CHAPTER 3.0 AFFECTED ENVIRONMENT

3.1 Project Area Description

The Columbia River Water Management Act created the Management Program to manage water within the portion of the Columbia River Basin in the state of Washington from the U.S.-Canada border to the river mouth at the Pacific Ocean (Figure 3-1). The VRA and information system portion of the legislation only applies to the portion of the basin between the Canadian border and Bonneville Dam. Below Bonneville Dam, the character of the Columbia River changes from a flowing river to a tidally influenced river. For this EIS, the project area is the portion of the Columbia River Basin within the state of Washington. Because most of the projects proposed under the Management Program are likely to be located in the area of eastern Washington east and south of the Columbia River, the affected environment focuses on that area.

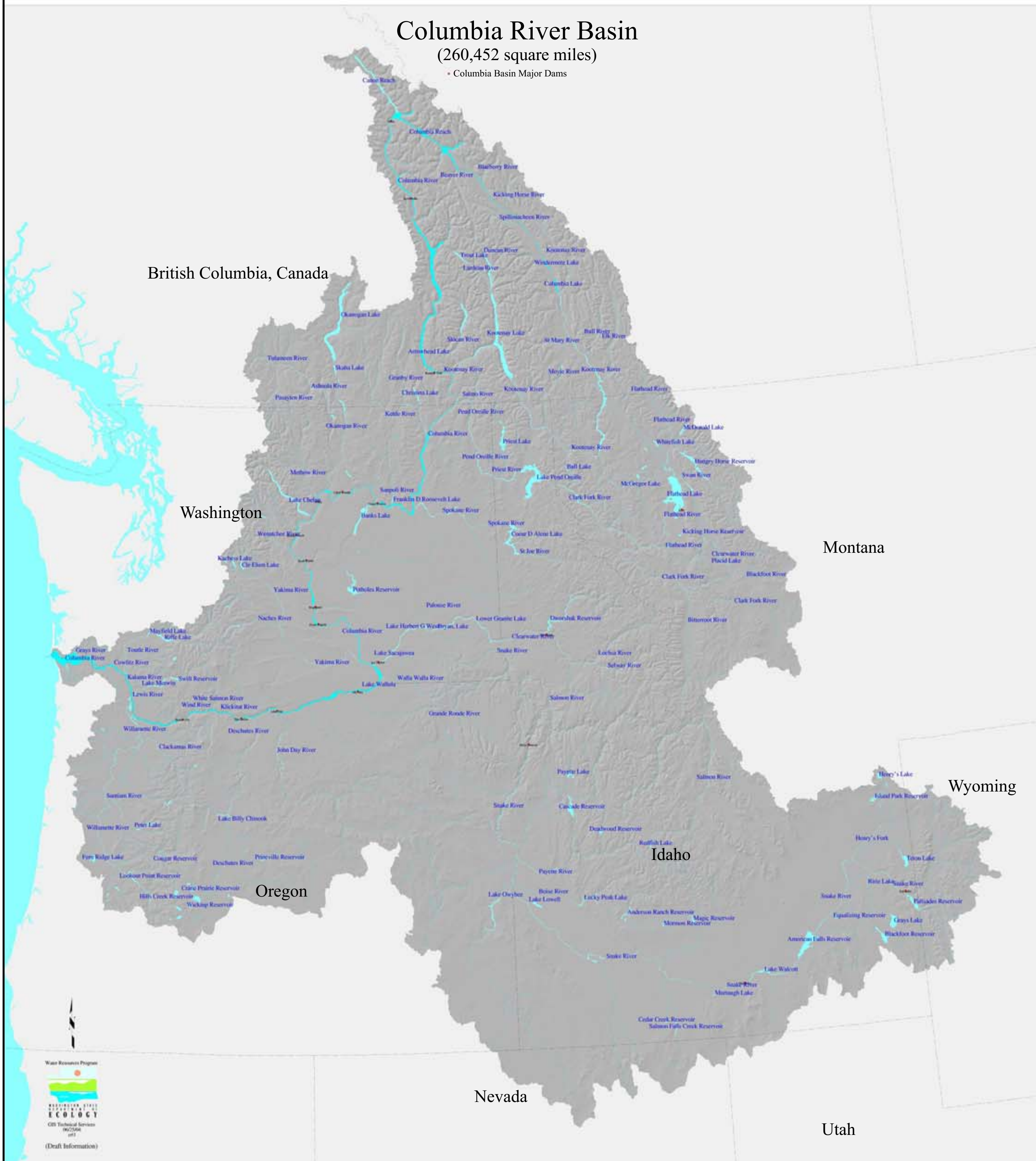
Section 3.1 presents a general description of the project area. Sections 3.2 through 3.13 provide more detailed information about specific aspects of the project area.

3.1.1 Columbia River Basin

The Columbia River watershed extends from the Canadian Rockies in British Columbia to the Pacific Ocean and encompasses portions of the states of Washington, Oregon, Idaho, Montana, Wyoming and Nevada in addition to portions of the province of British Columbia. The majority of the Columbia River Basin in Washington is arid to semi-arid. Dominant vegetation in the area is shrub-steppe in the lowlands and forest in mountainous areas. At the Washington-Oregon border, the Columbia River turns to flow west through an entrenched channel through the Cascade Range known as the Columbia River Gorge. The eastern end of the Gorge is arid and becomes increasing humid to the west, with vegetation changing from shrub-steppe to coniferous forest.

Most of the project area is farmed or ranched. A wide variety of crops are raised including potatoes, sugar beets, hops, fruit, vegetables, mint, wine grapes, hay, corn, wheat, barley, and lentils. Most of these crops are irrigated. A variety of livestock are also raised in the project area. Logging was historically important in the mountains that fringe the basin and in the Columbia River Gorge area, and forest management practices are still active in many areas.

The Columbia River is home to a rich variety of salmon species and fish and wildlife populations. Historically salmon were very abundant in the basin and were the foundation of the diets, culture, and economy of native people (National Research Council 2004). Salmon numbers have declined significantly since the late 1800s and several species and populations are listed as threatened or endangered under the Endangered Species Act (ESA). The construction of dams and land use changes have blocked access to habitat and altered streamflows and vegetation, contributing to the decline of salmon.



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SOURCE: Washington Department of Ecology, 2006.

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FIGURE 3-1

COLUMBIA RIVER BASIN

COLUMBIA RIVER WATER MANAGEMENT PROGRAM EIS

WASHINGTON

In Washington, the Columbia River Basin includes 25 counties (see Table 3-1 and Figure 3-2). Major cities in the Columbia River Basin in Washington include Spokane, Moses Lake, Wenatchee, Yakima, Richland, Pasco, Kennewick, Walla Walla, Vancouver, and Longview. The last two cities are located downstream of Bonneville Dam.

Table 3-1. Washington Counties in the Columbia River Basin

Adams	Klickitat
Asotin	Lincoln
Benton	Okanogan
Chelan	Pacific*
Clark*	Pend Oreille
Columbia	Skamania
Cowlitz*	Spokane
Douglas	Stevens
Ferry	Wakiakum*
Franklin	Walla Walla
Garfield	Whitman
Grant	Yakima
Kittitas	

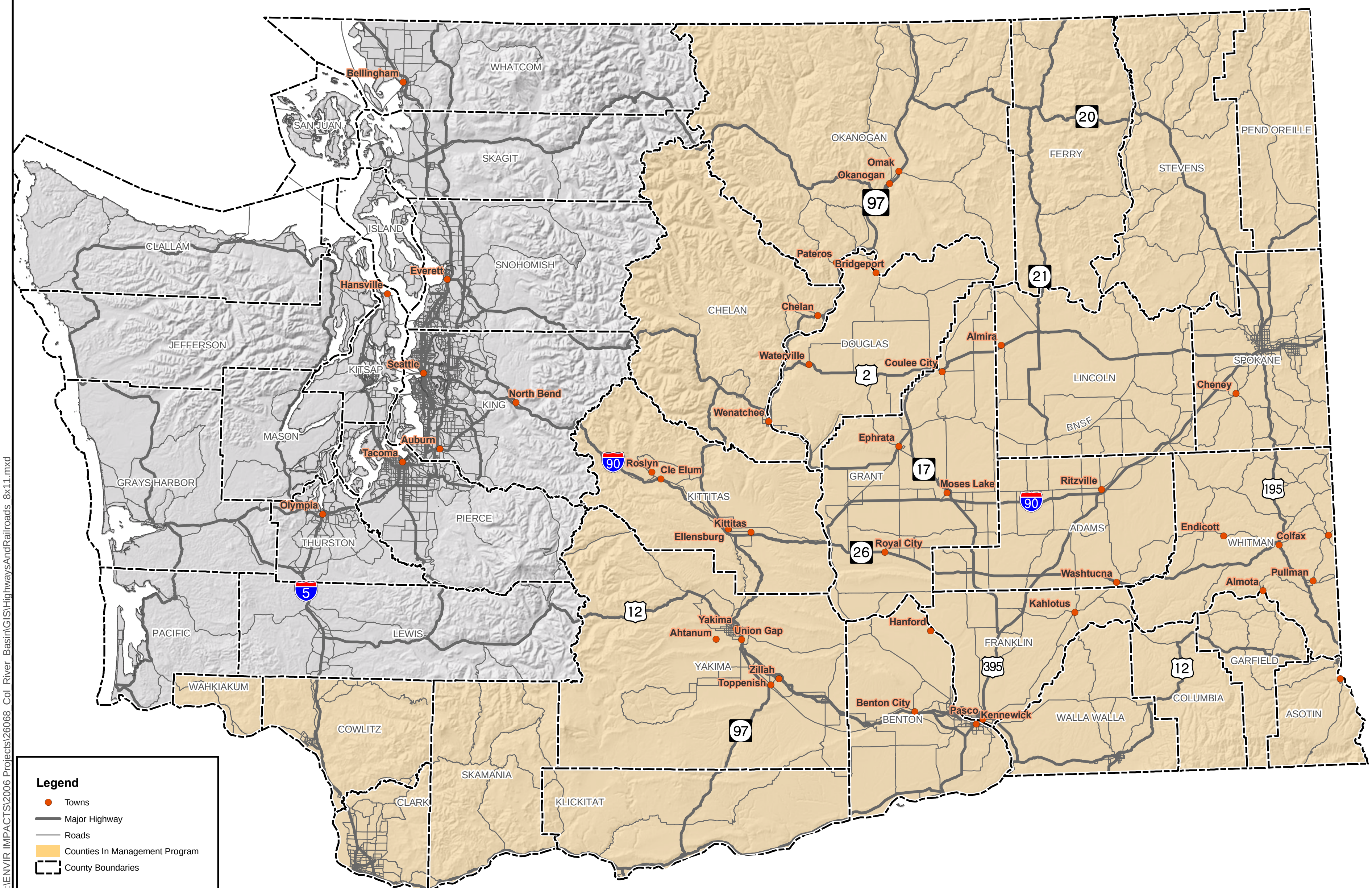
*These counties are downstream of Bonneville Dam

For purposes of water management, the state of Washington has designated the major drainage basins in the state as Water Resource Inventory Areas (WRIA) (Figure 3-3). Of the 62 WRIAs in the state, 39 are located within the Management Program project area. In 1998, the Washington Legislature established a process for local interests within the WRIAs to develop watershed plans to manage water resources. Many of the WRIAs in the Columbia River Basin have participated in the planning process and have completed watershed plans (Figure 3-4). The WRIAs currently served by the Columbia Basin Project are not included in the WRIA planning process.

3.1.2 Water Development in the Columbia River Basin

The Columbia River has been extensively modified for a variety of beneficial uses including flood control, hydropower, navigation, irrigation, and recreation. Major development began in the 1930s with the construction of Bonneville Dam on the lower Columbia River east of Portland, Oregon, and Grand Coulee Dam on the upper river west of Spokane, Washington. Although constructed to serve multiple purposes, the driving force behind the development of Columbia River dams was hydropower, and to a lesser extent, flood control. With its solid rock channel, low levels of silt, and relative steepness, the Columbia River was well suited for large-scale hydropower development. World War II increased pressure to further tap the river's hydroelectric power production potential, and between 1944 and 1945, Congress authorized several water projects in the basin. In the five years following the war, Chief Joseph, Albeni Falls, Libby, John Day, and The Dalles Dams were all authorized (Volkman 1997; National Research Council 2004).

Figure 3-5 shows the primary dams constructed within the Columbia River Basin. Support for federal dams in the Columbia River Basin declined during the 1950s, but licenses were issued to county public utility districts to construct Priest Rapids, Rocky Reach, Wanapum, and Wells Dams (Figure 3-5).



