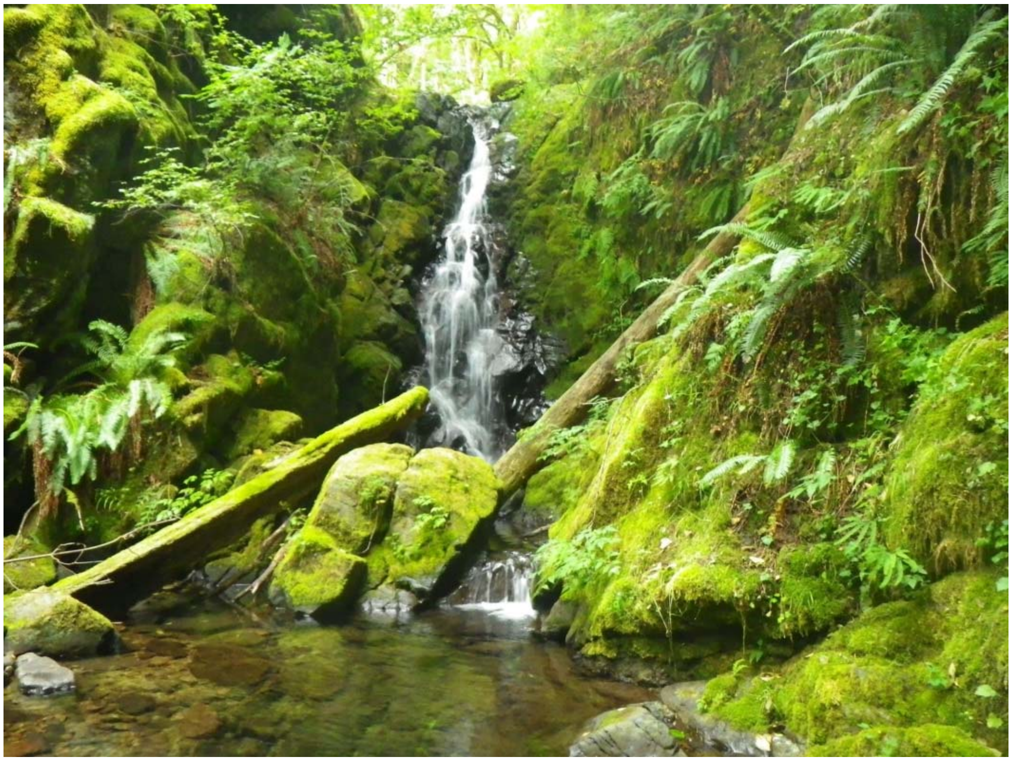
# Lewis River Hydroelectric Projects

*FERC Project Nos. P-2111, P-2213, P-2071 and P-935*



## *New Information Regarding Fish Transport into Lake Merwin and Yale Lake*

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Prepared for

PacifiCorp

June 24, 2016

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*FERC Project Nos. P-2111, P-2213, P-2071 and P-935*

***Prepared by:***

PACIFICORP

June 24, 2016

## 1.0 Introduction

This executive summary prepared by PacifiCorp and the Public Utility District No. 1 of Cowlitz County, Washington ("Cowlitz PUD") is for the National Marine Fisheries Service and the U.S. Fish and Wildlife Service (collectively the "Services"), Federal Energy Regulatory Commission (FERC) and the Lewis River Settlement Agreement Parties in consideration of article 4.1.9 *Review of New Information Regarding Fish Transport into Lake Merwin and Yale Lake* and 7.6 *In Lieu Fund* of the Lewis River Settlement Agreement (SA), the Services Section 18 Reservation of Authority per Swift No. 1, Yale and Merwin project FERC licenses, and licenses' article 401 (b) Requirement to File Amendment Applications. It has been prepared in consultation with the Aquatic Coordination Committee members. Comments from committee members on draft documents are presented in **Appendix E**.

### 1.1 Background

Located on the North Fork of the Lewis River in southwestern Washington, the Lewis River Hydroelectric System consists of four operationally coordinated projects (**Figure 1**). PacifiCorp owns the Swift No. 1 (FERC No. 2111), Yale (FERC No. 2071), and Merwin (FERC No. 935) projects which together generate 536 MW of electricity at full capacity. Cowlitz PUD owns the 82 MW Swift No. 2 Project (FERC No. 2213) which lies between the Swift No. 1 and Yale projects. Currently, PacifiCorp operates Swift No. 2 for Cowlitz PUD under contract.

#### 1.1.1 Lewis River Settlement Agreement

In response to the FERC relicensing of the hydroelectric projects, interested parties collaborated on establishing a settlement agreement concerning future operations and responsive protection, enhancement and mitigation measures. On November 30, 2004, (Effective Date) 26 Parties (including two Licensees, five federal agencies, two state agencies, eight local/county agencies, two tribes, two citizens-at-large, and five non-governmental organizations) signed the Lewis River Settlement Agreement (PacifiCorp and Cowlitz PUD 2004). In December 2004, the Licensees filed with the FERC the Lewis River Settlement Agreement along with a Joint Explanatory Statement and Supplemental Preliminary Draft Environmental Assessment (PacifiCorp and Cowlitz PUD 2004). The settlement agreement reflects the interests of all Parties; provides significant investments in fish and aquatic resources, wildlife and recreation; includes monitoring and evaluation and adaptive management; and includes ongoing coordination with the Parties through the Aquatics and Terrestrial Coordination Committees. The settlement agreement included support for 50-year licenses to allow the projects to continue to provide benefits to the Utilities' customers.

#### 1.1.2 Agency Terms and Conditions

The US Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) filed fishway prescriptions February 22, 2006 and February 14, 2006, respectively.

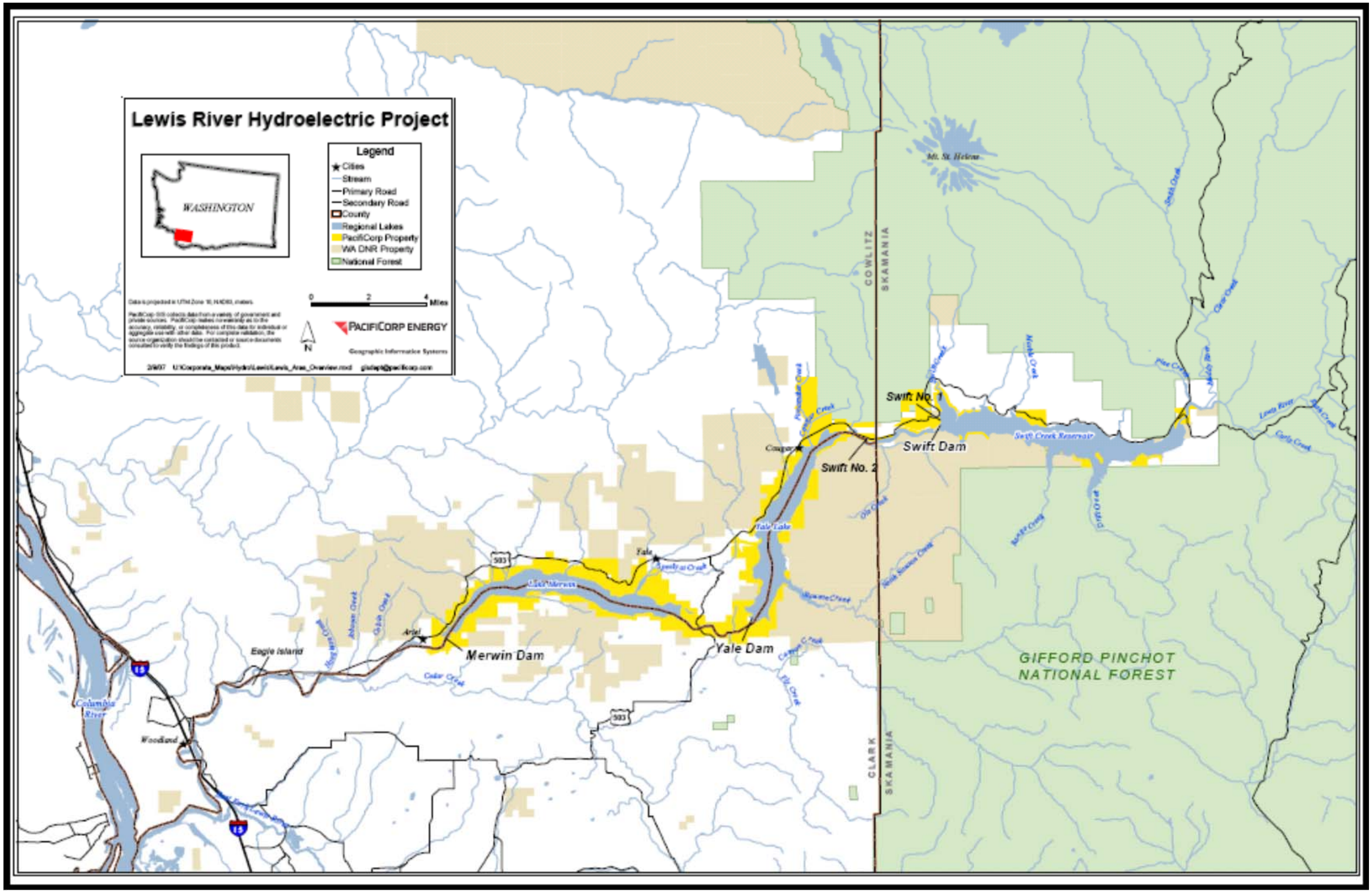

Figure 1. Map of the Lewis River Project area

### 1.1.3 Endangered Species Act Consultations

In January 2005, Cowlitz PUD and PacifiCorp filed with the FERC Biological Evaluations (BEs) covering federally listed fish and wildlife in the Lewis River basin ((PacifiCorp and Cowlitz PUD 2005a, PacifiCorp and Cowlitz PUD 2005b). The FERC modified the BEs, included them in the Final Environmental Impact Statement and submitted the documents to the Services. The Proposed Action in the BEs is the SA. On September 15, 2006, the USFWS issued a Biological Opinion covering bull trout, northern spotted owls and bald eagles. The National Marine Fisheries Service issued its Biological Opinion covering their respective listed species on August 27, 2007.

### 1.1.4 New FERC Licenses

On June 26, 2008, the FERC provided the utilities with new operating licenses for the Lewis River hydroelectric projects (Merwin Project No. 935, Yale Project No. 2071, Swift No. 1 Project No. 2111, and Swift No. 2 Project No. 2213). The license periods are each 50 years effective June 1, 2008. Each license includes the respective conditions of the Services biological opinions and respective conditions of the Washington Department of Ecology 401 certificates. In general, the licenses include terms of the Lewis River Settlement Agreement with few exceptions. Parties to the Lewis River Settlement Agreement continue to abide by the SA terms including those terms outside the FERC requirements.

## 1.2 Lewis River Settlement Agreement conditions relative to reintroduction of anadromous salmonids into Yale and Merwin Reservoirs

As noted in Section 3.1 of the Lewis River Settlement Agreement, the anadromous fish reintroduction outcome goal "is to achieve genetically viable, self-sustaining, naturally reproducing, harvestable populations above Merwin dam greater than minimum viable populations". Within the SA the utilities will make significant investments into a salmon and Steelhead reintroduction program. These include a suite of anadromous fish protection and restoration measures and actions implemented over a phased approach. To date, constructed facilities include the Merwin Upstream Fish Collector, three upper basin juvenile fish acclimation ponds and the Swift Downstream Fish Collector. A juvenile fish release facility located in Woodland, Washington is scheduled to be constructed in 2017. Additional program phases identified in the SA and subsequent FERC licenses require the construction and operation of the following future fish passage facilities:

- Downstream Passage at Yale Dam (SA article 4.5)
- Downstream Passage at Merwin Dam (SA article 4.6)
- Upstream Passage at Yale Dam (SA article 4.7)
- Upstream Passage at Swift Projects (SA article 4.8)

There is also the specific opportunity to consider an In Lieu Fund as an alternative to future fish passage facilities (Yale downstream, Merwin downstream, Yale upstream and Swift upstream). This opportunity is expressly granted in Section 4.1.9 of the Lewis River Settlement Agreement.

*4.1.9 Review of New Information Regarding Fish Transport into Lake Merwin and Yale Lake.*

*a. The Licensees shall construct and provide for the operation and maintenance of both upstream and downstream fish collection and transport facilities at each of Merwin Dam, Yale Dam, and the Swift Projects as provided in the schedule in this Agreement unless otherwise directed by the Services pursuant to this Section. New Information (defined below) relevant to reintroduction and fish passage into Yale Lake or Lake Merwin may be available to the Services that may influence the implementation of fish passage into and out of these reservoirs, or that could result in the Services determining that reintroduction or fish passage for anadromous fish is inappropriate. If the Services conclude upon review of the New Information that one or more of the passage facilities should not be constructed, in lieu of designing, permitting, constructing, and operating the passage facility, PacifiCorp shall provide additional funds for projects in lieu of fish passage, as set forth in Section 7.6. In this event, the Licensees shall also implement the bull trout passage measures as set forth in Section 4.10. The adult upstream fish passage facility at Merwin and juvenile downstream collector at Swift No. 1 are not subject to this review.*

*b. Upon receipt and review of New Information relevant to reintroduction and fish passage from any party, the members of the ACC may provide written comments to the Services regarding such New Information. Such comments shall be provided to the Services no later than five years prior to the date that PacifiCorp and/or Cowlitz PUD is to begin operating the relevant passage facility. If any New Information and comments are submitted to the Services, then approximately four and a half years prior to the date that PacifiCorp and/or Cowlitz PUD is to begin operating the relevant passage facility, the Licensees shall convene a meeting of the ACC for the purpose of discussing the New Information and comments. At such meeting, the Licensees shall solicit and obtain the Services' response to the New Information and related comments, unless the Services have provided the results of their review to the ACC earlier. If the Services have concluded that one or more of the passage facilities should not be constructed, then within 60 days after the meeting of the ACC, the Services shall advise the ACC in writing of such conclusion.*

*c. For purposes of this section, "New Information" is defined as information relevant to anadromous fish reintroduction and fish passage, including that presented by any Party, and provided to the Services and the Licensees. The Licensees must provide copies of such New Information to all the members of the ACC. This information may include, but is not limited to:*

> *(1) Experience with upstream fish collection and transport facilities at other sites, including Merwin Dam.*
>
> *(2) Experience with downstream fish collection facilities at other sites, including Swift No. 1 Dam.*
>
> *(3) Experience with the reintroduction*

*efforts of spring Chinook, coho, and steelhead above Swift No. 1 Dam.*

*(4) Consideration of broader contextual information beyond the Lewis River Basin, including regional anadromous fish recovery efforts.*

*d. The Licensees shall inform the Commission of any determination by the Services that one or more of the fish collection and transport facilities should not be constructed. In this event, PacifiCorp shall provide additional funds for projects in lieu of fish passage, as set forth in Section 7.6.*

As expressed in Section 4.1.9 (d) above, in the event the Services determine fish collection and transport facilities should not be constructed, the following Section 7.6 of the Lewis River Settlement Agreement would apply.

*7.6 In Lieu Fund. If NOAA Fisheries and USFWS determine, pursuant to Section 4.1.9, that reintroduction of anadromous salmonids into Yale Lake or Lake Merwin is not required, and if as a result of such determination one or more of the Merwin Downstream Facility, Swift Upstream Facility, and the Yale Upstream and Downstream Facilities are not designed, permitted, constructed, and operated, then PacifiCorp shall establish the "In Lieu Fund" to support mitigation measures for anadromous salmonids in lieu of passage. The In Lieu Fund shall be a Tracking Account maintained by the Licensees, with all accrued interest being credited to the In Lieu Fund. PacifiCorp shall provide funds according to the schedule set forth below.*

*7.6.1 PacifiCorp's Contributions.*

*a. PacifiCorp shall provide the following sums to the In Lieu Fund: $10 million in lieu of a juvenile surface collector at Yale Dam; $10 million in lieu of a juvenile surface collector at Merwin Dam; $5 million in lieu of an upstream adult fish passage facility at Yale; and $5 million in lieu of an upstream adult fish passage facility in the vicinity of the Swift Projects.*

*b. PacifiCorp shall allocate funds in lieu of the Yale Downstream Facility as follows: $3 million on each of the 11th and 12th anniversaries of the Issuance of the New License for the Yale Project, and $4 million on the 13th anniversary of the Issuance of the New License for the Yale Project. PacifiCorp shall allocate funds in lieu of the Merwin Downstream Facility as follows: $2.5 million on each of the 14th through the 17th anniversaries of the Issuance of the New License for the Merwin Project. PacifiCorp shall allocate funds in lieu of the Swift Upstream Facility as follows: $1.25 million on each of the 14th through the 17th anniversaries of the Issuance of the New License for the Swift No. 1 Project. PacifiCorp shall allocate funds in lieu of the Yale Upstream Facility as follows: $1.25 million on each of the 14th through the 17th anniversaries of the Issuance of the New License for the Yale Project. Funds shall be available for expenditure as soon as the decisions not to build the respective facilities are final* *and not subject to further review; provided that if any review delays the expenditure of In Lieu Fund monies for an extended period, the ACC will consult to discuss the delay and whether to propose an alternate course of action. PacifiCorp shall not be obligated to both spend In Lieu Funds and build the respective facilities.*

Context for the related sections is best provided through language in the settlement agreement Joint Explanatory Statement Section 3.2.6 Funding In Lieu of Passage.

*The Parties recognize that new information may become available to the Services prior to implementing the passage of anadromous fish into Yale Lake and/or Lake Merwin. This information could lead the Services to determine that fish reintroduction at one or both of these reservoirs is inappropriate. In that event, the Settlement Agreement calls for PacifiCorp to provide funding up to $30 million in lieu of construction of the respective passage facilities for use in achieving equivalent or greater benefits to anadromous fish populations as would have occurred if passage through Yale Lake and/or Lake Merwin had been provided. Emphasis for the use of these funds would be first placed on benefiting anadromous fish of the North Fork Lewis River, and if those opportunities are exhausted, then would be used to benefit other populations in the applicable ESUs. The list of potential projects in Schedule 7.6.2 of the Settlement Agreement illustrates projects in both the North Fork and East Fork of the Lewis River that would qualify as mitigation measures under the In Lieu Fund, for example:*

*Improve fish passage through identification and removal of diversions on Cedar Creek and other tributaries;*

- *Increase functional Large Woody Debris structures in appropriate stream reaches;*
- *Reconnect, enhance and restore degraded habitat and wetland areas;*
- *Fence livestock and control farm run-off.*

*Through this provision of the Agreement, the projects' impacts on anadromous fish migration in the basin will continue to be mitigated to achieve the Parties' overarching biological and ecological goals of restoring and enhancing fish populations to achieve viable, sustainable and harvestable levels of fish.*

Should the In Lieu Fund be selected, the SA sets forth requirements for the development of a strategic plan and administrative procedures to guide implementation of the In Lieu Fund (see Lewis River Settlement Agreement Sections 7.6.2 and 7.6.3), fund management (Section 7.7), reporting of fund activities and expenditures (Section 7.7.1), cost associated with management of Fund (Section 7.7.2), escalation of costs (Section 7.7.3) and execution of projects and mitigation measures (Section 7.8). Section 4.10 of the agreement would also be placed into effect.

*4.10.1 Yale and Merwin Downstream Bull Trout Facilities. If, pursuant to Section 4.1.9, PacifiCorp does not build the Yale Downstream Facility described in Section 4.5, then PacifiCorp, on or before the 13th anniversary of the Issuance of the New License for the Yale*

*Project, shall construct and provide for the operation of a downstream bull trout collection and transport facility in the Yale forebay (the "Yale Downstream Bull Trout Facility").*

*If, pursuant to Section 4.1.9, PacifiCorp does not build the Merwin Downstream Facility described in Section 4.6, then when USFWS determines that bull trout populations have increased sufficiently in Lake Merwin, but not sooner than the 17th anniversary of the Issuance of the New License for the Merwin Project, PacifiCorp shall construct and provide for the operation of a passage facility similar to the Yale Downstream Bull Trout Facility at Merwin Dam (the "Merwin Downstream Bull Trout Facility").*

*The Yale and Merwin Downstream Bull Trout Facilities shall be similar in magnitude and scale to modular floating Merwin-type collectors and are not intended to be passage facilities of the same magnitude and expense as the Yale Downstream Facility and the Merwin Downstream Facility described in Sections 4.5 and 4.6 (recognizing that monies shall be contributed to the In Lieu Fund described in Section 7 below in lieu of constructing those passage facilities). PacifiCorp shall provide for monitoring of performance as provided in Section 9, and make necessary and appropriate Facility Adjustments and Facility Modifications to the Yale and Merwin Downstream Bull Trout Facilities, in Consultation with the ACC and with approval of USFWS, to achieve relevant performance standards as provided in Section 4.1.4 above, provided that such modifications shall not require installation of a different type of passage facility. PacifiCorp shall provide preliminary (30%) designs to the ACC for the Yale and Merwin Downstream Bull Trout Facilities within 12 months after the Services' determination under Section 4.1.9. PacifiCorp shall follow the provisions in Sections 4.1.1 through 4.1.3 when developing designs for the facilities. Pursuant to Section 15.14, PacifiCorp shall submit final designs to the Commission upon approval by USFWS, subject to Section 15.14, but not later than 60 days after submission of the final design to USFWS.*

*4.10.2 Yale and Swift Upstream Bull Trout Facilities. If (1) pursuant to Section 4.1.9, the Licensees do not build the Swift Upstream Facility, and (2) USFWS determines on or before the 13th anniversary of the Issuance of the New License for the Swift No. 1 Project or the Swift No. 2 Project, whichever is later, that collect-and-haul methods established under Section 4.9.1 or 4.9.2 are not meeting bull trout performance standards provided in Section 4.1.4, then on or before the 17th anniversary of the Issuance of the New License for the Swift No. 1 Project or the Swift No. 2 Project, whichever is later, the Licensees shall complete construction of and provide for the operation of alternate passage facilities (the "Swift Upstream Bull Trout Facility").*

*If (1) pursuant to Section 4.1.9, PacifiCorp does not build the Yale Upstream Facility, and (2) USFWS determines on or before the 17th anniversary of the Issuance of the New License for the Yale Project that collect-and-haul methods established under Section 4.9.1 or 4.9.2 are not meeting bull trout performance standards provided in Section 4.1.4, then on or before the 17th anniversary of the Issuance of the New License for the Yale Project PacifiCorp shall complete construction of and provide for the operation of alternate passage facilities (the "Yale Upstream Bull Trout Facility").*

*The Yale and Swift Upstream Bull Trout Facilities are not intended to be passage facilities of the same magnitude and expense as the Yale Upstream Facility and the Swift Upstream Facility described in Sections 4.7 and 4.8 (recognizing that monies shall be contributed to the In Lieu Fund described in Section 7 below in lieu of constructing those passage facilities). PacifiCorp (for Yale) and the Licensees (for Swift No. 2) shall select an alternative passage facility design for the Yale and Swift Upstream Bull Trout Facilities, in Consultation with the ACC and with the approval of USFWS, and PacifiCorp (for Yale) and the Licensees (for Swift No. 2) shall construct and provide for the operation of such passage facilities for the remaining term of the respective New Licenses. The Licensees shall follow the provisions of Sections 4.1 through 4.1.3 as applicable when developing designs for the facilities.*

*PacifiCorp shall monitor performance of the Yale Upstream Bull Trout Facility as provided in Section 9, and make necessary and appropriate Facility Adjustments and Facility Modifications to the Yale Upstream Bull Trout Facility pursuant to Section 4.1.6. The Licensees shall monitor performance of the Swift Upstream Bull Trout Facility as provided in Section 9 and make Facility Adjustments and Facility Modifications pursuant to Section 4.1.6 to the Swift Upstream Bull Trout Facility.*

### 1.3 Development of New Information – Consultation with Lewis River Aquatic Coordination Committee

The following is a summary of consultation between PacifiCorp and the Lewis River Aquatic Coordination Committee (ACC).

In November 2011, PacifiCorp gave notice to the ACC representatives that the company would be taking steps to collect new information that would inform the Services' determination if additional fish passage facilities are warranted. In October 2012, PacifiCorp notified the ACC that PacifiCorp had contracted the US Geological Survey Northern Rocky Mountain Science Center to conduct the following:

1. Review information regarding fish transport into Lake Merwin and Yale Lake
2. Habitat assessment of tributaries to Swift Reservoir, Yale Lake and Lake Merwin
3. Assess adult potential for spawning success
4. Assess juvenile production potential and emigration success
5. Evaluate Lake Merwin predator impacts
6. Assess anadromous/resident interactions

These work tasks were vetted by the ACC prior to implementation, and results to-date reported to the ACC June 5, 2014, March 12, 2015, July 9, 2015, August 13, 2015, October 8, 2015, and April 14, 2016.

In May 2015, PacifiCorp informed the ACC that it had contracted Kevin Malone (DJ Warren and Associates) and Dr. Chip McConnaha and Karl Dickman (ICF International) to develop a new Ecosystem Diagnostics Treatment (EDT) model benchmark for the lower Lewis River. This effort would complement the new model benchmark for tributaries to Lake Merwin, Yale Lake and Swift Reservoir.

On December 24, 2015, PacifiCorp invited interested ACC representatives to a meeting to review the inputs and assumptions to be used in development of the Lewis River EDT3 fish production model. Thereafter known as the ACC EDT subgroup, the subgroup conducted four separate meetings (January 21, 2016, February 19, 2016, March 18, 2016 and June 13, 2016). As an outcome of the first subgroup meeting and in support of the EDT3 for the lower Lewis River, PacifiCorp contracted Mason, Bruce and Girard to conduct a review of known aquatic restoration projects completed in the lower Lewis River basin.

On February 11, 2016, PacifiCorp informed the ACC that it had contracted Dr. Phil Roni (Cramer Fish Sciences) to take a larger look at the North Fork Lewis River watershed. Specifically Dr. Roni addressed issues and opportunities related to fish habitat and fish production; what are limiting factors by life stage and habitat type and where might there be opportunities for restoration. At the same ACC meeting, Dr. Roni provided a presentation on his study objectives and tasks (ACC meeting notes and Dr. Roni's presentation is available at):

ACC Meeting Notes:
http://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Hydro/Hydro_Licensing/Lewis_River/li/acc/1142016%20-%20ACC%20FINAL%20Meeting%20Notes.pdf

Dr. Roni's Presentation:
http://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Hydro/Hydro_Licensing/Lewis_River/li/acc/LR_ACC_EDT_presen.pdf

On April 14, 2016, new information presentations were given by Dr. Robert Al-Chokhacy (USGS), Mike Bonoff (Mason, Bruce and Girard), Kevin Malone (DJ Warren and Associates), Dr. Phil Roni (Cramer Fish Sciences), and Jeremiah Doyle (PacifiCorp) to the ACC.

All presentations from the April 14, 2016 ACC meeting are available for viewing on PacifiCorp's Lewis River website at the following link:

http://www.pacificorp.com/es/hydro/hl/lr.html#

- License Implementation
- ACC
- Aquatics Coordination Committee – 2016

On April 26, 2016, PacifiCorp distributed draft versions of this executive summary and study reports to the ACC for a 30-day review and comment period.

On or before May 26, 2016, PacifiCorp received comment from the Lower Columbia Fish Recovery Board (see **Appendix E**).

## 2.0 Current Information

In the process of seeking new federal licenses for the Merwin, Yale and Swift hydroelectric projects, the utilities conducted a number of aquatic studies from 1996 through 2004. Reports of these studies are available on PacifiCorp's Lewis River website at:
http://www.pacificorp.com/es/hydro/hl/lr.html#

- Relicensing Reports
- Aquatics

In addition to relicensing studies and per requirements of the new FERC licenses, PacifiCorp has and continues to implement a number of aquatic resource programs. Each year since 2005, PacifiCorp and the Cowlitz PUD have prepared an Annual Summary of Settlement Agreement Implementation: Aquatic and Terrestrial Resources which presents the annual results of ongoing monitoring and evaluation of Lewis River aquatic resources. The 2015 annual report is available on PacifiCorp's Lewis River website at:
http://www.pacificorp.com/es/hydro/hl/lr.html#

- License Implementation
- Reports

## 3.0 New Information

As previously noted above, a number of New Information studies have been identified and completed to inform the Services regarding the decision of whether additional fish passage facilities should be built and operated at the Lewis River hydroelectric projects or should, and in lieu of new facilities, a fund be established to complete "mitigation measures' (SA section 7.6) (e.g., aquatic habitat restoration, etc.) towards the benefit of the anadromous fish reintroduction outcome goal. The following identifies each New Information study funded by PacifiCorp and provides a short study abstract. Complete individual reports are provided as Appendices to this Executive Summary.

### 3.1 Review information regarding fish transport into Lake Merwin and Yale Lake, US Geological Survey

Study purpose and methods:
Researchers conducted an extensive literature review to assess the effects of smolt acclimation facilities on salmon performance, the effectiveness of downstream and upstream fish collection and passage facilities, the interspecific effects of salmon reintroduction and supplementation on salmonid communities, and the potential effects of native and non-native taxa on anadromous fish reintroduction efforts.

Study results:
Contrasting the juvenile and adult collection operations across locations is challenging given different collection designs, hydrologic conditions, and reservoir bathymetry. Existing studies indicate the benefits of acclimation facilities (survival, stray rates, and residualization) are highly variable, Furthermore, acclimation facilities may not improve overall reintroduction success, particularly as no clear patterns in fitness have been observed.

The success of downstream collection facilities varies by metric and location. Downstream collection injury rates tend to be primarily descaling and mortality rates for target and non-target species are consistently low, a pattern consistent with data collected during the early stages of reintroduction in Swift Reservoir. Collection efficiency, however, is highly variable across species and locations. The variable collection efficiencies are likely driven by ambient abiotic conditions, bathymetric conditions within the reservoir and near the collector, and how fish are guided to the collectors. In Swift Reservoir, the proportion of juvenile salmon collected at the Swift Downstream Collector appears to be relatively low. Juvenile behavior near collection sites often drives such patterns. Recent studies in Swift Reservoir suggest modifications to the netting placement are likely to substantially increase the proportion of juveniles collected, highlighting the need to continue to adaptively modify and reevaluate designs and operations which can yield substantial increases in collections of juveniles and, consequently, the overall numbers of adult returns.

Adult collection facilities commonly report high survival and low injury rates, a pattern consistent with results from the Merwin upstream adult trap. Upstream collection efficiencies are rarely reported in the literature. Overall, collection efficiencies of adults were generally low at the Merwin upstream adult trap (9-62%), but the higher proportion of fish at the trap entrance (22-90%) suggests trap operations may explain the differences with collection efficiency. However, such data are preliminary and may be driven by the anomalous climatic conditions observed in 2015. Continued studies and modifications are needed and planned to improve collection efficiencies.

## 3.2 Habitat assessment of tributaries to Swift Reservoir, Yale Lake and Lake Merwin, US Geological Survey

Study purpose and methods:
Researchers assessed the habitat of tributaries to Swift Reservoir, Yale Lake, and Lake Merwin. In Swift Reservoir, assessments were targeted towards updating habitat information where recent surveys (within the last decade) were not available and/or in tributaries where Coho salmon have been observed during recent reintroductions. In tributaries to Lake Merwin and Yale Lake, researchers conducted surveys to quantify the extent and status of available habitat for potential salmon and Steelhead reintroductions. Information regarding the extent and quality of habitat was subsequently integrated with the Ecosystem Diagnosis and Treatment model for species-specific estimates of production potential in the Swift Reservoir, Yale Lake, and Lake Merwin basins (see study report "Ecosystem Diagnostics Treatment (EDT) model benchmark for the Lewis River", D.J. Warren and Associates and ICF International, **Appendix C**).
Study results:
Tributaries to Lake Merwin contain a limited amount of available spawning and rearing habitat for anadromous salmon (8.2 km/5.1 mi). The strong correlation between habitat availability and salmon population size coupled with extensive predation potential (see study report Evaluate Lake Merwin

predator impact studies, US Geological Survey) together suggest available habitat may limit the likelihood of developing self-sustaining populations within Lake Merwin.

Limitations of the available habitat in tributaries to Lake Merwin appear to be largely natural (i.e., natural geologic features) suggesting opportunities to enhance the capacity in Lake Merwin are limited and suggests little potential for establishing and maintaining viable populations of anadromous fishes in this reservoir. In general, and for most tributaries surveyed, empirical habitat data suggest little evidence that habitat quality will limit anadromous salmon reintroduction. Evidence of habitat degradation appear to be location specific and includes sediment degradation, some thermal constraints during the summer months in tributaries to Lake Merwin and Yale Lake, and riparian degradation.

Information from this study along with other available data can be used to specifically identify factors limiting salmonids in the Swift Reservoir, Yale Lake and Lake Merwin areas and to help quantify potential effectiveness of restoration. Ultimately, assessing the potential for viable populations will require consideration not only of habitat availability, but also biotic interactions between anadromous fishes and extant species.

### 3.3 Assessment of adult potential for spawning success, US Geological Survey

Study purpose and methods:
Understanding the ability of reintroduced anadromous species to successfully reproduce in the tributaries to Yale Lake and Lake Merwin is an essential component of the complete anadromous fish reintroduction program. Under current obligations, anadromous adults will be released into the reservoir systems, and with this, there remains considerable uncertainty in how these fish will sort and utilize available stream habitat. Here, researchers employed a test, releasing adult Coho salmon in the fall of 2014 into Lake Merwin (based on availability of surplus salmon) to evaluate tributary use and potential for recruitment.

Study results:
Researchers observed Coho spawning activity during surveys in Cape Horn Creek, Jim Creek, Indian George Creek, and Brooks Creek. No spawning activity was observed in Buncombe Hollow. However, use of existing tributaries is likely to vary considerably given the lack of natal homing in the test fish used in this study. During 2015 sampling surveys, no juvenile Coho were observed in Jim Creek and Indian George Creeks, but low densities of Coho were observed in Cape Horn Creek and in Brooks Creek. The low densities of juvenile Coho in the tributaries may also be a function of the location of observed redds and the amount of existing habitat. Downstream emigration of Coho fry can be common in streams with limited habitat and locations proximate to larger water bodies. Coho emigration at the fry stage appears to be relatively common in Swift Reservoir as over 18% of the Coho captured at the Swift floating surface collector in 2015 were fry. As such, the low densities of juvenile Coho may not be strong indicators of spawning capacity.

Other research suggests that Coho salmon can utilize a variety of habitats, albeit to varying densities. Such results are supported by the variability of habitats and tributaries utilized by adult Coho in Swift Reservoir (see "Assess anadromous/resident interactions", US Geological Survey, **Appendix A**). Furthermore, the colonization of spatially diverse tributaries indicates finding and accessing habitat is unlikely a limiting factor. Results suggest Coho adults will be capable of finding and accessing a range of habitats in tributaries to Lake Merwin and Yale Lake.

Ultimately, the distribution of spawning coupled with the extent and condition of tributary habitat may lead to increased use of reservoir habitat by juveniles. Early emigration to the reservoir environments may have profound influences on the potential predation of juvenile salmon by existing predators (see "Evaluate Lake Merwin predator impacts", US Geological Survey, **Appendix A**) and reservoir capacity throughout a year (see "Assess anadromous/resident interactions", US Geological Survey, **Appendix A**).

### 3.4 Assess juvenile production potential and emigration success, US Geological Survey

Study purpose and methods:
Given the differences in habitat and resident fishes in each of the Lewis River reservoirs, an important step of anadromous fish reintroduction is to evaluate the survival and behavior of smolts in both stream and reservoir environments. Furthermore, understanding the timing of anadromous species outmigration to reservoirs, particularly as it relates to ambient conditions (e.g., streamflow), will provide critical insight into the strength of these factors relative to intra-annual cycles (i.e., seasons). Due to the lack of anadromous fish currently present in Yale Lake and Lake Merwin, it was necessary to thoroughly evaluate these tasks via assessments in Swift Reservoir in combination with data collected from test smolts in Yale Lake.

Study results:
Data from this study's hydroacoustic surveys in Yale Lake with Coho salmon, previous radiotelemetry studies in Swift Reservoir with Spring Chinook and other studies suggest reservoir travel times to be relatively rapid. Concomitantly, researchers have consistently found considerably longer residence times for wild Coho and acclimation Spring Chinook in Swift Reservoir than observed in study test releases. Study results together with previous movement data suggest difficulties of fish "finding" the entrance to the Swift Floating Surface Collector (FSC), a pattern supported by recent test studies in other systems.

The influence of water temperature on juvenile salmon behavior and collection in trap and haul operations suggest temperatures during July through early September in Swift reservoir may act as a thermal barrier during these months. However, the relative short duration of warm surface temperatures is unlikely to disproportionately explain the low collection rates of juvenile salmon at the FSC. Together, these results highlight the need to consider alternative measures to enhance collection efficiency of the collector, particularly given the lack of understanding of the effects of residualized populations of Coho and Chinook on recovery efforts.

Quantifying how delays in capture at the FSC influence juvenile mortality and factors influencing such delays/capture rates are likely to be important in understanding the anadromous fish reintroduction success. Such information may be particularly important as the proportion of juvenile fish collected at the FSC (across species and data sources-PIT-tags, screw trap, etc.) is generally low when compared to data from similar trap and haul operations (see study report "Review information regarding fish transport into Lake Merwin and Yale Lake", US Geological Survey, **Appendix A**).

3.5 Evaluate Lake Merwin predator impacts, US Geological Survey

Study purpose and methods:
Northern Pikeminnow (*Ptychocheilus oregonensis)* was identified as an abundant predator of juvenile salmon in Lake Merwin in the 1950s and 1960s. The abundance of predatory sized Northern Pikeminnow (≥200 mm) was estimated around 350,000 fish in 1961; however, the population has not since been assessed. Additionally, the Washington Department of Fish and Wildlife began stocking approximately 1,000 Tiger Muskellunge (*Esox masquinongy* x *E. lucius*) annually in 1995 to limit the population of Northern Pikeminnow, but the efficacy of this program has not been formally evaluated. In this study, researchers evaluate the contemporary abundance, diet, growth, and temporal-spatial distribution of Northern Pikeminnow, Kokanee and Tiger Muskellunge to gauge how Northern Pikeminnow might affect populations of reintroduced anadromous salmonids. To achieve this objective, researchers characterized the temporal-spatial dimensions of the thermal environment, food supply, and the distribution, size, age, and diet of key predators and prey, and mapped the overall trophic structure of the food web through stable isotope analysis. Researchers then used these empirical data to inform bioenergetics simulations to estimate the seasonal and size-specific consumption rates and predation impact of Northern Pikeminnow on salmonids and alternative prey fish species.

Study results:
Northern Pikeminnow represent a substantial predation threat to anadromous smolts in Lake Merwin. Size distribution information suggests predation by large Northern Pikeminnow and Tiger Muskellunge on smaller Northern Pikeminnow resulted in an attenuated size structure that likely reduces the overall predation pressure on salmonids. Study simulations indicate that yearly consumption by a population of 1,000 large Northern Pikeminnow would be approximately 16,000–40,000 age–0 Spring Chinook salmon rearing in the reservoir based on their current feeding rate, consumption of resident salmonids, and the size distribution of the population. With a population of over 11,000 adult piscivorous Northern Pikeminnow the overall predation potential appears to be relatively high.

The study's estimate of consumption varies by month, a pattern consistent with previous studies of Northern Pikeminnow predation rates. Study researchers acknowledge, however, that their reported estimates of salmonid consumption may vary as a function of migration timing and reservoir thermal regimes. In Swift Reservoir, hatchery-reared Spring Chinook smolts rapidly emigrate to the reservoir environment (see study report "Assess juvenile production potential and emigration success", US Geological Survey, **Appendix A**) and the median rearing time in the reservoir is approximately two months, but considerable variability in rearing time is possible. For Coho salmon, rearing in Swift reservoir environment has been approximately four months. Despite the longer period of rearing for Coho smolts, estimates of predation by month suggest predation on Spring Chinook is likely to be higher given overlap during the periods of relatively high predation (e.g., spring-early summer). Further, the fact that nearly 30 percent of Chinook are rearing in the reservoir for more than nine months suggest the exposure to Northern Pikeminnow predation may be relatively high. Continued monitoring of reservoir rearing as FSC collection efficiencies improve will ultimately provide further insight into the likelihood of predation for fish with varying periods of reservoir rearing. Ultimately, considering such predation rates in the context of robust productivity measures will provide key insights into the ramifications of different predation levels on long-term persistence of reintroduced anadromous species into Lake Merwin.

## 3.6 Assess anadromous/resident interactions, US Geological Survey

Study purpose and methods:
The intent of this study is to assess the effects of anadromous fish introduction on resident fish species, and, conversely, assess the effects of resident fish on the reintroduced anadromous fish. Understanding interspecific interactions and likely risks of such interactions is considered an important component in anadromous salmon reintroductions.

Researchers focused on evaluating interactions between newly reintroduced salmon and resident fishes in tributary and reservoir environments. To address this study, researchers specifically evaluated the distribution, behavior and community interactions of anadromous salmon and resident fishes at different life stages. Within the reservoir environment, researchers also assess the forage base and capacity of reservoirs to support juvenile salmon.

Study results:
Reintroduced juvenile Spring Chinook have demonstrated rapid downstream emigration patterns where monitored in the Swift basin. These results suggest overlap and potential impacts to heterospecifics in tributaries is likely to be minimal. The low proportion of juvenile Spring Chinook collected at the Swift Floating Surface Collector and low collection efficiencies suggest relatively high densities of residualized fish are possible within the reservoir environment. It is unclear how such changes in fish densities may affect reservoir carrying capacity.

Coho salmon demonstrate considerable overlap with Bull Trout at multiple life stages. The later timing of Coho spawning and similar habitat use (e.g., substrate) suggest Coho redd superimposition may be possible, particularly during the period where large numbers of hatchery adults are released in areas with extant Bull Trout populations. Indeed, Coho redds were documented as superimposed on Bull Trout redds. Upon hatching, juvenile Coho demonstrate extensive spatial overlap and moderate-high diet overlap with juvenile Bull Trout. Where Coho densities are high, changes in Bull Trout behavior were not documented, but are possible. Within the reservoir environment, food web interaction studies indicated Bull Trout do not appear to be utilizing juvenile salmon (Coho or Chinook) as a food resource. Such results are likely driven by Bull Trout gape limitations and the size of salmon within the reservoir. It is uncertain, however if residualized salmon may act as competitors with Bull Trout.

Forage and distribution information coupled with depth-temperature profiles indicated carrying capacity of juvenile salmon above existing populations of salmonids is likely to vary across Lake Merwin (130,000), Yale Lake (330,000), and Swift Reservoir (150,000). Capacity estimates are likely to vary based on the timing and duration of reservoir rearing. Prolonged reservoir rearing either through earlier emigration to the reservoir environment or through residualization is likely to reduce these totals considerably.

Using models to evaluate the potential effects of salmon reintroductions suggested potential reductions in Bull Trout reservoir survival and/or changes in the carrying capacity of Bull Trout rearing habitat would have considerable, negative effects on extant Bull Trout populations. Such results appear possible given observed diet data, distribution information, and the density-dependent mechanisms observed in previous Bull Trout studies. Given the relatively small size of the extant Bull Trout populations, continued monitoring of Bull Trout populations and community dynamics is warranted.

### 3.7 Ecosystem Diagnostics Treatment (EDT) model benchmark for the Lewis River, D.J. Warren and Associates and ICF International

Study purpose and methods:
As part of the FERC relicensing of the Lewis River hydroelectric projects, an Ecosystem Diagnosis and Treatment (EDT) model was developed in 2004. During the current development of new information, the model was updated with new environmental data from the USGS habitat surveys (see "Habitat assessment of tributaries to Swift Reservoir, Yale Lake and Lake Merwin", US Geological Survey, **Appendix A**), relevant biological data from other research, and model assumptions as determined by a subgroup of the Lewis River Aquatic Coordination Committee.

Three types of analyses were completed as part of this study:

1. *Salmon Production*. The EDT model was used to estimate theoretical adult and juvenile salmon and steelhead production originating from the three geographic analysis areas (Merwin, Yale and Swift) for two different scenarios. For both scenarios, estimates of productivity, capacity, abundance and life history diversity were developed for adult and juvenile coho, spring Chinook and steelhead. Scenarios differed primarily with regard to harvest, upstream passage mortality, and fecundity.

2. *Habitat Limiting Factors and Reach Restoration Analysis*. The model was used to 1) identify stream habitat related factors that currently limit salmon and steelhead production in individual streams located in each geographic area of the basin, and 2) estimate the change in adult production with elimination of the limiting habitat factor.

3. *Watershed Restoration Analysis*. Under this analysis, habitat conditions in each stream were restored to historical conditions to determine resulting increase in salmon production. The results of this analysis are used to determine the key watersheds that, if restored, would produce the largest increase in adult abundance.

Because stream habitat conditions were identical for both scenarios, analyses 2 and 3 were only conducted for Scenario 1.

Study results:
Model results showed that the majority of fish production for all three species originates from the Swift geographic area (> 77 percent), followed by Yale (> 18 percent) and Merwin (>3 percent) under both

scenarios. Total EDT estimates for the combined three geographic areas (i.e., Lewis River and tributaries upstream of Merwin) under Scenario 1 for adult coho, spring Chinook and steelhead are 11,222 fish, 3,694 fish and 2,754 fish, respectively. For Scenario 2, adult abundance for coho, spring Chinook and steelhead was 8,537, 1,699 and 2,106, respectively. Scenario 2 numbers are lower than Scenario I due to modeling assumptions regarding harvest, adult fish passage survival and female egg production.

Fish passage currently in operation transports adult fish from Merwin Dam to upstream of Swift Dam, and juveniles from Swift Dam to downstream of Merwin Dam, making the Swift geographic area available for re-establishment of salmon and steelhead. The estimated production for this area under Scenario 1 is 8,599 coho, 2,073 steelhead, and 3,084 spring Chinook adults. In Scenario 2, adult production is lower for coho (6,441), lower for steelhead (1,561) and lower for spring Chinook (1,421).

With construction of fish passage facilities at Yale Dam (make available Yale reservoir and associated tributaries habitat), Scenario 1 is estimated to produce 2,028 coho, 543 steelhead and 610 spring Chinook. In Scenario 2, adult production is lower for coho (1,595), lower for steelhead (431) and lower for spring Chinook (278).

With construction of fish passage facilities at Merwin Dam (make available Merwin reservoir and associated tributaries habitat), Scenario 1 estimates coho and steelhead production at 595 and 138 adults, respectively. In Scenario 2, adult production is lower for coho (502) and steelhead (115). Because the only possible spring Chinook producing stream associated with Merwin (Speelyai Creek) is reserved for hatchery production, construction of fish passage facilities at Merwin dam alone did not increase spring Chinook production.

The Limiting Factors/Reach Restoration analysis was only done on Scenario 1 as stream habitat conditions do not change between scenarios. Analysis results indicated that spring Chinook, coho and steelhead adult production can be increased by addressing the key habitat limiting factor in stream reaches located in the Swift and Below Merwin geographic areas. The largest increase in adult production of spring Chinook and coho occurred however in stream reaches associated with the Swift geographic areas. For steelhead, reaches located below Merwin Dam provided the largest increase in adult production.

The results of the Watershed Restoration analysis for the Swift geographic area indicated that restoring stream habitat conditions to historic in Clear Creek, Muddy River and Pine Creek generally produced the most adults for all species combined. Other streams that if restored produced a substantial number of adults included Rush Creek, Clearwater Creek and the mainstem of the Lewis River. Restoring a combination of these streams could produce more adult spring Chinook (1,697), coho (4,747) and steelhead (739) than EDT estimates of adult production for tributaries associated with Merwin and Yale with the establishment of fish passage. The EDT adult production estimate for these two areas with fish passage was 610 spring Chinook, 2,623 coho and 681steelhead. Population productivity, capacity and life history diversity also increased at varying levels for the majority of the watersheds restored.

3.8 Review Aquatic Restoration Projects in the Lower Lewis River Basin, Mason, Bruce and Girard

Study purpose and methods:
This report summarizes work completed to support the development of the revised Ecosystem Diagnosis and Treatment (EDT) model for the Lower Lewis River, and subsequent model evaluation of potential or identified stream enhancement projects. Objectives were to 1) identify and confirm existing presence of restoration projects that have been completed since 2007 that have yet to be incorporated into the Lewis River EDT model, 2) parameterize those projects to provide input to the model, 3) develop conceptual models to link effectiveness of restoration strategies (e.g., riparian restoration) to EDT attributes and, 4) identify sources of information on culvert and passage barriers in the Lewis River that can be incorporated into the Lewis River EDT model.

Study results:
A total of 20 aquatic restoration projects located in the lower Lewis River basin (downstream of Merwin Dam) are described and results of project parameterization provided through individual project summaries. Outcomes of the project parameterizations have been incorporated into the EDT3 model benchmark (see study report "Ecosystem Diagnostics Treatment (EDT) model benchmark for the Lewis River", D.J. Warren and Associates and ICF International, **Appendix C**). With few exceptions, observed restoration projects were consistent with published descriptions and warranted positive change to key EDT attributes, reflecting increased habitat potential within applicable areas.

3.9 Identification of Restoration Alternatives in North Fork of Lewis River, Cramer Fish Sciences

Study purpose and methods:
This study conducted a limiting factors analysis to help identify limiting habitat and life stages for Lewis River Spring Chinook, Coho and Steelhead and to identify potential habitat restoration measures. Researchers reviewed existing habitat and environmental assessment data for the Lewis Basin and Lewis River Coho (*Oncorhynchus kisutch*), Winter Steelhead (*O. mykiss*) and Spring Chinook (*O. tshawytscha*). More than 50 relevant publications were located that provided information to assist with identifying limiting factors and with identifying restoration opportunities. These include physical habitat data for the entire basin from Ecosystem Diagnosis and Treatment (EDT) models, watershed assessment and process (e.g., sediment, hydrology, riparian conditions, and channel type) data and model outputs from NOAA, and habitat data upstream of Merwin Dam which were recently collected by the U.S. Geological Survey. To identify restoration opportunities researchers combined diverse GIS data sets from NOAA and EDT, and applied them to areas draining into the 26 reaches identified by EDT as the highest priority for restoration in the North Fork of Lewis basin.

Study results:
Limiting factors analysis indicated that summer habitat is limiting the production of coho in most subbasins except Merwin, which is limited by adequate spawning habitat. For Steelhead, summer or winter rearing habitat is limiting in all of the subbasins. In contrast, spawning habitat is limiting for Chinook salmon in Yale basin and summer rearing habitat is limiting in the Swift basin. Results for

Chinook and Coho salmon, are largely driven by the definition of littoral zone (<3 meter deep) or suitable rearing habitat in the reservoirs; changing these depth criteria by as little as one or two meters can make spawning habitat limiting in the Merwin, Yale or Swift basins. Using outputs from the GIS data sets and EDT and a suite of watershed process and habitat metrics, researchers made initial recommendations for restoration measures in each of the 26 reaches. Based on data on fish response to restoration in other basins, researchers also estimated potential increases in coho and steehead smolts for selected restoration actions. Preliminary cost estimates were developed for potential restoration actions. Finally, recommendations on data and analysis needed to refine potential restoration actions and translate them into specific on–the–ground restoration actions are included in the report.

## 4.0 Project Schedule

The following schedule identifies key milestones as identified in the Lewis River Settlement Agreement. During this period, PacifiCorp and Cowlitz PUD intend to engage the NMFS, USFWS, Yakama Nation, Cowlitz Indian Tribe and the ACC in review of information and possible outcomes.

| Action | Completion Date (no later than) |
|---|---|
| PacifiCorp submits New Information Reports to the National Marine Fisheries Service and U.S. Fish and Wildlife Service (Services), Tribes and Lewis River ACC | June 24, 2016 |
| Licensees shall convene a meeting of the ACC for the purpose of discussing the New Information and comments. At such meeting, the Licensees shall solicit and obtain the Services' response to the New Information and related comments, unless the Services have provided the results of their review to the ACC earlier | December 26, 2016 |
| If Services conclude that one or more should not be constructed then within 60 days after the meeting with ACC, the Services shall advise the ACC in writing | February 24, 2017 |

## 5.0 Citations

PacifiCorp Energy and Cowlitz PUD 2004. Settlement Agreement, Joint Explanatory Statement and Supplemental Preliminary Draft Environmental Assessment for the Lewis River Hydroelectric Projects (Merwin FERC Project No. 935; Yale FERC Project No. 2071; Swift No. 1 FERC Project No. 2111; and Swift No. 2 FERC Project No. 2213). November 30, 2004

PacifiCorp Energy and Cowlitz PUD. 2005a. Biological Evaluation of USFWS Listed, Proposed, and Candidate species As Related to PacifiCorp Energy and Cowlitz PUD's Lewis River Hydroelectric Projects. January 15, 2005.

PacifiCorp Energy and Cowlitz PUD. 2005b. Biological Evaluation of Listed, Proposed, and Candidate Salmon and Steelhead Species as Related to PacifiCorp Energy and Cowlitz PUD's Lewis River Hydroelectric Projects. January 15, 2005.

# Appendix A

# U.S. Geological Survey - Information and Studies to Anadromous Fish Reintroduction into Merwin and Yale Reservoirs

See the following USGS link to the finalized report:
https://pubs.er.usgs.gov/publication/ofr20181190

# Appendix B

# Mason, Bruce & Girard / ICF International – Ecosystem Diagnosis Treatment Benchmark Revision / Lower Lewis River Enhancement Projects

# EDT Benchmark Revision/Lower Lewis River Enhancement Projects

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ICF International

**June 24, 2016**

## 2.1 Introduction

This report has been prepared by Mason, Bruce & Girard and ICF International for PacifiCorp and the Public Utility District No. 1 of Cowlitz County, Washington ("Cowlitz PUD") to inform the National Marine Fisheries Service and the U.S. Fish and Wildlife Service (collectively the "Services"), Federal Energy Regulatory Commission (FERC) and the Lewis River Settlement Agreement Parties in consideration of article 4.1.9 Review of New Information Regarding Fish Transport into Lake Merwin and Yale Lake and 7.6 In Lieu Fund of the Lewis River Settlement Agreement.

## 2.2 Background

Located on the North Fork of the Lewis River in southwestern Washington, the Lewis River Hydroelectric System consists of four operationally coordinated projects. PacifiCorp owns Swift No. 1 (FERC No. 2111), Yale (FERC No. 2071), and Merwin (FERC No. 935) projects which together generate 536 MW of electricity at full capacity. Cowlitz PUD owns the 82 MW Swift No. 2 Project (FERC No. 2213) which lies between the Swift No. 1 and Yale projects. Currently, PacifiCorp operates Swift No. 2 for Cowlitz PUD under contract.

On June 26, 2008, the FERC provided the utilities with new operating licenses for the Lewis River hydroelectric projects. The license periods are each 50 years starting June 1, 2008. Each license includes the respective conditions of the Services biological opinions and respective conditions of the Washington Department of Ecology 401 certificates. In general the licenses include terms of the Lewis River Settlement Agreement with few exceptions. Parties to the Lewis River Settlement Agreement continue to abide by the agreement terms including those terms outside the FERC requirements.

## 2.3 Lewis River Settlement Agreement conditions relative to reintroduction of anadromous salmonids into Yale and Merwin Reservoirs

Section 3.1 of the Lewis River Settlement Agreement identifies the anadromous fish reintroduction outcome goal as "to achieve genetically viable, self-sustaining, naturally reproducing, harvestable populations above Merwin dam greater than minimum viable populations". Within the agreement the utilities will make significant investments into a salmon and steelhead reintroduction program. These include a suite of anadromous fish protection and restoration measures and actions implemented over a phased approach. To date, facilities include the Merwin Upstream Fish Collector, three upper basin juvenile fish acclimation ponds and the Swift Downstream Fish Collector. A juvenile fish release facility located in Woodland, Washington is scheduled to be constructed in 2017. Additional program phases identified in the settlement agreement and subsequent FERC licenses require the construction and operation of the following fish passage facilities:

- Downstream Passage at Yale Dam (SA article 4.5)
- Downstream Passage at Merwin Dam (SA article 4.6)
- Upstream Passage at Yale Dam (SA article 4.7)
- Upstream Passage at Swift Projects (SA article 4.8)

There is also the specific opportunity to consider an In Lieu Fund as an alternative to future fish passage facilities (Yale downstream, Merwin downstream, Yale upstream and Swift upstream). It is expressly granted in Section 4.1.9 of the Lewis River Settlement Agreement.

> *4.1.9 Review of New Information Regarding Fish Transport into Lake Merwin and Yale Lake.*
>
> *a. The Licensees shall construct and provide for the operation and maintenance of both upstream and downstream fish collection and transport facilities at each of Merwin Dam, Yale Dam, and the Swift Projects as provided in the schedule in this Agreement unless otherwise directed by the Services pursuant to this Section. New Information (defined below) relevant to reintroduction and fish passage into Yale Lake or Lake Merwin may be available to the Services that may influence the implementation of fish passage into and out of these reservoirs, or that could result in the Services determining that reintroduction or fish passage for anadromous fish is inappropriate. If the Services conclude upon review of the New Information that one or more of the passage facilities should not be constructed, in lieu of designing, permitting, constructing, and operating the passage facility, PacifiCorp shall provide additional funds for projects in lieu of fish passage, as set forth in Section 7.6. In this event, the Licensees shall also implement the bull trout passage measures as set forth in Section 4.10. The adult upstream fish passage facility at Merwin and juvenile downstream collector at Swift No. 1 are not subject to this review.*
>
> *b. Upon receipt and review of New Information relevant to reintroduction and fish passage from any party, the members of the ACC may provide written comments to the Services regarding such New Information. Such comments shall be provided to the Services no later than five years prior to the date that PacifiCorp and/or Cowlitz PUD is to begin operating the relevant passage facility. If any New Information and comments are submitted to the Services, then approximately four and a half years prior to the date that PacifiCorp and/or Cowlitz PUD is to begin operating the relevant passage facility, the Licensees shall convene a meeting of the ACC for the purpose of discussing the New Information and comments. At such meeting, the Licensees shall solicit and obtain the Services' response to the New Information and related comments, unless the Services have provided the results of their review to the ACC earlier. If the Services have concluded that one or more of the passage facilities should not be constructed, then within 60 days after the meeting of the ACC, the Services shall advise the ACC in writing of such conclusion.*
>
> *c. For purposes of this section, "New Information" is defined as information relevant to anadromous fish reintroduction and fish passage, including that presented by any Party, and provided to the Services and the Licensees. The Licensees must*

*provide copies of such New Information to all the members of the ACC. This information may include, but is not limited to:*

*(1) Experience with upstream fish collection and transport facilities at other sites, including Merwin Dam.*
*(2) Experience with downstream fish collection facilities at other sites, including Swift No. 1 Dam.*
*(3) Experience with the reintroduction efforts of spring Chinook, coho, and steelhead above Swift No. 1 Dam.*
*(4) Consideration of broader contextual information beyond the Lewis River Basin, including regional anadromous fish recovery efforts.*

*d. The Licensees shall inform the Commission of any determination by the Services that one or more of the fish collection and transport facilities should not be constructed. In this event, PacifiCorp shall provide additional funds for projects in lieu of fish passage, as set forth in Section 7.6.*

As expressed in Section 4.1.9 (d) above, in the event the Services determine that reintroduction of anadromous salmonids into Yale Lake or Lake Merwin is not required (i.e., fish collection and transport facilities should not be constructed), Section 7.6 of the Lewis River Settlement Agreement would apply. In general, Section 7.6 stipulates that PacifiCorp shall establish the “In Lieu Fund” to support mitigation measures for anadromous salmonids in lieu of passage.

## 2.4 Study

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## Introduction

This report summarizes work completed to date by PacifiCorp to support the development of the revised Ecosystem Diagnosis and Treatment (EDT) model for the Lower Lewis River, and subsequent model evaluation of potential or identified stream enhancement projects. This report 1) identifies and confirms existing presence of restoration projects that have been completed since 2007 that have previously not been incorporated into the Lewis River EDT model, 2) parameterizes those projects to provide input to the model, 3) develops conceptual models to link effectiveness of restoration strategies (e.g., riparian restoration) to EDT attributes and, 4) identifies sources of information on culvert and passage barriers in the Lewis River that can be incorporated into the Lewis River EDT model.

Parameterization as referred to above is the process of converting the descriptive information for a restoration project into quantitative changes in specific environmental attributes. In the next phase of this project, we will incorporate these parameterized projects into a new (2016) benchmark model for the Lewis River. All work discussed in this report pertains to activities downstream of Merwin Dam.

## Procedure

Previous EDT analysis in the Lewis River was conducted using the version referred to as EDT2. The Lewis River EDT2 model was last updated in 2007. Separate EDT2 models were created in the earlier work for the upper basin, upstream of Merwin Dam, and another one for the basin downstream of Merwin Dam (including the East Fork of the Lewis River). As part of the current Lewis River analysis, the Lewis River EDT models have been updated to the current version of the model referred to as EDT3, and there is now a single, unified Lewis River EDT3 model that encompasses the entire Lewis River watershed. The focus of this study is to update the Lewis River EDT3 model to reflect restoration projects completed since the last update in 2007.

Restoration projects that were completed downstream of Merwin Dam since the 2007 model update were identified using the on-line database maintained by the Lower Columbia Fish Recovery Board (see LCFRB Web Site) by querying for Type = Restoration and Status = Completed. This query identified 20 restoration projects that were parameterized for this phase of the project (Figure 1, Table 1).

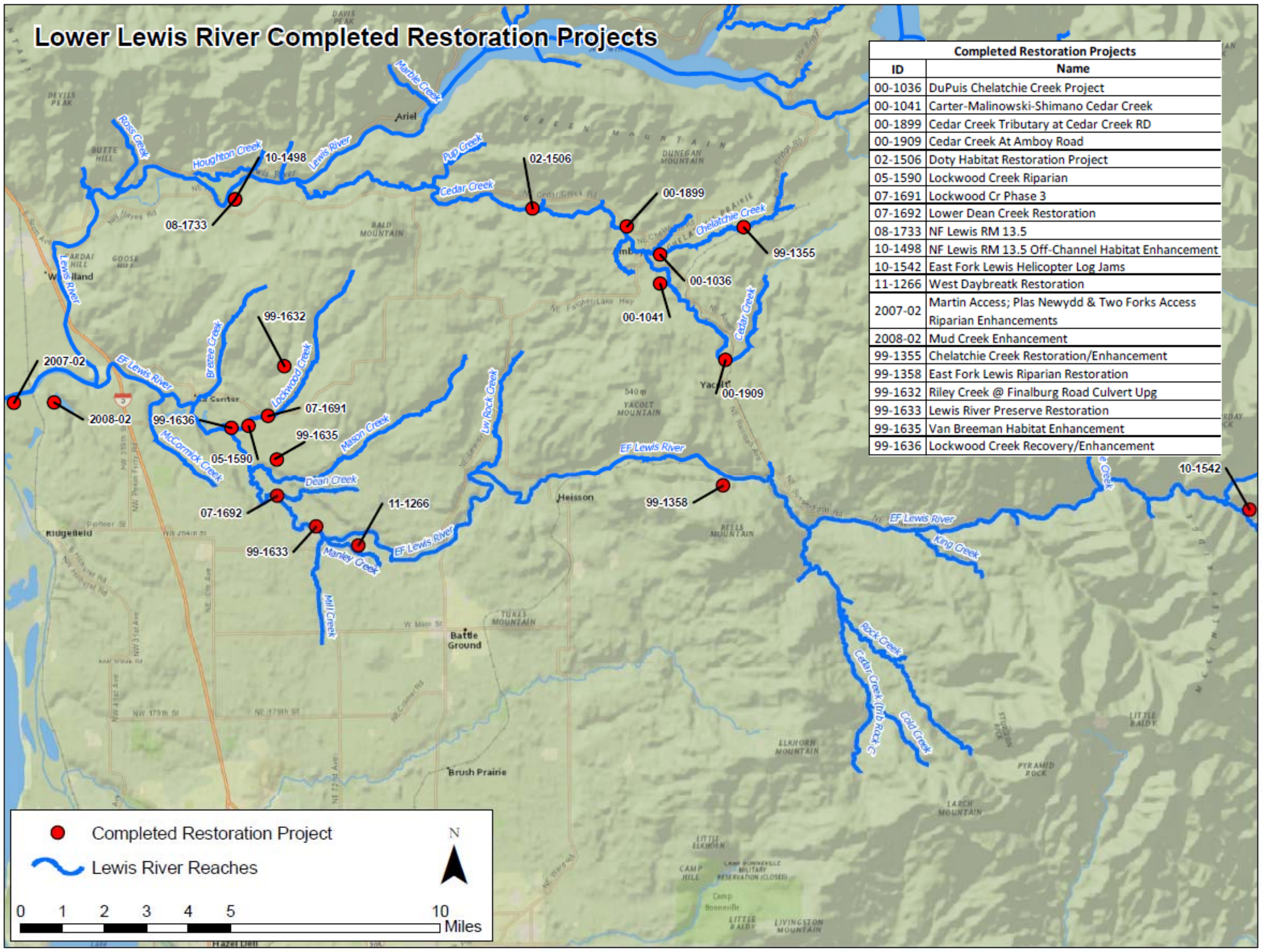



**Figure 1. Restoration projects completed in the lower Lewis River since 2007 that were verified for inclusion in the Lewis River EDT3 model.**

**Table 1. Completed restoration projects parameterized into the Lewis River EDT3 model**

| Project No. | Project Name | Sub-basin |
|---|---|---|
| **00-1036** | DuPuis Chelatchie Creek Project | NF Lewis |
| **00-1041** | Carter-Malinowski-Shimano Cedar Creek | NF Lewis |
| **00-1899** | Cedar Creek Tributary at Cedar Creek Road | NF Lewis |
| **00-1909** | Cedar Creek at Amboy Road | NF Lewis |
| **02-1506** | Doty Habitat Restoration Project | NF Lewis |
| **05-1590** | Lockwood Creek Riparian | EF Lewis |
| **07-1691** | Lockwood Cr Phase 3 | EF Lewis |
| **07-1692** | Lower Dean Creek Restoration | EF Lewis |
| **08-1733** | North Fork Lewis Rivermile 13.5 | NF Lewis |
| **10-1498** | NF Lewis RM 13.5 Off-Channel Habitat Enhancement | NF Lewis |
| **10-1542** | East Fork Lewis Helicopter Log Jams | EF Lewis |
| **11-1266** | West Daybreak Restoration Project | EF Lewis |
| **99-1355** | Chelatchie Creek Restoration/Enhancement | NF Lewis |
| **99-1358** | East Fork Lewis Riparian Restoration | EF Lewis |
| **99-1632** | Riley Creek at Finalburg Road Culvert Upgrade | EF Lewis |
| **99-1633** | Lewis River Preserve Restoration | EF Lewis |
| **99-1635** | Van Breeman Habitat Enhancement | EF Lewis |
| **99-1636** | Lockwood Creek Recovery/Enhancement | EF Lewis |
| **2007-02** | Martin Access; Plas Newydd & Two Forks Access Riparian Enhancements | NF Lewis |
| **2008-02** | Mud Creek Enhancement | NF Lewis |

## Parameterizing Restoration Projects

The purpose of parameterization is to convert the descriptive information on each of the restoration projects into expected changes in specific environmental attributes in the Lewis River EDT model. Incorporating parameterized projects "benchmarks" the model, allowing subsequent model runs to estimate benefits of new projects to Lewis River salmonids. Quantitative models (e.g., HEC-RAS) would always be the preferred way to parameterize projects for analysis in EDT. However, the restoration projects in Table 1 involve actions such as riparian restoration, large wood placement, fencing and bank stabilization for which no quantitative model is available. The parameterization procedure involves three elements:

> Scientific Effectiveness. This is a hypothesis based on the scientific literature that links categories of actions (e.g. large wood placement) to one or more EDT attributes. Effectiveness is described without reference to any project and without regard to feasibility or cost. For example, large wood placement has the potential to restore wood level to the historic condition, regardless of the logistical, economic or social challenges associated with wood placement. The scientific literature also indicates that these structures have a role, although not a dominant role, in determining stream channel configuration and creation of habitat types (e.g., pools and riffles) and supporting the aquatic food web.
>
> Implementation Intensity. Intensity refers to a specific project in a specific location and describes how the action was implemented. Intensity scales the effectiveness of an action category to the realities of a specific project. For example, a large wood placement project

may only supply 25% of the historic level of wood at a location due to cost, ownership, navigation or other implementation considerations.

