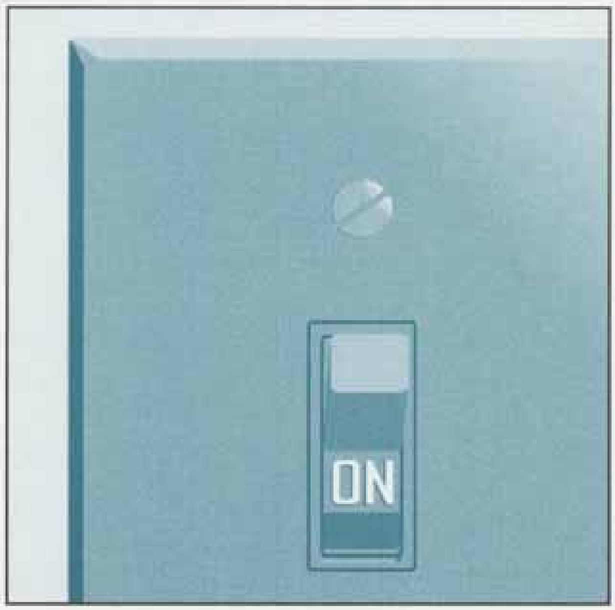

Daily/Hourly Hydrosystem Operation

How the Columbia River System Responds to Short-term Needs

Daily/Hourly Hydrosystem Operation:

How the Columbia River System Responds to Short-term Needs

U.S. Department of Energy, Bonneville Power Administration

U.S. Department of the Army, Corps of Engineers, North Pacific Division

U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region

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The following SOR publications are also available:

Streamline, a periodic newsletter that reports on the SOR;

The Columbia River: A System Under Stress, a four-page introduction to the SOR;

The Columbia River System: The Inside Story, an 85-page book that describes the Coordinated Columbia River System;

Screening Analysis: A Summary, a 30-page book on the SOR alternatives screening process;

Screening Analysis, a two-volume, 593-page report on screening;

Modeling the System: How Computers Are Used in Columbia River Planning, a 43-page report on how computer models are used to help plan and regulate hydro operations in the Columbia River Basin.

Power System Coordination: A Guide to the Pacific Northwest Coordination Agreement, a 46-page report on the Northwest's power system and an introduction to current coordinated hydro operations.

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Table of Contents

Introduction

The Columbia River system consists of the Columbia River and its tributaries, which drain about 57 million hectares (219,000 square miles) in the United States and 10 million hectares (39,500 square miles) in British Columbia. Federal agencies and other entities have built 30 major dams and dozens of other hydro projects in the Columbia River basin. The dams and their reservoirs are used to generate hydroelectricity and to provide non-power benefits such as flood control, navigation, and recreation.

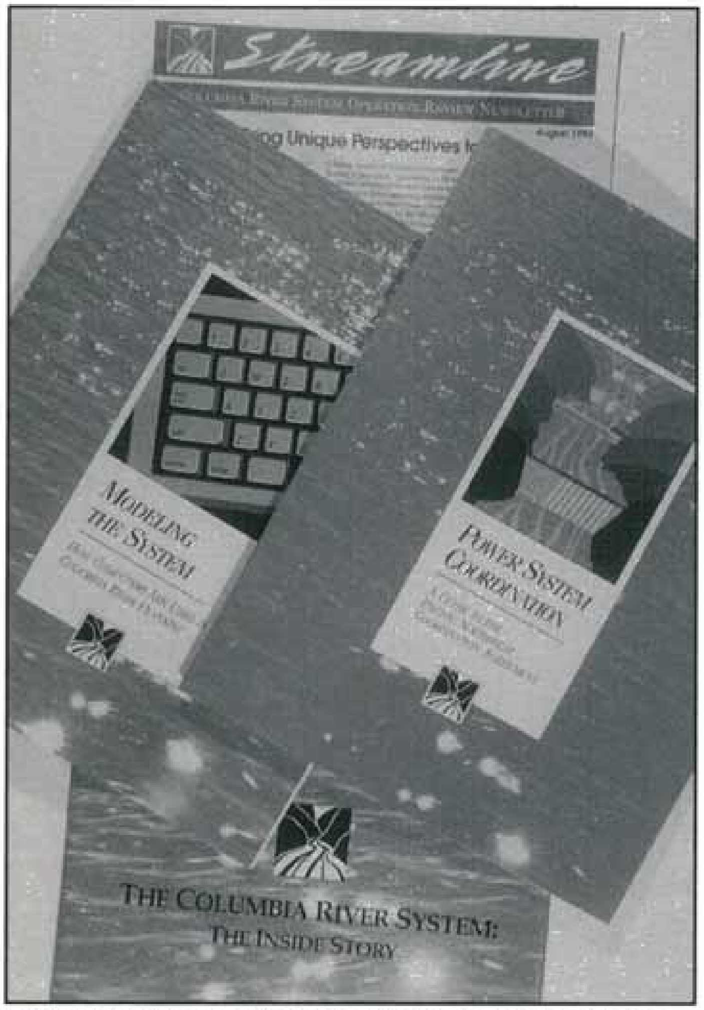
The System Operation Review, being conducted by the Bonneville Power Administration, the U.S. Army Corps of Engineers, and the U.S. Bureau of Reclamation, is analyzing current and potential future operations of the Columbia River system. One goal of the System Operation Review is to develop a new System Operation Strategy. The strategy will be designed to balance the many regionally and nationally important uses of the Columbia River system.

The System Operation Review also will provide information needed to assist with renegotiation of the Pacific Northwest Coordination Agreement and other agreements related to the Columbia River Treaty between the United States and Canada. These complex agreements are explained in earlier System Operation Review publications, *The Columbia River System: The Inside Story* and *Power System Coordination: A Guide to the Pacific Northwest Coordination Agreement.*

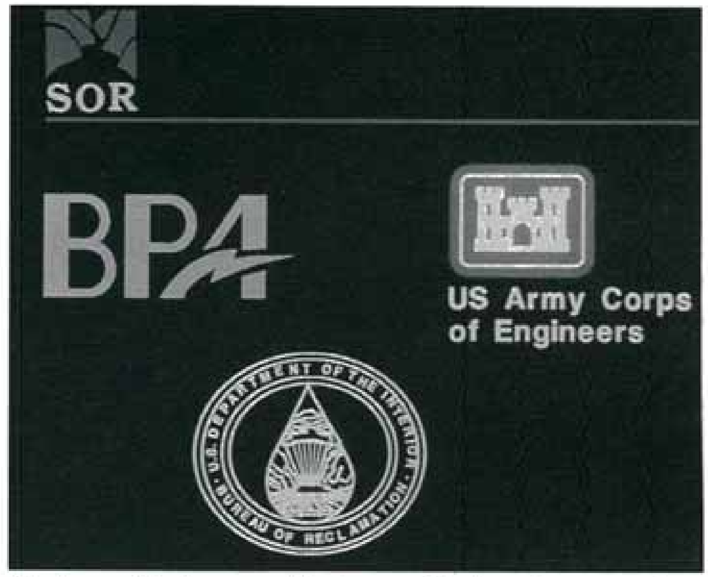
The Inside Story explains how system operations are planned and carried out. It describes the river system, those who operate and use it, the agreements and policies that guide system operations, and annual planning for multiple-use operation. Another System Operation Review publication that provides a good overview of system operations is *A River At Work.*

The Inside Story focuses on the types of system operations that take place annually and seasonally. This publication expands that knowledge by explaining how hydro system operations are planned and carried out in the short run — hourly, daily, and weekly. Short-term operations occur primarily for power production, to meet varying load demand, within the requirements imposed by all other system

Short-term operations of the hydro system — hourly, daily, and weekly — occur primarily for power production, to meet demand for electric power.



Earlier SOR publications have described coordination, planning and operation of the Northwest hydro system. This publication focuses on short-term operations.



The Corps of Engineers and the Bureau of Reclamation own and operate the projects in the federal hydro system. The Bonneville Power Administration markets the power produced, collects the money, and pays the bills. The three agencies are conducting the SOR.

The System Operation Review is analyzing current and potential future operations of the Columbia River system to balance the many uses of the system.

uses. Spill of water to assist fish passage and some flood control actions are a couple of the other short-term operations of the system.

Power System Coordination provides an overview of the Northwest's power system and describes current coordinated hydro operations. It begins by considering coordination as a concept, examines the Columbia River as a hydro resource and then reviews the elements that spurred river developments culminmating with the Columbia River Treaty. It concludes by providing a detailed look at the Pacific Northwest Coordination Agreement, its planning process and operating procedures.

To help you understand the principles and typical actions during short-term operations, this publication begins with two series of "newspaper articles." They describe a severe winter situation and, in contrast, a common spring situation.The articles provide examples of the principles discussed in the explanation of short-term operations that follows. In addition, several appendices provide detailed explanations, and there is a glossary with definitions. Appendix A lists short-term operational limits for the 14 projects included in the SOR. Appendix B provides an overview of the Northwest hydro system, including the agreements and legislation that govern planning and operations. Please see the glossary for terms used in the context of short-term operations.

If you have questions or comments about this publication, previous publications, or the System Operation Review, please contact the Interagency Team. The address and phone number of the team are on the inside cover of this publication.

Dateline: The Northwest: December 1990

Weather forecast

THE NORTHWEST — We could have a White Christmas after all. The intense storm that has western Canada in its grip is on its way south bearing record low temperatures, snow, and blustery winds.

"This major cold wave will hit the Northwest sometime Wednesday, December 19," predicted Neil Roberts at the National Weather Service. Roberts says another cold wave is predicted to hit about 10 days later.

Bonneville Power Administration (BPA) expects record peak demands for electricity. Turbines at the Northwest's hydro projects will be working hard, and planners, schedulers, and others are setting the stage for action.

System prepares

THE NORTHWEST — The hydro system is in good shape to meet the peak loads expected during the cold spell. Back in October and November BPA bought 650 megawatt-months of energy from BCHydro and from Idaho Power to meet forecasted fall and winter needs. Then heavy rainfall in the region required the system to operate to flood control elevations in November.

Current status of upstream projects: Hungry Horse is discharging near minimum outflow levels; Libby and Dworshak are discharging at full load level for flood control; Grand Coulee is operating in the top five feet of the reservoir.

"Intertie and generation maintenance scheduled for the next couple of weeks has been deferred," said Toni Phillips at BPA. "Maintenance on out of service generation units is proceeding on overtime to get them back on line."

Records set

THE NORTHWEST — Baby, it's cold! The Bonneville Power Administration's (BPA) service territory, especially the Puget Sound area, has been covered with abnormally high levels of snow and buffeted by extremely high winds.

Most of the utilities in the region have reported new system peaks, higher even than during the Siberian Express of February 1989. The new peaks were lower than they could have been, however, because many customers were out of service due to local outages. "We haven't had to curtail any customers' loads due to the cold spell," reported Toni Phillips at BPA.

Average temperatures in the Northwest Power Pool area yesterday were 27 degrees Farenheit below normal.

The System responds

THE NORTHWEST — At Grand Coulee Dam, the U.S. Bureau of Reclamation exceeded its 1.5 foot per day draft limit for a limited period of time, to 1.7 feet. "We used the higher draft limit to pass more water through the turbines, increasing generation," said Sandy Wilson at Grand Coulee.

The Corps of Engineers will operate John Day one foot above normal full pool and McNary half a foot above for limited periods to allow extra water to be stored to meet power demands during the cold weather.

"We have other operating requirements at those two projects," said Miki Sato at the Corps. "On weekends, holidays, and Wednesday mornings, we operate McNary close to full pool and John Day at the top of normal operating range for waterfowl hunting."

Yesterday Dworshak began spilling to increase flows into Lower Granite and the other three lower Snake projects to increase generation there. Shifting generation from the upper Columbia River to the lower Columbia and Snake Rivers takes the pressure off the north Cascade transmission lines, preventing overload and potential failure.

At Little Goose, in spite of the need for power generation, the Corps kept the reservoir high early this morning for a couple of hours to allow passage of two deep-draft tugs.

Normal temperatures expected

THE NORTHWEST — None too soon, the cold spell is about to end. "Beginning today, average regional temperatures should rise at least into the teens," predicted Neil Roberts at the National Weather Service.

"The warming trend should allow the hydro system to recover to some extent and let us prepare for future cold weather," said Toni Phillips at BPA. Lower Columbia and Snake River projects began to refill, after being drafted to meet the high loads of the past few days. As much water as possible will be stored to try to refill the headwater storage projects, which were drafted to meet loads.

"Since December 24 Grand Coulee has been drafting to meet the higher loads due to the cold weather," said Sandy Wilson at Grand Coulee Dam. "We'll begin refilling the reservoir as soon as this cold spell abates."

Miki Sato of the Corps of Engineers reported that as a result of high inflows and lack of light hour load, John Day was operated at a foot above normal full pool December 25 and 26. This will continue through December 31 to provide system operators flexibility to meet power loads during the rest of the holidays.

Similarly, Sato added, operation of the NcNary forebay half a foot above normal full pool is permitted December 28-31 if necessary. This operation is designed to provide reservoir space to reduce the possibility of spill.

Throughout this first major cold spell of the winter of 1990, the hydro system has demonstrated one of its major advantages. The hydro system's flexibility enables it to make short-term changes in response to system needs. The system can now begin to recover from these emergency operations so as to be ready to respond to the next onslaught of cold weather when it arrives.

Preparations:

- Weather Service forecasted heavy snow with record low temperature
- BPA purchased energy early in the fall to provide water later for contingencies
- Upstream reservoirs operated to the highest possible levels consistent with flood protection and minimum flows

Response:

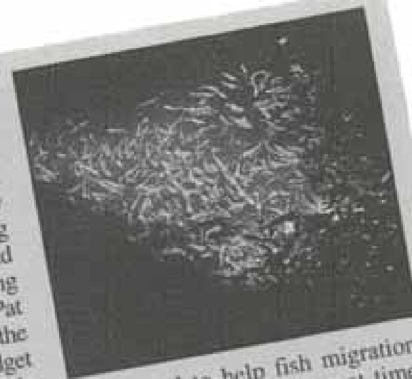
- Maintenance on the system accelerated to have all available units in service
- Permission is obtained to exceed short-term draft limits and other operating requirements at projects
- Generation shifted among Federal projects to relieve transmission line pressure

Results:

- Hydro system sets peak load record
- System demonstrates flexibility to respond to a high power demand

Dateline: The Northwest: April 1992

Fish flush begins



THE NORTHWEST — Yesterday, the Corps of Engineers announced the beginning of the fish flow operation. Young salmon are being "flushed" down the Snake and Columbia Rivers to the sea using water in the Water Budget. Pat Roberts, Chief of Operations for the Corps, explained, "The Water Budget is a specific amount of water stored in the reservoirs specifically to help fish. This water is released to increase river flow during the spring, when many juvenile fish are migrating."

The fish flow operation on the Snake River usually begins as early as April 15 every year and lasts through June 15. On the Columbia River the period is May 1-June 30. The timing and exact amounts of water released to help fish migration are decided upon by The Fish Passage Center, which includes representatives of fisheries agencies and Indian Tribes.

As much as possible, project operators generate power with the water used to help fish migration. Some projects spill water at times so that the fish avoid going through the turbines, which can be deadly to fish.

Roberts noted, "Although the fish flow operation is designed to help juvenile fish migrate downstream, adult fish are also in the river, migrating upstream. Therefore, spill is limited at some projects to make the upstream trip easier."

The project operators limit spill for a couple of reasons. One is that spill can cause nitrogen supersaturation of the water, which is harmful to fish.

The system prepares

THE NORTHWEST — Biologists expressed relief today that preparations on the Columbia River to aid juvenile salmon were nearly completed.

Lower Columbia and Snake River projects where fish are migrating will operate turbine units within 1% of peak turbine efficiency for fish passage. Studies show that fish passing through turbines suffer less mortality when turbines are operating at peak efficiency.

Lower Granite Dam on the Snake River was held to the top foot of its forebay range until last night. It will increase generation and be drafted about 4 feet, one foot above its minimum forebay elevation.

The water released is being stored in the next project downstream, Little Goose. Soon Little Goose will draft to the bottom of its forebay range and so on down the river. Biologists believe this operation will provide high flows on the Lower Snake in the evening when juvenile fish are most likely to be moving.

These operations also produce surplus generation in the evening when the water is being passed downstream. Since this will be done at only one dam at a time, the additional energy can be stored as water in other reservoirs on the system. The stored energy will contribute to the water being stored for release for fish passage in May and June.

The Lower Snake projects will continue to operate in a one-foot range at the bottom of forebay operating range to allow maximum water velocity for fish.

Starting last night and nightly through the fish flush period, Lower Monumental and Ice Harbor will spill for 12 hours each night. Bonneville Dam is spilling 53% of its flow, which will aid downstream migration of juvenile fish and not hamper upstream migration of adult fish.

Maintenance begins on thermal plants

THE NORTHWEST — Early yesterday morning the Centralia Coal Plant was shut down for its annual spring maintenance. Thermal plants generally are scheduled for annual maintenance during the fish flush period, when usually there is excess generation.

An official for the Washington Public Power Supply System also reported that their nuclear plant #2 was shut down for scheduled maintenance. Normally the generation lost during the maintenance time would be replaced by hydro generation from the high flows of the spring runoff and fish flow operation. This year the runoff is so low, however, that BPA is purchasing energy instead.

Weather causes concern for fish

THE NORTHWEST — The last few days have brought rain and warmer temperatures to the Northwest, increasing river flows. Under these conditions, power operations do not have much effect on flow, because fish requirements or flood control usually drive operations and daily outflows.

High springtime flows are filling up space in Northwest reservoirs quickly. To maintain reservoir space for flood control, projects will continue to provide high outflows. Some of the released water will generate nonfirm energy which BPA will sell through contracts signed earlier in the spring. The remaining water will be spilled.

To protect juvenile fish in passing downstream projects, The Fish Passage Center has requested that spill be limited. The Center distributes a spill priority list that specifies the preferred order of spill at the various projects, with the goal of minimizing dissolved gas levels in the water. The spill that the Center is concerned about occurs whenever there is more stream flow than needed to generate power and to help fish migration.

It is a complicated balancing act to maintain flows for fish passage and flood control while not hampering power operations or upstream fish migration and attempting to limit nitrogen supersaturation.

Spring operations

THE NORTHWEST — This year's spring operation for the Columbia River dams reflected the wide variety of uses that benefit from the projects. That was the message General Amblin, Corps of Engineers, delivered at the annual operations symposium held yesterday. The General described several examples. On Saturday, April 25, Bonneville was operated to maintain a constant outflow to permit 300 school children to clean up the shoreline below the dam.

Special operation of the first powerhouse occurred at Bonneville Dam from April 24 through May 5. Tests on juvenile bypass fish guidance efficiency at Bonneville's first powerhouse also required the discharge of specific amounts of flow.

McNary Reservoir was held near the top of its normal operating range from Thursday April 23 through Saturday April 25 for a intercollegiate rowing regatta near Richland. Operators maintained the water level while keeping in mind the requirement to operate McNary units to 1% efficiency for fish passage, which had priority over the water level or the regatta.

John Day was operated in the top foot of its operating range every three days to discourage waterfowl nesting at lower elevations from March to May.

Also at McNary special operations occurred to test prototype extended-length submersible traveling fish screens and bar screens.

Chief Joseph was operated near the top of its summer operating range. This prevented formation of land bridges, which would allow predators to reach waterfowl nests on nearby islands.

The Lower Snake plants operated within one foot of the bottom of their forebay range to maximize flow velocity for fish out migration.

And at Lower Monumental, the project's juvenile fish bypass facility was shut down April 21 for modification. Lower Monumental was forced to spill for juvenile fish passage, and one unit operated during the day for adult fish attraction. Tests of the new juvenile fish bypass system will begin in May.

Preparations:

- Development of juvenile salmon monitored to determine when to begin water release.
- Water stored in upstream reservoirs to provide flow augmentation for salmon.
- Annual spring maintenance scheduled for thermal plants.

Response:

- Water released to help downstream juvenile salmon migration
- Spill at dams managed to help with upstream adult migration and to control nitrogen supersaturation.
- Turbines operated within 1% of peak efficiency for best fish passage.

Results:

- BPA purchases energy because of low water runoff to provide full flow augmentation
- Fish Passage Center requests are satisfied during fish migration period
- System successfully balances flows for fish and storage space for flood control

Chapter One: Definition and Objective of Short-Term Operations

As the news articles illustrate, short-term operations of the Columbia River System are designed to meet the varying demand for electrical power efficiently and economically, while complying with non-power requirements. Power demand varies continuously with changes in industrial, commercial, and residential power use. These load variations are discussed in the next section.

Short-term operations for power occur within the other requirements placed on the system to meet the needs of other river users. Most river uses other than power do not normally cause as frequent of changes to discharges and reservoir levels at dams. Non-power requirements may affect how much hourly fluctuation can be provided for power production. Requirements on short-term operations for power use are discussed in the third section of this chapter.

