project, licensed to Chelan County PUD No. 1 (Chelan), is located on the Columbia River in central Washington, seven miles north of the town of Wenatchee. The dam, completed in 1962, consists of concrete gravity, spillway, and powerhouse sections which contains 11 generating units with a total capacity of 1,249 MW. To reduce turbine cavitation and decrease fish mortality, Chelan recently initiated a turbine replacement program. This program will cost approximately $67 million and is scheduled to be completed in 2001. To date the replacement of Unit Nos. 4, 5, and 7 has been completed, and Unit No. 6 turbine runner installation has been completed.

IX. ACKNOWLEDGMENTS

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APPENDICES

A. GLOSSARY

B. ABBREVIATIONS

C. PERTINENT DATA ON DAMS AND RESERVOIRS

D. CHARTS

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APPENDIX A

GLOSSARY

The following glossary contains an alphabetical listing of most of the key technical terms used in operational hydrology. For a graphic illustration of reservoir terms see Figures A1 and A2.

ACRE-FOOT - a unit of volume equal to one acre of area by one foot depth (equal to 43,560 ft^3 or 325,872 gallons). This unit is generally used to measure the volumes of water used or stored in reservoirs. Also used are thousands of acre-feet (kaf) and millions of acre-feet (maf).

ACTIVE STORAGE - water occupying active storage capacity of a reservoir.

ACTIVE STORAGE CAPACITY - the portion of the live storage capacity in which water normally will be stored or withdrawn for beneficial uses, in compliance with operating agreements or restrictions.

ADJUSTED STREAMFLOW - observed streamflow adjusted to eliminate effects of specified controls.

ADVERSE HISTORICAL STREAMFLOW SEQUENCE - see critical streamflow period.

ASSURED REFILL CURVE (ARC) - indicates the end-of-month storage content which would assure refill of a seasonal reservoir based on a specified historical volume of inflow for the whole or remaining portion of the refill period. The specified historical value for most projects in the Columbia basin is the second lowest of historical record. The year 1931 represents the second lowest of historical January-July volume inflows for the system as measured at The Dalles, Oregon.

ASSURED SYSTEM CAPACITY - the dependable capacity of system facilities available for serving system load after allowance for required reserve capacity, including the effect of emergency interchange agreements and firm power agreements with other systems.

AVERAGE - the sum of the items divided by the number of items; for other than the 1961-90 normal period. See also NORMAL.

AVERAGE STREAMFLOW - the average rate of flow at a given point during a specified period.

BANKFULL STAGE - The stage at which a stream first overflows its natural banks. (See also FLOOD STAGE. Bankfull stage is a hydraulic term whereas flood stage implies damage.)

BASE ENERGY CONTENT CURVE - The higher of the assured refill curve and the first year critical rule curve.

BASE LOAD - the minimum load in a stated period of time.

BASE LOAD PLANT - a power plant which is normally operated to carry base load and which, consequently, operates essentially at a constant load.

BASE POWER FLOW - observed streamflow adjusted to eliminate the effects of reservoirs, controlled lake regulation, and actual Grand Coulee pumping and then further adjusted to a given level of irrigation development.

BIOLOGICAL OPINION - A set of recommendations from NMFS defining what operations the Columbia River system operation should be in order to ensure that the endangered species are not placed into jeopardy.

BRIGHT - a fall chinook salmon that spawns in the upper river, say, above the Umatilla River, that enters the lower Columbia River in a bright silver condition but that has not yet begun it spawning metamorphosis. See also Tule.

CAPABILITY - the maximum load which a generator, turbine, transmission circuit, apparatus, station, or system can supply under specified conditions for a given time interval, without exceeding approved limits of temperature and stress.

CAPACITY - the load for which a generator, turbine, transformer, transmission circuit, apparatus, station, or system is rated. Capacity is also used synonymously with capability. NOTE: For definitions pertinent to the capacity of a reservoir to store water, see Reservoir Storage Capacity.

CONNECTED LOAD - the sum of the ratings of the electric power consuming apparatus connected to the system, or part of the system, under consideration.

COLUMBIA BASIN TELECOMMUNICATIONS (CBT) - the CBT is a medium speed leased line teletype communication system between major power producing projects, the agencies responsible for their operation, and

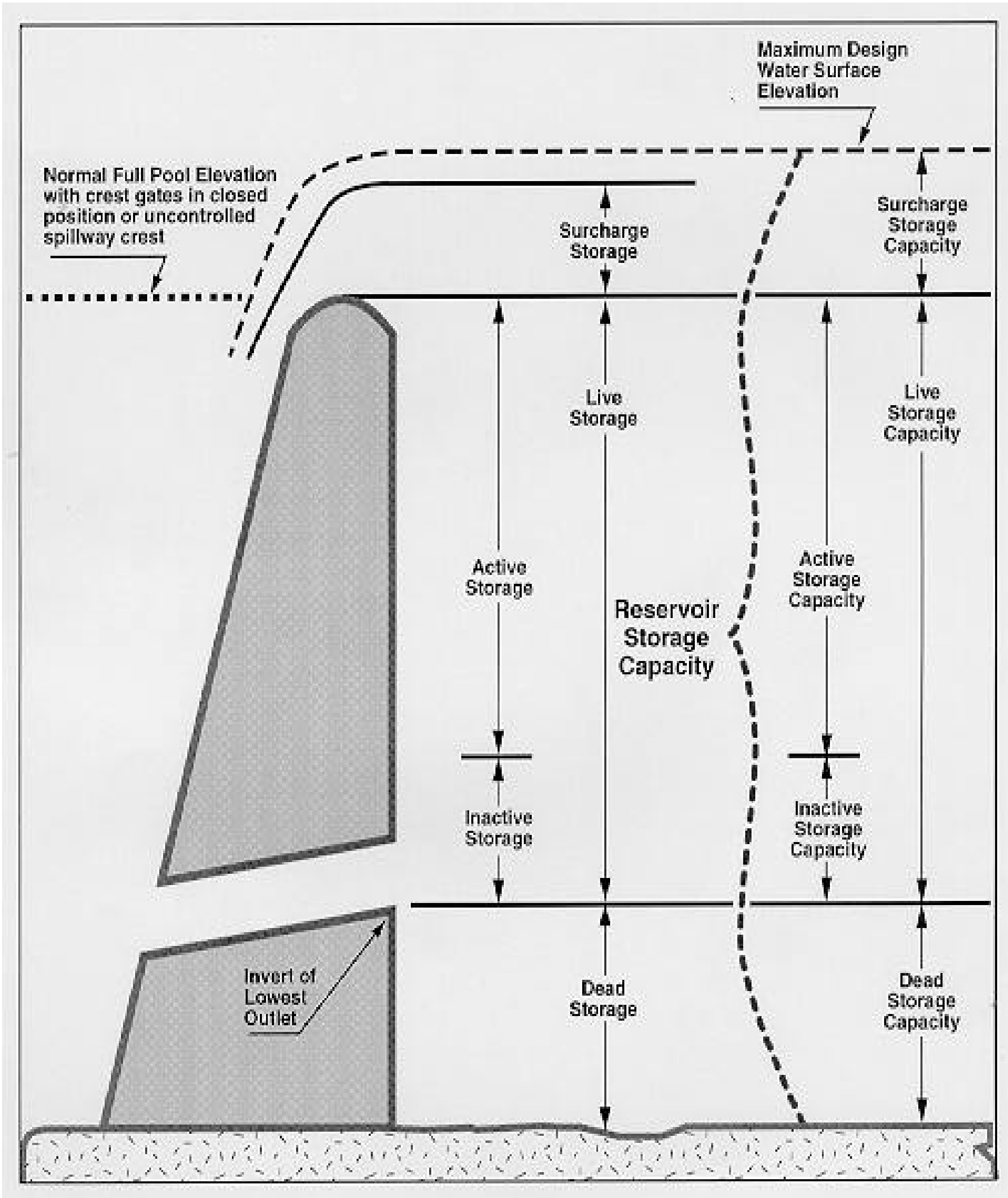
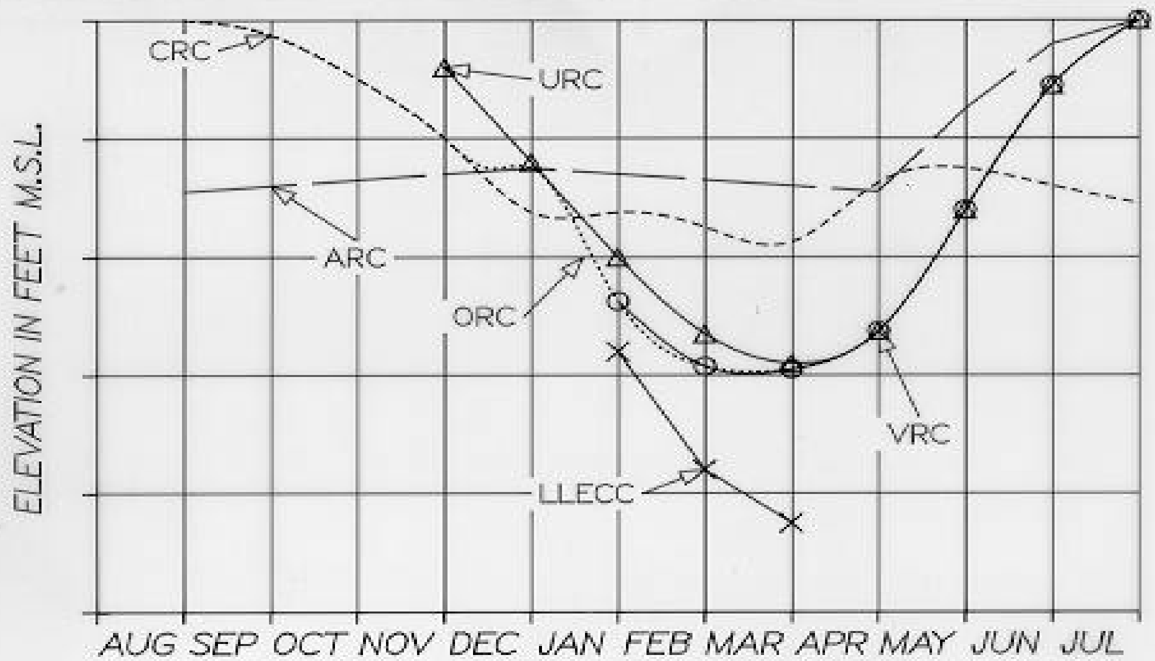


Figure A-1. ILLUSTRATION OF RESERVOIR TERMS



1. CRITICAL RULE CURVE (CRC). This curve is actually a family of one to four curves depending on the length of the critical period. These curves are developed in July of each operating year from historical flows and based on operating under adverse flow conditions.

2. ASSURED REFILL CURVE (ARC). This curve is the elevation that each project can refill if the second lowest historical water year (1931), January thru July run—off should occur.

3. VARIABLE REFILL CURVE (VRC). This curve depicts the reservoir elevation needed to refill with 95 % assurance based on the current run—off forecast.

4. UPPER RULE CURVE (URC). This curve for the period August thru December is based on historical flows and for the period January thru July is based on forecast flows. The URC reflects the amount of storage space needed to protect against a flood.

5. LOWER LIMIT ENERGY CONTENT CURVE (LLECC). This curve serves as a limit on the project draft in January, February, and March to protect the system's capability to meet firm loads until the start of the spring runoff. Limits are determined by using 1936—1937 water year to meet the system's firm energy loads.

6. OPERATING RULE CURVE (ORC). (August thru December) The ORC is the higher of the ARC or the CRC unless the URC is lower, then it controls. (January thru March) The ORC method is the same as August thru December period unless the VRC is lower, then it controls. When the VRC controls the ORC can be higher than the URC. But in no case can the ORC be lower than the LLECC. (April thru July) The ORC method is the same as January thru March period, except without the LLECC consideration.

Figure A-2. RULE CURVE DEFINITIONS

the operating/forecasting agencies. This system is used to transmit hydrologic data and reservoir operating instructions necessary for efficient project operation. This system replaced the older Columbia Basin Teletype network (CBTT) in 1983.

COORDINATED SYSTEM RESERVOIRS - the agencies of the Pacific Northwest who have ratified the Pacific Northwest Coordination Agreement, a formal contract for coordinating the seasonal operation of the generating resources of the member systems for the best utilization of their collective reservoir storage. Finalized in mid-August 1964, the Agreement became effective on January 4, 1965, and terminates on June 30, 2003. The member agencies are:

- Bonneville Power Administration
- The Montana Power Company
- Corps of Engineers
- Pacific Power and Light Company
- Bureau of Reclamation
- Pend Oreille County PUD #1
- Chelan County PUD #1
- Portland General Electric Company
- Colockum Transmission Company
- Puget Sound Power and Light Company
- Cowlitz County PUD #1
- Seattle City Light
- Douglas County PUD #1
- Tacoma City Light
- Eugene Water and Electric Board
- The Washington Water Power Company
- Grant County PUD #2

CONTINUOUS POWER - hydroelectric power available from a plant on a continuous basis under the most adverse hydraulic conditions contemplated.

CRITICAL PERIOD - period when the limitations of hydroelectric power supply due to water conditions are most critical with respect to system load requirements. This is the 42-1/2 month historical sequence of streamflows that occurred from August 16, 1928 through February 29, 1932. Also called Critical Hydro Period and Critical Streamflow Period.

CRITICAL RULE CURVE (CRC) - a schedule or budget of seasonal reservoir drafts, with respect to time, as determined from analysis of estimated loads and calculated resources based on critical flow water supply for the period. In the analysis, consideration is given first, to providing power so as to meet system firm loads; second, to economy of operation; and third, to providing power to meet interruptible loads. The schedule or budget of reservoir draft may be shown as a plot of reservoir elevation with respect to time, energy producible from reservoir draft with respect to time or by other similar means.

In multiple-year critical periods there will be a Critical Rule Curve for each corresponding year of the critical period, the first year's curve being the highest in indicated storage energy, the second year's being the next highest, etc.

CUBIC FEET PER SECOND (cfs) - unit of measure expressing rates of discharge. Also expressed as thousand cubic feet per second (kcfs).

DEAD STORAGE - the volume in a reservoir below the invert of the lowest controllable outlet.

DEAD STORAGE CAPACITY - the volume of a reservoir which is below the invert of the lowest outlet and cannot be evacuated by gravity.

DEMAND - the rate at which electric energy is delivered to or by a system, part of a system, or piece of equipment, expressed in kilowatts or other suitable unit, at a given instant or averaged over any period of time.

DEPLETIONS - Over the past 50 or more years, the natural streamflow patterns in the Columbia Basin have been altered by the gradual development of nearly 43 million acre-feet (53,000 hm^3) of reservoir storage and by nearly 8 million acres (3,240,000 hm^2) of land for irrigation. Storage reduces high flows when reservoirs are filling and increases low flows when storage is released. Irrigation not only alters the stream flow pattern by withdrawing water from the rivers but also depletes the water supply through evaporation and infiltration. Consequently, to more accurately compare historical streamflow records, these changes must be taken into consideration. This is done by the "depletions" process in which streamflow data are modified, on a monthly basis, by adjusting flows for both the storage changes in all major lakes and reservoirs and for the irrigation adjustments to a common time of development. The historical records for the Columbia basin have been "depleted" by the Depletions Task Force (DTF) of the CRWMG.

DISCHARGE - the rate of flow of a river or stream measured in volume of water per unit of time. The standard units of measure are cubic feet per second (cfs) or thousand cubic feet per second (kcfs).

DIVERSION DEMAND - the amount of water withdrawn from surface or groundwater sources.

DRAWDOWN - the distance that the water surface of a reservoir is lowered from a given elevation as the result of the withdrawal of water.

EFFICIENCY, STATION OR SYSTEM - the ratio of the energy delivered from the station or system to the energy received by it under specified conditions.

ELECTRIC POWER - a term used in the electric power industry to mean inclusively power and energy.

ENDANGERED SPECIES - any species which, as determined by the Fish and Wildlife Service, is in danger of extinction throughout all or a significant portion of its range other than a species of the class Insecta determined to constitute a pest whose protection would present an overwhelming and overriding risk to man.

ENERGY - that which does or is capable of doing work. It is measured in units of the work; electric energy is usually measured in kilowatt hours.

ENERGY CONTENT CURVE (ECC) - provides sufficient storage at all times so that the Coordinated System will be able to generate its Firm Energy Load Carrying Capability under a recurrence of any historical streamflow sequence. The ECC is obtained the same way as the Operating Rule Curve (defined in Figure A-2) except the proportional draft point needed to generate the Firm Energy Load Carrying Capability is also part of the ECC.

The curve is a guide to the use of storage water from each reservoir and is used to define certain operating rights, obligations and limitations. The ECC for each reservoir consists of a graphic, tabular or other representation of reservoir elevations at the end of specified periods.

EXTRA HIGH VOLTAGE (EHV) - a term applied to voltage levels of transmission lines which are higher than the voltage levels commonly used. At present, the electric industry generally considers EHV to be any voltage greater than 230,000 volts.

FEDERAL COLUMBIA RIVER POWER SYSTEM RESERVOIRS - the Federally-owned projects that generate hydroelectric power include the following existing and planned projects:

Albeni Falls	Hungry Horse
Anderson Ranch	John Day
Big Cliff	Ice Harbor
Black Canyon	Libby
Boise Diversion	Little Goose
Bonneville	Lookout Point
Chandler	Lost Creek
Chief Joseph	Lower Granite
Cougar	Lower Monumental
Detroit	McNary
Dexter	Minidoka
Dworshak	Palisades
Foster	Roza
Grand Coulee, incl Pumped Storage and Third Powerplant	Strube (Cougar Reregulator)[1]
	Teton[2]
	The Dalles
Green Peter	
Green Springs	
Hills Creek	

[1] Planned.
[2] Status undetermined.

FINGERLING - Fish whose size ranges from approximately 1 to 3 inches.

FIRM ENERGY - electric energy which is intended to have assured availability to the customer to meet all or any agreed upon portion of his load requirements.

FIRM ENERGY LOAD CARRYING CAPABILITY (FELCC) - the firm energy load that a system is able to supply in any period after deducting the required energy reserve and Forced Outage Reserve.

FIRM POWER - power intended to have assured availability to the customer to meet all or any agreed upon portion of his load requirements.

FISHPASS - a computer model developed by the Corps of Engineers to simulate anadromous smolt migration and survival as they travel through a river system. It allows analysis of the impacts of proposed migration such as the Water Budget fish screens, fish spill, and fish transportation on juvenile fish survival through river systems and past dams.

FLASH FLOOD - a flood with a very rapid rate of rise that is generally caused by intense rainfall, failure of ice jams or dams, etc. They occur in small drainages and the time between the peak rate of rainfall and the peak discharge is very small.

FLOOD CONTROL RULE CURVE - a curve or family of curves of reservoir contents, with respect to time, indicating space required to control flood flow. These curves are determined from analysis of magnitude, duration, and potential damage of flood flows throughout the year or for certain periods during the year. Also called Mandatory Rule Curve (MRC).

FLOOD PLAIN - the low lands adjoining the channel of a river, stream, watercourse, lake, or ocean, that have been or may be inundated by flood waters and other areas subject to flooding.

FOREBAY - that area of a reservoir immediately upstream of a dam and in the vicinity of the outlet structures.

FLOOD STAGE - The stage at which the overflow of the natural banks of a stream begins to cause damage in the reach in which the elevation is measured. (See BANKFULL STAGE.)

FORCED OUTAGE - the shutting down of a generating unit, transmission line, or other facility, for emergency reasons.

FRY - The stage in the life of a fish between the hatching of the egg and the absorption of the yolk sac. From this stage until they attain a length of one inch the young fish are considered advanced fry.

FUEL REPLACEMENT ENERGY - electric energy generated at a hydroelectric plant as a substitute for energy which would otherwise have been generated by a thermal-electric plant.

GENERATING UNIT - an electric generator together with its prime mover.

GENERATION - act or process of producing electric energy from other forms of energy; also the amount of electric energy so produced.

HABITAT - the natural abode of a plant or animal, including all biotic, climatic, or soil conditions or other environmental influences affecting life.

HATCHERY FISH - fish that are reared from fertilization in a hatchery environment.

HISTORICAL STREAMFLOW - synonymous with observed streamflow over the period of record.

HYDROELECTRIC PLANT - an electric power generating plant in which turbine-generator units are drives by falling or running water.

INACTIVE STORAGE - water occupying inactive storage capacity of a reservoir.

INACTIVE STORAGE CAPACITY - the portion of live storage capacity from which water normally will not be withdrawn, in compliance with operating agreements.

INSTALLED CAPACITY - the total of the capacities as shown by the nameplates of similar kinds of apparatus such as generating units, turbines, synchronous condensers, transformers, or other equipment in a station or system.

INTERCHANGE ENERGY - electric energy received by one electric utility system usually in exchange for energy delivered to the other system at another time or place. Interchange energy is to be distinguished from a direct purchase or sale, although accumulated energy balances are sometimes settled for in cash.

INTERRUPTIBLE LOAD - electric power load which may be curtailed at the supplier's discretion, or in accordance with a contractual agreement.

INTERRUPTIBLE POWER - power made available under agreements which permit curtailment or cessation of delivery by the supplier.

LINE LOSS - energy loss and power loss on a transmission or distribution line.

LIVE STORAGE - water occupying live storage capacity of a reservoir.

LIVE STORAGE CAPACITY - the volume of a reservoir exclusive of dead and surcharge storage capacity.

LOAD - the amount of electric power delivered at a given point.

LOAD FACTOR - the ratio of the average load over a designated period to the peak-load occurring in that period.

MANDATORY RULE CURVE - same as Flood Control Rule Curve.

MAXIMUM STREAMFLOW - the maximum rate of flow at a given point during a specified period.

MEDIAN STREAMFLOW - the rate of flow at a given point for which there are equal numbers of greater and lesser flow occurrences during a specified period.

MINIMUM STREAMFLOW - the minimum rate of flow at a given point during a specified period.

MODIFIED FLOW - the observed or historical flow which has been adjusted to a common level of development by correcting for the effects of diversion demand including evaporation, return flow, and changes in storage of upstream reservoirs and lakes. As used in this report, a modified flow is corrected to a 1990 level of irrigation development, and is the flow available for power generation.

NATURAL STREAMFLOW - is the rate of flow at a given point of an uncontrolled stream, or streamflow adjusted to eliminate the effects of all man-made development.

NET ENERGY FOR SYSTEM - the electric energy requirements of a system, including losses, defined as: (1) net generation of the system, plus (2) energy received from others, less (3) energy delivered to other systems for resale.

NONFIRM ENERGY - electric energy having limited or no assured availability.

NONFIRM POWER - power which does not have assured availability to the customer to meet his load requirements.

NORMAL - the average value on an element over the fixed period 1961-90.

OBSERVED STREAMFLOW - is the amount of water that has been historically measured or otherwise determined to have occurred at a specified point in the stream system.

ONE PERCENT ANNUAL CHANCE FLOOD - a flood of a magnitude that has a one-percent chance of being equaled or exceeded in any given year; often referred to as the 100-year flood.

OPERATING RULE CURVE - a curve, or family of curves, indicating how a reservoir is to be operated under specific conditions to obtain best or predetermined results.

OPERATING YEAR - The period from August 1 through July 31 of the following calendar year. The operating year is the time base used in energy production.

Prior to the operating year ending on July 31, 1991, the operating year had been defined as the period from July 1 through June 30 of the following calendar year. This revised definition is based upon an agreement between the signatories to the Pacific Northwest Coordinating Agreement (PNCA).

OUTAGE - the period during which a generating unit, transmission line, or other facility, is out of service.

OVERLOAD CAPABILITY - the maximum load that a machine, apparatus, or device can carry for a specified period of time under specified conditions when operating beyond its normal rating but within the limits of the manufacturer's guarantee, or in the case of expiration of the guarantee, within safe limits as determined by the owner.

PEAK LOAD - the maximum load in a stated period.

PEAKING CAPABILITY - maximum peak load that can be supplied by a generating unit, station, or system in a stated time period. It may be the maximum instantaneous load or the maximum average load over a designated interval of time.

PEAKING CAPACITY - generating equipment normally operated only during the hours of highest daily, weekly, or seasonal loads. Some generating equipment may be operated at certain times as peaking capacity and at other times to serve loads on a round-the-clock basis.

PEAK LOAD PLANT - a power plant which is normally operated to provide power during maximum load periods.

PLANT FACTOR - the ratio of the average load on the plant for the period of time considered to the aggregate rating of all the generating equipment installed in the plant.

POTENTIAL HYDRO ENERGY - the aggregate energy capable of being developed over a specified period by practicable use of the available streamflow and river gradient.

POWER - the time rate of transferring energy. NOTE: The term is frequently used in a broad sense, as a commodity of capacity and energy, having only general association with classic or scientific meaning (see also "Electric Power").

POWER STORAGE - that portion of the active storage, designated to be used for generating electric energy. Sometimes referred to as the power pool.

PRIMARY ENERGY - hydroelectric energy available from continuous power.

PRIME POWER - same as continuous power.

PUMPED STORAGE PLANT - a power plant using an arrangement whereby electric energy is generated for peak load use by using water pumped into a storage reservoir usually during off-peak periods. A pumped storage plant may also be used to provide reserve generating capacity.

RECURRENCE INTERVAL - the average interval in which a flood of a given size is equaled or exceeded as an annual maximum.

REDD - a type of fish-nesting area of a gravel streamed scoured out by salmonids for spawning.

REFILL YEAR - the period from August 1 through July 31 of the following year. The refill year is used in energy production studies.

REGULATED STREAMFLOW - the controlled rate of flow at a given point during a specified period resulting from an actual reservoir operation (observed streamflow below the project), or a theoretical operation.

RESERVE GENERATING CAPACITY - extra generating capacity available to meet unanticipated demands for power or to generate power in the event of loss of generation resulting from scheduled or unscheduled outages of regularly used generating capacity.

RESERVOIR STORAGE - the volume of water in a reservoir at a given time. Also Reservoir Contents.

RESERVOIR CONTENT CAPACITY - same as Reservoir Storage Capacity.

RESERVOIR STORAGE CAPACITY - the volume of a reservoir available to store water.

RETURN FLOW - that portion of the diversion demand that is returned to the stream system and is available for further downstream use.

REVERSIBLE TURBINE - a hydraulic turbine, normally installed in a pumped storage plant, which can be used alternately as a pump and prime mover.

RUN-OF-RIVER PLANT - a hydroelectric power plant using pondage or the flow of the stream as it occurs.

SCHEDULED OUTAGE - the shutdown of a generating unit, transmission line, or other facility, for inspection or maintenance, in accordance with an advance schedule.

SEASONAL STORAGE - water held over from the annual high-water season to the following low-water season.

SECOND-FOOT DAY - volume of water equal to one cubic foot per second flowing continuously for one day of 24 hours.

SECONDARY ENERGY - all hydroelectric energy other than primary energy.

SECTION 7 PROJECTS - those projects that qualify under Section 7 of the Flood Control Act approved 22 December 1944 (58 stat. 890; 33.U.S.C. 709). The Federal Power Act was approved 10 June 1920 (41 Stat. 1063; 16 U.S.C. 79(a)), and other references apply. See list in Appendix C.

SMOLT - an anadromous fish that is physiologically ready to undergo the transition from fresh water to salt water; age varies depending upon species and environmental conditions.

SPAWNING - the laying of eggs, especially by fish.

SPILL - the discharge of water through gates, spillways, or conduits which bypass the turbines of a hydroplant.

STAGE - the height of the water surface in a river or body of water measured above an arbitrary datum, usually at or near the river bottom. Measurements of reservoirs are generally measured above sea level.

STANDARD PROJECT FLOOD - a very large (low frequency) design flood standard applied to the design of major flood control structures and representing the most severe combination of meteorological and hydrological conditions considered reasonably characteristic of a particular region.

STORAGE CAPACITY - same as Reservoir Storage Capacity.

STREAMFLOW - the rate at which water passes a given point in a stream usually expressed in cubic feet per second.

STREAMFLOW DEPLETION - that portion of diversion demand that is permanently removed from the stream system.

SURCHARGE STORAGE CAPACITY - the volume of a reservoir between the crest of an uncontrolled spillway, or the volume between the normal full pool elevation with the crest gates in the normal closed position, and the maximum water surface elevation for which the dam is designated.

SURPLUS CAPACITY - the difference between assured system capacity and the system peak load for a specified period.

SURPLUS ENERGY - generally energy generated that is beyond the immediate needs of the producing system. Specifically for BPA, electric energy generated at Pacific Northwest hydroelectric projects of the Government which would otherwise be wasted because of the lack of a market therefor at any established rate. This energy is frequently sold on an interruptible basis.

TAILWATER - that portion of a river or water body immediately downstream of a dam or powerhouse.

TULE - a fall chinook salmon that spawn in the lower Columbia River that enters the river system in the spawning metamorphosis state and has already lost it shinny silver color.

UNREGULATED STREAMFLOW - regulated streamflow adjusted to eliminate the effects of reservoir regulation, but reflecting the effects of natural storage in lakes and river channels.

UPPER RULE CURVE (URC) - same as Flood Control Rule Curve.

VALLEY STORAGE - the natural storage capacity in a given reach of a stream both within and without the banks. It varies with the position of the water surface.

VARIABLE ENERGY CONTENT CURVE (VECC) - determined for certain large reservoirs which do not have all storage drafted to normal bottom elevation by Base Energy Content Curves. The Variable Energy Content Curves provide for drafts below the Base Energy Content Curve by the amount the forecasted volume inflow is in excess of total requirements for refill of the reservoir, minimum discharge requirements, non-owner requirements for water at-site and upstream, and water required to refill upstream reservoirs. The inflow volume at each reservoir may be reduced by deducting the 95% confidence forecast error, power discharge requirement, non-power requirements upstream (if any), and water required for refill at upstream reservoirs.

The rights, obligations and limitations are the same as those defined by the Energy Content Curve.

VARIABLE REFILL CURVE (VRC) - is the elevation needed to refill a reservoir with 95 percent assurance based on the current runoff forecast.

WATER BUDGET - a specific volume of water set aside in reservoirs to be released in a manner and at a time to provide benefit to the migration of salmonids.

WATER YEAR - The period from October 1 through September 30 of the following calendar year. It is the time base used in hydrology.

WILD FISH - fish that are spawned and reared in natural redds, as opposed to hatchery produced stock.

APPENDIX B

ABBREVIATIONS

ab or abv	- above
AER	- actual energy regulation
af	- acre-feet
AOP	- assured operating plan
ARC	- assured refill curve
BC Hydro	- British Columbia Hydro & Power Auth
BDT	- binary decimal transmitter
BIA	- Bureau of Indian Affairs
BiOp	- Biological Opinion
bl or blw	- below
BLM	- Bureau of Land Management
Bonneville	- Bonneville Power Administration
BPA	- Bonneville Power Administration
BWMP	- base water monitoring program
CAFE	- CROHMS automatic front end
CBIAC	- Columbia Basin Inter-Agency Committee
CBTT	- Columbia Basin Teletype Circuit
CBT	- Columbia Basin Telecommunications
CF	- Coast Fork
cfs	- cubic feet per second
COE	- Corps of Engineers
COFO	- Committee on Fishery Operation
Corps	- Corps of Engineers
CPO	- coordinated plan of operation
CRC	- critical rule curve
CRFS	- Columbia River Forecast Service
CRITFC	- Columbia River Inter-Tribal Fish Commission
CROHMS	- Columbia River Operational Hydromet Management System
CRT	- cathode ray tube
CRWMG	- Columbia River Water Management Group
DO	- dissolved oxygen
DTF	- Depletions Task Force
ECC	- energy content curve
EHV	- extra high voltage
EPA	- Environmental Protection Agency
FCRC	- flood control rule curve
FDR Lake	- Franklin D Roosevelt Lake (Grand Coulee Reservoir)
FELCC	- firm energy load carrying capability
FERC	- Federal Energy Regulatory Commission
FLCC	- firm load carrying capability
FPC	- Fish Passage Center
GOES	- Geosynchronous Orbiting Environmental Satellite
HDC	- Hydromet Data Committee
IDWR	- Idaho Department of Water Resources
IJC	- International Joint Commission
IPC	- Idaho Power Company
kaf	- thousand acre-feet
kcfs	- thousand cubic feet per second
ksfd	- thousand second-foot days
LARC	- limited automatic remote collector
LLECC	- lower limits energy content curve
m	- meter
Maf	- million acre-feet
mcy	- million cubic yards
MF	- Middle Fork
mg/l	- milligrams per liter
mm	- millimeters
MRC	- mandatory rule curve
MSL	- mean sea level
MWh	- MegaWatt-hours
NASA	- National Aeronautics and Space Admin
NF	- North Fork
NPD	- North Pacific Div, Corps of Engineers
NPP	- Portland District, Corps of Engineers
NPPC	- Northwest Power Planning Council
NPS	- Seattle District, Corps of Engineers
NPW	- Walla Walla Dist, Corps of Engineers
nr	- near
NRCS	- Natural Resources Conservation Service
NRFC	- Northwest River Forecast Center
NWS	- National Weather Service
ODFW	- Oregon Department of Fish and Wildlife
ORC	- operating rule curve
PNCA	- Pacific Northwest Coordination Agrem't
PNRBC	- Pacific Northwest River Basins Com
PUD	- Public Utility District
Puget Power	- Puget Sound Power and Light Company
R	- river
RCC	- Reservoir Control Center, NPD, COE
Reclamation	- US Bureau of Reclamation
RM	- river mile

SF	- South Fork
sfd	- second-foot day
SI	- System International d'Unites
Seattle	- City of Seattle, Department of Light
Tacoma	- City of Tacoma, Department of Light
URC	- upper rule curve
USBR	- US Bureau of Reclamation
USDA	- US Department of Agriculture
USFS	- US Forest Service
USGS	- US Geological Survey
VECC	- variable energy content curve
VRC	- variable refill curve
WDOE	- Washington Department of Ecology
WF	- West Fork
WQI	- water quality index
WY	- Water Year (Oct 1 - Sep 30)
YRBWEP	- Yakima River Basin Water Enhancement Project

NOTE: Additional abbreviations and their definitions will be found on page 140 of Appendix C.

APPENDIX C

PERTINENT DATA ON SELECTED DAMS AND RESERVOIRS

This appendix provides a comprehensive list of dams and reservoirs in the Columbia and coastal basins. The criteria for selecting the listed projects were to include all impoundments having 5,000 af or more of active storage or a minimum of five MegaWatts of hydroelectric generating capacity.

Reference sources used were:

1. RECLAMATION PROJECT DATA. United States Department of Interior.

2. RESERVOIRS AND HYDRO-ELECTRIC STATIONS. Northwest Power Pool.

3. ELECTRIC POWER PLANTS IN THE PACIFIC NORTHWEST AND ADJACENT AREAS.

4. COLUMBIA-NORTH PACIFIC REGION COMPREHENSIVE FRAMEWORK STUDY. Pacific Northwest River Basins Commission, Sept 1972.

5. PROJECT DATA AND OPERATING LIMITS, Columbia River and Tributaries Review Study (CRT) 49 (Revised), Book 1; and (CRT) 69, Book 2; both dated July 1989.

6. Other miscellaneous reports.

The pertinent data given in this appendix are the most complete information available at the time of publication. Any additions or corrections to the tabulation will be noted in further publications. Pertinent data included in the tabulations are:

1. CBT Identifiers. The three or four letter abbreviation used to identify projects when data are reported on the Columbia Basin Telecommunications and CROHMS data collection systems. For additional information consult the CBT USER'S MANUAL published by the North Pacific Division, Corps of Engineers, at the address inside the back cover of this report.

2. Year of Completion. Usually, the year the project began controlling the impoundment of water. This is usually prior to the completion of the installation of all the powerhouse generators. In some cases the date of completion is the date of the latest modification or installation of the last generator unit.

3. River. River on which the project is located, or, for off-stream impoundments, the stream from which the major water supply is derived.

4. River Mile. The distance, in statue miles, from the mouth of the river, on which the project is located, to the axis of the dam, as measured along the main river channel.

5. Owner or Operator. These include both publicly owned projects (Federal or other governmental bodies) and privately owned projects. Abbreviations are explained in last page of tabulations.

6. Remarks. Self-explanatory.

7. Project Functions. Water resource uses for which the project is authorized and operated. The major functions include one or more of the following: flood control, energy generation, irrigation, navigation, recreation, conservation, etc. Abbreviations are explained on last page of tabulation.

8. Normal Maximum Forebay. The top of the normal operating pool range, expressed in feet of elevation above mean sea level. Some projects may have surcharge above the listed maximum forebay elevation, either by adding flashboards or because the added head is required to pass inflow through the outlet structure. Some large natural lakes such as Kootenay, Pend Oreille, Coeur d'Alene and Flathead, will experience involuntary storage above the listed normal maximum pool during periods of unusually high inflows due to the constriction at the natural outlet of the lake.

9. Normal Minimum Forebay. The bottom of the normal operating range, expressed in feet of elevation above mean sea level. Under special conditions some reservoirs may be drawn below this level for a limited period of time.

10. Storage In 1,000 Acre-Feet. Active storage between normal maximum and normal minimum forebay elevations.

11. Top Foot Storage. The volume of storage, in 1,000 acre-feet, in the top foot of the reservoir.

12. Installed Generation. Number of units. The number of existing units or the number being installed under existing contracts.

13. Generation Capacity of all installed hydroelectric turbines, in cfs, rated according to the rate of water usage.

14. Generation Capacity of all installed hydroelectric generators, in MegaWatts, rated according to the amount of Power they can generate. (Nameplate capacity and Station service capacity if applicable, but not including Overload capacity.)

15. Normal Maximum Head. The difference, in

feet, between the normal maximum forebay and the average tailwater elevation with all units operating. The heads shown in this preliminary tabulation are those given in the Northwest Power Pool list of projects or the Reclamation Project Data publication.

16. Average Annual Discharges. Update to 25-year averages, where available.

For additional information on the following projects consult the **Project Data and Operating Limits,** CRT 49 Book 1 (Revised), and **Project Data and Operating Limits,** CRT 69 Book 2, both dated July 1989, published by the NPD, Corps of Engineers, address on the inside of the back cover.

PERTINENT DATA INDEX

The following table alphabetizes the projects listed in the Pertinent Data table at the end of this appendix. This latter table lists projects in downstream order whereas the former table cross references these projects numerically for quicker reference.

UPPER COLUMBIA

No.	Project
5	Aberfeldie
39	Albeni Falls
23	Ashley Lake
35	Black Lake
43	Boundary
41	Box Canyon
16	Brilliant
38	Cabinet Gorge
21	Como Lake
11	Corra Linn
10	Duncan
9	Erickson
18	East Fork Rock Creek
17	Flint Creek
54	Grand Coulee
48	Hayden Lake
26	Hubbart
4	Hugh Keenleyside
22	Hungry Horse
24	Kerr
32	Kicking Horse
12	Kootenay Canal
6	Libby
25	Little Bitterroot Lake
53	Little Falls
52	Long Lake
14	Lower Bonnington
28	Lower Crow
34	Lower Jocko Lake
31	McDonald
1	Mica
29	Mission
50	Monroe Street
7	Moyie Upper
19	Nevada Creek
51	Nine Mile
33	Ninepipe
37	Noxon Rapids
27	Pablo
20	Painted Rock Lake
47	Post Falls
40	Priest Lake
2	Revelstoke
44	Seven Mile
15	South Slocan
8	Smith Creek
42	Sullivan Lake
30	Tabor
36	Thompson Falls
46	Twin Lakes
13	Upper Bonnington
49	Upper Falls
45	Waneta
3	Whatshan

MID-COLUMBIA

No.	Project
23	Bumping Lake
28	Chandler
14	Chelan Lake
7	Chief Joseph
22	Cle Elum
24	Clear Lake
11	Conconully
20	Keechelus
21	Lake Kachees
12	Leader Lake
26	Naches
2	Nile Valley
1	North Dam - Dry Falls
5	O'Sullivan
6	Owhi
3	Pinto
19	Priest Rapids
17	Rock Island
15	Rocky Reach
27	Roza
10	Salmon Lake
16	Snow Lakes
4	Soda Lake
9	Spectale Lake
25	Tieton
18	Wanapum
13	Wells
8	Zosel

UPPER SNAKE

No.	Project	No.	Project	No.	Project
54	Agency Valley	3	Henrys Lake	43	Owyhee
13	American Falls	60	Horseshoe Bend	64	Paddock Valley
46	Anderson Ranch	49	Hubbard	2	Palisades
43	Antelope	4	Island Park	57	Payette Lake
47	Arrowrock	1	Jackson Lake	50	Pleasant Valley
5	Ashton	58	Lake Fork	12	Portneuf
63	Black Canyon	45	Little Camas	11	Ririe
10	Blackfoot	29	Little Wood	61	Sage Hen
35	Bliss	65	Lost Valley	21	Salmon Falls Creek
55	Bully Creek	34	Lower Malad	20	Shoshone Falls
66	C Ben Ross	28	Lower Salmon Falls	52	Silver Creek
37	C J Strike	48	Lucky Peak	38	Swan Falls
59	Cascade	25	Mackay	16	Twin Falls Creek
22	Cedar Creek	32	Magic	31	Twin Lakes
42	Chimney Creek	68	Mann Creek	33	Upper Malad
67	Crane Creek	18	Milner	27	Upper Salmon A
60	Deadwood	14	Minidoka	26	Upper Salmon B
51	Deer Flat	36	Mountain Home	53	Warm Springs
6	Falls River	39	Mountain View	40	Wild Horse
30	Fish Creek	24	Mud Lake	56	Willow Creek #3
8	Gem State	19	Murtaugh	17	Wilson Lake
7	Grassy Lake	15	Oakley	41	Wilson River
9	Grays Lake	23	One Thousand Springs		

LOWER-MIDDLE SNAKE

No.	Project	No.	Project	No.	Project
4	Brownlee	14	Ice Harbor	5	Oxbow
8	Brundage	11	Lower Granite	3	Thief Valley
10	Dworshak	13	Lower Monumental	1	Unity
7	Goose Lake	12	Little Goose	9	Wallowa Lake
6	Hells Canyon	2	Mason		

LOWER COLUMBIA

No.	Project	No.	Project	No.	Project
12	Arthur B Bowman	10	Haystack	15	Pelton
19	Bonneville	6	John Day	17	Powerdale
22	Bull Run	30	Mayfield	14	Round Butte
20	Bull Run #1	3	McKay	23	Swift #1
21	Bull Run #2	2	McNary	24	Swift #2
4	Cold Springs	26	Merwin	16	The Dalles
18	Condit	1	Mill Creek	11	Wasco
7	Crane Prairie	29	Mossyrock	8	Wickiup
9	Crescent Lake	13	Ochoco	5	Willow Creek
28	Cowlitz Falls	27	Packwood	25	Yale

WILLAMETTE

No.	Project	No.	Project	No.	Project
18	Big Cliff	25	Faraday	26	River Mill
11	Blue River	14	Fern Ridge	19	Scoggins
7	Carmen	16	Foster	8	Smith
5	Cottage Grove	15	Green Peter	22	Stone Creek
10	Cougar	1	Hills Creek	21	Timothy Lake
17	Detroit	12	Leaburg	9	Train Bridge
3	Dexter	2	Lookout Point	20	T W Sullivan
6	Dorena	24	North Fork	13	Walterville
4	Fall Creek	23	Oakgrove Powerhouse		

PUGET SOUND AND COASTAL

No.	Project	No.	Project	No.	Project
42	Agate	24	Glines Canyon	35	Prospect #1
19	Alder	5	Gorge	36	Prospect #2
47	Applegate	8	Henry M Jackson	37	Prospect #3
14	Cedar Falls	15	Howard A Hanson	3	Ross
27	Clearwater #1	44	Howard Prairie	32	Slide Creek
28	Clearwater #2	43	Hyatt	11	Snoqualmie #1
22	Cushman #1	1	Koma Kulshan	12	Snoqualmie #2
23	Cushman #2	45	Kenne Creek	33	Soda Springs
4	Diablo	20	La Grand	30	Toketee
18	Electron	9	Lake Chaplain	13	Tolt
39	Elk Creek	2	Lake Whatcom	10	Twin Falls
46	Emigrant Lake	26	Lemolo #1	6	Upper Baker
31	Fish Creek	29	Lemolo #2	17	White River
40	Fish Lake	38	Lost Creek	25	Wynoochee
41	Fourmile Lake	7	Lower Baker	21	Yelm
34	Galesville	16	Mud Mountain		

PERTINENT DATA FOR SELECTED DAMS AND RESERVOIRS

	DAM	CBTT IDENT	YEAR COMP-LETION	LOCATION RIVER	MILE	OWNER OR OPERATOR	REMARKS
	UPPER COLUMBIA RIVER						
1	MICA	MCDB	1973	COLUMBIA	1018.0	B C HYDRO	KINBASKET LK FORMLY MCNAUGHTON LK
2	REVELSTOKE	REVB	1983	COLUMBIA	934.0	B C HYDRO	
3	WHATSHAN	WSHB	1971	WHATSHAN	5.0	B C HYDRO	
4	HUGH KEENLEYSIDE	ARDB	1968	COLUMBIA	780.0	B C HYDRO	ARROW LAKE
5	ABERFELDIE	ABEB	1922	BULL	8.4	B C HYDRO	
6	LIBBY	LIB	1973	KOOTENAI	221.9	COE	LAKE KOOCANUSA
7	MOYIE UPPER		1941	MOYIE	1.8	B FERRY	
8	SMITH CREEK		1990	SMITH CREEK		SMITH	
9	ERICKSON		1933	GOAT	7.7	W KOOTENAY	
10	DUNCAN	DCDB	1967	DUNCAN	8.3	B C HYDRO	DUNCAN RESERVOIR
11	CORRA LINN	CORB	1932	KOOTENAY	16.1	W KOOTENAY	KOOTENAY LAKE
12	KOOTENAY CANAL		1975	OFF KOOTENAY	-	B C HYDRO	DIVERTS WATER FROM KOOTENAY LAKE
13	UPPER BONNINGTON		1907	KOOTENAY	14.8	W KOOTENAY	
14	LOWER BONNINGTON			KOOTENAY	14.3	W KOOTENAY	RUN-OF-RIVER PROJECTS D/S CORB
15	SOUTH SLOCAN		1928	KOOTENAY	13.4	W KOOTENAY	
16	BRILLIANT	BRDB	1944	KOOTENAY	1.9	COMINCO	
17	FLINT CR		1901	FLINT CR	38.8	MONTANA	GEORGETOWN LAKE
18	EAST FORK ROCK CR		1937	E F ROCK CR	9.7		
19	NEVADA CR		1938	NEVADA CR		S MONTANA	
20	PAINTED ROCK LAKE		1940	W F BITTERROOT	19.8		
21	COMO	CMO	1910	ROCK CR	5.0	USBR/BID	
22	HUNGRY HORSE *	HGH	1953	S F FLATHEAD	5.2	USBR	GENERATOR UPGRAGE 1993
23	ASHLEY LAKE			ASHLEY CR	26.2	ASH	
24	KERR *	KER	1938	FLATHEAD	72.0	MONTANA	FLATHEAD LAKE
25	L BITTERROOT LAKE		1918	LITTLE BITTERROOT	70.3		
26	HUBBART		1924	LITTLE BITTERROOT	55.8		
27	PABLO		1914	FLATHEAD		BIA	
28	LOWER CROW		1933	CROW CR	3.4	BIA	
29	MISSION		1935	MISSION CR	16.7	BIA	
30	TABOR		1919	DRY CR			ST MARYS LAKE
31	McDONALD		1919	POST CR	12.4	BIA	
32	KICKING HORSE		1930	CROW CR		BIA	
33	NINEPIPE		1911	FLATHEAD		BIA	
34	LOWER JOCKO LAKE		1937	N F JOCKO	15.0	BIA	
35	BLACK LAKE		1967	JOCKO CR		BIA	
36	THOMPSON FALLS	TOM	1917	CLARK FORK	208.0	MONTANA	
37	NOXON RAPIDS	NOX	1959	CLARK FORK	169.7	WWP	
38	CABINET GORGE	CAB	1953	CLARK FORK	149.9	WWP	
39	ALBENI FALLS	ALF	1955	PEND OREILLE	86.9	COE	LAKE PEND OREILLE
40	PRIEST LAKE	PSL	1951	PRIEST	42.0	WWP	STORAGE FOR D/S POWER
41	BOX CANYON	BOX	1955	PEND OREILLE	34.5	PEND	
42	SULLIVAN LAKE		1931	OUTLET CR	5.0	PEND	TRIBUTARY TO SULLIVAN CR
43	BOUNDARY	BDY	1967	PEND OREILLE	17.0	SEATTLE	
44	SEVEN MILE		1979	PEND d'OREILLE	6.0	B C HYDRO	
45	WANETA	WANB	1954	PEND d'OREILLE	0.5	COMINCO	
46	TWIN LAKES			STRANGER CR			
47	POST FALLS	POS	1906	SPOKANE	102.1	WWP	COEUR D'ALENE LAKE
48	HAYDEN LAKE	HAD	1948	HAYDEN CR		HAYDEN	
49	UPPER FALLS		1922	SPOKANE	74.2	WWP	DAM ADDED
50	MONROE STREET		1890	SPOKANE	74.2	WWP	
51	NINE MILE	NIN	1908	SPOKANE	58.1	WWP	POWERHOUSE REPLACED 1992
52	LONG LAKE	LLK	1915	SPOKANE	33.9	WWP	LAKE SPOKANE
53	LITTLE FALLS	LIT	1910	SPOKANE	29.3	WWP	
54	GRAND COULEE *	GCL	1942	COLUMBIA	596.6	USBR	FRANKLIN D ROOSEVELT LAKE

Sheet 1a of 5

PERTINENT DATA FOR SELECTED DAMS AND RESERVOIRS

DAM	FUNCTION	NORMAL MAXIMUM FOREBAY	NORMAL MINIMUM FOREBAY	STORAGE (1000 AC FT) ACTIVE	STORAGE (1000 AC FT) TOP FT	INSTALLED GENERATION NO OF UNITS	INSTALLED GENERATION CAP IN CFS	INSTALLED GENERATION CAP IN MW	NORMAL MAXIMUM HEAD	AVE ANN DISCHARGE (CFS)
U P P E R C O L U M B I A R I V E R										
MICA	FP	2475.0	2320.0	12046.0	106.00	4	41,600	1,740	615	20,510
REVELSTOKE	FP	1880.0	1830.0	1276.0		4	56,000	1,800	425	
WHATSHAN	P	2104.0	2084.0	83.8	4.36	1	1,330	50.0	677	
HUGH KEENLEYSIDE	FRPNI	1444.0	1377.9	7257.0	128.90	0		0.0	69	40,100
ABERFELDIE	P	2880.0						5.0	275	
LIBBY	FPrc	2459.0	2287.0	4979.5	46.40	5	24,100	525.0	337	11,350
MOYIE UPPER	P	2035.3						2.0	200	
SMITH CREEK	P					3		38		
ERICKSON	P							1.3	65	
DUNCAN	FPI	1892.0	1794.2	1398.6	18.25	0		0.0	120	3,534
CORRA LINN	PFI	1745.3	1733.3	673.0	111.67	3	12,600	40.5	58	27,570
KOOTENAY CANAL	P	1745.3	1729.0			4	26,000	528	245	
UPPER BONNINGTON	P	1682.7				6	13,500	60.0	71	
LOWER BONNINGTON	P					3	9,500	41.0	66	
SOUTH SLOCAN	P	1543.5				3	10,500	54.0	72	
BRILLIANT	PFI	1477.0	1472.0			4	18,000	108.8	98	30,650
FLINT CREEK	PR	6429.5	6398.0	31.0	3.00	2	30	1.1	717	30
EASTFORK ROCK CR	I	6055.5	5990.0	16.0	0.44					148
NEVADA CREEK	IR	4616.0	4551.5	12.6	0.38					37
PAINTED ROCK LAKE	IR	4725.5	4625.5	31.7	0.66					294
COMO	I	4242.7	4188.5	35.1	0.94					148
HUNGRY HORSE *	FPIrc	3561.0 %	3336.0	3161.0	23.91	4	8,900	428.0	484	3,517
ASHLEY LAKE	I			30.0	3.00					29
KERR *	PFR	2893.0	2883.0	1218.7	125.56	3	14,346	168.0	187	11,550
L BITTERROOT LAKE	I	3906.5	3898.0	26.0	2.90					
HUBBART	IR	3219.0	3140.0	12.1	0.46					
PABLO	I	3210.2	3179.0	27.1	2.04					
LOWER CROW	I	2877.0	2800.0	10.4	0.34					
MISSION	I	3406.0	3340.7	7.3	0.29					
TABOR	I	4024.0	3911.5	23.3	0.29					
McDONALD	I	3598.0	3545.0	8.2	0.20					
KICKING HORSE	I	3061.9	3042.0	8.4	0.79					
NINEPIPE	C	3010.0	2895.4	14.9	1.60					
LOWER JOCKO LAKE	IR	4340.0	4267.0	6.4	0.12					
BLACK LAKE	I			5.1						
THOMPSON FALLS	P	2396.0	2380.0	15.0	1.45	6	11,100	52.6	63	19,820
NOXON RAPIDS	P	2331.0	2295.0	231.0	7.93	5	50,000	396.9	156	19,370
CABINET GORGE	P	2175.0	2160.0	42.8	3.19	4	35,700	200	111	21,850
ALBENI FALLS	FPNr	2062.5	2051.0	1155.2	94.60	3	33,000	42.6	30	25,340
PRIEST LAKE	PF	2437.6	2434.6	71.3	23.8	0				1,180
BOX CANYON	P	2030.7	2014.0	6.9	2.78	4	28,500	60	42	15,970
SULLIVAN LAKE	P	2588.7	2564.0	31.0	1.29	0			548	
BOUNDARY	P	1990.0	1950.0	27.1	1.65	4	33,000	633.7	275	26,720
SEVEN MILE	P	1715.0	1690.0	21.2	0.48	3	36,000	605	197	26,800
WANETA	PI	1517.8	1502.0	4.2	0.36	4	25,000	283.0	205	27,820
TWIN LAKES	I			15.1	1.89					
POST FALLS	P	2128.0	2120.8	225.0	42.45	6	5,410	15.0	61	6,300
HAYDEN LAKE	ORC			73.0						72
UPPER FALLS	P	1870.5	1864.5	0.8	0.14	1	2,500	10.2	64	6,675
MONROE STREET	P	1806.0	1806.0			1	1,800	14.8	72	6,864
NINE MILE	P	1606.6	1590.0	4.6	0.42	4	5,000	26.0	70	7,220
LONG LAKE	P	1536.0	1512.0	104.2	5.00	4	6,300	70.0	174	7,793
LITTLE FALLS	P	1362.0	1351.0	2.2	0.26	4	7,200	32	84	7,793
GRAND COULEE *	FPIRC	1290.0 @	1208.0	5185.5	80.53	24	280,000	6,180.0	343	107,700

