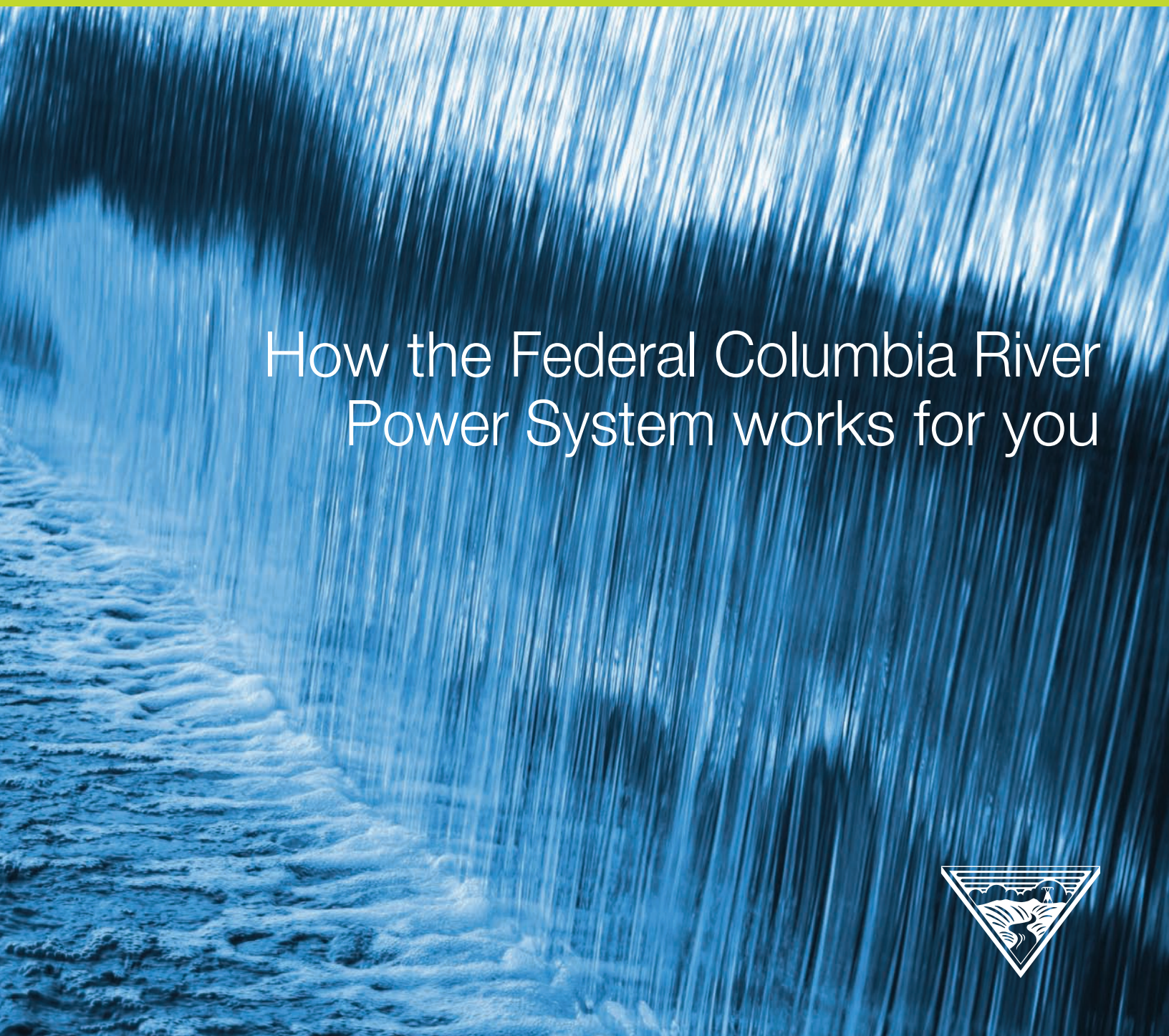
BONNEVILLE POWER ADMINISTRATION

Hydropower



How the Federal Columbia River Power System works for you

"River you can ramble where the sun sets in the sea, but while you're rambling river, you can do some work for me. Roll Columbia, roll."