Restoration Potential. This describes the potential to restore an attribute in a specific location. Using EDT, restoration potential is the difference in the rating of the attribute (e.g., large wood) in a specific reach between the Historic or Template condition and current or Patient condition. For example, if the Template rating for large wood in a reach is rated a 1.0 and the rating for the same reach in the Patient condition is 3.0[1], then the restoration potential is 3 – 1 = 2. This defines what is possible (but not necessarily feasible) with respect to restoration of an attribute in a specific location. The Template condition is designed to incorporate intrinsic limitations in the habitat caused by geology, climate, and other factors.

The change in an attribute due to a specific project in a specific reach is then calculated as follows:

**Change in an attribute in a reach = (Effectiveness × Intensity) × Restoration Potential of the Attribute**

Intensity acts as a scalar on Effectiveness to reflect the actual implementation of the action (e.g., how many pieces of wood were placed in the reach by the action). Restoration Potential incorporates the intrinsic condition of the attribute in the reach.

Our parameterization of the projects characterized the projects at full maturity. For example, riparian restoration was assumed to be successful resulting in a mature riparian forest. Importantly, actions such as this may take many years to be effective. Our characterization of these projects, therefore, may not represent current conditions at the restoration sites.

Effectiveness is a hypothesis based on the scientific literature relating to a category of project (Table 2). Conceptual models were developed that describe the effectiveness of each action category to change one or more EDT attributes. Effectiveness of some actions is a function of stream size. For example, the effectiveness of large wood in creating habitat for salmonids in small, headwater streams is much different than its effectiveness in large mainstem rivers. Separate project categories were therefore established reflecting these differences. Actions within other project categories were assumed to apply across all stream categories. Diagrammatic conceptual models for the project categories in Table 2 are provided in the Appendix.

**Table 2. Project categories based on LCFRB**

| |
|---|
| Fish Passage Improvement |
| In-Stream Habitat (LWD) |
| Riparian Conditions and Functions (small) |
| Riparian Conditions and Functions (large) |
| Floodplain Function/Channel Migration |
| Watershed Conditions and Hillslope Processes (Roads) |
| Bank Stabilization |

Intensity was evaluated from information provided in the LCFRB database, particularly the information described under “Project Categories” and “Project Milestones”. In most cases it was necessary to make qualitative conclusions, given the unknown/unverified extent of application of a particular action or action category.

[1] In EDT attribute ratings go from 0-4 with a 0 usually indicating a very good condition and a 4 indicating a very bad condition with respect to salmonids.

## Results: Parameterized Projects

The results of the project parameterization are provided in the following restoration project summaries. Each summary provides a description of the project, current conditions, the project category, and conclusion regarding the intensity of application of the project (0–1). The summary also includes a graph showing the attributes affected and conclusions regarding potential change in the attribute based on the procedure described above.

Project descriptions were obtained through the LCFRB database, supplemented by field visits. The latter were observational in nature; these visits compared major elements of the projects as originally described, e.g., constructed side channel, riparian plantings on both sides of the channel, large wood; with observations in the field. The field visits supported parameterization; however, changes made to EDT attributes were based on project descriptions as stated on the LCFRB web site and verified by site visits.

Intensity of application and changes in attributes do not apply to fish barrier removal projects and are not included in the project summaries. In the EDT model, fish passage barriers are represented by an instantaneous reduction in survival. Consequently, removal or mitigation of obstructions is represented by a change to the passage value; for example, from 33% to 100%. Consequently, the intensity/effectiveness concept does not apply to fish barrier removal projects.

Parameterization of completed projects described in this technical memorandum is a key step in benchmarking the Lewis River EDT3 model, ensuring that an assessment of passage benefits into Yale and Merwin reservoirs versus lower river enhancement projects reflects current conditions. This was a desktop exercise using information in the project descriptions published by LCFRB. In addition to the LCFRB descriptions the project team either field-verified or confirmed project performance based on personal communication with project sponsors.

## Culverts and Passage Barriers

Three of the restoration projects reviewed by PacifiCorp involved culvert replacement to improve fish passage and increase habitat availability for anadromous fish. In total, these projects have increased EDT reach lengths by approximately 18.7 km; approximately 13.6 km in Cedar Creek (North Fork Lewis River), and 5.1 km in Riley Creek, a tributary to Lockwood Creek in the East Fork Lewis River. These projects are further described in Appendix A.

**Table 3. Culvert removal/upgrade projects**

| Project | Name | Stream | EDT Reach Length above Barrier (km) |
|---|---|---|---|
| 00-1899 | Cedar Cr. at Cedar Creek Road | Columbia Tie Mill Creek | 2.9 |
| 99-1632 | Riley Creek at Finalburg Road Culvert Upgrade | Riley Creek | 5.1 |
| 00-1909 | Cedar Cr. at Amboy Rd. | Cedar Creek | 10.7 |

The 2007 Lewis River EDT model included information on barriers to fish passage based on information available at the time. Another goal of the current modeling effort has been to identify information that can be used to update barrier information for the 2016 Lewis River EDT model.

Updated information includes improved location information, identification of new, degraded, or restored barriers and better ratings of passage impediments to migrating salmonids. Culverts are inventoried by the Washington Department of Fish and Wildlife (WDFW), conservation districts and by PacifiCorp. Sources identified include the following:

- The Lower Columbia River Fish Recovery Board barrier inventory
- PacifiCorp inventory of barriers on PacifiCorp land (inventories will be incorporated into the Lewis River EDT3 model in the next phase of the project).
- Washington Lakes and Rivers Information System (WLRIS)
- Clark County Culvert Database
- StreamNet
- Waterfalls NW
- Salmon and Steelhead Habitat Inventory and Assessment Project (SSHIAP).

# Appendix A
# Project Summaries

**00-1036: DuPuis Chelatchie Creek Project**

**Description**

The State of Washington Salmon Recovery Funding Board (SRFB) funded restoration of degraded salmonid spawning habitat and improved stream complexity on 0.4 mile of Chelatchie Creek, in the Cedar Creek Watershed in Clark County, Washington. This watershed provides the majority of spawning and rearing habitat left for all species of anadromous fish in the lower North Fork Lewis River system. Chinook, coho, and steelhead (federally listed as threatened), and cutthroat trout are present in this system. The restoration area historically provided excellent salmon spawning and rearing habitat. However, this habitat had become degraded due to removal of large woody debris (LWD) and sedimentation of spawning gravels. This project was designed to create in-stream spawning beds anchored by large rock vanes and to add root wads and other LWD to improve in-channel habitat.

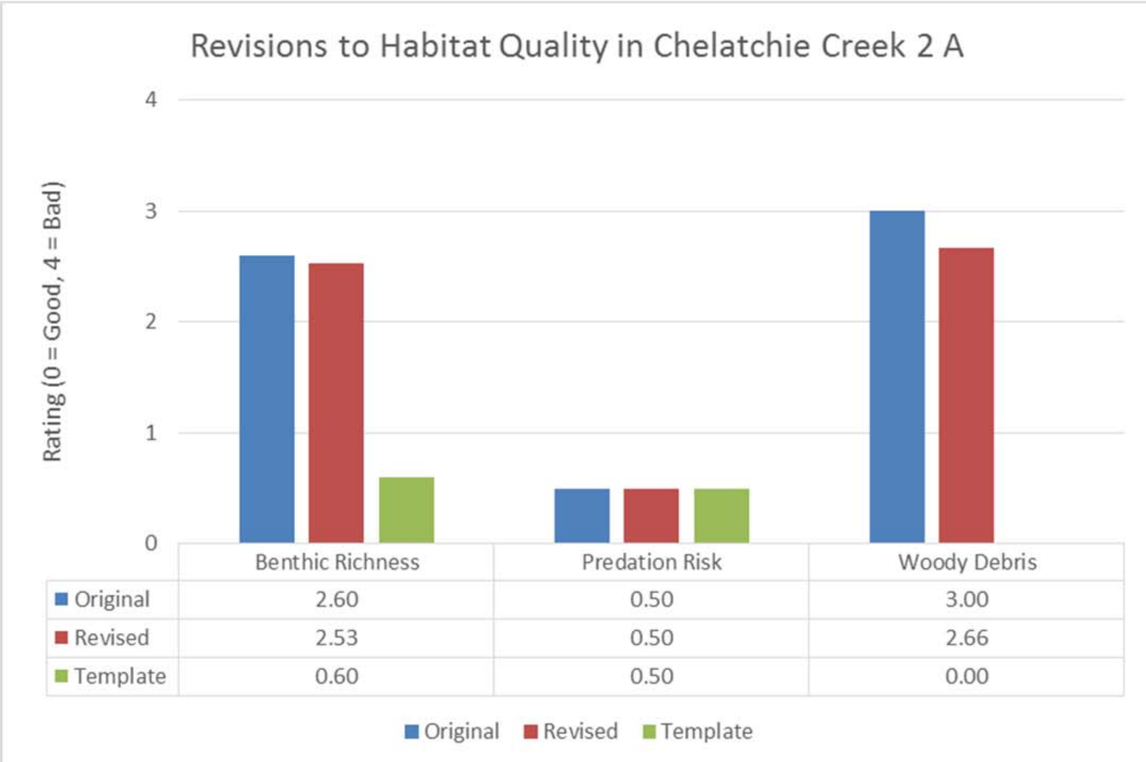
**Current Conditions**

Project team conducted field verification on November 11, 2015. Flows were sufficiently low to observe root wads, rock vanes and created pool habitat; key features/design elements are intact and the project appears to be functioning as intended.

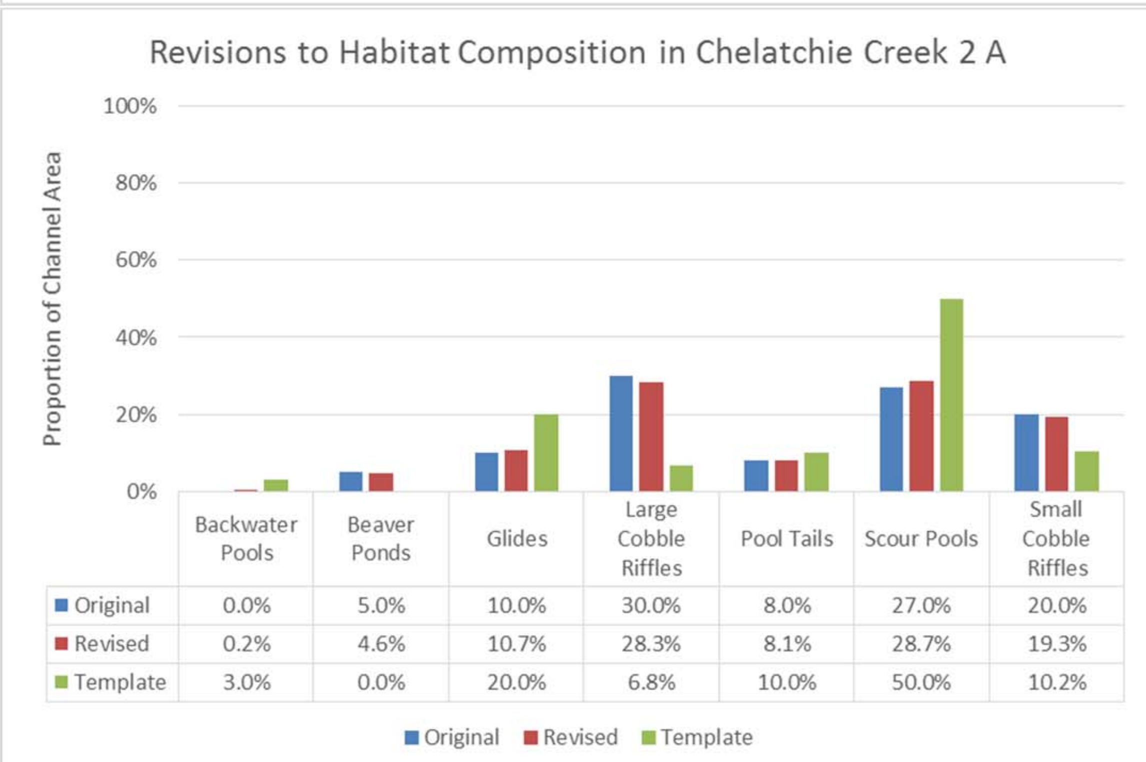
Photo 1: Rock vane in Chelatchie Creek.

Photo 2: Spawning gravel in Chelatchie Creek.

**Representation in EDT Model**
This project was categorized as construction of instream structures. The project was assigned an intensity of 0.112 based on the project length of 0.4 mi (644 m) relative to the 5760 m length of the EDT reach Chelatchie Creek 2 A.




| | Benthic Richness | Predation Risk | Woody Debris |
|---|---|---|---|
| Original | 2.60 | 0.50 | 3.00 |
| Revised | 2.53 | 0.50 | 2.66 |
| Template | 0.60 | 0.50 | 0.00 |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 0.0% | 5.0% | 10.0% | 30.0% | 8.0% | 27.0% | 20.0% |
| Revised | 0.2% | 4.6% | 10.7% | 28.3% | 8.1% | 28.7% | 19.3% |
| Template | 3.0% | 0.0% | 20.0% | 6.8% | 10.0% | 50.0% | 10.2% |

**00-1041: Carter-Malinowski-Shimano Cedar Creek**

**Description**

This project was designed to restore degraded salmonid spawning habitat, improve stream complexity, and recover and restore rearing habitat on 0.4 mile of Cedar Creek, a tributary of the North Fork Lewis River in Clark County, Washington. The Cedar Creek watershed provides the majority of spawning and rearing habitat left for all species of anadromous fish in the lower North Fork Lewis River system. Spawning and rearing habitat has become seriously degraded due to past removal of most LWD. This has resulted in loss of stream complexity, sedimentation of spawning gravel, and loss of access to high quality rearing habitat. This project is a continuation of work done in 1999, developing in-stream spawning beds anchored by large rock vanes, adding root wads and other LWD, and recovering lost rearing areas.

**Current Conditions**

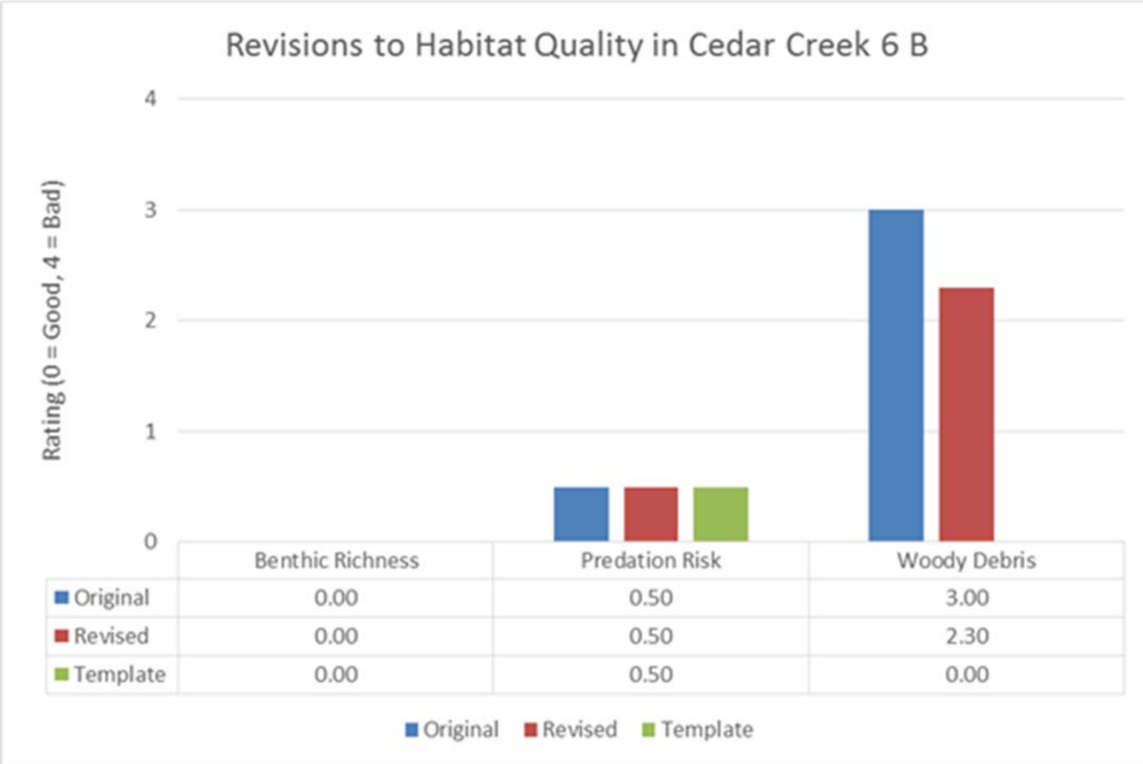
The Project Team conducted field verification on November 11, 2015. LWD has remained in place and the rock vanes are doing well. The project appears to be functioning as intended.

Photo 1: Rock vane and spawning gravel in Cedar Creek

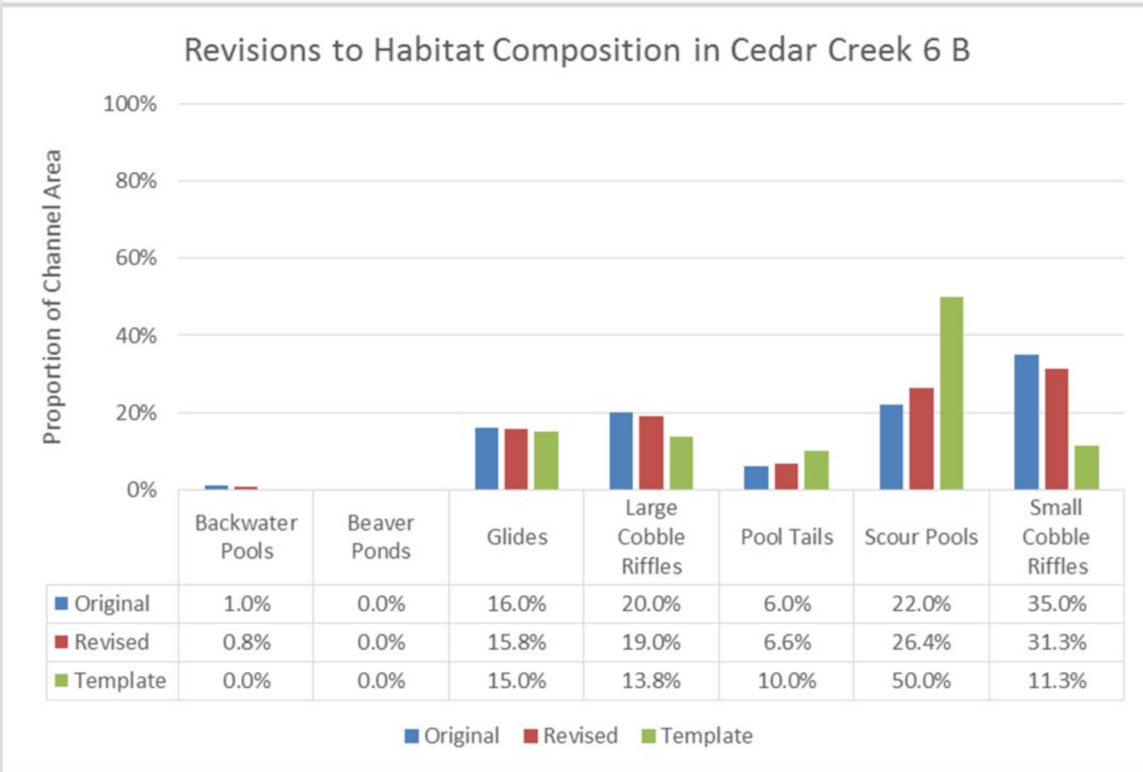
Photo 2: Channel complexity in Cedar Creek.

Photo 3: LWD in Cedar Creek.

**Representation in EDT Model**
This project was categorized as construction of instream structures. The project was assigned an intensity of 0.234 based on the project length of 0.4 mi (644 m) relative to the 2751 m length of the EDT reach Cedar Creek 6 B.




| | Benthic Richness | Predation Risk | Woody Debris |
|---|---|---|---|
| Original | 0.00 | 0.50 | 3.00 |
| Revised | 0.00 | 0.50 | 2.30 |
| Template | 0.00 | 0.50 | 0.00 |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 1.0% | 0.0% | 16.0% | 20.0% | 6.0% | 22.0% | 35.0% |
| Revised | 0.8% | 0.0% | 15.8% | 19.0% | 6.6% | 26.4% | 31.3% |
| Template | 0.0% | 0.0% | 15.0% | 13.8% | 10.0% | 50.0% | 11.3% |

**00-1899: Cedar Creek Tributary at Cedar Creek Road**

**Description**

The project is located on Cedar Creek, in the Lewis River Watershed, near the town of Amboy. The Salmon and Steelhead Habitat Limiting Factors, WRIA 27, states that "Cedar Creek provides the majority of spawning and rearing habitat left in the Lewis River system for steelhead and coho". In addition, the WDFW has a draft set of goals for Cedar Creek to protect, restore, and enhance the production and diversity of salmonids in the area. These goals include fish movement into new habitat. Steelhead, coho, and sea-run cutthroat trout are known to utilize the project area. Steelhead and coho are federally listed as threatened. In addition, there may be Chinook salmon present in the vicinity of the project, also federally listed as threatened. All four species are considered "depressed" by the WDFW. This project was designed to remove a culvert that is no longer needed and replace a second culvert under Cedar Creek Road. Both culverts were seasonal barriers to fish passage.

**Current Conditions**

The Project Team conducted field verification on November 11, 2015. The replacement culvert has a wide span and is filled with streambed rock allowing natural stream characteristics to develop within the culvert. Replacement of this culvert opened 10.7 km of high quality habitat, enhancing rearing and spawning opportunities for salmonids. Natural channel conditions exist within the replacement culvert and it is no longer a barrier to fish passage.

Photo 1: Natural channel conditions exist in this culvert on a tributary to Cedar Creek.


Photo 2: Looking upstream at natural channel conditions within the replacement culvert.

**Representation in EDT Model**
This project was modelled by setting the passage on the culvert on the EDT reach Columbia Tie Mill Cr 1 to 100% in the EDT model.

**00-1909: Cedar Creek at Amboy Road**

**Description**

The project is located on Cedar Creek just north of the Town of Yacolt. The Salmon and Steelhead Habitat Limiting Factors, WRIA 27 states that "Cedar Creek provides the majority of spawning and rearing habitat left in the Lewis River system for coho and steelhead". In addition, the WDFW has a draft set of goals for Cedar Creek to protect, restore, and enhance the production and diversity of salmonids in the area. These goals include fish movement into new habitat. Steelhead, coho, and sea-run cutthroat trout are known to utilize the project area. Steelhead and coho are federally listed as threatened. In addition, there may be Chinook salmon present in the vicinity of the project. Chinook are federally listed as threatened. All four species are considered "depressed" by the WDFW. The project resulted in replacement of a culvert under Amboy Road that was a seasonal barrier to fish passage.

**Current Conditions**

The Project Team conducted field verification on November 11, 2015. The new culvert has a much wider span and is filled with streambed rock allowing natural stream characteristics to develop within the culvert. This project opened four miles of quality habitat and enhanced rearing and spawning opportunities. The culvert was fish passable and no longer a barrier at normal flows.

Photo 1: View upstream into the replacement culvert on Cedar Creek.

Photo 2: Cedar Creek downstream on the Amboy Road culvert.

Photo 3: Pool below the Amboy Road culvert on Cedar Creek.

**Representation in EDT Model**
This project was modelled by setting the passage on the culvert on the EDT reach Cedar Creek 6 D to 100% in the EDT model.

**02-1506: Doty Habitat Restoration Project**

**Description**

This project was designed to restore degraded salmonid spawning habitat, improve stream complexity and cover and restore rearing habitat on 4,240 feet of the Amboy to Pidgeon Springs reach of Cedar Creek, a tributary of the North Fork of the Lewis River. The project objective was to restore stream complexity by installing rock vanes and the associated development of pools and spawning gravel, and placement of over 60 rootwads. In addition, the project was designed to reconnect over 700 feet of old stream channels to Cedar Creek as year-round rearing habitat.

**Current Conditions**

The Project Team conducted field verification on November 11, 2015 and found the project functioning as constructed.

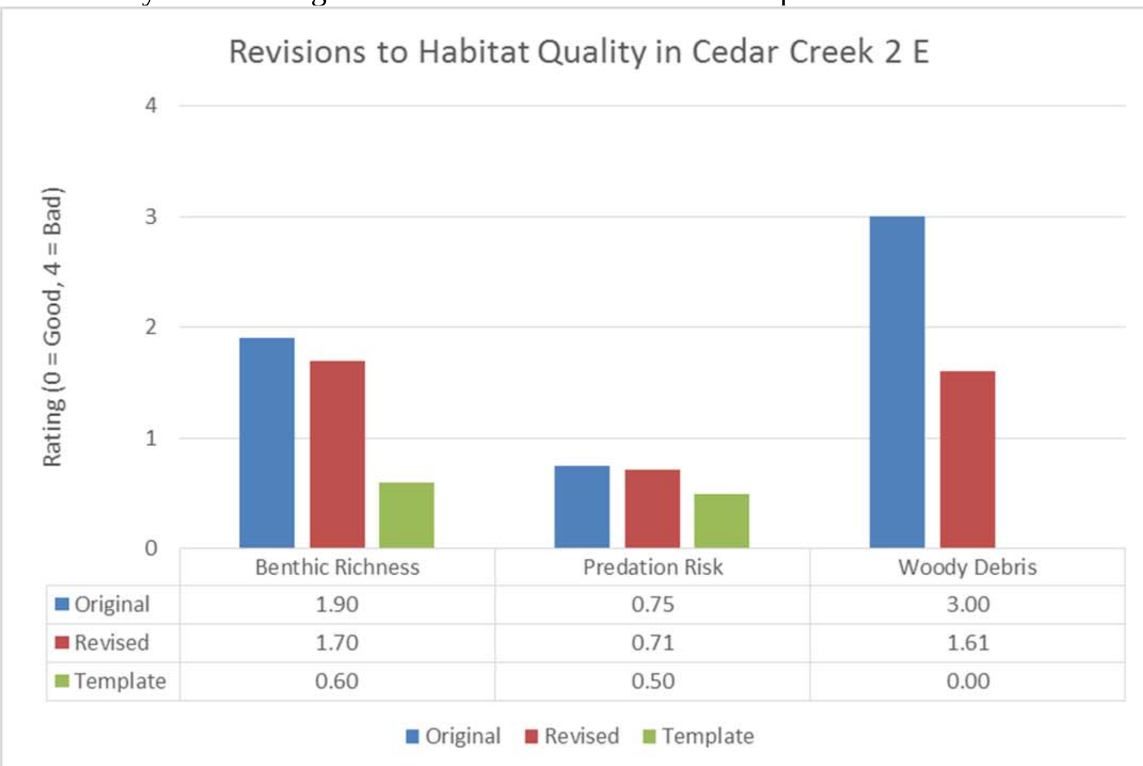
Photo 1: Rock vane and channel complexity in Cedar Creek.

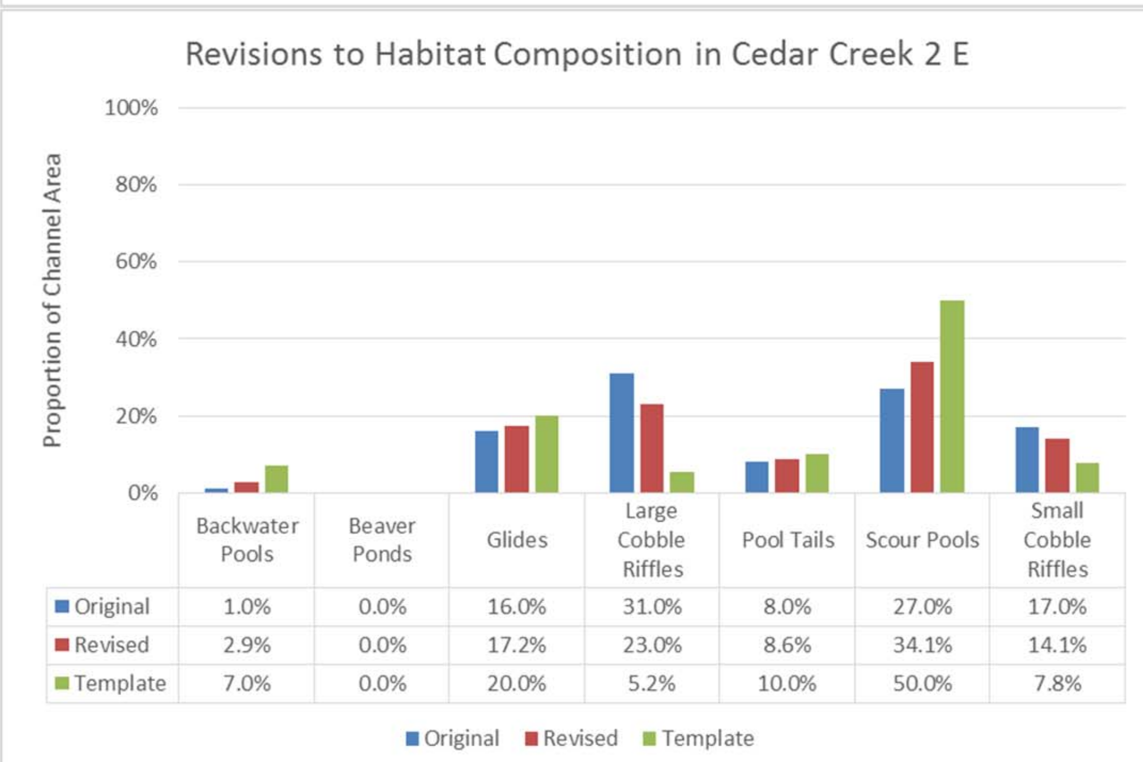
Photo 2: Good riparian cover on Cedar Creek.

Photo 3: Excellent plant establishment along Cedar Creek.

**Representation in EDT Model**

This project was categorized as construction of instream structures. The project was assigned an intensity of 0.465 based on the number of pieces of wood. The current EDT rating is equivalent to approximately 70 pieces of wood in EDT reach Cedar Creek 2 E. Adding 60 root wads increases the number of pieces to approximately 130. The corresponding improvement in the EDT woody debris rating of 1.39 is 46.5% of the restoration potential of 3 in this reach.



**05-1590: Lockwood Creek Riparian**

**Description**

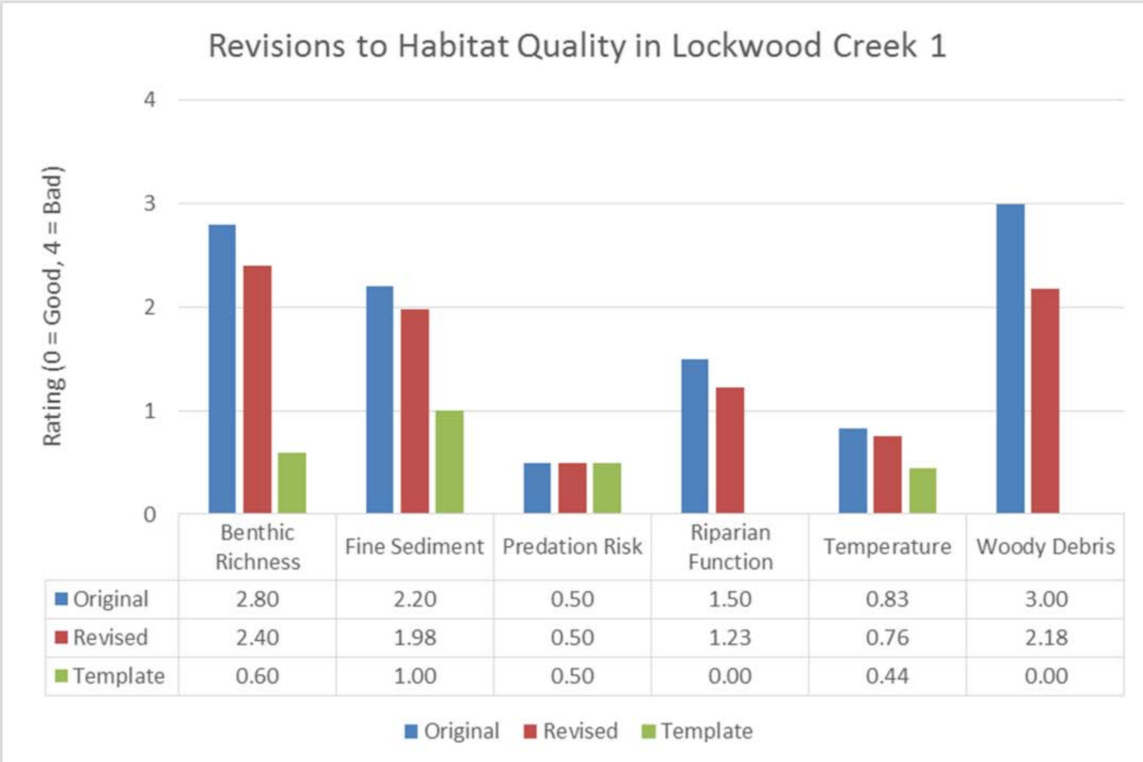
Clark Public Utilities used grant money to restore 2,000 linear feet of degraded floodplain habitat along Lockwood Creek at the confluence with the East Fork of the Lewis River. Lockwood Creek supports cutthroat, steelhead, and chum, Chinook and coho salmon. This grant was in addition to a $250,000 Centennial Clean Water grant. Combined, the two grants funded restoration on 26 acres of riparian habitat, placement of large woody debris in the creek for salmon habitat, construction of an off-channel rearing pond, and the reconnection of the creek to its floodplain and wetlands by removing a 2,500-foot-long dike.

**Current Conditions**

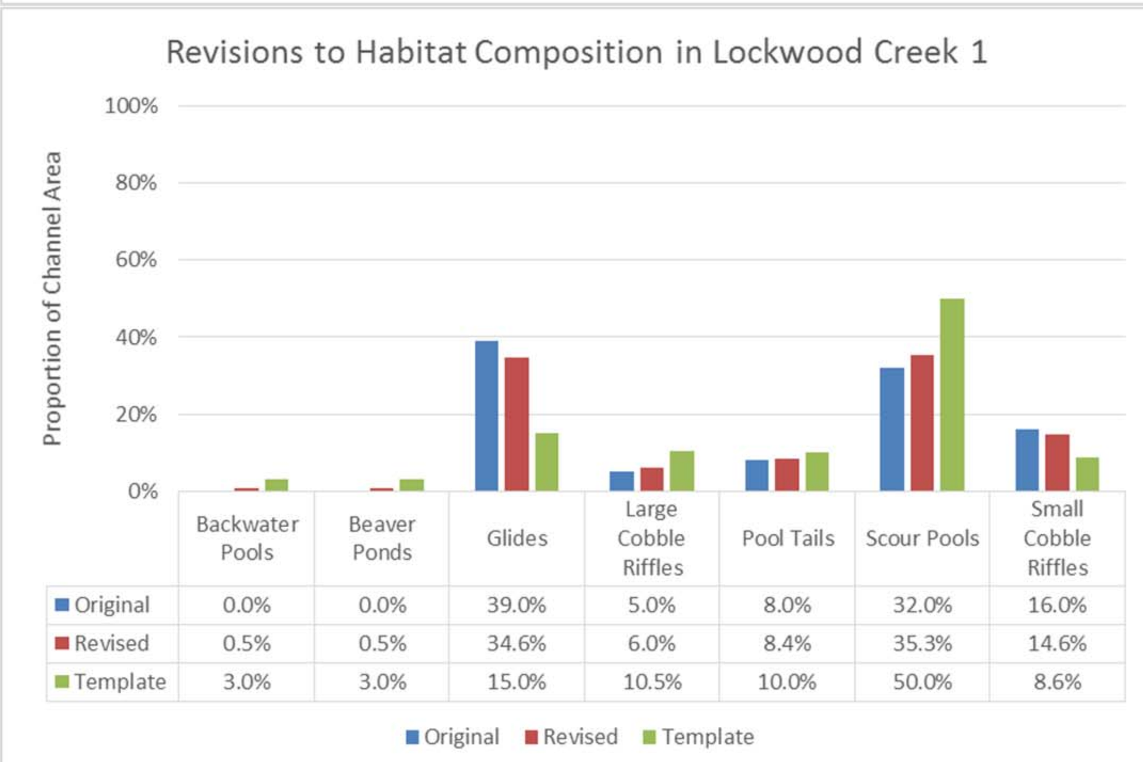
Field verification conducted October 21, 2015. Vegetation is very dense in this area making it difficult to delineate the treatment area from untreated riparian areas. However, observation of conifers, primarily cedar throughout the treatment area, were made during the field effort.

Photo 1: Lockwood Creek Riparian Project.

**Representation in EDT Model**
This project was categorized as riparian restoration and assigned an intensity of 0.273, based on the project length of 2000 ft (610 m) relative to the 2237 m length of the EDT reach Lockwood Creek 1.




| | Benthic Richness | Fine Sediment | Predation Risk | Riparian Function | Temperature | Woody Debris |
|---|---|---|---|---|---|---|
| Original | 2.80 | 2.20 | 0.50 | 1.50 | 0.83 | 3.00 |
| Revised | 2.40 | 1.98 | 0.50 | 1.23 | 0.76 | 2.18 |
| Template | 0.60 | 1.00 | 0.50 | 0.00 | 0.44 | 0.00 |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 0.0% | 0.0% | 39.0% | 5.0% | 8.0% | 32.0% | 16.0% |
| Revised | 0.5% | 0.5% | 34.6% | 6.0% | 8.4% | 35.3% | 14.6% |
| Template | 3.0% | 3.0% | 15.0% | 10.5% | 10.0% | 50.0% | 8.6% |

**07-1691: Lockwood Cr. Phase 3**

**Description**

The Lower Columbia Fish Enhancement Group used a grant to restore Lockwood Creek. Work included placing root wads and logs in the creek to create places for fish to rest, feed, and hide from predators. The project also created off-channel rearing habitat and stabilized stream banks with native plants. The site, which is at the junction of Lockwood and Riley Creeks, contains nearly 0.4 mile of stream and covers 12 acres of floodplain habitat. The creek is home to Chinook, coho, and steelhead, all federally listed under the Endangered Species Act. Restoration of this important salmon spawning stream began in 2000 with removal of a barrier at the confluence with the East Fork of the Lewis River near the town of La Center. Since then, restoration has progressed upstream several miles to this site.

**Current Conditions**

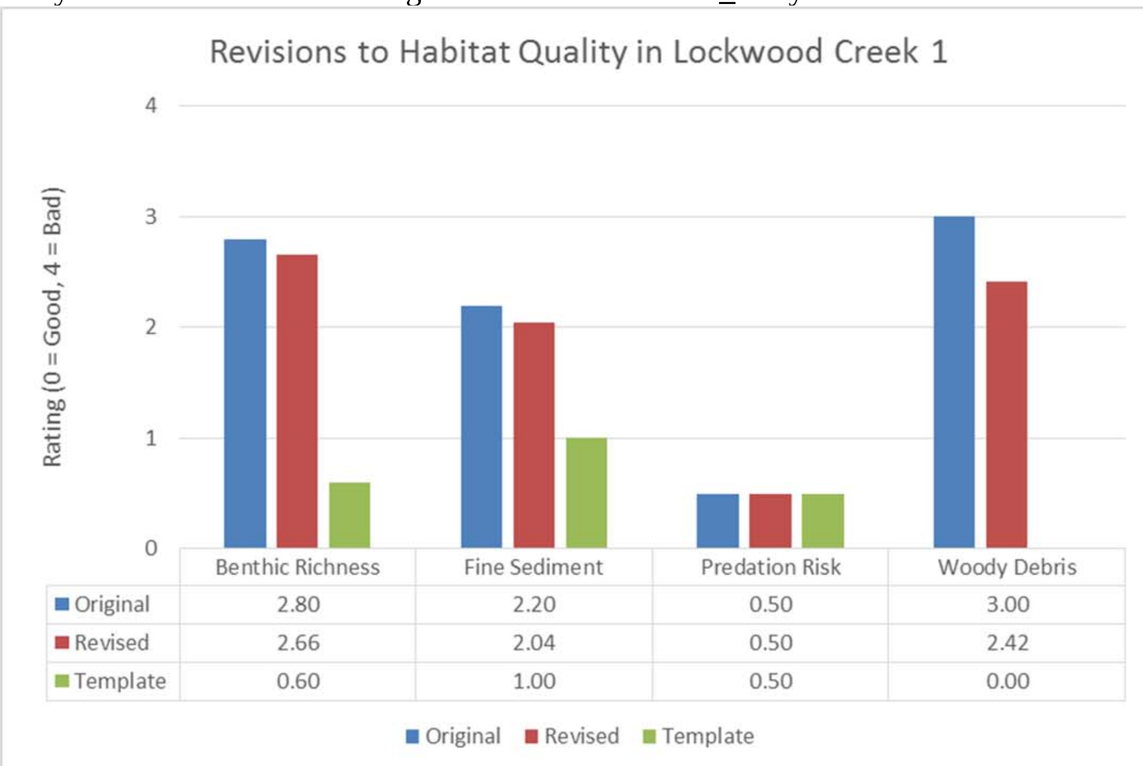
Field verified October 21, 2015. Successful planting of conifers (cedar) and deciduous trees along riparian area of Lockwood Creek. Both sides of the creek are treated upstream of the road culvert. Survival of tree plantings is estimated at 80 percent.

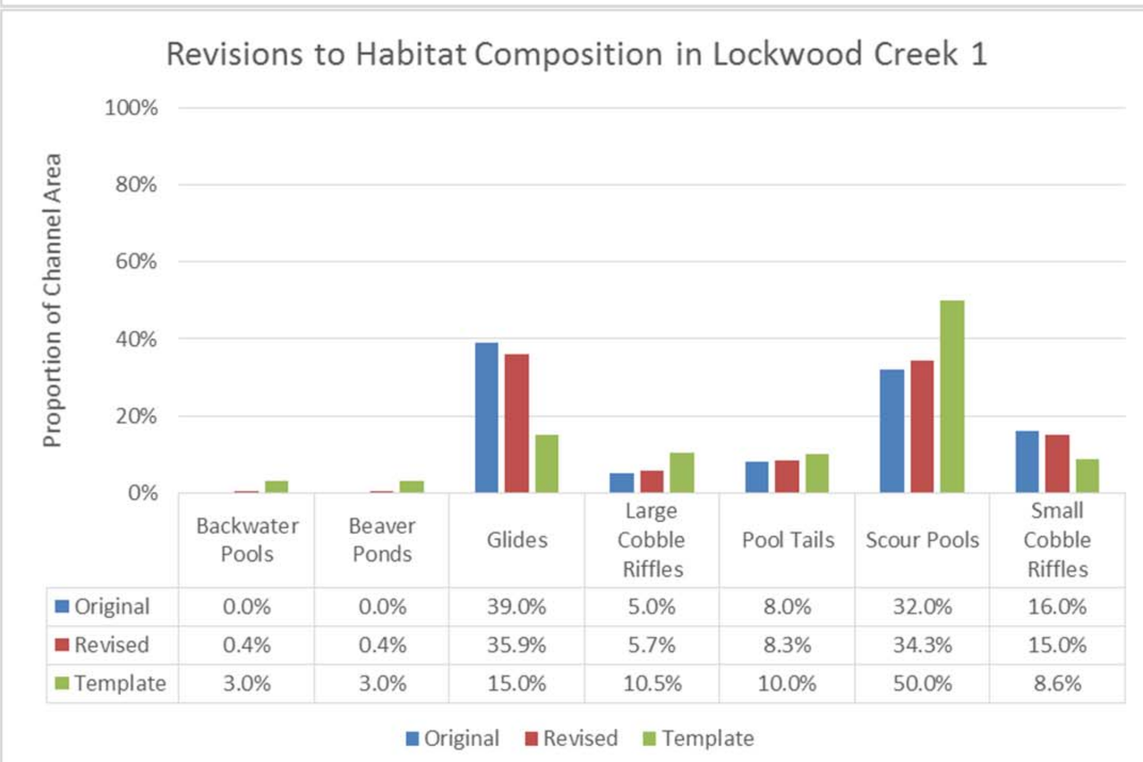
Photo 1: Lockwood Creek

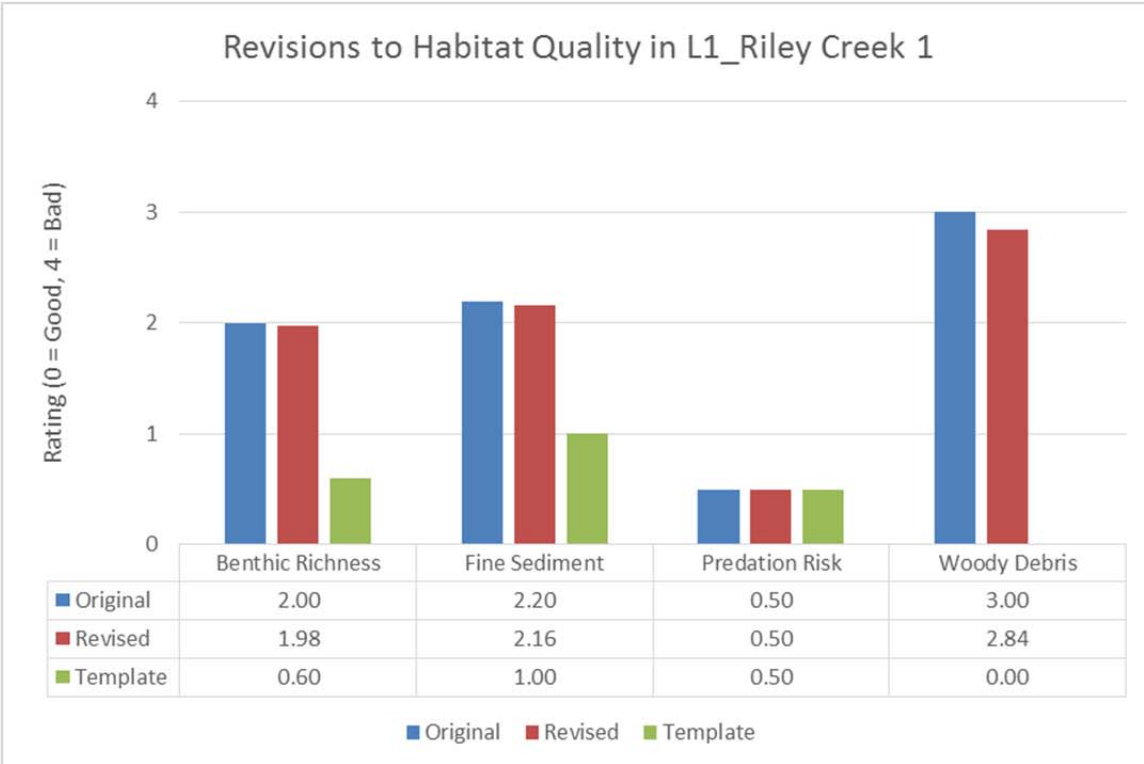
Photo 2: Plantings in riparian corridor of Lockwood Creek.

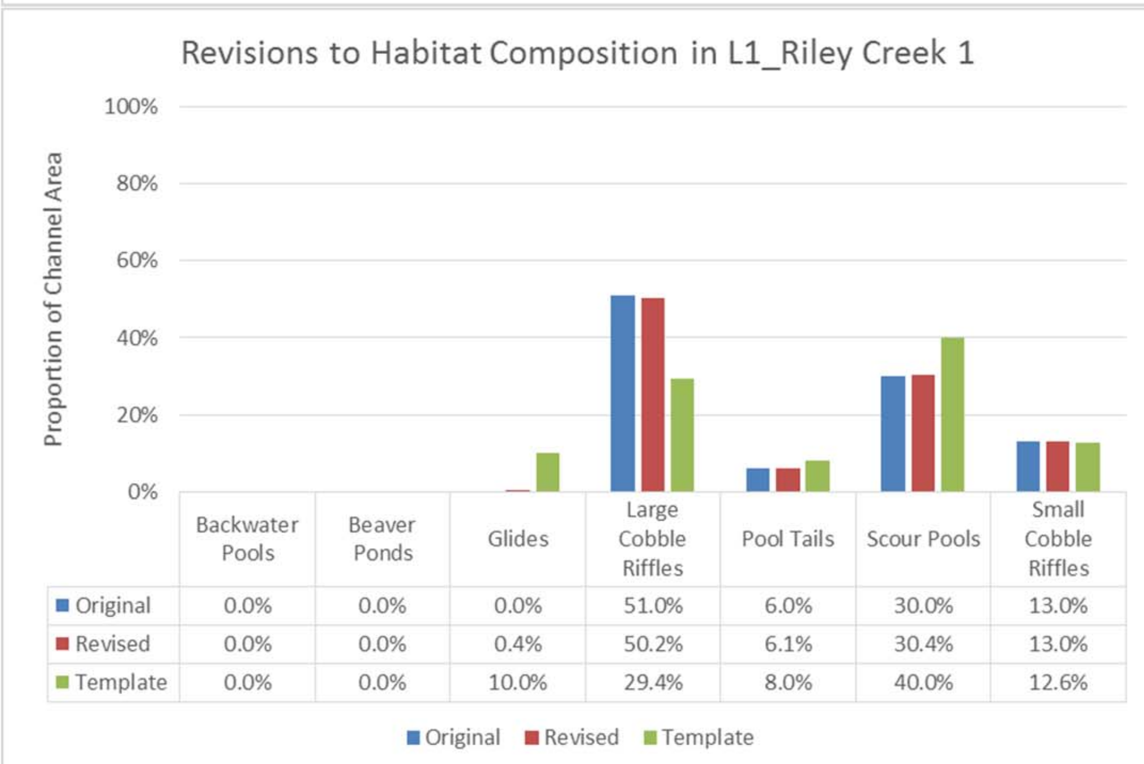
Photo 3: Plantings in riparian corridor of Lockwood Creek.

**Representation in EDT Model**
This project was categorized as construction of instream structures and bank stabilization. Of the 0.4 mi project length, 0.27 mi (435 m) was estimated to be on Lockwood and 0.13 mi (209 m) was estimated to be on Riley. The project was assigned an intensity of 0.194 on Lockwood relative to the 2237 m length of the EDT reach Lockwood Creek 1; the intensity of 0.053 on Riley relative to the 3942 m length of the EDT reach L1_Riley Creek 1.




Revisions to Habitat Quality in L1_Riley Creek 1
Rating (0 = Good, 4 = Bad)
4
3
2
1
0
Benthic Richness
Fine Sediment
Predation Risk
Woody Debris
Original 2.00 2.20 0.50 3.00
Revised 1.98 2.16 0.50 2.84
Template 0.60 1.00 0.50 0.00
Original
Revised
Template


Revisions to Habitat Composition in L1_Riley Creek 1
Proportion of Channel Area
100%
80%
60%
40%
20%
0%
Backwater Pools
Beaver Ponds
Glides
Large Cobble Riffles
Pool Tails
Scour Pools
Small Cobble Riffles
Original 0.0% 0.0% 0.0% 51.0% 6.0% 30.0% 13.0%
Revised 0.0% 0.0% 0.4% 50.2% 6.1% 30.4% 13.0%
Template 0.0% 0.0% 10.0% 29.4% 8.0% 40.0% 12.6%
Original
Revised
Template

**07-1692: Lower Dean Creek Restoration**

**Description**

The Lower Columbia River Fish Enhancement Group rehabilitated both sides of the lower 0.2 mile of Dean Creek and 0.3 mile of the East Fork Lewis River. Work included restoring 27 acres of floodplain riparian habitat on 52 acres owned by Clark County. Crews placed large woody debris and planted more than 22,000 trees along nearly 1 mile of stream bank. The streams are home to several species of fish on the federal Endangered Species Act list, including Chinook, chum, and coho salmon, and steelhead. The project was a partnership with Vancouver-Clark Parks and Recreation Commission and Clark Public Utilities Watershed Enhancement department.

**Current Conditions**

Field verification conducted October 21, 2015. Both sides of Dean Creek were planted with over 22,000 new trees. LWD has been placed along the bank of the East Fork Lewis just upstream of the Dean Creek confluence. Survival of trees appeared good, with slightly higher survival for conifers, primarily cedar.

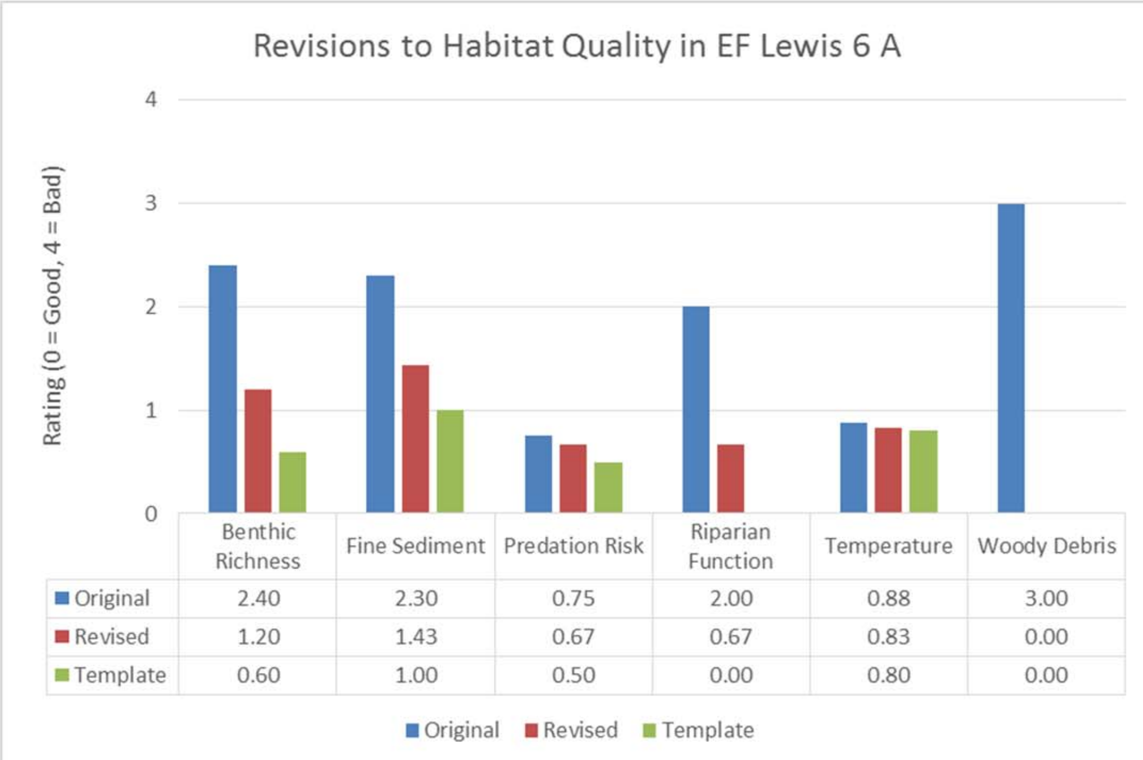
Photo 1: Instream habitat structure and bank armoring on the East Fork Lewis River.

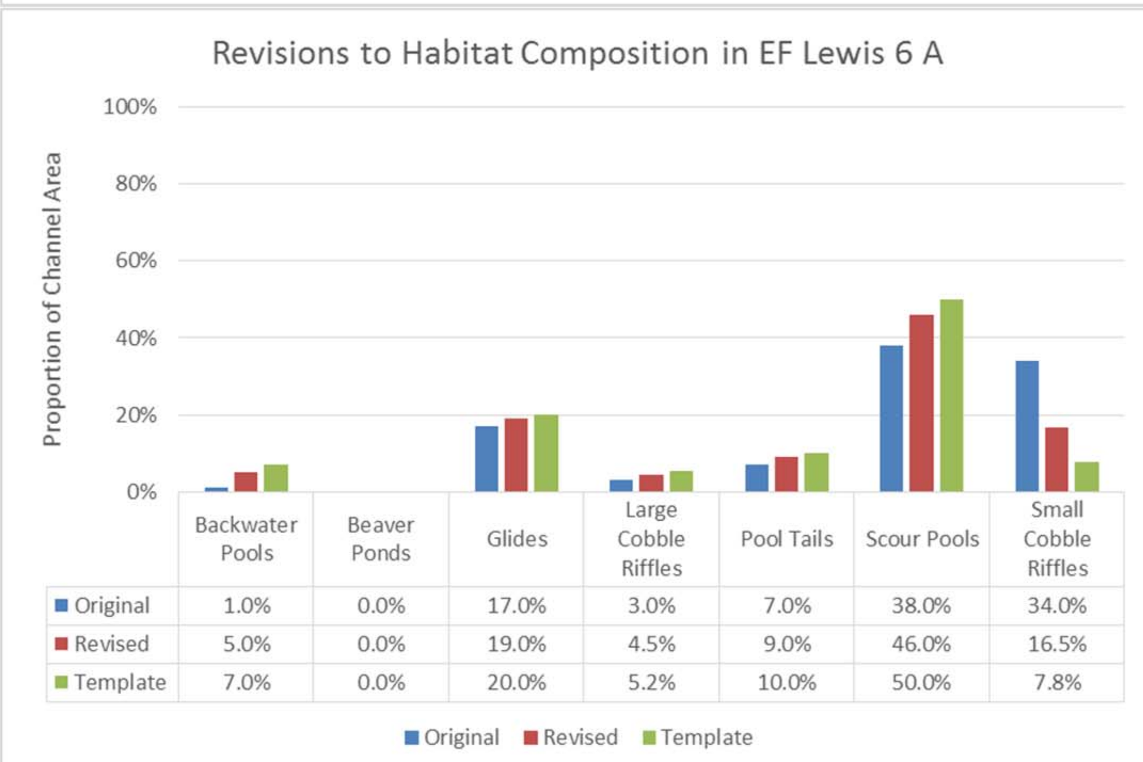

Photo 2: Riparian plantings along Dean Creek.

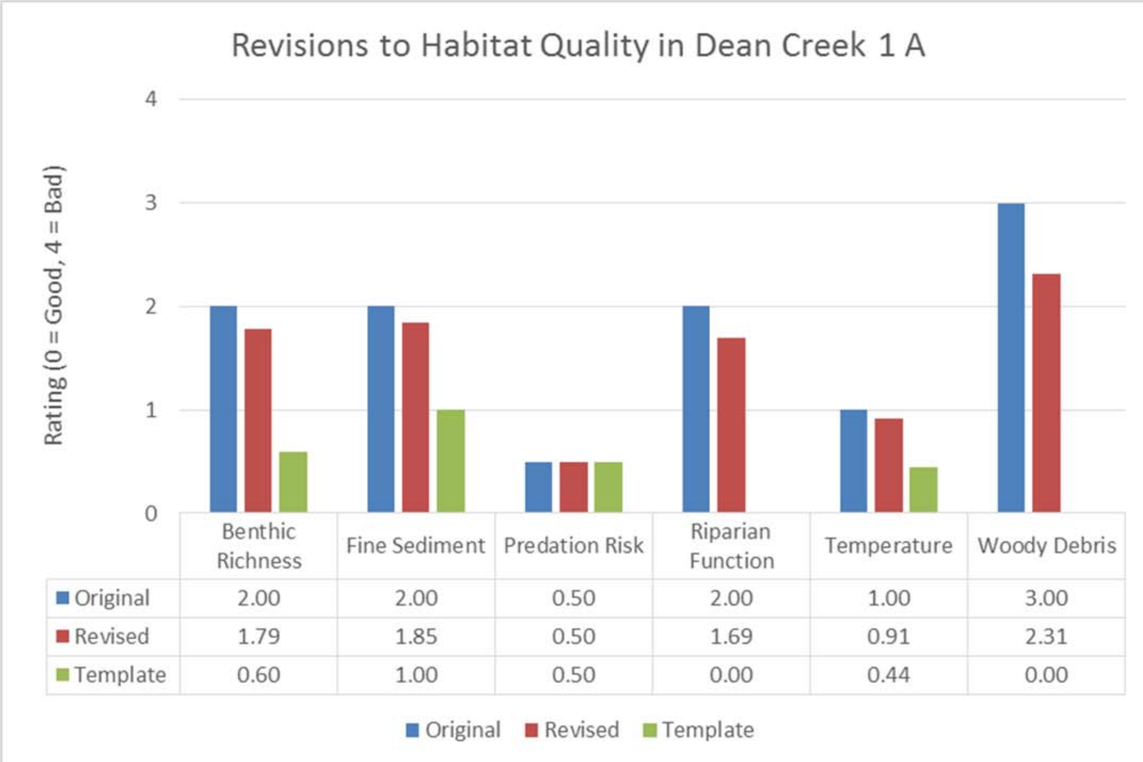
Photo 3: Riparian plantings along Dean Creek.

**Representation in EDT Model**

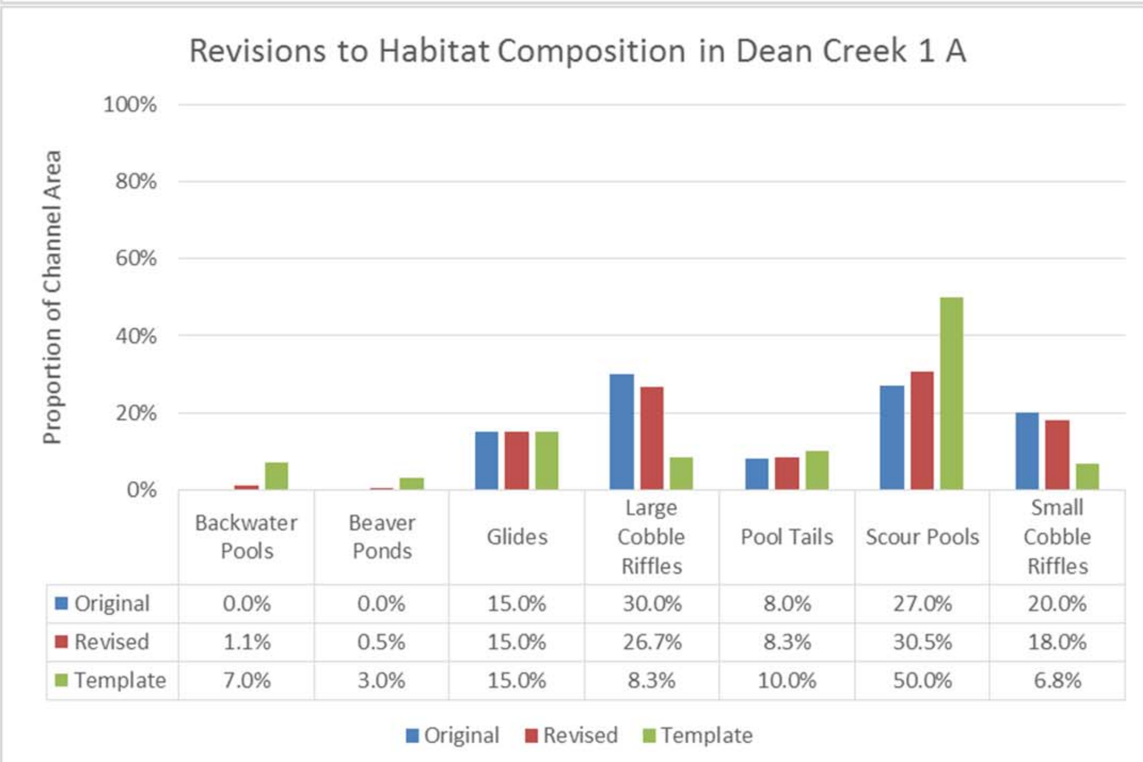
This project was categorized as riparian restoration and assigned an intensity of 0.230 for lower Dean Creek based on the project length of 0.2 mi (322 m) relative to the 1400 m length of the EDT reach Dean Creek 1 A. The project was assigned an intensity of 1 for the Lewis River mainstem based on the project length of 0.3 mi (483 m) relative to the 434 m length of the EDT reach EF Lewis 6 A.






| | Benthic Richness | Fine Sediment | Predation Risk | Riparian Function | Temperature | Woody Debris |
|---|---|---|---|---|---|---|
| Original | 2.00 | 2.00 | 0.50 | 2.00 | 1.00 | 3.00 |
| Revised | 1.79 | 1.85 | 0.50 | 1.69 | 0.91 | 2.31 |
| Template | 0.60 | 1.00 | 0.50 | 0.00 | 0.44 | 0.00 |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 0.0% | 0.0% | 15.0% | 30.0% | 8.0% | 27.0% | 20.0% |
| Revised | 1.1% | 0.5% | 15.0% | 26.7% | 8.3% | 30.5% | 18.0% |
| Template | 7.0% | 3.0% | 15.0% | 8.3% | 10.0% | 50.0% | 6.8% |

**08-1733: North Fork Lewis River - mile 13.5**

**Description**

This project is on the North Fork Lewis River (RM 13.5), in reach Lewis 5, a Tier 1 reach in the Lower Columbia River Salmon Recovery Plan. The site is downstream of the canyon, which is highly productive for Chinook spawning. The project was designed to create and enhance important early rearing habitat for juvenile Chinook, coho and steelhead that originate in the upstream reaches. The project has also shown increased steelhead redds post project completion.

Habitat in this reach before the project consisted of a long glide with little cover, complexity, or pools. The right bank was a rapidly eroding high terrace and the left bank was a low floodplain terrace extending up to 1,000 feet lateral to the stream. There was little bank vegetation available to provide stability and no LWD along the banks. The project installed log jams on approximately 500 feet of the eroding right bank and LWD/boulder structures along approximately 2000 feet of the left bank. LWD jams have increased cover and velocity refuge for juvenile Chinook, coho, and steelhead, and provide adult holding and spawning areas.

**Current Conditions**

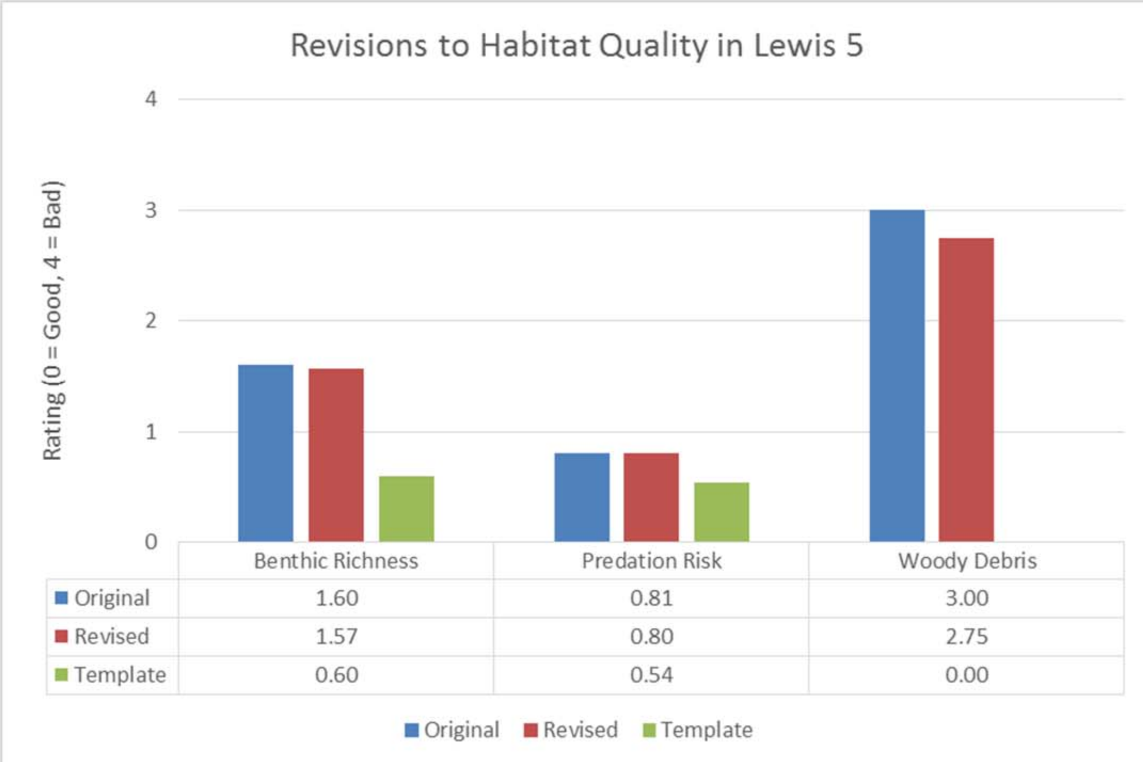
The survey team counted 20 instream habitat structures along the south margin of the river. All structures are intact and functioning. Flows at the time of the survey (October 2015) were 1,700 cubic feet per second (cfs). Past redd surveys have shown significant improvement in steelhead redd abundance along this treated area. Structures are also providing rearing areas for salmonids. Gravel retention is good to excellent along this margin. Sedimentation was not as pronounced as it was in the related side channel habitat project.