Sheet 1b of 5

PERTINENT DATA FOR SELECTED DAMS AND RESERVOIRS

	DAM	CBTT IDENT	YEAR COMP-LETION	LOCATION RIVER	LOCATION MILE	OWNER OR OPERATOR	REMARKS
	M I D L E C O L U M B I A R I V E R						
1	NORTH DAM(DRY FALLS)	BNK	1951	OFF COLUMBIA R	--	USBR	(PUMP-TURBINE GENERATORS) BANKS LK
2	NILE VALLEY		1918	WILSON CR		NVR	
3	PINTO	PIN	1948	OFF STREAM BANKS L	--	USBR	BILLY CLAPP LAKE FORMERLY (LONG LK)
4	SODA LAKE		1952	OFF STREAM	--	USBR	
5	O'SULLIVAN	POT	1949	CRAB CR	45.8	USBR/GRANT	S COLUMBIA BSN I D POWERHOUSE 1990
6	OWHI			LITTLE NESPELEM			
7	CHIEF JOSEPH	CHJ	1961	COLUMBIA	545.1	COE	RUFUS WOODS LAKE
8	ZOSEL		1927	OKANOGAN	77.4	WHITE	
9	SPECTACLE LAKE		1969	OFF TOATS COULLE CR	--		WHITE NEAR TONASKET, WA
10	SALMON LAKE	SAL	1921	OFF SALMON CR	--	OKANOGAN	CONCONALLY LK (NORTH)
11	CONCONULLY	CCL	1910	SALMON CR	15.5		OKANOGAN CONCONALLY RESERVOIR
12	LEADER LAKE		1910	LOUP LOUP CR		PVP	
13	WELLS *	WEL	1967	COLUMBIA	515.1	DOUGLAS	LAKE PATEROS
14	CHELAN	CHL	1927	CHELAN	4.8	CHELAN	
15	ROCKY REACH *	RRH	1961	COLUMBIA	473.7	CHELAN	LAKE ENTIAT
16	SNOW LAKES			SNOW CR		CI	
17	ROCK ISLAND	RIS	1933	COLUMBIA	453.4	CHELAN	2ND POWERHOUSE ADDED 1981
18	WANAPUM *	WAN	1964	COLUMBIA	415.8	GRANT	
19	PRIEST RAPIDS *	PRD	1961	COLUMBIA	397.1	GRANT	
20	KEECHELUS	KEE	1917	YAKIMA	214.5	USBR	
21	LAKE KACHESS	KAC	1912	KACHESS	0.9	USBR	
22	CLE ELUM	CLE	1933	CLE ELUM	8.2	USBR	
23	BUMPING LAKE	BUM	1910	BUMPING	17.0	USBR	
24	CLEAR LAKE	CLR	1914	N F TIETON	40.2	USBR	RAISED 18 FT IN 1918, REHAB 1964
25	TIETON	RIM	1925	TIETON	21.3	USBR	RIMROCK LAKE
26	NACHES		1906	NACHES	9.7	PP&L	
27	ROZA	RZA	1939	YAKIMA	127.9	USBR	
28	CHANDLER	CDR	1956	YAKIMA	47.1	USBR	
	U P P E R S N A K E R I V E R						
1	JACKSON LAKE	JCK	1911	SNAKE	1000.2	USBR	
2	PALISADES *	PAL	1957	SNAKE	901.6	USBR	REBUILT 1995
3	HENRYS LAKE	HEN	1923	HENRYS FORK	117.4	N FORK	
4	ISLAND PARK	ISL	1938	HENRYS FORK	1.7	USBR	
5	ASHTON		1917	HENRYS FORK	45.0	UP&L	
6	FALLS RIVER		1993	FALLS		MHP	
7	GRASSY LAKE	GRS	1939	GRASSY CR	48.0	USBR	INTER-BASIN TRANSFER TO BLACKFOOT
8	GEM STATE		1993	SNAKE		MHP	
9	GRAYS LAKE		1924	WILLOW CR		BIA	
10	BLACKFOOT	BLK	1910	BLACKFOOT	69.0	BIA	ENLARGED IN 1924, REHAB 1986
11	RIRIE *	RIR	1977	WILLOW CR	17.0	USBR	
12	PORTNEUF		1951	PORTNEUF	82.7	PM	
13	AMERICAN FALLS *	AMF	1927	SNAKE	714.0	USBR	
14	MINIDOKA	MIN	1911	SNAKE	675.0	USBR	LAKE WALCOTT
15	OAKLEY	OKL	1913	GOOSE CR	29.9	OAKLEY	
16	TWIN FALLS CREEK		1935	SNAKE	617.4	IDAHO	REBUILT 1995
17	WILSON LAKE		1909	OFF STREAM	7.4	N SIDE	
18	MILNER	MIL	1905	SNAKE	640.0	TF/IDAHO	REBUILT 1932, POWERHOUSE 1992
19	MURTAUGH		1905	OFF STREAM		TF	
20	SHOSHONE FALLS		1904	SNAKE	614.7	IDAHO	
21	SALMON FALLS CREEK	SAM	1911	SALMON FALLS CR	46.0	SALMON	
22	CEDAR CREEK		1920	CEDAR CR		CEDAR	
23	1000 SPRINGS		1912	SNAKE (SPRINGS)	584.7	IDAHO	
24	MUD LAKE	MUDI	1921	CAMAS CR		OWSLEY	TERMINAL LAKE WITH DIKES
25	MACKAY	MAC	1918	BIG LOST		B LOST R	
26	UPPER SALMON B		1947	SNAKE	580.8	IDAHO	
27	UPPER SALMON A		1937	SNAKE	579.6	IDAHO	
28	LOWER SALMON FALLS		1949	SNAKE	572.9	IDAHO	
29	LITTLE WOOD *	WOD	1936	LITTLE WOOD	78.8	USBR	PROJECT ENLARGED 1960
30	FISH CREEK			FISH CR (WOOD)		CAREY V	

Sheet 2a of 5

PERTINENT DATA FOR SELECTED DAMS AND RESERVOIRS

DAM	FUNC-TION	NORMAL MAXIMUM FOREBAY	NORMAL MINIMUM FOREBAY	STORAGE (1000 AC FT) ACTIVE	STORAGE (1000 AC FT) TOP FT	INSTALLED GENERATION NO OF UNITS	INSTALLED GENERATION CAP IN CFS	INSTALLED GENERATION CAP IN MW	NORMAL MAXIMUM HEAD	AVE ANN DISCHARGE (CFS)
M I D D L E C O L U M B I A R I V E R										
NORTH DAM(DRY FALLS)	IP	1570.0	1539.5	715.0	27.00	6	19,200	314.0	280	
NILE VALLEY	I			6.7						
PINTO	I	1335.0	1312.8	21.2		0				
SODA LAKE	I	1008.2	1008.2							
O'SULLIVAN	IFP	1046.5	1022.5	332.2	29.00	1		6.7		
OWHI	I			5.3	0.54					
CHIEF JOSEPH	Pirq	956.0	930.0	116.0	7.80	27	219,000	2,075.0	177	108,000
ZOSEL	M	911.5	909.0	17.0		0				
SPECTACLE LAKE	I	1371.0	1352.0	6.2		0				
SALMON LAKE	I	2324.3	2282.1	10.5	0.31	0				3
CONCONULLY	I	2287.0	2232.4	13.0	0.45					29
LEADER LAKE	IP			5.3						
WELLS *	PFR	781.0	771.0	74.0	10.70	10	220,000	774.3	72	112,500
CHELAN	PR	1100.0	1079.0	677.4	32.90	2	2,016	48.0	393	2,024
ROCKY REACH *	PFR	707.0	703.0	36.0	9.20	11	220,000	1,273.2	93	121,320
SNOW LAKES				12.5	0.18					
ROCK ISLAND	P	613.0	609.0	9.5	2.50	18	220,000	788.0	54	118,200
WANAPUM *	PFR	571.0	560.0	161.0	13.80	10	178,000	831.3	83.5	118,300
PRIEST RAPIDS *	PFR	488.0	481.5	44.0	7.00	10	187,000	288.5	82.5	118,400
KEECHELUS	I	2517.0	2425.0	158.0	2.56					330
LAKE KACHESS	I	2262.0	2192.8	239.0	4.54					285
CLE ELUM	I	2240.0	2110.0	436.9	4.80					909
BUMPING LAKE	I	3426.0	3389.6	33.7	1.30					291
CLEAR LAKE	I	3018.0	2960.0	5.3	0.27					
TIETON	I	2926.0	2766.0	198.0	2.53	0				489
NACHES	P	1496.4				2	495	4.5	151	
ROZA	PIC		1220.5			1	1,080	11.3	160	
CHANDLER	PI	618.5				2	1,500	12.0	122	
U P P E R S N A K E R I V E R										
JACKSON LAKE	IFrc	6760.0	6730.0	847.0	25.20	0				1,410
PALISADES *	IFPrc	5620.0	5497.9	1200.0	16.24	4	14,500	118.8	245	6,220
HENRYS LAKE	IPF	6473.9	6457.2	90.4						53
ISLAND PARK	I	6302.0	6239.0	127.3	7.80					585
ASHTON	P	5157.4				3	1,930	5.8	48	1,450
FALLS RIVER	P					2	750	9.1	252	
GRASSY LAKE	I	7210.0	7135.0	15.2	0.31					40
GEM STATE	P							22.4		
GRAYS LAKE	I	6388.0		40.0	22.00					
BLACKFOOT	I	6120.5	6086.0	350.0	17.30					
RIRIE *	FRC	5112.8	5023.0	80.5	1.56					180
PORTNEUF	I	5681.0		23.7						142
AMERICAN FALLS *	IFPmrc	4354.5	4295.8	1672.6	56.10	3	12,188	92.3	88	6,910
MINIDOKA	IPF	4245.0	4236.0	95.2	11.70	7	5,000	15.6		6,040
OAKLEY	I	4756.0	4619.0	74.4	1.25					62
TWIN FALLS CREEK	P	3519.4	3507.0	0.9	0.10	1	935	43.7	147	2,850
WILSON LAKE	I	4012.0		18.5	1.43					
MILNER	IPr	4133.8	4122.8			2		58.3		2,550
MURTAUGH	I			5.2						
SHOSHONE FALLS	IP	3362.0	3357.0	0.6	0.12	3	860	12.5	212	
SALMON FALLS CREEK	I	5025.8	4445.8	182.7	3.40	0				
CEDAR CREEK	I			23.7						27
1000 SPRINGS	P	3061.9	3061.9	0		3	560	8.0	182	
MUD LAKE	I			44.0						
MACKAY	I	6066.5	6007.0	44.4	1.36					306
UPPER SALMON B	P	2878.2	2876.2	1.2	0.60	2	6,500	19.5	37	
UPPER SALMON A	P	2841.3	2841.1			2	6,000	17.6	43	
LOWER SALMON FALLS	IP	2798.6	2792.6	4.6	0.83	4	16,000	70.0	60	8,410
LITTLE WOOD *	IC	5237.3	5127.4	30.0	0.57					135
FISH CREEK	I			12.7	0.56					

Sheet 2b of 5

PERTINENT DATA FOR SELECTED DAMS AND RESERVOIRS

	DAM	CBTT IDENT	YEAR COMPLETION	LOCATION RIVER	LOCATION MILE	OWNER OR OPERATOR	REMARKS
	UPPER SNAKE RIVER						
31	TWIN LAKES		1908	McKINNEY CR (WOOD)		TL	MORMAN RESERVOIR
32	MAGIC	MAG	1917	BIG WOOD	67.5	BIG WOOD	
33	UPPER MALAD		1949	MALAD	1.0	IDAHO	
34	LOWER MALAD		1911	MALAD	0.2	IDAHO	REBUILT 1948
35	BLISS	BLS	1949	SNAKE	560.3	IDAHO	
36	MOUNTAIN HOME		1906	RATTLESNAKE CR		MT HOME	
37	C J STRIKE	CJS	1952	SNAKE	492.0	IDAHO	
38	SWAN FALLS	SWA	1900	SNAKE	457.7	IDAHO	REBUILT 1918, 1994
39	MOUNTAIN VIEW		1969	BOYLE CR		DVR	BLUE LAKE
40	WILD HORSE	WLD		OWYHEE	286.0	BIA	NEAR ELKO, NV
41	WILSON RIVER			S F OWYHEE			
42	CHIMNEY CREEK			S F OWYHEE			
43	ANTELOPE			JACK CR		JORDAN	
44	OWYHEE	OWY	1938	OWYHEE	28.5	USBR/OID	POWERHOUSE ADDED 1991
45	LITTLE CAMAS		1912	LITTLE CAMAS CR	22.0	MT HOME	INTER-BASIN DIVISION
46	ANDERSON RANCH *	AND	1950	S F BOISE	43.5	USBR	
47	ARROWROCK *	ARK	1915	BOISE	75.4	USBR	DAM CREST RAISE 5' IN 1935
48	LUCKY PEAK	LUC	1961	BOISE	63.8	COE	POWERHOUSE CONSTRUCTED BY SCL 1994
49	HUBBARD		1902	OFF STREAM	--	BOISE	NEAR BOISE, ID
50	PLEASANT VALLEY		1925	BLACKS CR		PV	
51	DEER FLAT	LOW	1908	OFF STREAM	--	BOISE	LAKE LOWELL; DIV FROM BOISE R
52	SILVER CREEK		1969	SILVER CR			MOON RESERVOIR
53	WARM SPRINGS *	WAR	1919	M F MALHEUR	108.0	USBR	
54	AGENCY VALLEY *	BEU	1935	N F MALHEUR	15.0	USBR/VALE	BEULAH RESERVOIR
55	BULLY CREEK *	BUL	1963	BULLY CR	12.5	USBR/VALE	
56	WILLOW CREEK #3		1911	MALHEUR		ORCHARDS	
57	PAYETTE LAKE	PAY	1944	N F PAYETTE	75.4	LAKE	
58	LAKE FORK		1926	L F PAYETTE	18.0	LAKE	
59	CASCADE	CSC	1948	N F PAYETTE	40.2	USBR	
60	DEADWOOD	DED	1931	DEADWOOD	24.4	USBR	
61	HORSESHOE BEND		1993	PAYETTE		HBH	
62	SAGE HEN		1938	SAGE HEN CR		SQUAW	
63	BLACK CANYON	EMM	1924	PAYETTE	38.7	USBR	
64	PADDOCK VALLEY		1950	LITTLE WILLOW CR		L WILLOW	
65	LOST VALLEY		1929	LOST CR		L VALLEY	
66	C BEN ROSS		1936	OFF STREAM		L WEISER	
67	CRANE CREEK		1920	CRANE CR	12.5	CRANE	
68	MANN CREEK	MAN	1967	MANN CR	13.0	USBR	
69							
	LOWER AND MIDDLE SNAKE						
1	UNITY	UNY	1938	BURNT	63.6	USBR	
2	MASON *	PHL	1968	POWDER	133.7	USBR	PHILLIPS LAKE
3	THIEF VALLEY	THF	1932	POWDER	70.0	USBR	
4	BROWNLEE *	BRN	1959	SNAKE	285.0	IDAHO	
5	OXBOW *	OXB	1961	SNAKE	273.0	IDAHO	
6	HELLS CANYON *	HCD	1967	SNAKE	247.0	IDAHO	
7	GOOSE LAKE		1919	GOOSE CR		GOOSE	
8	BRUNDAGE		1935	BRUNDAGE CR		BRUNDAGE	ENLARGED IN 1987
9	WALLOWA LAKE	WAL	1929	WALLOWA LAKE		ADC	WALLOWA LAKE
10	DWORSHAK	DWR	1973	N F CLEARWATER	1.9	COE	
11	LOWER GRANITE	LWG	1975	SNAKE	107.5	COE	
12	LITTLE GOOSE	LGS	1970	SNAKE	70.3	COE	LAKE BRYAN
13	LOWER MONUMENTAL	LMN	1970	SNAKE	41.6	COE	LAKE HERBERT G WEST
14	ICE HARBOR	IHR	1961	SNAKE	9.7	COE	LAKE SACAJAWEA

Sheet 3a of 5

PERTINENT DATA FOR SELECTED DAMS AND RESERVOIRS

DAM	FUNCTION	NORMAL MAXIMUM FOREBAY	NORMAL MINIMUM FOREBAY	STORAGE (1000 AC FT) ACTIVE	STORAGE (1000 AC FT) TOP FT	INSTALLED GENERATION NO OF UNITS	INSTALLED GENERATION CAP IN CFS	INSTALLED GENERATION CAP IN MW	NORMAL MAXIMUM HEAD	AVE ANN DISCHARGE (CFS)
U P P E R S N A K E R I V E R										
TWIN LAKES	I			31.2	4.04					460
MAGIC	I	4935.0	4821.4	191.5	3.90					
UPPER MALAD	P	3001.3	3007.0			1	800	9.0	124	
LOWER MALAD	P	2876.6	2876.6	0		1	1,200	15.0	153	
BLISS	P	2654.0	2644.0	2.3	0.25	3	15,000	75	70	10,060
MOUNTAIN HOME	I			4.2						
C J STRIKE	P	2455.0	2450.0	36.8	7.40	3	13,800	89.1	88	9,970
SWAN FALLS	P	2314.2	2306.0	6.8	0.89	2	8,000	25	24	10,220
MOUNTAIN VIEW	MR			8.3						
WILD HORSE	I			71.7	2.93					
WILSON RIVER	I			9.0	.83					
CHIMNEY CREEK	I			9.0	0.54					
ANTELOPE	I			55.0						
OWYHEE	IP	2670.0	2590.2	715.0	13.90	1		8		1,604
LITTLE CAMAS	I	4924.0	4904.0	18.4	1.40					
ANDERSON RANCH *	IFP	4196.0	4044.0	418.0	4.74	2	20,000	27.0	330	963
ARROWROCK *	IF	3216.0	2974.0	285.5	3.12					2,411
LUCKY PEAK	FIqcrp	3055.0	2905.0	264.4	2.85	4	5,500	87.5		2,733
HUBBARD	I	2776.0	2757.3	4.1						
PLEASANT VALLEY	I			3.6						
DEER FLAT	I	2530.5	2503.5	169.0	9.84					
SILVER CREEK	I			5.7						
WARM SPRINGS *	IF	3406.0	3327.0	191.0	4.60	0				200
AGENCY VALLEY *	IF	3340.0	3263.2	59.9	1.90					141
BULLY CREEK *	IF	2516.0	2456.6	30.0	0.95					34
WILLOW CREEK #3	I			20.4						
PAYETTE LAKE	IR	4990.0	4984.0	27.7	5.00					369
LAKE FORK	I	5119.0	5101.0	20.4	1.50					147
CASCADE	IP	4828.0	4787.5	653.0	28.30					983
DEADWOOD	IR	5334.0	5202.8	162.0	3.00					235
HORSESHOE BEND	P					2	3,500		9.5	
SAGE HEN	I			5.2						
BLACK CANYON	IP	2497.5	2409.3	44.7	1.09	2	1,540	18.0	94	2,830
PADDOCK VALLEY	I			36.4	1.50					
LOST VALLEY	I	4774.7	4751.6	7.1						41
C. BEN ROSS	I			7.8	0.35					
CRANE CREEK	I	3245.0	3197.0	57.7	2.90					74
MANN CREEK	IR	2889.0	2825.0	11.7	0.28					
L O W E R & M I D D L E S N A K E										
UNITY	I	3820.0	3776.5	25.2	0.93	0				
MASON *	CIFP	4062.4	3985.5	52.5	2.45					100
THIEF VALLEY	I	3133.0	3084.0	17.4	0.74					117
BROWNLEE *	FPRN	2077.0	1976.0	975.3	14.50	5	34,500	675	272	17,650
OXBOW *	P	1805.0	1800.0	5.4	0.99	4	25,000	220.0	120	17,800
HELLS CANYON *	PN	1688.0	1635.0	98.8	2.38	3	30,000	450.0	210	18,760
GOOSE LAKE	I			6.6						
BRUNDAGE	I	6238.5		7.33	0.33					
WALLOWA LAKE	IR			37.5	1.29					
DWORSHAK	FPNcr	1600.0	1445.0	2015.8	17.85	3	10,500	400.0	627	5,820
LOWER GRANITE	PNcriq	738.0	733.0	53.0	10.70	6	130,000	810.0	100	49,680
LITTLE GOOSE	PNcriq	638.0	633.0	49.6	9.92	6	130,000	810.0	98	47,230
LOWER MONUMENTAL	PNcriq	540.0	537.0	20.0	6.74	6	130,000	810.0	100	
ICE HARBOR	PNcriq	440.0	437.0	25.0	8.33	6	196,000	603.0	100	

Sheet 3b of 5

PERTINENT DATA FOR SELECTED DAMS AND RESERVOIRS

	DAM	CBTT IDENT	YEAR COMP-LETION	LOCATION RIVER	LOCATION MILE	OWNER OR OPERATOR	REMARKS
	L O W E R C O L U M B I A R I V E R						
1	MILL CREEK	MLL	1942	OFF STREAM	--	COE	VIRGIL B. BENNINGTON LAKE
2	McNARY	MCN	1957	COLUMBIA	292.0	COE	LAKE WALLULA
3	McKAY	MCK	1927	McKAY CR	4.9	USBR	
4	COLD SPRINGS	CLS	1908	OFF STREAM		USBR/HERM	FED FROM UMATILLA RIVER
5	WILLOW CREEK	WIL	1984	WILLOW CR	52.4	COE	HEPPNER, OREGON
6	JOHN DAY	JDA	1968	COLUMBIA	215.6	COE	LAKE UMATILLA
7	CRANE PRAIRIE	CRA	1940	DESCHUTES	238.3	USBR/COID	
8	WICKIUP	WIC	1940	DESCHUTES	226.8	USBR	
9	CRESCENT LAKE	CRE	1922	CRESENT CREEK	29.9	USBR/TID	
10	HAYSTACK	HAY	1957	OFF HAYSTACK CR		USBR/NUID	NEAR MADRAS, OR
11	WASCO	WAS	1959	CLEAR CR	12.1	USBR	
12	ARTHUR B BOWMAN *	PRV	1962	CROOKED	72.5	USBR/OCH	PRINEVILLE RES
13	OCHOCO *	OCH	1920	OCHOCO	10.0	USBR/OCH	REHAB 1950
14	ROUND BUTTE	ROU	1964	DESCHUTES	110.6	PGE	LAKE BILLY CHINOOK
15	PELTON	PEL	1958	DESCHUTES	102.8	PGE	LAKE SIMTUSTUS
16	THE DALLES	TDA	1957	COLUMBIA	191.5	COE	LAKE CELILO, NWCPUD POWERHOUSE 1990
17	POWERDALE		1923	HOOD	3.5	PP&L	
18	CONDIT	UND	1913	WHITE SALMON	3.3	PP&L	
19	BONNEVILLE	BON	1937	COLUMBIA	146.1	COE	UNITS 11-17 IN 1974; 2ND PH 1982
20	BULL RUN #1	BUN	1928	BULL RUN	11.5	PORTLAND	
21	BULL RUN #2	RUN	1961	BULL RUN	6.5	PORTLAND	LAKE BEN MORROW
22	BULL RUN		1912	SANDY	6.5	PGE	LAKE ROSLYN
23	SWIFT #1	SWF	1958	LEWIS	47.9	PP&L	
24	SWIFT #2		1958	LEWIS	44.2	COWLITZ	OPERATED BY PP&L
25	YALE	YAL	1953	LEWIS	34.2	PP&L	
26	MERWIN	MER	1931	LEWIS	19.6	PP&L	LAKE MERWIN (FORMERLY ARIEL DAM)
27	PACKWOOD	PWD	1964	LAKE CR	5.3	WPP	PACKWOOD LAKE
28	COWLITZ FALLS *		1994	COWLITZ	88.6	LEWIS	
29	MOSSYROCK *	MOS	1968	COWLITZ	65.5	TACOMA	RIFFE LAKE (FORMERLY DAVISSON LAKE)
30	MAYFIELD *	MAY	1963	COWLITZ	52.0	TACOMA	
	W I L L A M E T T E R I V E R						
1	HILLS CREEK	HCR	1962	M F WILLAMETTE	47.8	COE	
2	LOOKOUT POINT	LOP	1955	M F WILLAMETTE	21.3	COE	
3	DEXTER	DEX	1955	M F WILLAMETTE	18.0	COE	
4	FALL CREEK	FAL	1965	FALL CR	7.2	COE	
5	COTTAGE GROVE	COT	1942	C F WILLAMETTE	29.7	COE	
6	DORENA	DOR	1949	ROW	7.5	COE	
7	CARMEN	CRM	1962	McKENZIE	87.6	EUGENE	POWER PLANT
8	SMITH	SMH	1963	SMITH	2.1	EUGENE	STORAGE FOR CARMEN POWER PLANT
9	TRAIL BRIDGE	TRB	1963	McKENZIE	81.0	EUGENE	
10	COUGAR	CGR	1963	S F McKENZIE	4.5	COE	
11	BLUE RIVER	BLU	1968	BLUE	1.8	COE	
12	LEABURG	LEA	1930	McKENZIE	33.3	EUGENE	
13	WALTERVILLE		1911	McKENZIE	20.8	EUGENE	
14	FERN RIDGE	FRN	1941	LONG TOM	25.6	COE	
15	GREEN PETER	GPR	1967	MIDDLE SANTIAM	5.5	COE	
16	FOSTER	FOS	1967	SOUTH SANTIAM	37.7	COE	
17	DETROIT	DET	1953	NORTH SANTIAM	60.9	COE	
18	BIG CLIFF	BCL	1953	NORTH SANTIAM	58.1	COE	
19	SCOGGINS *	SCO	1975	SCOGGINS CR	4.8	USBR	HENRY HAGG LAKE
20	T W SULLIVAN	ORC	1889	WILLAMETTE	26.6	PGE	WILLAMETTE FALLS, OREGON CITY
21	TIMOTHY LAKE	TMY	1956	CLACKAMAS	15.8	PGE	STORAGE FOR POWER D/S
22	STONE CREEK		1994	CLACKAMAS		EWEB	
23	OAKGROVE POWERHOUSE	OKG	1924	CLACKAMAS	5.1	PGE	SUPPLIED BY HARRIET & TIMOTHY LKS
24	NORTH FORK	NFK	1924	CLACKAMAS	31.1	PGE	
25	FARADAY	FAD	1907	CLACKAMAS	26.2	PGE	
26	RIVER MILL	EST	1911	CLACKAMAS	23.3	PGE	

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PERTINENT DATA FOR SELECTED DAMS AND RESERVOIRS

DAM	FUNC-TION	NORMAL MAXIMUM FOREBAY	NORMAL MINIMUM FOREBAY	STORAGE (1000 AC FT) ACTIVE	STORAGE (1000 AC FT) TOP FT	INSTALLED GENERATION NO OF UNITS	INSTALLED GENERATION CAP IN CFS	INSTALLED GENERATION CAP IN MW	NORMAL MAXIMUM HEAD	AVE ANN DISCHARGE (CFS)
L O W E R C O L U M B I A R I V E R										
MILL CREEK	FR	1235.0	1212.0	3.3	0.23	0				
McNARY	PNfriq	340.0	335.0	185.0	38.10	14	232,000	986.0	75	169,800
McKAY	IFRC	1322.0	1182.0	73.8	1.55					
COLD SPRINGS	I		560.0	44.6	3.93					
WILLOW CREEK	Fcri	2063.0	2047.0	9.8	.16	0				19
JOHN DAY	FPNcriq	268.0	257.0	534.0	54.10	16	322,000	2160.0	105	172,400
CRANE PRAIRIE	I	4445.0	4424.0	55.3	4.94					36
WICKIUP	I	4337.7	4250.8		10.60	0				710
CRESCENT LAKE	I	4847.0	4823.4	117.2	3.93					49
HAYSTACK	IF	2842.0	2780.0	5.6	0.26					
WASCO	I	3514.4	3488.0	11.9	0.56	0				15
ARTHUR B BOWMAN *	IFC	3234.8	3114.0	152.8	1.00					365
OCHOCO *	IF		3047.0	47.5	1.00	0				47
ROUND BUTTE	PR	1945.0	1860.0	274.3	3.99	3	11,200	244.1	368	4,115
PELTON	PR	1580.0	1573.0	3.8	0.56	3	11,200	97.2	151	4,315
THE DALLES	PNcriq	160.0	155.0	53.0	10.50	24	375,000	1814.0	85	177,900
POWERDALE	P	292.0	291.0			1	500	6.0	210	
CONDIT	P	301.0	296.0	1.1	0.01	2	1,400	9.6	179	1,128
BONNEVILLE	PNcrq	77.0	70.0	138.0	24.40	18	288,000	1080.2		183,300
BULL RUN #1	M	1044.0		30.7						603
BULL RUN #2	M	860.0		21.0						
BULL RUN	PM	655.0	648.0	0.9	0.16	3	1,120	21.0	326	659
SWIFT #1	P	1007.0	900.0	447.0	4.62	3	9,350	204.0	396	2,919
SWIFT #2	P	604.0	603.3	0.3	0.10	2	8,600	67.5	136	2,919
YALE	P	490.0	430.0	189.6	3.77	2	8,000	108.0	250	3,940
									70	
MERWIN	P	239.6	225.0	244.0	3.92	3	11,400	135	187	4,825
PACKWOOD	P	2855.5	2850.5	3.6	0.46	1	300	31.5	1,812	100
COWLITZ FALLS *	PRF	866.0		10.2		2	10,000	70	98	
MOSSYROCK *	PF	778.5	621.5	1397.0	11.63	2	14,500	300	347	5,108
MAYFIELD *	PR	425.0	415.0	21.4	2.20	4	10,150	162.0	182	6,148
W I L L A M E T T E R I V E R										
HILLS CREEK	FPNIcrq	1543.0	1414.0	234.3	2.68	2	1,800	30.0	320	1,087
LOOKOUT POINT	FPNIcrq	929.0	819.0	336.4	4.24	3	9,300	120.0	231	2,900
DEXTER	PFnir	695.0	690.0	4.8	0.99	1	4,200	15	59	2,900
FALL CREEK	FNIcqr	834.0	673.0	125.0	1.85	0				
COTTAGE GROVE	Fcr	791.0	719.0	31.8	1.14	0				264
DORENA	FINcqr	835.0	770.5	72.1	1.87	0				708
CARMEN	P	2605.0				2	3,400	80.0	513	
SMITH	P	2605.0	2525.0	9.9	0.17					96
TRAIL BRIDGE	P	2092.0	2045.0	2.2	0.07	1	1,900	10.0	82	1,009
COUGAR	FPINcqr	1699.0	1516.0	153.5	1.23	2	1,050	25.0	437	78
BLUE RIVER	FNIwrq	1357.0	1132.0	82.8	0.97	0				426
LEABURG	P	742.0	740.0	0.1	0.07	2	2,900	15.3	89	4,323
WALTERVILLE	P	598.0	601.0	0.3		1	2,575	8.0	54	4,461
FERN RIDGE	FINwqr	375.1	340.0	101.0	9.04	0				512
GREEN PETER	FPINwqr	1015.0	922.0	312.5	3.59	2	4,600	80.0	310	2,141
FOSTER	FPINwqr	641.0	609.0	28.3	1.19	2	3,200	20.0	110	2,141
DETROIT	FPINwqr	1569.0	1425.0	321.0	3.45	2	5,340	100.0	360	1,567
BIG CLIFF	Pr	1206.0	1182.0	3.0	0.14	1	3,100	18.0	96	2,524
SCOGGINS *	FIRMC	303.5	252.3	23.6	0.11	0				140
T W SULLIVAN	P	52.0		0		13	5,000	15.4	40	30,640
TIMOTHY LAKE	P	3190.0	3125.0	61.7	1.43	0				132
STONE CREEK	P	3048.0				1		12	680	
OAKGROVE POWERHOUSE	P	1988.0	1958.0	0.4	0.03	2	820	51.0	880	477
NORTH FORK	P	665.0	664.0	6.0	0.35	2	5,455	38.4	135	2,691
FARADAY	P	520.0	515.0	0.6	0.10	6	4,835	34.5	133	2,691
RIVER MILL	PM	388.8	381.6	0.5	0.11	5	4,510	19.1	81	2,691

Sheet 4b of 5

PERTINENT DATA FOR SELECTED DAMS AND RESERVOIRS

	DAM	CBTT IDENT	YEAR COMP-LETION	LOCATION RIVER	LOCATION MILE	OWNER OR OPERATOR	REMARKS
	PUGET SOUND & COASTAL						
1	KOMA KULSHAN		1990	ROCKY-SULPHUR-SANDY		KOMA	
2	LAKE WHATCOM		1937	WHATCOM CR		BELLINGHAM	
3	ROSS *	ROS	1956	SKAGIT	105.2	SEATTLE	
4	DIABLO	DIA	1929	SKAGIT	101.0	SEATTLE	
5	GORGE	GOR	1960	SKAGIT	96.6	SEATTLE	
6	UPPER BAKER *	UBK	1959	BAKER	9.1	PUGET	BAKER LAKE (NATURAL)
7	LOWER BAKER	SHA	1926	BAKER	1.1	PUGET	LAKE SHANNON
8	HENRY M JACKSON		1965	SULTON	16.5	PUD #1 SNO	SPADA LAKE, FRMLY GEO CALMBACK DAM
9	LAKE CHAPLAIN			CHAPLAIN CR	0.5		
10	TWIN FALLS		1989	SF SNOQUALMIE		TFH	
11	SNOQUALMIE #1		1898	SNOQUALMIE	40.5	PUGET	
12	SNOQUALMIE #2		1910	SNOQUALMIE	40.0	PUGET	
13	TOLT		1963	S F TOLT		SEATTLE	
14	CEDAR FALLS		1914	CEDAR	37.2	SEATTLE	
15	HOWARD A HANSON	HAH	1962	GREEN	64.5	COE	
16	MUD MOUNTAIN	MMD	1949	WHITE	29.6	COE	
17	WHITE RIVER	TAP	1911	OFF WHITE R	24.3	PUGET	LAKE TAPPS
18	ELECTRON		1904	PUYALLUP	41.7	PUGET	
19	ALDER	ALD	1945	NISQUALLY	44.2	TACOMA	LAKE ALDER
20	LA GRANDE	LGR	1912	NISQUALLY	42.5	TACOMA	
21	YELM		1930	NISQUALLY	26.2	CENTRALIA	
22	CUSHMAN #1	CSH	1926	N F SKOKOMISH	19.6	TACOMA	LAKE CUSHMAN
23	CUSHMAN #2		1930	N F SKOKOMISH	17.3	TACOMA	
24	GLINES CANYON		1927	ELWHA	10.0	JAMES	LAKE MILLS
25	WYNOOCHEE	WYN	1972	WYNOOCHEE	51.8	TACOMA	POWERHOUSE BUILT 1994
26	LEMOLO #1	LEM	1954	NORTH UMPQUA	88.6	PP&L	
27	CLEARWATER #1		1953	CLEARWATER R	9.0	PP&L	
28	CLEARWATER #2		1953	CLEARWATER R	5.7	PP&L	
29	LEMOLO #2		1956	NORTH UMPQUA	77.3	PP&L	
30	TOKETEE		1950	NORTH UMPQUA	75.4	PP&L	
31	FISH CREEK		1952	FISH CR	6.6	PP&L	
32	SLIDE CREEK		1951	NORTH UMPQUA	73.2	PP&L	
33	SODA SPRINGS		1952	NORTH UMPQUA	69.8	PP&L	
34	GALESVILLE *	GSV	1985	COW CREEK	60.0	DOUG CO	
35	PROSPECT #1		1912	N F ROGUE	169.4	PP&L	
36	PROSPECT #2		1928	N F ROGUE	122.0	PP&L	
37	PROSPECT #3		1932	S F ROGUE	10.5	PP&L	
38	LOST CREEK	LOS	1976	ROGUE	158.4	COE	
39	ELK CREEK	ELK	--	ELK CR	1.7	COE	CONSTRUCTION SUSPENDED
40	FISH LAKE		1908	N F LTL BUTTE CR	15.7	MID	REHAB 1923
41	FOURMILE LAKE $		1908	FOURMILE CR		MID	REBUILT 1922
42	AGATE	AGA	1966	DRY CR	3.0	USBR/ROG	
43	HYATT $	HYA	1923	KEENE CR		USBR/ROG	
44	HOWARD PRAIRIE $	HPD	1958	BEAVER CR		USBR/TAL	
45	KENNE CREEK $		1960	EMIGRANT CR	8.0	USBR/TAL	GREEN SPRINGS POWER PLANT
46	EMIGRANT LAKE *	EMI	1924	EMIGRANT CR	29.3	USBR/TAL	REBUILT 1960
47	APPLEGATE	APP	1980	APPLEGATE	45.7	COE	

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PERTINENT DATA FOR SELECTED DAMS AND RESERVOIRS

DAM	FUNCTION	NORMAL MAXIMUM FOREBAY	NORMAL MINIMUM FOREBAY	STORAGE (1000 AC FT) ACTIVE	STORAGE (1000 AC FT) TOP FT	INSTALLED GENERATION NO OF UNITS	INSTALLED GENERATION CAP IN CFS	INSTALLED GENERATION CAP IN MW	NORMAL MAXIMUM HEAD	AVE ANN DISCHARGE (CFS)
P U G E T S O U N D & C O A S T A L										
KOMA KULSHAN	P							12	1200	
LAKE WHATCOM	M			26.4	5.00					
ROSS *	FPR	1602.5	1475.0	1052.0	11.85	4	15,600	451.0	397	3,377
DIABLO	P	1206.0	1197.0	27.2	0.91	4	6,500	159.0	330	4,093
GORGE	P	875.0	964.0	6.6	0.24	4	7,400	183.0	380	4,458
UPPER BAKER *	FP	724.0	674.0	184.8	4.89	2	5,300	94.4	285	2,026
LOWER BAKER	P	438.6	363.6	142.4	2.22	1	4,300	64.0	263	2,593
HENRY M JACKSON	M,P	1450.0	1429.0	154.9		4	1,300	111.2		97
LAKE CHAPLAIN	M			13.4	0.44					
TWIN FALLS	P							20		
SNOQUALMIE #1	P	401.0		0.4	0.11	5	1,050	11.6	271	2,623
SNOQUALMIE #2	P	401.0	396.5	0.4	0.11	2	1,530	31.0	287	
TOLT	M			57.8						200
CEDAR FALLS	PM	1550.0	1510.0	38.8	1.82	0	700	28.4	620	311
HOWARD A HANSON	FA	1206.0	1040.0	25.0	1.73	0				1,074
MUD MOUNTAIN	F	1215.0	895.0	106.0	0.96	0				1,469
WHITE RIVER	P	543.0	515.0	46.7	2.52	4	2,000	63.0	489	
ELECTRON	P	1538.0	1484.0	54.0	0.01	4	372	23.6	874	534
ALDER	P	1207.0	1140.0	161.5	3.33	2	2,550	50.1	272	1,405
LA GRANDE	P	935.0	910.0	1.0	0.05	5	2,100	64.0	423	1,405
YELM	P	318.0				1		9	208	1,816
CUSHMAN #1	PR	738.0	615.0	372.1	4.20	2	2,500	43.2	257	746
CUSHMAN #2	P	480.0	460.0	2.5	0.11	3	2,700	81.0	480	753
GLINES CANYON	PM	588.3	559.3	21.8	0.44			17.4	192	1,510
WYNOOCHEE	PFCAIRM	800.0	700.0	69.4	1.12	1		12.8	165	556
LEMOLO #1	P	4148.0	4097.0	12.3	0.44	1	565	29.0	752	424
CLEARWATER #1	P	3861.0	3875.0	0.2		1	350	15.0	651	168
CLEARWATER #2	P	3101.3	3168.0			1	460	26 0	760	215
LEMOLO #2	P	3327.7	3325.5			1	620	33.0	729	583
TOKETEE	P	1635.0	2414.0	1.4	0.10	3	1,425	42.5	448	987
FISH CREEK	P	3024.0	3014.0			1	150	11.0	1,034	191
SLIDE CREEK	P	603.0	600.0			1	1,430	18.0	169	1,092
SODA SPRINGS	P	1805.5	1779.0	0.6	0.03	1	1,600	11.0	114	1,237
GALESVILLE *	WIFPR	1881.5	1744.0	42.2		2		1.8	135	
PROSPECT #1	P	2477.2	2477.0	--	--	1	145	3.8		
PROSPECT #2	P	2591.5	2594.5			2	935	32.0	607	804
PROSPECT #3	P	3375.7				1	160	7.2	720	174
LOST CREEK	FPRI	1872.0	1751.0	315.0	3.40	2	2,600	49.0	323	1,821
ELK CREEK	FICMRA	1726.0	1581.0	95.0	1.29	0			204	209
FISH LAKE	I	4641.5	4615.0	7.8	0.42	0				37
FOURMILE LAKE $	I	5746.5	5724.0	15.6		0				14
AGATE	I	1510.0	1467.0	4.7	0.90	0				
HYATT $	IP	5016.0	4981.7	16.2		0				12
HOWARD PRAIRIE $	FI	4526.6	4471.0	60.6	0.88	0				117
KEENE CREEK $	P	4403.5	4378.0	0.3	1.96	1	133	16.0	1,984	
EMIGRANT *	IF	2241.0	2131.5	39.0	0.81	0				31
APPLEGATE	FIR	1987.0	1854.0	75.2	0.99	0				405

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	OWNER OR OPERATOR		OWNER OR OPERATOR
ADC	ASSOCIATED DITCH COMPANY	MONTANA	MONTANA POWER COMPANY
ASH	ASHLEY IRRIGATION DISTRICT	MT HOME	MOUNTAIN HOME IRRIGATION CO
BELLINGHAM	CITY OF BELLINGHAM	N FORK	NORTH FORK RESERVOIR COMPANY
B FERRY	CITY OF BONNERS FERRY	N SIDE	NORTH SIDE CANAL COMPANY
BID	BITTERROOT IRRIGATION DISTRICT	NUID	NORTH UNIT IRRIGATION DISTRICT
B LOST R	BIG LOST RIVER CANAL COMPANY	NVR	NILE VALLEY RANCH
BC HYDRO	B C HYDRO & POWER AUTHORITY	OAKLEY	OAKLEY CANAL COMPANY
BIA	BUREAU OF INDIAN AFFAIRS	OCH	OCHOCO IRRIGATION DISTRICT
BOISE	BOISE PROJECT BOARD OF CONTROL	OID	OWYHEE IRRIGATION DISTRICT
BIG WOOD	BIG WOOD CANAL COMPANY	OKANOGAN	OKANOGAN IRRIGATION DISTRICT
BRUNDAGE	BRUNDAGE WATER USERS	ORCHARDS	ORCHARDS WATER CO
CAREY V	CAREY VALLEY RESERVOIR COMPANY	OWSLEY	OWSLEY CANAL COMPANY
CE	CORPS OF ENGINEERS	PORTLAND	CITY OF PORTLAND
CEDAR	CEDAR MESA COMPANY	PP&L	PACIFIC POWER & LIGHT COMPANY
CENTRALIA	CITY OF CENTRAILIA	PEND	PEND OREILLE COUNTY PUD
CHELAN	CHELAN COUNTY PUD NO 1	PEND MINES	PEND OREILLE MINES
CI	CHELAN IRRIGATION DISTRICT	PV	PLEASANT VALLEY IRRIGATION CO
COID	CENTRAL OREGON IRRIGATION DIST	PVP	PLEASANT VALLEY IRRI & POWER CO
COMINCO	COMINCO, LIMITED	PGE	PORTLAND GENERAL ELECTRIC
COWLITZ	COWLITZ COUNTY PUD	PM	PORTNEUF-MARSH VALLEY CO
CRANE	CRANE CREEK RESERVOIR COMPANY	PUGET	PUGET SOUND POWER & LIGHT CO
CROWN Z	CROWN ZELLERBACK	PUD #1 SNO	SNOHOMISH CO PUD & C OF EVERETT
DVR	SHOI-PAI TRIBE OF DVR	ROG	ROGUE RIVER VALLEY IRR DIST
DOUG CO	DOUGLAS COUNTY, OREGON	SALMON	SALMON RIVER CANAL
DOUGLAS	DOUGLAS COUNTY PUD NO 1, WA	S COL ID	SO COLUMBIA IRRIGATION DISTRICT
EUGENE	CITY OF EUGENE	SEATTLE	CITY OF SEATTLE
GOOSE	GOOSE LAKE RESERVOIR COMPANY	SQUAW	SQUAW CREEK IRRIGATION COMPANY
GRANT	GRANT COUNTY PUD NO 2	SMITH	SMITH CREEK HYDROPOWER
HAYDEN	HAYDEN L WATERSHED IMPROVEMENT	S MONTANA	STATE OF MONTANA
HBH	HORSESHOE BEND HYDRO	TACOMA	CITY OF TACOMA
HERM	HERMISTON IRRIGATION DISTRICT	TAL	TALENT IRRIGATION DISTRICT
IDAHO	IDAHO POWER COMPANY	TID	TUMALO IRRIGATION DISTRICT
JAMES	JAMES RIVER PAPER CO, INC	TFH	TWIN FALLS HYDRO ASSOCIATES
JORDAN	JORDAN VALLEY IRRIGATION CO	TW	TWIN LAKE RESERVOIR & IRR CO
KOMA	KOMA KULSHAN	TF	TWIN FALLS CANAL COMPANY
LAKE	LAKE IRRIGATION DISTRICT	UP&L	UTAH POWER & LIGHT COMPANY
LEWIS	LEWIS COUNTY PUD	USBR	U S BUREAU OF RECLAMATION
L VALLEY	LOST VALLEY RESERVOIR COMPANY	VALE	VALE IRRIGATION DISTRICT
L WEISER	LITTLE WEISER RIVER IRR DIST	WPPSS	WASHINGTON PUB POWER SUPPLY SYS
L WILLOW	LITTLE WILLOW CREEK IRR COMPANY	WWP	WASHINGTON WATER POWER COMPANY
MHP	MARYSVILLE HYDROPOWER PARTNERS	W KOOTENAY	WEST KOOTENAY POWER & LIGHT
MID	MEDFORD IRRIGATION DISTRICT	WHITE	WHITESTONE COULEE IRR DISTRICT

AUTHORIZED PROJECT FUNCTIONC (CAPS)
OTHER PROJECT FUNCTIONS (lower case)

P HYDROPOWER AT SITE AND/OR DOWNSTREAM
I IRRIGATION
F FLOOD CONTROL
N NAVIGATION
M MUNICIPAL AND INDUSTRIAL WATER SUPPLY
C FISH AND WILDLIFE CONSERVATION
A POLLUTION ABATEMENT OF LOW FLOW AUGMENTATION
R RECREATION
Q WATER QUALITY

* Section 7 Project.
% Includes 1-foot flashboards annually installed during the summers.
@ Includes 2-foot flashboards annually installed during the summers.
\+ Storage is a function of flow and pool elevation.
$ Klamath River Basin; flows diverted to Rogue Basin.

APPENDIX D

LIST OF CHARTS

FLOOD REGULATION (Cont'd)
April-July

Number

61 Duncan R at Duncan Dam, BC
62 Kootenay R at Kootenay Lake, BC
63 Columbia R at Birchbank, BC
64 SF Flathead R at Hungry Horse Dam, MT
65 Flathead R at Columbia Falls, MT
66 Flathead R at Flathead Lake, MT
67 Pend Oreille R at Pend Oreille Lake, ID
68 Columbia R at Grand Coulee Dam, WA
69 Snake R at Jackson Lake Dam, WY
70 Snake R nr Heise, ID
71 Snake R nr Shelley, ID
72 Boise R at Boise, ID
73 Payette R nr Emmett, ID
74 Snake R at Weiser, ID
75 Snake R at Brownlee Dam, ID-OR
76 NF Clearwater R at Dworshak Dam, ID
77 Clearwater R at Spalding, ID
78 Snake R bl Lower Granite Dam, WA
79 Columbia R at Vancouver, WA
80 Columbia R at The Dalles Dam, OR

FLOOD REGULATION
November-February

Number

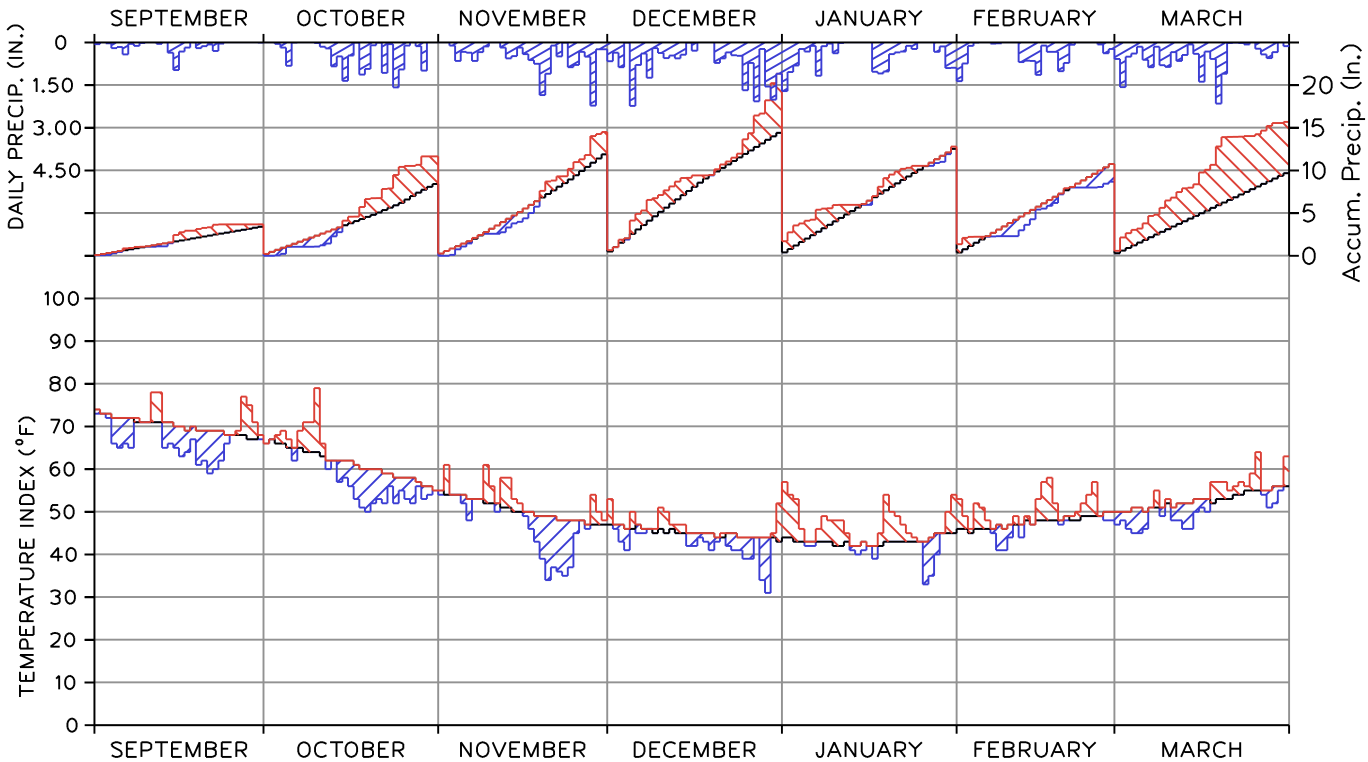
81 Willamette R at Eugene, OR
82 Willamette R at Albany, OR
83 Santiam R at Jefferson, OR
84 Willamette R at Salem, OR

SECTION 7 PROJECTS
Winter and Spring

85 Scoggins Dam and Lake
86 Galesville Dam and Lake
87 Emigrant Dam and Lake
88 Mason Dam and Lake

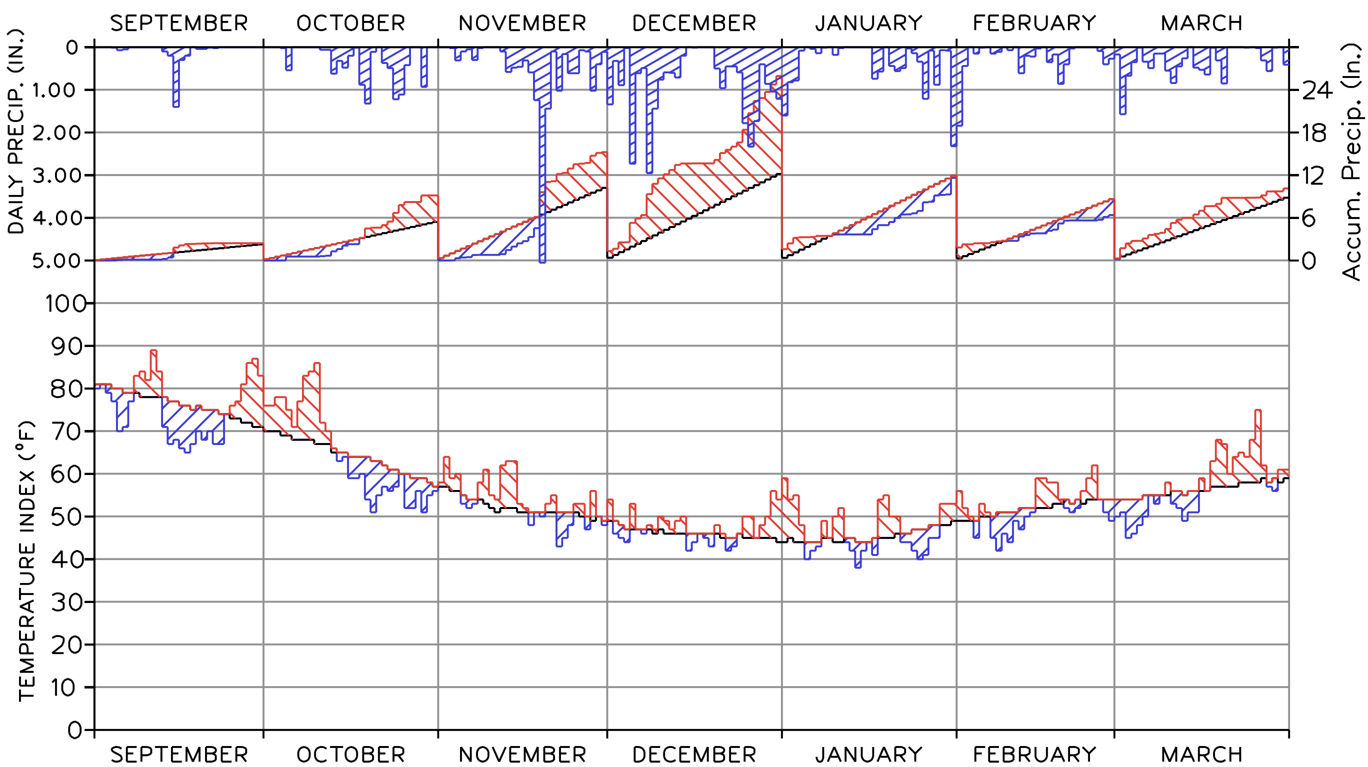
SUMMARY & ANNUAL HYDROGRAPHS
Water Year

89 Columbia R at Priest Rapids Dam, WA
90 Snake R nr Clarkston, WA
91 Columbia R at The Dalles Dam, OR
92 Willamette R at Salem, OR



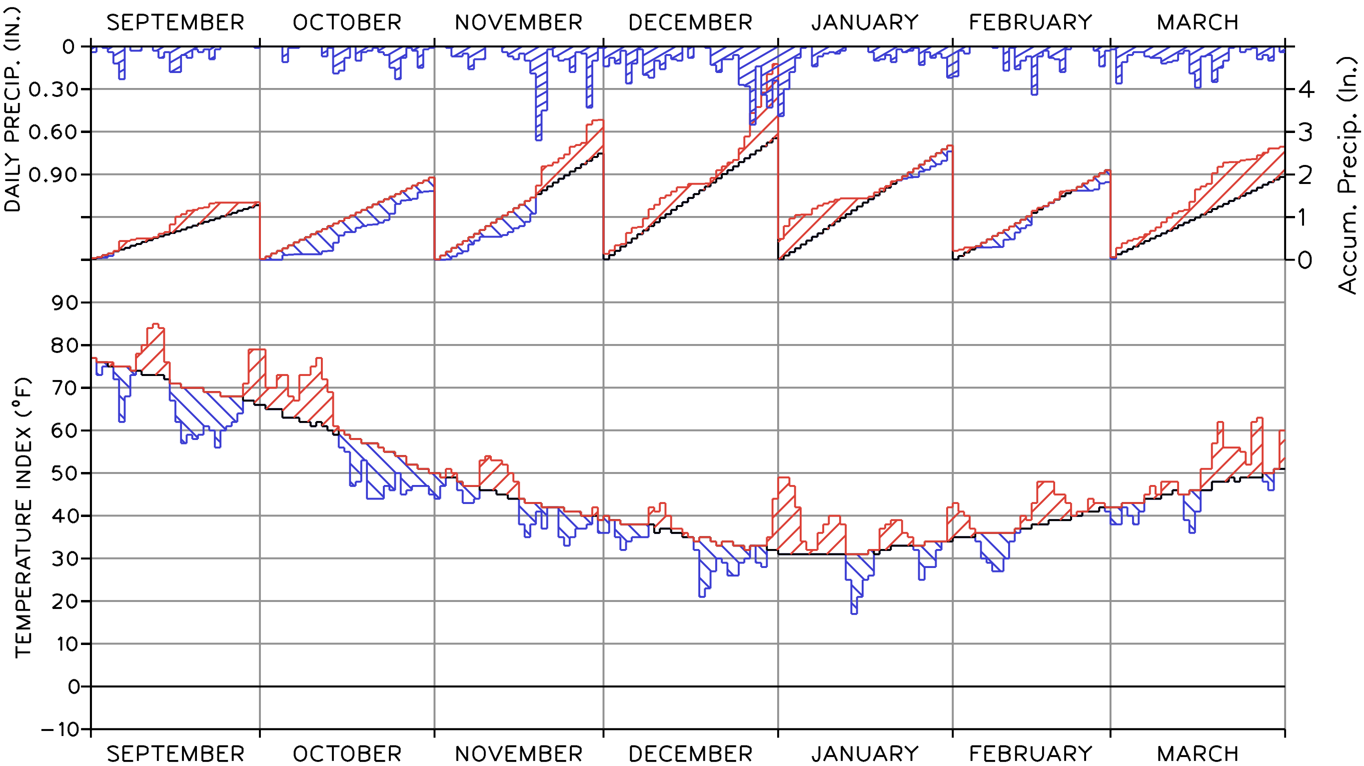
Back.

