USDA Forest Service

Gifford Pinchot National Forest

Existing Information Analysis

For

Aquatic Biology Resources

Prepared by: Kenneth Wieman

Date Last Edited: December 3, 2004

Abstract

Packwood Lake Hydroelectric project area is centered on a unique aquatic resource located in the upper Cowlitz subbasin of the Cowlitz Valley Ranger District. The proposed analysis area (16,409 acres) consists of Upper watershed (11,229 acres) and Lower Lake Creek basin (5,179 acres) which is separated by the natural stream barriers (e.g. chutes and falls) and the concrete dam at Packwood Lake (452 acres).

Packwood Lake was prehistorically formed by a landslide damming Lake Creek. In 1964 a concrete dam was constructed to retain water and regulate flows for power generation. The hydroelectric project seasonally draws down the lake level up to 8 feet and diverts the majority of Lower Lake Creek water volume through approximately six miles of penstock and tailrace channel water diversion system.

The lake is fed by roughly six fish bearing tributaries which total an approximate eight miles of fish accessible habitat important for reproduction and rearing for a native strain of uniquely adapted wild rainbow trout *(Oncorhynchus mykiss).* Packwood Lake rainbow trout evolved in the Upper Lake Creek basin and have maintained a self-sustaining population whose life cycle depends on the lake environment for adult holding and foraging and the tributaries for spawning and rearing habitat.

Lower Lake Creek subbasin has approximately 15 miles of fish-bearing stream including Lake Creek, Snyder Creek, Hall Creek and the Cowlitz River. These water bodies have a combined total of approximately 21 miles of resident and anadromous habitat with documented presence of rainbow/steelhead trout, cutthroat trout (*O. clarki*), Coho salmon (*O. keta*), chinook salmon (*O. tsuchaga*). Coho, chinook and steelhead are all listed as Proposed, Endangered, Threatened, Sensitive species (PETS).

A cursory review of the existing information available to the Packwood Lake Hydroelectric Project identified several preliminary issues concerning the aquatic ecosystem. Water control and diversion manipulates the timing and quantity of water discharge which can adversely impact the physical and biological process and function of the aquatic ecosystem. Hydroelectric infrastructure (e.g. dam, tailrace channel and screened intake) may impede, entrain, or impinge fish as well as restrict natural transport of sediment and large wood.

Current information on Packwood Lake analysis area is limited. Most information dates back more than a decade and predates significant natural and anthropogenic modifications including: floods, land management, and salmon reintroduction in the planning area. This report recommends full development of a study plan to explore eight issues related to biological conditions, aquatic habitat, and recreational opportunities influenced by the Packwood Lake Hydroelectric Project.

I. Existing Situation

Power Generation

The Packwood Lake Hydroelectric Project is located east of the community of Packwood, Washington in the Cascade Mountains (Photo 1). Packwood Lake lies within the Gifford Pinchot National Forest. The Project includes: a dam or drop-structure which regulates lake surface elevation and is located a short distance downstream from the natural outlet of the Lake; an intake structure; an approximately 23,000 ft-long, partially subterranean flowline; a surge tank; a 6,000 ft-long penstock; and a powerhouse (turbine-generator rated at 27,500 KVA). The powerhouse is located at the base of the mountain adjacent to the community of Packwood. The powerhouse tailrace flow discharges into a constructed stilling basin. It then travels through a lined tailrace channel about 8,000 ft in length to its confluence with the Cowlitz River. The tailrace includes a 200 ft. highway culvert and 360 ft. flume over Hall Creek and a lined concrete crossing over Snyder Creek.

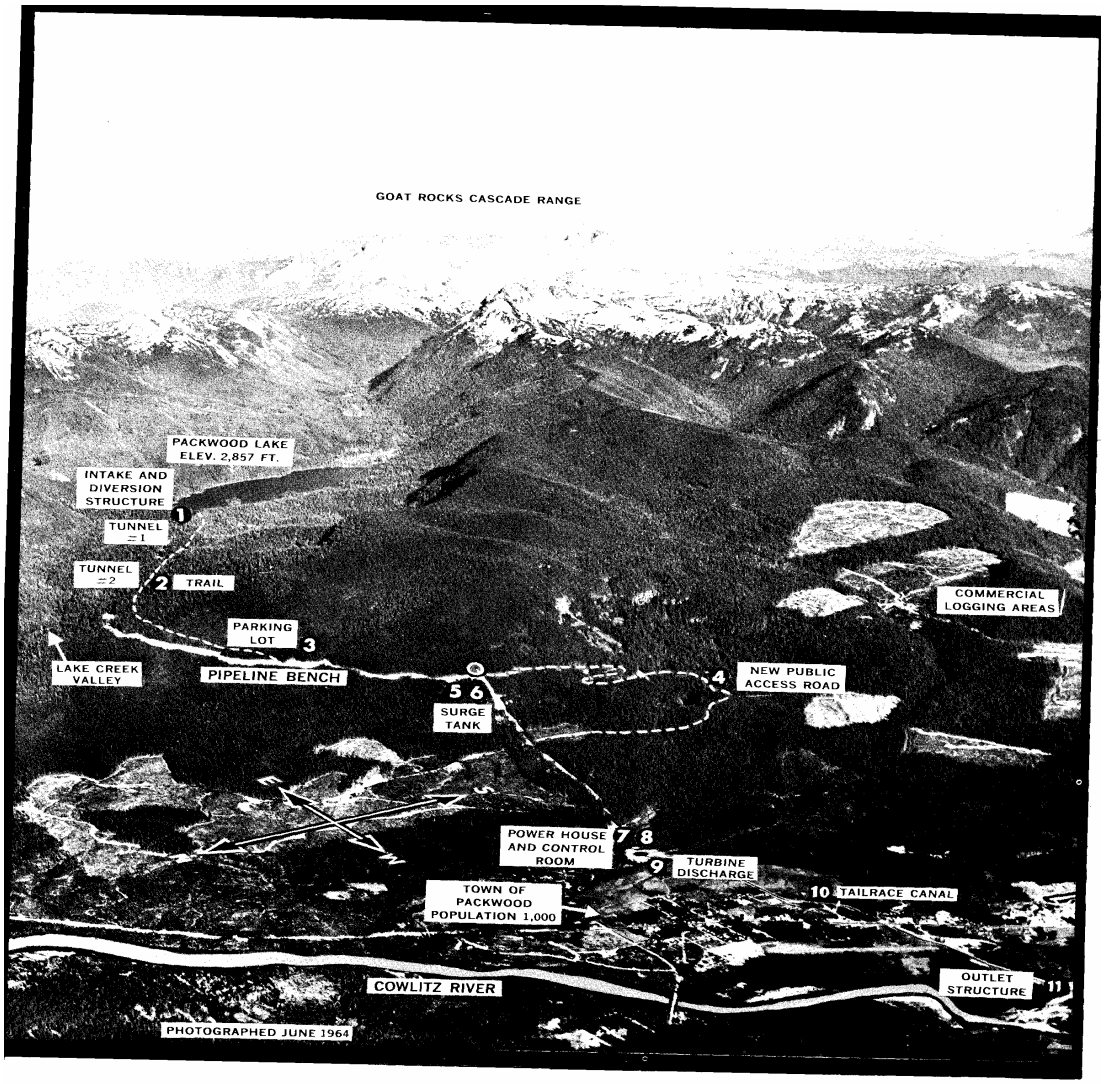

Photo 1. Oblique angle photo of Packwood Lake hydroelectric system. Lewis County, Washington. (from Washington Public Power Supply System, approx 1967)

The project is operated in a baseload manner depending upon water availability and power contracts. The Project has a water right for 260 CFS but the Project does not operate at capacity at all times. Average power production is 10 Mw relative to a turbine generator rated at 27,500 KVA).

