Attachment A

PRE-PROPOSAL FORM

Lewis River Aquatic Fund

1. Applicant organization.

Lower Columbia Fish Enhancement Group (LCFEG)

2. Organization purpose

The Lower Columbia Fish Enhancement Group is a non-regulatory, non-partisan 501(c)(3) salmon recovery organization founded by the state legislature in 1990. Working within specific watersheds throughout Clark, Skamania, Lewis, Wahkiakum, and Cowlitz Counties, we successfully leverage public funding through landowner partnerships and collaborations with individuals, groups, corporations, tribes, foundations and agencies. Our mission: To lead the process of salmon recovery in a way that ensures community involvement in habitat restoration so that abundant, naturally self-sustaining salmon and steelhead runs occur throughout the Lower Columbia River region.

3. Project manager (name, address, telephone, email, fax).

Peter Barber
12404 SE Evergreen Highway Vancouver, WA 98683
Peter@lcfeg.org
360-882-6671
www.lcfeg.org

Note: Please attach a resume or other description of the education and experience of the persons responsible for project implementation.

4. Project Title

Eagle Island – North Channel Restoration

5. Summary of Project proposal

Note: Please include description of how project addresses Lewis River Aquatic Fund priorities and identify any impacts to other resource areas (e.g. wildlife, recreation, etc.).

This proposal is for construction funding to implement designs for modifying the Lewis River at the upstream end of Eagle Island in order to increase flows into the North Channel to benefit salmonid habitat. During 2011, LCFEG was awarded a $167,000 Salmon Recovery Funding Board (SRFB) grant to create designs to address flow-related habitat impairments in the North Channel, Reach 4B (RM 10-12) at Eagle Island on the Lewis River. Historical aerial photography shows that the primary flow has been shifting from the North to the South channel since the 1930s; if these trends continue, it appears that flow in the North Channel could become too low to support juvenile salmon rearing during certain times of the year.

6. Project location (including River/Stream and Lat/Long coordinates if available).
The project area is Eagle Island on the NF Lewis River, Reach 4B (river mile 10-12). At approximately river mile 12, the river forks into what are known as the North and South channels around Eagle Island.

7. Expected products and results (Please attach any drawings).
The product of this effort is a constructed project that improves and protects habitat for ESA-listed salmonids through increasing and maintaining adequate flow through the North Channel during critical fish-use periods. See attached design drawings and design report.

8. Benefits of proposed Project
Chinook, chum, coho and steelhead trout are listed as threatened species under the ESA. This project will contribute to the recovery of these species by increasing the quantity and quality of habitat available to fish in the Eagle Island area, specifically the North Channel.

9. Project partners and roles.
WA Department of Fish and Wildlife is a key partner and primary landowner that has helped to coordinate and initiate this effort and is contributing technical support for project analysis and design. Other project partners are participating as part of a Technical Oversight Group that convenes to provide technical support and guidance throughout this effort. These partners include WDFW, Clark County, Cowlitz Indian Tribe, US Army Corps of Engineers, PacifiCorp, Lower Columbia Fish Recovery Board, WA Dept of Natural Resources, USFWS, and NOAA.

10. Community involvement (to date and planned).
Design for this project has been vetted through the LCFRB project review process, which included significant opportunity for community involvement and technical review. Final coordination with community, landowner, and recreational user representatives will be conducted as prior to submission of construction permitting.

11. Procedure for monitoring and reporting on results.
WDFW conducts regular monitoring of the lower NF Lewis River, which includes juvenile fish seining, enumeration, and tagging. This on-going monitoring effort will be used to evaluate project effectiveness. Any additional monitoring procedures will be developed collaboratively with WDFW after implementation of this restoration project. Reporting of results will be done using ACC protocols (if existing), or standard SRFB protocols, which include a final as-built report and photo summary.

12. Project schedule (anticipated start date, major milestones, completion date).
Project construction activities will commence in 2015 and extend through 2016. The specific final construction schedule will be developed as part of this project when funded.

13. Funding requested (estimated cost for project design, permitting (including necessary resource surveys), construction, signage, monitoring and administrative/insurance. Required insurance limits have been outlined below.

$100,000 of ACC funding is requested to assist with construction of the restoration work and will also be used as cost-share (match) for an anticipated SRFB grant (2014 Grant Round) that will be pursued to also help fund project construction. The design for the project was previously funded as a part of SRFB Project #11-1239.

14. Type and source of other contributions (Identify cash (C) and/or in-kind (IK), and status, pending (P) or confirmed (Co)).
$167,000 – Analysis, design, and permitting; SRFB Project #11-1239; C; Co
$TBD – Additional construction funding; SRFB (2014 Grant Round); C; P (anticipated)
$TBD – LCFEG; IK; P

15. If you have technical assistance needs for this project, please briefly describe such needs.
Technical assistance for design was previously provided by a Technical Oversight Group consisting of representatives from multiple entities including WDFW, Clark County, Cowlitz Indian Tribe, US Army Corps of Engineers, PacifiCorp, Lower Columbia Fish Recovery Board, WA Dept of Natural Resources, USFWS, and NOAA. It is anticipated that the TOG will be available to provide continued technical assistance during the construction and monitoring phase. Inter-Fluve is providing technical services for the design and will provide construction oversight and assistance.

16. If any boating hazards are an issue please note if any signage requirements.
Boater safety is an important consideration in project design. The design of the project, and construction methods, will incorporate boater safety considerations and will be vetted by recreational user representatives. Signage is anticipated for the project as has been conducted for other past restoration work on the lower NF Lewis in recent years. Signage may also be a requirement of the WA DNR aquatic land use authorization for the project.

Location: Eagle Island, NF Lewis (RM 10-12)


Butte Hill Rd
503
Lewis River Rd
Green Mountain Rd
Hillsdale Dr
Lewis River Rd
NW Hayes Rd
NE Hayes Rd
Insel Rd
NW Lyons Rd
NW 9th Ave
NE 12th Ave
5
Woodland
Bozarth Ave
NW 389th St


Project Site Map
North Channel
Lewis River Road (Hwy 503)
Island Boat Ramp
Treatment Area
Flow
Eagle Island
NW Hayes Road
South Channel
Treatment Area
0 250 500 1,000 1,500 Feet
Bing Aerial Photography

LEWIS RIVER – EAGLE ISLAND NORTH CHANNEL
HABITAT RESTORATION DESIGN REPORT

FINAL – MAY 2013

Prepared for:

Lower Columbia Fish Enhancement Group
12404 SE Evergreen Highway
Vancouver, WA 98683

Prepared by:

Inter-Fluve, Inc.
1020 Wasco Street, Suite 1
Hood River, OR 97031

Table of Contents

INTRODUCTION

This report describes analysis and design components for restoration alternatives for addressing flow-related habitat impairments in the North Channel at Eagle Island on the Lewis River (see locator map in Figure 1). The report provides a summary of data collection and analysis work as well as a description and evaluation of a suite of restoration alternatives that were investigated for the site. It also describes the preferred alternative that was developed based on input from the Technical Oversight Group (TOG).

BACKGROUND

The project area is Eagle Island on the NF Lewis River – Reach 4B (RM 10-12). At approximately river mile 12, the river forks into what are known as the North and South Channels around Eagle Island. Historical aerial photography shows that the primary flow has been shifting from the North to the South Channel since the 1930s; if these trends continue, it appears that flow in the North Channel could become too low to support high quality juvenile salmon rearing during certain times of the year. WDFW monitoring indicates that historically, the North Channel has supported large amounts of juvenile Chinook rearing, which has decreased in recent decades concurrent with a decrease in flows in the North Channel. Further dewatering of the North Channel could have serious consequences for fall Chinook and other salmonid production in the system. The need to address this issue is seen as a high priority in the basin and the region and was funded as part of SRFB Project#11-1239.

TECHNICAL OVERSIGHT GROUP

This project has occurred with input and guidance from the TOG, which is made up of agency and stakeholder group representatives. The TOG met three times during the course of this effort, including 1) an initial kick-off meeting – Aug 22, 2012, 2) following the concept design submittal – Jan 24, 2013, and 3) following the preliminary design submittal – March 6, 2013. The following people attended at least one of the meetings: Steve West (WDFW), Dave Howe (WDFW), Ron Roler (WDFW), Shane Hawkins (WDFW), Guy Norman (WDFW), Donna Bighouse (WDFW), Anne Friesz (WDFW), Pat Frazier (WDFW, then LCFRB), Jeff Breckel (LCFRB), Allen Lebovitz (WDNR), Pat Lee (Clark County), Frank Shrier, (PacifiCorp), Tony Meyer (LCFEG), Pete Barber (LCFEG), Steve Manlow (USACE), Peter Olmstead (USACE), Eli Asher (Cowlitz Tribe), Rudy Salakory (Cowlitz Tribe), Pollyanna Lind (Inter-Fluve), Bill Norris (Inter-Fluve), and Gardner Johnston (Inter-Fluve).

GOALS AND OBJECTIVES

Overall Goal

The intent of this project is to improve and protect habitat for ESA-listed salmonids by increasing and maintaining adequate flow through the North Channel during critical fish-use periods. In order to accomplish this, the channel at the upstream end of Eagle Island and within the upstream end of the North Channel will be re-configured to increase and maintain adequate flows into the North Channel. Other habitat enhancement actions, including placement of log jams and development of side-channel habitat, are also considered important goals, especially to the extent that they support and help accomplish the primary goal of ensuring adequate flow in the North Channel.

Figure 1. Locator map of Eagle Island area. Lewis River river miles (RM) are shown in yellow.

Flow and Habitat Objectives

Flow and habitat objectives were established to guide the analysis, assist in the development of alternatives, and to provide criteria for selecting a preferred alternative.

The flow required to maintain juvenile rearing in the North Channel is the crux of the problem and therefore is the focus of the primary design criteria. A flow "target" for the North Channel was developed based on two lines of supporting evidence: 1) fisheries data and observations from WDFW fish biology staff, and 2) geomorphic trends analysis primarily using historical aerial photography.

WDFW fisheries staff report that flow and habitat conditions around Eagle Island during the late 1970s and early 1980s provided more productive rearing for juvenile salmonids compared to current conditions (R Roler, WDFW Fisheries Biologist, personal communication, October 30, 2012). According to WDFW biologists, during the late 1980s, habitat conditions began to change and conditions became less favorable for salmonid rearing. This trend has continued until present. Fish sampling data (summarized later in this document) show that in the 1980s, catch rates of juvenile salmonids were consistently the highest at the top end of Eagle Island. Beginning in the late 1980s/early 1990s, catch rates were no longer consistently the highest in this area. The average proportional catch in the North Channel has also experienced a gradual decline since the early 1980s.