WINTER SEASON CHART 1
TEMPERATURE AND PRECIPITATION INDEX 1996–1997
WESTERN WASHINGTON



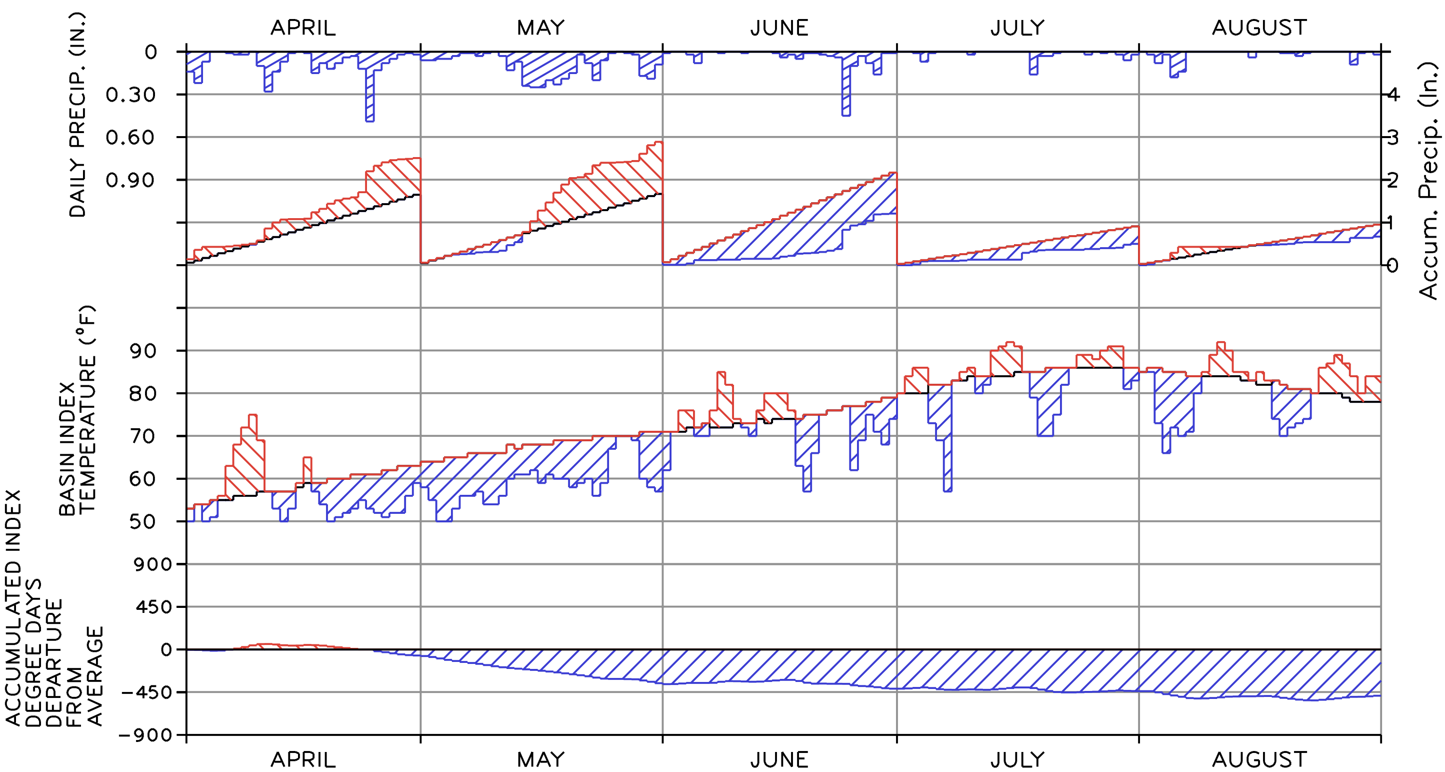
Back.

WINTER SEASON CHART 2
TEMPERATURE AND PRECIPITATION INDEX 1996–1997
WESTERN OREGON



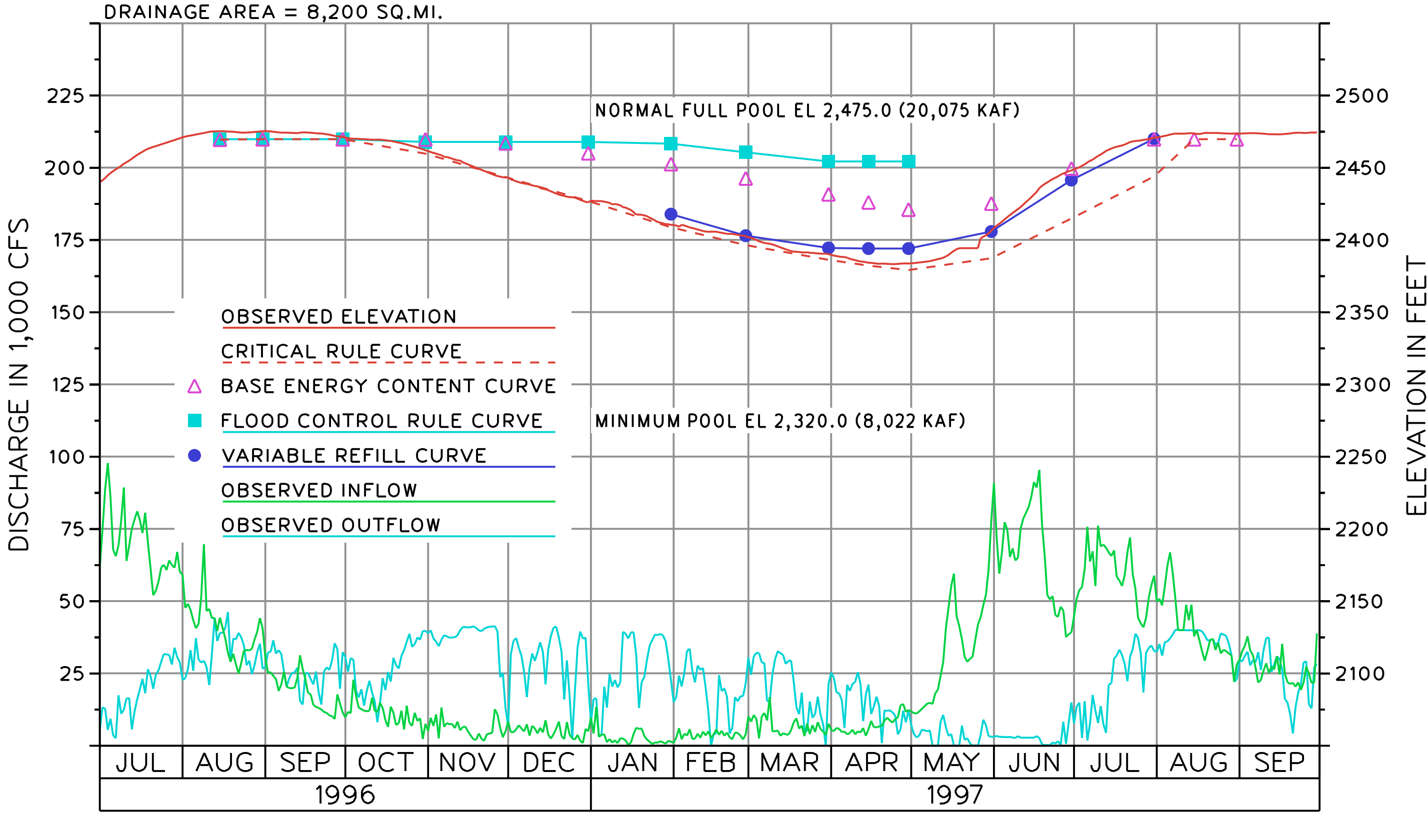
Back.

WINTER SEASON CHART 3
TEMPERATURE AND PRECIPITION INDEX 1996−1997
COLUMBIA RIVER BASIN ABOVE THE DALLES, OR



Back.

1997 SNOWMELT SEASON CHART 4
TEMPERATURE AND PRECIPITION INDEX
COLUMBIA RIVER BASIN ABOVE THE DALLES, OR

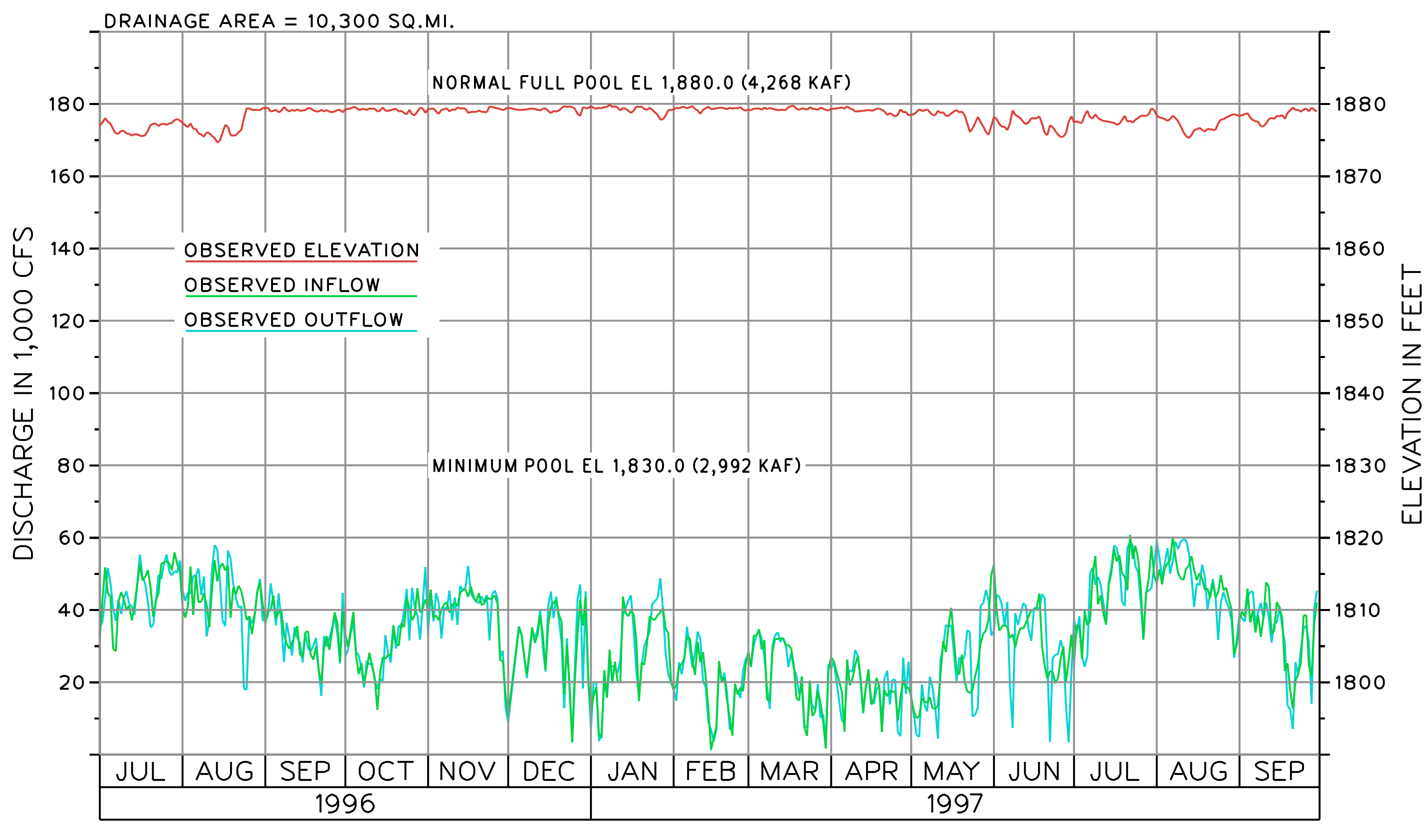


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

COLUMBIA RIVER AT MICA PROJECT, BRITISH COLUMBIA

Back

Chart 5

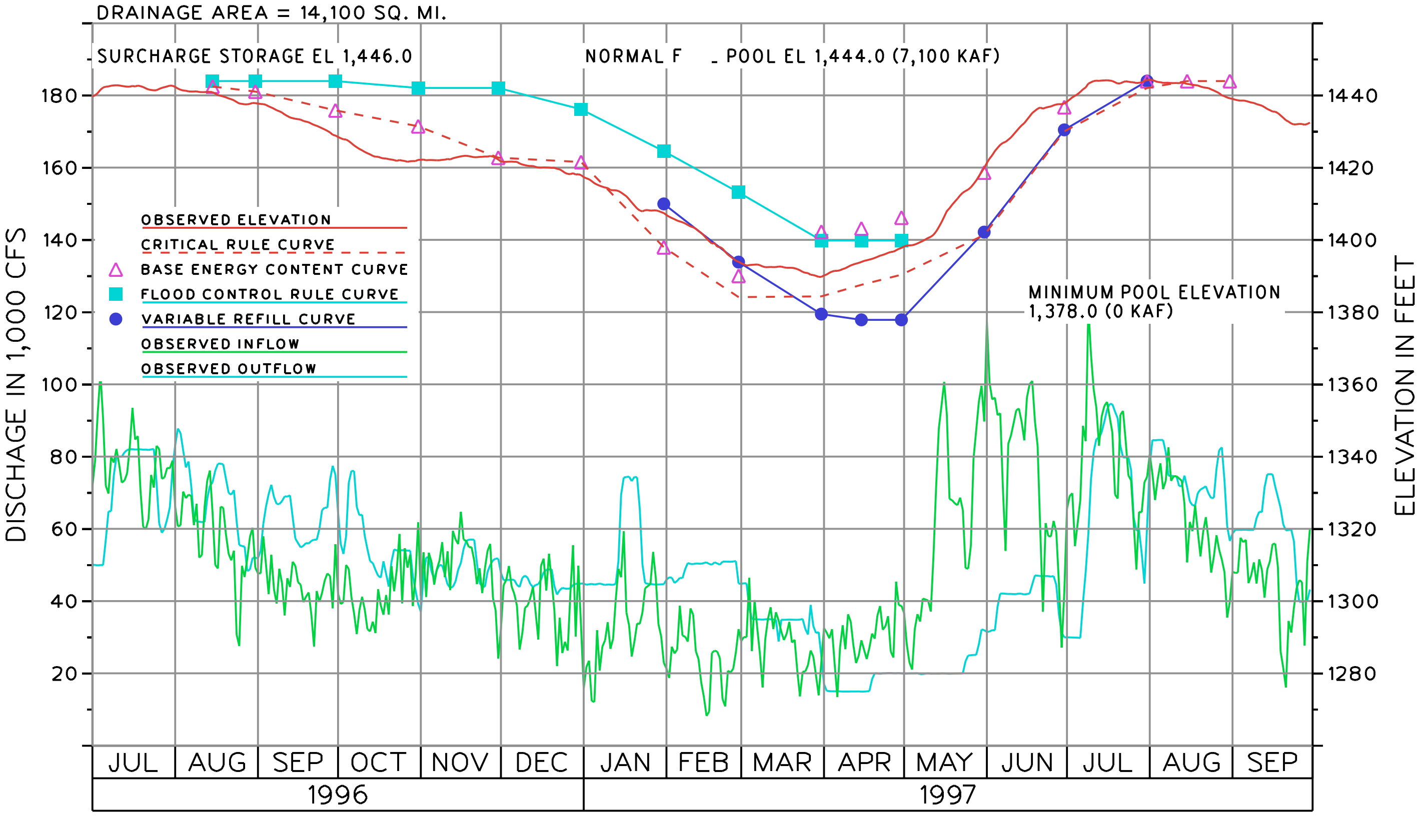


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

COLUMBIA RIVER AT REVELSTOKE PROJECT, BRITISH COLUMBIA

Back.

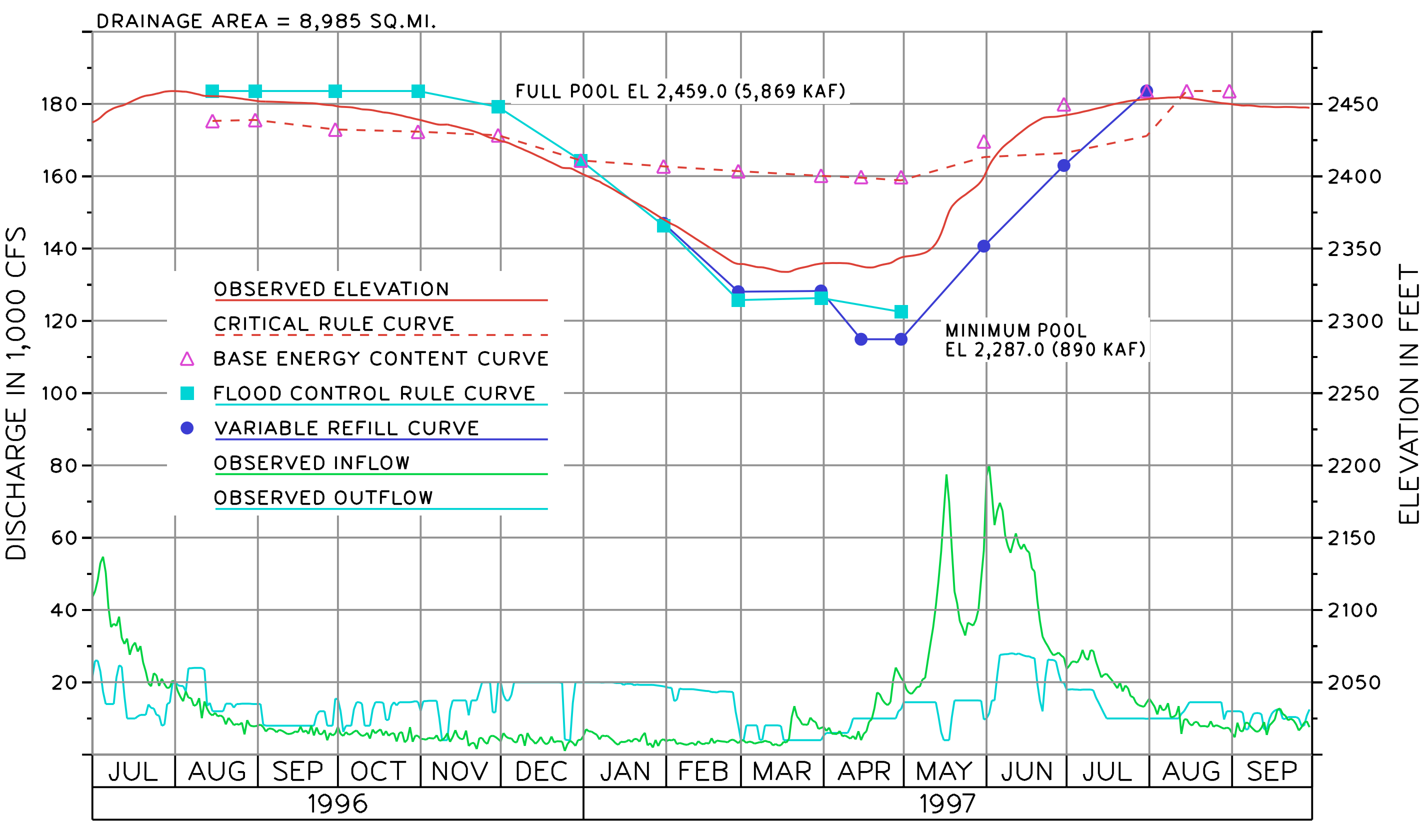
Chart 6



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

COLUMBIA RIVER AT ARROW PROJECT, BRITISH COLUMBIA

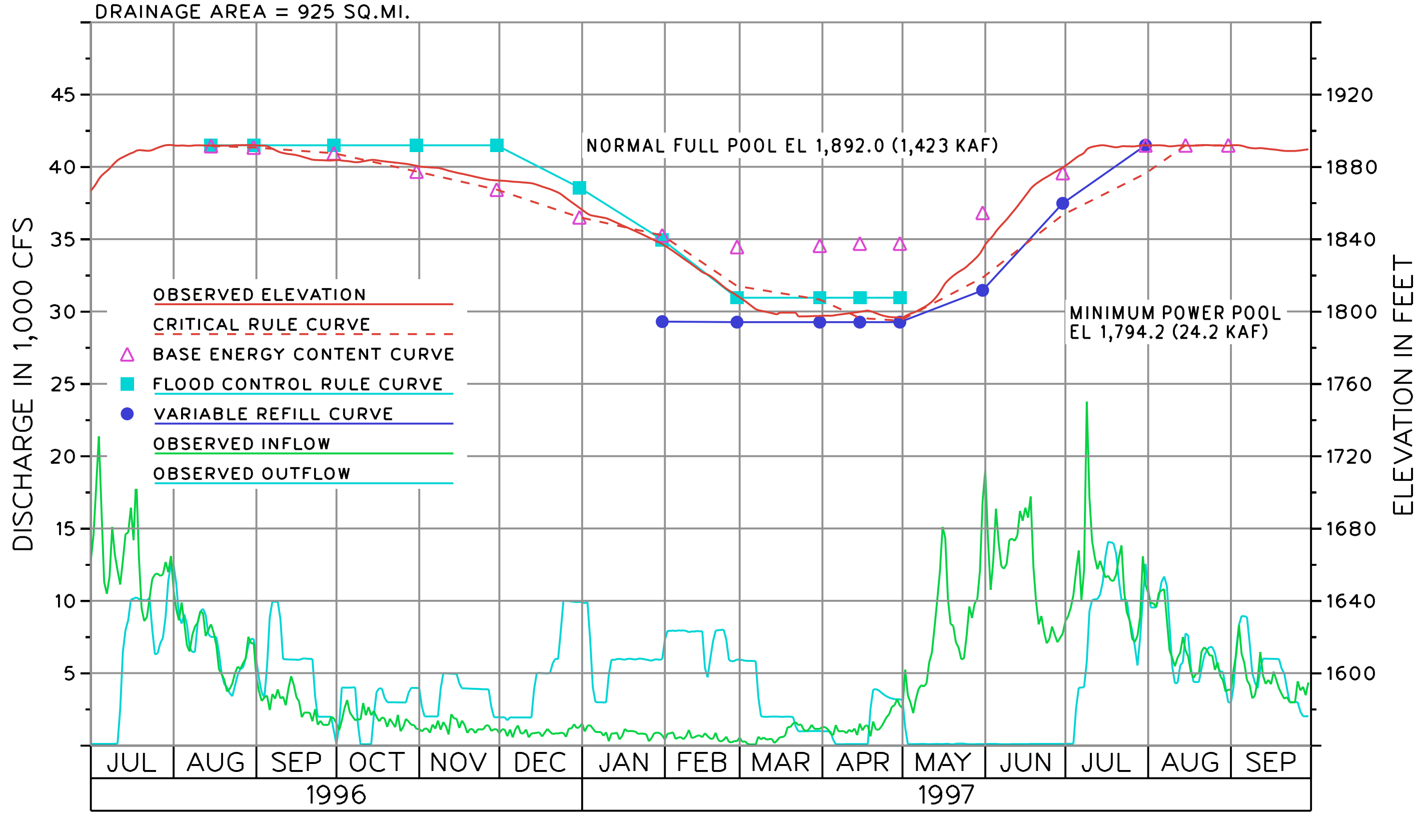
Chart 7 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

KOOTENAI RIVER AT LIBBY PROJECT, MONTANA

Chart 8 Back.

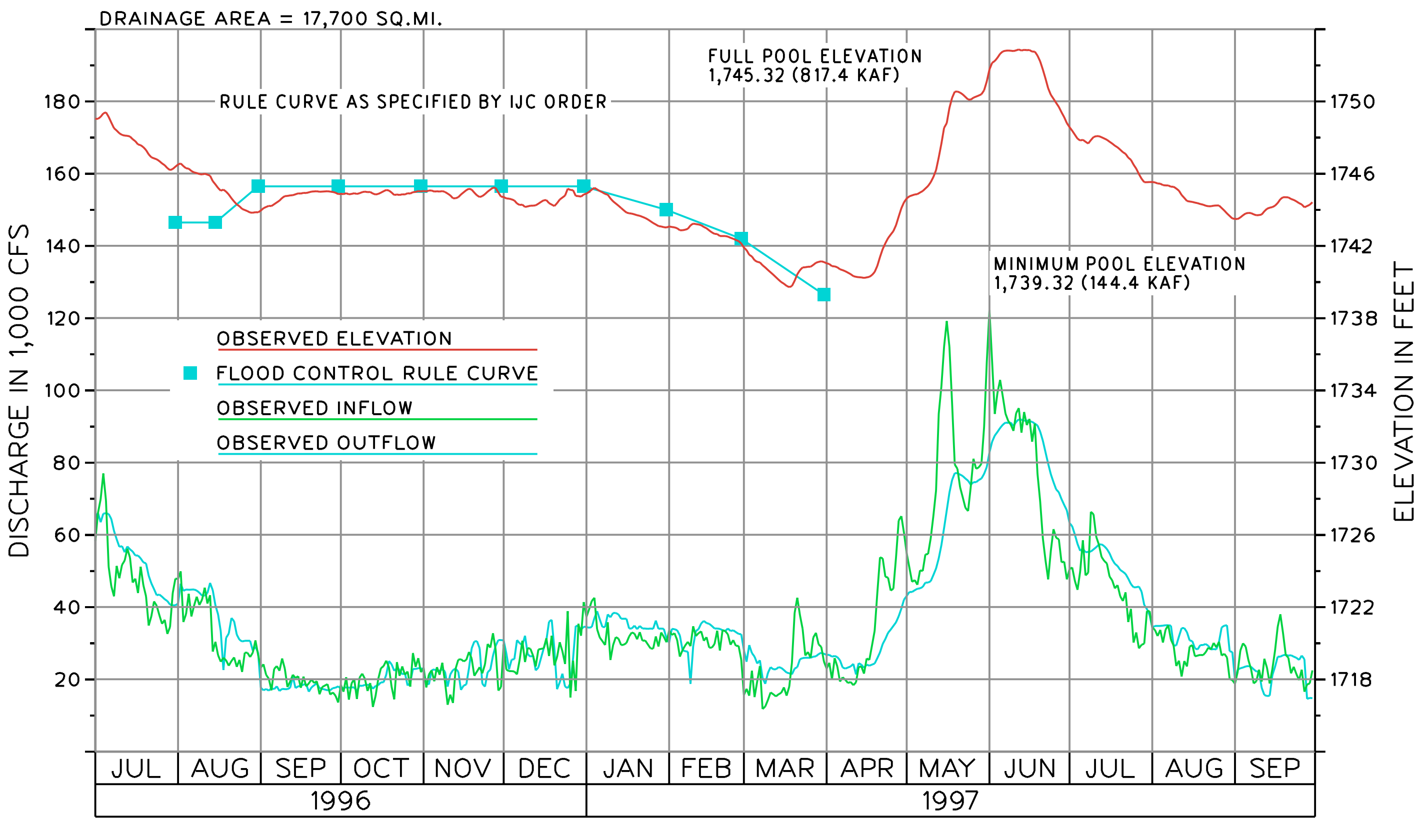


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

DUNCAN RIVER AT DUNCAN PROJECT, BRITISH COLUMBIA

Back.

Chart 9

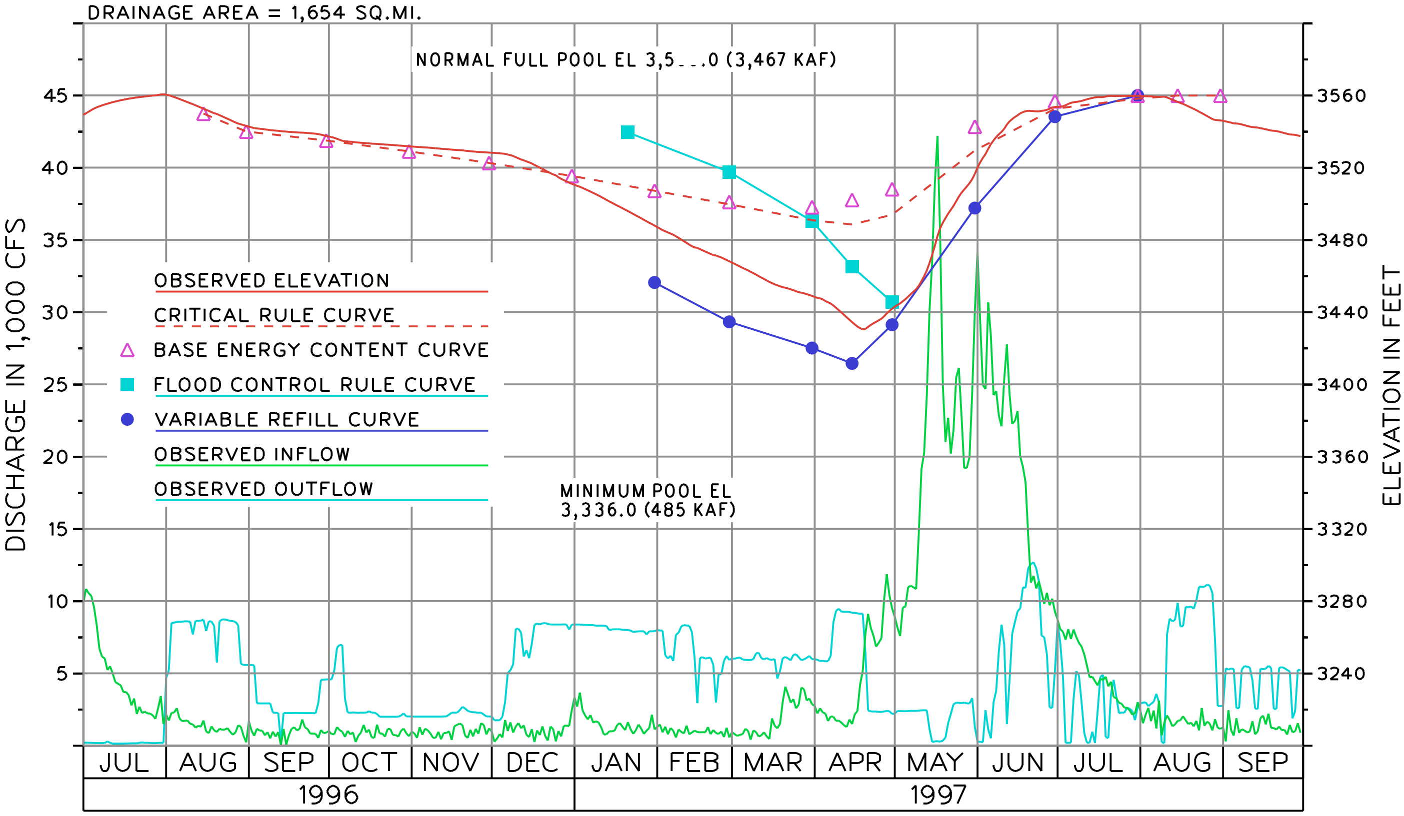


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

KOOTENAY RIVER AT KOOTENAY LAKE, BRITISH COLUMBIA

Back.

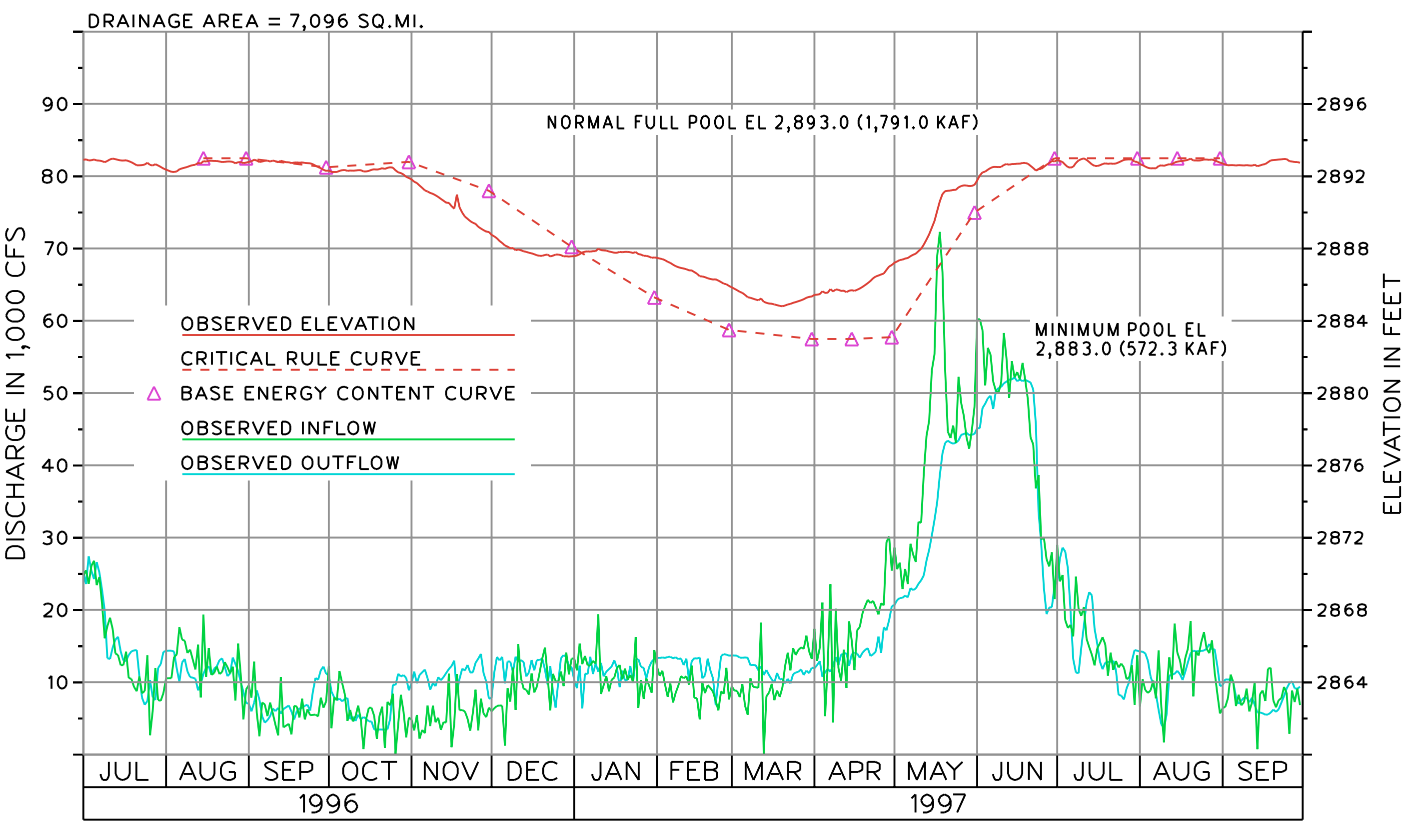
Chart 10



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

SOUTH FORK FLATHEAD RIVER AT HUNGRY HORSE PROJECT, MONTANA

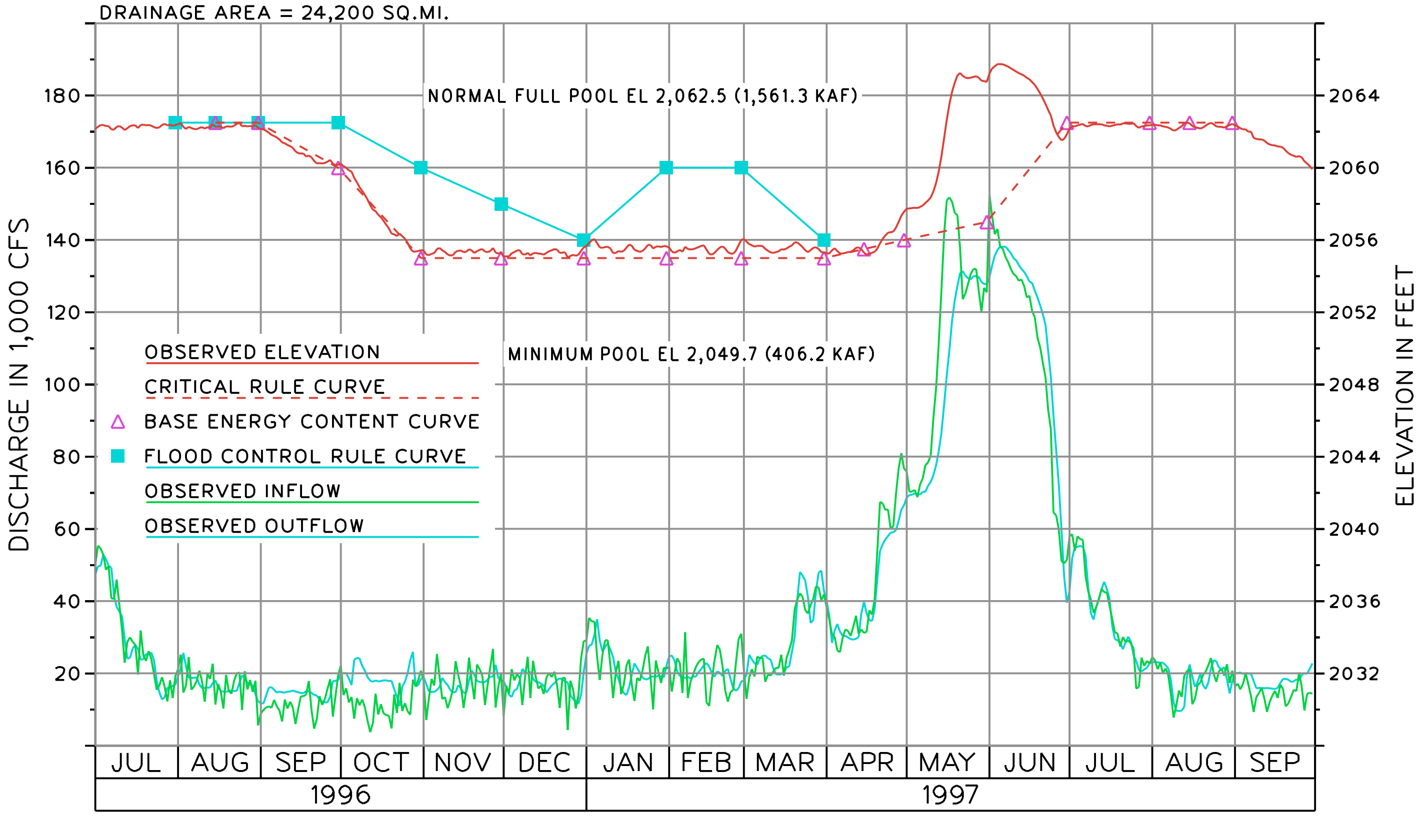
Chart 11 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

FLATHEAD RIVER AT FLATHEAD LAKE, MONTANA

Chart 12 Back.

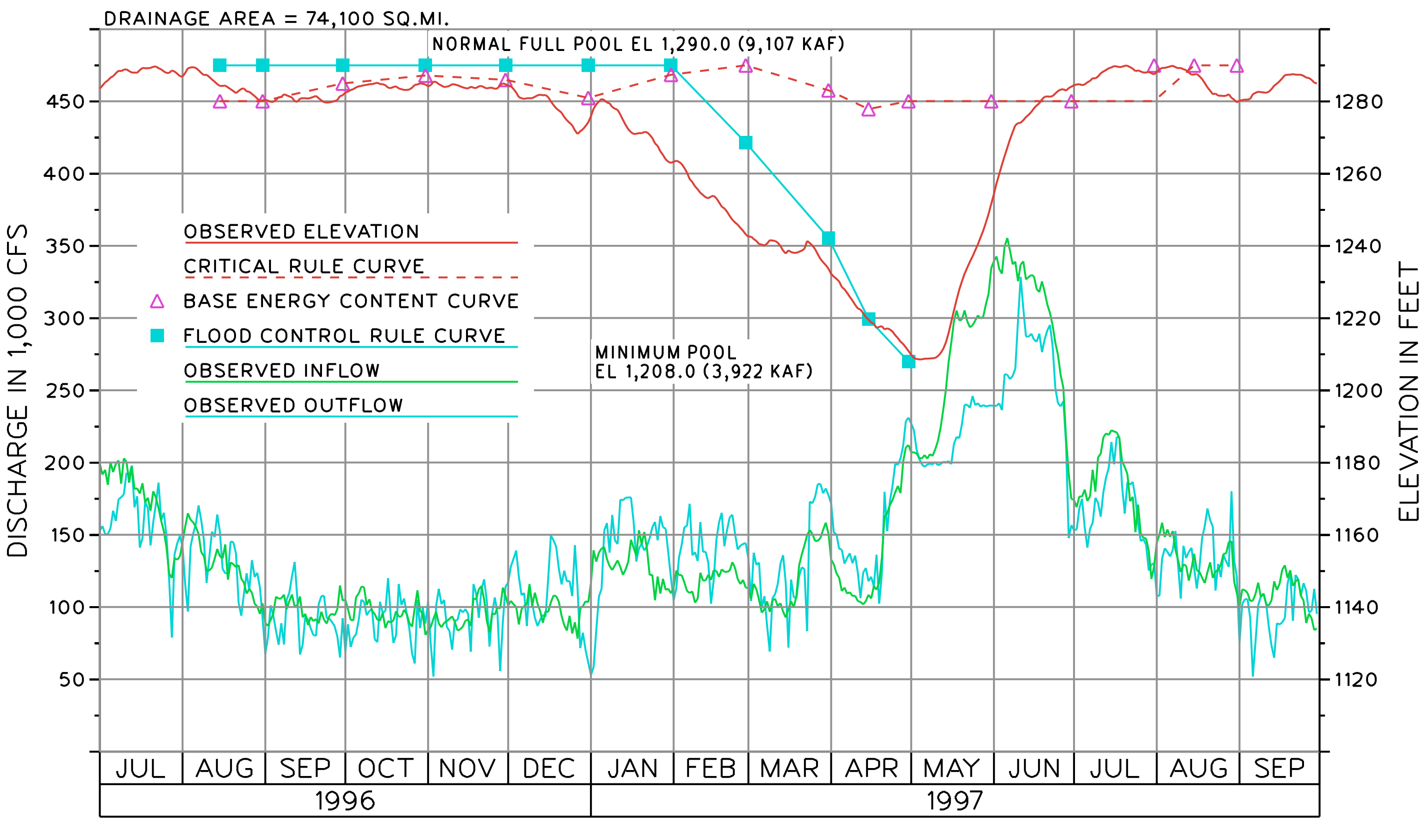


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

PEND OREILLE RIVER AT PEND OREILLE LAKE, IDAHO

Back.

Chart 13

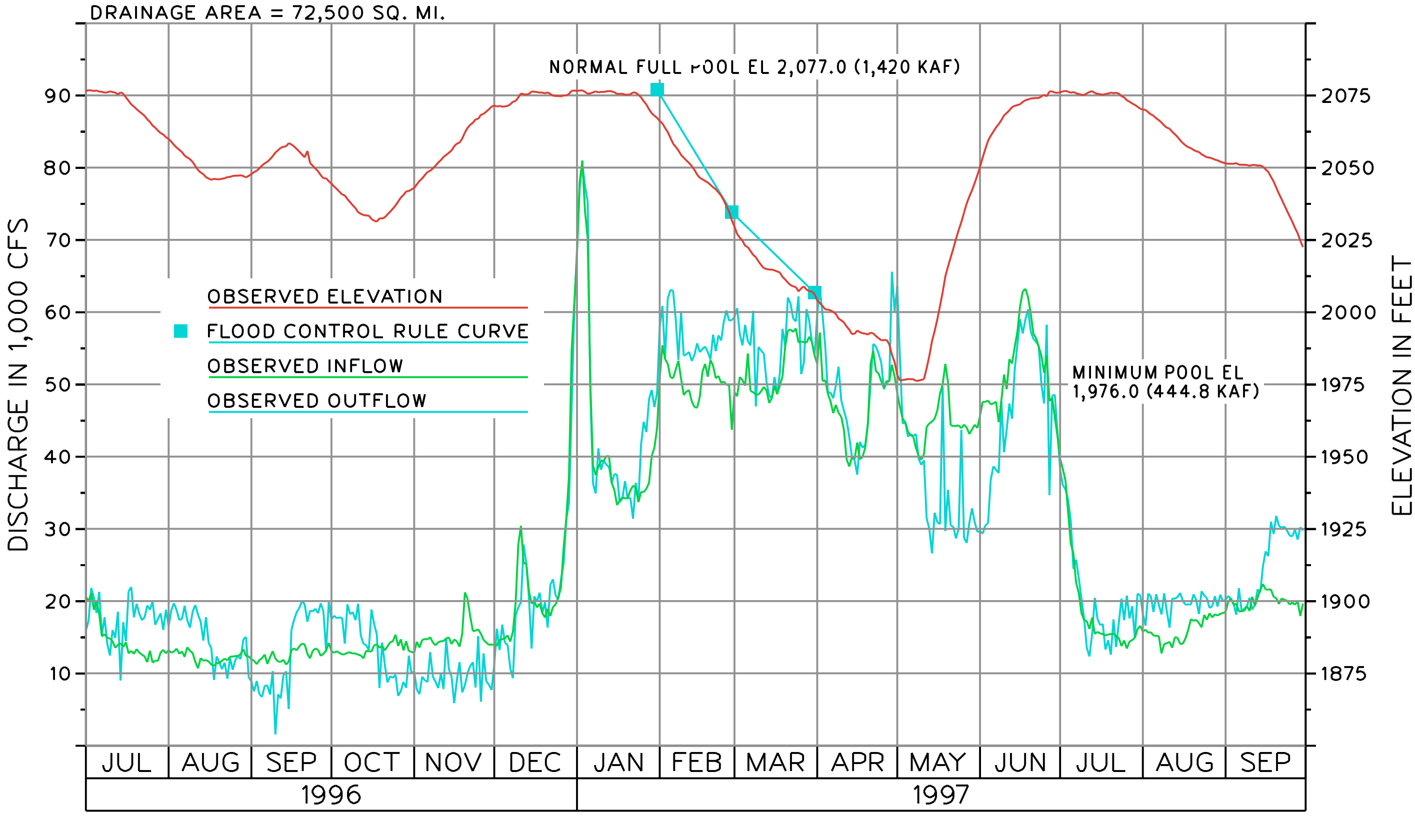


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

COLUMBIA RIVER AT GRAND COULEE PROJECT, WASHINGTON

Back.

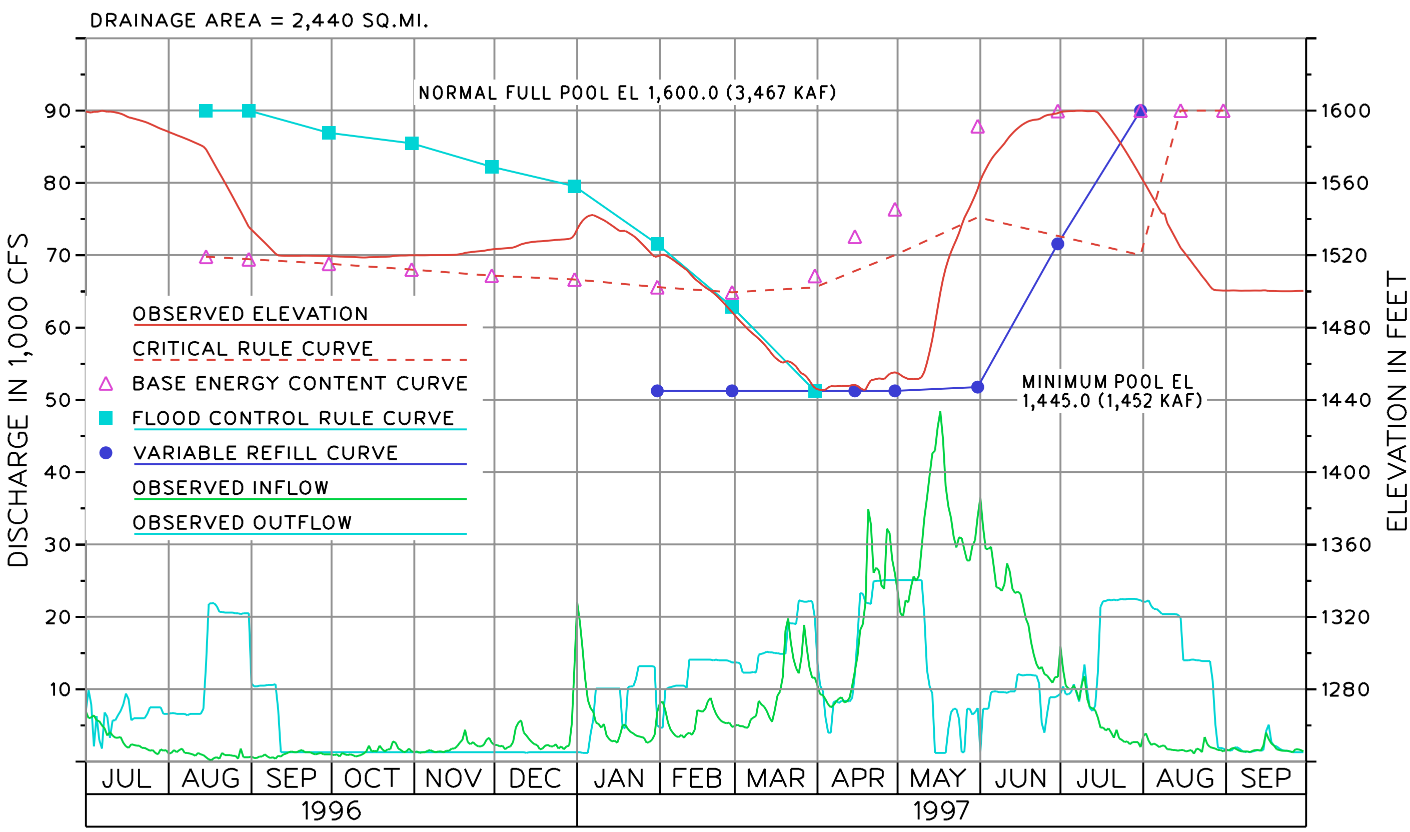
Chart 14



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

SNAKE RIVER AT BROWNLEE PROJECT, IDAHO – OREGON

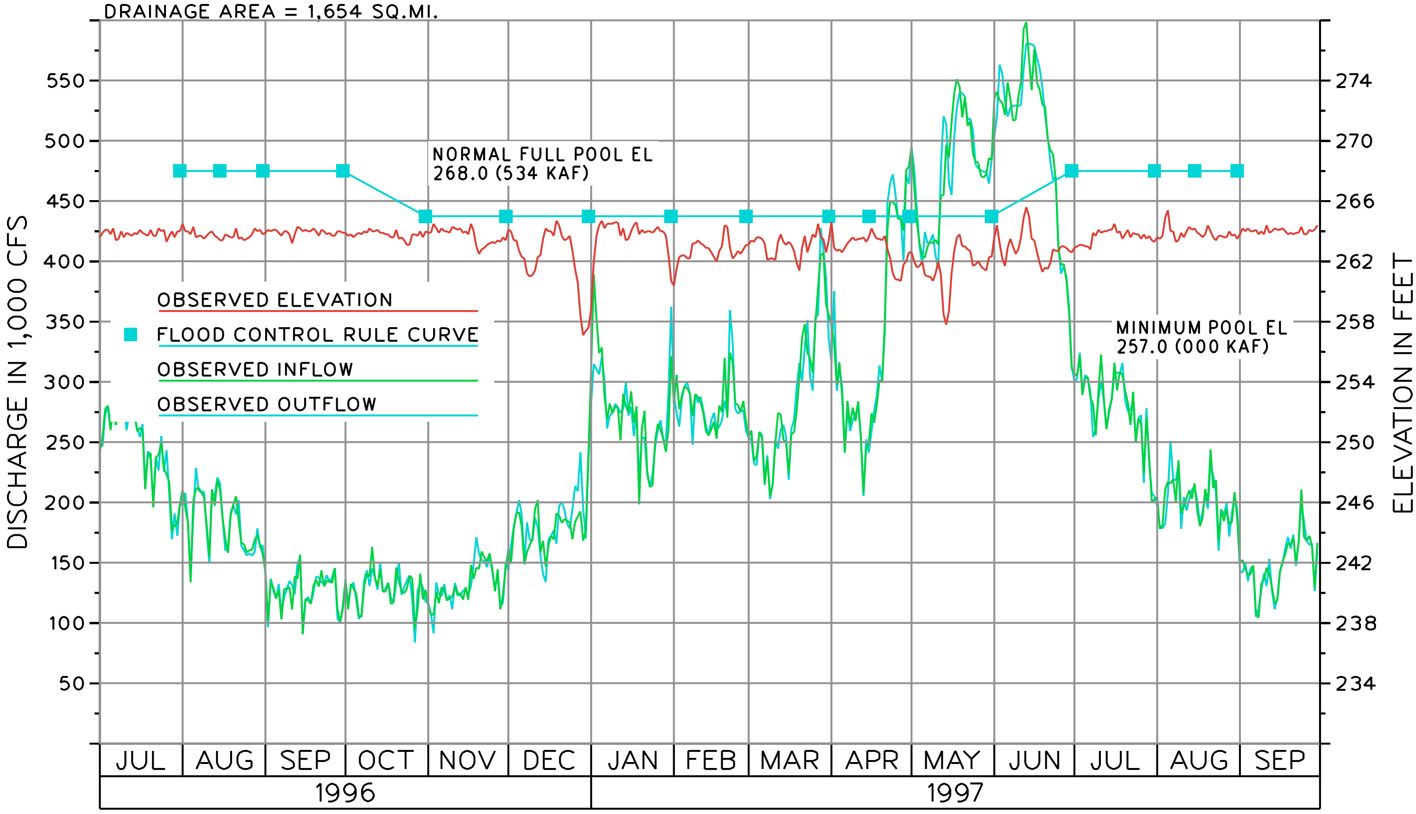
Chart 15 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

NORTH FORK CLEARWATER RIVER AT DWORSHAK PROJECT, IDAHO

Chart 16 Back.