Photo 1: Upstream end of the project.

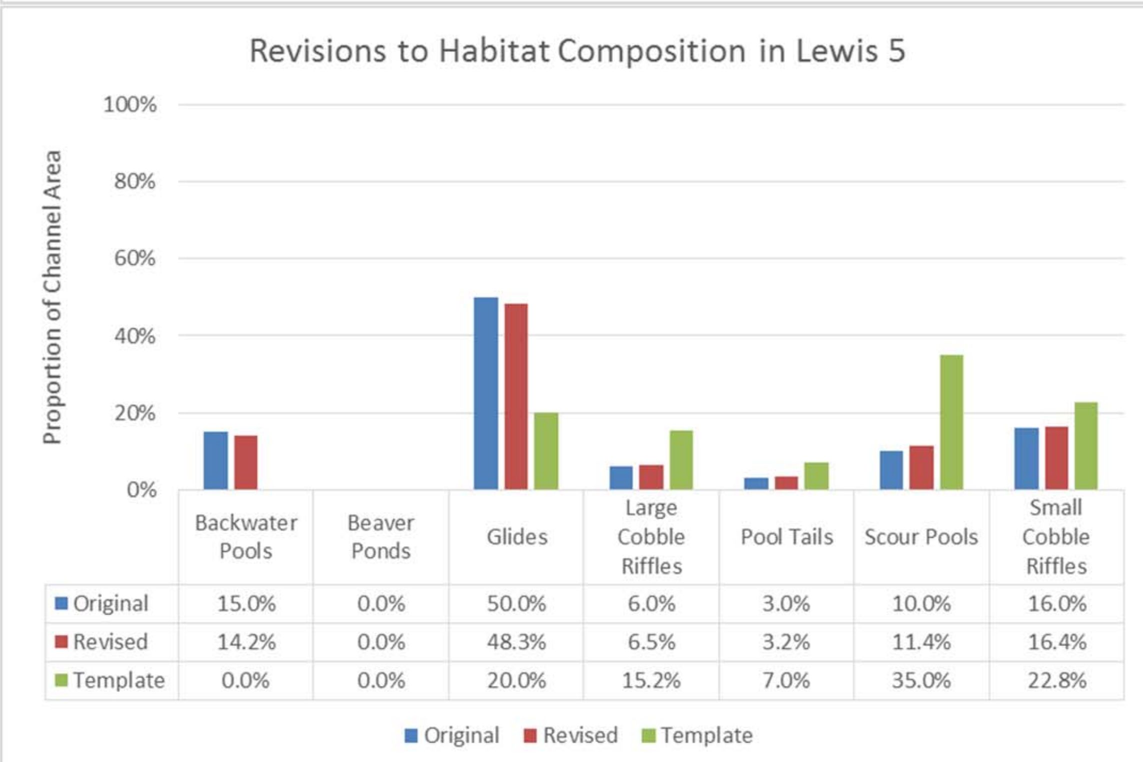
Photo 2: Typical instream habitat structure at the North Fork Lewis RM 13.5.

**Representation in EDT Model**

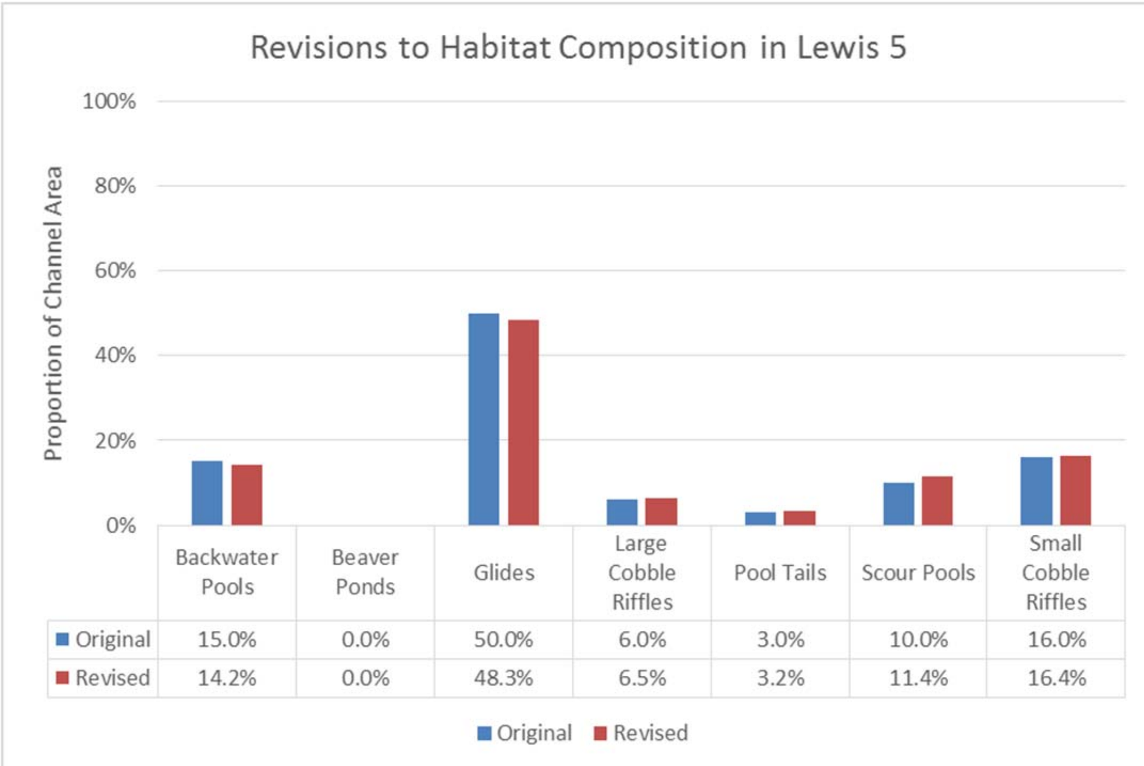
This project was categorized as construction of instream structures. The project was assigned an intensity of 0.084 based on the project length of 2000 ft (610 m) on left bank and 500 m on right bank (152 m) relative to the 4537 m length of the EDT reach Lewis 5. In terms of intensity, this is equivalent to a project of length 1250 ft (381 m) that restores both banks.




| | Benthic Richness | Predation Risk | Woody Debris |
|---|---|---|---|
| Original | 1.60 | 0.81 | 3.00 |
| Revised | 1.57 | 0.80 | 2.75 |
| Template | 0.60 | 0.54 | 0.00 |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 15.0% | 0.0% | 50.0% | 6.0% | 3.0% | 10.0% | 16.0% |
| Revised | 14.2% | 0.0% | 48.3% | 6.5% | 3.2% | 11.4% | 16.4% |
| Template | 0.0% | 0.0% | 20.0% | 15.2% | 7.0% | 35.0% | 22.8% |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 15.0% | 0.0% | 50.0% | 6.0% | 3.0% | 10.0% | 16.0% |
| Revised | 14.2% | 0.0% | 48.3% | 6.5% | 3.2% | 11.4% | 16.4% |

**10-1498: NF Lewis RM 13.5 Off-Channel Habitat Enhancement**

**Description**

This project is located in reach Lewis 5 on the North Fork Lewis River. It is a Tier 1 reach in the Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan (LCFRB 2010) near river mile 13.5. Connected side-channel habitat and LWD complexity have been reduced in this reach of the Lewis River due to past channel clean-outs, riparian clearing, hydro-regulation, and instream gravel mining. The project was designed to create and enhance important spawning, rearing, and adult holding habitat for ESA-listed salmonids. The project should enhance key habitat for ESA-listed salmonids through the construction of a 2,500-foot-long side-channel with pool-riffle habitat, LWD placements, and connection to off-channel (backwater) habitat. The project also includes the rehabilitation of approximately 200 feet of a perennial spring-fed tributary using channel re-grading and LWD placements and restored native riparian and floodplain vegetation within the disturbance limits of the project.

**Current Conditions**

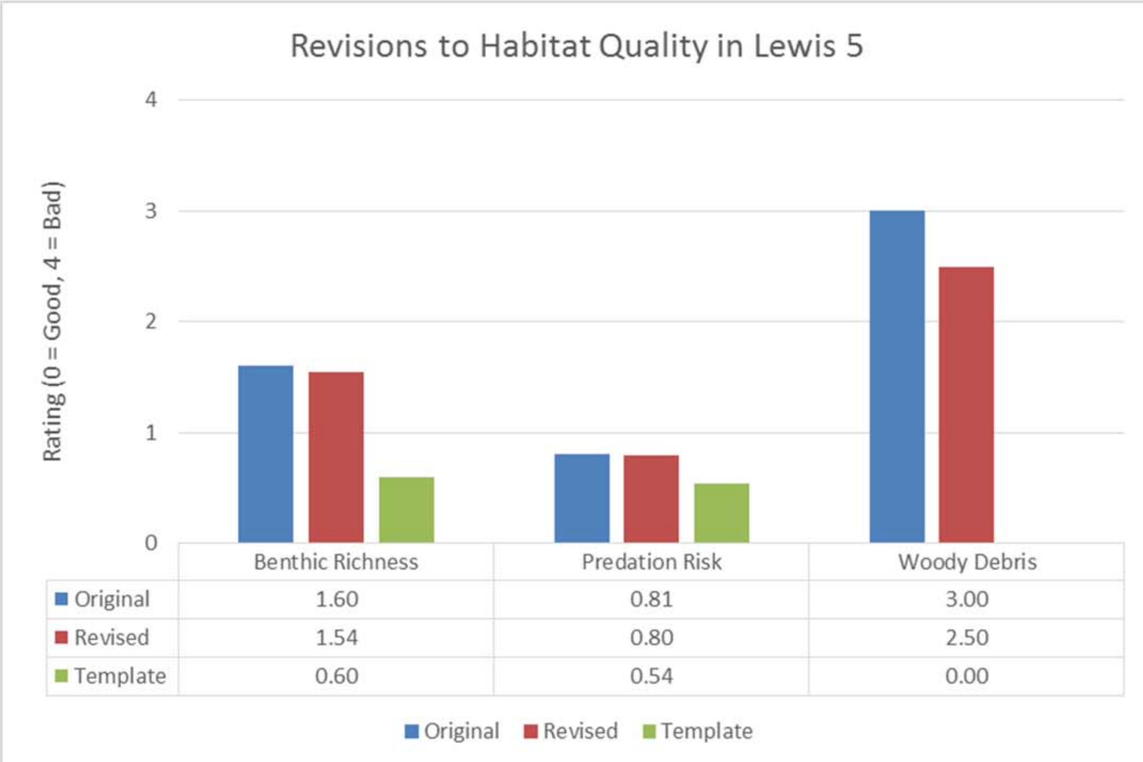
Field verification was conducted October 16, 2015. Habitat structures do not appear to have any loss of functionality. Grading along the margins is consistent with design criteria. Vegetation has stabilized the riparian area and very little erosion was observed. Two schools of salmonid parr appearing to be both spring Chinook and coho were observed (about 50 total) in the center of the channel during the team visit. Substrate is composed of cobble and gravel. Sedimentation within the channel is obvious. Whether sedimentation "flushes" out during higher flows is unknown. River flow at the time of the survey was 1,700 cfs.

Photo 1: LWD in the side channel shortly after construction in 2011.

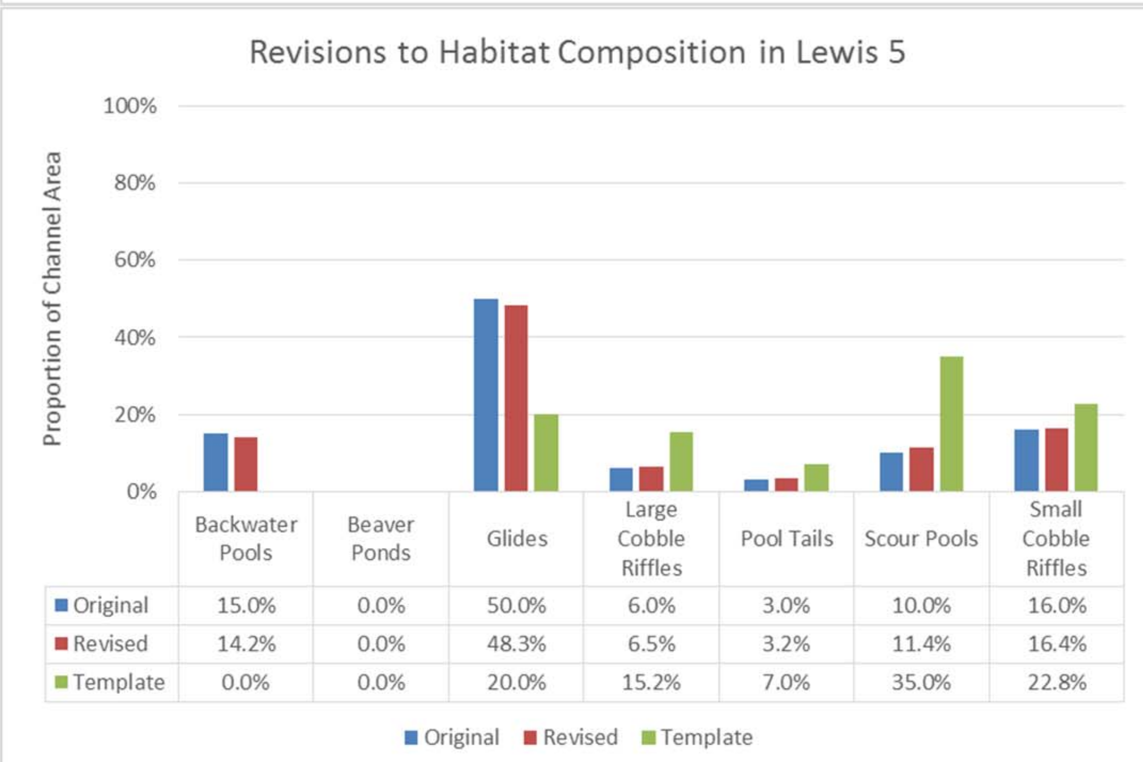

Photo 2: Stabilized banks in the side channel in 2015.


Photo 3: Sedimentation present in gravel substrate (2015). North Fork Lewis River Mile 13.5 Habitat Enhancement.

**Representation in EDT Model**
This project was categorized as construction of instream structures. The project was assigned an intensity of 0.168 based on the project length of 2500 ft (762 m) relative to the 4537 m length of the EDT reach Lewis 5.




| | Benthic Richness | Predation Risk | Woody Debris |
|---|---|---|---|
| Original | 1.60 | 0.81 | 3.00 |
| Revised | 1.54 | 0.80 | 2.50 |
| Template | 0.60 | 0.54 | 0.00 |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 15.0% | 0.0% | 50.0% | 6.0% | 3.0% | 10.0% | 16.0% |
| Revised | 14.2% | 0.0% | 48.3% | 6.5% | 3.2% | 11.4% | 16.4% |
| Template | 0.0% | 0.0% | 20.0% | 15.2% | 7.0% | 35.0% | 22.8% |

## 10-1542: East Fork Lewis Helicopter Log Jams

### Description

This project was designed to create eight logjams using 200 full length trees installed by a helicopter. Full length trees are essential to provide structure stability in this system. A nearby 35-acre timber unit was specifically created for stream restoration projects and thus the helicopter was able to carry logs directly from the source to the stream. The upper East Fork of the Lewis River is sorely in need of spawning gravel for threatened steelhead runs. The East Fork of the Lewis River is the only undammed fork of the Lewis River system, and the U.S Forest Service portions of the watershed are considered the best existing production areas for steelhead in the basin. Past floods and old stream cleanout projects removed much of the wood from the stream resulting in down cutting of the stream channel, and loss of spawning gravels and pool habitat. This project added log structures including full channel spanning logjams to capture gravel. This project built on the success of two other restoration projects in the East Fork Lewis River to create structures that capture spawning gravel, provide stream complexity, and create rearing pools.

### Current Conditions

The team visited all eight logjams denoted on project maps in October, 2015. Two of the eight logjams do not provide much enhancement other than overhead shade (low functioning). These logjams however do provide velocity breaks and cover during high flows. One logjam was compromised from high flows. Of the jams considered fully functioning, several had large deposits of gravel upstream of the jam. This was especially true in Reach 20A. In Reach 20B, the jams did not have as much gravel retention, but gravel pockets were visible upstream of the structures. Diameter of logs is 1 - 2 feet. The addition of these jams along with the 14 others placed from previous projects are creating spawning gravel and rearing cover for anadromous salmonids in a section of stream that is primarily composed of boulders and bedrock.

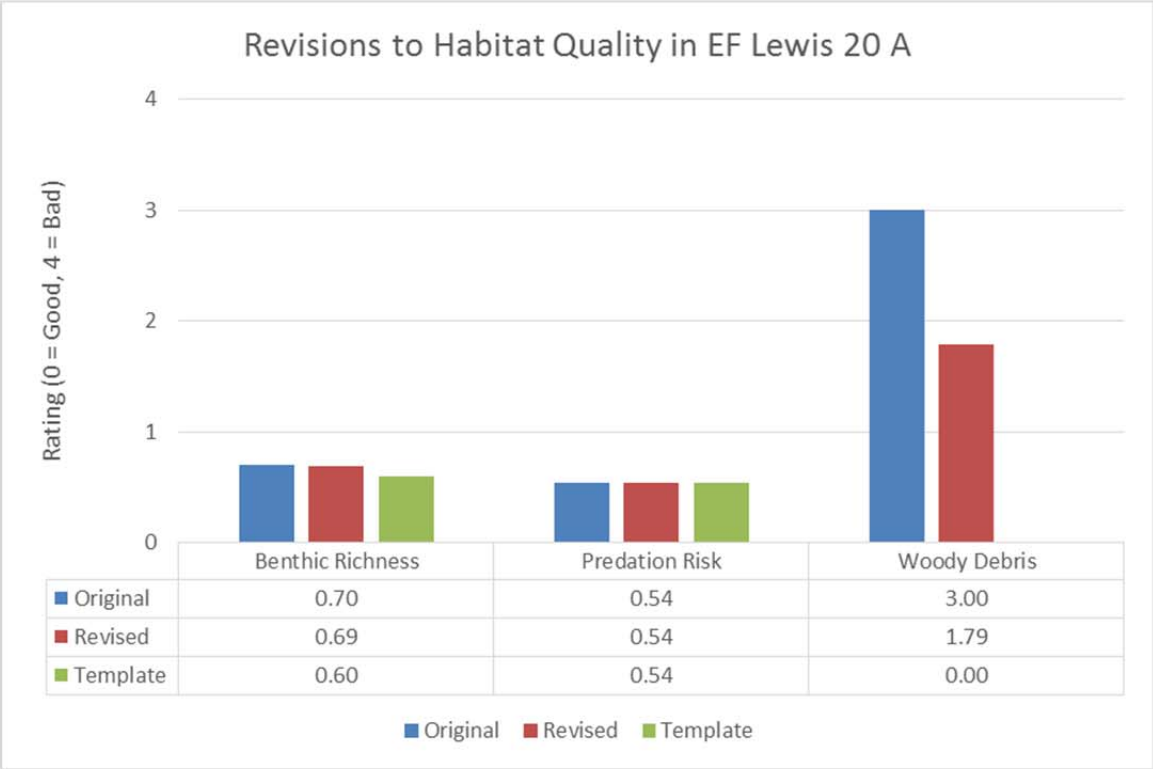
Photo 1: Gravel pocket forming upstream of logjam.


Photo 2: Low functioning structure.

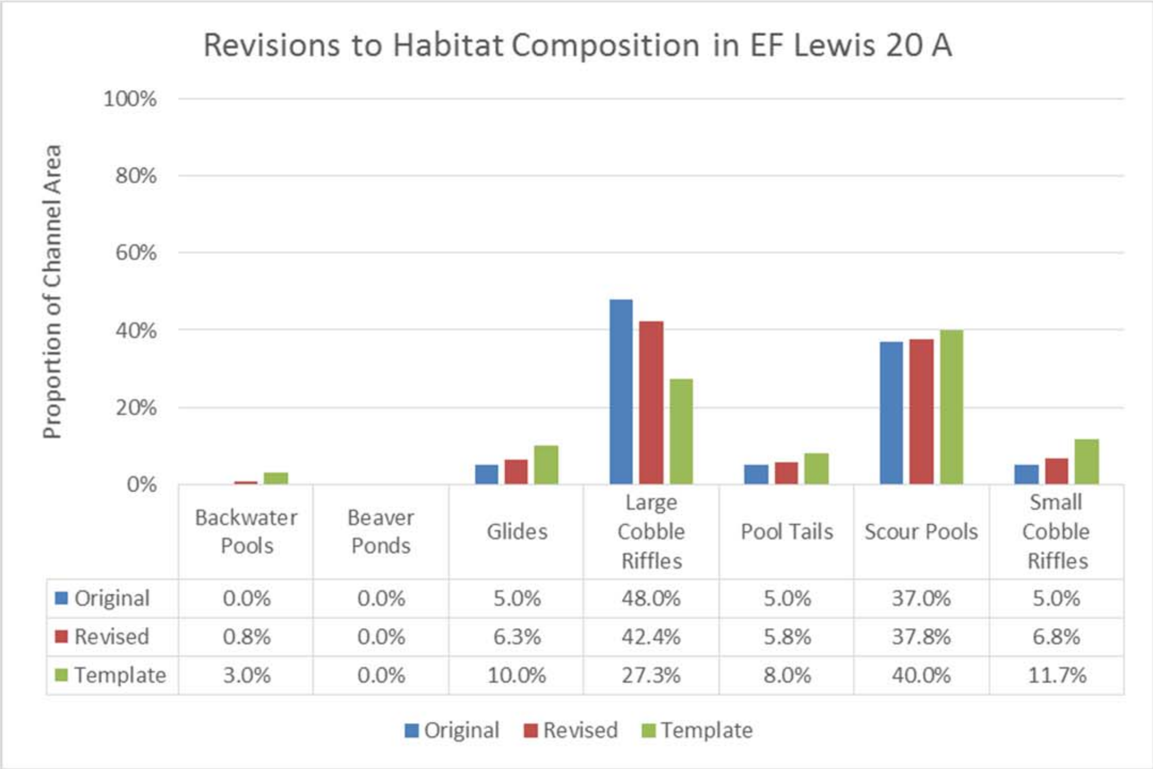

Photo 3: Gravel retention from habitat structure.

**Representation in EDT Model**

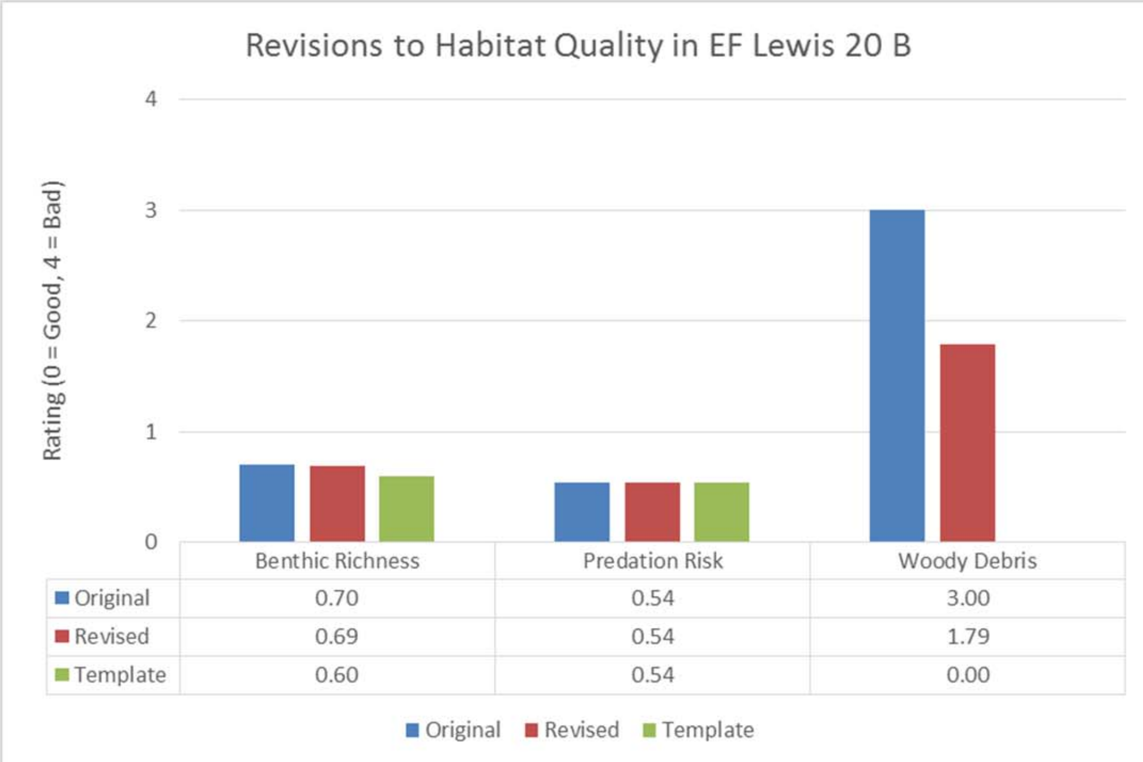
This project was categorized as construction of instream structures. The project was assigned an intensity of 0.405 based on the number of pieces of wood. The current EDT rating is equivalent to approximately 240 pieces of wood in the EDT reaches EF Lewis 20 A and EF Lewis 20 B. Adding 150 logs (of the eight structures placed, two were low functioning) increases the number of pieces to approximately 390. The corresponding improvement in the EDT woody debris rating of 1.22 is 40.5% of the restoration potential of 3 in this reach.



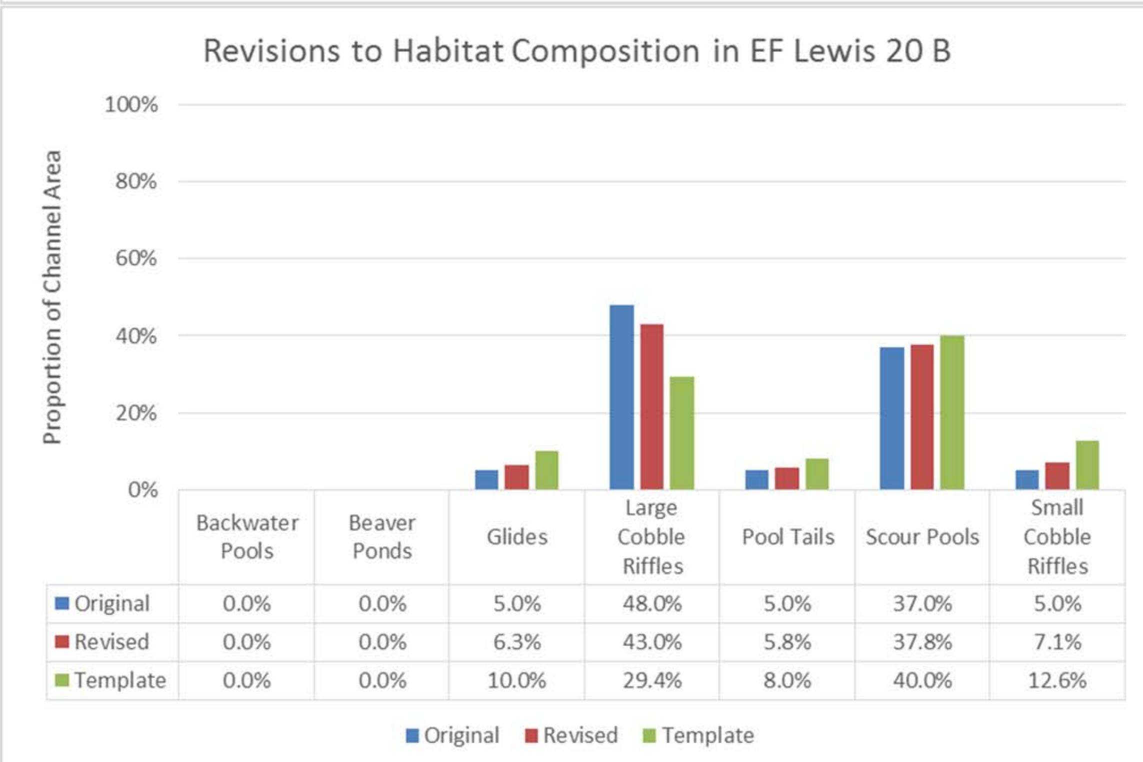

| | Benthic Richness | Predation Risk | Woody Debris |
|---|---|---|---|
| Original | 0.70 | 0.54 | 3.00 |
| Revised | 0.69 | 0.54 | 1.79 |
| Template | 0.60 | 0.54 | 0.00 |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 0.0% | 0.0% | 5.0% | 48.0% | 5.0% | 37.0% | 5.0% |
| Revised | 0.8% | 0.0% | 6.3% | 42.4% | 5.8% | 37.8% | 6.8% |
| Template | 3.0% | 0.0% | 10.0% | 27.3% | 8.0% | 40.0% | 11.7% |




| | Benthic Richness | Predation Risk | Woody Debris |
|---|---|---|---|
| Original | 0.70 | 0.54 | 3.00 |
| Revised | 0.69 | 0.54 | 1.79 |
| Template | 0.60 | 0.54 | 0.00 |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 0.0% | 0.0% | 5.0% | 48.0% | 5.0% | 37.0% | 5.0% |
| Revised | 0.0% | 0.0% | 6.3% | 43.0% | 5.8% | 37.8% | 7.1% |
| Template | 0.0% | 0.0% | 10.0% | 29.4% | 8.0% | 40.0% | 12.6% |

**11-1266: West Daybreak Restoration Project**

**Description**

The West Daybreak Restoration Project is located on the East Fork Lewis River, Clark County between river miles 9 and 10. The project site is west of the Daybreak Bridge, about 500 feet downstream, and continues approximately 4000 feet downstream. The project is located on a Tier 1 reach of the river, and benefits fall Chinook, chum, coho, and winter and summer steelhead. As designed, the project would increase diversity and complexity in the river reach, and provide enhanced habitat for spawning, rearing, and migrant transient holding. Key project elements include enhancement of 1100 feet of side channel, installation of five large woody debris structures along 300 feet of the mainstem, and, replanting of 1 acre of riparian buffer with native plants. The project is located in Daybreak Park, managed by Clark County, and recreational uses include fishing and nature observation.

**Current Conditions**

Field verification was conducted on December 15, 2015. Work on the mainstem (large wood addition, riparian plantings) has not been completed and erosion was observed in unrestored areas. The side channel portion of the project, approximately 20 feet wide x 350 feet long, was functioning as designed. Note: EDT parameterization for this project is currently confined to the side channel only (see below).

Photo 1: Uncompleted portion of the West Daybreak Restoration Project.

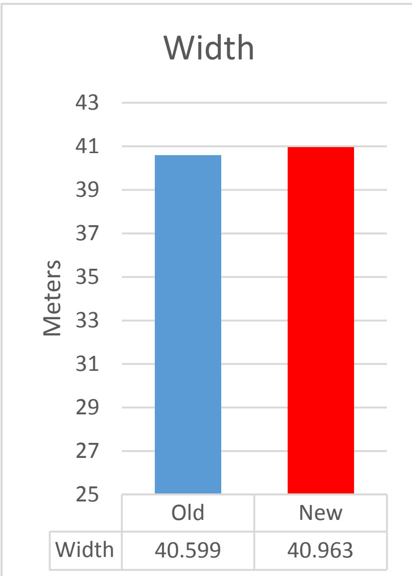

Photo 2: Erosion in the uncompleted portion of the project.

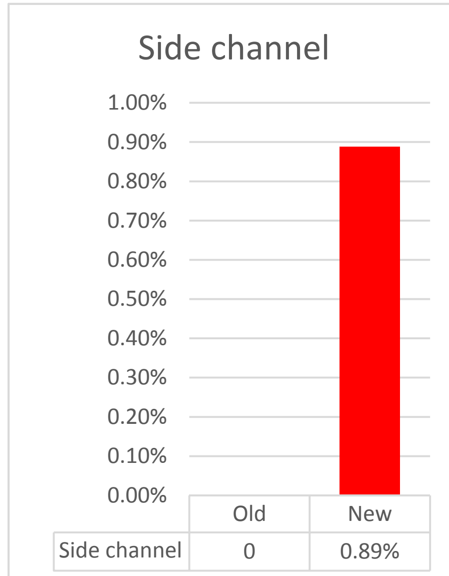

Photo 3: Completed side channel.


Photo 4: Completed side channel.

**Representation in EDT Model**

This project was categorized as side channel connection. The EDT reach EF Lewis 8 A was not previously categorized in the EDT model as having any side channel habitat. The newly connected side channel (approximately 120 m long and 6 m wide) has a surface area equal to 0.89% of the total channel area. The increase in channel area caused by the side channel connection also increased the average reach width (channel area divided by thalweg length) by 0.364 m.



**99-1355: Chelatchie Creek Restoration/Enhancement**

**Description**

This project was designed to help implement a comprehensive farm plan prepared by the Natural Resources Conservation Service (NRCS) and Clark County Conservation District. Chelatchie Creek, a tributary to Cedar Creek and the North Fork Lewis River, provides spawning and juvenile rearing habitat for coho and steelhead (federally threatened), and sea-run cutthroat trout. It is also adjacent to two dairies. This project should provide stream protection, shade, food, and woody debris for fish inhabiting Chelatchie Creek. A 2,400-foot section of Chelatchie Creek was to be re-vegetated and fenced to restrict livestock, thereby protecting water quality and riparian areas. 100-foot buffers were to have been established on both sides of the creek, a livestock crossing installed, and an alternative pasture was to have been created to compensate for pasture areas that were eliminated due to fencing.

**Current Conditions**

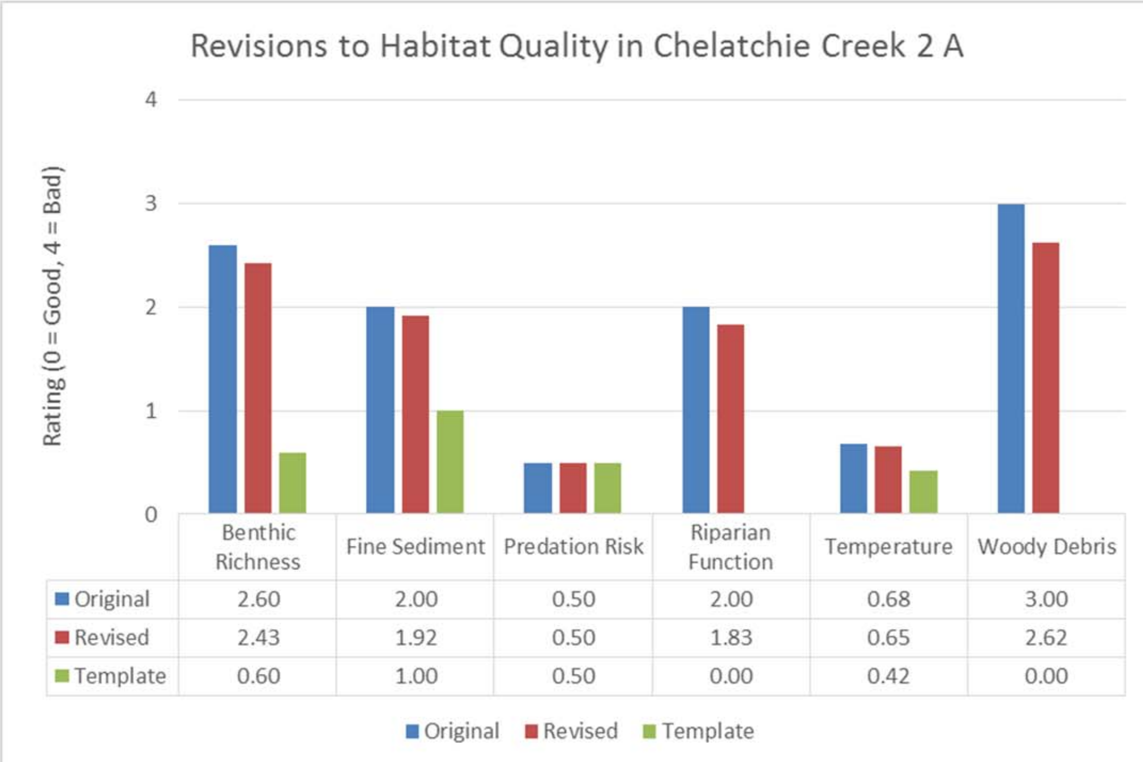
The project team attempted a field verification visit in December, 2015. They were not able to confirm the site as the livestock crossing had been replaced with a road bridge. However, satellite imaging shows mature plantings along riparian area.


Photo 1: Google Earth image from 1999 with very little riparian vegetation.

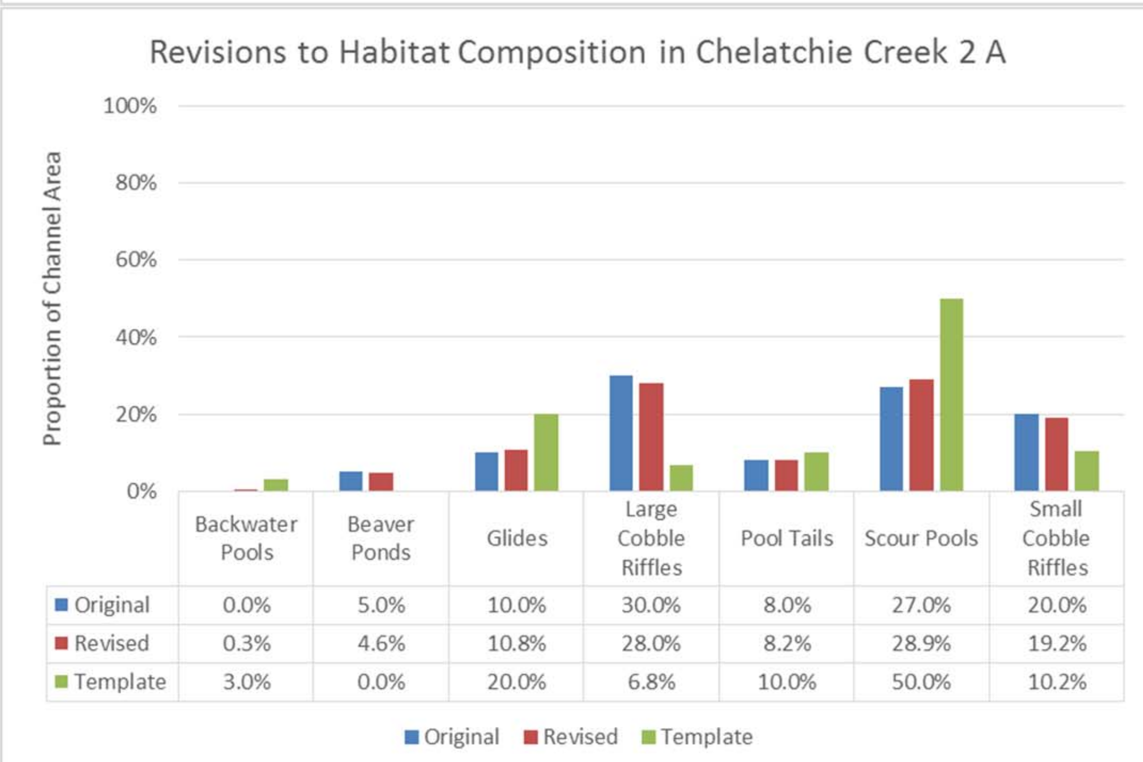
Photo 2: This image from 2015 shows a mature riparian buffer.

**Representation in EDT Model**

This project was categorized as riparian restoration. The project was assigned an intensity of 0.127 based on the project length of 2400 ft (732 m) relative to the 5760 m length of the EDT reach Chelatchie Creek 2 A.




| | Benthic Richness | Fine Sediment | Predation Risk | Riparian Function | Temperature | Woody Debris |
|---|---|---|---|---|---|---|
| Original | 2.60 | 2.00 | 0.50 | 2.00 | 0.68 | 3.00 |
| Revised | 2.43 | 1.92 | 0.50 | 1.83 | 0.65 | 2.62 |
| Template | 0.60 | 1.00 | 0.50 | 0.00 | 0.42 | 0.00 |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 0.0% | 5.0% | 10.0% | 30.0% | 8.0% | 27.0% | 20.0% |
| Revised | 0.3% | 4.6% | 10.8% | 28.0% | 8.2% | 28.9% | 19.2% |
| Template | 3.0% | 0.0% | 20.0% | 6.8% | 10.0% | 50.0% | 10.2% |

## 99-1358: East Fork Lewis Riparian Restoration

### Description

This project was designed to restore riparian habitat along 4,000 feet of the East Fork Lewis River. The project is located between river mile 23.5 and 24.5. Specific elements included replacing four under-sized upland drainage culverts, restoring five slide areas, revegetation, design, engineering, and monitoring. Sedimentation is a severe limiting factor in the East Fork Lewis. The East Fork Lewis is Clark County's largest free-flowing stream. It supports runs of summer and winter steelhead, Chinook, coho, and sea-run cutthroat trout. Historically, the East Fork Lewis also supported runs of chum. NMFS has listed lower Columbia steelhead, Chinook, coho and chum as federal threatened species. WDFW has documented, through aerial surveys, steelhead redds as close as 600 feet downstream of the project site. Geotechnical Resources estimates that slope failures have placed approximately 1,720 cubic yards of material (60% silt and 40% rock) into the East Fork Lewis River prior to this project. Another 1,000 - 1,200 cubic yards was predicted to enter the river without corrective measures.

### Current Conditions

Field verification conducted October 21, 2015. Treatment is along one side of the river. Numerous trees and shrubs have been planted, including cedar trees. Survival appears to be very high. In addition to the riparian plantings, Clark County has created a large side channel (> 1 mile) and replaced an existing culvert with a bridge. This channel was created from an engineered dike breach upstream of the East Fork Lewis Riparian Restoration project. The primary purpose of the new channel is enhanced juvenile rearing.

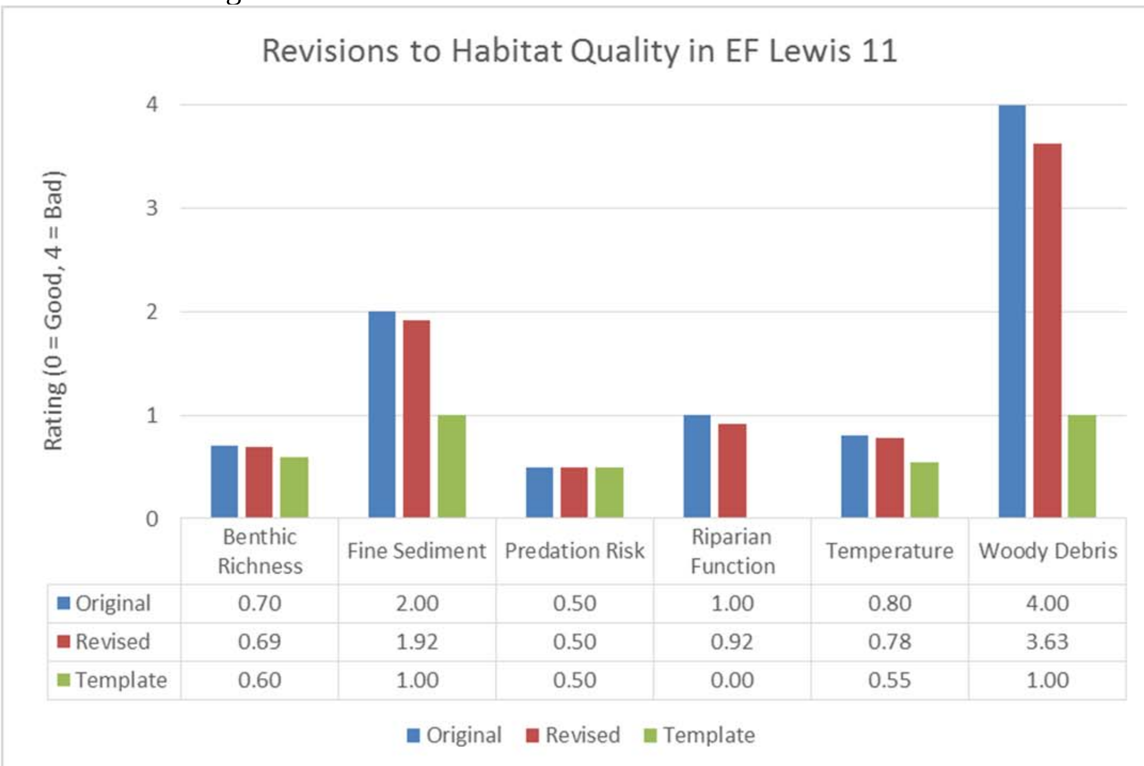
Photo 1: This bridge replaced an old culvert at the East Fork Lewis Riparian Restoration Project.

Photo 2: The bank has been stabilized with riparian plantings.

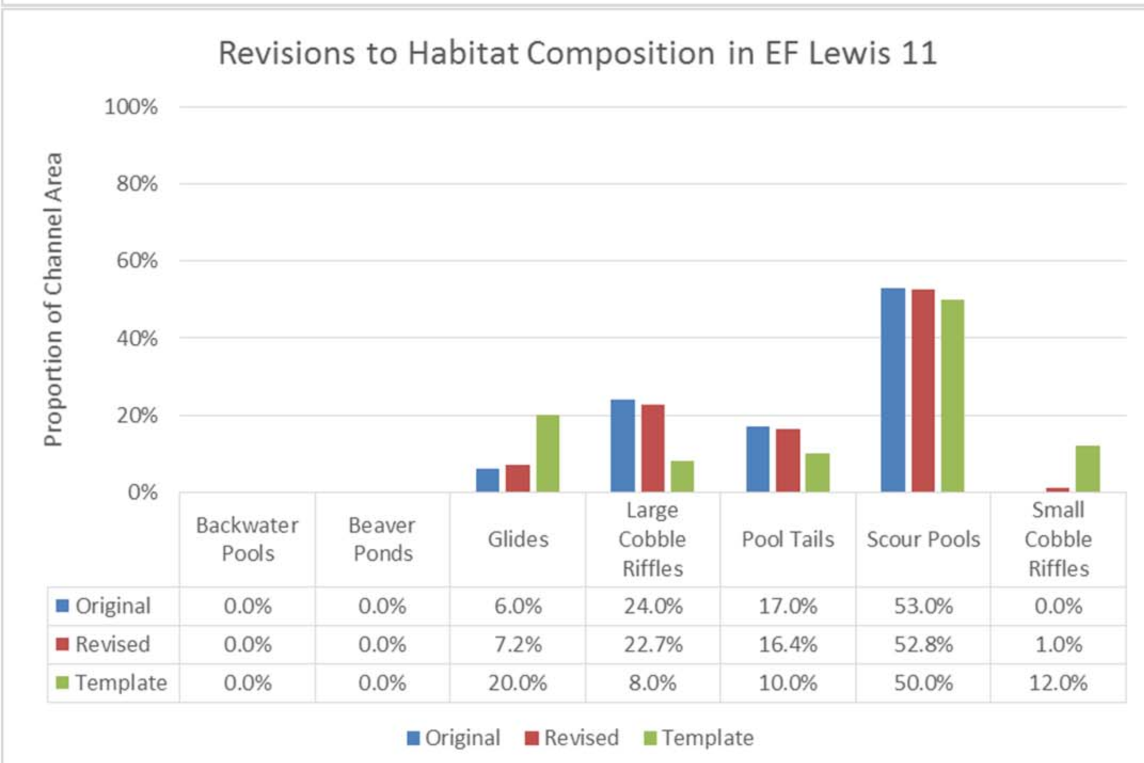
Photo 3: Side channel for rearing at the East Fork Lewis Riparian Restoration Project.

**Representation in EDT Model**

This project was categorized as riparian restoration. An intensity of 0.124 was assigned based on the project length of 4000 ft (1219 m) on one bank (equivalent to 610 m of both banks) relative to the 4907 m length of the EDT reach EF Lewis 11.




| | Benthic Richness | Fine Sediment | Predation Risk | Riparian Function | Temperature | Woody Debris |
|---|---|---|---|---|---|---|
| Original | 0.70 | 2.00 | 0.50 | 1.00 | 0.80 | 4.00 |
| Revised | 0.69 | 1.92 | 0.50 | 0.92 | 0.78 | 3.63 |
| Template | 0.60 | 1.00 | 0.50 | 0.00 | 0.55 | 1.00 |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 0.0% | 0.0% | 6.0% | 24.0% | 17.0% | 53.0% | 0.0% |
| Revised | 0.0% | 0.0% | 7.2% | 22.7% | 16.4% | 52.8% | 1.0% |
| Template | 0.0% | 0.0% | 20.0% | 8.0% | 10.0% | 50.0% | 12.0% |

**99-1632: Riley Creek at Finalburg Road Culvert Upgrade**

**Description**

This project was designed to remove the fish passage barrier that existed where Finalburg Road crosses Riley Creek. Riley Creek is located within the East Fork Lewis River subbasin. The culvert replacement is located approximately 2 miles east of La Center, WA, approximately 1.5 miles upstream of the confluence with Lockwood Creek. The former culvert's flow depths, velocities and outlet drop were barriers to fish passage. The project was to replace the culvert with an 8-foot wide corrugated pipe arch culvert. The bottom of the new culvert was countersunk and frames were installed to hold bedload material and provide a more natural bottom. A concrete fishway was to be constructed in the outfall area because of the high outlet drop. Suitable pooling facilities along with culvert depths and velocities were to be created to allow the passage of migratory fish.

**Current Conditions**

The Project Team conducted field verification on December 15, 2015. Two culverts were located on Riley Creek and it was unclear which one was the subject of the upgrade project. Riley Creek at Johnson Creek Rd. included a functioning concrete fishway; no fishway exists at the Riley Creek at Finalburg Road location. Consistency with WDFW or NMFS fish passage criteria was not assessed. Verification of this project is pending discussion with project sponsors.

Photo 1: Riley Creek at Finalburg Rd. culvert; an arch culvert closest to the LCFRB location but with no fishway. Approximately 5.1 km of habitat exists upstream of this location.


Photo 2: Riley Creek at Johnson Creek Rd.; a pipe culvert that does not fit the project description; but does have a fishway.

**Representation in EDT Model**

This project was modelled by setting the passage on the culvert Riley Creek Culv 2 to 100% in the EDT model.

**99-1633: Lewis River Preserve Restoration**

**Description**

Historically, gravel mining has severely degraded various properties on the lower East Fork Lewis River. The Lewis River Preserve is a 125-acre abandoned mine. The site is owned by the Environmental Enhancement Group, a 501(c) private nonprofit organization dedicated to restoring habitat values on abandoned mining sites. This project was designed to restore degraded habitat on the former mine site. Design elements included removal/control of invasive plants, planting native trees and shrubs, planting low-lying herbaceous vegetation, and reducing steep banks along shoreline margins. Project objectives included reducing sedimentation, restoring trees along riparian zones, reducing water temperatures, providing source wood for large woody debris, and reducing steep banks to restore the natural hydrology of the floodplain. Project design was led by Fish First, a 501(c) 3 organization dedicated to restoring salmon/steelhead runs in the Lewis River system.

**Current Conditions**

The project team conducted a field verification site visit on December 15, 2015. The project did not appear to be complete or functional. According to Dick Dyrland (Fish First), plantings did not survive due to the soil compaction in the area. Also, since the project was started, the channel has redirected during a flooding event causing the enhancement to no longer be in the channel. Note: the site visit was conducted downstream of the coordinates provided by LCFRB, see image below.


Photo 1: LCFRB coordinates vs. project site visit.

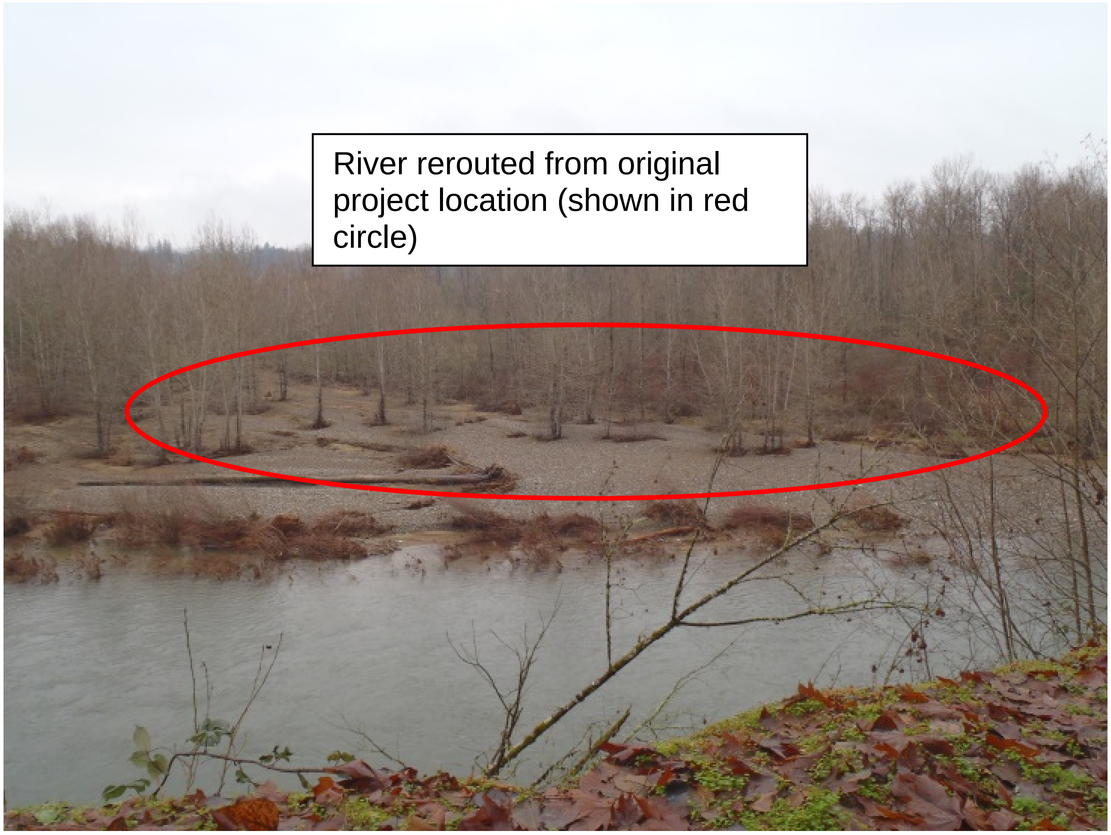
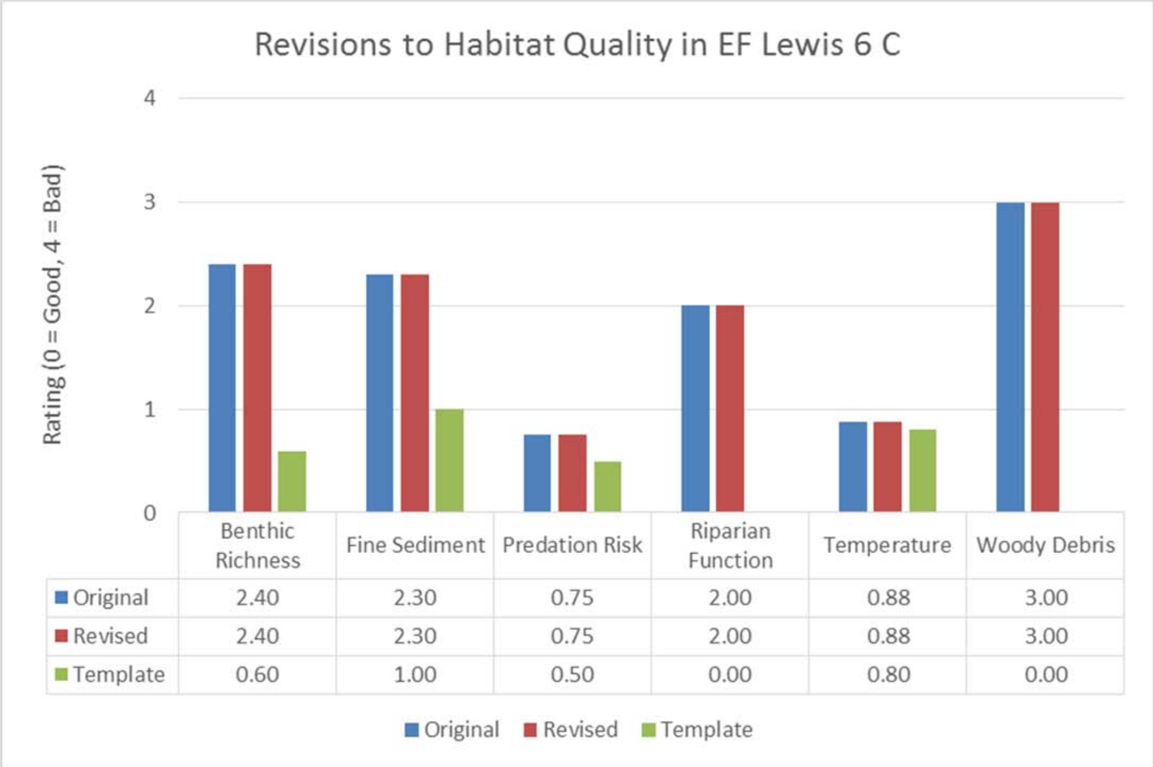


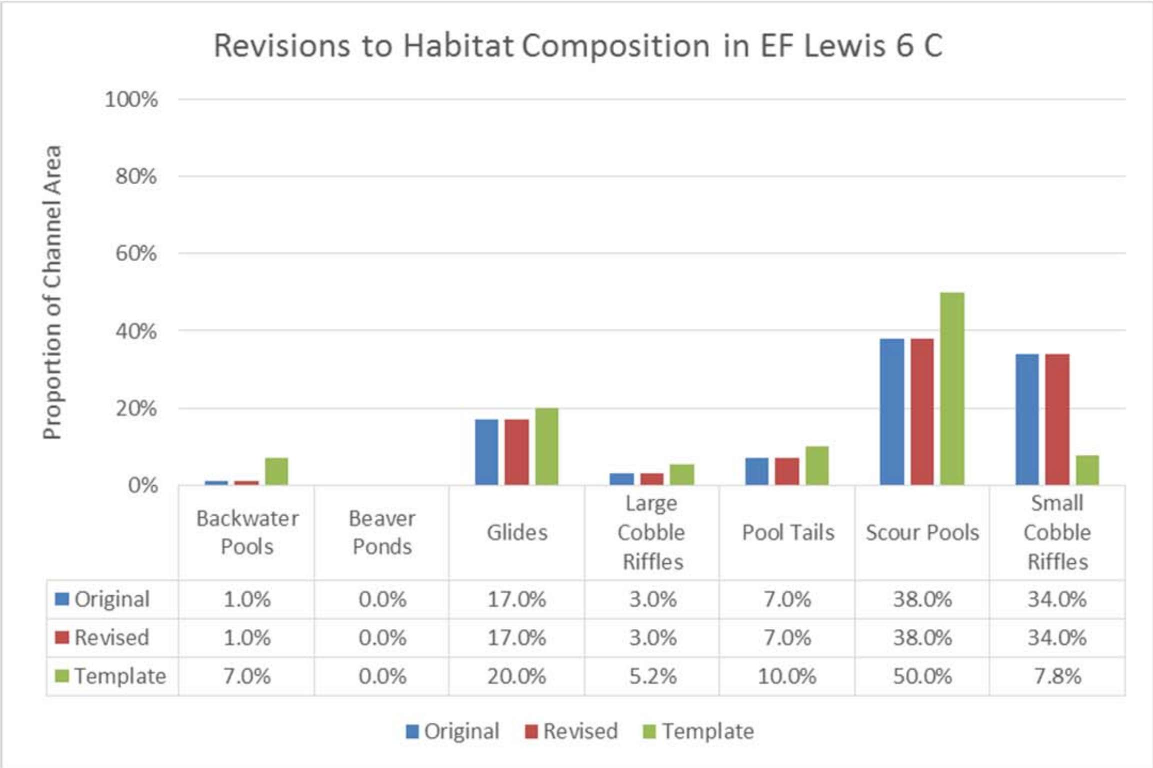

Photo 2: Project location.

## Representation in EDT Model

The project was not successfully implemented, so no revisions were made to the EDT model in reach EF Lewis 6 C.




| | Benthic Richness | Fine Sediment | Predation Risk | Riparian Function | Temperature | Woody Debris |
|---|---|---|---|---|---|---|
| Original | 2.40 | 2.30 | 0.75 | 2.00 | 0.88 | 3.00 |
| Revised | 2.40 | 2.30 | 0.75 | 2.00 | 0.88 | 3.00 |
| Template | 0.60 | 1.00 | 0.50 | 0.00 | 0.80 | 0.00 |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 1.0% | 0.0% | 17.0% | 3.0% | 7.0% | 38.0% | 34.0% |
| Revised | 1.0% | 0.0% | 17.0% | 3.0% | 7.0% | 38.0% | 34.0% |
| Template | 7.0% | 0.0% | 20.0% | 5.2% | 10.0% | 50.0% | 7.8% |

## 99-1635: Van Breeman Habitat Enhancement

### Description

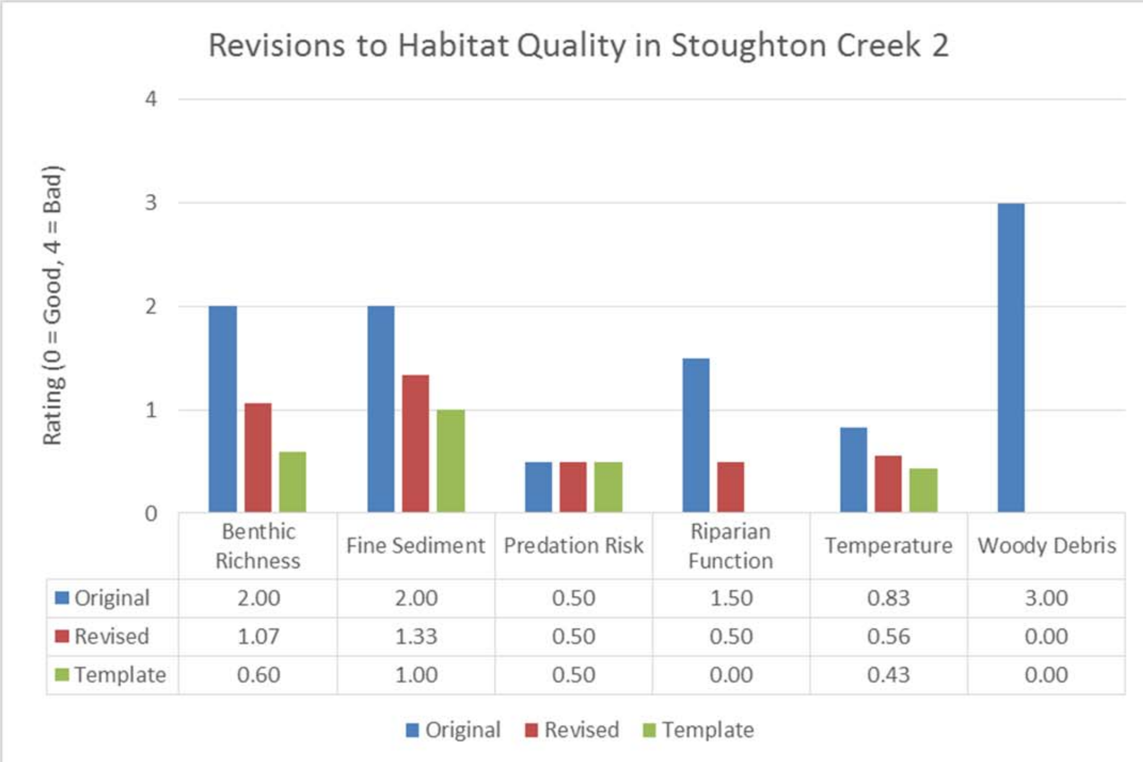
The Van Breeman Habitat Enhancement project is located on an unnamed class 3 stream that is a tributary to the East Fork of the Lewis River and enters just upstream from the Monahan (or Lockwood Creek) Project. This watershed was identified as needing more quality riparian habitat along smaller streams. As indicated by historic aerial photos, the riparian area had a sparse vegetation canopy prior to project completion. The project was designed to restore approximately 2,855 linear feet of stream bank. Project activities involved installing 4,010 feet of fencing to exclude domestic animals from the riparian corridors, providing an alternate water source for livestock, removing nonnative, invasive plants, and planting native trees and shrubs. The fencing and re-vegetated riparian zone should help prevent fecal coliform from reaching the water, provide shade to help reduce water temperature, decrease streambank erosion and subsequent turbidity and increase the habitat that supports the food chain for fish. These activities provide more woody debris, spawning ground gravel recruitment, predation protection and other riparian attributes beneficial to fish.

### Current Conditions

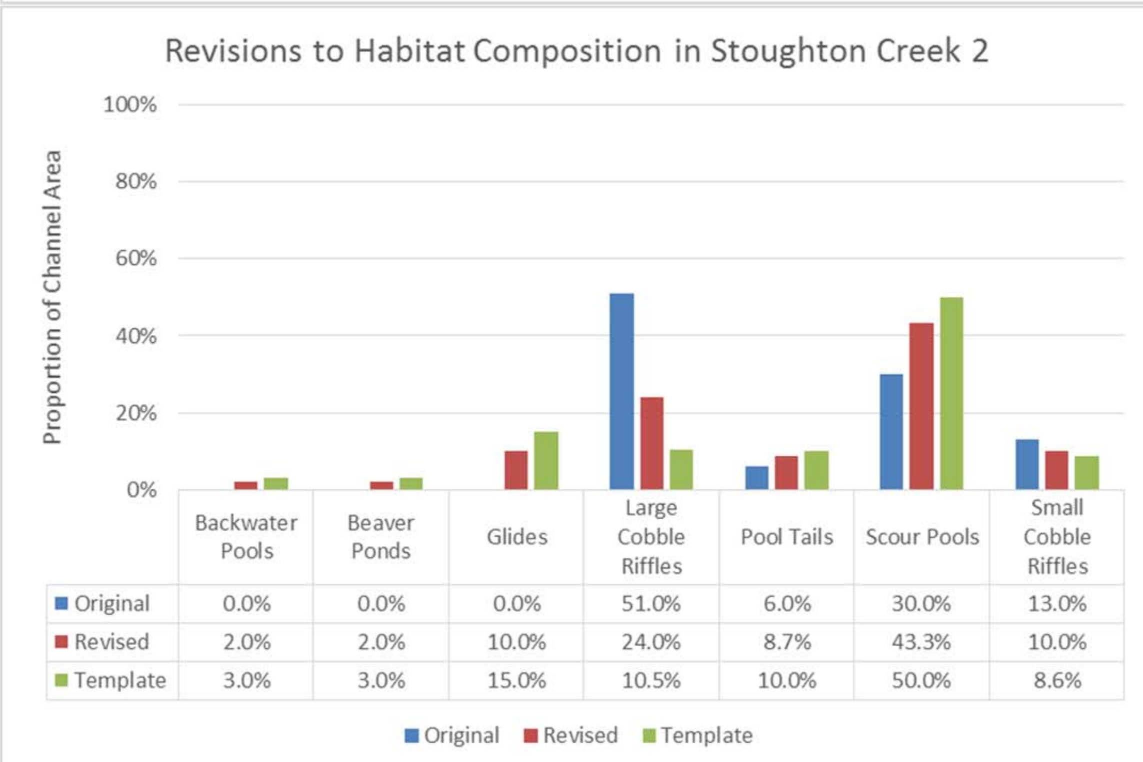
Denise Smee, Clark County Conservation District, stated that the project is functioning as designed (pers. comm., 10/29/15).