Geomorphic analysis (summarized later in this document) indicates that the distribution of flow between the North and South Channels has changed over time, possibly due to various factors including past instream gravel mining, hydro-regulation, vegetation encroachment, and channel incision; as well as natural geomorphic processes. From the late 1960s until the 1980s, the flow split between the two channels varied no more than 3% from an even 50/50 split. Since then, however, active channel width in the South Channel appears to have enlarged and in recent years it conveys considerably more flow than the North Channel (nearly a 40/60 split based on air photo analysis and a 35/65 split based on a recorded flow measurement). Hydraulic analysis using 2D modeling shows a similar flow split for the existing condition (31/69 split based on average split for a range of flows).

Although historical conditions will be useful for determining target conditions, it is acknowledged that channel form and geomorphic processes (e.g. sediment transport, hydrology, vegetation, and even possibly geology) have changed since the 1970s and so a return to those conditions is not possible. Therefore, the historical target conditions have been combined with hydraulic and geomorphic analyses to develop restoration alternatives that best accomplish the objectives while also fitting within the current hydro-geomorphic context. By working within this context we think the strategy that has the greatest long-term potential effectiveness can be found.

Based on the above considerations, the primary objective listed below was developed. Additional "secondary objectives" were also developed based on other available information and discussions with the TOG:

Primary Objective:

- Flow split between North and South Channels that is within 5% of an even 50/50 split during juvenile Chinook rearing periods.

Secondary Objectives

- Presence of active alluvial barforms with exposed coarse substrate
- Main channel and off-channel complexity
- Self-sustaining project (to the extent possible)
- No negative impacts on river recreational users

SITE ANALYSIS

DATA COLLECTION EFFORTS

Topographic survey. Site topography was surveyed in order to support hydraulic analysis, geomorphic analysis, and to develop grading plans for project design. Ground topography and channel bathymetry were surveyed. The topographic surveys extended from upstream of Eagle Island to downstream of Eagle Island and included cross-sections of the North and South Channels as well as the island and surrounding areas. Surveys were conducted in February and March 2012. Ground topography was surveyed using a total station and survey-grade GPS. Bathymetry was surveyed using a boat-based single-beam echosounder interfaced with a survey-grade GPS. Collected survey data was meshed with LiDAR data to create an existing conditions digital terrain model for use in the analysis and design.

LiDAR. LiDAR data was obtained through the National Oceanic and Atmospheric Administration (NOAA) Digital Coast Data Server. These data were collected in 2009/2010 for the US Army Corps of Engineers as part of a regional LiDAR effort in the Lower Columbia. These LiDAR data supersede previous LiDAR data collected by Clark County in 2002. The LiDAR data was collected to represent bare earth data within a 0.07 m tolerance.

Due to potential known errors in LiDAR data due to the effects of vegetation and water, the ground survey data were used as the primary topographic data source but were supplemented with LiDAR "bare earth" data at the outer limits of the project site or where ground survey data were not collected (e.g. private property) or was collected at low densities.

Substrate sampling. Substrate sampling was performed to support the hydraulic analysis, geomorphic analysis, and will be used in project design to determine appropriate methods of bedform manipulation and the fate of re-configured bed material. Bulk samples of bed substrate were collected from four locations near the upstream end of Eagle Island; one each in the North and South Channels and two on the bar at the upstream end of the island. Samples were sieved to determine the material size distributions. Substrate samples included samples of the armor and subarmor layers.

Hydrology. Hydrologic data and other information were obtained from multiple sources and studies. These include: 1) the USGS gaging station at Ariel, WA (#14220500), which is located just downstream of Merwin Dam and provides a long-term flow record (1908 – present), 2) a river stage recorder (data collector) located at the upstream end of the South Channel and that has been deployed since November 2011, 3) a recorded flow estimate in the North Channel taken on June 26, 2012, and 4) numerous existing reports. A summary of hydrologic conditions is provided later in this report.

Aerial photographs. Historical and recent aerial photography was obtained for this project in order to evaluate long-term geomorphic trends and the relationship to land-use in the study area. Air photos were obtained from numerous sources including the US Army Corps of Engineers, Clark County, PacifiCorp, USDA (NAIP imagery), and others. Photos were orthorectified and georeferenced when necessary using ArcGIS.

HYDROLOGY

Basin and site hydrology. The Lewis River encompasses a drainage area of 1,046 square miles. The headwaters of the Lewis are on Mount Adams and Mount St. Helens and their adjacent foothills. Basin hydrology is dominated by winter rains, but is driven by a combination of snow and glacier melt, rain, and groundwater flow. Major tributaries to the Lower Lewis include the East Fork Lewis, Johnson Creek, and Cedar Creek. Tidal influences extend up the Lower Lewis to approximately RM 11.

Mean average flow below Merwin Dam is 4,489 cfs. High flows occur in winter and spring as a result of rain and snowmelt. Occasional high flows occur in the fall as a result of heavy rains. An exceedance plot developed from Ariel Gage flows over the past 10 years is provided in Figure 2.

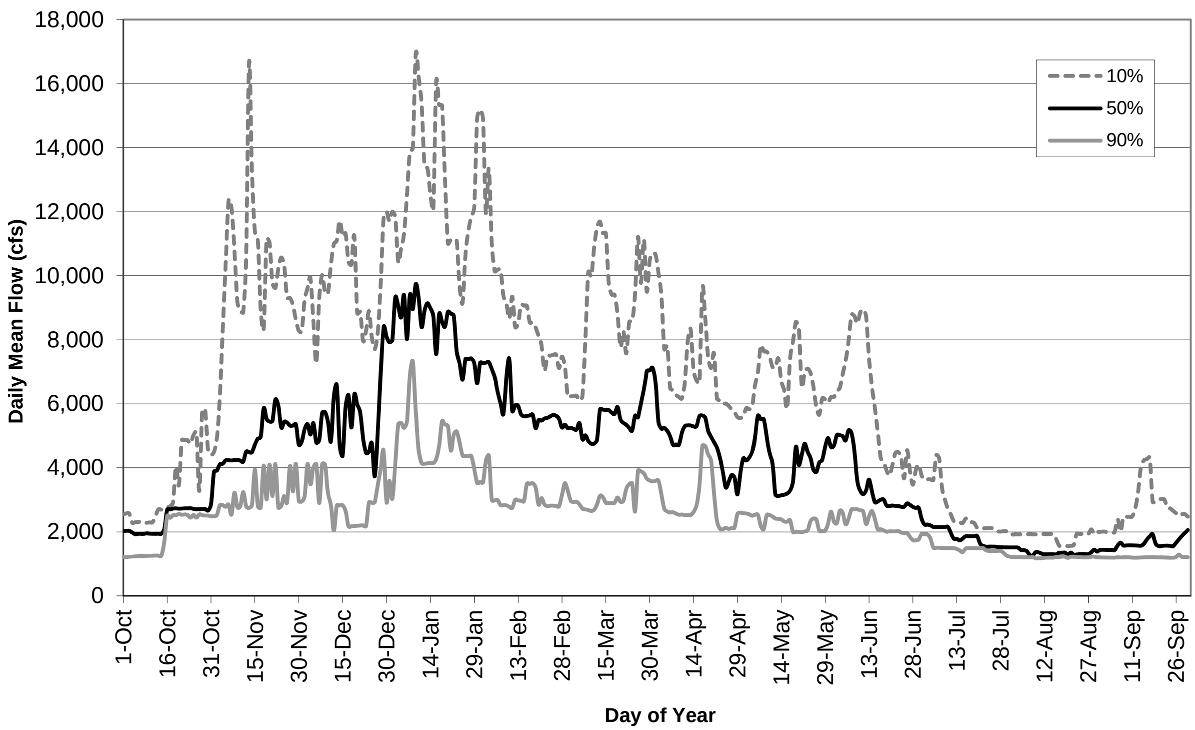

Figure 2. Hydrograph showing daily median flows and 10% and 90% exceedances flows for the period 2002 to 2011.

Hydro-regulation. The hydrology of the basin has been altered by the hydropower system, which includes three large hydro facilities: Swift Dam, Yale Dam, and Merwin Dam. Merwin Dam, which is the most downstream dam on the river, is located at river mile 19.5, approximately 8 miles upstream from Eagle Island. PacifiCorp operates the hydrosystem to produce power, manage peak (flood) flows, and augment late summer flows for fish in accordance with license requirements. In the lower river, hydro-regulation has led to less variability in seasonal hydrology, including increasing summer and fall low flows and reducing the magnitude of floods (see Figure 3). The effect on peak flows varies depending on the size and timing of the event and the amount of available storage in the reservoirs. For the flood of February 1996, the PacifiCorp FLD-1 Study (PacifiCorp 2004) estimated that the flood, which registered 86,400 cfs on the Ariel Gage, would have registered 111,400 cfs without hydro-regulation.

In order to maximize benefits to fish, minimum instream flow requirements were established as part of the Settlement Agreement; these flows are listed in Table 1.

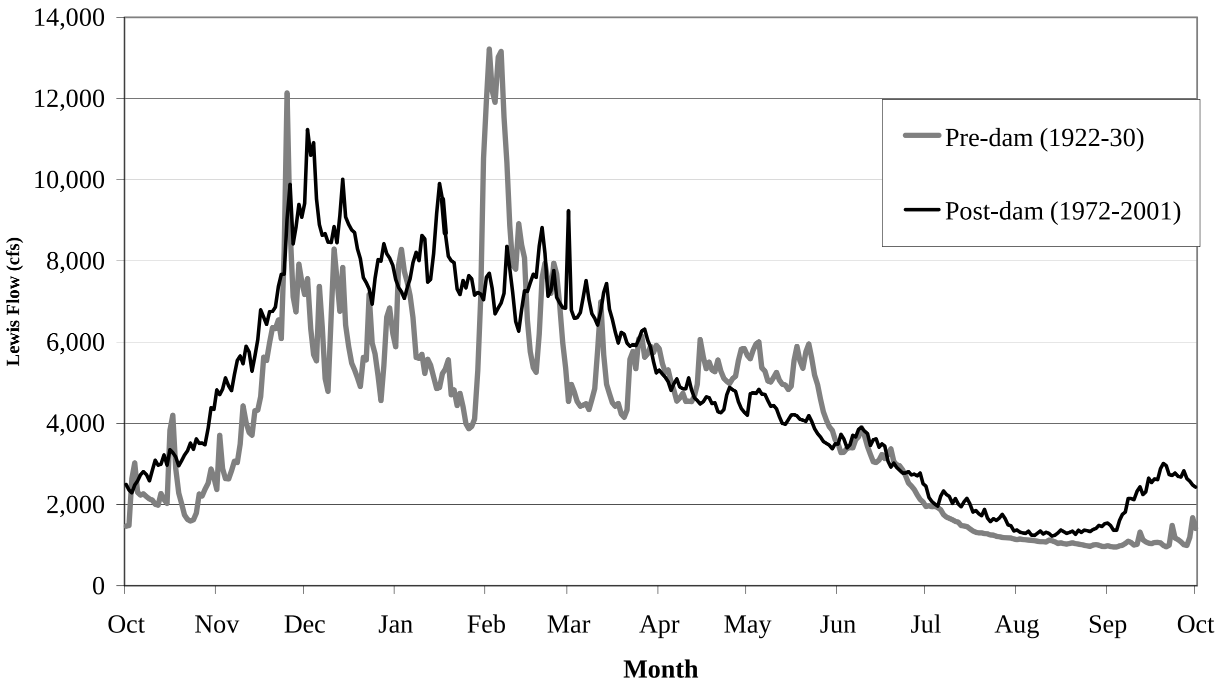

Figure 3. Lower Lewis River flow pre- and post-Merwin Dam (1931). Hydro-regulation has decreased flows in the spring and increased flows in the summer and fall. USGS Gage #14220500; Lewis River at Ariel, Wash.