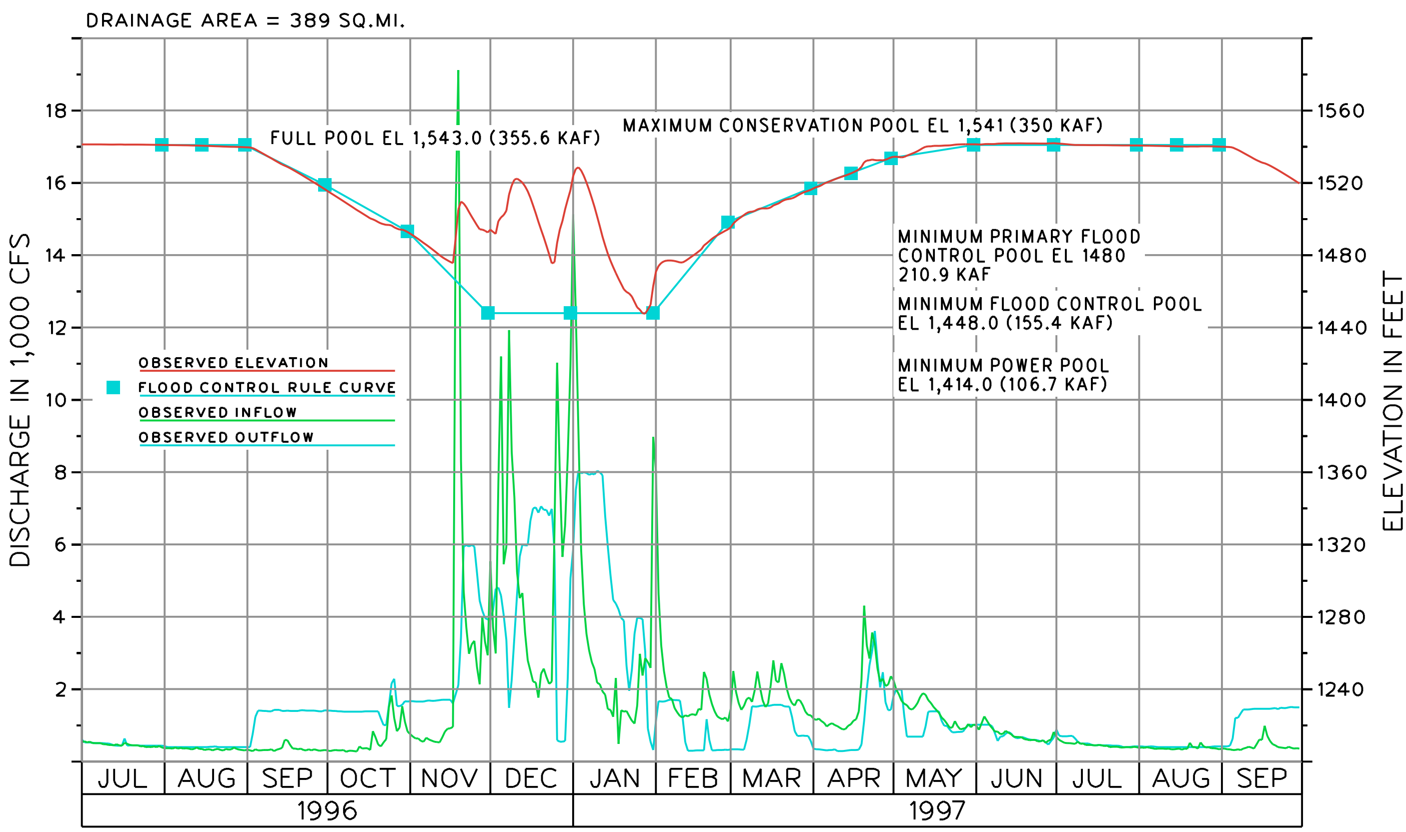


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

COLUMBIA RIVER AT JOHN DAY PROJECT, OREGON – WASHINGTON

Back.

Chart 17

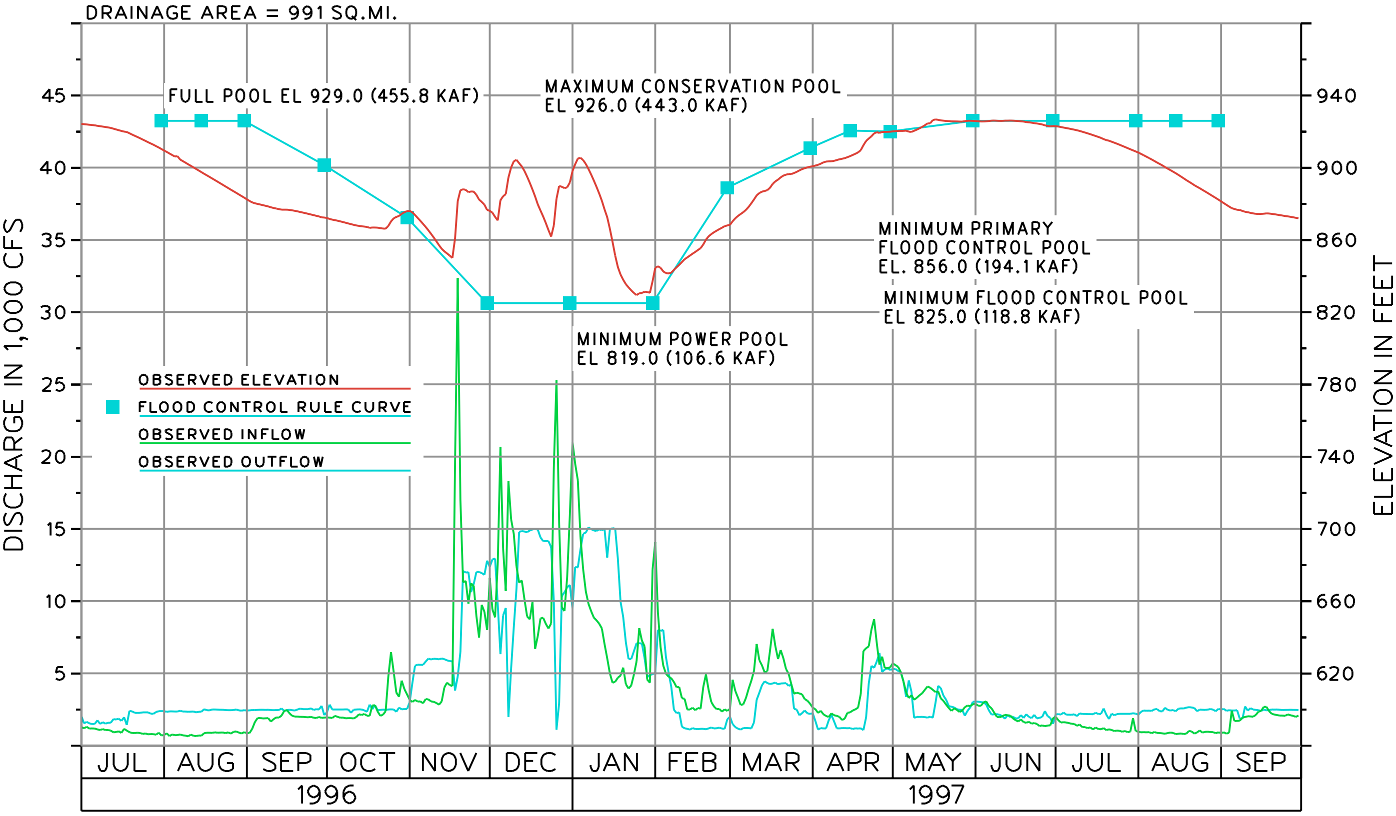


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

MIDDLE FORK WILLAMETTE RIVER AT HILLS CREEK PROJECT, OREGON

Back

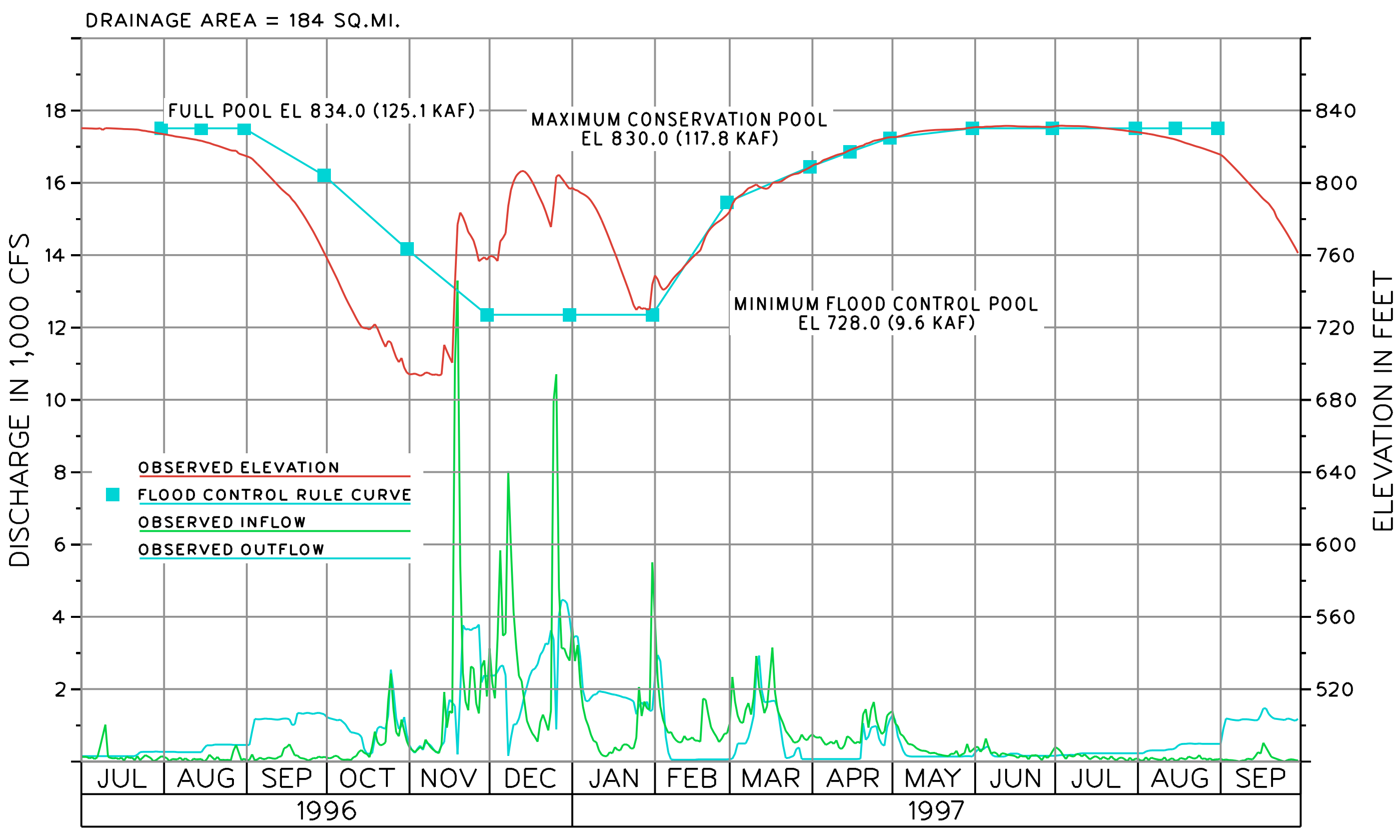
Chart 18



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

MIDDLE FORK WILLAMETTE RIVER AT LOOKOUT POINT PROJECT, OREGON

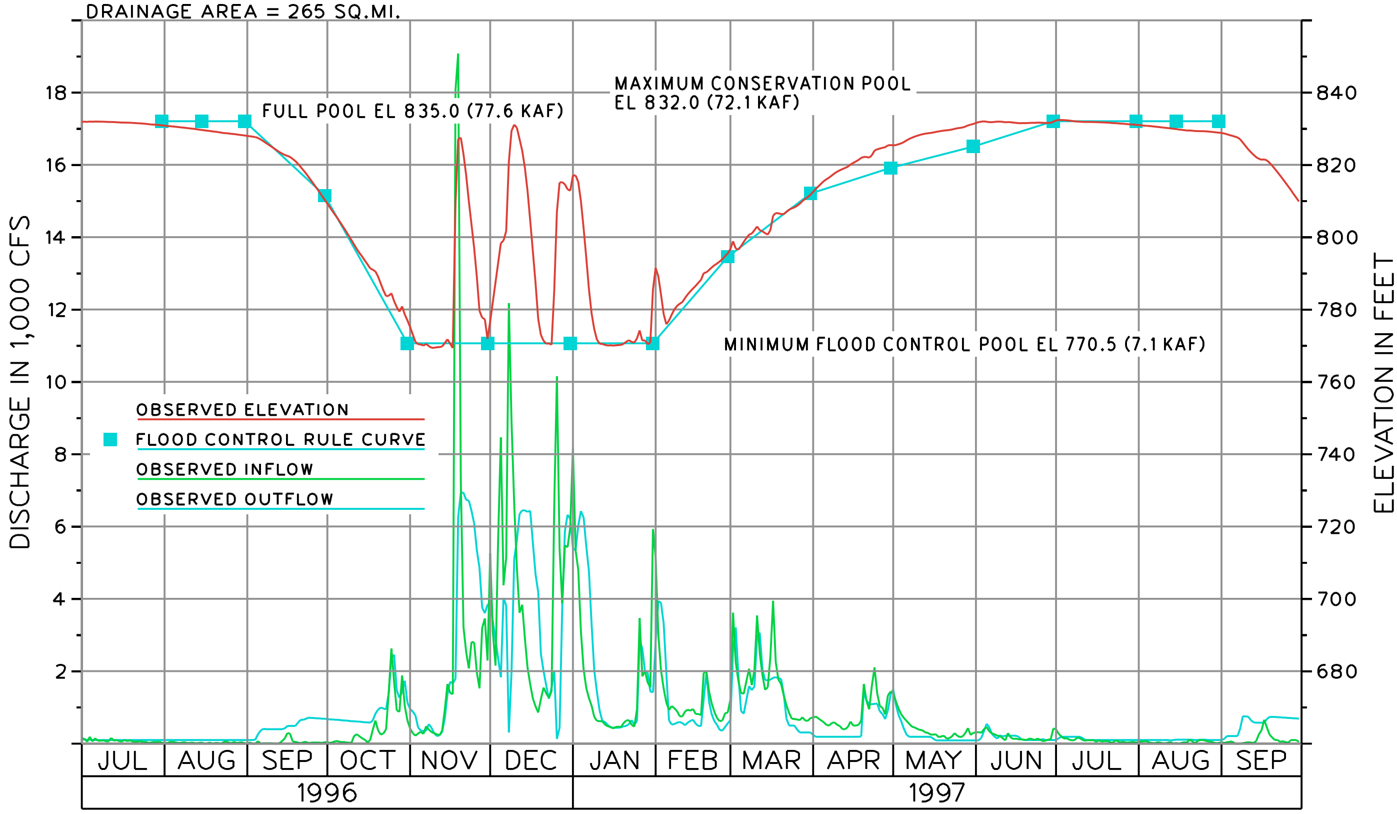
Chart 19 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

FALL CREEK AT FALL CREEK PROJECT, OREGON

Chart 20 Back.

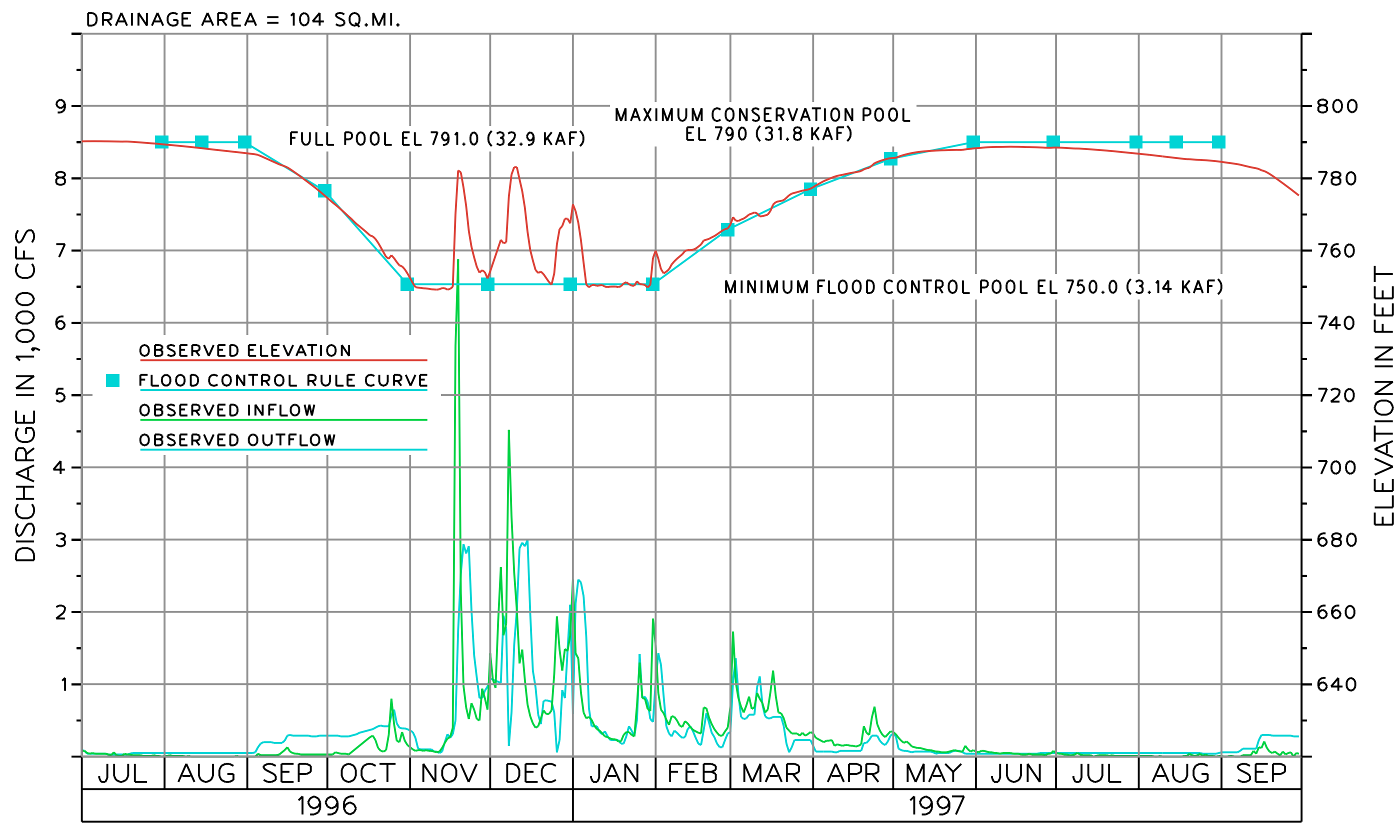


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

ROW RIVER AT DORENA PROJECT, OREGON

Back.

Chart 21

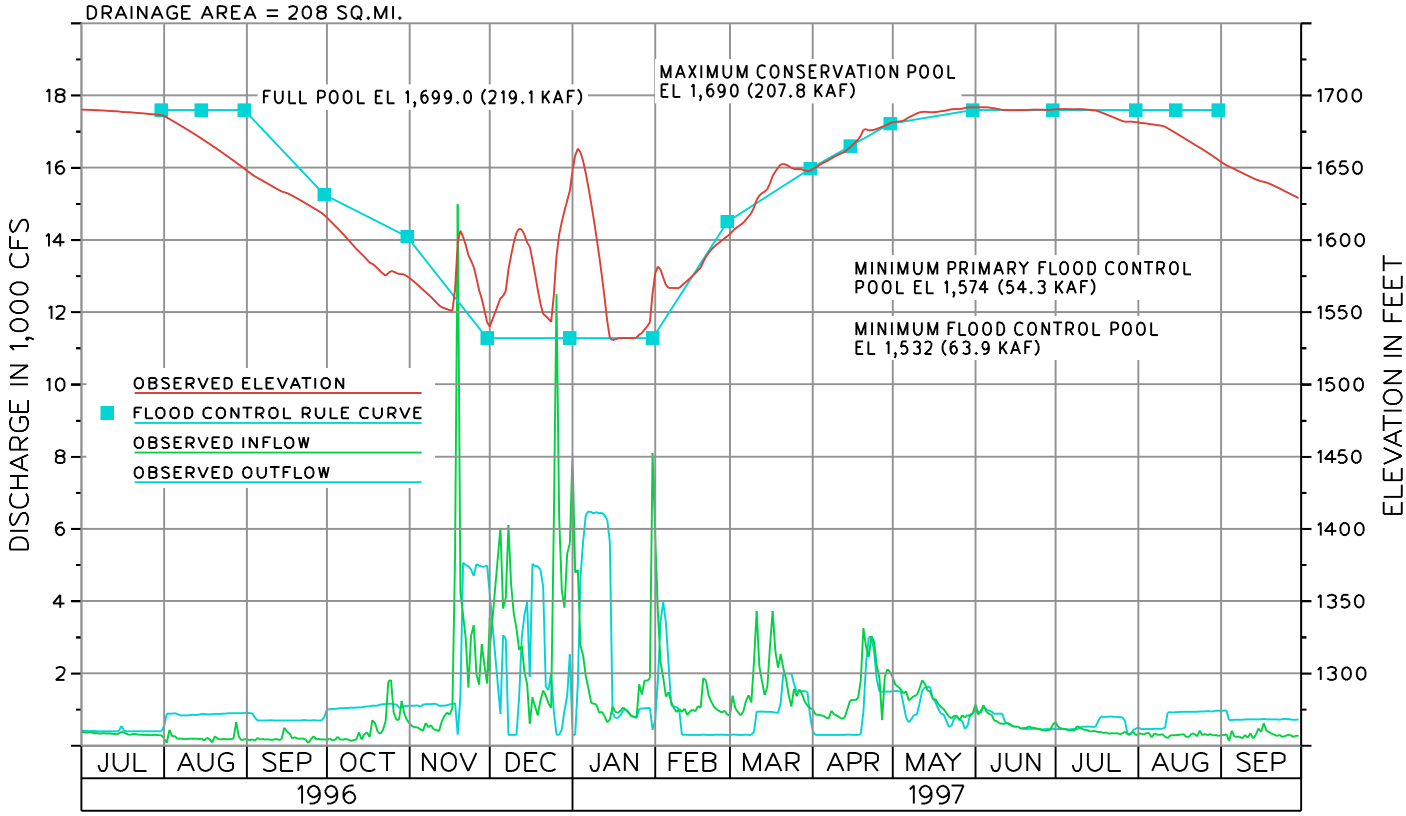


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

COAST FORK WILLAMETTE RIVER AT COTTAGE GROVE PROJECT,OREGON

Chart 22

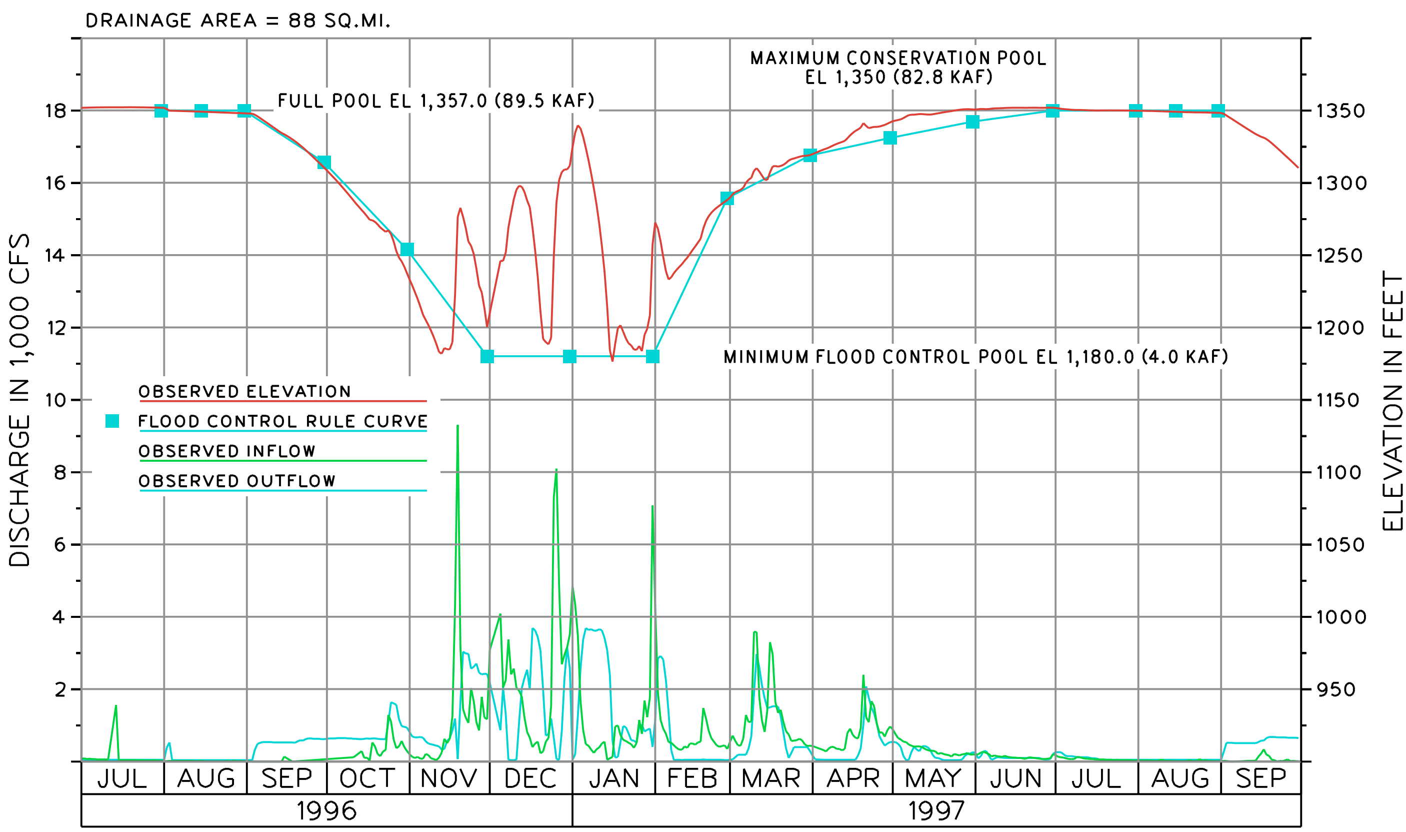
Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

SOUTH FORK McKENZIE RIVER AT COUGAR PROJECT, OREGON

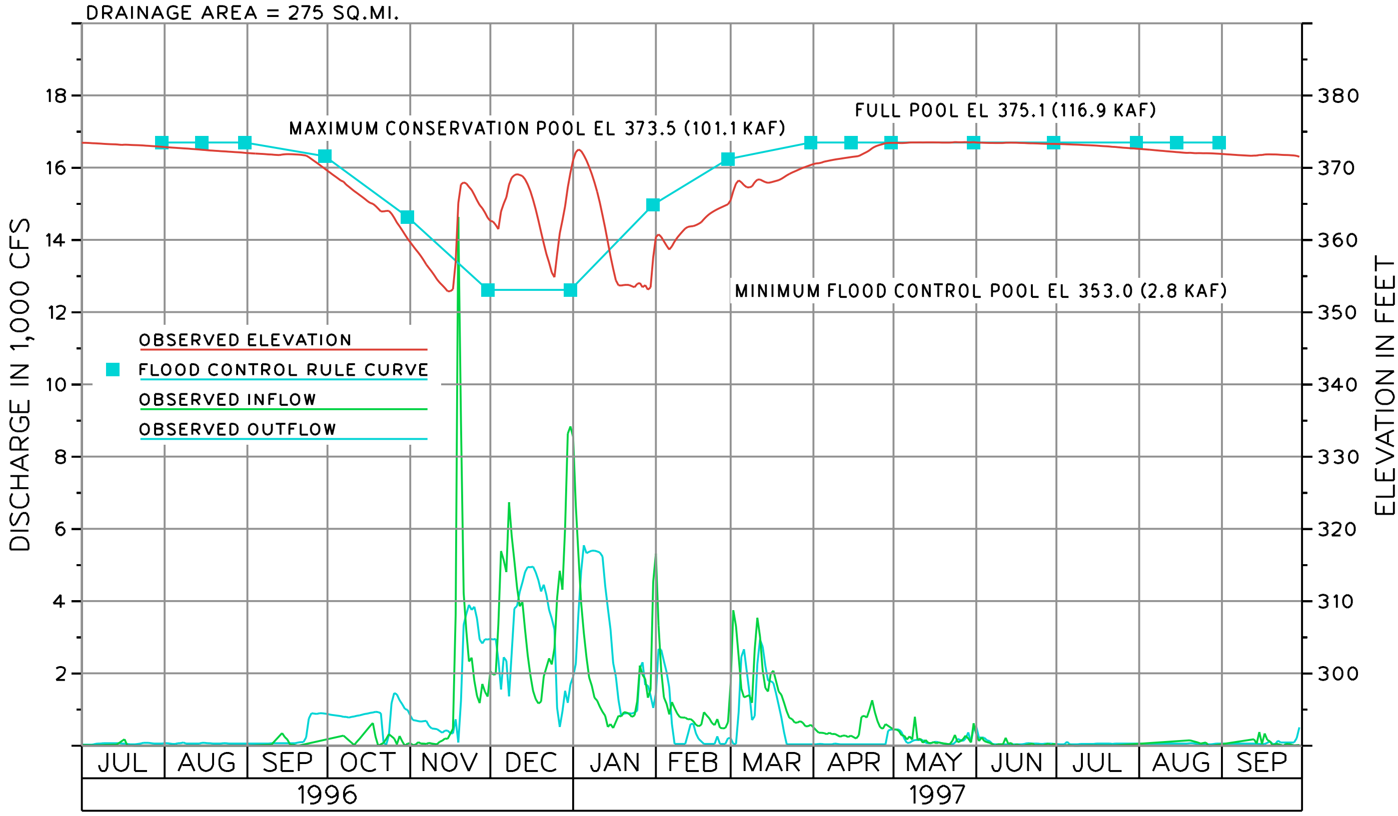
Chart 23 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

BLUE RIVER AT BLUE RIVER PROJECT, OREGON

Chart 24 Back.

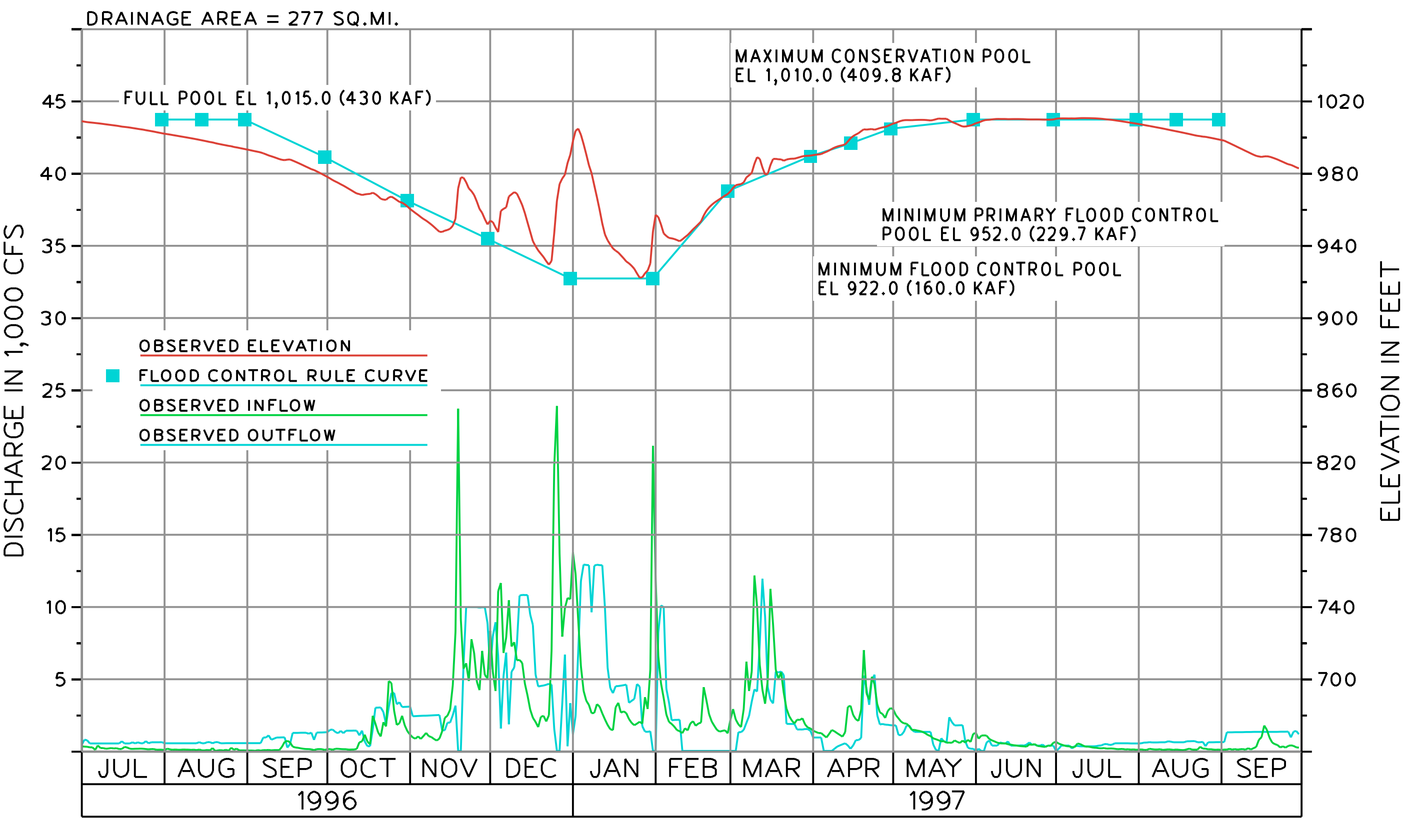


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

LONG TOM RIVER AT FERN RIDGE PROJECT, OREGON

Back.

Chart 25

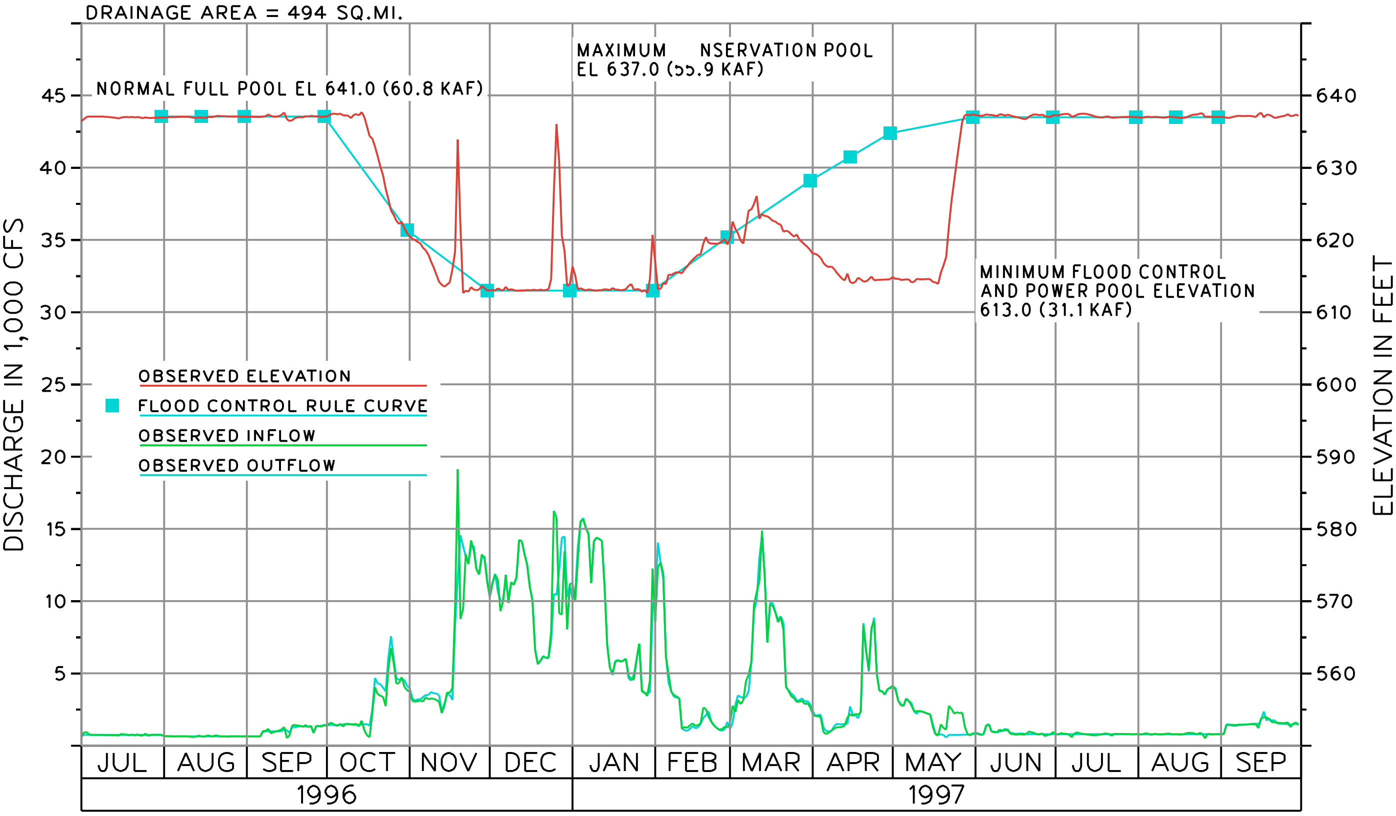


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

MIDDLE SANTIAM RIVER AT GREEN PETER PROJECT, OREGON

Back.

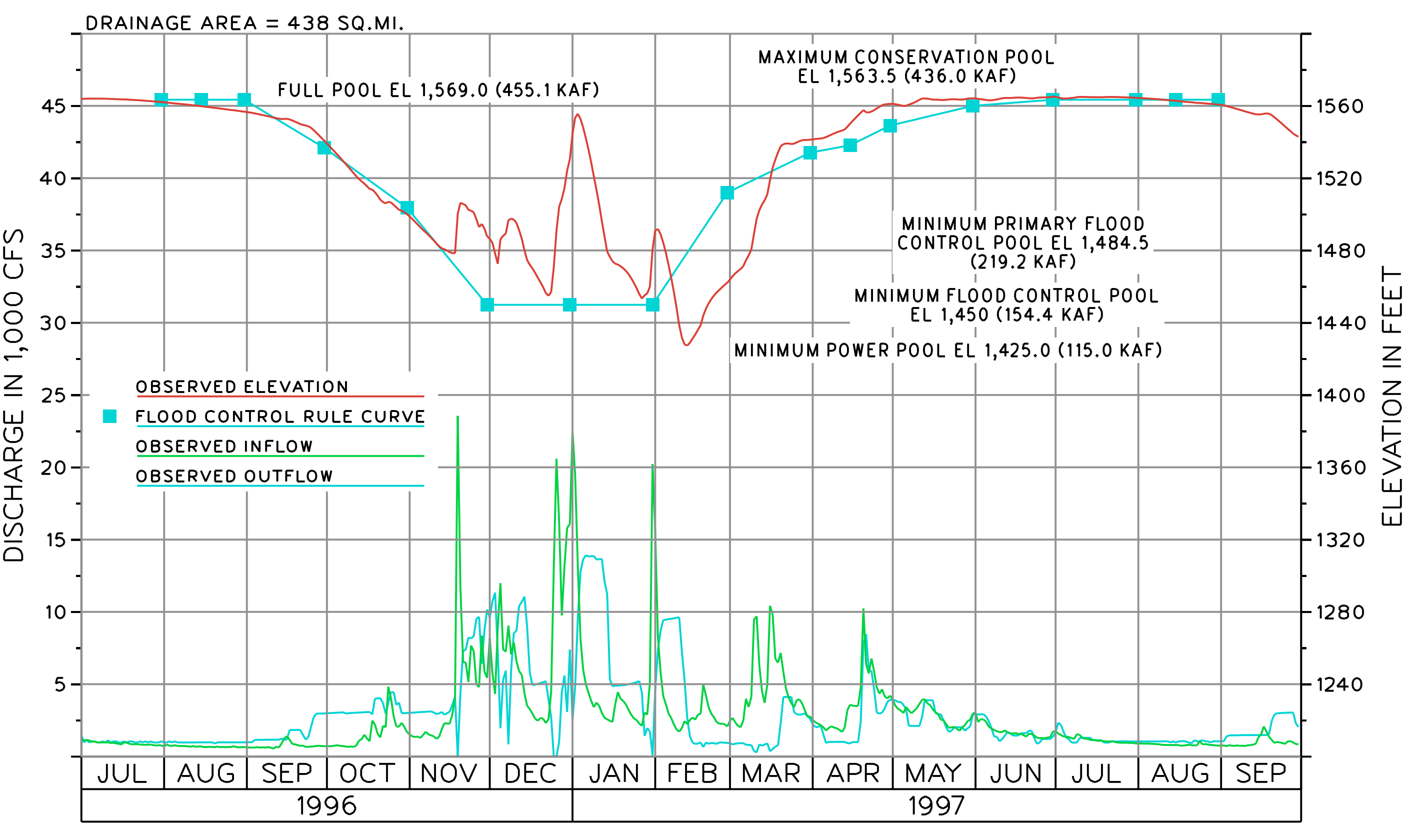
Chart 26



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

SOUTH SANTIAM RIVER AT FOSTER PROJECT, OREGON

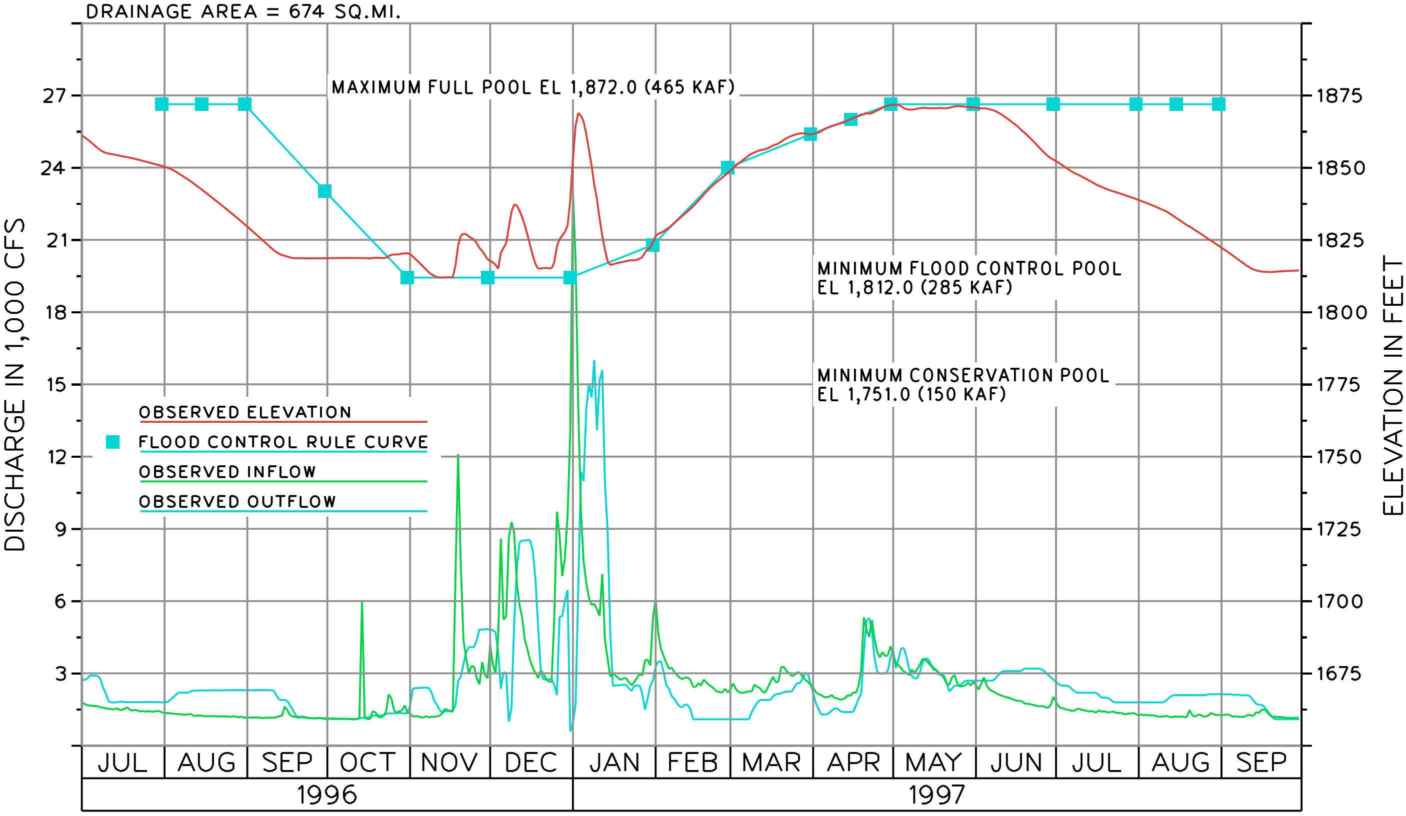
Chart 27 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

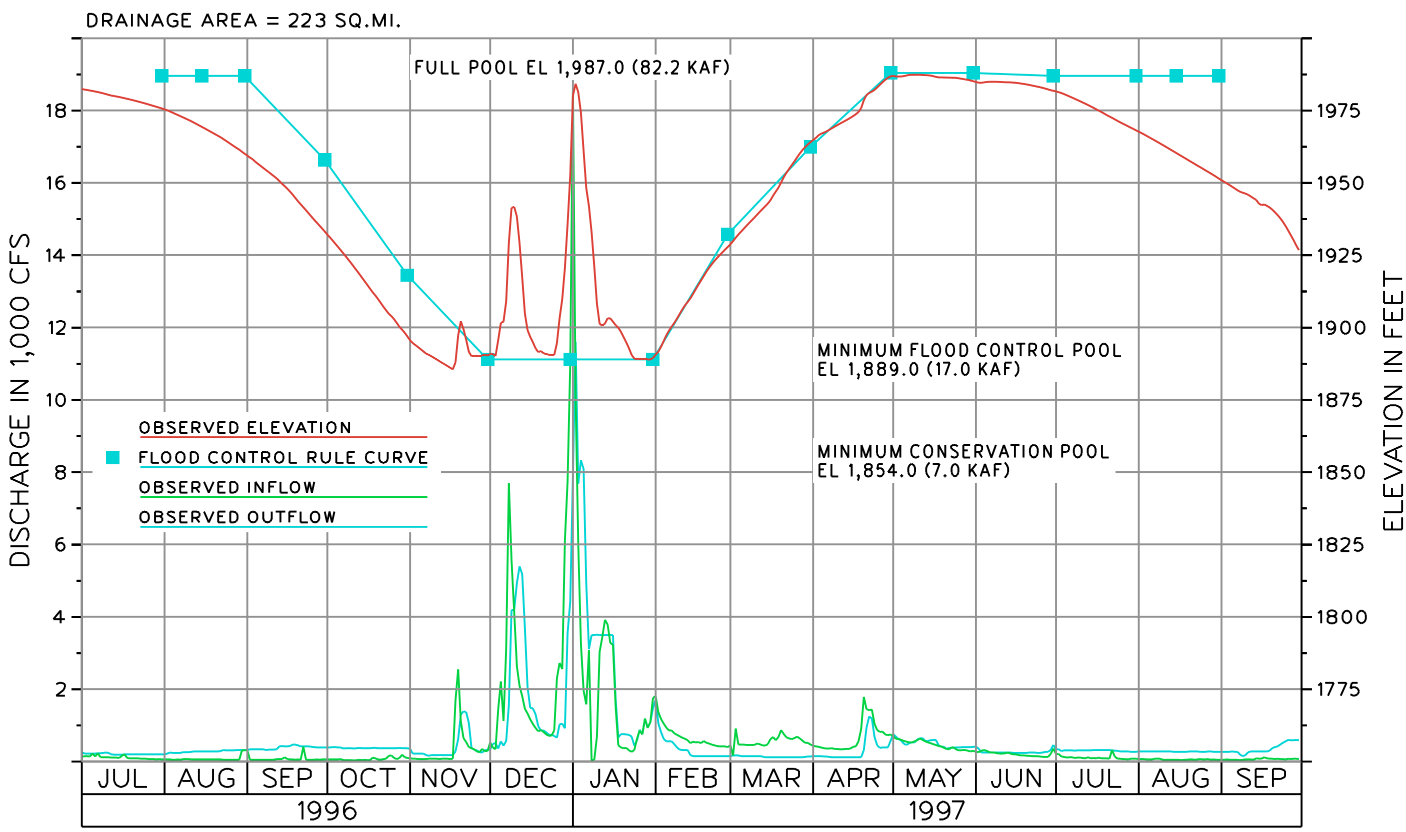
NORTH SANTIAM RIVER AT DETROIT PROJECT, OREGON

Chart 28 Back.



