Evaluation of Three Proposed Management Scenarios to Enhance Three Potential Bull Trout Nursery Habitats, Accessible to Lake Merwin and Yale Lake, Lewis River

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Note to Readers: This investigation was conducted during relicensing of the Lewis River Hydroelectric Projects. It did not evolve through the study plan process as did other investigations, therefore the format does not parallel other reports.

ABSTRACT

The USFWS (U. S. Fish and Wildlife Service) has defined populations and critical habitat for bull trout (USFWS 2002), a species of fish that is considered to be in peril and listed as Threatened under the Endangered Species Act. Within the Lewis River basin there are two bull trout populations and one of them appears to be at significant risk due to its small size and limited nursery area. The bull trout in Lake Merwin, Yale Lake and their tributaries are considered a single population by the USFWS. This Merwin/Yale bull trout appear to spawn in only one short stream, Cougar Creek, a tributary to Yale Lake. The spawning population appears to be quite small, as estimates imply that during most years within the past 2 decades less than 15 adults may have spawned annually.

In order to offset the risk of a single spawning area, the USFWS included three areas, not currently used by bull trout, as potential bull trout critical nursery habitats in stream segments accessible to Yale Lake and Lake Merwin. These are the Swift bypass reach, Ole and Rain creeks and lower Speelyai Creek. An examination of these sites suggests that none of them will provide a successful bull trout nursery area. One management intervention scenario has been proposed for each of these sites, in order to make them useable for bull trout. This document reviews these three proposals.

The intent of securing stream habitats, and the associated management proposals, is to increase early life history production and ultimately increase the adfluvial bull trout populations that use the Yale and Merwin pools. This document reviews whether the area would provide habitats in which the early life history stages of bull trout would be successful. It appeared that none of the three management intervention proposals offered at this time would permit the spawning of viable eggs that would incubate successfully resulting in consistent production of a first year fish.

Since the organizations working the Lewis River basin seek some solution, additional information is provided for evaluating future proposals, and their likely impact on bull trout production. This additional material is organized by life stage, as described by the BayVam model by Lee et al. (1997). The intent is to provide background to use the mathematical model to evaluate the likely relative success of bull trout production. To use the model it is assumed the management action in question will increase the survival of one, or several, bull trout life stages.

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INTRODUCTION

The USFWS (U. S. Fish and Wildlife Service) has identified areas in the Lewis River drainage as proposed critical habitat for bull trout (USFWS 2002), a species of fish that is considered to be in peril and listed as Threatened under the Endangered Species Act.

The Lewis River bull trout are one of three populations recognized in the Lower Columbia River basin recovery unit. The river has three impoundments that currently isolate segments of the watershed. Bull trout presence has been observed in all three reservoirs, the lower Lewis River below all the reservoirs and in the upper Lewis River upstream from all the reservoirs. The USFWS determined that there are two populations upstream from Merwin dam. One population includes those fish in Lake Merwin and Yale Lake and their tributaries. The second population consists of bull trout in Swift Creek Reservoir and its tributaries including the North Fork of the Lewis River. Bull trout relative abundance is higher in Swift Creek Reservoir than the other two reservoirs combined. Swift Creek Reservoir also has more miles of accessible stream habitat, and presumably more miles of suitable stream habitats, than Lake Merwin or Yale Lakes.

The Merwin/Yale bull trout population appears to be at risk due to its small size and limited distribution of nursery areas. Bull trout consistently spawn in only one short stream, Cougar Creek, a tributary to Yale. The possibility of a catastrophic event at this solitary spawning site implies the population is at risk. The USFWS identified three areas, not currently used by bull trout, as potential bull trout nursery habitats in stream segments accessible to Yale Lake and Lake Merwin. These are the Swift bypass reach, Ole and Rain creeks and lower Speelyai Creek. All of these sites will require some management for bull trout reproduction to be successful.

The intent of securing stream habitats for bull trout nursery sites is to increase early life history production, and ultimately increase the adfluvial bull trout populations that use the Yale and Merwin pools. This document offers a framework for evaluating the relative value of three bull trout nursery habitats using likely survival rates as the standard for success. The information presented here could be applied to the BayVam model by Lee et al (2000) to evaluate the likely relative success of bull trout production in the three areas of interest.

DEFINING THE POPULATION OF INTEREST

Physical access, demonstrated life histories, spawning locations, and genetic differences all contribute to the definition of a population. The relationship between physical access and life history strategies defines the situations and habitats that impact population production and stability

PHYSICAL ACCESS

All bull trout in the Lewis River upstream from Merwin dam have been isolated from other Columbia River bull trout populations since 1932 when Merwin dam closed. Yale Lake bull trout have been isolated from Lake Merwin fish since 1951, except for those individuals that presumably drift downstream, particularly during periods of spill. Bull trout upstream from Swift Dam have theoretically been isolated from Yale Lake and Lake Merwin since 1958.

The USFWS considers the bull trout in Lake Merwin and Yale Lake as a single population despite the lack of free passage between the two areas. The justification for this approach contends that the Yale Lake population is the source of all recruitment to Lake Merwin.

The following data provides limited evidence that bull trout production in tributaries upstream from Lake Merwin may contribute to downstream populations. Stream habitats supplying bull trout to Yale Lake may be a source of bull trout in Lake Merwin.

- There are no known spawning sites accessible to Lake Merwin. Therefore, local biologists believe that bull trout captured in the reservoir come from the upstream Yale Lake population. Confidence in this assessment results in an annual collect-and-haul program at the Yale tailrace. The fish are transported from Lake Merwin and released into Yale Lake's Cougar Bay.

- One tagged adult fish moved from Yale Lake downstream into Lake Merwin and survived (Erik Lesko, PacifiCorp 2003, pers. comm.). This individual was part of a group of fish trapped in Merwin and moved upstream to Yale.

- Bull trout in Merwin are rarely reported in locations other than the Yale tailrace and the Merwin population is assumed to be very small. However, there has not been a systematic search for bull trout throughout the reservoir. Casual observations of anglers indicate that bull trout use other areas such as the inlet below Canyon Creek (John Weinheimer, WDFW 2003, pers. comm.).

- Adult bull trout of unknown origin have occasionally been seen below Merwin dam (PacifiCorp & Cowlitz PUD 2002-AQU12; USFWS 2002). At least one was caught in the trap on the downstream site of Merwin dam in 1992 (Shrier 2000, citing R. Nicolay, 1999, pers. comm.). There are no known spawning sites downstream from Merwin dam, so this implies the fish came from above Merwin dam.

- Movement from Swift Creek Reservoir to Yale Lake is possible, but Swift fish do not appear to be contributing substantially to the Yale/Merwin population (see genetic differentiation discussion below).

LIFE HISTORY OF INTEREST

It is generally accepted that the bull trout throughout the Lewis River exhibit adfluvial characteristics. Federal regulations seek to enhance the adfluvial stocks in the basin below Twin Falls (PacifiCorp & Cowlitz PUD 2002 - AQU12; USFWS 2002).

The evidence that leads to the conclusion that Lewis River bull trout are adfluvial follows:

- The sizes of the fish in the basin are consistent with those observed for other migratory populations. Data supporting this statement can be found in many field evaluations conducted over the past twenty years (Graves 1980; Faler and Bair 1992; Lesko 2000, 2001, 2002, 2003).

- Tagged fish move from reservoirs upstream to the tributaries. Bull trout netted and tagged at the upstream end of Swift Creek Reservoir were later observed in tributary streams (Faler and Bair 1992). Similarly marked bull trout, collected from Lake Merwin and released into Cougar Bay (Yale Lake), moved upstream into Cougar Creek (PacifiCorp 1999).

- USFWS (2002) identified potential critical habitats in streams that are not currently in use by bull trout, which presumably would have to be colonized by migratory fish.

- Historical information on bull trout in the North Fork Lewis River basin is limited however it is possible that the bull trout in the Lewis River were fluvial, moving into the Columbia River, or anadromous. An occasional bull trout is captured in the ladder at the North Fork Lewis River hatchery or the trap at Merwin dam. The last documented bull trout in the lower North Fork Lewis River was captured at the Lewis River Hatchery ladder in 1992 (Shrier 2000, citing. R. Nicolay, WDFW 1999 pers. comm.)

While the population is adfluvial other life histories may exist and the USFWS intent is to re-establish all historic life histories (Gene Stagner, USFWS 2003, pers. comm.) The USFWS (2002) briefly mention the possibility of an isolated resident fish population above Twin Falls in the upper North Fork Lewis River basin, although they offer no supporting evidence (USFWS 2002). It is important to consider that resident stocks may exist. Nevertheless this document will focus only on adfluvial stocks.

LIMITED SPAWNING SITES FOR YALE LAKE

Fish populations are often defined by where spawning occurs and the level of isolation from other spawning sites.

- Cougar Creek is the only known spawning area for the bull trout of Yale Lake.

- Cougar Creek, tributary to Yale Lake, is the likely source of Lake Merwin bull trout through downstream drift. Local biologists consider this so likely that they have been augmenting the Yale bull trout population by moving fish from Merwin upstream to Yale, and releasing them in Cougar Bay.

- There are no known spawning sites in tributaries to Lake Merwin or to the river below Merwin dam. Unless there are spawning sites unknown to biologists, bull trout production must come from upstream sites (Yale Lake or Swift Reservoir).

GENETIC DIFFERENTIATION WITHIN THE LEWIS WATERSHED

This ability of bull trout to move downstream from Swift indicates that Yale Lake may not remain isolated from the Swift Creek Reservoir population as much as the genetic assessment implies (Spruell et al. 1998).

Some bull trout can survive the Swift 1 turbines and enter the Swift 2 canal.

- Forty-two live bull trout ranging in size from 133 mm to 604 mm were removed from the canal following the embankment failure in 2002 (USFWS 2002) and returned to Swift Creek Reservoir. Six dead bull trout ranging in size from 280 mm to 635mm were also recovered after the breach (Gene Stagner, USFWS 2003, pers. comm.). The USFWS collected 42 bull trout and estimate that 88 bull trout were present in the canal immediately prior to breaching (USFWS unpublished data).

- A recent entrainment evaluation (in press) confirmed two juvenile bull trout came from Swift Creek Reservoir into the Swift power canal (through one or more of the three turbines at Swift No.1) during February 2002 (Frank Shrier, PacifiCorp 2003, pers. comm.). There have not been entrainment evaluations that looked at fish movement through the two Swift 2 turbines.

The genetic data indicates there is not much mixing between the Swift and Yale/Merwin populations. Yet there is little evidence of introgression that would be typical of small populations.

- It appears that the bull trout in Merwin and Yale are genetically more similar to each other than either group is to the bull trout in Swift Creek Reservoir and its tributaries (Spruell, et. al 1998). It seems logical that some fish from Swift Creek

Reservoir can drift downstream and contribute to the Yale gene pool, especially during periods of spill, yet the genetics do not indicate a substantial contribution from the upper watershed to the Merwin/Yale gene pool. Spruell et al. (1998) suggest that the alleles that are rare in Yale/Merwin and common in Swift suggests that the populations are different and that there is little mixing between them.

- The genetic assessments of bull trout in the small Yale/Merwin population should be showing some introgression if the spawning populations have been as small as biologists believe them to have been since the St Helen's eruption. However the heterozygosity (a measure of genetic diversity) is high, implying there has not been introgression.

- Most of the genetic sample for the Merwin/Yale population consisted of individuals captured in Lake Merwin; only a few fish came from Yale Lake or Cougar Creek.

LIKELY EARLY SURVIVAL IN THREE CRITICAL HABITAT AREAS

The Yale/Merwin population appears to use only one spawning site. There are two problems with a single spawning site, limited population size and the risk of catastrophic extinction. It is likely that nursery area limits the size of the Yale Merwin bull trout population. The use of only one spawning site creates a risk of a single catastrophic event removing the population.