Table 1. Minimum flow requirements in the Lewis River below Merwin Dam (based on text from the 2004 Settlement Agreement).

Time Period	Minimum Flow Requirement
July 31 through October 15	1,200 cfs
October 16 through October 31	2,500 cfs
November 1 through December 15	4,200 cfs
December 16 through March 1	2,000 cfs
March 2 through March 15	2,200 cfs
March 16 through March 30	2,500 cfs
March 31 through June 30	2,700 cfs
July 1 through July 10	2,300 cfs
July 11 through July 20	1,900 cfs
July 21 through July 30	1,500 cfs

Flood frequency analysis. Flood flow magnitudes were developed for various flood recurrence intervals to be input into hydraulic modeling and design calculations (Table 2). The 10-, 50-, and

100-year flood flow magnitudes were obtained from the Lewis River Hydroelectric Projects Flood Management Technical Report (FLD-1) (PacifiCorp 2004) (Table 2). The flows for the flow scenario "Regulated flows with 70,000 acre-feet dependable flood control storage" at Woodland, WA were utilized. These flows are conservative (i.e. higher) estimates of floods for the project site because Woodland is located downstream of the project area (RM 6-7); however, there are no significant tributaries between the project site and Woodland.

The FLD-1 study did not provide 2-year event flows for Woodland, WA but provided 2-year event floods for Ariel (USGS Station #14220500) for the scenario “Regulated flows with actual historic flood control storage". Because a major tributary, Cedar Creek, enters the Lewis River downstream of Ariel, these flows were corrected for the subwatershed boundary (from LCFRB 2010) closest to the project area (RM 8.8 just downstream of Eagle Island). This was accomplished by calculating Cedar Creek flows as 17% of the East Fork near Heisson (USGS Station #14222500) flows, which is consistent with the methods outlined in the FLD-1 Study. The remainder of the tributary flows between Ariel and RM 8.8 were calculated using the USGS regional regression equations (Sumioka et al. 1998). Cedar Creek and other tributary flows were added to the 2-year flows at Ariel in order to obtain the 2-year event flows for the project area.

Table 2. Recurrence interval flows used for the project area. These flows account for contributions from Cedar Creek as well as hydropower regulation.

Return Interval	Flow (cfs)
2-year	24,800
10-year	65,600
50-year	92,600
100-year	98,400
500-year	150,500

Flood history. The dates of large floods (i.e. greater than a 5-yr recurrence interval) were obtained from the gage data and these events were used to evaluate potential impacts on channel pattern and conditions observed from the aerial photo record. The top 15 floods over the period of record are included in Table 3.

The flood of record occurred in December 1933 (Water Year 1934), and was estimated at 129,000 cfs. Merwin Dam had been in place for less than two years at the time of the flood and did not provide any flood control storage for the event. The 1933 flood had a profound impact on channel morphology and spawning habitat in the lower Lewis River. This flood was considerably greater than the second largest flood, which occurred in February 1996. It is estimated that the 1996 flood would have been approximately 111,400 cfs in the absence of flow regulation (PacifiCorp 2004). The most recent large flood was in January 2003 (49,300). Floods between 35,000 and 40,000 cfs occurred in November 2006, January 2009, and January 2011.

Table 3. Top 15 floods on the Lewis River from USGS Gage (Gage #14220500) at Ariel, WA. Flood volumes at the project area would be larger due to tributaries that enter the river between the USGS gage and the project site.

Event Rank	Water Year	Flow (cfs)	Event Rank	Water Year	Flow (cfs)
1	1934	129,000	9	1974	59,600
2	1996	86,400	10	1943	57,600
3	1963	75,500	11	1981	53,700
4	1978	71,900	12	1967	50,500
5	1947	67,300	13	2003	49,300
6	1976	64,500	14	1956	49,100
7	1928	62,600	15	1937	49,100
8	1938	61,500			

Flow data from study area. Flow and stage data were collected at the study area in order to calibrate the hydraulic model and to help determine split flow conditions in the channels. A stage recorder (Hobo U20 Water Level Logger) was placed at the upstream end of the South Channel in November 2011. This data provides stage data for the South Channel and was used to help calibrate the hydraulic model.

In addition, a flow measurement was recorded across the top riffle crest in the North Channel on June 26, 2012 in order to determine the flow split at the time of the measurement and to provide flow and velocity data for hydraulic model calibration. The recorded flow was 1,154 cfs. Mean flow for this day at the Ariel Gage was 3,060 cfs. Accounting for Cedar Creek flows (estimated at 7% of Ariel flows) brings it to approximately 3,270 cfs for the study area. This indicates that the North Channel conveyed approximately 35% of the total flow (35/65 split) on this day.

GEOMORPHOLOGY

Geomorphic setting. The Lewis River downstream of Merwin Dam can be divided into an upper and lower reach based on differences in the geomorphic character of each reach. The Eagle Island area is located within the lower reach, which extends from approximately RM 14 to RM 9. This reach is less confined and has lower elevation terraces than the upper reach. The gradient is lower, it is influenced by tidal backwater, and it has smaller and more mobile bed material than the upper reach. Eagle Island itself is set within a semi-unconfined valley with broad low-elevation alluvial terraces. The low gradient through this area has allowed for the deposition of coarse grain substrates, which are frequently remobilized by flood flows above the 2-year event.

Land uses impacting the study area include flow management associated with the Lewis River hydro-system, interruption of bedload and wood transport due to the hydro-system, past removal of wood from the river, past instream gravel mining, riparian clearing, and human development of floodplains and riparian areas. These practices have generally served to simplify habitats and reduce channel dynamics.

Observed trends from aerial photo and map record. Historical maps and aerial photos were examined for trends in geomorphic patterns and land-use. These trends help to understand the past and future potential trajectory of the river. Trends analysis included digital rectification of nineteen sets of aerial photographs (1938 to 2010) and one set of general land office (GLO) maps (1854). A subset of these maps and photos are provided in Appendix A (Historical Maps and Aerial Photos).

The 1854 General Land Office (GLO) survey map shows single-thread channel, generally comprising the North Channel at the upstream end, crossing over the island, and comprising more or less the South Channel at the downstream end, although with considerable variation from existing channel locations. Although GLO survey maps frequently have inaccuracies, for a river the size of the Lewis, they are probably relatively reliable. Although the channel boundaries may not be in exactly the locations noted, the presence of a single-thread channel is likely accurate.

The next data source is the 1938 (possibly 1939) aerial photo series. These photos show that the North Channel is the wetted channel and that the South Channel is minimally or not at all wetted. The South Channel does show signs of significant scour and deposition (exposed gravel deposits). The scour is likely a result of the 1933 flood, which has been estimated at 129,000 cfs and is the largest flood on record. There is also what appears to be some kind of diversion/levee structure (flood protection?) at the upstream end of the South Channel that may be responsible for surface flow being routed into the North Channel. There is considerable land use activity (houses, farms, roads) on the downstream half of the island but not the upstream half. One potential scenario is that sometime prior to 1933 the river was still single-thread (as in 1854) but the two bends had scrolled laterally and were primed for avulsion (tight radius of curvature and reduced slope). During the 1933 flood, or potentially over the course of multiple floods in this time period (there was also a large flood in 1917), avulsions occurred at both bends, likely at the upstream bend first, which would have loaded the downstream channel with eroded sediment thus initiating the avulsion of the downstream bend. Avulsion of the downstream bend in the 1933 flood is evidenced by lack of riparian vegetation on banks in the 1938 photos. And there is evidence of a low-water ford over the South Channel near RM 11.2 (because access was now blocked by avulsion into the North Channel). The 1938 photos also show that there was potentially some gravel mining at the downstream end on the right bank near RM 10.

In 1948, most flow is still in the North Channel. The diversion structure from 1938 is gone and there is more flow entering the South Channel. Most of this flow crossed over the middle channel of the island and into the North Channel. The low-water ford appears to still be in use near RM 11.2. Vegetation encroachment can be seen at the downstream end of the South Channel and midway through the North Channel. Gravel mining activity can be seen on the right-bank at RM 11.8, just upstream of the top of the island. Upstream of Eagle Island, at RM 12.5, the river migrated northward and threatened the highway. This likely occurred during the large 1946 flood (67,300 cfs).

By 1951, flow in the South Channel was no longer crossing over to the North Channel through the cutover channel and instead was flowing entirely through the South Channel. The crossover channel was beginning to be abandoned. By 1955 there appeared to no longer be any road access to the island, but structures are still visible and there may have still been active agriculture. The 1955 photos show a significant area of bank erosion and lateral channel migration on the south bank of the South Channel near RM 11.3 (site of existing large backwater area). This erosion appears to have been eroding farmland that was in use in prior years. By 1955, a large gravel mining operation was underway at the left-bank bar upstream of the island at RM 12.5.

In 1968, there were no longer any structures or agricultural activity visible on the island. The amount of flow conveyed by the South Channel had increased significantly and it appeared to be an even split. There was increasing vegetation in the crossover channel at RM 11.3 and it appeared to not have been scoured in recent years, despite the >Q20 event in 1963. The density and maturity of timber stands on the island continued to increase, especially on the upstream end of the island (historically the upstream island). There was significant bed re-configuration activity at the area of farmland erosion in the South Channel near RM 11.3. It appears possible that gravel was being mined from the upstream bar (current Site A project) and placed out in the channel to prevent continued erosion of farmland. This activity essentially created the large backwater now present on the left bank at RM 11.3 and also explains the origin of an existing levee and gravel mounds in the floodplain near the Site A project. By 1970, the island at Site A was beginning to form.

In the 1970 photos is when you begin to see increased gravel bars in the North Channel and at the top end of the island. At the upstream meander at RM 12.5, sometime prior to 1968, there was an avulsion through the gravel pit, creating the right-bank backwater that is present today. The channel lost approximately 1,400 feet of length from this avulsion and would have contributed a significant amount of bedload to the Eagle Island area. The bar at the upstream end of the island is first visible in the 1970 photo (1968 photo was during high water and the bar was likely covered).

