6.0 ENVIRONMENTAL IMPACT

The potential project impacts, both positive (i.e. benefits) and negative, to the aquatic resources are described in this chapter. The chapter first begins with a discussion of the amount of water supply potentially available from the project, followed by a description and rationale of the operational alternatives. Environmental baseline conditions are then described for Lake Wenatchee, the tributaries to Lake Wenatchee and the mainstem Wenatchee River including descriptions of the aquatic species, wetlands, and water quality. Following these descriptions, potential impacts to these aquatic resources from the five operational alternatives (Section 3.5) are assessed, along with their relative benefits, followed by a section of conclusions regarding such. We conclude the chapter with recommendations for and brief descriptions of additional studies that may be needed to address specific issues or concerns.

6.1 WATER AVAILABILITY

The relative magnitude of potential instream flow benefit ascribable to the water storage project is directly related to the amount of water that could be made available for downstream release. This study considered two lake elevations for determining the available quantity of water, 1872.4 feet and 1870.3 feet These lake elevations corresponded respectively to first, the 90% exceedence high water mark, and second, the ordinary high water mark. From a water storage perspective, the 1872.4 feet lake elevation would provide about twice the amount of water as would the 1870.3 feet elevation, and therefore, theoretically more biological benefits in the form of a higher magnitude and longer duration of instream flows that could be released downstream. The operational alternatives were therefore developed around these two lake elevations.

6.2 OPERATIONAL ALTERNATIVES

Given the two lake elevations under consideration (1872.4 and 1870.3 feet) and the respective volumes of water that would be available for each, the objective of the alternatives development process was to determine how to use the water in the most biologically meaningful fashion. Correspondingly, the development of the operational alternatives described in Section 3.5.2.5 was directed toward the release of supplemental flow to the mainstem Wenatchee River at those times that would provide the greatest benefit to fish. A number of factors were considered in this evaluation including; a) ESA status of the species; b) timing of when stored water would be available; and c) species periodicity/presence in the mainstem river during the time of water availability (Figure 6.3-1).

Consideration of those factors suggested that chinook salmon adult passage and spawning, and juvenile rearing should be the primary focus of the flow releases from the lake. Chinook are listed under the ESA and are present in the river when streamflows are characteristically the lowest (i.e. August through October). Important life history functions of chinook salmon during this period are as follows:

1) Adult passage occurs over a prolonged period extending from May through the end of September,
2) Spawning in the mainstem river is reported to occur as early as August and extend through October,
3) Egg incubation extends August through April, and

4) Juvenile rearing essentially occurs year-round.

Since flows in August average slightly higher than in September, the greatest potential biological benefit would likely be achieved by centering the flow releases from the rubber dam on September. During periods of extreme drought and low flow conditions, supplemental flow releases could potentially benefit chinook by providing more mainstem river spawning and juvenile rearing habitats.

Flow augmentation could also be directed toward providing some flow related benefits for sockeye salmon and spring chinook salmon upstream passage. Adult sockeye and spring chinook salmon move into and through Lake Wenatchee during the period from mid-June through July on their upstream migration to spawn in the upper tributaries (primarily Little Wenatchee and White rivers). Under conditions of extreme low flow during those periods, the provision of supplemental flows may provide some benefits related to upstream passage.

Based on these biological targets, the five alternatives described in Section 3.5.2.5 were developed. The first three alternatives assumed a lake elevation of 1872.4 feet and would make available additional stored water of about 12,300 acre-feet in excess of historic water levels. The last two alternatives (4 and 5) assumed an elevation of 1870.3 feet (OHWM) and would provide about half of the water (6,750 af) available in alternatives 1-3. Importantly, the use of the stored water would target low water/drought conditions when natural streamflows are well below average. Under normal or above average flow conditions, the rubber dam would generally not be used.

The five alternatives and their potential resource targets are summarized in Table 6.2-1.

Table 6.2-1. Description of five alternatives and their resource targets considered in the environmental impact analysis of the Lake Wenatchee Water Storage Feasibility Study.

Alternative Number, Lake Elevation and (Available Storage acre-feet (af))	Period of Seasonal Storage	Alternative Description	Resource Target
1 – El 1872.4 feet; (12,300 af)	July 1 – August 22	Upramp flows at 10 cfs increments from August 23-31; maintain flows at 100 cfs in excess of historic outflow from Sept. 1 until storage depletion	Mainstem chinook salmon spawning and juvenile rearing habitats
2 – El 1872.4 feet; (12,300 af)	July 1 – August 22	Upramp flows at 20 cfs increments from August 23-31; maintain flows at 200 cfs in excess of historic outflow from Sept. 1 until storage depletion (duration = ½ Alternative 1)	Mainstem chinook salmon spawning and juvenile rearing habitats
3 – El 1872.4 feet; (12,300 af)	June 1 – June 30	Pulse flows of 100 cfs released at 4 hour intervals from July 1 – August 15; maintain flows of 100 cfs in excess of historic outflow from August 16 until storage depletion	Upstream migration of spring chinook and sockeye salmon into Lake Wenatchee; early mainstem chinook salmon spawning and juvenile rearing habitat
4 – El 1870.3 feet; (6,750 af)	July 1 – August 22	Upramp flows at 5 cfs increments from August 23-31; maintain flows at 50 cfs in excess of historic outflow from Sept. 1 until storage depletion	Mainstem chinook salmon spawning and juvenile rearing habitats
5 – El 1872.4 feet; (6,750 af)	July 1 – August 22	Upramp flows at 10 cfs increments from August 23-31; maintain flows at 100 cfs in excess of historic outflow from Sept. 1 until storage depletion	Mainstem chinook salmon spawning and juvenile rearing habitats

6.3 ENVIRONMENTAL BASELINE OF THE AQUATIC RESOURCES

The baseline conditions of the aquatic resources in the Lake Wenatchee Water Storage Feasibility Study project area that may be influenced by the operation of the rubber dam are described in this section. The areas potentially influenced by the rubber dam are described as: 1) tributaries; 2) Lake Wenatchee; and 3) the mainstem Wenatchee River. Construction and operation of the rubber dam will have potential impacts on portions of the White River, the Little Wenatchee River, Nason Creek, the Wenatchee River, and Lake Wenatchee (Figure 1.0-1).

6.3.1 Areas Influenced by Lake Wenatchee Rubber Dam

The Wenatchee River basin is mainly within the rain shadow of the Cascade Mountains. The climate in the basin is characterized by heavy precipitation in the high elevations and semi-arid conditions in the lowermost portion of the basin. Most of the precipitation occurs as snow during the winter. Average annual precipitation is nearly 150 inches in the mountains and 8.5 inches or less in the city of Wenatchee (Andonaegui 2001). Stream flows are dominated primarily by snowmelt and the highest flows occur in May. Low flows typically occur from July until the fall rains in late September or October (Section 3.5).

6.3.1.1 Tributaries to Lake Wenatchee

Two rivers flow into Lake Wenatchee, the White River and the Little Wenatchee River. The general characteristics of these tributaries are described below.

6.3.1.1.1 Little Wenatchee River

The Little Wenatchee River flows into Lake Wenatchee at the western corner of the lake. The headwaters are in a broad high-elevation meadow that receives snowmelt from the mountains. The watershed is primarily forested and the U.S. Forest Service owns 97% of the land, with 61% of the watershed designated as wilderness (Hindes 1994). Logging has occurred on 7% of the watershed, mostly in the lower elevations (Hindes 1994). The lower two reaches of the river are depositional areas of an ancient lake bed, and both reaches are structurally complex, meandering, and connected to floodplain wetlands (USFS 1998). The downstream-most reach empties into Lake Wenatchee through a wetland delta and the stream substrate is sandy and there are several beaver ponds. Upstream of this reach, the riverbed contains a substantial number of gravel and cobble riffles, with most spawning habitat available at elevations above the usual high water lake level (Photograph 6.3-1). A gravel/sand mine is located in the vicinity of the gravel-sand transition region of the current stream, which indicates the upstream most extent of inundation-related effects from Lake Wenatchee. A natural barrier to upstream salmonid migration is located at RM 7.8 on the Little Wenatchee River (Mullan 1992). Salmon spawning correspondingly occurs between the reach influenced by lake backwater and the Little Wenatchee Falls (WDFW and WWTIT 1994).


Photograph 6-3.1. Little Wenatchee River near upper extent of lake backwater effect; the river contains extensive amounts of spawning gravel. Photos taken during November 2002 field reconnaissance.

6.3.1.1.2 White River

The White River drains snow and glaciers in the Cascade Mountains and Glacier Peak Wilderness. Although the entire river was identified as a potential Wild and Scenic River by the National Park Service, the lower third of the river flows through private lands including resorts and a golf course (Hindes 1994). The lower reach of the river is similar to the Little Wenatchee River in that it flows through a sandy-bottomed, complex wetland where it empties into Lake Wenatchee at the western corner of the lake (Photograph 6.3-2). However, the length of the lower White River influenced by high lake levels is considerably longer than in the lower Little Wenatchee River. A natural barrier to upstream salmonid migration is located at RM 14.3 (Mullan 1992), with most spawning occurring between the

Napeequa River and the White River Falls (WDFW and WWTIT. 1994), above the influence of the lake backwater.

Photograph 6.3-2. White River at FS Road 6500, looking downstream (left photo) and White River above lake influence zone. Photos taken during November 2002 field reconnaissance.

6.3.1.1.3 Other Tributaries

The outlet of Lake Wenatchee forms the Wenatchee River (RM 54.2)(Photograph 6.3-3), and Nason Creek flows in the Wenatchee at RM 53.6, downstream of the rubber dam location. There is a barrier to anadromy on Nason Creek at RM 16.8 (Mullan 1992). Other major tributaries that enter the Wenatchee River include the Chiwawa River (RM 48.4), and Icicle (RM 25.6), Chumstick (RM 23.5), Peshastin (RM 17.9), and Misson (RM 10.4) creeks (Figure 1.0-1).

Photograph 6.3-3. Lake Wenatchee looking upstream within outlet channel near proposed site of rubber weir (upper photo) and upstream view of Wenatchee River just below lake outlet at control riffle, from Highway 207 bridge (right photo). Photos taken during November 2002 field reconnaissance.

6.3.1.2 Mainstem Wenatchee River

Most of the annual stream flow in the Wenatchee River originates from tributaries in the upper basin including the White River (25%), Little Wenatchee River (15%) and Nason Creek (18%) (Bilhmer et al. 2002). At the outlet of Lake Wenatchee, the Wenatchee River is as at elevation 1,876 feet. The elevation at the confluence with the Columbia River is approximately 600 feet

For the purposes of this report, the mainstem Wenatchee River is referred to as the upper Wenatchee River, which extends from the outlet of Lake Wenatchee (RM 54.2) near Plain downstream to Tumwater Canyon (RM 35.6) and the lower Wenatchee downstream to the mouth at the city of Wenatchee (Photograph 6.3-4). The upper reach is characterized as a U-shaped valley consisting of glaciofluvial outwash deposits on the valley floor (Bilhmer et al. 2002). The river gradient in this reach is flat and has been reported as being approximately 0.3 percent (WDFW et al. 1990). The lower Wenatchee River includes the ten-mile stretch of Tumwater Canyon, which is a moderate gradient reach (<2%) through a bedrock canyon (Andonaegui 2001). At the downstream end of the canyon is Tumwater Dam (RM 31.0) and below this the river flows through a relatively confined channel that is down cut through a glacial floodplain. This includes the reach of the river below Leavenworth extending to Peshastin (Photograph 6.3-5) Dryden Dam is located at RM 17.0, and portions of the towns of Cashmere (RM 10.4) and Monitor (RM 6.0) and various orchards are located on the floodplain of the lower reach (Andonaegui 2001). At the mouth, Rock Island Dam at RM 453.4 on the Columbia River may at times impound water in the lower Wenatchee River (RM 468.4) resulting in deposition of fine sediment (Andonaegui 2001). Six other dams are on the Columbia River downstream of the Wenatchee River: Wanapum Dam at RM 415.8, Priest Rapids Dam at RM 397.0, McNary Dam at RM 292.0, John Day Dam at RM 215.6, Dalles Dam at 191.5, and Bonneville Dam at RM 146.1.

Photograph 6.3-4. Wenatchee River at Plain, looking downstream of Highway 209, and within Tumwater Canyon section above Leavenworth, Washington. Photos taken during November 2002 field reconnaissance.

Photograph 6.3-5. Upstream (left photo) and downstream (right photo) views of Wenatchee River near Peshastin, Washington. Photos taken during November 2002 field reconnaissance.

Normal low-flows in late summer/early-fall in the Wenatchee River are exacerbated by water withdrawals for irrigation (WDF et al. 1990). The largest water diversion on the river is the Dryden diversion at Dryden Dam (RM 17.0). In the upper Wenatchee River measured stream flows have not been greatly affected by water withdrawals. Water supply for small domestic systems and a single irrigation diversion near the town of Plain (RM 46.2) are the only uses upstream of the City of Leavenworth (RM 25.0) (Andonaegui 2001).

Minimum instream flow requirements were established in 1983 for three reaches on the Wenatchee River, as measured at gaging stations at the towns of Plain (RM 46.2), Peshastin (RM 21.5), and Monitor (RM 7.0) (WAC 173-545). The purpose of establishing minimum instream flows was to protect aesthetic, navigation, scenic, water quality, fish, wildlife, and other environmental values (Beery and Kelly 1983). These flows are often not met during the winter and late summer as a result of naturally low flows and diversions during the summer (WRWSC 1998).

6.3.1.3 Lake Wenatchee

Lake Wenatchee is a large, steep-sided lake located approximately 15 miles north of Leavenworth in the Wenatchee National Forest. It is fed principally by the Little Wenatchee River and the White River, and drains to the Wenatchee River. A large wetland is at the western end of the lake at the deltas of the Little Wenatchee and White rivers. A terminal glacial moraine at the east end of the lake is the natural dam that formed the lake. A diverse community of submerged aquatic vegetation along the shoreline extends to a depth of about 5.0 meters (Ecology 1997). The lake normally freezes over during the winter months and strong winds keep the lake mixed during much of the other seasons (Sylvester and Ruggles 1957). General physical characteristics of the lake (Ecology 1997) are presented below:

Size (acres)	2,480
Maximum Depth (feet)	244
Mean Depth (feet)	147
Lake Volume (acre-feet)	364,560
Drainage Area (square miles)	273
Altitude (feet)	1,875
Shoreline Length (miles)	13.3

6.3.2 Aquatic Species

Several populations of economically and culturally important fish species are found in the Wenatchee River system. Four species of anadromous (ocean-rearing) fish are present in the basin: chinook (*Oncorhynchus tshawytscha*), sockeye (*O. nerka*), steelhead (*O. mykiss*), and Pacific lamprey (*Lampetra tridentata*). While historically abundant, native coho (*O. kisutch*) have been extinct from the basin since the early 1900s. Reintroduction efforts were begun in 1997, with the first coho release in 1999. Other important salmonid species in the Wenatchee basin are bull trout (*Salvelinus confluentus*), kokanee (*O. nerka*), westslope cutthroat trout (*O. clarki lewisi*), and rainbow trout (*O. mykiss*). Three fish species in the Wenatchee River basin are protected under the federal Endangered Species Act (ESA). Steelhead and spring chinook in the Wenatchee River basin are listed as endangered under the ESA. Bull trout in the Wenatchee River basin are listed as threatened under the ESA.

The basin also supports a number of other native fish species including mountain whitefish (*Prosopium williamsoni*), mountain sucker (*Catastomus platyrhynchus*), largescale sucker (*Catostomus macrocheilus*), and bridgelip sucker (*Catostomus columbianus*), Umatilla dace (*Rhinichthys umatilla*), speckled dace (*Rhinichthys osculus*), redside shiner (*Richardsonius balteatus*), northern pikeminnow (*Ptychocheilus oregonensis*), peamouth chub (*Mylocheilus caurinus*), and three-spine stickleback (*Gasterostius aculeatus*) (Berg et al. 2002). Other species reported to be in the basin are longnose dace (*Rhinichthys cataractae*) and shorthead sculpin (*Cottus confusus*) (Hillman in Chapman 1989). In addition, the nonnative eastern brook trout (*Salvelinus fontinalis*) are distributed throughout the watershed (Berg et al. 2002). Isolated lakes in the watershed, including Fish Lake and several of the high alpine lakes are also stocked with a variety of nonnative game fish.

The Wenatchee River Subbasin is believed to contain 15 species of amphibians (Berg et al. 2002). Amphibian species likely to occur in the project area are the great basin spadefoot (*Spea internontana*), Pacific treefrog (*Hyla regilla*), roughskin newt (*Taricha granulosa*), and western toad (*Bufo Boreas*) (Hides 1994). In addition, the area potentially supports tailed frog (*Ascapus truei*) and two Washington State candidate/sensitive and Federal species of concern: the Columbia spotted frog (*Rana luteiventris*) and the Larch Mountain salamander (*Plethodon larselli*) (Berg et al. 2002). Additional important aquatic species that may be present in the watershed include two freshwater mussels species: the winged floater (*Anodonta nuttalliana* aka *A. oregonensis* or *A. wahlamatensis*), and the western ridge mussel (*Gonidea angulata*).

6.3.2.1 Fish Species

The salmonid and lamprey species in the Wenatchee River watershed share a set of common freshwater habitat needs, generally referred to as "cool, clean water." In particular, these species depend on water temperature cues to trigger upstream migrations and spawning activities. In addition, because these species lay their eggs in the gravel, they require areas where flows have sorted gravel by size and the substrate is relatively lacking in fine particles (such as sand and silt). Although each species have specific habitat requirements, in general, the requirements can be outlined as including:

- Clean, well oxygenated water;
- Adequate flows for migration, holding, spawning, and rearing;
- Cool water temperatures;
- Gravel areas for spawning that have less that 10% fines;
- Complex habitat containing pools, riffles, and structure (boulders or LWD); and
- Canopy cover to reduce heat adsorption.

The general life history of anadromous salmonid fish involves constructing nests (redds) in the gravel for spawning and incubation. Upon emergence from the gravel, the juvenile salmon rear in freshwater and then migrate to the ocean to feed and mature. The adult salmon then return to their natal sites to spawn and complete their life cycle. There are many variations on the timing and duration of these life cycles among species and from year to year within species. Each salmonid species present in the Wenatchee

River has a different length and timing of freshwater residence. Non-anadromous salmonid species complete their entire life cycle in freshwater.

Historically, all adult salmon and steelhead migrating up the Columbia River between 1939 and 1943 were intercepted at Rock Island Dam by the USFWS, as part of the Grand Coulee Dam Fish Maintenance (GCDFM) Project (Peven 1992). Fish collected at Rock Island Dam were then relocated to the Wenatchee, Entiat, Methow, and Okanogan river basins or they were used as broodstock at hatcheries located on Icicle Creek and the Entiat and Methow rivers (Peven 1992).