Loads and Load Shapes

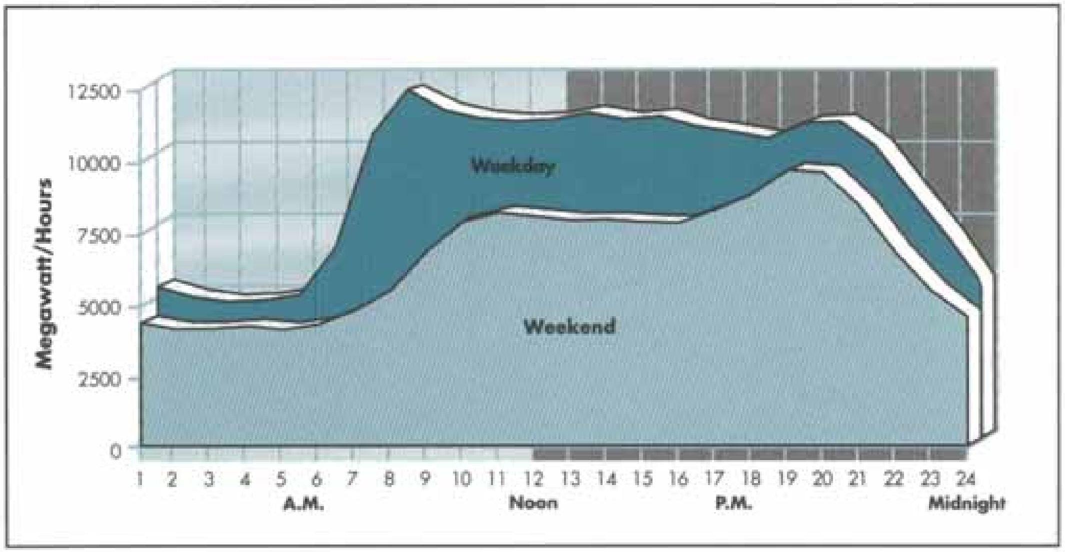
The factor that most affects demand for power is the usage patterns of consumers, or load. Consumers are industries, businesses, residences, and farms that use electricity to power machinery, pump water, and provide heat and light, thereby putting load on the power system.

Seasonally, demand for power in the Northwest is highest in the winter, when cold weather increases loads, mostly for space heating. In eastern Montana and much of California, in contrast, loads generally are highest in the summer due to air conditioning and irrigation and pumping needs.

Demand also varies within each week. Weekday usage is the highest, because many people are at work, stores are open for business, and manufacturing plants are operating. Saturday loads are lighter than weekdays, and Sunday loads are even lighter. Holiday loads vary widely from one holiday to another, depending on the nature of the holiday. Loads during the Labor Day weekend are low, because many companies close and people take time off work to recreate. But the load on Presidents' Day in February may be only slightly different from a normal winter weekday, since most businesses are open and people are at work.

Diurnally, or within a 24-hour day, loads increase and peak in the mid-morning to noon hours, as people arise and begin work. In the afternoon loads decline slightly but peak again about 6 p.m. The hours 6 a.m. through 10 p.m. Monday through Saturday are referred to as heavy load hours, and the rest of the week is light load hours. During the winter in the Northwest, the morning and evening peaks are more pronounced and the daytime plateau is higher than in the summer.

Graph of Typical Day



Demand for power, or load, is low during the night. Loads increase as people arise and begin their day's work, peaking in the morning and again in the early evening. Weekend day loads are much lower than weekday loads.

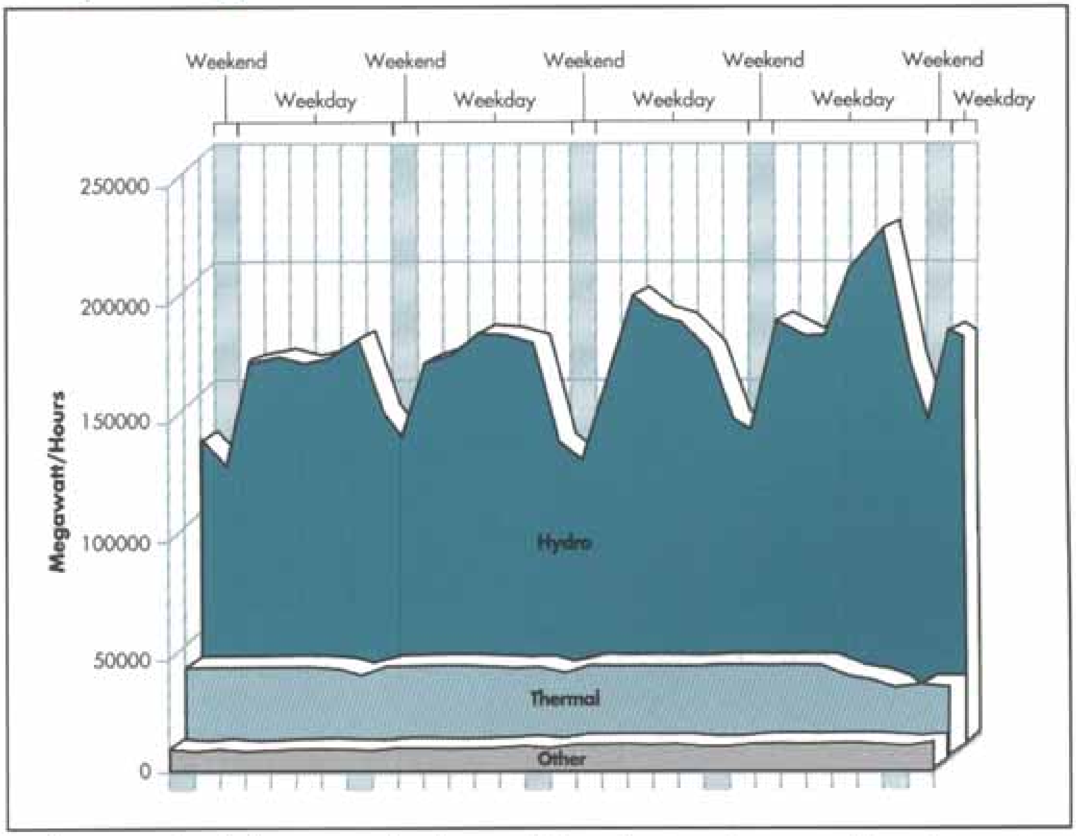
Uncertainty

The typical seasonal, weekly, and diurnal shapes of loads just described seem logical and easy to comprehend, because they depend on work routines, weather, and seasons. But several factors make it difficult to predict loads and plan for a responsive and efficient operation. Loads follow many different patterns, depending on the power usage patterns of consumers. For example, industrial demands for power are relatively constant as manufacturing processes continue every hour throughout the day and week. Residential loads, on the other hand, are as diverse as the people in the region and their patterns of eating, sleeping, and working.

Weather is probably the most significant variable, as illustrated in the news articles on the cold spell. In the Northwest, with its varied geography, weather is often unstable and unpredictable. Weather conditions can vary considerably from place to place within the region, as can people's responses to actual weather and forecasts. For example, when a hot spell is predicted, some people turn up their air conditioners and others head to the river to cool off.

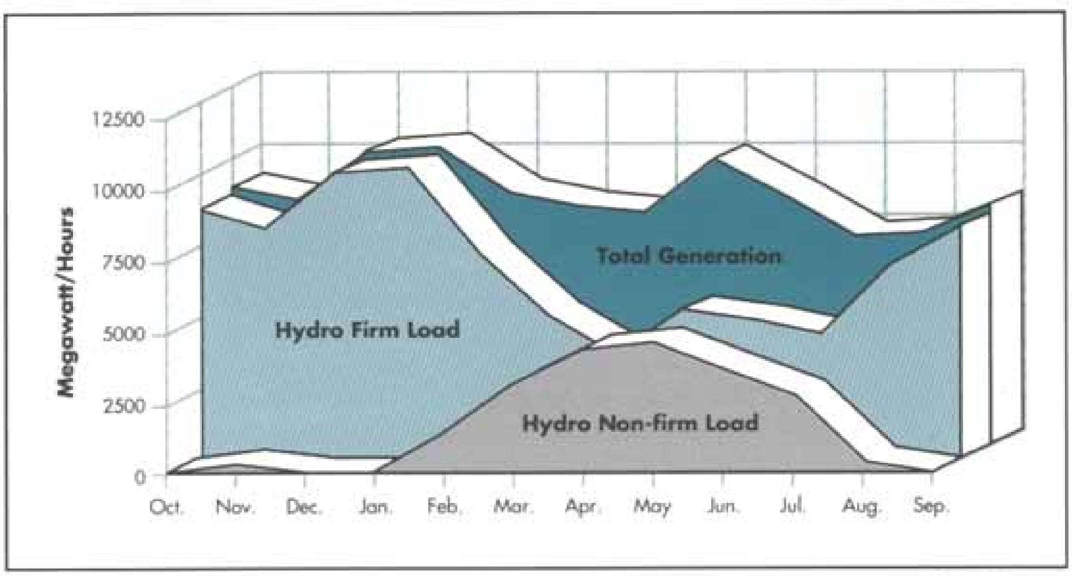
Another source of uncertainty in demand for power is transactions between utilities. These include year-round and seasonal sales of firm energy and capacity. Some firm sales may be seasonal, such as Northwest utilities' sales of capacity to California during the summer months. Other transactions may be seasonal exchanges, for example a Northwest utility

Graph of Typical Month



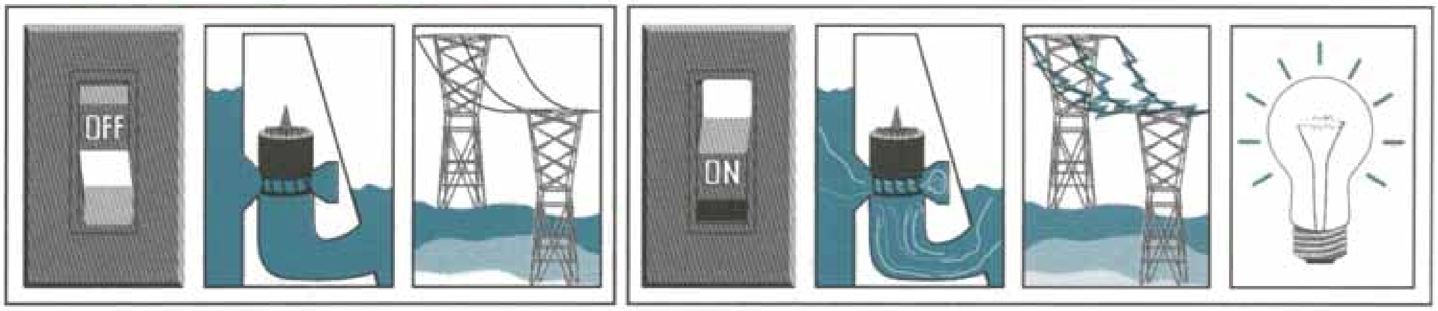
Loads are significantly lower on weekends, especially on Sundays, than on weekdays when most people are at work. The hydro system responds to changing loads, with thermal and other resources providing power to meet the relatively stable baseload.

Graph of Typical Year



Loads and power production also vary significantly during the year. Hydro projects are fueled by water flows, which are higher during the spring and summer as snowpack melts. Loads are highest in the winter in the Northwest, as people turn up their thermostats to keep warm. Surplus energy can be either sold in the Northwest or sent to California, which has higher loads in the summer, and California utilities can send energy back to the Northwest in the winter, when we need it.

What's Behind the Light Switch?



Electric power has to be where it is needed when the switch is flipped on. Water flows, the turbines turn, the power flows over the lines, and the light bulb glows.

providing summer energy to a California electric utility purchaser in return for energy during the winter when Northwest loads are higher. Some energy exchanges provide the parties with additional flexibility, such as conversion of the exchange to a sale under specified conditions.

While energy transactions usually are pre-scheduled for delivery in one-hour blocks, many energy transactions are at the buyer's option. Therefore, the delivering utility's loads may be greatly affected by power requirements on the receiving party's system. For example, if regional temperatures drop, BPA's system load will increase as purchasing utilities' loads increase as their respective customers turn up their thermostats. Interchange loads also may rise, if utilities call on BPA to deliver energy under certain firm contracts. These energy transactions add significant uncertainty to forecasting the obligations of the hydro system.

The Project Operators

The Federal projects in the Pacific Northwest are owned and operated by the U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation. These two agencies also set requirements for the non-power uses at the projects. The Corps operates 12 of the 14 projects being studied in the System Operation Review and is responsible for flood control at all major reservoirs in the Columbia River Basin. The Corps also maintains navigation channels.

Reclamation operates Grand Coulee and Hungry Horse Dams, two of the storage projects under study in the System Operation Review. Reclamation also operates numerous water resource projects in the Columbia Basin that provide irrigation and various other uses, although these projects are not relevant to short-term power operations.

BPA markets the energy produced by the Federal dams and transmits the power to its wholesale power customers, primarily utilities and direct service industries. BPA schedules and dispatches power within the operating requirements set by the Corps and Reclamation. System operation requires continuous communication and coordination among the three agencies and with other utilities that own generation resources, purchase power, and are interconnected by transmission facilities.

The five non-Federal mid-Columbia dams downstream of Grand Coulee and Chief Joseph are owned and operated by publicly owned utilities (public utility districts or PUD's) in the area. The five mid-Columbia projects, Grand Coulee, and Chief Joseph are operated as a subsystem, based on an hourly coordination agreement reached between the mid-Columbia participants and the three Federal agencies.

Other utilities also own and operate dams and generating PUD projects whose operations are planned and coordinated with the Federal agencies. BC Hydro controls projects on the upper Columbia River in Canada that provide storage for flood control and power generation. Canadian projects contain over one-third of the storage on the Columbia River system.

Wells Dam

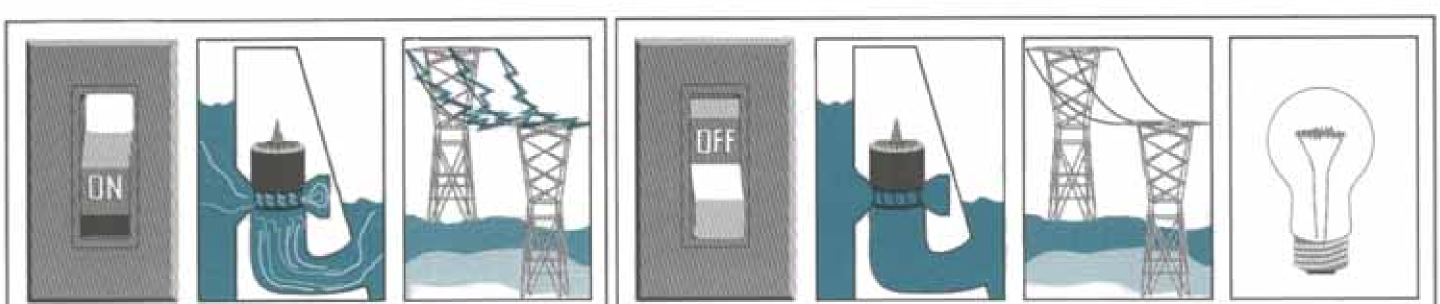
Rocky Reach Dam

Rock Island Dam

Wanapum Dam

These five dams lie on the mid-Columbia below Grand Coulee and Chief Joseph.

Priest Rapids Dam



When the switch is flipped to turn the light bulb off, the power stops flowing, the turbines stop turning, and the water is available for future use.

Chapter Two: Principles of Short-Term Operation

As explained earlier, weather causes significant variations in load demand. Variations in temperatures can make it difficult to match operations of each hydro project in the system with demand for power. Most of the Northwest's power demand peaks in the winter, when heating needs are greatest. At the same time, low temperatures can reduce snowmelt and freeze smaller streams, thus reducing streamflow for generation of power when it may be needed most to meet heating loads. Higher temperatures can increase streamflow by melting snowpack; the increased energy availability in the spring and summer often exceeds loads.

Precipitation can also make it harder to match generation with demand for power. Precipitation in the form of snow adds to snowpack and potential future energy production even as it causes loads to rise in the short run from the cold. Precipitation in the form of rain can add to streamflow and produce additional power. This is beneficial for future power supply if reservoir levels are not too high to store the water in excess of current power demands. If the increase in streamflows exceeds current power demands and there is no reservoir space in which to store the water, the generation is often sold as surplus at a relatively low price. If no market exists, water may be spilled.

Operation of the hydro system is also affected by the performance of thermal generating plants, such as coal and nuclear. Unplanned outages of thermal plants may require the hydro system or other thermal plants to make up the difference in generation. Planned thermal outages for maintenance occur primarily in the spring, because the high spring runoff and operations for fish produce higher levels of hydro generation (within other requirements; see below).

The following discussion explains generic short-term operation of the hydro system to meet power demand. First it is important to understand the difference between

Precipitation provides the fuel for the hydro system. Snowpack in British Columbia and in the upper Columbia River watershed provides spring and summer runoff, and rain adds to tributary flow. Depending on the weather for fuel can be risky.

run-of-river projects and storage projects. Then short-term operations are explained, first from the perspective of a single project, then considering multiple projects. *The Columbia River System: The Inside Story* and *A River at Work* provide an overview of operations in general. See also Appendix B.

Run of River vs. Storage Projects

As explained in detail in *The Inside Story*, the projects on the Columbia River and its tributaries fall into two major categories, storage and run-of-river. This distinction is less important in the context of hourly operations, because both types of projects store water for relatively short periods of time to control, or regulate, the river's natural flow patterns to conform more closely to hourly, daily, and weekly needs for power production and other short-term uses.

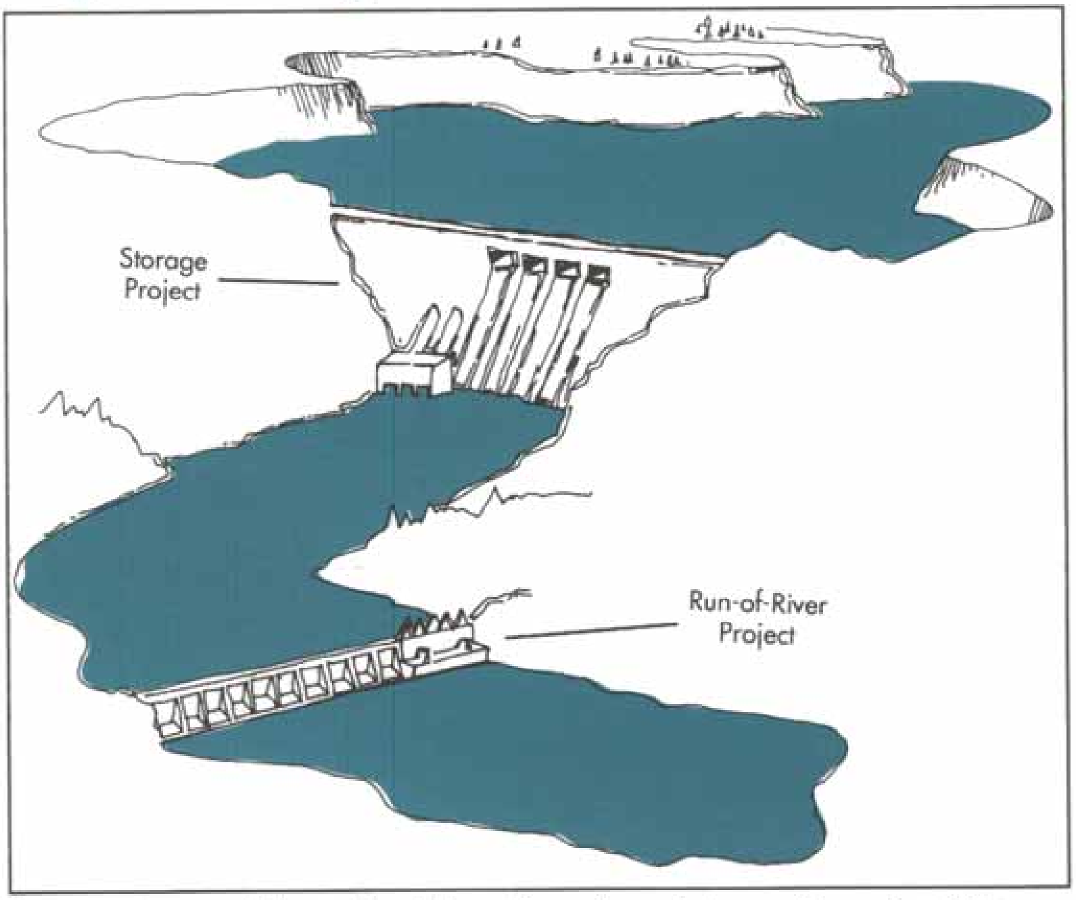
Storage projects have larger reservoir capacity than run-of-river projects. Normally storage projects are sited near the headwaters in a river system and have one or more run-of-river projects downstream of them. Storage reservoirs are used to store water seasonally, annually, and for multiple years. Very simply, runoff from snowmelt is stored in the spring and summer until it is needed in the fall and winter. Space is made available in reservoirs in the fall, winter, and early spring to hold runoff to prevent flooding.

The System Operation Review is studying 14 Federal hydro projects. The map on the next page shows these Federal dams along with most of the other major hydroelectric projects in the region. Five are storage dams — Libby, Hungry Horse, Albeni Falls, Grand Coulee, and Dworshak. All of the storage projects except Grand Coulee, which is on the mainstem Columbia, are on tributaries to the Columbia and Snake Rivers. Combined, they have extensive storage but smaller generation capacities than Grand Coulee and other projects on the Columbia and lower Snake Rivers.

At a pure run-of-river project, outflow is virtually the same as inflow. However, many run-of-river projects have a small amount of storage, called pondage. The lower Snake and Columbia River projects have 3 to 5 feet of pondage that provides hydraulic flexibility for hourly and weekly load factoring and may be used to provide sufficient water depth over rapids and other obstacles to permit barge navigation.