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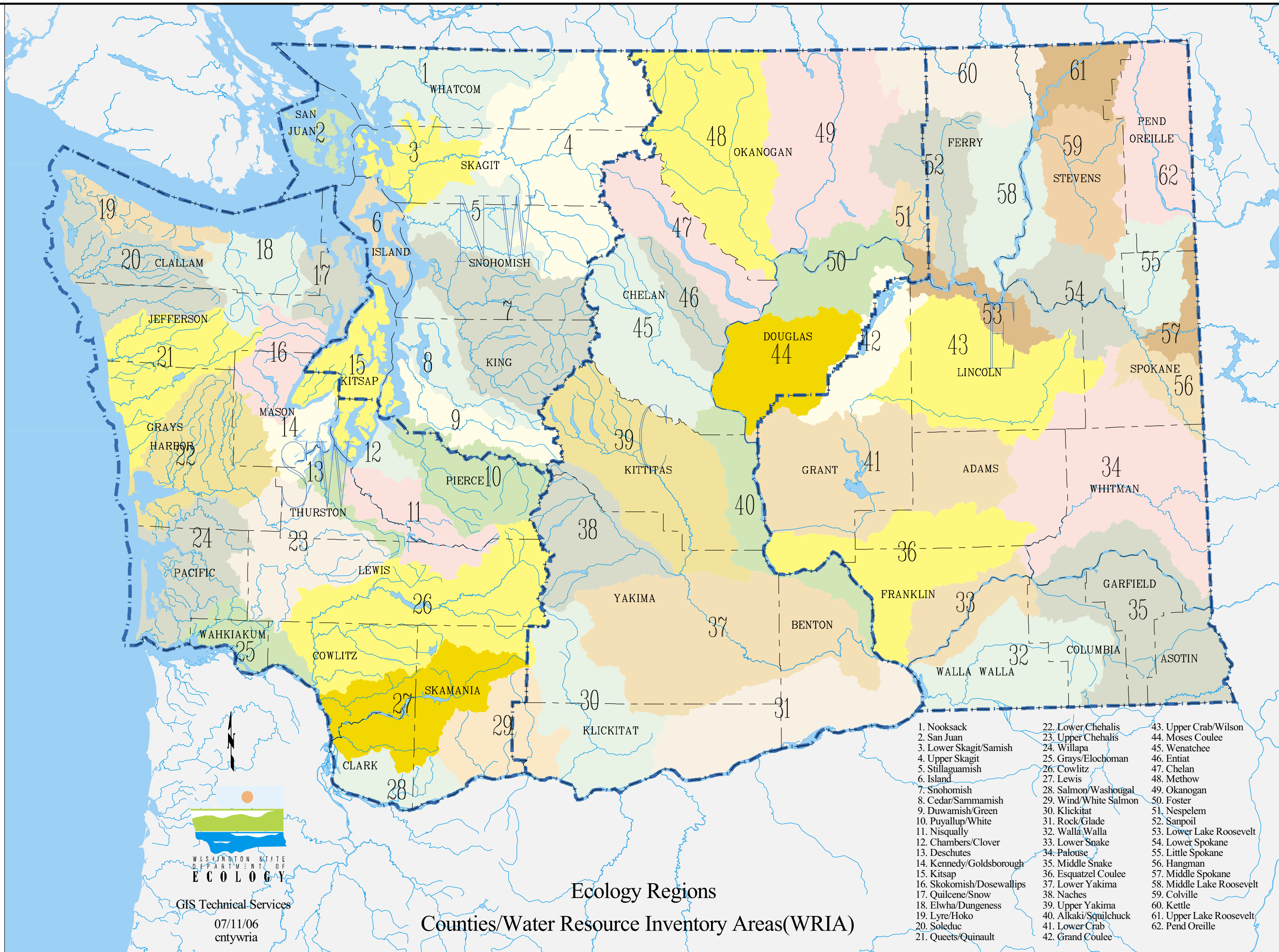
SOURCE:

FIGURE 3-2

MAJOR CITIES AND COUNTIES IN THE PROJECT AREA

COLUMBIA RIVER WATER MANAGEMENT PROGRAM EIS

WASHINGTON



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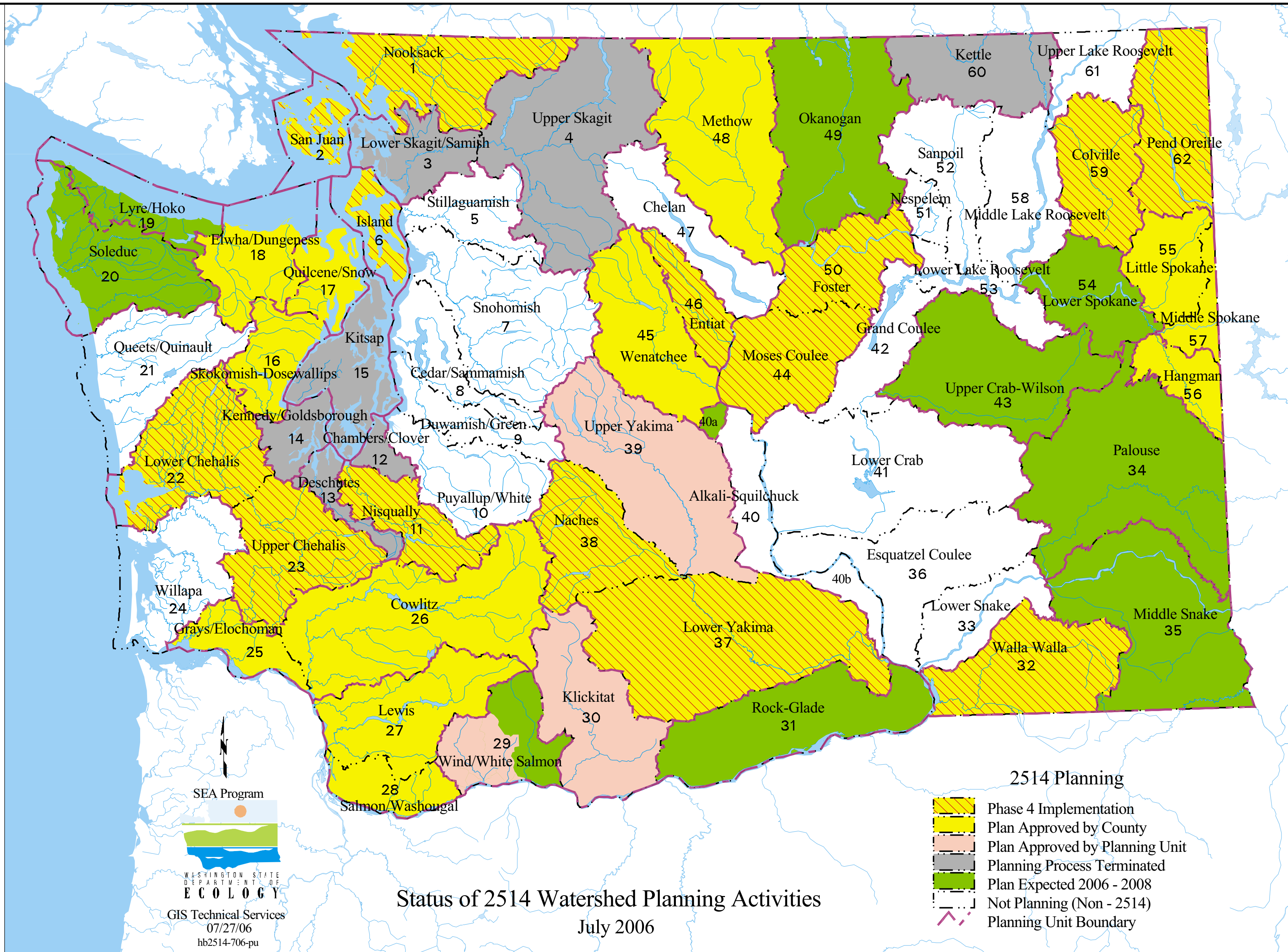
SOURCE: Washington State Department of Ecology, 2006.

FIGURE 3-3

WATER RESOURCE INVENTORY AREAS (WRIA) IN WASHINGTON

COLUMBIA RIVER WATER MANAGEMENT PROGRAM EIS

WASHINGTON



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SOURCE: Washington State Department of Ecology, 2006.

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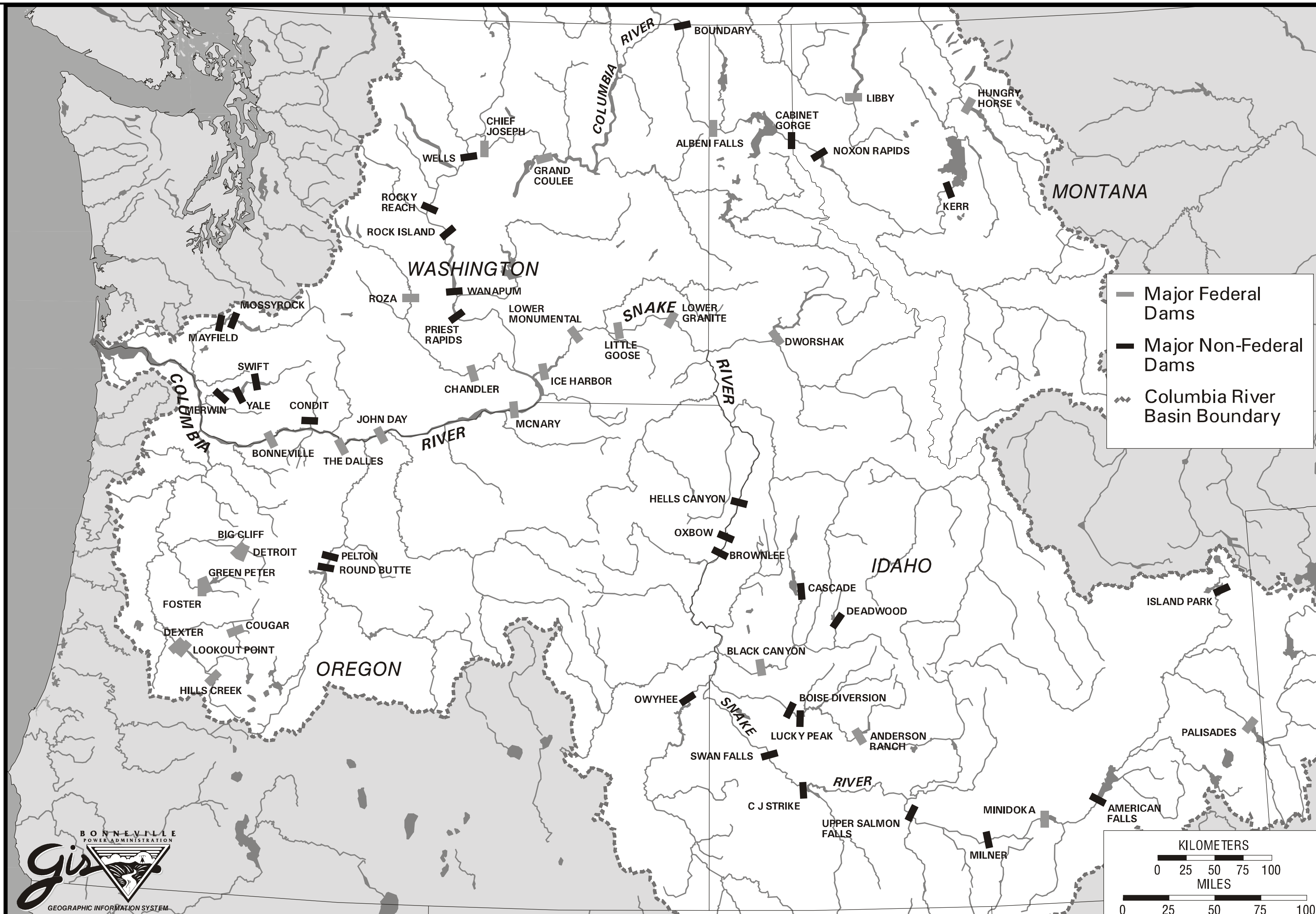
FIGURE 3-4

WATER RESOURCE INVENTORY AREAS WITH COMPLETED WATERSHED PLANS

COLUMBIA RIVER WATER MANAGEMENT PROGRAM EIS

WASHINGTON



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SOURCE: Bonneville Power Administration.

FIGURE 3-5

MAJOR DAMS IN THE COLUMBIA RIVER BASIN

COLUMBIA RIVER WATER MANAGEMENT PROGRAM EIS

WASHINGTON

Upstream dams that augmented storage and power production capabilities were constructed pursuant to the Columbia River Treaty signed between Canada and the U.S. in 1961. These dams included Libby Dam in Montana and Arrow Lakes, Duncan, and Mica Dams in Canada. The treaty focused primarily on addressing two main water uses: hydropower and flood control (National Research Council 2004). Hydropower dams in the Columbia Basin are part of the Federal Columbia River Power System (FCRPS) and are managed and operated by Bonneville Power Administration (BPA), Reclamation, and the Corps of Engineers. The Federal Columbia River Power System is a coordinated system for operating the dams on the river to maximize power production while meeting the other requirements of treaties, federal flood control statutes, and fish and wildlife statutes (BPA 2001).

Grand Coulee Dam is managed by Reclamation and was authorized for both hydropower and irrigation. Because of World War II, work on the irrigation system was delayed and the first project water deliveries did not occur until 1952. Irrigation water is pumped from Grand Coulee Dam to Banks Lake to supply the Columbia Basin Project. The Columbia Basin Project irrigates approximately 671,000 acres in an area southeast of the Columbia River extending to Pasco, Washington, at the junction of the Columbia and Snake Rivers.

Lake Roosevelt, the reservoir formed by Grand Coulee Dam, extends approximately 150 miles northeast from the dam toward Canada. Lake Roosevelt has a capacity of 9.4 million acre-feet and an active capacity of 5.2 million acre-feet. Most of the south and east shore of the lake is managed as the Lake Roosevelt National Recreation Area.

3.1.3 Management of the Columbia River

The Columbia River has been developed into a highly regulated river system. A variety of federal and state agencies and private utilities operate dams on the river for a variety of uses. In addition, there are international and tribal interests involved in managing the river. Several treaties, statutes, and management agreements guide river management and operations (Federal Columbia River Power System 2001).

The major owners and/or operators of water developments in the Columbia River Basin and their primary roles are shown in Table 3-2. Other agencies that act in regulatory or advisory capacities are presented in Table 3-3.