6.3.2.1.1 Chinook salmon (Oncorhynchus tshawytscha)

Chinook salmon are divided into three major run types: spring, summer and fall. Spring run fish are considered "stream type" while summer and fall run fish are "ocean type" (Healey 1983). Stream type fish spend one or more years in freshwater before outmigrating as smolts. Ocean type fish will generally spend less than one year in freshwater before outmigrating as subyearlings. Both stream and ocean type chinook are present in the Wenatchee River basin.

Adult spring chinook (stream-type) return to the Columbia River from the ocean in late March to early April and then enter the Wenatchee River during the period from May to June (Figure 6.3-1). Low summer stream flows through the Tumwater Canyon may delay entry into the Wenatchee River (WDFW 1994). Spawning takes place in August and September, peaking in mid- to late-August. Spawning areas for spring chinook in the Lake Wenatchee watershed include: Nason Creek, and the Chiwawa, Little Wenatchee, White, and mainstem Wenatchee rivers (Figures 6.3-2 and 6.3-3). After incubation, juvenile spring chinook emerge from the gravel from late March to early May. They generally spend their first summer rearing in the subbasin and outmigrate in late fall through the following spring. Numerous life history types may be exhibited in the Wenatchee basin including rearing and/or overwintering in tributaries, side channels, the mainstem Wenatchee, or Lake Wenatchee or outmigrating in the fall or winter (NMFS 1998). The extended use of freshwater habitats makes stream-type chinook more susceptible than ocean-type chinook to impacts from habitat alterations in the tributaries.

Four separate spring chinook stocks have been identified in the Wenatchee basin: Chiwawa River, Nason Creek, Little Wenatchee River and White River stocks (WDFW 1994). All four stocks were classified by WDFW as "Depressed" based on chronically low production (Andonaegui 2001). Adult fish are collected at upstream dams on the Chiwawa River and Nason Creek for hatchery broodstock at the Rock Island Fish Hatchery Complex. Hatchery supplementation of spring chinook in the Wenatchee basin has averaged 2,712,859 fish from 1982 to 1991. Spring chinook in the Upper Columbia Evolutionarily Significant Unit (ESU), including the Wenatchee basin, were listed as endangered under the ESA on March 16, 1999 (FR 64 14308). This listing includes all naturally spawned spring chinook as well as hatchery stock spring chinook from the White River, Nason Creek and Chiwawa River.

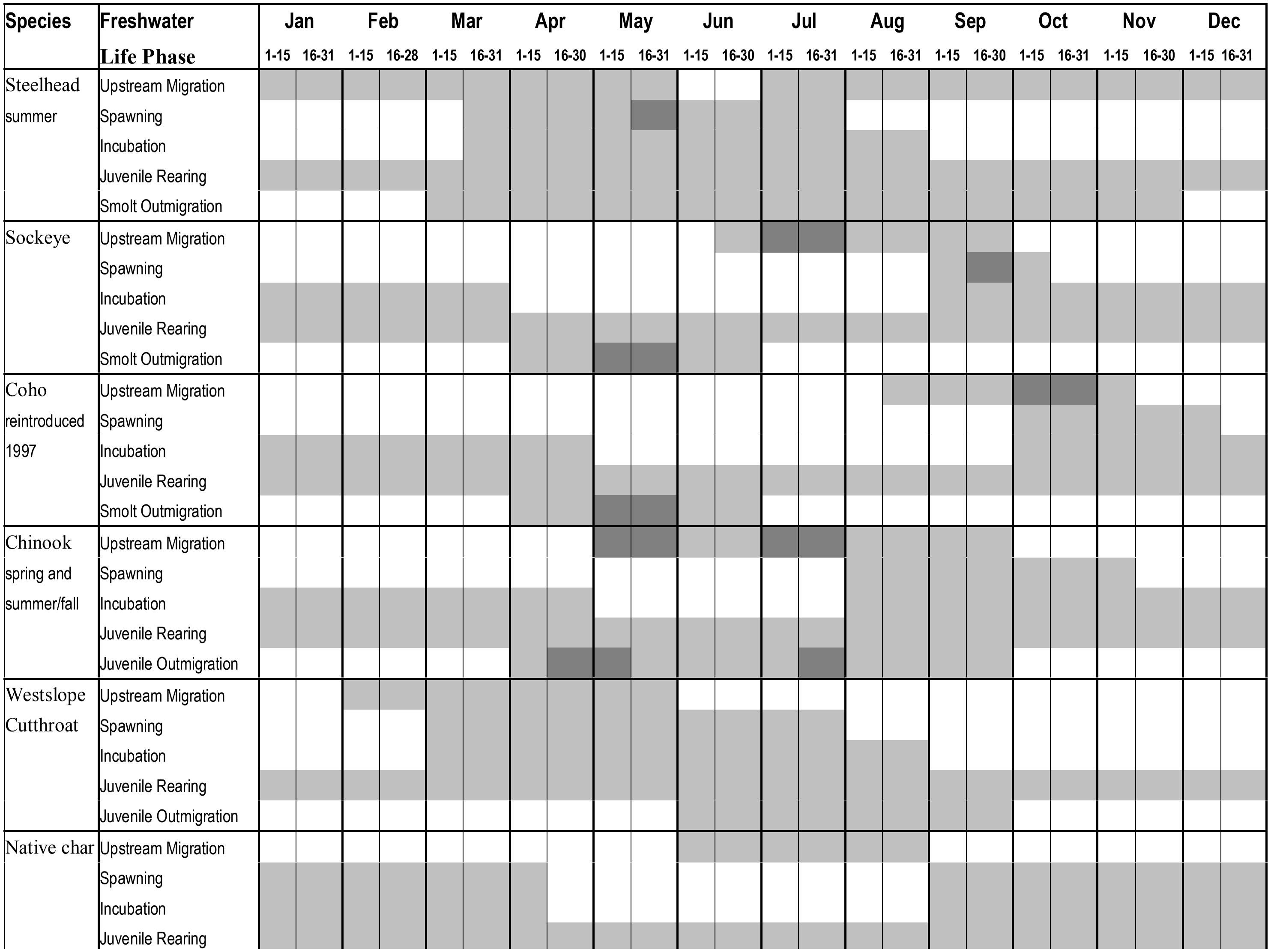

Figure 6.3-1. Temporal distribution of adult and juvenile salmonid habitat utilization in the Wenatchee River basin, Washington. Darker areas indicate times of peak occurrence at the mouth of the Wenatchee River. Data adapted from NMFS et al. 1998, Beery and Kelly 1982 and USFWS 1999.

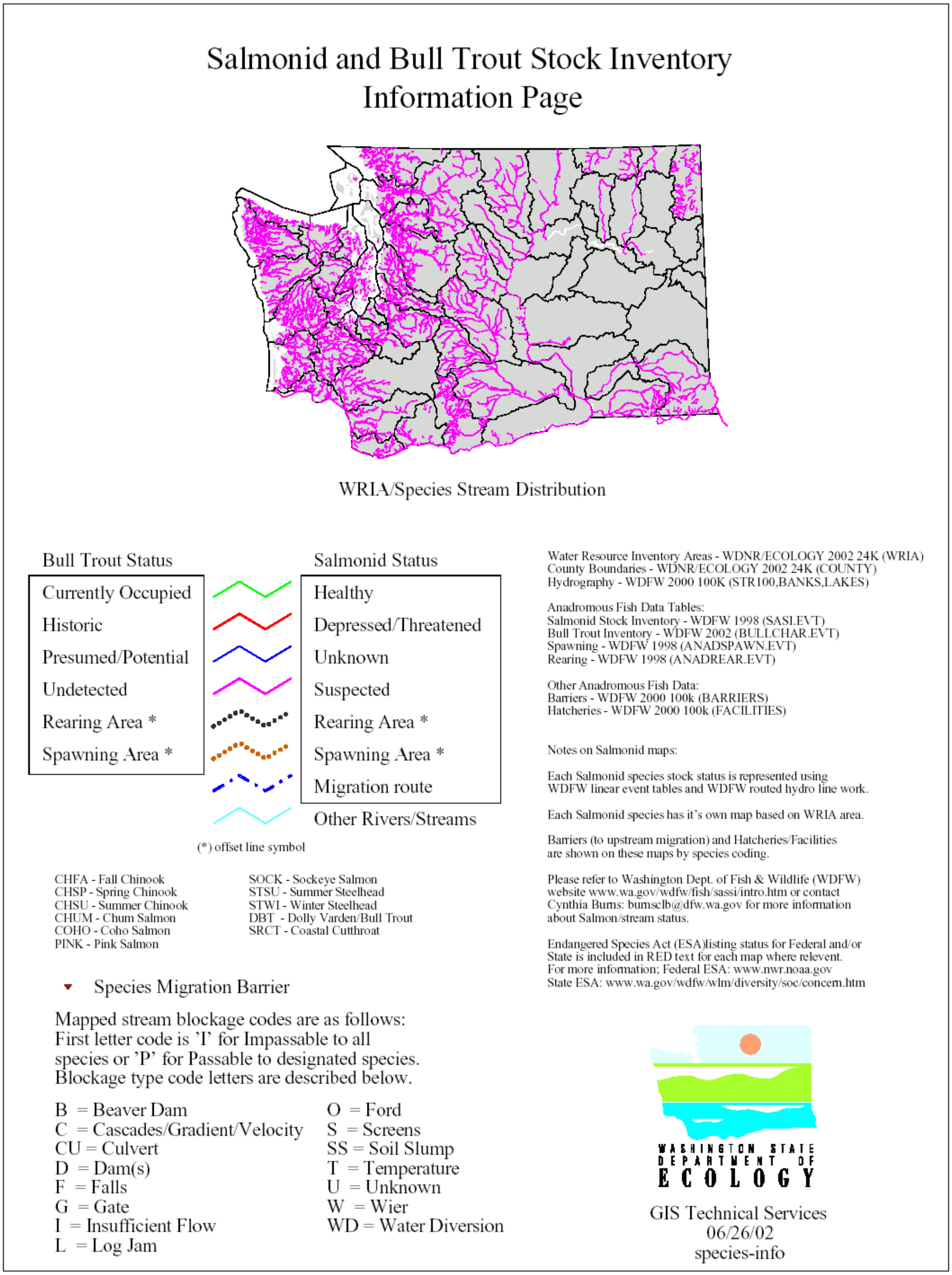

Figure 6.3-2. Legend and information page for the WRIA 45 fish distribution maps.

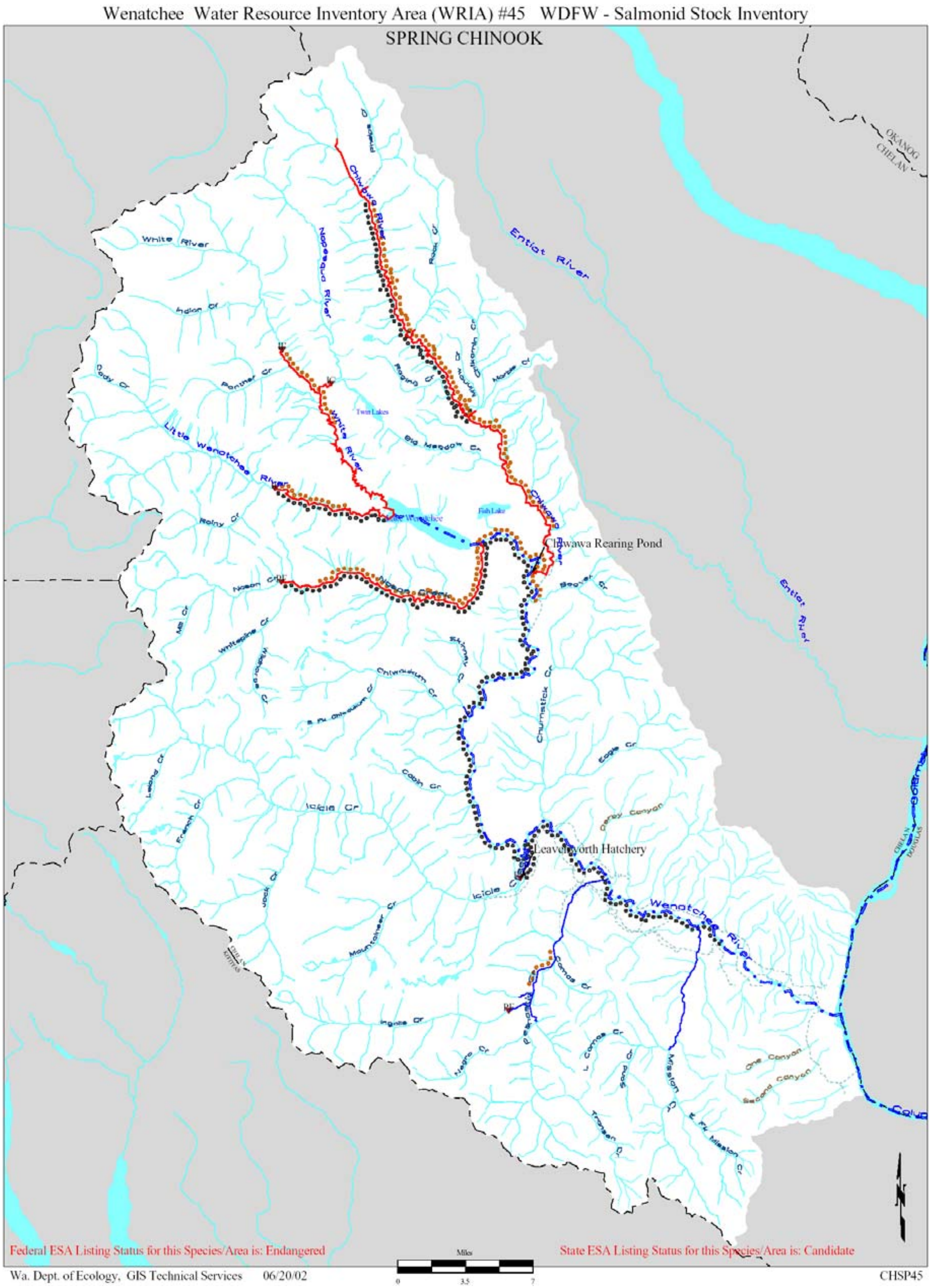

Figure 6.3-3. WRIA 45 spring chinook salmon distribution map.

Summer (ocean-type) chinook enter the Wenatchee River basin during the period from late June through August. Spawning starts in late September and continues into early November. Peak spawning occurs during early to mid-October (WDFW 1994). Summer chinook spawn in areas throughout the mainstem Wenatchee River, from the outlet of Lake Wenatchee downstream to its confluence with the Columbia River (NMFS et al. 1998). However, most of the spawning occurs within 8 miles of Leavenworth (WDFW 1994). Emerging summer chinook fry rapidly migrate downstream from the Wenatchee River during the period from late winter to spring, and typically exit the river basin prior to low streamflow conditions in the fall. This behavior indicates that conditions in the mainstem Columbia River and its reservoirs have a greater influence on the smolt survival of ocean-type chinook than the conditions in the Wenatchee River.

One summer chinook run has been identified in the Wenatchee River basin (WDFW 1994). This run is classified as "Healthy" based on escapement, and is the third largest naturally produced chinook run in the Columbia River basin (Andonaegui 2001). Recent summer chinook counts (1994 to 1998) at Rock Island Damon the Columbia River averaged approximately 18,400 chinook. The summer chinook run in the Upper Columbia River (including the Wenatchee River basin) are not listed under the ESA.

6.3.2.1.2 Sockeye salmon/kokanee (O. nerka)

Sockeye salmon differ from other salmon species by requiring a lake environment to complete their life cycle. Anadromous sockeye return to the Columbia River from the ocean beginning in mid-June with most returning in early July (WDFW 1994). The adults migrate into Lake Wenatchee during late July and early August, and they then spawn in September (Figure 6.3-1) (WDFW 1994; Andonaegui 2001). Principal sockeye spawning areas in the Lake Wenatchee basin include the Little Wenatchee River (RM 0 to 5), the White River (RM 5.5 to 9.3), and the Nepecqua River (RM 0 to 1.2) (NMFS et al. 1998) (Figures 6.3-2 and 6.3-4). Additionally, some fish may spawn along the shoreline at the upper end of Lake Wenatchee, but this has not been verified (NMFS et al. 1998).

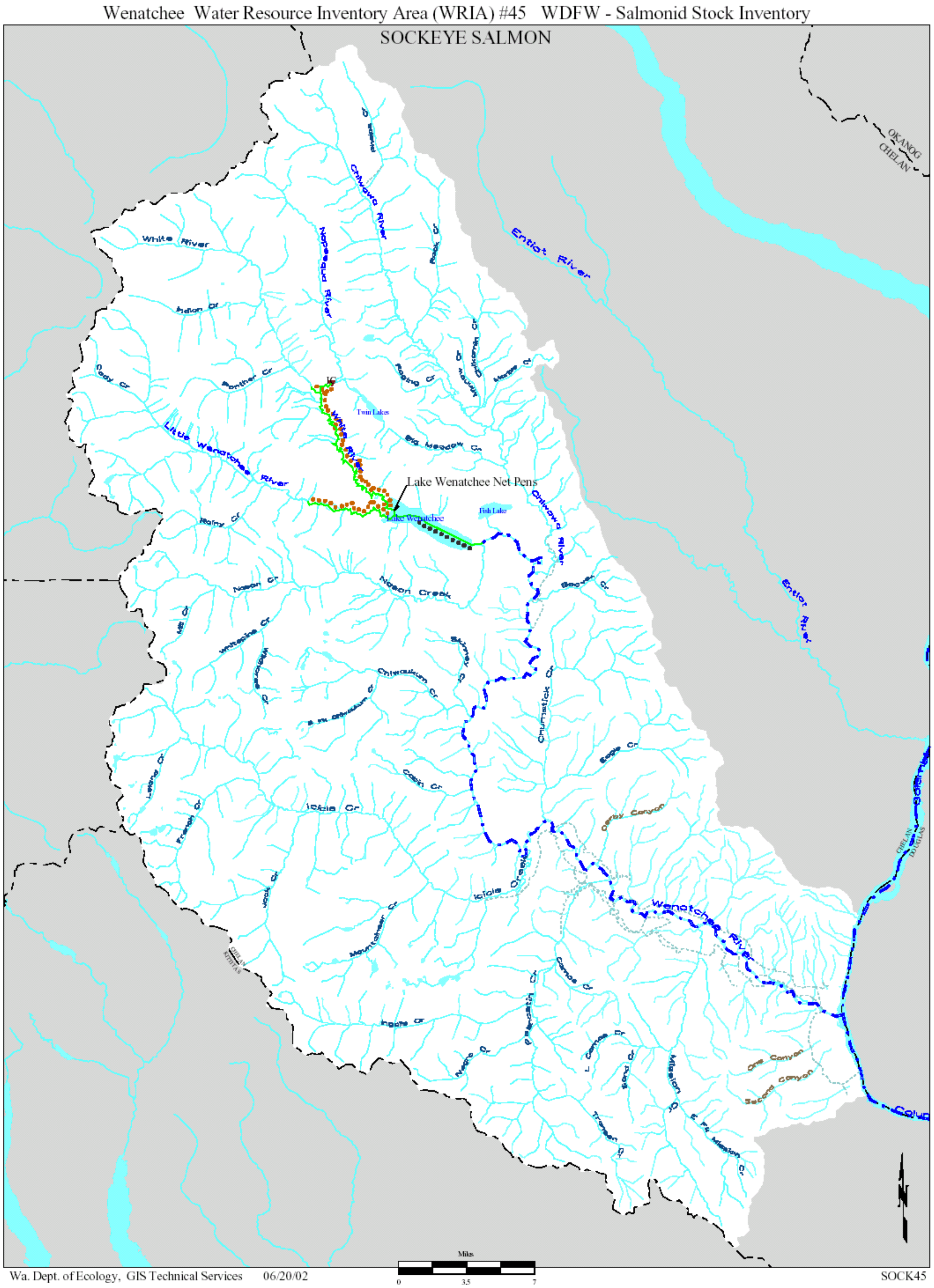

Figure 6.3-4. WRIA 45 sockeye salmon distribution map.