In order to reduce the risk of extinction, and potentially increase the number of fish within the Yale/Merwin population, the USFWS identified three areas that might serve as additional and early rearing habitats for adfluvial bull trout for the Yale/Merwin population. None of these areas currently support bull trout. Proposals exist for the enhancement of three stream areas, defined as critical habitats by the USFWS. They anticipate that an increase in available nursery sites will increase bull trout production.

The role of this work is to examine the relative likelihood that these three areas will contribute to the Yale/Merwin bull trout population. Each area has been described in detail by reports prepared by PacifiCorp & Cowlitz PUD (1999, 2002-AQU12, 2002a-WTS4, 2002b-AQU9 etc). Below is a brief description of each area, and the proposed management solution. Attempts to compare the potential for egg deposition and the survival of early age classes of bull trout in these three areas follow nursery site descriptions.

DESCRIPTION OF POTENTIAL NURSERY SITES

BYPASS CHANNEL

The old river channel between Swift dam and the Yale Lake pool is the bypass reach. Its reported length varies in the literature depending upon channel configuration and Yale Lake's pool elevation. This document will use the definition of Swift dam to the Swift 2 tailrace as the defined length of the reach.

The bypass reach measures 3.3 miles; 2.8 miles of the channel lies downstream from the spillway in the canal and 0.5 miles lie upstream from the spillway confluence (Frank Shrier, PacifiCorp 2003, pers. comm.). The water in the Swift Creek Reservoir is released into canal that runs parallel to this river channel. There is one mainstream channel and one braided stream section (PacifiCorp 1999). The braided stream section represents about 1/3 of the bypass channel, and lies entirely downstream from the canal's spillway.

On April 21, 2002 the power canal embankment just upstream from Swift No 2 powerhouse failed and flows breached the canal. The failure of the embankment above the Swift 2 powerhouse deposited materials into the confluence of the bypass channel and Yale Lake. These depositions increased the elevation of the old river channel. The maximum elevation of the river bottom in the area of the bypass reach bypass affected by the debris flow is 485.2 ft.-msl, 4.8 feet below Yale Lake's full pool elevation of 490 ft.-msl. (Diana Gritten-MacDonald, Cowlitz Co PUD 2003, pers. comm., April 18, 2003 survey). The Swift 2 repairs will include removing debris from the tailrace.

Discharge

There is no legal requirement to provide a minimum flow in this reach (PacifiCorp 1999). The historic base flow was 500-1,100 cfs during the low flow period of late summer and fall (PacifiCorp & Cowlitz PUD 2002a-WTS 4 pg 8). Under normal operations seepage within the first 0.4 miles below the dam (bypass reach RM 2.9-3.3) creates a flow of about 10 cfs in (PacifiCorp 1999). The spillway from the power canal may add water to the channel at this point (bypass reach RM 2.8). Small streams and groundwater re-charge provide additional water until the river reaches Yale Lake. Ole Creek flows into the bypass channel at bypass reach RM 1.0. Without spill, the channel would normally carry about 20-25 cfs by the time it reached Yale pool (PacifiCorp 1999; Frank Shrier, 2003 pers. comm.). The spawning bull trout observed in the bypass reach by S. Graves in the early 1980's would have been using the channel with streams flows of this magnitude.

Additional water flows into the channel at the Swift 1 spillway at some point during most years. Usually spill occurs only during high run-off events. Extreme flows (and spill) occur frequently and have exceeded 20,000 cfs approximately 2-3 times each decade since Swift dam closed in 1958. Spill levels > 20,000 cfs occurred in 1961, 1967, 1974, 1976, 1979, 1980, 1981, 1982, 1990, 1996, 1997, and 2003. In 1996 there were two periods of spill greater than 20,000 cfs, and one of these events was 45,000 cfs

(PacifiCorp & Cowlitz PUD 2002a-WTS-4). These high flow events all occurred between November and February, and over half of them occurred in January. Many of these flood events result from rain falling on an accumulation of snow. This type of winter flood event may be sufficient to move substrate and crush eggs or alevins in the affected riverbed. It may be possible to use existing channel morphology with spill data to predict the frequency of year class loss (see Kathy Dubé data compilation; G. Stagner USFWS, 2003, pers. comm.)

The Swift 2 plant has been out of service since April 21, 2002 when the power canal embankment failed. As a result all of the flow from Swift 1 spills into the bypass reach at the spillway (RM 2.9). Since the embankment failure at Swift 2, the by pass channel consistently carries considerably more flow than it has in over 4 decades. Spring flows of 5,000 cfs are not uncommon. Summer flows will be between 500 and 1,200 cfs, similar to the historic base flow for this channel. This condition will continue until the canal is repaired and FERC approves operation. Repairs will require approximately 2 more years (Frank Shrier, PacifiCorp 2003, pers. comm.)

Typically bull trout would select smaller waterways, than the by pass at its current discharge, as a nursery area but they may reside for periods in larger waterways. A few bull trout (<10 bull trout) were located snorkeling in the bypass channel in September and October of 2002 and none were observed spawning (discharge level of about 200 cfs). The fish were not measured but observers recorded enough information to classify most fish into 2 size groups <200 mm (2 fish) or between 200 and 500 mm (5 fish). At least some of these fish were probably using the channel as rearing space. It is unclear from the data if any of these fish were adults.

<u>Substrates and bedload</u>
The condition of substrate in a stream reach is dynamic. The addition of all sizes of sediment and bedload material should have declined after the construction of Swift dam. The breach event added substrate. Bedload continues to enter the bypass reach from the Ole/Rain Creek watershed and from the waterway during periodic high flow events associated with spill.

It is reasonable to anticipate that the configuration of the bypass reach will change as the higher flows move the substrate. The long-term increase in discharge should alter channel shape and deposition areas. The increase in elevation at the lower end of the channel should impact the distribution of substrate in the lower portion of the channel as well. It will be difficult to predict the condition of the stream habitat in the bypass reach and therefore potential gravel depositions, incubation survival rates or young-of-the-year survival rates in the modified bypass reach by the time Swift 2 is ready to operate again.

The bypass river channel has been described as broad, flat, and up to 600 feet wide in some areas (Frank Shrier, PacifiCorp 2003, pers. comm.). The channel has a low gradient of 1 percent or less. In the upper 2/3 of the reach the majority of the substrate is too large for spawning but might be suitable as fish cover. It might be expected that the braided reach provide gravels, however the configuration of the reach is atypical as a result of the gravel borrow pits used to construct the dam (Frank Shrier, PacifiCorp 2003, pers. comm.). No gravel other than isolated pockets and high benches were found upstream from Ole Creek confluence (PacifiCorp & Cowlitz PUD 2002a-WTS 4). There are several patches of gravel behind and within boulder/cobble riffles (G. Stagner, USFWS, 2003, pers. comm.). Additionally there are two large gravel bars within the active channel that will be able to provide gravel distribution during some of the smaller spill events. There is a gravel accumulation at the confluence of Ole Creek and the old river channel. The lower 1/3 of the reach, below Ole Creek, is a bedrock channel at low flow (Frank Shrier, PacifiCorp 2003, pers. comm.). There appears to be very little spawning gravel deposition space in the bypass channel itself USFWS (G Stagner, 2003 pers comm.) suggests projects creating more structures within the channel could provide much more optimal spawning gravel conditions. This document does not attempt to evaluate this enhancement approach.

The bypass canal, as presently configured and operated (with Swift 2 operational), does not provide suitable habitat for bull trout. The real question is could it be manipulated or enhanced to provide this habitat.

Water temperature.

In 1997 there was an evaluation of daily temperature fluctuations in several locations including the bypass channel. This would have been during a period when discharge was about 20-25 cfs. Hourly observations in August showed a maximum temperature of 17.6, minimum of 12 C and median of 13.8 C (Table 2.4-5 in PacifiCorp & Cowlitz PUD 2002a-WTS-4 on pg 13). Given the median, minimum and maximum temperatures it appears that most of the day the bypass channel would provide sub-optimum temperatures for adult bull trout. During the fall of 1996 temperatures were measured during a September sampling effort and found to be a little cooler, 10-13 C (PacifiCorp 1999 pg 3-38), but is still too warm for bull trout to initiate spawning. For some perspective, compare the temperatures in Cougar Creek (a known spawning site) on the same days, a maximum of 7.8 C, minimum of 6.5 C, and median of 6.7 C (Table 2.4-5 in PacifiCorp & Cowlitz PUD 2002

A 1999 evaluation looked at temperatures in the power canal at Swift 1 and several miles downstream at Swift 2. This is of interest because flow augmentation has been proposed for the Swift bypass channel when the operation of the Swift 2 power plant resumes. The water for this augmentation would likely come from the Swift 1 tailrace. There was a substantive difference in the temperatures between the Swift 1 and Swift 2 areas of the canal. Neither location had optimum temperatures for bull trout reproduction in 1999, but individuals would have been able to seek temperatures in which they could survive. Temperatures in the vicinity of Swift 1 were cooler than at Swift 2 in the summer months, and a little warmer during usual spawning period for bull trout in the fall. Water temperatures did not drop to 9 C or lower at either location until late in October or November. Temperatures of 7 C were not reported until December (PacifiCorp & Cowlitz PUD 2002a-WTS 4).

In addition there may be an egg fecundity problem for bull trout, depending upon the opportunities for behavioral thermoregulation that might occur (i.e. will bull trout stay in the reservoir until temperatures cool) as they attempt to use the by-pass channel, with or without augmented flows. Without flow augmentation (assuming flows of 20-25 cfs), the August observations include maximum temperatures reaching17.6 C, a minimum of 12 C and median of 13.8 C (Table 2.4-5 in PacifiCorp & Cowlitz PUD 2002a-WTS-4 on pg 13). Most of the day the bypass channel would provide sub-optimum temperatures for adult bull trout. Water from the canal might not improve the situation substantially.

Water temperatures are possibly the most critical issue here. Swift No 1 tailrace temperatures would not provide optimum temperatures during this period. It would be necessary to investigate taking water out of the reservoir to obtain suitable temperatures. Figure 1 demonstrates the range of temperatures that might be possible to obtain from the reservoir, depending on the depth of withdrawal (Data from USFWS, Gene Stagner 2003). Water of appropriate fall temperatures may only be found deep in the reservoir, at that point oxygen saturation data would be necessary to evaluate the suitability of this approach.

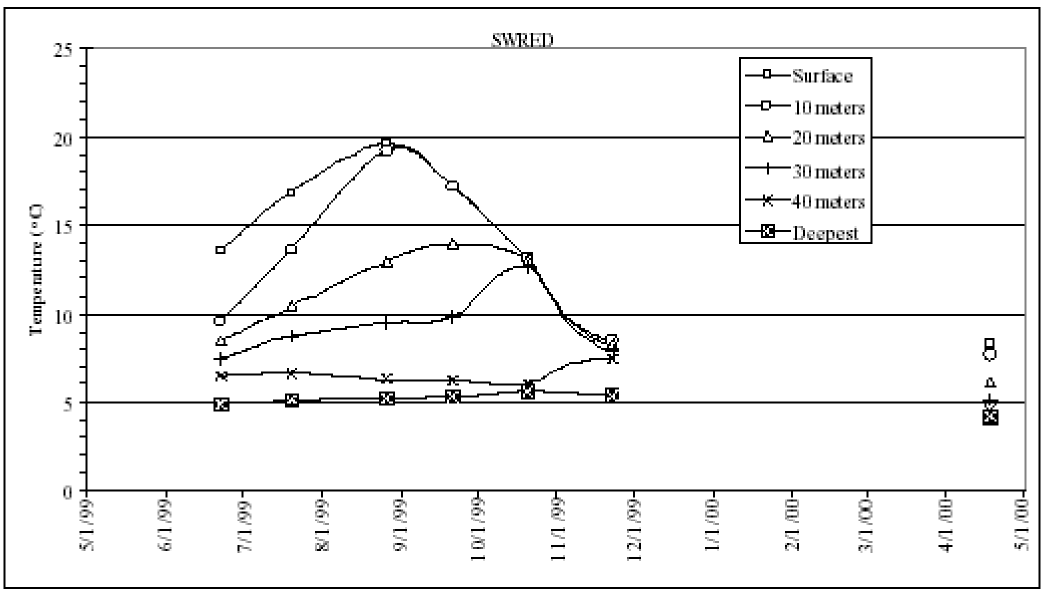

Figure 1. Temperatures in Swift Creek Reservoir, near the Swift 1 intake (data and Figure provided by Gene Stagner, USFWS, 2003). (NOTE: the bottom of the Swift intake is at 37 meters).