Table 3-2. Columbia River Water Managers

Owner/Operator	Primary Role
U.S. Army Corps of Engineers	Federal project operator Power generation, flood control, navigation Operates Columbia River Treaty reservoirs
U.S. Bureau of Reclamation	Federal project operator Power generation, irrigation Columbia Basin Project
Irrigation Districts (private)	Irrigation
Public and Private Utilities	Power generation and distribution
British Columbia Hydro and Power Authority	Flood control, power generation
Bonneville Power Administration	Power marketing, transmission facilities Funds fish and wildlife mitigation programs under the Northwest Power Planning and Conservation Act

Table 3-3. Agencies with Regulatory or Advisory Capacities

Agency	Primary Role
Federal Energy Regulatory Commission	Regulates interstate activities of electric and natural gas utilities and non-Federal hydropower producers
U.S. Department of State	Interacts with Canada on international treaty matters
National Marine Fisheries Service and U.S. Fish and Wildlife Service	Enforces Endangered Species Act and implements recovery plans
Environmental Protection Agency	Regulates water quality
State resource agencies	Water rights, land use, fish and wildlife management

Several native tribes have reservations and historic use areas in the Columbia River Basin. The native tribes have historic and treaty rights to take fish from the Columbia River and its tributaries, and have treaty rights to fish, hunt, and gather in usual and accustomed places. The federal government has a trust responsibility to provide services that protect and enhance the treaty rights of native people. Tribal rights and uses of the Columbia River Basin are described in more detail in Sections 3.6.1.3 and 3.10. The tribes implement fish and wildlife management programs in the Columbia River Basin and participate in river governance decisions.

Operation of the federal reservoirs is regulated by the authorizing legislation, which specifies the purpose of each reservoir. Federal flood control statutes also regulate uses of reservoirs authorized for flood control. Other laws and agreements that influence Columbia River Water Management are shown in Table 3-4.

Table 3-4. Laws and Agreements Influencing River Management

Law or Agreement	Effect on River Management
Endangered Species Act	A Biological Opinion has been developed to recover listed salmon species, but is the subject of on-going legislation. The Biological Opinion includes increased and more carefully timed flows, increased spill and reservoir drawdown.
Columbia River Treaty	The treaty between the United States and Canada affects flood control and hydropower production.
Pacific Northwest Coordination Agreement	The Coordination Agreement establishes a coordinated planning process to implement the Columbia River Treaty. It coordinates Canadian storage operations with federal and non-federal project operations.
Columbia Storage Power Exchange and the Canadian Entitlement Allocation Agreements	The Agreements divide the power benefits from the Columbia River Treaty between the federal and non-federal power generators in the United States.
Non-Treaty Storage Agreement	The Agreement allocates the additional power generated at Mica Dam that is not part of the Columbia River Treaty.
Pacific Northwest Electric Power Planning and Conservation Act, 1980	The Northwest Power and Conservation Council, composed of representatives appointed by the governors of Montana, Idaho, Washington and Oregon, developed a Fish and Wildlife Program and a Regional Electric Power and Conservation Plan that changed how the Coordinated Columbia River System is operated.

To implement these varied management objectives, the river system is operated as the Coordinated Columbia River System. Implementation of many of the components of the Management Program will require coordination with the various managing agencies to avoid conflicting with the Coordinated Columbia River System.

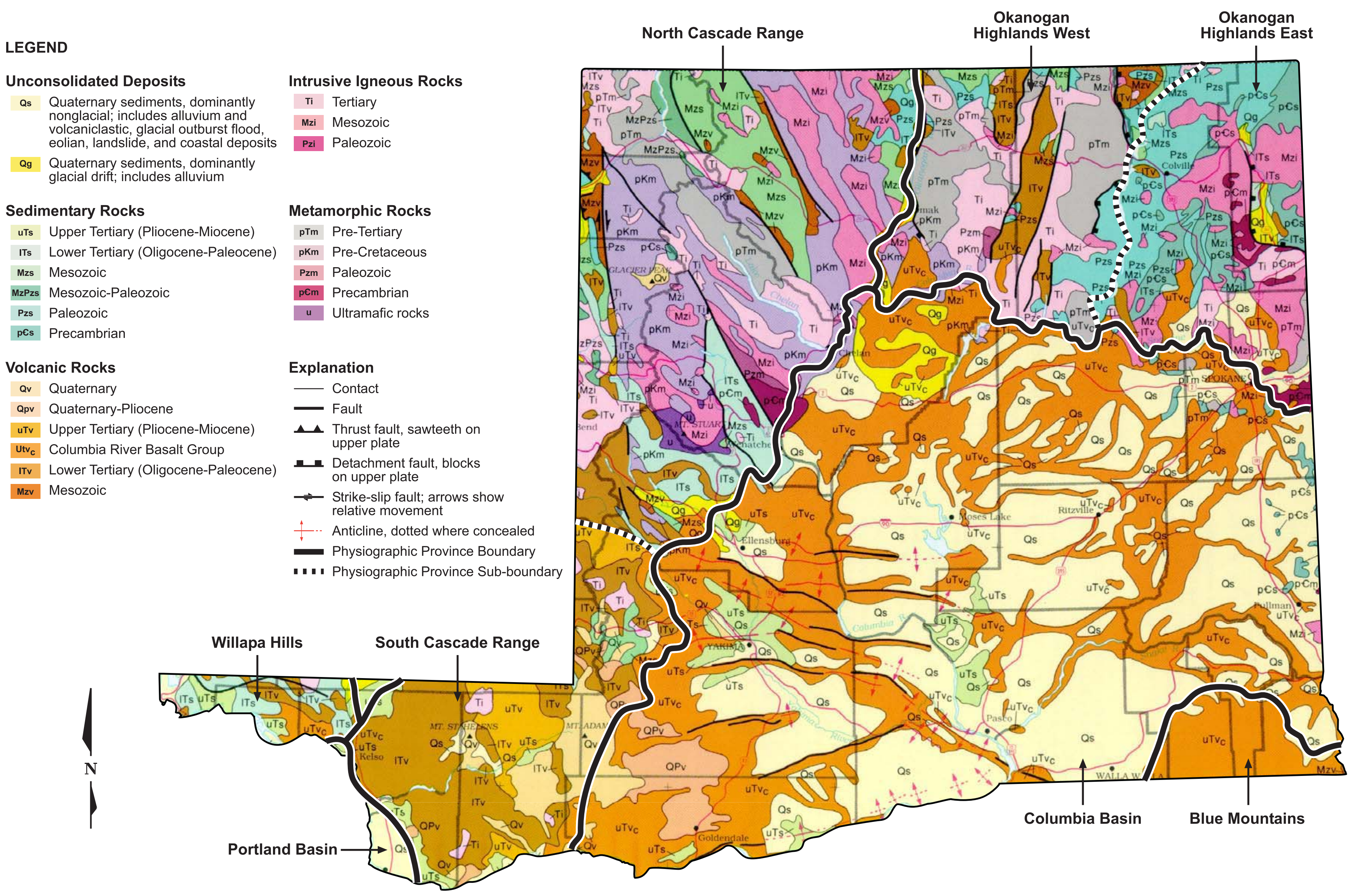
The following sections describe the elements of the environment potentially affected by the Management Program.

3.2 Earth

3.2.1 Geology and Physiography

The project area contains three major physiographic provinces (Columbia Basin, Okanogan Highlands, and Blue Mountains) and small portions of the Southern Cascades physiographic province. Figure 3-6 is a map of the geology and physiographic provinces in the Columbia Basin. The Washington State Department of Natural Resources (DNR) (2001) describes these provinces based on work by Lasmanis (1991), and the description below is based on the DNR summary.

The Columbia Basin physiographic province is characterized by incised rivers, extensive plateaus, and anticlinal ridges (ridges created by tilting and uplift) rising to 4,000 feet above sea level (DNR 2001). The geology of the plateau region is dominated by basalt flows that make up the Miocene-aged (about 5 million to 24 million years ago) Columbia River Basalt Group (Ecology and WDFW 2004).



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SOURCE: Golder Associates, 2006.

FIGURE 3-6

GEOLOGY AND PHYSIOGRAPHY OF THE PROJECT AREA

COLUMBIA RIVER WATER MANAGEMENT PROGRAM EIS

WASHINGTON

The Columbia River Basalt Group is composed of more than 300 lava flows, although only a few flows are exposed in the stream corridors. During the Miocene epoch, the Columbia River basalts erupted out of immense fissures near the Idaho/Washington border. The lava spread across a vast area of Idaho, Washington, and Oregon, in some instances reaching as far as the Oregon coast (Orr and Orr 1996; USGS 2006a). Toward the end of the Pleistocene epoch (also known as the Ice Age, 1.65 million until 10,000 years ago), massive continental glaciers advanced south from Canada into the northern portions of the Columbia River Basin and Okanogan Highlands. One lobe of continental ice blocked the Clark Fork River near the Idaho-Montana border and formed an immense lake (Lake Missoula), which spanned approximately 3,000 square miles. The ice dam bordering the lake failed and reformed repeatedly, releasing flood waters as many as 89 times across the Columbia Plateau (Benito and O'Connor 2003; USGS 2006a). These massive floods scoured the overlying loess (windblown soil) and eroded the Columbia River basalt, forming what is now known as "scablands."

The Okanogan Highlands physiographic province is situated east of the Cascade Range and north of the Columbia River. To the east and north, the highlands extend into northern Idaho and southern British Columbia, respectively, and are characterized by rounded mountains with elevations up to 8,000 feet above sea level and deep, narrow valleys. The Columbia River divides the Okanogan Highlands into two geographic regions: to the east of the river are the Selkirk, Chewelah, and Huckleberry Mountains; to the west are the Kettle, Sanpoil, and other mountains (DNR 2001). The eastern portion of the Okanogan Highlands contains the oldest sedimentary and metamorphic rocks in the state. To the west, the Okanogan Highlands are separated from the Cascades and the fold-thrust belt of the Methow terrain by a geological structure called the Pasayten fault zone (DNR 2001).

The Blue Mountains physiographic province is located south of the Snake River in the southeast corner of Washington. The Blue Mountains are characterized by a broad uplift, reaching elevations of more than 6,000 feet above sea level. Windows of Paleozoic or Mesozoic (543 million to 65 million years ago) eras metamorphic rocks are exposed where streams and rivers have incised deep canyons through the overlying rocks of the Columbia River Basalt Group. The basement rocks consist of Triassic-Jurassic periods (about 250 to 145 million years ago) limestone lenses, amphibole-quartz schist, greenstone, graywacke, sandstones, cherty dark argillite, and diorite (DNR 2001).

3.2.2 Soils

The soils in the project area are varied and include deep forested soils with volcanic-rich layers, drier silty loess, channels of stony scabland soils, and volcanic ash deposits (WSU 2006). Due to the combination of a relatively dry climate, high winds, soil that is typically composed of silt or fine sand sized particles, and thin vegetative cover, soils in the project area are typically highly susceptible to wind erosion (Saxton et al. 2001). Ground subsidence can occur from decaying or compacting organic deposits (such as peat or fill with abundant organics). The risk from ground subsidence in the project area is generally low (Walsh and Logan 1989).

The soil pattern in the Columbia Plateau physiographic province generally varies with precipitation, ranging from silty loams in wetter regions to dry, desert-type soils in dry regions. There are four soil regions in this physiographic province (Franklin and Dyrness 1988).

The soil pattern in the Okanogan Highlands physiographic province generally varies with elevation. Soils in the higher elevations are gravelly sandy loams. Lower elevations located along the margins of river valleys and the southern boundary of the province originate from glacial till and have a sandy loam to loam texture (Franklin and Dyrness 1988). Soils in the terraces and floodplains are coarse-textured glacial outwash sands and gravels that are well to excessively drained (Franklin and Dyrness 1988).

The soils in the Blue Mountains physiographic province also vary with elevation. Moderate-to-high elevations have a dark brown, fine sandy loam to silt loam (from loess) along the north-facing slopes. North-facing slopes in the eastern and western parts of the province are covered in a layer of volcanic ash and fine pumice. Lake-deposited sediments, which are present in the western part of the province, have created a silt loam at the surface and clay loam below. Well-drained to poorly drained soils with a silt loam to silty clay loam texture are found along major streams (Franklin and Dyrness 1988).

3.2.3 Geologic Hazards

Seismicity

The Columbia River Basin is located in a region of active tectonics where earthquakes occur. The largest historical earthquake reported (magnitude 6.8 to 7.4) in Washington happened in 1872 on a crustal fault near Lake Chelan (U.S. Geological Survey 2006b). Within the Columbia River Basin, the U.S. Geological Survey (2006c) report the following active faults:

- The Wallula Gap and Hite fault zones near Walla Walla;
- Several east-west trending fold and fault groups located between Moses Lake and the Oregon-Washington border, centered roughly around Yakima, known informally as the Yakima fold belt;
- The Straight Creek fault located north of Highway 2 in the Cascades; and
- Several relatively small northwest-southeast trending faults located roughly between The Dalles (in Oregon) and Walla Walla.

Active faults are defined by the U.S. Geological Survey (USGS) as faults that are "…believed to be sources of earthquakes greater than magnitude 6 during the Quaternary (the past 1,600,000 years)." The Wallula Gap fault zone is believed to be the source of the damaging Milton-Freewater (Oregon) earthquake in 1936 (Mann and Meyer 1993).

The primary risk from a large earthquake is strong ground motion. Based on USGS maps, the highest risk for strong ground motion can be expected at the western end of the Columbia River Basin project area, near Bonneville Dam. Generally, the risk of ground motion increases from east to west, except for a localized area of higher risk near Walla Walla (due to the presence of the Wallula fault). Earthquakes can also trigger landslides, as discussed in the following section.

Landslides

The project area encompasses an area of active landslides that can often damage or destroy structures and transportation routes.