Sockeye fry emerge from the gravel during the period from early to late spring and then the fry quickly migrate into Lake Wenatchee to rear. A snorkel survey in 2001 of Lake Wenatchee detected the presence of sockeye fry in the littoral areas starting on May 11, although other surveys have reported that sockeye fry enter Lake Wenatchee between March and May (Murdoch and LaRue 2002). Most juvenile sockeye rear for one year in the lake, although, some may rear for two years (NMFS et al. 1998). A small percentage of sockeye remain in Lake Wenatchee their entire lives. These non-anadromous sockeye are known as kokanee, and are described below. Outmigrating sockeye smolts typically pass the Mid-Columbia River dams during the period from April through May (Andonaegui 2001).

Lake Wenatchee sockeye are one of only two runs still existing in the Columbia River Basin (USFS 1998). Historically, sockeye were produced in eight river systems in the Columbia River basin (Peven 1992). Today, only about 5 percent of the pre-1900 nursery lake habitat in the Columbia River basin remains accessible today to sockeye salmon (Gustafson et al. 1997). Although the Lake Wenatchee sockeye run is believed not to be in danger of extinction in the foreseeable future, concerns about the overall health of this run include the effects of hydropower development on the Columbia River and the effects on genetic integrity as a result of hatchery production and potential interbreeding with non-native kokanee (Gustafson et al. 1997). The historical sockeye salmon abundance in the Wenatchee River basin was drastically depleted by irrigation diversions and over fishing in the early 1900s (Andonaegui 2001 and WDFW 1994). Specifically, Dryden and Tumwater dams had historically poor rates of adult passage. Both fishways have been rebuilt and are no longer major passage barriers for adults.

The current sockeye population in Lake Wenatchee is a mixture of native sockeye and descendants of fish transferred to the basin during the GCDFM Project that began in 1939. As part of that project, 2.4 million Quinault River sockeye were released into Lake Wenatchee. Sockeye production at the Leavenworth hatchery was discontinued in 1969, but a hatchery program to rear fry in Lake Wenatchee pens was initiated in 1990 (WDFW 1994). Since 1993, native sockeye counts at Rock Island Dam have ranged between 8,500 and 41,500 (Andonaegui 2001). WDFW considers the Wenatchee River sockeye natural stock status to be "Healthy" at this time, based on escapement (averaging 30,000 adult fish since 1977). Wenatchee Basin sockeye are considered part of the Lake Wenatchee ESU. This ESU is not federally listed under the ESA and provides a growing recreational fishery.

Kokanee (freshwater sockeye salmon) follow an adfluvial (lake-rearing) life history pattern. These fish mature in Lake Wenatchee, spawn in the tributaries or along the shore, and die after spawning. Their life history characteristics are similar to sockeye, except that they are not anadromous, and the kokanee generally mature at a smaller size than their anadromous counterparts (Gustafson et al. 1997).

Hatchery reared kokanee have been released in Lake Wenatchee, including native stock and stock from Lake Whatcom (Gustafson et al. 1997). Kokanee are considered by the NMFS to be part of the Lake Wenatchee sockeye salmon ESU, are not presently in danger of extinction, and are not believed likely to become endangered in the foreseeable future (Gustafson et al. 1997).

6.3.2.1.3 Summer steelhead / Rainbow trout (O. mykiss)

Steelhead in the Wenatchee River are summer-run fish that return to the Columbia River basin from the ocean as upstream migrating adults during June through August (Figures 6.3-2 and 6.3-5) (WDFW 1994). Steelhead migrate or hold in freshwater through the fall and winter until they spawn in the spring. In the

Wenatchee system, spawning occurs from March through June, or as late as July in colder headwaters. Peak steelhead spawning probably occurs in late May. Unlike salmon, most steelhead do not die after spawning and are capable of spawning again in the following years. Steelhead smolts typically outmigrate from the Wenatchee River in March through early June. Fish counts at Rock Island Dam on the Columbia River indicate that the majority of steelhead smolts pass the dam in May. Most Upper Columbia River steelhead mature for one or two years in the ocean before returning to their natal streams to spawn (WDFW et al. 1990).

Resident forms of steelhead are called rainbow or redband trout. The relationship between steelhead and resident forms is not clearly understood. Steelhead progeny can mature as resident fish, and resident rainbow trout have the ability to become anadromous (Peven 1992). Steelhead/rainbow are found in a number of systems within the Wenatchee River basin: Mission, Sand, Brender, Peshastin, Chumstick, Icicle, Chiwaukum, and Nason creeks and the Chiwawa, Little Wenatchee, White, and Wenatchee rivers (NMFS et al. 1998) (Figure 6.3-5).

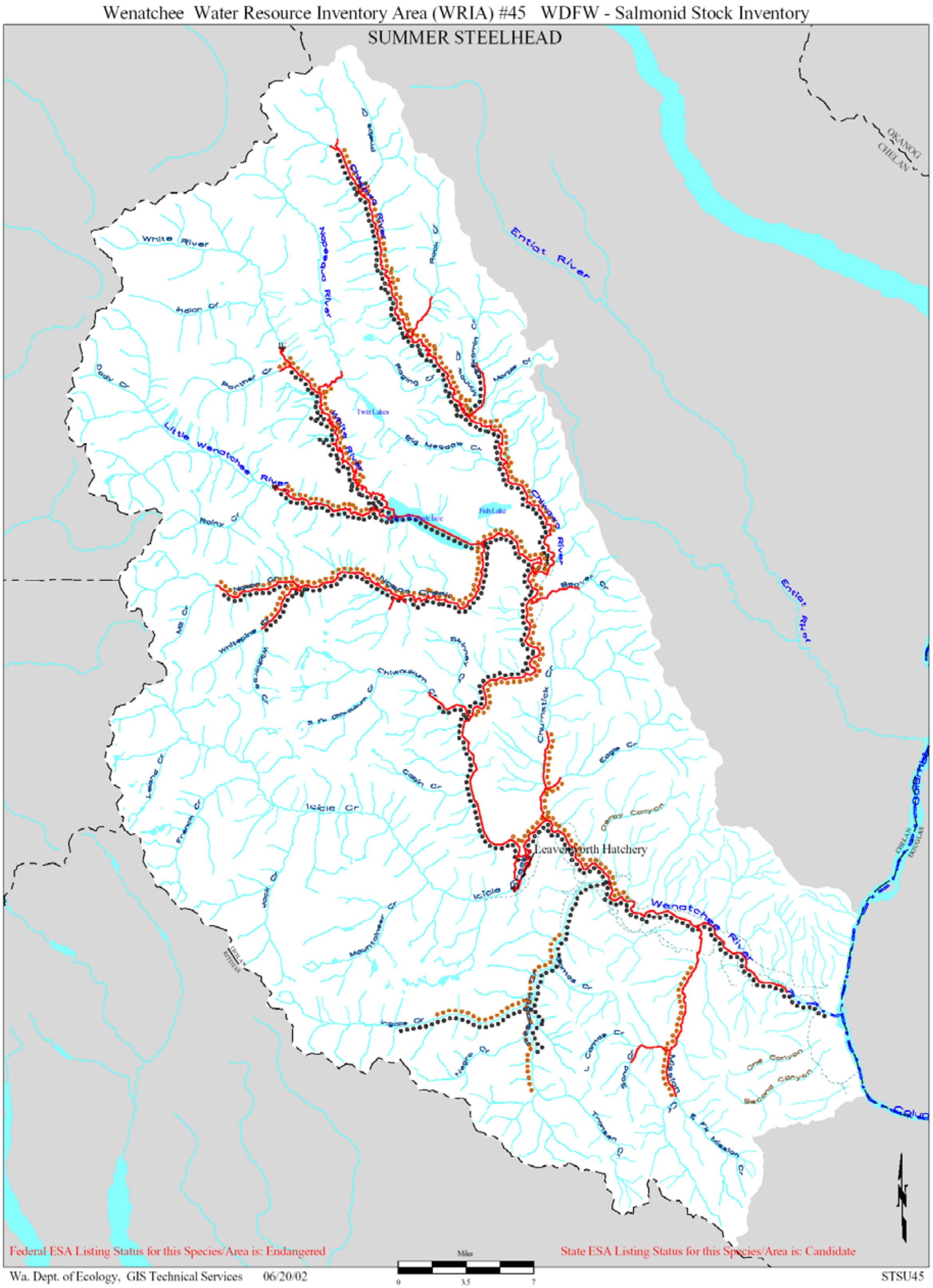

Figure 6.3-5. WRIA 45 steelhead distribution map.

The numbers of naturally spawning steelhead has declined over time. Peven (1992) reported that in 1987, hatchery steelhead accounted for 73 percent of the steelhead run entering the Columbia River. WDFW currently classifies the Wenatchee stock as "Depressed" due to chronically low production (WDFW 1994). The Upper Columbia ESU of summer steelhead, including the Wenatchee River basin, was listed as endangered under the federal ESA on August 18, 1997 (62 FR 43937).

6.3.2.1.4 Coho salmon (O. kisutch)

By the early 1900s, the Mid-Columbia coho salmon population was decimated, and today indigenous coho are not present in the Wenatchee River basin. Several factors contributed to the decline including harvest rates, impassable dams, unscreened irrigation diversions, logging, mining, grazing and water use practices in the tributaries (Andonaegui 2001). Historical adult coho populations in the Wenatchee subbasin were estimated by Mullan (1983 as cited in Andonaegui 2001) at 6,000 to 7,000. Historically, coho probably returned to the Wenatchee River in August and September and spawning likely occurred from October to mid-December (Figure 6.3-1) (Andonaegui 2001). Columbia River coho typically spend one year in freshwater before outmigrating as yearling smolts in April or May. Adult coho will spend approximately 18 months at sea before returning to spawn.

Because native coho salmon no longer occur in the Upper Columbia River system, the Wenatchee basin coho are not addressed under the ESA or by the WDFW (1994) Salmon and Steelhead Stock Inventory. The Yakima Nation has begun efforts to "restore coho salmon populations in mid-Columbia tributaries to levels of abundance and productivity sufficient to support sustainable annual harvest by tribal and other fishers" (Dunnigan 1999). In 1999, the Yakima Nation released approximately 525,000 coho smolts in the Wenatchee subbasin (Dunnigan 1999). In 2001, three coho redds were observed in Nason Creek (Murdoch and LaRue 2002).

6.3.2.1.5 Pacific lamprey (Lampetra tridentata)

One of the most primitive fishes found in the Wenatchee River system is the Pacific lamprey (NMFS et al. 1998). Pacific lamprey are often mislabeled as pest species due to the problems associated with the exotic sea lamprey (*Petromyzon marinus*) in the Great Lakes (Close et al. 1995). However, Pacific lamprey are native to the Wenatchee River. Lamprey have freshwater habitat requirements similar to the Pacific salmon, and therefore face the same habitat problems affecting salmonid abundance and distribution. In particular, elevated water temperatures (greater than 20ºC) and increased sediment in spawning gravels are two major habitat factors attributing to lamprey population decline (Close et al. 1995).

Pacific lamprey are anadromous and the adults return to freshwater in the fall and spawn in late-spring through early-summer (Close et al. 1995). Adult lamprey die after spawning and the spawned-out carcasses provide important nutrients to the stream system, as well as dietary items for other fish (Close et al. 1995). Juvenile lampreys, termed ammocoetes, swim up from the nest and are washed downstream where they burrow into mud or sand where they feed by filtering organic matter and algae (Moyle 1976). Ammocoetes generally remain in fresh water for 5 or 6 years (Wydoski and Whitney 1979). Larval lamprey transform to juveniles from July through October (Close et al. 1995). It is during this transition that they become ready for a parasitic lifestyle by developing teeth, tongue, eyes, and the ability to adapt to salt water. After metamorphosis, juvenile lamprey remain in fresh water for up to 10 months while migrating to the ocean. After reaching the ocean, Pacific lamprey attach themselves to and parasitically feed on other fish (Moyle 1976). They may remain in salt water for up to 3.5 years (Close et al. 1995).

Though historical and current population sizes of the lamprey are relatively unknown, it is clear that these fish were once a significant source of tribal subsistence as well as ceremonial and medicinal purposes. Recent reviews of the Jon Day, Umatilla, Walla Walla, Tucannon, and Grand Ronde subbasins revealed that Pacific lamprey populations are a fraction of past abundances in these basins (Jackson et al. 1997). Pacific lamprey are reported to occur in the White, Little Wenatchee, and mainstem Wenatchee rivers (Berg et al. 2002).

The USFWS was petitioned in February 2003 to protect Pacific lamprey under the ESA. However the USFWS stated that the species (and three other related lamprey species) would not be considered for ESA protection until there is more money to do the work.

6.3.2.1.6 Bull trout (Salvelinus confluentus)

Bull trout are a native char in the Wenatchee River system. Similar to steelhead and cutthroat trout, the species can spawn in more than one year. Bull trout spawning occurs in September and October, with timing dependent on cooling water temperatures. Bull trout life history strategies include anadromy as well as adfluvial (lake rearing), fluvial (river-rearing), and resident (stream rearing and spawning) forms (Pratt 1992). The Wenatchee River basin supports adfluvial, fluvial, and resident forms, and probably combinations thereof. The adfluvial form matures in Columbia River reservoirs or Lake Wenatchee and then ascends tributary streams to spawn. The juveniles rear for one to three years in the tributaries before migrating down to the lake or reservoir to mature. Fluvial populations move from rivers to smaller tributaries to spawn. Resident forms are generally smaller-bodied and spend their entire lives in headwater streams.

Adfluvial bull trout that rear in Lake Wenatchee spawn in the Chiwawa River and its tributaries, the White and Little Wenatchee rivers, and possibly in Nason Creek (WDFW 1994; Brown 1992) (Figures 6.3-2 and 6.3-6). The White River may also support a fluvial population (WDFW 1994). Resident populations are found only in the coldest streams and in streams without brook trout populations. Resident populations are believed to occur in Panther, Jack, Trout, Eightmile, Ingalls and French creeks and the Napecqua River. Bull trout spawning populations in the Wenatchee River basin are most abundant in Panther Creek (a tributary to the White River) and the Chiwawa River and its tributaries (Brown 1992). One of the major limiting factors to bull trout populations in the Wenatchee River basin is the presence of non-native brook trout. Similar habitat preferences and biology allow brook trout to hybridize with bull trout and eventually eliminate them (WDFW 1994).

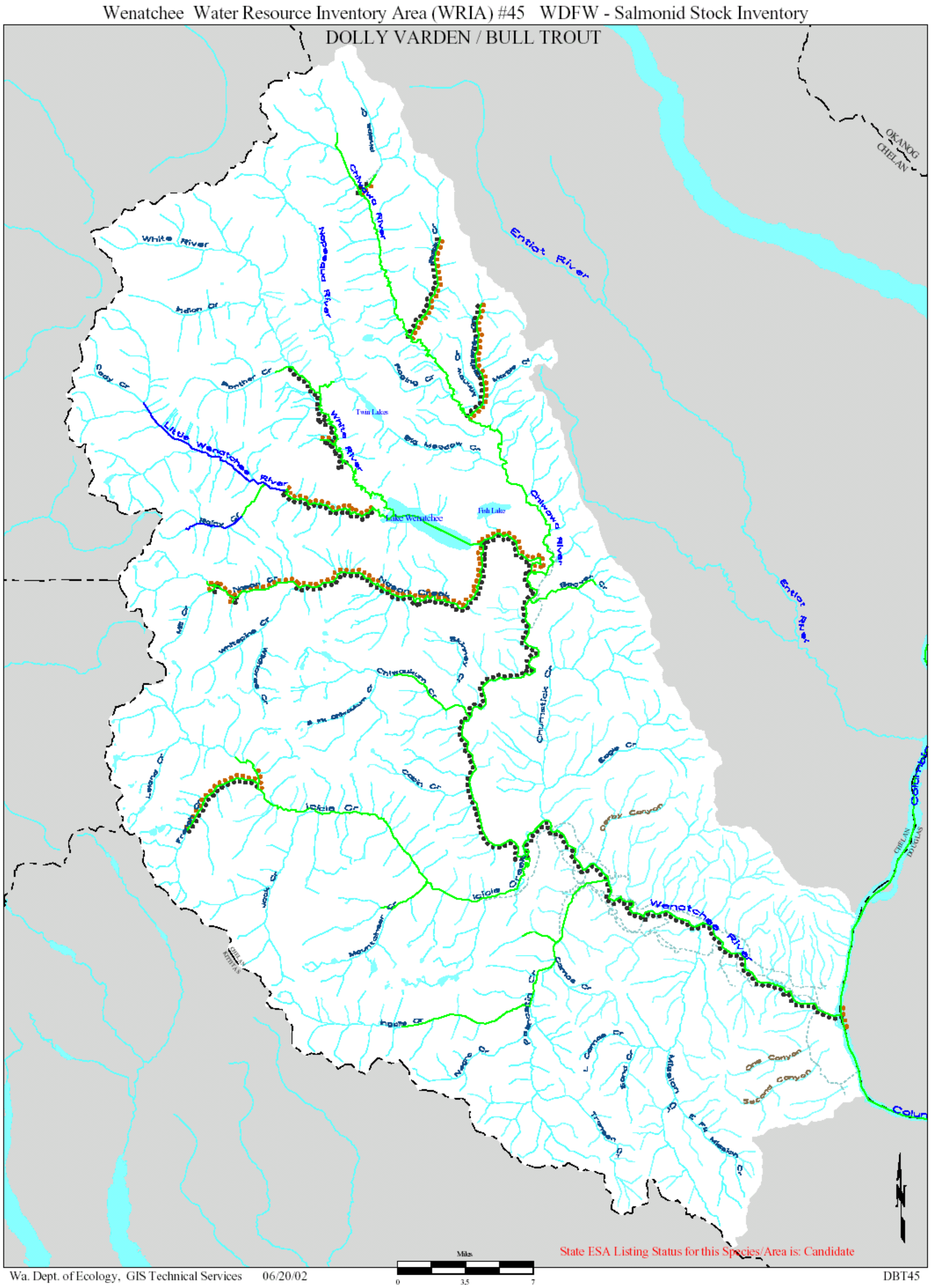

Figure 6.3-6. WRIA 45 bull trout distribution map.