<u>Presence of other species</u>

Lamprey, kokanee, rainbow, brown trout, brook trout, cutthroat trout, sculpins, suckers, dace and mountain whitefish have been observed in the bypass reach (PacifiCorp 1999 pg 3-39; Graves 1982, Lesko 2003). Coho are expected to use the area after the initiation of an extensive re-introduction project. This species grows to approximately the same size, and spawns at the same time, as the Yale Lake bull trout. The presence of coho on the bull trout spawning ground would present a risk that would require monitoring during the implementation of the planned coho production program.

OLE AND RAIN CREEKS

The waters of the Ole Creek watershed flow into the bypass reach at RM 1.0.
Ole Creek is a small watershed, only 7.4 sq miles, and all of the watershed lies below 865m msl (2,800 ft msl). It includes one named tributary, Rain Creek, draining 2.4 sq miles of the total basin (in PacifiCorp & Cowlitz PUD 2002a-WTS-4 pg 6).

An evaluation by PacifiCorp & Cowlitz PUD (2002 - AQU-12) states *"…current conditions in Ole Creek appear to support the majority of the habitat features necessary for bull trout spawning…Under current conditions lack of flow in the late summer/early fall precludes use of low gradient reaches by bull trout…when bull trout spawn…."* As a result the proposal is to increase the discharge of Ole and Rain Creeks by piping water from either Swift Creek Reservoir or the Swift Canal into Rain Creek.

Discharge

Discharge is highly variable ranging from intermittent to almost 300 cfs. Both Ole Creek and Rain Creek are ephemeral/intermittent during the summer months. Only the extreme upper reaches of these two streams could be classified as ephemeral streams. The intermittent period near the mouth of Ole Creek appears to vary between years. Periods without discharge extended from July through March during the 2000-2001 period (PacifiCorp & Cowlitz PUD 2002-AQU-12). The intermittent period must have been shorter in 1999 as temperature data exist for the period April through Oct 1999 and begin again in January 2000. The measured spring season discharge of Ole Creek in 2000 and 2001 was about 10 cfs less than predictions (based on watershed size) presumably due to a portion of the flow entering the alluvium in the lower reaches (PacifiCorp & Cowlitz PUD 2002-AQU-12). In the downstream reaches during low flow period about 610 m (2,000 ft) of Ole Creek is intermittent and 914 m (3,000 feet) of the Rain Creek is dry (PacifiCorp & Cowlitz PUD 2002-AQU-12). Research indicated that most of the discharge loss occurs in Rain Creek (PacifiCorp & Cowlitz PUD 2002-AQU-12). Ole Creek flows were *"either constant or showed a slight gain during higher flows"* (PacifiCorp & Cowlitz PUD 2002-AQU-12).

PacifiCorp and Cowlitz PUD proposed and studied the feasibility of piping water from Swift Creek Reservoir to the Ole/Rain Creek watershed in order to make the lower reaches usable (PacifiCorp & Cowlitz PUD AQU-12). The proposal suggests piping water into Rain Creek to water most of Rain Creek and the lower reach of Ole Creek below the confluence of Rain Creek. They predict a flow augmentation of 30 cfs from July through October would re-water about 1.5 miles of stream. Flow losses into the gravels in Rain Creek are about 20 cfs (PacifiCorp & Cowlitz PUD AQU-12 pg 17). The modeling effort conducted by PacifiCorp & Cowlitz PUD (AQU 12) suggests this augmentation would result in a surface flow of 10 cfs of "suitable" quality for bull trout spawning and rearing habitat.

Sediment and bedload in the reach

Excessive depositions of bedload and the associated intermittency exist in the lower reaches of Rain and Ole Creeks. This condition may be influenced by management practices in the watershed. There are 21 miles of roads in the Rain /Ole watershed (in PacifiCorp & Cowlitz PUD 2002a-WTS-4). This seems to be a high road density for watershed less than 7.5 sq miles. There has been substantial reduction in vegetative cover due to past land management practices, and this usually influences the input of sediment/bedload (PacifiCorp & Cowlitz PUD 2002-AQU-12). "*There are significant mass-wasting areas along stream in the upper reaches of Rain Creek and to a lesser degree Ole Creek. Most appear to be logging related although there are signs of natural instability. I looked at the area after the 1996 flooding (1999) and observed much of the riparian zone vegetation was starting to grow back and was older than the 1996 event. That being said, it appears that the aggradation observed near the mouths of these streams is working its way downstream but at what rate is hard to estimate*" (Gene Stagner, USFWS 2003 pers. comm.)

Evaluations vary substantially in their conclusions about the interaction between management and bedload sources. Sediment inputs evaluated via aerial photos 1963, 1974, 1980 1999 indicated that landslides offer 90% of the sediment and 10% of that input is related to land management (PacifiCorp & Cowlitz PUD 2002a -WTS 4). In contrast another evaluation states that about 65% of the sediment inputs come from management related landslides (PacifiCorp & Cowlitz PUD 2002 AQU-12). Rain Creek has a much higher sediment input rate and lower gradient than Ole Creek; this probably explains the more rapid loss of surface flow in Rain Creek.

If maintaining surface flow is a priority in the Ole and Rain Creeks, the land managers must address the watershed condition. These lands are part of the DNR's HCP with the USFWS as amended to include bull trout protection, so future management activities should be much less damaging (Gene Stagner, USFWS 2003, pers. comm.). While reducing the impact of future management is important, damage from past activities also requires active management

Water temperature

Temperature data in the watershed depends upon discharge. In years when the presence of surface water permits water temperature measurement, it appears that Ole Creek is generally <15 C. September and October temperatures in 1999 were between 10-15 C. During September 1996, maximum water temperatures were within the higher part of this range, 14-15 C (PacifiCorp 1999). Minimum water temperatures did not drop below 10 C (PacifiCorp 1999, FTR pg 14). Once again, the source of the water can make or break the optimum temperatures needed for specific life stages.

Presence of other species

Kokanee, cutthroat trout, and sculpins have been observed in lower Ole Creek (PacifiCorp 1999 pg 3-41-42). Coho may also begin to use this area if planned habitat enhancements and fish stocking programs are effective. This species grows to approximately the same size, and spawns at the same time, as the Yale Lake bull trout.

The presence of coho on the bull trout spawning ground would require monitoring during the implementation of the planned coho production program.

LOWER SPEELYAI CREEK

Speelyai Creek watershed is about 12.6 sq miles. All of the drainage lies below 865m msl (2,800 ft msl). It consists of two sections, Upper Speelyai, which flows directly into Yale Lake and Lower Speelyai, another distinct stream flowing directly into Lake Merwin. The object of this discussion is Lower Speelyai Creek.

Discharge

Lower Speelyai arises from springs and is currently independent of a surface flow connection to Upper Speelyai Creek. The spring is a 2.2 mile-long, low gradient area (1-2%) with an average discharge of 20-30 cfs (PacifiCorp 1999 pg 3-34; PacifiCorp & Cowlitz PUD 2002b-AQU-9). The water right for the hatchery is 30 cfs, but they typically do not use their entire water right (PacifiCorp & Cowlitz PUD 2002b-AQU-9). USFWS hopes to establish a bull trout nursery area in this stream segment. It is currently inaccessible to upstream migration. The management proposal is to provide passage past the hatchery weir and over the lower diversion in order to provide 2.2 miles stream habitat accessible to Lake Merwin.

Substrate

The stream is not subject to flushing flows and bedload depositions typical of longer streams with higher gradient uplands. The substrates tend to be fairly small, relatively stable gravel deposits.

Temperature

Temperatures are relatively consistent. The temperatures appeared to be quite suitable for rearing juveniles 10-12 C during the growing season. However the temperatures did not drop as much in the fall as might be necessary for use by bull trout. A summary of temperature records for 1997 showed that minimum temperatures were consistently above 9 C until the first week of November. Temperatures were not consistently below 9 C until December, and then were still above 8 C (PacifiCorp 1999 FTR, pg31). Given these fall temperatures it is not surprising that the hatchery staff does not recall ever seeing a bull trout in the spring outflow despite their active use of the area to capture kokanee in the fall.

Presence of other species

Cutthroat trout, and sculpins use Lower Speelyai Creek above the hatchery water diversion (PacifiCorp 1999 pg 3-39). Below the diversion there is about 0.25 miles to the hatchery weir. At the weir, large numbers of kokanee are collected for the Speelyai Hatchery. Coho used the area historically so it is likely that coho may begin to use this area again if planned habitat enhancements and fish stocking programs are effective.

LIKELIHOOD PROPOSED ACTIONS WILL INCREASE EARLY SURVIVAL

This section will review the likelihood that the production of bull trout young-of-the-year will increase based on the description of one management scenario for each of the three nursery areas of interest. The text explores issues leading to young-of-the-year production including egg viability, spawning initiation/egg deposition, and several incubation survival issues. After the description of biological constraints for each survival issue, the discussion refers back to the conditions previously described for the three sites, given the proposed habitat enhancement.

EGG VIABILITY AND TEMPERATURE

Summer temperatures, particularly the temperatures during the month prior to spawning impacts both egg maturation and egg viability in some North American char; but such evaluations are not currently available for bull trout. There are such data for brook trout, which tend to tolerate a broader range to temperatures than bull trout. Female brook trout will not complete maturation at temperatures 16 C and higher. Brook trout egg viability declines markedly when females are exposed to a maximum water temperature >16 C during the month prior to spawning. We might infer that bull trout egg maturation and viability is at least as sensitive to water temperatures as brook trout eggs.

Bypass Channel:

The temperatures of augmented flows in the bypass channel will likely mimic those reported in the power canal (Figure 2.4-14 pg 19 PacifiCorp & Cowlitz PUD 2002a-WTS 4). At the upstream end of the canal Swift 1 temperatures did not exceed 15 C. However temperatures increased as the water flowed downstream and the maximum temperatures in summer and early fall exceeded 16 C in the downstream portions of the canal. We might expect egg viability to be impacted if adult females could not find thermal refuge during July and August. Without some laboratory research to refine our understanding of the relationship between egg viability and temperature it is prudent to assume there is some risk to bull trout eggs. The tendency of adult bull trout to seek thermal refuge, given access to it, might minimize this problem. It is prudent to assume risk until on-site observational data confirms bull trout behavior or laboratory data confirms these temperatures will not modify egg viability.

Ole and Rain Creek:

Temperatures in Ole and Rain creeks appear to be slightly cooler than that predicted for the bypass reach with augmented flows. If Rain and Ole Creek flows were augmented with the same water as proposed for the bypass channel then there is a risk of egg viability reduction. Once again fish behavior might minimize the risk of reduced egg viability. It is prudent to assume risk until on-site observational data confirms bull trout behavior, or laboratory data confirms these temperatures will not modify egg viability.

Lower Speelyai Creek:

Adult bull trout held in Speelyai Creek are likely to have viable gametes.