The Columbia River Gorge has experienced a number of large landslides on the Washington side of the river. More than 50 square miles of landslides are found in the Columbia Gorge, and dams or other structures in the gorge are built on active or dormant landslides (Thorsen 1989). Examples include:

- The Cascade slide covering the five miles between North Bonneville and Stevenson. Bonneville Dam was built on part of the old slide material (Alt and Hyndman 1984).
- The active Wind Mountain slide, which has caused a hotel and spa to be abandoned, power lines to be rerouted, extensive maintenance problems on State Highway 14, and maintenance problems on a rail line (Thorsen 1989).

Landslides also commonly occur in the Okanogan Highlands, especially in the reservoirs behind Grand Coulee and Chief Joseph Dams. Filling and subsequent drawdown of the reservoirs causes extensive slope failures of unconsolidated Pleistocene sediments deposited by the Lake Missoula floods, which extend for hundreds of miles of shoreline along the reservoirs (Thorsen 1989).

Thorsen (1989) notes that landslide problems in the Columbia River Basin have dramatically increased with the advent of widespread irrigation. The increase in irrigation (as of 1989) has simulated a tenfold increase in precipitation and caused a corresponding increase in the volume and number of landslides in the basin.

3.3 Air and Climate

While neither air quality nor climate are expected to be substantially affected by the Management Program, climate plays an important part in the need for the water supplies that the Management Program aims to provide and in the effects that the program would have on other elements of the environment, such as water quality and fish and wildlife habitat. This section provides background on the region’s climate and predicted changes in climate over the coming decades.

The North Pacific Current offshore of western Washington and associated warm maritime air masses moderate temperatures throughout the Pacific Northwest region. Washington’s climate varies dramatically from west to east due to elevation, prevailing winds, proximity to marine water bodies and other factors. The majority of the Columbia River Basin is located in the eastern part of the state, where precipitation is a limiting factor for plant growth on most non-irrigated lands. A portion of the lower Columbia River Basin is in western Washington, where rainfall is higher and temperatures are more moderate.

3.3.1 Eastern Washington Climate

Many portions of eastern Washington receive less than 10 inches of total annual precipitation, and much of that precipitation falls in the form of snow. Total precipitation approaches 20 inches per year in areas closest to the Cascade Range and the Selkirk Mountains (Spatial Climate Analysis Service 2000).

Precipitation increases dramatically near the Cascade Range and other mountain ranges in eastern Washington. Spokane, at the eastern edge of the Columbia Plateau, receives approximately 20 inches of precipitation per year.

Temperature ranges in eastern Washington are more extreme than areas of the state moderated by the North Pacific offshore currents and associated warm maritime air masses. Characteristic eastern Washington average maximum temperatures in July are in the mid-80sº F to near 90º F. Average minimum temperatures in July are generally in the mid- to upper 50sº F. Average maximum temperatures in January are in the low to mid-30sº F, except in southeast Washington, where the average maximum temperatures are closer to 40º F. Average minimum temperatures in January are typically in the teens to mid-20sº F.

3.3.2 Western Washington Climate

Western Washington has frequent cloud cover and considerable fog and rain in the winter. Precipitation in the Puget trough, which intersects the Columbia River near Vancouver, Washington, typically ranges around 40 to 50 inches per year, with approximately 60 to 80 percent of that total falling in the six-month period between October and March. Near the mouth of the Columbia River, rainfall ranges up to 100 inches per year.

Precipitation also increases dramatically near the Cascade Mountains. Many areas on or near the west side of the Cascade crest receive annual average precipitation of 90 to 140 inches, most of which comes in the form of snow (Spatial Climate Analysis Service 2000).

Temperatures in western Washington are moderate. Typical average maximum temperatures in July for western Washington are about 70º F in coastal areas, and 5 to 10 degrees warmer inland. Average minimum temperatures in July are generally in the low to mid-50sº F. Average maximum temperatures in January are in the mid-40sº F with average minimum temperatures in the low 30sº F.

3.3.3 Climate Variability

As is the case with the Pacific Northwest as a whole, the climate of Washington has exhibited considerable variability over time. The two principal factors affecting climate variability are the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO).

ENSO involves a cyclical warming or cooling of sea surface temperatures in the equatorial Pacific Ocean to an extent sufficient to affect global weather patterns. ENSO episodes usually last 6 to 18 months and recur on a 2 to 7 year cycle (JISAO/SMA Climate Impact Group 1999). The effects of ENSO are most pronounced during late fall and winter. ENSO has a warm phase (El Niño) and a cold phase (La Niña). During the years in which El Niño is expressed, Northwest winters tend to be warmer and drier than average. During La Niña episodes, winters are typically cooler and wetter than average.

PDO involves cyclical changes in sea surface temperatures of the northern Pacific Ocean. PDO has two phases: a warm phase and a cool phase. These phases generally alternate approximately every 20 to 30 years. The warm phase PDO results from relatively warm sea surface temperatures in the north Pacific and influences Washington's climate towards a warm and dry pattern. The cool phase results from relatively cool sea surface temperatures in the north Pacific and has a cool and wet influence on the climate. The PDO phases have a more prolonged influence on Washington's climate than ENSO episodes. Generally, during the warm phase PDO, snow depth, precipitation, and stream flows are below average, while higher than average snow depth, precipitation, and stream flows are experienced during cool phases (JISAO/SMA Climate Impact Group 1999).

3.3.4 Climate Change

While the topic is subject to debate, a number of scientific assessments have concluded the Earth's average temperature will likely increase during the twenty-first century (Hamlet et al. 2001). Climate models used in these assessments predict that both temperature and precipitation will significantly increase in the Pacific Northwest over the next 50 years. The potential consequences to water resources in the Pacific Northwest associated with warmer temperatures, greater precipitation, and a shift in winter precipitation type from snow to rain include reduced snow packs, higher winter stream flows and accompanying increased flood potential, earlier snowmelt-generated peak flows, and lower summer flows (Hamlet et al. 2001). Similarly, rivers fed by glacial melt waters may be adversely affected by climate change. Pronounced reductions in the volume and amount of area covered by glaciers can result in significant reductions in the amount of water released to downstream rivers (Environment Canada 2003).

3.3.5 Air Quality in the Lake Roosevelt Area

Lake Roosevelt has received trace elements that were discharged as slag material from a smelter in Canada; approximately 360 metric tons were discharged per day from 1900 to 1998. While the majority of existing studies have focused on contaminants in water, sediment, and fish, there is recent concern over the potential threat of airborne contaminants to human health. Trace metal concentrations in exposed, formerly inundated, shoreline areas have the potential to become airborne in the lower atmosphere due to wind gusts. Once airborne, the dust particles are carried downwind various distances depending on their size and the magnitude and duration of the prevailing winds. During the spring, the reservoir water level decreases substantially and may expose reaches of contaminated sediments that, upon drying, may be transported via the prevailing wind throughout the Lake Roosevelt area. The U.S. EPA recently stated that airborne contaminants in Lake Roosevelt area may be of concern to human health and has recommended additional studies (USGS 2006c).

3.4 Surface Water

3.4.1 Surface Water Quantity

3.4.1.1 Streamflow

The Columbia River originates in two lakes that lie between the Continental Divide and Selkirk Mountains in British Columbia. The river flows over 1,000 miles before reaching the Pacific Ocean (Figure 3-1). It flows north for its first 200 or more miles, and then turns south toward the Canada-U.S. border. Within the U.S., the river flows southwest, skirting one of the Columbia Plateau's massive basalt flows, before turning southeast and cutting through a dramatic gorge in the volcanic shield near its junction with the Snake River. From its confluence with the Snake River, the Columbia River runs nearly due west to the Pacific Ocean (MWH 2005).

The Columbia River's annual discharge rate at The Dalles fluctuates with precipitation, ranging from 120,000 cubic feet per second (cfs) in a low water year to 260,000 cfs in a high water year (Ecology 2006). Average annual discharge at The Dalles is 138 million acre-feet or about 190,000 cfs (U.S. Army Corps 2006). Tributaries to the Columbia River Basin are primarily snow-fed (i.e., precipitation falls mainly as snow). These tributaries typically have low winter flows and strong spring and summer peaks with snow melt, which concentrates about 60 percent of the natural runoff to the Columbia River during May, June, and July (Ecology and WDFW 2004; USGS 2002). Tributaries that are fed by glacial melt in addition to snow pack along the Cascade Range or in Canada exhibit a different flow pattern. Glaciers contribute a considerable amount of flow to rivers during late summer and early fall after the snow has melted and when precipitation is normally low (Ecology and WDFW 2004).

The largest tributary to the Columbia River in the U.S. is the Snake River, which originates in Yellowstone National Park in Wyoming and drains 109,000 square miles in Wyoming, Idaho, Nevada, Utah, Oregon, and Washington (Ecology 1995). The Snake River flows for 180 miles in Washington and flows into the Columbia River near Pasco in Water Resource Inventory Area (WRIA) 33 (Ecology 1995). The largest tributary to the Columbia River in Canada is the Kootenai River, which originates in Kootenai National Park in Canada (British Columbia) and drains 16,180 square miles within the U.S. and Canada (NPCC 2004). The Kootenai River flows north and west east of the Selkirk Mountains and joins the Columbia River near Castelgar, British Columbia.

Other major tributaries to the Columbia River in Washington (with the river mile of their confluence in parenthesis) are listed in Table 3-5 (Ecology and WDFW 2004).

Table 3-5. Major Tributaries to the Columbia River

Eastern Washington	Cascade Range Crest to Pacific Ocean	Confluence of Snake River to Pacific Ocean
Pend Oreille (735.1)	Wind (154.5)	Umatilla River (289.0)
Kettle (706.4)	Washougal (120.7)	John Day River (218.0)
Colville (661.0)	Lewis (87.0)	Deschutes River (204.1)
Spokane (638.9)	Kalama (73.1)	Hood River (169.4)
Sanpoil (615.0)	Cowlitz (68.0)	Sandy River (120.5)
Okanogan (533.5)	Elochman (39.1)	Willamette River (101.5)
Methow (523.9)	Grays (20.8)	
Chelan (503.3)		
Entiat (483.7)		
Wenatchee (468.4)		
Crab Creek (410.8)		
Yakima (335.2)		
Walla Walla (314.6)		

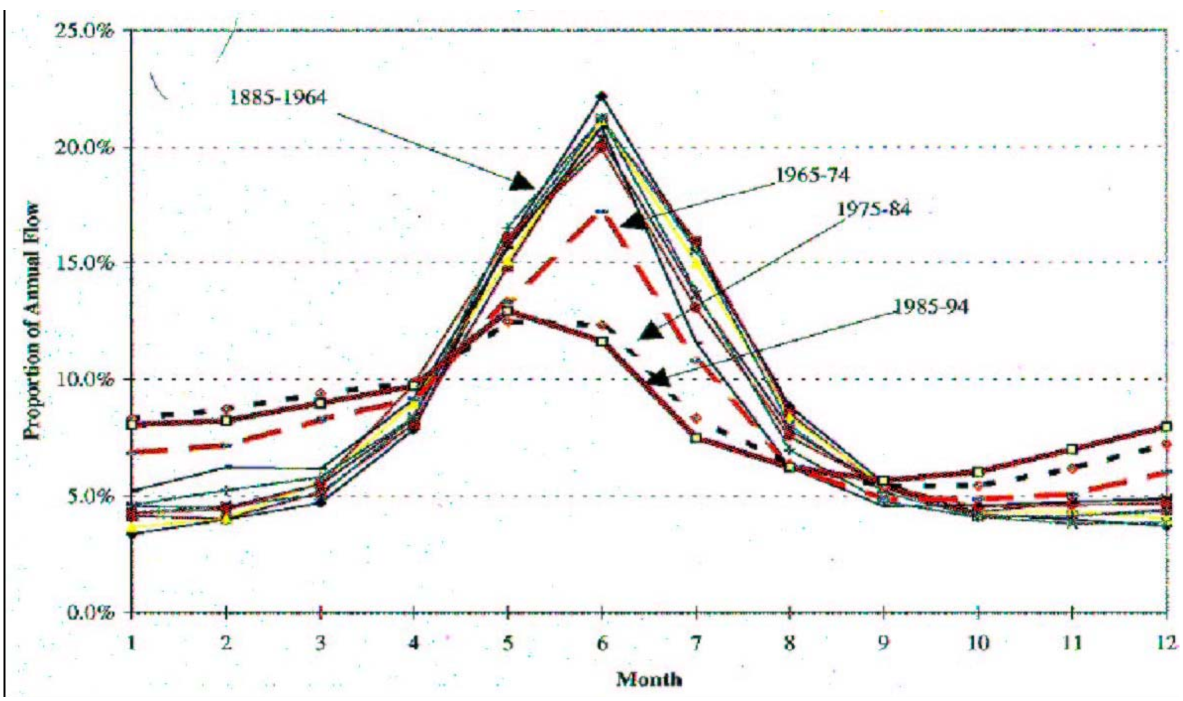
Eastern Washington	Cascade Range Crest to Pacific Ocean	Confluence of Snake River to Pacific Ocean
Klickitat (180.4)		
White Salmon (168.3)		
Little White Salmon (162.0)		

Hydropower Development

The construction and operation of the Columbia River dam and reservoir system have affected the hydrograph of the Columbia River. Figures 3-7 through 3-9 illustrate these changes. Figure 3-7 shows how Columbia River hydrologic seasonality has "flattened," as historical high seasonal (summer) flows have decreased and low seasonal (winter) flows have increased. Figure 3-8 shows how the distribution of flows between summer (April-September) and winter has changed since the late 1800s. Operation of the Columbia River hydropower system has evened out the natural summer-to-winter flow variations. In addition to the smoothing of the hydrograph, water velocities have decreased (National Research Council 2004).