By the late 1970s, conditions began to look like they do today. The backwater on the South Channel at RM 11.3 became progressively filled and colonized by vegetation. The island crossover channel became more vegetated and obscured. The near split flow condition continued until following the 1996 flood, when flow was increasingly conveyed by the south channel. It is very likely that the significant increase in the size of the mid-channel bar between 1990 and 1996 (post-flood) was due to the February 1996 flood, which caused significant bank erosion in upstream areas. In recent years (2000-present), the bar has become more vegetated and now resembles a more permanent and stable island feature.

Flow split analysis. This analysis was conducted in order to document trends in the flow split between the North and South Channels over time and to evaluate these changes within the context of flood history and land-use. For each photograph/map set, seven cross sections were digitized that spanned the Eagle Island North and South Channels (Figure 4). The cross sections were located in areas perpendicular to flow in the 2010-11 photos and in areas where change in active channel boundary width and location were likely to occur (e.g. apex of bends). Active channel width (as evidenced by changes in color and texture) was measured for each cross section and then averaged across each photo set. Flow split analysis also included digitization and comparison of active surfaces across photo sets. Active surfaces were defined as areas where scour was visible and with less than 30% vegetation establishment. All results were then compared with discharge data from the USGS gage at Ariel, WA (#14220500). Flood events of record (events greater than the Q5) that occurred between photo sets were compared with changes observed in photosets.

Figure 4. Eagle Island showing location of cross-sections used for the flow-split analysis.

Figure 5 shows the results of the flow split analysis. The earliest photos used for the analysis are the 1938 photos. As described earlier, these photos show the effects of the 1933 flood and also show a diversion structure at the head of the South Channel. However, regardless of the distribution of ***surface*** flows between the channels, the active channel widths are relatively similar; although these conditions are very much related to the recent flood and may not represent normal scouring flows during this period. By 1948, the South Channel diversion has disappeared and the active channel width becomes increasingly split between the North and South Channels. The channel then remains relatively static until 1955, when lateral scour removes 183,000 square feet of bank at RM 11.3. By 1968, this area has begun to be filled and transitioning towards a backwater, but appears to be still receiving scouring flows. The 1968 photos represent a nearly split active channel width, along with increasingly mature vegetation on Eagle Island and vegetation encroachment in the crossover channel. In 1970, active channel width remains evenly split and this condition persists into the 1980s. Beginning in the early 1990s, the South Channel became wider and by 2006 the split was nearly 40/60. This condition persists today despite the most recent measurement (2010), which shows a 45/55 split but is unlikely a new trend based on site observations in 2012. A flow measurement was taken at the head of the North Channel as part of this study on June 26, 2012. Comparing this flow to the flow recorded at the Ariel Gage suggests that the flow split at that time was approximately 35% North Channel and 65% South Channel.

Another trend that was documented in the flow split analysis is that the combined active channel width has become increasingly narrow (Figure 6). This is likely due vegetation encroachment due to a lack of scouring flows in recent years. This is discussed further in the next section.

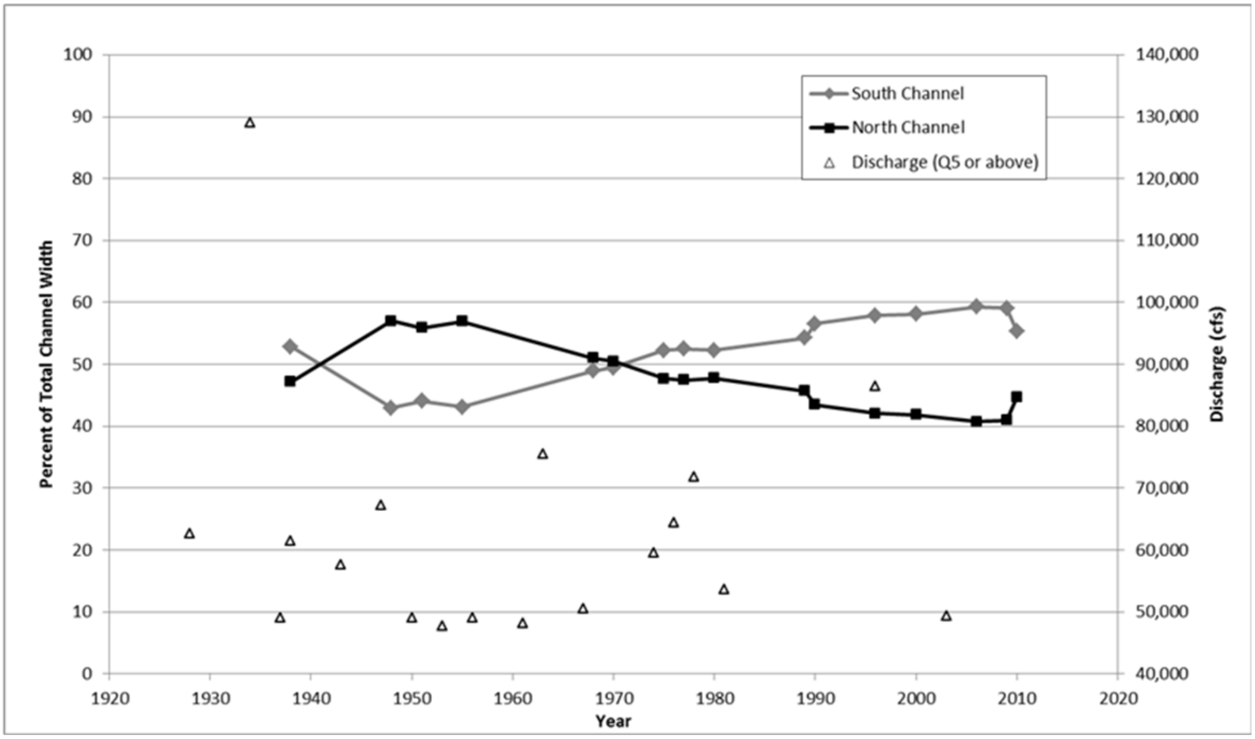

Figure 5. Changes in active channel width over time, plotted with discharges equal to or exceeding the 5-yr recurrence interval flood.

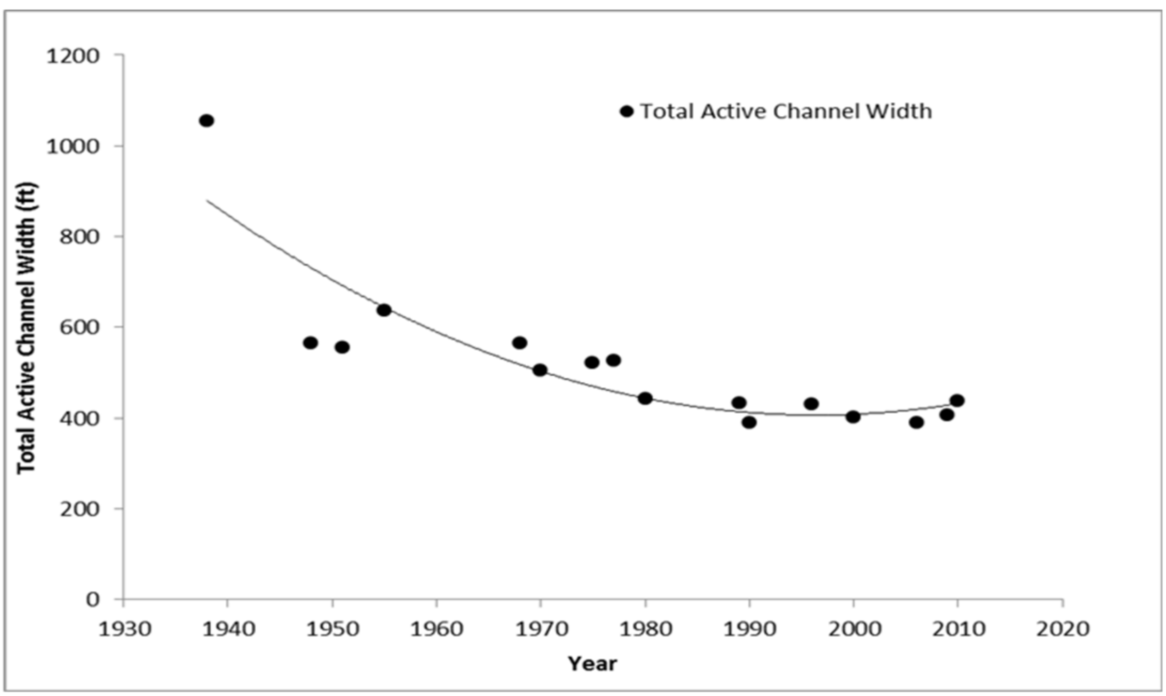

Figure 6. Trends in Total Active Channel Width (North and South Channels) over the aerial photo record.

Flow split configuration at top of island. The discussion thus far has focused on trends in the overall flow split between the North and South Channels but has not addressed specific bedform conditions that have developed at the top of the island where the channels diverge. These conditions have been evolving over time along with the more fundamental changes to flow volumes between the channels. The conditions here may have a pronounced effect on fish usage of the North Channel due to their effects on attraction flows into the North Channel during the juvenile Chinook outmigration period. Compared to historical conditions (see photo comparison in Figure 7), the flow split no longer forks evenly and is now comprised of only a few cross-over channels that penetrate the growing bar at the top of the island. This condition is particularly pronounced at low summer flows (as depicted in the photos) but would also have some effect on fish attraction during the spring outmigration. As a means of comparison, the cumulative width or "gap" of the cross-over channels in 1970 and 2012 were compared. The results are presented in Table 4. The flow of the river on the day of the photo is also included in the table for reference. These data suggest a significant reduction in surface water flow entering the North Channel. Even though flows in the 2012 photo were nearly three times the flows in the 1970 photo, the width of the cross-over channels in 2012 is less than 25% of what it was in 1970. These results suggest that if flows were not kept elevated due to hydro-regulated minimum flow requirements (2,300 cfs from July 1-10), then the North Channel could be at risk of being completely shut off to surface flows during low summer flow periods.

Figure 7. Photos of the top end of Eagle Island in July 1970 (top photo) and July 2012 (bottom photo). Note difference in accessibility of North Channel to fish and the decreased likelihood of adequate attraction flows for fish entry into the North Channel. This effect would be diluted during the higher outmigration flows in the spring, but would nevertheless have some effect on fish usage of the North Channel.

Table 4. Comparison of cross-over channel widths between 1970 and 2012.

Photo Date	Flow at Ariel Gage (cfs)	Cumulative width of cross-over channels (feet)
July 5, 1970	795	1,080
July 5, 2012	2,340	238

Vegetation encroachment. Vegetation encroachment and maturation has impacted channel planform and geomorphic function within the project reach. The lack of frequent scouring flows has limited the channel's capacity to mobilize surface sediments, which is needed to prevent vegetation encroachment on banks and bars.

In order to estimate the extent of vegetation encroachment over time in the study area, the spatial extent of active bars was measured using the historical photo record (Figure 8). These results demonstrate that although the number of active bars has stayed relatively constant, there is a decreasing trend in total surface area of active bars. This decreasing trend is likely due to multiple contributing factors including increased lateral stability, decreased magnitude of scouring floods, lower flows during the spring runoff, and higher summer flows. The higher summer flows required by the FERC license are likely a primary contributing factor to rapid and vigorous vegetation encroachment. Higher flows during the summer promote good growing conditions farther down on the banks because of increased water availability during the growing season.