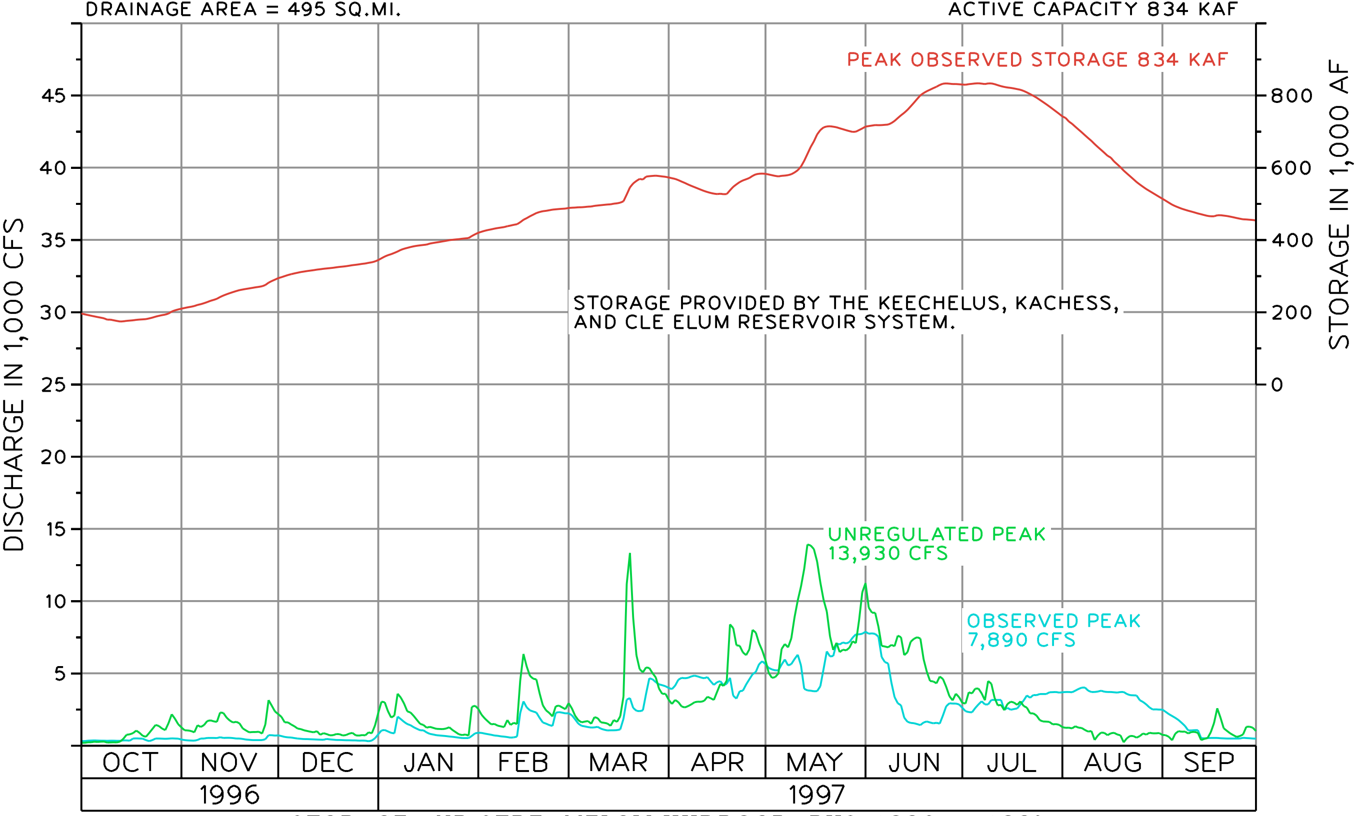
STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997
ROGUE RIVER AT LOST CREEK PROJECT, OREGON

Back. Chart 29



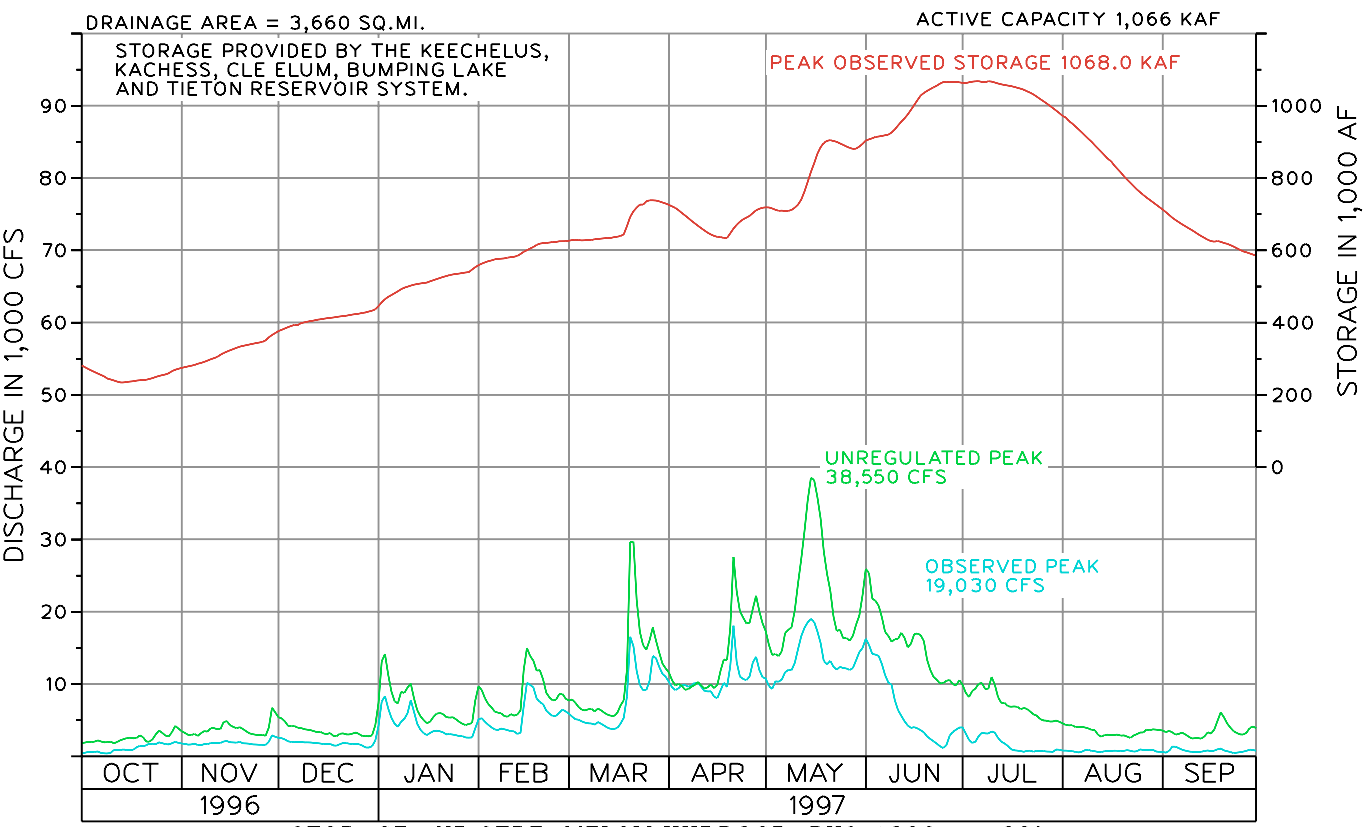
STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997
APPLEGATE RIVER AT APPLEGATE PROJECT, OREGON

Back. Chart 30



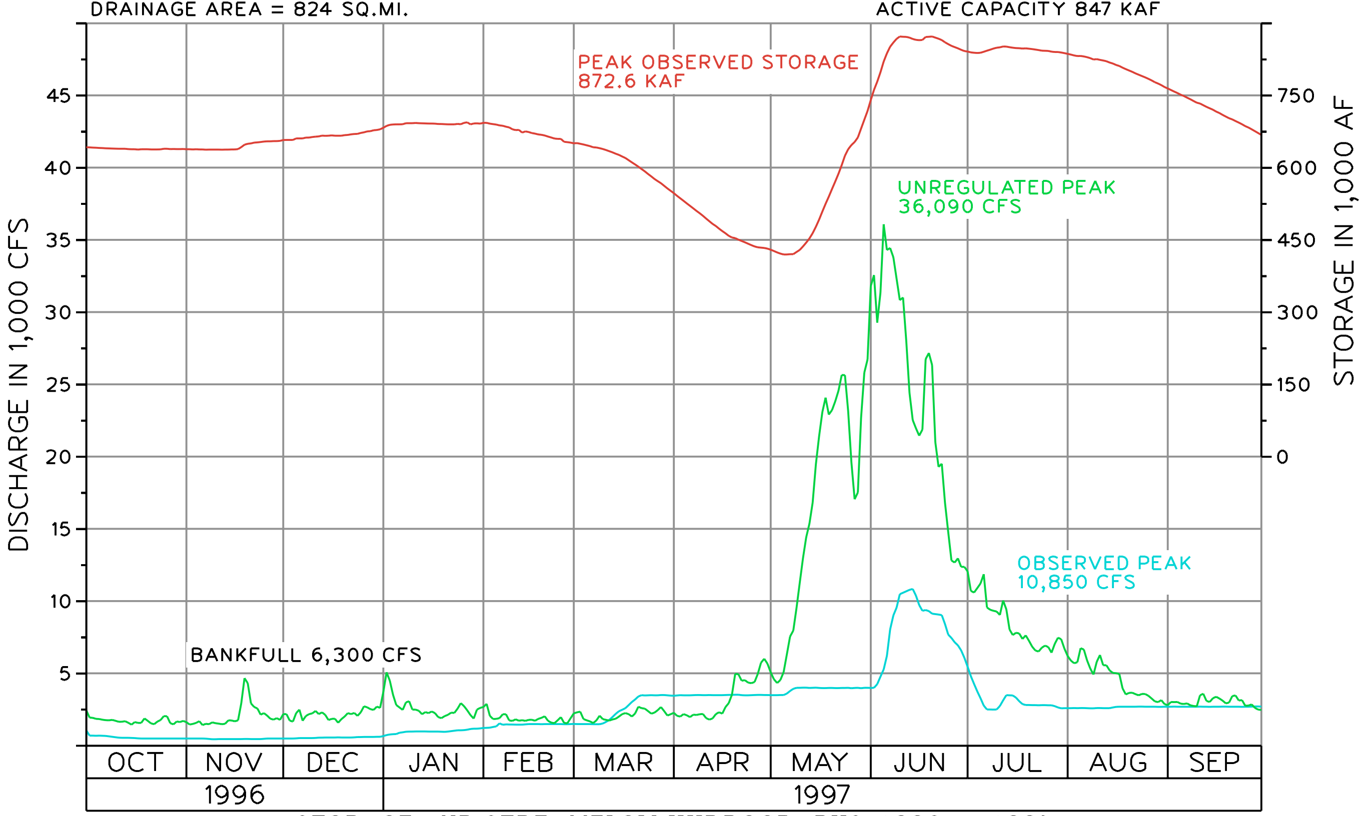
STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997
YAKIMA RIVER AT CLE ELUM, WASHINGTON

Chart 31 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997
YAKIMA RIVER AT PARKER, WASHINGTON

Chart 32 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

SNAKE RIVER AT JACKSON LAKE, WYOMING

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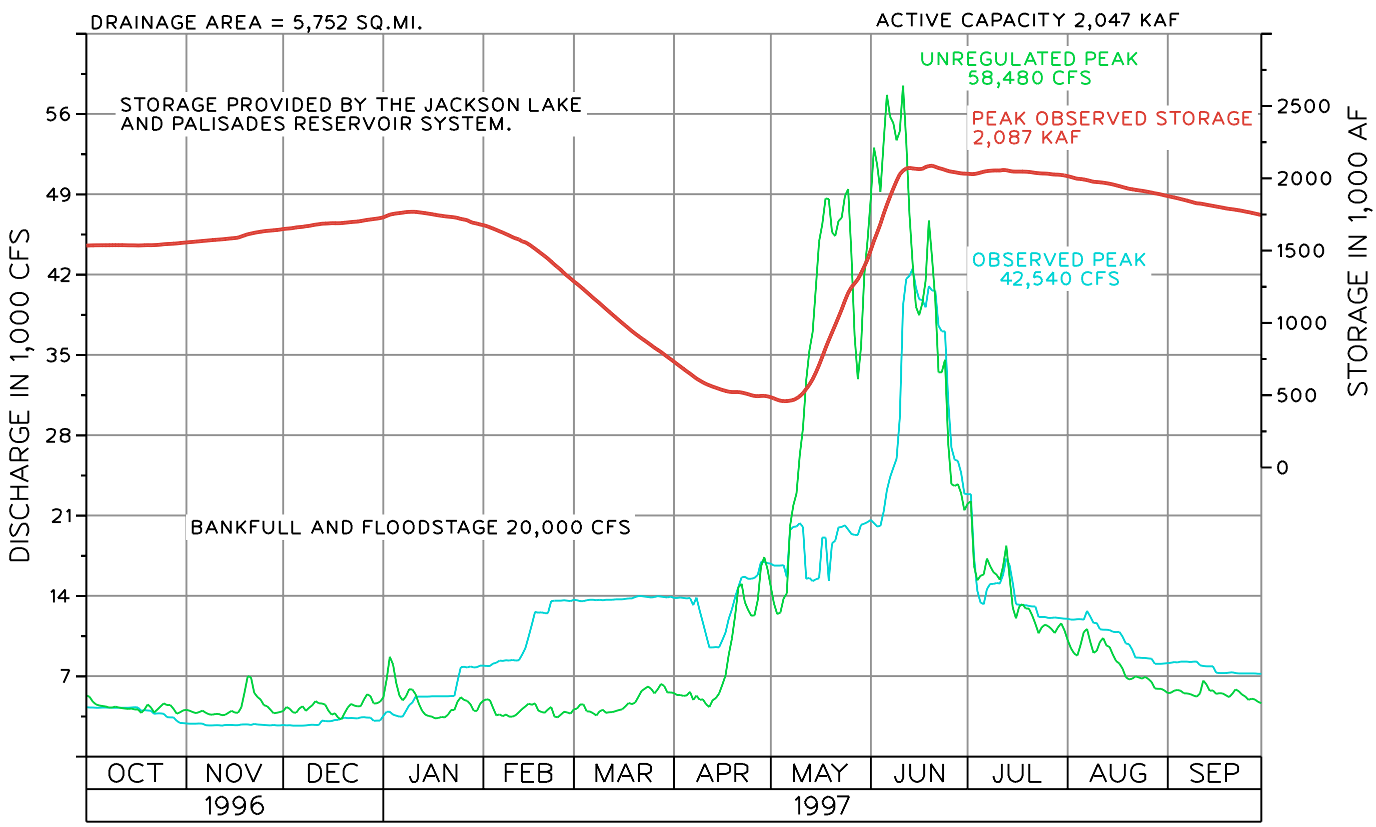
Chart 33

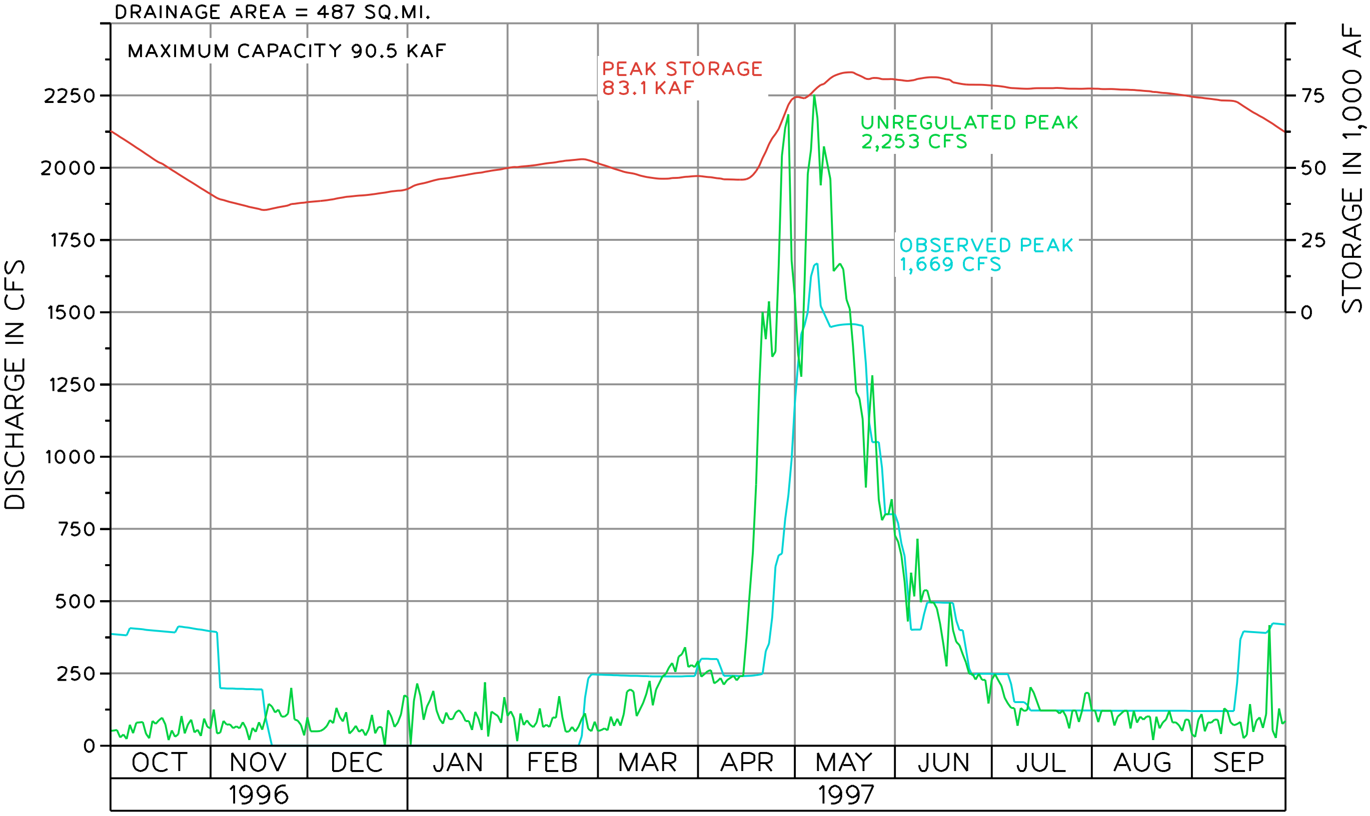


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

SNAKE RIVER NEAR HEISE, IDAHO

Back.

Chart 34

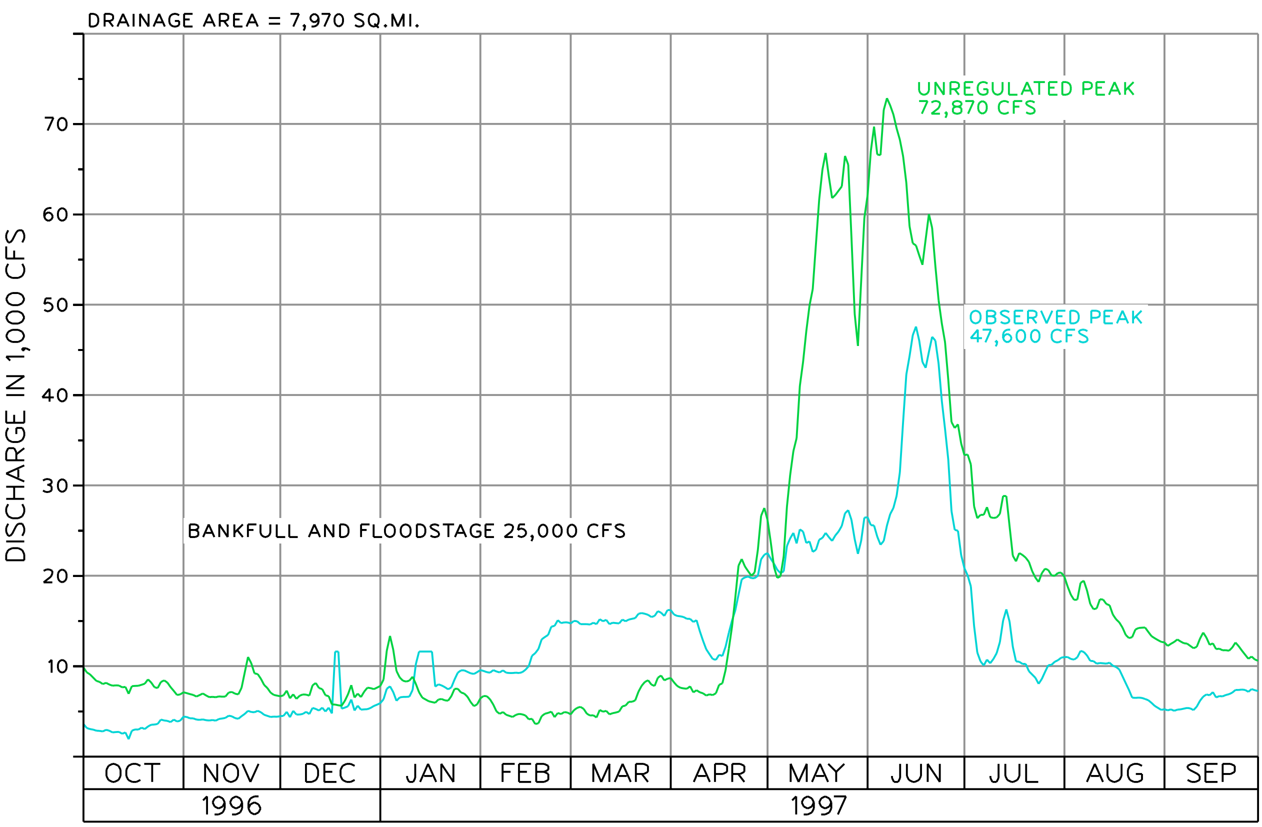


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

WILLOW CREEK AT RIRIE, IDAHO

Chart 35

Back.

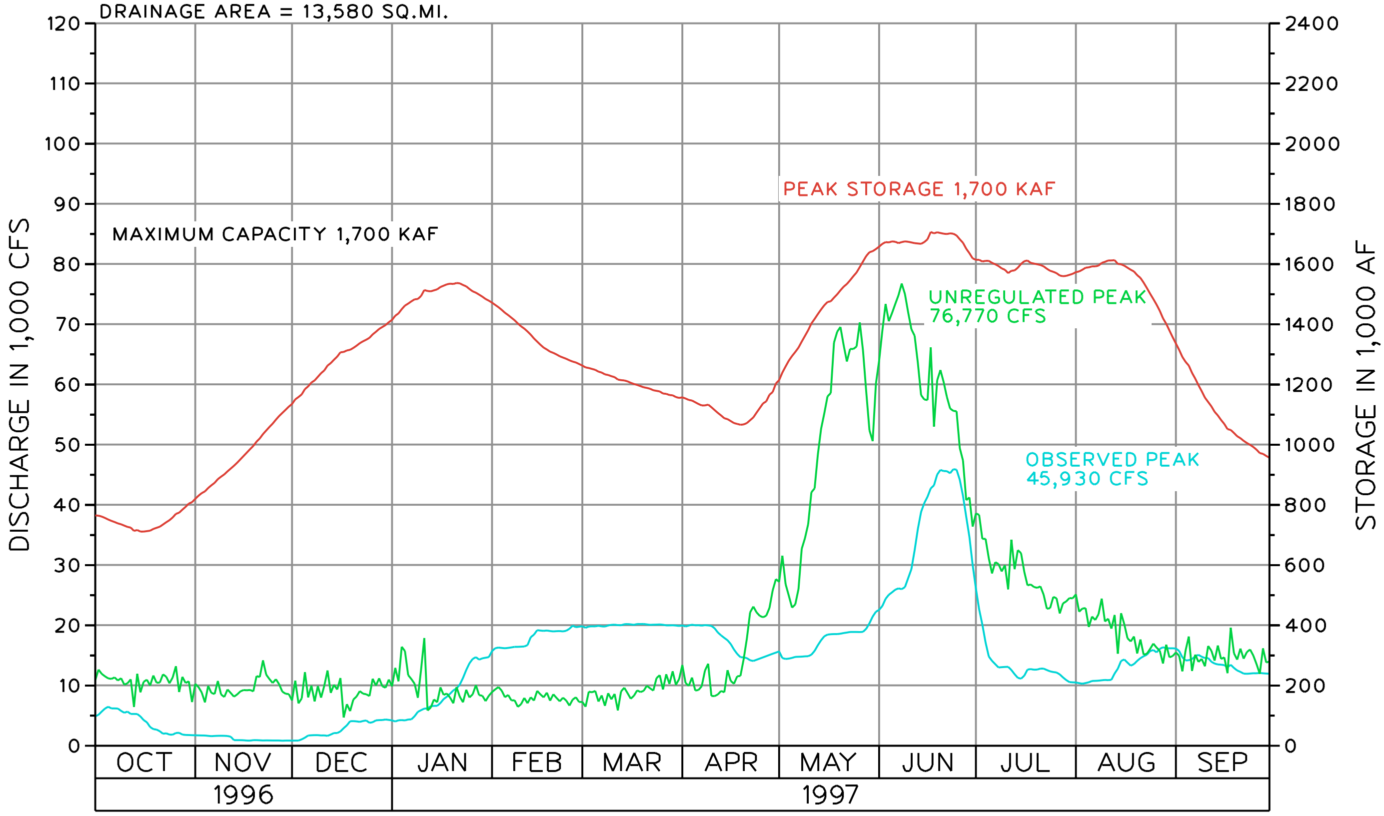


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

SNAKE RIVER NEAR SHELLEY, IDAHO

Chart 36

Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

SNAKE RIVER AT AMERICAN FALLS, IDAHO

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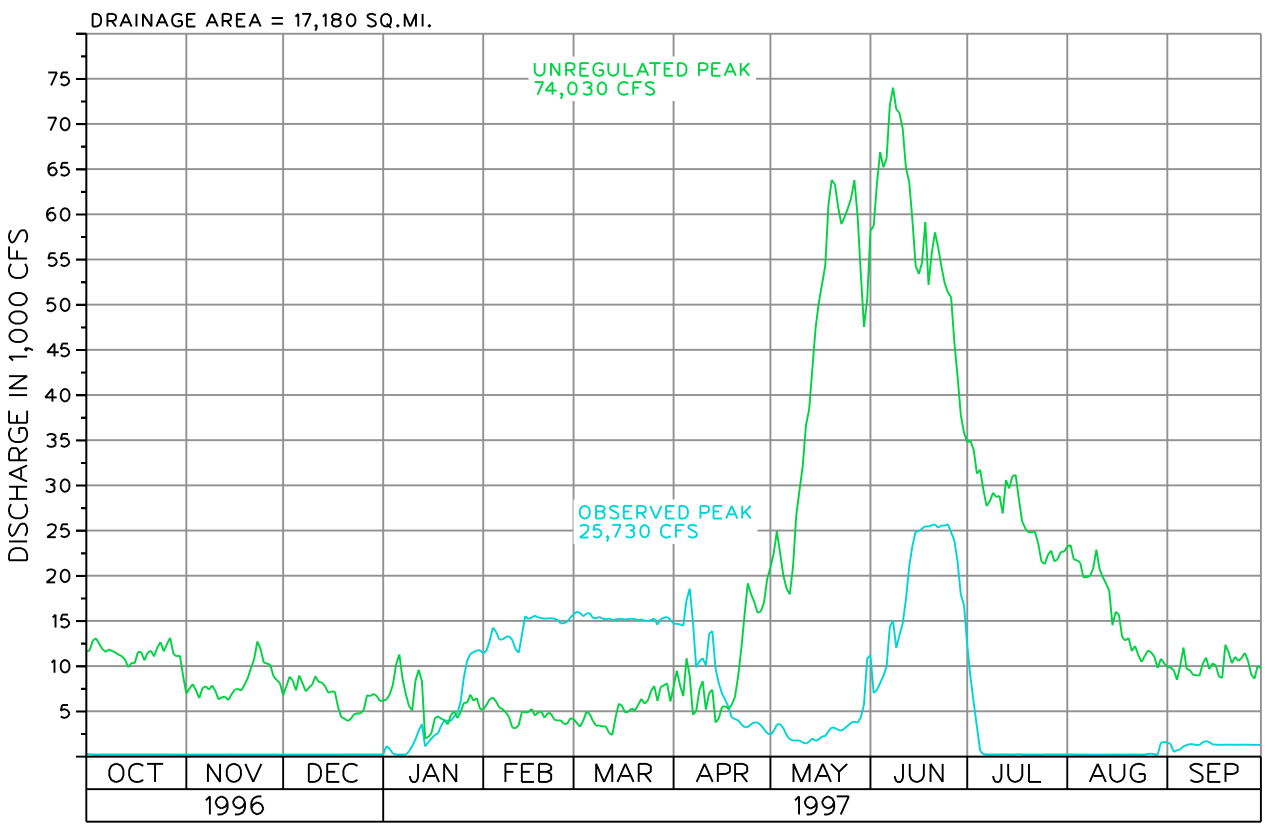
Chart 37

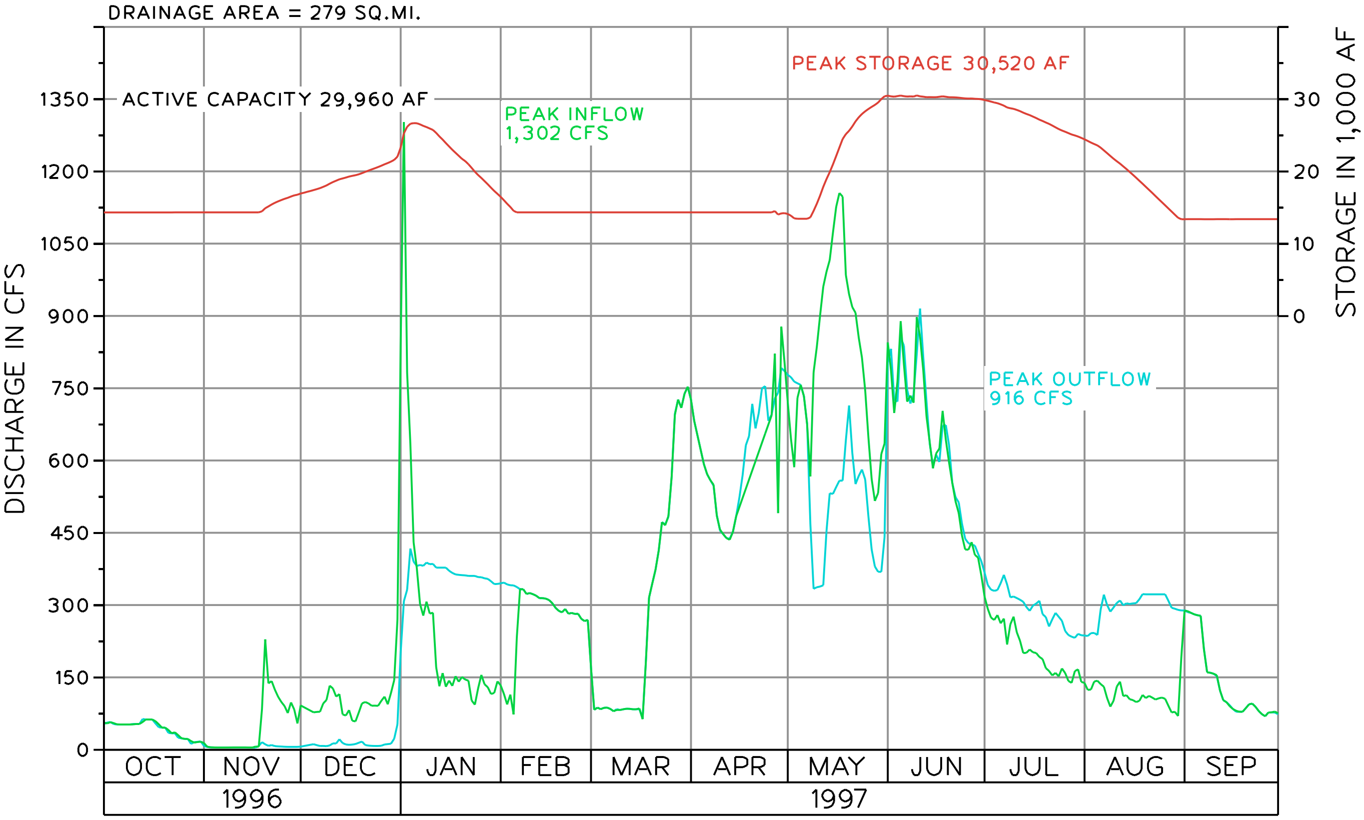


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

SNAKE RIVER AT MILNER, IDAHO

Back.

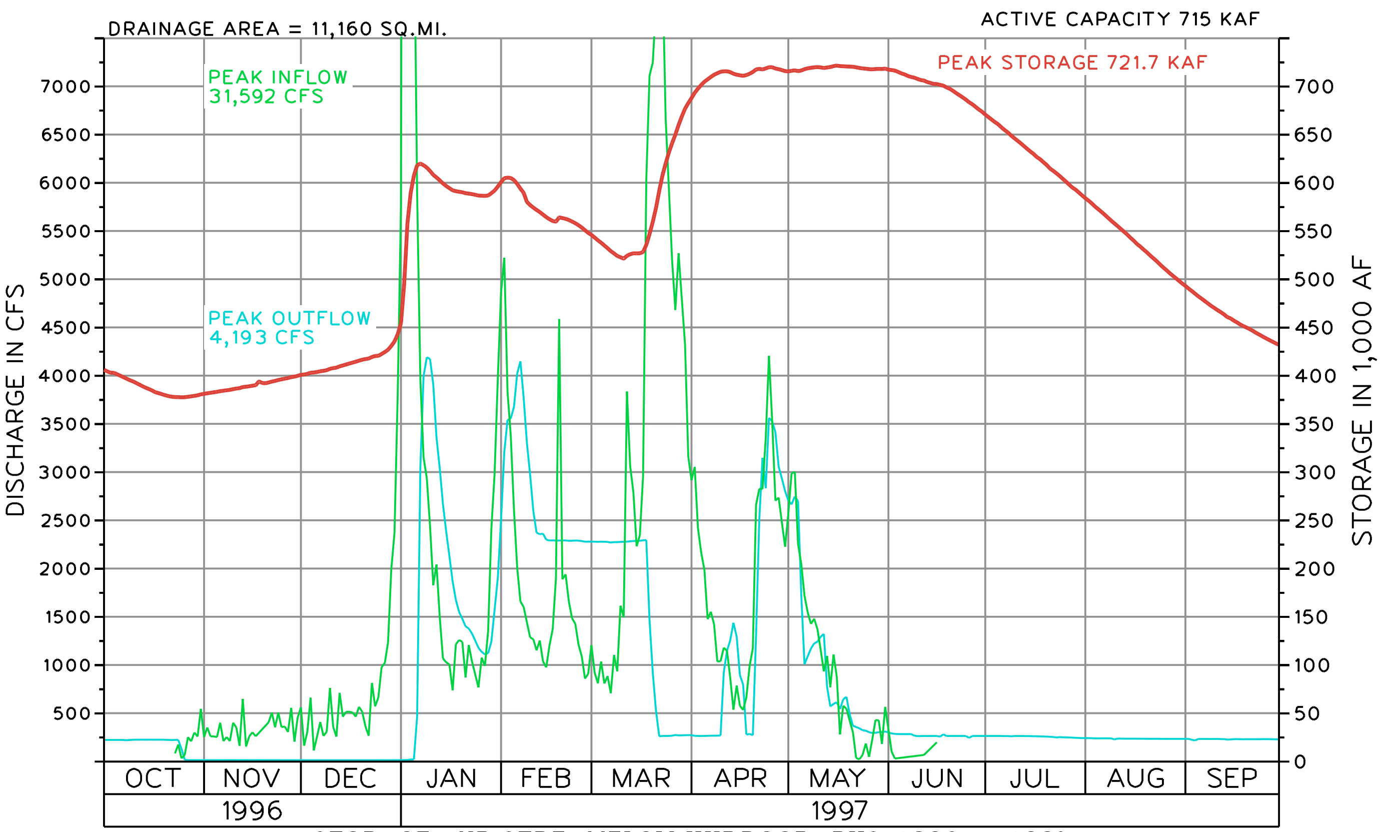
Chart 38



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

LITTLE WOOD RIVER AT LITTLE WOOD PROJECT, IDAHO

Chart 39 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

OWYHEE RIVER AT OWYHEE DAM, OREGON

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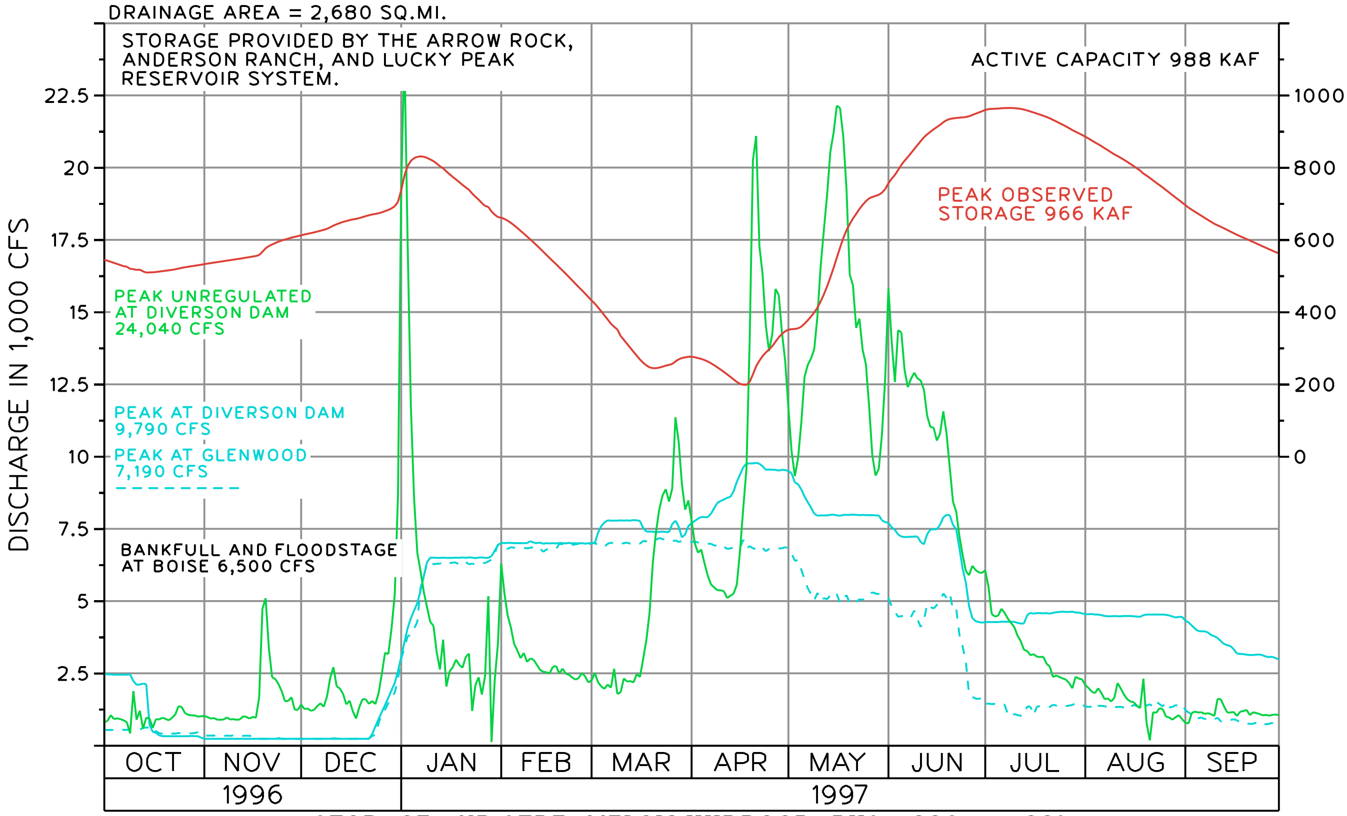

STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

BOISE RIVER AT AND NEAR BOISE, IDAHO

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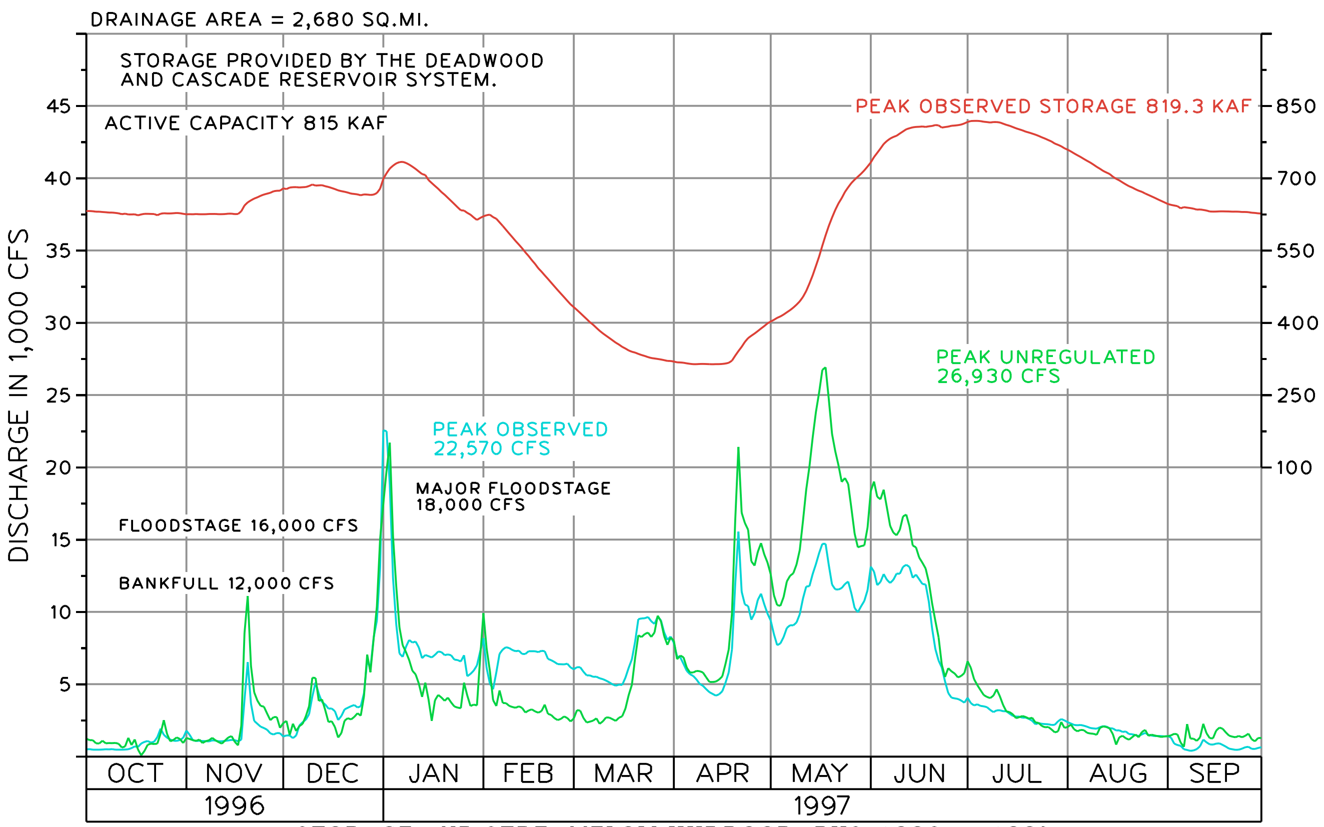
Chart 41



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

PAYETTE RIVER NEAR EMMETT, IDAHO

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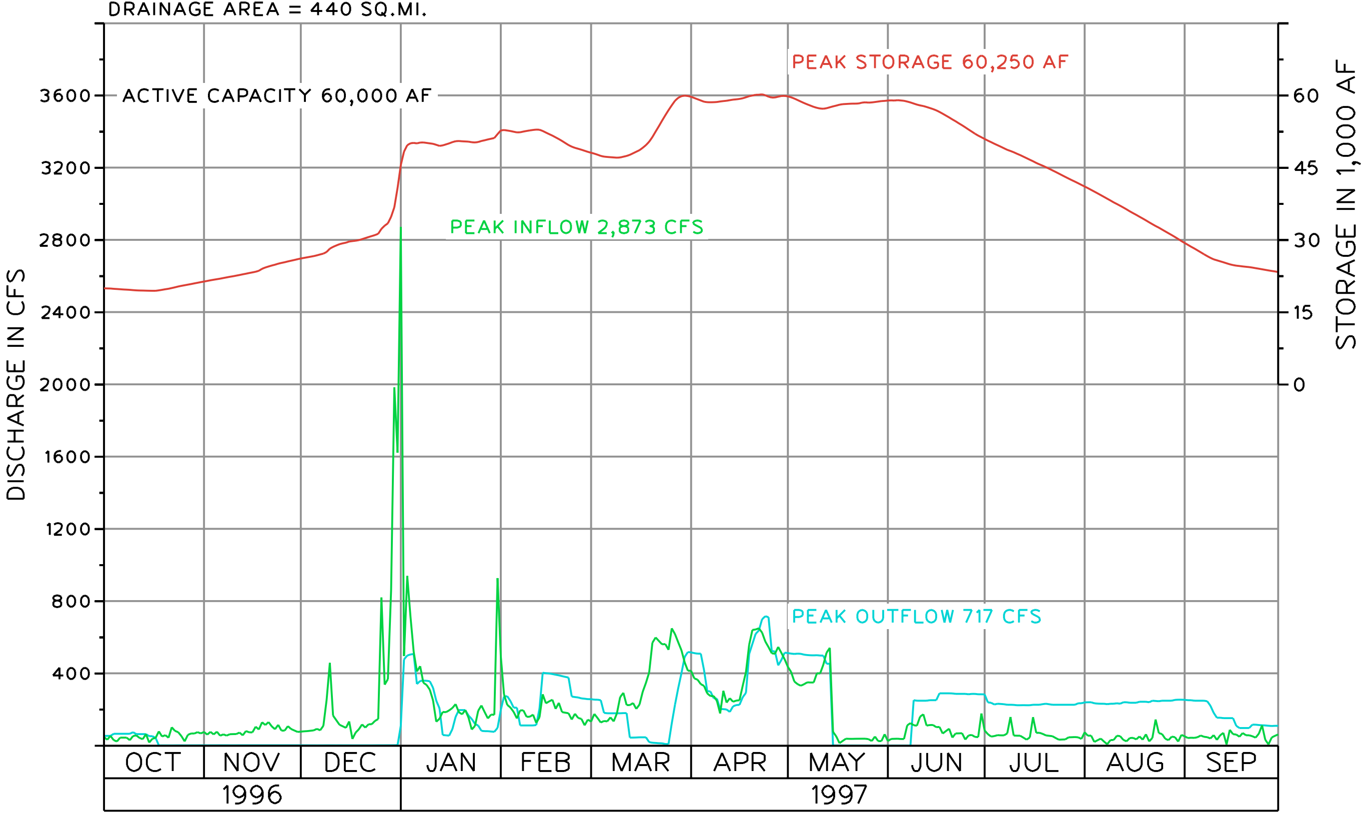
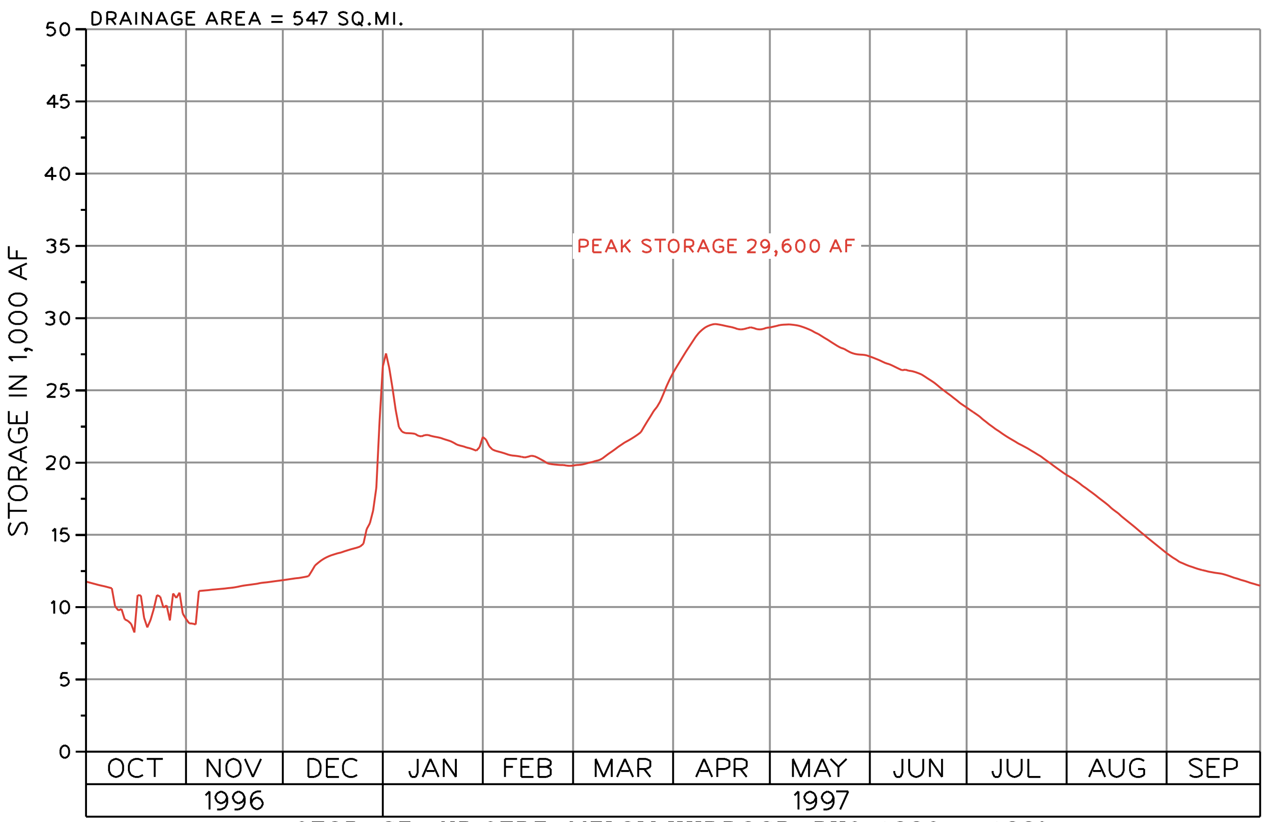
Chart 42



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

NORTH FORK MALHEUR RIVER AT AGENCY VALLEY PROJECT, OREGON

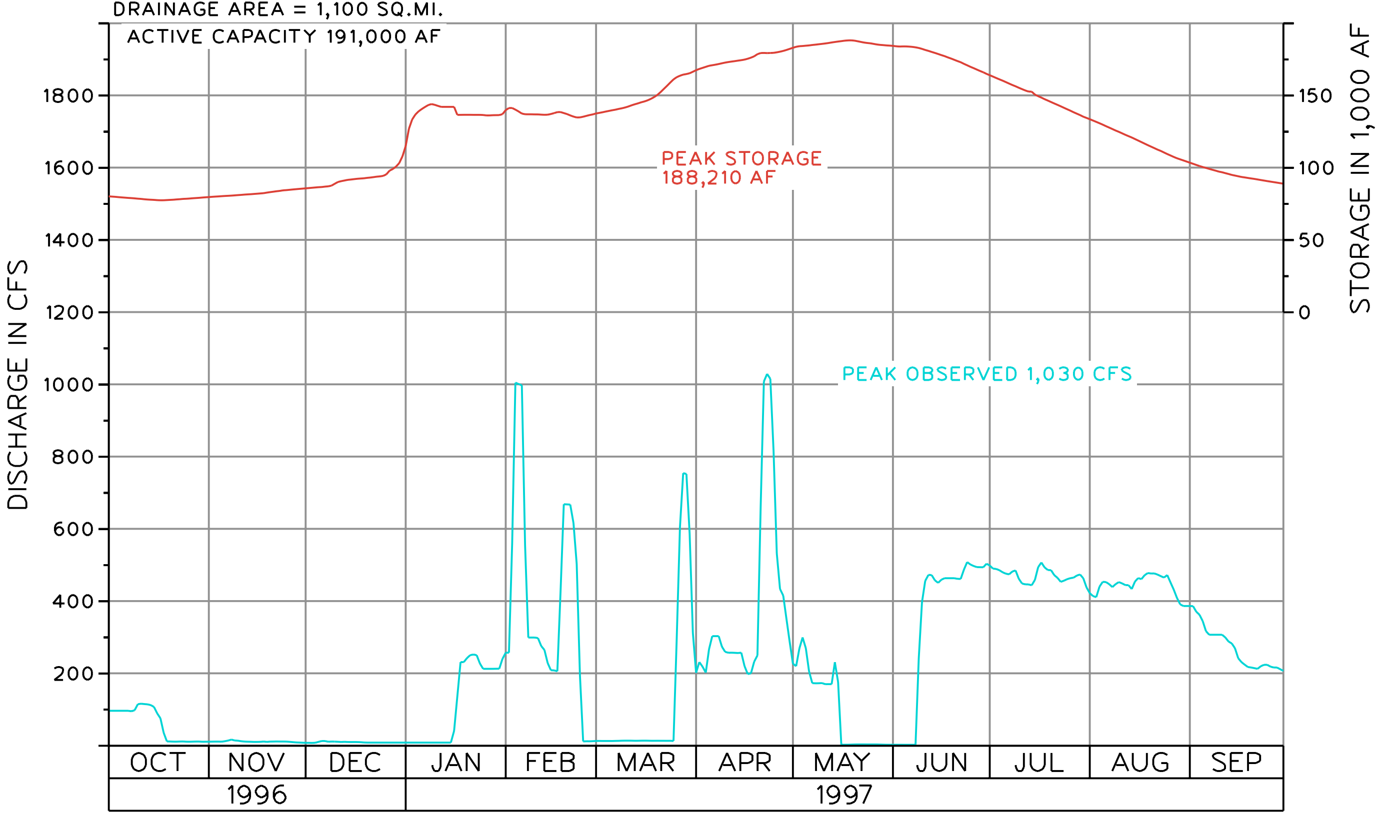
Chart 43 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

BULLY CREEK AT BULLY CREEK PROJECT, OREGON

Chart 44 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

MIDDLE FORK MALHEUR RIVER AT WARM SPRINGS PROJECT, OREGON

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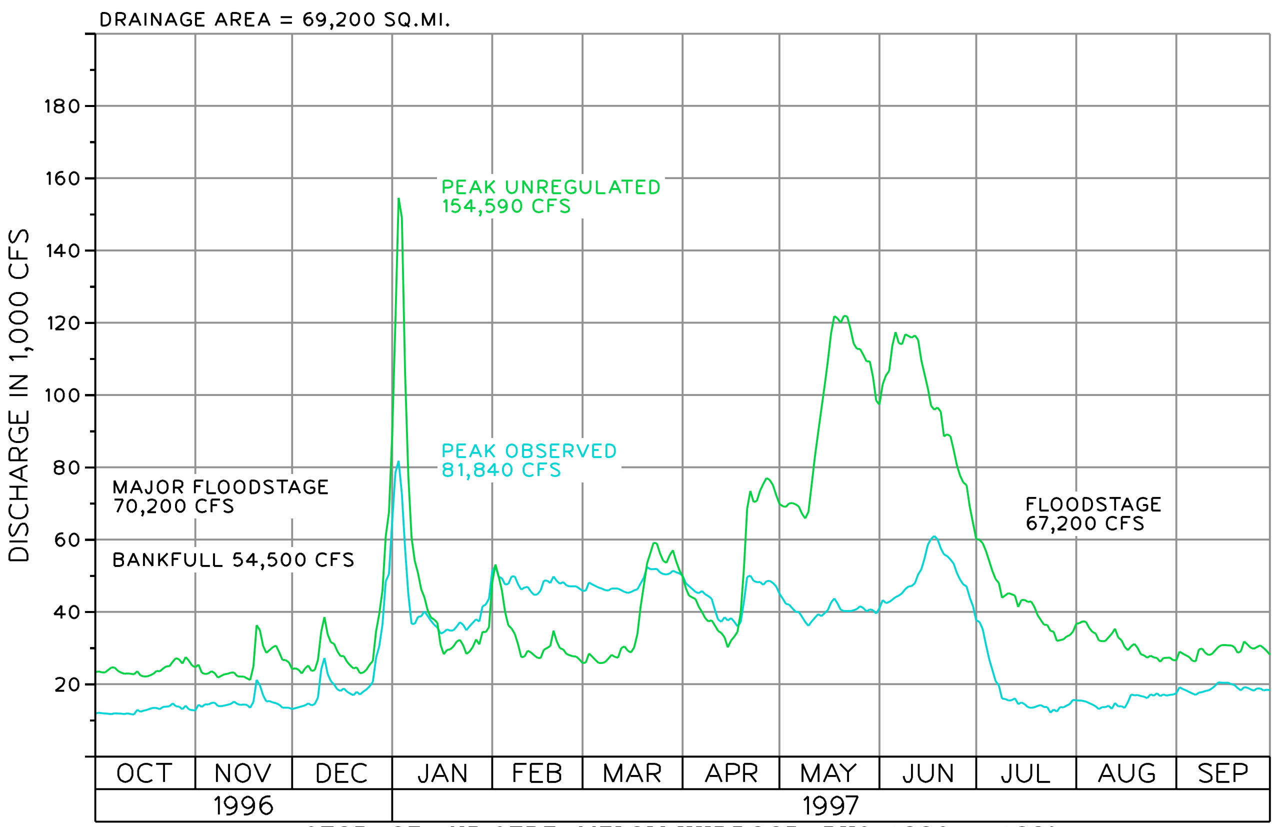
Chart 45