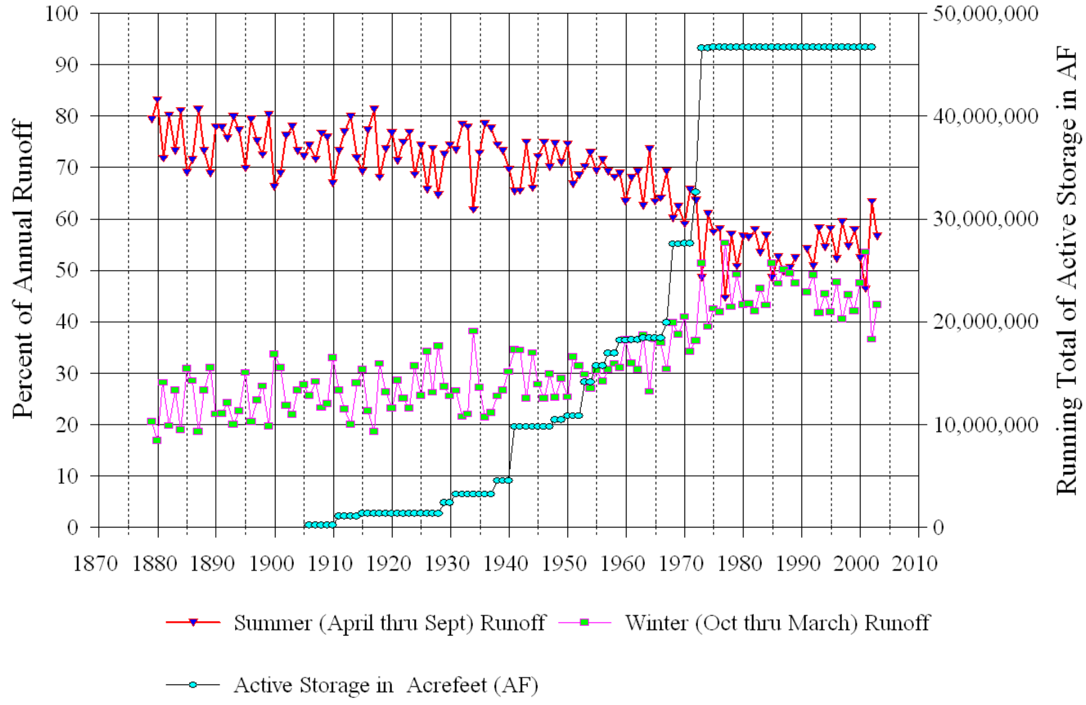
The hydrologic changes caused by Columbia River dams have not eliminated all variability of Columbia River flows. Figure 3-9 demonstrates that considerable variability of annual Columbia River discharge exists between years. Flows also continue to vary on other time scales; for example, daily flow patterns below hydropower dams often vary substantially as flows are adjusted to match demand for hydroelectric power (National Research Council 2004).

Figure 3-7. Annual Distribution of Monthly Flow at The Dalles by 10-year blocks.



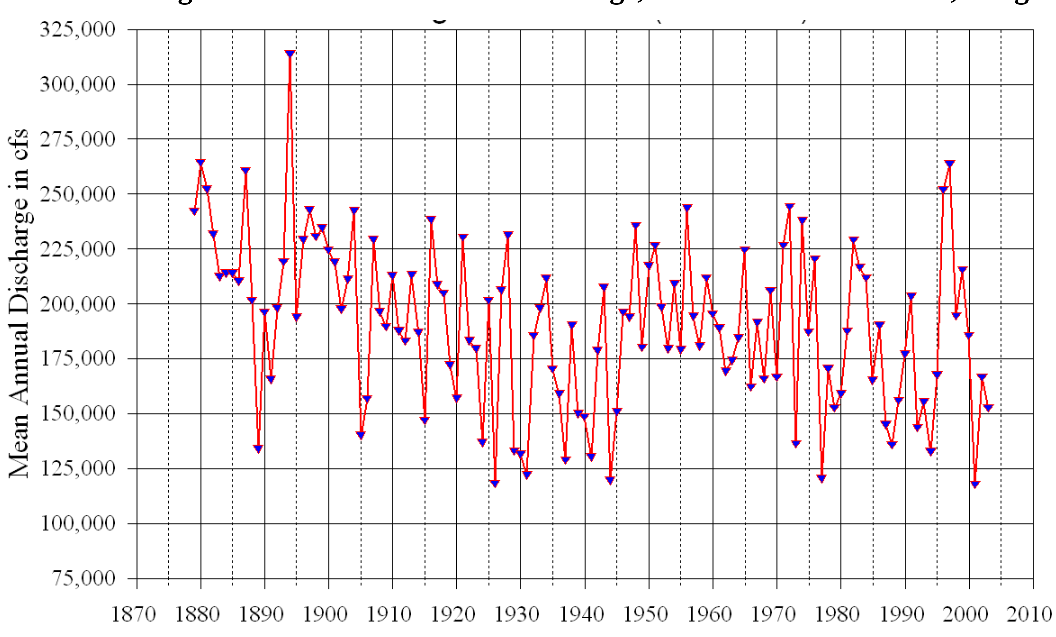
Source: Volkman (1997). (NRCNA 2004)

Figure 3-8. Change in Columbia River Hydrograph at The Dalles, 1879-2004.



Source Ecology and WDFW 2004

Figure 3-9. Columbia River Discharge, 1878-2004 at The Dalles, Oregon



Source: Ecology and WDFW 2004

Agreements, Laws, and Requirements that Affect Streamflow

Streamflow is affected by various instream and out-of-stream flow agreements. These laws and requirements regulate flows for instream and out-of-stream uses along the length of the Columbia River. This section outlines the various flow levels that are specified by instream flow agreements, laws, and requirements. See Section 3.6 for a description and discussion of the legal and policy implications of streamflow agreements, laws, and requirements.

International, Tribal, and Interstate Agreements

With the exception of the 2,500 cfs requirement for Canada to deliver under the Columbia River Treaty (National Research Council 2004), there are no other quantified international, interstate, or tribal instream or out-of-stream flow requirements (see Table 3-6).

Table 3-6. International, Tribal, and Interstate Agreements Affecting Columbia River Basin Streamflows

Agreement	Agreement Type	Quantity	Expiration
Boundary Waters Treaty of 1909	International	Not specified	None
Columbia River Treaty (signed 1961; ratified 1964)	International	2,500 cfs (from Kootenai River) provided by Canada	U.S. & Canada have option to terminate in 2024 with 10-years notice
Pacific Salmon Treaty of 1985	International	Not specified – adequate quantity and quality to sustain salmon fisheries	None
Tribal Reservations formalized through Treaties with the United States or by Executive Order[1]	Tribal	Not specified – fishing in Usual and Accustomed places; and hunting on open and unclaimed lands; practicably irrigable acres	None
Columbia River Compact	Interstate	Not specified – protect salmon fisheries	None

1 References in this EIS to "treaty tribes" or treaty fishing and hunting rights refer to those tribes whose reservations were established by Executive Order as well as those established by treaty.

State Laws (WAC 173-563)

Ecology passed an administrative instream flow rule (WAC 173-563) for the Columbia River mainstem in 1980, which was amended in 1998. Implications of the flow rule and subsequent amendments on the interruptibility of water right holders are indicated in Table 3-7. The flows are measured at the Chief Joseph, Wells, Rocky Reach, Rock Island, Wanapum, Priest Rapids, McNary, and John Day Dams. Appendix E presents the state administrative flows set at these control points under Washington Administrative Code (WAC) and flow objectives specified in the 2004 NOAA Fisheries Service Biological Opinion issued for the Federal Columbia River Power System (FCRPS) at the same location.

Table 3-7. Washington State Instream Flow Rule WAC 173-563 and Effects on Water Right Holders

Priority Date of Water Right	Source Water Associated with Water Right	Use	Interruptibility	Notes
1938	Columbia Basin Project	All	Uninterruptible	WAC 173-563-12-(5)
Pre-1980	Mainstem surface water and hydraulically connected ground water	All	Uninterruptible	--
Post-1980 to July 26, 1997	Mainstem surface water and hydraulically connected ground water	All except municipal and domestic	Interruptible	WAC 173-563-020(1) WAC 173-563-040: Interruptibility based on forecasts at The Dalles (See Table 3-3).
	John Day and McNary Pools of the Columbia River and the Lower Snake River Reservation	All except municipal and domestic	Interruptible	WAC 173-561A-060
On or after July 27, 1997	Mainstem surface water and hydraulically connected ground water	All	Determined on a case-by-case basis	WAC 173-563-020(4): Water right application evaluated for possible impacts on fish and existing water rights
	John Day and McNary Pools of the Columbia River and the Lower Snake River Reservation	All	Determined on a case-by-case basis	WAC 173-561A-060 – Subject to WAC 173-563-020(4): Water right application evaluated for possible impacts on fish and existing water rights

Notes: The Columbia Basin Project was authorized to irrigate 1,029,000 acres at its completion but currently irrigates 671,000 acres. The remainder is referred to as the "Second Half of the CBP".

Federal Requirements on FCRPS Management of Reservoirs

The 2004 NOAA Fisheries Service Biological Opinion issued for the Federal Columbia River Power System in November 2004 established flow targets for the Columbia River that were intended to protect threatened and endangered fish species (NMFS 2004). The Biological Opinion was remanded and a reconsultation is currently underway. Table 3-8 lists the flow objectives specified in the 2004 Biological Opinion.

Table 3-8. 2004 Biological Opinion Flow Objectives

Location	Spring		Summer	
	Dates	Flow Objective (kcfs)	Dates	Flow Objective (kcfs)
Snake River at Lower Granite Dam	4/03-6/20	85-100[1]	6/21-8/31	50-55[1]
Columbia River at McNary Dam	4/10-6/30	220-260[1]	7/01-8/31	200
Columbia River at Priest Rapids Dam	4/10-6/30	135	N/A	N/A
Columbia River at Bonneville Dam	11/1-emergence	125-160[2]	N/A	N/A

1 Objective varies according to water volume forecasts.
2 Objective varies based on actual and forecasted water conditions.
Kfcs=thousand cubic feet per second

3.4.1.2 Surface Water Bodies in the Region

The Columbia River Basin's surface water bodies include naturally formed lakes, constructed reservoirs on rivers and streams, and natural lakes that are artificially raised and/or controlled through constructed impoundments. Lakes are typically fed by water from in-flowing rivers or creeks but may also be fed by ground water and direct precipitation. Another source of water for some water bodies in the Columbia River Basin is irrigation return flow and direct discharge of irrigation water.

The largest natural lake in the Columbia River Basin is Lake Chelan, an approximately 55-mile-long glacial lake in north-central Washington that covers approximately 33,000 acres (Dion et al. 1976a). Other large lakes and reservoirs in the basin include Lake Roosevelt (83,200 acres), Potholes Reservoir (28,000 acres), Banks Lake (27,000 acres), Moses Lake (6,800 acres), Lake Osoyoos (5,800 acres; 35 percent in U.S.), Lake Spokane (also known as Long Lake, 25 miles long), Lake Wenatchee (2,500 acres), and Lenore Lake (1,300 acres).

3.4.1.3 Existing Storage Facilities

Hydropower projects on the Columbia River mainstem and other storage developments on its tributaries created reservoir storage projects with an active storage capacity in excess of 46 million acre-feet (Ecology and WDFW 2004). This volume is equivalent to one-third of the mean annual flow of the Columbia River at The Dalles, Oregon. This storage capacity occurs in four projects in excess of 5 million acre-feet, in six projects with a capacity range of 1 to 4 million acre-feet, and in dozens of smaller projects (Ecology and WDFW 2004).

According to the Columbia Basin Water Management Division of the U.S. Army Corps of Engineers (Corps of Engineers), there are 61 dams on the Columbia River mainstem and its tributaries. Of the 14 reservoirs located on the mainstem, three are in Canada (Mica, Revelstoke, and Keenlyside) and the remaining reservoirs are in the U.S. (Grand Coulee, Chief Joseph, Wells, Rocky Reach, Rock Island, Wanapum, Priest Rapids, McNary, John Day, The Dalles, and Bonneville). Only two of the remaining 47 dams in Washington are located off-stream from a Columbia River tributary (Salmon Lake Dam and Conconully Lake, an Okanogan Irrigation

District facility, and Mill Creek, a Corps of Engineers facility). The maximum storage capacity of the four off-stream storage reservoirs totals approximately 75,000 acre-feet, which is less than approximately 0.15 percent of the total storage in the Columbia River system (MWH 2005). The Snake River is also highly developed for hydroelectric power generation, with four dams (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor) in operation within Washington that create large run-of-river reservoirs of water (Ecology 1995).

Many reservoirs also store water for irrigation projects. The largest irrigation projects include the Columbia Basin Project, the Yakima Irrigation Project, and the Chief Joseph Dam Project. The Columbia Basin Project uses Columbia River water initially stored in Lake Roosevelt and diverted to Banks Lake and the Potholes Reservoir to irrigate approximately 671,000 acres of land (Postma, personal communication, 2007). The Yakima Irrigation Project uses water diverted from the Yakima, Naches, and Tieton Rivers and stored in Keechelus, Kachess, Cle Elum, Bumping, and Rimrock Lakes to supply irrigation water to 465,000 acres of which 361,000 acres are irrigated cropland (EES 2003). See Section 3.4.1.6 for more details about the irrigation projects in the Columbia River Basin.