INITIATION OF SPAWNING

Water temperature

Bull trout spawn in the fall during September, October and November (Needham and Vaughn 1952; Heimer 1965, Shepard et. al 1984). Spawning takes place as maximum daily temperatures drop below 9 C (Shepard et. al 1984). Weaver and White (1985) report that the adults may delay spawning if the temperatures remain at 9 C, and spawning did not occur until temperatures were 7 C. Use of areas for spawning with 4-8 C is common. There is no information about how long spawning might be delayed before females reabsorb their eggs.

Bypass Channel: The temperatures of augmented flows, while improving fall conditions could still delay or abort spawning. Flow augmentation would likely come from the Swift 1 tailrace. Both observed and modeled temperature regimes peak in October. October temperatures measured in 1999 were close to 14 C. The SSTEMP predicts slightly cooler waters of 12 C with augmented flows. Modeling implies that appropriate spawning temperatures would not occur until November or December (PacifiCorp 2002a –WTS-4).

Observations of bull trout spawning in the old river channel imply that temperatures suitable for the initiation of spawning can occur. Bull trout spawning was actually observed in the old river channel (presumably without augmented flows) in 1981 and 1982 (Graves 1982). *"Three pairs were seen spawning… September 24, 1981"* (Graves 1982). *"Two pairs were counted in 1982"*, but no date is given.

It is possible that smaller volumes of water will be more influenced by air temperatures in the fall than the SSTEMP model indicates. Certainly some warming occurred between Swift 1 and Swift 2. Perhaps additional modeling could be used to determine if another flow level would be more likely to cool to 9 - 7C during late September or sometime in October.

Ole and Rain Creek: The temperatures recorded in September and October of 1996 at the mouth of Ole Creek were >10 C all day. These temperatures are likely to delay spawning. The waters that would be used to augment these flows would have the same temperature regime as those at Swift 1 tailrace, and be too warm in the fall to permit spawning initiation.

It might be useful to model a few scenarios to predict the potential temperature with the 30 cfs augmentation within the 1.5 miles of Rain and Ole creeks. Mathematical gaming with other augmentation scenarios might provide a discharge scenario more likely to provide suitable temperatures and flow in the fall within in the short 1.5 miles affected.

Lower Speelyai Creek : Based on temperatures, it is unlikely that bull trout would spawn in lower Speelyai Creek. During 1997 minimum temperatures were consistently above 9 C until the first week of November. Temperatures were not consistently below 9 C until December, and then were still above 8 C (PacifiCorp 1999 Appendix FTR pg31).

Dissolved oxygen and spawning distribution:

Dissolved oxygen levels can impact fish behavior. Char tend to avoid areas where oxygen is <5 mg/L. For instance, the median threshold avoidance for adult lake trout is about 4.2 mg/ L (Evans et al 1991).

Bypass Channel: Dissolved oxygen levels in the augmentation water, as currently described, that would come from the canal would be adequate (PacifiCorp & Cowlitz PUD 2002b AQU-9 pg 16)

Ole and Rain Creek: Bull trout would likely avoid areas of low dissolved oxygen. Such conditions exist in Ole Creek at low flow. The source of the low DO appears to be more than a simple temperature issue. Augmented flows would theoretically be carrying water with a higher level of dissolved oxygen. Stream channel configuration would need to be reviewed to determine if cooler water additions would flow partially sub-surface and re-emerge as an upwelling of water suitable for incubation

Speelyai Creek: Dissolved oxygen levels in the spring are adequate.

EFFECTIVE EGG DEPOSITION ESTIMATES

Effective egg deposition, as I describe it, depends upon fecundity, and the potential to loose gametes via hybridization. It's a description of how many viable bull trout eggs get into the gravel.

Estimated Fecundity

Fecundity influences potential reproduction and growth rate of a population and resilience to exploitation and disturbance. Migratory stocks tend to be large and fecund. Robust individuals tend to carry more eggs than smaller fish. While there were no fecundity data for the Lewis River bull trout, the fish size data available implies Yale Lake can produce fish that are large and robust. The females that might colonize the three habitats of interest will likely carry 2,500-12,000 eggs per female. This is a wide range, but it might be refined with more recent data concerning fish length and condition.

Hybridization

Brook trout can hybridize with bull trout and usually create sterile hybrids (Leary et al 1983). The tendency to hybridize removes gametes from the bull trout population, reducing the potential bull trout production. In some basins bull trout are completely replaced by brook trout (Leary et al 1983). The tendency of these chars to hybridize means that brook trout pose a substantial threat to bull trout.

Brook trout are good at dispersing and colonizing habitats (Adams 1999). Dispersal does not necessarily occur at a steady pace. It may appear that there is little mixing of the species for many years, and then a rapid dispersal event occurs in response to a subtle habitat change via seasonal extreme or anthropomorphic change. This dispersal tendency assists in the replacement of bull trout by brook trout (Adams 1999).

Bull trout and brook trout habitats are similar. Subtle differences permit bull trout to remain in their habitats when brook trout invade and area. It is important to understand as much as possible about brook trout distribution in the basin so management strategies such as augmentation of flow do not promote brook trout populations instead of bull trout populations.

<u>Distribution of brook trout:</u>
Basic distribution data are necessary to describe the location and abundance of brook trout and their hybrids in tributaries to Yale, as well as the Lewis River basin above Swift dam, and the Swift 2 power canal. Brook trout have been observed in Yale Lake, the bypass reach, and the waters upstream. It is unclear how many brook trout were stocked, if they dispersed between stocking sites in the basin, or if there is natural production of resident or a migratory stocks using Yale Lake. Bull trout spawning areas, where hybridization with brook trout occurs, should be identified and managed if possible

Brook trout were found in Yale Lake, implying it is possible that some of the brook trout may be adfluvial. The brook trout were observed during a Yale Lake creel census in 1980 (8 fish) and 1981 (1 fish) (Graves 1982). Six of these fish were between 265 to 365 mm in length and were caught in Beaver Bay. The other three were caught in nets, and were only 19-23 mm; Graves (1982) states these small fish were captured with gill nets, which seems unlikely. These fish were found in the old river channel spill pool and Siouxon inlet.

The Swift Creek Reservoir bull trout population is also exposed to brook trout (Graves 1980; Faler and Bair 1992; E. Lesko, PacifiCorp, 2002 pers. comm). WDFW has stocked brook trout upstream from the primary bull trout spawning reach for the Swift bull trout population in Rush Creek (Frank Shrier, PacifiCorp 2003, pers. comm.). The contention was that brook trout would not survive the 80 ft falls between the stocking site and the bull trout's spawning site (Frank Shrier, PacifiCorp 2003, pers. comm.).

The brook trout in Swift Creek Reservoir move downstream, potentially into the area occupied by the Yale/Merwin bull trout population. During recent foot surveys in the bypass reach PacifiCorp personnel found five brook trout (Frank Shrier Pers. comm. 2003). Of the 2,346 fish salvaged after the Canal failure 5 were brook trout and 43 were bull trout. Since brook trout can move downstream, it would be useful to understand if brook trout are actively colonizing either the tributaries to Yale or the tributaries of the upper basin.

There are reports of both brook trout and at least one brook trout x bull trout hybrid upstream from Swift dam (Graves 1980, Faler and Bair 1992, Lesko 2002, Frank Shrier Pers. comm. 2003). At least one brook trout has also been observed in the Pine Creek watershed, the other spawning area for the Swift bull trout (Frank Shrier, PacifiCorp 2003, pers. comm.). It is not clear if this represents stocking in Pine Creek, dispersal from Rush Creek or some other source. At least one 473 mm brook trout x bull trout hybrid was found with gill nets in Swift Creek Reservoir (upstream from the bypass reach) in June 7, 2001 (Lesko 2002). The USWFS doubts the authenticity of this observation since tissues were not collected for genetic confirmation (Gene Stagner, USFWS 2003, pers. comm.).

Bypass Channel: There is some risk of brook trout presence and use of potential bull trout habitats in the bypass reach. Brook trout use the bypass channel, but there are no population estimates to describe their relative abundance there. Since brook trout are a slightly more tolerant species than bull trout the habitats in the bypass reach are at least as usable for brook trout as for bull trout.

Brook trout have been observed in the bypass reach in the late 1970's as well as more recently in the early 2000's. Graves (1982) observed brook trout in the by pass reach during the late 1970's when flows were at the 20-25 cfs level. Six brook trout were observed during the 2002 snorkel surveys in the bypass reach during October and November, when the river had additional flow, similar to historic base flows (Lesko 2003). Brook trout have been collected in the canal during salvage operations after the breach at Swift 2 (Lesko 2002; G. Stagner, USFWS, 2002 pers. comm.).

Ole and Rain Creek: There is some risk of developing brook trout use in the Ole/rain Creek area. I did not find records of brook trout in Ole or Rain Creek but they use the bypass channel nearby and certainly have access to the Ole/Rain habitats. Since brook trout are a slightly more tolerant species than bull trout the habitats developed by augmented flow strategies would be at least as usable for brook trout as for bull trout.

Speelyai Creek: I did not find reports of brook trout in Speelyai Creek, although the temperatures and other habitat criteria appear to favor the species. A creel survey conducted in Merwin (Eddy and Meyers 1985) did not observe brook trout in the catch with over 17,000 angler-hours expended. A more recent creel census in 1999 (PacifiCorp and Cowlitz PUD 2002c (AQU 7)) also did not observe brook trout in the Lake Merwin creel with over 3400 angler-hours expended.

INCUBATION SURVIVAL

The USFWS suspects the heavy influence of rainfall on water flows and therefore temperatures, west of the Cascade Mountains may have created an adaptation to more elevated temperatures for incubation than reported below (Gene Stagner, USFWS 2003, pers. comm.). However, there is no evidence to support this contention.

Water temperature

We can expect high mortality of eggs if water temperatures reach to 8-10 C highs, while eggs are in the gravels (McPhail and Murray 1979). Survival was <15% when temperatures reached 8 C (McPhail and Murray 1979). In a laboratory setting, the highest egg survivals (80-95%) were observed at 2-4 C (McPhail and Murray 1979). Brown also (1984) reports excellent incubation (95%) at 4 C. Survival rates were more variable but still high (60-90%) at 6 C. (McPhail and Murray 1979).

Bypass channel: The relationship between temperature and survival of eggs in the gravel depends upon timing of spawning (which may be delayed, see discussion above). If we can assume bull trout can delay spawning until temperatures drop to 7 C, and temperatures continue to drop during the spawning period, then there may be some egg survival. If spawning is not delayed, either the adults will reabsorb their eggs or the eggs will be exposed to temperatures in excess of 10 C and mortality will likely be complete.

Ole and Rain Creek: In years when flow exists in lower Ole Creek during the spawning season the temperatures are too warm for bull trout to spawn and would certainly kill any eggs deposited. Intermittency would eliminate egg deposition and survival in other years.

Substrate condition (including the proportion of fines) was not reviewed as other factors preclude the use of Ole and Rain Creeks as a nursery site. This substrate analysis should be completed since part of using these two streams is dependent on piping additional water into upper Rain. Although I expect that freeze core samples would should fairly high percentage of fines in the lower reaches.

Lower Speelyai Creek: It is highly unlikely that bull trout eggs would survive in the gravels of lower Speelyai Creek. The data presented in Figure 4.96 pg 14 of PacifiCorp & Cowlitz PUD (2002b-AQU 9) show that temperatures never drop to 6 C or the more suitable 2-4 C during the incubation period.

In order to use Lower Speelyai Creek as a bull trout nursery site the water would have to be cooled during the incubation period. Augmenting Speelyai Creek by piping additional water from Merwin or from groundwater accumulation tubes has been investigated (PacifiCorp & Cowlitz PUD 2002b-AQU9). The water would need to be cooler than currently reported for both surface flows and interstitial water upwelling into the channel in order to allow of egg survival.