### Representation in EDT Model

This project was categorized as riparian restoration. The project was assigned an intensity of 1 based on the project length of 2855 linear ft (732 m) of stream bank relative to the 870 m length of the EDT reach Stoughton Creek 2.




| | Benthic Richness | Fine Sediment | Predation Risk | Riparian Function | Temperature | Woody Debris |
|---|---|---|---|---|---|---|
| Original | 2.00 | 2.00 | 0.50 | 1.50 | 0.83 | 3.00 |
| Revised | 1.07 | 1.33 | 0.50 | 0.50 | 0.56 | 0.00 |
| Template | 0.60 | 1.00 | 0.50 | 0.00 | 0.43 | 0.00 |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 0.0% | 0.0% | 0.0% | 51.0% | 6.0% | 30.0% | 13.0% |
| Revised | 2.0% | 2.0% | 10.0% | 24.0% | 8.7% | 43.3% | 10.0% |
| Template | 3.0% | 3.0% | 15.0% | 10.5% | 10.0% | 50.0% | 8.6% |

**99-1636: Lockwood Creek Recovery/Enhancement**

**Description**

The Lockwood Creek recovery/habitat enhancement project is located upstream of the bridge at the mouth of the Lockwood Creek where it empties into the East Fork Lewis River, and extends upstream approximately 3,135 feet. This reach of stream was diked on both sides restricting the floodway and causing the channel to downcut. This project was designed to remove the dike on the south side of the stream, recreate the floodway, and vegetate the floodplain with native species indicative of Puyallup soil type (i.e., cottonwood, black hawthorne, willow and native grasses). Livestock exclusion fencing was also to be installed. The area was mostly void of riparian canopy prior to the project. The fencing and revegetated riparian zone is intended to prevent fecal coliform from reaching the water, provide shade to help reduce water temperatures, reduce streambank erosion and subsequent turbidity, and increase the habitat that supports the food chain for fish. These activities increase woody debris in the channel, spawning gravel recruitment, predation protection, and other riparian attributes beneficial to fish. These activities compliment the bridge installed at the mouth of Lockwood Creek in the summer of 1998 (installed to aid fish passage), fish passage installed in 1997 at Lockwood Creek Road and the other habitat enhancements done by Clark Public Utilities in the upper East Fork Lewis River watershed in 1996.

**Current Conditions**

Field verification was conducted on October 21, 2015. This is a large riparian planting at the mouth of Lockwood Creek. Many conifers were observed and all appeared healthy. Fencing is in excellent condition and includes an electric conductor to prevent livestock from breaching the fence.

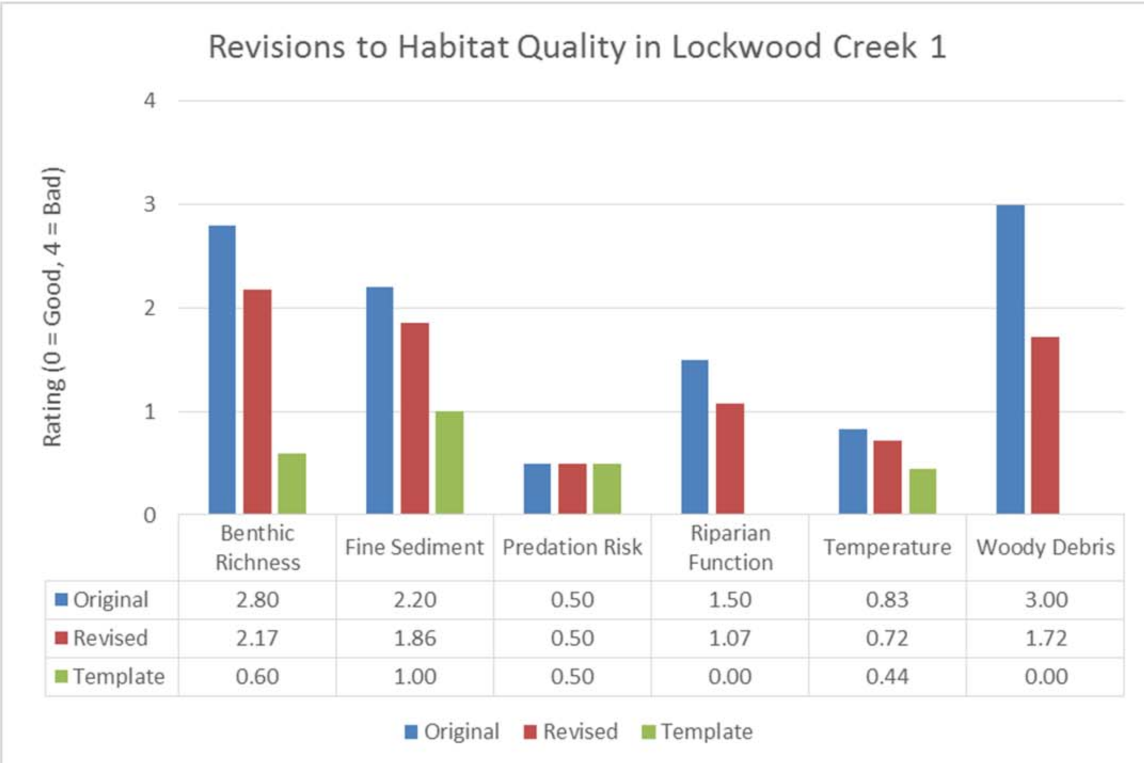
Photo 1: Conifer plantings at Lockwood Creek.

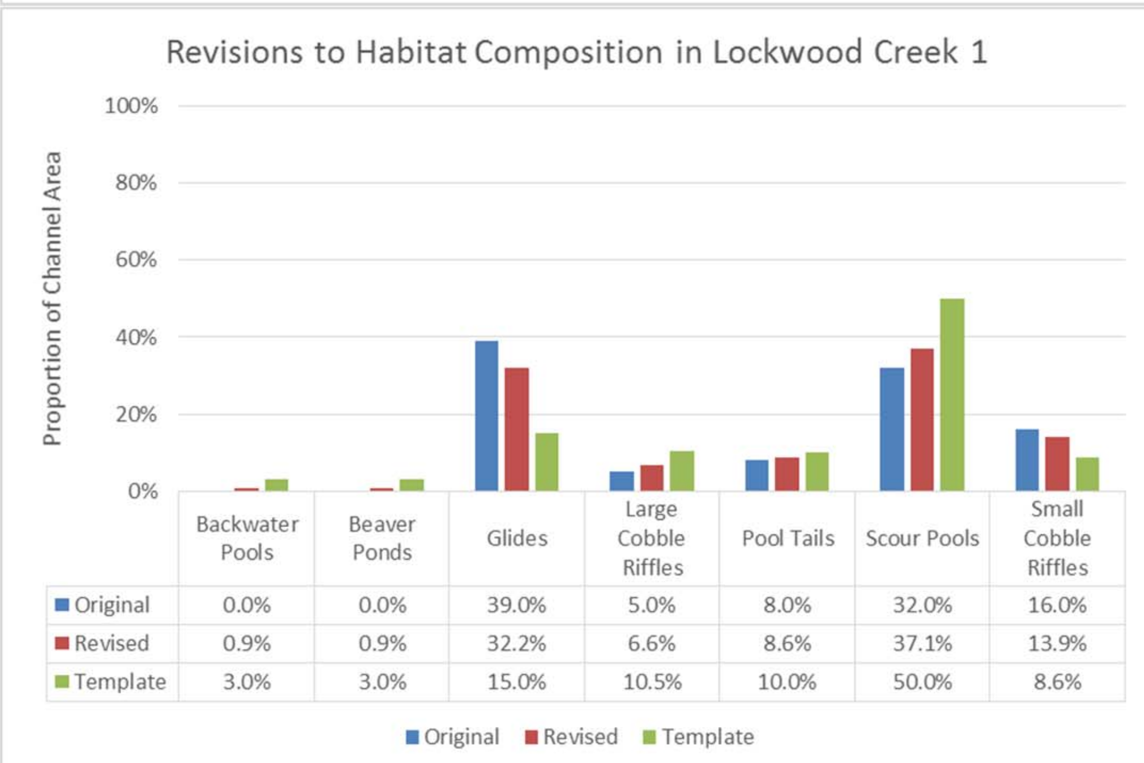

Photo 2: Plantings behind exclusionary fencing.

Photo 3: The mouth of Lockwood Creek.

**Representation in EDT Model**

This project was categorized as riparian restoration and assigned an intensity of 0.427 based on the project length of 3135 ft (956 m) relative to the 2237 m length of the EDT reach Lockwood Creek 1.



**2007-02: Martin Access; Plas Newydd & Two Forks Access Riparian Enhancements**

**Description**

This project included three linked projects: the Martin Access Riparian Forest and Off-channel Habitat Enhancement, the Two Forks Access Riparian Forest Enhancement, and the Plas Newydd Farm Riparian Forest Enhancement. A collection agreement between the Tribe and PacifiCorp was signed in June 2007. The Tribe obtained necessary rights of entry and access permission, and restoration on the three sites commenced in fall of 2007. The Tribe also was able to utilize a WDFW truck for three months (valued in-kind at $5,000) and landowner Rhidian Morgan of Plas Newyyd Farm provided over 400 cut willow poles 4' in length, ranging from 1" to 4" in diameter (also valued at $5,000 in-kind). Total project value was $85,000.

**Current Conditions**

Field verification was conducted March 30, 2016 near low tide and with Lewis River flows at approximately 5,000 cfs. Several series of anchored wood placements were visible near the mouth of Mud Creek (also known as Allen Creek) and the site appeared to be functioning as designed. Riparian plantings were observed in two sections on the Lewis River; the first in the photo below and another approximately ½ mile upstream, downstream of Pekin Ferry Rd.

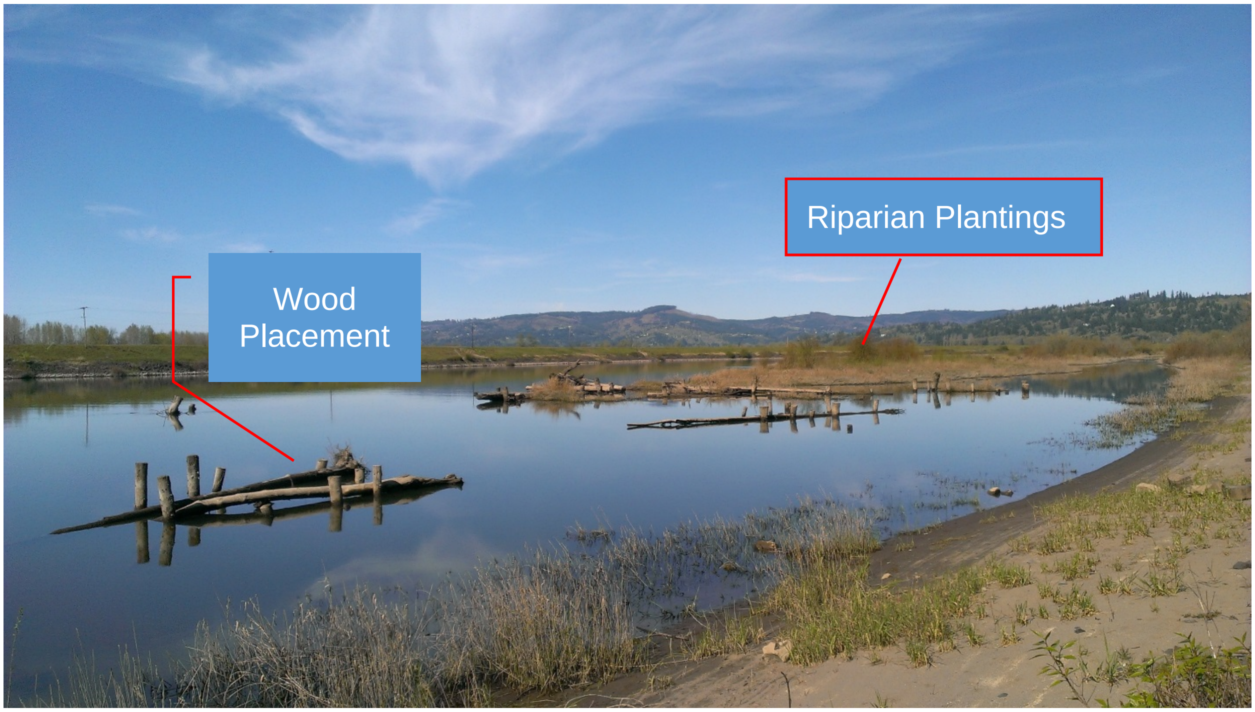
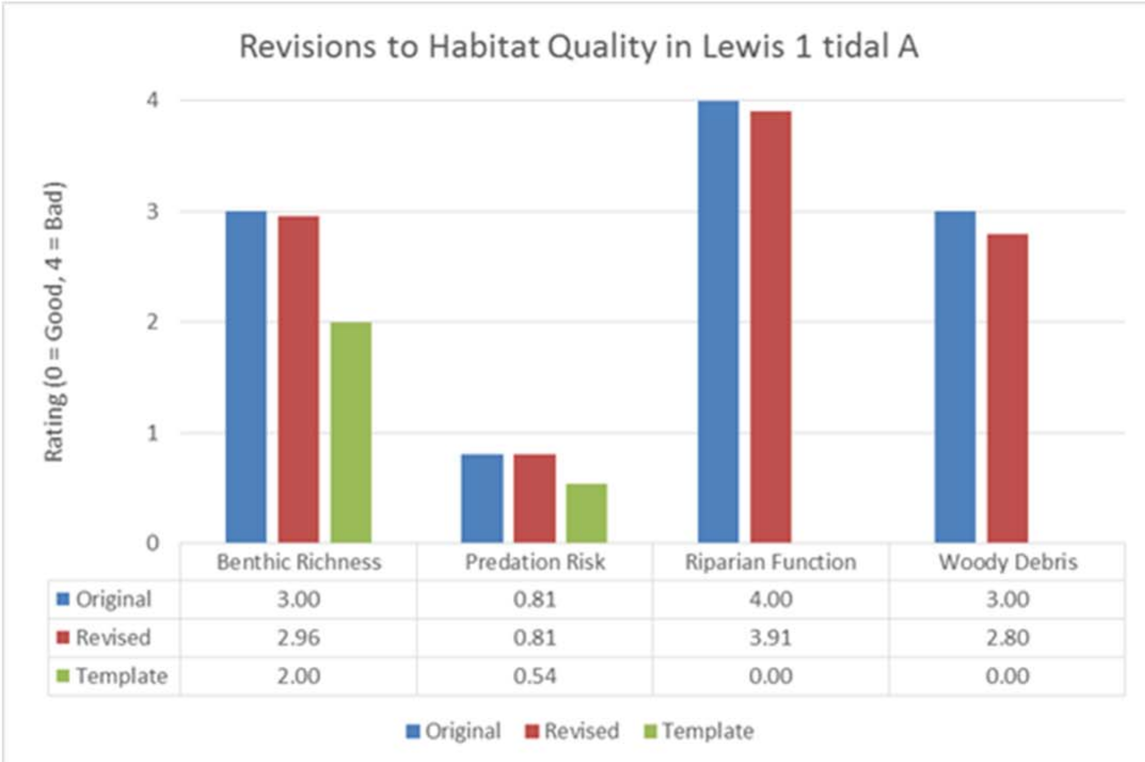
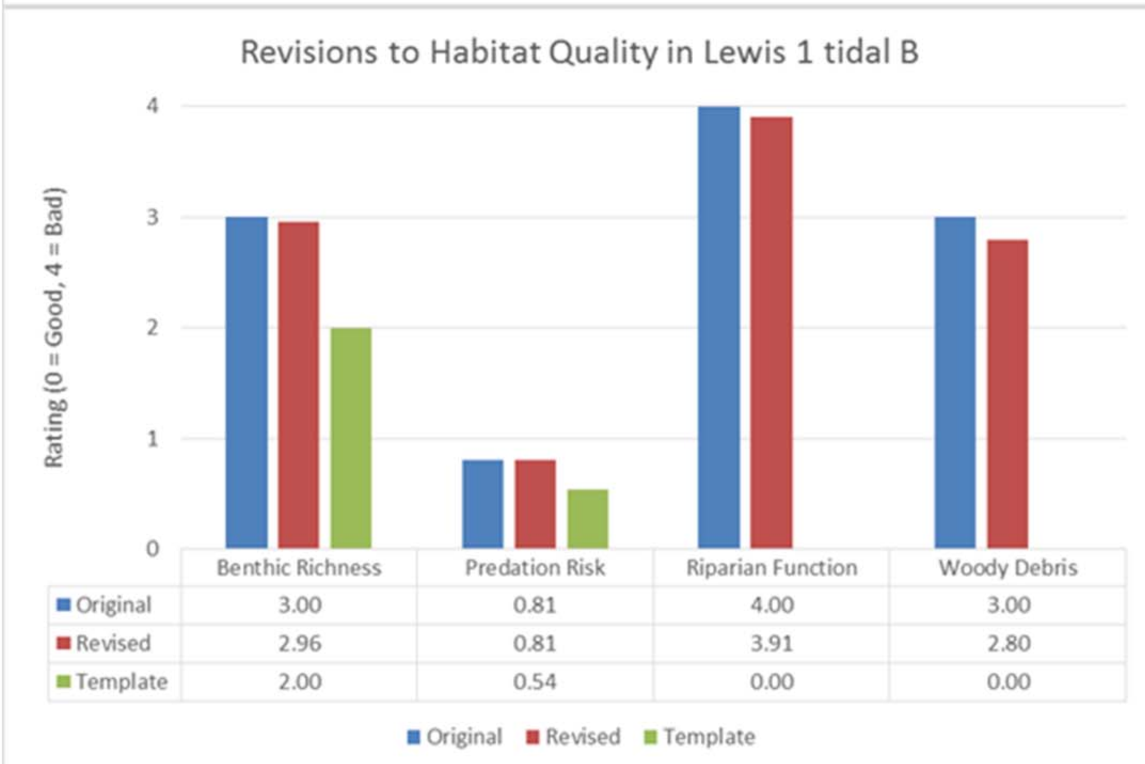


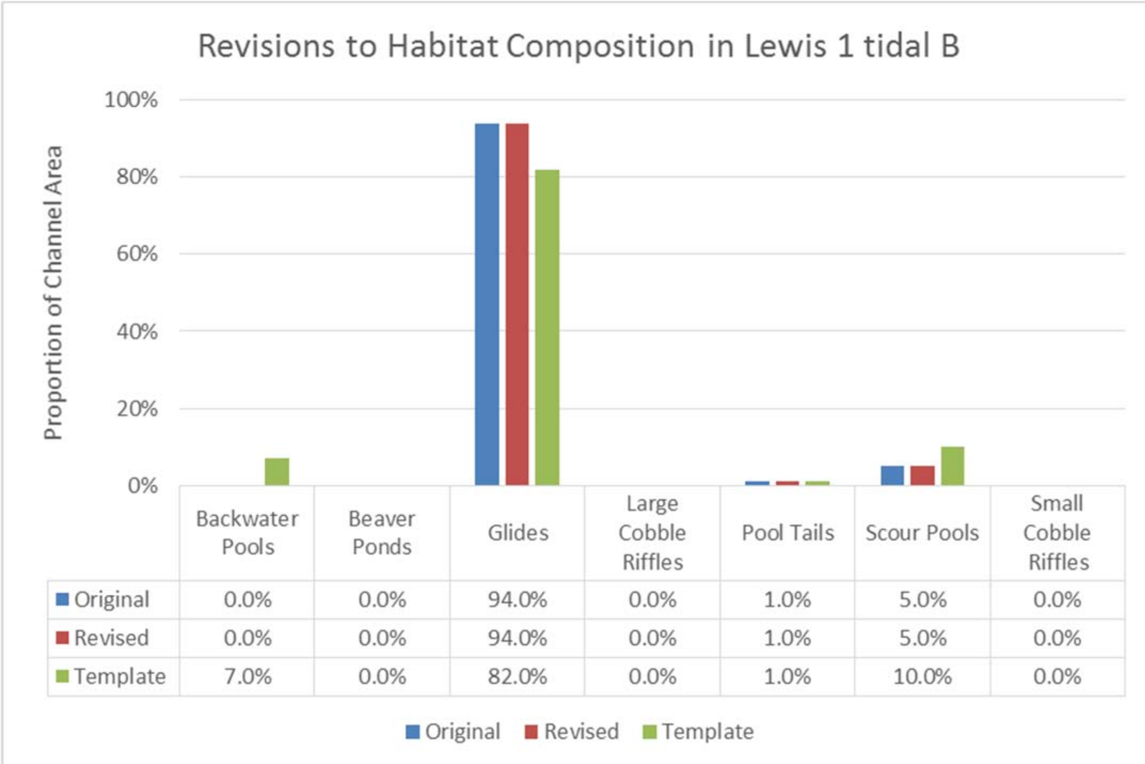

Photo 1. Large wood placement near mouth of Mud Creek.

**Representation in EDT Model**

This project was categorized as riparian restoration and assigned an intensity of 0.067 based on the project length of 1325 ft (404 m) relative to the 6018 m length of the EDT reaches Lewis 1 tidal A and Lewis 1 tidal B. Riparian restoration is assumed not to affect temperature in large rivers like the lower Lewis mainstem near the Columbia, these bars are not shown.


Revisions to Habitat Quality in Lewis 1 tidal A
Rating (0 = Good, 4 = Bad)
0
1
2
3
4
Benthic Richness
Predation Risk
Riparian Function
Woody Debris
Original 3.00 0.81 4.00 3.00
Revised 2.96 0.81 3.91 2.80
Template 2.00 0.54 0.00 0.00
Original
Revised
Template


Revisions to Habitat Quality in Lewis 1 tidal B
Rating (0 = Good, 4 = Bad)
0
1
2
3
4
Benthic Richness
Predation Risk
Riparian Function
Woody Debris
Original 3.00 0.81 4.00 3.00
Revised 2.96 0.81 3.91 2.80
Template 2.00 0.54 0.00 0.00
Original
Revised
Template




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 0.0% | 0.0% | 94.0% | 0.0% | 1.0% | 5.0% | 0.0% |
| Revised | 0.0% | 0.0% | 94.0% | 0.0% | 1.0% | 5.0% | 0.0% |
| Template | 7.0% | 0.0% | 82.0% | 0.0% | 1.0% | 10.0% | 0.0% |

## 2008-02: Mud Creek Enhancement

### Description

The Cowlitz Indian Tribe was to install approximately 30 small structures of large woody debris in Mud Creek (AKA Allen Creek). Mud Creek is the lowest tributary on the left bank of the mainstem Lewis River, entering at RM 2.0. This project would directly benefit anadromous fish by providing cover and instream and side channel habitat in the lower reach of Mud Creek.

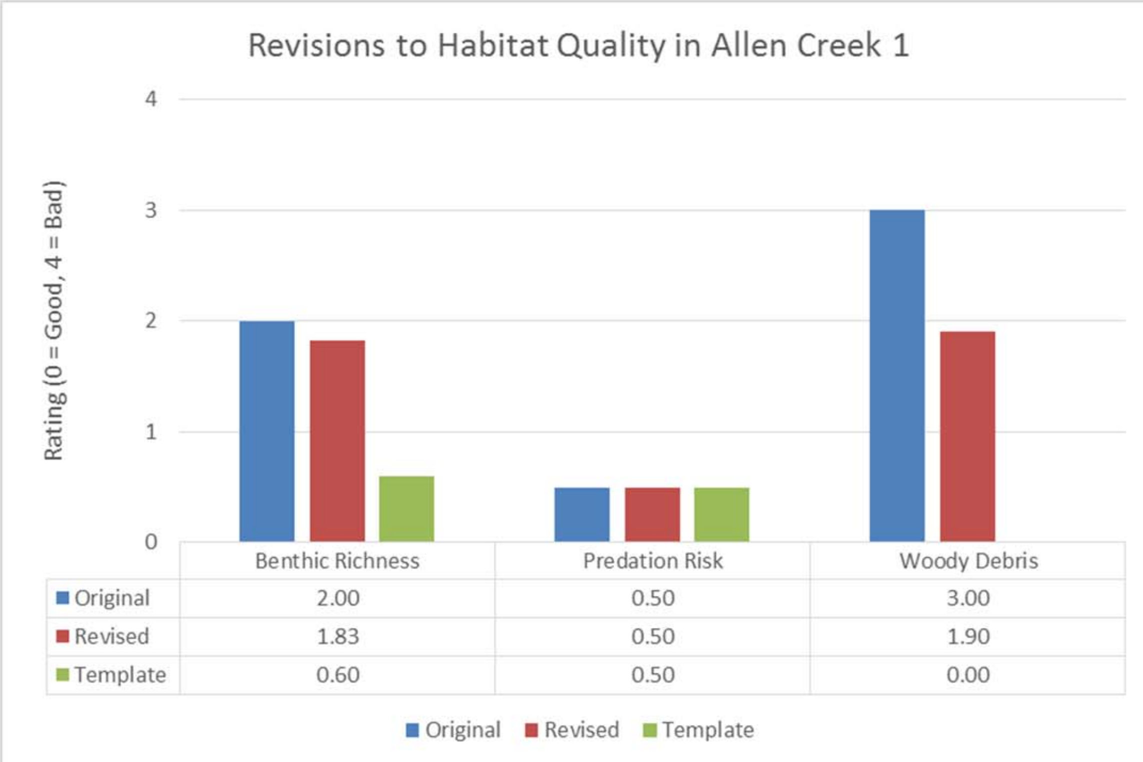
Mud Creek is a low-gradient stream, lying approximately 8 feet above mean sea level throughout its entire 0.5 mile length and arising from Mud Lake. The principal tributary to Mud Lake is Allen Canyon Creek. The outlet of Mud Lake is known by most as Mud Creek, but may alternatively be known as Allen Creek. Since Mud Creek is a low-gradient stream, and is so low in the watershed, the riparian function of Mud Creek is not that of a high-gradient headwater stream. Mud Creek functions like a tidal slough habitat and provides significant refuge and over-wintering habitat for both juvenile and adult salmonids in the otherwise highly constrained floodplain of the lower Lewis River. Mud Lake received a significant sediment impact from an adjacent gravel quarry in 2007. Fines resulting from the sediment discharge were put towards the restoration of the creek.

### Current Conditions

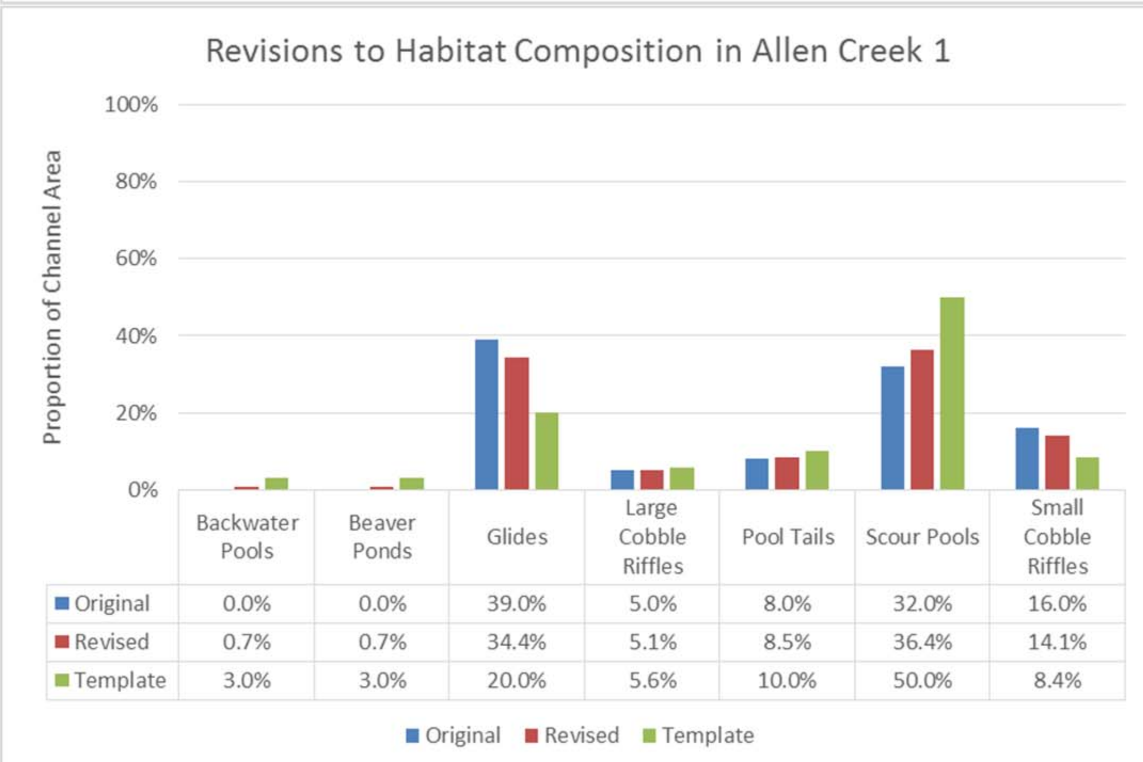
Field verification was conducted March 30, 2016. Based on discussion with Kelley Jorgansen, Program Manager for the Plas Newydd Conservation Program, permitting issues prevented placement of large wood in Mud Creek itself; instead wood structures were placed in the Lewis River near the mouth Mud Creek mouth (see discussion above for Project 2007-02).

### Representation in EDT Model

No changes were made to intensity related to wood placement in EDT reach Allen Creek 1 (graphs shown below to be revised accordingly).




| | Benthic Richness | Predation Risk | Woody Debris |
|---|---|---|---|
| Original | 2.00 | 0.50 | 3.00 |
| Revised | 1.83 | 0.50 | 1.90 |
| Template | 0.60 | 0.50 | 0.00 |



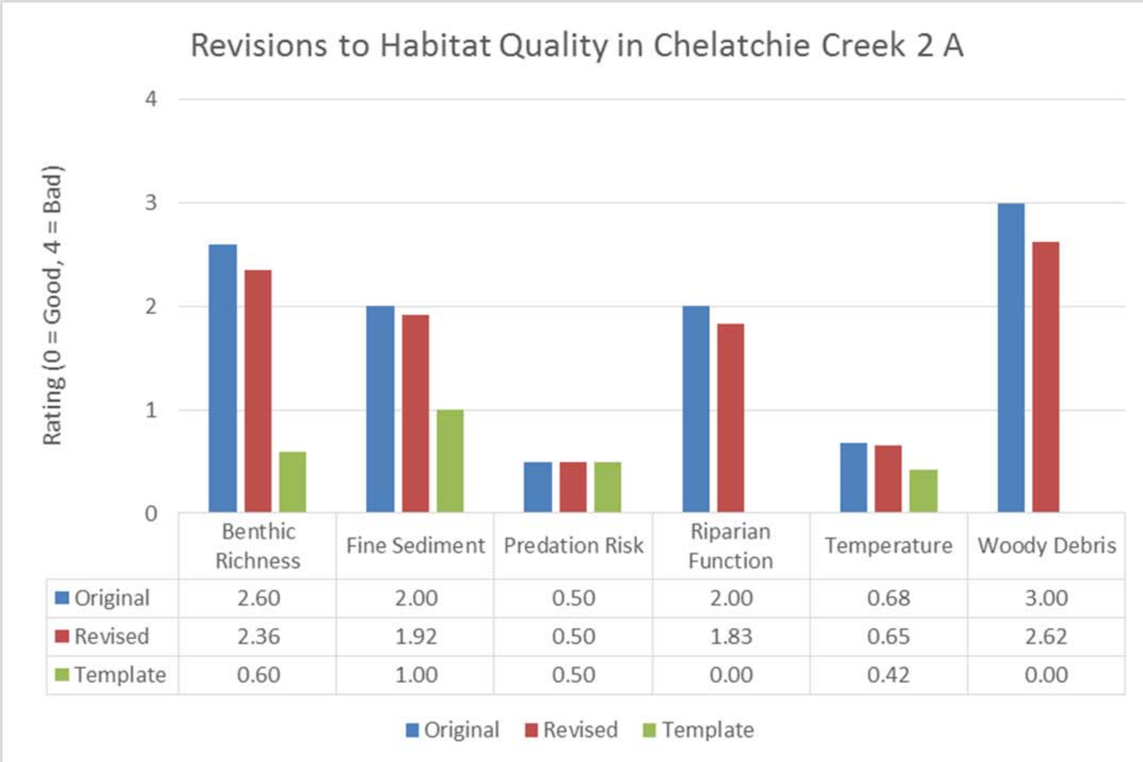

| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 0.0% | 0.0% | 39.0% | 5.0% | 8.0% | 32.0% | 16.0% |
| Revised | 0.7% | 0.7% | 34.4% | 5.1% | 8.5% | 36.4% | 14.1% |
| Template | 3.0% | 3.0% | 20.0% | 5.6% | 10.0% | 50.0% | 8.4% |

**Cumulative Intensity**

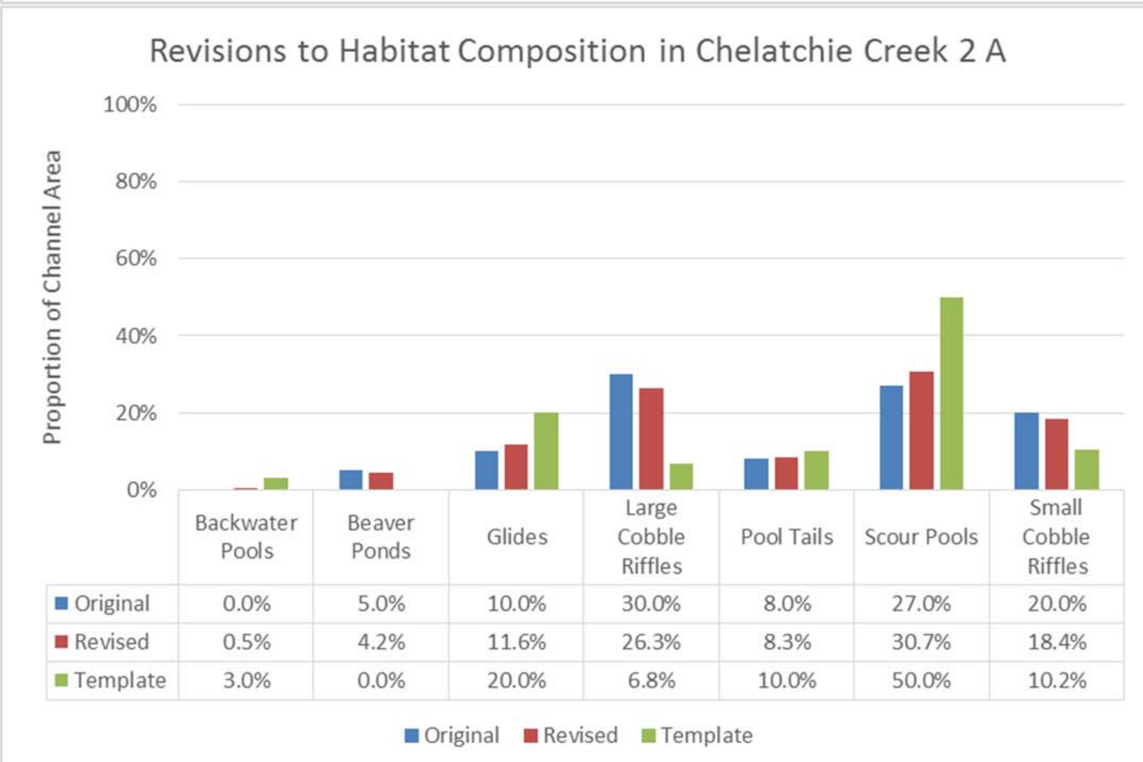
Three of the EDT reaches had more than one restoration project: Chelatchie Creek 2 A, Lewis 5, and Lockwood 1. The ratings entered into the EDT model need to account for the cumulative effect of all restoration projects carried out in a reach. If more than one project of the same type occurred within a reach, then the cumulative intensity of the two projects was modelled based on the size of the non-overlapping project areas relative to the size of the reach. If more than one restoration project occurred within a reach but the projects were of different types, then the project with the longest-term effects was considered. For example, riparian function was assumed to have a longer-term effect on habitat conditions than wood structure placement. Reach specific cumulative changes are discussed below.

**Cumulative Restoration on Chelatchie Creek 2 A**

Two restoration projects were carried out on the EDT reach Chelatchie Creek 2 A: 99-1355 Chelatchie Creek Restoration/Enhancement (riparian restoration) and 00-1036 DuPuis Chelatchie Creek Project (rock vane and wood structure placements). Riparian restoration is assumed to have a larger long-term effect on woody debris than wood structure placement, so the effect of 00-1036 was ignored when computing the cumulative woody debris rating.



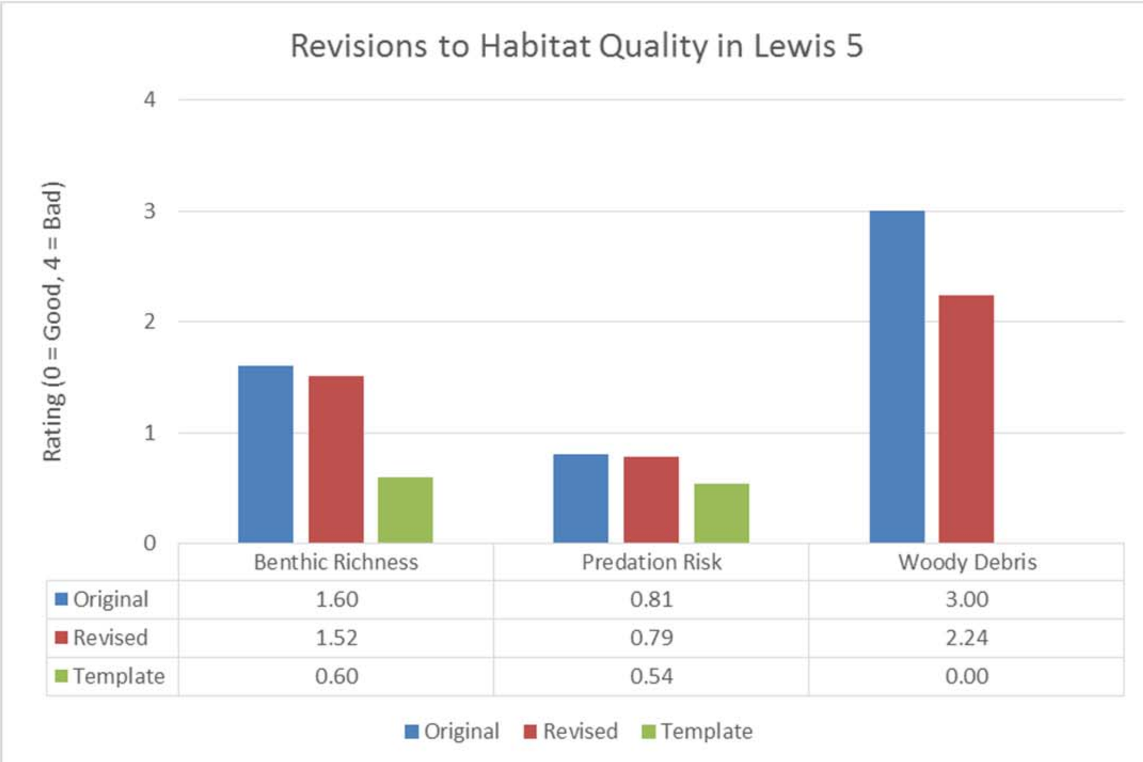

| | Benthic Richness | Fine Sediment | Predation Risk | Riparian Function | Temperature | Woody Debris |
|---|---|---|---|---|---|---|
| Original | 2.60 | 2.00 | 0.50 | 2.00 | 0.68 | 3.00 |
| Revised | 2.36 | 1.92 | 0.50 | 1.83 | 0.65 | 2.62 |
| Template | 0.60 | 1.00 | 0.50 | 0.00 | 0.42 | 0.00 |



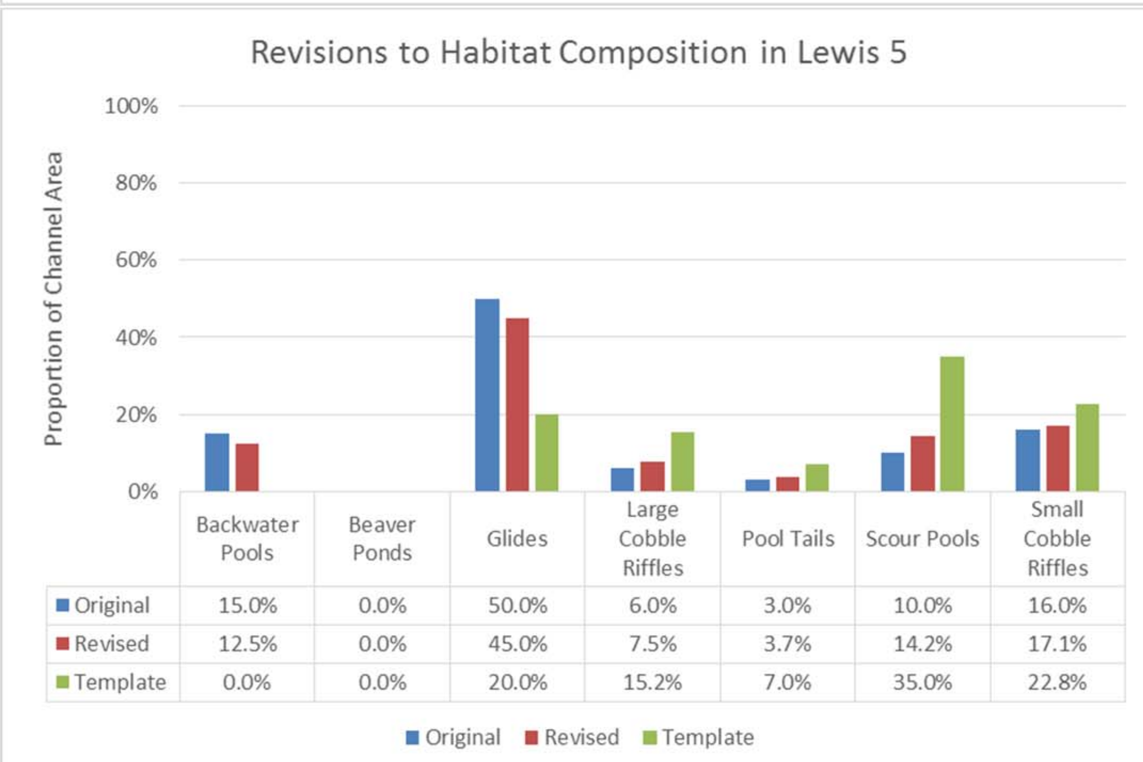

| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 0.0% | 5.0% | 10.0% | 30.0% | 8.0% | 27.0% | 20.0% |
| Revised | 0.5% | 4.2% | 11.6% | 26.3% | 8.3% | 30.7% | 18.4% |
| Template | 3.0% | 0.0% | 20.0% | 6.8% | 10.0% | 50.0% | 10.2% |

**Cumulative Restoration on Lewis 5**

Two restoration projects were carried out on the EDT reach Lewis 5: 08-1733 North Fork Lewis Rivermile 13.5 and 10-1498 NF Lewis RM 13.5 Off-Channel Habitat Enhancement. Because these projects were carried out in non-overlapping areas, the cumulative restoration benefit was the simple sum of the restoration benefits of the two projects.



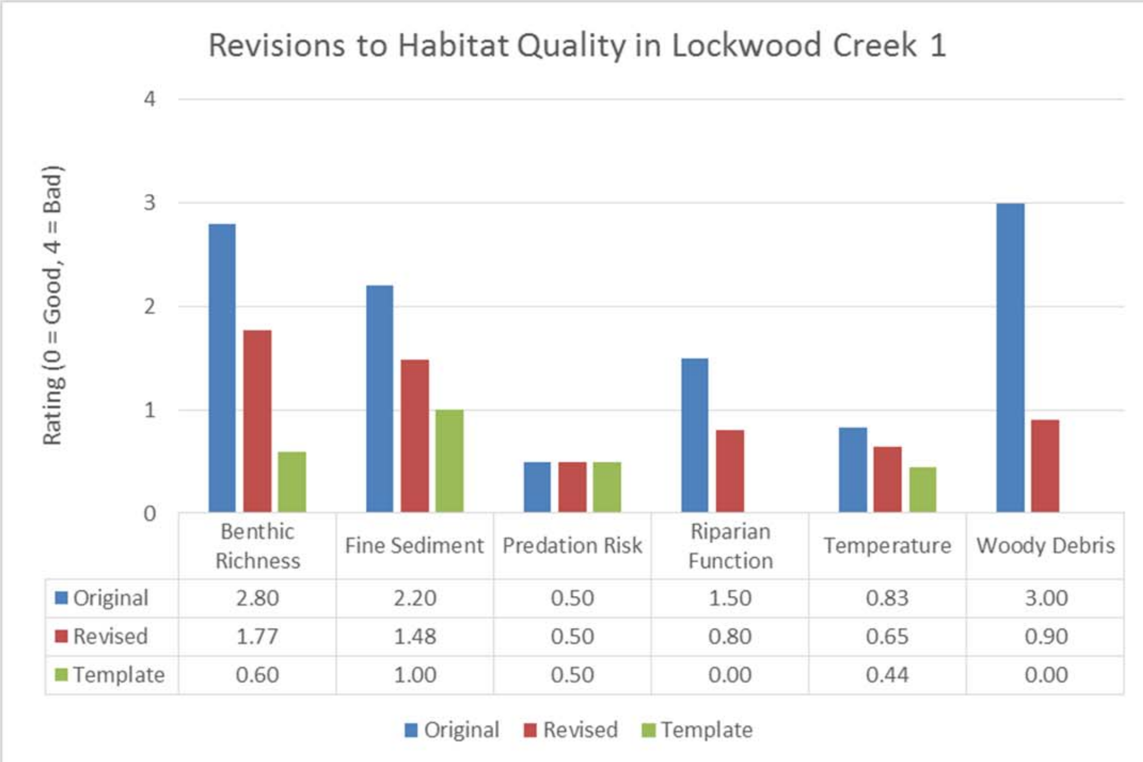

| | Benthic Richness | Predation Risk | Woody Debris |
|---|---|---|---|
| Original | 1.60 | 0.81 | 3.00 |
| Revised | 1.52 | 0.79 | 2.24 |
| Template | 0.60 | 0.54 | 0.00 |



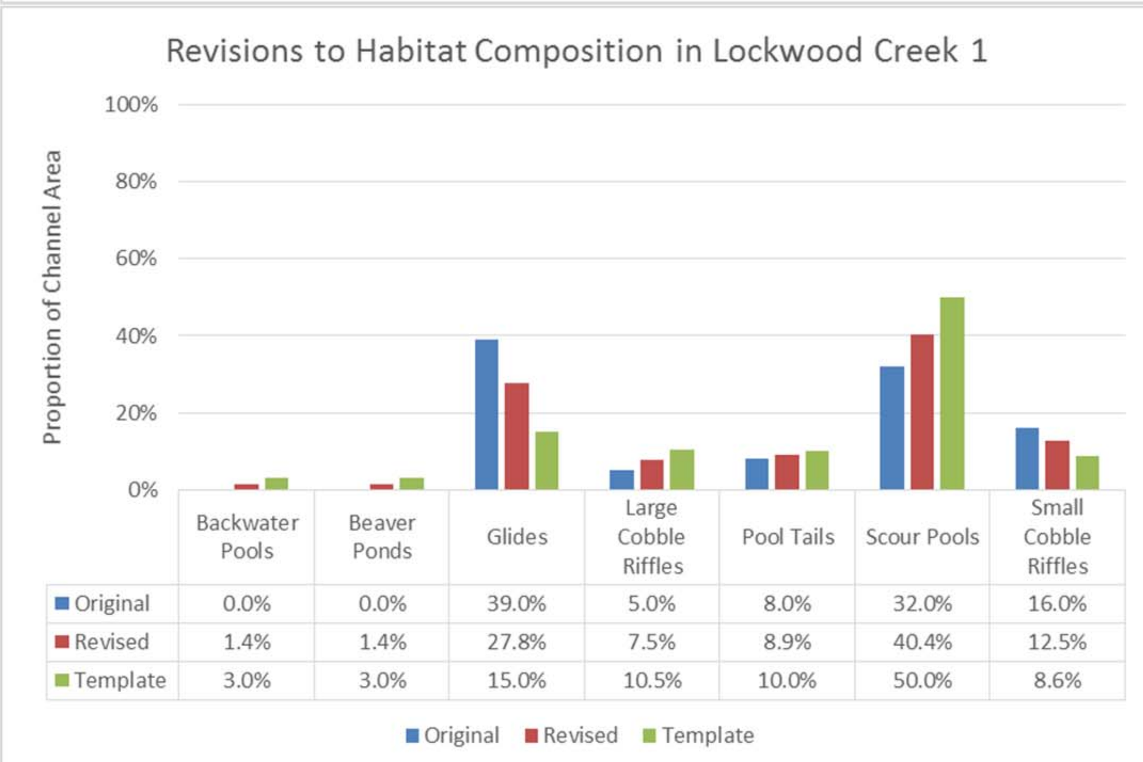

| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 15.0% | 0.0% | 50.0% | 6.0% | 3.0% | 10.0% | 16.0% |
| Revised | 12.5% | 0.0% | 45.0% | 7.5% | 3.7% | 14.2% | 17.1% |
| Template | 0.0% | 0.0% | 20.0% | 15.2% | 7.0% | 35.0% | 22.8% |

**Cumulative Restoration on Lockwood 1**

Three restoration projects were carried out on the EDT reach Lockwood Creek 1: 99-1636 Lockwood Creek Recovery/Enhancement (riparian restoration), 05-1590 Lockwood Creek Riparian (riparian restoration), and 07-1691 Lockwood Cr Phase 3 (wood structures). For the purposes of calculating the cumulative restoration benefit, only riparian restoration was considered because it was assumed that riparian restoration has a larger long term effect on habitat conditions than wood structure placement. The two riparian restoration projects had a combined intensity of 0.670.

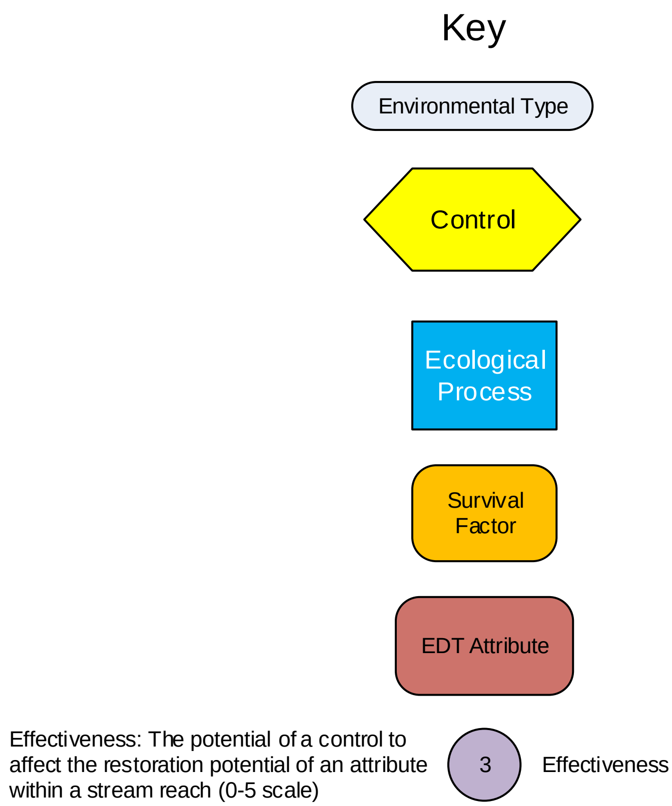



| | Benthic Richness | Fine Sediment | Predation Risk | Riparian Function | Temperature | Woody Debris |
|---|---|---|---|---|---|---|
| Original | 2.80 | 2.20 | 0.50 | 1.50 | 0.83 | 3.00 |
| Revised | 1.77 | 1.48 | 0.50 | 0.80 | 0.65 | 0.90 |
| Template | 0.60 | 1.00 | 0.50 | 0.00 | 0.44 | 0.00 |




| | Backwater Pools | Beaver Ponds | Glides | Large Cobble Riffles | Pool Tails | Scour Pools | Small Cobble Riffles |
|---|---|---|---|---|---|---|---|
| Original | 0.0% | 0.0% | 39.0% | 5.0% | 8.0% | 32.0% | 16.0% |
| Revised | 1.4% | 1.4% | 27.8% | 7.5% | 8.9% | 40.4% | 12.5% |
| Template | 3.0% | 3.0% | 15.0% | 10.5% | 10.0% | 50.0% | 8.6% |

# Appendix B
# Effectiveness Conceptual Models


Key
Environmental Type
Control
Ecological Process
Survival Factor
EDT Attribute
Effectiveness: The potential of a control to affect the restoration potential of an attribute within a stream reach (0-5 scale)
3
Effectiveness

***Fish Passage Improvement.*** Obstructions, either natural or human-created, impede the connectivity of habitat across the salmonid life history. There are two elements relating to obstructions that are captured in EDT: the direct survival impact and the quantity and quality of habitat above the obstruction (Figure 1). Obstructions vary in their degree of impediment to connectivity by species, life stage month, and water condition. Under any of these variables the impact of obstructions can range from no impact on passage up to a complete blockage and can affect both upstream and downstream passage. EDT treats obstruction impacts as a mortality that affects productivity across the trajectory. A completely blocking obstruction (100% mortality) ends a trajectory.

An obstruction also diminishes the value of all upstream habitat and completely eliminates that habitat in the case of a blocking obstruction. Similarly, eliminating an obstruction eliminates the proximal mortality of the obstruction and adds the value of all upstream habitat[2].

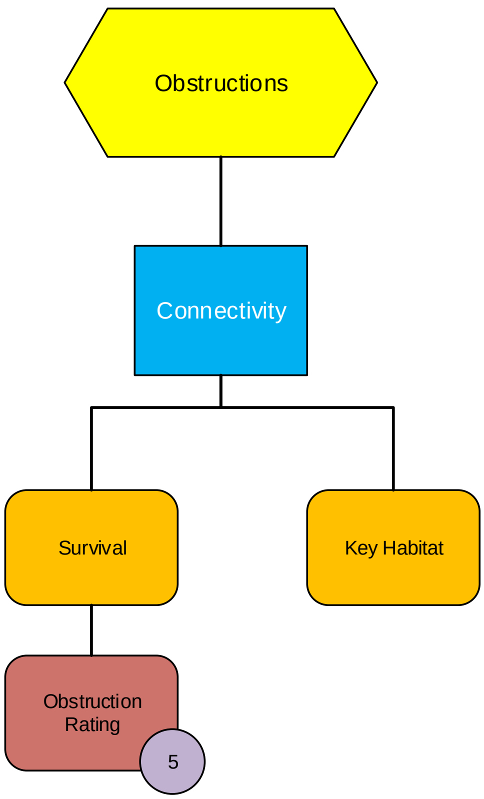



Figure 1. Conceptual model for fish passage and its relationship to EDT attributes.

[2] To evaluate the value of habitat above an obstruction in EDT, life history trajectories must start above the location of the obstruction.

***Riparian Condition and Function. T***he riparian zone is the forested fringe along a stream course and extends some distance upslope. The key role of riparian forest in controlling conditions in aquatic systems is widely recognized (Gregory et al. 1991; Kauffman et al. 1997; Naiman et al. 1998). A generalized conceptual model linking riparian forest restoration to attributes of the aquatic environment contained in EDT is provided below (Figure 2). Ecological processes affected by riparian forest and riparian restoration include the following:

***Shade.*** Trees provide shade and can moderate stream water temperature. Stand height is important especially relative to the channel width (McDade et al. 1990). Trees of sufficient height can form a closed canopy over small streams and provide shade through all or most of the day. The proximal value of trees to moderate temperature is limited; however, the cumulative impact of shade over a stream course on water temperatures can be significant (Gregory et al. 1991).

***Food.*** In small, heavily shaded streams, the major source of primary production is allochthonous material (leaves and twigs) that are processed by insects (Cummins 1979) that provide food for juvenile salmonids. Terrestrial insects that fall into streams from riparian vegetation also contribute to food supply in streams.

***Instream structure.*** Trees along the riparian corridor are the major source of large wood that provides habitat structure and complexity (Benda 2004). Wood can accumulate locally and also be transported in from upstream tree falls. Large wood derived from riparian forests have a large role in the formation of channel unit types including pools and riffles.
Channel form. Riparian forests have a major impact on stream channel form. Root masses can stabilize banks and create hydraulic impediments that enhance channel complexity. The increase in lateral channel movement can enhance floodplain connectivity, although the effect is likely minor in most cases.

***Water Quality.*** Riparian forests can process and filter pollutants and enhance water quality (Dosskey et al. 2010).

EDT also contains an attribute of Riparian Function that captures the indirect effect of riparian forests not captured in the five directly affect attributes above (Figure 1).

The effect of riparian forest is an inverse function of stream order or channel width (Vannote et al. 1980). The role is greatest in small headwater streams where a closed canopy can form while downed wood provides a major structural element. The role of riparian forest diminishes as stream channel width increases and becomes more localized in larger rivers. However, wood derived from upstream riparian forests can accumulate and affect channel structure in large rivers (Abbe and Montgomery 2003).

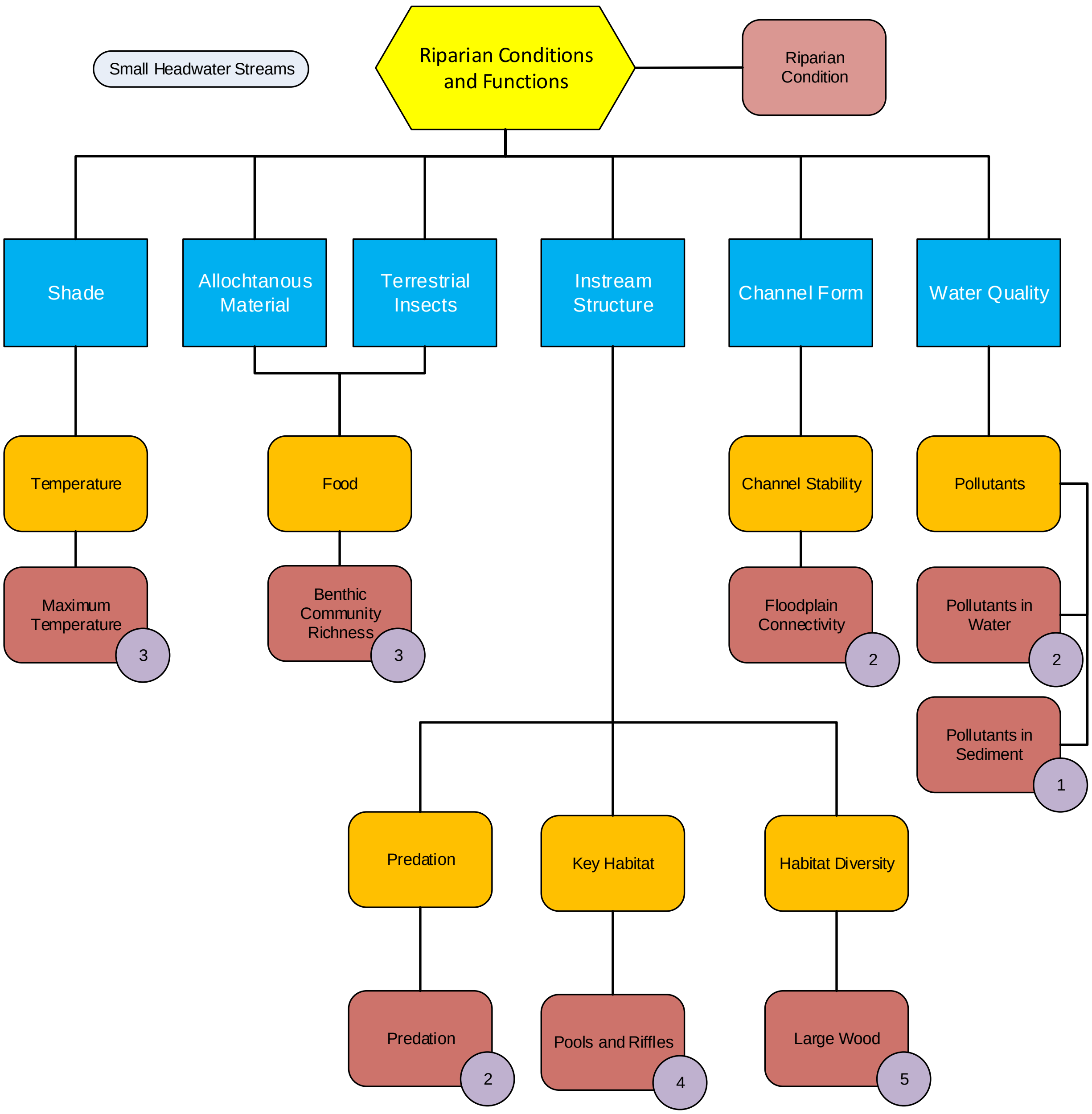



Figure 2. Conceptual model for riparian function and its relationship to EDT attributes.

***Floodplain Function.*** Floodplains are the low gradient area adjacent to the active river channel. It can include the riparian forest area. Floodplains, riparian corridors and stream channels are contiguous elements of most stream systems. In human-dominated systems, floodplains are often separated from the stream by incision or by construction of dikes and levees. A generalized conceptual model for the value of reconnecting floodplains along with connections to EDT attributes is shown in Figure 3. This model draws on the more complex conceptual model of Opperman (2012). The following ecological functions of floodplains are recognized:

***Key Habitat.*** A major effect of the floodplain during periods of inundation is the lateral expansion of the river, thereby increasing capacity for certain species. This is captured in EDT as the area of floodplain habitat types.

***Food.*** Floodplains can enhance food production due to exposure of the river to terrestrial detritus as well as in situ primary production. In some cases, floodplains provide enhanced growth of juvenile salmonids due to abundance of food relative to adjacent river channels (Sommer et al. 2001).

***Instream structure.*** Large wood can be deposited on floodplains during high flow events and subsequently transported through system (Collins et al. 2012). This can provide some enhancement of instream structure although this is better covered in other attributes.
Channel Form. Floodplain connection is a normative condition for streams and reconnecting lost floodplain areas thereby enhances channel form. EDT captures a productivity effect of floodplain connection in the Floodplain Connectivity attribute Figure 2. Connected riparian zones also support riparian vegetation.

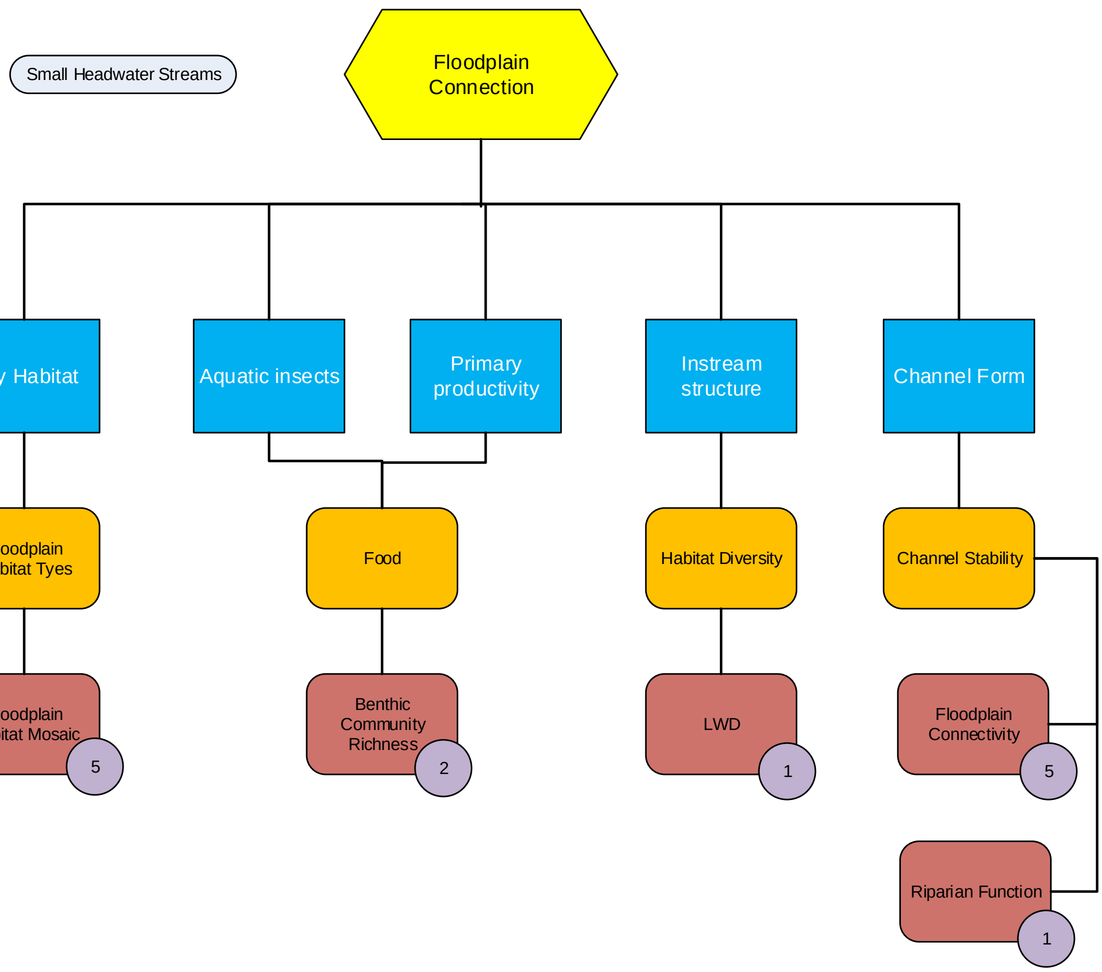



*Figure 3. Conceptual model for floodplain function and its relationship to EDT attributes.*

***Instream Habitat (LWD).*** Instream structural elements, primarily large wood debris (LWD), are significant components on streams that create key habitat elements and provide other attributes conducive to salmonid production (Roni and Quinn 2003). Placement of large wood is one of the most common restoration action in streams (Roni et al. 2014). A generalized model of the ecological functions of structural elements and their relationship to attributes in EDT is shown in Figure 4. Ecological functions of instream structures in the model include the following:

***Cover.*** Large wood can provide cover from predators for juvenile salmonids and other fishes while at the same time providing cover for ambush predators such as largemouth bass (Schenk et al. 2014).

***Substrate.*** Large wood provides a substrate for the formation of biofilms and for insects that support the higher trophic levels (Testa et al. 2011).

***Bank stabilization and channel form.*** Large wood can retain sediment and create features such as point bars and meanders. Logs can stabilize banks while at the same time creating scour and cut banks. Logs also retain leaves, salmon carcasses and other organic matter where it is processed locally.

***Formation of stream unit types.*** A primary impact of large wood in streams is its role in the formation of channel units especially pools and corresponding riffles (Montgomery and Buffington 1998). Logs create scour pools and backwaters, retain sediment and greatly add to the complexity and variety of habitats in stream systems.

***Hydrologic diversity.*** Structural elements such as large wood and boulders provide hydrologic complexity in addition to creating a diversity of physical habitats (Hafs et al. 2014; Tullos and Walter 2014). Structure creates low energy refugia, feeding lanes and other features that enhance salmonid performance. This role can be captured in the EDT large wood attribute (Figure 3).