— Woody Guthrie

High in the Rocky Mountains near Glacier National Park, snow melts into a swelling creek and swirls downstream. Within days, those droplets are part of the Pacific Ocean.

But as that water rushed downstream through the Columbia Basin, it worked hard. It carried juvenile salmon seaward, floated grain barges toward ships taking goods to world markets and turned giant turbines at dams. It might even have doused one very cold windsurfer.

The Columbia River defines much of what is unique about the Northwest. It has made the deserts bloom thanks to irrigated agriculture. It provides a great highway for Northwest goods traveling to the Pacific Rim. Its fish and wildlife are sacred to many of the region's tribes and important to others as well. Its scenic beauty and recreational areas call people here from all over the world. And the river and its tributaries have given the Northwest some of the nation's cheapest and cleanest electric power.

The Columbia is not the nation's longest or biggest river, but it produces by far the lion's share of hydropower in the United States. While most of the nation is powered by coal and natural gas, the Northwest runs primarily on water. Federal and nonfederal dams in the Pacific Northwest produce about half of the region's electric energy.

The U.S. Army Corps of Engineers and the Bureau of Reclamation own and operate 31 dams in the Federal Columbia River Power System. The Bonneville Power Administration markets wholesale power generated at these dams at cost, primarily to the region's consumer-owned utilities. In good water years, surplus power is sold in and outside the region, and the revenues from these sales help keep Northwest electricity rates low.

Hydropower fuel: renewable, clean and free

Hydropower is a renewable resource; its fuel is naturally replenished by nature. The Columbia River Basin's annual snowpack and runoff fuel the Northwest's hydropower system. The Columbia carries the fourth largest volume of runoff in North America.

Unlike coal, oil, nuclear or natural gas power plants, hydropower plants do not consume their fuel; the water simply spins a turbine as it passes downstream, unchanged. Every drop

Grand Coulee Dam is the largest producer of hydroelectric power in the United States and the third largest such facility in the world. It irrigates over half a million acres of Columbia River Basin farm land and provides abundant wildlife and recreation areas.

of water produces electricity at each dam on its path to the ocean as it flows through the turbines.

Because they are powered by water, dams do not produce emissions like a fossil-fuel burning resource, making the Northwest's power system the cleanest in the nation. Replacing even 1,000 average megawatts of hydropower with a carbon dioxide-emitting, natural gas plant would bring more than 4 million metric tons of CO_2 into the Northwest each year. All together, the Northwest's federal and nonfederal dams produce 12,000 megawatts of firm hydropower, thereby avoiding roughly 50 million metric tons of carbon emissions each year.

And since the fuel source — water — falls without charge from the sky, hydropower is one of the least expensive sources of energy. Most Northwest residents have a significantly lower electric bill than residents in other parts of the country. At the same time, the region's federal hydro system pays its own way; its costs are paid from sales of electric power, not from taxes.