3.4.1.4 Aquifer Storage

Currently several municipalities in the Columbia Basin are actively pursuing aquifer storage as part of their overall water management strategy. The City of Walla Walla, Washington, started evaluation of aquifer storage and recovery (ASR) in 1999 to provide a peaking and emergency backup water supply for the City. The City relies on surface water from Mill Creek to meet most of the demand. Seven deep wells completed in the Columbia River Basalt provide a secondary source when flows in Mill Creek decline from late spring through the fall months until rain events occur on a regular basis, or during peak flows when the water is too turbid for treatment. Two of the seven wells have been converted to ASR wells, with a recharge capacity of 2,900 gallons per minute (4.2 million gallons per day). The recharge water is diverted under the City's existing rights on Mill Creek, treated using ozonation and chlorination, and recharged to the aquifer. Since the City of Walla Walla began ASR operations in 1999, over 3 billion gallons (9,200 acre-feet) of water have been stored.

The City of Pendleton, Oregon, is also currently evaluating ASR in the Columbia River Basalt using up to five wells to store about 600 million gallons (1,840 acre-feet). The Cities of Kennewick and Richland have also investigated the feasibility of ASR in the Columbia River Basalt. The City of Yakima is also studying an ASR program for municipal water supply.

Preliminary feasibility studies of aquifer storage have also been conducted as part of WRIA-based storage assessments (under Watershed Planning). These are included in the following section.

3.4.1.5 Potential Storage Opportunities by WRIA

Under the Watershed Planning Act (RCW 90.82) local governments have the opportunity to conduct storage assessments as part of the watershed planning process. The assessments include an evaluation of potential storage opportunities in a WRIA. Several WRIAs located in the Columbia Basin have completed a watershed assessment and have identified opportunities for increasing storage (see Figure 3-3 for locations of the WRIAs). The storage opportunities include large reservoirs such as Black Rock and Wymer in the Yakima Basin, pump exchange systems, smaller off-channel facilities, and aquifer recharge and storage facilities. A summary of storage opportunities in each WRIA is presented in Appendix F.

3.4.1.6 Irrigation

There are approximately 6.8 million acres of irrigated cropland in the U.S. portion of the Columbia River Basin, including parts of Idaho, Montana, Washington, Oregon, Wyoming, Utah, and Nevada. Approximately 1.5 million acres are irrigated in Washington alone. Irrigation accounts for over 22 million acre-feet of surface water diverted in the Columbia River Basin. Table 3-9 lists the irrigated acres and amount of water that was withdrawn (ground water and surface water) within the Columbia River Basin and Washington by county in 2000 (USGS 2005).

Table 3-9. Columbia River Basin Irrigated Acres in Washington by County in 2000

County	Acres Irrigated	Ground Water Withdrawn (acre-feet/year)	Surface Water Withdrawn (acre-feet/year)	Total Water Withdrawn (acre-feet/year)
Adams	135,060	120,050	89,350	209,400
Asotin	460	40	360	400
Benton	140,440	20,400	247,100	267,500
Chelan	28,270	3,520	54,000	57,520
Clark	4,150	4,370	2,210	6,580
Columbia	3,300	310	4,600	4,910
Cowlitz	3,310	0	4,160	4,160
Douglas	19,570	3,460	24,510	27,970
Ferry	4,300	910	4,200	5,110
Franklin	201,740	134,670	355,650	490,320
Garfield	670	30	580	610
Grant	407,730	289,340	755,550	1,044,890
Kittitas	69,340	0	223,550	223,550
Klickitat	18,540	18,550	11,370	29,920
Lincoln	43,960	31,290	9,260	40,550
Okanogan	43,690	22,230	59,650	81,880
Pend Oreille	1,440	310	520	830
Skamania	450	0	560	560
Spokane	11,020	9,860	2,780	12,640
Stevens	9,240	1,730	9,160	10,890
Wahkiakum	200	90	190	280
Walla Walla	88,750	47,370	92,090	139,460
Whitman	5,140	720	2,570	3,290
Yakima	253,070	69,620	570,410	640,030
Total	**1,494,470**	**778,870**	**2,524,380**	**3,303,250**

Along the lower Columbia River and Snake River, 380,000 acres are irrigated by pumping directly from the rivers. Some of this acreage is located in Oregon and Idaho (BPA 1995).

Along the middle Columbia River, the largest diversion is for the Columbia Basin Project at Grand Coulee Dam. The Columbia Basin Project begins at the head of the Grand Coulee and extends south 125 miles to the confluence of the Snake and Columbia Rivers. The Columbia River forms the western boundary of the Columbia Basin Project near Quincy, and the project extends east 60 miles near Odessa and Lind. The Columbia Basin Project includes land in Grant, Lincoln, Adams, Franklin, and Walla Walla Counties. The Columbia Basin Project irrigates about 671,000 acres. The average annual diversion for the Columbia Basin Project is 2.65 million acre-feet as measured at the Main Canal during the 2000 to 2004 period.

The Quincy-Columbia Basin Irrigation District, East Columbia Basin Irrigation District, and South Columbia Basin Irrigation District operate and maintain the irrigation delivery systems (MWG 2003) (see Figure 2-2). Banks Lake and Potholes Reservoir are large reservoirs used to regulate irrigation water after it is pumped from the Columbia River. Banks Lake is a 27-mile-long reservoir enclosed by North Dam and Dry Falls Dam and has an active storage capacity of 715,000 acre-feet. Potholes Reservoir, created by O'Sullivan Dam, covers 27,000 acres and has an active storage capacity of 407,000 acre-feet (MWG 2003; MWG 1995).

Several smaller irrigation districts located along the middle Columbia River divert surface water from the river. The Greater Wenatchee Irrigation District irrigates 9,300 acres with three diversions from the Columbia River located at Howard Flats near Chelan, Brays Landing near Entiat, and at East Wenatchee. The average diversion from the Columbia River is 29,000 acre-feet per year (MWG 2000). The Brewster Flat Irrigation District irrigates 2,400 acres with a pump station at Brewster. The average diversion is 8,000 acre-feet per year (MWG 2002). Numerous private orchards and farms also pump directly from the Columbia River. An estimate of the number of water users and acreage served along the Columbia River was obtained from water right records and is presented in Section 3.6.1.1.

Within tributary basins to the Columbia River mainstem, the Yakima Project is the largest irrigation project. The Yakima Project supplies water to approximately 465,000 acres in Kittitas, Yakima, and Benton Counties of which about 361,000 acres is irrigated cropland (EES 2003). This irrigation project diverts water from the Yakima, Naches, and Tieton Rivers. Five major reservoirs are located within the Yakima Project—Keechelus, Kachess, Cle Elum, Bumping Lake, and Rimrock Lake. These reservoirs have a total combined capacity of 1,065,000 acre-feet. Numerous smaller irrigation districts, irrigation companies, private farms, and other entities withdraw water from tributaries to the Columbia River for irrigation purposes.

3.4.2 Surface Water Quality

Surface water quality is influenced by natural geology and land cover, point and nonpoint contaminant sources, the quality of ground water that discharges to surface water, and the natural flow regime. Land use practices have increased the level of nutrients and pesticides in streams in the Central Columbia Plateau. The U.S. Geological Survey (USGS) has studied the area as part of the Central Columbia Plateau/Yakima River Basin National Water-Quality Assessment study unit. The USGS has found high nutrient loading, elevated concentrations of water-soluble pesticides, elevated concentrations of organochlorine compounds (e.g., DDT), and other pollutants in both bed sediment and fish (USGS 2006a). Instream structures (such as dams and irrigation impoundments) can also affect surface water quality by inhibiting mixing, introducing elevated concentrations of dissolved gases, and trapping contaminated sediments.

Reclamation published a study on water quality of the Columbia Basin Project in 1982 (Reclamation 1982) that tracked water quality parameters as water moved through the project. There was a general decline in quality as water moves through the project. Reservoirs, notably Potholes, were found to strip nitrogen and phosphorus from the water through plant growth and sedimentation. Return flows to the Columbia River contained greater concentrations of dissolved salts and nutrients than the original source water. Data provided from this study include measurements of pH, temperature, bicarbonates, chlorides, boron, suspended solids, nitrate, nitrite, ammonia, orthophosphate, total phosphorus, and fecal coliform bacteria at a number of water quality monitoring stations within the Columbia Basin Project. Pesticide (22 insecticides and 3 herbicides) levels in water, sediment, and fish tissue were also measured at various locations on the project.

On June 2, 2005, Ecology submitted the 2004 federal Clean Water Act Section 303(d) list to the U.S. Environmental Protection Agency (EPA) identifying surface waters that Ecology had determined to be out of compliance with water quality standards. The Columbia River (from WRIA 28 to the Canadian border) was listed for temperature, dissolved oxygen, fecal coliform, and a number of toxins (total PCBs, chlordane, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, aldrin, Alpha BHC and mercury) (Ecology 2005c). Tributaries of the Columbia River have their own 303(d) listings. These can be found, by tributary, on the Department of Ecology website available at http://www.ecy.wa.gov/programs/wq/303d/index.html.

The EPA has also studied bioaccumulation of toxic chemicals in fish species throughout the Columbia Basin (EPA 2002a). DDE, Aroclors, zinc, and aluminum were the chemicals found in the highest concentrations throughout the Columbia Basin. DDE was the most commonly found pesticide in fish tissue. Fish collected from the Hanford Reach of the Columbia River and the Yakima River tended to have higher concentrations of organic chemicals than other study sites (EPA 2002a).

Temperature

Water temperature varies at a number of temporal and spatial scales. Water temperature varies seasonally and during the course of a day in response to air temperature and solar radiation. Water temperature often varies with water depth, with cooler water at the bottom and warmer water near the surface during the summer. Tributary inflow temperatures, shade levels, geographic aspect, water surface area, and elevation all have an influence on water temperature. The Columbia River exhibits a dynamic and variable temperature regime.

Water temperature is important for the health and survival of native fish and aquatic communities. Temperature can affect embryonic development, juvenile growth, adult migration, competition with non-native species, and the relative risk and severity of disease (Ecology and WDFW 2004). Washington is currently working with Idaho, Oregon, and the EPA in coordination with the Columbia Basin Tribes[1] to develop a Total Maximum Daily Load (TMDL) report for temperature on the Columbia and Snake Rivers (EPA 2005).

Water temperature can be elevated above natural conditions by a number of human activities. Point sources, such as municipal waste treatment plants, or pulp and paper mills, discharge thermal energy directly to the river and can cause temperature plumes near the discharge point, but do not measurably affect the cross-sectional temperature of the Columbia River (EPA 2002b). Dams alter river temperature by changing the flow regime, stream geometry, current velocity, and floodplain interactions of the river. Dams increase the length of time the temperature exceeds the numeric criterion, and cause the Columbia River to be warmer during the late summer and fall (EPA 2002b). In addition, withdrawing water from the river can indirectly affect water temperature (Ecology and WDFW 2004).

Total Dissolved Gas

Spill events at large dams can elevate total dissolved gas in water. Water plunging from a spill entrains air and carries it to a depth where hydrostatic pressure forces gas into solution at high levels. Total dissolved gas (TDG) is generally most problematic at large, high dams with deep plunge pools. Spills can occur at any time for several reasons including fish passage operations and if the flow exceeds the powerhouse capacity. Spills can occur at all of the Columbia River mainstem dams (Pickett et al. 2004).

The water quality standards for Washington State, the Colville Tribe, and the Spokane Tribe have an identical TDG criterion: 110 percent of saturation not to be exceeded at any point of measurement. The criteria for Washington State and the Colville Tribe do not apply to flows above the seven-day, ten-year frequency flow (7Q10) flood. In addition, special limits for TDG are established as a special condition in Washington rules, to allow higher criteria with specific averaging periods during spills for fish passage, if approved within a gas abatement plan (WAC 173-201A-200(1)(f)) (Pickett et al. 2004).

The 1998 303(d) listing for TDG on the Columbia River was removed in 2004. The TMDL report associated with the 1998 listing was published in June 2004 (Pickett et al. 2004). EPA approved Ecology's submittal of total dissolved gas TMDLs for the Mid-Columbia River and Lake Roosevelt on July 27, 2004. This TMDL, developed jointly by Washington, the Spokane Tribe of Indians, and EPA, addresses total dissolved gas in the Columbia River and Lake Roosevelt from the international border with Canada to the Snake River confluence near Pasco. Elevated total dissolved gas levels, which can cause "gas bubble trauma" in fish, are caused by spills at seven dams in the Mid-Columbia and by sources upstream of the international border. Loading capacities and load allocations are set in terms of: (1) percent saturation for fish passage

[1] As listed in the Memorandum of Agreement: Columbia/Snake Rivers Total Maximum Daily Load for Total Dissolved Gas and Temperature (EPA 2000), the Columbia Basin Tribes include the Burns Paiute Tribe of the Burns Paiute Indian Colony of Oregon; Coeur d'Alene Tribe of the Coeur d'Alene Reservation, Idaho; Confederated Salish and Kootenai Tribes of the Flathead Reservation, Montana; Confederated Tribes of the Colville Reservation, Washington Confederated Tribes of the Umatilla Indian Reservation, Oregon; Confederated Tribes of the Warm Springs Reservation of Oregon; Confederated Tribes and Bands of the Yakama Nation, Washington; Kalispel Indian Community of the Kalispel Reservation, Washington; Kootenai Tribe of Idaho; Nez Perce Tribe, Idaho; Shoshone-Bannock Tribes of the Fort Hall Reservation of Idaho; Shoshone-Paiute Tribes of the Duck Valley Reservation, Nevada; and Spokane Tribe of the Spokane Reservation, Washington.

conditions, and (2) excess pressure above ambient during non-fish passage conditions. Allocations must be met below each dam at a specific distance below the spillway (near the end of the aerated zone). The implementation plan describes short-term and long-term compliance with both Endangered Species Act and TMDL requirements (Pickett et al. 2004).