Results from a recent USFWS radio-tag study indicated that adult bull trout in the Wenatchee River system migrate upstream and downstream and from one tributary to another (Ringel and DeLaVergne 2001). Adult bull trout tagged in Lake Wenatchee were found to migrate downstream into the Chiwawa, or upstream into the White or Little Wenatchee river systems to spawn (Ringel and DeLaVergne 2001) (Figure 6.3-6). Adult bull trout tagged in the Chiwawa were later found in the Chiwawa River system as well as upstream in Lake Wenatchee and the Little Wenatchee River and downstream in the Wenatchee River. It has also been reported that some adfluvial bull trout in Lake Wenatchee may migrate downstream into Nason Creek to spawn (WDFW 1994). Adult bull trout can also migrate upstream from the Columbia River and into these tributaries to spawn, although it is believed that the majority of fish spawning in the Chiwawa River system are adfluvial fish that migrate downstream from Lake Wenatchee (Murdoch et al. 2001; Ringel 2003). A separate radio-telemetry study on adult bull trout tagged in the Columbia River found that these fish migrated into the Wenatchee River in late June through September (Figure 6.3.1) (BioAnalysts 2002). Bull trout spawning populations in the Wenatchee River basin are most abundant in Panther Creek (a tributary to the White River) and the Chiwawa River and its tributaries (Brown 1992).

Data from a WDFW smolt trap on the Chiwawa River indicate that juvenile bull trout outmigrate from the Chiwawa during March through November with a peak outmigration during the period September to November when flows tend to be low, although large numbers also outmigrate with high flows in April, May and June (Ringel 2003). Many of these juvenile fish likely migrate upstream for almost 6 miles to rear in Lake Wenatchee although some migrate downstream to rear in the Columbia River.

Bull trout and Dolly Varden (*S. malma*) are difficult to distinguish based on physical characteristics, and both have similar life history traits and habitat requirements (WDFW 1998). Because the species are closely related and have similar biological characteristics, the WDFW manages bull tout and Dolly Varden together as “native char” (WDFW 1998). WDFW (1994) recognizes eleven bull trout/Dolly Varden stocks in the Wenatchee watershed: Icicle, Ingalls, Chiwaukum, Chikamin, Rock, Phelps, Nason and Panther Creeks, and Little Wenatchee, Chiwawa and White River stocks (Figure 6.3-6). Four of the eleven (Chikamin, Rock, Phelps and Panther creeks) have been categorized as “Healthy”, with the remaining seven listed as “Unknown”. Bull trout in the Columbia River Distinct Population Segment (DPS) (including the Wenatchee basin) are listed as threatened under the ESA. Section 4(e) of the ESA provides for the listing of a non-threatened species if the listing of this species provides a greater level of protection to the listed species. The USFWS indicated in January 2001 that Dolly Varden are being considered for listing as threatened due to their similarity of appearance to bull trout (66 FR 1628).

6.3.2.1.7 Westslope cutthroat trout (O. clarki lewisi)

Westslope cutthroat trout are a native subspecies of cutthroat trout (*O. clarki*). This interior species spends its entire life in freshwater. The species usually matures at 4 or 5 years of age and then spawns in small tributaries. Similar to steelhead/rainbow trout and bull trout, the westslope cutthroat trout typically does not die after spawning. Although cutthroat trout can spawn in consecutive years, individual fish may not spawn every year. Three life history strategies are utilized by westslope cutthroat trout: adfluvial, fluvial, and resident. Juvenile fish exhibiting adfluvial life histories mature in lakes and reservoirs. In the tributaries, adult and juvenile resident cutthroat remain in pools and runs that have temperatures of 7 to 16C and provide a diversity of cover (USFWS 1999). Westslope cutthroat trout feed predominately on macroinvertebrates, such as aquatic insects and zooplankton, avoiding competition with piscivorous fish such as bull trout (Behnke 1992).

The original distribution of westslope cutthroat trout is not clearly known, and because the species hybridizes with other trout species, especially rainbow trout, genetically “pure” and “essentially pure” (as defined by NMFS) populations currently exist in the Wenatchee Watershed (NMFS et al. 1998). The pure stocks primarily occur in high-elevation headwater streams where temperatures may exclude competition and hybridization with other fish species. There are populations of westslope cutthroat trout present in the Chiwawa, Little Wenatchee, and White rivers, and Nason, Icicle and Negro creeks. Other creeks that were not sampled may also support pure or essentially pure stocks.

The USFWS considers the westslope cutthroat trout a species of concern. The USFWS received a formal petition to list the westslope cutthroat trout as threatened pursuant to the ESA. A status review determined a listing of the species was not warranted at this time. Responding to requests to more thoroughly take into account the hybridization issue from numerous agencies, the USFWS reopened the public comment period until March 31, 2003 (67 FR 77466).

6.3.2.1.8 Mountain sucker (Catastomus platyrhynchus)

The mountain sucker is a small fish (6 to 8 inches) that spawns in late-spring or early-summer (Scott and Crossman 1973). Mountain suckers prefer cool stream habitat and they feed primarily on algae and diatoms. Recently, mountain sucker have been observed near the smolt trap by Lake Wenatchee (Berg et al. 2002).

The mountain sucker is included in this summary of important aquatic resources since it is listed as a Washington State priority habitat species. However, little is known about its population status and distribution in the Wenatchee River basin.

6.3.2.1.9 Umatilla dace (Rhinichthys umatilla)

Umatilla dace are a small minnow that occur in three Columbia River drainages including the Wenatchee River subbasin (Berg et al. 2002). The Umatilla dace has only recently been verified as a species distinct from the leopard dace (*R. falcatus*). Umatilla dace prefer flowing water habitat with cobble or gravel bottoms and relatively warm, productive waters. Umatilla dace are a Washington State priority habitat species, however, little is known about its distribution and population status.

6.3.2.2 Amphibians

6.3.2.2.1 Columbia Spotted Frog (Rana luteiventris)

The Columbia spotted frog and the Oregon spotted frog were originally regarded as the same species (the spotted frog, *Rana pretiosa*). Recent genetic studies have concluded they are two separate species, but that they cannot be reliably distinguished by morphology. However, the two species have allopatric (non-overlapping) ranges, so they may be reliably identified based upon location (USGS 2003).

The Columbia spotted frog is always found in close association with water. Columbia spotted frogs breed in shallow (<60cm) water emergent wetlands such as edges of ponds and small lakes. Breeding takes place in late winter or early spring depending on levels of ice present. In the Columbia basin breeding typically occurs in late March or April. Eggs are deposited in still shallow water atop vegetation mats or wetland plants. The tadpoles will emerge from the eggs in a few weeks. Tadpoles metamorphose into froglets in their first summer or fall of rearing.

The Columbia spotted frog is classified as a Washington State candidate species and a Federal species of concern. As a State candidate species, WDFW will review species information for possible listing as endangered or threatened.

6.3.2.2.2 Larch Mountain Salamander (Plethodon larselli)

The Larch Mountain salamander is one of the rarest amphibian species in the Pacific Northwest, and hence little is known concerning their life history or distribution (Leonard et al. 1993). The species is terrestrial, associated with moss-covered talus slopes, and the species may occur in some upland areas of the White and Little Wenatchee rivers (NPPC 2002). The Larch Mountain salamander is classified as a Washington State sensitive species and a Federal species of concern due to its vulnerability and likeliness to become endangered or threatened.

6.3.2.3 Other Aquatic Species

Freshwater mollusks have freshwater habitat and water quality requirements similar to anadromous salmon, and the distributions of freshwater mussels are dependent on host relationships with fish (Gustafson et al. 1997). The mussel larvae (glochidia) parasitize the gills or fins of fish and, therefore, require fish hosts to complete their life cycle. Freshwater mussels associated with the distribution of sockeye salmon include the winged floater (*Anodonta nuttalliana*) and the western ridge mussel (*Gonidea angulata*). Other species of mussels, snails and clams may also be present in the Wenatchee watershed.

6.3.3 Wetlands

At the western end of the lake there is an extensive complex of wetlands associated with the outlets of the Little Wenatchee and White rivers. These delta wetlands include littoral wetlands along the lake shore, floodplain wetlands including abandoned oxbow channels, and beaver ponds. Based on analysis of aerial photographs, information from the Department of Ecology (Ecology 1997), and general observations, vegetation in these wetlands includes:

- aquatic plant communities composed of such species as waterweed (*Elodea* spp.), pondweed (*Potamogeton* spp.), and yellow water lily (*Nuphar polysepala*);
- emergent herbaceous communities dominated by sedges (*Carex* spp.), rushes (*Juncus* spp.), spikerushes (*Eleocharis* spp.), horsetail (*Equisetum* spp.), and bur-reed (*Sparganium angustifolium*);
- shrub communities composed primarily of willows (*Salix* spp.), and
- a few small stands of cottonwood (*Populus trichocarpa*).

Because the area to the west of the lake is an ancient lake bed (see Section 6.1.1), it has a very low gradient away from the lake. Channel movement, and associated sediment deposition and erosion, by the Little Wenatchee and White rivers has resulted in some relief to the land surface, which contributes to the heterogeneity of vegetation within the wetlands. Except for wetlands along the immediate shoreline of the lake, it is not known to what degree these wetlands are connected hydrologically with Lake Wenatchee. However it is likely that the influence of the lake on groundwater and wetland hydrology extends some distance, perhaps a hundred feet or more.

6.3.4 Water Quality

Water quality in any system is determined by the water source, watershed condition, geology, and the interrelated factors of water quantity and channel form. For example, a river that is dominated by snowmelt in a forested system will generally have colder and cleaner water than a river that receives rainfall that washes over a developed watershed. The water quality in the Wenatchee River basin is similarly varied between the upper tributaries that drain melting glaciers, the water in Lake Wenatchee, and in the Wenatchee River downstream of the towns of Leavenworth and Wenatchee. The water quality variables that are of the most concern to the protection of native salmon, trout, and char species in the Wenatchee River basin are low instream flows and elevated water temperatures (NPPC 2002). In many streams, such as the Wenatchee River, low instream flows can result in higher water temperatures since the temperature of rivers with smaller volumes equilibrate faster, leading to higher maximum water temperatures in the summer (USEPA 2002).

Currently two water quality criteria for temperature to protect aquatic life are used in the Wenatchee River system. Tributaries and the Wenatchee River from the headwaters to the National Forest boundary near Leavenworth are rated Class AA (extraordinary) by the State of Washington. This classification requires that water temperatures not exceed 16ºC due to human activities. The lower Wenatchee River is rated Class A (excellent) with the requirement that water temperatures not exceed 18ºC due to human activities.

In an effort to meet the requirements of the Clean Water Act and the ESA, the U.S. Environmental Protection Agency (USEPA) recently developed a set of draft recommended criteria for water temperature to protect native char and other salmonids (USEPA 2002). Most of these recommended temperature criteria focus on the maximum water temperatures that occur in the summer, although additional criteria are recommended for temperature-sensitive salmonid uses that occur in the spring to early summer and late summer to fall (Table 6.3-1). The criteria are based on average maximum temperatures calculated from the maximum temperatures over a seven-day period (7DADM: Maximum 7 Day Average of the Daily Maximums). The use of a 7DADM criterion as a guideline for water quality is different than the single temperature criteria Ecology currently used for Class AA and Class A waters.

Table 6.3-1. USEPA recommended temperature water quality guidelines for Pacific Northwest salmonid fish.

Salmon Species and Life Stage	Recommended Criteria
Bull Trout Juvenile Rearing Applies to waters where summer juvenile bull trout rearing currently occurs and may potentially occur. This use is generally in a river basin's upper reaches.	12°C (55°F) 7DADM
Bull Trout Spawning Applies to waters where and when bull trout spawning, egg incubation and fry emergence currently occurs and may potentially occur. This criteria is designed to protect bull trout spawning, which generally occurs in the fall in the same waters that bull trout juveniles use for summer rearing. If this criterion is met during spawning, the natural seasonal temperature pattern will likely result in protective temperatures for egg incubation (<6°) that occurs over the winter. This use is defined from the average date that spawning begins to the average date incubation ends (the first 7DADM is calculated 1 week after the average date that spawning begins).	9°C (48°F) 7DADM
Salmon/Trout "Core" Juvenile Rearing Applies to core juvenile rearing habitat. Generally, core juvenile rearing applies to the furthest downstream extent of current summer use for areas of degraded habitat where current summer distribution is shrunken relative to historical distribution. For areas of minimally degraded habitat, this use would apply to waters of core use based on density and/or habitat features. This use also applies to juvenile rearing waters that currently meet this criteria. This use is generally in a river basin's mid-to-upper reaches, downstream from juvenile bull trout rearing areas. However, in colder climates, such as the Olympic mountains and the west slopes of the Cascades, this use may apply all the way to the saltwater estuary. This use is designed to protect high quality summertime juvenile rearing habitat for salmon and trout. Protection of these waters for juvenile rearing also provides protection for adult spring chinook salmon that hold throughout the summer prior to spawning and bull trout migration.	16°C (61°F) 7DADM
Salmon/Trout Juvenile Rearing and Juvenile/Adult Migration Applies to waters where summer salmon and trout juvenile rearing and juvenile/adult migration currently occurs and may potentially occur. This use extends downstream from the "core" juvenile rearing use. In many river basins in the Pacific Northwest, this use will apply all the way to river basin's terminus (i.e. confluence with the Columbia or Snake rivers or saltwater). This use is designed to protect juvenile rearing that extends beyond "core" juvenile rearing areas and migrating juveniles and adults.	18°C (64°F) 7DADM
Salmon/Trout Migration on Lower Mainstem Rivers Applies in the lower reaches of mainstem rivers (e.g. mid-lower Columbia river, lower Snake river, and possibly the lowest reaches of other large mainstem rivers) in the Pacific Northwest where based on best available scientific information (e.g. temperature modeling and predisturbance temperature data) maximum temperatures likely reached 20ºC prior to significant human alteration of the landscape. The narrative cold water refugia provision would require all feasible steps be taken to restore and protect the river functions (e.g,. alluvial floodplains) that could provide cold water refugia in these river segments. *Note: this recommendation is a combination of a numeric criteria (20°C) and a narrative WQS requiring effective protection of cold water refugia that together protects this use.*	20°C (68°F) 7DADM, with a coldwater refugia narrative provision

Salmon Species and Life Stage	Recommended Criteria
Salmon/Trout Spawning, Egg Incubation, and Fry Emergence Applies to waters where and when salmon and trout spawning, egg incubation, and fry emergence currently occurs and may potential occur. Generally, this use occurs: a) in late spring-early summer for trout (mid-upper reaches), b) in late summer-fall for spring chinook (mid-upper reaches), c) in the fall for coho (midreaches), pink, chum, and fall chinook (latter three in lower reaches). This use is defined from the average date that spawning begins to the average date incubation ends (the first 7DADM is calculated 1 week after the average date that spawning begins).	13°C (55°F) 7DADM
Steelhead Smoltification Applies to waters where the early stages of smoltification occurs in steelhead trout. Generally applies in April and May for rivers where juvenile outmigration occurs except for the mid and lower Columbia and lower Snake rivers (e.g. the criteria would apply at the mouth of the major tributaries of the Columbia river basin). This use is designed to protect the early stages of steelhead smoltification. Smoltification of other salmonids is generally protected vis-a-vis the summer maximum criteria, but this criteria provides an added level of protection for other salmonids which can successfully smolt at higher temperatures than steelhead.	14°C (61°F) 7DADM
Notes: 1) 7DADM: Maximum 7 Day Average of the Daily Maximums; 2) "Salmon" refers to Chinook, Coho, Sockeye, Pink, and Chum salmon; 3) "Trout" refers to Steelhead and coastal cutthroat trout; 4) "may potentially occur" refers to waters that will likely support the use if temperatures are restored (from USEPA 2002, Table 3. Recommended Criteria That Apply To Summer Maximum Temperatures).	

Ecology has identified three probable causes of high water temperatures in the Wenatchee subbasin resulting from human activities:

- Riparian vegetation disturbance that compromises stream surface shading, through reductions in riparian vegetation height and density
- Channel widening (increased width-to-depth ratios) that increases the stream surface area exposed to energy processes, namely solar radiation; and
- Reduced summertime baseflows resulting from instream withdrawals or from wells in hydraulic continuity with the stream (Bilhimer et al. 2002).

Other water quality concerns in the Wenatchee River basin include low dissolved oxygen concentrations (DO) and elevated pH levels; and the presence of DDT, its byproducts and other insecticides in fish tissue. The locations of stream reaches in the Wenatchee River basin listed as impaired for water quality are shown in Figure 6.3-7. In the upper Wenatchee River basin, impaired reaches include the mouth of the Little Wenatchee River and Nason Creek for elevated water temperatures, and the Wenatchee River for elevated water temperatures and low instream flow. Misson Creek near the town of Cashmere was listed as impaired by Ecology for agricultural pesticides.