The many uses of the Columbia River

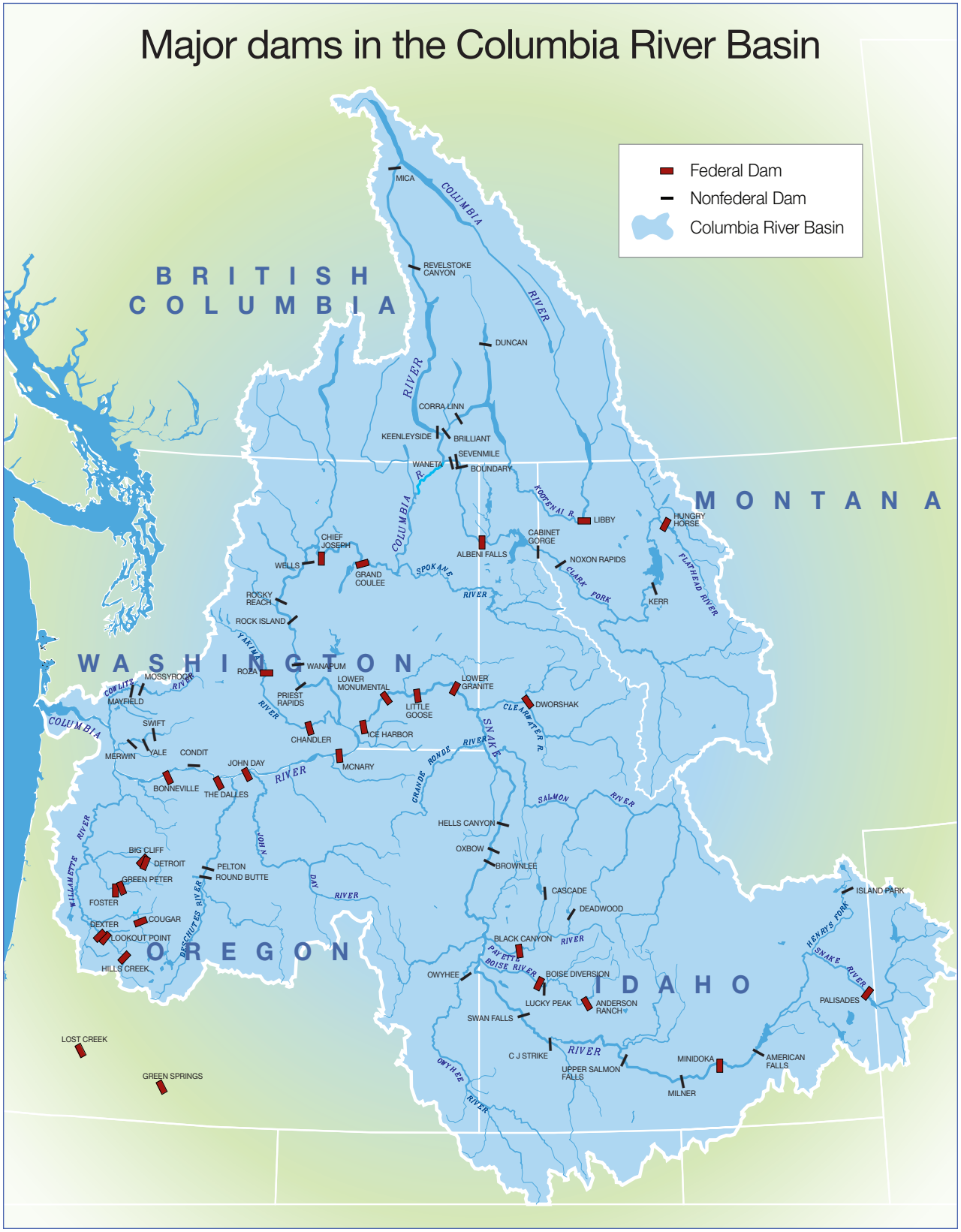
Congress authorized construction of each of the federal dams for one or more specific purposes — to control floods, provide irrigation, produce power, allow safe navigation on the river and provide public recreation.

Windsurfing has become a popular activity in the Columbia River Gorge near Hood River, Ore.

To assure all these needs are constantly and efficiently met, along with protection of fish, the Corps and Reclamation operate Columbia River system dams to produce optimal storage and release of water to meet needs year round. In addition, to maximize their values, federal and nonfederal dams are operated as a single system under a coordination agreement.

The following examples show how carefully the system must be choreographed to meet competing needs.

- **Flood control:** The Corps determines how much empty space each reservoir must maintain each month through winter and spring to capture potential flood waters.
- **Irrigation:** About 6 percent of the Columbia's flow is used for irrigation (some of which returns to the river downstream of irrigated land).
- **Navigation:** Dams that provide river navigation must maintain reservoirs deep enough to float river barges at all times.