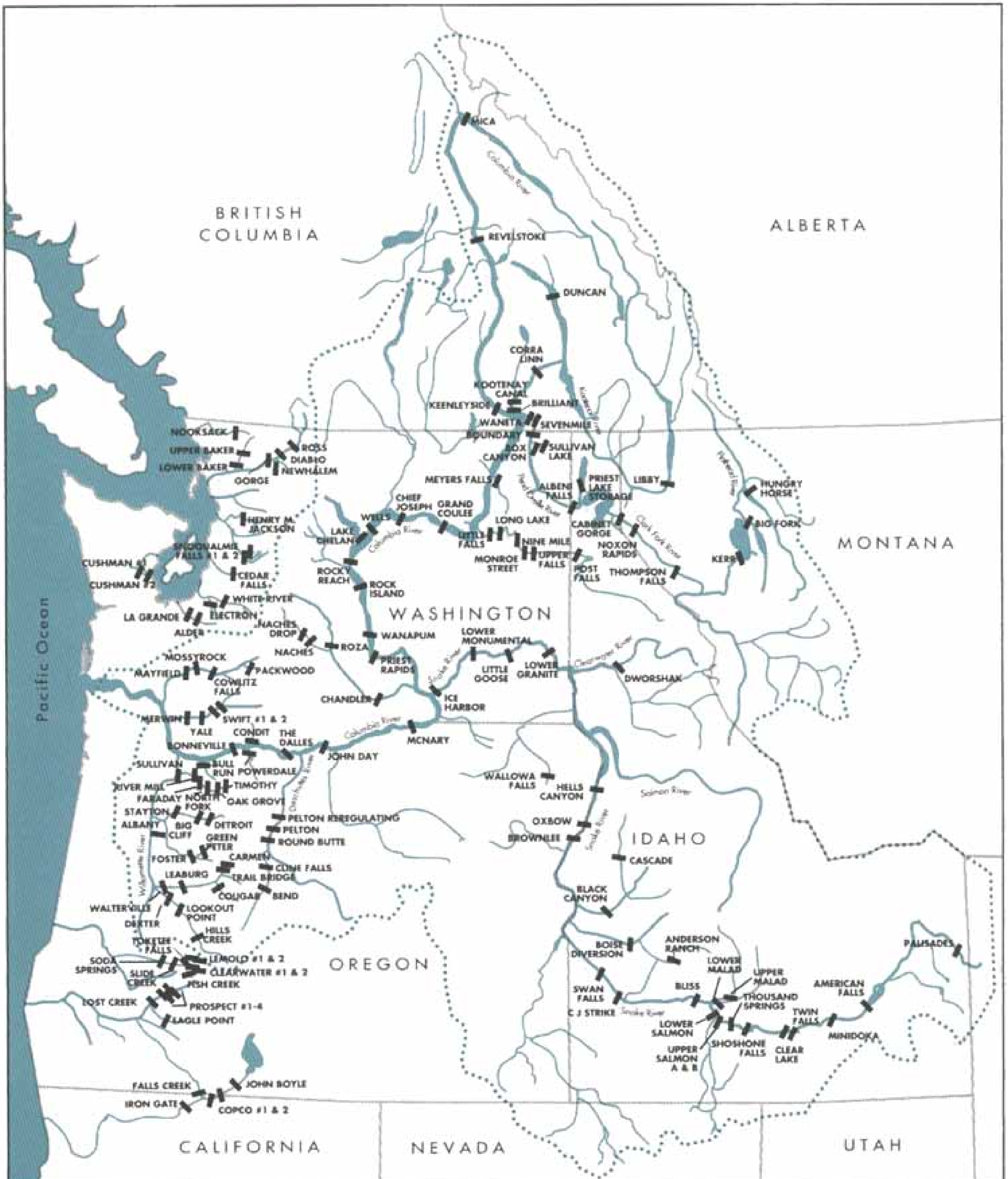
Nine of the projects in the System Operation Review are run-of-river projects. They are Chief Joseph, McNary, John Day, The Dalles, and Bonneville, on the Columbia River, and Lower Granite, Little Goose, Lower Monumental, and Ice Harbor, on the Snake River. They have large generating capacities and high average annual rates of discharge.

Diagram of Storage and ROR Dams/Reservoirs



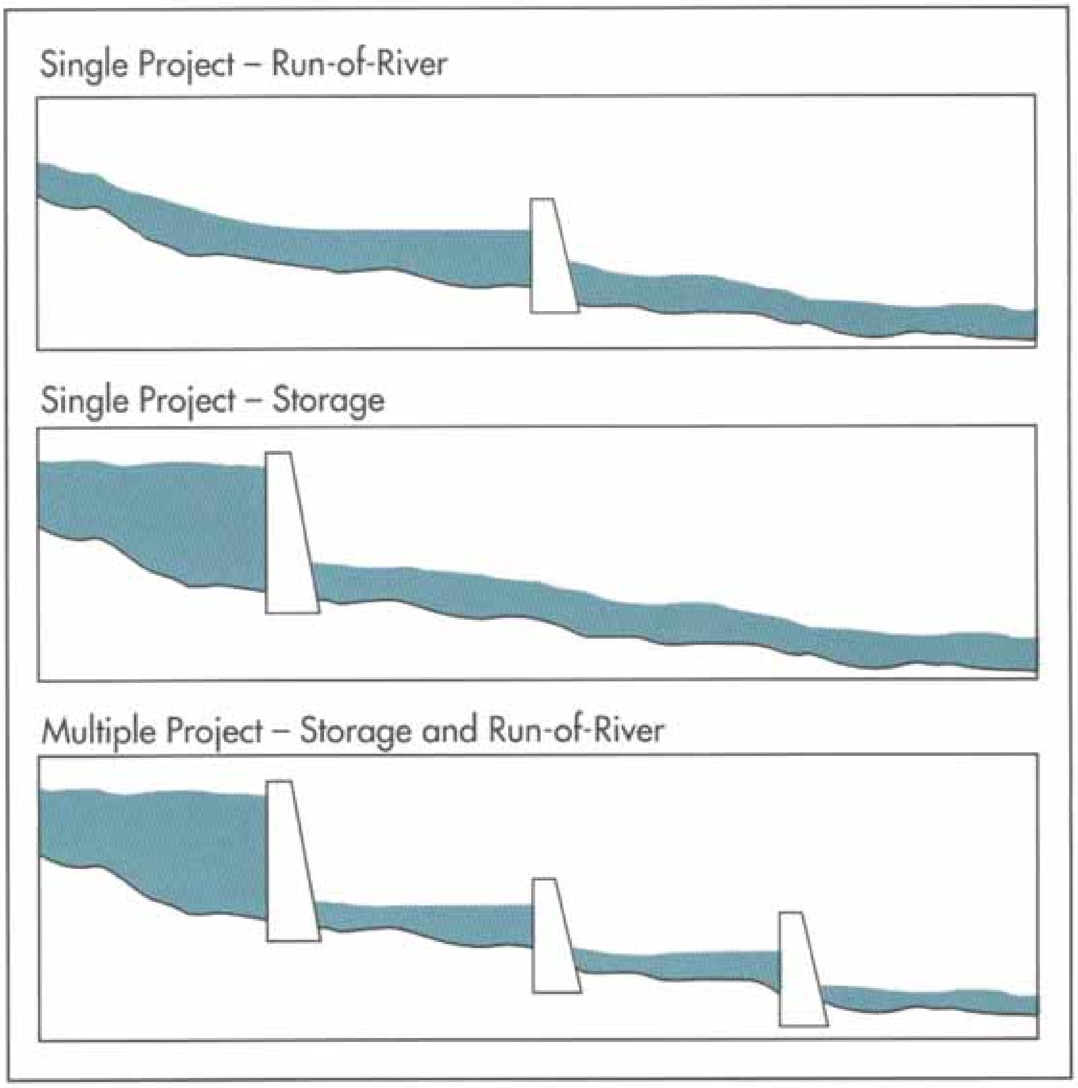
Storage projects may hold water from high runoff years for use in low runoff years. Run-of-river projects, on the other hand, draft and fill in a matter of hours or days.

Pacific Northwest Hydro Projects



All projects store and release water to regulate the rivers' natural flow patterns to conform more closely to hourly, daily, and weekly needs for electric power and the needs of other short-term uses. This map shows the major hydroelectric dams in the Pacific Northwest.

Single Versus Multiple Project Interactions



At a single run of river project, water must be used as it arrives and outflow pretty much equals inflow, because there is little or no storage. At a single storage project, flows may be shaped: water can be stored when demand for power is low and released when loads are higher. In a multiple-project subsystem, water may be stored and flows shaped to meet short- and long-term power needs and to serve other uses.

...A Single Project

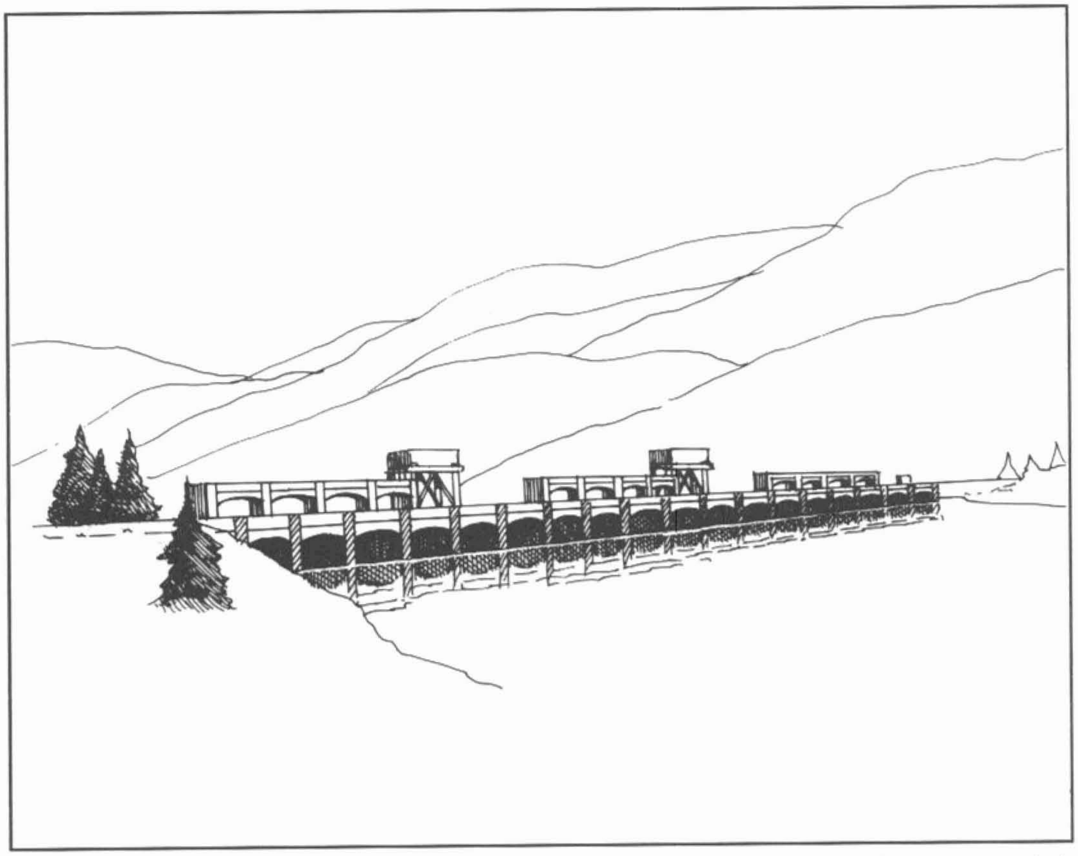
If the system consisted of only one run-of-river project, with no storage capability and no non-power requirements on operations, generation would follow water availability exactly. The project would generate more electricity in the spring and summer, when most of the runoff occurs, and generate less in the fall and winter, when the lowest flows occur. If upstream storage were available, natural inflows could be captured and released at later times and different rates to better the seasonal load patterns. However, at a pure run-of-river project, generation could not respond to seasonal, weekly, daily, or hourly load shape. Without at-site storage, project outflows for generation and any spill must equal project inflows.

The run-of-river projects in the Northwest do have some storage, called pondage. If there were no non-power requirements and pondage was sufficient to store the amount of water needed for a day's worth of power, generation and pondage levels would fluctuate with the minute-by-minute load demand. Assuming a constant inflow, each night while the load and thus generation were low, the reservoir would fill. In the morning, water would be released as generation increases to meet loads. Then tailwater would rise, and the reservoir elevation would drop. The outflows and generation would remain relatively high all day with the outflows exceeding the more constant inflow.

By evening, the reservoir level would be near its minimum level, and generation, outflow, and tailwater level would decrease in response to declining loads. The low reservoir would provide space to allow storage of the night's inflow. By morning, the reservoir would once again be at its high level and ready for the next day's load.

...Multiple Projects

With other major Federal and non-Federal projects, the projects being studied in the System Operation Review form three main subsystems: Dworshak and the four lower Snake river projects; Grand Coulee, Chief Joseph, and the five non-Federal mid-Columbia projects; and the four lower Columbia projects. Dams within each subsystem are

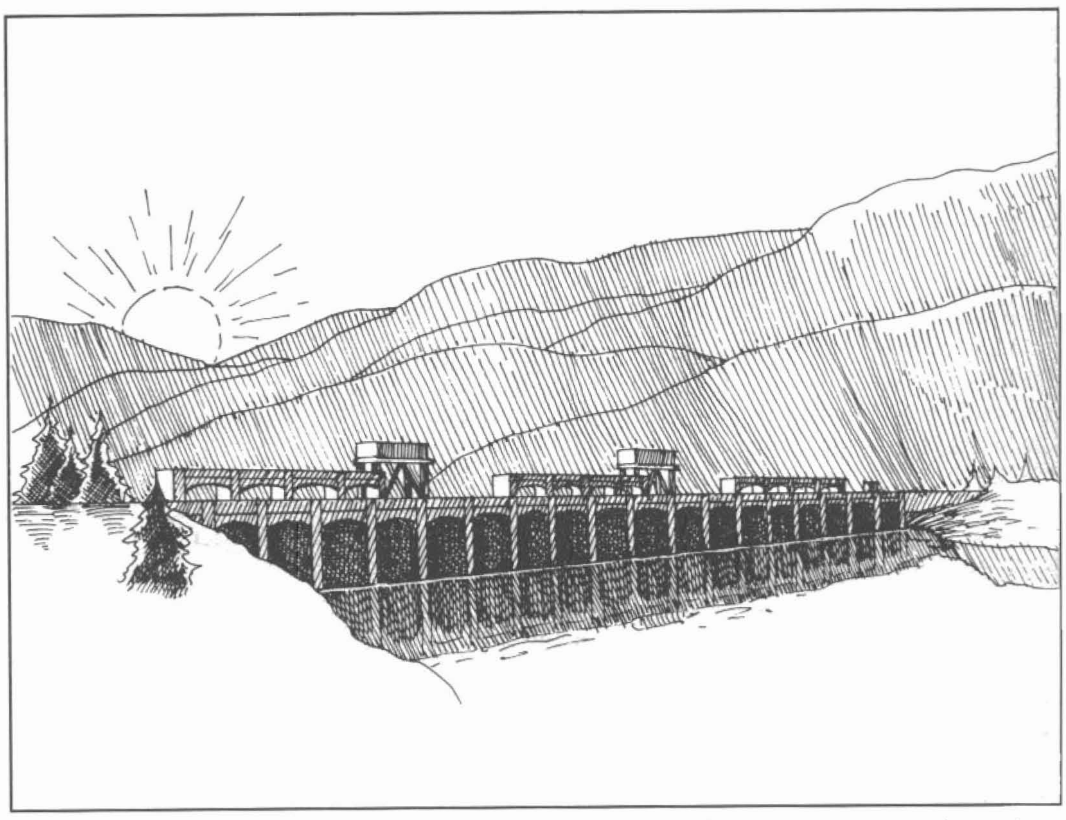


Morning: *At the beginning of the day, the reservoir is full and poised to generate the energy needed to meet the day's need for power.*

linked hydraulically — water released from an upstream dam soon becomes inflow at the next downstream dam.

Within a subsystem, the uppermost or "headwater" project is used to prime the system. That is, the headwater projects generally are run at a high and sustained level during the day to produce energy to meet loads and release water to be used by projects downstream.

The intermediate projects in a subsystem match their generating pattern to loads as much as possible, using their storage and inflow shaped by the headwater project. The lowermost project in a subsystem may reregulate flows to meet downstream open river fluctuation criteria. That is, the reregulating dam's reservoir stores some of the inflow during the daytime and



Evening: *After a day of generation, the reservoir is depleted and ready to store water during the night to be ready to meet the next day's needs for power.*

releases water at night to maintain a relatively steady flow downstream. Steady flows are especially important in open river reaches such as the Hanford reach below Priest Rapids Dam and the Columbia below Bonneville Dam, which are heavily used by campers, anglers, and boaters.

Where the dams are relatively close together, the time it takes water released at one dam to appear as an increase in reservoir elevation at the next project downstream is usually only one or two hours. For example, if water is released to generate power to meet daytime loads, the inflow to the next dam downstream can also be used to generate to meet that day's loads rather than being stored for the next day.

Water releases are monitored to assure that they can be stored or used to generate at the downstream projects, with the goal of avoiding spill, except when needed for juvenile fish passage. A project downstream may be "mismatched" in generating capacity with the dams upstream that supply it with water. For example, because it has a smaller generating capacity than the three projects upstream of it, Ice Harbor Dam can pass less water than the other lower Snake projects. Ice Harbor's reservoir is frequently low in the early morning hours so it can store the volume of water coming down from the three larger projects upstream.

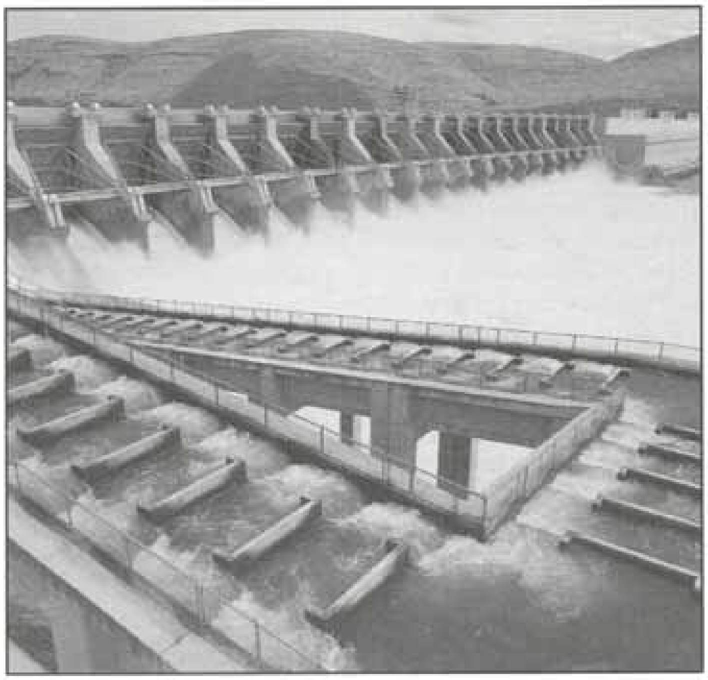
If the upstream project is many hours away from the downstream project(s), its outflow may not arrive at the next project in time to help meet the demand for power production. That is, water released to generate power to meet midday loads at an upstream project (such as Libby, Hungry Horse, Albeni Falls, or Dworshak) may not reach the downstream project until nighttime. At night power loads are light, so the water would be stored until needed, such as for the next daily peak.

Non-Power River Uses

Non-power uses are met by establishing elevation or flow requirements on the operation of the hydro system, often limiting generation and the ability to shape generation to load. On occasion these requirements can result in production of nonfirm energy during light load hours and limit ability to meet peak loads in heavy load hours. Non-power operating requirements can be permanent, seasonal, or for only a few weeks, days, or hours.

Recreation is a major use of the reservoirs in the Columbia Basin. Recreational opportunities include boating, fishing, swimming, camping, sightseeing, and wind surfing. Recreational users like the reservoirs to remain as high as possible, especially from Memorial Day weekend to Labor Day weekend. It also is desirable to keep water levels high and stable to maintain aesthetics and avoid jeopardizing public safety. Operations may be changed within other requirements, such as using McNary for the regatta and Bonneville for the trash cleanup mentioned in the news articles.

Recreation is one of several non-power uses of the river that must be accommodated while meeting short-term power needs. Boaters, anglers, and campers prefer to have the water level high and stable for their activities.