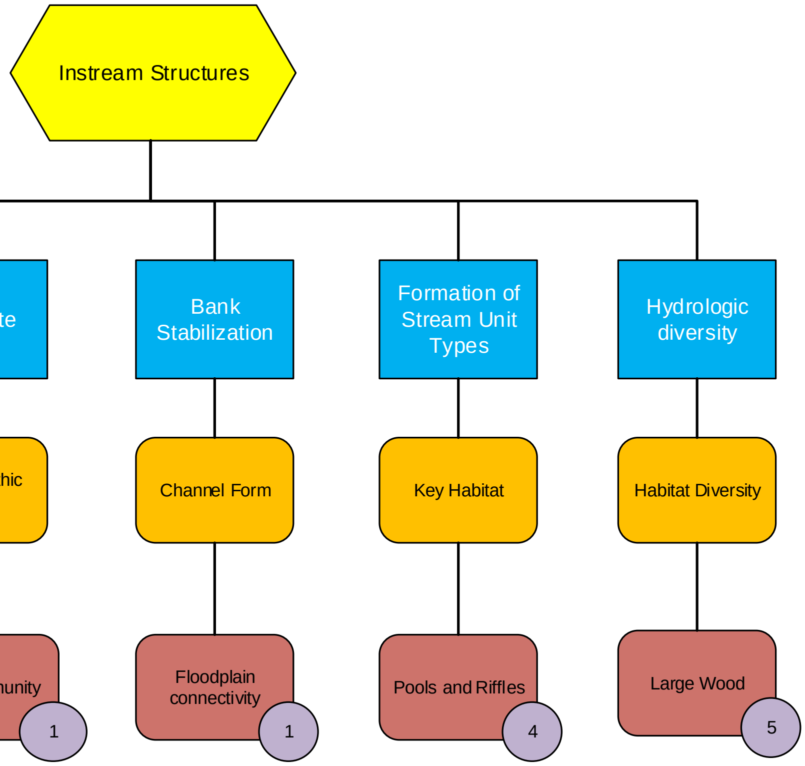



Figure 4. Conceptual model for instream structure (LWD) and its relationship to EDT attributes.

***Watershed Conditions and Hillslope Processes (Roads)***. Road networks across a watershed can have significant impacts on conditions in streams (Gucinski et al. 2001). The effect of road networks across a watershed are cumulative and change over time from initial construction to senescence (Angermeier et al. 2004). The localized effect of roads may be minimal but cumulatively across a watershed they can create significant problems. De-commissioning of un-used forest roads is often done to reduce their impacts. Roads have three primary impacts on aquatic systems as captured in the conceptual model in Figure 5 that are brought into EDT.

***Sediment Input.*** Precipitation that flows across unpaved roads washes sediment downslope and into streams. Roads can also initiate erosions that further adds to downslope sediment movement. Pollutant input. Similar to sediment, pollutants from pavement and from vehicles moves downslope with precipitation into streams.

***Channel Form.*** Larger roads often follow river courses and are constructed adjacent to the channel. Armoring and other efforts to stabilize the road confine the channel and prevent lateral movement.

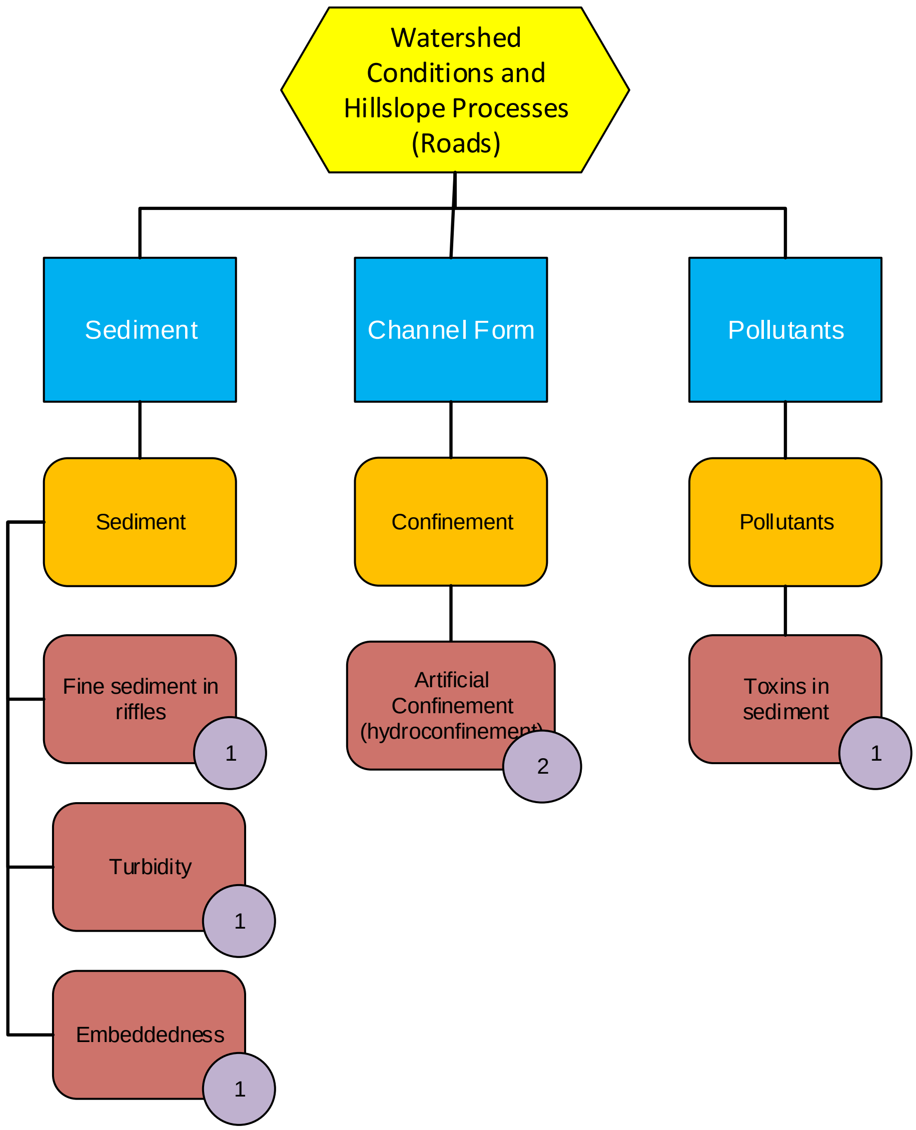



Figure 5. Conceptual model for the impact of roads and their relationship to EDT attributes.

**References Cited**

Abbe, T. B., and D. R. Montgomery. 2003. Patterns and processes of wood debris accumulation in the Queets River basin, Washington. *Geomorphology* 51:81-107.

Angermeier, P. L., A. P. Wheeler, and A. E. Rosenberger. 2004. A conceptual framework for assessing impacts of roads on aquatic biota. *Fisheries* 29(12):19-29.

Benda, L. E. 2004. Wood recruitment to streams. Lee Benda and Associates, Inc: Campbell Timerland Management.

Collins, B. D., D. R. Mongomery, K. L. Fetherston, and T. B. Abbe. 2012. The floodplain large-wood cycle hypothesis: A mechanism for the physical and biotic structuring of temperate forested alluvial valleys in the North Pacific coastal ecoregion. *Geomorphology* 139-140:460-470.

Cummins, K. W. 1979. The natural stream ecosystem. Pages 7-24 in J. V. Ward and J. A. Stanford (eds.). *The ecology of regulated streams*. New York: Plenum Press.

Dosskey, M. G., P. Vidon, N. P. Gurwick, C. J. Allan, T. P. Duval, and R. Lowrance. 2010. The Role of Riparian Vegetation in Protecting and Improving Chemical Water Quality in Streams. *JAWRA Journal of the American Water Resources Association* 46(2):261-277.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. *BioScience* 41(8):540-551.

Gucinski, H., M. J. Furniss, R. R. Ziemer, and M. H. Brookes. 2001. *Forest Roads: a synthesis of scientific information*. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Hafs, A. W., L. R. Harrison, R. M. Utz, and T. Dunne. 2014. Quantifying the role of woody debris in providing bioenergetically favorable habitats for juvenile salmon. *Ecological Modelling* 285:30-38.

Kauffman, J. B., R. L. Beschta, N. Otting, and D. Lytjen. 1997. An ecological perspective of riparian and stream restoration in the Western United States. *Fisheries* 22(5):12-24.

McDade, M. H., F. J. Swanson, W. A. McKee, J. F. Franklin, and J. Van Sickle. 1990. Source distances for coarse woody debris entering small streams in western Oregon and Washington. *Canadian Journal of Forestry Research* 20:326-330.

Montgomery, D. R., and J. M. Buffington. 1998. Channel processes, classification and response. Pages 13-42 in R. J. Naiman and R. E. Bilby (eds.). *River ecology and management: lessons from the Pacific coastal ecoregion*. New York: Springer.

Naiman, R. J., K. L. Fetherston, S. J. McKay, and J. Chen. 1998. Riparian Forests. Pages 289-323 in R. J. Naimon and R. E. Bilby (eds.). *River ecology and management: Lessons from the Pacific Coastal Ecoregion*. New York: Springer-Verlag.

Opperman, J. J. 2012. A Conceptual Model for Floodplains in the Sacramento-San Joaquin *Delta. San Francisco Estuary and Watershed Science 10(3).*

Roni, P., T. J. Beechie, G. R. Pess, and K. M. Hanson. 2014. Wood Placement in River Restoration: Fact, Fiction and Future Direction. *Canadian Journal of Fisheries and Aquatic Sciences*.

Roni, P., and T. P. Quinn. 2003. Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. *Canadian Journal of Fisheries and Aquatic Sciences* 58:282-292.

Schenk, E. R., J. W. McCargo, B. Moulin, C. R. Hupp, and J. M. Richter. 2014. The influence of logjams on largemouth bass (*Micropterus salmoides*) concentrations on the lower Roanoke River, a large sand-bed river. *River Research and Applications* 2014(DOI: 10.1002/rra.2779).

Sommer, T., B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001. California's Yolo Bypass: evidence that flood control can be compatible with fisheries, wetlands, wildlife and agriculture. *Fisheries* 26(8):6-16.

Testa, S., F. Douglas Shields, and C. M. Cooper. 2011. Macroinvertebrate response to stream restoration by large wood addition. *Ecohydrology* 4(5):631-643.

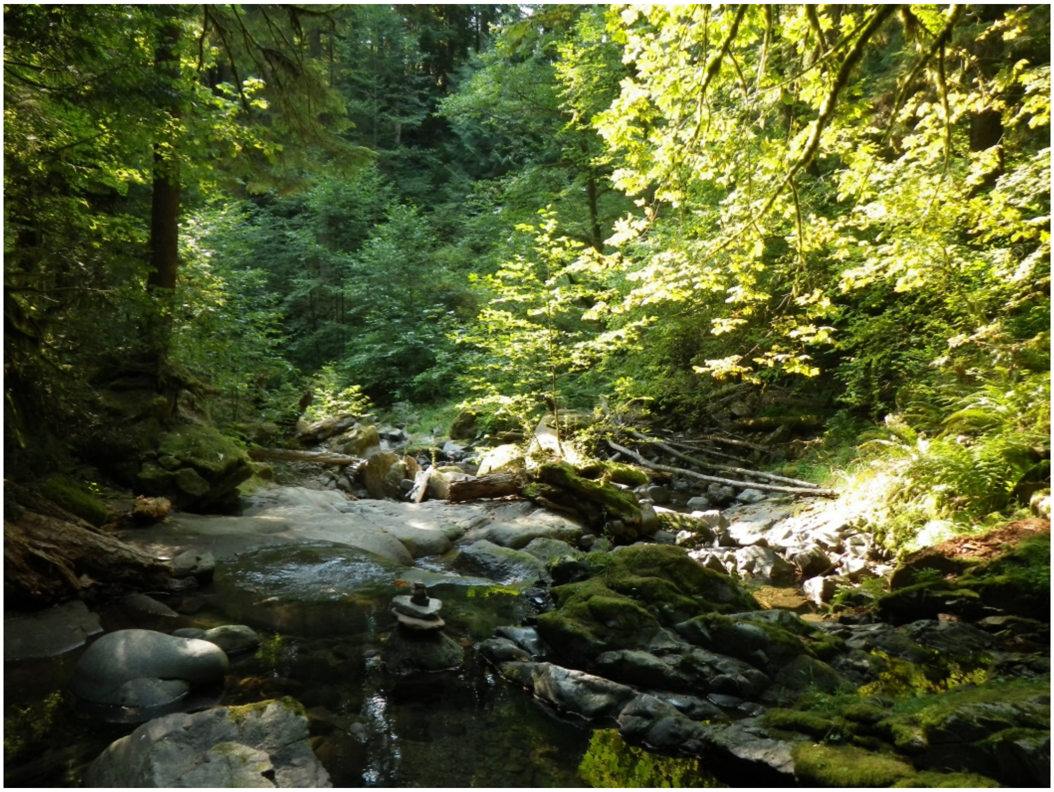
Tullos, D., and C. Walter. 2014. Fish use of turbulence around wood in winter: physical experiments on hydraulic variability and habitat selection by juvenile coho salmon, *Oncorhynchus kisutch*. *Environmental Biology of Fishes*:1-15.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. *Canadian Journal of Fisheries and Aquatic Science* 37(1):130-137.

# Appendix C

# D.J. Warren & Associates, Inc. / ICF International – Upper Lewis River Ecosystem Diagnosis and Treatment Analysis

# UPPER LEWIS ECOSYSTEM DIAGNOSIS AND TREATMENT ANALYSIS



Lewis River Hydroelectric Project
(FERC Project Nos. P-2111, P-2213, P-2017 and P-935)

*Prepared for:*
PacifiCorp
825 N.E. Multnomah, Suite 1500
Portland, OR 97232

*Prepared by:*
D.J.Warren & Associates, Inc.

**June 24, 2016**

## 3.1 Introduction

This report has been prepared by D.J. Warren and ICF International for PacifiCorp and the Public Utility District No. 1 of Cowlitz County, Washington ("Cowlitz PUD") to inform the National Marine Fisheries Service and the U.S. Fish and Wildlife Service (collectively the "Services"), Federal Energy Regulatory Commission (FERC) and the Lewis River Settlement Agreement Parties in consideration of article 4.1.9 Review of New Information Regarding Fish Transport into Lake Merwin and Yale Lake and 7.6 In Lieu Fund of the Lewis River Settlement Agreement.

## 3.2 Background

Located on the North Fork of the Lewis River in southwestern Washington, the Lewis River Hydroelectric System consists of four operationally coordinated projects. PacifiCorp owns Swift No. 1 (FERC No. 2111), Yale (FERC No. 2071), and Merwin (FERC No. 935) projects which together generate 536 MW of electricity at full capacity. Cowlitz PUD owns the 82 MW Swift No. 2 Project (FERC No. 2213) which lies between the Swift No. 1 and Yale projects. Currently, PacifiCorp operates Swift No. 2 for Cowlitz PUD under contract.

On June 26, 2008, the FERC provided the utilities with new operating licenses for the Lewis River hydroelectric projects. The license periods are each 50 years starting June 1, 2008. Each license includes the respective conditions of the Services biological opinions and respective conditions of the Washington Department of Ecology 401 certificates. In general the licenses include terms of the Lewis River Settlement Agreement with few exceptions. Parties to the Lewis River Settlement Agreement continue to abide by the agreement terms including those terms outside the FERC requirements.

## 3.3 Lewis River Settlement Agreement conditions relative to reintroduction of anadromous salmonids into Yale and Merwin Reservoirs

Section 3.1 of the Lewis River Settlement Agreement identifies the anadromous fish reintroduction outcome goal as "to achieve genetically viable, self-sustaining, naturally reproducing, harvestable populations above Merwin dam greater than minimum viable populations". Within the agreement the utilities will make significant investments into a salmon and steelhead reintroduction program. These include a suite of anadromous fish protection and restoration measures and actions implemented over a phased approach. To date, facilities include the Merwin Upstream Fish Collector, three upper basin juvenile fish acclimation ponds and the Swift Downstream Fish Collector. A juvenile fish release facility located in Woodland, Washington is scheduled to be constructed in 2017. Additional program phases identified in the settlement agreement and subsequent FERC licenses require the construction and operation of the following fish passage facilities:

- Downstream Passage at Yale Dam (SA article 4.5)
- Downstream Passage at Merwin Dam (SA article 4.6)
- Upstream Passage at Yale Dam (SA article 4.7)
- Upstream Passage at Swift Projects (SA article 4.8)

There is also the specific opportunity to consider an In Lieu Fund as an alternative to future fish passage facilities (Yale downstream, Merwin downstream, Yale upstream and Swift upstream). It is expressly granted in Section 4.1.9 of the Lewis River Settlement Agreement.

> *4.1.9 Review of New Information Regarding Fish Transport into Lake Merwin and Yale Lake.*
>
> *a. The Licensees shall construct and provide for the operation and maintenance of both upstream and downstream fish collection and transport facilities at each of Merwin Dam, Yale Dam, and the Swift Projects as provided in the schedule in this Agreement unless otherwise directed by the Services pursuant to this Section. New Information (defined below) relevant to reintroduction and fish passage into Yale Lake or Lake Merwin may be available to the Services that may influence the implementation of fish passage into and out of these reservoirs, or that could result in the Services determining that reintroduction or fish passage for anadromous fish is inappropriate. If the Services conclude upon review of the New Information that one or more of the passage facilities should not be constructed, in lieu of designing, permitting, constructing, and operating the passage facility, PacifiCorp shall provide additional funds for projects in lieu of fish passage, as set forth in Section 7.6. In this event, the Licensees shall also implement the bull trout passage measures as set forth in Section 4.10. The adult upstream fish passage facility at Merwin and juvenile downstream collector at Swift No. 1 are not subject to this review.*
>
> *b. Upon receipt and review of New Information relevant to reintroduction and fish passage from any party, the members of the ACC may provide written comments to the Services regarding such New Information. Such comments shall be provided to the Services no later than five years prior to the date that PacifiCorp and/or Cowlitz PUD is to begin operating the relevant passage facility. If any New Information and comments are submitted to the Services, then approximately four and a half years prior to the date that PacifiCorp and/or Cowlitz PUD is to begin operating the relevant passage facility, the Licensees shall convene a meeting of the ACC for the purpose of discussing the New Information and comments. At such meeting, the Licensees shall solicit and obtain the Services' response to the New Information and related comments, unless the Services have provided the results of their review to the ACC earlier. If the Services have concluded that one or more of the passage facilities should not be constructed, then within 60 days after the meeting of the ACC, the Services shall advise the ACC in writing of such conclusion.*
>
> *c. For purposes of this section, "New Information" is defined as information relevant to anadromous fish reintroduction and fish passage, including that presented by any Party, and provided to the Services and the Licensees. The Licensees must*

> *provide copies of such New Information to all the members of the ACC. This information may include, but is not limited to:*
>
> > *(1) Experience with upstream fish collection and transport facilities at other sites, including Merwin Dam.*
> > *(2) Experience with downstream fish collection facilities at other sites, including Swift No. 1 Dam.*
> > *(3) Experience with the reintroduction efforts of spring Chinook, coho, and steelhead above Swift No. 1 Dam.*
> > *(4) Consideration of broader contextual information beyond the Lewis River Basin, including regional anadromous fish recovery efforts.*
>
> *d. The Licensees shall inform the Commission of any determination by the Services that one or more of the fish collection and transport facilities should not be constructed. In this event, PacifiCorp shall provide additional funds for projects in lieu of fish passage, as set forth in Section 7.6.*

As expressed in Section 4.1.9 (d) above, in the event the Services determine that reintroduction of anadromous salmonids into Yale Lake or Lake Merwin is not required (i.e., fish collection and transport facilities should not be constructed), Section 7.6 of the Lewis River Settlement Agreement would apply. In general, Section 7.6 stipulates that PacifiCorp shall establish the “In Lieu Fund” to support mitigation measures for anadromous salmonids in lieu of passage.

# 3.4 Study

## 1.0 OVERVIEW

The following report describes the results of Ecosystem Diagnosis and Treatment (EDT) modeling of coho, spring Chinook and steelhead production in river reaches of the Lewis River located upstream of Merwin Dam. Three types of analysis were completed as part of this report:

1. Salmon Production- The EDT model was used to estimate theoretical salmon adult and juvenile production originating from the three geographic analysis areas (Merwin, Yale and Swift) for two different scenarios. For both scenarios, estimates of salmon productivity, capacity, abundance and life history diversity were developed for adult and juvenile coho, spring Chinook and steelhead.

2. Habitat Limiting Factors and Reach Restoration Analysis- The model was used to 1) identify stream habitat related factors that currently limit salmon and steelhead production in individual streams located in each geographic area of the basin, and 2) estimate the change in adult production with elimination of the limiting habitat factor.

3. Watershed Restoration Analysis – Under this analysis, habitat conditions in each stream were restored to historical conditions to determine resulting increase in salmon and steelhead production. The results of this analysis are used to determine the key watersheds that, if restored, would produce the largest increase in adult abundance.

Model assumptions were developed and agreed to by a subgroup of the Lewis River Aquatic Coordination Committee (ACC) in a series of meetings held during 2015 and 2016. The ACC agreed that two scenarios would be analyzed. The assumptions for each scenario are provided below.

<u>Scenario 1</u>

- System Configuration – Under Lewis River Settlement Agreement Phase 3 fish passage conditions, juvenile fish (including fry) are collected at each dam, transported and sent to the release ponds in the Lower Lewis River for eventual release to the lower river. Adult fish arriving at each dam would be collected, transported and released to the reservoir associated with each project. For example, adult fish heading to streams upstream of Swift Dam would have to pass all three dams to reach their natal stream.

- Fish Passage Survival Rates – Juvenile and adult passage survival rates were those as described in the Lewis River Settlement Agreement for the Project.

- Smolt-to-Adult Survival Rates (SAR) – The SAR values used in modeling were provided by the Washington Department of Fish and Wildlife (WDFW) for each analysis species. The SARs represent adult returns absent harvest.

- Reservoir Littoral Zone – The three (3) meter depth line at full pool was used to define the littoral zone for each of the three reservoirs.

- Harvest – The model was run with harvest in ocean and freshwater fisheries turned off.

- Female Fecundity – Set to 4,200 eggs per female based on assumption that this rate is typical of a wild spring Chinook.

<u>Scenario 2</u>

The difference in assumptions between Scenario 1 and 2 are as follows:

- Harvest is turned on. Harvest rates for natural origin spring Chinook, coho and steelhead were set at 25%, 15% and 10%, respectively. These rates roughly reflect current harvest levels on lower Columbia River natural populations. It should be noted that EDT cannot account for sliding scale harvest management that is based on adult abundance; therefore an average harvest rate was used.
- Adult upstream passage mortality has been increased by 5% per dam to account for stress/handling effects of fish having to pass through multiple reservoir/facilities.
- Spring Chinook fecundity was set at 3,400 eggs per female to reflect values observed for hatchery fish that will be used for reintroducing spring Chinook to stream reaches upstream of Merwin Dam.

Model results showed that the majority of fish production for all three species originates from the Swift geographic area (> 77 percent), followed by Yale (> 18 percent) and Merwin (>3 percent) areas under both scenarios. Total EDT estimates for the combined three geographic areas (i.e., Lewis River and tributaries upstream of Merwin) under Scenario 1 for adult coho, spring Chinook and steelhead are 11,222 fish, 3,694 fish and 2,754 fish, respectively. For Scenario 2, adult abundance for coho, spring Chinook and steelhead was 8,537, 1,699 and 2,106, respectively.

Fish passage currently in operation transports adult fish from Merwin Dam to upstream of Swift Dam and juveniles from Swift Dam to downstream of Merwin Dam has made available the Swift geographic area for re-establishment of salmon and steelhead. The estimated production for this area under Scenario 1 is 8,599 coho, 2,073 steelhead, and 3,084 spring Chinook adults. In Scenario 2, adult production is lower for coho (6,441), lower for steelhead (1,561) and lower for spring Chinook (1,421).

For both scenarios, the construction of fish passage facilities at Yale Dam (make available Yale reservoir and associated tributaries habitat) is estimated to produce 2,028 coho, 543 steelhead and 610 spring Chinook. In Scenario 2, adult production is lower for coho (1,595), lower for steelhead (431) and lower for spring Chinook (278).

For both scenarios constructing fish passage facilities at Merwin Dam (make available Merwin reservoir and associated tributaries habitat) results in coho and steelhead production of 595 and 138 adults for scenario 1 and 502 coho and 115 steelhead for scenario 2, respectively. Because the only possible spring Chinook producing stream associated with Merwin (Speelyai Creek) is reserved for hatchery production, construction of fish passage facilities at Merwin dam alone did not increase spring Chinook production.

The limiting factors and reach restoration analysis was only done on Scenario 1 as habitat conditions do not change between scenarios. Analysis results indicated that spring Chinook, coho and steelhead adult production can be increased by addressing the key habitat limiting factor in stream reaches located in the Swift and Below Merwin geographic areas. The largest increase in adult production of spring Chinook and coho occurred however in stream reaches associated with the Swift geographic areas. For steelhead, reaches located below Merwin Dam provided the largest increase in adult production.

The results of the Watershed Restoration analysis for the Swift geographic area indicated that restoring stream habitat conditions to historic in Clear Creek, Muddy River and Pine Creek generally produced the most adults for all species combined. Other streams that if restored produced a substantial number of adults included Rush Creek, Clearwater Creek and the mainstem of the Lewis River. Restoring a combination of these streams may produce a total of adult spring Chinook (1,697), coho (4,747) and steelhead (739). Population productivity, capacity and life history diversity also increases at varying levels for the majority of the watersheds.

# 2.0 METHODS

A detailed description of the EDT model can be found at the following link:

http://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Hydro/Hydro_Licensing/Lewis_River/rr/aqu/AQU_18_Appendix_E.pdf

The linked report describes the methods, inherent assumptions and results for the EDT analysis completed for the Upper Lewis River (i.e. upstream of Merwin Dam) in January of 2004. The 2004 analysis was used as the starting point for this 2016 EDT analysis.

ENVIRONMENTAL DATA

Environmental data used in conducting an EDT analyses can be broken down into three categories:

- Hydrologic Characteristics—Flow variation and hydrologic regime.
- Stream Corridor Structure—Channel morphometry, confinement, habitat type, obstructions, riparian and channel integrity, and sediment type.
- Water Quality—Stream temperature variation and chemistry.
- Biological Community—Community effects and macroinvertebrates.

The environmental data used for populating the 2004 model were developed by the Aquatic Resource Group (ARG). Data sources included existing reports and analysis, data collected as part of the Federal Energy Regulatory Commission (FERC) relicensing process, new field data collection and professional opinion (primarily for attributes and reaches where data were lacking). Data sources were documented in the 2004 EDT Questionnaire (Figure 2-1).

For the 2016 EDT analysis, the United States Geological Survey (USGS) updated EDT environmental data by conducting stream habitat surveys in the Upper Lewis River from 2013-2016 (See USGS – Appendix A). Specifically, the USGS collected new data on the following habitat attributes:

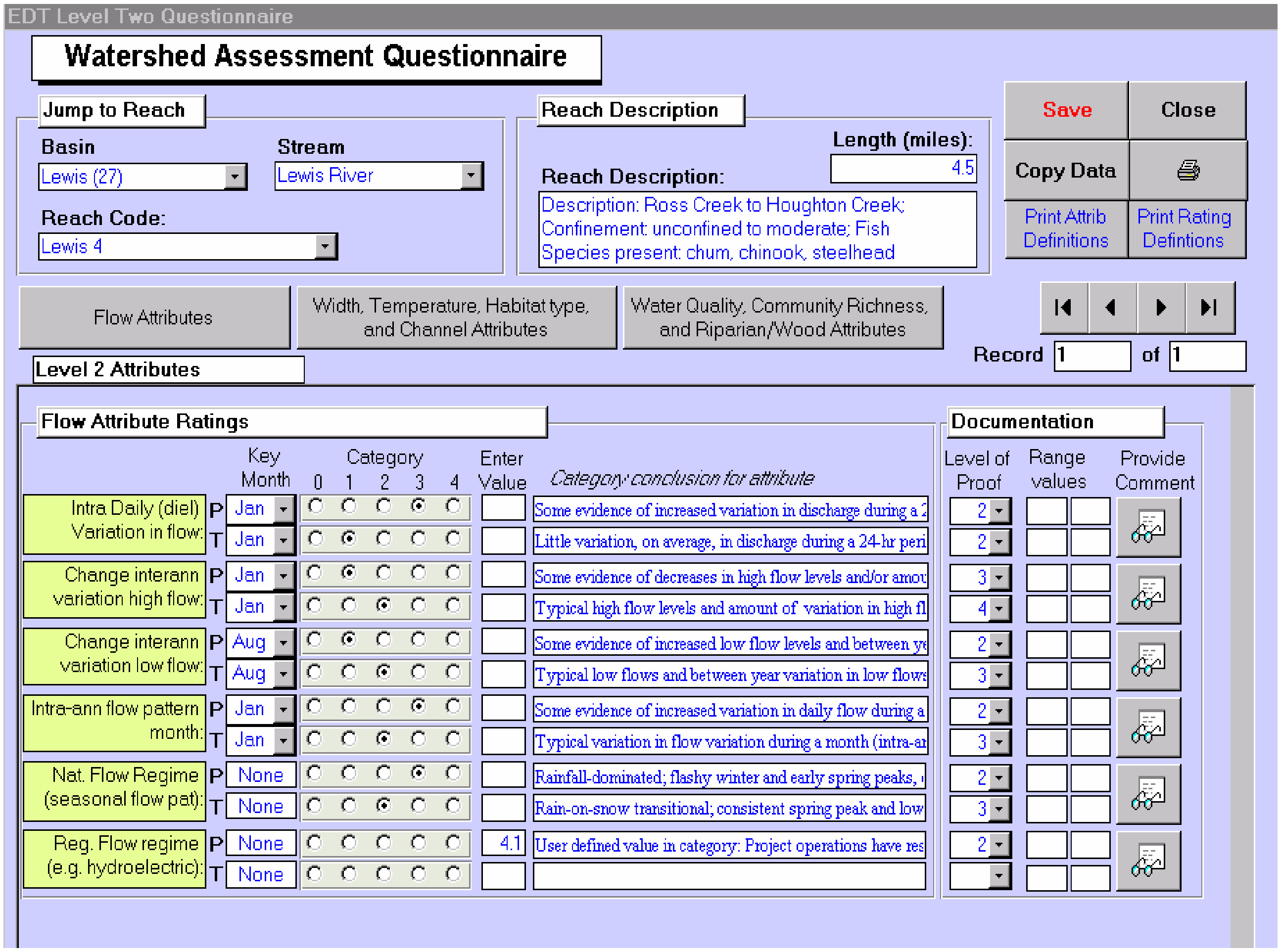



**Figure 2-1. Screen Capture of Lewis River EDT Questionnaire.**

- Habitat type (pools, riffles etc.)
- Stream length and width
- Fine Sediment
- Substrate composition
- Stream gradient
- Large Woody Debris (LWD)
- Riparian condition
- Stream temperature and discharge

These habitat attributes fall under the categories of Stream Corridor Structure and Water Quality.

No changes were made to any of the 2004 EDT attribute ratings associated with Biological Community or Hydrological Characteristics.

Data collected by the USGS was entered into the latest version of EDT (EDT3) by staff from ICF International.

BIOLOGICAL DATA

The biological data used in the 2016 analysis is described below.

2.1.1 Analysis Species

Spring Chinook, coho and late winter steelhead were the species selected for analysis in 2016. Although fall Chinook were modeled in 2004, they were not modelled in 2016 as this race of Chinook will not be reintroduced upstream of Merwin Dam.

2.1.2 Populations and Spawning Distribution

As was the case in 2004, fish populations were defined and modeled based on geographic distribution in the basin. Five geographic areas were modeled:

1. Below Merwin Dam- NF Lewis River and all tributaries downstream of Merwin Dam not including East Fork Lewis River
2. East Fork Lewis River
3. Merwin- Streams located between Merwin Dam and Yale Dam
4. Yale- Streams located between Yale and Swift Dam
5. Swift – Streams located upstream of Swift Dam

Stream accessibility by species for the Merwin, Yale and Swift was based on the results of USGS habitat surveys and fish barrier analyses (See USGS – Appendix A).

A list of spawning reaches for the Merwin, Yale and Swift geographic areas is provided in Appendix A. Spawning reaches for East Fork Lewis River and Below Merwin Dam were taken from documents produced by the Lower Columbia Fish Recovery Board (http://www.lcfrb.gen.wa.us/)

The rationale used to define spawning reaches for each of the analysis species is provided below.

2.1.2.1 Spring Chinook

Spring Chinook enter the Lewis River from late March through May. This race of Chinook seeks out deep, large and relatively cold water pools and glides to hold in until they spawn in the late summer and early fall (August and September) in low gradient streams (PacifiCorp 2004). Busch et al. (2011) concluded that Chinook generally did not use streams with gradients greater than 7 percent or minimum widths less than 3.7 meters (~12 ft.) for spawning and juvenile rearing[1]. These values are similar to those developed by Cooney and Holzer (2006) for Columbia River spring Chinook. Parken et al. (2006) provided data showing that Chinook are generally limited to 3rd order or larger streams so long as there are no downstream migration barriers preventing fish access. Agrawal et al. (2005) concluded that streams with mean annual discharge of greater than ~10 cubic feet per second (cfs) provided the best habitat for spring Chinook.

#### 2.1.2.2 Late Winter Steelhead

Late winter steelhead enter the Lewis River starting in late December or early January. Spawning takes place from March through late June. Cooney and Holzer (2006) concluded that streams with a gradient ranging from 4-7 percent had the highest intrinsic potential to produce steelhead. They also noted that streams with gradients ranging from 7-15 percent had low intrinsic potential. The authors based their analysis on data presented in McElhany et al (2003). McElhany et al. (2003) concluded that possible steelhead spawning and rearing occurred in streams with gradients 0.5-6 percent and 1.5-7 percent, respectively. The Cooney and Holzer (2006) analysis indicated that streams with a bank full width less than 3.8 meters (12.5 ft.) had little potential to produce steelhead. The authors' note that the WDFW recommends that a 2 meter (6.6 ft.) wetted width be set as the lower boundary for steelhead production.

#### 2.1.2.3 Coho

Type-S and Type-N coho enter the Lewis River from mid-September to late November and spawn from mid-October through late December (PacifiCorp 2004). Burnett et al. (2007) assumed that coho do not generally use streams with gradients greater than 7 percent. Lestelle (2007) stated that coho salmon primarily spawn in small low gradient streams or in side channels in larger rivers. Agrawal et al. (2005) reported that streams having a relatively large valley width to stream width ratio, gradient less than 7 percent, and mean annual flows less than 20 cfs had the highest coho production potential.

### 2.1.3 Juvenile Life History

EDT modeling of coho and steelhead assumed that these fish would migrate primarily as yearling (1+) and 2+ smolts, respectively. Spring Chinook were modeled using a 70/30 split of subyearling (0+) and yearling (1+) smolts. The 70/30 split used in modeling was based on juvenile run-timing and abundance data from the Clackamas River (Pers. Comm. Garth Wyatt Portland General Electric, 2016). Fish biologists on the Clackamas classify spring Chinook as either pre-smolt or smolt based on size, coloration and run-timing. For this analysis pre-smolts were considered subyearlings and smolts yearlings. It should be noted that few fry (<60 mm) are captured at passage facilities in the Clackamas River. Because it is not known what proportion of each juvenile life history will be exhibited in the Lewis River, the model was run using a range of different life history splits. The results of this analysis is presented in Appendix B.

[1] The low flow period in the Lewis River corresponds with spawn-timing of spring Chinook.

### 2.1.4 Fish Passage Configuration

The ACC EDT subgroup agreed on February 19, 2016 that the Lewis River Settlement Agreement Phase 3 fish passage configuration would be used for modeling fish production upstream of Merwin Dam for both Scenario 1 and Scenario 2. Under Phase 3 conditions, juvenile fish are collected at each dam, transported and sent to the release ponds in the Lower Lewis River for eventual release. Adult fish arriving at each dam would be collected, transported and released to the reservoir associated with each project. For example, adult fish heading to streams upstream of Swift Dam would have to pass all three dams and through Merwin, Yale, and Swift reservoirs to reach their natal stream.

### 2.1.5 Fish Passage Survival Rates

On February 19, 2016 the subgroup agreed that fish passage survival rates for scenario 1 at each project would be set to achieve survival criteria as outlined in the Lewis River Settlement Agreement. The survival criteria are as follows:

- Overall Downstream Survival (ODS) rate of greater than or equal to 80% until such time as the Yale Downstream Facility is built or the In Lieu Fund in lieu of the Yale Downstream Facility becomes available to the Services, after which time ODS shall be greater than or equal to 75%; UPS of greater than or equal to 99.5%

- A Collection Efficiency (CE) of equal to or greater than 95% and (ii) a Collection Survival (CS) of equal to or greater than 99.5% for smolts and 98% for fry, and (iii) adult bull trout survival of equal to or greater than 99.5%. Design performance objectives for Injury are less than or equal to 2%.

- Upstream Passage Survival (UPS) equal to or greater than 99.5%

- Adult Trap Efficiency of 98%.

Because the EDT Model does not model fish collection efficiency, the ODS and UPS survival values of 80% and 100% were used to set passage survival for juveniles and adults for each dam and reservoir, respectively.

The only difference in fish passage assumptions for Scenario 2 is that adult upstream passage mortality was increased by 5% per dam to account for stress/handling effects of fish having to pass through multiple reservoirs/facilities.

### 2.1.6 Smolt-to-Adult Return Rate (SAR)

SARs for each analysis species were set by the Washington Department of Fish and Wildlife. The SAR values used to model each species are shown in Table 2-1. The SARs represent adult return rates to the spawning grounds absent harvest in ocean and freshwater fisheries[2].

*Table 2-1. Minimum, average and maximum Smolt to adult survival rate (SAR) used in EDT Modeling for spring Chinook, Coho and Late Winter Steelhead.*

| Species | Minimum | Average | Maximum |
|---|---|---|---|
| Spring Chinook Subyearlings | 0.1% | 0.8% | 2% |
| Spring Chinook Yearlings | 1% | 3% | 6% |
| Coho | 1% | 4% | 9% |
| Late Winter Steelhead | 1.5% | 5% | 12% |

The SARs used in the analysis have a direct bearing on resulting fish production from the basin. The higher the SAR, the higher the number of adults returning to the basin. The average SAR value in Table 2-1 by species was used to produce EDT estimates of fish production.

### 2.1.7 Harvest Rate

For Scenario 1, harvest associated with in ocean and freshwater fisheries was turned off.

For Scenario 2, harvest rates for natural origin spring Chinook, coho and steelhead were set at 25%, 15% and 10%, respectively. These rates roughly reflect current harvest levels on lower Columbia River natural populations. It should be noted that EDT cannot account for sliding scale harvest management that is based on adult abundance; therefore an average harvest rate was used.

## EDT MODEL OUTPUT

For this analysis, the EDT model was used to generate a population, habitat limiting factors and reach restoration analysis and watershed restoration analysis.

### 2.1.8 Population Report

The Population report produces estimates of adult and juvenile abundance, productivity, capacity, and diversity by stream and geographic area (Merwin, Yale and Swift). Definitions for each of these terms are presented below:

Productivity. This element represents the relative success of the species to complete its life cycle within the environment it experiences.[3] Productivity determines resilience to mortality pressures, such as from fishing, dams, and further habitat degradation. Habitat quality (including water quality) is a major determinant of a population’s productivity. This performance element is

[2] The SAR is calculated in EDT as #of juveniles leaving Lewis River/ # adults on spawning grounds

[3] The productivity rate is the reproductive rate measured over a full generation that would occur at low population density, i.e., when competition for resources among the population is minimal.

especially important when efforts are being made to reverse long-term downward trends in population abundance. The model estimates productivity for the population of interest under specific management scenarios, expressed as the average number of adult progeny produced per parent spawner (at low population density). A life cycle productivity less than 1 for any part of the population is, by definition, unsustainable. As population productivity approaches 1 (e.g., values less than 2),[4] the population is clearly at risk. The model also calculates a juvenile productivity value that refers to the number of juveniles produced per spawner at very low abundance.

Capacity. This element defines how large a population can grow within the environment it experiences, as a result of finite space and food resources. It determines the effect of this upper limit on abundance to survival and distribution. Habitat quantity is a major determinant of the environmental capacity to support population abundance. In the analysis presented here, we frequently refer to “abundance” rather than capacity. Here we are describing the equilibrium run size abundance (or average abundance under steady state conditions), which highly correlates with capacity. The model estimates both capacity and equilibrium abundance for the population (both adults and juveniles) of interest corresponding to specific management scenarios.

Life History Diversity. This element represents the multitude of pathways through space and time available to, and used by, a species in completing its life cycle. Populations that can sustain a wide variety of life history patterns are likely to be more resilient to the influences of environmental change. Thus, a loss of life history diversity is an indication of declining health of a population (Lichatowich and Mobrand 1995) and perhaps its environment. The model computes an index of life history diversity as the percentage of possible life cycle pathways (i.e., life *trajectories* in space and time that members of a population might follow across the aquatic landscape) having a productivity greater than 1.

The algorithms used to calculate population parameters are based on the Beverton-Holt survival function (after Beverton and Holt 1957). All of the estimates are made for steady state conditions.

#### 2.1.9 Habitat Limiting Factors and Reach Restoration Analysis

Based on differences in habitat inputs between current and historical habitat conditions, the EDT model is able to determine the habitat factors that limit salmon and steelhead production in the three geographic areas. The analysis is done by substituting the habitat parameters associated with what are referred to in EDT as the Level 3 Survival Factors (Table 2-2), width and stream length and then re-running the model. Because there are 16 Level 3 Survival Factors plus width and length the model is re-run 18 times. Results can be presented as percent change in fish life history diversity, productivity, capacity and abundance (both juvenile and adult). For this analysis results are presented as percent change in adult abundance as this population parameter is the most easily understood and is the unit of measure that may be used to consider the alternatives of fish passage at Merwin Dam and Yale Dam or in-lieu habitat actions.

[4] The life cycle productivity needed to sustain a population in the face of environmental uncertainty has not been defined.

*Table 2-2. EDT Level 3 Survival Factors and definitions.*

| Factor | Definition |
|---|---|
| Channel stability | The effect of stream channel stability (within reach) on the relative survival or performance of the focus species; the extent of channel stability is with respect to its streambed, banks, and its channel shape and location. |
| Chemicals | The effect of toxic substances or toxic conditions on the relative survival or performance of the focus species. Substances include chemicals and heavy metals. Toxic conditions include low pH. |
| Competition (with hatchery fish) | The effect of competition with hatchery produced animals on the relative survival or performance of the focus species; competition might be for food or space within the stream reach. |
| Competition (with other species) | The effect of competition with other species on the relative survival or performance of the focus species; competition might be for food or space. |
| Flow | The effect of the amount of stream flow, or the pattern and extent of flow fluctuations, within the stream reach on the relative survival or performance of the focus species. Effects of flow reductions or dewatering due to water withdrawals are to be included as part of this attribute. |
| Food | The effect of the amount, diversity, and availability of food that can support the focus species on the its relative survival or performance. |
| Habitat diversity | The effect of the extent of habitat complexity within a stream reach on the relative survival or performance of the focus species. |
| Harassment | The effect of harassment, poaching, or non-directed harvest (i.e., as can occur through hook and release) on the relative survival or performance of the focus species. |
| Key habitat | The relative quantity of the primary habitat type(s) utilized by the focus species during a life stage; quantity is expressed as percent of wetted surface area of the stream channel. |
| Obstructions | The effect of physical structures impeding movement of the focus species on its relative survival or performance within a stream reach; structures include dams and waterfalls. |
| Oxygen | The effect of the concentration of dissolved oxygen within the stream reach on the relative survival or performance of the focus species. |
| Pathogens | The effect of pathogens within the stream reach on the relative survival or performance of the focus species. The life stage when infection occurs is when this effect is accounted for. |
| Predation | The effect of the relative abundance of predator species on the relative survival or performance of the focus species. |
| Sediment load | The effect of the amount of the amount of fine sediment present in, or passing through, the stream reach on the relative survival or performance of the focus species. |
| Temperature | The effect of water temperature with the stream reach on the relative survival or performance of the focus species. |
| Withdrawals (or entrainment) | The effect of entrainment (or injury by screens) at water withdrawal structures within the stream reach on the relative survival or performance of the focus species. This effect does not include dewatering due to water withdrawals, which is covered by the flow attribute. |

### 2.1.10 Watershed Restoration Analysis

In a watershed restoration analysis, all stream habitat in the target watershed is restored to historical conditions. The model is then re-run to determine resulting increase in salmon production for each species. The results of this analysis are used to determine the key watersheds that could provide significant value towards population recovery/benefit following habitat restoration.

# 3.0 RESULTS AND DISCUSSION

EDT modeling results for Upper Lewis River fish populations are presented below by geographic area and individual stream in Section 3.1. The results of the habitat limiting factors analysis is discussed in section 3.2.

GEOGRAPHIC AREA POPULATION ANALYSIS

EDT estimates of fish performance by scenario for each of the three geographic areas, and tributaries associated with each, are presented below

### 3.1.1 Fish Distribution

A comparison of fish distribution used in the EDT analysis to WDFW theoretical distribution is shown graphically in Figure 3-1. In general, the WDFW and EDT assumed fish distribution for stream reaches upstream of Merwin Dam are similar. Using data recently collected by USGS, PacifiCorp is currently reviewing differences in fish distribution between the two analyses, which are likely a function of waterfalls or other barriers to anadromous fish.

### 3.1.2 EDT Population Analysis

Scenario 1

For Scenario 1, total adult and juvenile salmon production for all five geographic areas combined is 26,634 and 1,677,106 respectively (Table 3-1). The adult numbers reflect run-size absent harvest in ocean and freshwater fisheries.

For geographic areas upstream of Merwin, the majority of the adult and juvenile production (77% to 78%) comes from the Swift geographic area (Table 3-2). Spring Chinook are not produced in the Merwin geographic area because hatchery operations prevent this species from entering the only stream that could support such production, Speelyai Creek.

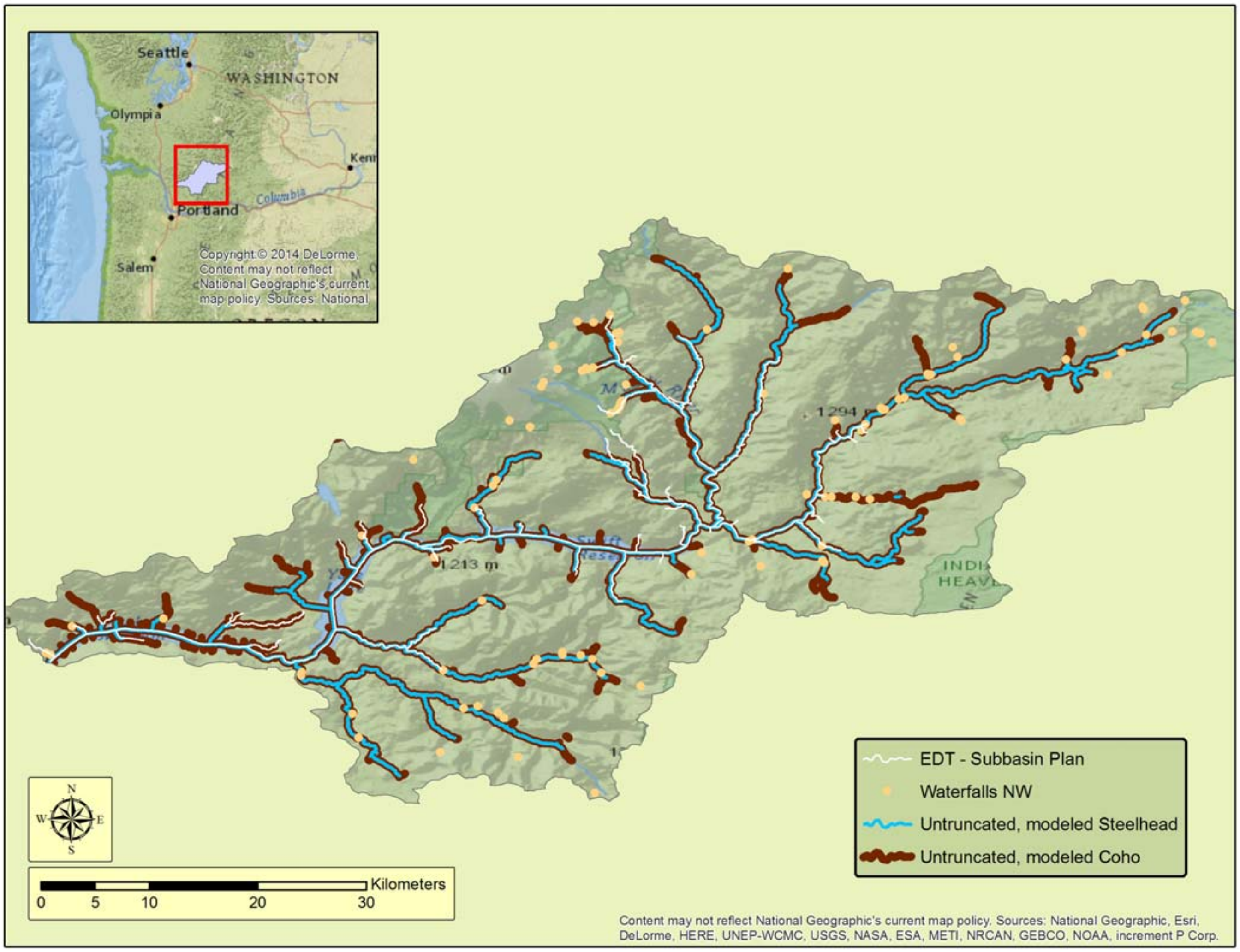



**Figure 3-1. WDFW modeled Steelhead and Coho distribution and EDT reaches upstream of Merwin Dam.**

*Table 3-1. EDT estimates of salmon adult diversity, productivity, capacity, abundance, and smolt-to-adult survival rate (SAR) and juvenile abundance for all geographic areas – Scenario 1.*

| | Adult | | | | Juvenile | | | |
|---|---|---|---|---|---|---|---|---|
| **Geographic Area** | **Diversity** | **Productivity** | **Capacity** | **Abundance** | **Productivity** | **Capacity** | **Abundance** | **SAR** |
| **Spring Chinook** | **73%** | **4.8** | **4,606** | **3,694** | **261** | **367,312** | **259,706** | **1.3%** |
| Yale | 88% | 4.3 | 794 | 610 | 285 | 78,905 | 54,083 | 1.1% |
| Swift | 59% | 5.2 | 3,812 | 3,084 | 237 | 288,407 | 205,623 | 1.5% |
| **Coho** | **71%** | **5.4** | **21,191** | **17,360** | **199** | **3,631,488** | **1,302,292** | **2.8%** |
| Below Merwin Dam | 75% | 5.1 | 4,478 | 3,606 | 233 | 1,640,468 | 449,647 | 0.8% |
| East Fork Lewis River | 69% | 4.3 | 3,307 | 2,532 | 374 | 1,674,956 | 593,329 | 0.4% |
| Merwin | 72% | 5.8 | 720 | 595 | 130 | 17,603 | 14,331 | 4.2% |
| Yale | 59% | 5.3 | 2,503 | 2,028 | 121 | 63,490 | 50,243 | 4.0% |
| Swift | 79% | 6.4 | 10,182 | 8,599 | 136 | 234,971 | 194,742 | 4.4% |
| **Winter Steelhead** | **59%** | **12.0** | **6,067** | **5,580** | **132** | **135,976** | **115,108** | **4.9%** |
| Below Merwin Dam | 39% | 11.3 | 758 | 691 | 130 | 16,661 | 13,962 | 4.9% |
| East Fork Lewis River | 67% | 11.4 | 2,340 | 2,135 | 128 | 47,554 | 40,456 | 5.3% |
| Merwin | 64% | 9.6 | 154 | 138 | 106 | 3,304 | 2,663 | 5.2% |
| Yale | 64% | 13.4 | 587 | 543 | 148 | 12,929 | 11,086 | 4.9% |
| Swift | 63% | 14.4 | 2,229 | 2,073 | 149 | 55,528 | 46,941 | 4.4% |
| Grand Total | | | | 26,634 | | | 1,677,106 | |

*Table 3-2. EDT estimates of salmon adult diversity, productivity, capacity, abundance, and smolt-to-adult survival rate (SAR) and juvenile abundance for Swift, Yale and Merwin geographic areas – Scenario 1.*

| | Adult | | | | Juvenile | | | |
|---|---|---|---|---|---|---|---|---|
| **Geographic Area** | **Diversity** | **Productivity** | **Capacity** | **Abundance** | **Productivity** | **Capacity** | **Abundance** | **SAR** |
| **Spring Chinook** | **73%** | **4.8** | **4,606** | **3,694** | **261** | **367,312** | **259,706** | **1%** |
| Yale | 88% | 4.3 | 794 | 610 | 285 | 78,905 | 54,083 | 1.1% |
| Swift | 59% | 5.2 | 3,812 | 3,084 | 237 | 288,407 | 205,623 | 1.5% |
| **Coho** | **70%** | **5.8** | **13,406** | **11,222** | **129** | **316,064** | **259,316** | **4.2%** |
| Merwin | 72% | 5.8 | 720 | 595 | 130 | 17,603 | 14,331 | 4.2% |
| Yale | 59% | 5.3 | 2,503 | 2,028 | 121 | 63,490 | 50,243 | 4.0% |
| Swift | 79% | 6.4 | 10,182 | 8,599 | 136 | 234,971 | 194,742 | 4.4% |
| **Winter Steelhead** | **64%** | **12.5** | **2,969** | **2,754** | **134** | **71,760** | **60,690** | **4.8%** |
| Merwin | 64% | 9.6 | 154 | 138 | 106 | 3,304 | 2,663 | 5.2% |
| Yale | 64% | 13.4 | 587 | 543 | 148 | 12,929 | 11,086 | 4.9% |
| Swift | 63% | 14.4 | 2,229 | 2,073 | 149 | 55,528 | 46,941 | 4.4% |

| **Total** | **Adults** | **% of Total Adults** | **Juveniles** | **% of Total Juveniles** |
|---|---|---|---|---|
| Merwin | 733 | 4.1% | 16,994 | 2.9% |
| Yale | 3,181 | 18.0% | 115,412 | 19.9% |
| Swift | 13,756 | 77.9% | 447,306 | 77.2% |
| Grand Total | 17,670 | 100.0% | 579,712 | 100.0% |

The model estimates that adult production upstream of Merwin Dam will be dominated by coho salmon (11,222). Steelhead and spring Chinook production is estimated at 2,754 and 3,694 adults, respectively.

Adult productivity values range from a low of approximately 4.3 for Yale spring Chinook to a high of 14.4 for steelhead originating from streams upstream of Swift Dam (Table 3-2). The higher the productivity value the more resilient the population is to mortality (e.g. harvest) and the quicker the population can rebound from periods of poor ocean and freshwater survival.

The diversity scores in Table 3-2 reflect the percent of the modeled life histories that were successful (i.e. produced adults). Higher scores indicate that successful trajectories occurred over a longer time period. The analysis shows that spring Chinook in the Yale geographic area population had the greatest life history score (88%). Populations that can sustain a wide variety of life history patterns are likely to be more resilient to the influences of environmental change (e.g. drought and floods). For Scenario 1, the total number of adults of each species gained with the establishment of fish passage facilities at all three projects compared to Swift only is as follows:

- Spring Chinook- 610
- Coho – 2,623
- Steelhead – 681.

Scenario 2

For scenario 2, total adult and juvenile salmon production for all five geographic areas combined is 20,242 and 1,487,494 respectively (Table 3-3). The adult numbers reflect run-size with harvest in marine and freshwater fisheries, a decrease in female fecundity and an increased mortality associated with adult fish passage.

For geographic areas upstream of Merwin, the majority of the adult and juvenile production (approximately 77%) comes from the Swift geographic area (Table 3-4). Spring Chinook are not produced in the Merwin geographic area because hatchery operations prevent this species from entering the only stream that could support such production, Speelyai Creek.

As was the case for Scenario 1, the steelhead from the Swift geographic area had the highest productivity (11.3). Swift origin coho exhibited the highest diversity score at 77 percent.

*Table 3-3. EDT estimates of salmon adult diversity, productivity, capacity, abundance, and smolt-to-adult survival rate (SAR) and juvenile abundance for all geographic areas – Scenario 2.*

| | Adult | | | | Juvenile | | | |
|---|---|---|---|---|---|---|---|---|
| **Geographic Area** | **Diversity** | **Productivity** | **Capacity** | **Abundance** | **Productivity** | **Capacity** | **Abundance** | **SAR** |
| **Spring Chinook** | **38%** | **2.5** | **2,758** | **1,699** | **190** | **367,312** | **163,974** | **1.0%** |
| Yale | 50% | 2.3 | 498 | 278 | 211 | 78,905 | 33,539 | 0.8% |
| Swift | 27% | 2.7 | 2,260 | 1,421 | 170 | 288,407 | 130,436 | 1.1% |
| **Coho** | **69%** | **4.6** | **17,711** | **13,936** | **202** | **3,628,267** | **1,211,937** | **2.3%** |
| Below Merwin Dam | 74% | 4.7 | 4,051 | 3,185 | 235 | 1,638,071 | 416,089 | 0.8% |
| East Fork Lewis River | 66% | 3.9 | 2,985 | 2,214 | 379 | 1,673,562 | 548,165 | 0.4% |
| Merwin | 70% | 5.0 | 628 | 502 | 130 | 17,636 | 13,885 | 3.6% |
| Yale | 58% | 4.4 | 2,064 | 1,595 | 124 | 63,591 | 47,895 | 3.3% |
| Swift | 77% | 5.2 | 7,985 | 6,441 | 141 | 235,407 | 185,904 | 3.5% |
| **Winter Steelhead** | **58%** | **10.2** | **5,087** | **4,607** | **134** | **135,976** | **111,582** | **4.2%** |
| Below Merwin Dam | 38% | 10.2 | 678 | 611 | 131 | 16,661 | 13,688 | 4.5% |
| East Fork Lewis River | 66% | 10.3 | 2,093 | 1,889 | 129 | 47,554 | 39,713 | 4.8% |
| Merwin | 63% | 8.2 | 131 | 115 | 106 | 3,304 | 2,569 | 4.5% |
| Yale | 61% | 11.0 | 474 | 431 | 151 | 12,929 | 10,722 | 4.0% |
| Swift | 60% | 11.3 | 1,712 | 1,561 | 153 | 55,528 | 44,890 | 3.5% |
| **Grand Total** | | | | **20,242** | | | **1,487,494** | |

*Table 3-4. EDT estimates of salmon adult diversity, productivity, capacity, abundance, and smolt-to-adult survival rate (SAR) and juvenile abundance for Swift, Yale and Merwin geographic areas – Scenario 2.*

| | Adult | | | | Juvenile | | | |
|---|---|---|---|---|---|---|---|---|
| **Geographic Area** | **Diversity** | **Productivity** | **Capacity** | **Abundance** | **Productivity** | **Capacity** | **Abundance** | **SAR** |
| **Spring Chinook** | **38%** | **2.5** | **2,758** | **1,699** | **190** | **367,312** | **163,974** | **1%** |
| Yale | 50% | 2.3 | 498 | 278 | 211 | 78,905 | 33,539 | 0.8% |
| Swift | 27% | 2.7 | 2,260 | 1,421 | 170 | 288,407 | 130,436 | 1.1% |
| **Coho** | **68%** | **4.9** | **10,676** | **8,537** | **132** | **316,634** | **247,683** | **3.5%** |
| Merwin | 70% | 5.0 | 628 | 502 | 130 | 17,636 | 13,885 | 3.6% |
| Yale | 58% | 4.4 | 2,064 | 1,595 | 124 | 63,591 | 47,895 | 3.3% |
| Swift | 77% | 5.2 | 7,985 | 6,441 | 141 | 235,407 | 185,904 | 3.5% |
| **Winter Steelhead** | **61%** | **10.2** | **2,316** | **2,106** | **137** | **71,760** | **58,181** | **4.0%** |
| Merwin | 63% | 8.2 | 131 | 115 | 106 | 3,304 | 2,569 | 4.5% |
| Yale | 61% | 11.0 | 474 | 431 | 151 | 12,929 | 10,722 | 4.0% |
| Swift | 60% | 11.3 | 1,712 | 1,561 | 153 | 55,528 | 44,890 | 3.5% |
| **Total** | **Adults** | **% of Total Adults** | **Juveniles** | **% of Total Juveniles** | | | | |
| Merwin | 616 | 5.0% | 16,454 | 3.5% | | | | |
| Yale | 2,304 | 18.7% | 92,155 | 19.6% | | | | |
| Swift | 9,422 | 76.3% | 361,230 | 76.9% | | | | |
| **Grand Total** | **12,342** | **100.0%** | **469,838** | **100.0%** | | | | |

For Scenario 2, the total number of adults of each species gained with the establishment of fish passage facilities at all three projects compared to Swift only is as follows:

- Spring Chinook- 278
- Coho – 2,097
- Steelhead - 546

### 3.1.3 Stream Population Analysis

Salmon production estimates for each analysis species by stream are presented in Tables 3-5 to 3-7 for Scenario 1 and 3-8 to 3-10 for Scenario 2. Because juvenile production is correlated with adult production the discussion below focuses on EDT estimates of adults.

Scenario 1

The two largest producers of spring Chinook are Clear Creek (872) and the Lewis mainstem upstream of Swift (1,090) (Table 3-5). Both of these tributaries are located upstream of Swift Dam. The EDT model estimates that the Yale geographic area will produce 610 adults (Table 3-2).

Coho are produced in streams located in all geographic areas. The two largest producers of coho are Clear Creek (2,445) and the Lewis mainstem upstream of Swift reach (1,759) (Table 3-6). The model also estimates Muddy River coho production at 1,565 adults. The major coho producing streams in Merwin and Yale are Brooks Creek (175) and Lewis Mainstem above Yale (516), respectively.

The two largest steelhead producing streams are Lewis mainstem above Swift (452) and Muddy River (398) Both of these streams are located in the Swift geographic area (Table 3-7). Brooks Creek (55) and Speelyai Creek (171) are the largest producers of steelhead in the Merwin and Yale geographic areas.

For all three analysis species, juvenile productivity is highest for streams located upstream of Swift dam. Higher juvenile productivity values result from better habitat conditions. Therefore, habitat quality is greatest in the Swift geographic area, followed by Yale and then Merwin for spring Chinook and steelhead. Coho productivity is higher in Merwin than for Yale.

*Table 3-5. EDT estimates of adult and juvenile spring Chinook, diversity, productivity, capacity and abundance for each analysis stream in the Yale and Swift geographic areas – Scenario 1.*

| | | Adult | | | | Juvenile | | |
|---|---|---|---|---|---|---|---|---|
| | **Geographic Area** | **Diversity** | **Productivity** | **Capacity** | **Abundance** | **Productivity** | **Capacity** | **Abundance** |
| Lewis Mainstem above Yale | Yale | 53% | 4.3 | 351 | 270 | 285 | 39,852 | 26,249 |
| Siouxon Creek | Yale | 98% | 4.3 | 326 | 251 | 285 | 28,778 | 20,512 |
| Cougar Creek | Yale | 100% | 4.3 | 116 | 89 | 285 | 10,275 | 7,322 |
| Lewis Mainstem above Swift | Swift | 97% | 5.2 | 1,348 | 1,090 | 237 | 100,780 | 72,487 |
| S10 | Swift | 39% | 5.2 | 17 | 14 | 237 | 1,480 | 1,025 |
| S15 | Swift | 91% | 5.2 | 36 | 29 | 237 | 3,241 | 2,197 |
| Swift Campground Creek | Swift | 0% | 5.2 | 0 | 0 | 237 | 0 | 0 |
| Pine Creek | Swift | 77% | 5.2 | 190 | 153 | 237 | 17,585 | 11,851 |
| Muddy River | Swift | 6% | 5.2 | 503 | 407 | 237 | 51,134 | 33,411 |
| Clear Creek | Swift | 100% | 5.2 | 1,078 | 872 | 237 | 68,797 | 51,612 |
| Clearwater Creek | Swift | 51% | 5.2 | 263 | 213 | 237 | 16,424 | 12,390 |
| Smith Creek | Swift | 33% | 5.2 | 272 | 220 | 237 | 20,206 | 14,565 |
| Ape Canyon Creek | Swift | 12% | 5.2 | 10 | 8 | 237 | 736 | 526 |
| Curly Creek | Swift | 100% | 5.2 | 44 | 36 | 237 | 3,920 | 2,677 |
| Little Creek | Swift | 100% | 5.2 | 41 | 33 | 237 | 3,458 | 2,402 |
| Crab Creek | Swift | 75% | 5.2 | 10 | 8 | 237 | 644 | 479 |
| | | | | | | | | |

*Table 3-6. EDT estimates of adult and juvenile coho, diversity, productivity, capacity and abundance for each analysis stream in the Merwin, Yale and Swift geographic areas – Scenario 1.*

| | | Adult | | | | Juvenile | | |
|---|---|---|---|---|---|---|---|---|
| | **Geographic Area** | **Diversity** | **Productivity** | **Capacity** | **Abundance** | **Productivity** | **Capacity** | **Abundance** |
| Brooks Creek | Merwin | 56% | 5.8 | 211 | 175 | 130 | 5,459 | 4,400 |
| M14 | Merwin | 97% | 5.8 | 130 | 107 | 130 | 3,188 | 2,594 |
| Buncombe Hollow Creek | Merwin | 76% | 5.8 | 49 | 40 | 130 | 1,256 | 1,013 |
| Indian George Creek | Merwin | 67% | 5.8 | 166 | 138 | 130 | 3,948 | 3,234 |
| Jim Creek | Merwin | 77% | 5.8 | 95 | 78 | 130 | 2,294 | 1,871 |
| Cape Horn Creek | Merwin | 80% | 5.8 | 70 | 57 | 130 | 1,458 | 1,220 |
| Lewis Mainstem above Yale | Yale | 95% | 5.3 | 637 | 516 | 121 | 14,372 | 11,681 |
| Siouxon Creek | Yale | 50% | 5.3 | 587 | 476 | 121 | 13,912 | 11,202 |
| Speelyai Creek | Yale | 41% | 5.3 | 537 | 435 | 121 | 17,528 | 13,147 |
| Dog Creek | Yale | 88% | 5.3 | 285 | 231 | 121 | 6,321 | 5,154 |
| Cougar Creek | Yale | 64% | 5.3 | 194 | 157 | 121 | 4,917 | 3,906 |
| Panamaker Creek | Yale | 40% | 5.3 | 20 | 16 | 121 | 459 | 371 |
| Ole Creek | Yale | 94% | 5.3 | 137 | 111 | 121 | 3,222 | 2,599 |
| Lewis Mainstem above Swift | Swift | 84% | 6.4 | 2,083 | 1,759 | 136 | 45,972 | 38,570 |
| S10 | Swift | 87% | 6.4 | 23 | 19 | 136 | 3,160 | 1,428 |
| S15 | Swift | 50% | 6.4 | 112 | 94 | 136 | 2,933 | 2,389 |
| Swift Campground Creek | Swift | 0% | 6.4 | 0 | 0 | 136 | 0 | 0 |
| Pine Creek | Swift | 41% | 6.4 | 677 | 572 | 136 | 18,421 | 14,899 |
| Muddy River | Swift | 76% | 6.4 | 1,853 | 1,565 | 136 | 43,270 | 35,967 |
| Clear Creek | Swift | 100% | 6.4 | 2,895 | 2,445 | 136 | 62,611 | 52,702 |
| Clearwater Creek | Swift | 99% | 6.4 | 945 | 798 | 136 | 20,539 | 17,276 |
| Bean Creek | Swift | 76% | 6.4 | 105 | 89 | 136 | 2,581 | 2,126 |
| Smith Creek | Swift | 95% | 6.4 | 1,291 | 1,090 | 136 | 30,374 | 25,217 |
| Ape Canyon Creek | Swift | 35% | 6.4 | 61 | 51 | 136 | 1,705 | 1,370 |
| Curly Creek | Swift | 100% | 6.4 | 56 | 47 | 136 | 1,338 | 1,107 |
| Rush Creek | Swift | 46% | 6.4 | 45 | 38 | 136 | 1,081 | 896 |
| Crab Creek | Swift | 75% | 6.4 | 36 | 31 | 136 | 984 | 796 |

*Table 3-7. EDT estimates of adult and juvenile steelhead, diversity, productivity, capacity and abundance for each analysis stream for Merwin, Yale and Swift geographic areas – Scenario 1.*

| | | Adult | | | | Juvenile | | |
|---|---|---|---|---|---|---|---|---|
| | Geographic Area | Diversity | Productivity | Capacity | Abundance | Productivity | Capacity | Abundance |
| Brooks Creek | Merwin | 64% | 9.6 | 62 | 55 | 106 | 1,346 | 1,094 |
| M14 | Merwin | 66% | 9.6 | 23 | 21 | 106 | 458 | 380 |
| Buncombe Hollow Creek | Merwin | 50% | 9.6 | 10 | 9 | 106 | 209 | 172 |
| Indian George Creek | Merwin | 87% | 9.6 | 27 | 24 | 106 | 571 | 467 |
| Jim Creek | Merwin | 71% | 9.6 | 26 | 23 | 106 | 436 | 370 |
| Cape Horn Creek | Merwin | 33% | 9.6 | 5 | 5 | 106 | 283 | 179 |
| Lewis Mainstem above Yale | Yale | 65% | 13.4 | 85 | 78 | 148 | 1,717 | 1,496 |
| Siouxon Creek | Yale | 66% | 13.4 | 163 | 151 | 148 | 4,018 | 3,406 |
| Speelyai Creek | Yale | 60% | 13.4 | 185 | 171 | 148 | 3,926 | 3,400 |
| Dog Creek | Yale | 71% | 13.4 | 30 | 28 | 148 | 691 | 593 |
| Cougar Creek | Yale | 71% | 13.4 | 83 | 77 | 148 | 1,380 | 1,231 |
| Panamaker Creek | Yale | 75% | 13.4 | 14 | 13 | 148 | 243 | 216 |
| Ole Creek | Yale | 69% | 13.4 | 17 | 16 | 148 | 752 | 567 |
| Rain Creek | Yale | 38% | 13.4 | 10 | 9 | 148 | 203 | 177 |
| Lewis Mainstem above Swift | Swift | 65% | 14.4 | 485 | 452 | 149 | 12,219 | 10,340 |
| Diamond Creek | Swift | 0% | 14.4 | 0 | 0 | 149 | 0 | 0 |
| Range Creek | Swift | 62% | 14.4 | 7 | 6 | 149 | 91 | 83 |
| Drift Creek | Swift | 52% | 14.4 | 19 | 17 | 149 | 385 | 335 |
| S10 | Swift | 50% | 14.4 | 17 | 16 | 149 | 364 | 315 |
| S15 | Swift | 52% | 14.4 | 37 | 34 | 149 | 854 | 731 |
| Swift Campground Creek | Swift | 0% | 14.4 | 0 | 0 | 149 | 0 | 0 |
| Pine Creek | Swift | 64% | 14.4 | 380 | 354 | 149 | 8,469 | 7,296 |
| Muddy River | Swift | 56% | 14.4 | 428 | 398 | 149 | 10,234 | 8,727 |
| Clear Creek | Swift | 69% | 14.4 | 384 | 357 | 149 | 11,668 | 9,569 |
| Clearwater Creek | Swift | 69% | 14.4 | 164 | 152 | 149 | 3,943 | 3,359 |
| Bean Creek | Swift | 94% | 14.4 | 27 | 25 | 149 | 537 | 469 |
| Smith Creek | Swift | 60% | 14.4 | 119 | 110 | 149 | 3,163 | 2,652 |
| Ape Canyon Creek | Swift | 59% | 14.4 | 10 | 10 | 149 | 408 | 318 |
| Curly Creek | Swift | 56% | 14.4 | 15 | 14 | 149 | 124 | 117 |
| Pepper Creek | Swift | 63% | 14.4 | 8 | 7 | 149 | 115 | 104 |
| Rush Creek | Swift | 64% | 14.4 | 29 | 27 | 149 | 563 | 495 |
| Little Creek | Swift | 67% | 14.4 | 23 | 21 | 149 | 455 | 397 |
| Mid Big Creek | Swift | 67% | 14.4 | 7 | 6 | 149 | 130 | 114 |
| Spencer Creek | Swift | 67% | 14.4 | 25 | 23 | 149 | 709 | 588 |
| Cussed Hollow | Swift | 79% | 14.4 | 24 | 22 | 149 | 496 | 431 |
| Crab Creek | Swift | 50% | 14.4 | 9 | 8 | 149 | 273 | 222 |
| Chickoon Creek | Swift | 64% | 14.4 | 14 | 13 | 149 | 326 | 280 |

Scenario 2

Results for Scenario 2 are generally similar to Scenario 1, in regards to streams with largest adult production. EDT estimates of population diversity, productivity, capacity and abundance are less than Scenario 1 as a result of including harvest, lower female fecundity and lower adult fish passage survival rates. Streams that ranked high in adult and juvenile production in Scenario 1 were also the major producers in Scenario 2.