Major dams in the Columbia River Basin
Federal Dam
Nonfederal Dam
Columbia River Basin
BRITISH COLUMBIA
MONTANA
WASHINGTON
OREGON
IDAHO
MICA
REVELSTOKE CANYON
DUNCAN
CORRA LINN
KEENLEYSIDE
BRILLIANT
SEVENMILE
WANETA
BOUNDARY
LIBBY
HUNGRY HORSE
CABINET GORGE
ALBENI FALLS
NOXON RAPIDS
KERR
CHIEF JOSEPH
WELLS
GRAND COULEE
ROCKY REACH
ROCK ISLAND
WANAPUM
ROZA
PRIEST RAPIDS
LOWER MONUMENTAL
LOWER GRANITE
LITTLE GOOSE
DWORSHAK
ICE HARBOR
CHANDLER
MCNARY
JOHN DAY
THE DALLES
BONNEVILLE
CONDIT
YALE
MERWIN
SWIFT
MAYFIELD
MOSSYROCK
BIG CLIFF
DETROIT
GREEN PETER
FOSTER
DEXTER
LOOKOUT POINT
HILLS CREEK
COUGAR
PELTON ROUND BUTTE
LOST CREEK
GREEN SPRINGS
HELLS CANYON
OXBOW
BROWNLEE
CASCADE
DEADWOOD
BLACK CANYON
OWYHEE
BOISE DIVERSION
LUCKY PEAK
ANDERSON RANCH
SWAN FALLS
C J STRIKE
UPPER SALMON FALLS
MINIDOKA
MILNER
AMERICAN FALLS
PALISADES
ISLAND PARK
COLUMBIA RIVER
KOOTENAI R.
SPOKANE RIVER
CLARK FORK
FLATHEAD RIVER
CLEARWATER R.
SNAKE RIVER
GRANDE RONDE RIVER
SALMON RIVER
JOHN DAY RIVER
DESCHUTES RIVER
WILLAMETTE RIVER
COWLITZ RIVER
YAKIMA RIVER
PAYETTE RIVER
BOISE RIVER
HENRYS FORK
OWYHEE RIVER

- **Fish and wildlife:** System operators assure water at key salmon spawning grounds stays deep enough through winter and spring to avoid drying out nests of salmon eggs. And the entire system is operated, especially in spring and summer, to help young salmon grow and migrate safely to and from the ocean.
- **Hydropower:** Operators use reservoirs to adjust the river's seasonal flow patterns to more closely match electricity use, so long as these adjustments are consistent with other river uses.
- **Recreation:** Thousands of people enjoy year-round activities that include fishing, hiking, camping, boating, windsurfing and kayaking.

How dams produce electricity

The force of falling water produces hydropower. As water funnels through the dam into a powerhouse, the pressure of that falling water turns a large turbine that looks like a ship's propeller. The spinning turbine turns a shaft that rotates a series of magnets past copper coils in a generator to create electricity. From the powerhouse, transmission lines carry electricity to communities, where local utilities distribute it to their consumers.

Projects (dams and their reservoirs) fall into two categories: run-of-river and storage. Run-of-river projects were developed primarily for navigation and hydropower generation. Water runs through these projects essentially as it arrives at each dam. The larger reservoirs of storage projects hold water from season to season to be released for various system needs. Generally, storage reservoirs are drawn down in winter and early spring to provide power and to make room for heavy spring runoff and prevent flooding downstream. In April through August, water is stored and then released to aid fish migration.

Water released from storage dams near headwaters flows through all the dams downstream, creating electricity every time it passes through another turbine. Some impounded water is drawn from the river system to irrigate farmland.

Columbia reservoir storage limited

The ability to store water is limited by topography. There are eight major storage reservoirs in the federal Columbia River system, three of which are in Canada. Libby Dam is in the United States, but its reservoir backs up into Canada. Other federal dams with major storage reservoirs include Dworshak, Hungry Horse, Grand Coulee and Albeni Falls. Each dam has specific rules for use.

The total water storage in the Columbia River Basin represents only about 30 percent of an average year's runoff. In comparison, dams on the Missouri River system can hold two to three times the system's annual runoff, giving operators on that river system much more flexibility in responding to nature's vagaries.

Columbia River system operators must make full use of the available storage to enhance power generation while assuring needs for fish protection, irrigation, flood control and other river uses are met.

Making hydro work for fish

To make downstream migration safer for salmon and steelhead, the dams have been reconfigured and their operation revamped in recent years. The federal goal is to safely pass 96 percent of spring chinook and steelhead and 93 percent of subyearling fall chinook through each dam each year. Most fish now use non-turbine routes through the dams.