The total area drained by Lake Creek and Packwood Lake amounts to approximately 12,288 acres (19.2 square miles) at the drop-structure and 16,960 acres (26.5 square miles) upstream of the confluence of Lake Creek and the Cowlitz River. The total surface area of the lake is 452 acres (0.7 square miles). The natural lake elevation (El) is 2,857 ft MSL, which is approximately 1,800 ft above the powerhouse.

The Project seasonally regulates the lake level so that it is at El 2,857 ft ±6″ in summer recreation months (June – August) and drawn down to no lower than El 2,849 ft MSL during winter months (September – May). This provides 8 ft vertical storage usable by

the project. According to Energy Northwest, the lake is drawn to its lowest level prior to the annual maintenance shutdown in October. When lake level rises above the drop-structure crest elevation and the intake is at capacity (or not operative), the flow spills over the drop-structure into Lake Creek downstream of the lake. The lip of the drop structure is at 2858.5 feet MSL which is 1.5 feet above the natural lake level.

Analysis Area

The area of analysis for the Packwood Lake Hydroelectric Project should cover the extent of fish distribution and include both upper and lower Lake Creek subwatersheds. Furthermore, analysis should encompass the Cowlitz River where stream flows are modididfed downstream of Lake Creek. Lastly, the tailrace channel, up to the tailrace pond should be included in the analysis area.

Lake Creek Hydrology

Two USGS gauging stations have been operated on Lake Creek. The gage immediately down-stream of the drop-structure (No. 14225500. El. 2,844.62 ft. 18,555 daily flows) operated from October 1, 1911 through September 30, 1980, with a drainage area of 12,288 acres (19.20 square miles). Another gage was operated from September 1, 1907 through November 22, 1977, upstream from the confluence of Lake Creek with the Cowlitz River (No. 14226000. El. 1,190.0 ft. 7,798 daily flows), with a drainage area of 16,960 acres (26.50 square miles). Mean annual flow as measured at the drop-structure was 101.5 CFS. Details concerning hydrology for Lake Creek are included in the *Existing Information Assessment for Flow and Sediment*.

Lower Lake Creek Stream Flow And Temperature

The instream flow in Lower Lake creek is largely dictated by the water release operations at the dam (a.k.a. drop-structure) and the inflows recharging (i.e. ground water and surface water) entering the channel. Currently, the FERC license for the Project requires a minimum instream flow of 3 CFS, at the drop-structure immediately downstream of the outlet of Packwood Lake and there is also an instream flow requirement of 15 CFS at the confluence of Lake Creek with the Cowlitz River. Energy Northwest is not currently required to measure this flow. Estimated stream inflows for the period January and June is reported to be equal to or greater than 18 CFS (USDA, 1967).

Stream temperature in Lake Creek appears to be warmed by lake water (Figure 1). As evidence, in 1993 stream temp was as fairly constant between reaches 1-4. However, as surveys approach the lake, reaches 5- 6 show a dramatic increase of 3.5 ^{o}C and 7 ^{o}C respectively.

Stream temperature was monitored in summer 1995 above Lake Creek County Road (MP 1.0). The one day maximum temperature was 13.9 C and persisted for three consecutive days starting July 18. The seven day moving average high was 13.4 ^{o}C, and occurred on July 21 and 22. The measured streamflow on September 20, 1995 was 7.5 CFS.

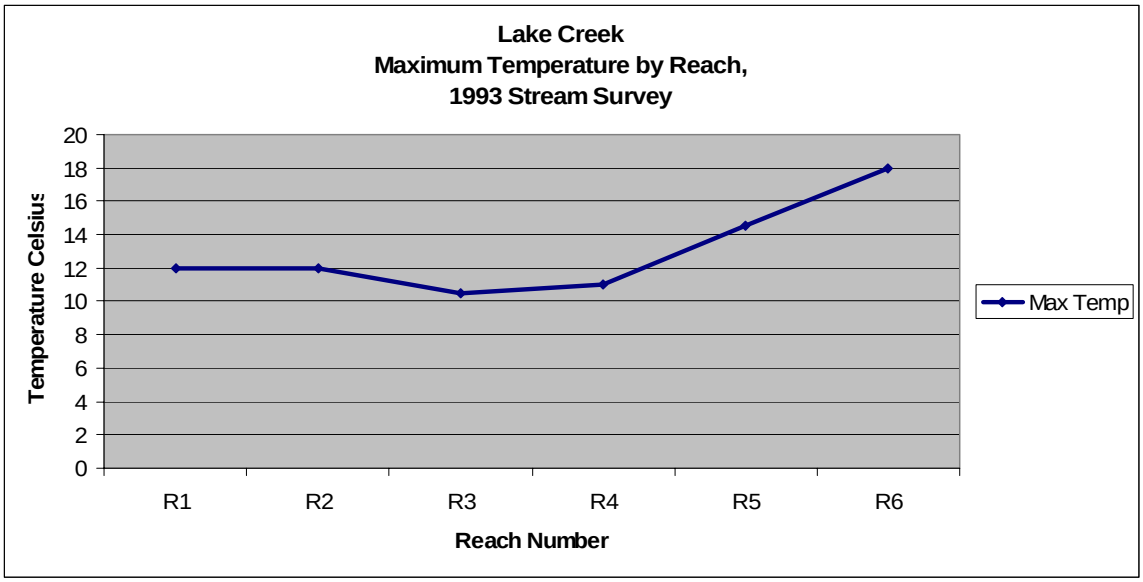

Figure 1. Maximum stream temperature for Lake Creek measured between the mouth (R1) to Packwood Lake (R6). Lewis County, Washington (USFS 1993).

Physical environment: Packwood Lake/Lake Creek Watershed

The natural water elevation of Packwood Lake lies at 2,857 ft, approximately 1,800 ft above the Project powerhouse. Packwood Lake and Lake Creek are bounded on the southwest by Snyder Mountain, elevation 5,030 ft, and on the northwest by mountain ridges with elevations ranging to 5,300 ft (Washington Public Power Supply System 1971). Originating as rainfall and snowmelt in the Goat Rocks Wilderness Area and the Cascade Mountains draining into Packwood Lake (surface area of 452 acres), Lake Creek flows to the northwest approximately 5.3 miles to the upper Cowlitz River. Lake Creek empties into the upper Cowlitz River at approximately River Mile 129.2. The Packwood Lake drainage is mostly contained within the Gifford Pinchot National Forest boundary (the first 0.7 miles are private lands).

The channel gradient of lower Lake Creek is relatively high, averaging about 6.3% from the lake to its confluence with the Cowlitz River. Segment gradients range from a low of about 2% immediately upstream the mouth (river mile(RM) 0.1) to 20% in the canyon reach (RM 2.0-3.1) (Table 2).