<u>Fine sediment</u>

The literature offers sediment and incubation survival relationships. Ground water can reduce the impact of sediment on incubation survival. If there are substrate data available for bull trout spawning sites, it is possible to apply the literature's estimates of incubation survival based on percent fines in the substrate (as measured by hollow core sampling techniques). If groundwater (of suitable temperature and DO) is present, some increase in the estimated survival rate based on fines alone may occur.

Based on hollow core data, the average bull trout incubation survival to emergence is 50-60% where fines are <30% of the substrate (Shepard et al 1984; Weaver and White 1985). When fine sediments (<6.35 mm) increase to about 30% of the substrate, survival begins to decline. When 40% of the substrate is <6.35 mm, survival was 20% or less; when fines represent 50% of the substrate bull trout egg survival is zero (Shepard et. al 1984; Weaver and White 1985).

Weaver and Fraley (1991) report bull trout incubation survivals, in a natural setting, were more dependent upon interstitial DO than the percentage of fines (Weaver and Fraley 1991). Upwelling in the spawning sites and the cleaning of the gravels by the female while digging redds reduced mortality in the field, compared to laboratory channels with similar gravel compositions. Laboratory tests showed reductions in bull trout survival as sediment (<9.5 mm particles) levels reach 30% fines (Weaver and White 1985). Field survival rates were somewhat better. In either environment, sediment levels reaching 40% fines (<9.25 mm) resulted in substantial decreases in incubation survival. At 50% fines, groundwater was unable to reduce the mortality from sediment impacts.

Bypass Channel: The rare gravels available in the bypass reach were sampled. The substrate depositions had fairly small materials, with a mean diameter of 13-17 mm (0.5-0.7 inches), only 4-9 % particles were finer than 2 mm, and the Fredle index was 7-10 (PacifiCorp & Cowlitz PUD 2002a-WTS 4). The way these data are presented it the text it is not possible for me to compare to bull trout egg survival rates, based on the presence of either 6.35 mm fines or 9.35 mm fines (Weaver and White 1985). They describe small gravels as 2.0-6.4 mm and large gravel as 6.4-64.0 mm. Bull trout used large gravel and cobble (64-254 mm for spawning in the river basin where Weaver and White (1985) did their work. I suspect the raw data for the bypass channel could be re-examined, with the work of Weaver and White (1985) in mind.

Ole and Rain Creek Intermittency would eliminate egg deposition and survival without flow augmentation. Ole and Rain Creek channels, with augmentation would have “medium gravel” (38%) and “small cobble (21%)” in the newly watered channel (PacifiCorp and Cowlitz PUD 2002 AQU 12). If investigators classified substrate similarly to Weaver and White (1985), and the fines (<6.35mm diameter) were <30% it would likely provide desirable habitat. The high percentage of sand, silt and clay in the soil surrounding the watershed implies that fine substrate could be present in the interstices of the gravel and cobble. Therefore it would be useful to use hollow core sampling techniques to evaluate the fines before flow augmentation.

Lower Speelyai Creek The substrate evaluation I found focused on sediment inputs in Upper Speelyai, which were significant. I found no information on Lower Speelyai sediment levels.

PHYSICAL DESTRUCTION OF EGGS

Physical destruction of eggs by exotic species of fish

In an area with limited spawning habitat, superimposition by conspecific and other species might impact incubation survival by disturbing the eggs. Conspecific superimposition may be a problem if spawning sites are limited in relation to adult bull trout abundance. The exotics likely to superimpose of bull trout redds are brook trout, brown trout, and kokanee. Coho reintroduction has been proposed. This native species also spawns in the fall, is of similar size to an adfluvial bull trout, and would use habitats that potentially include the bull trout spawning areas. The impact of all these species depends upon timing of spawning and their size relative to the size of the bull trout (and therefore how deep the eggs get buried).

Bypass Channel: Kokanee, brook trout, and brown trout have been observed in either the bypass channel or the Swift 2 tailrace at the entrance to the bypass channel. Kokanee have been observed spawning in the limited gravel near the mouth of Ole Creek. Brook trout have been observed in the reach, but no spawning has been observed. One brown trout (473 mm) was found in the Swift 2 tailrace (at the confluence of the bypass reach and Yale Lake) and moved upstream into Swift Creek Reservoir. I did not find reports of brown trout spawning. The source of the brown trout is unknown. Coho used the by-pass reach historically it is likely they would resume use of this area if flows and temperatures were suitable after their reintroduction.

Ole and Rain Creek: Kokanee have been observed spawning in the lower 0.4 miles of Ole Creek (PacifiCorp 1999 pg 3-32).

Lower Speelyai Creek: Kokanee run into the hatchery at the lower end of the springs. However, these kokanee are collected for brood fish. Coho have used Speelyai Creek in the past, so it is likely they would resume use of this stream if passage into the stream were possible after their reintroduction.

<u>Physical destruction of eggs during spates</u>

Eggs can be destroyed by spates, resulting in substrate scour, during the incubation period.

Bypass Channel: It is reasonable to believe that if bull trout used the bypass channel for spawning that there would be year class losses due to flooding. It is likely that at least three out of every ten bull trout year classes would be lost due to channel scour caused by high flow events and spill during the winter period. See comments above. A spill event does not automatically result in a loss of a complete year class. Very high spill events would likely cause this but lesser events would have a corresponding lesser effect on incubation.

Ole and Rain Creek: Spawning sites within Ole and Rain Creek may not be subject to as frequent or severe flow changes as the bypass channel. The watershed is quite small and lies at a fairly low elevation for snow accumulation. While spates may occur, it is unclear if it is likely to move enough substrate to remove bull trout eggs. It might be more likely to deposit additional substrate and further bury bull trout eggs.

Lower Speelyai Creek: Potential spawning sites within Lower Speelyai Creek may not be subject to frequent or severe enough changes in discharge to crush eggs buried in the gravel by an adult adfluvial bull trout. Lower Speelyai is a spring fed stream arising in a fairly low elevation area. The upper diversion on Speelyai Creek prevents natural flooding, observed in Upper Speelyai Creek, from reaching Lower Speelyai Creek.

APPENDIX A - BAYESIAN BELIEF MODEL

Lee et al. (2000) prepared a mathematical model, based on probable categories of various population parameters. This appendix provides a brief description of the variables with a brief application of that category to the Merwin/Yale population.

Please note that the BayVam model is based on the female portion of the population. Therefore, all nodes or variables should be parameterized accordingly.

INITIAL POPULATION - BULL TROUT ABUNDANCE IN MERWIN/YALE

There are no bull trout population estimates for Yale Lake and Lake Merwin. Instead an initial determination of population size, or spawning population estimates, might be offered as ranges of possible values. This exercise, while not statistically defensible, is important to provide some perspective about the probable size of the Merwin/Yale population. The model only requires an estimate of the likelihood that the population of interest is expressed by one of three categorizations of the initial population size (Table A1). Using any method proposed below the Merwin/Yale bull trout population will be classified in the smallest category (50-450 female adult fish).

Table A1: A guess for the variable (input node) initial numbers of female adults for the Lake Merwin and Yale Lake population.

Likely initial abundance of adult (female bull trout in each population)	Merwin	Yale	Combined
50-450 females	100%	100%	100%
450-850 females	0%	0%	0%
850-1,250 females	0%	0%	0%

Several lines of logic, presented below, suggest that less than 100 adult bull trout spawn in waters accessible to Yale Lake. Inferred annual population sizes ranges from <15 to 60 spawners, and perhaps as many as 90 adults. The larger estimate of adult fish compared to spawners is reasonable as some adults may not spawn annually. If we assume a 50:50 sex ratio its likely that there are less than 50 female bull trout in the Yale Lake population. Therefore it is 100% likely that initial population of Yale Lake bull trout fall in the smallest category defined as 50-450 female bull trout. Lake Merwin is considered a smaller population by local biologists so both Lake Merwin and the combined Merwin/Yale population would be in the same category.

Angler harvest as an indication of initial population size

Angler harvest data (1977-1982) implies bull trout are rare in Lake Merwin. (TableA2). Harvest in Yale Lake was substantially higher and more variable with 4-57 fish harvested annually. While the harvest was larger during the years prior to the eruption of Mt St Helens (May,1980), it was still modest. The total for Merwin/Yale combined before the eruption was >50 bull trout; after the eruption the harvest was 30 the first year and declined to ≤ 15 fish (TableA2). The harvested fish are likely to include adult and sub-adult individuals.

Table A2. Bull trout harvest records available before and after Mt St Helens eruption in 1980 and prior to bull trout harvest closure in 1992.

Year	Merwin	Yale	Merwin +Yale	Swift	Citation
1978	9	57	66	65	S. Graves 1980
1979	0	55	55	274	S. Graves 1980
1980	0	30	30	6	S. Graves 1982
1981	0	15	15	5	S. Graves 1982
1982	3	4	7	59	S. Graves 1982

Spawning ground counts an indication of initial population size

Cougar Creek is the only known nursery area for Yale Lake's bull trout. Estimates of spawning adult bull trout have been recorded most years between 1979 and 2002 (Table a3). Annual spawning surveys do not provide population estimates, but are useful as the only long-term abundance data available for the Yale population. There are two sorts of spawning count trend numbers, a maximum daily count, and an additive count during the spawning season. Some of the counts include the addition of fish from Lake Merwin, released into Yale.

In an attempt to increase the number of spawners using Cougar Creek, beginning in 1995, biologists tagged and moved between 7 and 15 fish annually from Merwin to the mouth of Cougar Creek (in 1999 and 2001 no fish were moved). Each year only 1 or 2 of these marked individuals would be observed upstream in Cougar Creek on the bull trout spawning grounds. Summaries of these data can be found in the annual bull trout monitoring reports Lesko (2000, 2001, 2002, 2003).

The largest number of adults reported for Cougar Creek was from a cumulative count of 40 bull trout during the fall of 1979 (Lesko 2003, citing Graves 1982). Other high counts occurred in 1988 (22 adults) 1989 (30 adults), 1993 (29 adults) 1994 (37 adults). The highest daily counts of the decade occurred when biologists spent more than the usual amount of time on the counts, with either the assistance of a weir or the use of weekly counts for 8 weeks (Lesko 2003, PacifiCorp 1999). During the past decade the daily counts, or maximum daily counts recorded, indicate less than 15 spawning adults per year, and frequently less than 10 spawners. In 2002 we have both a cumulative estimate of spawners and a maximum daily count to compare. The results were about 30 spawners in 2002, or twice the daily count (Lesko 2003). WDFW estimated 25-35 spawning bull trout in Cougar Creek during the 2002 season (Gene Stagner, USFWS 2003, pers. comm based on WDFW comments on LoCoBT recovery plan). At least some of these fish did not spawn due to predation (see Adult Mortality section).

The minimum spawning population for the Merwin/Yale might be the maximum number of bull trout observed on a single day on Cougar Creek. As described earlier, the most likely minimum number of spawners is the maximum daily count; in recent years that number has been <15 adults. Even if the maximum daily count represents half the spawners, this is a small population. If the Merwin/Yale fish persist with this very small spawning population it is likely that a reduced level of genetic variation should become evident.

Table A3. The miles of known bull trout nursery areas, and the miles of critical habitat bull trout habitat identified by USFWS (2002).