It's working. Young salmon now survive their downstream trip through the hydro system at rates as good as or better than in the 1960s, when there were only four dams in the lower Columbia and Snake rivers.

The smooth green water of a fish weir lets young salmon slide over a dam in the surface water they prefer. (U.S. Army Corps of Engineers photo)

In the last decade, the Corps has installed new, safer fishways in all eight federal dams that lie in the major migratory path of Columbia River salmon. Six now feature spillway weirs that let fish slide smoothly over a dam in the surface water, where they naturally swim.

Virtually 100 percent survive passage through the "corner collector" at Bonneville Dam. And, at The Dalles Dam, an 830-foot "spillwall" guides young salmon quickly to the deepest, safest part of the river downstream. Most dams also feature fish screens and bypass systems that direct fish away from turbines.

Fish protection gets top priority after flood control for hydro system operation. During the spring and summer, fish-laden water is spilled through spillways, allowing the fish to avoid a dam's turbines. Water also is released from reservoirs to help speed their travel between dams. This is called flow augmentation. Some fish, especially in low water years, are transported around dams in barges.

The whole point of helping fish downstream, of course, is to help assure more return as adults to spawn. All eight lower Columbia and Snake river dams were originally built with fish ladders that have been very successful. Adult salmon swim upstream through the fish ladders at a success rate of 98 percent at each dam.

Hydro operators also help fish by adjusting or limiting changes in water levels through most of the year. For example, Vernita Bar in the mid-Columbia is a major nursery for chinook salmon eggs from fall through May. During this time, BPA, Reclamation and Grant County Public Utility District manage streamflows to keep the redds (fish nests) from being dewatered and drying out the fish eggs.

One renewable supports another

In the last decade, the hydropower system has picked up a new function — balancing variations in the Northwest's burgeoning wind power resource. The amount of power entering the transmission grid must equal the amount being consumed at all times. Because wind

Why hydropower is valuable

Hydropower has a number of special attributes that give it enormous value as an energy resource.

1. **Hydropower is renewable.** It is the nation's most abundant source of renewable energy.
2. **Hydropower is efficient.** Hydropower plants at dams convert about 90 percent of the energy in falling water into electrical energy. By comparison, fossil-fueled plants lose more than half of the energy content of their fuel as waste heat and gases.
3. **Hydropower is clean.** Hydropower produces no carbon dioxide, nitrous oxides or other air emissions. There are no liquid or waste products or gases that contribute to air pollution, acid rain or global warming.
4. **Hydropower is secure.** Water from our rivers is largely a domestic resource that is not subject to disruptions from foreign suppliers, cost fluctuations in power markets, international political crises or transportation outages.
5. **Hydropower is flexible.** Hydropower production can be increased or decreased very quickly to match variations in demand for electricity.
6. **Hydropower supports other renewable resources.** Hydropower can back up wind when it is not blowing and back down when it is. This helps meet a fundamental requirement of an electric grid, which is that power consumed must match the power supplied at all times to keep the system stable.
7. **Hydropower is low-cost.** Essentially, the fuel — water — is free, which keeps operating costs low and immune to fluctuations in fuel prices. Since the region's hydropower dams were built years ago when construction costs were low, over the years they have consistently provided among the nation's cheapest electricity.
8. **Hydropower keeps electricity rates lower.** In years of ample runoff, hydropower plants produce energy in excess of Northwest needs. This surplus energy can be sold outside the region, bringing in "outside" revenues, thus reducing power costs within the Northwest.

power is variable and difficult to predict, it must be backed up with another resource such as hydropower.

Within operating limits for the river's other uses, hydropower can respond quickly to shifts in wind power output, and the dams have been instrumental in managing large swings in wind power. BPA is using hydropower to support wind power and is adapting its power and transmission practices to include other techniques to support the wind resource as it continues to grow.

The weather reigns

River operations depend on the water cycle — evaporation, condensation, precipitation and runoff. In a typical year, operations can be divided into three seasons.