Fluctuating water levels at Packwood Lake shoreline instigated sloughing along 600 feet of shoreline following hydroelectric development. A USDA report (1967) concluded that the bank instability was attributed to lake level drawdown and could affect the eastern shoreline below waterline and the western shoreline above the waterline. USFS Reports state that aesthetic qualities have been compromised by shoreline instability.

Stream Conditions

This analysis divides Lake Creek into two segments, an upper and lower watershed, to reflect the distinct influence which the hydroelectric project has on the two zones. Streams in the project area are impacted in different ways depending if they are upstream or downstream of the hydroelectric project. Upstream of hydro-electric operations, for

example, aquatic concerns are focused on resident fish and stream process influenced by fluctuating reservoir water levels. Downstream of the hydroelectric project, effects of water diversion to instream flow and habitat are key functional modifications to the aquatic ecosystem. The project area has approximately 21 miles of fish bearing water in 11 streams. Seven of those streams are in Upper Lake Creek and four are in Lower Lake Creek (Table 1)

Data collected on streams in the project area include three Level II stream surveys; two on Lower Lake Creek (RM 0.0-5.4) and one on Hall Creek. Snyder Creek has a preliminary fish habitat survey completed in 1983.. WDFW and consultants have conducted biological survey including resident and anadromous spawner surveys (WDFW, 2004). No other stream survey data is known to exist for the project area.

The most recent field review was completed in 1993 on Lake Creek extending from its confluence with the Cowlitz River (Reach 1) T13N, R9E, S11, up to the outlet of

Table 1. Summary of fish bearing streams and aquatic surveys conducted in the upper and lower zone of influence within the Packwood Hydro-electric project planning area.

Id No.	Stream Name	Zone of Influence (upper /lower)	Estim Stream Length (River Mile)	Fish Distribution		Surveys conducted		Data Source
				Resident	Anadromous	Physical	Biological	
1	Upper Lake Ck	Upper	7.0– 9.5	Y	N	N	Y	spawner estm
2	Osprey Ck	Upper	0.0 – 0.2	Y	N	N	Y	spawner estm
3	Muller Ck	Upper	0.0 – 0.2	Y	N	N	Y	spawner estm
4	Trapper Ck	Upper	0.0 – 0.2	Y	N	N	Y	spawner estm
5	Crawford Ck	Upper	0.0 – 0.2	Y	N	N	Y	spawner estm
	Beaver Bill Ck	Upper	0.0 – 0.4	Y	N	N	Y	spawner estm
7	Trib SE of Trap Ck	Upper	0.0 – 0.3	Y	N	N	Y	spawner estm
8	Hall Ck	Lower	0.0 – 3.1	Y	Y	Y	Y	spawner estm, Level II (1994)
9	Snyder Ck	Lower	0.0 – 1.0	Y	Y	Y	Y	1983 fish habitat
10	Lower Lake Ck	Lower	0.0 – 5.4	Y	Y/ N	Y	Y	spawner estm, barrier analysis, Level II (1993, 1995), guage data,
11	Cowlitz River	Lower	124-129.2	Y	Y	Y	Y	spawner estm, gage data

Packwood Lake T13N, R10E, S21 (Reach 6) (USFS 1993). The survey divided Lake Creek into six reaches based on the habitat conditions of the creek (Table 2.)

Table 2. Summary of the 1993 Level II stream survey conducted on Lower Lake Creek. Lewis County, Washington.

Reach No.	River Mile	Channel Type		Bankfull Width (ft)	Pools/Mi. (# pools)	LWD/Mi. (# pieces)	Substrate	Riparian Veg
		Rosgen	Grade (%)					
1	0.0 – 0.7	B	3	10	37.1	0.0	SB/C	ST
2	0.7-1.3	A	10	15.6	40	6.3	SB/LB	ST
3	1.3—2.2	B	8	17.6	28.9	9.2	SB/G	ST
4	2.2 – 3.1	A	8	28.9	41.4	18.1	LB/C	ST
5	3.1 – 4.9	B	5	10.9	31.7	16.5	C/G	ST
6	4.9– 5.4	B	8	23.6	44.0	7.4	C/G	LT

Key:
Substrate: SB = small boulders, LB= large boulders, G= gravel, C= cobble
Riparian vegetation: ST= small trees (21- 32 in. dbh), , LT = Large Trees (>32 in. dbh),

Channel Conditions

Habitat conditions vary from poor to fair in the lower reaches below Packwood Lake. Qualities contributing to the low rating of this channel include; steep channel gradient, lack of quality instream wood, deficient quality spawning substrate and early seral riparian vegetation development which have poor potential for large wood recruitment.

Upper Lake Creek and other tributaries staggered around the lake basin, including Beaver Bill, Miller, Crawford and Osprey Creeks, have never had a Level II stream survey. Upper Lake Creek is a glacial-fed system which provides most of the lake inflow. The other tributaries are typically small spring-fed drainages (400-700 acres) that descend in steep mountain headwall channels. The lower .25 - .75 miles transition to a moderate gradient (< 4%) and are accessible to anadromous fish. These small streams have a bankfull width typically < 10 ft wide and low flow at an estimated volume of 3-6 CFS. Abundant overhanging vegetation, fallen logs, and undercut banks provide a plentiful hiding habitat. Isolated pockets of gravel provide necessary spawning substrate for resident trout (Table 2).

Sediment

Substrate composition in lower Lake Creek is generally coarse and composed primarily of large and small boulders. Gravel and cobble size material provides suitable spawning sites in the tailout of major pools. The substrate appears to be similar to other streams in the area with the same channel types. The best anadromous spawning conditions appear to be at the confluence of the Cowlitz River.

Reservoirs tend to disrupt the sediment transport process by capturing coarse sediment and retaining it behind the dam. Sediment filling the lake is sometimes a consequence of dam operations. The design of the Packwood Lake diversion structure does not substantially change the transport of fine sediments to the stream below. Coarse sediments settle out in the lake, and this is unchanged by the project. No focused data collection or analysis has been completed on Packwood Lake and/or lower Lake Creek to evaluate the distribution of substrate particle size. Two factors influencing the sediment balance in the bypass reach include; (1) inherently unstable valley walls may be an adequate source of substrate in lower lake creek below the dam (2) the prehistoric landslide forming Packwood Lake may have functioned as a sediment retention device and naturally stored sediment in the lake prior to dam construction.

Large Wood

Accumulation large woody debris (LW) ranges from 0 – 18.1 pieces per mile (USFS 1993). All reaches surveyed rated poor for accumulation of LW which may be attributed to past harvest of riparian timber and loss of connectivity with upper lake creek reaches. As with sediment movement, the dam may adversely impact the transport function of the aquatic ecosystem by either retaining LW in the reservoir and reducing the frequency and duration of peak flows necessary to move instream LW.