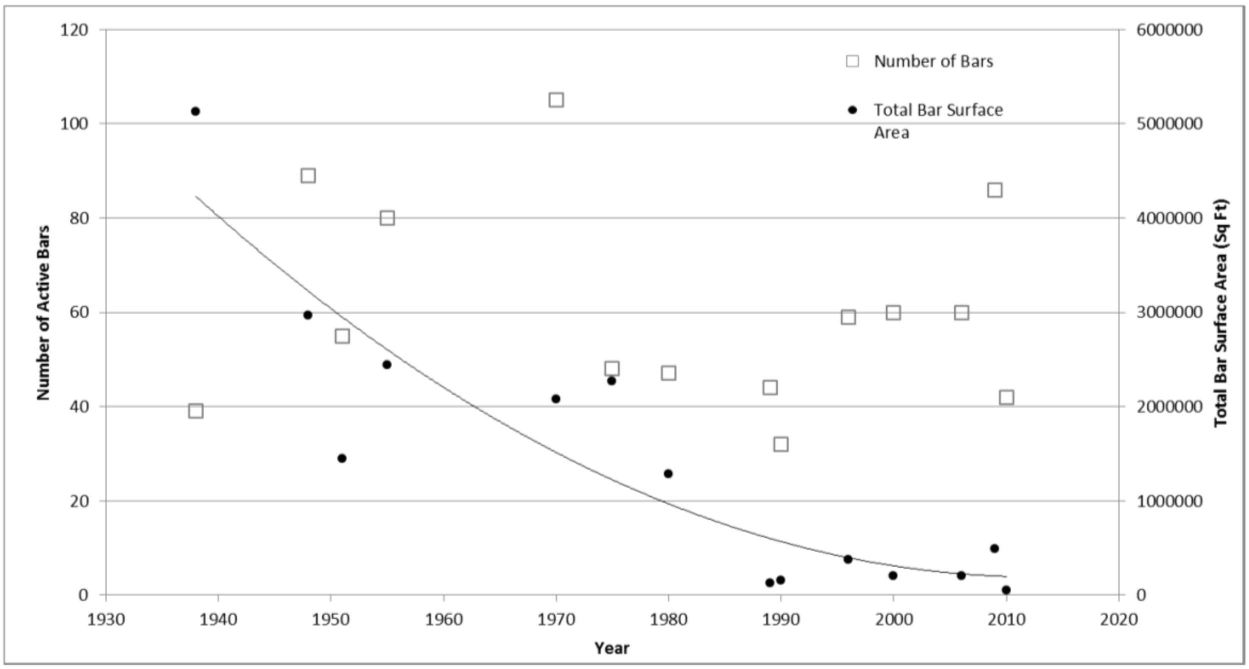

Figure 8. Number of Active Bars present in aerial photo records. Visibly active surfaces (depositional or erosive) within the active channel boundary (color and texture used to delineate stable vegetated bars from active surfaces). A vegetative density of ~30% was used to delineate active surfaces.

Summary of geomorphic trends and land-use influences. The above discussions are summarized in a timeline of geomorphic trends in the study area (Table 5).

Table 5. Summary of geomorphic trends.

Time period	Trend/conditions
1850s – early 1900s	Unknown but possibly a single-thread channel during much of this period.
1930s – 1960s	Period of active channel dynamics including shifting planform and development of split flow conditions. Active channel dynamics due to the 1933 flood, gravel extraction, fill, and human-induced avulsions.
1970s – early 2000s	Period of increasing stability marked by less channel shifting, greater veg encroachment, and an increasing dominance of the

Time period	Trend/conditions
	South Channel. Likely experiencing influence of hydro-regulation on peak flow dampening, sediment interruption, incision, and veg encroachment due to elevated low flows.
Early 2000s – Present	Appear to have passed a threshold of channel shifting, with increasing closure of North Channel, especially at low flows. Sediment deposits at top of island growing and becoming more vegetated. More flow in South Channel fuels this cycle.

FISHERIES STUDIES AND TRENDS

Juvenile salmonid sampling. WDFW has been sampling juvenile salmonids in the lower river below Merwin Dam since at least the late 1970s. These data, along with personal observations by long-time WDFW staff working on the river, provide some insight into how fish use the lower river and how conditions have changed for fish use over time.

Juvenile fish are sampled via seining at numerous sites (over 60 sites currently) located between Woodland and Merwin Dam. The sampling is conducted for coded wire tagging (CWT) of juvenile Chinook. The CWTs are later retrieved during adult spawner surveys; these data are used to make population and escapement estimates. Sampling typically occurs May to July. The individual sites have been grouped by WDFW into general areas of the river. The areas include the following: 1) Below Island = downstream of Eagle Island to near Woodland; 2) Above Island = upstream of Eagle Island and extending to near Merwin Dam; 3) Top of Island = approximately 0.5 mi stretch at top end of island (where large bar has formed); 4) North Channel = within the North Channel of Eagle Island; and 5) South Channel = within the South Channel of Eagle Island.

The total catch numbers by general area since 1983 are plotted in Figure 9. The trends for the Top of Island and North Channel sites are bolded so they can be more easily seen. From the early 1990s to 2005, catches above the island were greatest, followed by the top of island, then North Channel, then South Channel, and then below the island. Since 2005, catches at all sites have decreased, which may be related to a decrease in seine mesh size at that time. The mesh size was increased in 2005 in order to select for larger fish (personal communication with Shane Hawkins, WDFW, January 24, 2013).

Although these data are useful for understanding trends in fish use, they need to be evaluated within the proper context. The primary goal of these sampling efforts has not been to determine fish use of habitat types or areas, but rather to make population and survival estimates; so the data must be interpreted accordingly. In particular, the number of seining sets per area has not been held constant, which means that the total catch numbers by area are not necessarily indicative of relative abundance by area. For this reason, catch per unit effort (CPUE) values are presented in Figure 10 as a potentially more accurate estimate of relative fish use of areas over time. The data are plotted as a proportion of the maximum CPUE for each year in order to remove the variation associated with year-to-year differences in catch rates and other variables such as effects of flow and the change in mesh size in 2005.

Catch rates (CPUE) of juvenile salmonids were consistently the highest at the top end of Eagle Island in the 1980s. Beginning in the late 1980s/early 1990s, catch rates were no longer consistently the highest in this area. Since 1997, there appears to be a general trend of decreasing CPUE in the South Channel. The other areas of the river have maintained relatively similar variability in catch rates over the sampling record.

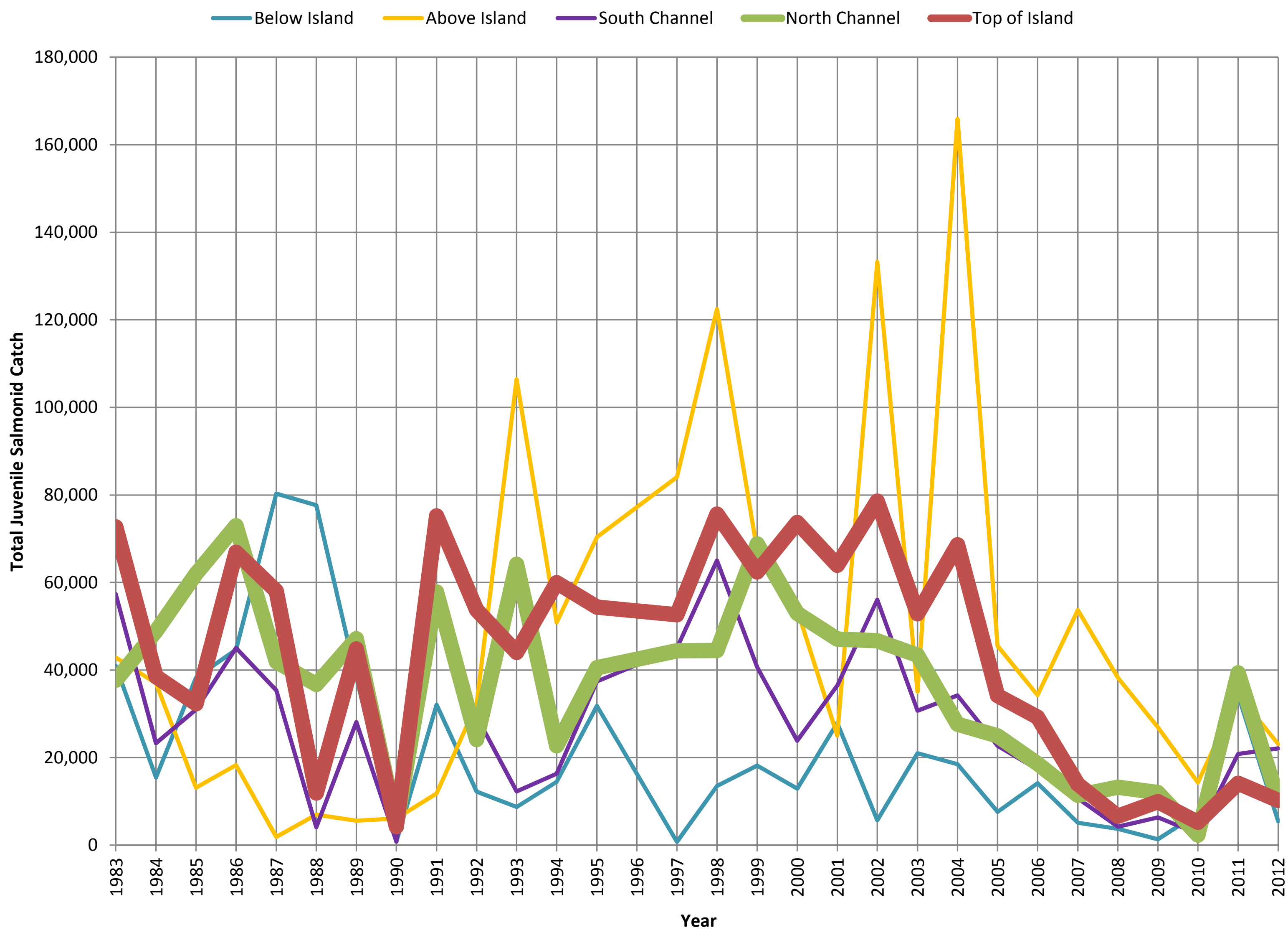

Figure 9. Plot of total catch data from WDFW juvenile salmonid sampling on the lower NF Lewis River 1983-2012 (WDFW unpublished data). Note, in 2005, the seine net was changed to a larger mesh size to select for larger fish (personal communication with Shane Hawkins, WDFW, January 24, 2013). This change affects the total catch rates and is likely the reason the catch numbers decrease since that time.