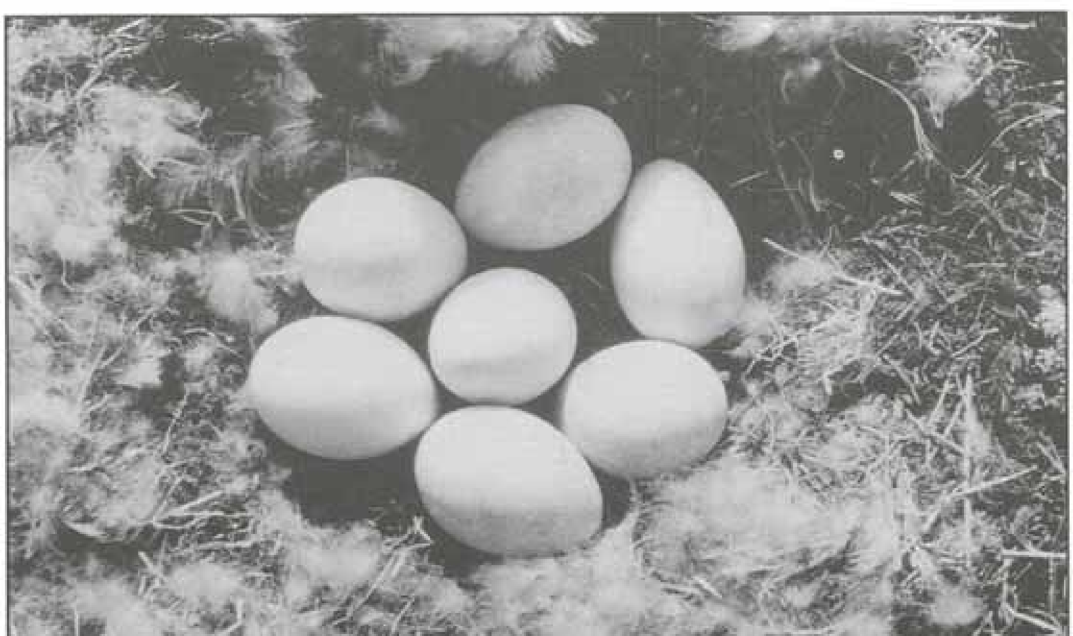


Short-term operations can affect the migration of adult anadromous fish. Adult fish, travelling mostly in the daytime when power generation is highest, can be confused in their search for fish ladders by eddying water below turbines.

Anadromous fish use the Columbia River and tributaries for spawning and migrating to and from their spawning sites. Short-term operations must consider the timing and patterns of spawning and migration to assist these activities and to maintain fish habitat. For example, water levels should remain high enough to make spawning gravels accessible when needed, and once eggs are laid, water levels must remain high enough so redds (nests) are not exposed. During migration periods, higher discharges are maintained at some projects while other projects are operated within a narrow pool range near minimum pool to assist fish migration. Spill is a major component of short-term operations for fish, as described in the news articles on the fish flush. Also, as mentioned in the news articles on the fish flush, turbines may be required to operate at the top of their efficiency range to allow the safest possible passage for fish through the turbines.

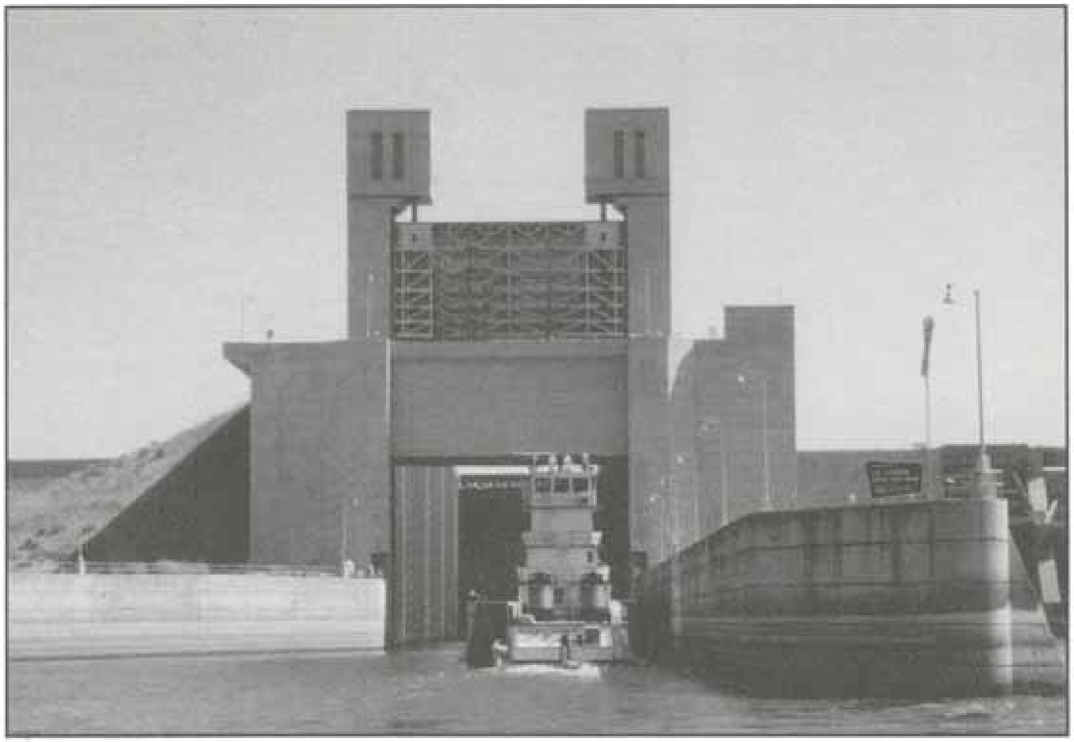
Resident fish, unlike anadromous fish, do not migrate to the ocean. They spawn in the reservoirs and tributaries where they live, and water levels must be monitored to assure that spawning and feeding habitat is available when needed.

Wildlife species live throughout the Basin, often concentrating around water sources such as the Federal project reservoirs. One major concern for short-term operations is nesting areas for geese, as mentioned in the news articles on the fish flush. During the spring nesting season, water levels are kept high enough at McNary and John Day so that geese do not nest in areas that may be inundated later. The reservoir at Chief Joseph is kept high to prevent access to nests by predators. McNary and John Day also operate near the upper elevation of the operating range at times in the winter to facilitate access by waterfowl hunters.



Short-term operations are managed to protect nests, which can be flooded if water is too high or found by predators if low water exposes land bridges.

Navigation has always been important to the region for transport of goods between seaports and inland ports. The system of locks and reservoirs at the Federal projects has made navigation up the Columbia and Snake Rivers possible at all times of year. System operations that maintain reservoir levels between normal minimum and maximum points are necessary to provide adequate navigation depths. Occasionally, operations for power may be changed to accommodate shipping, as described in the news article on the cold spell. Navigation companies are notified of operational changes to avoid disrupting their business.



Produce and manufactured products are shipped to seaports and into the interior by barge. Barges depend on sufficient channel depth and occasionally run aground due to shifting sediment or low water levels. Short-term operations can release water to temporarily raise the river level to refloat stranded barges.

Irrigation has allowed the Pacific Northwest to develop one of its top industries, agriculture. Water storage and releases for irrigation affect tributaries, such as the Snake River above Brownlee Dam, more than the mainstem Columbia, which carries more water. Diversions for irrigation generally are not affected by short-term operation except that reservoir levels must not drop below pump intakes, as they may affect a diversion dam or intake to a canal.

Water quality includes operational concerns about and requirements regarding water temperature and dissolved gas levels. Streamflows from reservoir projects can be adjusted to help maintain water quality requirements. Minimum outflow requirements for each project, which may be seasonal, are based on downstream conditions. Short-term operations may be required to improve conditions occurring downstream.

Municipal water supply is a relatively minor use of the Columbia River system. A few cities and industries are supplied by diversion, but these diversions have little effect on short-term system operation as long as pump intakes function within the normal fluctuation range of the reservoir, as mentioned above.

Flood control often has priority over a project's other uses. If there is a flood situation, a storage project may at first increase its outflow to pass the excess inflow and maintain flood control space. If the flows keep rising, the project may need to reduce outflow and store the inflow to prevent flooding downstream. As the flows downstream recede from flood levels, the reservoir will start releasing water to empty its flood control space.

Storage projects, excluding Grand Coulee and Dworshak, generally are operated at minimum discharge in the spring and summer for refill purposes. Streamflows that are uncontrollable at the mid-Columbia and lower Columbia projects, plus releases from Grand Coulee and Dworshak for fish, provide enough or more than enough water to meet load requirements. In extreme runoff conditions, John Day and some of the mid-Columbia projects may be drawn down to provide additional flood control storage.

Chapter Three: Short-Term Operating Requirements

Virtually all short-term operating requirements are designed to provide for non-power river uses. Almost all operating requirements are defined in terms of river flow or water surface elevation. Operating requirements for project flows include minimum and maximum instantaneous discharge, minimum and maximum daily discharge, and maximum hourly and daily rates of change. Operating requirements for reservoir elevations include minimum and maximum reservoir (forebay) levels, downstream water surface (tailwater) elevations, and maximum hourly and daily rates of change.

Operating requirements can be either site-specific or systemwide. Most are site-specific, meaning they apply to only one project or one location on the river. Systemwide requirements such as the Water Budget can affect project operations throughout the U.S. portion of the Columbia Basin. Depending on objectives, requirements can be set to avoid going above or below a certain outflow or above or below a certain storage elevation. They fall along a continuum from "hard" to "soft." The hardest are not to be violated. Softer requirements are those that may be relaxed under certain conditions, although violations are minimized.

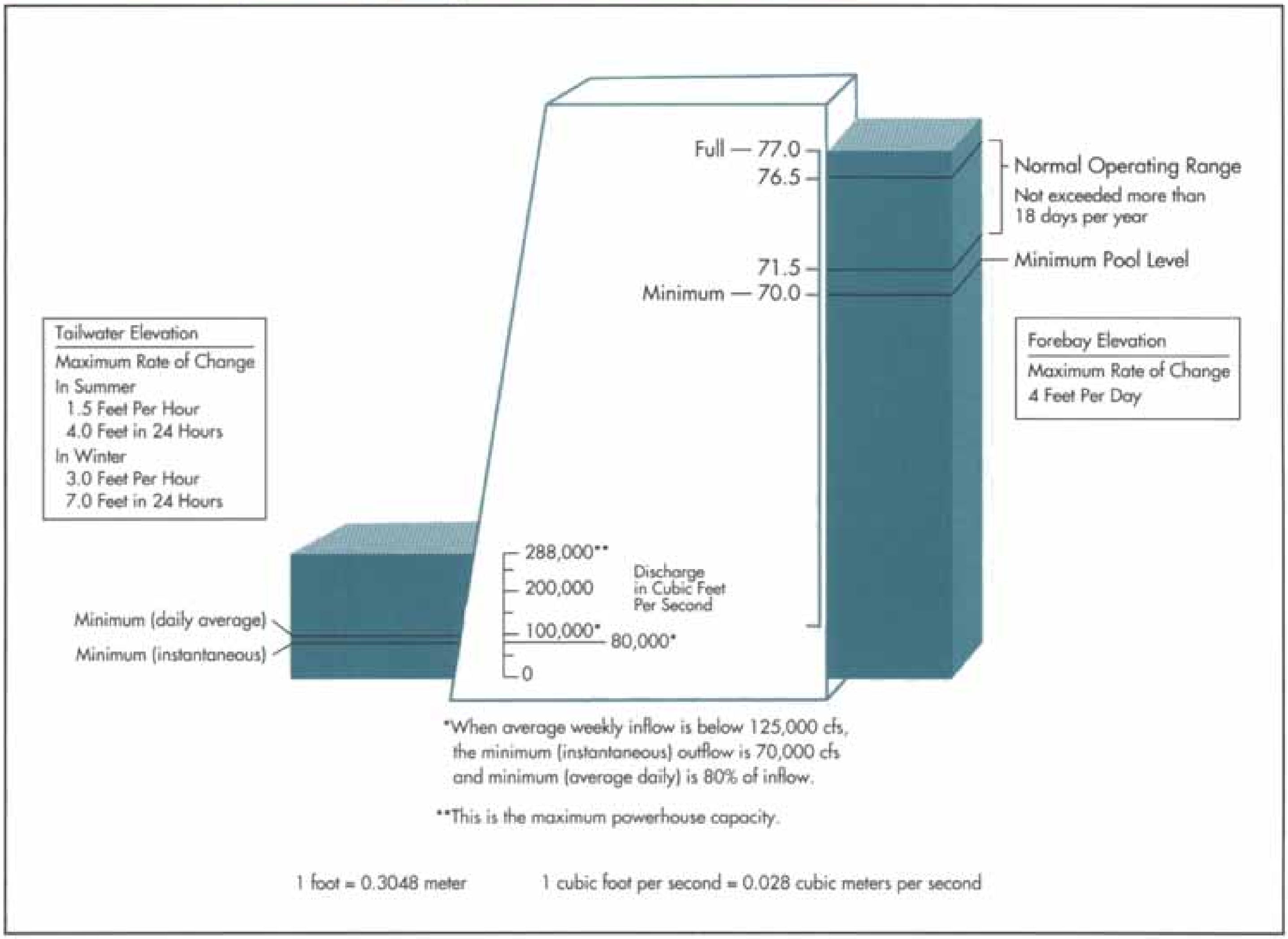
Flow requirements that specify instantaneous and daily minimum or maximum discharges are used to maintain river flows below the dam for fisheries and other uses. Several examples of operations using flow requirements appear in the news articles on the fish flow operation. Short-term outflow limits are used for such needs as flow enhancement for fisheries, lowering a stretch of river for redd (fish nest) counts, providing optimum conditions for a windsurfing contest or rowing regatta, or reducing current immediately below a dam to make upstream passage easier for barges. Longer-term outflow limits are likely to be used to permit flood control, to provide flows for fish, to enhance fishing conditions, or to maintain stable conditions downstream for recreation.

Hourly and daily maximum rates of change are primarily for the safety and convenience of boaters, the shipping industry, and anglers and other persons using the river. Sudden increases in flows can be especially hazardous. Limiting rates of change also helps reduce bank erosion.

Elevation requirements place limits on the water levels on the upstream (forebay) or downstream (tailwater) side of a dam and the rate of change of such levels. All projects have maximum and minimum forebay limits. These limits are normally permanent and are considered hard. Some

Maximum and minimum elevation levels and rates of change of these levels are common short-term operating requirements.

Short-Term Operating Requirements at Bonneville



Most projects have a combination of forebay elevation and tailwater requirements that define how fast the project can respond to power demand and other water uses, such as these requirements at Bonneville Dam.

projects also have a normal operating range within the maximum and minimum forebay limits, which can be exceeded on a limited basis to meet other non-power requirements or power needs. For example, Bonneville Dam has a forebay range of 21-23 meters (70.0 to 77.0 feet) and a normal operating range of 22-23 meters (71.5 to 76.5 feet).

The normal operating range may be exceeded for short periods if the project operator determines that no problems will be caused by doing so. Within the operating range there may be a soft requirement, for example to operate above a certain elevation on summer weekends as much as possible for recreation. This soft requirement could be violated if necessary.

Forebay requirements can also vary over time. The reservoir elevation can be kept low to maintain flood control space, or as full and stable as possible for navigation, recreation, and irrigation. As explained in the news article on the fish flush, at McNary and John Day minimum forebay elevations assure that waterfowl do not nest below the normal maximum reservoir level. Operators raise the reservoir near the maximum limit every three days during nesting season. Later, high forebay limits are used to prevent land bridges from forming that would allow predators to reach waterfowl nests on islands. During the fall and winter, other high elevations may be required to provide hunters access to waterfowl areas.

Short-term forebay requirements also are used to provide special conditions for construction, recreation, tree planting, flotation of grounded vessels, fishery activities, and ease of navigation. Tailwater elevation limits often are used for such activities as construction work, recreation, and navigation.

The other type of forebay elevation requirement limits rate of change, which is the rate at which the water level in a reservoir may be changed. Usually only drafting is a concern. At Grand Coulee, for example, there is a draft limit of 46 centimeters (1.5 feet) per day to allow the shoreline to drain so that the saturated banks do not slough off into the reservoir. As reported in the news article on the cold spell, a specified exceedence of the draft limit at Grand Coulee was permitted for a limited time to allow higher generation levels.

Other Factors That Influence Short-Term Operations

Operating requirements, addressed above, are the result of decisions reached to achieve various goals. This section, in contrast, addresses requirements that generally are otherwise imposed.

Physical requirements result from the natural and constructed environment at each project. The maximum pool elevation is determined by the height and design of the dam and by the reservoir level needed to protect or serve features around the reservoir. The minimum pool elevation may be set to provide water levels within the design limits of powerhouse units.

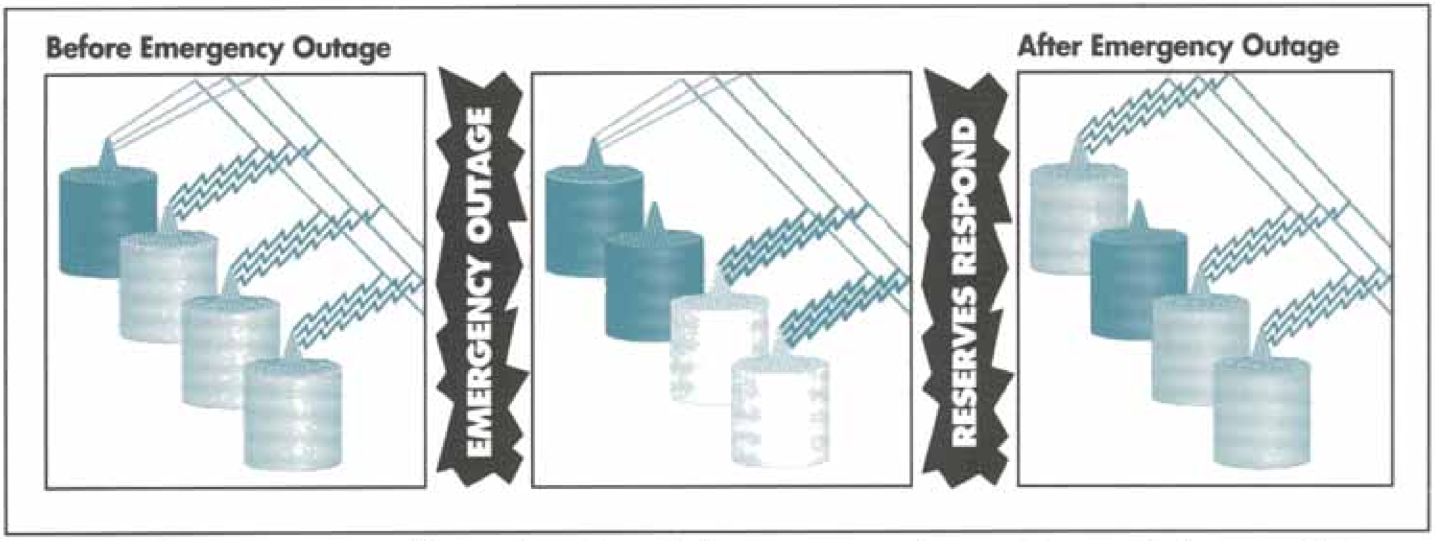
The rate of inflow and amount of water a reservoir can be expected to draft determine the amount of power that can be generated in the short run. The hydraulic and electrical capacities of the powerplant also affect short-term operations. Turbines and spill gates have a maximum release rate. Maximum generation levels are designed to prevent overheating and damage of generators and related electrical equipment. There are certain generation levels at which generators and turbines cannot operate, due to vibration or possible turbine damage. There are also certain levels at which facilities operate most efficiently. In the news articles on the fish flow operation, for example, all projects operated turbine units within one percent of peak turbine efficiency for fish passage.

Other, rare generation limitations can occur upstream or downstream of a project. For instance, ice may build up in the powerhouse trash racks and reduce the level at which the turbines can run, reducing power production. Or river ice downstream of a reservoir may break up, pile up on a bridge or other barrier, and act as a dam, threatening to flood the surrounding area if water were released from the reservoir. Limitations such as these can require the other projects on the system to generate more to compensate.

At Grand Coulee, the river bank is prone to collapse into the river. The Bureau of Reclamation has set a maximum draft limit that allows the bank to drain, reducing the possibility of sloughing.

Traveling the Fine Line

Ignoring short-term operating requirements can have many consequences. Operators are constantly monitoring how well power supply matches demand and trying to meet other system requirements as well.



During normal circumstances, some turbines are kept at the ready for emergency use. If a generator goes out of service suddenly, spinning reserves are called into action to quickly meet the load the failed generator was carrying.

Load-following operations are the key to meeting peak power loads. Through the hours of each day, loads can rise and fall gradually or instantaneously, or remain at a high or low level. A utility's obligation to serve load requires constant adjustments to generation according to the total load placed upon it by all of its customers. Projects are "load factored" to meet the basic shape of daily load. Intra-hour changes to respond to actual loads that vary from those scheduled may be several hundred megawatts or more, depending on the size of the utility and the makeup of its customers.

Each major utility also is responsible for maintaining the frequency of electricity at 60 cycles per second in its load control area, which is the area the utility serves. If not enough energy is being produced to meet the demand for electricity, the frequency will fall below 60 cycles per second; if there is too much generation, the frequency will rise above 60. The frequency must be maintained in a narrow range to prevent damage to consumers' electrical equipment and to the generators themselves.

Intra-hourly fluctuations on the Federal system normally are handled by the "controller" plants. These projects automatically adjust minute by minute to match the generation to the load within an hour. BPA usually uses a combination of Grand Coulee, Chief Joseph, McNary, John Day, and The Dalles for control. These projects are used because they are large and have many units, and depending on the time of year, have sufficient flexibility to follow load.

A change of generation is usually spread among several projects to minimize the impact on operating requirements. This reduces large fluctuations in generation or discharges at any one project. Using projects that are hydraulically linked, such as John Day and The Dalles, allows efficient load following with minimum forebay fluctuation. The water released from the upstream project can be used soon after to generate additional power at the next dam downstream.