Fisheries Resources *Anadromous fish*

Suitable anadromous fish habitat is confirmed in lower Lake Creek, Hall Creek and Snyder Creek. Surveys were conducted of Lake Creek in 1993, Snyder Creek in 1983, and Hall Creek in 1994. Lake Creek anadromous distribution extends from the mouth to river mile 1.9 where the first natural permanent fish migration barrier (25 ft fall) is expected to preclude passage (USDA, 1995). Lucas (WDFW 1992) also identified RM 1.9 as the probable end of anadromous fish distribution and cited three independent surveys to support his conclusions including WDFW foot survey (1992), Bryant (1949) and Kray – WDW (1957).

Anadromous species documented as present in Lake Creek include, Chinook salmon, Coho salmon, and steelhead trout. Of these fish, the National Oceanic and Atmospheric - Fisheries (NOAAF) has listed Evolutionary Significant Units (ESUs) including: Lower Columbia River steelhead trout (*Onchorhynchus mykiss*), Lower Columbia River Chinook salmon (*O. tshawyscha*), as threatened under the Endangered Species Act . Coho salmon are listed as a proposed species. Chum salmon (*O. keta*) populations have never been documented in the Cispus River watershed, and are not expected to be included in salmon reintroduction efforts above the mainstem Cowlitz River dams. Steelhead trout, Chinook and Coho salmon are transported (trucked) around the three dams on the Cowlitz River making the upper Cowlitz River and its tributaries accessible to these species.

The tailrace channel crosses over both Snyder and Hall Creeks and join at a large swamp less than one mile below the powerhouse. The structure is documented as a migration barrier for anadromous and resident fish in their respective stream survey reports.

Smolt production was estimated for Hall Creek and Lower Lake Creek by modeling the Smolt Habitat Capability (SHC) existing and potential future conditions (USFS 1994 and USFS 1995). Table 3 summarizes the anadromous production which is based on habitat conditions and anticipated reintroduction efforts necessary to initiate natural reproduction. Estimates were made from mostly measured values for either populations or habitat parameters. SHC is limited in both Hall and Lake Creek by less than optimal habitat elements including pools and large wood. Hall Creek currently has a migration barrier which blocks approximately1.2 miles of anadromous habitat that, if restored, could substantially increase SHC and resident rainbow production (USFS 1994).

Table 3. Existing and potential Smolt Habitat Capability (SHC) for Hall and Lake Creeks located in the Packwood Hydroelectric Project planning area. Lewis County, Washington. (USFS 1994 and USFS 1995)

Anadromous species	**Existing Smolt Habitat Capability (ESHC)**		**Potential Smolt Habitat Capability (PSHC)**	
	Hall Creek	Lake Creek	Hall Creek	Lake Creek
Coho	602	551	4818	4468
Spring Chinook	160	272	11885	9418
Winter Steelhead	48	37	1606	1030

Resident fish

Resident salmonids present in Lake Creek include cutthroat trout (*Oncorhynchus clarki*) and rainbow trout (*O. mykiss*) (USDA 2001). There are no known reports of TES listed resident fish in the planning area (USDI, 2001). Bull trout (*Salvelinus confluentus*) are the only listed resident TES documented in the Upper Cowlitz subbasin. Non-native char including eastern brook trout (*S. fontinalis*) have been documented in the Upper Cowlitz River subwatershed. The Gifford Pinchot National Forest Fish Biologist has determined bull trout to not be present in the Upper Cowlitz basin (Perez- Rose, person. comm. 2003). The Regional Forester's list of sensitive fish includes Redband trout (*O. mykiss spp*.) which, by definition, are only found east of the Cascades (Benke 1995) and pygmy whitefish (*Prosopium coulteri*) which are limited to nine known locations in the Washington State all outside of Lewis County (WDFW 1998).

Table 4. The Evolutionarily Significant Units (ESU), Distinct Population Segments (DPS), designated or proposed critical habitat, and candidate ESUs considered in the Cowlitz River Basin Packwood Hydroelectric analysis area.

Species	ESU, DPS, or Critical Habitat	Distribution in Project Area (present/absent)	ESA Status	Federal Register Notice and Date
Chinook Salmon	Lower Columbia River	Present	Threatened	64 FR 14308 3/24/99
	Puget Sound *	Absent	Threatened	64 FR 14308 3/24/99
Chum Salmon	Columbia River *	Absent	Threatened	64 FR 14508 3/25/99
Steelhead	Lower Columbia River	Present	Threatened	63 FR 13347 3/19/98
	Middle Columbia River *	Absent	Threatened	64 FR 14517 3/25/99
Coho Salmon	Lower Columbia River/Southwest Washington	Present	Proposed	60 FR 38011 7/25/95
Bull Trout	Columbia River	Absent	Threatened	63 FR 31647 6/10/98
Interior Red Band Trout	NA *	Absent	Sensitive	
Pygmy Whitefish	NA *	Absent	Sensitive	
* ESA listed species not present in Packwood Lake Hydroelectric planning area.				

Resident rainbow trout were observed in Lake Creek on all six survey reaches of the 1995 stream survey between the mouth and the dam (USFS 1995). Adult and juvenile age classes were observed suggesting there is a viable population with natural reproduction (Table 5).

Table 5. Fish numbers observations during 1995 snorkel survey on Lake Creek. (USFS 1995).

Reach	Species	Adult	Juvenile	Total
1	Rainbow	3	1	4
2	Rainbow	14	40	54
3	Rainbow	16	39	55
4	Rainbow	52	116	168
5	Rainbow	28	90	118
6	Rainbow	18	47	65
Total		131	333	

Packwood Lake supports an adfluvial population of rainbow trout which move between the lake and its tributaries. Annual WDFW spawner surveys documented a relatively stable population of fish averaging around 500 fish between 1980 and 2003 (Table 6).

Table 6. Adult salmonid count from annual spawning survey in major tributaries to Packwood Lake between 1981 and 2003. Lewis County, Washington. (WDFW 2003)

Date	Osprey Cr	Trap Cr	Muller Cr	Upper Lake Cr	Beaver Bill Cr	Trib SE of Trap Ck	TOTAL
1980			194				**194**
6/18/81	16	18	67	5			**106**
6/29/82		0	0	0			**0**
6/20/83	0		0				**0**
1994			55	317		40	**412**
6/26/85	3	0	14	200		0	**217**
6/27/86			13	112			**125**
6/9/87			78	332			**410**
6/16/88		180	61	721		4	**966**
6/14/89	490	160	180	405	82	5	**1322**
6/15/90	24	5	149	60			**238**
6/19/91	314	94	399	363		0	**1170**
6/20/95	1	0	86	166			**253**
6/28/96	0	3	299	238			**540**
6/25/97	29	13	590	214			**846**
6/24/98	28	9	374	220			**631**
7/6/99	19	30	155	107			**311**
6/29/00	355	27	249	153			**784**
6/25/02	138	60	414	**265**		8	**885**
6/25/03	181	6	201	305		0	**693**
AVG	**114**	**40**	**178**	**232**	**82**	**8**	**522**
N	**14**	**15**	**19**	**18**	**1**	**7**	**19**

Rainbow Trout Life History in Packwood Lake

In early, June rainbow trout move from Packwood Lake into small streams to spawn. Rainbow trout typically deposit an estimated 200 to 400 eggs/female The eggs are fertilized by a male and covered with gravel. Hatching normally takes about three to four weeks when water temperatures are near 8^0 C. Typically after 3-4 weeks fry emerge from the gravel. Small salmonids gather in groups and take shelter along the stream margins or protected lakeshore, commonly feeding on crustaceans, plant material, and aquatic insects and their larvae. The young trout probably eat mostly invertebrates including insects. Eventually, mature rainbow trout move into Packwood Lake and likely feed on a diet of small fish, amphibians, and crustaceans.