*Table 3-8. EDT estimates of adult and juvenile spring Chinook, diversity, productivity, capacity and abundance for each analysis stream in the Yale and Swift geographic areas – Scenario 2.*

| | | Adult | | | | Juvenile | | |
|---|---|---|---|---|---|---|---|---|
| | **Geographic Area** | **Diversity** | **Productivity** | **Capacity** | **Abundance** | **Productivity** | **Capacity** | **Abundance** |
| Lewis Mainstem above Yale | Yale | 23% | 2.3 | 222 | 124 | 211 | 39,852 | 15,787 |
| Siouxon Creek | Yale | 52% | 2.3 | 203 | 113 | 211 | 28,778 | 13,059 |
| Cougar Creek | Yale | 68% | 2.3 | 73 | 41 | 211 | 10,275 | 4,693 |
| Lewis Mainstem above Swift | Swift | 53% | 2.7 | 798 | 502 | 170 | 100,780 | 46,142 |
| S10 | Swift | 0% | 2.7 | 10 | 7 | 170 | 1,480 | 633 |
| S15 | Swift | 18% | 2.7 | 22 | 14 | 170 | 3,241 | 1,343 |
| Swift Campground Creek | Swift | 0% | 2.7 | 0 | 0 | 170 | 0 | 0 |
| Pine Creek | Swift | 18% | 2.7 | 115 | 72 | 170 | 17,585 | 7,225 |
| Muddy River | Swift | 0% | 2.7 | 299 | 188 | 170 | 51,134 | 19,614 |
| Clear Creek | Swift | 82% | 2.7 | 637 | 400 | 170 | 68,797 | 34,161 |
| Clearwater Creek | Swift | 15% | 2.7 | 154 | 97 | 170 | 16,424 | 8,217 |
| Smith Creek | Swift | 3% | 2.7 | 162 | 102 | 170 | 20,206 | 9,301 |
| Ape Canyon Creek | Swift | 0% | 2.7 | 6 | 4 | 170 | 736 | 336 |
| Curly Creek | Swift | 27% | 2.7 | 27 | 17 | 170 | 3,920 | 1,656 |
| Little Creek | Swift | 68% | 2.7 | 25 | 15 | 170 | 3,458 | 1,492 |
| Crab Creek | Swift | 25% | 2.7 | 6 | 4 | 170 | 644 | 316 |

*Table 3-9. EDT estimates of adult and juvenile coho, diversity, productivity, capacity and abundance for each analysis stream in the Yale and Swift geographic areas – Scenario 2.*

| | | Adult | | | | Juvenile | | |
|---|---|---|---|---|---|---|---|---|
| | **Geographic Area** | **Diversity** | **Productivity** | **Capacity** | **Abundance** | **Productivity** | **Capacity** | **Abundance** |
| Brooks Creek | Merwin | 56% | 5.0 | 185 | 148 | 130 | 5,466 | 4,258 |
| M14 | Merwin | 89% | 5.0 | 113 | 90 | 130 | 3,195 | 2,511 |
| Buncombe Hollow Creek | Merwin | 74% | 5.0 | 42 | 34 | 130 | 1,257 | 977 |
| Indian George Creek | Merwin | 67% | 5.0 | 146 | 117 | 130 | 3,959 | 3,142 |
| Jim Creek | Merwin | 77% | 5.0 | 82 | 66 | 130 | 2,299 | 1,812 |
| Cape Horn Creek | Merwin | 80% | 5.0 | 60 | 48 | 130 | 1,459 | 1,185 |
| Lewis Mainstem above Yale | Yale | 95% | 4.4 | 523 | 404 | 124 | 14,398 | 11,179 |
| Siouxon Creek | Yale | 48% | 4.4 | 481 | 372 | 124 | 13,923 | 10,689 |
| Speelyai Creek | Yale | 40% | 4.4 | 444 | 343 | 124 | 17,546 | 12,414 |
| Dog Creek | Yale | 84% | 4.4 | 235 | 182 | 124 | 6,338 | 4,945 |
| Cougar Creek | Yale | 61% | 4.4 | 160 | 124 | 124 | 4,923 | 3,726 |
| Panamaker Creek | Yale | 40% | 4.4 | 16 | 12 | 124 | 459 | 354 |
| Ole Creek | Yale | 94% | 4.4 | 113 | 88 | 124 | 3,227 | 2,487 |
| Rain Creek | Yale | 38% | 4.4 | 90 | 70 | 124 | 2,776 | 2,101 |
| Lewis Mainstem above Swift | Swift | 82% | 5.2 | 1,623 | 1,309 | 141 | 46,009 | 36,812 |
| S10 | Swift | 73% | 5.2 | 18 | 14 | 141 | 3,153 | 1,225 |
| S15 | Swift | 50% | 5.2 | 89 | 72 | 141 | 2,950 | 2,284 |
| Swift Campground Creek | Swift | 0% | 5.2 | 0 | 0 | 141 | 0 | 0 |
| Pine Creek | Swift | 41% | 5.2 | 544 | 439 | 141 | 18,542 | 14,260 |
| Muddy River | Swift | 70% | 5.2 | 1,452 | 1,171 | 141 | 43,333 | 34,309 |
| Clear Creek | Swift | 100% | 5.2 | 2,262 | 1,824 | 141 | 62,663 | 50,368 |
| Clearwater Creek | Swift | 99% | 5.2 | 739 | 596 | 141 | 20,555 | 16,508 |
| Bean Creek | Swift | 76% | 5.2 | 84 | 68 | 141 | 2,593 | 2,037 |
| Smith Creek | Swift | 95% | 5.2 | 1,017 | 820 | 141 | 30,466 | 24,102 |
| Ape Canyon Creek | Swift | 35% | 5.2 | 49 | 40 | 141 | 1,720 | 1,315 |
| Curly Creek | Swift | 95% | 5.2 | 44 | 36 | 141 | 1,343 | 1,059 |
| Rush Creek | Swift | 46% | 5.2 | 36 | 29 | 141 | 1,082 | 855 |
| Crab Creek | Swift | 75% | 5.2 | 30 | 24 | 141 | 996 | 769 |

*Table 3-10. EDT estimates of adult and juvenile coho, diversity, productivity, capacity and abundance for each analysis stream in the Yale and Swift geographic areas – Scenario 2.*

| | | Adult | | | | Juvenile | | |
|---|---|---|---|---|---|---|---|---|
| | **Geographic Area** | **Diversity** | **Productivity** | **Capacity** | **Abundance** | **Productivity** | **Capacity** | **Abundance** |
| Brooks Creek | Merwin | 64% | 8.2 | 53 | 46 | 106 | 1,346 | 1,056 |
| M14 | Merwin | 62% | 8.2 | 20 | 18 | 106 | 458 | 368 |
| Buncombe Hollow Creek | Merwin | 50% | 8.2 | 9 | 8 | 106 | 209 | 167 |
| Indian George Creek | Merwin | 87% | 8.2 | 23 | 20 | 106 | 571 | 452 |
| Jim Creek | Merwin | 71% | 8.2 | 22 | 19 | 106 | 436 | 359 |
| Cape Horn Creek | Merwin | 33% | 8.2 | 4 | 4 | 106 | 283 | 167 |
| Lewis Mainstem above Yale | Yale | 59% | 11.0 | 68 | 62 | 151 | 1,717 | 1,451 |
| Siouxon Creek | Yale | 66% | 11.0 | 131 | 120 | 151 | 4,018 | 3,286 |
| Speelyai Creek | Yale | 57% | 11.0 | 149 | 136 | 151 | 3,926 | 3,294 |
| Dog Creek | Yale | 66% | 11.0 | 24 | 22 | 151 | 691 | 573 |
| Cougar Creek | Yale | 64% | 11.0 | 67 | 61 | 151 | 1,380 | 1,200 |
| Panamaker Creek | Yale | 75% | 11.0 | 12 | 11 | 151 | 243 | 210 |
| Ole Creek | Yale | 69% | 11.0 | 14 | 12 | 151 | 752 | 536 |
| Rain Creek | Yale | 29% | 11.0 | 8 | 8 | 151 | 203 | 172 |
| Lewis Mainstem above Swift | Swift | 63% | 11.3 | 372 | 339 | 153 | 12,219 | 9,887 |
| Diamond Creek | Swift | 0% | 11.3 | 0 | 0 | 153 | 0 | 0 |
| Range Creek | Swift | 62% | 11.3 | 5 | 5 | 153 | 91 | 81 |
| Drift Creek | Swift | 52% | 11.3 | 14 | 13 | 153 | 385 | 323 |
| S10 | Swift | 50% | 11.3 | 13 | 12 | 153 | 364 | 303 |
| S15 | Swift | 48% | 11.3 | 28 | 26 | 153 | 854 | 701 |
| Swift Campground Creek | Swift | 0% | 11.3 | 0 | 0 | 153 | 0 | 0 |
| Pine Creek | Swift | 62% | 11.3 | 293 | 267 | 153 | 8,469 | 7,013 |
| Muddy River | Swift | 51% | 11.3 | 328 | 299 | 153 | 10,234 | 8,362 |
| Clear Creek | Swift | 68% | 11.3 | 295 | 269 | 153 | 11,668 | 9,083 |
| Clearwater Creek | Swift | 65% | 11.3 | 126 | 114 | 153 | 3,943 | 3,217 |
| Bean Creek | Swift | 89% | 11.3 | 20 | 19 | 153 | 537 | 452 |
| Smith Creek | Swift | 59% | 11.3 | 91 | 83 | 153 | 3,163 | 2,531 |
| Ape Canyon Creek | Swift | 55% | 11.3 | 8 | 7 | 153 | 408 | 298 |
| Curly Creek | Swift | 56% | 11.3 | 11 | 10 | 153 | 124 | 115 |
| Pepper Creek | Swift | 63% | 11.3 | 6 | 5 | 153 | 115 | 101 |
| Rush Creek | Swift | 56% | 11.3 | 23 | 21 | 153 | 563 | 478 |
| Little Creek | Swift | 67% | 11.3 | 17 | 16 | 153 | 455 | 383 |
| Mid Big Creek | Swift | 67% | 11.3 | 5 | 5 | 153 | 130 | 110 |
| Spencer Creek | Swift | 58% | 11.3 | 19 | 17 | 153 | 709 | 560 |
| Cussed Hollow | Swift | 79% | 11.3 | 18 | 17 | 153 | 496 | 415 |
| Crab Creek | Swift | 50% | 11.3 | 7 | 6 | 153 | 273 | 211 |
| Chickoon Creek | Swift | 64% | 11.3 | 11 | 10 | 153 | 326 | 268 |

## HABITAT LIMITING FACTORS AND REACH RESTORATION ANALYSIS

Results of the habitat limiting factors reach restoration analysis are presented in Tables 3-11 through 3-13 for the Swift and downstream of Merwin geographic areas for Scenario 1. Results are only presented for Scenario 1 as the limiting factors do not change between scenarios (i.e. the habitat ratings are the same for each). The numbers in the tables represent the total percent increase in adult abundance upstream of Merwin Dam if the identified limiting habitat factor was restored to historical conditions. It should be noted that the historic condition includes the same passage assumptions as used for Scenario 1 and presence of the reservoirs.

For spring Chinook, addressing the key habitat factors for Clear Creek Lower and Lewis 20 reaches results in the largest increase in adult abundance; ranging from 1.8% to 2.51% (Table 3-11). Addressing the habitat limiting factors in all reaches combined produces a total of 783 adult spring Chinook.

*Table 3-11. Spring Chinook habitat limiting factors analysis results for streams associated with the Swift and downstream of Merwin geographic areas.*

| Reach | Limiting Factor | Length Kilometers | % Increase Adult Abundance with Restoration | # Adults W/ Restoration | Cumulative Increase Adult Abundance |
|---|---|---|---|---|---|
| Clear Creek Lower | Key Habitat | 9.9 | 2.51% | 93 | 93 |
| Lewis 20 | Sediment load | 8.9 | 1.80% | 67 | 159 |
| Muddy R 1A | Key Habitat | 7.1 | 1.42% | 52 | 211 |
| S15 | Key Habitat | 2.1 | 1.38% | 51 | 262 |
| Lewis 7 B | Key Habitat | 5.2 | 1.31% | 48 | 311 |
| Pine Creek 1 | Key Habitat | 2.8 | 1.20% | 44 | 355 |
| Clear Creek | Habitat diversity | 9.9 | 1.11% | 41 | 396 |
| Lewis 18 | Key Habitat | 1.1 | 0.97% | 36 | 432 |
| Clear Creek | Food Index | 9.9 | 0.81% | 30 | 462 |
| Lewis 23 | Habitat diversity | 5.6 | 0.73% | 27 | 489 |
| Lewis 4 B | Key Habitat | 4.2 | 0.66% | 24 | 513 |
| Lewis 4 A | Key Habitat | 3.5 | 0.53% | 20 | 533 |
| P8 | Key Habitat | 6.8 | 0.40% | 15 | 548 |
| Pine Creek 6 | Key Habitat | 4.4 | 0.35% | 13 | 561 |
| Lewis 21 | Key Habitat | 1.6 | 0.35% | 13 | 574 |
| Lewis 2 tidal C | Key Habitat | 3.2 | 0.33% | 12 | 586 |
| Lewis 1 tidal B | Predation | 3.0 | 0.33% | 12 | 598 |
| Lewis 2 tidal C | Predation | 3.2 | 0.30% | 11 | 609 |
| Lewis 5 | Key Habitat | 4.5 | 0.28% | 10 | 620 |
| P3 | Key Habitat | 1.6 | 0.27% | 10 | 630 |
| Curly Creek | Sediment load | 0.8 | 0.24% | 9 | 639 |
| Clear Creek Small Tribs | Sediment load | 3.2 | 0.23% | 8 | 647 |
| Lewis 7 A | Key Habitat | 0.9 | 0.22% | 8 | 655 |
| Lewis 23 | Channel Stability | 5.6 | 0.21% | 8 | 663 |
| Pine Creek 3 | Key Habitat | 1.6 | 0.20% | 8 | 670 |
| Lewis 19 | Food Index | 0.8 | 0.18% | 7 | 677 |
| Cougar Creek 3 | Chemicals | 2.5 | 0.18% | 7 | 683 |
| Lewis 2 tidal A | Predation | 2.0 | 0.17% | 6 | 689 |
| Muddy R 3 | Sediment load | 5.6 | 0.17% | 6 | 696 |
| Pine Creek 3 | Habitat diversity | 1.6 | 0.17% | 6 | 702 |
| Muddy R 3 | Temperature | 5.6 | 0.15% | 6 | 707 |
| Crab Creek | Key Habitat | 0.8 | 0.15% | 5 | 713 |
| Lewis 6 | Key Habitat | 0.6 | 0.14% | 5 | 718 |
| Lewis 3 | Key Habitat | 1.2 | 0.13% | 5 | 723 |
| Lewis 4 C | Key Habitat | 0.7 | 0.13% | 5 | 728 |
| Lewis 2 tidal D | Key Habitat | 1.4 | 0.13% | 5 | 733 |
| Lewis 2 tidal D | Predation | 1.4 | 0.13% | 5 | 738 |
| Lewis 22 | Habitat diversity | 1.8 | 0.12% | 5 | 742 |
| Pine Creek 2 | Key Habitat | 0.8 | 0.11% | 4 | 746 |
| S10 | Sediment load | 0.6 | 0.11% | 4 | 750 |
| Little Creek | Key Habitat | 1.1 | 0.10% | 4 | 754 |
| Pine Creek 4 | Key Habitat | 1.6 | 0.08% | 3 | 757 |
| Pine Creek 5 | Habitat diversity | 1.6 | 0.08% | 3 | 760 |
| Lewis 22 | Channel Stability | 1.8 | 0.08% | 3 | 763 |
| P7 | Key Habitat | 1.8 | 0.07% | 3 | 765 |
| Lewis 24 | Channel Stability | 0.6 | 0.06% | 2 | 768 |
| Lewis 26 | Habitat diversity | 1.4 | 0.06% | 2 | 770 |
| Lewis 26 | Channel Stability | 1.4 | 0.06% | 2 | 772 |
| Lewis 24 | Habitat diversity | 0.6 | 0.06% | 2 | 774 |
| P7 | Habitat diversity | 1.8 | 0.05% | 2 | 776 |
| Lewis 25 | Sediment load | 0.5 | 0.04% | 1 | 778 |
| P1 | Sediment load | 1.4 | 0.04% | 1 | 779 |
| Lewis 27 | Sediment load | 0.3 | 0.04% | 1 | 780 |
| Swift Campground Creek | Sediment load | 1.9 | 0.03% | 1 | 781 |
| Ape Canyon Creek | Temperature | 1.6 | 0.03% | 1 | 782 |
| P1 | Key Habitat | 1.4 | 0.02% | 1 | 783 |
| Total Adults | | | | 783 | |

The largest increase in coho adult abundance results from working on the key habitat limiting factors (habitat diversity and key habitat) is in Lewis 18, S15 and Rush Creek. The percent improvement in coho adult abundance for these three streams ranges from 0.49% to 1.45%. Addressing the habitat limiting factors in all reaches combined produces 876 adult coho (Table 3-12).

*Table 3-12. Coho habitat limiting factors analysis results for streams associated with the Swift and downstream of Merwin geographic areas.*

| Reach | Limiting Factor | Length Kilometers | % Increase Adult Abundance w/ Restoration | # Adults W/ Restoration | Cumulative Increase Adult Abundance |
|---|---|---|---|---|---|
| Lewis 18 | Key Habitat | 1.1 | 1.45% | 163 | 163 |
| S15 | Key Habitat | 2.1 | 0.70% | 79 | 242 |
| Rush Creek | Key Habitat | 4.0 | 0.49% | 55 | 297 |
| Pine Creek 1 | Key Habitat | 2.8 | 0.48% | 53 | 350 |
| Lewis 18 | Food Index | 1.1 | 0.28% | 32 | 382 |
| Muddy R 1 | Habitat diversity | 7.1 | 0.24% | 27 | 410 |
| Speelyai 3 | Key Habitat | 1.0 | 0.24% | 27 | 437 |
| Clear Creek | Habitat diversity | 9.9 | 0.22% | 24 | 461 |
| Lewis 19 | Key Habitat | 0.8 | 0.20% | 23 | 484 |
| Lewis 2 tidal B | Predation | 2.5 | 0.19% | 22 | 505 |
| Lewis 4 B | Habitat diversity | 4.2 | 0.19% | 21 | 526 |
| Crab Creek | Key Habitat | 0.8 | 0.18% | 20 | 546 |
| Lewis 18 | Sediment load | 1.1 | 0.17% | 20 | 566 |
| Lewis 19 | Food Index | 0.8 | 0.17% | 19 | 585 |
| Muddy R 1 | Food Index | 7.1 | 0.16% | 18 | 603 |
| Clear Creek Lower | Food Index | 9.9 | 0.16% | 18 | 620 |
| Lewis 4 C | Key Habitat | 0.7 | 0.15% | 17 | 638 |
| Muddy R 1A | Key Habitat | 7.1 | 0.15% | 17 | 655 |
| Lewis 2 tidal D | Predation | 1.4 | 0.15% | 17 | 672 |
| Pine Creek 2 | Key Habitat | 0.8 | 0.15% | 16 | 688 |
| Clear Creek Lower | Key Habitat | 9.9 | 0.14% | 16 | 704 |
| Muddy R 1 | Key Habitat | 7.1 | 0.14% | 15 | 719 |
| Clear Creek | Key Habitat | 9.9 | 0.13% | 15 | 734 |
| Lewis 1 tidal B | Predation | 3.0 | 0.13% | 15 | 749 |
| Lewis 1 tidal A | Predation | 3.1 | 0.13% | 14 | 763 |
| Lewis 2 tidal C | Predation | 3.2 | 0.13% | 14 | 778 |
| Pine Creek 3 | Key Habitat | 1.6 | 0.12% | 13 | 791 |
| Lewis 6 | Habitat diversity | 0.6 | 0.12% | 13 | 804 |
| Lewis 4 A | Habitat diversity | 3.5 | 0.12% | 13 | 817 |
| Lewis 4 B | Key Habitat | 4.2 | 0.12% | 13 | 831 |
| Lewis 21 | Key Habitat | 1.6 | 0.11% | 12 | 843 |
| Brooks Creek | Width | 1.8 | 0.10% | 11 | 854 |
| P8 | Key Habitat | 6.8 | 0.10% | 11 | 865 |
| Lewis 7 A | Habitat diversity | 0.9 | 0.10% | 11 | 876 |
| Total Adults | | | | 876 | |

The percent increase in adult steelhead production from addressing the key habitat limiting factor is less than 1% for all reaches examined in this analysis (Table 3-13). Fixing the key limiting habitat factor for all reaches combined results in the production of 210 steelhead adults. What this analysis indicates is there is no single key habitat limiting factor in the vast majority of reaches that if addressed results in substantial improvement in adult abundance. To increase steelhead abundance by more than 210 adults would require that the majority of the habitat factors be addressed in each reach. In other words, restoration of entire streams or watersheds which is presented in the following section of this report.

*Table 3-13. Steelhead habitat limiting factors analysis results for streams associated with the Swift and downstream of Merwin geographic areas. Results represent the percent increase in adult abundance.*

| Reach | Limiting Factor | Length Kilometers | % Increase Adult Abundance w/ Restoration | # Adults W/ Restoration | Cumulative Increase Adult Abundance |
|---|---|---|---|---|---|
| Lewis 1 tidal A | Habitat diversity | 3.06 | 0.91% | 25 | 25 |
| Lewis 2 tidal B | Habitat diversity | 2.48 | 0.70% | 19 | 44 |
| Pine Creek 6 | Key Habitat | 4.43 | 0.55% | 15 | 59 |
| Lewis 3 | Habitat diversity | 1.16 | 0.50% | 14 | 73 |
| Lewis 4 A | Habitat diversity | 3.48 | 0.40% | 11 | 84 |
| Lewis 1 tidal B | Habitat diversity | 2.96 | 0.40% | 11 | 95 |
| Lewis 5 | Habitat diversity | 4.54 | 0.32% | 9 | 104 |
| Rush Creek | Key Habitat | 4.02 | 0.28% | 8 | 112 |
| S15 | Key Habitat | 2.09 | 0.27% | 7 | 119 |
| Lewis 4 C | Habitat diversity | 0.74 | 0.27% | 7 | 126 |
| Pepper Creek | Key Habitat | 0.64 | 0.26% | 7 | 134 |
| Lewis 2 tidal C | Habitat diversity | 3.23 | 0.25% | 7 | 140 |
| P3 | Key Habitat | 1.61 | 0.22% | 6 | 147 |
| Lewis 2 tidal A | Habitat diversity | 1.98 | 0.20% | 6 | 152 |
| Muddy R 1 | Food Index | 7.08 | 0.18% | 5 | 157 |
| P8 | Key Habitat | 6.76 | 0.17% | 5 | 162 |
| Lewis 19 | Food Index | 0.81 | 0.14% | 4 | 166 |
| Lewis 18 | Food Index | 1.13 | 0.14% | 4 | 169 |
| Lewis 7 B | Habitat diversity | 5.20 | 0.10% | 3 | 172 |
| Pine Creek 4 | Sediment load | 1.61 | 0.10% | 3 | 175 |
| P7 | Key Habitat | 1.77 | 0.10% | 3 | 177 |
| Pine Creek 4 | Key Habitat | 1.61 | 0.09% | 3 | 180 |
| Lewis 27 | Sediment load | 0.32 | 0.09% | 2 | 182 |
| Range Creek | Key Habitat | 1.06 | 0.09% | 2 | 185 |
| Pine Creek 5 | Key Habitat | 1.61 | 0.09% | 2 | 187 |
| Spencer Creek | Key Habitat | 0.96 | 0.08% | 2 | 189 |
| S10 | Sediment load | 0.64 | 0.07% | 2 | 191 |
| Lewis 25 | Sediment load | 0.48 | 0.07% | 2 | 193 |
| Clear Creek Small Tribs | Sediment load | 3.17 | 0.06% | 2 | 195 |
| Lewis 7 A | Harvest | 0.93 | 0.06% | 2 | 196 |
| Lewis 6 | Harvest | 0.64 | 0.06% | 2 | 198 |
| Clearwater Tribs | Sediment load | 1.29 | 0.06% | 2 | 199 |
| Crab Creek | Key Habitat | 0.81 | 0.05% | 1 | 201 |
| Drift Creek | Key Habitat | 2.57 | 0.05% | 1 | 202 |
| P10 | Key Habitat | 0.48 | 0.04% | 1 | 203 |
| Lewis 24 | Width | 0.64 | 0.03% | 1 | 204 |
| P1 | Sediment load | 1.45 | 0.03% | 1 | 205 |
| P10 | Sediment load | 0.48 | 0.03% | 1 | 206 |
| Lewis 22 | Food Index | 1.77 | 0.03% | 1 | 207 |
| Bean Creek | Sediment load | 1.13 | 0.03% | 1 | 208 |
| Little Creek | Habitat diversity | 1.13 | 0.02% | 1 | 208 |
| Curly Creek | Sediment load | 0.81 | 0.02% | 1 | 209 |
| Cussed Hollow | Key Habitat | 1.13 | 0.02% | 0.49 | 209 |
| Mid Big Creek | Sediment load | 0.48 | 0.01% | 0.34 | 210 |
| B1 | Food Index | 0.81 | 0.01% | 0.31 | 210 |
| Chickoon Creek | Key Habitat | 0.81 | 0.01% | 0.28 | 210 |
| Total Adults | | | | 210 | |

## WATERSHED RESTORATION ANALYSIS

The data in Tables 3-14 to 3-16 show the change in adult diversity, productivity, capacity and adult abundance with all stream habitat restored to historic conditions in each watershed associated with the Swift geographic area. Note that in this analysis stream habitat outside of the restoration area remains at current conditions as modeled in Scenario 1.

Analysis results indicate that fully restoring habitat in Clear Creek, Pine Creek, Muddy River, Clearwater Creek, Rush Creek, Smith Creek, Clearwater Creek and the Lewis Mainstem above Swift produce the most adults of all three species. Restoring a combination of these streams may produce the same or more adult spring Chinook (1,697), coho (4,747) and steelhead (739) than EDT estimates for tributaries associated with Merwin and Yale with the establishment of fish passage. Population productivity, capacity and life history diversity also increases at varying levels for the majority of the watersheds (Tables 3-14, 3-15 3-16).

*Table 3-14. Percent change in adult steelhead diversity, productivity, capacity and number of adults produced with full restoration of each watershed/stream in the Swift geographic area.*

| Watershed/Stream | Kilometers of Stream | % Change in Diversity | % Change in Productivity | % Change in Capacity | # of Adults Produced |
|---|---|---|---|---|---|
| Pine Creek | 24.9 | 2.3% | 22.4% | 8.1% | 264 |
| Muddy River | 22.2 | 3.0% | 20.5% | 6.0% | 202 |
| Lewis Mainstem above Swift | 22.7 | 1.0% | 12.7% | 2.1% | 83 |
| Clear Creek | 23.0 | 0.2% | 7.1% | 0.8% | 37 |
| Rush Creek | 4.0 | 0.1% | 1.3% | 1.2% | 35 |
| Swift Campground Creek | 1.9 | 1.3% | 0.0% | 1.2% | 32 |
| Clearwater Creek | 9.7 | 0.3% | 7.1% | 0.5% | 29 |
| S15 | 2.1 | 0.0% | 0.0% | 0.6% | 17 |
| Smith Creek | 32.4 | 0.3% | 2.4% | 0.4% | 16 |
| Drift Creek | 2.6 | 0.2% | 0.3% | 0.2% | 5 |
| Pepper Creek | 0.6 | 0.0% | 0.0% | 0.2% | 5 |
| Range Creek | 1.1 | 0.0% | 0.1% | 0.1% | 4 |
| Spencer Creek | 1.0 | 0.0% | 0.1% | 0.1% | 2 |
| Little Creek | 2.6 | 0.1% | 0.3% | 0.0% | 2 |
| Crab Creek | 0.8 | 0.0% | 0.2% | 0.0% | 2 |
| S10 | 0.6 | 0.1% | 0.3% | 0.0% | 2 |
| Cussed Hollow | 1.1 | 0.0% | 0.2% | 0.0% | 1 |
| Bean Creek | 1.1 | 0.0% | 0.5% | 0.0% | 1 |
| Ape Canyon Creek | 1.6 | 0.0% | 0.2% | 0.0% | 1 |
| Curly Creek | 0.8 | 0.0% | 0.1% | 0.0% | 1 |
| Chickoon Creek | 0.8 | 0.0% | 0.0% | 0.0% | 0 |
| Mid Big Creek | 0.5 | 0.0% | 0.1% | 0.0% | 0 |
| Diamond Creek | 0.2 | 0.0% | 0.0% | 0.0% | 0 |
| Total Adults | | | | | 739 |

*Table 3-15. Resulting percent change in adult coho diversity, productivity, capacity, and number of adults produced with full restoration of each watershed/stream in the Swift geographic area.*

| **Watershed/Stream** | **Kilometers of Stream** | **% Change in Diversity** | **% Change in Productivity** | **% Change in Capacity** | **# of Adults Produced** |
|---|---|---|---|---|---|
| Muddy River | 22.2 | 2.82% | 15.59% | 8.61% | 1,284 |
| Clear Creek | 23.0 | 0.00% | 24.15% | 5.77% | 1,090 |
| Pine Creek | 24.9 | 6.92% | 0.46% | 4.35% | 500 |
| Smith Creek | 32.4 | 0.28% | 10.81% | 2.18% | 459 |
| Lewis Mainstem above Swift | 22.7 | 2.76% | 5.24% | 3.04% | 452 |
| Clearwater Creek | 9.7 | 0.00% | 8.94% | 1.12% | 304 |
| Rush Creek | 4.0 | 0.13% | 0.01% | 2.01% | 226 |
| Swift Campground Creek | 1.9 | 1.44% | 0.28% | 1.77% | 205 |
| S15 | 2.1 | 0.00% | -0.06% | 1.64% | 183 |
| Crab Creek | 0.8 | 0.06% | 0.05% | 0.16% | 19 |
| Curly Creek | 0.8 | 0.00% | 0.16% | 0.08% | 12 |
| Bean Creek | 1.1 | 0.10% | 0.10% | 0.00% | 8 |
| S10 | 0.6 | 0.06% | 0.06% | 0.03% | 4 |
| Ape Canyon Creek | 1.6 | 0.44% | 0.02% | -0.01% | 0 |
| Total Adults | | | | | 4,747 |

*Table 3-16. Resulting percent change in adult spring Chinook diversity, productivity, capacity, and number of adults produced with full restoration of each watershed/stream in the Swift geographic area.*

| Watershed/Stream | Kilometers of Stream | % Change in Diversity | % Change in Productivity | % Change in Capacity | # of Adults Produced |
|---|---|---|---|---|---|
| Muddy River | 22.2 | 20.96% | -2.26% | 12.34% | 405 |
| Lewis Mainstem above Swift | 22.7 | 0.83% | 14.20% | 5.83% | 342 |
| Pine Creek | 24.9 | 5.32% | 3.37% | 7.25% | 285 |
| Clear Creek | 23.0 | 0.00% | 8.41% | 4.53% | 239 |
| Smith Creek | 32.4 | 21.86% | 2.03% | 3.42% | 138 |
| Clearwater Creek | 9.7 | 4.07% | 5.31% | 1.74% | 111 |
| S15 | 2.1 | 0.16% | 0.39% | 1.91% | 70 |
| Swift Campground Creek | 1.9 | 2.02% | 0.16% | 1.83% | 65 |
| Little Creek | 2.6 | 0.00% | 0.48% | 0.21% | 12 |
| Curly Creek | 0.8 | 0.03% | 0.66% | 0.15% | 11 |
| S10 | 0.6 | 0.38% | 0.05% | 0.22% | 8 |
| Crab Creek | 0.8 | 0.22% | 0.11% | 0.20% | 8 |
| Ape Canyon Creek | 1.6 | 1.38% | -0.09% | 0.07% | 2 |
| Total Adults | | | | | 1,697 |

# **4.0** REFERENCES

Agrawal, A., R.S. Schick, E.P. Bjorkstedt, R.G. Szerlong, M.N. Goslin, B.C. Spence, T.H. Williams, and K.M. Burnett. 2005. Predicting the potential for historical coho, Chinook and steelhead habitat in Northern California. NOAA Technical Memo NMFS-SWFSC-379.

Beverton, R. J. H. and S. J. Holt. 1957. On the Dynamics of Exploited Fish Populations. Chapman & Hall, London.

Burnett, K., G. Reeves, D. Miller, S. Clarke, K. Vance-Borland, K. Christianson. 2007. Distribution of Salmon-Habitat Potential Relative to Landscape Characteristics and Implications for Conservation. Ecological Applications. 17(1), 2007, pp. 66-80.

Busch D, M. Sheer, K. Burnett, P. McElhaney, T. Cooney. 2011. Landscape-Level Model to Predict Spawning Habitat for Lower Columbia River Fall Chinook Salmon (Oncorhynchus Tshawytscha)

Cooney, Tom and D. Holzer. 2006. Appendix C: Interior Columbia River Basin Stream Type Chinook Salmon and Steelhead Populations: Habitat Intrinsic Potential Analysis.

Beverton, R. J. H. and S. J. Holt. 1957. On the Dynamics of Exploited Fish Populations. Chapman & Hall, London.

Lestelle, L. 2007. Coho Salmon (*Oncorhynchus kisutch*) Life History Patterns in the Pacific Northwest and California.

Lichatowich, J. A. and L. E. Mobrand. 1995. Analysis of Chinook salmon in the Columbia River from an ecosystem perspective. Project number 92-18; Contract No. DE-AM79-92BP25105. Final Report. Bonneville Power Administration, Portland, Oregon.

McElhany P., T. Backman, C. Busack, S. Heppel, S. Kolmes, A. Maule, J. Myers, D. Rawding, D. Shively, A. Steel, C. Steward and T. Whitesel. 2003. Interim Report on Viability Criteria for Willamette and Lower Columbia Basin Pacific Salmonids. Willamette/Lower Columbia Technical Recovery Team.

PacifiCorp 2004. AQU 4- Assessment of Potential Anadromous Fish Habitat Upstream of Merwin Dam.

Parken C. K., R.E. McNicol and J.R. Irvine. 2006. Habitat-based Methods to Estimate Escapement Goals for Data Limited Chinook Salmon Stocks in British Columbia, 2004.

# Appendix A
# EDT Spawning Reaches

# Appendix A
# EDT Spawning Reaches for Spring Chinook, Coho and Steelhead

The EDT model requires the user to identify spawning reaches for each species (coho, spring Chinook and steelhead). For this analysis spawning reaches were based on professional opinion using such factors such as stream order, gradient, streamflow, expected stream depth, location of barriers and life history characteristics of the species. Professional opinion was used because there are no natural populations of coho, steelhead or spring Chinook present within the analysis area (Merwin, Yale and Swift) from which to observe natural spawning over multiple years.

The stream habitat data used in assigning spawning reaches was obtained from the 2014/2015 USGS Habitat Surveys and from the April 2004 AQU-4 report produced during relicensing (PacifiCorp 2004)[5]. A summary of key habitat parameters by stream is presented in Table A1 and Table A2.

A brief description of the rationale used to assign spawning reaches is presented below for each of the three analysis species. It should be noted that because of hatchery operations, the lower end of Speelyai Creek (reach 1) was not included as a spawning reach for any of the three species. This reach is reserved for hatchery operations.

<u>Spring Chinook</u>

Spring Chinook enter the Lewis River from late March through May. This race of Chinook seeks out deep, large and relatively cold water pools and glides to hold in until they spawn in the late summer and early fall (August and September) in low gradient streams (PacifiCorp 2004). Busch et al. (2011) concluded that Chinook generally did not use streams with gradients greater than 7 percent or minimum widths less than 3.7 meters (~12 ft.) for spawning and juvenile rearing[6]. These values are similar to those developed by Cooney and Holzer (2006) for Columbia River spring Chinook. Parken et al. (2006) provided data showing that Chinook are generally limited to 3rd order or larger streams as long as there are no downstream migration barriers preventing fish access. Agrawal et al. (2005) concluded that streams with mean annual discharge of greater than ~10 cfs provided the best habitat for spring Chinook. Based on these criteria spring Chinook spawning reaches used in the analysis are shown in Table A3 and Table A4.

[5] Note that the appendix to the AQU- 4 report has photos and a summary of habitat conditions in each stream surveyed.

[6] The low flow period in the Lewis River corresponds with spawn-timing of spring Chinook.

Table A1. Habitat parameters for Merwin and Yale tributaries.

| Reach Name | Stream Order | Length of Accessible Stream Channel (ft) | Average Gradient | Maximum or Bank full Width (ft) | Minimum Width (ft) | Estimated Streamflow (cfs) |
|---|---|---|---|---|---|---|
| **Merwin** | | | | | | |
| **Marble Creek** | 2nd | 40 | 22.50% | 15.2 | 8.2 | 1 |
| Cape Horn Creek | 2nd | 1,585 | 6.50% | 33.2 | 18 | 5 |
| Jim Creek | 2nd | 3,166 | 4.50% | 40.4 | 11.7 | 4 |
| Indian George Creek | 2nd | 4,921 | 5.80% | 31 | 16.9 | 2 |
| Buncombe Hollow Creek | 2nd | 4,222 | 3.35% | 15.6 | 9.6 | 1.5 |
| **M4** | 1st | 3,900 | 10.10% | 11.5 | | 0.5 |
| Rock Creek | 3rd | 320 | 6.10% | 47.5 | 37 | 20 |
| Brooks Creek | 2nd | 11,072 | 4.87% | 23.4 | 6.8 | 8 |
| B1 | 2nd | 2,650 | 7.00% | 23.4 | 13.8 | 5 |
| M14 | 2nd | 6,335 | 2.50% | 35.7 | 12 | 0.2 |
| Canyon Creek | 3rd | 0 | 1.70% | | | |
| Total Merwin (ft) | | 38,211 | | | | |
| Total Merwin (mile) | | 7.2 | | | | |
| **Yale** | | | | | | |
| Siouxon Creek | 4th | 29,564 | 2.95% | 89.8 | 45.1 | 150 |
| Speelyai Creek | 3rd | 24,144 | 5.90% | 56.6 | 21 | 4 |
| Y8 | 2nd | 1,260 | 15.60% | 23.4 | 5.7 | 0.5 |
| Dog Creek | 2nd | 7,392 | 4.30% | 32.4 | 25.7 | 0-1.0 |
| Cougar Creek | 3rd | 17,194 | 1.60% | 52.8 | 25.7 | 75 |
| Panamaker Creek | 2nd | 1,584 | 5.80% | 92.8 | 5 | 0.5 |
| North Fork Lewis River (Lewis 12) | Bypass Reach | 14,252 | 0.71% | 167.2 | 44.6 | |
| Ole Creek | 3rd | 4,222 | 1.87% | 54.8 | 18.3 | 0-1.0 |
| Rain Creek | 2nd | 4,698 | 0.50% | 29 | 0 | 0 |
| Total Yale (ft) | | 104,310 | | | | |
| Total Yale (mile) | | 19.8 | | | | |

Table A2. Habitat parameters for Swift tributaries

| Reach Name | Stream Order | Length of Accessible Stream Channel (ft) | Average Gradient | Maximum or Bank full Width (ft) | Minimum Width (ft) | Estimated Streamflow (cfs) |
|---|---|---|---|---|---|---|
| Swift | | | | | | |
| Lewis Mainstem above Swift | 5th | 74,439 | 0.66% | 210.5 | 87.6 | 500 |
| Swift Creek | 4th | 1,585 | 8.40% | 33.0 | 29.8 | 128 |
| Diamond Creek | 2nd | 528 | 10% | 28.5 | 5.6 | 0.5 |
| Range Creek | 2nd | 3,484 | 8.90% | 44.9 | 18.9 | 3.5 |
| Camp Creek | 2nd | 1,319 | 0% | 0.0 | 0.0 | |
| Drift Creek | 2nd | 8,445 | 11.20% | 48.1 | 26.7 | 24.6 |
| S10 | 2nd | 2,113 | 6.70% | 24.7 | 5.3 | 0.5 |
| S15 | 2nd | 6,864 | 6.70% | 33.2 | 15.0 | 4 |
| Swift Campground Creek | 2nd | 6,335 | 0.10% | 20.0 | 5.0 | |
| Pine Creek | 3rd | 80,243 | 3.62% | 46.9 | 5.9 | 127.8 |
| Muddy River | 5th | 72,854 | 4.39% | 147.0 | 24.0 | 263.9 |
| Clear Creek | 3rd | 75,328 | 0.89% | 142.1 | 5.0 | 54.6 |
| Clearwater Creek | 4th | 31,673 | 0.76% | 155.7 | 5.0 | 25 |
| Bean Creek | 3rd | 3,694 | 7% | 28.5 | 18.6 | |
| Smith Creek | 4th | 106,263 | 1.28% | 31.5 | 5.0 | 20.2 |
| Ape Canyon Creek | 2nd | 5,279 | 6% | 9.1 | 8.3 | |
| Curly Creek | 1st | 2,641 | 1% | 25.3 | 23.0 | |
| U8 | 2nd | 1,585 | 13% | 15.7 | 2.7 | 0.2 |
| Rush Creek | 4th | 13,199 | 8% | 54.3 | 25.9 | 100 |
| Little Creek | 3rd | 3,694 | 1% | 22.9 | 21.0 | 20.3 |
| Mid Big Creek | 2nd | 1,585 | 15% | 45.0 | 23.0 | |
| Spencer Creek | 2nd | 3,166 | 7.70% | 91.0 | 32.3 | 0.2 |
| Cussed Hollow | 2nd | 3,694 | 8% | 47.6 | 26.6 | 9.2 |
| Crab Creek | 2nd | 2,641 | 1% | 15.4 | 14.0 | |
| Chickoon Creek | 3rd | 0 | 1% | 0.0 | 0.0 | 6.8 |
| Pepper Creek | 2nd | 2,113 | 7.0% | 33.8 | 12.3 | 2,113 |
| Total Swift (ft) | | 512,651 | | | | |
| Total Swift (mile) | | 97.1 | | | | |



Table A3. Spring Chinook spawning streams for Merwin and Yale

| Reach Name | Stream Order | Length of Accessible Stream Channel (ft) | Average Gradient | Maximum or Bank full Width (ft) | Minimum Width (ft) | Estimated Streamflow (cfs) |
|---|---|---|---|---|---|---|
| **Merwin** | | | | | | |
| No Chinook | | | | | | |
| **Yale** | | | | | | |
| Siouxon Creek | 4th | 29,564 | 2.95% | 89.8 | 45.1 | 150 |
| Cougar Creek | 3rd | 17,194 | 1.60% | 52.8 | 25.7 | 75 |
| North Fork Lewis River (Lewis 12) | Bypass Reach | 14,252 | 0.71% | 167.2 | 44.6 | |
| Total Yale (ft) | | 61,010 | | | | |
| Total Yale (mile) | | 11.6 | | | | |

Table A4. Spring Chinook spawning streams for Swift

| Reach Name | Stream Order | Length of Accessible Stream Channel (ft) | Average Gradient | Maximum or Bank full Width (ft) | Minimum Width (ft) | Estimated Streamflow (cfs) |
|---|---|---|---|---|---|---|
| **Swift** | | | | | | |
| Ape Canyon Creek | 2nd | 5,279 | 6.0% | 9.1 | 8.3 | |
| Clear Creek | 3rd | 75,328 | 0.9% | 142.1 | 5 | 54.6 |
| Clearwater Creek | 4th | 31,673 | 0.8% | 155.7 | 5 | 25 |
| Crab Creek | 3rd | 2,641 | 1.0% | 15.4 | 14 | |
| Curly Creek | 3rd | 2,641 | 1.0% | 25.3 | 23 | |
| Lewis Mainstem above Swift | 5th | 74,439 | 0.7% | 210.5 | 87.6 | 500 |
| Little Creek | 3rd | 3,694 | 1.0% | 22.9 | 21 | 20.3 |
| Muddy River | 5th | 72,854 | 4.4% | 147 | 24 | 263.9 |
| Pine Creek | 3rd | 80,243 | 3.6% | 46.9 | 5.9 | 127.8 |
| S10 | 2nd | 2,113 | 6.7% | 24.7 | 5.3 | 0.5 |
| S15 | 2nd | 6,864 | 6.7% | 33.2 | 15 | 4 |
| Smith Creek | 4th | 106,263 | 1.3% | 31.5 | 5 | 20.2 |
| Swift Campground Creek | | 6,335 | 0.1% | 20 | 5 | |
| Total Swift (ft) | | 470,367 | | | | |
| Total Swift (mile) | | 89.1 | | | | |

Late Winter Steelhead

Late winter steelhead enter the Lewis River starting in late December or early January. Spawning takes place from March through late June (PacifiCorp 2004). Cooney and Holzer (2006) concluded that streams with a gradient ranging from 4-7 percent had the highest intrinsic potential to produce steelhead. They also noted that streams with gradients ranging from 7-15 percent had low intrinsic potential. The authors based their analysis on data presented in McElhany et al. (2003). McElhany et al. (2003) concluded that possible steelhead spawning and rearing occurred in streams with gradients 0.5-6 percent and 1.5-7 percent, respectively. The Cooney and Holzer (2006) analysis indicated that streams with a bankfull width less than 3.8 meters (12.5 ft.) had little potential to produce steelhead[7]. The authors' note that the Washington Department of Fish and Wildlife (WDFW) recommends that a 2 meter (6.6 ft.) wetted width be set as the lower boundary for steelhead production. Based on this information late winter spawning reaches used in the EDT analysis are shown in Table A5 and Table A6.

Table A5. Late winter steelhead spawning reaches Merwin and Yale

| **Reach Name** | **Stream Order** | **Length of Accessible Stream Channel (ft)** | **Average Gradient** | **Maximum or Bank full Width (ft)** | **Minimum Width (ft)** | **Estimated Streamflow (cfs)** |
|---|---|---|---|---|---|---|
| **Merwin** | | | | | | |
| Cape Horn Creek | 2nd | 1,585 | 6.50% | 33.2 | 18 | 5 |
| Jim Creek | 2nd | 3,166 | 4.50% | 40.4 | 11.7 | 4 |
| Indian George Creek | 2nd | 4,921 | 5.80% | 31 | 16.9 | 2 |
| Buncombe Hollow Creek | 2nd | 4,222 | 3.35% | 15.6 | 9.6 | 1.5 |
| Brooks Creek | 2nd | 11,072 | 4.87% | 23.4 | 6.8 | 8 |
| M14 | 2nd | 6,335 | 2.50% | 35.7 | 12 | 0.2 |
| Total Merwin (ft) | | 31,301 | | | | |
| Total Merwin (mile) | | 5.93 | | | | |
| **Yale** | | | | | | |
| Siouxon Creek | 4th | 29,564 | 2.95% | 89.8 | 45.1 | 150 |
| Speelyai Creek | 3rd | 24,144 | 5.90% | 56.6 | 21 | 4 |
| Dog Creek | 2nd | 7,392 | 4.30% | 32.4 | 25.7 | 0-1.0 |
| Cougar Creek | 3rd | 17,194 | 1.60% | 52.8 | 25.7 | 75 |
| Panamaker Creek | 2nd | 1,584 | 5.80% | 92.8 | 5 | 0.5 |
| North Fork Lewis River (Lewis 12) | Bypass Reach | 14,252 | 0.71% | 167.2 | 44.6 | |
| Ole Creek | 3rd | 4,222 | 1.87% | 54.8 | 18.3 | 0-1.0 |
| Rain Creek | 2nd | 4,698 | 0.50% | 29 | 0 | 0 |
| Total Yale (ft) | | 103,050 | | | | |
| Total Yale (mile) | | 19.5 | | | | |

[7] The authors noted that steelhead spawn in the late spring on the end of the freshet, and therefore bankfull width is a more appropriate measure than minimum width.

Table A6. Late winter steelhead spawning reaches - Swift

| Reach Name | Stream Order | Length of Accessible Stream Channel (ft) | Average Gradient | Maximum or Bank full Width (ft) | Minimum Width (ft) | Estimated Streamflow (cfs) |
|---|---|---|---|---|---|---|
| **Swift** | | | | | | |
| Ape Canyon Creek | 2nd | 5,279 | 6% | 9.1 | 8.3 | |
| Bean Creek | 3rd | 3,694 | 7% | 28.5 | 18.6 | |
| Chickoon Creek | 3rd | 0 | 1.0% | 0.0 | 0.0 | 6.8 |
| Clear Creek | 3rd | 75,328 | 0.89% | 142.1 | 5 | 54.6 |
| Clearwater Creek | 4th | 31,673 | 0.76% | 155.7 | 5 | 25 |
| Crab Creek | 2nd | 2,641 | 1.0% | 15.4 | 14.0 | |
| Curly Creek | 1st | 2,641 | 1.0% | 25.3 | 23.0 | |
| Cussed Hollow | 2nd | 3,694 | 8.0% | 47.6 | 26.6 | 9.2 |
| Diamond | 2nd | 528 | 10.0% | 28.5 | 5.6 | 0.5 |
| Drift Creek | 2nd | 8,445 | 11.2% | 48.1 | 26.7 | 24.6 |
| Lewis Mainstem above Swift | 5th | 74,439 | 0.66% | 210.5 | 87.6 | 500 |
| Little Creek | 3rd | 3,694 | 1.0% | 22.9 | 21.0 | 20.3 |
| Muddy River | 5th | 72,854 | 4.39% | 147 | 24 | 263.9 |
| Pepper Creek | 2nd | 2,113 | 7.0% | 33.8 | 12.3 | |
| Pine Creek | 3rd | 80,243 | 3.62% | 46.9 | 5.9 | 127.8 |
| Range Creek | 2nd | 3,484 | 8.9% | 44.9 | 18.9 | 3.5 |
| Rush Creek | 4th | 13,199 | 8% | 54.3 | 25.9 | 100 |
| S10 | 2nd | 2,113 | 7% | 24.7 | 5.3 | 0.5 |
| S15 | 2nd | 6,864 | 7% | 33.2 | 15.0 | 4 |
| Smith Creek | 4th | 106,263 | 1.28% | 31.5 | 5 | 20.2 |
| Spencer Creek | 2nd | 3,166 | 7.7% | 91.0 | 32.3 | 0.2 |
| Swift Campground Creek | 2nd | 6,335 | 0.1% | 20.0 | 5.0 | |
| Total Swift (ft) | | 508,691 | | | | |
| Total Swift (mile) | | 96.3 | | | | |

Coho

Type-S and Type-N coho enter the Lewis River from mid-September to late November and spawn from mid-October through late December (PacifiCorp 2004). Burnett et al. (2007) assumed that coho do not generally use streams with gradients greater than 7 percent. Lestelle (2007) stated that coho salmon primarily spawn in small low gradient streams or in side channels in larger rivers. Agrawal et al. (2005) reported that streams having a relatively large valley width to stream width ratio, gradient less than 7 percent, and mean annual flows less than 20 cfs had the highest coho production potential. Based on this information coho spawning reaches used in the analysis are shown in Table A7 and Table A8.

Table A7. Coho spawning reaches for Merwin and Yale

| Reach Name | Stream Order | Length of Accessible Stream Channel (ft) | Average Gradient | Maximum or Bank full Width (ft) | Minimum Width (ft) | Estimated Streamflow (cfs) |
|---|---|---|---|---|---|---|
| **Merwin** | | | | | | |
| Cape Horn Creek | 2nd | 1,585 | 6.50% | 33.2 | 18 | 5 |
| Jim Creek | 2nd | 3,166 | 4.50% | 40.4 | 11.7 | 4 |
| Indian George Creek | 2nd | 4,921 | 5.80% | 31 | 16.9 | 2 |
| Buncombe Hollow Creek | 2nd | 4,222 | 3.35% | 15.6 | 9.6 | 1.5 |
| Rock Creek | 3rd | 320 | 6.10% | 47.5 | 37 | 20 |
| Brooks Creek | 2nd | 11,072 | 4.87% | 23.4 | 6.8 | 8 |
| M14 | 2nd | 6,335 | 2.50% | 35.7 | 12 | 0.2 |
| Total Merwin (ft) | | 31,621 | | | | |
| Total Merwin (mile) | | 5.99 | | | | |
| **Yale** | | | | | | |
| Siouxon Creek | 4th | 29,564 | 2.95% | 89.8 | 45.1 | 150 |
| Speelyai Creek | 3rd | 24,144 | 5.90% | 56.6 | 21 | 4 |
| Dog Creek | 2nd | 7,392 | 4.30% | 32.4 | 25.7 | 0-1.0 |
| Cougar Creek | 3rd | 17,194 | 1.60% | 52.8 | 25.7 | 75 |
| Panamaker Creek | 2nd | 1,584 | 5.80% | 92.8 | 5 | 0.5 |
| North Fork Lewis River (Lewis 12) | Bypass Reach | 14,252 | 0.71% | 167.2 | 44.6 | |
| Ole Creek | 3rd | 4,222 | 1.87% | 54.8 | 18.3 | 0-1.0 |
| Rain Creek | 2nd | 4,698 | 0.50% | 29 | 0 | 0 |
| Total Yale (ft) | | 97,312 | | | | |
| Total Yale (mile) | | 18.4 | | | | |

Table A8. Coho spawning reaches for Swift

| Reach Name | Stream Order | Length of Accessible Stream Channel (ft) | Average Gradient | Maximum or Bank full Width (ft) | Minimum Width (ft) | Estimated Streamflow (cfs) |
|---|---|---|---|---|---|---|
| **Swift** | | | | | | |
| Ape Canyon Creek | 2nd | 5,279 | 6.0% | 9.1 | 8.3 | |
| Bean Creek | 3rd | 3,694 | 7.0% | 28.5 | 18.6 | |
| Chickoon Creek | 3rd | 0 | 1.0% | 0.0 | 0.0 | 6.8 |
| Clear Creek | 3rd | 75,328 | 0.9% | 142.1 | 5 | 54.6 |
| Clearwater Creek | 4th | 31,673 | 0.8% | 155.7 | 5 | 25 |
| Crab Creek | 2nd | 2,641 | 1.0% | 15.4 | 14.0 | |
| Curley Creek | 1st | 2,641 | 1.0% | 25.3 | 23.0 | |
| Lewis Mainstem above Swift | 5th | 74,439 | 0.7% | 210.5 | 87.6 | 500 |
| Little Creek | 3rd | 3,694 | 1.0% | 22.9 | 21.0 | 20.3 |
| Muddy River | 5th | 72,854 | 4.4% | 147 | 24 | 263.9 |
| Pepper Creek | 2nd | 2,113 | 7.0% | 33.8 | 12.3 | |
| Pine Creek | 3rd | 80,243 | 3.62% | 46.9 | 5.9 | 127.8 |
| S10 | 2nd | 2,113 | 6.7% | 24.7 | 5.3 | 0.5 |
| S15 | 2nd | 6,864 | 6.7% | 33.2 | 15.0 | 4 |
| Smith Creek | 4th | 106,263 | 1.28% | 31.5 | 5 | 20.2 |
| Swift Campground Creek | 2nd | 6,335 | 0.1% | 20.0 | 5.0 | |
| Total Swift (ft) | | 476,174 | | | | |
| Total Swift (mile) | | 90.2 | | | | |

## References

Agrawal, A., R.S. Schick, E.P. Bjorkstedt, R.G. Szerlong, M.N. Goslin, B.C. Spence, T.H. Williams, and K.M. Burnett. 2005. Predicting the potential for historical coho, Chinook and steelhead habitat in Northern California. NOAA Technical Memo NMFS-SWFSC-379.

Burnett, K., G. Reeves, D. Miller, S. Clarke, K. Vance-Borland, K. Christianson. 2007. Distribution of Salmon-Habitat Potential Relative to Landscape Characteristics and Implications for Conservation. Ecological Applications. 17(1), 2007, pp. 66-80.

Cooney, Tom and D. Holzer. 2006. Appendix C: Interior Columbia River Basin Stream Type Chinook Salmon and Steelhead Populations: Habitat Intrinsic Potential Analysis.

Lestelle, L. 2007. Coho Salmon (*Oncorhynchus kisutch*) Life History Patterns in the Pacific Northwest and California.

PacifiCorp 2004. AQU 4- Assessment of Potential Anadromous Fish Habitat Upstream of Merwin Dam.

Parken C. K., R.E. McNicol and J.R. Irvine. 2006. Habitat-based Methods to Estimate Escapement Goals for Data Limited Chinook Salmon Stocks in British Columbia, 2004.

# Appendix B- Spring Chinook Juvenile Life History Analysis

Information on the likely juvenile life history exhibited by Lewis River spring Chinook was not available for the EDT analysis. Therefore, EDT modeling results presented in the body of this report relied on juvenile data collected in the Clackamas River. The juvenile spring Chinook population in the Clackamas River system consist of a combination of smaller subyearling (70 percent) and larger yearling (30 percent) migrants. EDT estimates of spring Chinook adult abundance, productivity and capacity under the assumption of 30 percent yearlings was 3,084, 5.2 and 3,812 respectively.
To determine the effect various mixes of subyearling and yearling migrants would have on adult production estimates the EDT model was run with the yearling migrants' portion of the population set from 0-100 percent (Figure B-1). Modeling results indicated that spring Chinook adult abundance for the Swift geographic area ranged from 2,712 to 3,439 fish. Adult productivity - measured as adult recruits per spawner – ranged from 3.6 to 7.7 and capacity (~3,800) remained relatively constant.

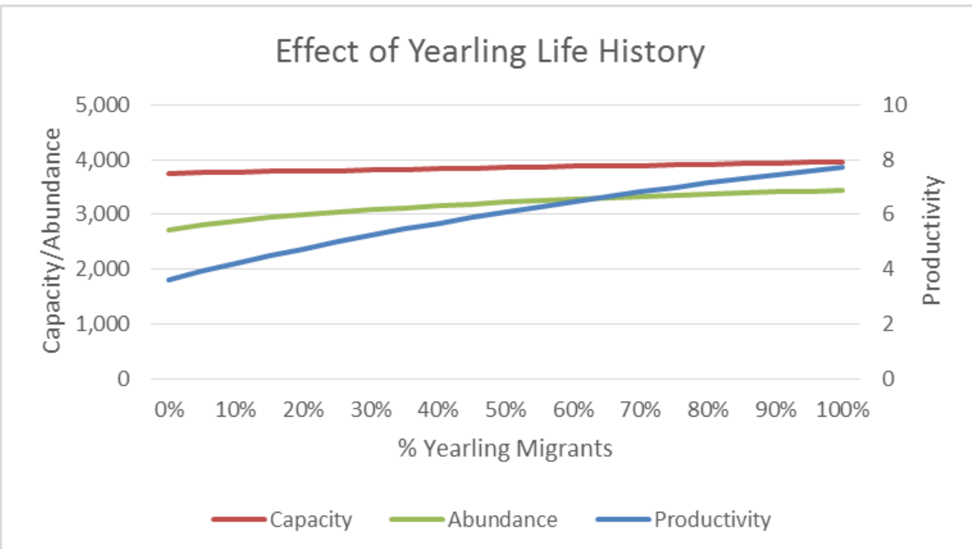
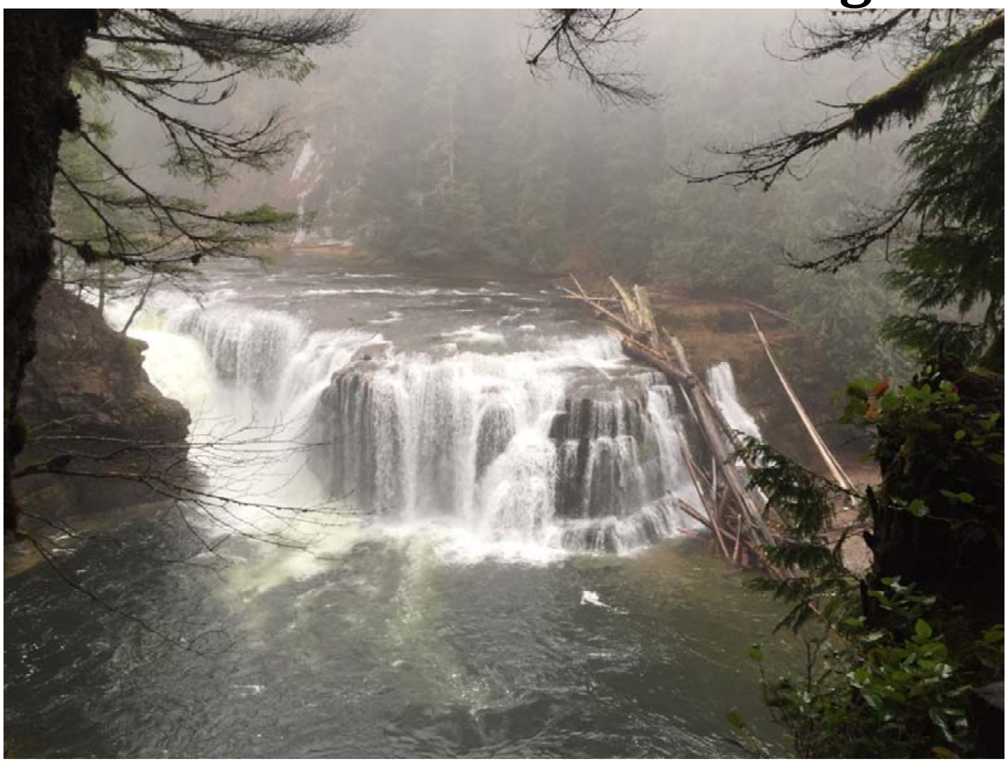



*Figure B-1. EDT estimated spring Chinook adult abundance, productivity and capacity for various percentages of yearling migrants.*

# Appendix D

# Cramer Fish Sciences – Limiting Factors and Identification of Restoration Alternatives to Fish Passage

# Lewis River Project – Limiting Factors and Identification of Restoration Alternatives to Fish Passage



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**June 24, 2016**

## 4.1 Introduction

This report has been prepared by Cramer Fish Sciences for PacifiCorp and the Public Utility District No. 1 of Cowlitz County, Washington ("Cowlitz PUD") to inform the National Marine Fisheries Service and the U.S. Fish and Wildlife Service (collectively the "Services"), Federal Energy Regulatory Commission (FERC) and the Lewis River Settlement Agreement Parties in consideration of article 4.1.9 Review of New Information Regarding Fish Transport into Lake Merwin and Yale Lake and 7.6 In Lieu Fund of the Lewis River Settlement Agreement.

## 4.2 Background

Located on the North Fork of the Lewis River in southwestern Washington, the Lewis River Hydroelectric System consists of four operationally coordinated projects. PacifiCorp owns Swift No. 1 (FERC No. 2111), Yale (FERC No. 2071), and Merwin (FERC No. 935) projects which together generate 536 MW of electricity at full capacity. Cowlitz PUD owns the 82 MW Swift No. 2 Project (FERC No. 2213) which lies between the Swift No. 1 and Yale projects. Currently, PacifiCorp operates Swift No. 2 for Cowlitz PUD under contract.

On June 26, 2008, the FERC provided the utilities with new operating licenses for the Lewis River hydroelectric projects. The license periods are each 50 years starting June 1, 2008. Each license includes the respective conditions of the Services biological opinions and respective conditions of the Washington Department of Ecology 401 certificates. In general the licenses include terms of the Lewis River Settlement Agreement with few exceptions. Parties to the Lewis River Settlement Agreement continue to abide by the agreement terms including those terms outside the FERC requirements.