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

SNAKE RIVER AT WEISER, IDAHO

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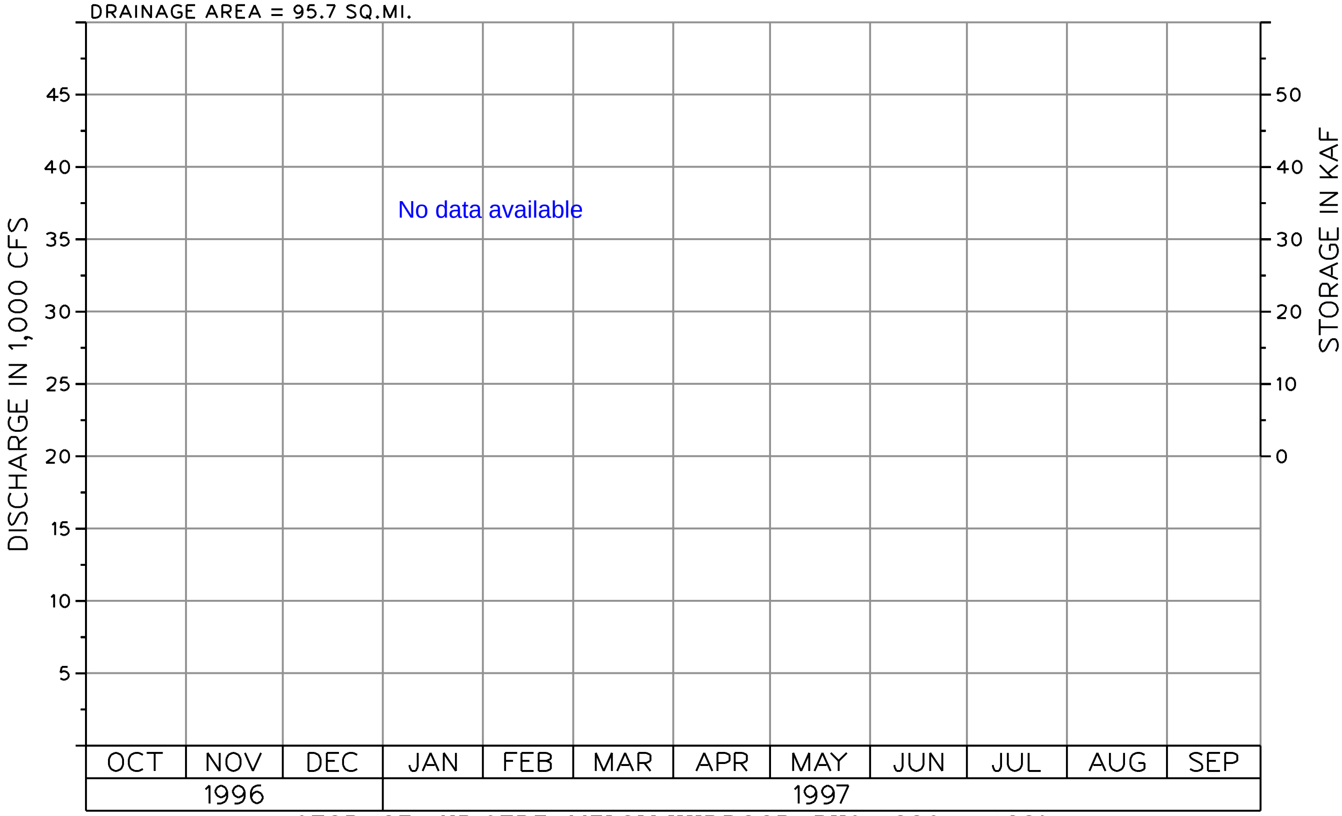
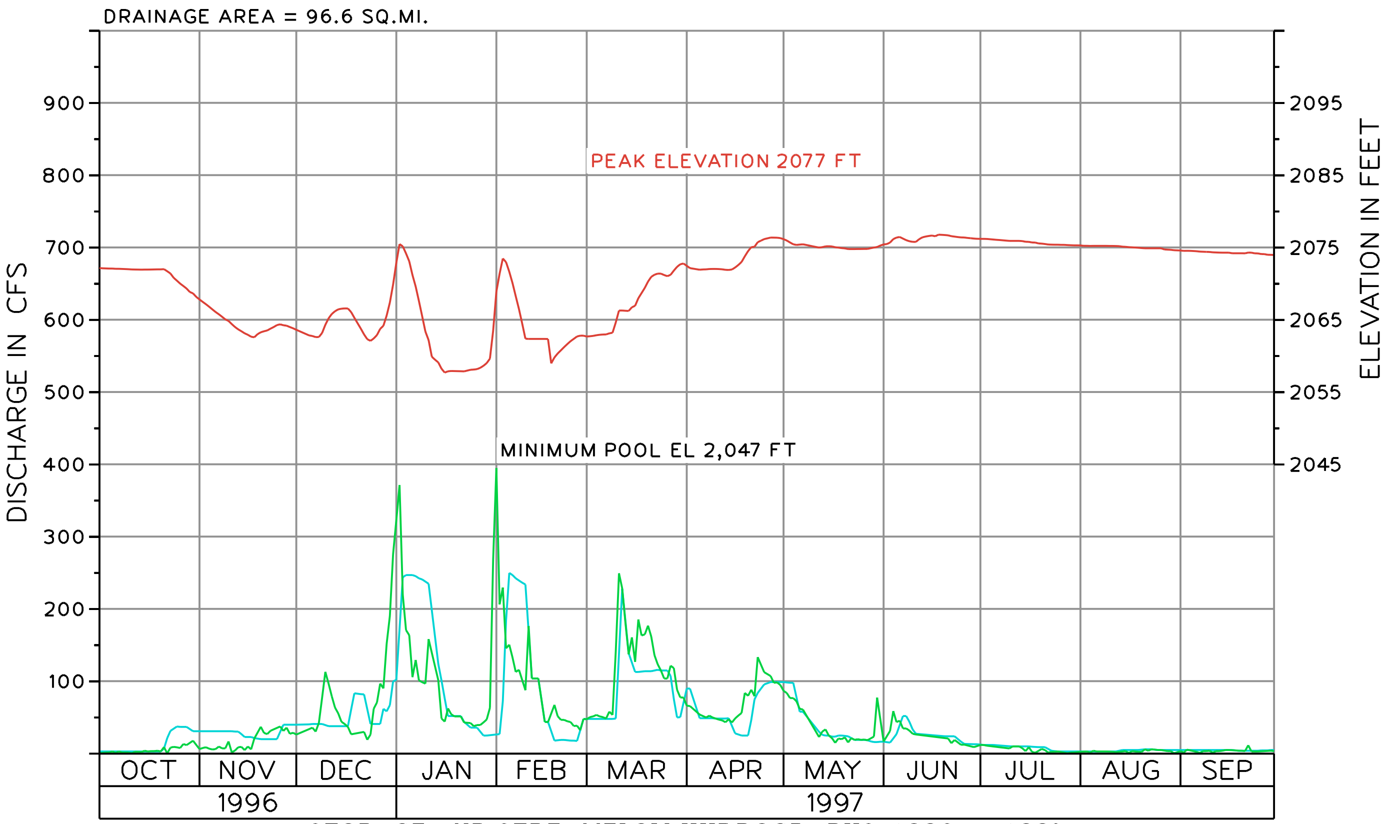
Chart 46



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

MILL CREEK AT MILL CREEK PROJECT, WASHINGTON

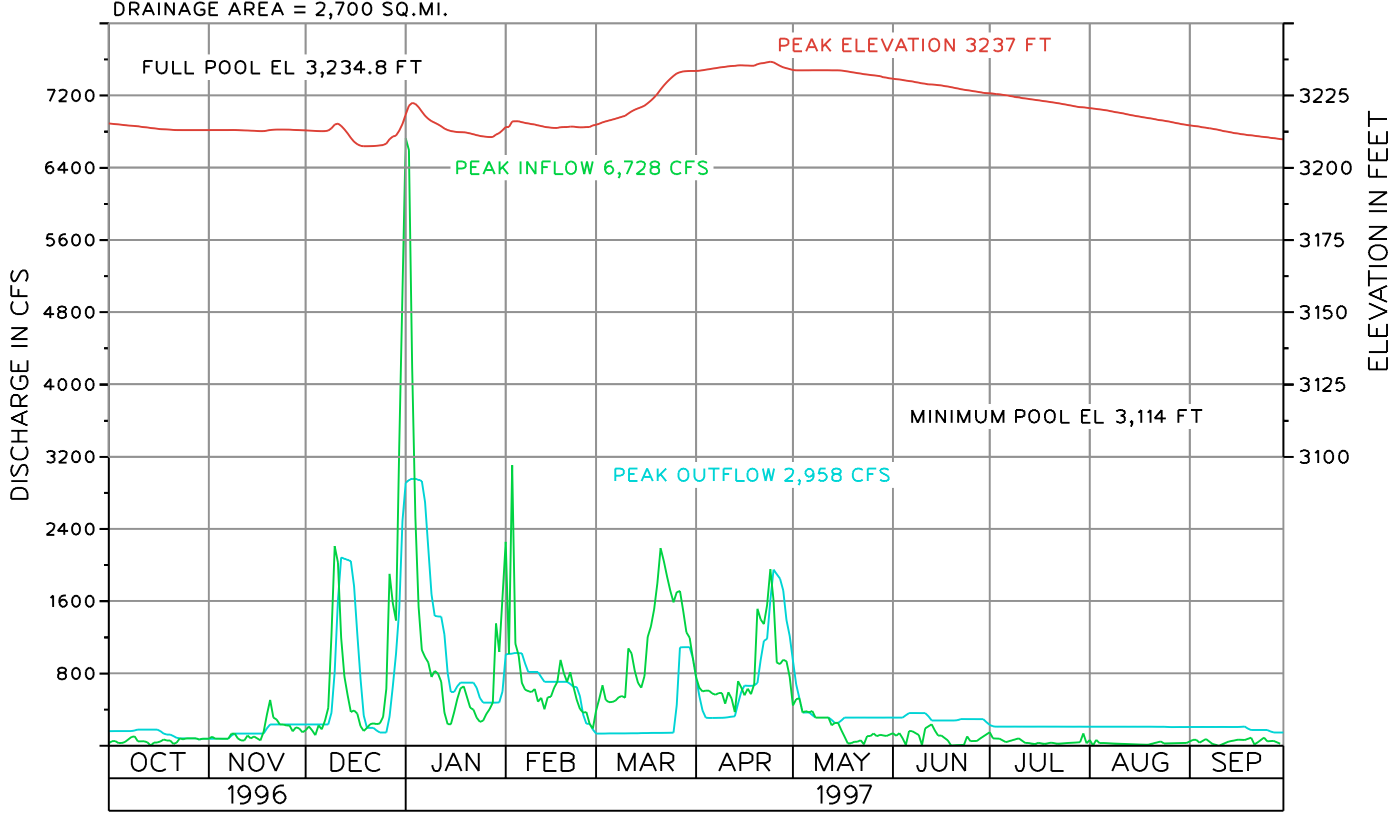
Chart 47 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

WILLOW CREEK AT WILLOW CREEK PROJECT, OREGON

Chart 48 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

CROOKED RIVER AT PRINEVILLE PROJECT, OREGON

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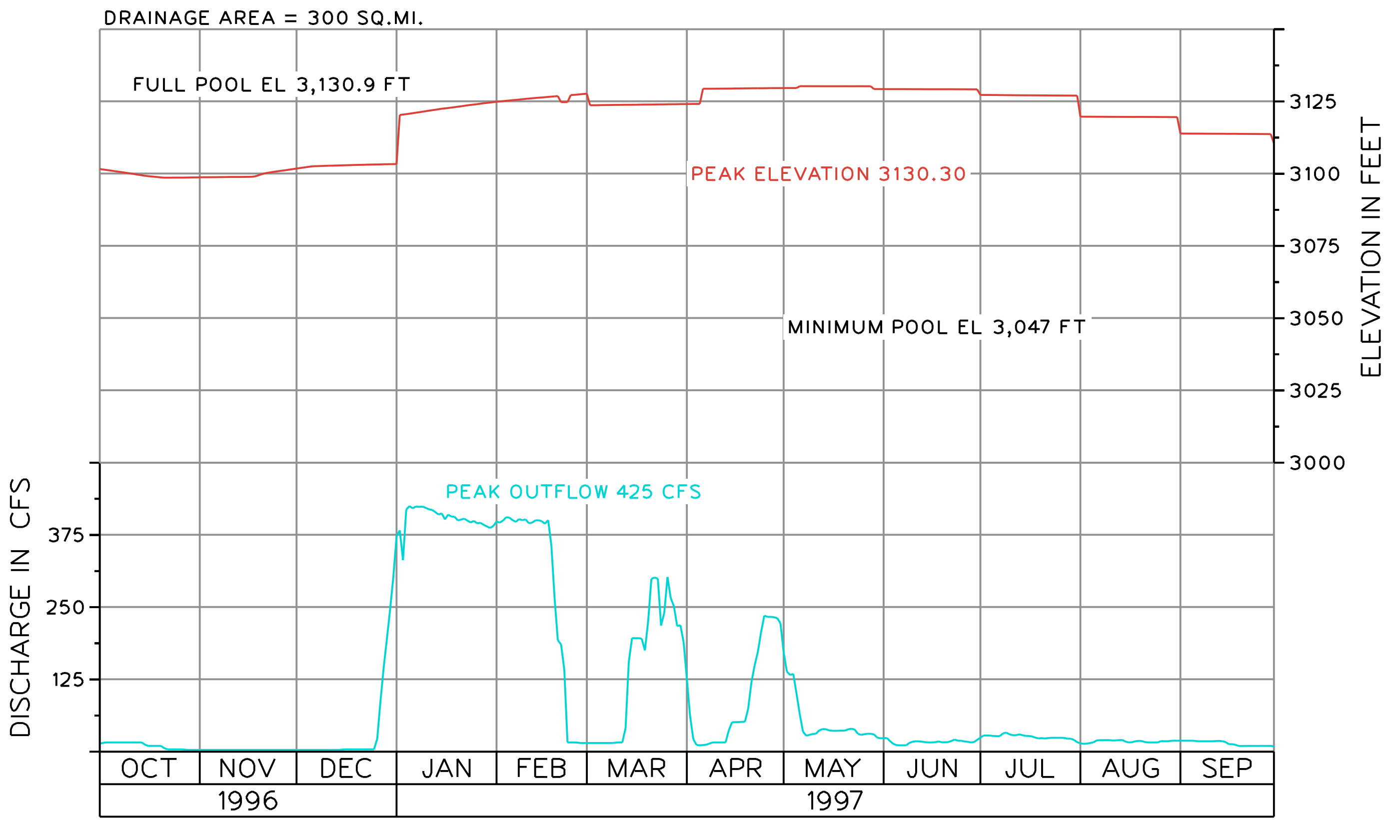
Chart 49



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

OCHOCO RIVER AT OCHOCO PROJECT, OREGON

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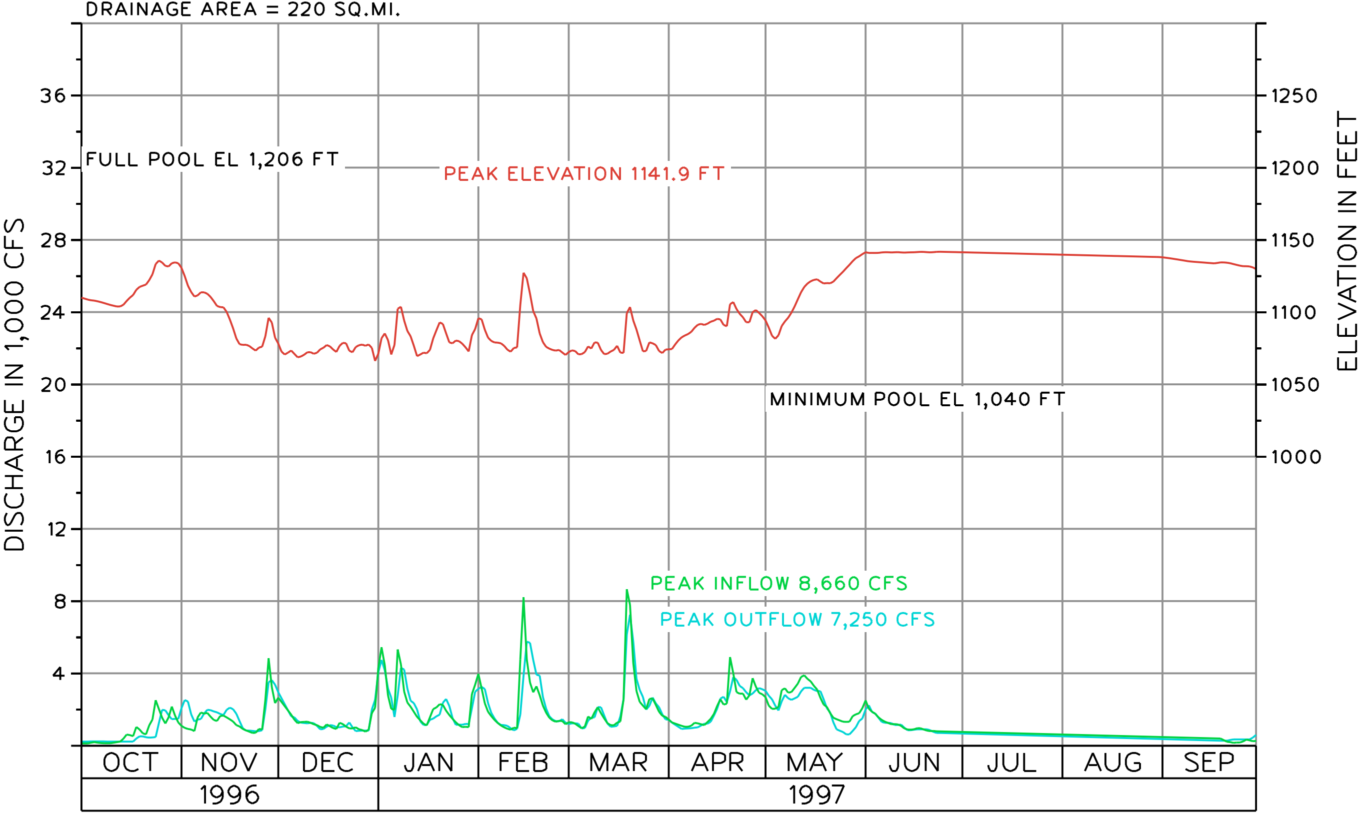
Chart 50



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

GREEN RIVER AT HOWARD A. HANSON PROJECT, WASHINGTON

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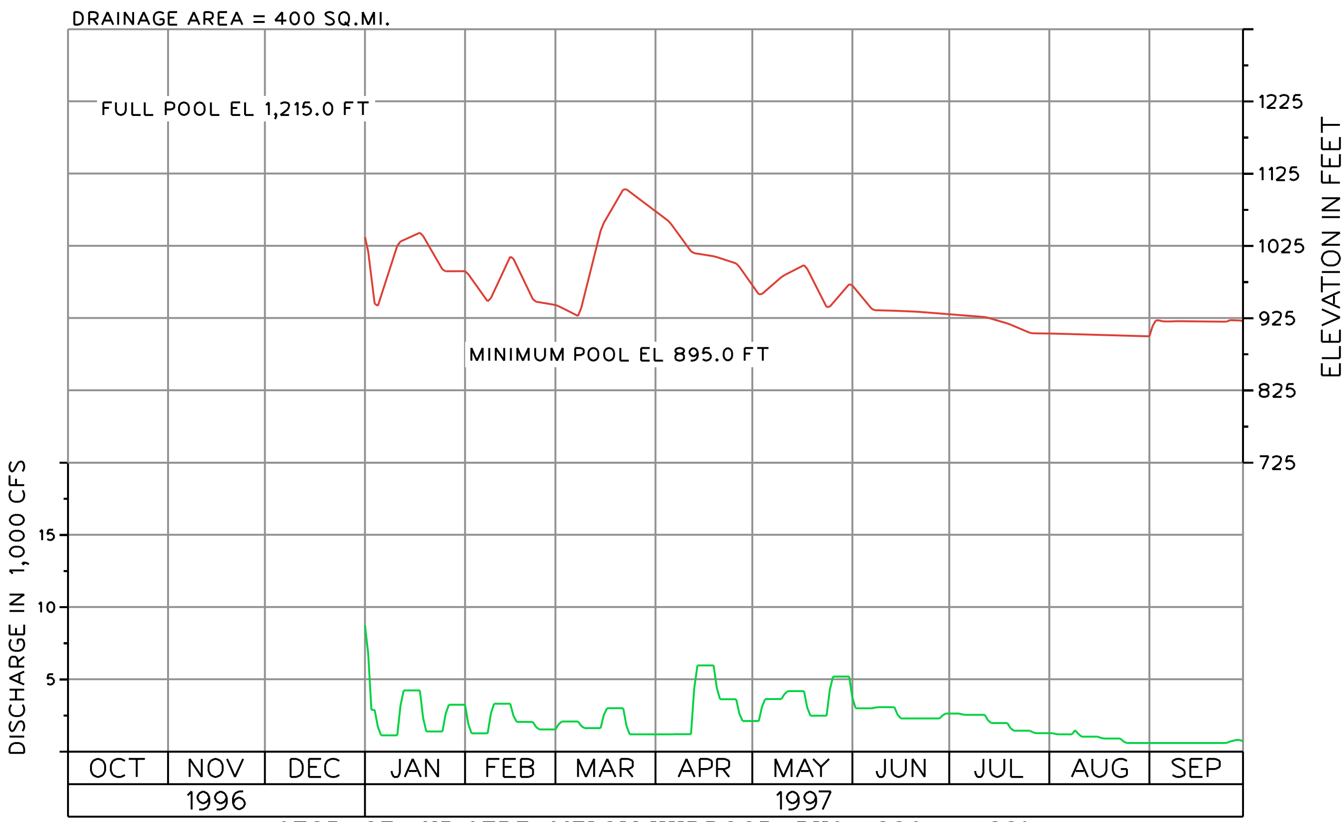

STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

WHITE RIVER AT MUD MOUNTAIN PROJECT, WASHINGTON

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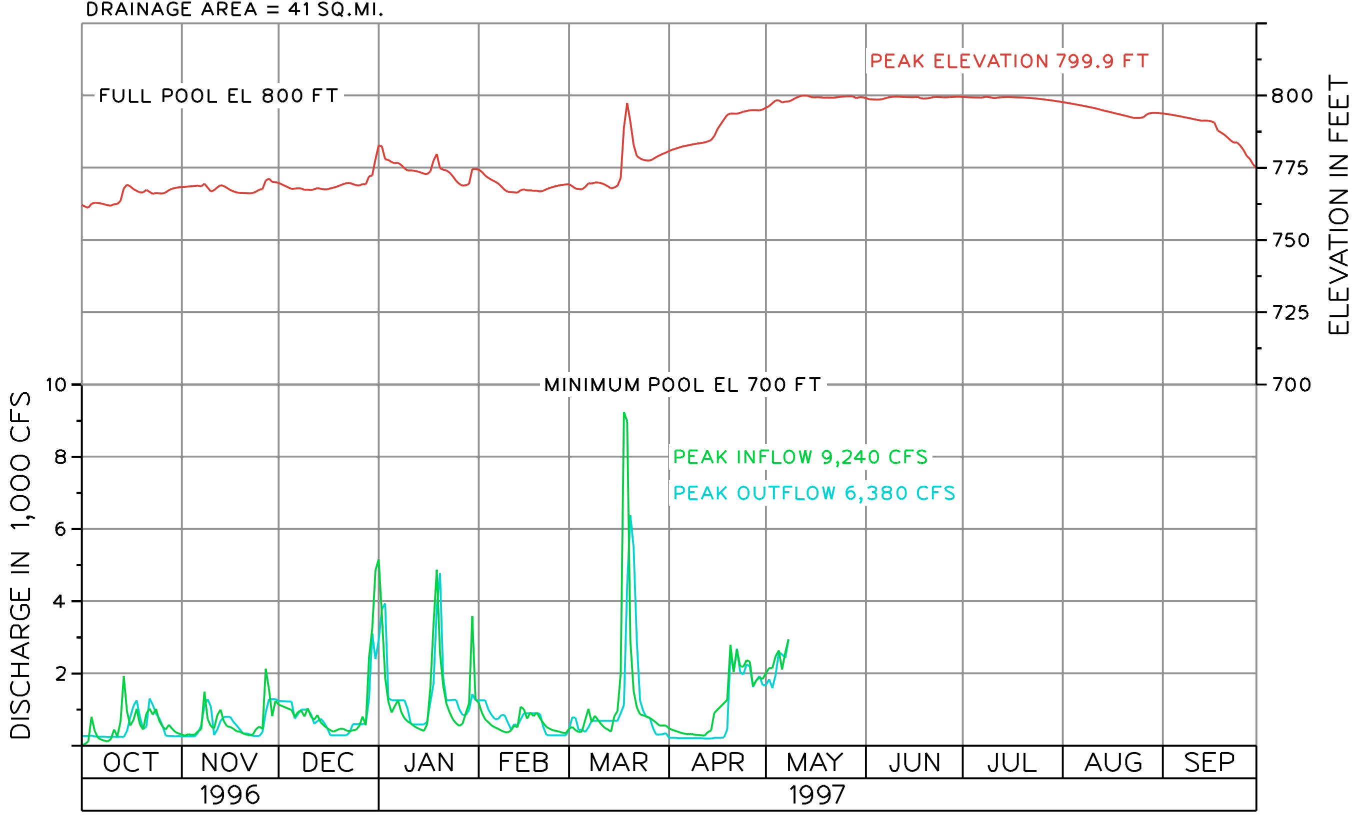

STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

WYNOOCHEE RIVER AT WYNOOCHEE PROJECT, WASHINGTON

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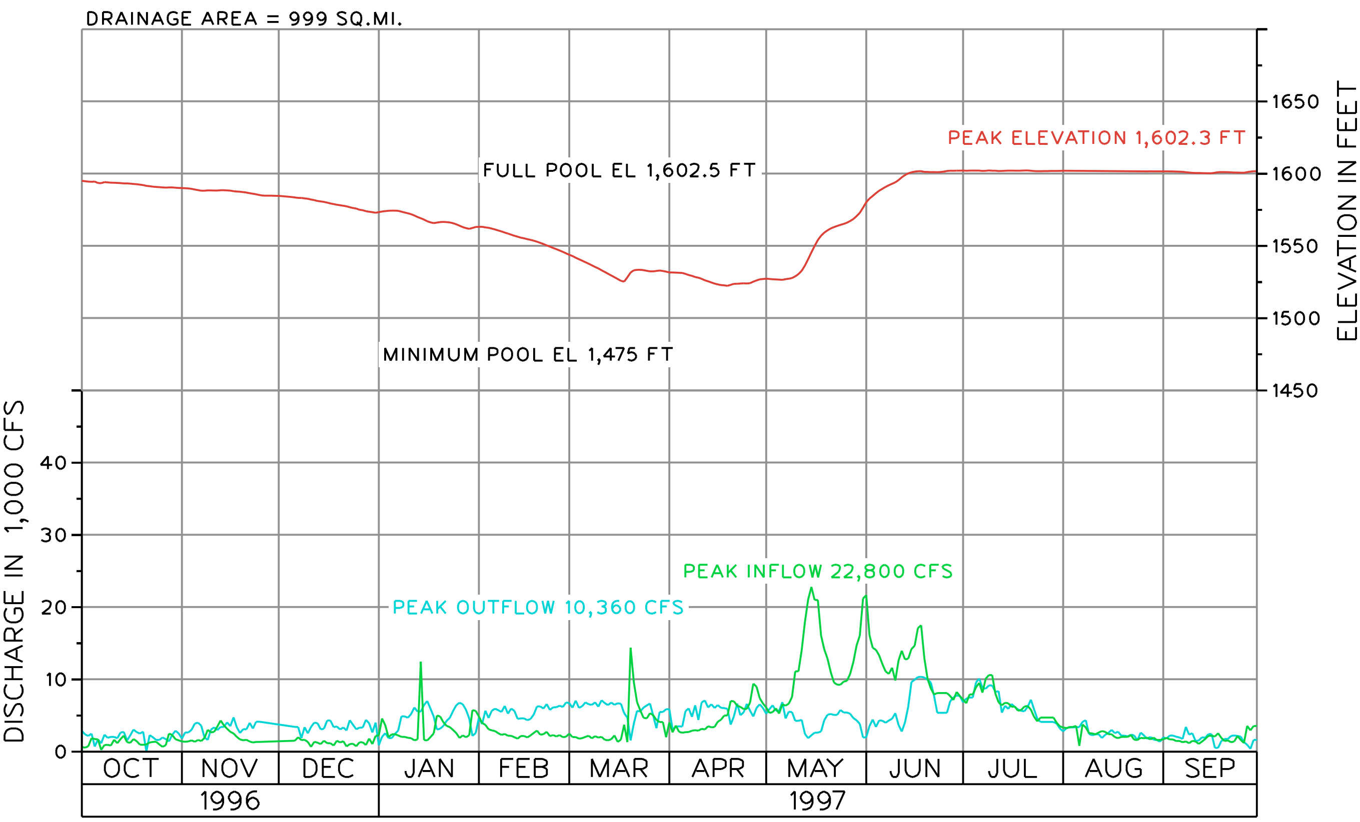

STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

SKAGIT RIVER AT ROSS PROJECT, WASHINGTON

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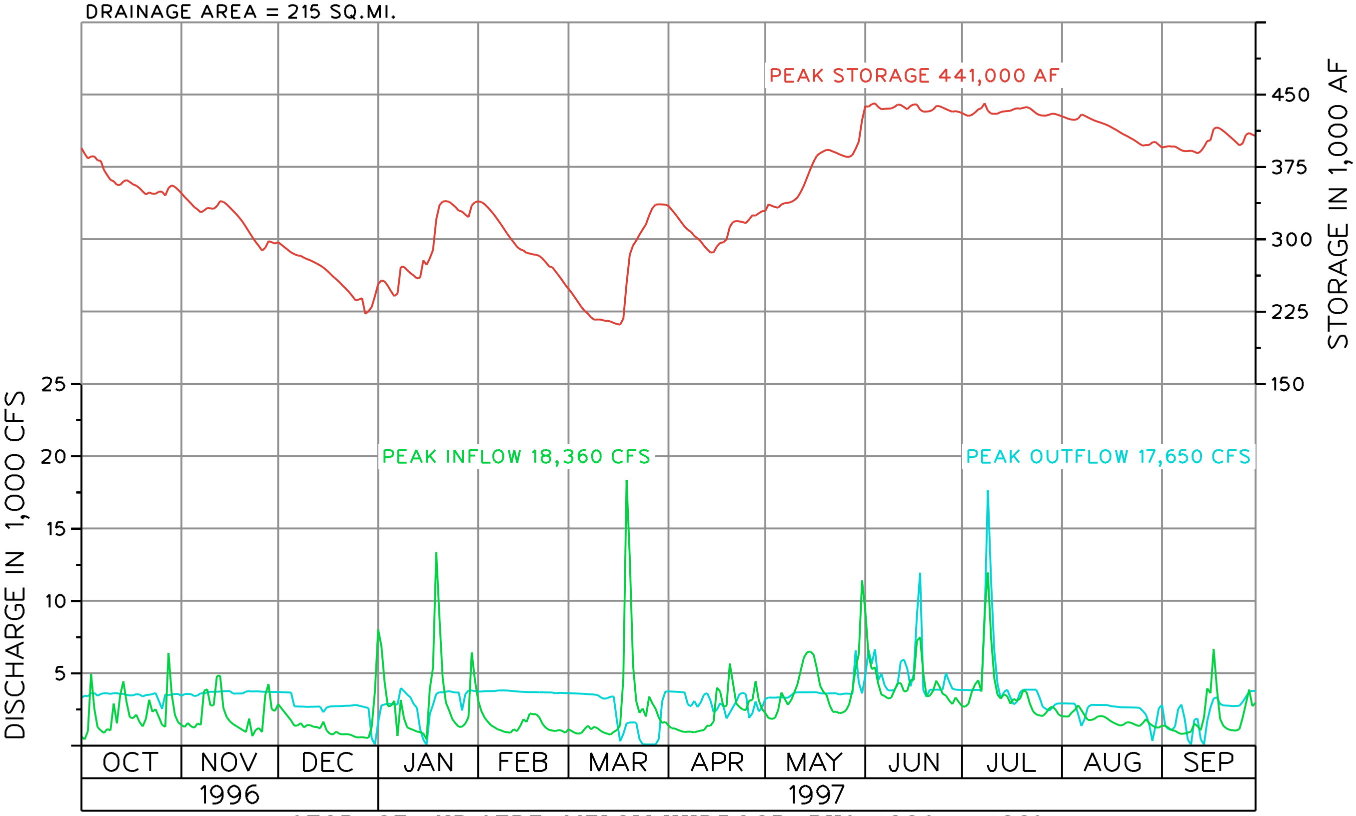
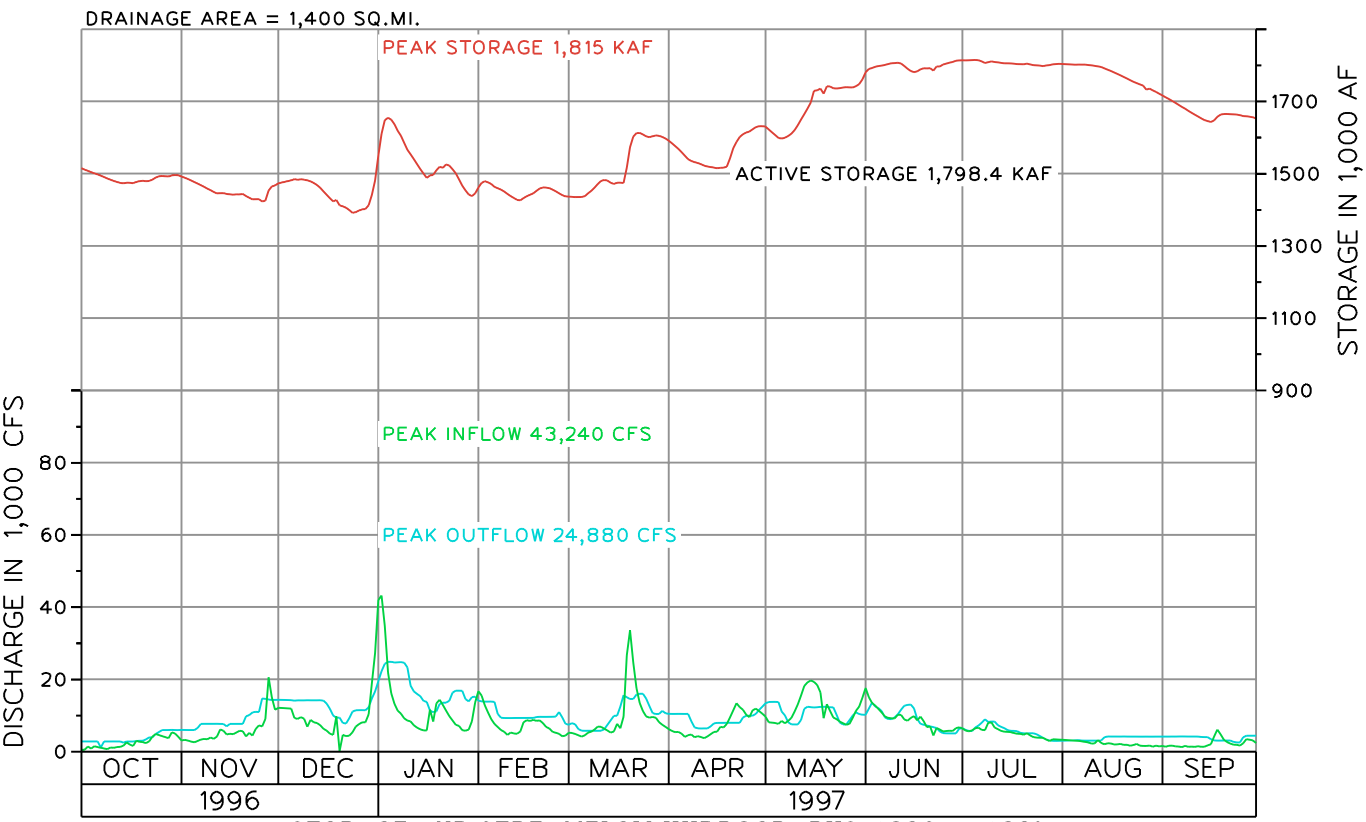


STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

BAKER RIVER AT UPPER BAKER PROJECT, OREGON

Chart 55 Back.



STORAGE AND STREAMFLOW HYDROGRAPHS 1996 – 1997

COWLITZ RIVER AT MAYFIELD/MOSSYROCK PROJECTS, WASHINGTON

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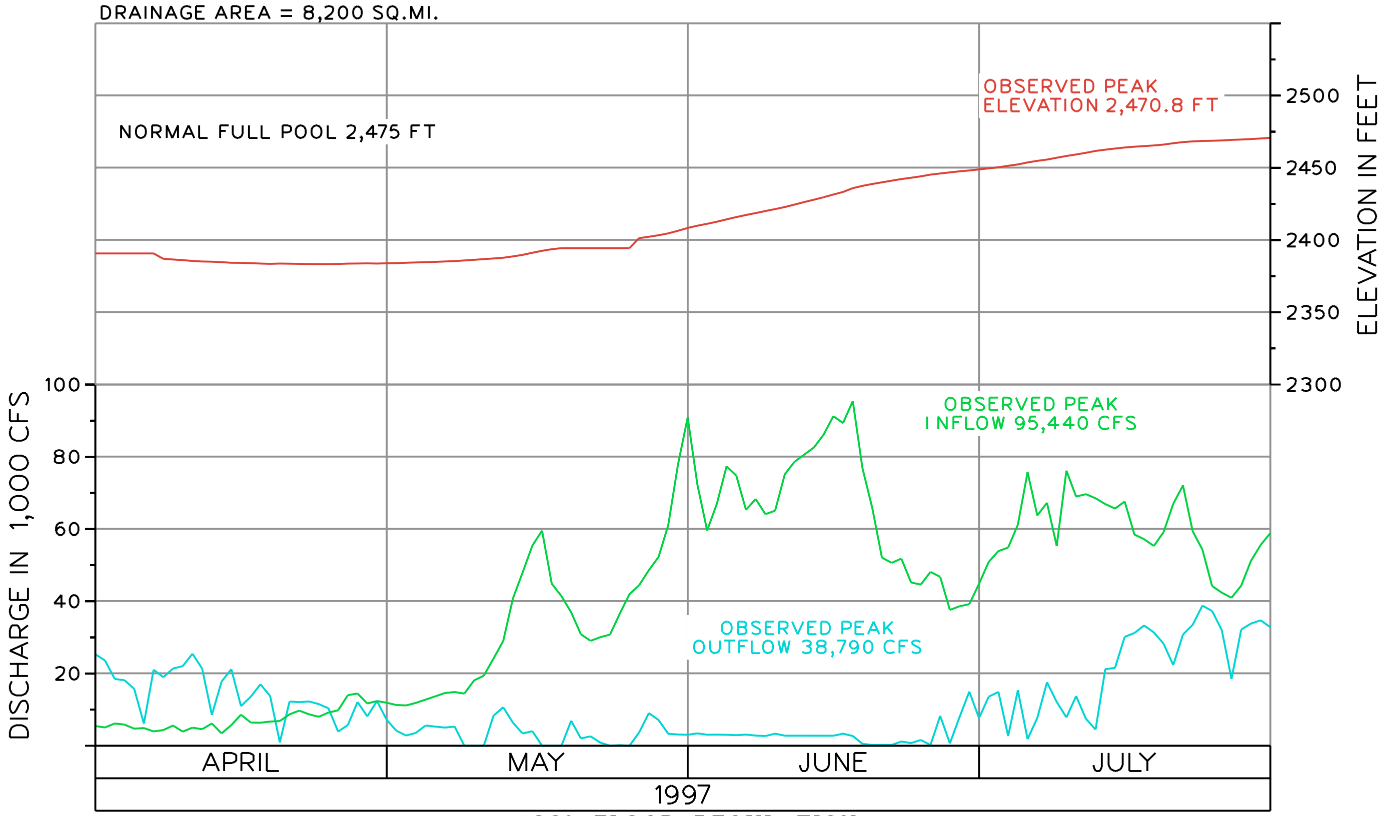

1997 FLOOD REGULATION

COLUMBIA RIVER AT MICA PROJECT, BRITISH COLUMBIA

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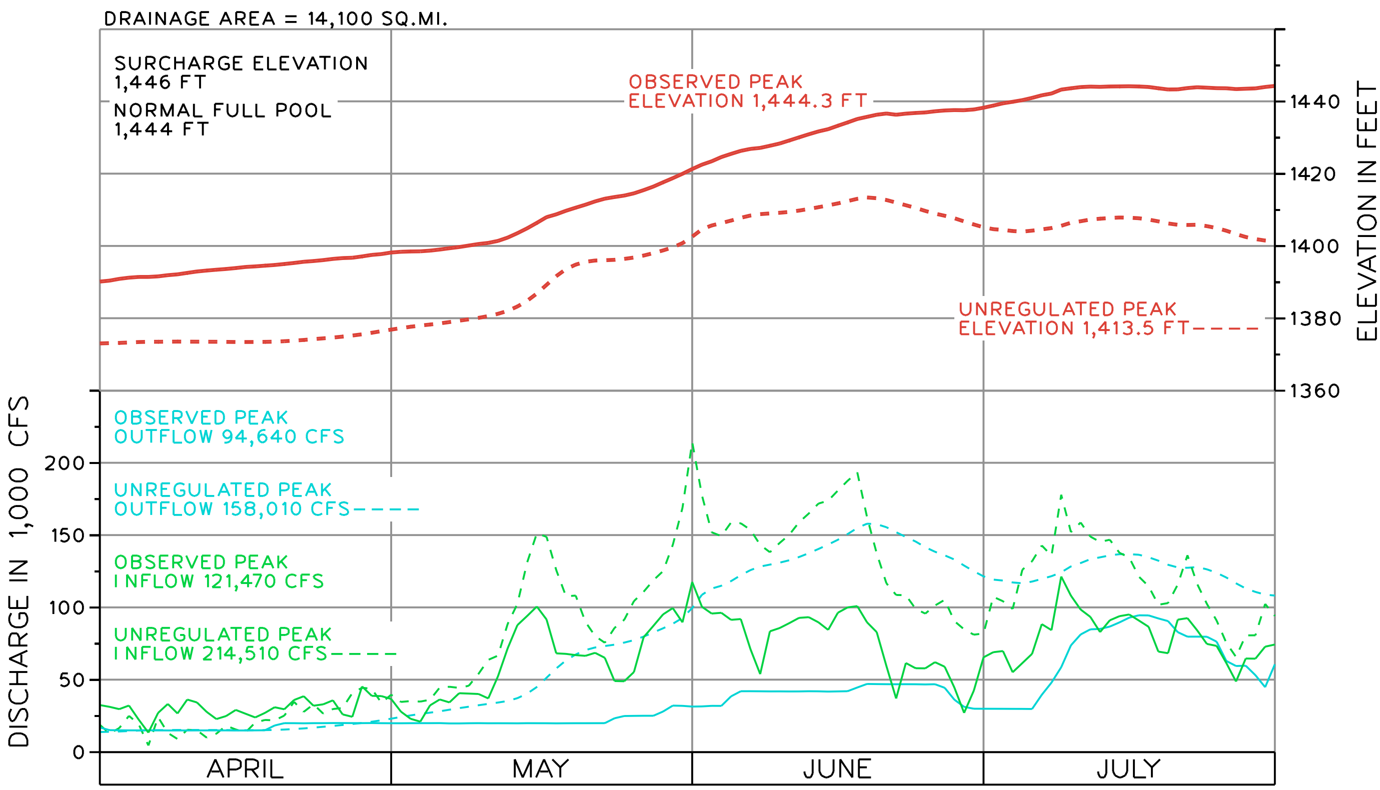
Chart 57



1997 FLOOD REGULATION

COLUMBIA RIVER AT ARROW PROJECT, BRITISH COLUMBIA

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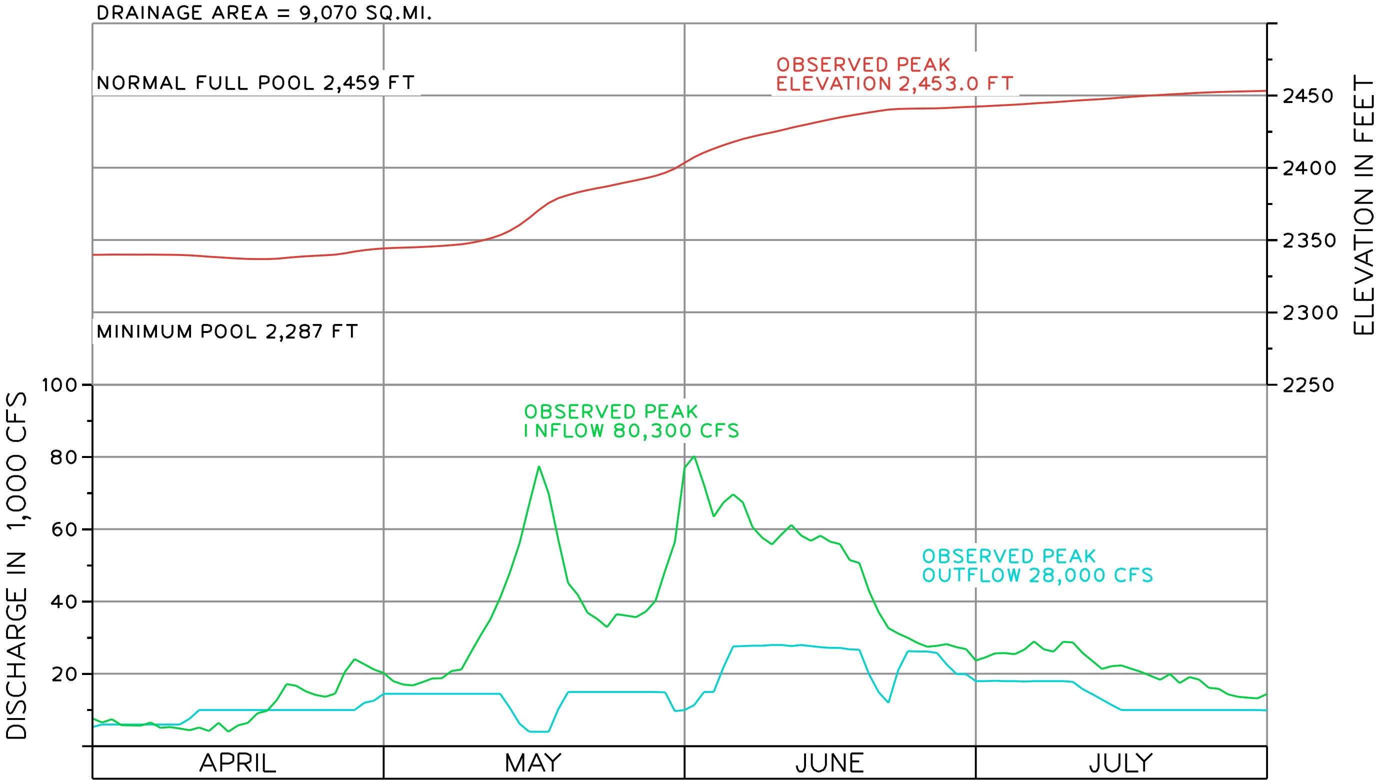
Chart 58



1997 FLOOD REGULATION

KOOTENAI RIVER AT LIBBY PROJECT, MONTANA

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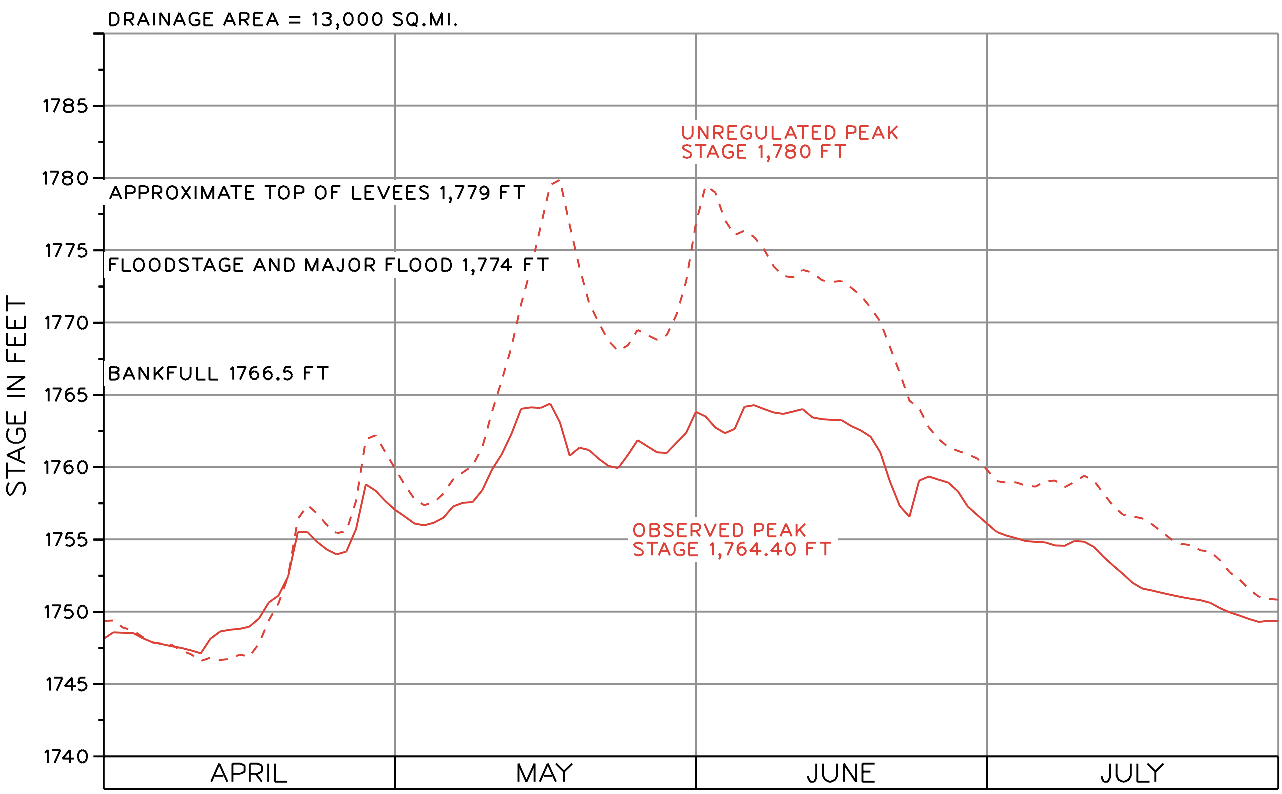
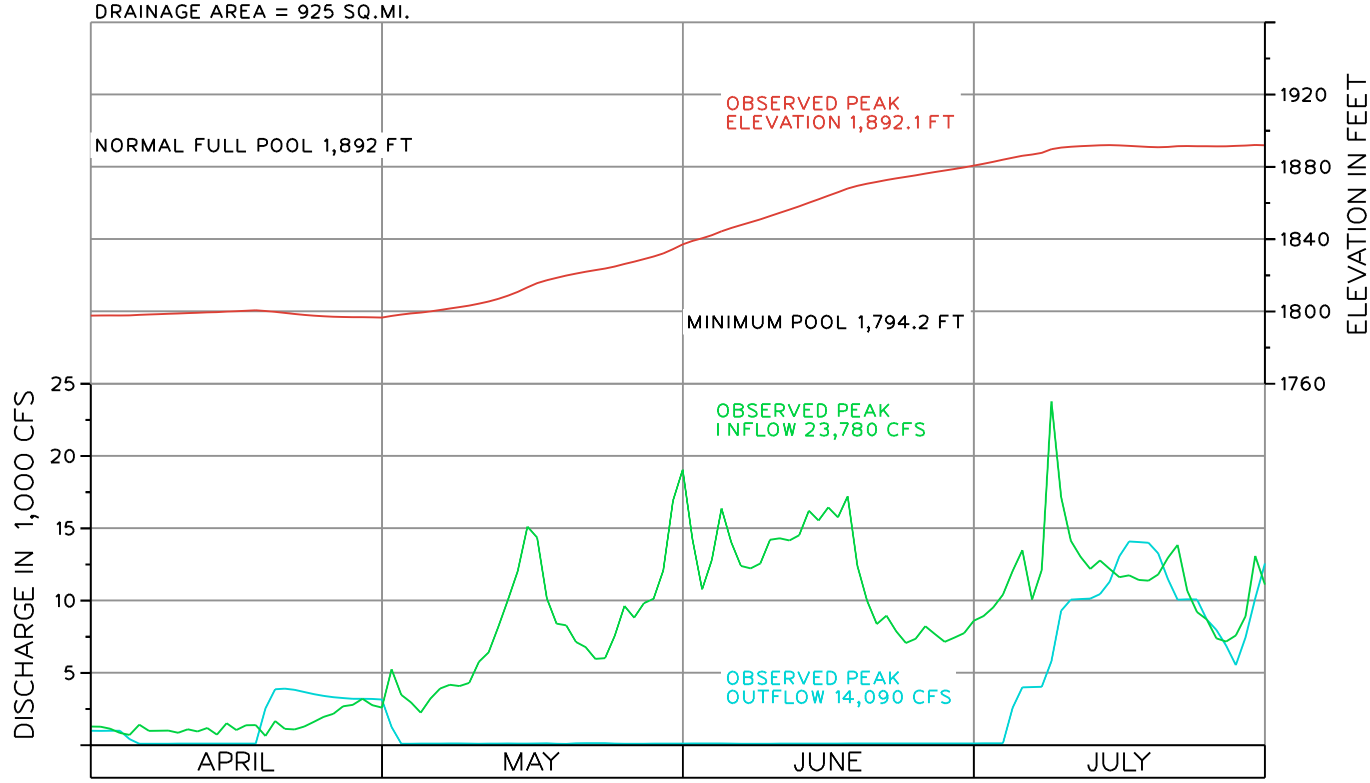


1997 FLOOD REGULATION

KOOTENAI RIVER AT BONNERS FERRY, IDAHO

Chart 60 Back.