Table 7. Typical life history of fish found in the Packwood Hydroelectric Project. Lewis County, Washington.

Species	Migrate to steams	Spawn	Emergence	Months in Streams	Out migration
Steelhead	March-May	Mar - Apr	Late July	2	April-June
Cutthroat	Oct - Nov	Feb - Mar	Late July	2	May
Chinook	Late July - Aug	Aug -Sept	Mar-April	0	July-Aug
Coho	Nov-Jan	Dec - Jan	Mar - April	1	May - Aug
Rainbow trout	May - June	June	July	?	?

Hatchery Programs- Introduction And Brood Stock Programs

Packwood Lake fish has been used as both a source of Washington Department of Fish and Wildlife brood stock collection and as a location for stocking hatchery fish. Introductions have been used to supplement the Packwood Lake sport fishery (Lucus 2004, Person. comm.) into the 1970's. There is also a history (approximately 30 years) of trapping fish from Packwood Lake tributaries to develop WDFW resident hatchery fish programs (Crawford 2004, Person. comm.).

Donaldson Trout

University of Washington professor, Dr. Lauren Donaldson researched Packwood Lake fishes in the 1950's. He crossbred rainbow trout with steelhead, and the hybrids, called Donaldson trout, are known for their ability attain a large body size in a short period of time and their ability to produce more eggs than usual. Trout normally reach sexual maturity in about 4 years and weigh on the order of 1.5 pounds. In contrast, Donaldson Trout matured in 2 years, weighed 10 pounds, and produced many more eggs than unselected trout. The Donaldson Trout is now used around the world in commercial aquaculture operations.

II. Management Direction

Management direction for aquatic resources is contained in a variety of laws, policy and management plans. Following is a summary of specific rules and regulation providing direction to the Packwood Lake relicensing.

Gifford Pinchot Land and Resource Management Plan

The Gifford Pinchot National Forest Land and Resource Management Plan (1990), as amended by the Northwest Forest Plan in 1994, provides the management direction for all National Forest System lands and their associated resources directly affected by or within the project vicinity of the Packwood Lake hydroelectric system. This plan was developed and enacted consistent with the requirements of the Forest and Rangeland Renewable Planning Act, as amended by the National Forest Management Act. The Aquatic Conservation Strategy (ACS), a core component of the Northwest Forest Plan, provides management direction aimed at maintaining or restoring the ecological health

and functioning of watersheds and the aquatic ecosystems contained within them. ACS objectives that apply most to this issue are:

> *Objective 1 – Maintain and restore the distribution, diversity, and complexity of watershed and landscape-scale features to ensure protection of the aquatic systems to which species, populations, and communities are uniquely adapted.*
>
> *Objective 2 – Maintain and restore spatial and temporal connectivity within and between watersheds. Lateral, longitudinal, and drainage network connections include floodplains, wetlands, upslope areas, headwater tributaries, and intact refugia. These network connections must provide chemically and physically unobstructed routes to areas critical for fulfilling life history requirements of aquatic and riparian-dependent species.*
>
> *Objective 3 – Maintain and restore the physical integrity of the aquatic system, including shorelines, banks, and bottom configurations.*
>
> *Objective 4 – Maintain and restore water quality necessary to support healthy riparian, aquatic, and wetland ecosystems. Water quality must remain within the range that maintains the biological, physical, and chemical integrity of the system and benefits survival, growth, reproduction, and migration of individuals composing aquatic and riparian communities.*
>
> *Objective 5 – Maintain and restore the sediment regime under which aquatic ecosystems evolved. Elements of the sediment regime include the timing, volume, rate, and character of sediment input, storage, and transport.*
>
> *Objective 6 – Maintain and restore in-stream flows sufficient to create and sustain riparian, aquatic and wetland habitats and to retain patterns of sediment, nutrient, and wood routing. The timing, magnitude, duration, and spatial distribution of peak, high, and low flows must be protected.*
>
> *Objective 7 – Maintain and restore the timing, variability, and duration of floodplain inundation and water table elevation in meadows and wetlands.*
>
> *Objective 9 – Maintain and restore habitat to support well-distributed populations of native plant, invertebrate and vertebrate riparian-dependent species.*

Additionally, Northwest Forest Plan Standard and Guideline LH-2 states: "During the relicensing of hydroelectric projects, (the Forest Service shall) provide written and timely license conditions to FERC that require flows and habitat conditions that maintain or restore riparian resources and channel integrity."

Forest Service Manual Direction

Forest Service Manual (FSM) 2670.12 directs the Forest Service to:

- *Manage habitats for all existing native and desired nonnative plants, fish, and wildlife species in order to maintain at least viable populations of such species,*

- *Conduct activities and programs to assist in the identification and recovery of threatened and endangered plant and animal species, and*

- *Avoid actions that may cause a species to become threatened or endangered.*

Forest Service Manual (FSM) 2670.22 directs the Forest Service to:

- *Maintain viable populations of all native and desired nonnative wildlife, fish, and plant species in habitats distributed throughout their geographic range on National Forest System lands*. A viable population is further defined by FSM 2670.5 as *one that has the estimated numbers and distribution of reproductive individuals to ensure the continued existence of the species throughout its existing range (or range required to meet recovery for listed species) within the planning area.*

Federal Power Act (FPA)
Section 4(e) of the FPA provides the USDA Forest Service, as administrators of reserved lands affected within the project area, authority to attach mandatory terms and conditions to Project licenses. This section of the FPA states, "that licenses shall be subject to and contain such conditions as the Secretary of the department under whose supervision such reservation falls shall deem necessary for the adequate protection and utilization of such reservation." Section 4(e) also states that "…the Commission (FERC), in addition to the equal power and development purposes for which licenses are issued, shall give equal consideration to the purposes of enhancement of, fish and wildlife (including related spawning grounds and habitat)…". Forest Service terms and conditions are based upon management direction contained in amended Forest Plans. If the project being relicenced is not located on Forest Service land but affects resources managed by the agency (i.e. migratory fish that historically used NFSL), Section 10(a) provides authority by which the Forest Service can make recommendations regarding management of those resources to FERC.

Executive Order 12962
Under the Recreational Fisheries Executive Order (Executive Order 12962 of June 7, 1995, Federal Register Notice 60(111): 30769-30770), the President of the United States directs federal agencies to cooperate with state and tribal governments to improve aquatic resources for increased recreational fishing opportunities by:

- Identifying recreational fishing opportunities limited by degraded habitat and water quality,
- Restoring habitat and water quality,
- Providing access and promote awareness of recreational fishing opportunities,
- Stimulating angler participation in conservation and restoration,
- Using cost-share programs and implementing laws to conserve, restore, and enhance aquatic systems to support recreational fisheries,

- Evaluate effects of federally funded, permitted, or authorized actions on aquatic systems and recreational fisheries and document those effects relative to the purpose of this order, and
- Assisting private landowners to conserve and enhance aquatic resources.