- **September through December** (the fixed drawdown season): The goal is to ensure that reservoirs reach specific elevations to ensure sufficient electricity for winter needs. Beginning in October, flows at Grand Coulee and Chief Joseph dams are managed to keep the Vernita Bar salmon redds covered. In November, flows at Bonneville Dam are managed to enhance chum salmon spawning and rearing.
- **January into April** (the variable drawdown season): Operations are guided by forecasts of runoff volume. Reservoirs are drafted to provide flood control space and produce power, while sufficient water must be available early in April to help propel the spring migration of juvenile anadromous fish to the ocean. Vernita Bar and chum operations continue.
- **April through August** (the refill season): The hydro system is operated to enhance the survival of summer and fall juvenile anadromous fish. Operations for flood control continue. Meanwhile, power operations remain challenging in summer as, thanks to air conditioning, the region has become a dual-peaking system — winter and summer.

Each year is unique, and operators must make adjustments depending on the amount and shape of the runoff. Climate change may ultimately shift these seasonal operations by weeks or months.

During dry years with little snowpack, for example, it may be difficult to refill reservoirs, and there may not always be enough water to meet all demands on the system. When there is little runoff and storage is either low or designated for nonpower requirements such as fish, BPA purchases power on the market to meet the needs of Northwest utilities that rely on federal power supply.

Making it all work

Following all of the laws and guidelines, river operators must assure that adequate storage space is available for flood control; that enough water flows through the dams to support fish migration and nests, meet electric power demand and provide back-up reserves for wind.

Federal Columbia River Power System operation is a unique collaboration among three federal

Many needs, one coordinated plan

While the operation of the Columbia River hydro system is the responsibility of many dam owners and operators who have many needs, planning studies are made as if the total coordinated system had a single owner. This coordination maximizes the benefits of the dams and reservoirs. A great deal of collaborative planning goes into this. Operations are guided by a complex and interrelated set of laws, treaties, agreements and guidelines. Below are a few significant factors in operations planning.

- The 1964 Columbia River Treaty between the U.S. and Canada first called for construction of storage projects in Canada, and now calls for operating plans for the Columbia River six years in advance and subsequently for every operating year. Within each year, one or more Special Operating Agreements address fishery and other nonpower needs. BPA and the Corps represent the U.S. in planning and carrying out Columbia River Treaty operations, and B.C. Hydro represents Canada.
- The 1964 Pacific Northwest Coordination Agreement, a contract among federal agencies, investor-owned utilities and consumer-owned utilities who own generation from the Columbia River, calls for annual planning to accommodate all the purposes of the Columbia River hydro projects. The agreement enables the region's power producers to optimize system reliability and power production after giving priority to nonpower objectives.
- The 1974 Endangered Species Act protects those species classified as threatened or endangered. In the Columbia Basin, endangered or threatened species include salmon and steelhead. River operations must emphasize their protection and recovery to sustainable runs.
- The 1980 Pacific Northwest Electric Power Planning and Conservation Act created an eight-member Northwest Power and Conservation Council that prepares a Columbia Basin Fish and Wildlife Program to protect, mitigate and enhance fish and wildlife affected by hydropower development. This plan is not limited to threatened or endangered species — it places additional requirements on hydro operations to support and protect all fish and wildlife affected by hydropower development.

agencies working on behalf of the Pacific Northwest who act as stewards of this great resource — BPA, the U.S. Army Corps of Engineers and Bureau of Reclamation. They are assisted by the U.S. Fish & Wildlife Service and the National Marine Fisheries Service in protecting natural resources.

The social, economic and environmental demands that society has placed on the system are heavy, but the Bonneville Power Administration and its fellow federal agencies are committed to meeting those demands in an economically and environmentally responsible way.

In sum, federal hydropower is a public resource operated for the public good.

For additional information, please call 503-230-INFO (4636) in Portland, or toll free 1-800-622-4520 outside of Portland.

The Columbia River and its tributaries have given the Northwest some of the nation's cheapest and cleanest electric power.

Bonneville Power Administration

P.O. Box 3621, Portland, OR 97208

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