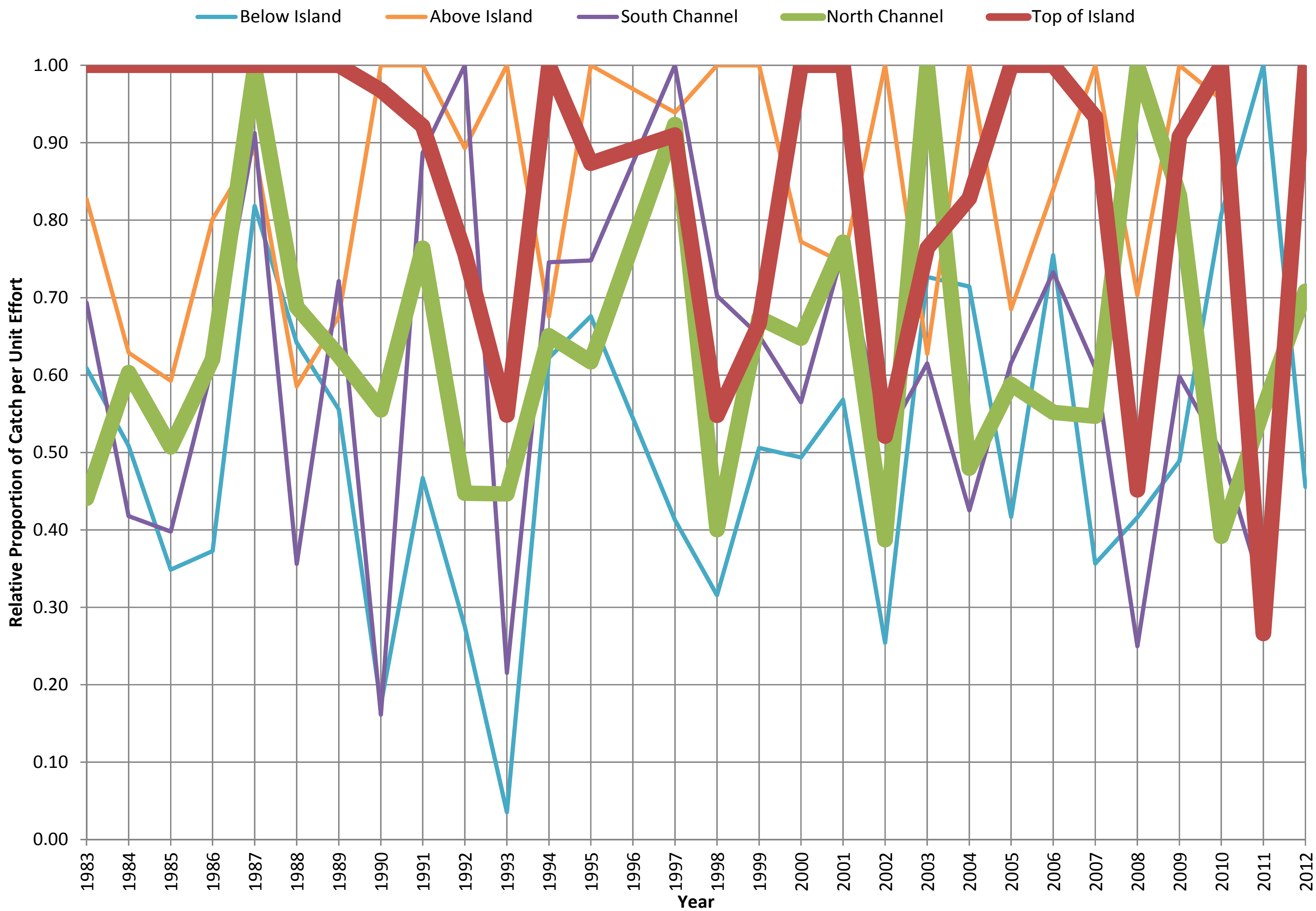

Figure 10. Plot of catch per unit effort (CPUE) data from WDFW juvenile salmonid sampling on the lower NF Lewis River 1983-2012 (WDFW unpublished data). Data at each site for each year are plotted as a proportion of the max site CPUE for that year; this was done in order to look at relative changes among sites irrespective of year-to-year variability in catch numbers and irrespective of the changes to seine mesh size beginning in 2005.

Fish use of the North Channel. Because of the relevance to this project, we looked more specifically at current use and historical trends in fish use of the North Channel in relation to other areas in the lower NF Lewis. Understanding fish usage of the North Channel helps to understand the significance of this area for fish production in the system and the potential loss of production if flow in the North Channel were further reduced. In Figure 11, the total catch results are compared among areas. The North Channel is a large producer of fish, with a median juvenile catch of over 40,000 each year, which is the second largest of the 5 sites and makes up 24% of the total catch (all sampling years combined). Note that these data do not account for level of sampling effort, as discussed in the previous section.

Historical catch data for the North Channel are plotted in Figure 12. These are the same data plotted above in Figure 9 but for only the North Channel sites and instead of total catch numbers, the values are plotted as a percentage of the total catch for all areas combined. This allows for an analysis of how the catch in the North Channel has changed over time in relation to the other sampling areas. In general, catch numbers in the North Channel show a slightly decreasing trend over time; ranging from 15-35% of the total catch in the 1980s down to 7-28% in more recent years.

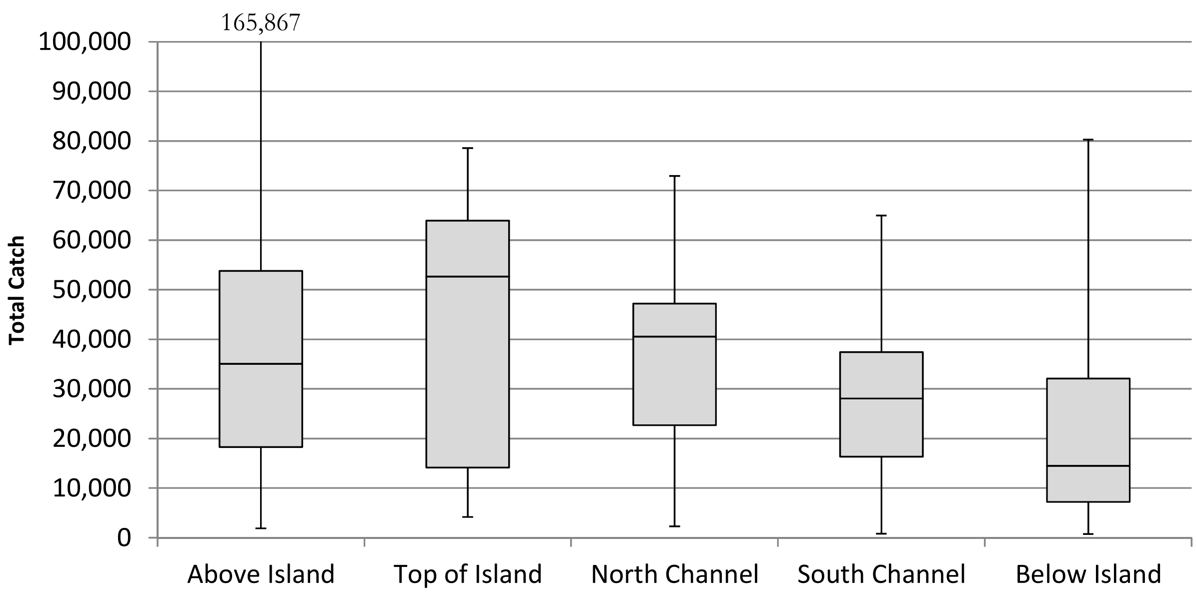

Figure 11. Box plots of total juvenile salmonid catch results from 1983-2012 by general area (WDFW unpublished data).

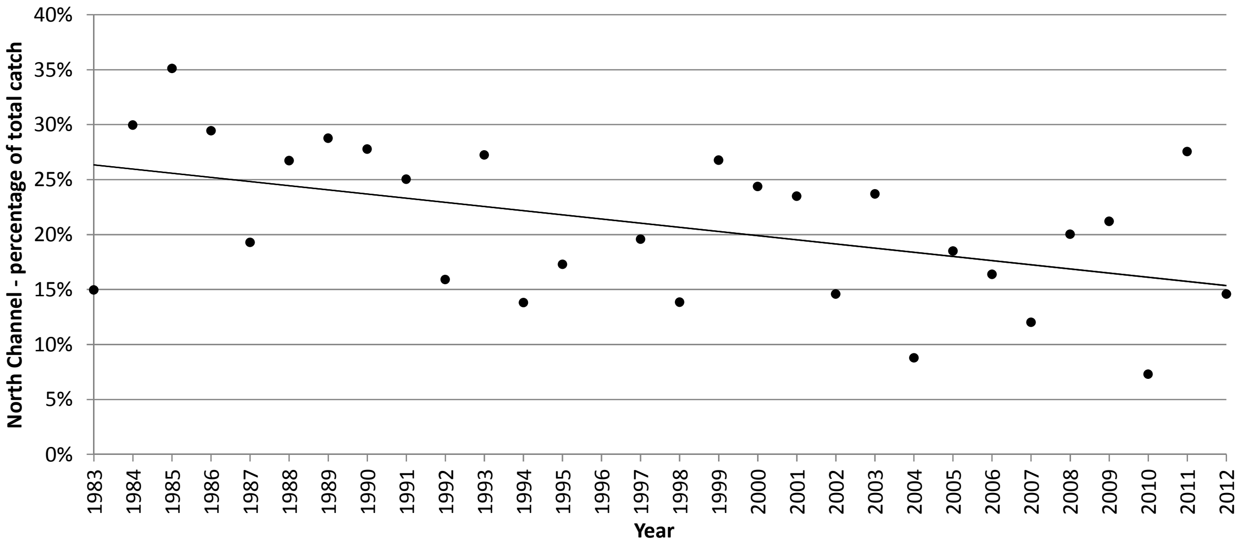

Figure 12. Catch of juvenile salmonids in the North Channel as a percent of the total catch in the lower NF Lewis River (WDFW, unpublished data).

IFIM Study. An Instream Flow Incremental Methodology (IFIM) study was performed in the early 1980s to help inform the development of instream flow requirements in the lower river as part of hydro-relicensing. The IFIM study involved developing habitat suitability criteria and then pairing these criteria with flow conditions to estimate the optimal flows for juvenile salmonid rearing. The study site for the IFIM study was located at the top end of Eagle Island where the large bar has been forming in recent decades.