National Forest Management Act

36 CFR 219 covers the planning process for development of National Forest Land and Resource Management Plans. The Code of Federal Regulations provides the implementing direction for the National Forest Management Act (1976).

In the 1982 edition of the regulations at 36 CFR 219.19, paragraph 1 states, *Fish and Wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area. For planning purposes, a viable population shall be regarded as one which has the estimated numbers and distribution of reproductive individuals to insure its continued existence is well distributed in the planning area. In order to insure that viable populations will be maintained, habitat must be provided to support, at least a minimum number of reproductive individuals and that habitat must be well distributed so that those individuals can interact with others in the planning area.*

-219.19 (2) *Planning alternatives shall be stated and evaluated in terms of both amount and quality of habitat and of animal population trends of the management indicator species. For the Gifford Pinchot NF, cutthroat trout, steelhead trout and bull trout were selected as management indicator species.*

-219.19 (3) *Biologists from State fish and wildlife agencies and other Federal agencies shall be consulted in order to coordinate planning for fish and wildlife, including opportunities for the reintroduction of extirpated species.*

Section 219.27(g) Diversity states in part, *Management prescriptions, where appropriate and to the extent practicable, shall preserve and enhance the diversity of plant and animal communities, including endemic and desirable naturalized plant and animal species.*

Memorandum of Understanding (MOU)

Master MOU Washington Department of Fish and Wildlife and USDA Forest Service Region Six

Signatory parties agreed under this MOU to consult on fish and wildlife actions that occur or may affect USDA Forest Service Region Six Forests. Listed below are four key elements of this MOU.

Section A #2. The Forest Service agrees to recognize WDFW as being responsible for the protection, perpetuation, and management of all game fish and wildlife in the State of Washington.

Section B #2. WDFW agrees to solicit Forest Service participation in establishing the desired level of fish and wildlife populations on the National Forests…

Section B #4. WDFW agrees to consider Forest Service's goals and objectives in the development of Fish and Wildlife plans.

Section B #6. WDFW agrees to cooperate with the Forest Service in preparation and conduct of research plans of mutual interest.

Tribal Governments

The Gifford Pinchot National Forest has memoranda of understanding with the Cowlitz Tribe and the Yakima Indian Nation. These agreements provide that the Forest Service shall consult and cooperate with the tribes in the management and protection of natural and cultural resources on the National Forest.

III. Forest Plan Desired Condition

The desired condition or properly functioning condition of the Pacific Northwest forest aquatic ecosystems have been discussed in several planning documents including the Columbia River Basin Anadromous Fish Habitat Manage Policy Implementation Guide (USDA 1991), Forest Ecosystem Management Assessment (FEMAT 1993) the Northwest Forest Plan (USDA and USDI 1994) and PACFISH. Sources state that the aquatic environment is dynamic influenced by disturbance factors such as landslides and floods (Reeves 1991) and constantly changing over time and space (Pringle et al 1988). Attempts to quantify a properly function condition should be viewed on a site-specific basis. Key physical component of a fully functioning aquatic ecosystem include complex habitats consisting of floodplains, banks, channel structure (i.e. pools and riffles), water column and sub-surface waters (FEMAT 1993).

Habitat Conditions

With the help of historic inventory and survey data, as well as current research, "good" anadromous fish habitat conditions have been defined by PACFISH (USDA and USDI 1994b) and the PIG (USDA 1995). Riparian conditions were evaluated by comparing quantitative habitat surveys, completed between 1989 and 1992, with surveys done by the Bureau of Fisheries, now NOAA Fisheries, between 1934 and 1941 on 116 watersheds in Alaska, Idaho, Oregon and Washington. "Good" habitat has been defined using physical features as surrogates for the processes that form salmonid habitat. One key feature (pool frequency) and four supporting features (water temperature, amount of large woody debris interacting with stream channels, streambank stability and bank angle, and width to depth ratio of stream channels) are used to describe habitat quality.

Riparian Management

Goals call for the maintenance or restoration of: the following:

- water quality to a degree that provides for stable and productive ecosystems (i.e. timing and character of temperature, sediments and nutrients),
- stream channel integrity, channel processes and sediment regime under which the ecosystems developed (e.g. timing, volume, and character of sediment input and transport),
- instream flows to support desired riparian and aquatic habitats, stream channel stability and effective function, and ability to route flood discharges,

- natural timing and variability of the water table elevation in meadows and wetlands,
- diversity and productivity of native and desired non-native plant communities,
- riparian vegetation so the amount and distribution of large woody debris is characteristic of natural riparian and aquatic ecosystems,
- habitat for populations contributing to viability of riparian-dependent communities (i.e. native and desired non-native plants, vertebrates, and invertebrates),
- riparian vegetation for adequate summer and winter thermal regulation,
- riparian vegetation so the rates of surface and bank erosion and channel migration are similar to the rates under which the communities developed, and
- riparian and aquatic habitats for the unique genetic stocks that evolved within that specific geo-climatic region.

Pool Frequency (pools per mile).
Table 8 displays desired pool frequency corresponding to wetted stream width from 10 to 200 feet.

Table 8. Pool frequency (pools / mile) based on channel width in a properly functioning stream. From PACFISH (1994b)

Wetted Width	10	20	25	50	75	100	125	150	200
Pools / mi,	96	56	47	26	23	18	14	12	9

Water Temperature. Compliance with State water quality standards generally provides adequate protection for salmonid assemblages, except that summer temperatures should be less than 68 ^{0} F (16^{0} C).

Large Woody Debris. The amount of large woody debris needed varies by geographic location. For westernWashington State the goal is greater than 80 pieces per mile that exceed a 24 inch diameter and 50 foot length.

Bank Stability and Lower Bank Angle (for non-forested settings).

Bank stability exceeds 80%, and 75% of banks should be undercut.

Width to Depth Ratio: less than 10 in all systems (measured as mean wetted width divided by mean depth).

Land Resource Mananagment Plan – Land Allocations

Late-Successional Reserves

The project area on NFS lands is within the Packwood Late-Successional Reserve. The objective of late-successional reserves is to protect and enhance conditions of late-successional and old-growth related species, inclding the northern spotted owl. (Gifford Pinchot Forest Plan 1995 p. 5-1.) The Gifford Pinchot Late-Successional Reserve Assessment (p. 3-3) describes the desired condition for riparian associated species. “Healthy, functioning riparian habitats will occur across the landscape. These areas will

provide protected microclimates, large coarse woody debris, and cold, clear water for fish, amphibians, and other riparian dependent species."

Key Watersheds

Lake Creek is identified as a key watershed which specifies the watershed is important for reasons as follows: 1) recovery of "at risk" stocks, and/or 2) currently is in "good" condition or has a high potential for restoration to ensure long-term viability of anadromous fish resources. Key watersheds receive top priority for watershed analysis and restoration activities.

Riparian Reserves

The LRMP identifies riparian reserves as particular sensitivity areas to include riparian corridors along permanent fish-bearing streams, and also include areas of unstable soils, wetlands, intermittent headwater streams, and other areas where proper ecologic function is crucial to maintenance of the stream's water, sediment, woody debris and nutrient delivery systems. Riparian reserves are not "buffers" in the traditional sense where management activities are prohibited. They are areas where special care is taken to assure protection of watershed and riparian processes and functions. Land use activities that are compatible with attainment of riparian goals and objectives are permitted within riparian reserves.