## 4.3 Lewis River Settlement Agreement conditions relative to reintroduction of anadromous salmonids into Yale and Merwin Reservoirs

Section 3.1 of the Lewis River Settlement Agreement identifies the anadromous fish reintroduction outcome goal as "to achieve genetically viable, self-sustaining, naturally reproducing, harvestable populations above Merwin dam greater than minimum viable populations". Within the agreement the utilities will make significant investments into a salmon and steelhead reintroduction program. These include a suite of anadromous fish protection and restoration measures and actions implemented over a phased approach. To date, facilities include the Merwin Upstream Fish Collector, three upper basin juvenile fish acclimation ponds and the Swift Downstream Fish Collector. A juvenile fish release facility located in Woodland, Washington is scheduled to be constructed in 2017. Additional program phases identified in the settlement agreement and subsequent FERC licenses require the construction and operation of the following fish passage facilities:

- Downstream Passage at Yale Dam (SA article 4.5)
- Downstream Passage at Merwin Dam (SA article 4.6)
- Upstream Passage at Yale Dam (SA article 4.7)
- Upstream Passage at Swift Projects (SA article 4.8)

There is also the specific opportunity to consider an In Lieu Fund as an alternative to future fish passage facilities (Yale downstream, Merwin downstream, Yale upstream and Swift upstream). It is expressly granted in Section 4.1.9 of the Lewis River Settlement Agreement.

> *4.1.9 Review of New Information Regarding Fish Transport into Lake Merwin and Yale Lake.*
>
> *a. The Licensees shall construct and provide for the operation and maintenance of both upstream and downstream fish collection and transport facilities at each of Merwin Dam, Yale Dam, and the Swift Projects as provided in the schedule in this Agreement unless otherwise directed by the Services pursuant to this Section. New Information (defined below) relevant to reintroduction and fish passage into Yale Lake or Lake Merwin may be available to the Services that may influence the implementation of fish passage into and out of these reservoirs, or that could result in the Services determining that reintroduction or fish passage for anadromous fish is inappropriate. If the Services conclude upon review of the New Information that one or more of the passage facilities should not be constructed, in lieu of designing, permitting, constructing, and operating the passage facility, PacifiCorp shall provide additional funds for projects in lieu of fish passage, as set forth in Section 7.6. In this event, the Licensees shall also implement the bull trout passage measures as set forth in Section 4.10. The adult upstream fish passage facility at Merwin and juvenile downstream collector at Swift No. 1 are not subject to this review.*
>
> *b. Upon receipt and review of New Information relevant to reintroduction and fish passage from any party, the members of the ACC may provide written comments to the Services regarding such New Information. Such comments shall be provided to the Services no later than five years prior to the date that PacifiCorp and/or Cowlitz PUD is to begin operating the relevant passage facility. If any New Information and comments are submitted to the Services, then approximately four and a half years prior to the date that PacifiCorp and/or Cowlitz PUD is to begin operating the relevant passage facility, the Licensees shall convene a meeting of the ACC for the purpose of discussing the New Information and comments. At such meeting, the Licensees shall solicit and obtain the Services' response to the New Information and related comments, unless the Services have provided the results of their review to the ACC earlier. If the Services have concluded that one or more of the passage facilities should not be constructed, then within 60 days after the meeting of the ACC, the Services shall advise the ACC in writing of such conclusion.*
>
> *c. For purposes of this section, "New Information" is defined as information relevant to anadromous fish reintroduction and fish passage, including that presented by any Party, and provided to the Services and the Licensees. The Licensees must*

*provide copies of such New Information to all the members of the ACC. This information may include, but is not limited to:*

*(1) Experience with upstream fish collection and transport facilities at other sites, including Merwin Dam.*
*(2) Experience with downstream fish collection facilities at other sites, including Swift No. 1 Dam.*
*(3) Experience with the reintroduction efforts of spring Chinook, coho, and steelhead above Swift No. 1 Dam.*
*(4) Consideration of broader contextual information beyond the Lewis River Basin, including regional anadromous fish recovery efforts.*

*d. The Licensees shall inform the Commission of any determination by the Services that one or more of the fish collection and transport facilities should not be constructed. In this event, PacifiCorp shall provide additional funds for projects in lieu of fish passage, as set forth in Section 7.6.*

As expressed in Section 4.1.9 (d) above, in the event the Services determine that reintroduction of anadromous salmonids into Yale Lake or Lake Merwin is not required (i.e., fish collection and transport facilities should not be constructed), Section 7.6 of the Lewis River Settlement Agreement would apply. In general, Section 7.6 stipulates that PacifiCorp shall establish the “In Lieu Fund” to support mitigation measures for anadromous salmonids in lieu of passage.

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16 ## 4.4 Study

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# EXECUTIVE SUMMARY

To assist PacifiCorp with providing additional information on restoration alternatives in lieu of additional fish passage in the Lewis River Basin, we reviewed existing habitat and environmental assessment data for the Lewis Basin and Lewis River coho (*Oncorhynchus kisutch*), winter steelhead (*O. mykiss*) and spring Chinook (*O. tshawytscha*). Based on this information we were able to conduct a limiting factors analysis to identify limiting habitat and life stages for Lewis River spring Chinook, coho and steelhead and to identify potential habitat restoration measures in lieu of fish passage. More than 50 relevant publications were located that provided information to assist with identifying limiting factors and with identifying restoration opportunities. These include physical habitat data for the entire basin from Ecosystem Diagnosis and Treatment (EDT) models, watershed assessment and process (e.g., sediment, hydrology, riparian conditions, and channel type) data and model outputs from NOAA Northwest Fisheries Science Center, and habitat data upstream of Merwin Dam which were recently collected by the U.S. Geological Survey. Our limiting factors analysis indicated that summer habitat is limiting the production of coho in most subbasins—except Merwin, which is limited by adequate spawning habitat. For steelhead, summer or winter rearing habitat is limiting in all of the subbasins. In contrast, spawning habitat is limiting for Chinook salmon in Yale basin and summer rearing habitat is limiting in the Swift basin. Our results for Chinook and coho salmon, are largely driven by the definition of littoral zone (<3 m deep) or suitable rearing habitat in the reservoirs; changing these depth criteria by as little as one or two meters can make spawning habitat limiting in the Merwin, Yale or Swift basins. To identify restoration opportunities we combined diverse GIS data sets from NOAA and EDT, and we applied them to areas draining into the 25 reaches identified by EDT as the highest priority for restoration in the North Fork of Lewis basin. Using outputs from this analysis and a suite of watershed process and habitat metrics, we made initial recommendations for restoration measures in each of the 25 reaches. Based on data on fish response to restoration in other basins, we also estimated potential increases in coho and steehead smolts for selected restoration actions. Finally, we provide preliminary cost estimates for potential restoration actions and recommendations on data and analysis needed to refine these actions and translate them into on–the–ground measures.

# 1. INTRODUCTION

On June 26, 2008, PacifiCorp and the Public Utility District No. 1 of Cowlitz County (Cowlitz PUD) were issued new license Orders by the Federal Energy Regulatory Commission (FERC) accepting nearly every article of the Lewis River Settlement Agreement (SA) and granting new licenses for the North Fork Lewis River Hydroelectric Projects. The FERC licenses for the Lewis River Hydroelectric projects require fish passage to be provided, over a specific schedule, at each Lewis River dam. However, it also provides for an alternative (In Lieu Fund), should the US Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) determine that fish passage into Merwin and/or Yale reservoirs is not required. The opportunity to consider an In Lieu Fund as an alternative to future fish passage facilities (Yale downstream, Merwin downstream, Yale upstream and Swift upstream) is expressly granted in section 4.1.9 (*Review of New Information Regarding Fish Transport into Lake Merwin and Yale Lake*) of the Lewis River Settlement Agreement. Several studies were initiated to determine if fish passage into Merwin and/or Yale reservoirs and associated tributaries or In Lieu restoration measures will be most beneficial. To assist with providing additional information on alternatives to fish passage, PacifiCorp contracted Cramer Fish Sciences (CFS) to:

1) Review existing data relative to the physical and biological environment of Lewis River Basin and Lewis River coho (*Oncorhynchus kisutch*), winter steelhead (*O. mykiss*) and spring Chinook (*O. tshawytscha*);

2) Identify limiting factors (life stage and habitat type) for fish populations of interest;

3) Identify potential habitat restoration measures that are feasible and practical to implement "In Lieu" of fish passage, and

4) Make recommendations on data and analysis needed to refine these potential restoration actions.

The following report summarizes our methods, findings and recommendations for these four tasks. Our effort focused on the entire North Fork of the Lewis River including the mainstem Lewis River downstream from the confluence of the East Fork.

# 2. REVIEW OF EXISTING DATA RELATIVE TO THE PHYSICAL AND BIOLOGICAL ENVIRONMENT

Prior to conducting limiting factors analysis and identification of potential restoration actions, we reviewed the existing information relative to the physical and biological environment in the Lewis River Basin and the life history of Lewis River coho, spring Chinook and winter steelhead. This included reviewing data, reports and publications provided by PacifiCorp and the Lower Columbia Fish Recovery Board, as well as web searches to locate any other documents. Below we summarize the existing information and its utility for use in limiting factors analysis and identifying potential restoration actions.

There are considerable data on the Lewis River Basin and the North Fork of Lewis River in particular. We obtained published reports and data from four primary sources: 1) PacifiCorp, 2) Lower Columbia Fish Recovery Board, 3) NOAA Northwest Fisheries Science Center, and 4) various other sources (e.g., Cramer Fish Science archives, county records, web searches). We focused on reports and data sources that would be useful in assessing watershed conditions, limiting factors, and restoration opportunities. Because there were so many data sources and reports (> 50), we combined them into major categories of data/reports and we screened them to determine what steps in the restoration process (as identified by Roni and Beechie 2013) they would assist with (Table 1). We provide an annotated bibliography of all reports and published data in Appendix A with additional details. We also provide a summary of other data sources that are not in report format including spawner surveys, smolt trapping data, data on channel types and watershed assessments done by NOAA and others. Other reports that provided useful background information were assimilated but not included in our summary or annotated bibliography.

**Table 1.** Summary of major information and data sources, coverage, and whether they provide data to assist with assessing habitat conditions, identifying limiting life-stage and habitat, identifying restoration opportunities, prioritizing reaches and restoration actions, or providing background.

| | Data type | | | Provides data to assist with | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Description of Data/Info** | **Report** | **GIS, Excel, etc.** | **Geographic Coverage** | **Assess Instream Habitat** | **Assess Watershed Process** | **Limiting life-stage or habitat** | **Rest. I.D.** | **Prioritiz-ation** | **Back-ground Info** |
| **Fish or Habitat Models** | | | | | | | | | |
| EDT outputs and source data | | X | Basin | X | | X | | X | X |
| Salmon PopCycle Model | X | X | Basin | | | | | | X |
| **Assessments** | | | | | | | | | |
| Integrated Watershed Assessment | X | X | Basin | | X | | | | X |
| Shoreline Master Plan, B.A.s, etc. | X | | NF. Lewis | | | | | | X |
| Recovery Planning reports/data | X | | Lower | | | | X | X | X |
| Watershed Assessment Models | X | X | Basin | | X | | X | | |
| LWD assessment | X | | Lower | X | | | | | |
| Channel types | | X | Basin | | X | | X | | X |
| **Monitoring Data** | | | | | | | | | |
| Habitat and LWD surveys (USGS) | | X | Upper Basin | | X | | X | | X |
| Parr, smolt, spawner etc. surveys | X | X | Various | | | | | | X |
| Other habitat survey data | X | | Various | | | | | | X |

While there is considerable data—and there have been previous fish-habitat modeling exercises, particularly prior to/during relicensing (Ecosystem Diagnosis and Treatment [EDT], Pop-cycle lifecycle model) or for subbasin/recovery planning efforts—much of these are based on similar data which are often incomplete (i.e., only cover certain reaches or tributaries) and, in some cases are only available in report format.

Three notable sources of habitat and assessment data were located that are important for identifying limiting factors, assessing watershed conditions, and, most importantly, identifying potential restoration measures. These include previous watershed assessments, habitat data recently collected by United States Geological Survey (USGS), and EDT model inputs and related data.

*Watershed Assessments* – Two basin-wide watershed assessments have been done: one by Cramer Fish Sciences for the Lower Columbia Fish Recovery Board, and another, more detailed and comprehensive, by the NOAA Northwest Fisheries Science Center. While both of these efforts are 5 to 10 years old, they provide relevant data related to riparian and sediment processes and channel conditions. The NOAA effort is very fine-scale and detailed and we were able to obtain the model outputs and much of the original data[1] in GIS and tabular format. The NOAA data are linked to both EDT reaches and Beechie channel types (Beechie and Imaki 2014). Thus it will be particularly useful for identify underlying causes of degradation at a reach and subbasin scale, and identifying appropriate restoration measures.

*Habitat data* – The habitat data collected by USGS upstream of Merwin Dam are useful for identifying limiting factors (limiting life-stages and habitat) and identifying restoration opportunities. We have the data files provided by USGS to ICF International (ICF) for surveys of tributaries above Merwin. We also obtained GIS and Excel® files of Beechie channel types (Beechie and Imaki 2014) for the entire Lewis Basin from NOAA. These should also be useful for identifying restoration measures as Beechie and Imaki (2014) provide channel types, bankfull width and depth, shear stress, and floodplain width, which will be helpful for identifying restoration measures—particularly for wood placement of floodplain restoration.

*EDT input and related data* – Summary habitat data, habitat affinity ratings and other information used in the EDT model were provided by ICF. The habitat data in the EDT model for tributaries and upstream of Merwin Dam are largely from recent USGS habitat surveys. Habitat data downstream of Merwin Dam appear to be disparate and, to date, we have not located other sources that cover more than individual tributaries. The EDT model appears to have already assimilated and incorporated these disparate data sources for the river downstream of Merwin Dam. Rather than attempt to assimilate the original data (some of which are based on maps or professional opinion), habitat summaries (e.g., area, percent pool, LWD) by reach from EDT can be used to estimate habitat quantity in different reaches and subbasins and used in our limiting factors analysis to identify limiting habitats and life stages for each species of interest. The EDT rankings of reaches should also prove useful for prioritizing reaches for restoration (Steel et al. 2009). These priorities can be linked to the NOAA assessment data to further identify habitat condition, causes of degradation, priority reaches, and likely restoration opportunities and actions. These data would help focus future field surveys to confirm and design specific restoration actions.

# 3. Limiting Factors - Identifying limiting habitat & life stage

A critical part of determining appropriate watershed restoration actions for increasing salmon populations is understanding which life-stage and habitat are limiting population size (Beechie et

[1] Rerunning the models with more recent land cover and other data would be costly, the results would be unlikely to change, and is not recommended.

al. 2003). While several different life-cycle modeling approaches have been used for salmon recovery planning (e.g., Kareiva et al. 2000; Scheurell et al. 2006), these focus on where survival is lowest but do not indicate what specific habitat types are limiting salmon production. In contrast, the limiting factors approach of Reeves et al. (1989), Beechie et al. (1994), Pollock et al. (2006) and others, which is based on habitat area and capacity, provides a straightforward approach to determining which life stage and habitat are limiting salmon at a population scale. In other words, what is the habitat "bottleneck" that is preventing the population from increasing? This is critical for restoration planning, because without this information one could possibly spend large sums of money restoring habitat or reaches which are unimportant to a particular species. For, example in the Skagit Basin, Beechie et al. (1994) showed that overwinter habitat, particularly loss of floodplain habitat, was limiting coho smolt production and restoration measures were focused on overwinter habitat. Had restoration efforts focused on increasing summer rearing or spawning habitat, coho salmon smolt production would not likely have increased despite increased summer rearing habitat.

In this task, we focused on identifying the life stage and habitat limiting coho salmon, spring Chinook salmon, and winter Steelhead using available information on habitat, habitat use, and fish densities. This will be critical for identifying restoration opportunities (Section 4).

# Methods

To estimate limiting life stage and habitat requires two main pieces of information:

1. An estimate of the amount of current summer and winter rearing habitat, and spawning habitat available for each species;

2. Habitat specific densities of juveniles and spawning adults as well as survival factors or "smolt factors" used to convert capacity for each life stage to a common currency of smolt production potential for each life stage (Reeves et al. 1989). At its simplest, smolt production potential (*SPP*) is the product of area (*A*), average fish density (*D*), and survival to the smolt life stage (*SS*) within a specific habitat type i (Equation 1).

(1) $SPP_i = A_i \times D_i \times SS_i$

Comparing SPP among subbasins or watersheds requires making independent estimates of the total fish abundance each habitat type can support (i.e., capacity). Thus, the capacity (*N*) of a habitat for each life stage (e.g., spawning, summer rearing, winter rearing) in a given subbasin is estimated in equation 2, where $A_{ij}$ is the sum of areas of all habitat units (j =1 through n) of type i, and $d_i$ is the density of fish in habitat type i (Beechie et al. 2003).

(2)

$$N_i = \sum_{j=1}^{n} A_{ij} \times D_i$$

To compare capacities among life stages and identify which habitats may be limiting smolt production, the estimated number of summer or winter parr (N) in a given habitat is multiplied by the smolt production potential (SPP). SPP is the density independent survival to smolt stage, so the capacities can be compared in terms of number of smolts ultimately produced (Reeves et al. 1989). For this analysis we define a smolt as a 1-year old (yearling) spring migrant for both coho and spring Chinook, and a 2-year old spring migrant for steelhead.

## *Current Habitat Quantity and Quality*

We first quantified the current area of summer and winter rearing habitat, and spawning habitat availability for each species based on major habitat types (mainstem, side-channels, tributaries[2], lakes/reservoirs, and ponds) (Beechie et al. 1994; Pollock et al. 2004). Tributary habitat was further divided into pools, riffles and glides. Since much of this information has already been assimilated for the most recent EDT analyses, we used reach level summaries of the proportion of each habitat type provided by ICF. Because EDT included only reaches accessible to anadromous salmonids (K. Dickman ICF, pers. comm.), we first assumed that all accessible reaches were suitable for all three species, we then excluded all those that were too steep or too small or large, as outlined in Table 2.

**Table 2.** Criteria used to select which steams and reaches had suitable habitat to support use by coho, steelhead or spring Chinook. Spring Chinook data included only tributaries upstream of Yale Dam. Since EDT provides monthly estimates of habitat area, Month represents the month in which the wetted width and habitat area were used for a particular life stage. For juvenile life stages, this was done in summer and winter.

| Species | Life stage | Month | Gradient | Wetted Width | Source |
|---|---|---|---|---|---|
| **Coho** | Juvenile | Aug. & Jan. | <3% | All | Reeves et al. 1989 |
| **Coho** | Spawning | Nov. | <3% | <25 m | Reeves et al. 1989 |
| **Steelhead** | Juvenile | Aug. & Jan. | <5% | All | Reeves et al. Unpublished |
| **Steelhead** | Spawning | April | <5% | See source | WDFW salmonscape |
| **Spring Chinook** | Juvenile | Aug. & Jan. | <5% | All | |
| | Spawning | Oct. | <3% | >10 m | |

EDT calculates habitat area on a monthly basis so we used estimates of wetted width from August and January for summer and winter juvenile rearing, respectively. For spawning habitat, we used wetted width estimates from October, November, and April for spring Chinook, coho, and winter Steelhead spawning, respectively. We then calculated wetted area of all glides, pool tails, and small cobble riffles, and applied the EDT habitat affinity factors (percent of usable habitat) to determine the total area in each reach that was suitable habitat (Table 3).

[2] Tributaries were defined as streams less than 10 m wetted width at low flow.

**Table 3**. Proportion of glides, pool tails, and small cobble riffle area that is suitable spawning habitat as determined by EDT (Lastelle 2005).

| | Habitat | Coho | Steelhead | Chinook |
|---|---|---|---|---|
| **Low flow < 3 cfs** | Glides | 0.4 | 0.3 | 0.4 |
| | Pool Tails | 0.8 | 0.6 | 0.8 |
| | Small Cobble Riffles | 0.6 | 0.45 | 0.6 |
| **Headwater** | Glides | 0.4 | 0.275 | 0.4 |
| | Pool Tails | 0.8 | 0.55 | 0.8 |
| | Small Cobble Riffles | 0.6 | 0.4125 | 0.6 |
| **Low Stream Order** | Glides | 0.15 | 0.25 | 0.4 |
| | Pool Tails | 0.25 | 0.5 | 0.8 |
| | Small Cobble Riffles | 0.25 | 0.375 | 0.6 |
| **Mid Stream Order** | Glides | 0.05 | 0.15 | 0.4 |
| | Pool Tails | 0.1 | 0.3 | 0.8 |
| | Small Cobble Riffles | 0.1 | 0.225 | 0.6 |
| **High Stream Order** | Glides | 0.03 | 0.05 | 0.4 |
| | Small Cobble Riffles | 0.05 | 0.075 | 0.6 |

Our calculations of area for each type of habitat for each species are based on the following assumptions:

- EDT estimates of total amount of habitat for each month are accurate
- Spawning habitat criteria in Table 3 were appropriate
- Area of reservoir < 3 m deep accurately represent amount of rearing habitat in summer and winter

We summarized the total area of habitat in each of these into four subbasins, defined as follows:

1. Lower North Fork – all habitat accessible to anadromous fish downstream of  Merwin Dam, excluding East Fork of the Lewis and its tributaries.
2. Merwin – Merwin reservoir and all potential anadromous tributaries except Speelyai Creek.
3. Yale – Yale reservoir habitat and all potential anadromous tributaries including the Swift bypass reach and Speelyai Canal.
4. Swift – Swift reservoir and all anadromous tributaries.

We examined each of these subbasins separately because parr and fry cannot move freely among these four areas because of the dams. As noted previously, while some historic information exists on habitat conditions in the Lewis Basin, we were not able to locate adequate historic data to do a historic reconstruction of limiting habitat and life stage.

## Densities and Smolt Production Potential

We assimilated estimates of summer and winter habitat-specific densities for coho, steelhead, and Chinook salmon from the literature. Limiting factors models for coho were readily available and we used the numbers and survival factors from Pollock et al. (2004) (Table 4). Densities for steelhead were taken from Reeves et al. (Unpublished) with data for tributaries obtained from Roni (2003) (Table 4). In addition, Reeves et al. (1989) and Reeves et al. (Unpublished) provided factors for converting spawning habitat area into potential smolt production. Limiting factors models for spring Chinook have not been developed, though data on summer habitat use and spawning habitat are readily available, thus for Chinook we used summer juvenile estimates from Bartz et al. (2006) (Table 4). Converting these to smolt-production potential requires life-stage specific survival estimates, which are not readily available for each spring Chinook life stage in western Washington and Oregon. In absence of those specific for Chinook, we used survival rates provided by Reeves et al. (1989) for coho and applied those to Chinook densities to estimate smolt production potential factors per square meter (Table 4). While this is not ideal, it provides an interim approach to convert densities to SPP in absence of data from the Lewis or other basins, assuming no density dependence for Chinook. Because we did not locate winter habitat densities for spring Chinook by habitat type, we did not calculate SPP for winter habitat. Moreover, Chinook rear in lakes and reservoirs in both summer and winter (Tabor et al. 2011; Monzyk et al. 2013), both Swift and Yale reservoirs provide large amounts of Chinook rearing habitat, and winter habitat is unlikely to be limiting in either of these basins. To calculate SPP by square meter of spawning habitat, we followed the methods of Reeves et al. (1989), substituting Chinook salmon redd size (3.3 $m^2$; Burner 1951) and mean fecundity of spring Chinook (3,200, E. Lesko pers. comm.) from the Lewis River Hatchery for those of coho. Finally, this limiting factors analysis assumes full seeding, that densities of fish in different habitat types from other data sources are applicable to Lewis Basin, that habitat quality in a reach or stream is reflected accurately in amount or proportion of different habitat types (pools, riffles, glides), and that summary habitat data are accurate for all reaches. We also assume that the proportion of spawnable habitat is accurate (shown previously in Table 3).

**Table 4.** Factors used to convert usable habitat area by season and life stage into common currency of smolt production potential (SPP). These values are based on habitat specific densities multiplied by survival at each of remaining life stage and assume full seeding and no other density dependent influences. Appendix B provides detailed tables for each species and data source. NA = not available.

| | **Smolt Production Potential (fish/$m^2$)** | | |
|---|---|---|---|
| **Habitat Type** | Coho | Steelhead | Spring Chinook |
| **Side channel** | | | |
| **Summer** | 0.32 | 0.05 | 0.11 |
| **Winter** | 0.78 | 0.19 | NA |
| **Tributaries** | | | |

| | Smolt Production Potential (fish/$m^2$) | | |
|---|---|---|---|
| **Habitat Type** | Coho | Steelhead | Spring Chinook |
| **Summer pool** | 0.43 | 0.06 | 0.13 |
| **Summer Glide** | | 0.06 | 0.03 |
| **Summer riffle** | 0.21 | 0.05 | 0.02 |
| **Winter pool** | 1.09 | 0.02 | N.A. |
| **Winter Glide** | | 0.01 | N.A. |
| **Winter riffle** | 0.00 | 0.00 | N.A. |
| **Mainstem** | | | |
| **Summer** | | 0.01 | 0.02 |
| **Winter** | | 0.01 | |
| **Pond/Lake** | | | |
| **Summer pond** | 0.38 | 0.00 | 0.01 |
| **Winter pond** | 0.78 | 0.00 | NA |
| **Summer reservoir** | 0.003 | 0.00 | 0.02 |
| **Winter reservoir** | 0.003 | | NA |
| **Spawning habitat** | | | |
| **Spawning habitat** | 60.00 | 8.08 | 52.40 |

# Results and Recommendations

The total summer SPP for the four major subbasins (Lower NF, Merwin, Yale, and Swift) ranged from 116,620 to 245,390, from 3,127 to 41,720, and from 476,526 to 620,109 for coho, winter steelhead and spring Chinook, respectively (Figure 1). Total winter habitat SPP ranged from 123,407 to 496,546 and from 1,414 to 40,625 for coho and winter Steelhead, respectively. Total SPP for spawning habitat ranged from 31,161 to 1,326,777, from 3,257 to 640,329, and from 157,765 to 1,624,546 for coho, winter steelhead and spring Chinook, respectively. The SPP for summer and winter rearing for coho and Chinook is driven primarily by the large amount of littoral habitat in the three reservoirs. This also assumes that mortality in the reservoir would be similar to stream habitats, which may not be the case depending upon quality of littoral rearing habitat, food resources, and predation. The high SPP for spawning habitat upstream of Swift and downstream of Merwin suggest that estimates of the amount of spawning area are high.

For a given species and basin, the habitat with the lowest SPP is limiting the population. For coho salmon, it appears that spawning habitat is limiting production in Merwin, while summer habitat is limiting production in other subbasins. This is consistent with expectations, as little spawning habitat exists in Merwin. It is surprising that summer rearing habitat is limiting in Yale for coho, but differences in SPP among summer, winter, and spawning habitat are relatively small. Moreover, this analysis is sensitive to the amount of useable habitat in Yale Reservoir. We used a < 3 m depth criteria and, just by increasing the depth criteria from <3 m to <4 m, the total littoral habitat in Yale Reservoir increases by 60%, which would result in significant changes in SPP and makes spawning habitat limiting. Defining the littoral habitat as less than 3 m is well supported for coho in lakes, ponds, and streams, Chinook in lakes (Tabor et al. 2011), but studies in reservoirs have suggested use of deeper habitats by juvenile Chinook (Monzyk et al. 2013).

For steelhead, summer or winter rearing habitat is limiting in all of the subbasins. This assumes that little or no rearing habitat exists for steelhead within the reservoirs. In contrast, spawning habitat is limiting for Chinook salmon in Yale basin. Similar to coho, this is driven by the fact that juvenile spring Chinook can rear in the reservoirs in both summer and winter. Increasing the definition of littoral habitat from less than 3 to less than 4 meters would make SPP nearly equal between spawning and rearing habitat. Increasing the definition of littoral habitat to less than 5 m would also make spawning habitat limiting for Chinook salmon in the Swift Basin as well. We did not have data on winter rearing densities or SPP for spring Chinook salmon, but previous studies indicate that spring Chinook salmon rear in large lakes and reservoirs during both summer and winter (Tabor et al. 2011; Monzyk et al. 2013). Juvenile spring Chinook also appear to use a greater range of depths in winter months than in summer months. Therefore, SPP would be higher for winter than summer habitat for Chinook salmon and winter habitat would likely not be limiting spring Chinook production in the Swift Basin.

### *Limitations and uses of smolt production potential*

SPP converts life stages to common currency of smolts and assumes full seeding and standardized survival at subsequent life stages. Habitat quality is only indirectly incorporated through data on amount of pool and other habitats from source habitat data. Like all models, estimates of SPP, while based on an approach that has been validated in other basins (e.g., Reeves et al. 1989; Beechie et al. 1994; Pollock et al. 2004), are limited by the quality of habitat data and the habitat-specific fish density used. Moreover, other factors such as fine sediment, wood loading, temperature, and predation—whose impacts can be significant but are difficult to quantify—will influence production, survival, and capacity at a reach scale.

In addition, one should not look at the habitat with the highest smolt production potential and assume that extensive restoration would allow smolt production up to that level. For example, while there may be extensive spawning potential upstream of Swift, it may have always been limited by rearing habitat and there are limits to how much one can increase the amount or capacity of rearing or other habitat types. This in part explains why having estimates of the amount and quality of historic habitat is important as it allows one to put a limit on what might be possible in terms of both habitat restoration and fish production.

Despite these assumptions and limitations, limiting factors analysis provide a useful tool for identifying bottlenecks for production in the different Lewis River subbasins. Moreover, it is useful for guiding the types of habitat that restoration strategies should focus on. For example, efforts to restore coho spawning habitat in tributaries to Swift or the North Fork of the Lewis and its tributaries downstream of Merwin Dam are unlikely to lead to an increase in smolt production or returning adults because these reaches are limited by the amount of summer rearing habitat. Thus, efforts for restoring habitat in these subbasins should focus on increasing the amount and quality of summer and/or winter rearing habitat.

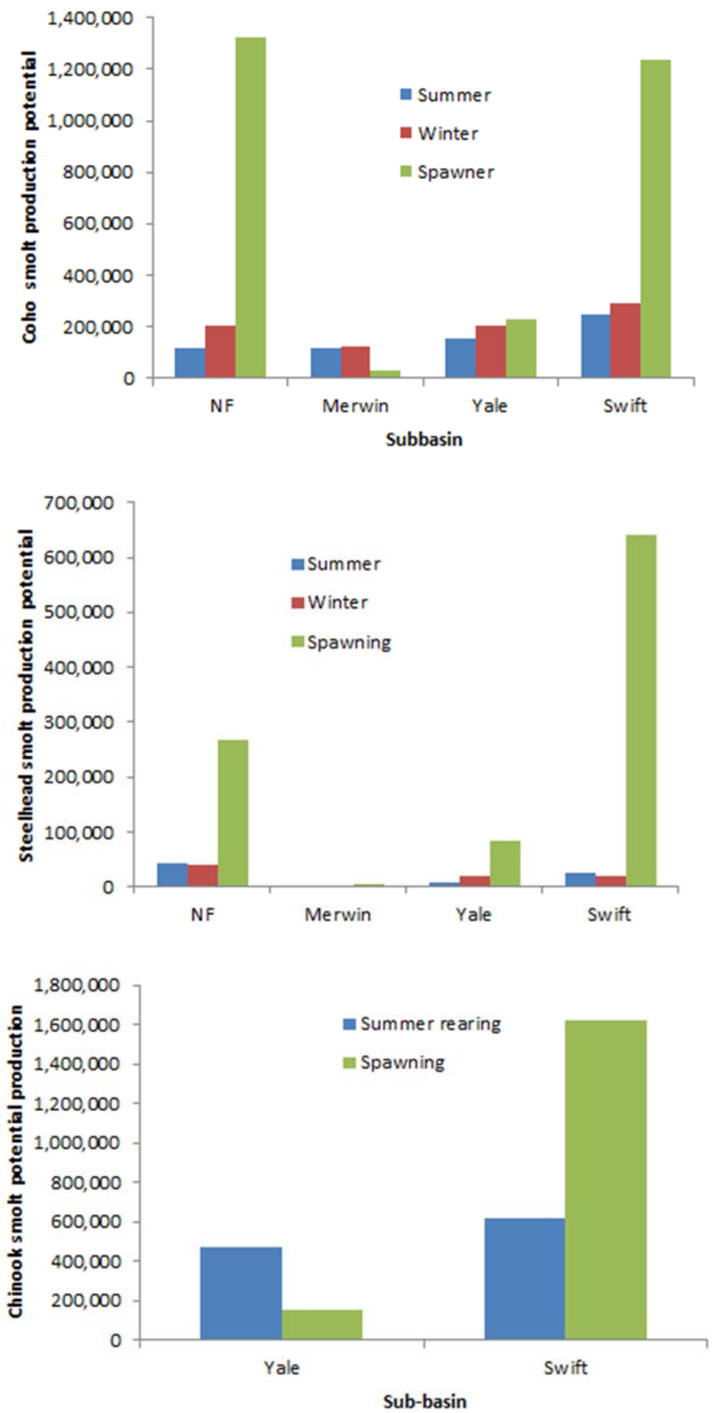


**Figure 1.** Total smolt production potential (SPP) for each major habitat type and life stage, including juvenile summer rearing, juvenile winter rearing (coho and steelhead only) and spawning habitat for coho (top figure), winter steelhead (middle figure), and spring Chinook (bottom figure).

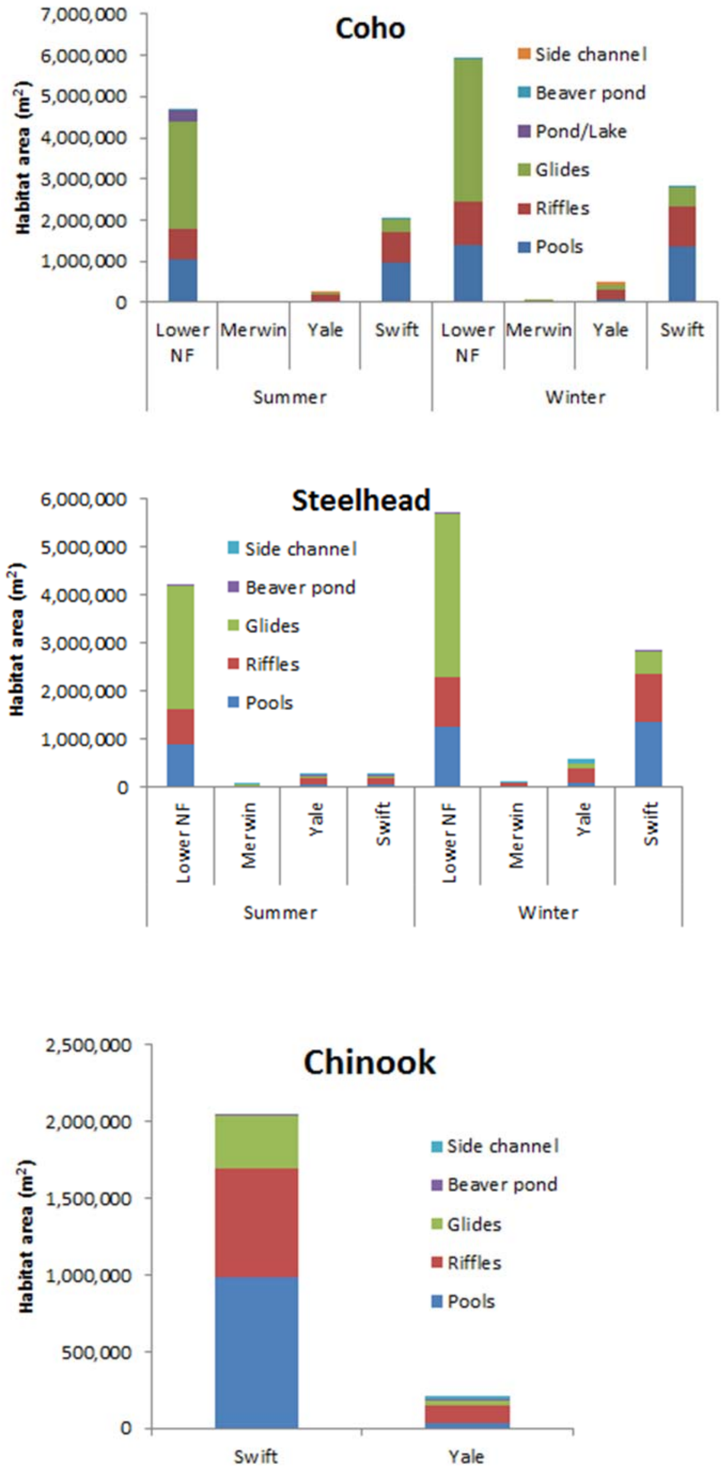


**Figure 2.** Total area (m²) of different riverine habitat types for each subbasin (Lower North Fork, Merwin, Yale, and Swift) in the North Fork of Lewis. Habitat area for each habitat type is based on habitat data used in the EDT model and provided by ICF. Littoral reservoir habitat (area < 3m depth at full pool) was not included as it represents 99% of wetted area in Merwin, Yale and Swift basins and would make riverine habitat difficult to see. Total wetted area of reservoir habitat was 47,19,6,883 m² for Merwin, 44,716,236 m² for Yale, and 54,939,5122 m² for Swift.

**Table 5.** Summary of major types of restoration that will address limiting habitat types (summer rearing, winter rearing, and spawning habitat). Modified from Roni and Beechie (2013).

| Limiting life stage and habitat | Major restoration categories |
| --- | --- |
| **Summer rearing** | Improve instream habitat, remove impassible barriers, reconnect side channels, restore riparian areas to increase instream wood recruitment and reduce temperatures |
| **Winter rearing** | Improve instream habitat, remove impassible barriers, reconnect side channels, reconnect floodplain habitat, levee setback or removal, remeander straightened channels, increase beaver ponds, enhance beaver populations, construct side channels or off-channel habitat, restore riparian areas to increase instream wood recruitment |
| **Spawning Habitat** | Remove migration barriers that prevent access to spawning habitat, reduce fine sediment (restore roads, riparian and upslope areas), scour (disconnect road network, remove bank armoring), restored floodplain habitat and side channels, gravel addition, addition of wood or logjams to increase pools and improve spawning habitat (move channel type from plane bed to forced pool-riffle) |

# 4. IDENTIFICATION OF POTENTIAL RESTORATION ACTIONS

## Background and Methods

Identifying potential restoration actions is perhaps the most challenging task in developing a watershed restoration plan (Beechie et al. 2013). This is particularly challenging when identifying actions for particular species or groups of species such as Pacific salmon. Even in situations where extensive amounts of data on riparian condition, water quality, sediment, woody debris, habitat, and other watershed processes are available, linking the physical processes and habitats to outputs of life cycle models and actions that will benefit species of interest is particularly difficult. Moreover, in basins such as the North Fork of the Lewis, where hundreds of kilometers of habitat and literally hundreds of multi-kilometer reaches exist, narrowing those reaches down to the most important is extremely challenging. To assist with this, we used six pieces of information to screen out lower priority reaches and identify potential restoration actions in high priority reaches, including:

1) EDT outputs from ICF to identify highest priority reaches (Figure 3; Tables 6 and 7);

2) Limiting habitat and life stage from our limiting factors analysis (Table 7);

3) Watershed assessment data from previous analysis on riparian, sediment, and hydrologic condition (Tables 6, 8 and 9);

4) Geomorphic channel characteristics and channel type provided by Beechie and Imaki (2014) (Figure 4; Tables 6 and 9);

5) Information on watershed processes and habitats improved by various restoration strategies (Table 4 and Roni et al. 2013); and

6) Information on specific reaches from previous recovery planning efforts (Keefe et al. 2004; LCFRB 2010).

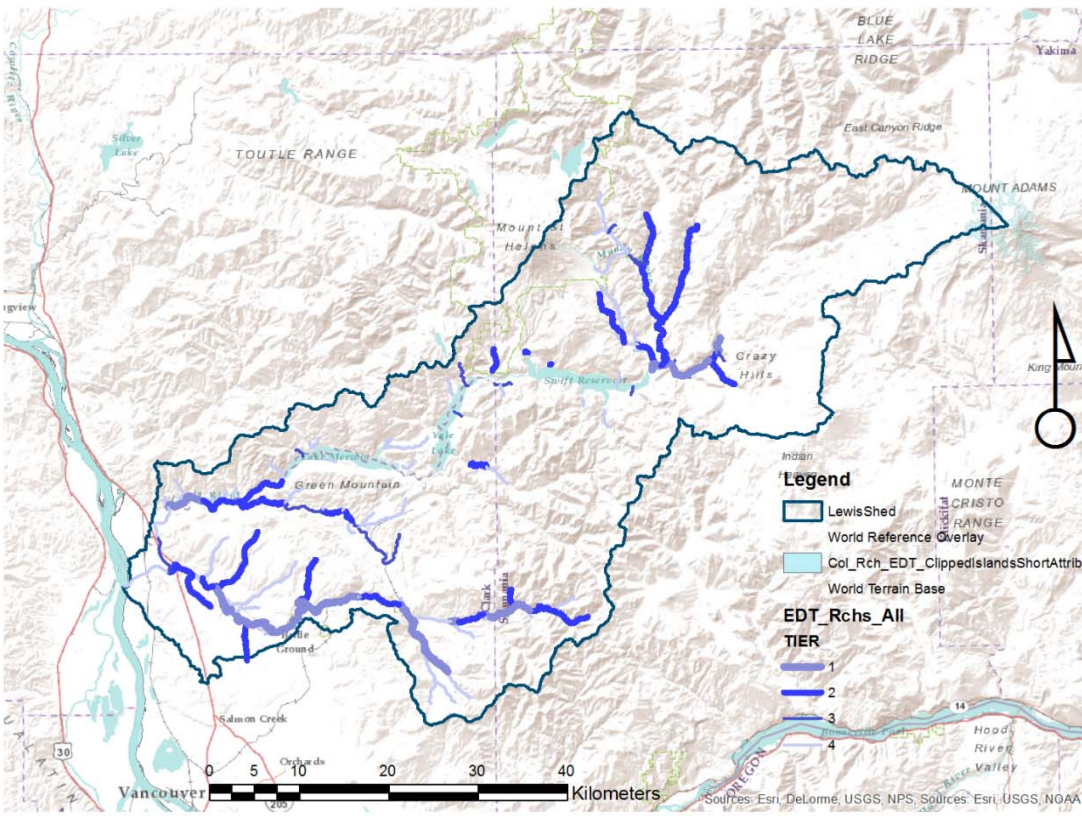


**Figure 3.** Priority EDT reaches for restoration based on latest run of EDT by ICF. Data courtesy of ICF.

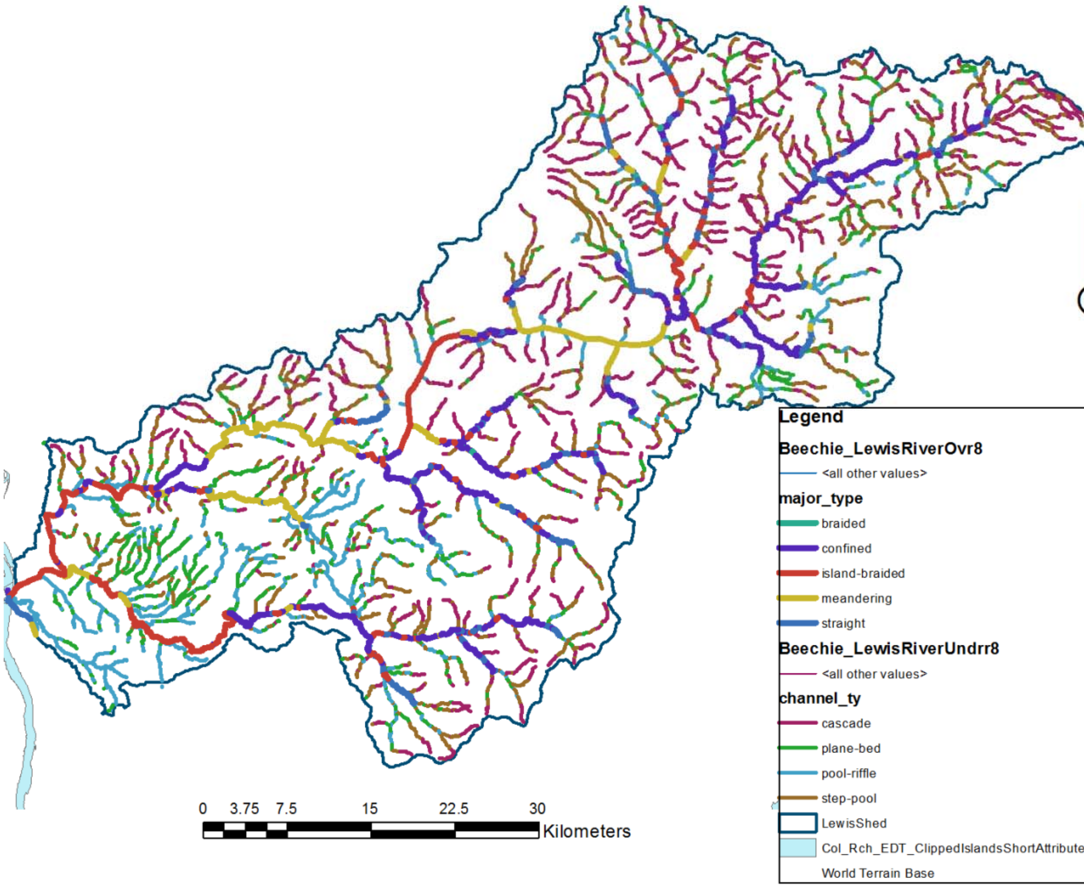


**Figure 4.** Channel types for North Fork of Lewis River. Channels less than 8m bankfull width were classified using Montgomery and Buffington (1997) channel types. Those greater than 8m were classified using the Beechie channel types (Beechie and Imaki 2014).

First, while there is some debate about the accuracy and precision of EDT population abundance and productivity, EDT has been shown to be a robust tool for ranking of reaches for restoration and protection (Steel et al. 2010; McElhany et al. 2010). Therefore, we first used EDT ranking of reaches (Tier 1 to 4) to identify suitable reaches (Table 7). Because there were 542 EDT reaches in the North Fork and Lower Lewis River alone, and we were only interested in the highest priority reaches, we selected only those reaches that were identified by EDT as Tier 1 or Tier 2 reaches for further examination. This resulted in 25 reaches identified as highest priorities. Second, using the output of our limiting factor model, we determined whether those reaches were a priority for particular species and life stage.

Third, we compared the EDT limiting habitat factor to the suite of outputs from the watershed assessment data (Fullerton et al. 2006, 2010a,b) and geomorphic channel assessment (Beechie and Imaki 2014), as well as data on stream crossing and road density from other sources. A digital elevation model (DEM) was developed to determine the watershed landscape areas that drain to each EDT reach (See Appendix C for DEM methods). These "EDT Sheds" were our basic unit of analysis for summarizing landscape conditions. We used the locations (X, Y coordinates) of the EDT reach breaks to define upslope contributing watersheds, landscape conditions, and their spatial connection to streams in the valley bottoms. Summaries were generated for each EDT Shed and coupled with information from three different stream layers for the drainage. Each stream layer was derived with different methods, covered different spatial extents, and contained unique information (Table 6). While this process seems straightforward, it overlooks the large effort needed to combine very disparate datasets. This was particularly difficult because EDT reaches were not consistently identified in all data sources, reach codes were not consistent in all databases, GIS coordinates of reach breaks were only provided for a portion of all EDT reaches in the basin, and reach lengths differed between Fullerton et al. (2006, 2010a,b), Beechie and Imaki (2014) and EDT. Thus, considerable effort was needed to rectify all the datasets.

Fourth, based on the above, Table 4, and Roni et al. (2013), we made initial predictions of restoration measures. Moreover, because Beechie et al. (2006) provides estimates of the amount of side channel for different channel types, we used the Beechie channel type in channels greater than 8m bankfull width in order to help determine whether side-channel restoration might be necessary. If the channel type was island braided, we assumed side channel restoration was appropriate given that under natural conditions the side channel to main channel ratio in this channel type exceeds one. Finally, for the Lower North Fork and mainstem, we looked at recommendations from Keefe et al. (2004; Kalama, Washougal and Lewis River Habitat Assessments), to further refine our initial recommendations. It should be noted that Keefe et al. (2004) used EDT reach priorities followed by field surveys to identify restoration opportunities in priority reaches in the Lower North Fork. Many of these same reaches were identified as priorities in the latest rerun of EDT.

**Table 6.** Summary of data sources used to help with identification of restoration opportunities.

| Dataset | Variables | Characteristics | Source |
|---|---|---|---|
| **SSHIAP Streams** | Segment ID | 33807 stream segments in the Lewis drainage. | Fullerton et al. (2006, 2010a,b) |
| | Steam Name | Name of stream segment | |
| | Subwatershed Name | Subwatershed draining to the stream segment | |
| | Seral Stage | Early (E), Mid (M), Late (L), Old growth (O), and Mixed. | |
| | Rosgen Class | Aa+ (very steep) through G (entrenched, narrow, and deep) | |
| **Roads** | Surface Type | Paved, Aggregate | |
| | Road Class | Permanent (All-Season, Seasonal), Temporary | |
| | Ownership | WDNR, USFS, Private | |
| **EDT Reaches** | EDT Reach ID | Locators for upstream and downstream extents of EDT reaches (161 stream segments subset from SSHIAP) | ICF unpublished |
| | Confinement | Unconfined, Moderately Unconfined, | |

| Dataset | Variables | Characteristics | Source |
|---|---|---|---|
| | Rating | Moderately Confined, Confined | |
| | Tier | 1 through 4 | |
| | Fish Suitability / Priorities | Identified usage by species and life history type. | |
| | EDT Diagnostic Ratings | Unique alpha-numeric codes that correspond to specific limiting factors. | |
| | Environmental Drivers for Limiting Factors | Low flow <3cfs, Low Stream Order, Large Reservoirs, etc. | |
| **Geomorphic Channel Predictions** | | 1089, 200m long main channel river types in the Lewis "Over8" dataset. 7895, 200m long tributary channel stream types in the Lewis "under8" dataset | Beechie and Imaki (2014) |
| | Major Geomorphic Channel Pattern Type | Island Braided, Braided, Meandering, Straight (Beechie and Imaki (2014) | |
| | Channel Type | Cascade, Step pool, Plane bed, Pool riffle, Dune ripple (Montgomery and Buffington 1997) | |
| | Floodplain Width | Average floodplain width (m) among all aggregated reaches | |
| | Average Bankfull Width | Average bankfull width (m) | |
| | Average Bankfull Depth | Average bankfull depth (m) | |
| | Average Gradient | Average channel slope among all aggregated reaches | |
| | Shear stress | The product of the gravitational constant and a relationship between bankfull width and depth. | |

**Table 7.** Summary of EDT data and outputs, and limiting factors model results (life stage and habitat) used to assist with identifying restoration actions. Tier = EDT reach tiers (priorities). LWD score ranges from 0 to 4, with 0 being best and 4 worst. Limiting life stage and habitat are from limiting factors model (see previous section). Sum. =summer rearing habitat, Wint. = winter rearing habitat, Spawn. = spawning habitat, CH = Chinook, CO = coho, ST = steelhead.

| | EDT Data and Model Outputs | | | | | Limiting Life Stage & Habitat Model | | |
|---|---|---|---|---|---|---|---|---|
| **Reach** | **Reach length km** | **Tier** | **Limiting Factor** | **% Pool** | **LWD Score** | **Sum.** | **Wint.** | **Spawn.** |
| | | | **Lower North Fork** | | | | | |
| **Lewis 1 tidal A** | 3.06 | 2 | Habitat diversity | 0.05 | 2.6 | CO | ST | |
| **Lewis 2 tidal B** | 2.48 | 1 | Habitat diversity | 0.05 | 3.0 | CO | ST | |
| **Lewis 2 tidal D** | 1.38 | 2 | Habitat diversity | 0.25 | 3.0 | CO | ST | |
| **Lewis 3** | 1.16 | 2 | Key Habitat | 0.25 | 3.0 | CO | ST | |
| **Lewis 4 A** | 3.48 | 2 | Key Habitat | 0.25 | 3.0 | CO | ST | |
| **Lewis 4 A** | 3.48 | 2 | Habitat diversity | 0.25 | 3.0 | CO | ST | |
| **Lewis 4 C** | 0.74 | 2 | Key Habitat | 0.25 | 3.0 | CO | ST | |
| **Ross Creek 1 E** | 1.37 | 2 | Sediment load | 0.27 | 3.0 | CO | ST | |
| **Ross Creek 1 E** | 1.37 | 2 | Channel Stability | 0.27 | 3.0 | CO | ST | |
| **Cedar Creek 1 B** | 1.59 | 1 | Temperature | 0.25 | 3.0 | CO | ST | |
| **Cedar Creek 1 C** | 2.99 | 1 | Temperature | 0.25 | 3.0 | CO | ST | |
| **Cedar Creek 2 C** | 1.11 | 1 | Temperature | 0.28 | 3.0 | CO | ST | |
| **Cedar Creek 2 C** | 1.11 | 1 | Sediment load | 0.28 | 3.0 | CO | ST | |
| **Cedar Creek 5** | 1.00 | 1 | Sediment load | 0.27 | 3.0 | CO | ST | |
| **Cedar Creek 6 B** | 2.75 | 2 | Sediment load | 0.27 | 2.4 | CO | ST | |
| **Cedar Creek 6 C** | 1.16 | 1 | Sediment load | 0.23 | 3.0 | CO | ST | |
| **John Creek 1** | 1.77 | 2 | Channel Stab. | 0.27 | 3.0 | CO | ST | |
| | | | **Swift Basin** | | | | | |
| **Lewis 18** | 1.13 | 1 | Key Habitat | 0.17 | 2.5 | CH | | |
| **Lewis 18** | 1.13 | 2 | Key Habitat | 0.17 | 2.5 | CH | | |
| **Lewis 19** | 0.81 | 2 | Sediment load | 0.35 | 2.5 | CH | | |
| **Lewis 21** | 1.61 | 1 | Sediment load | 0.17 | 2.5 | CH, CO, ST | ST | |
| **Campground Cr.** | 1.93 | 2 | Sediment load | 1.00 | 2.0 | CO, ST | | |
| **Muddy R 1** | 7.08 | 2 | Food Index | 0.48 | 3.5 | CH, CO, ST | | |
| **Muddy R 1** | 7.08 | 2 | Key Habitat | 0.48 | 3.5 | CH, CO, ST | | |
| **Muddy R 1** | 7.08 | 2 | Habitat diversity | 0.48 | 3.5 | CH, CO, ST | | |
| **Clearwater Tribs** | 1.29 | 2 | Sediment load | 0.26 | 2.0 | CH, CO, ST | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Rush Creek** | 4.02 | 2 | Key Habitat | 0.02 | 3.0 | CH, CO, ST |
| **Little Creek** | 1.13 | 2 | Channel Stability | 0.21 | 3.2 | CH, CO, ST |
| **Spencer Creek** | 0.96 | 1 | Key Habitat | 0.10 | 3.1 | CH, CO, ST |
| **Crab Creek** | 0.81 | 2 | Key Habitat | 0.12 | 2.5 | CH, CO, ST |

**Table 8**. Summary of riparian conditions and fine sediment production (kg/yr.) from Fullerton et al. (2006; 2010a, b) used to assist with identification of restoration actions. Seral stage, E = early, O = old, L = Late, M = Mid, and Mixed. Shade, pool-forming conifers, LWD and riparian function scores range from 0 to 3 with 0 being low and 3 being high (ideal).

| Reach | Seral Stage | Shade Factor | Pool-Forming Conifers | LWD Score | Riparian Function Score | Fine Surface Sediment | Fine Mass Wasting Sediment | Fine Road Sediment |
|---|---|---|---|---|---|---|---|---|
| **Lower North Fork** | | | | | | | | |
| **Lewis 1 tidal A** | O | 2 | 0 | 2 | M | 60,153 | 878 | 1,602 |
| **Lewis 2 tidal B** | O | 1 | 0 | 1 | P | 115,594 | 379 | 23,790 |
| **Lewis 2 tidal D** | O | 3 | 0 | 1 | M | 7,521 | 556 | 500 |
| **Lewis 3** | O | 3 | 0 | 1 | M | 7,520 | 555 | 500 |
| **Lewis 4 A** | O | 2 | 0 | 2 | M | 60,153 | 878 | 1,602 |
| **Lewis 4 C** | O | 2 | 0 | 2 | M | 60,153 | 878 | 1,602 |
| **Ross Creek 1 E** | O | 2 | 0 | 2 | M | 60,153 | 878 | 1,602 |
| **Cedar Creek 1 B** | D | 3 | 1 | 2 | M | 13,406 | 301 | 593 |
| **Cedar Creek 1 C** | MIX | 3 | 1 | 2 | M | 13,406 | 301 | 593 |
| **Cedar Creek 2 C** | O | 1 | 0 | 1 | P | 88,369 | 747 | 7,386 |
| **Cedar Creek 5** | D | 3 | 1 | 2 | M | 11,585 | 164 | 445 |
| **Cedar Creek 6 B** | O | 1 | 0 | 1 | P | 149,978 | 1,830 | 5,019 |
| **Cedar Creek 6 C** | O | 1 | 0 | 1 | P | 149,978 | 1,830 | 5,019 |
| **John Creek 1** | O | 2 | 0 | 2 | M | 60,153 | 878 | 1,602 |
| **Swift Basin** | | | | | | | | |

| Reach | Seral Stage | Shade Factor | Pool-Forming Conifers | LWD Score | Riparian Function Score | Fine Surface Sediment | Fine Mass Wasting Sediment | Fine Road Sediment |
|---|---|---|---|---|---|---|---|---|
| Lewis 18 | O | 2 | 0 | 2 | M | 55,276 | 320 | 1,684 |
| Lewis 19 | O | 2 | 0 | 2 | M | 55,276 | 320 | 1,684 |
| Lewis 21 | O | 2 | 0 | 2 | M | 182,849 | 597 | 5,274 |
| Campgrnd Cr. | MIX | 3 | 1 | 3 | G | 16,149 | 792 | 1,619 |
| Muddy R 1 | O | 2 | 0 | 2 | M | 117,161 | 1,477 | 3,135 |
| Clearwater Tribs | L | 3 | 0 | 3 | G | 19,447 | 972 | 1,658 |
| Rush Creek | L | 3 | 0 | 3 | G | 8,649 | 289 | 88 |
| Little Creek | O | 2 | 0 | 2 | M | 60,153 | 878 | 1,602 |
| Spencer Creek | O | 2 | 0 | 2 | M | 87,635 | 1,243 | 2,641 |
| Crab Creek | NA | NA | NA | NA | NA | NA | NA | NA |

**Table 9.** Summary of geomorphic data from Beechie and Imaki (2014) and from the digital elevation model (EDT Sheds) for EDT Tier 1 and 2 reaches. Channel types: Beechie =Beechie and Imaki (2014), M & B = Montgomery and Buffington (1997), braided = island braided, meander = meandering PB = plane-bed, PR =pool-riffle, CA = cascade, SP = step-pool. Confinement rating: MU = moderately unconfined and MC = moderately confined. NA = not available. BFW = predicted bankfull width. % = predicted gradient in percent.

| | | | | Channel Type | | | | |
|---|---|---|---|---|---|---|---|---|
| **Reach** | **% Fine Sed.** | **No. Stream Crossings** | **Road Density** | **Beechie** | **M & B** | **Confinement Rating** | **BFW (m)** | **%** |
| | | | | **Lower North Fork** | | | | |
| **Lewis 1 tidal A** | 10.5 | 0 | | confined | PR | MU | 44.4 | 0.00 |
| **Lewis 2 tidal B** | 10.5 | 0 | 0.00 | braided | PR | NA | 44.4 | 0.00 |
| **Lewis 2 tidal D** | 22.3 | 105 | 1.02 | braided | PR | MC | 44.3 | 0.01 |
| **Lewis 3** | 17.3 | 23 | 0.85 | braided | CA | MC | 44.5 | 0.00 |
| **Lewis 4 A** | 15.2 | 75 | 1.02 | braided | PR | MU | 44.5 | 0.01 |
| **Lewis 4 C** | 15.2 | 75 | 1.02 | braided | SP | MU | 44.5 | 0.01 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Ross Creek 1 E** | | 8 | 0.85 | | PR | MC | 3.92 | 0.02 |
| **Cedar Creek 1 B** | 7.7 | 0 | 0.96 | braided | | Confined | 13.09 | 0.01 |
| **Cedar Creek 1 C** | 12.5 | 67 | 0.95 | braided | | MU | 9.85 | 0.04 |
| **Cedar Creek 2 C** | 10.5 | 0 | 0.95 | meander | PR | MU | 11.98 | 0.00 |
| **Cedar Creek 5** | 11.5 | 56 | 1.01 | Straight | | MU | 10.25 | 0.02 |
| **Cedar Creek 6 B** | 10.5 | 0 | 1.01 | | PR | MU | 7.87 | 0.06 |
| **Cedar Creek 6 C** | 11.4 | 0 | 1.01 | | PR | MU | 7.87 | 0.06 |
| **John Creek 1** | | | 1.16 | | PB | MC | 4 | 0.03 |
| **Swift Basin** | | | | | | | | |
| **Lewis 18** | 12.2 | 13 | 0.89 | confined | PB | MC | 32.46 | 0.01 |
| **Lewis 19** | 15.4 | 31 | 0.53 | meander | CA | MC | 32.46 | 0.01 |
| **Lewis 21** | 21.9 | 9 | 0.50 | confined | CA | Confined | 11.81 | 0.17 |
| **Campground Cr.** | 25.6 | 4 | 0.89 | | CA | NA | 8.03 | 0.04 |
| **Muddy R 1** | 9.5 | 31 | 0.53 | braided | PB | MC | 21.87 | 0.01 |
| **Clearwater Tribs** | 8.8 | 0 | 0.61 | confined | PR | MU | 13.35 | 0.00 |
| **Rush Creek** | 20.2 | 70 | 0.32 | confined | PB | Confined | 11.96 | 0.10 |
| **Little Creek** | 17.4 | 8 | 0.50 | | SP | MU | 4.83 | 0.01 |
| **Spencer Creek** | 31.2 | | | confined | PR | MU | | |
| **Crab Creek** | NA | NA | NA | confined | PR | NA | NA | NA |

## Potential Restoration Actions

We identified five major categories of restoration actions among the 25 Tier 1 and Tier 2 reaches above Swift Dam and below Merwin Dam (Table 10). We did not examine restoration measures in Speelyai Canal (the one priority reach in the Merwin or Yale basins) because this reach would not be accessible to salmon or steelhead in lieu of fish passage. The primary focus of all restoration measures from a limiting habitat perspective for reaches above Swift and below Merwin dams is improving summer and winter rearing habitat. Because of the low level of pools and LWD in most reaches, LWD placement was the most common restoration measure recommended. Side channel restoration, which could include reconnecting side channels and creating new side channels, was recommended for larger reaches that were determined to be island-braided channel types. The feasibility of doing this would need to be confirmed in the field, and would obviously be difficult at a large scale in mainstem reaches downstream of Merwin Dam. High levels of fine sediment were noted in some reaches, but a strong linkage with high surface erosion or road sediment was observed in one reach (Swift Campground Creek).

The EDT reaches are long reaches and it is likely that restoration measures listed in Table 10 are only appropriate for portions of each reach. Moreover, confirming these restoration measures and identifying specific restoration opportunities will require more detailed site visits and additional data collection in Tier 1 and Tier 2 reaches.

**Table 10.** Tier 1 and Tier 2 EDT reaches, initial recommendations for restoration measures, and rationale for selecting specific restoration measures. This is a preliminary list and field surveys are needed to confirm specific measures and locations. Keefe et al. (2004) provided recommended restoration measures for Lower North Fork and tributaries.

| Reach | Restoration Measure Recommended | Rational for selecting restoration measure |
|---|---|---|
| | **Lower North Fork** | |
| **Lewis 1 tidal A** | Side channels, LWD, Riparian | Low wood, percent pools, moderate riparian function, Keefe et al. (2004) |
| **Lewis 2 tidal B** | Side channels, LWD, Riparian | Low wood, percent pools, poor riparian function, Keefe et al. (2004) |
| **Lewis 2 tidal D** | Side channels, LWD, Riparian | Low wood, percent pools, moderate riparian function, Keefe et al. (2004) |
| **Lewis 3** | Side channels, LWD | Low wood, percent pools, moderate riparian function, Keefe et al. (2004) |
| **Lewis 4 A** | Side channels, LWD | Island-braided channel type, low LWD |
| **Lewis 4 C** | Side channels, LWD | Island-braided channel type, low LWD |
| **Ross Creek 1 E** | Invasive removal, livestock & riparian planting to reduce fine sediment, LWD | Low LWD, percent pool, and Keefe et al. (20040 |
| **Cedar Creek 1 B** | LWD, side channels | Low LWD, channel type |
| **Cedar Creek 1 C** | LWD, side channels | Low LWD, channel type |
| **Cedar Creek 2 C** | Riparian and LWD | Low LWD, percent pool, poor riparian function |
| **Cedar Creek 5** | Riparian and LWD | Low LWD, percent pool, Keefe et al. (2004) |
| **Cedar Creek 6 B** | Riparian and LWD | Low riparian function, LWD and percent pool |
| **Cedar Creek 6 C** | Riparian and LWD | Low riparian function, LWD and percent pool |
| **John Creek 1** | Riparian and LWD | Moderate riparian function, LWD and percent pool, and plane bed channel type |
| | **Swift Basin** | |
| **Lewis 18** | LWD | low LWD and percent pool |
| **Lewis 19** | LWD, side channels | Low LWD, percent pool and channel type |
| **Lewis 21** | LWD, roads restoration | Low percent pool, LWD, high sediment yield |
| **Swift Campground Creek** | Roads | High percent fines, campground area |

| | | |
|---|---|---|
| **Muddy R 1** | Side channels, LWD | Low LWD scores, and island braided channel type |
| **Clearwater Tribs** | NA (high levels of fines appears to be due to headwaters in blast zone of Mt. St. Helens. | Mt. St. Helens blast zone appears to be source of sediment |
| **Rush Creek** | Protection (steep channel) | Steep channel |
| **Little Creek** | LWD | Poor LWD and pool area |
| **Spencer Creek** | LWD | Poor LWD and pool area |
| **Crab Creek** | LWD | Poor LWD and pool area |

## Potential Increases in Coho and Steelhead Smolts

In addition to identifying restoration measures, we estimated the potential increase in coho and steelhead salmon smolts for selected restoration actions proposed for Tier 1 and Tier 2 Reaches in the North Fork of the Lewis using methods of Roni et al. (2010). This includes published values on increases in coho salmon smolts for large woody debris (LWD), engineered log jam (ELJ) and side-channel reconnection or creation (Table 11). These estimates are based on field studies in western Washington and Oregon (e.g., Roni and Quinn 2001; Morley et al. 2006; Pess et al. 2012). These values were coupled with estimates of the total length of habitat to be restored to predict potential increases in smolt production. We assumed that LWD would be placed in “tributaries” and that ELJs would be placed in main stem reaches. Accurate estimates of potential side-channel habitat to be restored in priority reaches would require detailed field surveys and an initial restoration plan. Because the literature suggests that side channel length in island braided reaches (those we recommended for side channel restoration) typically are equal to or greater than mainstem channel length (Beechie et al. 2006), we assumed that side channel length could be increased by 20% of mainstem channel length either through reconnecting side-channels or constructing side channels. While this is a relatively small amount of side channel compared to what may have been present historically, this is a realistic estimate of the proportion typically reconnected or constructed for projects of this type.

Using these data and a Monte Carlo simulation, we estimated the range and mean of possible increases in smolt production for all reaches combined (Manly 2006). We used the mean and standard deviation of coho salmon or steelhead for each restoration technique to create a distribution of project effectiveness values as inputs to the model (simulation). We then ran a Monte Carlo simulation with 10,000 model runs to estimate the distribution of possible outcomes for each restoration technique. The results for each technique were then multiplied by the total length or area to be restored for all reaches combined (Table 12). The results for each habitat restoration type were combined to calculate the range of possible increases in coho and steelhead smolts.