Year	Cougar spawning ground counts	Merwin Reservoir-Cougar Escapement	Swift Reservoir Population Estimate	Data Source
1978				Graves 1980
1979	40			Graves 1980
1980	8			Graves 1980
1980				Graves 1982
1981	0			Graves 1982
1982	0			Lesko 2003
1983				Lesko 2003
1984	2			Lesko 2003
1985				Lesko 2003
1986				Lesko 2003
1987				Lesko 2003
1988	22	22		WDFW SaSSI 1998
1989	30	30		WDFW SaSSI 1998
1990	17	17		WDFW SaSSI 1998
1991	13	19	46	WDFW SaSSI 1998
1992	10	10		WDFW SaSSI 1998
1993	29	29		WDFW SaSSI 1998
1994	37	37	101	WDFW SaSSI 1998
1995	7	7	246	PacifiCorp 2002
1996	11	11	325	PacifiCorp 2002
1997	14	14	287	PacifiCorp 2002
1998	7	7	437	PacifiCorp 2002
1999	9	9	248	PacifiCorp 2002
2000	9	9	288	PacifiCorp 2002
2001	10	9	542	PacifiCorp 2002
2002	15			Lesko 2003

Inferences based on space and the density of redds

Redd counts have recently fallen out of favor as a relative abundance technique where accuracy and precision are required (Dunham et al. 2001). However I still consider redd counts a source of relative or likely abundances when more reliable data are not available.

This method takes the spawning space (stream length) times redd densities found in the literature. Cougar Creek is about 1.7 miles (2.7 km) long. Most bull trout spawn upstream from the Panamaker Creek confluence (RM 0.5). This means there are about 1.2 miles of stream that might be used by bull trout for spawning. Redd densities have been reported in the literature for migratory bull trout stocks as 1.7-16.7 redds/km (Ratliff 1992). In the Flathead basin a high density redd area was >6.9 redds/km (Fraley and Shepard 1989). If we use 7 redds/km as a reasonably high density we might expect less than 15 - 20 redds in Cougar Creek. Adults per redd might be estimated as 2 fish per redd or we might use 3 fish based on Fraley et al. (1981). In this case, the inference is 30-60 spawners.

Inferences from spawning space and population size

If the reservoirs of the Lewis River basin are likely to have similar productivity, and the limiting factor is spawning space, then it might be possible to compare the relative magnitude of the bull trout production using Swift Creek Reservoir and associated nursery habitat to the bull trout habitat and production situation downstream in Yale and Merwin. While this is not a recommended way of predicting population size, there is some logic that it might offer an upper end to the probable number of bull trout.

Bull trout production in Merwin/Yale seems to come from a space (1.7 miles) that is at least 80% smaller than that used by Swift fish (9.7 miles, Table A4). Estimates for the spawning escapement in the upper Lewis (i.e. Swift fish) range from about 100 to 790 fish, with a median of 288 bull trout spawners annually (Lesko 2001, 2002, 2003). If we assume that the Merwin/Yale population can only be 20% of the Swift population due to nursery space (Table 2) limitations then the Merwin/Yale population might be 20-160 fish. Using the median population values we might expect 60 spawners annually.

USFWS asked what this habitat method might predict if only the 1.7 miles of Rush Creek were used as a surrogate for the 1.7 miles of Cougar Creek. Using the habitat space logic, without regard to the differences in habitat structure between the two streams, we would assume similar numbers of fish in these two streams. In order to provide estimates comparable to those above, its necessary to be able to separate out the Rush Creek portion of the population for the years of record and use the range and median to predict a probable range of spawning adult abundance.

Table A4. The miles of known bull trout nursery areas, and the miles of critical habitat bull trout habitat identified by USFWS (2002).

Stream or segment name	Accessible nursery miles	Accessible nursery km
MERWIN/YALE		
Speelyai Creek	None listed	None listed
Cougar Creek	1.7	2.7
By pass Reach	2.3	4.3
Ole Creek	0.08	1.3
Rain Creek	0.9	1.4
MERWIN-YALE SUBTOTAL used	1.7	2.7
MERWIN/YALE SUBTOTAL theoretical	4.98	9.7
SWIFT POPULATION		
Upper River -to first falls	13	21
Upper River -1st falls to twin falls	14	22.6
Upper River -multiple falls section	2.6	4.1
Upper River -above the falls	Not listed	Not listed
Rush Creek	1.7	2.7
Pine Creek	8	12.9
Pine Creek - trib P7 @ rm 2.9	1.1	1.8
Pine Creek - trib P8 @ rm 3.7	4.2	6.7
Pine Creek - trib P10 @ rm 5.2	0.3	0.4
Trib to reservoir S-15	1.3	2
Swift Creek	0.3	0.5
SWIFT UPPER LEWIS used	9.7	15.6
SWIFT UPPER LEWIS theoretical	46.5	74.7

POTENTIAL ANNUAL EGG DEPOSITION

Potential egg deposition is calculated by the model, rather than entered separately by the user. Egg deposition depends upon the female part of the population, which the model defines as initial population. A sex ratio, applied to an initial population of spawning fish, provides an idea of how many female fish might contribute eggs each year (Table A5). Without field data to define the sex ratio, it is reasonable to assume a 50:50 ratio for the Merwin/Yale bull trout population.

Table A5. Summary of inferred spawning population sizes in Yale Lake and the associated number of females likely to deposit eggs annually.

Total spawners	Female Spawners	Source of ball-park estimator
<15	<7	Single-day maximum counts
30	15	Cumulative counts for the season
60	30	Likely abundance based on space and productivity assumptions

FECUNDITY

Fecundity will influence potential reproduction and growth rate of a population and resilience to exploitation and disturbance. Fecundity is related to fish size. Migratory stocks tend to be larger and more fecund than resident fish.

Based on sizes of fish in the Merwin Yale population compared to the literature it might be estimated that there will be at least 1,200 eggs per female. Most of these fish area large migrants so its not surprising that the initial guess places most of the emphasis in the range of 1,100-1,250 female eggs/female. Justification of Table A6 follows the table.

Table A6: A guess for the variable (input node) fecundity for each of the five local populations.

Range of fecundity female eggs/female adult	**Yale/Merwin**
50-200	0%
200-350	0%
350-500	0%
500-650	0%
650-800	0%
800-950	0%
950-1100	0%
1100-1250	100%

Fecundity records for Lewis River bull trout stocks were not available but were estimated from fish size and fecundities noted in other basins. Bull trout of similar size should have similar fecundities. Eggs per pound data can be found in the literature (Table A7). Migratory adults may carry 800-1200 eggs per pound.

Table A7. Comparisons of migratory bull trout fecundity relationships, found in the literature.

Topic	Evidence	Citation
Adult sizes	400-800 mm 455-723 mm 17.8 in-31.7 in 409-550 mm	Pratt 1992 Brunson 1952 MDFWP 1979 McPhail & Murray 1979
Eggs per female	2,136-6,753 2,125-9,625 1,337-7,382 1,350-8,800 1,340-1,607	Heimer 1965 MDFWP 1979 Brunson 1952 Pratt 1992 McPhail & Murray 1979
Eggs per weight	795-1210 eggs/pound (bulls) 851 eggs/pound (bulls)	Brunson 1952 MDFWP 1979

Paired length and weight data for bull trout in the Lewis River basin are sparse. Graves (1982) provides some weight data, and there are a few data points from unpublished PacifiCorp data (Table A8). Applying the 800-1,200 eggs per pound average from the literature (Table A7) implies possible fecundities for the paired data (Table A8).

Table A8. Reported bull trout weights in the Lewis River basin, adapted from Graves (1982) and unpublished data (PacifiCorp)

Length (mm)	Weight (lbs)	Fecundity range	Female eggs/female
295	0.6	459 to 688	229 to 344
330	0.7	573 to 860	287 to 430
360	1	785 to 1,177	392 to 589
400	1.3	1,041 to 1,561	520 to 780
430	2	1,623 to 2,434	811 to 1,217
514	5	4,000 to 6,000	2,000 to 3,000
530	3.8	3,000 to 4,500	1,500 to 2,250
533	3.3	2,600 to 3,900	1,300 to 1,950
534	7.5	5,996 to 8,995	2,998 to 4,497
555	4.3	3,400 to 5,100	1,700 to 2,550
585	3.8	3,034 to 4,550	1,517 to 2,275
590	3.9	3,086 to 4,630	1,543 to 2,315
600	6	4,800 to 7,200	2,400 to 3,600
635	11.5	9,185 to 13,778	4,593 to 6,889
640	5.5	4,362 to 6,542	2,181 to 3,271
699	9.5	7,600 to 11,400	3,800 to 5,700
800	10.8	8,616 to 12,923	4,308 to 6,462

WDFW provides one more recent data point to describe fecundity of a particular length of fish. The observed 560 mm female carcass, "could have held 2,500-3,000 eggs", but no counts were made (Gene Stagner USFWS, 2003, pers. comm. based on WDFW comments on LoCoBT recovery plan). Their observation implies the bull trout they observed (in the Swift bypass channel) would have a modest or low number of eggs for a bull trout of its length compared to other basins.

Most of the spawning adults in the Merwin/Yale are probably >500 and <800 mm. This assumes two things: (1) length frequency data (Table A8) represented the adult population that might use Cougar Creek, or colonize the other habitats of interest, and (2) that the spawning population was well represented by the fall catch, (Table A7; Figure A1, Table A8). Length frequencies of the fish caught in Lake Merwin and Cougar Creek (Yale Lake population) indicate that >90% of the fall sample were fish >500 mm (Figure A1, Table A8). Bull trout captured at the Yale tailrace (1995-1998) were of similar size ranging in length from 381 to 820 mm (fork length) (PacifiCorp 1999).

Applying the fecundity data in Table A7, and the length frequency (Figure A1) we can estimate that bull trout > 500 mm carry at least 2,500 eggs and may carry as many as 12,000 eggs as they reach 800 mm (Table A8). Recent models looking at bull trout viability use, ranges of likely fecundity based on female eggs per female. Again there is no information on sex ratios for bull trout eggs, so a 50:50 ratio may be an appropriate approximation. Using the data in Table A9, it is possible to justify the initial judgment about likely fecundities (Table A6), or modify it slightly to account for a few small spawners in the population.

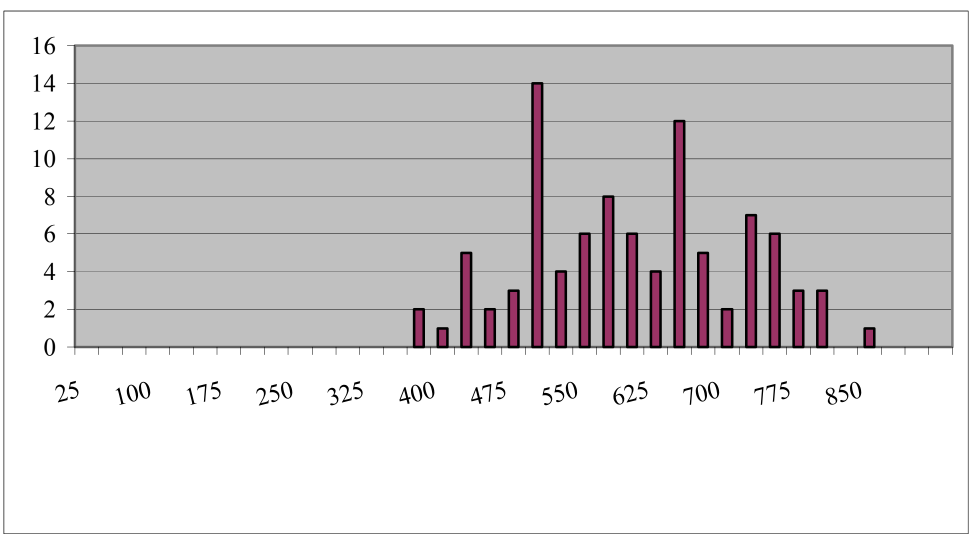

Figure A1: Lengths (mm) of bull trout during the fall season (Sept-Nov) in Lake Merwin and Cougar Creek (representing Yale Lake)

Table A9. Sizes of bull trout sampled during the fall in the Merwin and Cougar Creek (Yale), presented as a proportion of the catch within each 100 mm length class (unpublished data provided by PacifiCorp) and their associated estimated fecundity.