1997 FLOOD REGULATION

DUNCAN RIVER AT DUNCAN PROJECT, BRITISH COLUMBIA

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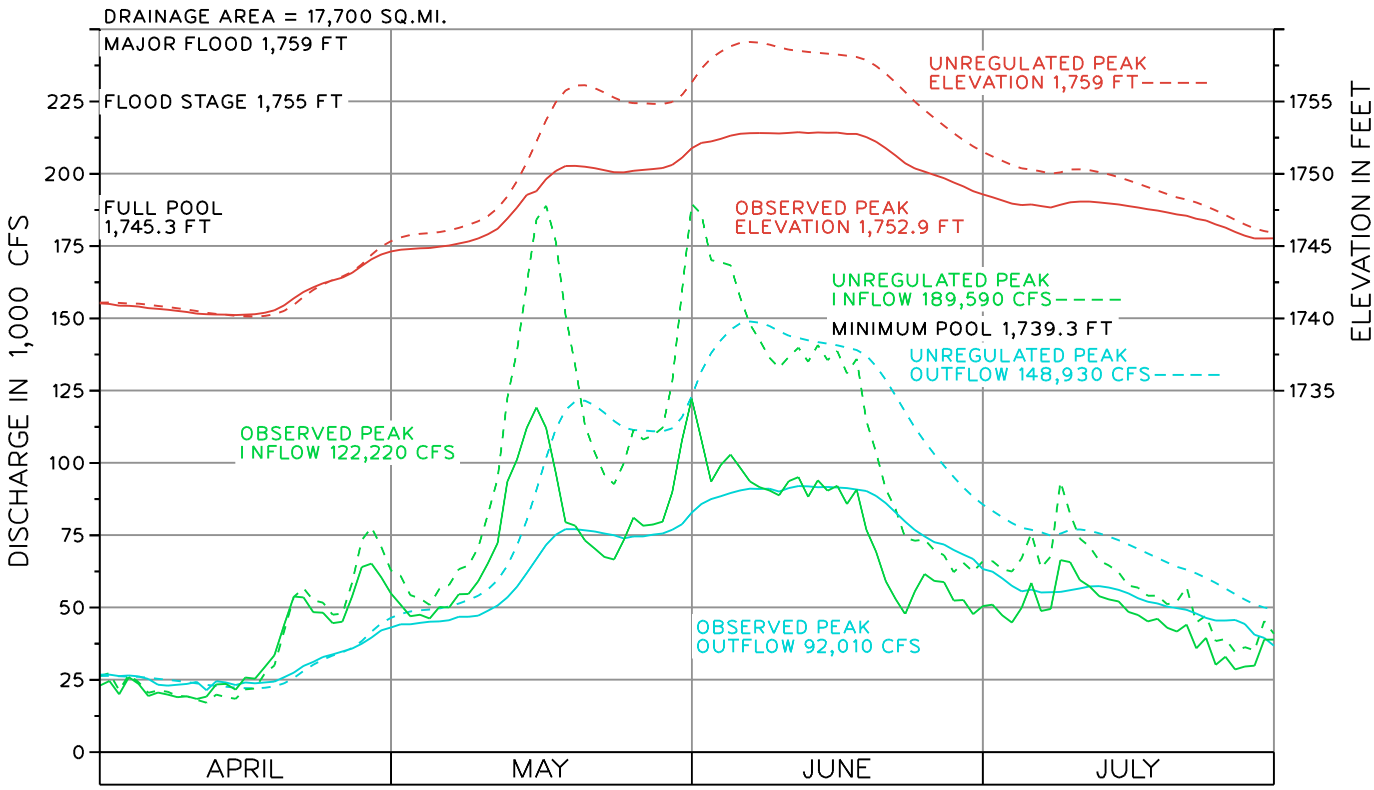

1997 FLOOD REGULATION

KOOTENAY RIVER AT KOOTENAY LAKE, BRITISH COLUMBIA

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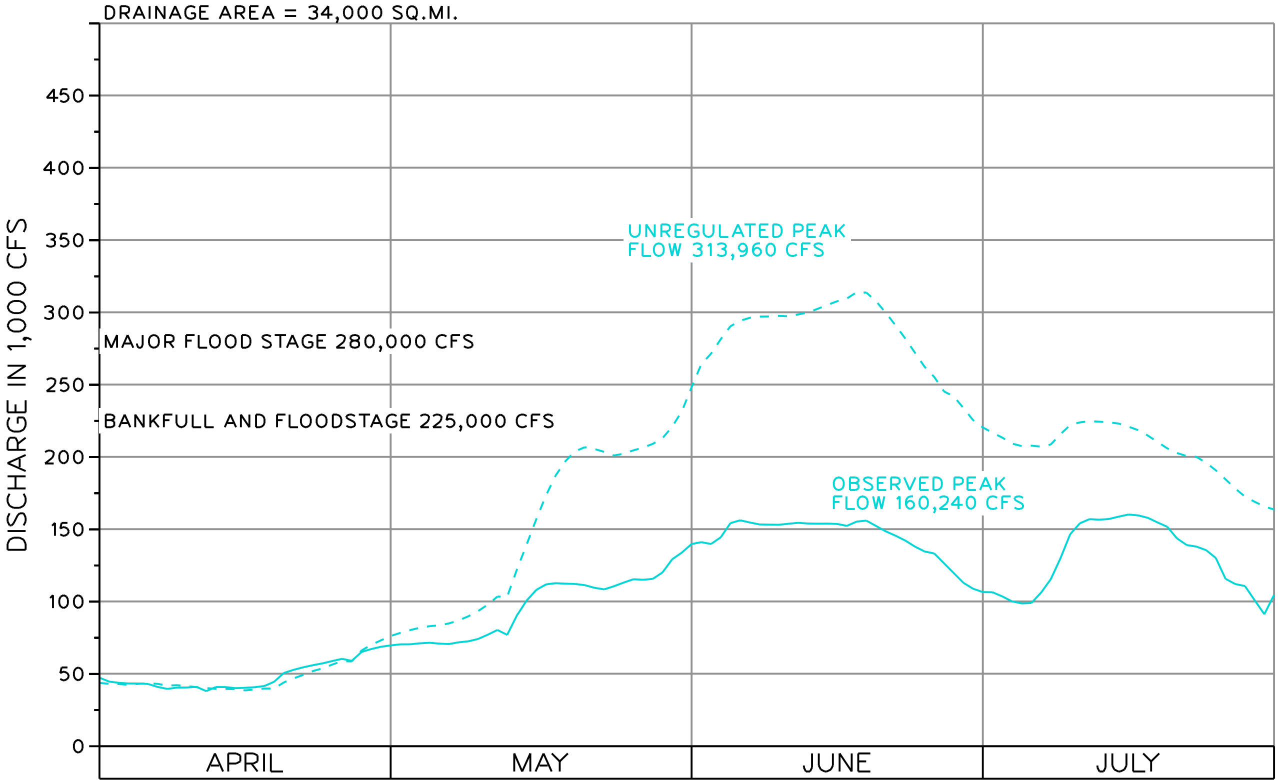
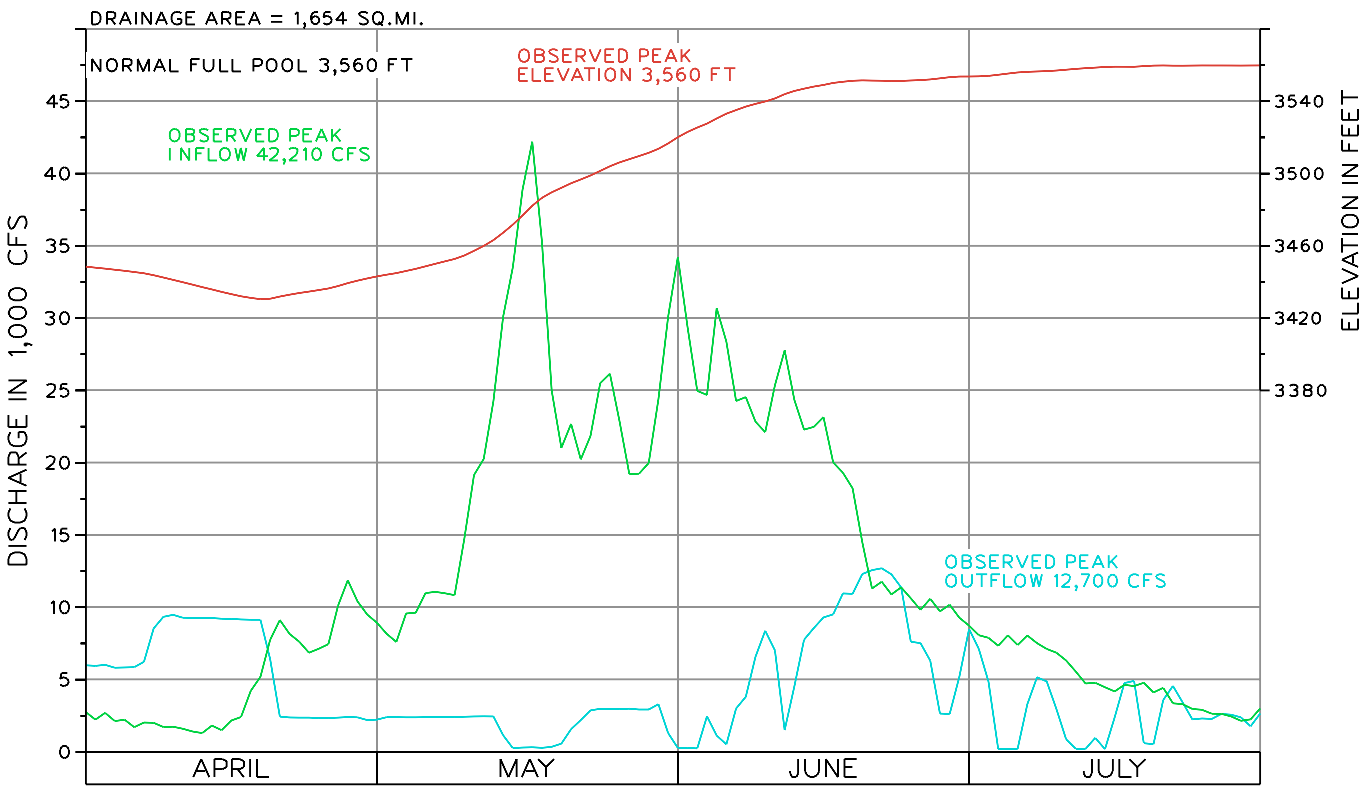


1997 FLOOD REGULATION

COLUMBIA RIVER AT BIRCHBANK, BRITISH COLUMBIA

Chart 63 Back.



1997 FLOOD REGULATION

SOUTH FORK FLATHEAD RIVER AT HUNGRY HORSE, MONTANA

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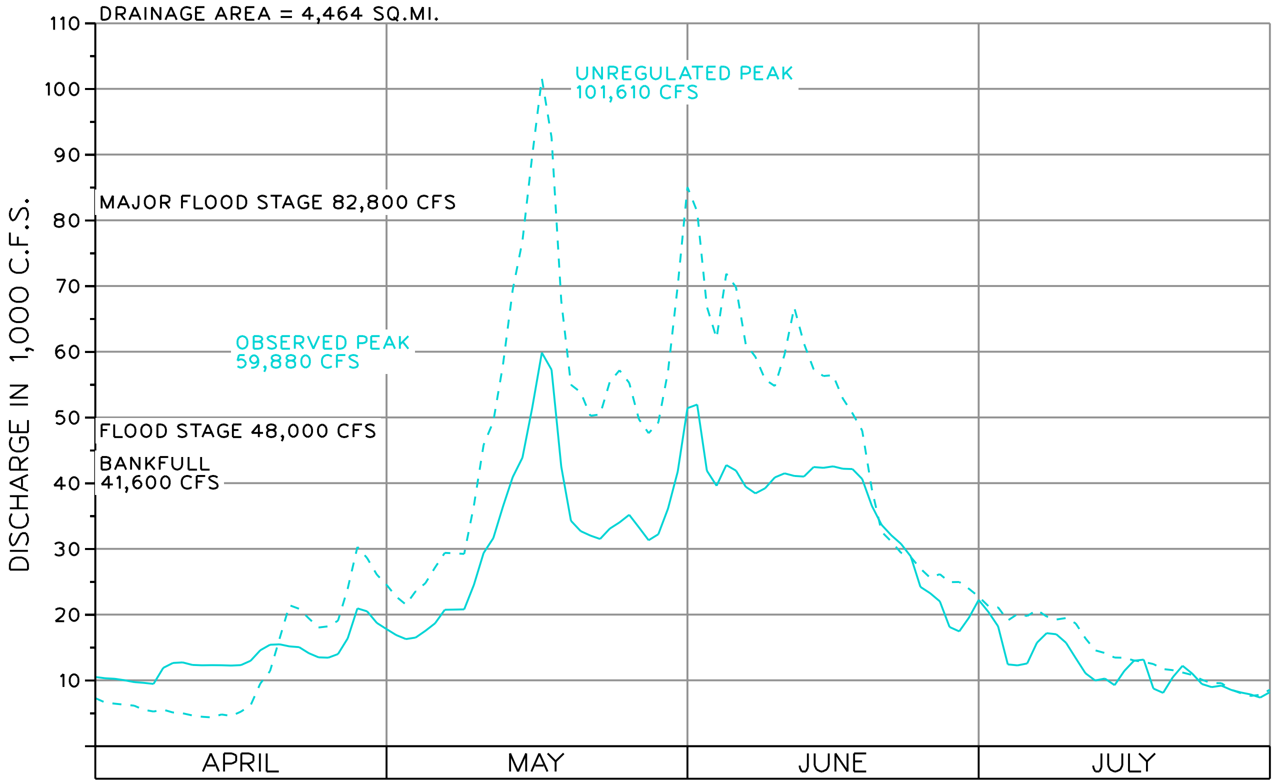

1997 FLOOD REGULATION

FLATHEAD RIVER AT COLUMBIA FALLS, MONTANA

Chart 65

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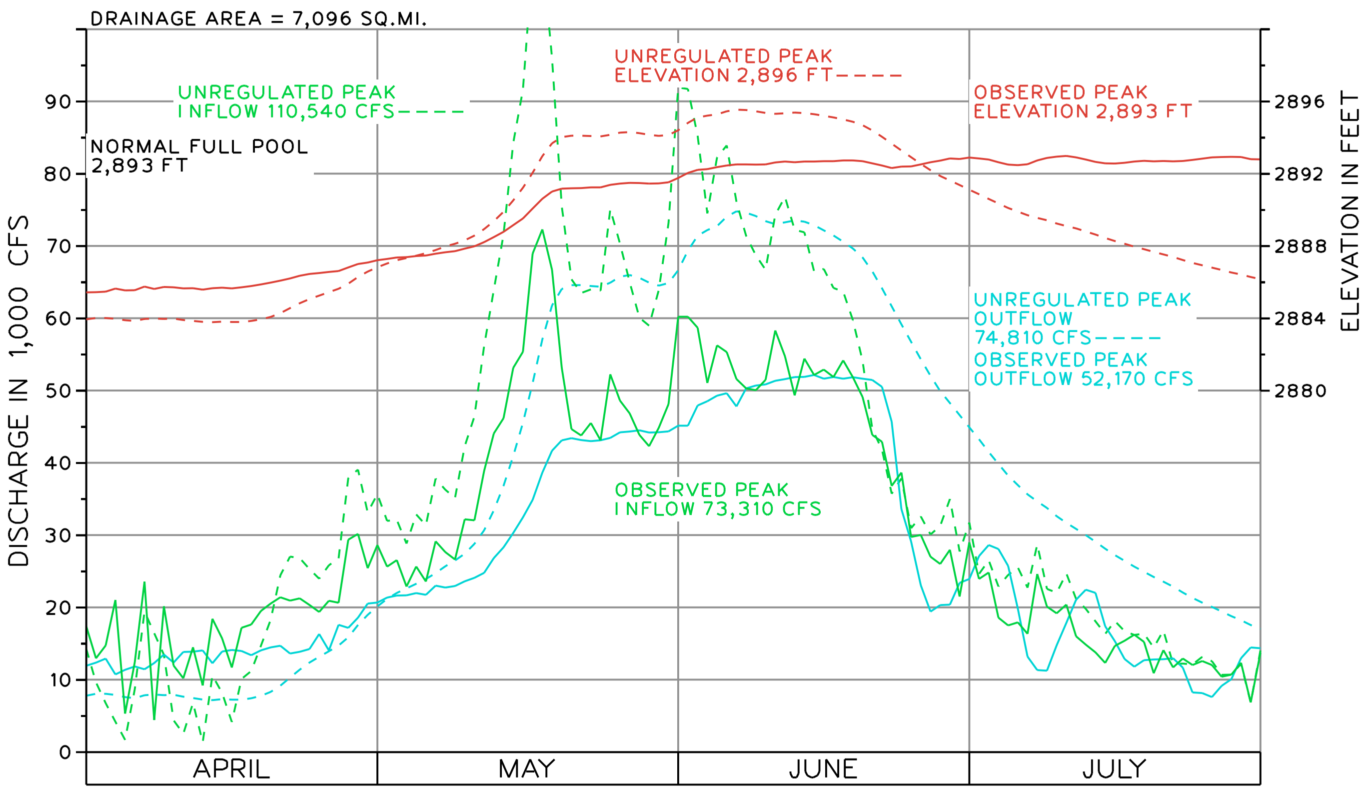

1997 FLOOD REGULATION

FLATHEAD RIVER AT FLATHEAD LAKE, MONTANA

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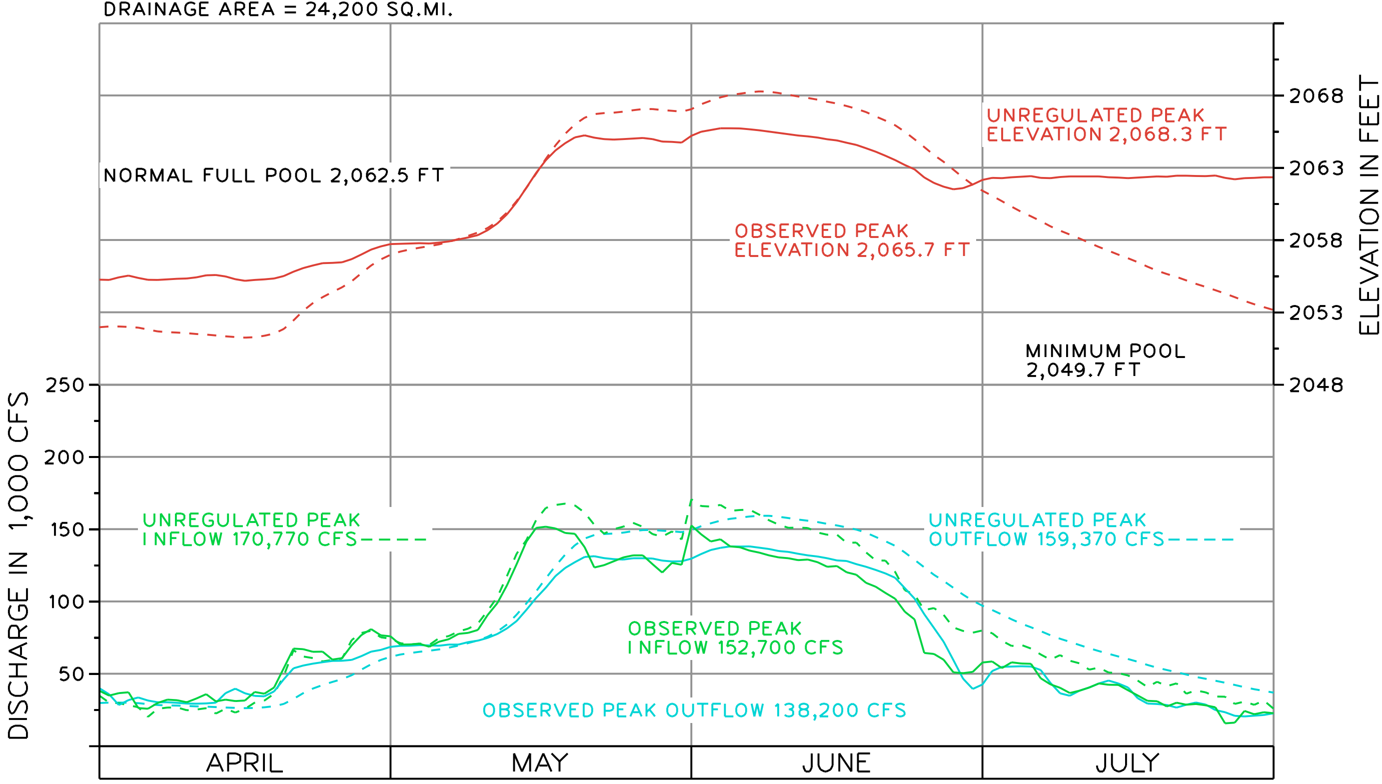
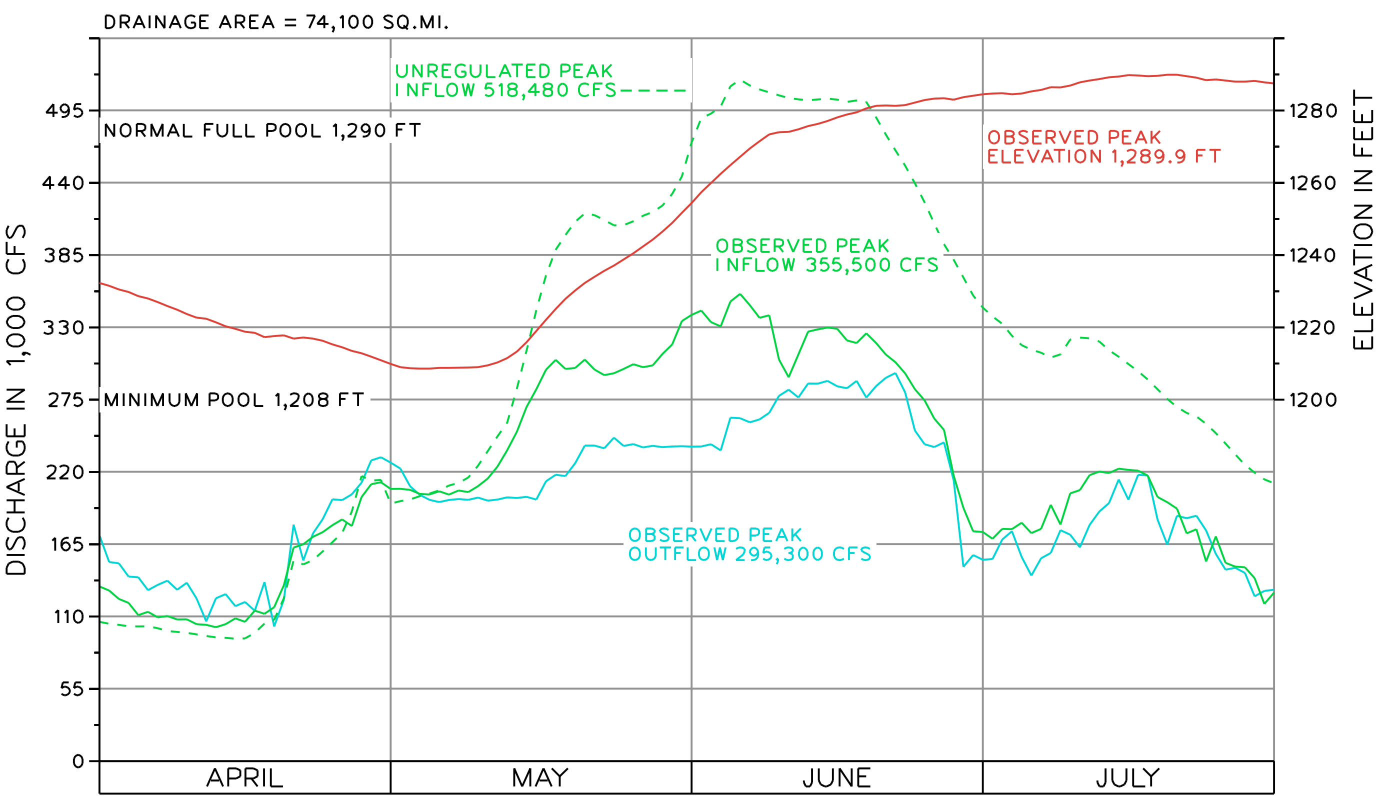
Chart 66



1997 FLOOD REGULATION

PEND OREILLE RIVER AT PEND OREILLE LAKE, IDAHO

Chart 67 Back.



1997 FLOOD REGULATION

COLUMBIA RIVER AT GRAND COULEE PROJECT, WASHINGTON

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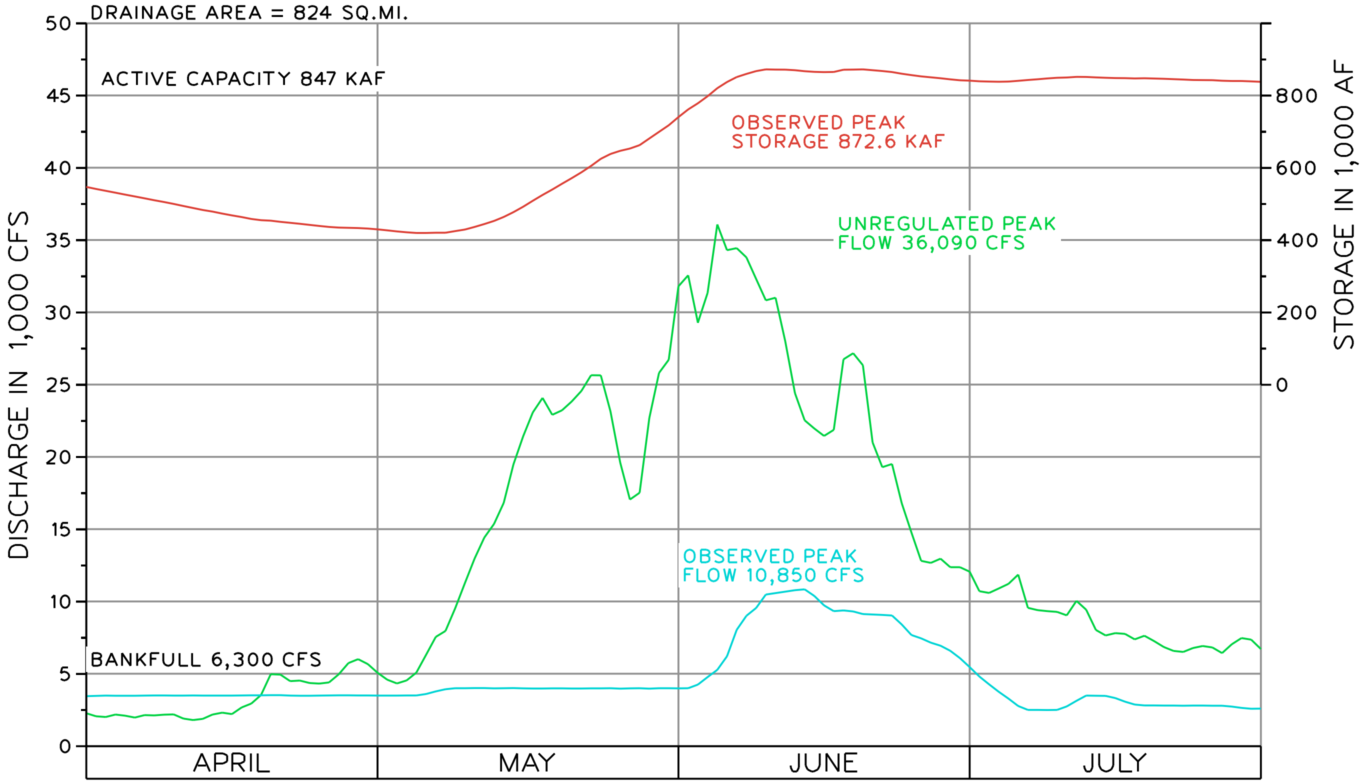

1997 FLOOD REGULATION

SNAKE RIVER AT JACKSON LAKE, WYOMING

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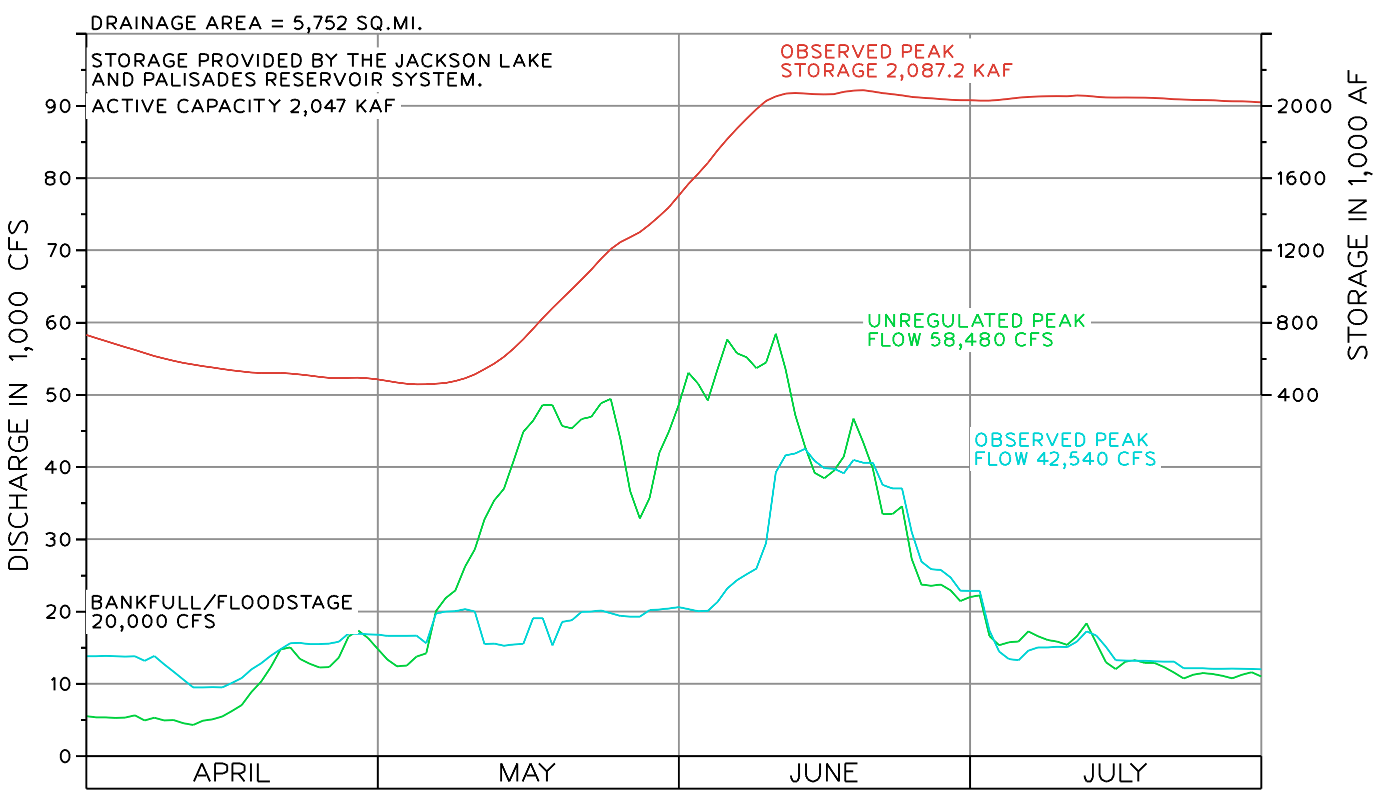

1997 FLOOD REGULATION

SNAKE RIVER NEAR HEISE, IDAHO

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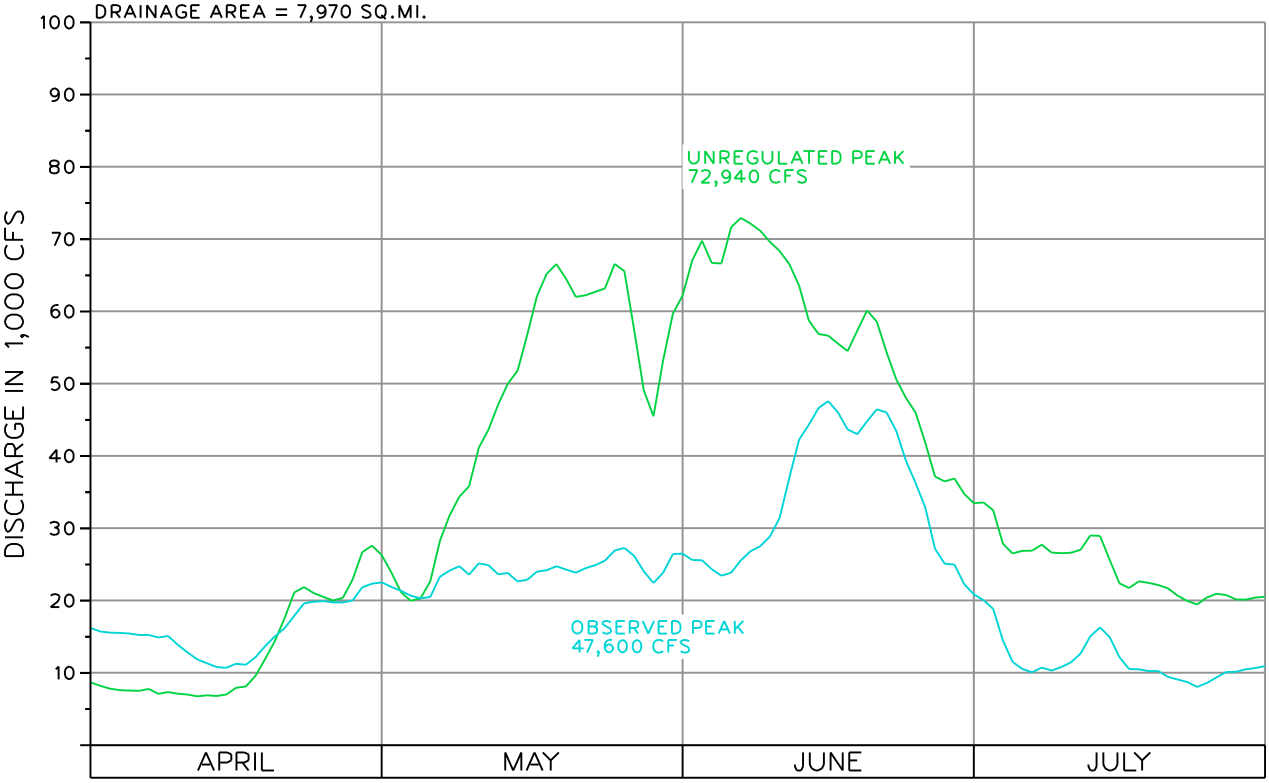

1997 FLOOD REGULATION

SNAKE RIVER NEAR SHELLEY, IDAHO

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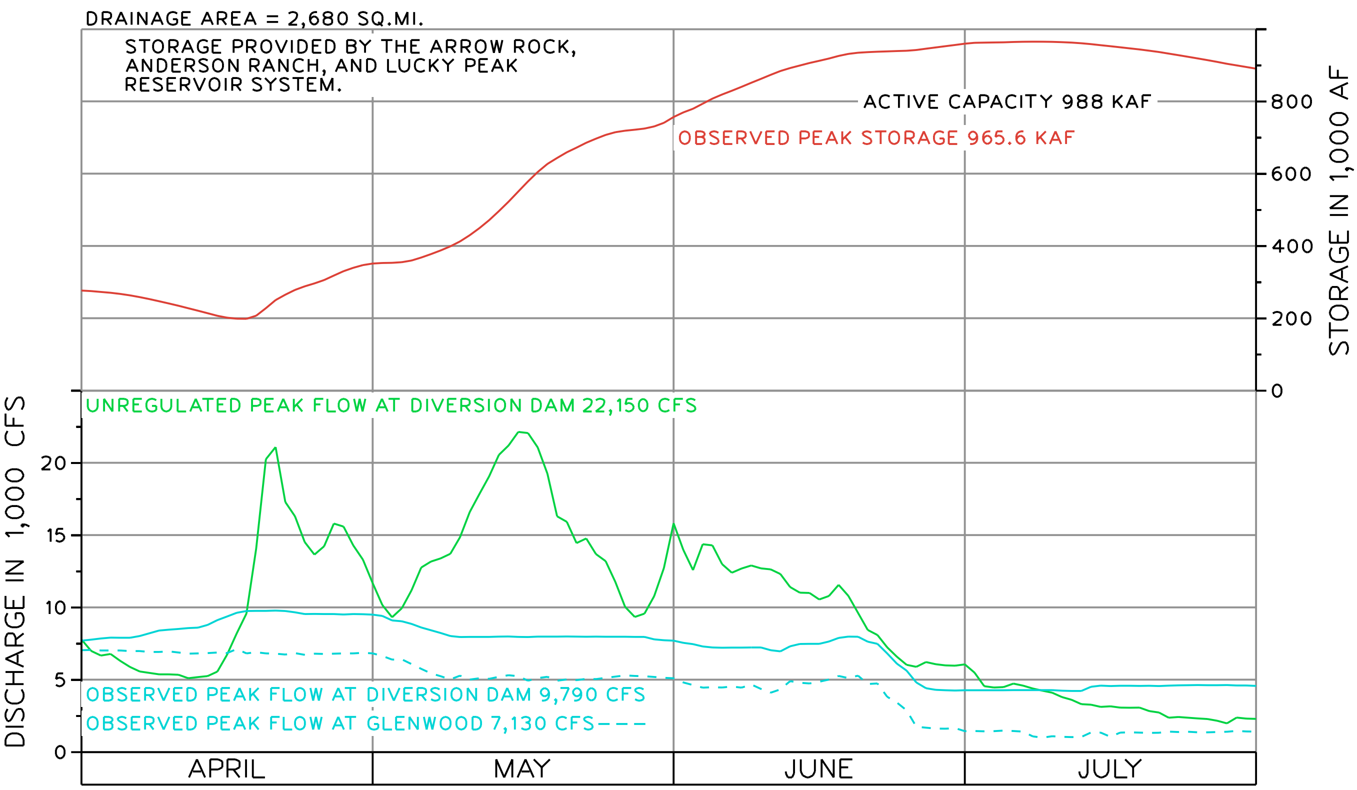

1997 FLOOD REGULATION

BOISE RIVER AT AND NEAR BOISE, IDAHO

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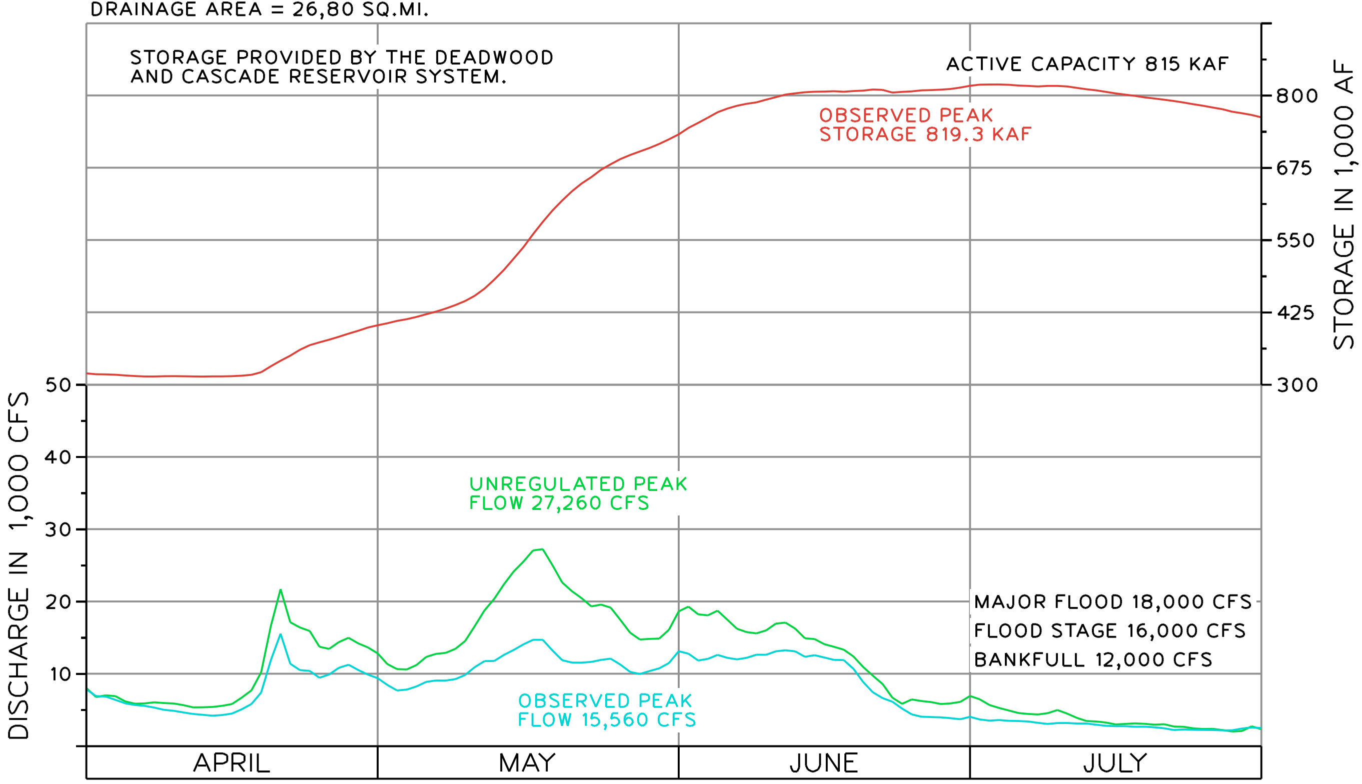

1997 FLOOD REGULATION

PAYETTE RIVER NEAR EMMETT, IDAHO

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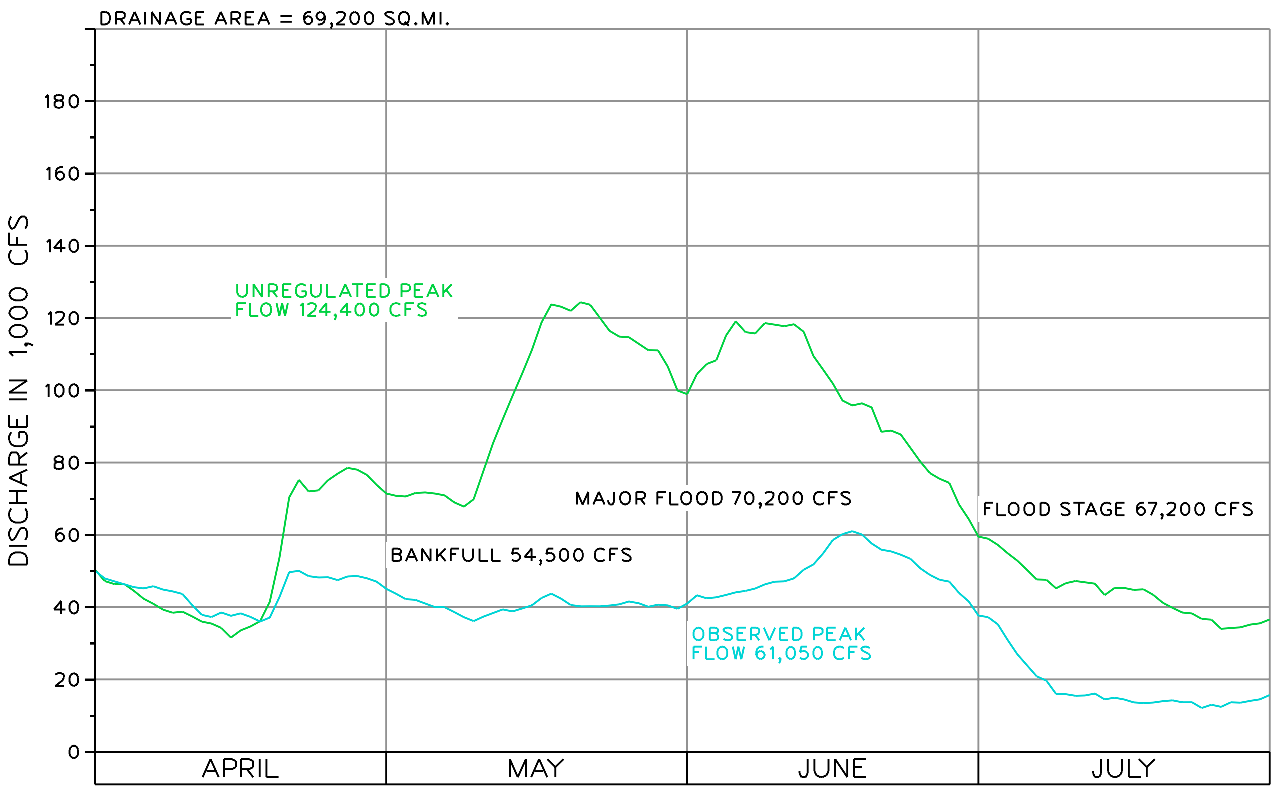
Chart 73



1997 FLOOD REGULATION

SNAKE RIVER AT WEISER, IDAHO

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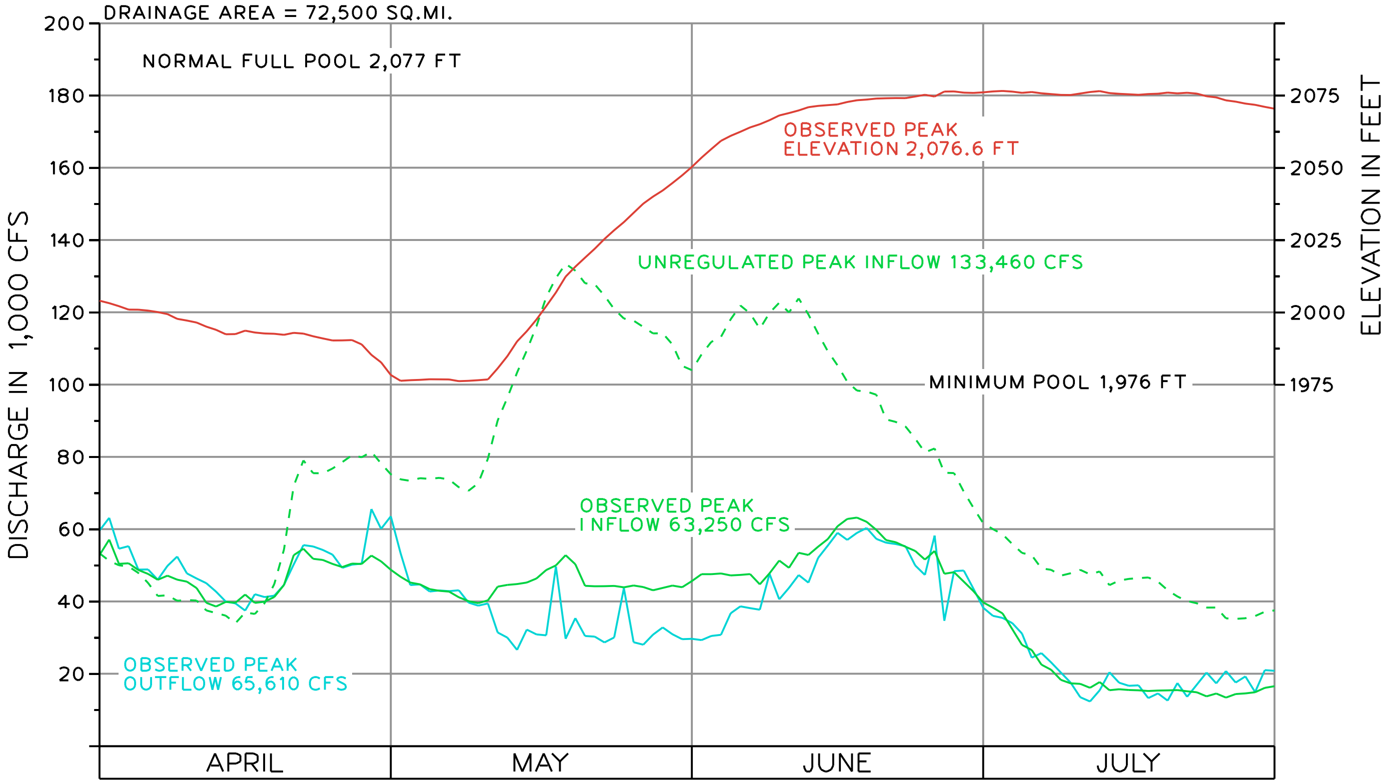
Chart 74



1997 FLOOD REGULATION

SNAKE RIVER AT BROWNLEE PROJECT, IDAHO–OREGON

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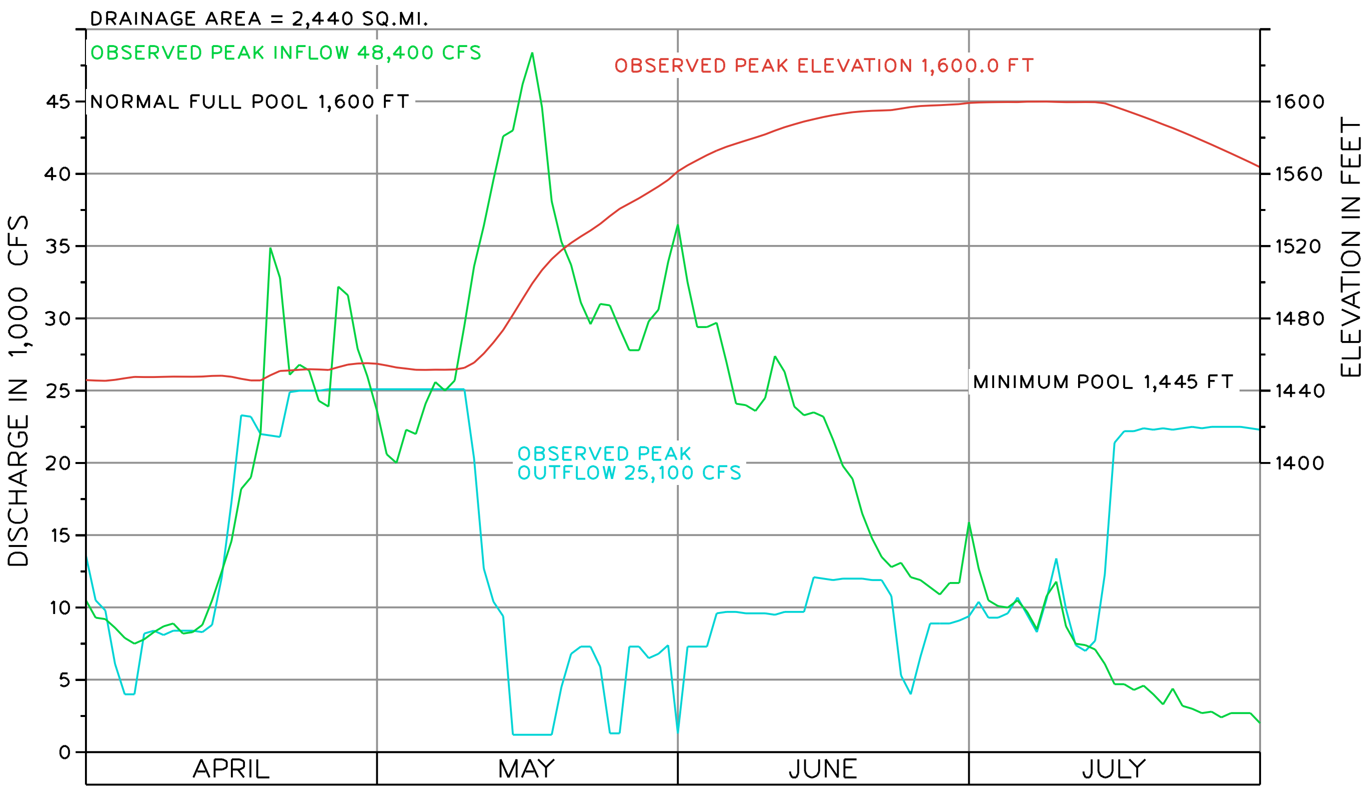
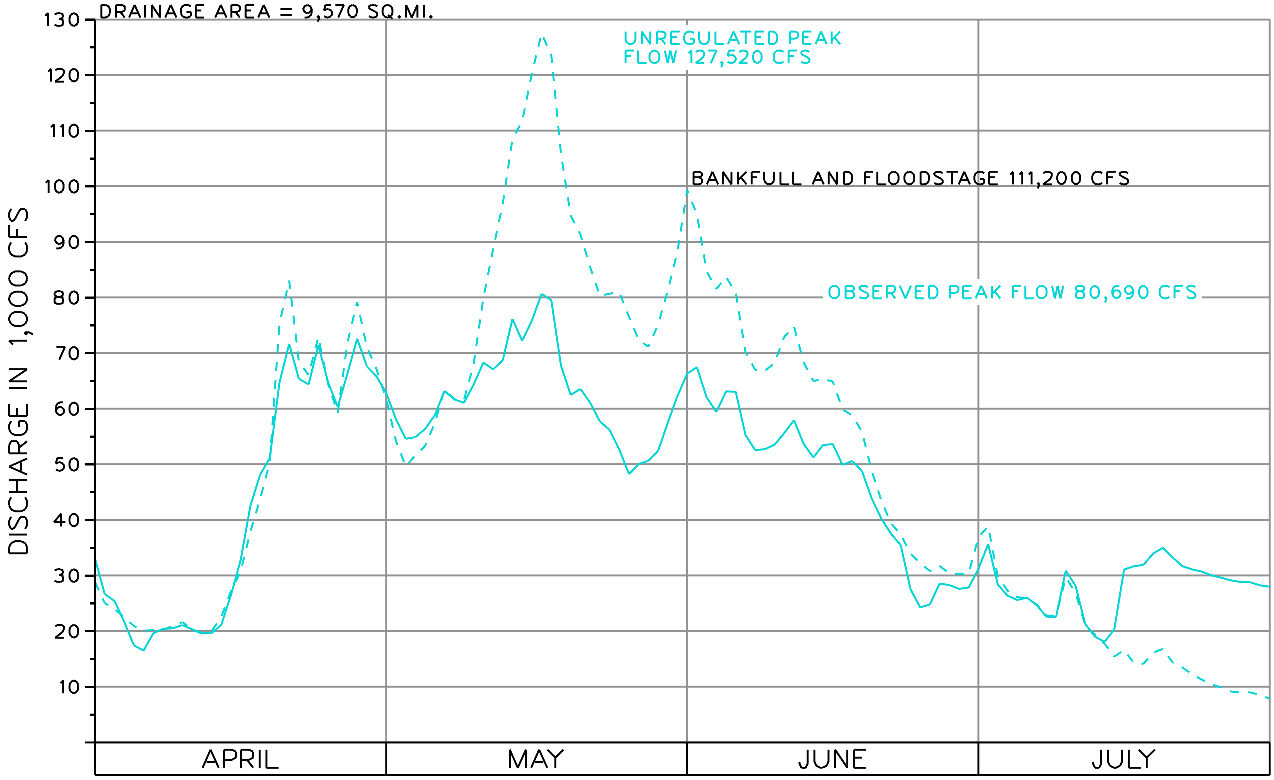


1997 FLOOD REGULATION

NORTH FORK CLEARWATER RIVER AT DWORSHAK PROJECT, IDAHO

Chart 76 Back.