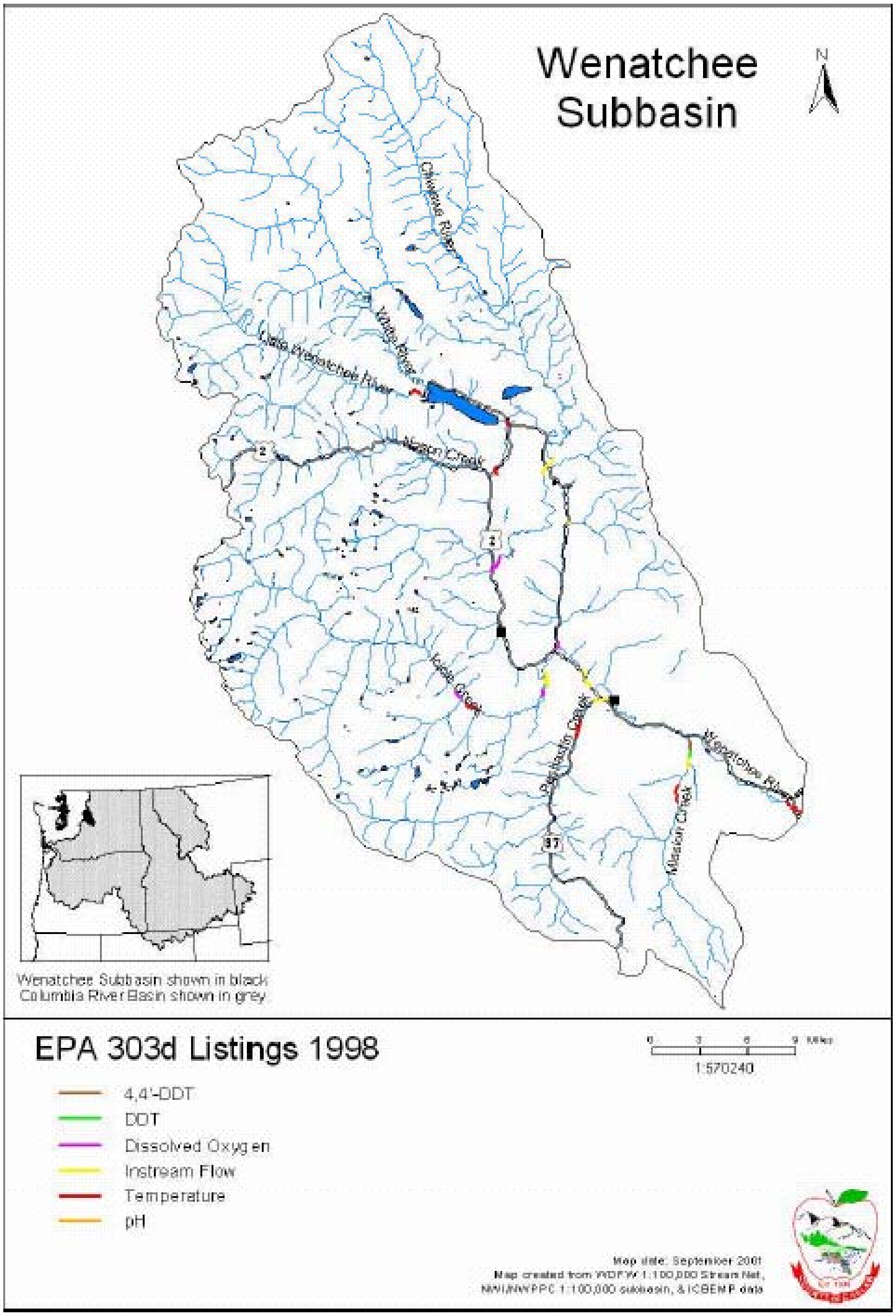

Figure 6.3-7. Map of the Wenatchee River basin indicating stream reaches that were included on the 1998 303(d) list of impaired waters (from NPPC 2002).

6.3.4.1 Tributaries

In the White River, melting glaciers maintain cool water temperatures and also result in highly turbid waters during the spring, early summer, and for short periods in the fall. The relatively pristine watershed helps maintain good water quality in the river, and typical of glacial rivers, the water is cold, well oxygenated, has low conductivity, and is low in nutrients (WRSC 1998). Water temperatures measured in the mainstem at the mouth of the White River during 1995/1996 ranged from 1.8 to 12.6ºC (WRSC 1998).

The Little Wenatchee River does not receive glacial melt water and it is therefore less turbid than the White River. However, sediment loads in the Little Wenatchee River from mass wasting are high, although it is unknown if this is related to natural flood-related pulses or if the rate of sediment loading is accelerated (USFS 1998). In addition, a gravel and sand mine located adjacent to the lower reach of the Little Wenatchee River is a testimony to the historical deposition of sediments in the river floodplain. Although water quality in the Little Wenatchee River is protected by its forested and relatively unaltered watershed, the river has a history of high water temperatures, and because of this the river was included on the 1996 and 1998 state 303(d) lists of impaired water (Ecology 1998). The causes of higher water temperatures in the Little Wenatchee River are currently being investigated and modeled by Ecology (Bilhimer et al. 2002). It is possible that the measurements of high water temperatures reflected lake water conditions rather than stream conditions, as most water temperatures were recorded near the mouth of the river where the river is dominated by wetlands and backwatering from Lake Wenatchee. Other researchers have questioned whether the higher water temperatures in this river are related to inadequate riparian shade in the harvested areas of the watershed or if the water temperatures are naturally high concomitant with greater bedrock influence to the channel and less hydrologic storage in the valley bottom till (USFS 1998). In addition, several large beaver dam complexes on the lower river are likely sources of warm water inputs. Although water temperatures at the mouth of the Little Wenatchee River sometimes exceed the 16ºC criterion, it rarely exceeds 17ºC.

Nason Creek enters the Wenatchee River (at RM 53.6) just downstream of Lake Wenatchee (RM 54.2). Nason Creek was identified as a source of thermal loading to the upper Wenatchee River during a study using Forward Looking Infra-Red (FLIR) thermal photography (Chelan Conservation District, 2003). During this study the water temperature in the river was 17.6ºC at RM 53.5 on August 16, 2002. Nason Creek was included on the 1996 and 1998 state 303(d) lists of impaired water for high water temperatures, as a result of measurements near the creek mouth (Ecology 1998). Water temperatures in Nason Creek measured during 1995/1996 ranged from 0.3 to 16.2ºC (WRWSC 1998).

6.3.4.2 Mainstem Wenatchee River

The Wenatchee River was included on the state's 303(d) list of impaired waters in 1996 and 1998 for low flows during the late summer and early fall, high water temperature, high pH, and low DO levels (Ecology 1998). High pH and low DO levels are typically indicators of nutrient enrichment. Exceedences of pH and DO were measured in the Wenatchee River downstream of the town of Leavenworth.

The uppermost reach of the Wenatchee River reflects the water temperature in Lake Wenatchee. Water temperatures measured in the mainstem at the Lake Wenatchee Bridge during 1995/1996 ranged from 0.7 to 17.1ºC (WRWSC 1998). Just downstream of the lake however, Nason Creek has been identified as a source of thermal loading. Water temperatures continue to increase in a downstream direction. An August 16, 2002 FLIR study measured surface water temperatures as 17.6ºC at RM 53.5, between 18.1º and 18.9ºC between the Chiwawa River (RM 48.4) and Leavenworth (RM 24.4), and between 19.7º and 20.3ºC in the lower approximately ten miles of river (Chelan Conservation District, 2003).

To address the high water temperature exceedences in the river, Ecology has developed a cooperative study with several other agencies to establish a Total Maximum Daily Load (TMDL) for water temperature (Bilhimer et al. 2002). This plan includes assessments of water quality in the Wenatchee River, and the mouths of the White River, the Little Wenatchee River, and Nason Creek.

6.3.4.3 Lake Wenatchee

Lake Wenatchee is an oligotrophic lake based on relatively high water clarity and low concentrations of phosphorous (Ecology 1997). Oligotrophic lakes are generally defined as being low-nutrient systems, with <10 mg/m^3 phosphorus, <200 mg/m^3 nitrogen, and <2 mg/m^3 chlorophyll a. Average summertime secchi depth (water transparency) in Lake Wenatchee was estimated as 20 feet and phosphorous concentrations were 4.8 ug/L (Ecology 1997). Although there are approximately 170 homes along the shoreline of Lake Wenatchee, septic systems are no longer used and all of the houses have been attached to a sewer system since around 1989. Recreational uses on the lake include: swimming, fishing, motor boating, jet skiing, camping, hunting, picnicking, and camping.

Relatively little information exists on the water quality and limnology of Lake Wenatchee. Water temperatures collected from depths of 10 feet and lower indicated that the lake does not strongly stratify into a distinct warmer upper layer and a cooler lower layer with associated layers of high and low DO and pH (Table 6.3-2) (Sylvester and Ruggles 1957). The data for June through October, 1955 (shown in Table 6.3-2) suggest that temperature declines gradually between 10 feet and 60–75 feet, and is notably lower at depths ranging from 150 to 175 feet. However, coincident measurements of DO and pH suggest that deeper waters of the lake do not received sufficient organic matter to substantially depress values of either parameter. In many other temperate lakes, the upper layer of water is warmed through the summer as it absorbs solar radiation and this layer does not mix with the lower, darker layer of water, which generally exhibits a markedly cooler water temperature and depressed DO and pH in summer through fall months. However, Lake Wenatchee is subjected to high winds that apparently keep the waters mixed throughout the year resulting in similar water temperatures and levels of dissolved oxygen and pH in the upper approximately 100 feet of the water column.

Other water quality parameters measured in Lake Wenatchee by Sylvester and Ruggles (1957) included total alkalinity, hardness, turbidity, conductivity and several metals. Their results from June 1955 through February 1957 provide a characterization of the lake as low alkalinity, very low hardness, very clear water with little turbidity and color, and low specific conductance. A single summertime chlorophyll a value of 1.7 ug/L measured in the lake (Ecology 1997) suggests phytoplankton algae levels are very low. All these features are characteristic of an oligotrophic lake, typically with low primary (algae) and secondary (zooplankton) productivity.

Little additional water quality data are available for Lake Wenatchee since the comprehensive surveys in the 1950. Some data were collected from August 1995 monthly through July 1996 at the Lake Wenatchee bridge (WRWSC 1998). These data were assumed to represent lake surface water conditions and indicate the following: 1) the surface lake waters remain very clear and of low turbidity; 2) nitrogenous nutrients (nitrate/nitrite and ammonia) were low enough to restrict algal growth; 3) total phosphorus was generally low, except for two mid-winter measurements; 4) water pH remained near 7.0 (neutral), except for 1 reading of 8.87 in February 1996; 5) dissolved oxygen was measured to be above 9.0 mg/L, except for two low values in August and September 1995 (both were above 90% of air saturation); and 6) specific conductance ranged slightly higher than in the 1950s, possible indicating a slight increase in water hardness and alkalinity. Lake surveys of water transparency, total phosphorus and chlorophyll were conducted periodically from 1989 through 1997 (Ecology 1997). The results showed that water transparency is high (secchi depths >20 feet) and chlorophyll and total phosphorus are very low. These available data, although somewhat sparse, suggest the lake waters remain oligotrophic with little evidence of effects from land use changes and development since the 1950s.

Table 6.3-2. Lake Wenatchee depth profiles of temperature, dissolved oxygen and pH (from Sylvester and Ruggles 1957).

Date	Depth (feet)	Temperature (C)	DO (mg/L)	pH
6/27/55	10	7.7	11.0	6.9
	135	6.6	11.0	6.8
7/12/55	10	9.4	10.8	6.9
	80	7.8	10.8	6.7
7/26/55	10	10.2	10.7	6.65
	50	10.1	10.5	6.95
	150	8.6	10.8	6.70
8/9/55	10	13.0	10.0	7.3
	75	10.3	9.95	7.2
	175	8.2	10.1	7.1
8/25/55	15	13.2	9.9	7.6
	75	NA	9.9	7.5
	140	NA	9.4	NA
9/7/55	10	15.2	9.75	6.9
	75	10.0	9.85	6.7
	175	NA	10.0	6.6
9/21/55	10	13.3	9.7	7.35
	60	13.1	9.7	7.32
	120	9.1	9.6	6.95
	170	8.3	9.45	6.90
10/23/55	10	10.8	9.5	7.1
	75	10.2	9.3	7.1
	175	7.8	8.7	6.8

NA = Not available

6.3.5 Sediment Quality

In the summer of 1992 and 1993, sediment samples were collected from ten stream sites in the Wenatchee River watershed including a site on the Little Wenatchee River, two sites on Nason Creek and on the Wenatchee River at Lake Wenatchee (Hindes 1994). The samples were analyzed for organic pollutants and heavy metals. The only contaminants detected were low concentrations of DDD (2.9 µg/kg) and DDE (1.0 µg/kg), which are both breakdown products of DDT, and trace amounts of copper, nickel and zinc (Hinde 1994). An earlier study indicated that bridgelip sucker and mountain whitefish collected in the Wenatchee River had high accumulations of arsenic, zinc, and DDT (Hopkin et al. 1985 as reported in Stanford 1988). Currently, only Misson Creek in the Wenatchee River basin is listed as impaired due to pesticides in fish tissues (Ecology 1998).

6.4 ENVIRONMENTAL IMPACTS AND BENEFITS OF RUBBER DAM OPERATIONS

The general types of environmental impacts and benefits that may occur as a result of the Lake Wenatchee Water Storage project are described in this section. Project effects focus on the potential impacts resulting from water storage in Lake Wenatchee and release of water to the Wenatchee River under the five alternatives (described in Sections 3.5 and 6.2). The potential short-term effects of project construction are not discussed.

Potential impacts (negative or positive) of project operations were evaluated in part using a set of matrix forms that included three flow-dependent ecosystem components; Fish Habitat and Life-stage Use; Ecosystem Processes; and Water Quality Conditions. The analysis was completed for three geographic areas that included; upper tributaries and the wetlands habitat at the confluence of the White and Little Wenatchee rivers (Tributaries), the mainstem Wenatchee River below the lake (Wenatchee River), and Lake Wenatchee. The assessment was made by comparing the baseline condition (i.e. existing conditions without construction and operation of the rubber dam), with conditions that would result from each of the five alternatives. The analysis consisted of qualitatively rating each of the flow-dependent ecosystem components as they would be influenced by each alternative relative to baseline conditions. A ranking system was used for this that denoted; no impact or change from baseline (=), negative impacts (-); and positive (benefits) impacts (+), and variations thereof. Rankings were defined as follows:

=	Component is or is approximately equal to Baseline Condition
=–	Indicator Component is approximately equal to or slightly reduced relative to Baseline Conditions.
=+	Indicator Component is approximately equal to or slightly improved relative to Baseline Conditions.
+	Indicator Component is improved or impact reduced relative to Baseline condition.
++	Indicator Component is substantially improved or impact substantially reduced relative to Baseline condition
–	Indicator Component is reduced or impact increased relative to Baseline condition; and
––	Indicator Component is substantially reduced or impact substantially increased relative to Baseline condition

The impacts analysis relied almost entirely on existing information and data and the matrix forms served to guide the assessment based on established scientific principles and current understanding of ecosystem relationships. However, more detailed analysis were completed with respect to evaluating the potential benefits associated with the release of supplemental instream flows and potential impacts related to wetlands inundation due to elevated lake levels. These are described in the respective sections below.

6.4.1 Effects of Rubber Dam Operations on Fish Habitat and Fish Use

Fish use is extensive in Lake Wenatchee during the summer period when lake levels would be higher than normal. The lake supports juvenile rearing and smolt outmigration of char, steelhead, and salmon during this period. Fish use in the mainstem Wenatchee River during the historical low-flow period in late-summer/early-fall (August and September) includes juvenile rearing and upstream migration of native char, steelhead, and salmon. Chinook salmon can also begin spawning in the mainstem Wenatchee River as early as August.

The operation of the rubber dam would generally result in increased lake levels (1872.4 feet – Alternatives. 1-3; 1870.3 feet – Alternatives 4-5) during some or all of the months of July, August and September, and increased flows [from 50 cfs (Alternative 4) to 200 cfs (Alternative 2)] in the mainstem Wenatchee River during portions of August and September (Section 3.5). As noted in Section 6.2 the lake elevation associated with alternatives 1-3 would provide about 12,300 af of supplemental water that could be released to augment instream flows above historical levels; alternatives 4-5 would provide slightly more than one-half of that amount (6,750 af).

Although a detailed instream flow study was not conducted as part of the feasibility assessment, several comparisons were made between existing conditions and those that would be provided via the alternatives, as a means to evaluate potential benefits of the supplemental flow releases on fish habitat. First off, it is important to note that average monthly flows directly below the outlet of Lake Wenatchee and near Plain are currently associated with relatively good habitat conditions in terms of quantity. This observation is indicated by comparing the mean monthly flows derived from USGS gage data and used in the operations model with general instream flow criteria set by Tennant (1976). The pre-project mean monthly flow below the outlet is roughly 52% (691 cfs) and 29% (379 cfs) of the mean annual flow (1318 cfs; see Table 3.5-3) in August and September, respectively. Tennant's (1976) approach suggests that a base flow around 30% of mean annual flow is associated with "good" habitat conditions, whereas a minimum (threshold) instream base flow could be considered to be around 10 percent of the mean annual flow. Although these criteria may not apply strictly to the Wenatchee River (they were based on streams and rivers in Montana), they should be approximately transferable for purposes of a screening level analysis.

However, under conditions of a low water year, flows within the river may be substantially lower than average flows; e.g. September flows in 1942 were 230 cfs compared with an average September flow of 379 cfs (Table 3.3-3). It would be during those times that the greatest benefits to fish habitat would be afforded by the five alternatives.

A broad estimate of the change in mean depths and mean velocities in the vicinity of the Plain gage that may result from the alternatives was made using an approximate stream width of 200 feet, an assumed Manning's n, and a reach slope derived from 1:24,000 USGS topographic maps. As indicated in Table 6.4-1, the mean depth and velocity increases that would occur are relatively small in both August and September for mean monthly flow conditions and flow augmentations of 50, 100 and 200 cfs. The mean depth is likely to increase by 0.1 feet for each 100 cfs added at mean monthly conditions. During lower flows, the depth increase would be greater as a greater proportion of flow is added.

Table 6.4-1. Estimated mean depth and velocity increases at the outlet of Lake Wenatchee and the Plain gage during August and September.