**Table 11.** Mean increase of coho and steelhead smolts in response to different restoration techniques used in Monte Carlo simulation. Data from Roni et al. (2010). Sample sizes (N) represent the number of restoration projects or streams that were evaluated and mean response in smolts per meter (LWD and ELJs) or per meter squared (side channels). SD = standard deviation.

| | Coho | | | Steelhead | |
|---|---|---|---|---|---|
| | N | Mean | SD | Mean | SD |
| **LWD** | 22 | 0.21 | 0.33 | 0.04 | 0.02 |
| **ELJ** | 8 | 0.19 | 0.29 | 0.09 | 0.16 |
| **Side channels** | 22 | 0.34 | 0.42 | 0.03 | 0.03 |

**Table 12.** Length of priority reaches for restoration, length of LWD placement and area of side-channels restored (constructed) used in predictions of potential increase in smolt production.

| Reach | Restoration Measure Recommended | Reach Length (km) | Length of LWD or ELJ placement (m) | Length of side-channel restored ($m^2$) |
|---|---|---|---|---|
| | | **Lower North Fork** | | |
| **Lewis 1 tidal A** | Side channels, LWD, Riparian | 3.1 | 3,057 | 6,114 |
| **Lewis 2 tidal B** | Side channels, LWD, Riparian | 2.5 | 2,478 | 4,956 |
| **Lewis 2 tidal D** | Side channels, LWD, Riparian | 1.4 | 1,384 | 2,768 |
| **Lewis 3** | Side channels, LWD | 1.2 | 1,158 | 2,316 |
| **Lewis 4 A** | Side channels, LWD | 3.5 | 3,475 | 6,950 |
| **Lewis 4 C** | Side channels, LWD | 0.7 | 740 | 1,480 |
| **Ross Creek 1 E** | Invasive removal, livestock & riparian planting to reduce fine sediment, LWD | 1.4 | 1,368 | |
| **Cedar Creek 1 B** | LWD, side channels | 1.6 | 1,593 | 3,186 |
| **Cedar Creek 1 C** | LWD, side channels | 3.0 | 2,993 | 5,986 |
| **Cedar Creek 2 C** | Riparian and LWD | 1.1 | 1,110 | |
| **Cedar Creek 5** | Riparian and LWD | 1.0 | 998 | |
| **Cedar Creek 6 B** | Riparian and LWD | 2.8 | 2,751 | |

| | | | | |
|---|---|---|---|---|
| **Cedar Creek 6 C** | Riparian and LWD | 1.2 | 1,158 | |
| **John Creek 1** | Riparian and LWD | 1.8 | 1,770 | |
| | | **Swift Basin** | | |
| **Lewis 18** | LWD | 1.1 | 1,126 | |
| **Lewis 19** | LWD, side channels | 0.8 | 805 | 1,610 |
| **Lewis 21** | LWD, roads restoration | 1.6 | 1,609 | |
| **Swift Campground Creek** | Roads | 1.9 | | |
| **Muddy R 1** | Side channels, LWD | 7.1 | 7,080 | 14,160 |
| **Clearwater Tribs** | NA (high levels of fines appears to be due to headwaters in blast zone of Mt. St. Helens. | 1.3 | | |
| **Rush Creek** | Protection (steep channel) | 4.0 | | |
| **Little Creek** | LWD | 1.1 | 1,126 | |
| **Spencer Creek** | LWD | 1.0 | 965 | |
| **Crab Creek** | LWD | 0.8 | 805 | |
| **Total length or area** | | 47 km | 40,032 m | 49,526 $m^2$ |

We also estimated the approximate cost for restoration of priority reaches. As noted previously in this report, site visits are needed to confirm feasibility of restoration measures and to provide initial cost estimates. Estimating costs without actual site visits is problematic as ownership, access, and many other factors can greatly affect costs of restoration and protection measures. However, we made some very preliminary estimates of restoration cost in Tier 1 and Tier 2 reaches based on reach length and restoration costs reported in Roni et al. (2010) and Fullerton et al. (2010). The numbers in Roni et al. (2010) and Fullerton et al. (2010) were based on 2003 dollars, so we adjusted these numbers to 2016 dollars based on the consumer price index (CPI) (http://data.bls.gov/cgi-bin/cpicalc.pl). Costs for LWD and ELJ placement were $72,800 and $273,000 per kilometer, while side channel construction and reconnection and riparian placement were $1.93 and $4.82 per square meter of area treated. These are costs for design and construction and do not include any land purchase, easements or other costs that are often necessary to implement projects. For LWD and ELJs we assumed the entire reach was treated. Side channel areas were consistent with previous restoration estimates (20% of reach length). Riparian actions were assumed to occur adjacent to the active channel for 20m along both banks of target reaches. All costs should be considered preliminary and used for planning purposes only. Actual costs could be affected by materials costs, haul distances, and local access to each respective site. Finally, owing to the wide variability associated with road construction costs, no attempt was made to include road construction and maintenance costs in this estimate.

Our modeling effort predicts that LWD, ELJ, and side channel restoration in Tier 1 and Tier 2 reaches would on average lead to an increase of approximately 25,000 coho and 4,000 steelhead smolts—though the variation around that prediction is high (Table 13). This variation is largely a result of the mean and standard deviation reported in response to techniques (Table 11). This also suggests that results could be potentially higher or lower, depending on the level of success of restoration efforts. The predicted mean increase in steelhead or coho smolts and adults by reach is provided in

Table **14**. Given that the data we used are from evaluation of restoration projects completed several years ago, it is likely that some improvements have been made in techniques and therefore success rates of more recent projects should be higher than those predicted. It should be noted that we did not have estimates for increases in fish production for riparian planting, road restoration, or other techniques that focus on restoring processes. Thus, our predictions are likely conservative as these other treatments should also lead to increases in smolt production—though the response would be much slower than for instream (LWD and ELJs) or floodplain (side channel) restoration. Similarly, a number of other factors could influence response of fish to restoration actions and thus our predictions should be used with caution. Studies evaluating response of Chinook salmon to restoration are rare and we did not have adequate data to estimate spring Chinook response to restoration. Given their habitat preferences, it is likely their response to different restoration techniques is somewhere between that of coho and steelhead.

**Table 13.** Predicted increase in number of coho and steelhead smolts based on data in Table 11 and 12 and Monte Carlo simulation for all reaches combined.

| | **Coho** | **Steelhead** |
|---|---|---|
| LWD | 3,652 | 645 |
| ELJ | 4,302 | 2,158 |
| Side channels | 16,988 | 1,276 |
| **Total** | **24,943** | **4,079** |
| 95% Prediction Interval | -19,587 to 69,992 | -3,629 to 11,527 |

**Table 14.** Mean predicted increase in coho and steelhead smolts by reach and estimated adult returns using smolt to adult return rates used in EDT analysis. Smolt-to-adult return rates are assumed to be 4% for coho and 5% for steelhead.

| **Reach** | **Total Coho Smolts** | **Total Steelhead Smolts** | **Total Adult Coho** | **Total Adult Steelhead** |
|---|---|---|---|---|
| | | **Lower North Fork** | | |
| **Lewis 1 tidal A** | 2687 | 442 | 107 | 22 |
| **Lewis 2 tidal B** | 2178 | 358 | 87 | 18 |

| | | | | |
|---|---|---|---|---|
| **Lewis 2 tidal D** | 1217 | 200 | 49 | 10 |
| **Lewis 3** | 1018 | 167 | 41 | 8 |
| **Lewis 4 A** | 3055 | 502 | 122 | 25 |
| **Lewis 4 C** | 650 | 107 | 26 | 5 |
| **Ross Creek 1 E** | 291 | 55 | 12 | 3 |
| **Cedar Creek 1 B** | 1433 | 146 | 57 | 7 |
| **Cedar Creek 1 C** | 2692 | 267 | 108 | 13 |
| **Cedar Creek 2 C** | 236 | 42 | 9 | 2 |
| **Cedar Creek 5** | 212 | 38 | 8 | 2 |
| **Cedar Creek 6 B** | 585 | 104 | 23 | 5 |
| **Cedar Creek 6 C** | 246 | 44 | 10 | 2 |
| **John Creek 1** | 377 | 67 | 15 | 3 |
| | | **Swift Basin** | | |
| **Lewis 18** | 217 | | 9 | |
| **Lewis 19** | 708 | 116 | 28 | 6 |
| **Lewis 21** | 310 | | 12 | |
| **Swift Campground Creek** | | | | |
| **Muddy R 1** | 6223 | 1023 | 249 | 51 |
| **Clearwater Tribs** | | | | |
| **Rush Creek** | | | | |
| **Little Creek** | 240 | 43 | 10 | 2 |
| **Spencer Creek** | 205 | 37 | 8 | 2 |
| **Crab Creek** | 171 | 31 | 7 | 2 |
| | | | | |
| **Total** | **25,054** | **3,806** | **1,002** | **190** |

A rough estimate of the cost of restoration measures is approximately $20 million (Table 15). This does not include any purchases or easements needed for restoration. Moreover, we were not able to estimate costs of road restoration. One can assume $5 million may be needed for easements and road restoration, which would put costs of restoring Tier 1 and Tier 2 reaches at about $25 million. It needs to be emphasized that these are just ball park estimates for planning purposes. Site visits would be required to confirm restoration measures and to gather information in order to begin to develop more accurate cost estimates.

**Table 15.** Estimate of costs in U.S. dollars for proposed restoration measures (LWD, ELJ, side channels, riparian) based on reach length and area and restoration measures recommended. Costs for road restoration were not estimated and are not included. Costs are for design and construction and do not include purchasing of land, easements, permitting or other costs. These estimates are approximate and site visits would be needed to confirm restoration feasibility and provide data needed to develop more accurate restoration costs.

| Reach | Restoration Measure Recommended | LWD | ELJ | Side Channel | Riparian | Total Cost |
|---|---|---|---|---|---|---|
| | | | **Lower North Fork** | | | |
| **Lewis 1 tidal A** | Side channels, LWD, Riparian | | 834,561 | 1,192,230 | 589,756 | **2,616,547** |
| **Lewis 2 tidal B** | Side channels, LWD, Riparian | | 676,494 | 966,420 | 478,056 | **2,120,970** |
| **Lewis 2 tidal D** | Side channels, LWD, Riparian | | 377,832 | 539,760 | 267,001 | **1,184,593** |
| **Lewis 3** | Side channels, LWD | | 316,134 | 451,620 | | **767,754** |
| **Lewis 4 A** | Side channels, LWD | | 948,675 | 1,355,250 | | **2,303,925** |
| **Lewis 4 C** | Side channels, LWD | | 202,020 | 288,600 | | **490,620** |
| **Ross Creek 1 E** | Invasive removal, livestock & riparian planting to reduce fine sediment, LWD | 99,590 | | | 263,915 | **363,505** |
| **Cedar Creek 1 B** | LWD, side channels | 115,970 | | 621,270 | | **737,240** |
| **Cedar Creek 1 C** | LWD, side channels | 217,890 | | 1,167,270 | | **1,385,160** |
| **Cedar Creek 2 C** | Riparian and LWD | 80,808 | | | 214,141 | **294,949** |
| **Cedar Creek 5** | Riparian and LWD | 72,654 | | | 192,534 | **265,189** |
| **Cedar Creek 6 B** | Riparian and LWD | 200,273 | | | 530,723 | **730,996** |
| **Cedar Creek 6 C** | Riparian and LWD | 84,302 | | | 223,401 | **307,704** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **John Creek 1** | Riparian and LWD | 128,856 | | | 341,468 | **470,324** |
| | | | **Swift Basin** | | | |
| **Lewis 18** | LWD | | 308,490 | | | **308,490** |
| **Lewis 19** | LWD, side channels | | 221,130 | 313,950 | | **535,080** |
| **Lewis 21** | LWD, roads restoration | | 439,530 | | | **439,530** |
| **Swift Campground Creek** | Roads | | | | | |
| **Muddy R 1** | Side channels, LWD | | 1,932,840 | 2,761,200 | | **4,694,040** |
| **Clearwater Tribs** | NA | | | | | **0** |
| | | | | | | |
| **Rush Creek** | Protection (steep channel) | | | | | **0** |
| **Little Creek** | LWD | 81,973 | | | | **81,973** |
| **Spencer Creek** | LWD | 70,252 | | | | **70,252** |
| **Crab Creek** | LWD | 58,604 | | | | **58,604** |
| | | | | | | |
| **Approximate Total Cost** | | | | | | **20,227,446** |

# 5. Data and Analysis needed to refine Restoration actions

In our review of available data, limiting habitat and life stage analysis, and identification of restoration opportunities, we have identified four major data needs or analyses that would help improve and refine potential restoration strategies should aquatic habitat enhancement become the objective. These include additional habitat data needs, historic habitat reconstruction, fish density and use data and field surveys to identify specific restoration actions. We describe each of these in detail below.

## Additional Habitat Data Needs

The habitat data used in both the EDT model and our limiting factors analysis are based on disparate habitat surveys conducted largely in the summer. The most consistent and, presumably, most relevant are habitat surveys conducted recently by USGS in tributaries to Merwin, Yale and Swift reservoirs. However, some of these surveys were conducted during the summer and others during fall and winter (Swift Basin), which creates some inconsistencies as there can be large differences in amounts of habitat in summer and winter, particularly for side channels and floodplains, as well as for pools and glides. For example, it is difficult to quantify during summer surveys what floodplain or side channel habitats are flowing and connected to the channel. While the USGS habitat data collected above appear to be of high quality, the habitat data for the lower basin are from multiple sources, including maps and professional opinion. In addition, many of these are from a previous run of EDT and are more than 10 years old. Thus, there is a large inconsistency in quality of data for the upper (upstream of Merwin) and lower basin that will influence the results of any habitat modeling efforts. To rectify these habitat data problems, we first recommend summer habitat surveys for anadromous reaches of the North Fork of Lewis and its tributaries downstream of Merwin Dam, similar to those conducted by USGS upstream of Merwin Dam. Second, winter (December to February) habitat surveys should be conducted in anadromous reaches of the entire basin, as summer habitat surveys cannot be relied upon to measure key winter habitat types such as side channels and other seasonally wetted areas. Both the summer and winter surveys, should be modified to collect important information on restoration opportunities (e.g., bank armoring, disconnected side channels, beaver ponds).

Other habitat data that would be useful for identifying restoration opportunities include survey of bank armoring and levees throughout the North Fork of Lewis Basin and quantifying current beaver dams and off-channel habitats. Both of these could initially be collected during habitat surveys recommended above, though identification of beaver ponds may need to be initially conducted using aerial photographs or other remote sensing.

## Historic Habitat Conditions

While subbasin/recovery planning efforts have provided some cursory estimates of the loss of habitat prior to dam construction (Keefe et al. 2004), detailed information on the historic channel habitat conditions were not available for the North Fork of Lewis and lower mainstem. This information would be very helpful for identification of historic habitat loss and loss in fish production due to channelization and agricultural development, to identify potential restoration opportunities, and to assess factors which may have historically limited fish production. We've obtained the General Land Office (GLO) maps and notes from 1870s and later, and these could be coupled with historic aerial photographs (digital ortho photos) to map historic channel conditions and habitat loss. Keefe et al. 2004 did some initial examination of historical aerial photos in North Fork downstream of Merwin dam, but these are only available in text format and restricted to upstream of Eagle Island. Historic habitat conditions for many of the tributaries to Merwin, Yale, and Swift could be estimated based on "reference" conditions in areas of the basin that have not been heavily impacted from human activity. Presumably there are some areas in tributaries to Swift on U.S. Forest Service land that provide reference conditions which could be applied to other areas of the watershed.

Prior to trapping and European settlement, beavers and the associated habitat they create were widespread in the Lewis basin and elsewhere in the Pacific Northwest. Protecting and enhancing beaver populations has been demonstrated to be a strategy for restoring habitats, reconnecting floodplains, increasing salmon production, and ameliorating impacts of climate change (Pollock et al. 2003, 2004; Beechie et al. 2013; Devries et al. 2012). Estimating the loss of historic beaver habitat and the potential areas of enhancing beaver and beaver ponds throughout the North Fork of Lewis Basin would provide important information on loss of salmon production and in identifying restoration opportunities.

## Fish Density and Use

Because no data on juvenile coho, steelhead, or spring Chinook habitat use were available for Lewis basin, we relied on habitat specific fish densities from other areas to determine limiting habitat and life stage. Both Beechie et al. (1994) and Reeves et al. (1989) recommended using local data when possible to conduct limiting factors analysis using their methods. While extensive data exist for coho salmon in western Washington, limited data exist for steelhead, and almost no data are available for juvenile spring Chinook. This could be rectified by sampling a subset of major habitat types (pools, riffles, glides, beaver ponds, side channels, mainstems, tributaries) during summer and winter to determine local densities of juvenile coho, steelhead and spring Chinook. A potential drawback for spring Chinook is that levels are likely so low that densities would be low in all habitats. However, adequate numbers of coho and steelhead are likely to be found in areas downstream of Merwin Dam and perhaps in some tributaries to Swift Reservoir. Having basin-specific data on juvenile coho, Chinook, and steelhead densities in both mainstem and tributary habitat types would greatly improve the accuracy of estimates of fish capacity and production potential. Moreover, it would help identify restoration opportunities by providing specific biological data in habitats of differing quality and type.

The large amount of reservoir habitat and the limited information on the size and depth of littoral habitat used by Chinook and coho, highlight the need for detailed information on the use of reservoirs by juvenile Chinook and coho for rearing. This information could be obtained from periodic snorkel or dive surveys combined with trapping in order to quantify the depth at which and season during which fish use different parts of the reservoir. It would also help refine estimates of the capacity and smolt production from reservoirs.

## Detailed Surveys to Identify Specific Restoration Actions

We identified initial reaches that are priorities for restoration based on available instream habitat surveys, remote sensing and modeling, EDT modeling, and limiting life stage and habitat analysis. To confirm that restoration opportunities do exist in these reaches, and to identify specific restoration opportunities, requires more detailed field investigations in each of these reaches. First, site visits would be needed to confirm restoration opportunities and determine existing habitat, geomorphic and hydraulic conditions for restoration design. Second, based on these initial surveys, specific restoration opportunities would be identified within reaches and then reaches reprioritized. Next, the highest priority sites would be revisited, surveyed, and a base map created to assist in project design and the development of design alternatives. This process would produce a list of specific projects and conceptual designs which could then be prioritized and selected for complete design and implementation.

# References

Bartz, K. K., K. M. Lagueux, M. D. Scheuerell, T. Beechie, A. D. Haas, and M. H. Ruckelshaus. 2006. Translating restoration scenarios into habitat conditions: an initial step in evaluating recovery strategies for Chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 63(7):1578-1595.

Beechie, T., E. Beamer, and L. Wasserman. 1994. Estimating coho salmon rearing habitat and smolt production losses in a large river basin, and implications for habitat restoration. North American Journal of Fisheries Management 14(4):797-811.

Beechie, T., M. Liermann, E. M. Beamer and R. Henderson. 2005. A classification of habitat types in a large river and their use by juvenile salmonids. Transactions of the American Fisheries Society 134:717-729.

Beechie, T.J., M. Liermann, M. M. Pollock, S. Baker, and J. Davies. 2006 Channel pattern and river-floodplain dynamics in forested mountain river systems. Geomorphology 78:124–141.

Beechie, T. , G. Pess, S. Morley, L. Butler, P. Downs, A. Maltby, P. Skidmore, S. Clayton, C. Muhlfeld, and K. Hanson. 2013. Watershed assessments and identification of restoration needs. Pages 50 to 113 in Roni, P. and Beechie, T. (eds.) Stream and watershed Restoration: A Guide to Restoring Riverine Processes and Habitats. Wiley-Blackwell, Chichester, UK.

Beechie, T., and H. Imaki. 2014. Predicting natural channel patterns based on landscape and geomorphic controls in the Columbia River basin, USA. Water Resources Research 50, 39–57, doi:10.1002/2013WR013629,

Beechie, T., H. Imaki, J. Greene, A. Wade, H. Wu, G. Pess, P. Roni, J. Kimball, J. Stanford, P. Kiffney, and N. Mantua. 2013. Restoring salmon habitat for a changing climate. River Research and Applications 29: 939–960.

Burner, C. J. 1951. Characteristics of spawning nests of Columbia River salmon. Fishery Bulletin 52:97-110.

DeVries, P., K. L. Fetherston, A. Vitale, and S. Madsen. 2012. Emulating riverine landscape controls of beaver in stream restoration. Fisheries 37(6):246-255.

Giorgi, H. and K. Malone. 2013. Reservoir rearing and migration issues Willamette Basin Projects: Chinook. Unpublished report.

Fullerton, A. H., T. J. Beechie, S. E. Baker, J. E. Hall, and K. A. Barnas. 2006. Regional patterns of riparian characteristics in the interior Columbia River basin, Northwestern USA: applications for restoration planning. Landscape Ecology 21(8):1347-1360.

Fullerton, A. H., D. Jensen, E. A. Steel, d. Miller and P. McElhany. 2010a. How certain are salmon recovery forecasts? A watershed-scale sensitivity analysis. Environmental monitoring and assessment 15: 13-26.

Fullerton, A. H., E. A. Steel, I. Lange, and Y. Caras. 2010b. Effects of spatial pattern and economic uncertainties on freshwater habitat restoration planning: A simulation exercise. Restoration Ecology 18:354-369.

Lastelle, L. C. 2005. Guidelines for Rating Level 2 Environmental Attributes in Ecosystem Diagnosis and Treatment (EDT). Jones and Stokes, Inc.

Keefe, M., R. Campbell, P. DeVries, S. Madsen, and D. Riser. 2004. Chapter 3: The North Fork Lewis Basin. Prepared by R2 Natural Resource Consultants for Lower Columbia Fish Recovery Board, Longview, Washington. 114 pages.

McElhany, P., E. A. Steele, K. Avery, N. Yoder, and C. Busack. 2010. Dealing with uncertainty in ecosystem models: lessons from a complex salmon model. Ecological Applications 20:465-482.

Montgomery, D. R., and J. M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin 109(5):596-611.

Monzyk, F.R., R. Emig, J.D. Romer and T. A. Friesen. 2013. Life-history characteristics of juvenile spring Chinook salmon rearing in Willamette Valley Reservoirs. Prepared for U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Morley, S. A., P. S. Garcia, T. R. Bennett, and P. Roni. 2005. Juvenile salmonid (*Oncorhynchus* spp.) use of constructed and natural side channels in Pacific Northwest rivers. Canadian Journal of Fisheries and Aquatic Sciences. 62(12):2811-2821.

Kareiva, P., M. Marvier, and M. McClure. 2000. Recovery and management options for Spring/Summer chinook salmon in the Columbia River Basin. Science 290(5493):977-979.

Keefe, M., R. Campbell, P. DeVries, S. Madsen, and D. Riser. 2004. Chapter 3: The North Fork Lewis Basin. Prepared by R2 Natural Resource Consultants for Lower Columbia Fish Recover Board, Longview, Washington. 114 pages.

LCFRB. 2010. North Fork of Lewis Sub basin. Chapter K in Lower Columbia River Fish and Wildlife Sub basin Plan. 222 pages.

Manly, B. F. J. 2006. Randomization, bootstrapping, and Monte Carlo methods in biology. Taylor and Francis, London.

Morley, S. A., P. S. Garcia, T. R. Bennett, and P. Roni. 2005. Juvenile salmonid (*Oncorhynchus spp.*) use of constructed and natural side channels in Pacific Northwest rivers. Canadian Journal of Fisheries and Aquatic Sciences. 62(12):2811-2821.

Pess, G., M. Liermann, M. McHenry, R. J. Peters and T.R. Bennett. 2012. Juvenile salmonid response to the placement of engineered logjams (ELJs) in the Elwha River. River Research and Applications 28:872–881.

Pollock, M. M., M. Heim, and D. Werner. 2003. Hydrologic and geomorphic effects of beaver dams and their influence on fishes. Pages 213-233 *in* S. V. Gregory, K. L. Boyer, and A. M. Gurnell, editors. The Ecology and Management of Wood in World Rivers - Proceedings of the International Conference on Wood in World Rivers. American Fisheries Society, Corvallis, OR.

Pollock, M. M., G. R. Pess, and T. J. Beechie. 2004. The importance of beaver ponds to coho salmon production in the Stillaguamish River basin, Washington, USA. North American Journal of Fisheries Management 24(3):749-760.

Reeves, G. H., F. H. Everest, T. E. Nickelson and E. Thomas. 1989. Identification of physical habitats limiting the production of coho salmon in western Oregon and Washington. USDA For. Serv. Pac. NW. Res. Stn., PNW-GTR-245, Portland, Oregon.

Reeves, G. H., F.H. Everest, and F. H. Nickelson, and E. Thomas. Unpublished. Identification of physical factors limiting the production of summer-run steelhead trout (Oncorhynchus mykiss) in streams of Oregon and Washington. Unpublished report. USDA For. Serv. Pac. NW. Res. Stn.

Roni, P. 2003. Habitat use by fishes and Pacific giant salamanders in small western Oregon and Washington streams. Transactions of the American Fisheries Society 131:743-761.

Roni, P., and T. P. Quinn. 2001. Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58: 282–292.

Roni, P., C. Dietrich, D. King, S. Morley, and P. Garcia. 2006. Coho smolt production from constructed and natural floodplain habitats. Transactions of the American Fisheries Society 135:1398–1408.

Roni, P., G. Pess, S. T. Beechie and S. Morley. 2010. Estimating changes in coho salmon and steelhead abundance from watershed restoration: how much restoration is needed to measurably increase smolt production? North American Journal of Fisheries Management 30:1469–1484.

Roni, P. and T. Beechie. 2013. Stream and watershed restoration: a guide to restoring riverine processes and habitats. Wiley-Blackwell, Chichester, U.K.

Roni, P., G. Pess, K. Hanson, and M. Pearsons. 2013. Chapter 5: Selecting appropriate stream and watershed restoration techniques. Pages 144-188 in Roni, P. and Beechie, T. (eds.) Stream and watershed Restoration: A Guide to Restoring Riverine Processes and Habitats. Wiley-Blackwell, Chichester, UK.

Scheuerell, M. D., R. Hilborn, M. H. Ruckelshaus, K. K. Bartz, K. M. Lagueux, A. D. Haas, and K. Rawson. 2006. The Shiraz model: a tool for incorporating anthropogenic effects and fish–habitat relationships in conservation planning. Canadian Journal of Fisheries and Aquatic Sciences 63(7):1596-1607.

Steel, E. A., P. McElhany, N. J. Yoder, M. D. Purser, K. Malone, B. E. Thompson, K. A. Avery, D. Jensen, G. Blair, C. Busack, M. D. Bowen, J. Hubble, and T. Kantz. 2009. Making the best use of modeled data: multiple approaches to sensitivity analysis of a fish-habitat model. Fisheries 34(7):330-339.

Tabor, R.A., K. L. Fresh, R. M. Piaskowski, H. A. Gearns and D. B. Hayes. 2011. Habitat use by juvenile Chinook Salmon in the nearshore areas of Lake Washington: effects of depth, lakeshore development, substrate, and vegetation. North American Journal of Fisheries Management, 31:4, 700-713, DOI: 10.1080/02755947.2011.611424

# APPENDIX A: HABITAT SPECIFIC DENSITIES AND SMOLT PRODUCTION POTENTIAL

**Table A-1.** Habitat specific densities, survival to smolt stage and smolt production potential for Coho salmon. Modified from Pollock et al. (2004) which was based on Reeves et al. (1989) and Beechie et al. (1994).

| Habitat Type | Density/m2 | Survival to smolt stage | Smolt Production Potential (smolts $m^{-2}$) |
|---|---|---|---|
| **Side channel** | | | |
| **Summer** | 1.275 | 0.25 | 0.319 smolts $m^{-2}$ |
| **Winter** | 2.5 | 0.31 | 0.775 smolts $m^{-2}$ |
| **Tributaries (<10m low flow width)** | | | |
| **Summer pool** | 1.7 | 0.25 | 0.425 smolts $m^{-2}$ |
| **Summer glide** | 1.19 | 0.25 | 0.297 smolts $m^{-2}$ |
| **Summer riffle** | 0.85 | 0.25 | 0.213 smolts $m^{-2}$ |
| **Winter pool** | 3.5 | 0.31 | 1.085 smolts $m^{-2}$ |
| **Winter riffle** | | | 0.000 smolts $m^{-2}$ |
| | | | |
| **Main stem** | | | |
| **summer** | | | 600 smolts $km^{-1}$ |
| **winter** | | | 600 smolts $km^{-1}$ |
| | | | |
| **Pond** | | | |
| **Summer pond (all sizes)** | 1.5 | 0.25 | 0.375 smolts $m^{-2}$ |
| **Winter pond < 500 m2** | 5 | 0.31 | 1.550 smolts $m^{-2}$ |
| **Winter pond > .500 m2** | 2.5 | 0.31 | 0.775 smolts $m^{-2}$ |
| | | | |
| **Lake/Reservoir** | | | 25 $hectare^{-1}$ |
| | | | |
| **Spawning** | | | 60 smolts $m^{-2}$ |

**Table A-2.** Habitat specific densities, survival to smolt stage and smolt production potential for steelhead. Sources Reeves et al. (Unpublished)(spawning habitat), Roni et al. (2003)(tributaries), and Morley et al. (2005)(side channels), Beechie et al. (2005)(main stem).

| Habitat Type | Parr/smolt density ($m^{-2}$) | Survival to smolt stage | Smolt Production Potential (smolts/$m^{-2}$) |
|---|---|---|---|
| **Side channel** | | | |
| **Summer** | 0.09 | 0.57 | 0.051 |
| **Winter** | 0.32 | 0.6 | 0.192 |
| **Small and large tributaries (<10m low flow width)** | | | |
| **Summer pool** | 0.104 | 0.57 | 0.059 |
| **Summer glide** | 0.0965 | 0.57 | 0.055 |
| **Summer riffle** | 0.089 | 0.57 | 0.051 |
| **Winter pool** | 0.0407 | 0.6 | 0.024 |
| **Winter glide** | 0.02385 | 0.6 | 0.014 |
| **Winter riffle** | 0.007 | 0.6 | 0.004 |
| | | | |
| **Main stem** | | | |
| **Summer** | 0.011 | 0.57 | 0.006 |
| **Winter** | 0.011 | 0.6 | 0.007 |
| | | | |
| **Spawning** | | | |
| **Spawning** | | | 8.08 |

**Table A-3.** Habitat specific densities, survival to smolt stage and smolt production potential for spring Chinook salmon. Source Bartz et al. (2006). Survival to smolt stage from Reeves et al. (1989) except reservoir survival from Giorgi and Malone (2013).

| Habitat | Parr density | Survival to smolt stage | Smolt Production Potential (smolts/m$^{-2}$) |
|---|---|---|---|
| **Side channel - summer** | 0.45 | 0.25 | 0.11 |
| | | | |
| **Tributaries -summer** | | | |
| **Summer pool** | 0.505 | 0.25 | 0.13 |
| **Summer glide** | 0.138 | 0.25 | 0.03 |
| **Summer riffle** | 0.071 | 0.25 | 0.02 |
| | | | |
| **Main stem -summer** | | | |
| **Main stem pool** | 0.072 | 0.25 | 0.02 |
| **Main stem riffle** | 0.011 | 0.25 | 0.00 |
| **Main stem glide** | 0.146 | 0.25 | 0.04 |
| **Main stem avg.** | 0.076333 | 0.25 | 0.02 |
| | | | |
| **Ponds** | 0.032 | 0.25 | 0.01 |
| | | | |
| **Lake/Reservoir** | 0.056 | 0.19 | 0.01 |
| | | | |
| **Spawning** | | | |
| **Spawning habitat** | | | 52.4 |

# APPENDIX B: ANNOTATED BIBLIOGRAPHY

Al-Chokhachy, M. Sorel, D. Beauchamp, and C. Clark. 2015. Development of New Information to Inform Fish Passage Decisions at the Yale and Merwin Hydro Projects on the Lewis River: Annual Progress Report, August, 2015. 103 pp.

*This annual report presents a biophysical assessment of Lake Merwin and Yale Lake on the Lewis River. There are estimates of relative abundances of species in both reservoirs as well as habitat assessments that include tributary streams for each reservoir. The evaluation includes an assessment of habitat in the reservoirs, including tributary habitats, the potential for adult spawning success, the juvenile production potential and emigration success, predator impacts in Lake Merwin, and interactions between resident and anadromous fish populations. Habitat parameters evaluated include tributary size, surface area of habitat units, average depth, LWD and fine sediment, streambed particle size distributions, summer and fall temperatures for 2013 and 2014, DO, gradient, and riparian function, and a map of barriers. Objectives included assessments of potential adult spawning success and juvenile production potential and emigration success. In addition, there was an evaluation of predator impacts in Lake Merwin, and modeling of interactions between resident and anadromous populations of fish.*

Beechie, T. and H. Imaki. 2014. Predicting natural channel patterns based on landscape and geomorphic controls in the Columbia River basin, USA. Water Resources Research 50:39-57.

*Columbia Basin wide analysis using available geospatial data sets to calculate reach slopes, channel types, 2 year flood discharge, valley confinement as well as predict sediment load and size. This includes maps of predicted channel types and valley confinement for Lewis River Basin. [T. Beechie at NOAA provided us with all data and maps for Lewis River Basin]*

Chambers, J.S. 1957. Report on the 1956 survey of the North Fork of the Lewis River above Yale Dam. State of Washington Department of Fisheries. WA-1-539, 9:L585-957. 41 pp.

*This report presents the results of the 1956 investigation of existing conditions for salmon spawning and rearing in the North Fork Lewis River and tributaries above Yale Dam, with special emphasis on stretches suitable for salmon spawning and those areas that will be inundated by the dam impoundments. A supplemental experiment to determine the feasibility of estimating the spawning population of Chinook salmon below Merwin Dam was also carried on. The purposes of the research were to determine: salmon migration barriers; suitable spawning habitat following reservoir inundation; loss of spawning habitat due to inundation; location of juvenile rearing; migration timing into stream, duration and extent of spawning; and, ranges of water temperatures and flows. This work was performed on coho salmon because they were the only fish that returned to the trap at Merwin dam from 1953 to 1956.*

Clark County Coalition. 2010. Lewis River Shoreline Inventory and Characterization. Chapter 8 in: Shoreline Master Program WRIA 27 Shoreline Inventory and Characterization Volume 1: Lewis and Salmon-Washougal Watersheds and Rural Areas. Vancouver, WA. pp. 1-68

*This document describes the shoreline conditions of designated waterbodies within the Lewis River basin, part of the Lewis River watershed (Water Resource Inventory Area (WRIA) 27). Waterbodies that drain directly to the Lewis River and lakes within the floodplain of the Lewis River are included. The Lewis River basin includes three shorelines of statewide significance (Lewis River, Lake Merwin and Yale Reservoir), and 11 other shorelines of the state. The document describes the physical and biological conditions in the watershed including designated land use proportions and conditions; and habitat conditions in wetlands, riparian areas, tributaries, mainstem rivers, and lakes. Critical and priority habitats are described as are the species that are known to use them. There is a section on restoration and protection, followed by a reach scale assessment of habitat conditions. This document contains a fairly exhaustive list of references from work done on shoreline and aquatic ecosystems in the Lewis River.*

Clark County Coalition. 2012. Shoreline Master Program WRIA 27 Shoreline Inventory and Characterization Vancouver, WA. pp. 1-106.

*This document presents the approaches taken by Clark County in their Shoreline Master Program (SMP) to meet the requirements of the Shoreline Management Act of 1971, Revised Code of Washington (RCW) Chapter 90.58, and Washington Administrative Code (WAC) Chapter 173-26 as amended. The document lays out goals, policies, and regulations for shoreline use and protection. The goals, policies, and regulations contained herein are tailored to the specific geographic, economic, and environmental needs of Clark County. The final SMP was approved by the Washington Department of Ecology in 2012.*

FERC 2004. Settlement agreement concerning the relicensing of the Lewis River Hydroelectric project FERC Project Nos. 935, 2071, 2111, 2213 Cowlitz, Clark and Skamania counties, Washington. Federal Energy Regulatory Committee, Washington, D.C.

*Licensing agreement laying out the terms between PacifiCorp agencies and other interested parties for the licensing and operation of the Lewis River hydroelectric projects. Of particular interest is Schedule 7.2 which outlines list of potential habitat enhancement projects in lieu of fish passage on Yale and Merwin.*

Fullerton, A.H., D. Jensen, E. A. Steel, D. Miller, and P. McElhany. 2010. How certain are salmon recovery forecasts? A watershed-scale sensitivity analysis. Environmental Model and Assessment 15:13–26

*This study presents a model of compared geospatial models of Lewis River fish habitat conditions. The approach explicitly addresses uncertainty in the data. Specific models tested included riparian functions; sediment and water supply; spawning habitat suitability; egg to fry survival for Chinook, chum, and steelhead; and Chinook spawner capacity. One interesting finding is that for Chinook, the biggest source of variability in smolt output was the age of adult at spawning -Not habitat conditions. [A. Fullerton (NOAA) provided us all model outputs and initial data used in model]*

Fullerton, A.H., E.A. Steel, I. Lange, and Y. Caras. 2010. Effects of spatial pattern on economic uncertainties on freshwater habitat restoration planning: A simulation exercise. Restoration Ecology. doi: 10.1111/j.1526-100X.2009.00620.x. 16pp.

*This paper presents an evaluation of restoration alternatives in the Lewis River. The study found that each subwatershed responded to various restoration actions differently and that* *there was a cumulative benefit to fish that is proportionate with economic investment. One key finding was that the spatial allocation of restoration actions influences the impact on aquatic habitats and associated biota. For example, Chinook egg-to-fry survival all showed greater improvements when restoration actions occurred in contiguous reaches. Managers need tools for prioritizing those projects that are likely to have the greatest success, given economic and spatial constraints. The spatial allocation of restoration actions should influence their impact on aquatic habitats and associated biota. There is extensive literature on the presence of spatial patterns in landscape conditions, land use, and species distributions and on the importance of connectivity of essential habitats for species persistence.*

HDR and EES. 2006. Salmon-Washougal and Lewis Watershed Management Plan WRIA 27-28. Prepared for Lower Columbia Fish Recovery Board, July 2006.

*This planning document describes human and ecosystem components and needs in WRIAs 27 and 28. Considerations of land use and the economy including water resources management (hydropower, ground water, water rights, surface and ground water quality, are covered. in addition, habitat conditions are assessed and described in a tiered ranking of stream reaches. The report focusses on the development of water management strategies into the future and considers their effects on instream conditions. Chapter 7 is dedicated to the management of fish habitat conditions. Chapter 8 outlines the implementation of the plan including adaptive management strategies.*

ICF, Meridian Environmental, Inc., R2 Resource Consultants, and Skalski Statistical Services. 2010. PacifiCorp Energy and Cowlitz County PUD No. 1: Aquatic Monitoring and Evaluation Plan for the Lewis River. 164 pp.

*This is a lengthy report with 22 objectives describing the monitoring and evaluation requirements of the Lewis River Settlement Agreement. The primary focus of the plan is to evaluate upstream fish collection facilities and Merwin Dam, and downstream collection facilities at Swift Dam. Reintroduction is a big part of the plan. However, metrics determining the effectiveness of reintroduction were not developed when this report was prepared. As a result, the plan focuses on those studies needed to determine when the performance standards established in Section 4 of the Settlement are achieved. The plan also provides methods used to monitor and evaluate adult fish spawning escapement, fish passage facility hydraulic performance, flow and ramping rates, resident and anadromous fish interactions, and bull trout and kokanee populations.*

Johnston, G., M. Fox, and J. Lando. 2008. Lewis River Large Woody Debris Assessment. PacifiCorp. Portland, OR. 114pp.

*This report provides an evaluation of historical and contemporary conditions regarding large woody debris (LWD) in the Lewis River. The authors quantified sources and patterns of wood quantities, mechanisms of delivery to streams, and management impacts. In addition, they identified project opportunities intended to restore the basin's supply, and offered project design targets. Finally, the report evaluates fish (Lower Lewis River salmon and steelhead) benefits of proposed LWD restoration actions. These benefits are couched in terms of the physical and biological benefits of LWD, and potential fish productivity.*

Johnston, G., N. Ackerman, and B. Gerke. (CFS) 2005. Chapter 4. East Fork of Lewis Basin habitat assessment. Prepared for Lower Columbia Fish Recovery Board. Cramer Fish Sciences, Gresham, Oregon. 245 pages.

*This is a very detailed and complete assessment of hydromodifications, riparian conditions, stream habitat conditions, and sediment sources. This is the kind of assessment that should be done in every watershed as it includes analysis of historical channel conditions using aerial photos and GLO notes and remote sensing coupled with field surveys to determine impairments and identify restoration actions. They also compare their results with that from EDT and the integrated watershed assessment. Finally, restoration opportunities are identified based on these analyses. Moreover, there are estimates of historic floodplain habitats that would allow a limiting factors analyses, which appears to be the only missing piece.*

Joint explanatory statement for the Settlement Agreement concerning the relicensing of the Lewis River Hydroelectric project FERC Project Nos. 935, 2071, 2111, 2213 Cowlitz, Clark and Skamania counties, Washington. Federal Energy Regulatory Committee, Washington, D.C.

*The purpose of this Explanatory Statement is to summarize the rationale for the measures in the Settlement Agreement. It does not change terms of agreement. In relation to habitat it outlines the aquatic fund, large woody debris program, spawning gravel program, predator study and habitat preparation plan and a summary of aquatic measures for the in lieu of passage. It provides a good summary of criteria for selecting and prioritizing habitat restoration/rehabilitation actions but little detail.*

Jonston, G., and K. Arendt. 2009. Lower East Fork Lewis River Habitat Restoration Plan, Chapter 6, Project Opportunities, Prioritization, and Conceptual Ideas. Hood River, OR. 48 pp.

*This document provides specifics on the 55 restoration projects identified in the previous document. Projects were identified and scored according to the methods described in Chapters 4 and 5. Projects are ranked and estimated costs provided.*

Jonston, G., and K. Arendt. 2009. Lower East Fork Lewis River Habitat Restoration Plan. Hood River, OR. 34 pp.

*This report presents a suite of restoration and assessment opportunities that address reach-scale objectives and strategies. Projects identify life stage limiting factors. Projects are ranked in a final list. There are 55 restoration projects presented in this analysis.*

Keefe, M., R. Campbell, P. DeVries, S. Madsen, and D. Riser. 2004. Chapter 3: The North Fork Lewis Basin. Prepared by R2 Natural Resource Consultants for Lower Columbia Fish Recover Board, Longview, Washington. 114 pages.

*This is an assessment of hydromodifications, riparian and instream habitat conditions and sediment sources including assessment of historic (pre 1930s) floodplain habitat in the lower river. As such, it is very similar, but not as thorough as work done by Johnston et al. (2004) for East Fork of Lewis River. There is a verification of Integrated Watershed Assessment and comparison with EDT for some parameters. Finally, restoration opportunities are identified but in less detail than Johnston et al. (2004). The data and maps* *in this report would be very useful for both assessment and confirming restoration opportunities.*

Keefe, M., R. Campbell, P. DeVries, S. Madsen, and D. Riser. 2004. Kalama, Washougal and Lewis River habitat assessments Chapter 1: Introduction and methods. Prepared by R2 Natural Resource Consultants for Lower Columbia Fish Recover Board, Longview, Washington. 114 pages.

*This provides the methods for the assessments done by R2 Natural Resource consultants on the Lower North Fork of Lewis and other basins. Results of assessments are provided in Chapter 3.*

LCFRB. 2010. Appendix E. Coho capacity. Appendix to Lower Columbia River Fish and Wildlife Sub basin Plan. 12 pages

*This report provides the results of a model to estimate coho capacity based on overwinter habitat in Lower Columbia River Tributaries (including Lower North Fork and East Fork of Lewis basins). It uses the Habitat Limiting Factors Model from Nickelson et al. (1992) and Solazzi et al. (1998). Results were compared to EDT outputs of coho capacity. Winter habitat areas were estimated from summer habitat using regression based on Nickelson (1998), habitat quality was determined from EDT outputs, no estimates of beaver ponds were available or used, and habitat areas for channels greater than 15 meters had to be estimated. This information could be useful for capacity estimates for entire North Fork of Lewis, but has a number of limitations that may have been addressed in Beechie et al. (1998). Note report is dated 2010, but work was done in 2004 and not updated for 2010 LCFRB Plan.*

LCFRB. 2010. Appendix E. Integrated Watershed Assessment. Appendix to Lower Columbia River Fish and Wildlife Sub basin Plan. 12 pages

*This Chapter of the Lower Columbia Salmon Recovery and Fish and Wildlife Sub basin Plan provides and assessment of sediment, hydrology, and riparian conditions in the context of watershed processes. It includes predictions of future trends and makes specific management recommendations. The authors view it as a screening level evaluation useful for preliminary identification of priority areas, and probably sources of some important habitat limiting factors.*

LCFRB. 2010. East Fork of Lewis Sub basin. Chapter L in Lower Columbia River Fish and Wildlife Sub basin Plan. 108 pages.

*This plan follows the same format and analysis as that for North Fork of Lewis and includes similar assessments and analyses (e.g., Integrated Watershed Assessment (IWA), Ecosystem Diagnosis and Treatment(EDT)) Priorities for habitat restoration include: restore floodplain function, riparian function and stream habitat diversity; manage growth and development to protect watershed processes and habitat conditions; manage forest lands to protect and restore watershed processes; restore passage at culverts and other artificial barriers; and address immediate risks with short-term habitat fixes (chum spawning channels, alcoves, engineered log jams). Much of this was determined from IWA and EDT analysis with additional information coming from Wade (2000), USFS Watershed Analysis (1995) in Upper East Fork and Lower East Fork (1996), as well as Sweet et al. (2003) analysis of gravel mining operation. There is a decent list of high level restoration* *and protection actions and reach priorities that will be useful for updating potential restoration actions. There is good information on historic channel conditions in Lower EF and it appears that Sweet et al. (2003) has done historical analysis using GLO notes and aerial photographs. Similarly CFS (Johnston et al. 2004), did an analysis of historic photos in EF Lewis.*

LCFRB. 2010. North Fork of Lewis Sub basin. Chapter K in Lower Columbia River Fish and Wildlife Sub basin Plan. 222 pages.

*This Plan describes a vision, strategy, and actions for recovery of listed salmon, steelhead, and trout species to healthy and harvestable levels, and mitigation of the effects of the Columbia River Hydro system for the North Fork of Lewis Sub basin. This plan for the Lower North Fork Lewis River Basin describes implementation of the regional approach within this basin, as well as assessments of local fish populations, limiting factors, and ongoing activities that underlie local recovery or mitigation actions. The plan was developed in a partnership between the Lower Columbia Fish Recovery Board (LCFRB), Northwest Power and Conservation Council (NPCC), federal agencies, state agencies, tribal nations, local governments, and others. Priorities for habitat restoration include: restore floodplain function, riparian function and stream habitat diversity; manage growth and development to protect watershed processes and habitat conditions; manage forest lands to protect and restore watershed processes; restore passage at culverts and other artificial barriers; and address immediate risks with short-term habitat fixes (chum spawning channels, alcoves, and engineered log jams). Habitat conditions are described based on integrated watershed assessment (IWA). Other than hydropower system, there are some other barriers. Good general description of habitat limiting factors - most of which appear to come from Wade (2000). This includes indicating riparian analysis which was done in 1994 and 1995 and loss of floodplain habitat in lower River of 50%. Stream habitat analysis for Lower and Upper N.F. Lewis were done separately using EDT. Integrated Watershed Assessment for Lower and Upper N.F. Lewis were also done separately and provide information on sub basins with impaired sediment, riparian and hydrology. Priority areas for restoration and limiting factors were determined through the technical assessment, including primarily EDT analysis and the Integrated Watershed Assessment (IWA). Finally, there is a decent list of high level restoration and protection actions and reach priorities that will be useful for updating potential restoration actions.*

Lestelle, L.C. 2005. Guidelines for Rating Level 2 Environmental Attributes in Ecosystem Diagnosis and Treatment (EDT). Mobrand - Jones & Stokes. 148 pp.

*This document provides guidelines for rating Level 2 Environmental Attributes used in Ecosystem Diagnosis and Treatment (EDT). Level 2 Environmental Attributes are a standardized set of attributes for characterizing the freshwater environment as it affects salmonid fish species. The EDT model estimates the biological potential of a stream based on the Level 2 characterization. Fish performance in an environment is estimated by linking the species-neutral Level 2 characterization to a species-specific Level 3 characterization of survival and capacity of the environment for the species. EDT uses a set of species-habitat relationships or "rules" to link the Level 2 Environmental Attributes to the Level 3 Survival Factors.*

Loxterman, J. 2003. Technical Memo to WDFW, PacifiCorp, and Cowlitz PUD evaluating the genetic structure of rainbow trout and steelhead in the Lewis River watershed. Washington

State Department of Fish and Wildlife Fish Program, Science Division, Genetics Lab. 16 pp.

*This technical memo outlines an evaluation of the genetic structure of rainbow trout and steelhead in the Lewis River watershed. The goals of the study were to determine 1) the genetic composition of stocks in the Lewis River watershed, 2) how the different stocks are related to one another, and 3) the most suitable steelhead stock for reintroduction into the upper Lewis River. To One potentially important conclusion from this work is that the introduction of non-native steelhead (i.e. Merwin Hatchery) into the NF Lewis River could compromise the genetic integrity of the NF Lewis River O. mykiss subpopulation.*

McElhany, P., A. Steel, K. Avery, N. Yoder, C. Busack, and B. Thompson. 2010. Dealing with uncertainty in ecosystem models: lessons from a complex salmon model. Ecological Applications, 20(2), 2010, pp. 465–482.

*This paper presents a sensitivity analysis on EDT. The authors evaluated variation in output, prediction intervals, and sensitivity. Results suggest EDT is probably more useful as a relative measure of fish performance than as an absolute measure. Take Home: "...With slightly different yet plausible inputs, the EDT model could produce quite different results for two commonly used model outputs: capacity and productivity."*

Mobrand Biometrics. 2004. Appendix E: Upper Lewis EDT Analysis. In: In: S.P. Cramer & Associates. Lewis River Fish Planning Document. S.P. Cramer & Associates, Gresham, OR. pp E-1- E-65.

*This document is an appendix to the Lewis River Fish Planning Document prepared by S.P. Cramer & Associates. It presents Ecosystem Diagnosis and Treatment (EDT) modeling results from the East Fork of the Lewis River. The effort was undertaken to determine the potential of the stream habitat upstream of Merwin Dam to support anadromous salmonids. To achieve this objective PacifiCorp in consultation with the Aquatic Resources Group modeled habitat potential using the EDT methodology and modeling tools. The reach analysis estimates differences in survival by life stage based on historic and current habitat conditions. Results suggested that current (2004) habitat conditions could produce approximately 17% as many salmon as historic conditions.*

NMFS. 2013. ESA Recovery Plan for Lower Columbia River coho salmon, Lower Columbia River Chinook, Columbia River chum, and Lower Columbia River Steelhead. NMFS Northwest Region, Portland, OR.

*This is a lengthy recovery plan for Lower Columbia River Chinook salmon, Steelhead, coho and Columbia River chum in Oregon and Washington. It outlines general recovery goals for four species with particular emphasis on viable salmon population parameters and limiting factors. Critical habitat and habitat limiting factors are only discussed cursorily and there is little specific information related to Lewis Basin.*

Northwest Power and Conservation Council. 2004. Volume VI: Chapter 6, EDT Application.

*In this Appendix to the Salmon Recovery Plan for the Lower Columbia, 83 populations were assessed through the EDT model. The modeling represents all of the major basins with significant anadromous fish use on the Washington side of the Lower Columbia River. Populations include native runs of winter and summer steelhead, chum, fall and spring*

*Chinook, and coho. EDT modeling runs were completed for the Lower NF Lewis, EF Lewis (WDFW LCFRB 2003/ 2004), and the Upper NF Lewis (PacifiCorp, 2003). The Lower NF Lewis and EF Lewis models included all fish listed above except spring Chinook. The Upper NF Lewis modeling focused on spring Chinook, winter steelhead, and coho. One objective of these modeling exercises was to generate reach rankings for preservation and restoration actions. The models attempt to combine all life stages within a reach to estimate the relative contribution of a reach to overall population abundance. The report evaluates the model including potential sources of errors and compares results against empirical observations. One of the potentially most important future comparisons called for in this report is between EDT and the Integrated Watershed Assessment to identify potential limits in each approach.*

PacifiCorp. 2004. Schedule 7.2: Scope of Spawning Gravel Study, In: Lewis River Hydroelectric Projects Settlement Agreement. 17 pp.

*This section of the Lewis River Hydroelectric Agreement outlines a list of projects and priorities, some of which qualify as mitigation. They are presented in a prioritized fashion, ranging from "High" to "Low". Information is presented in a large table of limiting factors similar to those used by the Lower Columbia Fish Recovery Board. Limiting factors are presented for a wide range of factors, not simply those related to spawning gravel conditions. They include fish passage, riparian condition, floodplain condition, sediment, channel/ LWD conditions, water quality, water quantity, and other biological processes.*

S.P. Cramer & Associates. 2004. Appendix B: Salmon PopCycle Model Structure Instructions for Use and Assumptions. In: S.P. Cramer & Associates. Lewis River Fish Planning Document. S.P. Cramer & Associates, Gresham, OR. Pp B-1-B-32.

*This document is an appendix to the Lewis River Fish Planning Document prepared by S.P. Cramer & Associates. It presents an application of the Salmon PopCycle model is a series of mathematical equations used to estimate future salmon or steelhead numbers based on numbers of eggs, juveniles, or adults outplanted or passed above Merwin, Yale, or Swift dams, survival rates, and reproduction rates. The model breaks the salmon life cycle into different stages so that the effects of specific activities and limiting factors can be evaluated. The model has some important limitations that stem from modeling assumptions. For example, all species are assumed to be the same. In addition, the model is run at an annual time step.*

Simenstad, C.A., J.L. Burke, J.E. O'Connor, C. Cannon, D.W. Heatwole, M.F. Ramirez, I.R. Waite, T.D. Counihan, and K.L. Jones. 2011. Columbia River Estuary Ecosystem Classification - Concept and Application.

*This report describes a hierarchical ecosystem classification of the Columbia River estuary that integrates saline and tidal freshwater reaches and includes the tidally influenced reaches of the Lewis River. The classification captures the scales and categories of biophysical ecosystem structures and processes influencing distinct geomorphic landforms, structures, ecosystems, habitats, and components of the estuarine landscape. The Classification is intended to support metadata analyses of abiotic and biotic conditions among different estuary systems.*

Smoker, W.M., J.M. Hurley, and R.C. Meigs. 1951. Compilation of observations on the effect of Ariel Dam on the production of salmon and trout in the Lewis River. State of Washington Department of Fisheries and State of Washington Department of Game. Seattle, WA. 28 pp.

*This report presents findings of a study of the ways in which fish runs have changed since the construction of the Ariel Dam on the Lewis River and to try to predict the effect that construction of the Yale Dam might have on fish runs. It also presents a needs assessment of additional fish facilities relative to those expected impacts. The study recounts impacts to fish runs caused by the dam operations, minimally effective fish passage, hatchery failures, and natural production failure from spillway operations.*

Steel, E.A., A. Fullerton, Y. Caras, M.B. Sheer, P. Olson, D. Jensen, J. Burke, M. Maher, and P. McElhany. 2008. A spatially explicit decision support system for watershed-scale management of salmon. Ecology and Society 13(2): 50. [online] URL:http://www.ecologyandsociety.org/vol13/iss2/art50/

*This peer-reviewed paper presents a spatially explicit model that evaluates watershed-scale management actions for Pacific salmon in the Lewis River watershed. The model identified strategies, and actions and their expected effect on the landscape. Modeled predictions of the quantity, quality, and distribution of restoration actions and how these restoration scenarios affect habitat capacity and survival rates for multiple species of salmonid fishes.*

Sweet, H.R. 2003. Habitat Conservation Plan - J.L. Storedahl & Sons, Inc. Daybreak Mine Expansion and Habitat Enhancement Project. R2 Resource Consultants, Inc. Redmond, Washington.

*Habitat conservation plan for Daybreak Gravel Mine Expansion on East Fork of Lewis. Contains some information on current and historic habitat conditions that might be useful if additional restoration measures are identified in East Fork. However, much of this information should have been in Johnston et al. (2004).*

Vanderwal Dune, K. 2004. WTS2 Appendix 1: Monthly Flow Duration Curves. 47 pp.

*This technical appendix presents hydrology studies for the Lewis River Hydroelectric Projects for FERC licenses Project Nos: 935, 2071, 2111, and 2213. The study analyzed daily flows and peak flows to characterize the hydrology in 6 reaches of the Lewis River, Speelyai Creek, and the Swift No. 2 Canal. The study objectives included typical hydrologic patterns of flow such as monthly flow duration, daily exceedance curves, baseflow magnitudes and timing, and flood frequency. These analyses were compared to historic conditions back to 1910 in some cases. The intent was to understand historical and current hydrologic patterns to quantify the effects of the hydropower facilities.*

Vanderwal Dune, K. 2004. WTS3 Stream channel, morphology, and aquatic habitat study. 126 pp.

*This technical appendix focusses on stream channel morphology and aquatic habitat conditions in the Lewis River between Merwin Dam and Eagle Island, the Swift bypass reach, and Speelyai Creek. The study aims to document existing habitat conditions, assess how Lewis River hydropower dam operations affect stream morphology and habitat, and estimate effects of potential management on water, wood, and sediment inputs in affected reaches. Channel changes back through time, as well as LWD inputs were assessed to see if* *they were related to Chinook spawning distributions. Anthropogenic activities such as gravel mining and bank hardening have caused channel simplification and straightening. Active bars decreased, and vegetated bars increased. By contrast, no incision or aggradation has occurred since 1974 suggesting stable sediment dynamic.*

Wade, G., 2000. Salmon and Steelhead Habitat Limiting Factors: Water Resource Inventory Area 27. Washington State Conservation Commission Final Report. Olympia, WA. 120 pp.

*This report describes habitat limiting factors for salmon (spring Chinook, fall Chinook, coho, and chum) and winter and summer steelhead in WRIA 27 including the Lewis River. It presents different results for the Lewis both above and below Merwin Dam and the east fork Lewis. Results are presented in terms of habitat in need of protection, habitat limiting factors, and highlights important data gaps. Results include slopes and elevations, stream discharge and temperature, fish distributions, WUA estimates (Kalama and EF Lewis), channel migration rates in the EF Lewis, and various water quality problems. Habitat limiting factors are summed by subbasin. General findings include a lack of LWD, poor riparian conditions, water quality and quantity issues, and disconnection of river and floodplain habitats. Recommendations for addressing these challenges are presented.*

Watershed Sciences. 2001. Aerial Surveys in the Lewis River Basin: Thermal Infrared and Color Videography. Report to PacifiCorp. March 22, 2001. Portland, OR. 26 pp.

*This report is a thermal assessment of approximately 40 combined miles of the lower Lewis River, lower EF Lewis River, and lower Cedar Creek in the Lewis River drainage. Forward looking infrared (FLIR) sensors and color videography were used to measure the thermal characteristics of the study reaches on the morning of March 22, 2001. The timing of the flight was set to detect relatively warm inputs of groundwater that might indicate desirable habitat conditions or opportunities for restoration. The data were spatially corrected and analyzed as grids in ArcGIS. The report contains FLIR images paired with still shots of the same area that were collected simultaneously.*

## ADDITIONAL DATA SOURCES AND MAPS

| Description | File Location | Year |
|---|---|---|
| Disk7 – Fullerton Model Details | NOAA Data Fullerton | 2010 |
| EDT Basics | NOAA Data Fullerton | 2010 |
| Habitat Survey Files | NOAA Data Fullerton | 2010 |
| Historic Channel | NOAA Data Fullerton | 2010 |
| IVMP Files | NOAA Data Fullerton | 2010 |
| Lewis Basin channel type data | NOAA Data Beechie | 2014 |
| Lewis DSS | NOAA Data Fullerton | 2010 |
| Lewis DSS zip | NOAA Data Fullerton | 2010 |
| Lewis Long Profiles | NOAA Data Fullerton | 2010 |
| Lewis Model Best Files | NOAA Data Fullerton | 2010 |
| Lewis TIR | NOAA Data Fullerton | 2010 |
| Meta Poly | NOAA Data Fullerton | 2010 |
| More IVMP | NOAA Data Fullerton | 2010 |
| Shapefiles | NOAA Data Fullerton | 2010 |
| Slope Stability | NOAA Data Fullerton | 2010 |
| Fish Distribution Maps | PacifiCorp Aquatic Relicensing Reports Aquatics Appendices AQU 1 Appendix 1 | 2004 |
| WRIA 27 Fish Distribution Maps and Barriers | PacifiCorp Aquatic Relicensing Reports Aquatics Appendices AQU 1 Appendix 2 | 2004 |
| Species Periodicity in Relation to Flows Downstream of Merwin Dam | PacifiCorp Aquatic Relicensing Reports Aquatics Appendices AQU 3 Appendix 3 | 2004 |
| Habitat Data Summary Sheets and Photographs of Reaches Potentially Accessible to Anadromous Fish Above Merwin Dam | PacifiCorp Aquatic Relicensing Reports Aquatics Appendices AQU 4 Appendix 1 | 2004 |
| Location of Radio-tagged Juvenile Coho Salmon in Swift Reservoir | PacifiCorp Aquatic Relicensing Reports Aquatics Appendices AQU 14A Appendix 1 | 2004 |
| Location of Radio-tagged Juvenile Chinook Salmon in Swift Reservoir | PacifiCorp Aquatic Relicensing Reports Aquatics Appendices AQU 14B Appendix 1 | 2004 |
| USGS data for EDT analyses. Include: Excel spreadsheet of habitat in Merwin, Yale, and their tributaries. Access Database. Excel Spreadsheet of | These data were collected and reported in Al-Chochasky et al., 2015 | 2015 |

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| summary data. | | |

## OTHER SUPPLEMENTAL REPORTS

| Description | File Location | Year |
|---|---|---|
| Evaluation of three proposed management Scenarios to enhance three potential Bull Trout nursery habitats, accessible to Lake Merwin and Yale Lake, Lewis River | *K.L. Pratt Prepared for PacifiCorp, in cooperation with Cowlitz PUD, USFWS, WDFW* | 2003 |
| Habitat Suitability Criteria for Swift Bypass Reach and Meeting Participants | PacifiCorp Aquatic Relicensing Reports Aquatics Appendices AQU 2 Appendix 1 | 2004 |
| Aquatic Resources Report that goes with Appendices AQU1 Appendices 1 & 2 | PacifiCorp / Cowlitz PUD Lewis River Hydroelectric Projects FERC Project Nos. 935, 2071, 2111, 2213 | 2004 |
| Species Periodicity in Relation to Flows Downstream of Merwin Dam (AQUA 3 Appendix 3) | PacifiCorp / Cowlitz PUD Lewis River Hydroelectric Projects FERC Project Nos. 935, 2071, 2111, 2213 | 2004 |
| Assessment of potential anadromous fish habitat upstream of Merwin Dam (AQU 4) | PacifiCorp / Cowlitz PUD Lewis River Hydroelectric Projects FERC Project Nos. 935, 2071, 2111, 2213 | 2004 |
| Evaluation of anadromous salmon behavior and habitat selection in the Upper Lewis River Watershed (AQU 13) | PacifiCorp / Cowlitz PUD Lewis River Hydroelectric Projects FERC Project Nos. 935, 2071, 2111, 2213 | 2004 |
| Evaluation of hatchery origin coho salmon behavior, productivity, and habitat selection in the Upper Lewis Basin (AQU 10)....................................................... | PacifiCorp / Cowlitz PUD Lewis River Hydroelectric Projects FERC Project Nos. 935, 2071, 2111, 22132004 | 2004 |
| Migratory behavior of radio-tagged juvenile Chinook salmon through Swift Reservoir, 2002 (AQU 14B) | PacifiCorp / Cowlitz PUD Lewis River Hydroelectric Projects FERC Project Nos. 935, 2071, 2111, 2213 | 2004 |
| Migratory behavior of radio-tagged | PacifiCorp / Cowlitz PUD | 2004 |

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| juvenile coho salmon through Swift Reservoir, 2001 (AQU 14A) | Lewis River Hydroelectric Projects FERC Project Nos. 935, 2071, 2111, 2213 | |
| Speelyai Creek connectivity and Speelhyai Hatchery protection study (AQU 9) | PacifiCorp / Cowlitz PUD Lewis River Hydroelectric Projects FERC Project Nos. 935, 2071, 2111, 2213 | 2004 |
| Swift Bypass Reach Instream Flow Study (AQU 2) | PacifiCorp / Cowlitz PUD Lewis River Hydroelectric Projects FERC Project Nos. 935, 2071, 2111, 2213 | 2004 |
| Quantification of in-river residency and optimization of release strategies for hatchery coho salmon smolts in the lower Lewis River (2001) (AQU 11A) | PacifiCorp / Cowlitz PUD Lewis River Hydroelectric Projects FERC Project Nos. 935, 2071, 2111, 2213 | 2004 |
| Quantification of in-river residency and optimization of release strategies for hatchery coho salmon smolts in the lower Lewis River (2002) (AQU 11B) | PacifiCorp / Cowlitz PUD Lewis River Hydroelectric Projects FERC Project Nos. 935, 2071, 2111, 2213 | 2004 |
| Upper Lewis River EDT Analysis (AQU 18 Appendix E) | PacifiCorp / Cowlitz PUD Lewis River Hydroelectric Projects FERC Project Nos. 935, 2071, 2111, 2213 | 2004 |

# APPENDIX C: DIGITAL ELEVATION MODEL METHODS

A digital elevation model (DEM) was developed to determine the watershed landscape areas that drain to each EDT reach. These "EDT Sheds" are the basic unit of analysis for this part of the study. The DEM was compiled from 36 individual 7.5 minute datasets downloaded from USGS through datageo.com. The elevation data had a spatial resolution of 10m. These data were reprojected, merged together into a single file, and clipped to the Lewis River drainage boundary. The merge was necessary because local upslope watershed areas relative to the EDT reach breaks often occurred on multiple 7.5minute data tiles. The EDT reach breaks were provided by ICF in the form of X and Y coordinates associated with the EDT stream modeling efforts. Each upstream and downstream EDT reach break was used to calculate the upslope contributing watershed draining to each EDT stream segment. The resulting EDT Sheds were determined by evaluating DEM grid cells in a neighborhood analysis to determine the elevation of every grid cell in relation to every grid cell surrounding it. EDT Shed boundaries were determined by finding the elevation maxima (i.e., ridgelines) relative to every EDT reach break. All EDT Shed analyses were completed using the "Hydrologic Analysis" tools in ArcGIS 10.1. Once these EDT Shed boundaries were defined, they were converted to polygons that were then used to summarize landscape variables that could be important for fish.

# Appendix E

# Comment Matrix

| Agency | Comment | Utility Response |
| --- | --- | --- |
| LCFRB | In our earlier comments regarding the Lower Lewis River Enhancement Project review, we expressed concern that intensity ratings were assigned based on the physical proportion of the treatment area to entire reach, including untreated areas. We are not seeing where this concern was addressed. This approach seems to result in a dilution of realized and potential habitat lift. For example, a wood placement project may be highly effective within the area actually treated, and could bring that area up to fully functioning condition as intended by the project. The intent is seldom to treat the whole EDT reach. By assigning a reduced intensity rating based on the entire reach length, including areas not intended to be treated, it appears that we are underestimating potential lift from habitat work. If the goal is to estimate potential lift, it seems more appropriate to assign an intensity rating based only on the area treated, and then extrapolate that to the entire reach. | Modelling of restoration actions is conducted at a reach level, and actions are captured as a change in conditions across the reach. The reach-level change in conditions due to an action is weighted by the extent (intensity) of the action within the reach length. For example, if an action adds large wood to a 100 meter section of a 1 km reach, then the change in large wood at the reach scale will be scaled by the extent of treatment (100/1000)—wood abundance is not changing across the entire length of the reach but only 1/10 of its length. This amount of change in large wood is captured in the reach-level wood rating in the model. The change in large wood is then captured in the performance of life stages and integrated into the change in population level performance (e.g. abundance). For example – the DuPuis Chelatchie Creek Project (00-1036) added stream spawning beds anchored by large rock vanes within EDT reach Chelatchie Cr 2A. Modeled effects of rock vanes and LWD assume a half a mile of spawning habitat within the reach – not the entire 3.6 mi length of Chelatchie Cr 2 A. |