The various projects in the Northwest hydro system have different sizes and numbers of generator units. The head, or height of water level above the turbines, also varies from project to project. Hence, different projects can produce different amounts of energy from the same amount of water, depending on the vertical distance of "fall" of such water into the turbine blades that turn the generators. A project with multiple generator units can adjust to load levels by bringing units on line as needed to maintain efficient loading on each unit. The system as a whole must keep generation capability in reserve (see below). Multiple unit projects permit this practice.

Hydro-thermal system operation, depending on availability of water and fuel supply, can meet loads more efficiently than a purely hydro or purely thermal system could. Hydroelectric projects, especially those with multiple units, can quickly produce more or less electricity as loads increase and decrease, simply by releasing more or less water through the turbines. Large thermal plants, such as coal and nuclear, cannot adjust to load changes as rapidly or efficiently by design: they generally generate at full capacity around the clock to meet "baseload" demands.

Utilities in the Pacific Northwest market power produced by the hydrothermal system to several types of customers. They also may transfer blocks of energy to one another, by pre-schedule or on demand, depending on arrangement. In BPA's case, it serves large direct-service industries and provides power to other industries through utilities. It also sells power to utilities that serve residential customers. BPA also provides and takes delivery of interchange energy to and from other utilities.

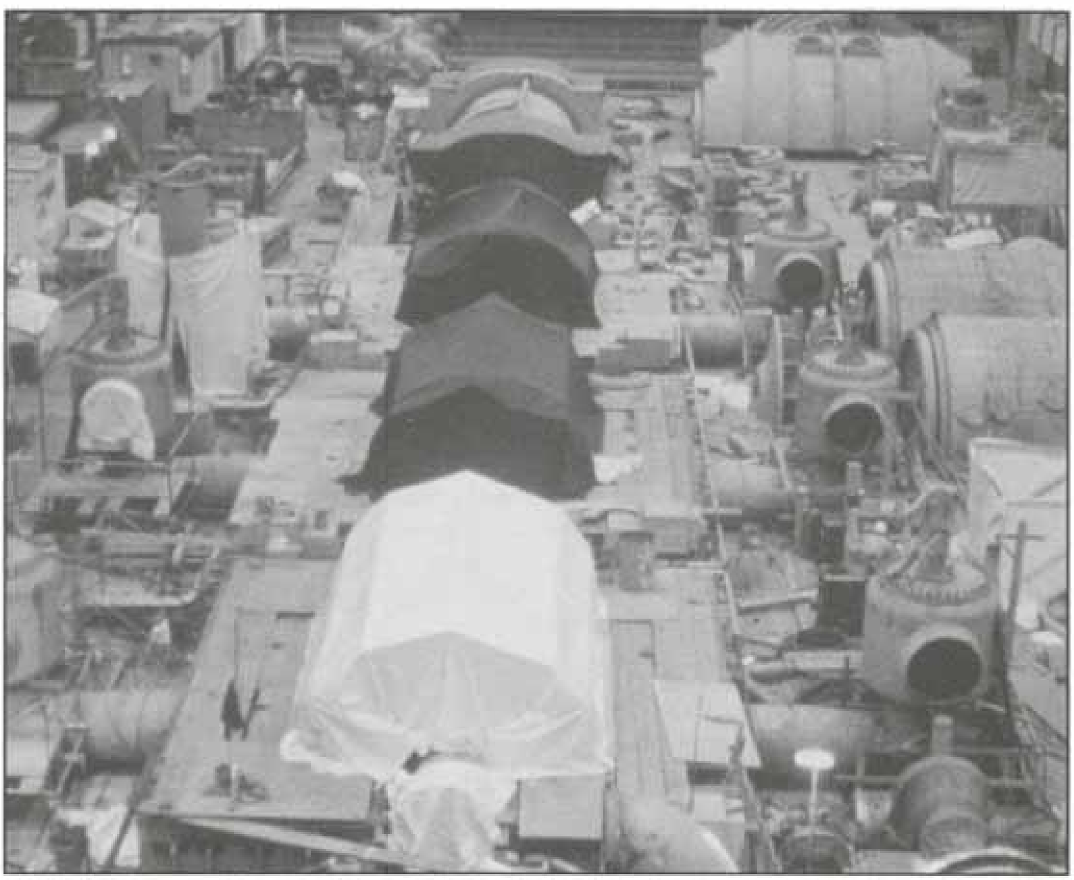
System reserves are needed to cover emergency conditions, such as the loss of a large thermal unit or a sudden increase in loads. A certain amount of reserve capacity is required and is maintained by not using some available units for routine generation needs, leaving them free for use during outages. Spinning reserves are provided by units in service that are able to increase generation immediately. Other reserves must be available to produce energy within 10 minutes.

Generator outages may be scheduled or forced (unplanned).

Some scheduled outages are planned months in advance for reasons such as annual maintenance, testing, modifications, and transformer work. Most scheduled maintenance, however, consists of outages that are set up a day, or even a few hours, in advance and last a few hours to a few days. These outages are normally for minor maintenance, repairs, or adjustment and can usually be deferred for a few days if necessary.

Forced outages occur when the project operator takes a unit out of service to prevent damage to the generator or related equipment. Or a protective relay may automatically shut a generator down to prevent significant damage to that generator or to other parts of the power system. Forced outages, especially if due to damage, can be long term, with units being unavailable for several weeks to a year or more.

Transmission of power from the project's switchyard to the customers generally is not a limiting factor for generation. In the Pacific Northwest, however, power is generated by projects located east of the Cascade mountains, while the larger load centers are on the west side. Thus power transmission can be a problem at times of system stress. Temperature extremes and wind can cause equipment overload, failure, and damage. The



Planned outages for maintenance, repair, or testing are scheduled to occur when substitute generation is available, such as during the spring when water for hydropower is plentiful.

Can You Tell the Difference Among These Pictures? (answer below)

Answer: *The first photo is of spilling to provide water to move juvenile fish downstream. The second photo is during forced spill, when the amount of flow exceeded turbine capacity. The third photo is during overgeneration spill, when water was available and turbine capacity was available, but there was no market for the power that could have been generated. The photos all look the same, because spill is always the passage of water past the dam without generation of power.*

result can be voltage instability or interruption of service.

Solutions to transmission problems include cooperation with other utilities to serve load, shedding of direct-service industrial customer load, additional power purchases, and shifting of Federal system generation from one project to another.

Voltage instability (primarily low voltage, which can damage consumer equipment) is a concern during heavy transmission of power east to west across the Cascade mountains as load centers west of the Cascades are placing heavy load demands on the power system. The risk is especially high in the Puget Sound area.

The Northwest Power Pool has procedures that specify steps to take at several levels of risk. Under more severe conditions such as the cold spell described in the news articles, repositioning of Columbia River generation may occur when possible to relieve transmission line loadings. That is, generation may be increased for a time at the lower Columbia and Snake River projects (within existing limits, such as water availability) and decreased at the upper Columbia River projects. In addition, operation of combustion turbines in the Puget Sound area may be increased.

BPA and other utilities buy, sell, and exchange power with other utilities using the Interties, the large transmission lines that connect the Pacific Northwest with other regions. Insufficient Intertie availability due to lines being filled up or out of service can reduce options for meeting loads economically. Incremental purchases and generation become increasingly expensive as more are needed.

Spill is the passage of water at a dam without generation of power. Controlled spill occurs when necessary to assist fish migration. One type of requirement is to spill a certain number of thousand cubic feet (or cubic meters) per second for a specified number of hours. Another type is to spill a fixed percentage of the hourly flow for a number of hours. Spill also may occur as part of local or systemwide flood control operations.

Each dam has a number of spill gates, and opening different gates by different amounts can produce different patterns of spill with the same total amount of spill. As described in the news articles on the fish flush, there are spill patterns used for moving juvenile fish away from turbines and other patterns for moving adult fish upstream. Grand Coulee also spills small amounts of water in the summer as a tourist attraction.

A requirement not to spill may be due to construction downstream or at the dam itself. At some projects, spill is avoided to maximize the number of smolts entering the juvenile bypass system so they can be collected for transportation downstream by barge or truck.

Uncontrolled spill occurs when there is no choice. Uncontrolled spill may be forced spill, which occurs when the outflow exceeds turbine capacity with all available units running full load. Forced spill occurs at a specific project, in quantities determined by the amount of flow in excess of turbine capacity, and cannot be shifted to another location.

Another type of uncontrolled spill is overgeneration spill, which occurs when there is water available and generators that could be run but there is no market for the energy. Minimum discharge requirements, flood control requirements, full reservoirs, and runoff at downstream run-of-river projects may already be causing overgeneration, and thus the water must be spilled.

Unless there is some non-power requirement in effect, the extra water can be spilled anywhere on the system. It may be possible to spill at projects where extra spill can help migrating steelhead and salmon smolts. Spill may be shifted from one project to another so spill occurs at a location where less nitrogen supersaturation occurs. Spill may be shifted off the Columbia system entirely, through energy schedules with other Northwest utilities, to reduce nitrogen supersaturation.

Overgeneration spill usually occurs during the spring, when runoff and snowmelt flows are high. It is more likely to occur during light load periods.

Serving electrical loads in the Pacific Northwest is frequently complicated by having most of the generation capability east of the Cascade Mountain Range while major load centers are west of this range. Transmission system overload and voltage instability are just two concerns engineers and operators worry about.

Chapter Four: Planning Actual Operation

System planning and scheduling are the comprehensive thinking and preparations that guide dispatching and actual operations. Data regarding expected weather, streamflows, system loads, and generation and transmission availability are collected from various sources, such as Reclamation, the Corps, BPA forecasts, maintenance schedules from respective project operators, the National Weather Service forecasts, and Northwest Power Pool input.

The primary task of power system operations is to match the supply of power, or generation, with demand for power, or loads. Load must be met, the desired frequency must be maintained, and sufficient reserves must be available to assure reliability. In the Northwest, where utilities are interconnected, intertie loadings must be monitored the same as intra-system activity. At the same time, as explained earlier, non-power uses of the rivers must be considered and reflected in hydrosystem operations.

BPA's coordination, planning, and implementation of short-term operations is done at its Dittmer Control Center in Vancouver, Washington. The Corps' coordinated planning for short-term operation is handled by their Reservoir Control Center in Portland, Oregon. Reclamation's coordinated planning for short-term operation is handled by their Water Resources and Operations Branch in Boise, Idaho.

Modern, state-of-the-art communication technology is used to coordinate short-term system operations and to pass critical data among projects, substations, and operators.

BPA's planning for short-term operation starts with the running of a computer simulation of the next 90 days of operation, in weekly increments. This simulation is used to determine how to make use of the water stored in the upstream reservoirs for power.

Every week, Northwest utilities independently perform computer studies to "look ahead" at the next 30 days' resource capabilities and expected requirements. BPA's study uses actual and planned generator outages and predicted loads, weather, and streamflows for the first few days and then trends to the expected values thereafter. The process is to simulate the first few days hourly, the next few days in 8-hour periods, then a one-week period and a two-week period.

The output is examined and adjustments are made to allow the system to meet load within the requirements that are placed upon it. If it is not possible to meet load over the next week or so, the power schedulers start to make arrangements to resolve the shortage. The measures taken normally include some or all of the following: purchasing or selling energy; adjusting energy schedules with other utilities; rescheduling or canceling generator outages; adjusting the generation schedules of the upstream projects; curtailing industrial loads; and contacting the project operators to modify or lift one or more of the "soft" non-power requirements.

Hourly schedules of energy and capacity are coordinated between the utilities in the Northwest, Canada, and California. Each day the utilities in the Northwest estimate their hourly energy loads for the next few days and determine the energy needed to meet these loads. The required energy deliveries to and from other utilities are determined and scheduled in hourly blocks. BPA is the largest Northwest power marketer and owns the main transmission grid, and normally has several hundred active schedules each day. Energy is transferred to and from most Northwest and California utilities under a variety of contracts. Once all of the schedules for the next day have been completed, they are verified to assure that they are within contractual limits, transmission line capacities, and other power system requirements.

At Sylmar Substation, outside Los Angeles, California, power from the Northwest is often delivered to serve peak summer loads in the Southwest. During high Northwest load periods, power is delivered to Southwest utilities. This substation forms one end of the direct current (DC) intertie transmission link between the two regions.

In BPA's case, another short-term computer run is made late in the day to project the next day's hourly operation. This run provides the next day's estimated hourly energy requirements from the Federal hydrosystem and a listing of unit outages, non-power requirements, and other relevant data. These estimates guide plans for meeting all requirements for the upcoming day. Plans may include such things as providing space by midnight to store water in run-of-river reservoirs such as Lower Granite and McNary. Sufficient water also must be available by 7 a.m. at system reservoirs to meet the morning peaks and the energy requirements for the day.

If there is insufficient load in the light load hours corresponding to generation from minimum flows, the scheduler will find additional load, if possible, or arrange for spill. This overgeneration spill may occur at the Federal projects or be transferred elsewhere, depending on the time of year and needs of fish.

If it appears that load will exceed power available in the daytime, the scheduler will take steps to reduce the deficit by cutting nonfirm sales or acquiring energy from storage accounts or by making purchases. The scheduler may consider canceling generator outages and finding other means to assure that all possible generators would be available to meet the morning peak.

Each hour as the new day progresses, the scheduler experiences deviations from the predicted Federal system load, receives requests for changes in scheduled energy from the other utilities, and initiates changes as necessary. The scheduler enters all of these changes into the computer, usually by 20 minutes to the hour, and uses this information to work up a "basepoint." The basepoint specifies the generation levels to which Grand Coulee and each of the major Federal run-of-river dams will operate for the upcoming hour.

In determining the basepoint, the scheduler must keep in mind what operation is projected for the rest of the day, requirements to maintain a smooth hydro operation, and flexibility of the system to respond to unexpected contingencies.

Once the scheduler is satisfied with the basepoint, it is sent to the generation dispatcher, who implements it. Automated allocation of

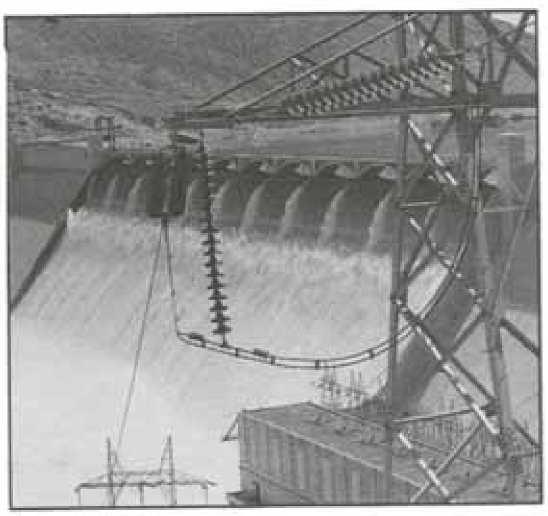
The Cycle of Operations

Collect Data

- *Weather forecasts, including precipitation, temperature, and wind*
- *Forecast streamflows and loads*
- *Determine non-power requirements and maintenance objectives*

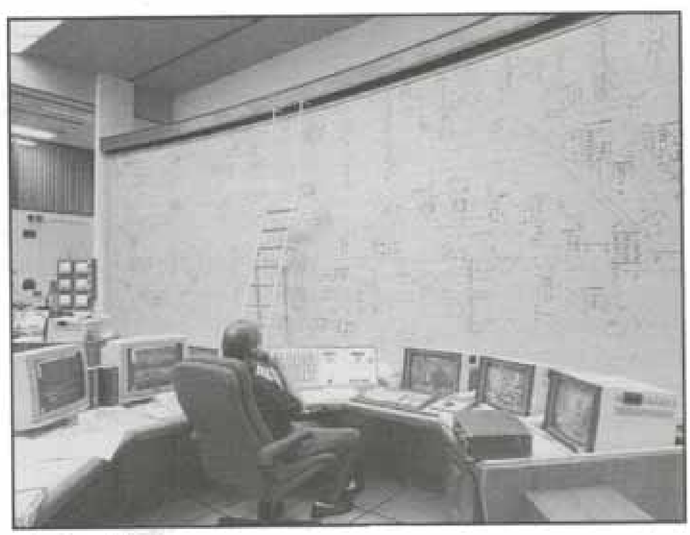
Three Locations

- *Corp's Reservoir Control Center monitors water resource conditions and schedules project operations*
- *Reclamation's Water Resources and Operations Branch monitors and directs project operations*
- *BPA's Dittmer Control Center (shown here) preschedules, schedules, and dispatches system power*



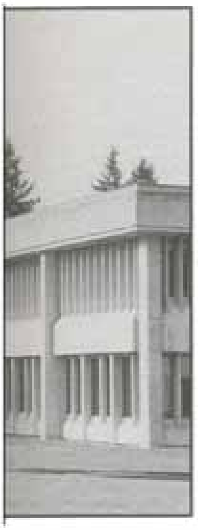
Project

- *Actually generates the power from available water*
- *Responsible for maintaining generators, scheduling maintenance, and monitoring non-power requirements*



Dispatching

- *Monitors transmission and second-by-second generation levels*
- *Responsible for line switching and substation operations*
- *Schedules line and substation outages*
- *Responsible for matching generation and load*



30-Day Computer Study
- *Simulates next month of system operations*
- *Uses projected streamflows, loads, and weather*
- *Highlights potential problems*
- *Helps plan operation of reservoirs*

Preschedule
- *All utilities plan loads for the next day*
- *Plan and verify next day's schedules with other utilities*
- *Schedule generation for some dams*
- *Verify loads and resources can be matched*

Scheduling
- *Plans hydro-operations for the next few hours*
- *Implements and modifies plan as required*
- *Accepts or rejects energy transfers with other utilities hour-by-hour*
- *Monitors operations of hydrosystem minute-by-minute*
- *Responsible for maintaining hydro operations within constraints and balancing river flows with generation*

generation among projects and coordination of Federal and non-Federal projects permit efficient system operations. The BPA dispatchers control the transmission lines, substations, and generation requests and are responsible for the minute by minute integrity of the system. The project operators, such the Corps and Reclamation, control the operation of their projects. If a loss of generation or load occurs, or routine maintenance is scheduled, the dispatchers take the necessary steps to maintain frequency and electric service. Hydro system generation and other generation are set to meet load conditions while meeting non-power requirements.

Examples of Hourly Project Operation

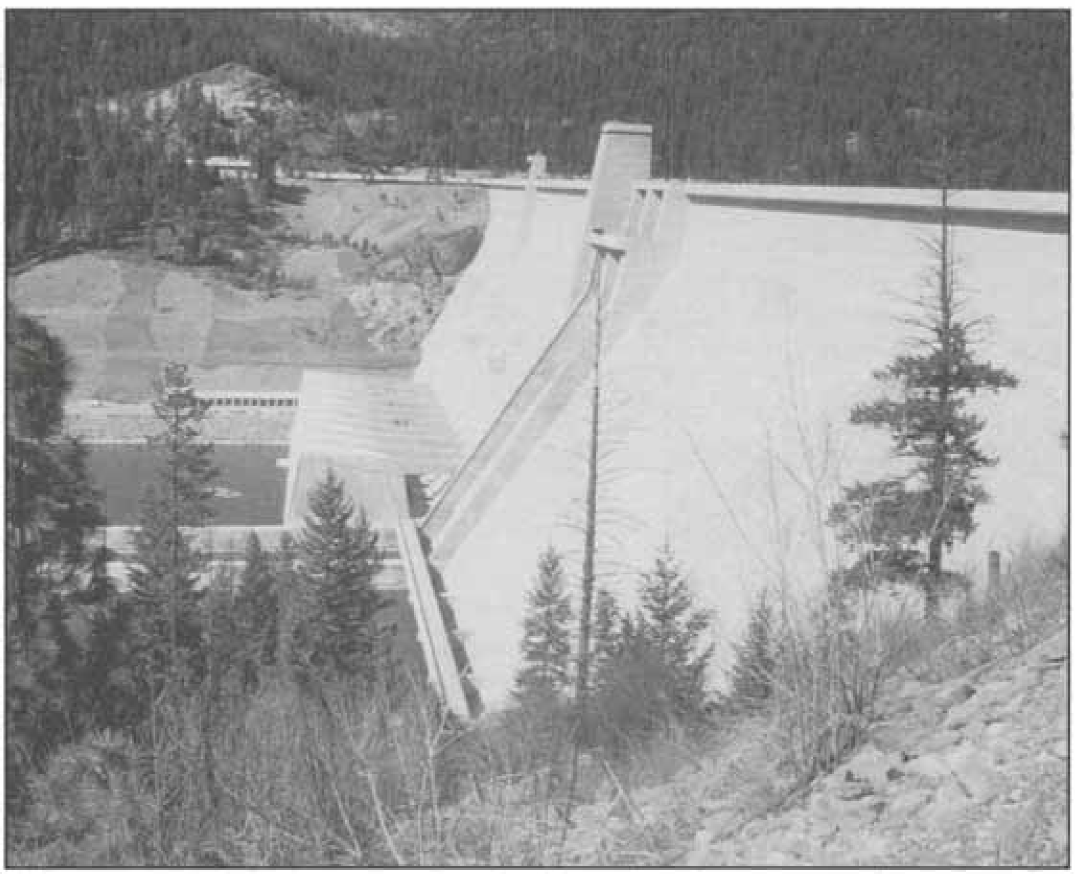
U.S. Headwater projects include Libby, Hungry Horse, and Dworshak. Libby is on the Kootenai River in Montana; Hungry Horse is on the South Fork of the Flathead River in Montana; and Dworshak is on the North Fork of the Clearwater River in Idaho. All of these rivers are tributaries to the Snake and Columbia Rivers.