The TMDL established loading capacities that range from 72 to 75 millimeters of mercury for the Mid-Columbia and Lake Roosevelt. The capacities were calculated to meet the 110 percent saturation criterion during critically low barometric pressure conditions. Loading capacity during fish passage conditions was directly based on Washington's fish passage TDG criteria for the forebay and tailrace of each of the five dams downstream of the Okanogan River confluence (Pickett et al. 2004).

Load allocations are equal to loading capacity throughout the TMDL area, including each dam's forebay and tailrace. TMDL load allocations apply year-round from the international border to Grand Coulee Dam, and from March through September downstream of Grand Coulee Dam when flows are below the 7Q10 flood flows for waters below the Spokane River confluence. Loading capacities established for Lake Roosevelt and the Mid-Columbia River were:

- 72 mm Hg above saturation: International border to Grand Coulee Dam, including Lake Roosevelt, Spokane Arm, and Grand Coulee Dam forebay;
- 73 mm Hg above saturation: Grand Coulee Dam to Okanogan River;
- 115 percent saturation (average of 12 highest hourly readings in a 24-hour period): Forebays of Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids Dams;
- 120 percent saturation (average of 12 highest hourly readings in a 24-hour period) or 125 percent saturation (maximum one-hour average): Tailrace of Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids Dams;
- 73 mm Hg above saturation: Okanogan River to Wells Dam;
- 74 mm Hg above saturation: Wells Dam to Yakima River; and
- 75 mm Hg above saturation: Yakima River to Snake River.

When the TMDL is fully implemented, spills from dams downstream of the international border must meet the allocations (except during flows above a 7Q10 flood) (Pickett et al. 2004).

Nutrients

Nutrients are an important indicator of surface water quality. Inorganic nitrogen (nitrate and ammonia) and phosphorus affect the growth of aquatic plants and the overall aquatic conditions of surface water bodies. Excessive nutrients can increase the growth of aquatic plants such that persistent algal blooms can inhibit the beneficial uses of the lake, including recreation, habitat, and fish and other aquatic organisms. Nutrients can also affect dissolved oxygen concentrations as well as aquatic organisms.

Naturally occurring concentrations of nutrients in the environment also contribute to water quality concerns. Land use practices have added to the level of nutrients in the environment. Sources of inorganic nitrogen to streams include runoff from agriculture and residential areas and ground water. The application of fertilizers to crops can result in elevated concentrations of phosphorus due to soil erosion, which carries the phosphorus or nitrogen to the streams. Feedlots and wastewater treatment plants are also sources of nutrients (Williamson et al. 1998).

Pesticides

The USGS has studied the occurrence, distribution, and transport of pesticides in agricultural irrigation return flow from four drainage basins in the Columbia Basin Project (Wagner et al. 2006). The study describes the land use within each of the four drainage basins and provides a baseline indication of the concentration of pesticides and nutrients in the surface water due to land use practices in the Columbia Basin Project. Forty-two pesticides and five metabolites were detected in samples from the four irrigation return-flow drainage basins in the CBP from July 2002 to October 2004 (Wagner et al. 2006). See Wagner et al. (2006) for the range of concentrations detected for each pesticide.

Dissolved Oxygen

Fish and other aquatic life are sensitive to dissolved oxygen levels and thrive within a specific range. Dissolved oxygen levels are affected directly by temperature. As temperature increases, the amount of oxygen at saturation decreases. In addition, biological activity involving respiration increases with temperature, thus depleting dissolved oxygen if it is not replenished by aeration or photosynthesis. Therefore at higher temperatures, potential dissolved oxygen levels in a stream or lake are lower. Similar to temperature, dissolved oxygen levels vary at different spatial and temporal scales. The Columbia River exhibits a dynamic and variable dissolved oxygen regime. The dissolved oxygen levels in the Columbia River generally meet the dissolved oxygen standards except for violations in WRIAs 61, 53 (Lake Roosevelt area) and 41 in 2002/2004 (Ecology 2005c).

Metals

Metals are substances that have the potential, either singularly or cumulatively, to adversely affect characteristic water uses, cause acute or chronic toxicity to the sensitive biota, or adversely affect public health. The concentrations of metals that are considered toxic to humans can differ from levels that are considered toxic to aquatic biota. For example, aquatic organisms are more sensitive to copper concentrations than humans; therefore, the regulatory limit for copper is lower for natural water bodies than it is for drinking water. A number of acute and chronic metals standards are calculated as a function of the total water hardness because the toxicity of some metal ions decreases as hardness increases. Cycling and release of metals from contaminated lakebed sediments to the water column is a complex but common phenomenon. The process is very dynamic and related to multiple physical, biological, and chemical processes that occur at the sediment-water interface.

3.4.2.1 Early Action Study Areas

Lake Roosevelt Drawdown

Water Quantity. Columbia River water is impounded in Lake Roosevelt by the Grand Coulee Dam. Lake Roosevelt extends approximately 150 miles northeast of Grand Coulee Dam to the Canadian border and up the Spokane River, a tributary of the Columbia, to within 37 miles of Spokane. The total storage capacity of the reservoir is about 9.4 million acre-feet, and the active capacity is about 5.2 million acre-feet. The average annual inflow to Lake Roosevelt is 99.3 million acre-feet. A majority of the flow into Lake Roosevelt occurs during the spring runoff season, which lasts from April to July and accounts for 65 to 70 percent of the total annual inflow volume. The annual volume inflow has varied from a minimum of 48.5 million acre-feet to a maximum of 111.8 million acre-feet.

The purposes for which the Columbia Basin Project and Lake Roosevelt were constructed are flood control, irrigation, and hydropower. For flood control, sufficient volume is maintained in Lake Roosevelt to control the flow in the Columbia River at The Dalles Dam to a maximum of 450,000 cubic feet per second. Flood control parameter curves specify the amount of storage space required based on the forecasted runoff at The Dalles and adjusted for available upstream storage capacity other than at Grand Coulee Dam. The forecast of runoff at The Dalles is made by the Corps of Engineers Reservoir Control Center at Portland, Oregon. The flood control operation for the entire Columbia River is dictated by the Corps of Engineers during the flood control season.

Lake Roosevelt is the primary source of irrigation water for the Columbia Basin Project. Water is pumped from the lake at Grand Coulee Dam to the Feeder Canal, which leads to Banks Lake, a re-regulating reservoir for the Columbia Basin Project. The average annual volume of water diverted from Lake Roosevelt and the Columbia River is 2.4 million acre-feet.

Grand Coulee Dam regulates Lake Roosevelt water levels between 1,208 feet mean sea level (minimum pool) and 1,290 feet mean sea level (full pool). Figure 3-10 illustrates Lake Roosevelt levels for three different years that represent a dry (2003), wet (1997), and average year (2002). The lake level varies throughout the year, depending on flood control, power, irrigation, fisheries, and recreational needs. For example, flood control needs mandate that by late April or early May, Lake Roosevelt must be drawn down to a level that provides a high probability that downstream flood control needs will be met. This action, however, can affect the amount of water available to supplement flows for downstream fisheries. Likewise, spring drawdowns of the reservoir must be done in a manner that ensures refill of Lake Roosevelt by summer. This refill affects not only meeting recreational needs, but the availability of water releases to assist downstream fisheries in August and September.

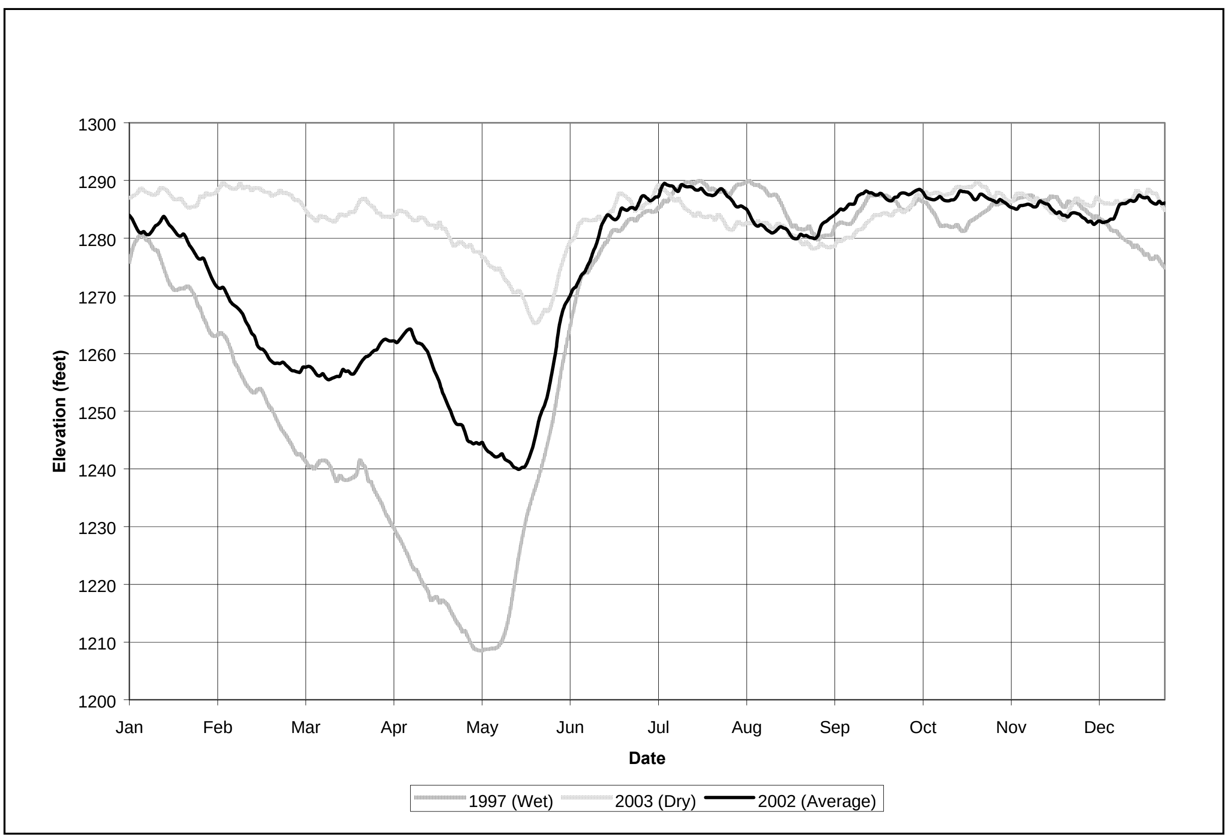
During July and August, lake elevations generally fluctuate between 1,278 and 1,290 feet mean sea level. Water can be released to supplement instream flows for downstream juvenile salmon migration within the guideline of not reducing the lake level below an elevation of 1,280 feet mean sea level. This guideline can be exceeded by an additional two feet in below-average water years. There is an effort to maintain lake level elevations between 1,283 and 1,285 feet during October to assist with Lake Roosevelt's kokanee fishery—specifically for collection brood stock and ensuring their access to tributaries. Fall and winter lake levels may also be varied to support flows for spawning downstream chum salmon.

Water Quality. A number of technical studies related to water quality have been conducted on Lake Roosevelt. A bibliography of related studies is provided in Appendix G. The primary issues of concern with respect to water quality relate to toxic contaminants that are present in the lakebed sediments and their potential for release to the water column.

The lake is contaminated with trace elements discharged as slag material from a smelter in Canada. Approximately 360 metric tons were discharged per day from 1900 to 1998. A study by the USGS reported that Lake Roosevelt bed sediments were contaminated based on high metals concentrations, impaired benthic invertebrate communities, and laboratory sediment bioassays. The majority of previous studies have focused on contaminants in water, sediment, and fish. The potential effects to air quality are described in Section 3.3.5. Recently concern has risen over the potential threat of airborne contaminants to human health.

Lake Roosevelt, identified as Franklin D. Roosevelt Lake, is listed on Ecology's 2002/2004 303(d) list 14 times (Ecology 2005c). Category 5 parameters (water quality-limited areas that require a TMDL) include two listings for dissolved oxygen, two listings for temperature, and one listing for mercury in tissue. Other 303(d) listings include dioxins in both tissue and water, total dissolved gas, total polychlorinated biphenyls (PCBs) in tissue, mercury in tissue, pH, and arsenic.

Figure 3-10. Lake Roosevelt Water Elevations



3.4.2.2 Supplemental Feed Route

Water Quantity

The proposal for providing a Supplemental Feed Route for Potholes Reservoir is described in Section 2.6.2. At present, the Potholes Canal System serves approximately 204,000 acres, requiring up to 990,000 acre-feet annually from Potholes Reservoir. To meet this supply from Potholes Reservoir requires up to 350,000 acre-feet of feed annually. There are three feed routes being used currently (see Figures 2-1 and 2-4). The primary route is through the East Low Canal to Rocky Coulee Wasteway then into Upper Crab Creek, Moses Lake and finally into Potholes Reservoir. The two secondary routes are through Lind Coulee Wasteway and through Frenchman Hills Wasteway. Water is spilled from the East Low Canal to Lind Coulee Wasteway, which flows directly to Potholes Reservoir. The other secondary route spills water from the West Canal to the Frenchman Hills Wasteway, which also flows directly to Potholes Reservoir.

Winter and spring spill from Potholes Reservoir, if needed, is passed down Lower Crab Creek. Naturally occurring flood water can also be passed down Lower Crab Creek.