The final conclusion of the IFIM study was that the optimum flow for fall Chinook rearing is between 800 and 1,400 cfs (Leder and Neuner 1984). Above this flow, the 'weighted usable area' for rearing decreased rapidly. It was not clear whether flows greater than 3,000 would provide greater habitat (in margin areas) or whether these benefits would be offset by losses of rearing areas in the channel. A study comparing juvenile fish abundance and flows (Norman et al. 1987) contradicted the IFIM findings and instead found that higher flow years produced populations that were roughly twice the size in low flow years. Regardless of the accuracy of the final IFIM conclusions, the development of habitat suitability criteria and observations of fish and habitat relationships (by lifestage) may be useful for evaluating potential restoration alternatives. These relationships and habitat criteria are provided in Campbell et al. (1984). A summary of the depth and velocity ranges where fish were found, and the narrower preference ranges that contained the most fish, are presented in Table 6. The preference ranges were used in conjunction with the hydraulic modeling in order to evaluate the potential benefits of restoration alternatives and to optimize habitat conditions at the top of the island for the preferred alternative.

Table 6. IFIM Study Fish Preference Information.

Life-Stage	Velocity Range (ft/s)	Velocity Preference (ft/s)	Depth Range (ft)	Depth Preference (ft)
Fry (25-50mm)	0 - 2	0 - 1	0 - 4	0 - 2
Juvenile (55-110mm)	0 - 3	0 - 1.5	0.7 - 6	1.5 - 4

HYDRAULICS ANALYSIS

Hydraulic Model Development

Site hydraulics evaluation included developing a Two-Dimensional (2-D) hydraulic model for the North Fork Lewis River at the Eagle Island reach, which extends upstream and downstream of the island. The extent of the model domain and site topography in meters is shown in Figure 13.

A 2-D model calculates hydraulic parameters within a mesh (or grid) laid over the river and surrounding landscape. A 10 meter square grid was used for this model to optimize model resolution and computational time. The grid used for the hydraulic model is shown with an overlay of the 100-year recurrence interval flood inundation (the largest magnitude flow modeled) in Figure 14.

Hydraulic parameters are calculated by balancing conservation of momentum and conservation of mass through the boundaries of each element of the 2-D mesh, which is generated from the grid overlaid on site topography and bathymetry. The hydraulic model utilizes the Surface-water Modeling Solution (SMS) proprietary pre- and post-processing software and the TUFLOW proprietary hydrodynamic model. TUFLOW is a hydrodynamic model that tends to be computationally stable compared to some other two-dimensional models which are prone to crashing when evaluating a large range of flows and split flow conditions such as around the Eagle Island area. TUFLOW uses only metric units as model input and output. This report provides measurements in both metric and U.S. common units. In some cases, conversions back to common U.S. units are provided for model output using a data calculator within the SMS software.

Hydraulic roughness is represented by materials characteristics assigned as polygons within the SMS software. Figure 15 displays different materials properties assigned to the project site. Table 7 provides roughness values assigned for various materials properties used. The Manning's roughness value for the channel materials property resulted from model calibration.

Table 7. Roughness values used in the model.

Materials Property	Manning's Roughness Value
Agriculture	0.045
Channel	0.015
Forb	0.04
Forest	0.065
Log Jam	0.28
Residential	0.03
Residential Rough	0.06
Shrub	0.085

Model calibration was based off survey data and a water level data recorder that captured a flow that was near the 2-year recurrence interval flow. A series of edge of water points were taken during the February 24, 2012 survey and used as calibration points when the USGS gage at Aerial consistently recorded 15-minute flow data as 11,500 cfs for that day and the day prior. A data logger also recorded water surface elevation on December 30, 2011 when the Aerial Gage recorded flows in the range of 17,500 to 17,900 cfs. The 17,900 cfs flow was used for calibration of the December 30, 2011, calibration point. The model was calibrated by changing Manning's roughness within the channel since calibration flows are within the channel boundaries. The calibration table below (Table 8) provides the date, flow, and location of calibration points; as well as Water Surface Elevation (WSE), model output elevation, and percent error associated with channel roughness values of

0.025, 0.020, and 0.015. The calibration table shows good agreement, based on calibration points and model output, with a channel roughness value of 0.015.

Hydraulic modeling was performed without a downstream backwater condition. Modeling without a downstream backwater condition assumes a typical winter flow condition when the Columbia River is relatively low and so there is no significant backwater condition in the lower reaches.

Table 8. Calibration flow and roughness.

Date	Flow (cfs)	Easting (m)	Northing (m)	WSE Elev. (m)	Model Elev. (m)	% Error	Model Elev. (m)	% Error	Model Elev. (m)	% Error
Manning's Roughness Value					**Chan. n=0.025**		**Chan. n=0.020**		**Chan. n=0.015**	
2/24/2012	11,500	330273.67	68690.84	6.35	6.89	9%	6.75	6%	6.32	0%
2/24/2012	11,500	330466.95	69499.77	7.59	8.11	7%	8.01	6%	7.62	0%
2/24/2012	11,500	330768.67	69595.26	8.08	8.27	2%	8.15	1%	8.08	0%
2/24/2012	11,500	330699.89	69693.37	7.95	8.17	3%	8.06	1%	7.98	0%
12/30/2011	17,900	330625.17	69537.81	8.66	8.72	1%	8.62	0%	8.52	2%

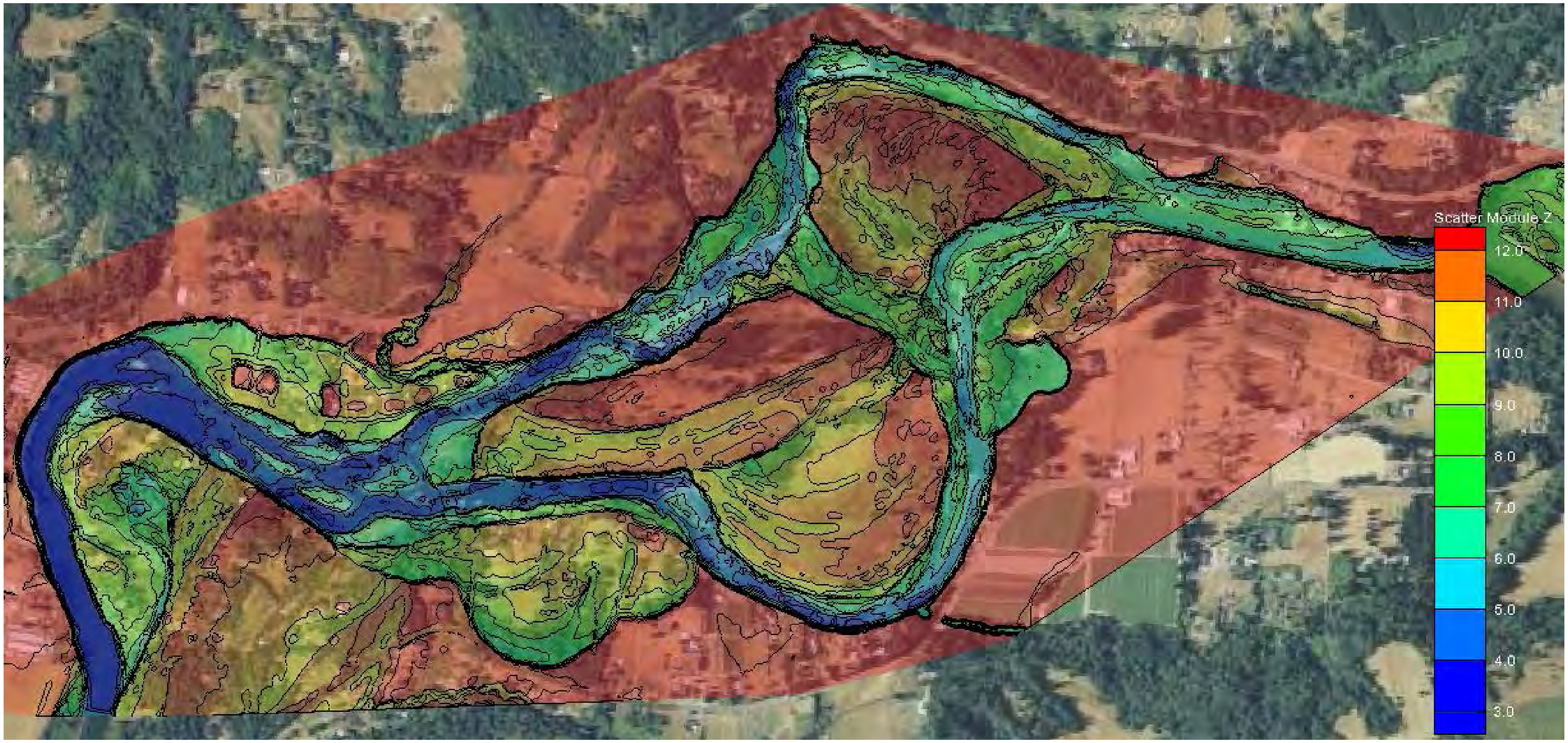

Figure 13. Existing topography (Topography displayed in Meters (m))

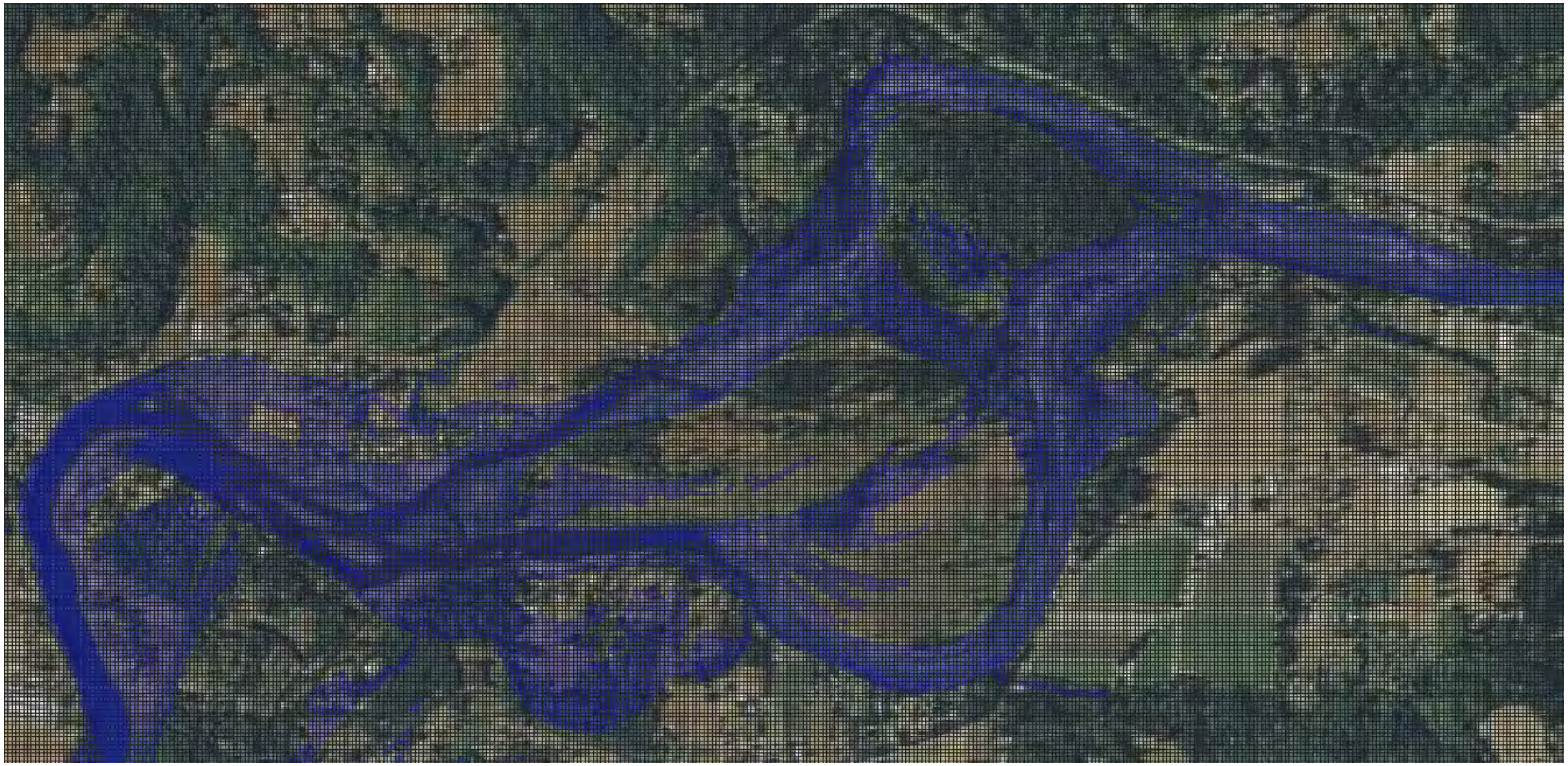

Figure 14. 10 meter grid, 100-yr flood.