All three headwater or upstream projects are storage dams with large reservoirs that can be drafted significantly. Because of their location, these upstream projects have their inflows shaped only by nature and are especially useful to protect against floods. It takes about 12 hours for water released at Libby, Hungry Horse, Albeni Falls, or Dworshak to reach the next project downstream. During extreme weather conditions one or more may need to spill to make water available downstream for generation during high load periods.

The lower Snake projects include Lower Granite, Little Goose, Lower Monumental, and Ice Harbor. These run-of-river projects operate as a subsystem, adjusting generation with load variations, in coordination with the rest of the hydro system.

For the past few years, the Northwest has been in drought, and water availability has been a problem on the Snake. There is limited water available for generation in the winter, too, because normally most of the precipitation in the Snake River watershed falls as snow, providing no immediate runoff. Therefore, peaking needs generally are met by Grand Coulee, Chief Joseph, and the lower Columbia River Federal projects.

During times of extreme high system load, water may be released (sometimes spilled) from Dworshak to the lower Snake projects. This may be necessary since Grand Coulee is restricted by its draft limit. Using the lower Snake projects alleviates voltage stability problems with cross-Cascades transmission, especially to the Puget Sound area. Other gains from using Dworshak and the Snake projects are more



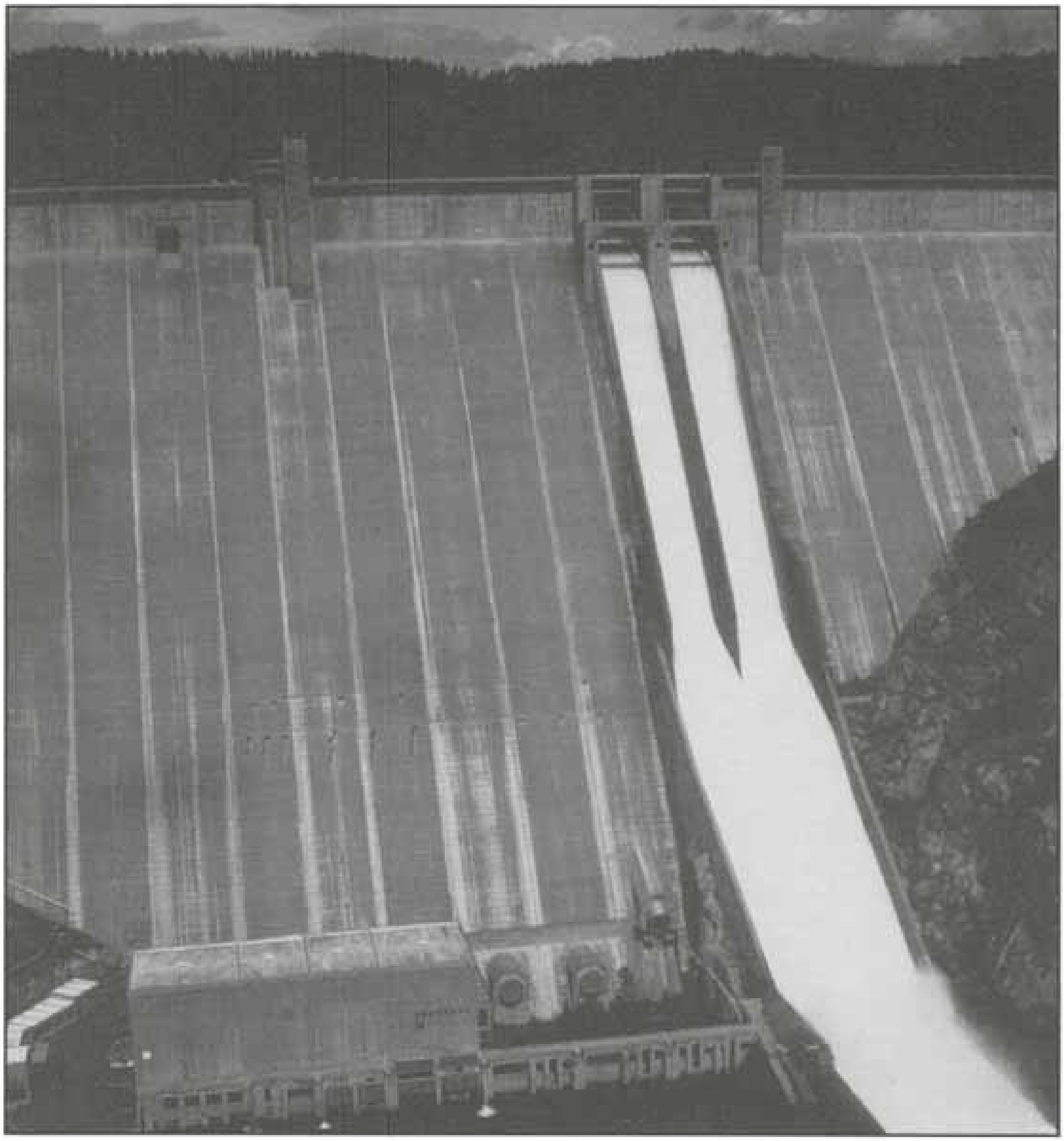
Libby project in Northwest Montana is a large headwater dam whose operation reflects U.S. and Canadian cooperation on power generation, flood control, and other uses. It was one of four projects allowed under the Columbia River Treaty and backs up water in the Kootenai (U.S. spelling) or Kootenay (Canadian spelling) River from Montana into Canada.

energy per unit of water released than if Grand Coulee and Chief Joseph were used, and use of the short-term peaking capability of the lower Snake projects.

The time it takes for water from Dworshak to arrive at the Snake River projects is longer than the time it takes water to reach the mid-Columbia subsystem from Grand Coulee. Also, water that can be released from Dworshak is limited compared to the amounts on the Columbia and is much harder to replace because the ratio of inflow to storage is lower at Dworshak. All these considerations must be kept in mind when deciding how to operate the hydro system in the short run.

The mid-Columbia projects — Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids — are five non-Federal dams downstream of Chief Joseph Dam on the Columbia River. They are owned and operated by PUDs in the area. Each PUD also serves as coordinating entity for the investor-owned utilities and municipalities that purchase the output from these projects. Each of these PUDs also uses its respective projects for load following, with thermal resources or purchases filling in to carry a small portion of their baseload.

An agreement between the mid-Columbia participants and BPA, the Corps, and Reclamation provides for coordination of hourly operations of the subsystem including the five mid-Columbia dams, Grand Coulee, and Chief Joseph. The agreement allows the mid-Columbia operators more control over their inflow and encourages efficient use of water to generate energy.



During high system loads, spill at Dworshak is sometimes needed to move water to the lower Snake River projects. This increases flows at these four projects resulting in more power to serve short-term needs.

McNary Dam is the first run-of-river project on the lower Columbia River downstream of the confluence of the Snake River. McNary operates as a subsystem with John Day, The Dalles, and Bonneville Dams. McNary receives water from Ice Harbor Dam, just upstream on the Snake, and from Priest Rapids, one of the mid-Columbia dams.

Water takes only an hour or two to reach McNary from Ice Harbor but takes about 11 hours to arrive from Priest Rapids. This means that McNary receives high flows from Priest Rapids in the middle of the night and has a period of low inflows in the middle of the day. McNary has a relatively large reservoir and can do some shaping, but if the forebay range is limited for some reason, the lack of synchronism of the inflows and loads can be a problem. Without sufficient storage to shape the inflows, the high inflow at night may have to be released when power isn't needed. On the other hand, in the daytime when McNary's inflows are low, power needs might not be met.

McNary also has smaller turbine capacity than John Day and The Dalles, the next two projects downstream. In times of high load, McNary will run near full load around the clock in an attempt to keep John Day and The Dalles supplied with water.

Other lower Columbia projects include John Day, The Dalles, and Bonneville. McNary, John Day, and The Dalles Dams often are used for control or load following in combination with Grand Coulee and Chief Joseph.

With McNary shaping flows for power generation, John Day and The Dalles generally pass inflow to meet moderate loads. If loads are high, John Day may draft during the day and refill at night. The Dalles, with its small forebay, would just pass the inflow from John Day. John Day and The Dalles often provide reserves for power emergencies, because they have more generating capacity than McNary's.

Bonneville Dam is the closest project upstream on the Columbia River from the large population centers of Portland and Vancouver. Bonneville Dam usually provides less peaking in an attempt to provide a more stable water level downstream on the lower Columbia. Thus, Bonneville's reservoir fills during the day, when the upstream projects are releasing large amounts of water, and then drafts at night, when the inflows are relatively low.

Willamette projects are limited in their operations for power, because the Willamette River and tributary flows are low and other uses often have priority. Normal operation of the Willamette projects is for projects with storage reservoirs, such as Detroit, to generate for a few hours per day, usually peaking either morning or evening with loads. A downstream reregulating dam, such as Big Cliff, reshapes the water released by the upstream projects, generating a constant level of energy and releasing a constant flow to provide a stable water level downstream.

Other tributary projects shape and supply water to the projects identified above. For example, Idaho Power Company operates Brownlee, a storage reservoir, and Oxbow and Hells Canyon, two run-of-river projects, located on the Snake River above Lower Granite Dam. Many other Federal and non-Federal hydroelectric projects in the Northwest and Canada serve load and regulate river flow.

Power Impacts of System Operation Review Alternatives

Three types of limits on operations have been proposed for analysis by the System Operation Review — forebay limits, specified flows, and drawdowns to specified levels at the Snake projects.

Forebay limits include requiring constant forebays or operation to a set of predetermined reservoir elevations, such as upper rule curves or minimum operating pools. Limits on changes in forebay elevations in the short run could be beneficial to uses of the river that value stable elevations and flows, such as navigation, recreation, resident fish, and wildlife. Other uses, however, such as power and flood control, which need to be responsive to short-term seasonal fluctuations in loads and flow, may be negatively affected.

Use of the hydro system to produce power, the primary reason for short-term operations, could be severely hampered. The hydro system would be unable to respond quickly to peak or light load demands, causing potential increases in the need for other generation at times of system peak and spill during light load hours.

Analyses performed for the System Operation Review will have to determine how much short-term operational flexibility is associated with application of the potential forebay limits. Questions to be answered include: Is an elevation limit applied hourly, daily, or as an end of month target? Is there a range about the target, such as within X feet or centimeters? Under what conditions could forebay limits be violated?

Flow targets likely would be specifications of minimum flows or target flows. Currently minimum flow levels are used to provide water for fish, especially in the spring and summer when loads and power generation are low. Again, because power generation is the primary determinant of short-term operations, alternatives for specified flows could reduce use of the system for power, causing spill on light load hours, as well as drafting reservoirs if minimum flows are set too high.

Questions to be answered for analysis include: Are specified flows instantaneous, hourly, daily, weekly, or monthly averages? Under what conditions could flow targets be violated?

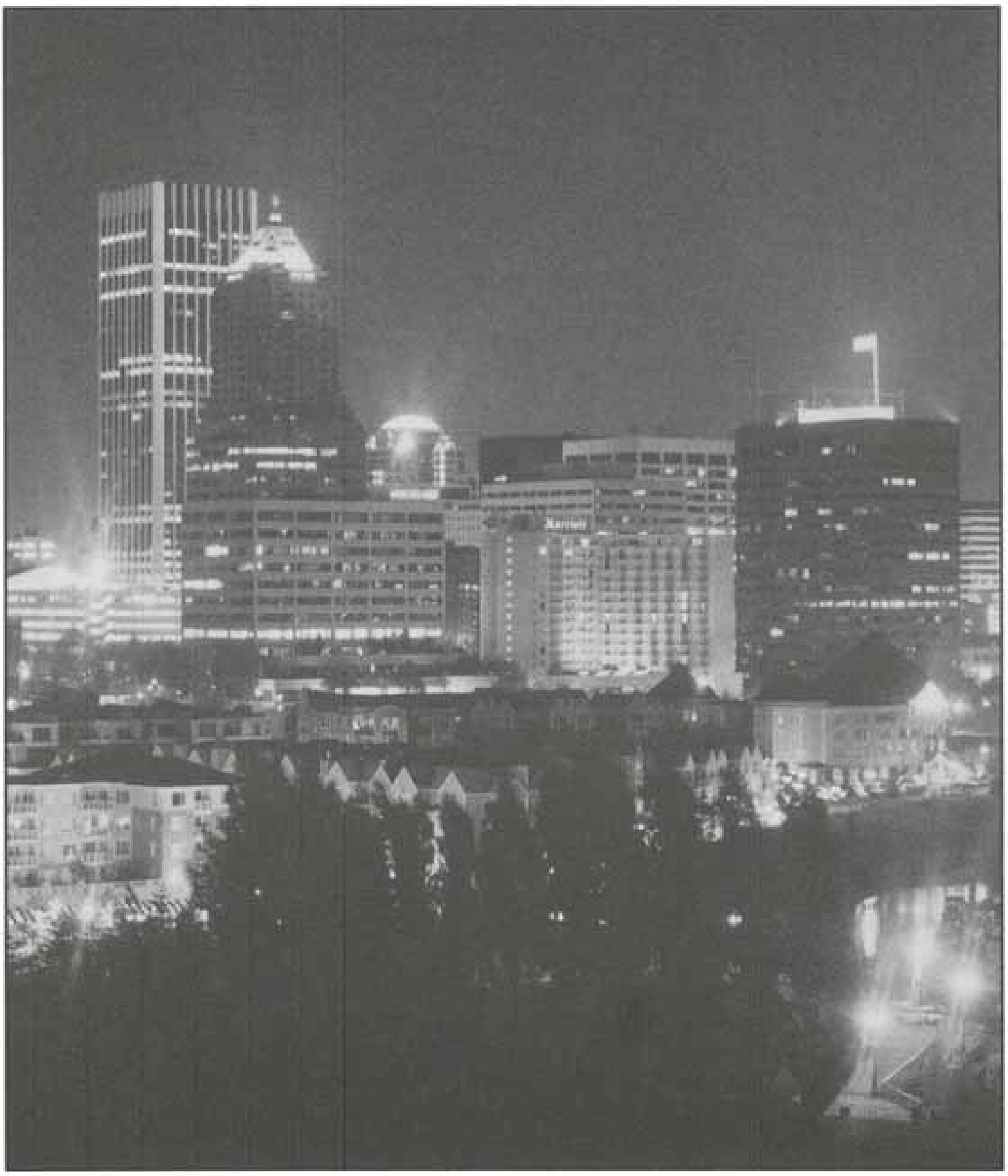
Drawdowns to specified levels include reductions of operating elevations of the four lower Snake projects to near river bed or to spillway crests. The purpose of drawdowns is primarily to approximate natural flows to increase water velocity for fish migration. The drawdowns would be below minimum operating pool, which would significantly reduce power generation and stop navigation. Flows when reservoirs would draft would be higher than usual on the Snake River, and flows when reservoirs would fill would be lower than usual.

Questions to be answered for analysis include: Where would the water come from for refill after drawdown? How often would drawdown occur, and who would make the decision? How would the amount of drawdown be decided upon?

Summing It Up

Short-term operations address the dynamics that affect the Northwest hydro system and its multiple uses. Demands for electrical power and natural streamflows change constantly and thus are not precisely predictable. Other uses of the hydro system have constantly changing needs, too, many of which can interfere with other uses.

Project operators must address various river needs, physical limitations, weather, and streamflow conditions while maintaining the stability of the electric system and keeping your lights on. It takes staffing around the clock to manage the hour-to-hour changes that occur and the challenges that face project operators all the time.



The Northwest generation and transmission systems are managed around the clock to provide reliable electric power that matches the needs of customers.

Appendix A: Short-Term Operational Limits

Hungry Horse Dam and Lake

Project Description

Location	South Fork Flathead River; Hungry Horse, MT
Owner	U.S. Bureau of Reclamation
Type	storage
Status	completed in 1953
Powerhouse	4 units/285 MW
Hydraulic capacity	8,900 cfs
Useable storage (3,560.0 to 3,336.0)	3,161,000 AF

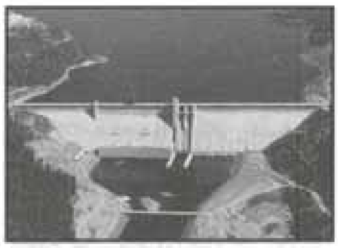
Short-term Operational Limits

Lake Elevation

Normal full pool	3,560 ft
Minimum pool	3,336 ft

Discharge

Minimum	145 cfs
Maximum (limit during flood control operations)	500-3,000 cfs



Libby Dam and Lake Koocanusa

Project Description

Location	Kootenai River; Libby, MT
Owner	U.S. Army Corps of Engineers
Type	storage
Status	completed in 1973
Powerhouse	5 units/525 MW
Hydraulic capacity	24,100 cfs
Useable storage (2,459.0 to 2,287.0)	4,979,500 AF

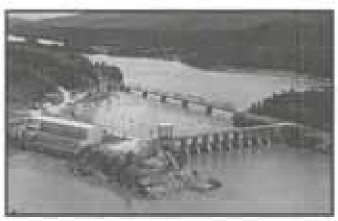
Short-term Operational Limits

Lake Elevation

Full pool	2,459 ft
Minimum pool	2,287 ft

Discharge

Minimum instantaneous	2,000 cfs
Minimum daily flow	3,000 cfs
Rate of change of tailwater elevation	
May 1 - September 30 (1 ft/hr)	4 ft/24 hrs
October 1 - April 30 (1 ft/ 1/2 hr)	6 ft/24 hrs



Albeni Falls Dam and Pend Oreille Lake

Project Description

Location	Pend Oreille River; Newport, WA
Owner	U.S. Army Corps of Engineers
Type	storage
Status	completed August 1955
Powerhouse	3 units/42 MW
Hydraulic capacity	33,000 cfs
Useable storage (2,062.5 to 2,051.0)	1,155,200 AF

Short-term Operational Limits

Lake Elevation (at Hope)

Normal full	2,062.5 ft
Normal minimum	2,051.0 ft

Maximum daily lake elevation change

Above Elevation 2,058	0.4 ft
Below Elevation 2,058	0.5 ft

Discharge

Minimum instantaneous	4,000 cfs
Minimum 24-hour mean	4,000 cfs
Maximum rate of change	
Normal 60-minute limit	5,000 cfs/hr
Maximum 60-minute increase or reduction	1.0 ft/hr
Maximum daily increase	10,000 cfs/24 hr
Maximum daily reduction below 50,000 cfs	10,000 cfs/24 hr
Minimum daily reduction — 50,000 to 75,000 cfs	2.0 ft/24hr
Minimum daily reduction above 75,000 cfs	1.0 ft/24 hr

Special requirements

Lake level is maintained at or near the observed November 20 elevation through December 31 to protect Kokanee spawning areas and prevent dewatering of nests.

Grand Coulee Dam and Lake Roosevelt

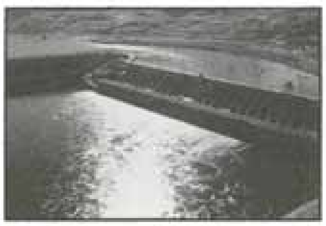
Project Description

Location .... Columbia River; Grand Coulee, WA
Owner .... U.S. Bureau of Reclamation
Type .... storage
Status .... 18 units completed in 1942
2 units completed in 1974, third powerhouse in 1982, 4 units in 1984
Powerhouse .... 24 units/6,494 MW
Hydraulic capacity .... 280,000 cfs
Useable storage (1,290.0 to 1,208.0) .... 5,185,500 AF

Short-term Operational Limits

Lake Elevation
Normal full pool .... 1,290 ft
Normal minimum pool .... 1,208 ft
Maximum daily drawdown .... 1.5 ft
Maximum 6-hour drawdown .... 1.5 ft

Discharge
Above tailwater elevation 957 ft .... 3.0 ft/hr
Below tailwater elevation 957 ft .... 2.0 ft/hr



Chief Joseph Dam and Rufus Woods Lake

Project Description

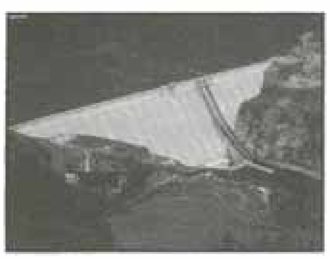
Location .... Columbia River; Bridgeport, WA
Owner .... U.S. Army Corps of Engineers
Type .... run-of-river
Status .... units 1 - 16 completed in 1961
.... units 17 - 27 completed in 1979
Powerhouse .... 27 units/2,069 MW
Hydraulic capacity .... 219,000 cfs

Short-term Operational Limits

Lake Elevation
Full pool .... 956 ft
Minimum pool .... 930 ft
Summer operating range .... 950 - 956 ft

Discharge
Minimum instantaneous .... No limit
Minimum daily .... 35,000 cfs
Maximum rate of change .... No limit

Special Requirements
Based on providing 36,000 cfs at Priest Rapids Dam, Chief Joseph outflow may be less if the 36,000 cfs at Priest Rapids is provided by tributary flow or from storage at another project.