Interim riparian reserves buffer width is based on tree site growing potential as described in Table 9.

Table 9. Riparian reserve interim buffer width. From Gifford Pinchot Land Resource Management Plan (USDA 1995).

Riparian Type	Site Tree Slope Widths	Slope Width
Fish bearing streams	2	300
Lake and natural ponds	2	300
Perennial , nonfish-bearing streams	1	150
Constructed ponds, reservoirs wetlands greater than 1 acre in size	1	150
Wetlands less than 1 acre	N/A	Site dependent*
Intermittent stream s	1	100

See Forest Plan p. 2-6

Lake Creek Stream Survey

The Lake Creek Stream survey (USDA 1993) identified the future desired conditions as follows:

- Stream temperature range between 45^0 F and 65^0 F
- Eighty pieces of downed wood per mile of stream length, wood 36 inches dbh
- pool: riffle ratio approaching 40:60 by area
- Width:Depth, < 10
- Approximately fifty-six (56) pools per mile (based on Lake Creek avg wetted perimeter of 20 feet).
- Side channels are present in low gradient stream reaches.
- Fisheries included a viable population of anadromous and resident species

- Channel gradients of less than 2% are less entrenched.
- Substrate would be gravel / cobble mixture intermixed with small boulder
- Road density of less than 2.0 miles per square mile

Water control and fish passage structures
Fish passage at Packwood Lake Dam should comply with all agencies (local state and federal) that have authority over aquatic resources. Fisheries Handbook of Engineering Requirement s and Biological Criteria (USCOE 1991) describes applicable guidelines to promote fish passage which include, but are not limited to, the following:

- Manage water control structures to provide flow characteristics necessary for the safe and efficient upstream and downstream passage of all fish at all life stages
- Maintain approach velocities less than juvenile salmonid swimming speed (approx 0.4 feet per second (fps)) on all submerged openings.
- Sweeping velocities should exceed approach velocities to prevent entrapment.
- Drop velocities over the dam should not reach lethal speeds (greater than 21 fps)
- Minimize the potential for impacts of contact with hardened dam infrastructure (e.g. concrete buttresses, pipelines) that increase the risk of drop mortality or injury. Flow conditions to guide fish migration while providing intermittent resting water to promote safe and efficient passage.
- Provide attraction flows for upstream migrants at approximately 6 fps during peak adult migration flows.
- Eliminate false leaping signals which are may be present the existing spillway and fish bypass.

As an alternative to the above provision for fish passage, the license holder may comply with in-lieu settlements such as the reclamation of fish habitat or development of alternative resource protection mitigation measures.

IV. Need for Change

Issue 1: Fish distribution in the upper Cowlitz basin has been influenced by natural dissemination, stocking and reintroduction efforts. The relicensing process should be informed by current and historical fish distributions, species composition and abundance which can be used to facilitate analysis of subsequent physical and biological studies.

Issue 2: There may be a need to improve the aquatic ecosystem in the Lake Creek bypass reach (RM 0.0 - 5.4). The influence of stream flows on aquatic organisms, channel processes, form and functions is a major factor in improving habitat. Instream flows are substantially influenced by hydropower operations.

Issue 3: There may be a need for re-establishing connectivity between Packwood Lake and tributaries. Drawdown of Packwood Lake level resulting from hydroelectric operations may modify stream connectivity, fish passage, and total available habitat in tributaries upstream of the Packwood Lake. Proposed study plans should include the interface of lake tributaries where fluctuating lake levels are an issue.

Issue 4: Changes to the rate and frequency of flow fluctuations may improve available habitat and aquatic organism use downstream of Packwood Lake. The variable stream flows in the tailrace channel downstream of the power generator and in the bypass

channel (e.g. Lake Creek) and may have an adverse impact on channel function and process and aquatic habitat.

Issue 5: Physical processes associated with the water diversion such as false attraction, impingement and entrainment may have direct impact to fish populations.

Issue 6: Increased opportunities for recreational fisheries at Packwood Lake may be available. Are project operations impacting recreational fishing at Packwood Lake, Lake Creek bypass, tailrace and Cowlitz River?

Issue 7: Improvements in stream connectivity and fish passage may be available in the concrete flume and raised metal flume which cross perennial fish bearing streams including Hall Creek and Snyder Creek.

Issue 8: Improvments in connectivity of large wood (LW) transport between upper basin supply and the lower bypass reach may be possible. Accumulation of LW ranges from 0 – 18.1 pieces per mile (USFS 1993). All reaches surveyed rated poor for accumulation of LW which may be attributed to past harvest of riparian timber and loss of connectivity with upper lake creek reaches. The dam may adversely impact the transport function of the aquatic ecosystem by retaining LW in the reservoir.

V - USDA Forest Service Interests and Preliminary Objectives

- Implement Gifford Pinchot Land Resource Management Plan and all management plans tiered to this document.
- Provide diverse aquatic habitat components necessary to maintain viable fish populations and aquatic-dependent terrestrial species.
- Mange lake level to provide passage to tributaries for all species during all life stages.
- Provide instream flow in Lower Lake Creek necessary to support all species and all life stages of aquatic life.
- Provide large wood and spawning gravels in Lower Lake Creek as would occur under a natural, unobstructed flow regime.
- Maintain a stream temperature regime in Lower Lake Creek within Washington State guidelines for a healthy aquatic ecosystem.
- Provide free and efficient fish passage within Washington State guideline to prevent entrainment or impingement, harm or harassment by Project facilities. This is most applicable to Lake Creek, Snyder Creek and Hall Creek.
- Provide adequate screening at the tailrace entrance to prevent fish entrapment or as an alternative manage the tailrace channel to provide adequate anadromous fish habitat.
- Restore degraded watersheds and aquatic habitat particularly in key watersheds where “at risk” species are impacted.
- Provide recreational fishing opportunities on the National Forest.

VI. USDA Forest Service Study Requests

A review of the existing information available to the Packwood Lake Hydroelectric Project identified several preliminary issues related current project operations. Key questions and consequent study questions were developed to address these issues.

Issue 1: Fish distribution in the upper Cowlitz basin has been influenced by natural dissemination, stocking and reintroduction efforts. The relicensing process should be informed by current and historical fish distribution, species composition and abundance which can be used to facilitate analysis of subsequent physical and biological studies.

Issue 2 and 4: Lake Creek bypass reach (RM 0.0- Packwood Lake) instream flows are substantially influenced by hydropower operations. Operational flow fluctuations and ramping rates can modify available habitat and aquatic organism use downstream of Packwood Lake. The relicensing process should include adequate surveys and modeling to evaluate and monitor the influence of stream flows on aquatic organisms, channel processes, form and functions.

Issue 3: Modifications to Packwood Lake level resulting from hydroelectric operations may modify fish passage and available habitat upstream of the Packwood Lake Dam. The proposed study plan should include influence areas upstream of Packwood Dam. The study objective should be to delineate and generally characterize existing stream reaches above Packwood Lake Dam that may become periodically inaccessible to fish due to hydroelectric operations.