	August		September	
	at outlet	at Plain	at outlet	at Plain
Mean Monthly Flow (cfs)	691	1131	379	623
Mean Depth (ft)	1.2	1.6	0.8	1.1
Mean Velocity (fps)	2.9	3.5	2.3	2.8
Depth (ft) (+50 cfs)	1.2	1.6	0.9	1.2
Mean Velocity (fps) (+50 cfs)	3.0	3.6	2.4	2.9
Depth (ft) (+100 cfs)	1.3	1.7	1.0	1.2
Mean Velocity (fps) (+100 cfs)	3.1	3.7	2.5	3.0
Depth (ft) (+200 cfs)	1.4	1.8	1.1	1.3
Mean Velocity (fps) (+200 cfs)	3.2	3.8	2.7	3.1

n= 0.03
S= 0.0027
width (ft) = 200

These changes would likely become less noticeable/detectable in lower reaches of the river as additional tributary inflow occurs and channel width correspondingly increases. However, these are average values and do not reflect the variability in localized depths and velocities that occur in river systems and that serve to define fish habitats. Thus, although changes in average depths and velocities may be small, the actual amount of habitat afforded by the supplemental flows is unknown and will likely vary by specific location and associated channel characteristics. For example, there would likely be some localized benefits to upstream fish passage provided in areas such as Tumwater Canyon where channel constrictions result in defined fish passage portals under low flow conditions. Thus, provision of supplemental flows during naturally occurring periods of extremely low flow may facilitate upstream passage of adults. Additional study would be needed to determine the location and extent to which such flows would be beneficial.

The assessment of potential impacts and benefits resulting from project operations is presented below based on specific life history functions.

6.4.1.1 Adult Migration And Holding

Adult salmonid fish migrate upstream from the Pacific Ocean (anadromous life-forms) or the Columbia River or mainstem Wenatchee River (fluvial life-forms) to spawn in the mainstem Wenatchee River or to continue into Lake Wenatchee and the tributary habitat to spawn. During this migration, the actual upstream movement is an alteration of rapid travel through shallower riffle area and holding/resting in deeper pools. Bjornn and Reiser (1991) indicated a minimum depth of 24 centimeters is required for chinook salmon passage and at least 12 centimeters is necessary for other salmonid species. The mix of salmonid species in the Wenatchee River system creates a situation where migrating adults of at least one species are present in the river in every month of the year (Figure 6.3-1). However, from a flow magnitude perspective, the most difficult time for upstream passage and adult holding would likely occur during low flow periods, such as during August through October.

The operation of the rubber dam to augment flows in the mainstem Wenatchee River during late-summer/early-fall could provide some benefit to the upstream migration and holding of adult steelhead, chinook, and to a lesser degree coho salmon. The degree of potential benefit would be related to the amount and timing of flow available and hence alternative 3 and 2 would likely have the greatest and alternative 4 the lowest potential benefit (Tables 6.4-2 to 6.4-6). The largest benefits to migration and holding would likely be to steelhead and summer chinook during the lowest flow years, since these species spawn in the mainstem Wenatchee, and they would likely spend some time holding in the river prior to spawning. The pulse flow operational alternative (Alternative 3 – rated as +) specifically targets adult passage for spring chinook and sockeye during low flow conditions that may occur in July. It was postulated that pulse flows occurring during that period would facilitate passage of these species through Tumwater Canyon and into Lake Wenatchee where they would continue their migration into either the Little Wenatchee or White rivers.

Although adult coho transferred to the Wenatchee River could use the river as a transportation corridor, coho spawn in tributaries to the mainstem Wenatchee and, therefore, are unlikely to hold in the river for significant periods of time. Adult sockeye salmon could also be migrating in the mainstem Wenatchee River during the low flow period, although they typically complete their upstream migration to holding habitat in Lake Wenatchee by early August. Fluvial bull trout from the Columbia River could also be in the mainstem Wenatchee River during the critical low-flow period, although they are most likely to begin their migration up the Wenatchee River during high-flow in June.

Operation of the rubber dam is not anticipated to affect flows or water levels important to adult salmonid migration and holding in the tributaries or in Lake Wenatchee.

As described in Section 3.5.3.2, the rubber dam would be approximately 200 feet long from shore to shore and installed as a single span. The foundation of the structure would be a cast-in-place concrete slab with a flat surface, and the structure would be oriented at about a 5-degree angle with respect to a perpendicular line drawn from shore to shore to aid in upstream passage of fish. A fish ladder would be in operation during the spring and summer water storage months. During other times of the year, the rubber dam will be partially or fully deflated and a fish ladder will not be used. A fish ladder will need to be designed to allow adult and juvenile salmon, trout and native char (bull trout) to migrate upstream of the dam when the weir is fully inflated (Section 3.5.3.6). This is especially important for bull trout given the results of recent study findings that indicate adult and juvenile bull trout from the Chiwawa River move upstream into Lake Wenatchee. Even with provision of a ladder, it is possible there could be some delayed or impeded upstream migration for some individual fish during the time when the dam is inflated.

Table 6.4-2. Aquatic and fisheries impact evaluation matrix for three segments of the Wenatchee Watershed potentially influenced by project operations under Alternative 1 of the Lake Wenatchee Water Storage Feasibility Study.

Alternative 1 - Max Lake Level: 1872.4 feet; Supplementation: 10 cfs/day Aug. 23 – Aug 31; 100 cfs Sept 1 - ?				
	Conditions with Rubber Dam: Alternative 1			
Ecosystem Component	Baseline Conditions	Tributaries	Wenatchee River	Lake Wenatchee
FISH HABITAT AND LIFE-STAGE USE				
Adult Migration/Holding	=	=/=	= +/= +	=/=
Spawning/Incubation	=	=/=	= +/=	=/=-
Juvenile Rearing	=	=	=+	=
Juvenile Outmigration	=	=	=+	=
Predation/Competition	=	=/=	=+/=	=+/=
Stranding/Direct Mortality	=	=/=	= –/=	=/=
ECOSYSTEM PROCESSES				
Sediment Transport	=	=	=	=
Woody Debris Recruitment	=	=	= –	= –
Side-channel Connectivity	=	= +	= +	=
1° and Invertebrate Production	=	=	=	=
Littoral Zone	=	=	=	=-
Wetlands	=	–	=	–
WATER QUALITY CONDITIONS				
Water temperature	=	=	=	=
Dissolved Oxygen	=	=	=	=
Nutrients/BOD	=	=/=	=/=	=/=
pH	=	=	=	=
Suspended Sediment/Turbidity	=	=/=	=/=	=/=

Table 6.4-3. Aquatic and fisheries impact evaluation matrix for three segments of the Wenatchee Watershed potentially influenced by project operations under Alternative 2 of the Lake Wenatchee Water Storage Feasibility Study.

Alternative 2 - Max Lake Level: 1872.4 feet; Supplementation: 20 cfs/day Aug. 23 – Aug 31; 200 cfs Sept 1 - ?				
	Conditions with Rubber Dam: Alternative 2			
Ecosystem Component	**Baseline Conditions**	**Tributaries**	**Wenatchee River**	**Lake Wenatchee**
FISH HABITAT AND LIFE-STAGE USE				
Adult Migration/Holding	=	=/=	+/+	=/=
Spawning/Incubation	=	=/=	+/= –	=/= –
Juvenile Rearing	=	=	= +	=
Juvenile Outmigration	=	=	= +	=
Predation/Competition	=	=/=	= +/=	= +/=
Stranding/Direct Mortality	=	=/=	= –/=	=/=
ECOSYSTEM PROCESSES				
Sediment Transport	=	=	=	=
Woody Debris Recruitment	=	=	= –	= –
Side-channel Connectivity	=	= +	= +	= +
1° and Invertebrate Production	=	=	=	=
Littoral Zone	=	=	=	=
Wetlands	=	–	=	–
WATER QUALITY CONDITIONS				
Water temperature	=	=	=	=
Dissolved Oxygen	=	=	=	=
Nutrients/BOD	=	=/=	=/=	=/=
pH	=	=	=	=
Suspended Sediment/Turbidity	=	=/=	=/=	=/=

Table 6.4-4. Aquatic and fisheries impact evaluation matrix for three segments of the Wenatchee Watershed potentially influenced by project operations under Alternative 3 of the Lake Wenatchee Water Storage Feasibility Study.

Alternative 3 - Max Lake Level: 1872.4 feet; Supplementation: 100 cfs pulses Jul. 1 – Aug 15; 100 cfs Aug 16 - ?				
	Conditions with Rubber Dam: Alternative 3			
Ecosystem Component	**Baseline Conditions**	**Tributaries**	**Wenatchee River**	**Lake Wenatchee**
Adult Migration/Holding	=	=/=	+/+	=/=
Spawning/Incubation	=	=/=	=/=	=/=-
Juvenile Rearing	=	=	=+	=+
Juvenile Outmigration	=	=	=+	=
Predation/Competition	=	=/=	=/=	= +/=
Stranding/Direct Mortality	=	=/=	–/=	=/=
ECOSYSTEM PROCESSES				
Sediment Transport	=	=	=	=
Woody Debris Recruitment	=	=	= –	= –
Side-channel Connectivity	=	= +	= +	= +
1° and Invertebrate Production	=	=	=	=
Littoral Zone	=	=	=	=-
Wetlands	=	–	=	–
WATER QUALITY CONDITIONS				
Water temperature	=	=	=	=
Dissolved Oxygen	=	=	=	=
Nutrients/BOD	=	=/=	=/=	=/=
pH	=	=	=	=
Suspended Sediment/Turbidity	=	=/=	=/=	=/=

Table 6.4-5. Aquatic and fisheries impact evaluation matrix for three segments of the Wenatchee Watershed potentially influenced by project operations under Alternative 4 of the Lake Wenatchee Water Storage Feasibility Study.

Alternative 4 - Max Lake Level: 1870.3 feet; Supplementation: 5 cfs/day Aug. 23 – Aug 31; 50 cfs Sept 1 - ?				
	Conditions with Rubber Dam: Alternative 4			
Ecosystem Component	**Baseline Conditions**	**Tributaries**	**Wenatchee River**	**Lake Wenatchee**
FISH HABITAT AND LIFE-STAGE USE				
Adult Migration/Holding	=	=/=	= + /= +	=/=
Spawning/Incubation	=	=/=	= + /= +	=/=
Juvenile Rearing	=	=	= +	=
Juvenile Outmigration	=	=	= +	=
Predation/Competition	=	=/=	=/=	= +/=
Stranding/Direct Mortality	=	=/=	=/=	=/=
ECOSYSTEM PROCESSES				
Sediment Transport	=	=	=	=
Woody Debris Recruitment	=	=	= –	= –
Side-channel Connectivity	=	= +	= +	= +
1º and Invertebrate Production	=	=	=	=
Littoral Zone	=	=	=	=
Wetlands	=	–=	=	– =
WATER QUALITY CONDITIONS				
Water temperature	=	=	=	=
Dissolved Oxygen	=	=	=	=
Nutrients/BOD	=	=/=	=/=	=/=
pH	=	=	=	=
Suspended Sediment/Turbidity	=	=/=	=/=	=/=

Table 6.4-6. Aquatic and fisheries impact evaluation matrix for three segments of the Wenatchee Watershed potentially influenced by project operations under Alternative 5 of the Lake Wenatchee Water Storage Feasibility Study.

Alternative 5 - Max Lake Level: 1870.3 feet; Supplementation: 100 cfs/day Aug. 23 – Aug 31; 100 cfs Sept 1 - ?				
	Conditions with Rubber Dam: Alternative 5			
Ecosystem Component	Baseline Conditions	Tributaries	Wenatchee River	Lake Wenatchee
FISH HABITAT AND LIFE-STAGE USE				
Adult Migration/Holding	=	=/=	= +/= +	=/=
Spawning/Incubation	=	=/=	= +/=	=/=-
Juvenile Rearing	=	=	= +	=
Juvenile Outmigration	=	=	= +	=
Predation/Competition	=	=/=	= +/=	= +/=
Stranding/Direct Mortality	=	=/=	= –/=	=/=
ECOSYSTEM PROCESSES				
Sediment Transport	=	=	=	=
Woody Debris Recruitment	=	=	=-	=
Side-channel Connectivity	=	= +	= +	= +
1° and Invertebrate Production	=	=	=	=
Littoral Zone	=	=	=	=
Wetlands	=	–=	=	–=
WATER QUALITY CONDITIONS				
Water temperature	=	=	=	=
Dissolved Oxygen	=	=	=	=
Nutrients/BOD	=	=/=	=/=	=/=
pH	=	=	=	=
Suspended Sediment/Turbidity	=	=/=	=/=	=/=

LEGEND:

= Component is or is approximately equal to Baseline Condition

=– Indicator Component is approximately equal to or slightly reduced relative to Baseline Conditions.

=+ Indicator Component is approximately equal to or slightly improved relative to Baseline Conditions.

\+ Indicator Component is improved or impact reduced relative to Baseline condition.

++ Indicator Component is substantially improved or impact substantially reduced relative to Baseline condition

– Indicator Component is reduced or impact increased relative to Baseline condition

–– Indicator Component is substantially reduced or impact substantially increased relative to Baseline condition.

N/A Indicator Component is Not Applicable for the reach evaluated.

6.4.1.2 Spawning and Incubation

Adult salmonids select areas for spawning that can be defined by combinations of water depth and velocity in association with substrate of a certain size (Bjornn and Reiser 1991). In streams and rivers, spawning areas are typically located in pool tailouts and pool-riffle interchange areas containing clean substrates. Negative impacts to spawning habitat from human developments are typically the result of barriers to upstream migration (loss of habitat), increased rates of sedimentation (degradation of spawning gravels), or alterations in flow regimes resulting in redds that are subsequently inundated, exposed, or scoured.

Successful incubation of the embryos requires gravels with low concentrations of fines sediments and organic material (Spence et al. 1996; Bjornn and Reiser 1991). Large amounts of silt and sand can fill-in the gravel interstices of redds, diminishing intragravel flow and reducing available oxygen. High sediment levels can also entomb alevins and fry, preventing successful emergence. Variations in flow during incubation can also reduce successful incubation if reduced flows expose redds built during higher water levels, subjecting the developing embryos to freezing or desiccation. Extreme flows can also mobilize the bedload and wash the embryos downstream.

Supplemental water released to the mainstem Wenatchee River during late-summer/early-fall may potentially enhance to varying degrees (alternatives 1, 4 and 5 (= +); alternative 2 (+)) the amount of spawning habitat available to chinook in the mainstem Wenatchee River. The timing of the flow releases associated with alternative 3 and the limited amount of supplemental flow under alternative 4 suggest the benefits to chinook spawning habitat in the mainstem would be small compared to the other alternatives. If the fall rains coincide with the end of the period of supplemental water and water levels are not subsequently reduced during incubation, the increased spawning habitat could be a beneficial impact to spring and summer/fall chinook. Flows during the second half of October are on average 25% higher than those in the later half of September (NMFS et al. 1998). Negative impacts to incubating chinook embryos could occur if areas used for spawning are subsequently dewatered during the period between flow augmentation from the Lake Wenatchee Water Storage project and the onset of the fall rains. The only other salmonid species that spawn in the mainstem are steelhead. Steelhead spawning will not be affected by project operations, because steelhead spawn in the spring

The release of water stored in Lake Wenatchee during late-summer/early-fall could coincide with the peak of sockeye spawning in late September. Although it is unknown if sockeye spawn along the shoreline of Lake Wenatchee, the species is known to use this type of habitat in other lakes. Reduced lake levels during the period of sockeye spawning could result in redds being built in areas that would subsequently become dewatered as the stored water is released to the mainstem Wenatchee River. Thus, there is some potential negative impacts to lake-shore spawning (if it occurs) related to all of the alternatives (= –) (see Tables 6.4-2 through 6.4-6).

6.4.1.3 Juvenile Rearing

There is a large variation in the rearing habits of juvenile salmon. With the exception of summer chinook and the resident fish, the other species of juvenile salmonid fish in the Wenatchee River system rear for at least one winter before migrating downstream to the Columbia River. The salmonid species that specifically rear in the mainstem Wenatchee River are spring chinook, steelhead, and coho.

The amount of stream and river habitat available for rearing is a function of streamflow, channel morphology, gradient, and instream cover. Increased space and complexity can increase the carrying capacity. In general, limiting habitats for juvenile salmonid fish during low-flow summer conditions are cool water refugia. Juvenile rearing during high-flow conditions is often limited by a lack of low-velocity areas such as pools, accumulations of large woody debris, and off channel areas. Both high-flow and low flow refuge habitat were identified as two bottlenecks that can limit total juvenile salmonid densities in the mainstem Wenatchee River (Andonaegui 2001). The lack of high-flow refuge habitat can reduce survival of post-emergent fry and then the lack of low-flow, late-summer rearing capacity can further limit juvenile abundances (WDF et al. 1990). The large difference between the annual high-flow and low-flow in the Wenatchee River results in very little cover for rearing fish during low-flow conditions when the undercut banks and shoreline vegetation may be yards away from the water's edge (WDF et al. 1990).

Operation of the rubber dam will not affect high-flow rearing habitat in the mainstem Wenatchee River. The release of water stored in Lake Wenatchee during late-summer/early-fall may temporally increase the amount of low-flow refuge habitat and may afford some benefit (= +) to juvenile salmon species rearing in the river, with Alternative 4 providing the least benefit. The effects of extending the period of high water levels in Lake Wenatchee during the summer on juvenile fish rearing in the lake and at the mouths of the Little Wenatchee and White rivers are unknown. Higher water levels throughout the summer could benefit juvenile fish rearing in the wetland complex on the western end of the lake if the higher water levels help maintain open water and transportation corridors between ponded areas and the main lake (indicated as = + in matrix tables). However, baseline information on the habitat condition, use and productivity of this wetland area is lacking. In general, ponded wetlands connected to streams or lakes are highly productive for rearing coho. Inundated wetlands along the littoral areas of a lake can also provide productive feeding areas for juvenile sockeye, chinook, and other salmonid fishes. Conversely, fish rearing in these areas could become stranded when lake levels drop and connections to open water are lost.

As noted above, a fish ladder will need to be designed to allow both adult and juvenile salmon, trout and native char (bull trout) to migrate upstream of the dam when the weir is fully inflated (Section 3.5.3.6). This is especially important for adult and juvenile bull trout that have been shown to move from the Chiwawa River upstream into Lake Wenatchee.

6.4.1.4 Juvenile Outmigration

Flow and depth play physical roles in determining the timing and speed of juvenile salmonid migration (Spence et al. 1996). Low flow conditions on the Columbia River have been shown to increase the travel time for smolt outmigration (Bjornn and Reiser 1991). In the Wenatchee River system, smolt outmigration typically begins in the spring during March or April as the river flows are increasing, and steelhead and chinook can continue to move downstream throughout the summer. This timing is before the period when lake levels would be influenced by the rubber dam, thus the project is not expected to adversely or beneficially influence smolt outmigration patterns or survival.

Operation of the rubber dam will similarly not affect high-flow conditions in the mainstem Wenatchee River. Augmented flows in late-summer/early-fall could provide some benefit (= +) to steelhead and chinook smolts outmigrating in the mainstem Wenatchee River. The project operation is not anticipated to affect juvenile outmigration in the tributaries or in Lake Wenatchee, provided suitable fish passage facilities are integrated into the dam design..