Dworshak Dam and Reservoir

Project Description

Location .... North Fork Clearwater; Ahsahka, ID
Owner .... U.S. Army Corps of Engineers
Type .... storage
Status .... completed in 1973
Powerhouse .... 3 units/400 MW
Hydraulic capacity .... 10,500 cfs
Useable storage (1,600.0 to 1,445.0) .... 2,015,800 AF

Short-term Operational Limits

Lake Elevation
Full pool .... 1,600 ft
Minimum pool .... 1,445 ft

Discharge
Minimum .... 1,000 cfs
Maximum weekly average (October 1 - November 15) .... inflow + 1,300 cfs
Rate of change (Peck Gage)
Hourly .... 1 ft
24-Hour (October 1 - November 15) .... 40% of previous weekly avg outflow
Downstream flood control limit Clearwater River at Spalding
Bank full .... 85,000 cfs
Flood stage .... 105,000 cfs
Lewiston levee capacity .... 150,000 cfs

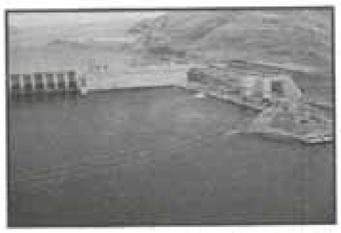
Lower Granite Dam and Lake

Project Description

Location	Snake River; Almota, WA
Owner	U.S. Army Corps of Engineers
Type	run-of-river
Status	units 1-3 completed in 1975, 4-6 completed in 1978
Powerhouse	6 units/810 MW
Hydraulic capacity	130,000 cfs

Short-term Operational Limits

Lake Elevation	
Normal full pool	738 ft
Normal minimum pool	733 ft
Discharge	
Minimum	
December - February	None
March - November	11,500 cfs
Maximum rate of change per hour	70,000 cfs



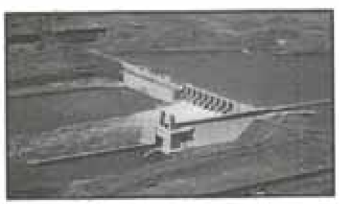
Little Goose Dam and Lake Bryan

Project Description

Location	Snake River; Starbuck, WA
Owner	U.S. Army Corps of Engineers
Type	run-of-river
Status	units 1-3 completed in 1970, 4-6 completed in 1978
Powerhouse	6 units/810 MW
Hydraulic capacity	130,000 cfs

Short-term Operational Limits

Lake Elevation	
Full pool	638 ft
Minimum pool	633 ft
Discharge	
Minimum	
December - February	None
March - November	11,500 cfs
Maximum rate of change per hour	70,000 cfs



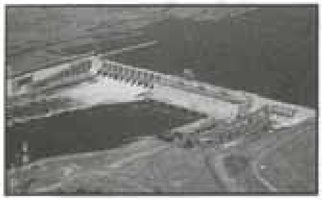
Lower Monumental Dam and Lake Herbert G. West

Project Description

Location	Snake River; Matthaw, WA
Owner	U.S. Army Corps of Engineers
Type	run-of-river
Status	units 1-3 completed in 1970, 4-6 completed in 1978
Powerhouse	6 units/810 MW
Hydraulic capacity	130,000 cfs

Short-term Operational Limits

Lake Elevation	
Normal pool	738 ft
Normal minimum pool	733 ft
Discharge	
Minimum	
December - February	None
March - November	11,500 cfs
Maximum rate of change per hour	70,000 cfs



Ice Harbor Dam and Lake Sacajawea

Project Description

Location .... Snake River; Pasco, WA
Owner .... U.S. Army Corps of Engineers
Type .... run-of-river
Status .... units 1-3 completed in 1962, units 4-6 in 1975
Powerhouse .... 6 units/603 MW
Hydraulic capacity .... 106,000 cfs

Short-term Operational Limits

Lake Elevation
Full pool .... 440 ft
Minimum pool .... 437 ft
Discharge
Minimum
December - February .... None
March - July .... 9,500 cfs
August - November .... 7,500 cfs
Maximum rate of change per hour .... 20,000 cfs

McNary Dam and Lake Wallula

Project Description

Location .... Columbia River; Umatilla, OR
Owner .... U.S. Army Corps of Engineers
Type .... run-of-river
Status .... completed in 1957
Powerhouse .... 14 units/980 MW
Hydraulic capacity .... 232,000 cfs

Short-term Operational Limits

Lake Elevation
Normal full pool .... 340 ft
Minimum pool .... 335 ft
Discharge
Minimum
December - February .... 12,500 cfs
March - November .... 50,000 cfs
Maximum rate of change per hour .... 150,000 cfs

John Day Dam and Lake Umatilla

Project Description

Location .... Columbia River; Rufus, OR
Owner .... U.S. Army Corps of Engineers
Type .... run-of-river/storage
Status .... completed in 1971
Powerhouse .... 16 units/2,160 MW
Hydraulic capacity .... 322,000 cfs
Useable storage (268.0 to 257.0) .... 534,000 AF

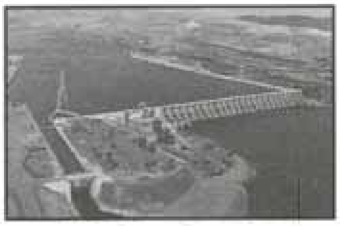
Short-term Operational Limits

Lake Elevation
Full pool .... 268 ft
Minimum pool .... 257 ft
Discharge
Minimum
December - February .... 12,500 cfs
March - November .... 50,000 cfs
Maximum change per hour .... 200,000 cfs
Special Requirements

Normal minimum elevation in spring is 262 feet for protection of geese during nesting period March 1 - May 15.

Reservoir is to be operated between elevation 264-265 once every three days during the goose nesting period, March 1 - May 15.

Reservoir is to be operated between elevation 262.5-264 during juvenile fish outmigration period from May 1 - August 31 unless higher levels are required for irrigation withdrawals.



The Dalles Dam and Lake Celilo

Project Description

Location	Columbia River; The Dalles, OR
Owner	U.S. Army Corps of Engineers
Type	run-of-river
Status	units 1-14 completed in 1960, unit 15-22 in 1973
Powerhouse	22 units/1,780 MW
Hydraulic capacity	375,000 cfs

Short-term Operational Limits

Lake Elevation	
Full pool	160 ft
Minimum pool	155 ft
Discharge	
Minimum	
December - February	12,500 cfs
March - November	50,000 cfs
Maximum rate of change per hour	150,000 cfs

Bonneville Dam and Lake

Project Description

Location	Columbia River; Bonneville, OR
Owner	U.S. Army Corps of Engineers
Type	run-of-river
Status	first powerhouse completed in 1938
	first powerhouse completed in 1982
First powerhouse	10 units/518 MW/136,000 cfs
Second powerhouse	8 units/532 MW/152,000 cfs

Short-term Operational Limits

Lake Elevation	
Full pool	77.0 ft
Minimum pool	70.0 ft
Normal forebay operating range	71.5 - 76.5 ft
Maximum 24-hr fluctuation at Stevenson gage	4.0 ft
Tailwater Elevation	
Rate of Change	
Summer (April 1 - September 30) 60-min limit	1.5 ft
Normal - 24 hr limit	4.0 ft
Maximum - 24 hr limit (no more than 10 times per season)	5.0 ft
Winter (October 1 - March 31) 60-min limit	3.0 ft
Normal - 24 hr limit	7.0 ft
Maximum - 24 hr limit (no more than 18 times per season)	10.0 ft
Discharge	
Minimum instantaneous	80,000 cfs
Minimum daily average	100,000 cfs

Special requirements

Normal operating range will not be exceeded more than 18 days per year.

When average 7-day inflow is below 125,000 cfs, the minimum instantaneous outflow limit is 70,000 cfs and the minimum daily average discharge limit is 80 percent of the 7-day average inflow.

Appendix B: Overview

Introduction. Much of the information in this appendix appears in other documents produced for the System Operation Review, including *The Columbia River System: The Inside Story* and *A River at Work*. Repeating this information here provides easy reference and supplements the material that appears in this document on short-term operations.

The Basin. The Columbia River Basin includes the drainage of the Columbia River and its tributaries, an area of about 567 000 square kilometers (219,000 square miles) in the United States and 102 000 square kilometers (39,500 square miles) in Canada. The boundaries of the Columbia Basin are the Rocky Mountains to the east and north, the Cascade Range on the west, and the Great Basin to the south. The basin covers portions of seven western states, including Washington, Oregon, Idaho, Montana, Wyoming, Nevada, and Utah.

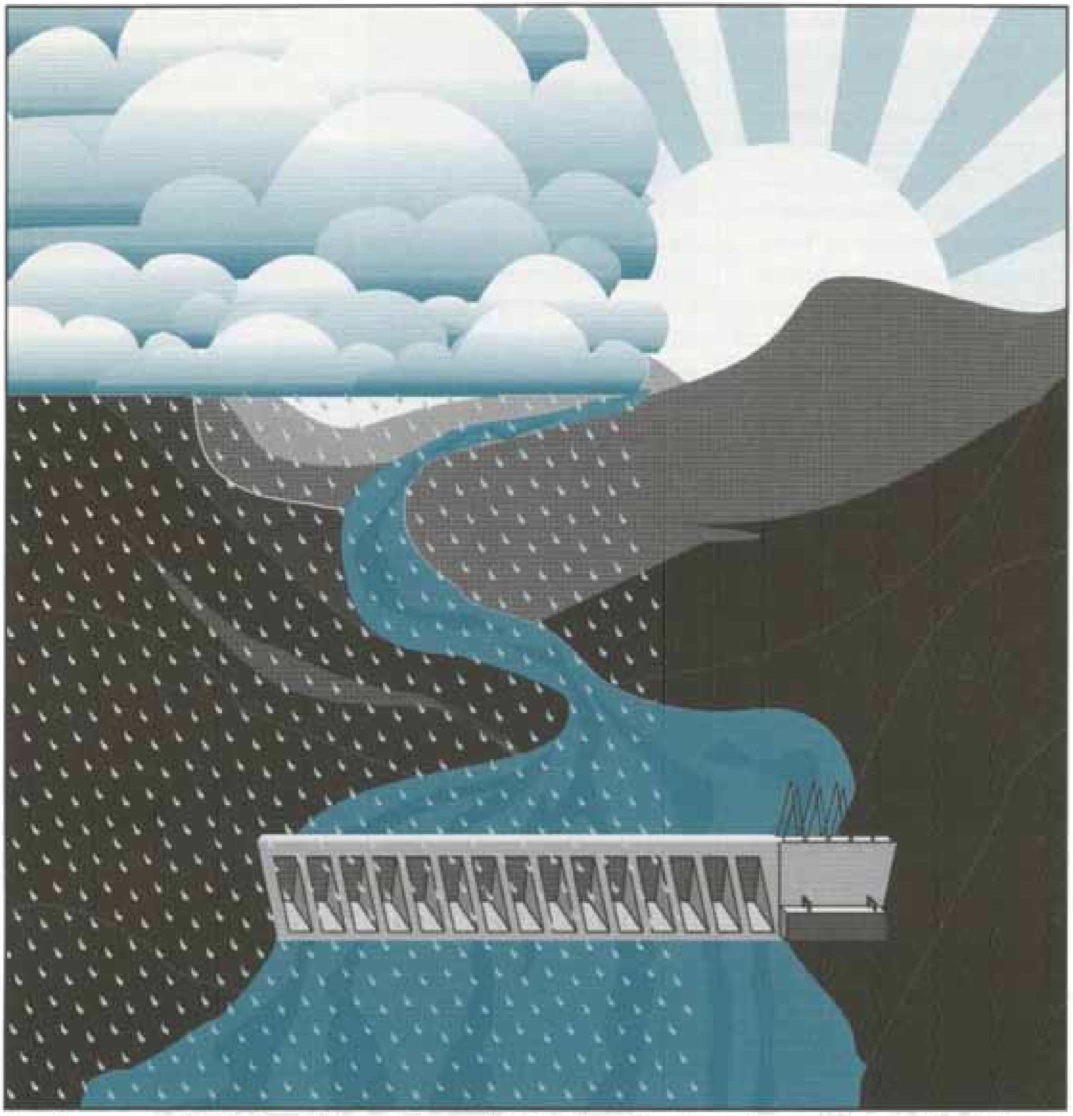
The River. The Columbia River originates at Columbia Lake on the west slope of British Columbia's Rocky Mountain Range, 320 kilometers (200 miles) north of the U.S. border. The river flows from Canada into the United States and eventually becomes the border between Oregon and Washington. The Columbia River is 1 955 kilometers (1,214 miles) long; it flows into the Pacific Ocean near Astoria, Oregon. The Columbia's major tributaries in the United States are the Kootenai, the Clark Fork-Pend Oreille, and the Snake. The average annual runoff of the Columbia River is 244 billion cubic meters (198 million acre-feet). The river's natural flows are extremely erratic from year to year and season to season, depending on precipitation type and amount, and runoff amount and timing.

The Dams. There are 255 hydro projects in the Northwest, including 31 Federal dams. Fourteen of the Federal dams are being studied in the System Operation Review: these large-scale projects play a key role in the multipurpose use of the Columbia River system. Dworshak is on the North Fork of the Clearwater River in Idaho, a tributary of the Snake. Lower Granite, Little Goose, Lower Monumental, and Ice Harbor are on the Snake River in Washington. Hungry Horse is on the South Fork of the Flathead River in Montana; Libby is on the Kootenai River in Montana; and Albeni Falls is on the Pend Oreille River in Washington, all of which are tributaries to the Columbia. Grand Coulee and Chief Joseph are on the Columbia River in Washington. McNary, John Day, The Dalles, and Bonneville are on the Columbia River on the Oregon/Washington border.

River Uses. The primary uses of the Columbia River system are navigation, flood control, irrigation, electric power generation, fish migration, fish and wildlife habitat, recreation, cultural resource protection, and water supply and water quality.

Types of Projects. Projects may be differentiated into storage and run-of-river categories. A storage project uses its reservoir to adjust the river's natural flow patterns to conform more closely to water uses. Storage projects in the Columbia and Snake River Basins capture spring and summer runoff for flood control and to provide water flows for uses later in the year. The reservoirs release water during the late summer and fall, when natural streamflows are low, to aid fish migration and to provide water for power generation and other uses. Run-of-river projects have little storage capability and release water at about the same rate it enters. Run-of-river projects provide hydraulic head for power generation and depth over river obstacles such as rapids to permit barge navigation.

Project Operators. The U.S. Army Corps of Engineers and the Bureau of Reclamation operate the Federal water projects in the Northwest. The Corps operates 12 of the 14 projects under study in the System Operation Review. The Corps is responsible for flood control at all major reservoirs in the Columbia River Basin and maintains navigation channels. Reclamation operates Grand Coulee and Hungry Horse Dams, two of the storage projects that are included in the System Operation Review. Reclamation also operates water resource projects throughout the Columbia Basin for irrigation and other uses. The Bonneville Power Administration markets and distributes the power produced by the projects. BPA sells power from the dams and other generating plants to public and private utilities and direct-service industries, and it builds and operates transmission lines to deliver the electricity. Public utility districts, municipal utilities, and private utility companies own and operate dams and generation projects in the Columbia River Basin. Irrigation districts operate and



Short-term operations balance the many uses of the hydro system, including power generation, fish and wildlife, and recreation, using the conditions supplied by nature, such as precipitation and streamflow.

maintain pumping plants and irrigation canals in the region. British Columbia Hydro operates water projects on the upper Columbia River in Canada.

Agreements Affecting Operations

The Columbia River Treaty between the United States and Canada, signed in 1961 and put into effect in 1964, provided for building four storage reservoirs, including Libby. The reservoirs built and operated under the Treaty, three of which are in Canada, represent almost half the water storage on the Columbia River system. Water released from reservoirs in Canada is used to produce power at dams in the U.S. The benefits of the projects were divided between the two nations in related agreements. Canada sold its share of the power for the first 30 years of project operation. The Treaty does not specify an end date; either country has the option to terminate the Treaty after 2024.

The Columbia Storage Power Exchange was formed by 41 utilities in the U.S. to purchase the Canadian power benefits of the Treaty beginning in 1968. CSPE utilities receive Canadian power from BPA and the three mid-Columbia public utility districts with projects on the mainstem Columbia River.

The Canadian Entitlement Allocation Agreements are contracts that divide the Treaty's power benefits and obligations among the non-Federal beneficiaries in the United States. There are five Allocation Agreements, one for each of the five public utility district-owned dams on the mid Columbia. The agreements determined how much power each of the five utilities will generate from Canadian flows for delivery to the CSPE utilities. These agreements, which begin to expire in 1998, are being renegotiated to establish future obligations regarding Columbia River Treaty power benefits.

The Pacific Northwest Coordination Agreement was inspired by the Columbia River Treaty. It is a complex contract for planned operation among the Federal project operators and power generating utilities of the Pacific Northwest. It was signed in 1964 and expires in 2003. The Coordination Agreement calls for annual planning, which must accommodate all the authorized purposes of the Columbia River hydro projects as well as project and system requirements. All Coordination Agreement parties coordinate planning and operations to meet system requirements.

The Non-Treaty Storage Agreement is a contract between BPA and B.C. Hydro to coordinate the use of an additional portion of the water stored in the reservoir behind Mica Dam in British Columbia. This water storage is not covered in the Columbia River Treaty (thus "non-treaty" storage agreement). The NTSA covers 4.5 million acre-feet of water storage. The power generating capability represented by the storage will be shared equally by BPA and B.C. Hydro. The owners of the five non-Federal mid-Columbia hydroelectric projects and their power purchasers are interested parties to the NTSA and share its obligations and benefits. BPA has completed a companion agreement with these owners, and with many of the utilities that purchase power from these projects, because the hydropower benefits represented by the NTSA depend on the cooperation of the mid-Columbia dam operators. In October 1990, BPA signed a related agreement with the Columbia Basin Fish and Wildlife Authority, which represents Northwest fish and wildlife agencies and 13 Indian Tribes. The agreement aims to assure, through operating guidelines and regular communication, that use of non-Treaty storage water will pose no significant risks to fish.

The Vernita Bar Agreement provides that project operators will arrange for certain flow levels on the Columbia River at Vernita Bar below Priest Rapids Dam from fall to early spring to protect and preserve salmon spawning and hatching.

The Long-Term Spill Agreement established a plan among fisheries agencies, Indian Tribes, and BPA for spilling water to aid migration of juvenile salmon and steelhead from their spawning grounds to the ocean. The agreement provides that a specific amount of water be passed over the spillways of four Corps projects — Lower Monumental, Ice Harbor, John Day, and The Dalles — in the spring and summer.

Authorizing Legislation. Congress specified the major intended uses in the authorizing legislation for each Federal hydro project. Most were authorized for one or more purposes including flood control, navigation, irrigation, and power production. The laws seldom contain explicit provisions for operating individual projects or for their coordinated operation within the total system. The Federal agencies and other project operators have developed principles and agreements among themselves.

Other Legislation

The National Environmental Policy Act (NEPA) requires environmental scrutiny of actions proposed by Federal agencies. The System Operation Review includes an Environmental Impact Statement prepared pursuant to NEPA, which analyzes alternatives for renewal or renegotiation of the Pacific Northwest Coordination Agreement and Canadian Entitlement Agreements, system operations and the following implementation process.

The Endangered Species Act is designed to conserve endangered and threatened species of flora and fauna and their ecosystems. Several species of salmon in the Northwest have been targeted for protection under the act. Some protective measures, such as increased flow and reservoir drawdowns, have been implemented, and others are under study.

The Pacific Northwest Electric Power and Conservation Act created the Northwest Power Planning Council, which developed and continues to update and implement the Fish and Wildlife Program for the Columbia Basin. The program established goals for restoring and protecting fish populations in the basin. The goals have resulted in changes in how the coordinated hydro system is operated. For example, the Water Budget provides for the release of specific amounts of water in the upper Columbia and on the Snake River to aid the spring downstream migration of juvenile salmon.

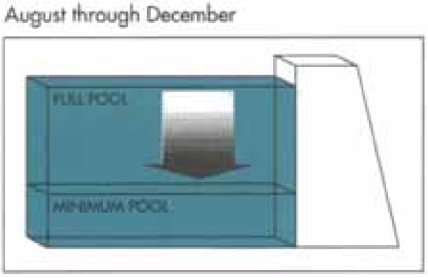
Operational Planning. Planning for power generation factors in all uses of the system to determine how much water will be available for power production, and it coordinates generation so as to provide the amount of power needed. The Columbia River Treaty requires the U.S. (the Corps and BPA) and Canada (B.C. Hydro) to prepare operating plans each year. These plans are the basis for the operating rule curves for the Treaty projects in Canada. They are factored into the annual plan developed by parties to the Pacific Northwest Coordination Agreement, because releases of water from the Canadian storage reservoirs are crucial for coordinated system planning in the U.S. Annual planning for coordinated system operations occurs pursuant to the PNCA. Planning studies are made as if the total coordinated

Three Seasons of Reservoir Operation

Flow Measured at The Dalles, Oregon

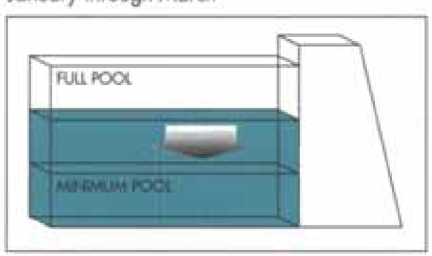
Three Seasons of Reservoir Operation

August through December



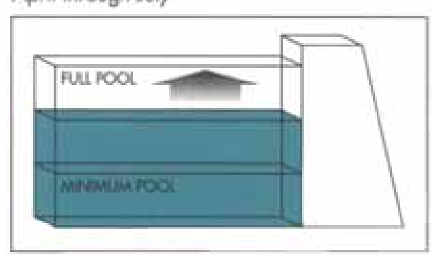
Fixed Drawdown: During the late summer and fall when the volume of the next spring runoff is unknown, reservoir operations are guided by fixed rule curves that follow historical patterns.