Issue 4: Operational flow fluctuations and ramping rates can influence available habitat and aquatic organism use downstream of Packwood Lake. The objective of this multi-faceted study is to identify the effect of the Packwood Lake flow release regime on ESA listed salmonid species and other aquatic species.

Issue 5: Water diversion operations my have direct impact to fish through physical processes such as impingement and entrainment. The proposed study plan should include an assessment of dam operations that may harm or disturb fish. The goal of this study is to identify species composition and relative abundance of fishes entrained by the Packwood Lake Dam Project. Species composition and relative abundance should be monitored on a seasonal basis to evaluate temporal differences in these indices.

Issue 6: Hydroelectric operations may impact recreational fishing at Packwood Lake, Lake Creek bypass, tailrace and Cowlitz River. The goal of the Recreational Angler Creel Surveys Study is to evaluate project effects on recreational fishing in the area. The specific objectives of these creel surveys should be as follows:

1. Quantify recreational angling uses (e.g. angler effort (hours), angler catch rates, angler harvest by fish species (number of fish) and ,
2. Gain biological information (lengths, origins, possibly age) for those sport fishing targeted species.

Issue 7**.** Hydroelectric infrastructure including the tailrace flume and lined channel intersecting stream courses including Hall Creek and Snyder Creek may impact fish migration and channel connectivity. The goal of the study is to establish if the tailrace

channel is a barrier to fish and/or has a negative impact on channel connectivity. Is the flume acting as a barrier on Snyder Creek and Hall Creek?

Issue 8. The goal of the study is to establish if hydroelectric management practices have a negative impact on channel transport processes and total available LW downstream of the dam. Is the dam and reservoir management impacting the transport and total available LW.

VII. References Cited or Reviewed

Behnke, R.J. 1992. Native trout of western North America. American Fisheries Society Monograph 6. Bethesda, Maryland.

Bjornn and Reiser. 1991. Habitat Requirements of Salmonids in Stream. American Fisheries Society Special Publication 19:83-138

Crawford, B. 2004. Personal communication. Washington Department of Fish and Wildlife. Vancouver, Washington.

Forest Ecosystem Management Assessment Team. 1993. Forest ecosystem management: an ecological, economic and social assessment. US Forest Service, National Marine Fisheries Service, Bureau of Land Management, US Fish and Wildlife Service, National Park Service, US Environmental Protection Agency. Portland Oregon and Washington, DC.

Hunter, M.A. 1992. Hydropower flow fluctuations and salmonids: A review of the biological effects, mechanical causes, and options for mitigation. State of Washington Department of Fisheries, Technical Report No. 119, Olympia, WA.

Lucas, B. 2004. Personal communication. Washington Department of Fish and Wildlife. Vancouver, Washington.

Perez-Rose, Diana . 2004. Personal Communications. USDA, Forest Service. Gifford Pinchot National Forest. Vancouver, WA.

Megahan, W.F. 1982. Channel Sediment Storage Behind Obstructions in Forested Drainage Basins Draining the Granitic Bedrock of the Idaho Batholith. In Sediment Budgets and Routing in Forested Drainage Basins. USDA Forest Service Pacific Northwest Forest and Range Experiment Station. General Technical Report PNW-141. pp 114-121.

Office of the Federal Register. 1995. Code of Federal Regulations; Parks, Forests, and Public Property Title 36 Sections 200 to End.

Powers, P.D. and J.F. Orsborn. 1985. Analysis of barriers to upstream fish migration. An investigation of the physical and biological conditions affecting fish passage success at culverts and waterfalls. Part 4 of 4. Bonneville Power Administration. Contract DE-A179-82BP36523. Project 82-14.

U.S. Army Corps of Engineers. 1990. Fisheries handbook of engineering requirements and biological criteria. Fish passage development and evaluating program, Corps of Engineers, North Pacific Division. Portland, Oregon.

USDA, Forest Service. 1967. Lake Creek Study Report. Gifford Pinchot National Forest. Vancouver, Washington.

USDA, Forest Service. 1983. R-6 Stream survey level II. Snyder Creek. Gifford Pinchot National Forest. Packwood Ranger Districts.

USDA, Forest Service: Region 6 Office. 1991. Columbia River Basin Anadromous Fish Habitat Management Policy and Implementation Guide. Portland, Oregon: U. S. Department of Agriculture, Forest Service.

USDA, Forest Service. 1993. R-6 Stream survey level II. Lake Creek. Gifford Pinchot National Forest. Randle/Packwood Ranger Districts.

USDA, Forest Service; U.S. Department of the Interior, Bureau of Land Management. 1994. Final Supplemental environmental l impact statement on management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl (Northwest Forest Plan). [Portland, Or]: U.S. Department of Agriculture, Forest Service: U.S. Department of Interior, Bureau of Land Management [irregular pagination].

USDA, Forest Service and United States Department of the Interior (USDI) Bureau of Land Management. 1994b. Environmental Assessment for the Implementation of Interim Strategies for Managing Anadromous Fish-producing Watersheds in Eastern Oregon and Washington, Idaho, and Portions of California (PACFISH).

USDA, Forest Service, 1994. Unpublished data. Policy implementation guide (PIG) watershed summary. Gifford Pinchot National Forest. Packwood Ranger Districts.

USDA, Forest Service. 2000. Unpublished Report. Bull Trout Survey. Cowlitz Valley Ranger District, Gifford Pinchot National Forest. Randle, Washington.

USDA Forest Service 2003. Unpublished Report. Gifford Pinchot National Forest water quality monitoring data. Randle, WA.

USDI, Fish and Wildlife Service. 2001. Unpublished Report. Gifford Pinchot National Forest Bull Trout Consultation Baseline, Version 7.0. U.S. Fish and Wildlife Service. Lacey, Washington.

USDI, Fish and Wildlife Service. 1998. Klamath River and Columbia River bull trout population segments: status summary and supporting documents lists.

USDI, Fish and Wildlife Service. 1997. Endangered and Threatened Wildlife and Plants; proposal to List the Klamath River Population Segment of Bull Trout as an Endangered Species and Columbia River Population Segment of Bull Trout as a Threatened Species. June 13, 1997. Federal Register 62(114):32268-32284

Washington Department of Ecology (WDOE) and Washington Department of Fish and Wildlife (WDFW) (2004). Draft instream flow guidelines. Technical and habitat suitability issues.

WDFW, 1998. Washington state status report for the pygmy whitefish. Washington Department of Fish and Wildlife Fish Management Program. Olympia, Washington.

WDFW. 1992. Memo from Bob Lucas to Cowlitz Falls Advisory Group re: Upper Cowlitz River Anadromous Zones. Washington Department of Fish and Wildlife. Vancouver, Washington.

WDFW. 1999. Memo from Bob Lucas to John Weinheimer re: Packwood Lake rainbow trout spawner surveys. Washington Department of Fish and Wildlife. Vancouver, Washington.

WDFW. 2000. Memo from Bob Lucas to John Weinheimer re: Packwood Lake rainbow trout spawner surveys. Washington Department of Fish and Wildlife. Vancouver, Washington.

Washington Public Power Supply System (WPPSS). 1971. Environmental report for Packwood Lake hydroelectric Project. No. 73.