6.4.1.5 Predation and Competition

In general, predation and competition are increased as water levels decrease. Low-flow conditions can increase the rates of predation and competition by reducing the amount of habitat and therefore reducing the amount of areas available to juvenile salmonids to avoid predation and competition. Low-flow conditions can also result in increased travel time for juvenile outmigration (Section 6.4.1.4) resulting in an increased risk of predation. Shifts in water quality characteristics associated with reduced flows during the summer period, such as increased water temperature and reduced DO, can favor predatory species such as sculpin, increasing the predatory risk to downstream migrating juvenile salmonids.

The increased flows provided by alternatives 1,2, 4and 5 during late summer may temporarily reduce predation and competition (= +) on juvenile salmonids in the mainstem Wenatchee River by providing some increased habitat area. Timing and the general low amount of supplemental flows in alternatives 3 and 4 suggest such benefits would be small. Juvenile salmonids most likely to be present in the mainstem Wenatchee River during supplemental late-summer/early-fall flows are steelhead and spring chinook.

The increased period of high water levels in Lake Wenatchee during the summer may reduce the rate of predation (= +) on juvenile sockeye as a result of increased lake volume and its associated increased refuge habitat. However, low lake productivity (cold, nutrient poor-water) and not predation is likely the most important limiting factor for sockeye production in Lake Wenatchee. Operation of the rubber dam is not anticipated to affect predation and competition in the tributaries.

6.4.1.6 Stranding and Direct Fish Mortality

Flow regulation can result in fish stranding if the fish do not leave habitats that are subsequently dewatered or isolated as flow levels are decreased. The risks of potential stranding in the mainstem Wenatchee River from the operation of the rubber dam would most likely affect juvenile fish that can utilize shallow edge habitats and side channels in which they would then subsequently be stranded when flows are decreased. The extent of these potential risks differs among the five operating alternatives. The largest risks of stranding in the Wenatchee River would occur under alternatives 3 and 2 in that order. Stranding could occur (= +) under Alternative 2 at the end of the period of supplementation in September if flows are not subsequently maintained by fall rains. Under Alternative 3 stranding could potentially occur (–) between the 4-hour pulses of augmented flows during July and mid-August. However, stranding can be minimized or avoided by ensuring that downramping rates are sufficiently low that fish have time to move with the declining water level.

Direct fish mortality is unlikely to occur from operation of the rubber dam for any of the alternatives (=). Some direct morality could occur, however, during the construction phase of the project as a result of water diversion and temporary sediment impacts.

Release of water stored in Lake Wenatchee to supplement late-summer/early-fall flows in the mainstem Wenatchee River will result in the lowering of the lake levels and potential stranding of juvenile fish rearing in the littoral areas. However, because the shoreline of Lake Wenatchee is generally steep, shallow littoral areas where stranding could occur are limited to the wetland area in the vicinity of the confluence with the Little Wenatchee and White rivers, at the western end of the lake. It is believed that trapping and stranding effects would be minimal in this area (=) because of the complex morphology occurring within the wetland habitat, and the generally low temperatures expected during the summer because of vegetative shading and connection with groundwater. Juveniles that are trapped would likely find over-summer refuge in beaver channels and pools. It is therefore possible that the project might result in increased occurrence of extended rearing. Whether such effects would be adverse is unknown. However, most actively migrating smolts should have exited the lake by the time the rubber dam would influence lake level (Figure 6.3-1), so most fish that are trapped in the wetlands area later in the summer would have been expected to rear in the system for another year anyway. Moreover, such wetlands can provide productive habitats for rearing juvenile salmonids (Section 6.2.3).

6.4.2 Effects of Rubber Dam Operations On Riverine And Lacustrine Ecosystem Processes

There are a number of flow dependent ecosystem processes that interact to create and maintain habitat quality and diversity in rivers such as the Wenatchee River. Fundamentally, it is the natural interannual and seasonal variability in flood flows that serves to shape channel morphology, transport sediments, distribute wood, and establish connectivity with floodplain and side channel areas. Operation of the rubber dam under the five alternatives will not affect flood and peak flows. Each alternative would however, typically increase discharge during some portion of the late-summer/early fall low-flow period in the mainstem Wenatchee River and they would increase the duration of high water levels in Lake Wenatchee during the summer. Our understanding of existing conditions and modeled storage and release strategies were used to determine and describe potential project effects on ecosystem processes.

6.4.2.1 Sediment Transport and Shoreline Erosion

Delivery rates and composition of sediments to channels within the Lake Wenatchee watershed and downstream are affected by many factors, including: geology, hydrology, climate, topography, and land use. Sediment transport rates within channels potentially affected by the project are influenced by hydrograph magnitude and timing, channel gradient and confinement, and particle size. Sediment delivery in the Little Wenatchee River has been particularly characterized as high as a result of both natural-origin and timber harvest –related mass wasting (USFS 1998).

The lower reaches of the White and Little Wenatchee rivers are depositional areas, reflecting the influence of backwater from the lake during the spring snowmelt runoff period. Cobble and gravel materials deposit in the vicinity of the high lake level elevation, and sand deposits more extensively between the high and low lake level elevations. The general location of the gravel-sand transition in the Little Wenatchee River is indicated by the presence of the gravel and sand pit. Sediment transport in the lower White River includes a large fraction of suspended fine sediments derived from glacial melt.

Lake Wenatchee is generally a sediment sink, and the location of the rubber dam is thus relatively armored. Primary fine and coarse sediment sources below the lake include riverbanks, tributaries, and the riverbed itself. There are some depositional areas between the outlet of Lake Wenatchee to the confluence with the Chiwawa River (RM 48.4) where the gradient is relatively low, as evidenced by a meandering channel form and broad floodplain. Downstream of this reach, the gradient increases through the Tumwater Canyon where sediments are generally transported downstream to below the confluence of Icicle Creek (RM 25.6), where some deposition occurs.

The effect of the rubber dam on sediment transport will likely be negligible (=) both above, within, and below Lake Wenatchee. Because the lake is essentially a sediment sink, effects below it are restricted to changes in the peak flow hydrograph and the corresponding changes in transport capacity and bank erosion. There will generally be no significant changes in extreme or moderate peak flow event magnitudes. Such events generally occur prior to the filling period (see hydrologic model runs for each alternative in Section 3.5), including in dry years. Some reduction in peak flow is expected for moderate magnitude events occurring during the filling period, which could decrease bank erosion and transport rates downstream. However, based on the hydrologic analysis, it appears that most sediment transport below the lake (if any) would occur prior to the filling period. More detailed analysis would be needed to determine if the effect were significant, including determining when sediment transport and bank erosion occur. In any case, the potential changes in sediment delivery and transport could balance each other, with negligible net effect on transport rates and deposition or erosion downstream at spawning locations.

Upstream of the lake, effects to sediment transport are expected to be negligible (=). Sediment transport occurs in the Little Wenatchee and White rivers primarily during snowmelt runoff, at a time when the lake level is already elevated and prior to the projected filling period. Significant transport should have subsided before the time that the lake level normally drops without the project. The operation of the rubber dam will delay the start of decreasing lake levels in Lake Wenatchee until late-summer. In an average year, the ordinary high lake level begins to decrease in mid July (Section 3.5). Project operations will result in elevated lake levels being held through late August under most alternatives. As lake levels decrease, stream velocities in the delta areas at the mouths of the White and Little Wenatchee rivers can increase, resulting in increased localized bedload movement (scour). However, the area affected in each stream corresponds to the existing location of the gravel-sand transition. Hence, there may be some redistribution of sand and fine gravel in the vicinity of the 1870-1873 feet elevation range as the lake level drops, but the area affected will likely not be significantly different from the area affected by without-project decreases in lake level. In addition, salmon, trout and char generally spawn upstream of the gravel-sand transition, and the timing of natural scour and project-related scour would both occur after incubating salmonid have emerged from the gravel. The project is therefore unlikely to impact survival to emergence of salmonids. In general, the areas that could be subjected to scour as a result of decreasing lake levels are locations dominated by sandy substrates that are unsuitable for spawning by salmonid species.

An extended water level during the summer could result in shoreline erosion occurring at a higher than normal elevation during the summer because of recreational powercraft. and wind-generated waves. Potential effects to shoreline vegetation would generally follow those outlined in section 6.3.6 relative to different lake levels. Section 3.4 provides a discussion of potential changes in shoreline erosion.

6.4.2.2 Woody Debris Recruitment

Large woody debris (LWD) has important functions in many rivers and streams, serving as cover and refuge for juveniles, smolts, and adult salmonids. LWD can also act as bed control structures that moderate bedload movement, creating and maintaining important spawning areas. LWD can also create lateral channel migration and complex channel forms. LWD is naturally recruited to stream channels as a result of stream bank undercutting, debris slides, seasonal flooding, and fire events.

The amount of LWD throughout the mainstem Wenatchee River is reduced from predevelopment levels (Andonaegui 2001). The amount of LWD is low even in the upper reach of the river from Lake Wenatchee (RM 54.2) downstream to the confluence of the Chiwawa River (RM 48.4), where in general, impacts to natural channel functions have been less than in the lower reaches. Recruitment of additional LWD to the channel is limited in this reach by the moderately confined nature of the channel as a result of downcutting through the glacial outwash (Andonaegui 2001). The lower reaches of the Wenatchee River have little to no LWD.

The operation of the rubber dam will not affect (=) recruitment of LWD into the tributaries since the dam will not affect debris slides, flooding, or other disturbance events that cause LWD to fall into those channels. The movement of LWD in Lake Wenatchee may be altered (= –), however, as a result of extending the period of high lake levels. Floating logs that would have been deposited along the shoreline with the naturally receding spring waters may remain mobile during the summer as additional water is stored behind the rubber dam and lake elevations remain high. The rubber dam may also temporally accumulate LWD floating out of the lake and delay its movement downstream (= –).

6.4.2.3 Side Channel Connectivity

Off-channel habitats can provide important areas for juvenile salmonid rearing and refuge from high flows (Groot and Margolis 1991). These habitats are typically low-velocity side channel, backwater sloughs, wetlands, or beaver ponds. Channelization and construction of levees, revetments, roads, and shoreline developments has considerably limited the available off-channel habitat on the lower Wenatchee River (Andonaegui 2001). The upper Wenatchee River has more off-channel habitat in the form of oxbows and adjacent wetlands than the lower reaches (Andonaegui 2001). However, the State Highway 207 crossing just downstream of Nason Creek has been identified disconnecting the flow to side-channels in this area during extreme high water events (Andonaegui 2001). Other road placements and developments have eliminated other off-channel habitats in the upper reach. The lower reaches of the White and Little Wenatchee rivers have abundant off-channel habitat as the low gradient, depositional reaches braid and meander through a series of wetland complexes.

The operation of the rubber dam will temporally increase the mainstem river minimum instream flows during the late-summer/early fall period and may help maintain or restore connections with off-channel habitats that could otherwise become dewatered or isolated from the main channel. As noted in section 6.4.1, the effects of this would likely be relatively small (= +) due to the comparatively low amount of water that would be supplemented to the lower river compared to natural flows. The operation of the rubber dam will not affect side-channel habitat in the tributaries, upstream of the lake influence. However, higher water levels throughout the summer in Lake Wenatchee could result in increased open water and transportation corridors (= +) between off channel areas in the wetland complex on the western end of the lake, including the lower portions of the tributaries, and the main lake.

6.4.2.4 Primary Production and Invertebrate Production

Primary production is the conversion of inorganic matter (nutrients) to organic matter through the process of photosynthesis. Primary production is highest in warm, sunny waters that contain high concentrations of nutrients. Primary production in forest streams in the Pacific Northwest is often limited by lack of sunlight and low concentrations of phosphorus and nitrogen. Primary production is higher in open backwater areas, such as off-channel wetlands and in lakes that are open to the sun. Primary production is an important food resource for zooplankton and aquatic insects and the fish that eventually feed on them. In shady forested streams, aquatic insects often rely on the input of terrestrially derived primary productivity (leaf litter) as the base of their food chain. Invertebrate production important to salmonid populations in the Wenatchee River system includes zooplankton in Lake Wenatchee and aquatic macroinvertebrates, such as immature insects, in the river and tributaries.

Increased rates of primary production and the associated invertebrate production above pre-development conditions likely occur in the lower reaches of the mainstem Wenatchee River as a result of removal of the riparian forests (more sunlight) and agricultural and residential run-off of fertilizers. Lake Wenatchee and the upper mainstem Wenatchee River exhibit naturally low rates of primary production as a result of cold water temperatures and the nutrient-poor waters of the tributaries that drain the forested upper basin. In many Pacific Northwest systems, productivity has been altered as a result of decreased numbers of returning adult salmon that would subsequently die and contribute ocean-derived nutrients to the stream and riparian area (Bilby et al. 1998). It is unknown to what extent the reduction of these nutrients has had on the productivity of Lake Wenatchee and the upper basin.

The operation of the rubber dam will likely have little to no effect (=) on the current levels of productivity in the river, tributaries or in Lake Wenatchee. Biological studies of plankton in Lake Wenatchee during late 1930's and 1956–1957 were reported by Sylvester and Ruggles (1957). Their findings showed that the lake was oligotrophic, with little phytoplankton collected by net hauls and a sparse zooplankton community. They deduced that the plankton production in the lake was limited by nutrients governing phytoplankton growth. The zooplankton populations were dominated by rotifers, followed by cladocerans and copepods, and zooplankton abundance was characterized as being sparse, highly variable with time within an annual cycle, and probably controlled by grazing of the fish community.

There is little additional data on the plankton community of the lake. However, the lake remains highly transparent and low in nutrients that are needed to support primary producers (Ecology 1997). Prolonging higher lake elevation using the rubber dam would provide no mechanism to affect changes in the pelagic plankton community's composition or interactions. A change in depth of 3 feet or approximately 2% of the lake's mean depth for 2 to 3 months would be imperceptible to microscopic organisms.

6.4.2.5 Littoral Zone

The littoral zones of lakes are the areas where the water is shallow enough that light needed to support primary production can reach the bottom. The extent of the littoral zone is dependent on the bathymetry of the lake and the water clarity. Water clarity in Lake Wenatchee is relatively high. However, the overall shape of the lake is narrow and steep sided that limits the area of shallow littoral water. Most of the littoral zone is associated with the large wetland area on the western end of the lake where the White and Little Wenatchee rivers flow into the lake. A shoreline survey in 1994 (Ecology 1997) suggested that a healthy, diverse community of submerged aquatic vegetation extends to a depth of about 5.0 meters.

The operation of the rubber dam will extend the duration of high lake levels through late-summer. The extent and composition of submergent vegetation along the perimeter of the lake would likely stay the same. It is possible, however, that increased water depths during the summer could result in an upslope migration of submerged vegetation (from the deeper water towards the OHWM) as the plants respond to available light levels. This would likely be more pronounced for alternatives 1-3 (lake elevation 1472.4 feet) than alternatives 4 and 5 (lake elevation 1470.3 feet), although because of uncertainty in overall effects, all five are noted as = – in the matrices.

6.4.2.6 Wetlands

Wetlands are an important component of many river systems, providing areas of high primary productivity, nutrient cycling, and groundwater recharge and discharge. In some cases, wetlands are also littoral areas. On the mainstem Wenatchee River, approximately 585 acres of wetlands exist in the upper one mile of river from the mouth of Lake Wenatchee (RM 54.2) downstream to Fish Lake Run (RM 53.0) (Andonaegui 2001). An extensive complex of wetlands on Lake Wenatchee is associated with the outlets of the Little Wenatchee and White rivers.

The operation of the rubber dam could impact the wetlands on Lake Wenatchee as a result of changes in the water regime, or hydroperiod. Hydroperiod is defined as the depth, duration, frequency, and timing of inundation or soil saturation, and is one of the primary controls on the distribution of wetland plant species (Mitsch and Gosselink 1986). The typical pattern of vegetation zonation around lake shores, along river banks, and in wetlands is the result of variation in the degree of flood tolerance by wetland plant species. That is, plant species differ in their ability to tolerate increasingly greater depth, duration, and frequency of inundation or soil saturation. Plants are particularly sensitive to flooding during the growing season, so the timing or seasonality of inundation is important to consider in evaluating the effects of hydroperiod on plant species. Although many studies have shown an effect of hydroperiod on plant species distribution in wetlands, there are few quantitative data on how each component of hydroperiod affects wetland plant communities and how much of a change in each component is needed to significantly impact a particular plant species.

Several published studies have shown how changes in hydroperiod can affect wetland vegetation (e.g., Farney and Bookhout 1982; Kadlec 1962; Millar 1973; van der Valk et al. 1994). However, most primarily address wetland herbaceous vegetation and few (e.g., Farney and Bookhout 1982) have examined lake-associated changes in wetlands resulting from changing lake levels. Except for experimental studies (e.g., van der Valk et al. 1994), effects of specific hydroperiod components have rarely been examined.

An unpublished study of wetland changes in deltas of Chester Morse Lake (CML) in the western Cascade Mountains provides data specific to the question of changes in Lake Wenatchee wetlands in response to increases in lake level (Raedeke Associates 1997). As a major source of water for the City of Seattle, lake elevation in CML fluctuates in response to both natural, unregulated inflows and regulation of outflows to supply municipal water and instream flow needs. Delta wetlands at the eastern end of CML are characterized by extensive sedge and willow communities, with willow occurring at higher elevation than willow. Although variation in lake level is not entirely consistent year to year, there have been a higher frequency and duration of higher water levels in the lake since the early 1980s. Raedeke Associates (1997) found that concurrent with higher lake level and duration of inundation, there has been an upslope migration in the boundary between sedge dominated wetlands and unvegetated areas and in the boundary between sedge and willow dominated areas.

In Lake Wenatchee, the OHWM (1870.3 feet) generally marks the edge of perennial vegetation, and this elevation is probably similar to the lower elevation of emergent wetland vegetation. Wetland vegetation extends some elevation above this, but probably becomes dominated by upland species when flooding, or soil saturation, is infrequent. Generally, wetland vegetation occurs when soils are saturated to within 1 feet of the surface, although this depth can vary depending on soil permeability (ACOE 1987).

Based on studies in riparian zone of a semiarid region of Central Oregon, hydrophytic (i.e., wetland) vegetation was flooded on average at least once every 4.5 years (Chapin et al. 2000). Although this relationship has not been evaluated elsewhere, it provides a reasonable estimate of flood frequency occurring in wetland vegetation from a region climatically similar to the Lake Wenatchee area.