Length class (mm)	% of Fall popualtion	Total Fecundity	Female eggs per female
0- 100	0		
200	0		
300	0		
400	0.09	1,000-2,400	500-1,200
500	0.24	2,600-5,000	1,300-2,500
600	0.26	5,000-10,400	2,400-5,200
700	0.28	5,000-12,000	2,400-6,000
800	0.13	7,200- 11,400	3,800-5,700
>800	0.01	8,000-12,000	4,000-6,000

IMPACT OF EXOTIC SPECIES ON EXPRESSED FECUNDITY

Brook trout can hybridize with bull trout and usually create sterile hybrids (Leary et al 1983). The tendency to hybridize removes gametes from the bull trout population, reducing the potential bull trout production. In some basins bull trout are completely replaced by brook trout (Leary et al 1983). The tendency to hybridize means that brook trout can effectively remove bull trout gametes from the population and therefore pose a substantial threat to bull trout production. I suggest showing this hybridization risk by reducing fecundity values used in the model, suggesting a portion of the egg deposition would no longer represent bull trout production.

The presence of brook trout in the basin has been documented, however the relative abundance and distribution of this exotic species is unknown. I would suggest that any evidence of brook trout use of bull trout habitats in the Merwin/Yale area presents a substantive risk. Brook trout are good at dispersing and colonizing habitats (Adams 1999). Dispersal does not necessarily occur at a steady pace. It may appear that there is little mixing of the species for many years, and then a rapid dispersal event occurs in response to a subtle habitat change via seasonal extreme or anthropomorphic change. This dispersal tendency assists in the replacement of bull trout by brook trout (Adams 1999).

Brook trout use Lake Yale and the bypass channel. There were no reports of brook trout in Cougar Creek. Temperatures in Cougar Creek tend to be cool enough that we would not anticipate brook trout invasion.

INCUBATION SURVIVAL

Incubation survival is influenced by water temperature, sediment, inter-gravel dissolved oxygen and agents of physical destruction as described in a previous section. The highlights of the previous discussion are reviewed and an estimate is offered for the situation in Cougar Creek, Ole/Rain, the bypass channel and Speelyai Creek.

It is assumed, that the situation in Cougar Creek permits egg survival. It's a cold spring so the waters are 6-7 C, and it is likely that inter-gravel flow is high. Cougar likely has good survival rates unless eggs are destroyed by superimposition; spates are likely inconsequential in this small watershed (Table A10).

Its unlikely that eggs will survive in the three proposed nursery areas. Speelyai Creek is too warm in the winter for incubation. Ole/Rain temperatures with the augmented flow regime proposed and the modeling describing its effect, implies that temperatures would be too warm to initiate spawning, and would be too warm during early incubation if spawning occurred. Additionally it is unclear if the low DO that exists in parts of this habitat will or will not resolve itself with the increased flow level proposed. The Swift bypass reach is also too warm to initiate spawning, similar to the Ole/rain situation. There is also the threat of physical destruction of eggs from spates and perhaps other fall spawning species.

Table A10: A guess, based on the assumptions presented above, for the variable (input node) fecundity for each potential and existing spawning site.

Likely incubation survival Proportion of female eggs surviving to emergence	Cougar	Ole/Rain	Swift bypass	Speelyai
10-20%		100%	100%	100%
20-30%				
30-40%				
40-50%				
50-60%	50%			
60-70%	50%			

MAXIMUM FRY SURVIVAL (THROUGH THE FIRST WINTER OF LIFE)

This survival category includes the summer and winter survival of bull trout their first year; these fish are typically 25-75 mm. High mortality during this period is common in many fishes and may restrict the capability of the population to recover from disturbance.

Precise estimates of early survival are generally unavailable. There is virtually no work estimating survival rates of bull trout from fry to age 1.

In the Lewis River basin young-of-the-year and juveniles are rarely seen and survival rates based on year class abundance changes over time are not available. If juvenile population estimates by age class were available, it might have been reasonable to use the estimated survival from age 1 to age 2 as a surrogate for fry survival. Without the preferred empirical survival rate data, we rely on habitat data.

Abundance and survival are believed to be related to the quality of the habitat, particularly off-channel pools, the relative productivity of streams, and the occurrence of potential predators and competitors (Rieman and McIntyre 1993). Studies of other fishes suggest that maximum survival rate of 40% is probably optimistic for this life stage (Rieman and McIntyre 1995).

Table A11: A guess for the variable (input node) maximum fry survival for each used and potential nursery area accessible to Yale Lake or Lake Merwin.

Range of likely Maximum Fry Survival (Proportion of female fry surviving to age 1)	Cougar	Ole/Rain	Swift bypass	Speelyai
10-16%		30%	20%	
16-22%		40%	20%	
22-28%		30%	20%	
28-34%	50%		20%	50%
34-40%	50%		20%	50%

STREAM HABITAT CHARACTERISTICS

Temperatures
Cougar and Speelyai Creeks have consistent temperatures suitable for rearing bull trout, good woody cover (but low substrate cover) and a low likelihood of spates.

Temperatures and the presence of exotics create less favorable situations for young fish in Ole/Rain and the bypass channel. There is a potential for regions of low DO which could reduce survival in some areas. The substrate is diverse in the bypass reach and may provide cover. Spates potentially move the smaller substrates, reducing its value as cover. Woody debris within the wetted summer channel is more limited than in Cougar Creek.

Instream cover
Superior habitat conditions should infer higher survival rates. Extensive off-channel and stream margin habitats and high levels of woody debris will be important for some species. Saffel (1994; Saffel and Scarnecchia 1995) reports that 88% of the young-of-

the-year used channel margins. Unembedded, cobble substrates should be widely available particularly for species in the intermountain area. Unembedded substrate offers the dispersed, visually isolating cover juvenile bull trout need (Pratt 1984). In many bull trout habitats winter flows are relatively stable, and groundwater minimizes ice, so unembedded cover is a relatively secure habitat. In the winter juvenile bull trout have been found as much as 10 cm below the substrate in unembedded areas (Bonneau 1994).

Low fry survival rates are likely in systems where early rearing habitats are not widely distributed, or cover is not available for small fish. Channel instability can result in reduced suitable cover for bull trout fry. This instability might be expressed in the channel as highly embedded substrates, particularly where alternative cover is lacking. There are no data that evaluate mortality of fry when discharge is high enough to move the substrate. We might assume that the fry are able to respond by moving and escape being crushed. On the other hand, if flows changed abruptly (as it might when spill occurs) and at a time of year when their metabolic rate is low (such as winter) it may be difficult to evacuate locations deep within the substrate.

Dissolved oxygen

The response of bull trout to dissolved oxygen has not been carefully investigated. However we have data for other char that might provide some insight into likely responses by bull trout. DO level and its rate of fluctuation appear to impact char in terms of distribution, growth rate and survival (Shepard 1955; Martin and Olver 1980).

Juvenile char (lake trout) avoid areas with dissolved oxygen levels around 4 mg/L and use areas where DO was >5 mg/L, (and usually 6.5-9.5 mg/L) throughout the summer (Martin and Olver 1980) The median threshold avoidance for adult lake trout seems to be 4.2 mg/L (Evans et al 1991). It has been suggested that the dissolved oxygen level should be at least 5.5 mg/L to protect lake trout at all life stages. Some authors use a lower oxygen limit of 4 mg/l for usable habitat, and 6 mg/L for optimum lake trout habitat (Ryan and Marshal 1994).

The fluctuation of oxygen levels impacts juvenile char growth. Juvenile brook trout exposed to constant oxygen levels grew faster than those in fluctuating oxygen levels (Ryan and Marshal 1994). At temperatures of 8.4-11.7 C, oxygen fluctuations (from 11mg/l to 5.3 mg/l to 3.6 mg/l and 3.5 mg/L) depressed the growth of yearling brook trout and most fish were unable to tolerate fluctuations of over 2.0 mg/L.

The interaction between temperature and oxygen needs at the upper limit of bull trout temperature requirements is likely to impact competitive interactions between individual bull trout and brown trout. The consumption of oxygen is related to temperature and activity. All chars have an activity optimum (i.e. maximum cruising speed) well below their UILT (upper incipient lethal temperatures). This is not the case for the brown trout, or rainbow trout; they exhibit a continuous rise in cruising speed as fish approaches lethal temperatures (Beamish 1964).

Dissolved oxygen levels are adequate for survival in the bypass reach, and lower Speelyai Creek. (PacifiCorp & Cowlitz PUD 2002b - AQU-9; PacifiCorp & Cowlitz PUD-AQU-12). In contrast, low dissolved oxygen levels (44%, 4.4 mg/l) have been reported for the Ole/Rain site when surface water exists during the low flow period, when temperatures are relatively warm (PacifiCorp & Cowlitz PUD-AQU-12 pg 11). Augmented flows may improve the oxygen in Ole/Rain. There is a chance that 20% diel change in oxygen levels might reduce the growth rates of juvenile char using the augmented flows in the by pass reach and the newly oxygenated Ole/Rain site or (PacifiCorp & Cowlitz PUD 2002b AQU-9 pg 16). This seems like a small risk, unless brown trout or rainbow trout predators are present.

PREDATION

Other native fishes, exotic fish species, birds, mammals and other bull trout can all prey upon small bull trout. When exotic species that either act as predators, or may compete for space and food, occur within the watershed, low young-of-the-year survival is likely. If the exotics are (or could be), widely distributed the problem is exacerbated. If restricted to a relatively minor portion of the watershed, unused by bull trout, their impact would be less. The predacious exotics in stream habitats in the Lewis River basin include brook trout, and brown trout. Rainbow trout and coho enhancement programs are either currently active or proposed. More information about the distribution of these fishes compared to bull trout young-of-the-year distribution should be collected and considered..

FOOD

I did not review the availability of juvenile foods in the four potential nursery sites available for Yale/Merwin fish.

FEMALE PARR 1+ CAPACITY

Parr are defined as age 1+ fish. For bull trout this usually refers to individuals that are 75-120 mm (Shepard et. al 1984).

The availability of habitat critical to early rearing and overwinter survival can limit the ultimate size of a population. Such habitats may be restricted in availability or distribution. High parr capacity refers to habitat capable of supporting more than 7,000-10,000 age 1 fish (Lee et. al 2000). The presence of exotics can reduce the habitat's capacity to rear bull trout through competition for food and space.

Suitable data, such as juvenile density data, unembedded substrate surface area, or age class population estimates, were unavailable for predicting par at any of the potential or used nursery sites accessible to Yale Lake. Therefore the best guess is the default of equally weighted categories.

Table A 12: A guess of the variable (input node) <u>parr capacity</u> for each nursery area accessible to Yale Lake.

Likely parr capacity Maximum abundance of female parr	Cougar	Rain/Ole	By-pass Channel	Speelyai
1,000-4,000	33.3%	33.3%	33.3%	33.3%
4,000-7,000	33.3%	33.3%	33.3%	33.3%
7,000-10,000	33.3%	33.3%	33.3%	33.3%

A few examples of strategies to obtain parr capacity estimates, if data were available, follow.

- The literature offers several ways to get a general idea of parr capacity. One way is to estimate the amount of unembedded substrate in streams with suitable temperatures. Leathe and Enk (1985) present a numerical relationship between a substrate score and the density of >75mm bull trout. The substrate score is a combination of 6 particle size classifications and 5 embeddedness classifications.