Description of Supplemental Feed Route Alternatives

The purpose of a Supplemental Feed Route is to provide flexibility in the ability to supply feed water to Potholes Reservoir. A minimum fall feed water program with maximum spring feed and small amounts of summer feed water would allow the system to be operated with the greatest degree of flexibility and least likelihood of Potholes Reservoir spill. A need exists for a Supplemental Feed Route that has the ability to increase feed water capacity after runoff until fall, without impacting Potholes Reservoir winter storage capacity. Reclamation states that the Supplemental Feed Route should have the ability to feed a minimum of 25 percent of the current maximum feed water amount of 350,000 acre-feet (Blanchard 2006).

Three alternative routes for Potholes Reservoir supplemental conveyance have been proposed. They are identified as the Crab Creek, W20 Canal, and Frenchman Hills Wasteway.

Crab Creek Alternative

This alternative would release water from Billy Clapp Lake into Brook Lake, a natural water body within the Crab Creek channel. The water would then be conveyed down the natural Crab Creek channel to Moses Lake and through Moses Lake to Potholes Reservoir. The Brook Lake outlet of Billy Clapp Lake would be improved so water will not back up on the toe of Pinto Dam. A measuring location would be added near the Brook Lake outlet. The Crab Creek channel would be modified to minimize sediment transport and capacity issues.

Table 3-10 shows the discharge of Crab Creek at the USGS Irby station (Site 12465000) located approximately 18 miles upstream of Brook Lake (USGS 2006f).

Table 3-10. Crab Creek Discharge (cfs) at Irby
Period of Record 1942-2005

Month	Discharge[1]		
	90%	50%	10%
April	19.7	78.5	202
May	11.9	38.1	96.5
June	8.4	26.5	55.7
July	4.6	18.0	32.1
August	2.6	10.6	23.3
September	1.6	7.3	19.7

[1] % is percentage of time flow is exceeded

Another gaging station is located on Crab Creek 3.5 miles upstream from Moses Lake (Site 12467000). The average monthly discharges at this gage are shown in Table 3-11 (USGS 2006f). The flows are affected by return flows from irrigated area and discharges from the East Low Canal to Rocky Coulee Wasteway to feed Potholes Reservoir.

Table 3-11. Crab Creek Discharge (cfs) at Moses Lake
Period of Record 1951-2005

Month	Discharge[1]		
	90%	50%	10%
April	10.4	41.1	217
May	21.1	32.0	111
June	19.7	41.6	82.4
July	32.5	48.2	103
August	39.7	57.7	119
September	40.4	62.2	122

[1] % is percentage of time flow is exceeded

The current proposal is to provide a base rate of water flow from Billy Clapp Lake of around 100 cubic feet per second (cfs) year-round with larger discharges during spring and summer as needed. The 100 cfs base inflow would add 72,000 acre-feet annually to Potholes Reservoir with 30,000 acre-feet added to the winter inflows. Targeting an October end-of-month storage at 1,028 feet mean sea level (msl) would still leave room for a 25-year runoff volume in Potholes Reservoir. To meet the winter releases, Billy Clapp Lake would be drawn down to an elevation of 1,300 feet msl by March 1 and be refilled to 1,326 feet by March 18. In addition to the base feed water supply, this route could also be used during the spring and summer months to increase water supply during drought years. The exact amount would vary due to the volume of runoff from Upper Crab Creek and irrigation demands. The ability to convey an additional 500 cfs from April through June, as needed, would supply 90,300 acre-feet.

West Canal

The West Canal would be used for both the W20 Canal and the Frenchman Hills Wasteway alternative. The West Canal is usually filled with water starting on March 22. The Quincy-Columbia Basin Irrigation District treats the West Canal system for aquatic weeds during its operations. Restrictions on the chemicals used require that no water can be released to a feed route while a treatment is taking place. Because of the difficulty of making large changes in canal flows, Reclamation has assumed that large supplemental flows will not occur after the first chemical weed treatment. Chemical treatments in the West Canal start at mile 23, with the first treatment beginning on May 10. The W20 Canal is treated beginning a week later than the West Canal.

W20 Lateral Alternative

For this alternative, supplemental water would be conveyed from Billy Clapp Lake via the Main Canal and West Canal to the W20 Canal diversion. Water would then be conveyed down the W20 Canal and diverted to Moses Lake, which flows to Potholes Reservoir.

The diversion from the West Canal into the W20 Canal averages 150,000 acre-feet annually (approximately 380 cfs) throughout the irrigation season with a maximum of 33,000 acre-feet (approximately 540 cfs) in July (MWG Mar 2002).

Currently the W20 Canal below the Naylor Siphon has a capacity of 850 cfs. The existing Naylor Siphon, which starts at the West Canal and crosses under a railroad and State Route 28, has a capacity of 590 cfs. The route from the W20 Canal to Moses Lake would be designed to have a flow of 600 cfs. Flows with an enlarged Naylor Siphon would be limited to between 600 and 500 cfs due to available space in the W20 Canal. Currently, the last feed date is May 18 due to aquatic weed treatment.

Assuming a second Naylor Siphon is constructed, the W20 Canal would have the capacity to add a maximum of 50,100 acre-feet to the spring supplemental. The West Canal above the W20 Canal does not limit flow via the W20 Canal during the months of April and May, but because of West Canal constraints, the W20 Canal route would not have any capacity to add to the summer feed even if weed treatment were not a constraint. The W20 Canal would not be used in the fall.

Frenchman Hills Wasteway

Water would be conveyed from Billy Clapp Lake via the Main Canal and West Canal to the Frenchman Hills Wasteway. The water would then be discharged through the Frenchman Hills Wasteway into Potholes Reservoir.

Discharges were collected at USGS Site 12471090 within the Frenchman Hills Wasteway from October 1993 to September 1994. The discharges for April to September 1994 are listed in Table 3-12 (USGS 2006f).

Table 3-12. Frenchman Hills Wasteway Discharge April-September 1994

Month	Discharge (cfs)
April	360
May	424
June	466
July	449
August	560
September	543

Frenchman Hills Wasteway crosses under two county roads, Dodson Road and Road C SE. The existing Dodson Road crossing has a capacity of 1,100 cfs and the Road C SE crossing has a capacity of 500 cfs.

Frenchman Hills Wasteway is currently used during the spring feed operation. It is anticipated that this will continue and the use of Frenchman Hills Wasteway as a supplemental route would be in addition to the current operation. Currently feed water supply from Frenchman Hills Wasteway is limited to between 100 to 150 cfs because of Road C SE culvert flow capacity above current return flows. Return flows during April and May usually range from 350 to 400 cfs.

In addition to constraints posed by aquatic weed treatments, capacity must be maintained in the West Canal for emergency shutdown of five main pumping plants: Quincy, Babcock, Evergreen, Frenchman Springs, and Frenchman Hills. Table 3-13 shows the maximum April to May pumping rates for the years of 1996 to 2005 for each pumping plant.

Table 3-13. Large Pumping Plants on the West Canal

Pumping Plant	Maximum April-May Flow (cfs)
Quincy (Mile 26)	410
Babcock (Mile 35.9)	270
Evergreen (Mile 44)	220
Frenchman Springs (Mile 53.1)	170
Frenchman Hills (Mile 61)	300

In the event of a loss of the Quincy pumping plant, the water that was being pumped will be diverted out the Winchester Wasteway. Similarly if the Frenchman Hills pumping plant goes down, the water that was being pumped will go out the Frenchman Hills Wasteway. However, if one of the Babcock, Evergreen or Frenchman Springs pumping plants shuts down, there must be space in the West Canal for this flow, over and above any feed flows. Of these pumping plants, Babcock is the controlling pumping plant. A lateral diversion at West Canal mile 35.9 delivers water to the Babcock pumping plant. This lateral canal is just upstream of the W36 Check. The W36 Check, and the West Canal below it to Frenchman Hills Wasteway, must maintain space for 270 cfs. The capacity of the W36 Check is the controlling point for this section of canal. The W36 Check limits the maximum flow via the West Canal to 700 cfs beginning on April 1 and ending at 150 cfs on May 10. If all plants go down during feed, then it is assumed that the Winchester Wasteway, Columbia River Wasteway, and Frenchman Hills Wasteway, which have a combined capacity of over 2,000 cfs, would be used to pass the approximate total of 1,370 cfs.

Frenchman Hills Wasteway must be designed to pass the maximum feed and the maximum flow in case of canal failure in the 5th Section of the West Canal or the Royal Branch Canal. The maximum flow reported for the Royal Branch Canal is 580 cfs and for the West Canal 5th Section is 510 cfs for the period from 1996 to 2005. Frenchman Hills Wasteway should be designed to pass approximately 1,500 cfs if it is used as a feed route with the maximum feed being 700 cfs.

Currently Frenchman Hills Wasteway conveys approximately 21,000 acre-feet in the spring to Potholes Reservoir. Assuming enlarged culvert crossings, the West Canal would have a capacity to feed an additional 25,000 acre-feet in the spring via Frenchman Hills Wasteway. The Frenchman Hills Wasteway route does not have any capacity to add to summer feed. The Frenchman Hills Wasteway would not be used for fall feed.

Water Quality

The Supplemental Feed Routes would involve linking existing water bodies and waterways that have different water quality. The geographic extent of the affected environment for each of the Supplemental Feed Routes is as follows:

- <u>Crab Creek Route Alternative</u>: Billy Clapp Lake, Brook Lake, Upper Crab Creek from Brook Lake to Moses Lake, Moses Lake and Potholes Reservoir;
- <u>W20 Route Alternative</u>: West Canal, Moses Lake, and Potholes Reservoir; and
- <u>Frenchman Hills Route Alternative</u>: West Canal, Frenchman Hills Wasteway, and Potholes Reservoir.

These Supplemental Feed Routes are within the Columbia Basin Project area. Water quality in the Columbia Basin typically declines as the water moves through the project with the addition of agricultural return flows. The contribution of phosphorus, nitrates, and sediment from return flows in Moses Lake and Potholes Reservoir is greater than contributions upstream where there is less influence from the surrounding land use. However, some sediment settles out when it reaches slow-moving water bodies such as Moses Lake and Potholes Reservoir, and nitrate levels can be diluted with increased water inputs or from the uptake of nitrate by vegetation (Reclamation 1982).

The water quality in Billy Clapp Lake, Brook Lake, and the West Canal is generally good. Crab Creek's water quality is generally good in terms of fecal coliform and dissolved oxygen (Ecology 1996). However, Crab Creek and the Frenchman Hills Wasteway have problems with temperature and pH, which have led to their inclusion on the 2002/2004 303(d) list (Ecology 2005c).

Excess nutrients present in Moses Lake have been linked to eutrophic or hypereutrophic conditions during the summer months, resulting in persistent algal blooms that can inhibit public use of the lake (Ecology 2003). A meso-eutropic lake is one that has an adequate amount of organic material to support a variety of aquatic species (Czech 2005). An eutrophic lake has an excessive amount of organic material that inhibits the growth of aquatic species (Czech 2005). As a consequence, the lake is listed as an impaired water body on the 2002/2004 Clean Water Act 303(d) list (Ecology 2005). Moses Lake also has elevated concentrations of pesticides and is on the 2002/2004 303(d) list for 2,3,7,8-TCDD and total PCBs (Ecology 2005c).

Potholes Reservoir is generally a meso-eutrophic to eutrophic lake and has elevated concentrations of the pesticide dieldrin, which is accumulating in the tissues of the reservoir's aquatic life. The reservoir was listed as an impaired water body on the 2002/2004 303(d) list for the dieldrin violations (Ecology 2005c).

3.4.2.3 Voluntary Regional Agreements

Volunteer Regional Agreements (VRAs) could be formed anywhere in the Columbia River Basin. The surface water quality for VRAs would be the same as described above for the Columbia River Basin (see Section 3.4.2).

3.5 Ground Water

Washington state defines ground water as:

> . . . all waters that exist beneath the land surface or beneath the bed of any stream, lake or reservoir, or other body of water within the boundaries of this state, whatever may be the geological formation or structure in which such water stands or flows, percolates or otherwise moves . . . (RCW 90.44.035).

Ground water is underground water found in pore spaces between grains of soil or rock or within fractured rock formations. Ground water typically originates as precipitation that infiltrates through soil and underlying unsaturated geologic materials until reaching the water table. The saturated zone is referred to as an aquifer when it is capable of yielding sufficient water to a supply well. Saturated zones composed of coarse sands and gravels or those occupying large fractures in bedrock are generally the most productive aquifers. An aquifer is recharged by the process of infiltration and percolation of water to the zone of saturation (Ecology and WDFW 2004).

Surface water bodies and aquifers, particularly shallow aquifers, are often interconnected. Stream flow derived from ground water discharge during low-flow periods is referred to as baseflow. Baseflow is important in maintaining year-round flow in streams fed by rain and snowmelt runoff (Hermanson 1991).

Ground water in the Columbia River Basin in Washington is predominantly associated with the flood basalts of the Columbia River Basalt Group, but also with sediments that overlie or are interbedded with the basalts. The entire aquifer system underlies approximately 50,600 square miles of the Columbia Plateau in Washington, Oregon, and parts of northwest Idaho (Figure 3-11) (Bauer 2000).

A large portion of this area is included in the Central Columbia Plateau/Yakima River Basin National Water-Quality Assessment study unit that has generated numerous ground water technical investigations by the USGS. Work in the study unit is intended to focus on separating the mechanisms and effects of various agricultural management practices on ground water, surface water, and stream ecosystem conditions to characterize how natural and anthropogenic chemicals move through the hydrologic system. This information is intended to help local, regional, state, and federal land managers produce sound decisions regarding water and land management within the study area.