Historic average monthly May-June water levels in Lake Wenatchee (generally when the yearly high water level) were above 1872.0 feet once in four years and above 1873.0 feet once in ten years (Section 3.5). In the absence of a topographic survey, a reasonable estimate of the upper elevation of the wetland vegetation affected by lake water level would be 1873.0 feet. This elevation is equivalent to that flooded once every four years, or 1872.0 plus 1 foot to account for saturated soils above the level of inundation. Different communities of wetland vegetation would be distributed across this elevation range (1870.3 to 1873.0 feet) and an increase in depth, duration, or frequency of inundation in this elevation range due to the rubber dam could alter this distribution.

Several components of hydroperiod would be affected by raising water level with the rubber dam. Although a variety of hydrologic statistics can be used to quantify hydroperiod, average monthly water levels are a metric that captures much of the intra-annual variation in water level and is relatively convenient to use (Figure 6.4-1, Table 6.4-7). If wetland vegetation occurs between elevations of 1870 and 1873 feet, Alternatives 1, 2, and 3 would result in a generally greater depth of flooding. Lake levels under alternatives 1, 2, and 3 (average monthly elevations of 1872.08, 1872.08, and 1872.51 feet, respectively) would be higher than the historic annual high average monthly level of 1871.34 feet, occurring in June. There would be no change in annual high average monthly water levels under Alternatives 4 and 5.

Frequency of flooding for wetlands would also increase under alternatives 1, 2, and 3. Inundation to 1872 feet would flood most of the wetland elevation zone and result in saturated soils for the entire estimated zone (i.e., up to 1873 feet). During the 1933 to 1958 period of record, average monthly lake levels reached 1872 feet in 13 of 26 years. Under Alternatives 1 and 2, average monthly water levels at this elevation would occur in 24 of 26 years, according to the operational models. Average monthly water levels of at least 1872 feet would occur in all 26 years under Alternative 3. There would be no change from historic frequency of average monthly lake elevation reaching at least 1872 feet under alternatives 4 and 5.

Under alternatives 1 and 2 the rubber dam would also result in a shifting of the period of the annual high average monthly lake levels, according to operation models. Historically, the highest lake levels were generally in May to June. Alternatives 1 and 2 would result in annual high water levels occurring generally during July and August. Annual high water levels would still occur in either May or June under Alternatives 3, 4, and 5.

Under alternatives 1 and 2, duration of flooding would be greater. Average monthly water levels under historic conditions are above 1870 feet, the minimum required to inundate wetland areas, from May to June, and drop below 1870 feet through the rest of the year. Under alternatives 1 and 2, water levels would remain above 1870 feet from May through September, with water levels above 1872 feet in July and August. Inundation to 1870 feet would occur from May through July under Alternative 3. Under alternatives 4 and 5, inundation would remain above 1870 from May through August, but only the lower zone of wetlands (less than 1871 feet) would be affected.

Table 6.4-7. Predicted change in hydroperiod components as a result of five alternative rubber dam scenarios, Lake Wenatchee, WA.

Hydroperiod component	Historic	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Magnitude of flooding[1]	1871.34	1872.08	1872.09	1872.51	1871.34	1871.34
Frequency of inundation to 1872 feet[2]	0.50	0.92	0.92	1.00	0.50	0.50
Timing of peak water level	May-June	July-Aug	July-Aug	May-June	May-June	May-June
Duration of inundation above 1870 feet	May-June	May-Sept	May-Sept	May-July	May-Aug	May-Aug

1 Annual high of average monthly water level.

2. Fraction of years in which average monthly water level is equal to or greater than 1872.0 feet.

The CML study by Raedeke (1997) shows two things pertinent to the question of rubber dam operation on Lake Wenatchee wetlands. One, a change in inundation duration of 30 to 50 days is associated with an upward shift in the lower elevation of sedge and willow dominated plant communities (although this component of hydroperiod is likely correlated with other components). And, two, the particular species present in the CML deltas can tolerate specific periods of inundation. Sedges at CML (shore sedge [*Carex lenticularis*] and inflated sedge *[Carex vesicaria*] can persist with inundation during as much as 140 out of 180 growing season days. Willow species occurring at CML (Pacific willow [*Salix lucida lasiandra*], Sitka willow [S. *sitchensis*]) can persist with as much as 70 days of inundation during the growing season. Sedge and willow at species at Lake Wenatchee probably have a parallel difference in maximum inundation periods, but the specific length of the period may be different due to differences in climate and growing season between CML and Lake Wenatchee.

Based on the extent and magnitude of hydroperiod changes predicted under the five alternative operational scenarios presented in Table 6.4-6, Alternatives 1, 2 and 3 have a high probability of altering wetland vegetation (–) in the delta wetlands of Lake Wenatchee. Alternatives 4 and 5 have a moderate probability (= –) of affecting wetland community structure in at least the lower elevation wetland zone (i.e., 1870 to 1871 feet). Changes in wetland vegetation resulting from these scenarios (assuming they would be maintained and not varied year-to-year) would likely consist of a movement up slope of plant communities presently occurring in the wetlands, but could also involve changes within plant communities. Under all alternatives, more flood tolerant species such as spikerush and bur-reed may displace sedges and rushes, with the OHWM (the interface between bare substrate and emergent vegetation) also moving up in elevation. Under alternatives 1, 2, and 3, willows would likely die back at the lower end of their elevational distribution and be replaced by more flood tolerant herbaceous species, such as sedges. Other woody tree species affected by lake water level, such as cottonwood, may also experience some mortality. Colonization of new areas by willow upslope of their present limit would be expected in time, but may take decades depending on the occurrence of fluvial or other disturbance to create open substrates for willows to become established.

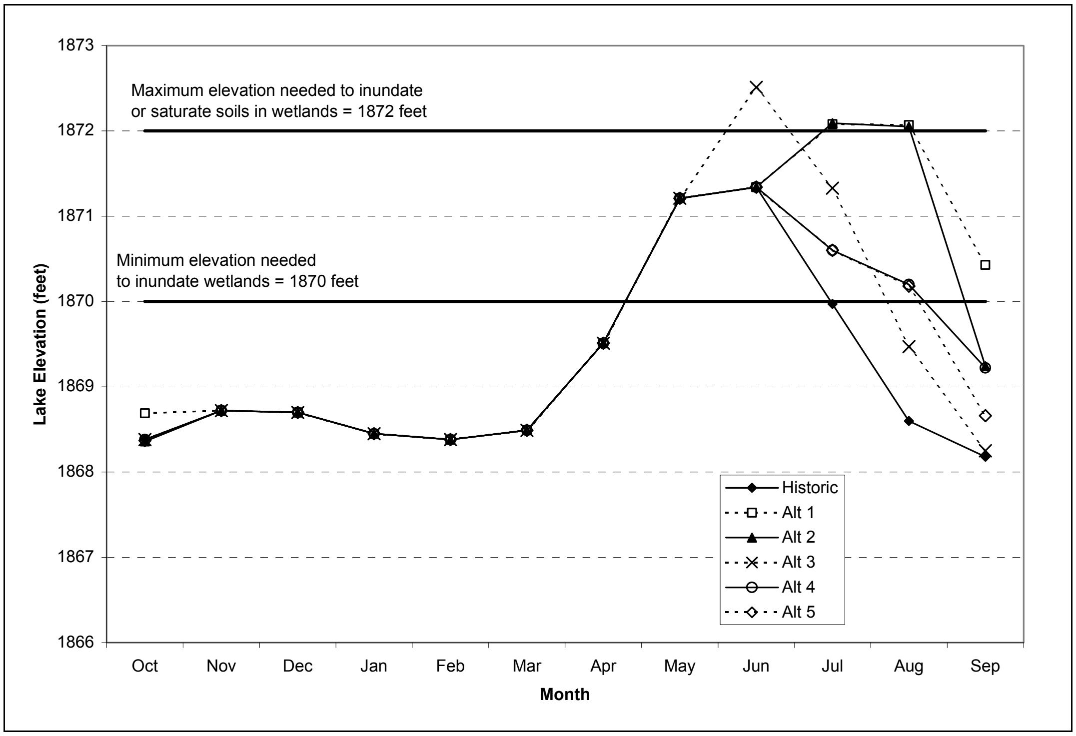

Figure 6.4-1. Average lake level elevations under different rubber dam operational models, Lake Wenatchee Water Storage Feasibility Study.

6.4.3 Effects Of Rubber Dam Operations On Water Quality Conditions

The general types of impacts that may occur to the water quality in Lake Wenatchee, the mainstem Wenatchee River and the major tributaries as a result of the operation of the rubber dam under the five alternatives are discussed in this section. Our understanding of existing conditions and modeled storage and release strategies were used to determine and describe potential project effects on water quality.

6.4.3.1 Water Temperature

Salmonids are cold water species and are considered at risk when temperatures exceed 23-25ºC (Bjornn and Reiser 1991). Upper lethal thermal limits range from 22.8ºC for cutthroat trout to 26.2ºC for chinook salmon (Bjornn and Reiser 1991). However, these values may vary according to recent temperature acclimation by the fish. A recent review of temperature requirements for Pacific Northwest salmonids used to support the draft. USEPA Region 10 guidance for temperature water quality standards suggests that adult salmon can generally survive a week or more at constant temperatures as high as 21ºC and can tolerate temperatures as high as 18ºC for prolonged periods under controlled experimental conditions (USEPA 2002). Additionally, water temperatures above 15.5^{o}C may contribute to low DO levels, another water quality parameter potentially limiting to salmonid populations.

High water temperatures are a limiting factor for salmonids in the mainstem Wenatchee River during the summer and potentially for salmonids near the mouth of the Little Wenatchee River. The causes of high water temperatures in the mainstem Wenatchee River is the object of an on-going study being conducted by Ecology (Bilhimer et al. 2002). Generally, low instream flows can result in higher water temperatures since the temperature of rivers with smaller volumes equilibrate faster, leading to higher maximum water temperatures in the summer (USEPA 2002). The operation of the rubber dam will have little effect on the overall lake surface temperature regime. The rubber dam would retain additional water in the lake basin during a portion of the period from July through September. The additional water mass of colder spring runoff (at <10 C) would tend to delay the normal rise in seasonal water temperature to some slight extent depending on annual solar heating regimes. As the anticipated increase in lake volume is between 12,000 and 6,000 acre feet and the nominal lake volume is 364,560 acre feet, the increase of between 3.3 and 1.65% in the spring is not expected to result in a significant seasonal temperature change. As a result, there would likely be little if any temperature benefits resulting from the release of supplemental flows from the lake to the mainstem river for any of the alternatives (=). Temperature modeling would be required to quantify the potential change in water temperature from release of additional flow.

6.4.3..2 Dissolved Oxygen

Low levels of dissolved oxygen (DO) may affect survival and growth of all salmonid freshwater life stages. Bjornn and Reiser (1991) concluded that DO levels of 8 to 9 mg/L are needed to ensure normal physiological function in salmonids. DO concentrations in forested rivers and streams are typically at saturation because of turbulent aeration and low primary productivity (Welch et al. 1998). Lakes and areas of calm open water, on the other hand, can have varied levels of DO dependent on seasonal and diurnal patterns of photosynthesis and decomposition. Lake Wenatchee, however, exhibits a relatively constant level of DO throughout its water column and throughout the year (Table 6.3-2), presumably as a result of wind-driven mixing (Sylvester and Ruggles 1957). DO concentrations are also dependent on water temperature, with the solubility of oxygen decreasing as water temperatures increase. The lower Wenatchee River was included on the state's 303(d) list of impaired waters in 1996 and 1998 for low dissolved oxygen levels (Ecology 1998).

The operation of the rubber dam will not likely influence DO levels in the mainstem Wenatchee River, nor will it affect DOs in the tributaries or in Lake Wenatchee (=). As noted below, high spring runoff flows in late May and June of 1996 were not associated with substantially higher nitrogenous or total phosphorus nutrients. Therefore, the DO regime is not expected to be modified by higher plankton productivity in the lake.

6.4.3.3 Nutrients and Biochemical Oxygen Demand

The source of nutrients in the Wenatchee River system includes autochthonous (algal and plant production within the stream/lake) and allochthonous (production from outside the stream/lake), such as from terrestrial leaf litter and spawned out salmon carcasses. High nutrient concentrations do not themselves generally create conditions that are directly harmful to salmonid species. It is the influence of the nutrients and organic pollution on the biochemical oxygen demand (BOD) that can lead to low DO concentrations that impact fish and other aquatic organisms (Hynes 1974). BOD is a measure of the rate at which DO is demanded by the microbial community to digest organic matter (Welch et al. 1998).

The operation of the rubber dam will not likely have measurable effects on nutrient concentrations or BOD in Lake Wenatchee, the Wenatchee River or the tributaries (=). Results of monthly water quality sampling in 1996, indicate that high springtime flows out of the lake are not characterized by substantially increased nitrogenous and total phosphate nutrient levels (WRWSC 1998). Retaining these flows behind the rubber dam would, therefore, be insufficient to promote planktonic algal growth to the extent that increased BOD would result later in the year.

6.4.3.4 pH

The pH of river and stream water naturally increases as streams flow downstream because of the increased time the water is in contact with bedrock and the increased amounts of solutes that enter the water (Welch et al. 1998). Ecologically, an acceptable pH range is between about 6 and 9 (Welch et al. 1998). Low pH waters can be naturally associated with wetland drainages that can contain high amounts of humic acids and it is common to find low pH waters in the stratified bottom layers of lakes. High pH waters can occur naturally as a result of high rates of photosynthesis, although in some cases the photosynthesis may be stimulated by increased amounts of nutrients from run-off, sewage, or other human derived sources. The lower Wenatchee River was included on the state's 303(d) list of impaired waters in 1996 and 1998 for high pH levels (Ecology 1998).

The operation of the rubber dam will not likely affect a measurable change in the pH regime in Lake Wenatchee, the Wenatchee River or the tributaries (=). In the absence of increased nutrient concentrations, noted above, increased algal productivity and hence pH increases should not occur. The pH values measure near the lake outfall in May and June 1996 (WRWSC 1998) remained within the acceptable range for salmonids (6.0 to 9.0 pH units) in the flows the dam would retain in the lake. Therefore, retaining the spring runoff for later flow augmentation should have no measurable effect on lake water pH levels.

6.4.3.5 Suspended Sediments and Turbidity

Fine particles suspended in the water column are typically measured as turbidity, which is a measure of the amount of light scattered by the particles in suspension. Rivers that drain glacial meltwater naturally have high amounts of suspended "glacial flour" and high turbidity with a characteristic milky color. Highly productive lakes also sometimes have high levels of turbidity resulting from phytoplankton and zooplankton in the water. In a river, it is natural for turbidity to increase as the water flows downstream and more solutes enter the water. Unnatural sources of suspended sediments and increased turbidity can include run-off from unpaved roads, increased rates of mass wasting resulting from timber harvest, increased rates of primary production, and increased rates of bank erosion and bedload movement resulting from increased flood or peak flows. Roads and housing development downstream of the Chiwawa River (RM 48.4) on the upper Wenatchee River may elevate sediment input to the river at this location (Andonaegui 2001).

The operation of the rubber dam will not likely have a substantial effect on the suspended solids or turbidity of Lake Wenatchee, the Wenatchee River or the tributaries (=). Water quality data collected in the spring of 1996 indicated that turbidity at the lake outfall did not increase with highest measured flows in May. However, total suspended solids increased from 0.2 to 5 mg/L from the May to June measurement (WRWSC 1998). Although turbidity did not show a similar increase, the operation of the rubber dam may retain an increased amount of sediment in the lake that otherwise would pass downstream. This sediment, if retained, would precipitate to the lake bottom during the three-month retention period. Consequently, the water later release for flow augmentation would carry a reduced sediment load.

6.5 CONCLUSIONS REGARDING POTENTIAL ENVIRONMENTAL IMPACTS AND BENEFITS

Until this study, it was not known how much water could be provided through construction and operation of a rubber dam at the outlet of the lake. Reconnaissance level studies had suggested that the OHW elevation would be higher (approximately to the 1872 feet elevation) than what the field surveys determined, suggesting that a reasonable amount of yearly stored water would be in the range of 11-12,000 acre-feet. However, as described in Section 3.2, the actual OHW was determined to be 1870.3 feet, which would provide approximately one-half of that amount.

This study identified several potential negative environmental impacts or issues that may result from project implementation. These included the potential impacts to existing wetlands and shoreline plant communities, and as well concerns related to bull trout connectivity between lake and riverine habitats.

Although specific field studies were not conducted that would help to define incremental benefits in terms of fish habitat relative to different streamflows, it can be surmised that such benefits in terms of supplementation of 50-100 cfs, would be relatively small when considering the channel dimensions of the Wenatchee River. River widths in the range of 150-200 feet are not uncommon, especially in wide riffle habitats, and even under extremely low flows (e.g. 300 cfs at Plain[1]) the additional 50 to 100 cfs for a short period of time (one month) would likely result in relatively small changes in water depth (≈ 1-2 inches). How these changes in water depth translate into changes in fish habitat is not known. However, extremely low flows that occur during warm summer months can create especially stressful conditions to fish. During such periods, the provision of even relatively small amounts of flow may temporally and spatially benefit fish populations. Clearly, the potential environmental impacts and benefits of the Lake Wenatchee Water Storage Project warrant further consideration.

6.7 POTENTIAL ADDITIONAL STUDIES

For many of the potential impacts identified on the mainstem Wenatchee River, instream flow modeling (habitat and temperature) would assist in the quantification of potential effects. Additional studies on the bathymetry and topography of the lake shoreline would also assist in the quantification of potential impacts within the lake. The following list outlines additional studies and information needed to fully evaluate potential project impacts:

- Temperature modeling in the mainstem river to assess the potential impacts/benefits of increased water released from Lake Wenatchee and to generally understand thermal regime characteristics of the watershed.
- Instream flow study to determine horizontal and longitudinal extent of potential impacts in the Wenatchee river from increased water released from Lake Wenatchee.
- Instream flow fish passage study to identify areas for which flow related migration delays may occur and to derive recommended passage flows that would facilitate upstream migration of adult salmonids.
- Construction details, sequence, and impact analysis.

[1] The 95% exceedence flow at Plain for September was computed as 344 cfs. This flow would be equaled or exceeded 95% of the time and therefore represents a extremely low flow condition.

- Fish passage details and impact analysis.
- Longitudinal survey of the lake shoreline and of the Little Wenatchee and White rivers to identify potential spawning habitat that could be inundated, exposed, or scoured as a result of manipulated lake levels.
- Topographic survey to determine elevational range of plant communities and accessibility of off-channel fish habitat at specific lake levels
- Characterization of wetland plant species composition and distribution of wetland plant communities to provide better information for assessing impacts to the wetlands along the lake
- Installation and monitoring of ceilometres to determine the extent of hydrologic influence by the lake and how groundwater or disconnected surface water responds to lake level fluctuation to provide better information for assessing impacts to the wetlands along the lake