1997 FLOOD REGULATION
CLEARWATER RIVER AT SPALDING, IDAHO

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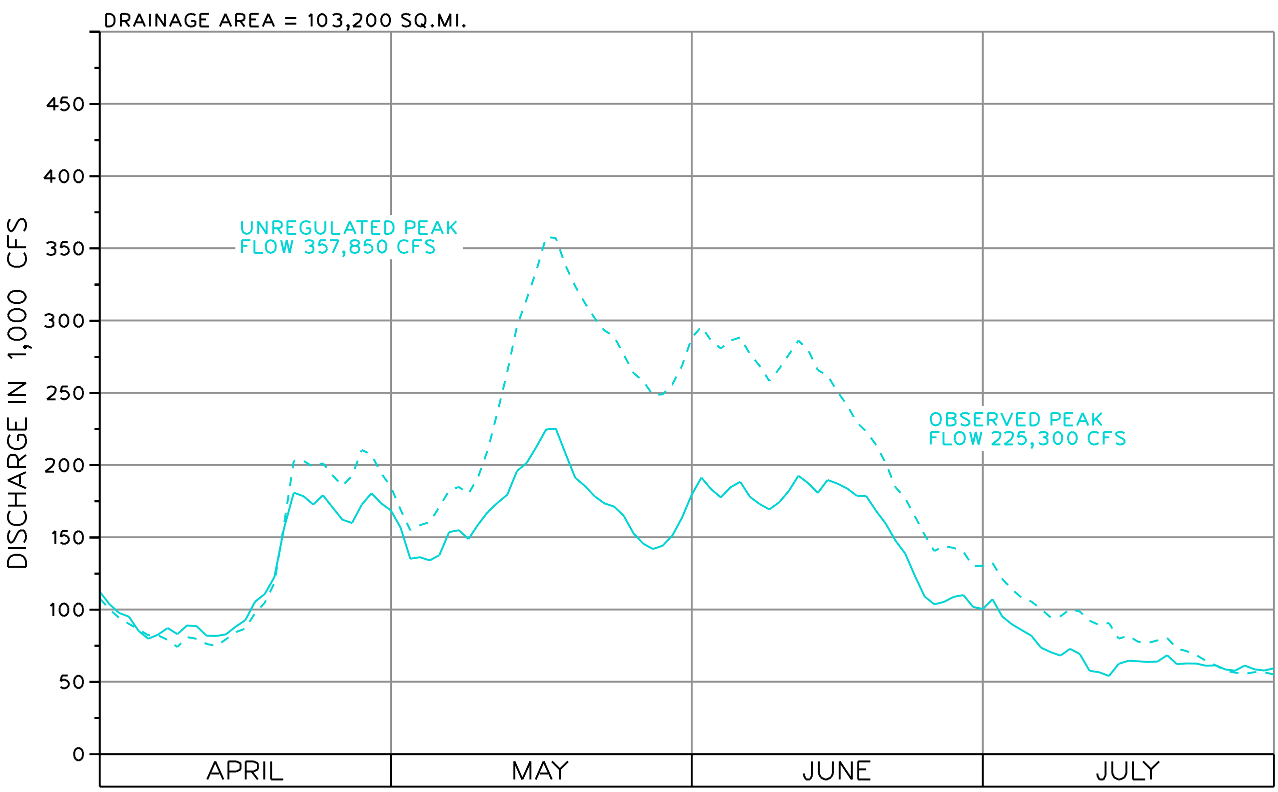
Chart 77



1997 FLOOD REGULATION
SNAKE RIVER BELOW LOWER GRANITE DAM, WASHINGTON

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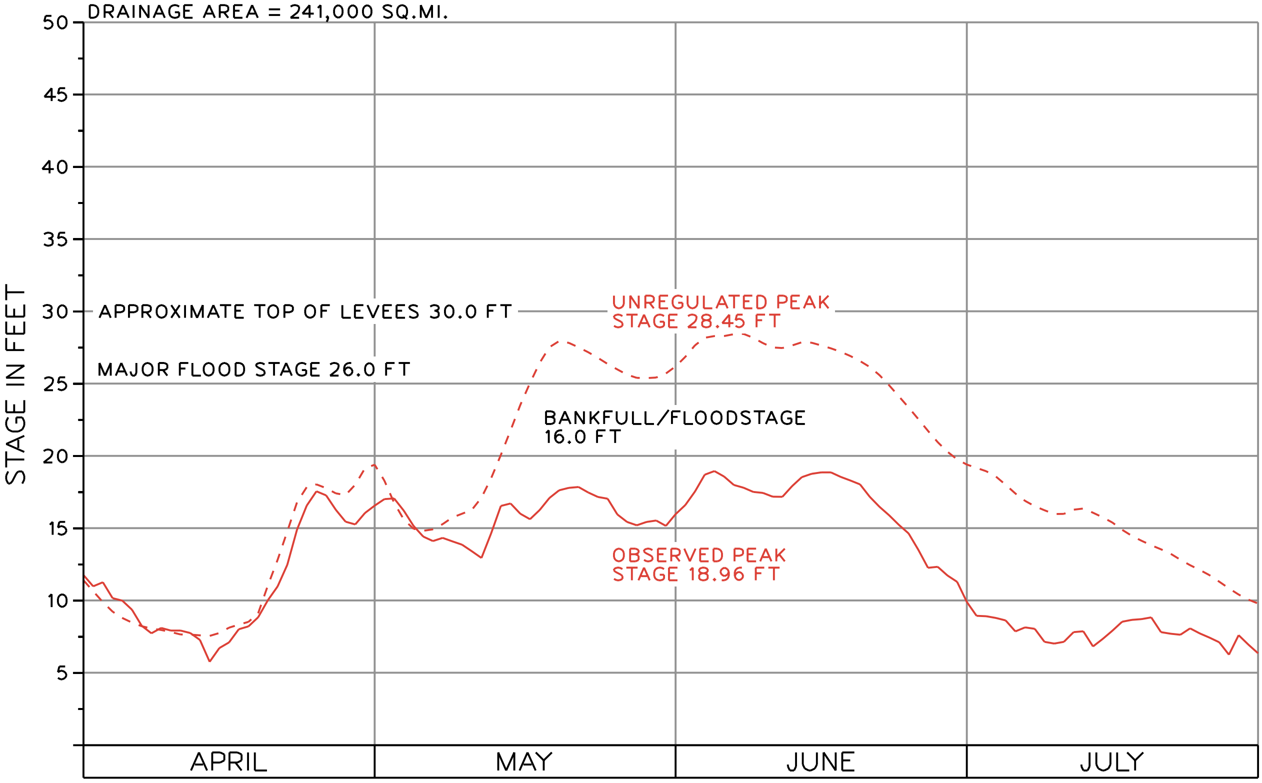
Chart 78



1997 FLOOD REGULATION

COLUMBIA RIVER AT VANCOUVER, WASHINGTON

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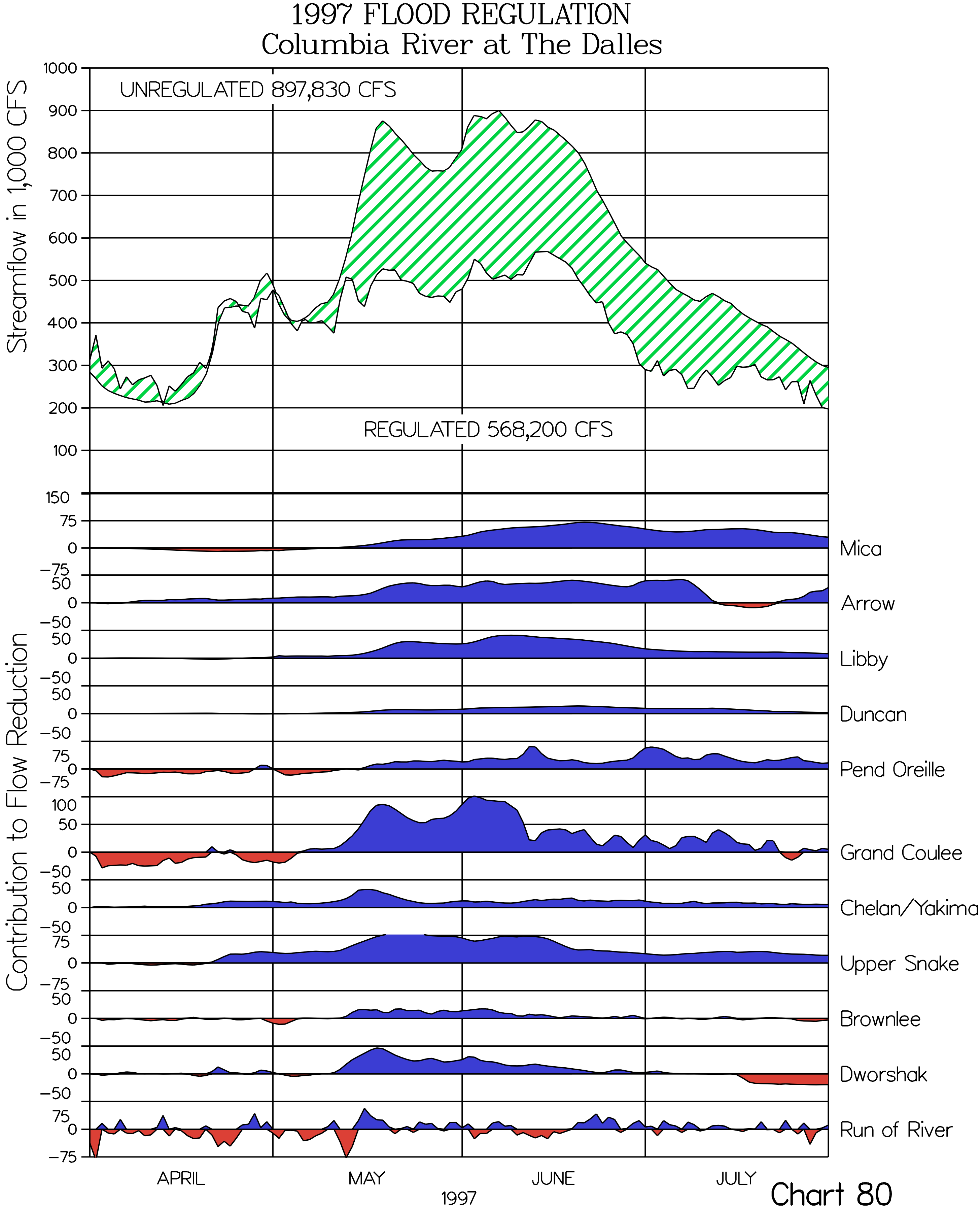

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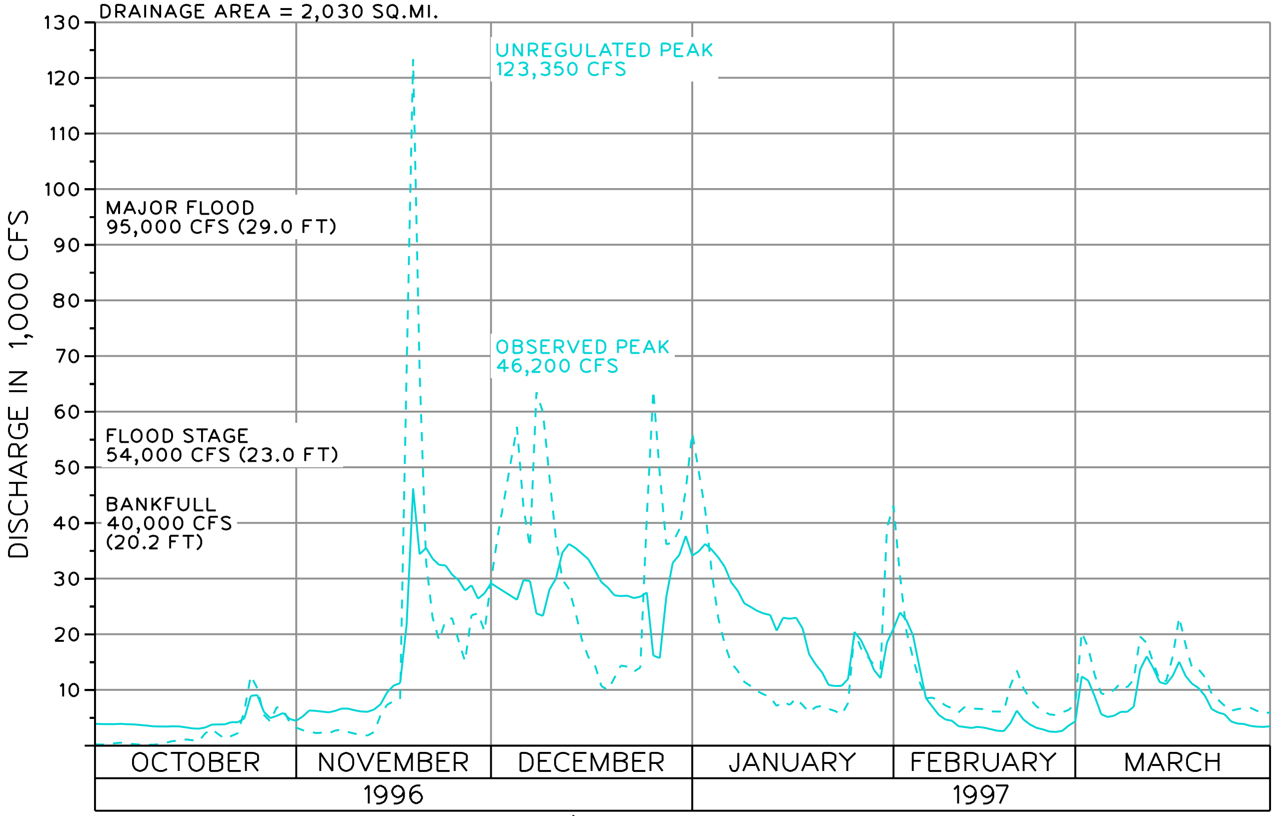

1996/97 FLOOD REGULATION

WILLAMETTE RIVER AT EUGENE, OREGON

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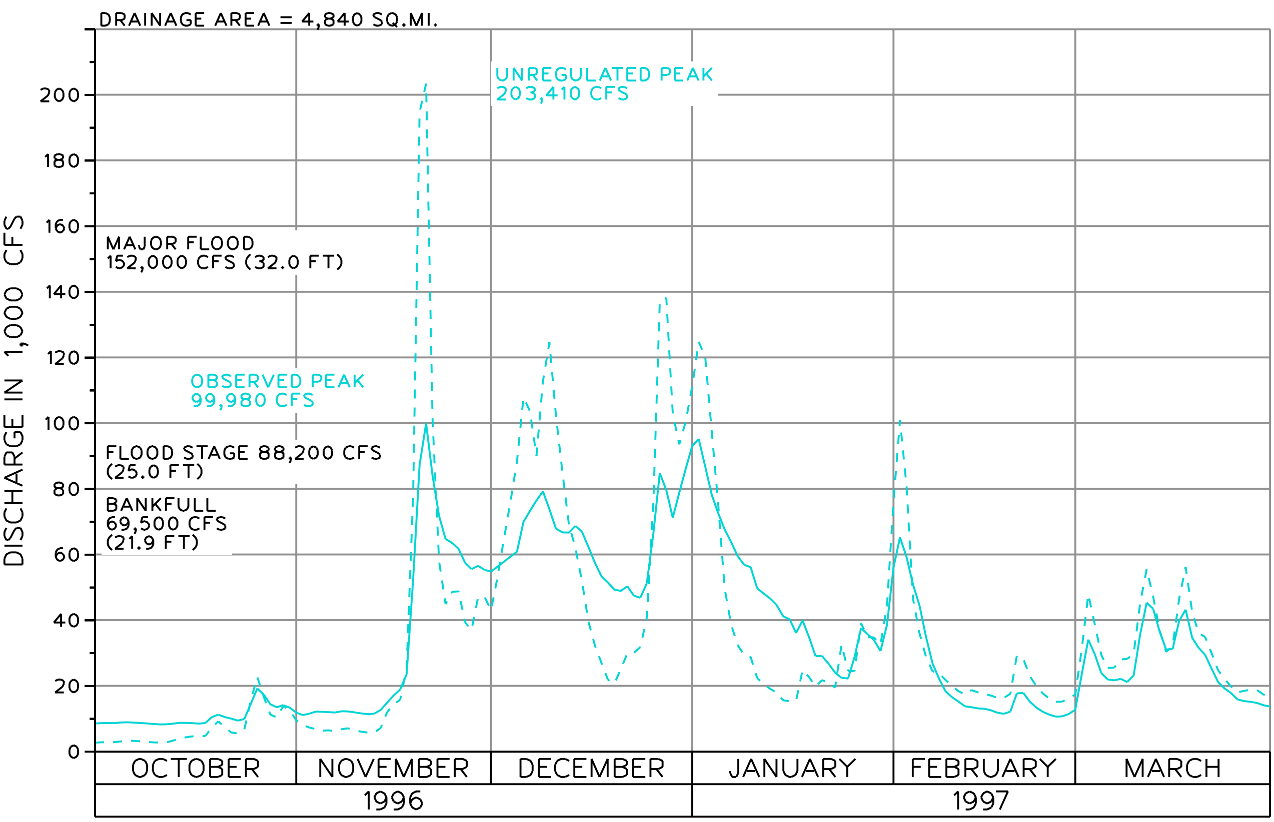

1996/97 FLOOD REGULATION

WILLAMETE RIVER AT ALBANY, OREGON

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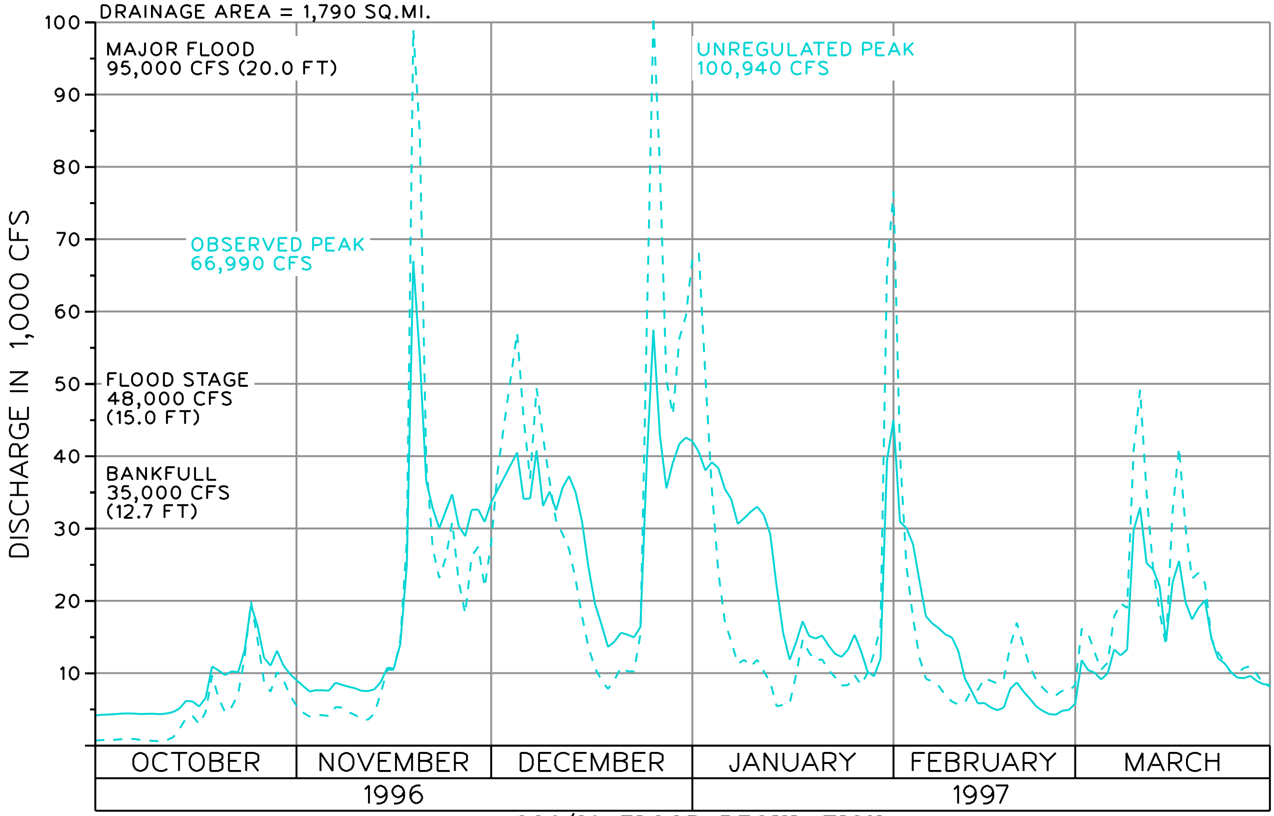

1996/97 FLOOD REGULATION

SANTIAM RIVER AT JEFFERSON, OREGON

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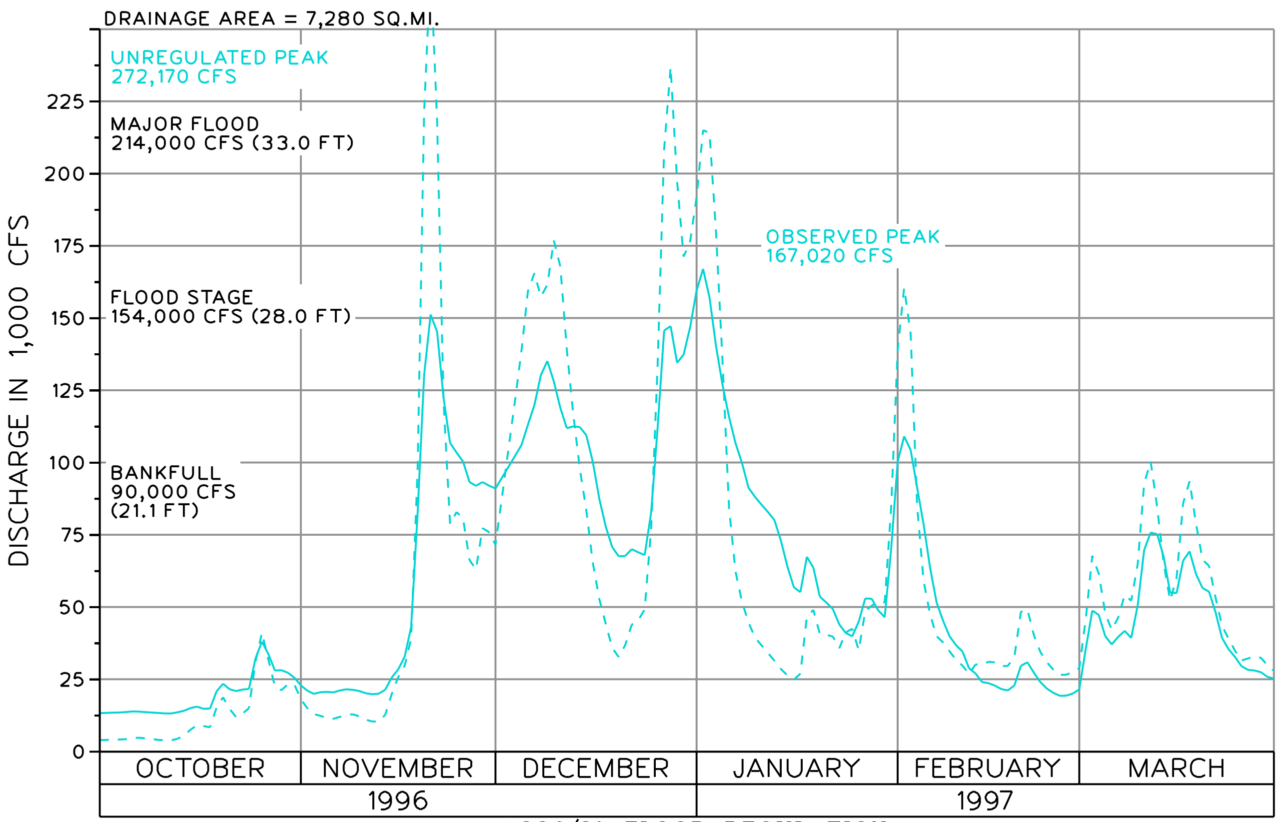

1996/97 FLOOD REGULATION

WILLAMETTE RIVER AT SALEM, OREGON

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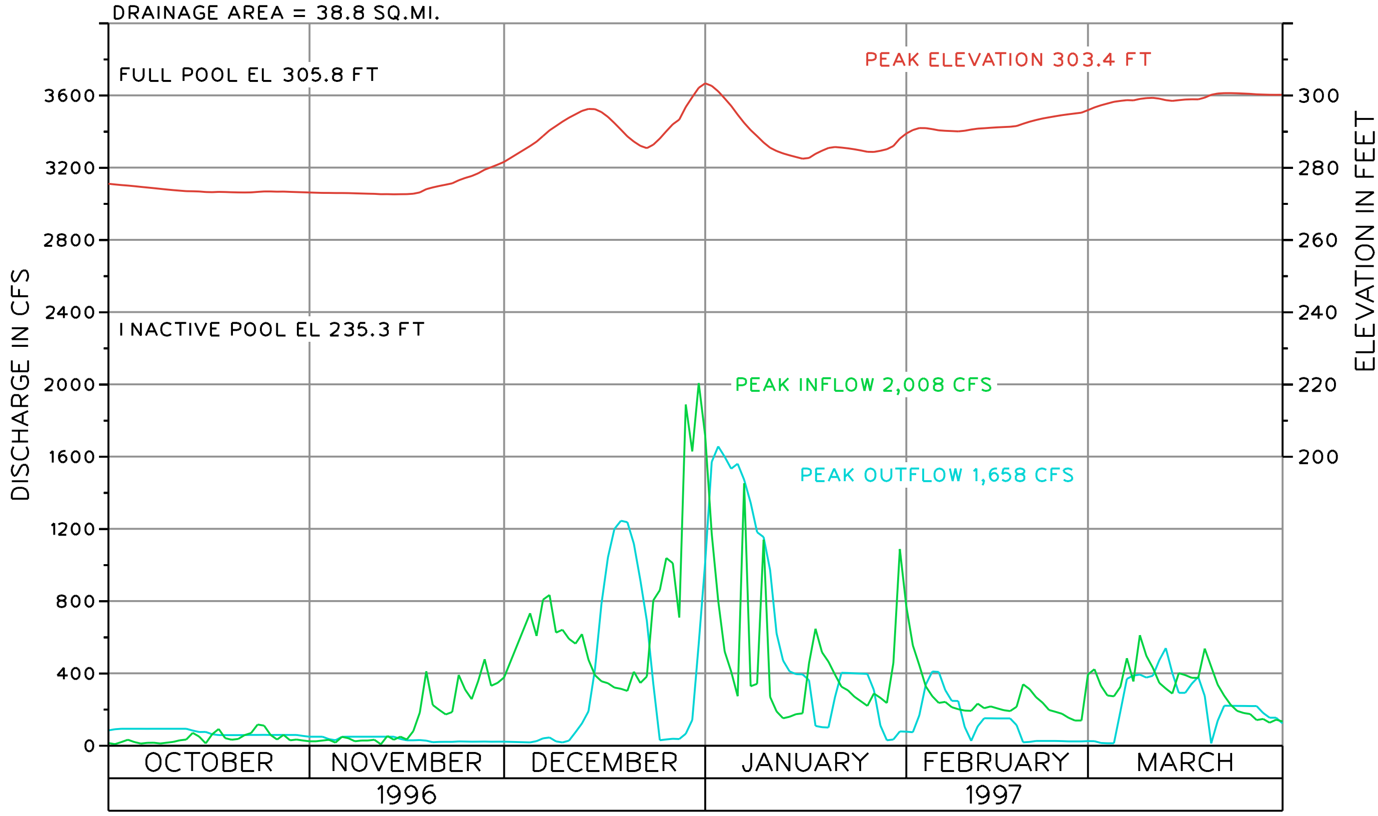

1996/97 FLOOD REGULATION

SCOGGINS DAM & HENRY HAGG LAKE NEAR GASTON, OREGON

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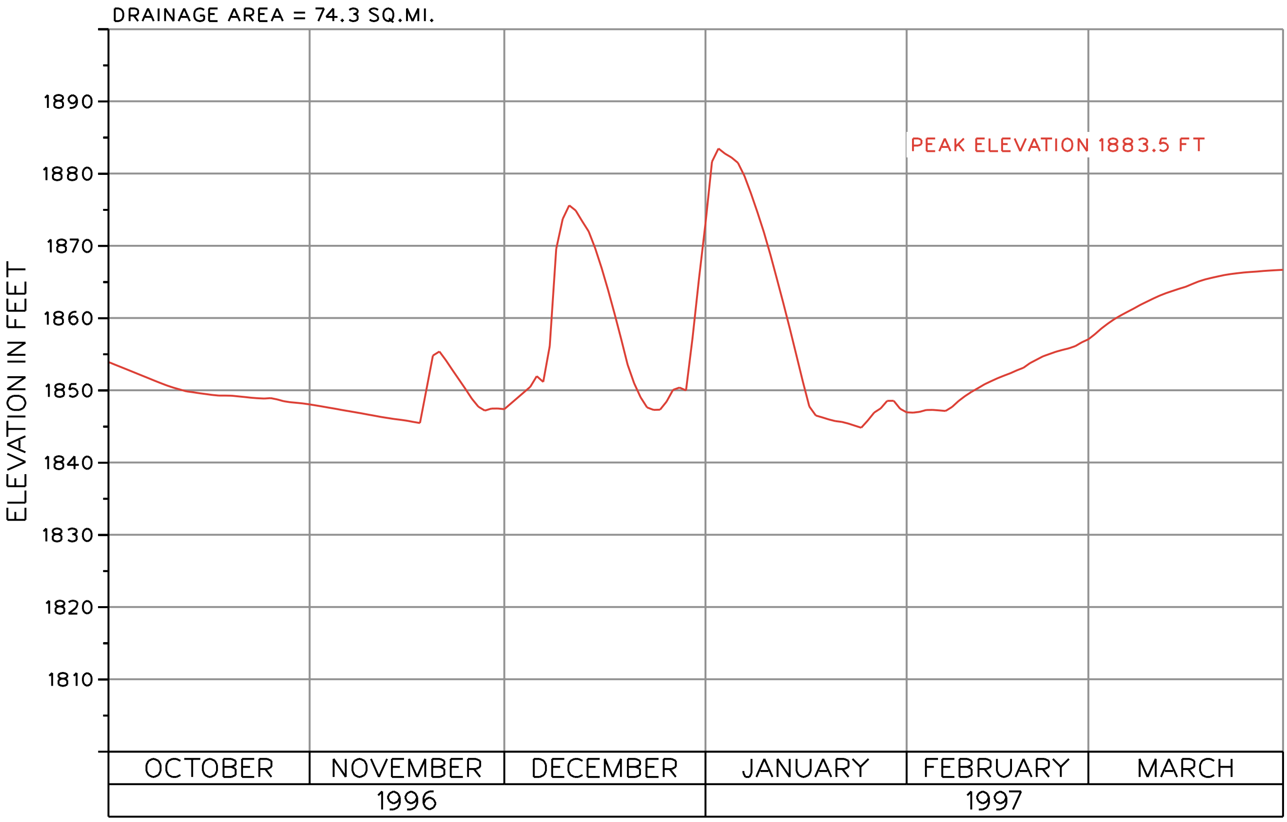

1996/97 FLOOD REGULATION

GALESVILLE RESERVOIR NEAR AZALEA, OREGON

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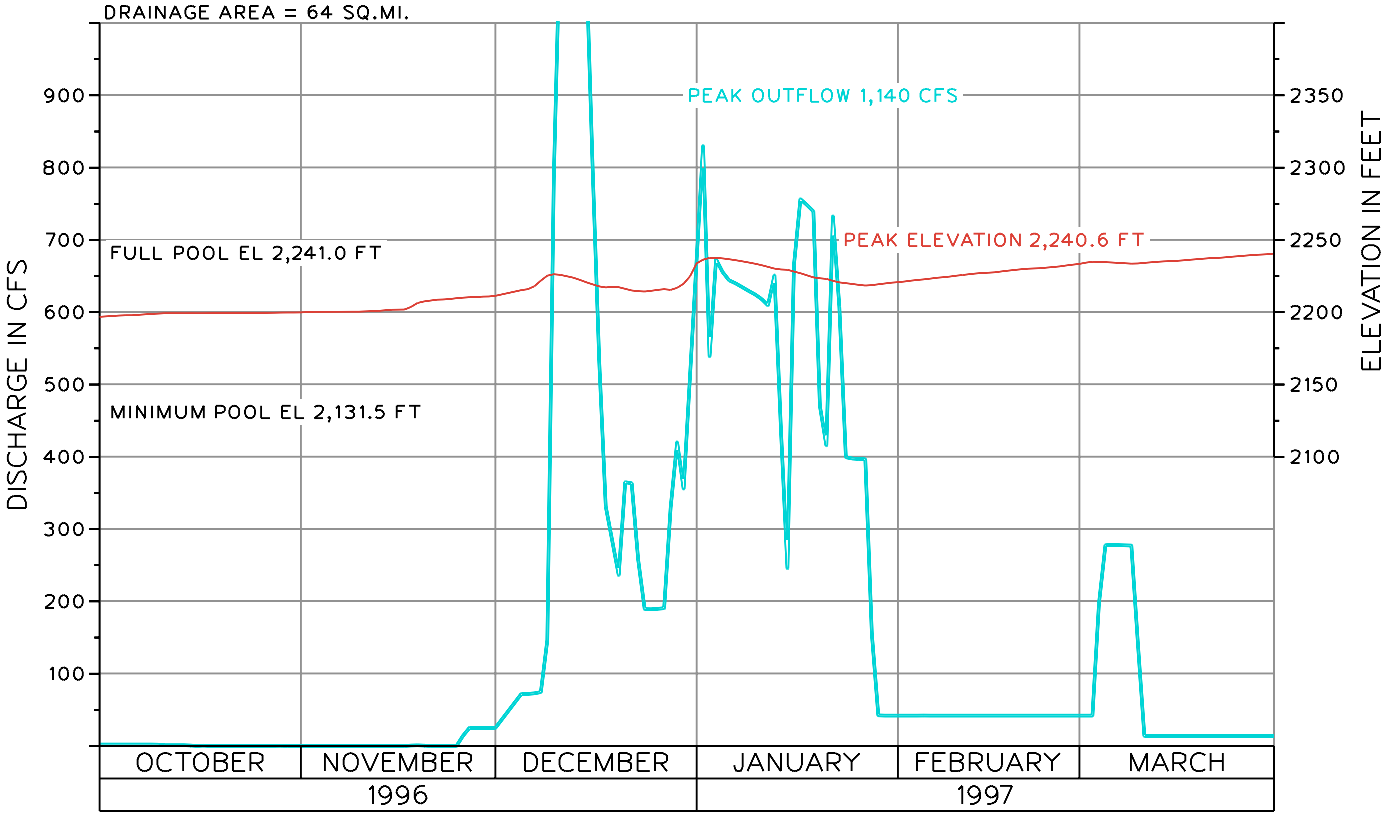

1996/97 FLOOD REGULATION

EMIGRANT DAM & RESERVOIR NEAR TALENT, OREGON

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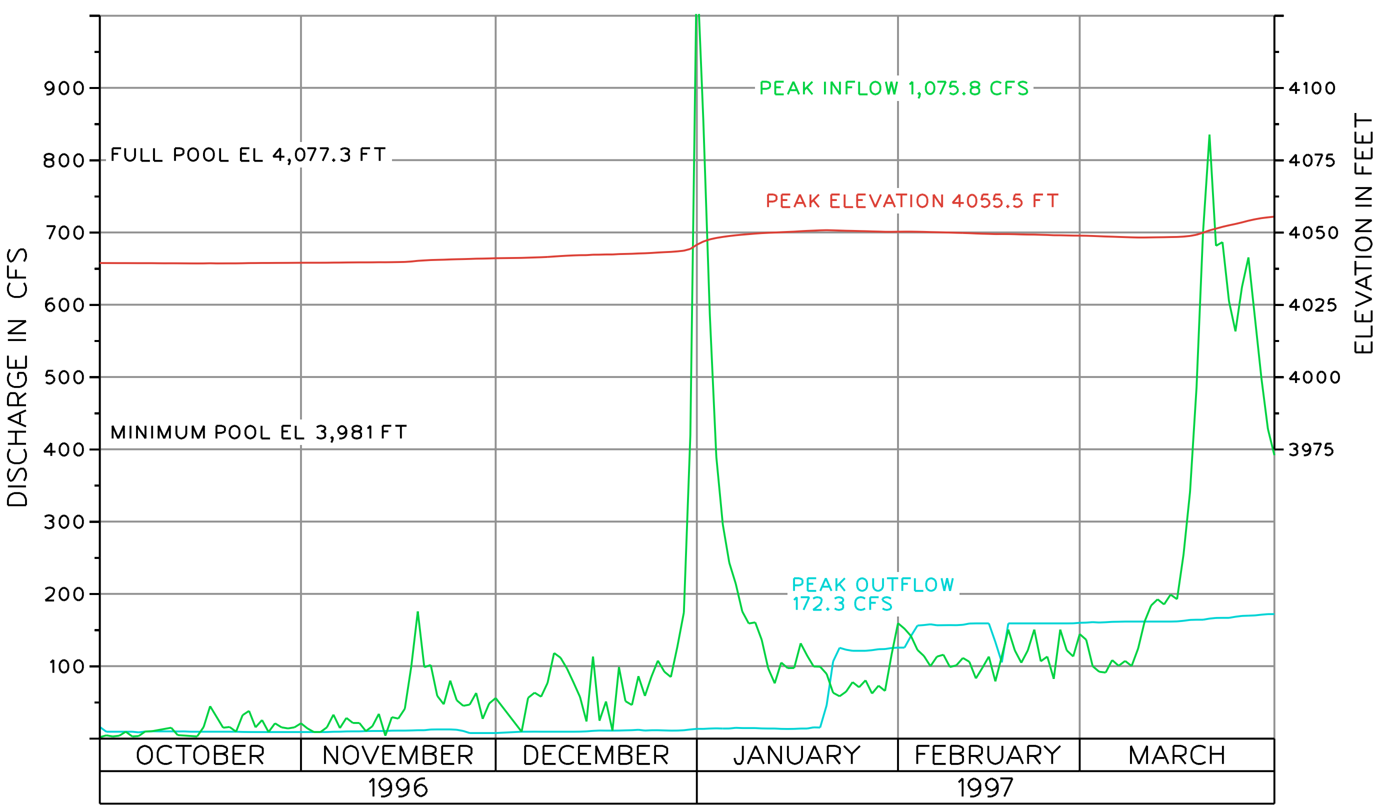

1996/97 FLOOD REGULATION

MASON DAM & PHILLIPS LAKE NEAR BAKER, OR

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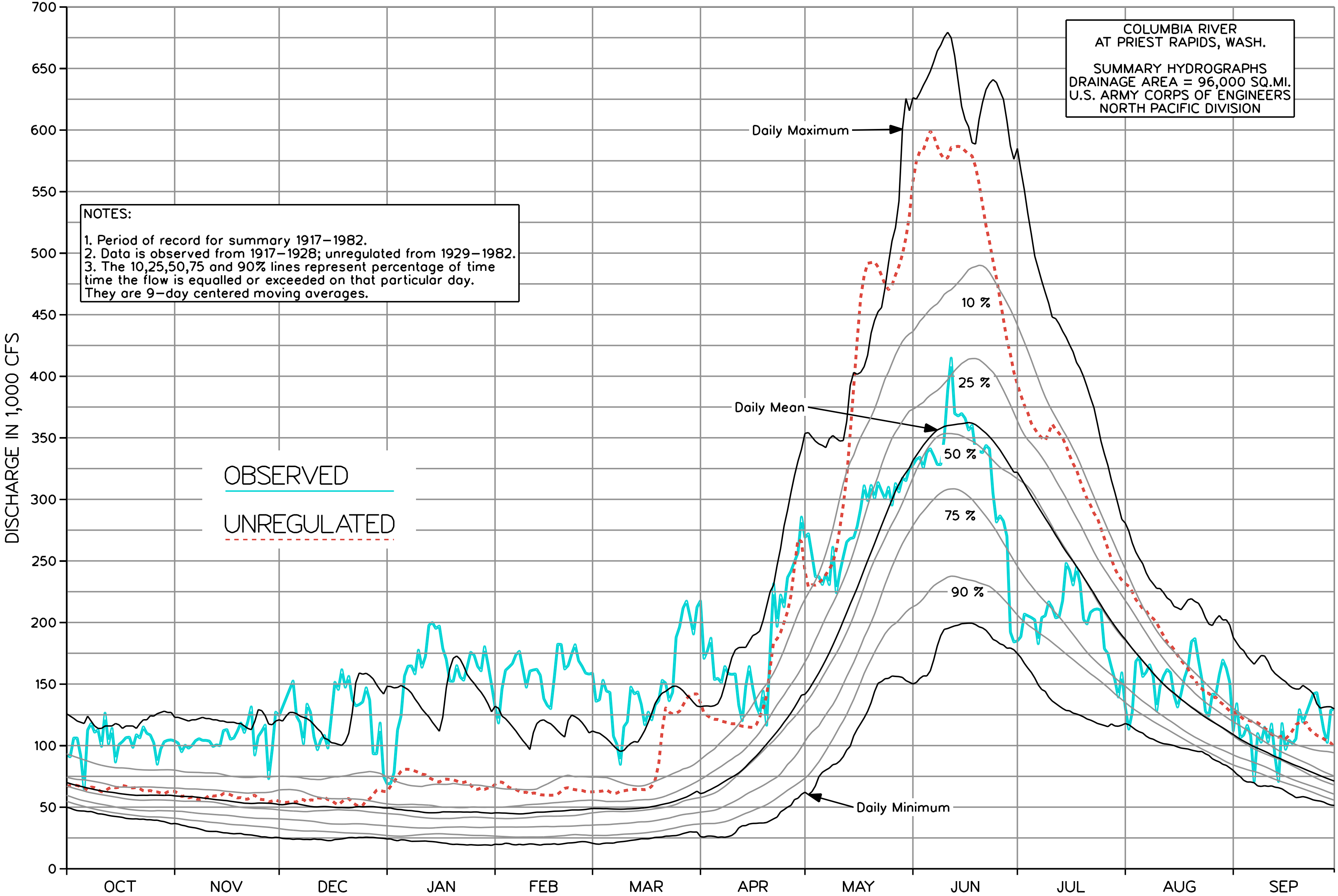

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CHART NO. 89

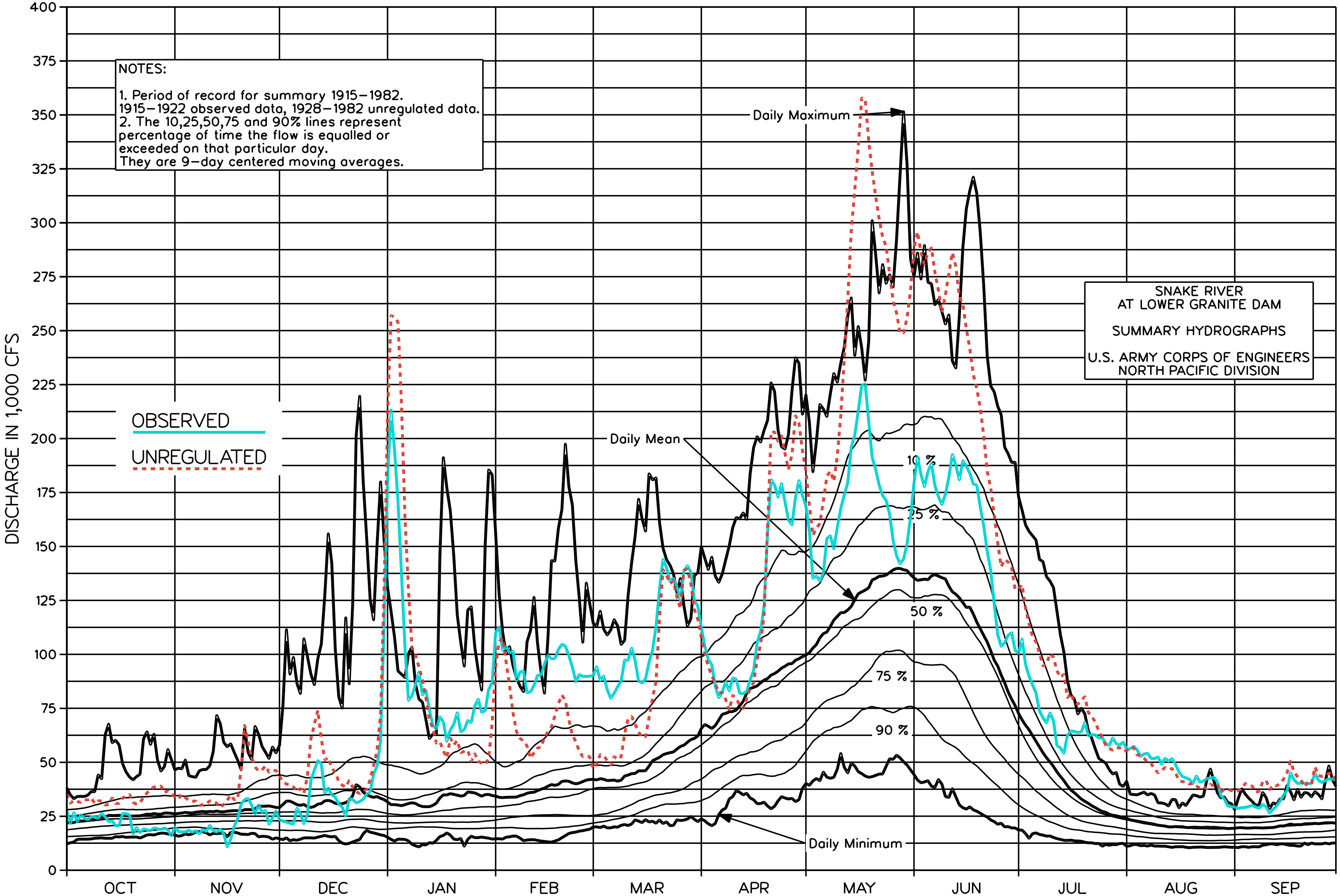

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CHART NO. 90

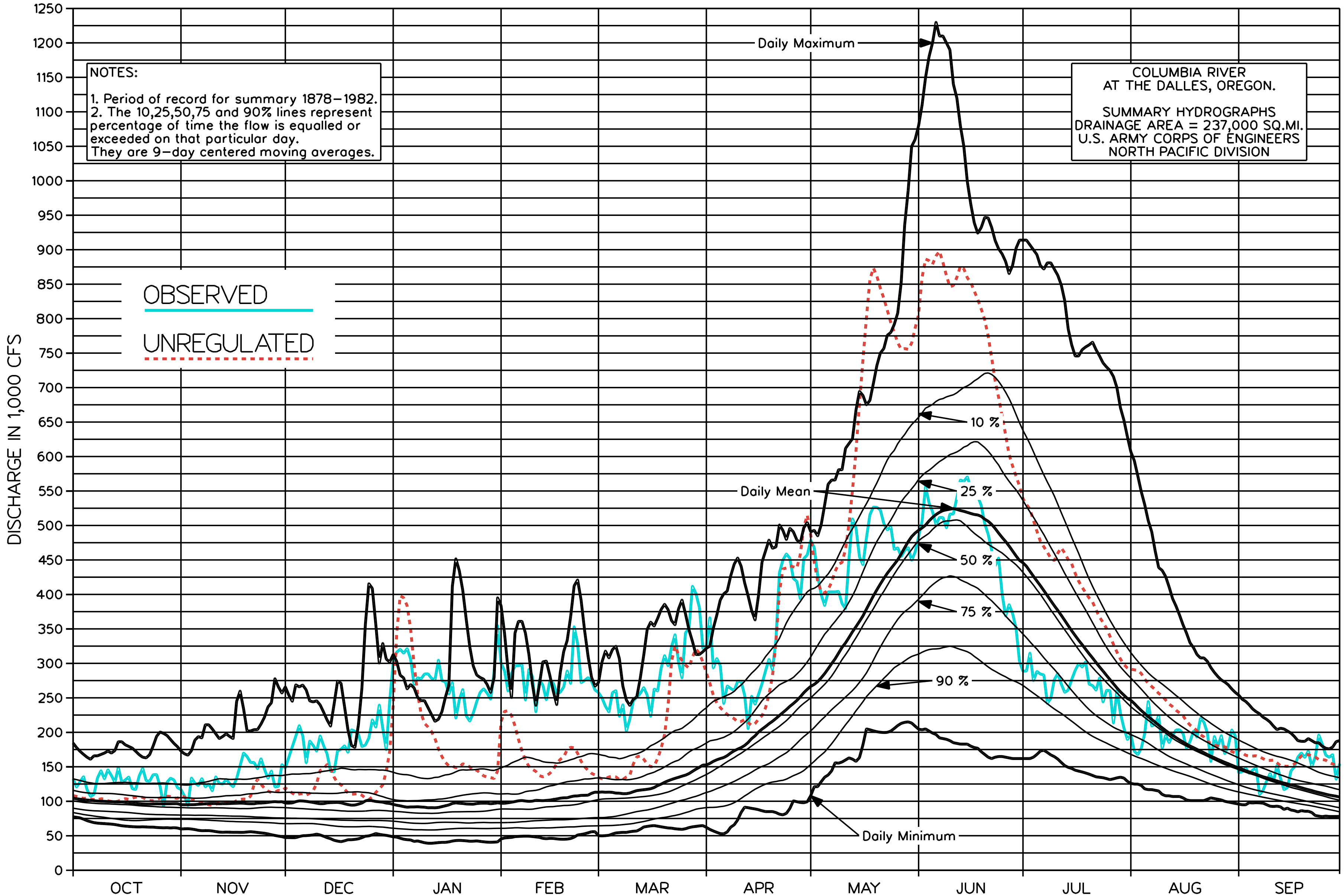

CHART NO. 91

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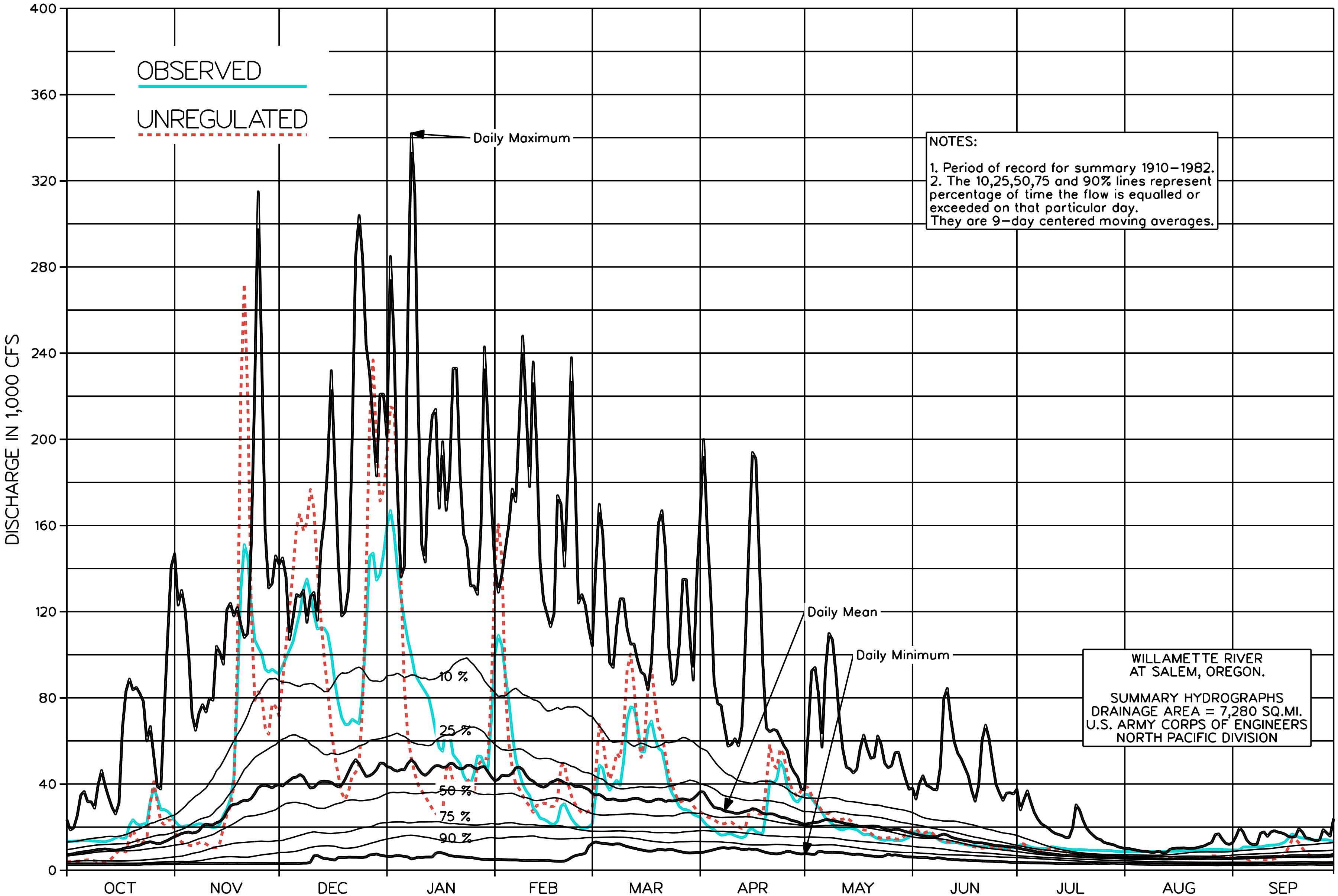

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CHART NO. 92

COLUMBIA RIVER WATER MANAGEMENT GROUP

Representative and Alternates

Member Agency	Representative	Alternate
Bureau of Reclamation	James Fodrea	Ted Day
Bonneville Power Administration	Nancy Stephan	Lisa von der Heydt
Corps of Engineers	Peter Brooks	Cynthia Henriksen
National Weather Service	Harold Opitz	Tom Fero
U.S. Geological Survey	L Ed Hubbard	
Environmental Protection Agency	Jack Gakstatter	Thomas Robertson
U.S. Forest Service	Bruce McCammon	
Soil Conservation Service	Ken Jones	Dan Moore
Bureau of Land Management	Bill Brookes	
Federal Energy Regulatory Commission	Harry Hall	Walter Boyle
U.S. Fish and Wildlife Service	Michael Spear	Marvin Yoshinaka
National Marine Fisheries Service	William Steele	
Oregon Water Resources Department	Barry Norris	
Washington Department of Ecology	Fred Olson	Doug McChesney
Idaho Department of Water Resources	Bill Ondrechen	
Nevada State Engineer	Mike Turnipseed	
Wyoming State Engineer	Gordon Fassett	
Montana Department of Natural Resources and Conservation	Jack Stults	

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