- One estimator is juvenile density times stream space. This assumes that densities available by size class and that bull trout in the study area exhibit the same size at age trends as show in the literature. It also assumes that there is a way to determine suitable habitat for parr. Lee et al. (2000) estimates usable space (based on elevation of the stream reach) and then multiply by the maximum observed densities of age-1 bull trout reported in the literature, 14-20/100 m^2 (Platts and Partridge 1983, Pratt 1984, Goetz 1989, Goetz 1997). They then compare the maximum densities to the site-specific densities for the population in question. Even at maximum capacity, juvenile bull trout will not exceed 20/100 m^2, and will probably be present at much lower densities. Thus, even if habitats within the subject stream were in highly productive condition, the area is so small that we cannot expect it to support more than the smallest category of parr capacity offered in the BayVam model (<4,000 fish).

- Paul et al. (2000) provides a habitat capacity model of survival and intercohort interactions. They suggest that annual age-1 and age-2 bull trout survival can be related to an index of total consumption, implying a density dependent effect. This appears to be an inter-cohort interaction (predation) model. The use of this tool is not possible with the data currently available for the Lewis River basin.

<u>JUVENILE ANNUAL SURVIVAL</u>

Juvenile survival of females has an important influence on the structure of salmonid populations, influencing year-class strength and resilience. Survival from age 1 to adult includes fish that are >75 mm living in either streams or lake type environments, making

the range of considerations quite substantial. This model entry represents annual survival rates experienced by fish for 3-5 years, possibly in multiple environments.
Without any juvenile data for the Lewis River basin, it might be wise to use the default values until some reason can be found to change the values shown (Table A 13).

Table A13. A guess for the variable (input node) juvenile survival for the used or potential nursery sites accessible to Lake Yale bull trout.

Likely juvenile survival rates	Cougar Creek	Bypass Channel	Rain/Ole	Lower Speelyai
15-21%	14.3%	14.3%	14.3%	14.3%
21-27%	14.3%	14.3%	14.3%	14.3%
27-34%	14.3%	14.3%	14.3%	14.3%
34-41%	14.3%	14.3%	14.3%	14.3%
41-48%	14.3%	14.3%	14.3%	14.3%
48-54%	14.3%	14.3%	14.3%	14.3%
54-60%	14.3%	14.3%	14.3%	14.3%

Few estimates of bull trout sub adult survival exist in the literature. Some estimates are hard to interpret as they include exploited migratory populations. For instance, Pratt (1985) estimated that total annual mortality (including fishing mortality) for sub adult adfluvial bull trout ranged from 47%-82% (survival rates of 18%-23%). WWP (1996) reports a low annual survival rate of 18-23% for juveniles in stream habitats. The combined survival of young -of- the-year and older fish described by Bonneau et al. (1995) suggests overwinter survival rates of about 40%.

Juvenile bull trout have not been effectively sampled in nursery sites on the Lewis. Interpretation is not possible from so little data. Generally juvenile densities and length frequencies in nursery sites can provide some data for guidance. Some emigrating juveniles from the North Fork Lewis/Swift Creek Reservoir population have been collected in a screw trap (Lesko 2003). Graves (1982) provides a little observational data for a few small individuals from stream habitats associated both Swift and Yale pools.

No data exist for this variable, however the relative survival of juveniles in Merwin will likely be lower than the survival of juveniles in Yale Lake. There is a rather effective predator in Lake Merwin, the tiger muskellunge. This is a predatory exotic species introduced by the state of Washington as a sport fish. Tiger muskellunge survive well enough in Merwin to appear in the electroshocking samples for 1997 and 1998 (Hillson and Tipping 1999). Tiger muskellunge are active under summer temperature regimes not preferred by bull trout. Nonetheless the reservoir is homothermous a large part of the year eliminating potential thermal barriers. There are also large numbers of large northern pike minnows in Lake Merwin. Some people believe they also prey upon bull trout; I am less concerned as bull trout evolved with pike minnows and likely have some ability to survive in the presence of this species.

AGE AT FIRST MATURITY

Age of first maturity, and longevity will influence potential reproduction and growth rate of a population, and its resilience to exploitation and disturbance. This variable is concerned only with the age at first maturity.

There is no reason to think that age at first maturity would vary for bull trout dispersing from Yale Lake to new nursery sites. Given the uncertainly of the data, modeling should presume a portion of the population matures for the first time as age 4, 5, or 6. The relationship between age and length composition would be useful to refine our understanding of the production potential. A discussion follows to provide some detail for discussion.

Site specific data is the best determinant of expected age of maturity but useful approximations are possible from the literature. Populations with similar growth and migration trends usually have similar maturity schedules (Lee et. al 2000). Most bull trout mature at age 4, 5 or 6 (Shepard et al 1984; Pratt 1985). In the Flathead basin the majority of the population matured as 5 and 6 year olds, mature 4 year olds were rare (Shepard et al 1984). In the Pend Oreille system maturation at age 4 and 5 was more common than age 6 (Pratt 1985). Resident bull trout may mature with a similar schedule, although they would be much smaller individuals at maturity. For example, the Methow River basin about 20% of the resident bull trout population matured at age 5 and 80% at age 6 (Mullan et. al 1992).

Site-specific information refining this variable will have a large impact on the usefulness of the model because this variable has a large impact on population growth and resilience. The only source of age data in the Lewis basin is from Graves (1982). Based on the data table on page 55 and page 88, I suspect her aging missed at least the first annulus, and in some cases the first 2 annuli. The youngest fish from Yale Lake were 152-178 mm and listed as 0+ fish. I interpreted the 0+ as an abbreviation as a young-of-the-year classification. This would be extraordinary growth in a stream habitat. The youngest fish were 110-150 mm in Swift, and also called 0+. This would also be unusually rapid growth for young-of-the-year.

A more typical scenario for bull trout would be that young-of-the-year were <90-100mm and that the 110-150 individuals were 1+ and the 150 – 178 mm fish were 2 +. My tendency is to assume she was consistent in her techniques but that she underestimated ages. However there is a possibility that the Lewis River fish exhibit very different rates of growth in the early years and that this somehow impacts age at first maturity. I recommend that old scale samples be re-examined or new age data collected.

At this time there is no reason to think that age at first maturity would vary for bull trout dispersing from Yale Lake to new nursery sites. I recommend an age at first maturity typical to the species until basin specific data to the contrary can be confirmed. Modeling could presume a portion of the population matures for the first time as age 4, 5, or 6 (Table A14).

Table A14: A guess for the variable (input node) age at first maturity for the Yale/Merwin population.

Likely Age at First Maturity Average age of female maturity	Yale/Merwin
Age 3	0%
Age 4	20%
Age 5	60%
Age6	20%

ADULT SURVIVAL

Annual survival refers to the years during and following the year of first maturity. Adult bull trout may spawn several times during their lifetime.

Prior to the ESA listing, exploitation was one of the annual survival considerations and adults of migratory bull trout stocks were commonly harvested. With a few exceptions, legal bull trout harvest is no longer permitted in their native range. In the Lewis harvest has been prohibited since 1992. Some hooking mortality occurs when bull trout are in the by-catch. Unintentional harvest is likely to occur due to misidentification of the species. Some harvest likely occurs as poaching.

Without harvest considerations, survival should be fairly high when habitat conditions provide abundant food and cover for adult fish (post maturity) throughout the year. In the Lewis River system the adults return to a reservoir where we assume they can seek optimum temperatures, have sufficient oxygen and food is relatively abundant for this piscivorous species.

The only local data concerning adult mortality is an estimate of river otter mortality. Known predation accounted for 14-16% mortality of observed spawners in Cougar Creek. (Gene Stagner, USFWS 2003, pers. comm.; based on WDFW comments on LoCoBT recovery plan). This would not be unusual and is reported in other areas (Chandler 2001).

I did not look for reservoir differences that might impact adult survival rates, because the objective of this work is the comparison of potential nursery sites. However, there are some issues of note making Merwin less desirable (Table A15). For instance, Lake Merwin has a population of an exotic predator, known for its voracious appetite, versatile diet and rapid rate of growth, the tiger muskellunge; this species in not present in Yale Lake. Early research in Lake Merwin (late 1930's) notes that the bottom can be anoxic, typical benthos is not present and the water was relatively warm at 100 ft (Smith 1943); the current conditions in Lake Merwin should be examined.

Table A15: A guess for the variable (input node) adult survival rate for Lake Merwin and Yale Lake.

Likely Adult female survival rate assuming annual spawning	Yale Lake	Lake Merwin
15-30%	0%	25%
30-45%	60%	50%
45-60%	40%	25%
60-75%	0%	0%
75-90%	0%	0%

IMMIGRATION

Immigration is a measure of the ability of the populations to mix. Physical barriers, migratory habits, and genetics data influence our perception of stock mixing. Some level of immigration allows a population to persist in small numbers for a long time.

The prevalence of bull trout in the canal implies that some downstream drift occurs. Spill might permit more mixing. Interpretations of genetic data vary from one fish every five years maintaining diversity (Jeff Chan, USFWS, 2003, personal communications), to a suggestion of very little drift as there is an allele present in the upstream population that appears very rarely downstream. This variable should be examined through mathematical gaming. Certainly the assumption that the new habitats will be colonized assumes that some immigration occurs to those sites (Table A16). The genetic diversity in Cougar Creek despite its small population also implies drift (Table A16).

Table A16: A guess for the variable (input node) risk of catastrophe for each of the four potential or used nursery sites accessible to Yale Lake

Likely immigration	Cougar Ck	By pass	Ole/Rain	Speelyai
Zero				
1-6 individuals annually	100%	100%	100%	100%
7-13 individuals annually				
14-20 individuals annually				

RISK OF CATASTROPHE

This variable indicates the likelihood of an event that would reduce the fish population numbers substantially. Small populations that use restricted areas are particularly vulnerable to catastrophic events as extinction becomes more likely. Table A17 offers one perception of the four sites in question.

Table A17: A guess of the variable (input node) risk if catastrophe for each potential or used bull trout nursery site accessible to Yale Lake.

Range of likely Risk of Catastrophe	Cougar Creek	Rain/Ole Creeks	Bypass Channel	Lower Speelyai
120-170 years	33%	0%		33%
70-120 years	34%	50%		34%
20 - 70 years	33%	50%	100%	33%

There are two types of impacts in a catastrophe. First the population is at risk through the event itself. Second the population is likely to be less resilient and therefore at greater risk to some future disturbance due to a combination of reduced popuatlion and reduced habitat capacity.

High catastrophic potential would be appropriate where a half or more of the population could be lost in a single event expected within 20 to 70 years.

CV OF JUVENILE SURVIVAL

The model assumes temporal variability in the population results from fluctuations in juvenile survival. Time series data required for estimating this variable is rarely available. Therefore it is recommended to leave the default values in the model.

High temporal variability is expected where year-class failures are common, such as in the bypass channel. Discharge records imply year class losses 3 out of 10 years from rain-on-snow events and the associated high spill.. Such populations would often show uneven distribution of age classes. Extreme flow events (rain on snow, drought) or bedload scour might be common.

High variability in year class strength can also occur when there is only one tributary stream available for any life stage (such as the Cougar Creek -Yale Lake situation). This is particularly a problem when extreme events are likely. In the case of a small watershed with primarily ground water flow, such as Cougar Creek, a catastrophic event would more likely be a landslide than a severe flood event.

In a low CV situation there should be no evidence or expectation of year class failures, and all age classes would be fully represented in population samples. Low temporal variability might be inferred from low variability in channel events that likely influence spawning and incubation (such as constant discharge or constant suitable temperature). Complex habitats and spatial diversity of habitats should reduce temporal variability (as in Cougar Creek). Migratory stocks generally have the stabilizing advantage that there are refuges and multiple nursery sites over a broad area (the Yale population does not currently have this advantage). The presence of multiple productive nursery sites would reduce the vulnerability of the entire population to localized disturbance.

APPENDIX - B - CITATIONS

Adams, S. B. 1999. Mechanisms limiting a vertebrate invasion: Brook tout in mountain streams of the Northwestern USA. PHD. University of Montana. Missoula, Montana. 221 pgs.

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