January through March



Variable Drawdown: Spring runoff forecasts are available beginning in January. They are the basis for rule curves that guide operations through the runoff and refill season.

April through July



Refill Season: Operators focus on capturing enough runoff to refill reservoirs by the end of July. When runoff is low, reservoirs may not refill, and future operations are partially shaped by how low reservoir levels are on July 31.

Operations on the Columbia River system are built around seasonal streamflow conditions. The water in the river can vary dramatically from month-to-month, depending upon precipitation and snowmelt.

system had a single owner, synchronizing operations to maximize power production.

The annual planning process starts each February. Each reservoir owner submits multiple-use operating requirements that must be accommodated in the resulting plan. Utility parties also submit forecasts of their electricity loads, the output of their non-hydro generating resources, and planned maintenance outages for their resources. Studies are conducted to identify the critical period. Assuming critical period conditions, firm energy load carrying capability is determined for the system as a whole and for each PNCA party. After iterative analysis and comment from the parties, the final critical rule curves and FELCC are published for each month in the critical period.

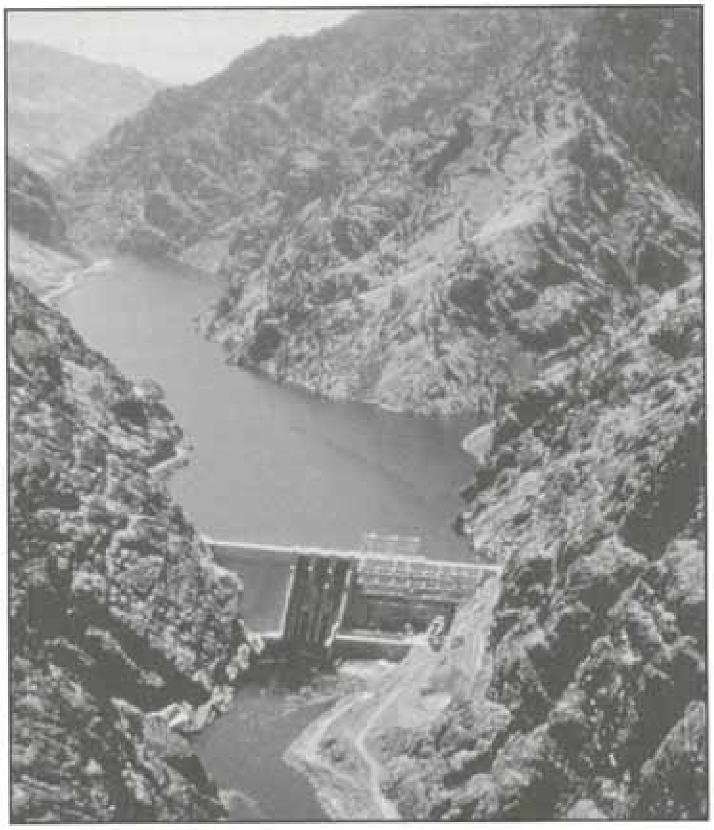
The Coordination Agreement Refill Test is conducted by the Corps. It simulates how the hydro system would operate under the runoff conditions in each of 50 years of streamflow records. The refill test determines whether the energy content curves are constructed in a way that does not threaten the coordinated system's ability to generate its firm energy capability under historical streamflow conditions. It determines the reservoir draft limit for nonfirm energy by developing rule curves with a 95 percent chance of refill.

Seasons. The operating year for the Columbia River system can be divided into three seasons. August through December is the fixed drawdown period, in which reservoirs are operated according to predetermined rule curves because runoff forecasts from the snowpack are not available until January. January through March is the variable drawdown period, in which operation of the reservoirs is guided by the runoff forecasts. Reservoirs are drafted to provide flood control space and to meet power needs, while retaining enough water for spring fish flows and to ensure a high likelihood of reservoir refill by summer. April through July is the refill season, in which reservoirs store spring runoff. Water is released to help young salmon and steelhead migrate to the sea, and operations for flood control and power sales continue as needed.

Conflicting Objectives. Actual operation of the system over the year is based on meeting several related but sometimes conflicting objectives:

- Providing adequate flood storage space for control of the spring runoff.
- Maintaining a high probability that reservoirs will refill to meet recreation needs and to provide water for next year's power operations.
- Providing flows to aid downstream migration of juvenile fish.
- Maximizing power generation within the requirements imposed by other objectives.

Real Time Operations. Reservoir operators use rule curves that are based on historical streamflows. Operators also must meet project and system requirements and meet electricity loads with a combination of hydro and other power plants. To reconcile all of these requirements, an Actual Energy Regulation is produced at least twice a month throughout the operating year. One result of these studies is an energy content curve for each storage project that accounts for specific conditions in the current operating year. The AER combines each utility's firm energy load carrying capability with actual and current estimates of streamflow and defines draft points to produce the FELCC and meet other system and project requirements. In low water years, when reservoirs must be drafted below their energy content curves to produce FELCC, the AER sets proportional draft points to equitably distribute the draft among all reservoirs.



Hells Canyon Dam, an Idaho Power Company project, is located on the Snake River in Oregon.

Glossary

Acre-foot — The volume of water that will cover an area of one acre to a depth of one foot (326,000 gallons or 0.5 second foot days). It equals 1,233.5 m^3.

Actual energy capability (AEC) — Each PNCA party's generating capability based on operating the coordinated system's reservoirs to the energy content curve or to proportional draft points.

Anadromous fish — Fish, such as salmon or steelhead trout, that hatch in fresh water, migrate to and mature in the ocean, and return to fresh water as adults to spawn.

Annual operating plan — A yearly plan for operating reservoirs on the Columbia River. Such a plan is specifically required by the Columbia River Treaty and by the Pacific Northwest Coordination Agreement.

Assured operating plan — A study mandated by the Columbia River Treaty that determines U.S. and Canadian benefits of Treaty projects.

Assured refill curve (ARC) — A representation of the lowest drawdown level from which a reservoir could refill given a repetition of the third-lowest runoff year of record.

Average megawatt (aMW) — The average amount of energy (in megawatts) supplied or demanded over a specified period of time; equivalent to the energy produced by the continuous operation of one megawatt of capacity over the specified period.

Baseload — In a demand sense, a load that varies only slightly in level over a specified time period. In a supply sense, a plant that operates most efficiently at a relatively constant level of generation.

Bypass system — Structure in a dam that provides a route for fish to move through or around the dam without going through the turbines.

Canadian Entitlement — Canada's share of hydropower generated at downstream projects by the use of the Columbia River Treaty projects.

Canadian Entitlement Allocation Agreements — Contracts that specify how much power is to be provided by five mid-Columbia projects as a result of increased flows made possible by the Columbia River Treaty projects.

Capacity — The maximum sustainable amount of power that can be produced by a generating resource at specified times under specified conditions or carried by a transmission facility; also, the maximum rate at which power can be saved by a nongenerating resource.

Capacity/energy exchange — A transaction in which one utility provides another with capacity service in exchange for additional amounts of firm energy (exchange energy) or money, under specified conditions, usually during offpeak hours.

Columbia River Treaty — U.S.-Canadian agreement for bilateral development and management of the Columbia River to achieve flood control and increased power production.

Columbia Storage Power Exchange (CSPE) — A nonprofit corporation of 11 Northwest utilities that issued revenue bonds to purchase the Canadian Entitlement and sell it to 41 Northwest utilities through a BPA exchange agreement.

Composite reservoir — A PNCA operational procedure that simplifies in-lieu energy transactions by treating Federal upstream reservoirs as one reservoir located at Grand Coulee and assuming the same flow time between these upstream reservoirs and the mid-Columbia projects.

Coordinated operation — The operation of interconnected electrical systems to achieve greater reliability and economy; as applied to hydro resources, the operation of a group of hydro plants to obtain optimal power benefits.

Content — An amount of water stored in a reservoir, usually expressed in terms of KSFD or MAF.

Critical period — That portion of the historical 50-year streamflow record which, when combined with the drafting of all storage reservoirs from full to empty, would produce the least amount of energy shaped to seasonal load patterns.

Critical rule curves (CRC) — A set of curves that define reservoir elevations that must be maintained to ensure that firm energy requirements can be met under the most adverse historical streamflow conditions. Critical rule curves are derived for all years in the critical period. They are used for proportional draft of reservoirs.

Critical water — Streamflows that occurred during the critical period, that portion of the historical 50-year streamflow record which, when combined with the drafting of all storage reservoirs from full to empty, would produce the least amount of energy shaped to seasonal load patterns.

Cubic feet per second (cfs) — A unit of measurement pertaining to flow or discharge of water. One cfs is equal to 449 gallons per minute. A thousand cubic feet per second is abbreviated as kcfs.

Demand — The rate at which electric energy is used, whether at a given instant, or averaged over any designated period of time.

Discharge — Volume of water released from a dam or powerhouse at a given time, usually expressed in cubic feet per second.

Displacement — The substitution of less-expensive energy generation for more-expensive energy generation (usually hydroelectric energy transmitted from the Pacific Northwest or Canada is substituted for more expensive coal and oil-fired generation in California). Such displacement usually means that a thermal plant can reduce or shut down its production, saving money and often reducing air pollution.

Draft — Release of water from a storage reservoir.

Drawdown — The distance that the water surface of a reservoir is lowered from a given elevation as water is released from the reservoir. Also refers to the act of lowering reservoir levels. (Similar to draft.)

Elevation — Height in feet above sea level. Usually refers to reservoir forebay; used interchangeably with content because a forebay elevation implies a specific reservoir content. Tailwater level is also expressed as an elevation.

Energy — The ability to do work (i.e., exert a force over distance). Energy is measured in calories, joules, KWH, BTUs, MW-hours, and average MWs.

Energy content curves (ECC) — A set of curves that establishes limits on the amount of reservoir drawdown permitted to produce energy in excess of FELCC.

FELCC — Firm energy load carrying capability (FELCC) is the amount of energy the region's generating system, or an individual utility or project, can be called on to produce on a firm basis during actual operations. FELCC is made up of both hydro and nonhydro resources, including power purchases.

Firm energy — The amount of energy that can be generated given the region's worst historical water conditions. It is energy produced on a guaranteed basis.

Fish ladders — A series of ascending pools constructed to enable salmon or other fish to swim upstream around or over a dam.

Fish passage facilities — Features of a dam that enable fish to move around, through, or over without harm. Generally an upstream fish ladder or a downstream bypass system.

Fixed drawdown period — The late summer and fall when the volume of the next spring runoff is not yet known, and reservoir operations are guided by fixed rule curves based on historical streamflow patterns.

Flood control rule curve — A curve, or family of curves, indicating the minimum reservoir drawdown required to control floods. (Also called Mandatory Rule Curve or Upper Rule Curve).

Flow — The volume of water passing a given point per unit of time. Same as streamflow.

Forced outage — An unforeseen outage that results from emergency conditions.

Forced outage reserves — Peak generating capability planned to be available to serve peak loads during forced outages of generating units.

Forebay — The portion of a reservoir at a hydro project that is immediately upstream of a dam or powerhouse.

Forebay elevation — Height of top of the forebay above sea level.

Freshet — A rapid temporary rise in streamflow caused by heavy rains or rapid snowmelt.

Generation — Act or process of producing electric energy from other forms of energy. Also refers to the amount of electric energy so produced.

Headwater benefits — Gains in useable downstream energy as a result of upstream storage.

Historical streamflow record — The unregulated streamflow data base of the 50 years beginning in July 1928; data are modified to adjust for factors such as irrigation depletions and evaporations for the particular operating year being studied.

Hydraulic head — The vertical distance between the surface of the reservoir and the surface of the river immediately downstream from the dam. Head is the difference between forebay and tailwater elevations.

Hydroelectricity — The production of electric power through use of the gravitational force of falling water.

Hydrology — The science dealing with the continuous cycle of evapotranspiration, precipitation, and runoff.

Hydrometeorological observations — Data that combine snowpack measurements and climatic forecasts to predict runoff.

Inflow — Water that flows into a reservoir or forebay during a specified period.

In-lieu energy — Energy provided by a reservoir owner instead of water to which a downstream party is entitled.

Intake — The entrance to a conduit through a dam or water facility.

Interchange energy — Electric energy received by one utility system usually in exchange for energy to be delivered to another system at another time or place. Interchange energy is different from a direct purchase or sale, although accumulated energy balances are sometimes settled in cash.

Interruptible — A supply of power which, by agreement, can be shut off on relatively short notice (from minutes to a few days).

Juvenile — The early stage in the life cycle of anadromous fish when they migrate downstream to the ocean.

KAF — A thousand acre feet; same as .504 thousand second foot days.

KCFS — A measurement of water flow equivalent to 1,000 cubic feet of water passing a given point for an entire second.

KSFD — A volume of water equal to 1,000 cubic feet of water flowing past a point for an entire day. Same as 1.98 KAF.

Levee — An embankment constructed to prevent a river from overflowing.

Load — The amount of electric power or energy delivered or required at any specified point or points on a system. Load originates primarily at the energy-consuming equipment of customers.

Lock — A chambered structure on a waterway closed off with gates for the purpose of raising or lowering the water level within the lock chamber so ships, boats, and tugs/barges can move from one elevation to another along the waterway.

MAF — Million acre feet. The equivalent volume of water that will cover an area of one million acres to a depth of one foot. One MAF equals 1,000 KAF.

Mainstem — The principal river in a basin, as opposed to the tributary streams and smaller rivers that feed into it.

Megawatt-hour (MWh) — A unit of electrical energy equal to one megawatt of power applied for one hour.

Megawatts (MW) — A megawatt is one million watts, a measure of electrical power or generating capacity. A megawatt will typically serve about 1,000 people. The Dalles Dam produces an average of about 1,000 megawatts.

Mid-Columbia — The section of the Columbia River from Grand Coulee Dam to its junction with the Snake River.

Nitrogen supersaturation — A condition of water in which the concentration of dissolved nitrogen exceeds the saturation level of water. Excess nitrogen can harm the circulatory systems of fish.

Nonfirm energy — Energy in excess of firm energy, which is available when water conditions are better than those in the critical period; generally such energy is sold on an interruptible (nonguaranteed) basis. Also called secondary energy.

Nonpower operating requirements (NPR) — Operating requirements at hydroelectric projects that pertain to navigation, flood control, fish and wildlife, recreation, irrigation, and other uses of the river besides power generation.

Northwest Power Pool Coordinating Group — An operating group made up of BPA, the Corps, Reclamation, and public and private generating utilities in the Northwest. One of the group's functions is administering the Pacific Northwest Coordination Agreement.

Offpeak hours — Period of relatively low demand for electrical energy, as specified by the supplier (such as the middle of the night).

Operating limits — Also called operating requirements or constraints. Limits or requirements that must be factored into the planning process for operating reservoirs and generating projects. (Also see nonpower operating requirements, above, and operating requirements, below.)

Operating procedure — Alternative method substituted for a provision in the PNCA contract by agreement of parties, clarification of the contract, or method for carrying out a procedure.

Operating requirements — Guidelines and limits that must be followed in the operation of a reservoir or generating project. These requirements may originate from authorizing legislation, physical plant limitations, environmental impact analysis or input from government agencies and other entities representing specific river uses. Operating requirements are submitted annually to the Northwest Power Pool by project owners for planning purposes.

Operating rule curve — A composite curve, derived from a family of curves, indicating how a reservoir is to be operated under specific conditions. The operating rule curve accounts for multiple operating objectives, including flood control, hydropower generation, releases for fish migration, and refill.

Operating year — The 12-month period from August 1 through July 31.

Outage — In a power system, the state of a component (such as a generating unit, transmission line, etc.) when it is not available to perform its function due to some event directly associated with the component.

Outflow — The water that is released from a project during a specified period.

Pacific Northwest Coordination Agreement (PNCA) — A binding agreement among BPA, the Corps, Reclamation, and the major hydro generating utilities in the Pacific Northwest that stemmed from the Columbia River Treaty. The Agreement specifies a multitude of operating rules, criteria, and procedures for coordinating operation of the Pacific Northwest hydropower system for power production. It directs operation of major generating facilities as though they belonged to a single owner.

Peak load — The maximum electrical demand in a stated period of time. It may be the maximum instantaneous load or the maximum average load within a designated period of time.

Project — Run-of-river or storage dam and related facilities; also a diversion facility.

Project outflow — The volume of water per unit of time released from a project. Same as discharge and outflow.

Proportional draft — A condition in which all reservoirs are drafted between rule curves in the same proportion to meet FELCC.

Proportional draft point (PDP) — Reservoir elevation that guides operations whenever drafting to the ECC will not produce FELCC; all reservoirs' PDPs are the same proportional percent between the critical rule curves unless restricted by NPRs.

Provisional energy — Energy produced by drafting below the ECC or PDP and delivered under contracts which provide for the return of the energy to the delivering utility under certain conditions. Provisional energy is called Advance Energy in contracts between BPA and its direct service industrial customers.

Refill — The point at which the hydro system is considered full from the seasonal snowmelt runoff. Also, refers to the annual process of filling a reservoir.

Reliability — For a power system, a measure of the degree of certainty that the system will continue to meet load for a specified period of time.

Reregulation — Storing erratic discharges of water from an upstream hydroelectric plant and releasing them uniformly from a downstream storage plant.

Reregulating reservoir — A reservoir located downstream from a hydroelectric peaking plant having sufficient pondage to store the widely fluctuating discharges from the peaking plant and release them in a relatively uniform manner downstream.

Reservoir content — See content and reservoir storage.

Reservoir draft rate — The rate at which water, released from storage behind a dam, reduces the elevation of the reservoir.

Reservoir elevation — The height above sea level of the water stored behind a dam. Same as forebay elevation.

Reservoir storage — The volume of water in a reservoir at a given time. Same as reservoir content. Reservoir storage implies a reservoir elevation. Tables are used to convert content to elevation at each reservoir.

Resident fish — Fish species that reside in fresh water throughout their lives.

Restoration — Adjustments that permit all PNCA projects to carry the same firm energy load with as without Canadian Treaty storage; projects losing load-carrying capability are restored by projects gaining capability.

Rule curves — Water levels, represented graphically as curves, that guide reservoir operations. See critical rule curves, energy content curves, and flood control rule curves.

Run-of-river dams — Hydroelectric generating plants that operate based only on available inflow and a limited amount of short-term storage (daily/weekly pondage).

Secondary energy — Hydroelectric energy in excess of firm energy, often used to displace thermal resources. Sometimes called nonfirm energy.

Secretary's Principles — The framework of rights and obligations that forms the basis of PNCA.

Shaping — The scheduling and operation of generating resources to meet seasonal and hourly load variations. Load shaping on a hydro system usually involves the adjustment of reservoir releases so that generation and load are continuously in balance.

Shifting — In planning, moving surplus or deficit FELCC from one year of the critical period to another to increase the FELCC's value.

Smolt — A juvenile salmon or steelhead migrating to the ocean and undergoing physiological changes to adapt its body from a freshwater to a saltwater environment.

Spawning — The releasing and fertilizing of eggs by fish.

Spill — Water passed over a spillway or regulating outlets and not going through turbines to produce electricity. Spill can be forced, when there is not enough storage capability and flows exceed turbine capacity, or planned, for example, when water is spilled to enhance juvenile fish survival.

Spillway — Overflow structure of a dam.

Storage energy — The energy equivalent of water stored in a reservoir above normal bottom elevation.

Storage reservoirs — Reservoirs that have space for retaining water from springtime snowmelts. Careful scheduling of reservoir refill serves to prevent floods in high runoff years. Retained water is released as necessary for multiple uses — power production, fish passage, irrigation, and navigation.

Streamflow — The rate at which water passes a given point in a stream, usually expressed in cubic feet per second (cfs).

Surplus — Energy generated that is beyond the immediate needs of the producing system. This energy may be sold on an interruptible basis or as nonfirm power.

Tailwater — Water immediately below the power plant. Tailwater elevation refers to the level of that water.

Thermal power plant — Generating plant that converts heat energy into electrical energy. Coal, oil, and gas-fired power plants and nuclear power plants are common thermal resources.

Thermal resource — Electrical generating means that rely on conventional fuels such as coal, oil, and gas.

Transmission — Transporting electric energy in bulk from one point to another in the power system rather than to individual customers.

Transmission grid — An interconnected system of electric transmission lines and associated equipment for transferring electric energy in bulk.

Turbine — Machinery that converts kinetic energy of a moving fluid, such as falling water or steam, to mechanical power. Turbines are used to turn generators that convert mechanical energy to electricity.

Useable storage — Water occupying active storage capacity of a reservoir.

Useable storage capacity — The portion of the reservoir storage capacity in which water normally is stored, or from which water is withdrawn for beneficial uses, in compliance with operating agreements.

Variable energy content curve (VECC) — The January through July portion of the energy content curve. The VECC is based on the expected amount of spring runoff.

Water budget — A volume of water to be reserved and released during the spring if needed to assist in the downstream migration of juvenile salmon and steelhead.

Water rights — Priority claims to water. In western States, water rights are based on the principle "first in time, first in right," meaning older claims take precedence over newer ones.

Watt — A measure of the rate at which energy is produced, exchanged, or consumed.

Wheeling — Using transmission facilities of one system to transmit power of and for another system.