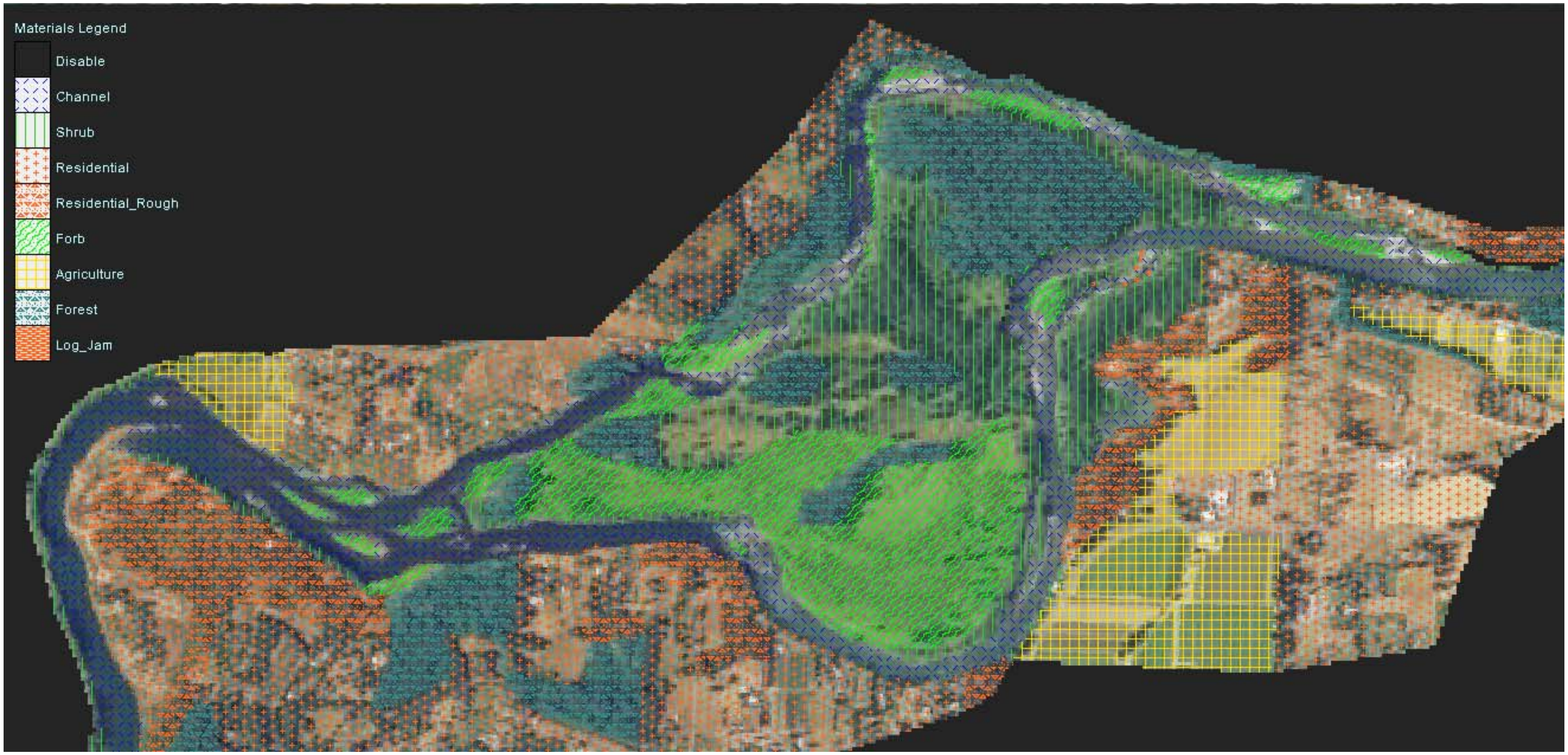

Figure 15. Roughness materials properties.

Hydraulic Model Analysis Methods

The hydraulic model was used to evaluate existing conditions and potential restoration alternatives. Modeling was performed for a range of flows that were developed as part of the hydrology analysis (described previously). The 2-, 10-, 50-, and 100-year recurrence interval floods were evaluated. In addition, a 'low fish presence flow' and an 'average fish presence flow' were used in order to evaluate conditions during the juvenile fall Chinook rearing period. The low fish presence flow was selected as the low end of the 90% exceedance flow for the period March 1 – June 30, which is approximately 2,000 cfs (Figure 2). This flow represents a conservative estimate of flow during the rearing period, with the assumption that higher flows will provide an even greater amount of available habitat. The average fish presence flow was selected as the average 50% exceedance flow for this period, which is approximately 4,500 cfs. This flow was used for analyzing habitat conditions at the top end of the island for refinement of the preferred alternative.

Existing conditions model output is shown in Appendix B (Hydraulic Model Outputs – Existing Conditions). Model output includes: Water Surface Elevations (WSE), depths, and velocities for probable fish presence flow, 2-, 10-, 50-, and 100-year recurrence interval flows. Modeling results for the potential restoration alternatives are presented in the Restoration Alternatives section at the end of this document.

Limitations of Model with Respect to Long-Term Channel Changes

Although restoration alternatives are designed to achieve sediment competency, future sediment deposition and transport dynamics will alter the flow split between the North and South Channels over time and in uncertain ways. Hydraulic modeling only evaluates conditions that would immediately follow construction of various alternatives. However, sediment transport dynamics will cause conditions to evolve following project implementation. There is insufficient sediment transport data available to predict the specific extent and rate of channel changes in order to direct a meaningful modeling effort of future conditions. There are, however, model outputs that allow for estimating where sedimentation or erosion may occur following project implementation. The conventional independent variables used in sediment transport studies are water discharge, average flow velocity, shear stress, and energy (water surface slope). More recently, the use of stream power and unit stream power have gained increasing acceptance for evaluating sediment transport rate or concentration (Yang 2006). By evaluating stream power immediately upstream of the island, an evaluation of relative sediment competency was performed to understand risk of sedimentation or scour associated with the restoration alternatives. These are discussed in the alternatives evaluation section below.

Sediment Sources and Dynamics

Overview. Based on the historical photo record (and observed trends in recent decades), the river in the vicinity of the Eagle Island is laterally and vertically dynamic and regularly recruits coarse and fine alluvial deposits and transports them downstream. This typically happens during flood events. Although a sediment/bedload budget for the Lewis River is beyond the scope of this study, a few particular areas of significant bank erosion and deposition are worth noting. One area of severe bank erosion is the river-right bank just upstream of the golf course (RM 13.5). This eroding bank, which stretches approximately 1,000 lineal feet and has a maximum height of approximately 18 feet, has laterally migrated over 300 feet at its maximum point since 1939. A similar bank on the right-bank of the South Channel at Eagle Island has migrated a maximum of approximately 400 feet since 1939.

Other less severely eroding banks are also located within or upstream of the study area. Significant areas of deposition are also present, including most notably the large gravel bar that has formed at the upstream end of Eagle Island (now approximately 2.2 acres at low flow).

These active erosion and deposition processes are indicators of continuing changes in channel planform and continual erosion and downstream movement of bed and bank material. Over time, this activity will result in channel incision and widening (although mitigated by vegetation encroachment) because of the interruption of bedload transport due to the hydro-system. In the near-term, channel incision may lead to subsequent widening as the channel attempts to create new inset floodplain surfaces. In the longer-term, however, the channel bed would be expected to become more stable and to experience less coarse bedload transport as the bed becomes armored due to hydro-regulation. This stability would be further reinforced by vegetation encroachment.

Bedload composition. Riverbed sediment follows a trend from coarser to finer sediment as you move from Merwin Dam downstream to the project area. Bed sediment at the upstream end of Eagle Island is comprised primarily of gravels and cobbles, with gravels dominant and cobbles sub-dominant. Bed material samples were taken at the upstream ends of the North and South Channels. Summaries of the results are presented in Table 9 and Table 10.

Table 9. Substrate sampling results for the upstream end of the North Channel

Material	Percent Composition
Fines	0.3%
Sand	6.7%
Gravel	53%
Cobble	40%
Boulder	0%

Size Class	Size percent finer than (mm)
D5	1.2
D16	8.4
D50	52.3
D84	92.4
D95	>101.6
D100	>101.6

Table 10. Substrate sampling results for the upstream end of the South Channel

Material	Percent Composition
Fines	0.1%
Sand	11%
Gravel	76%
Cobble	13%
Boulder	0%

Size Class	Size percent finer than (mm)
D5	0.7
D16	4.8
D50	33.0
D84	61.0
D95	76.2
D100	101.6

Effects of hydropower system on sediment dynamics. Dams frequently interrupt and modify sediment transport processes, which can lead to channel bed armoring, loss of bedload, and/or incision downstream of dams. The effect of the Lewis River hydro-system on spawning gravels below Merwin Dam was analyzed as part of a spawning gravel study in 2006 (Stillwater Sciences 2006). The report concluded that spawning gravel availability below Merwin is stable but limited. The stability of the material is evidenced by heavy use by fish, prevalence of spawning dunes that do not wash away, tracer gravel studies that confirmed stability, and a lack of a large flood nearing the magnitude of the 1933 flood of record. They do note that there has been significant vegetation encroachment of gravel bars since the 1933 flood. Although the study did not show significant transport of bedload out of the upper reaches, they did note that bedload within the lower reaches (e.g. Eagle Island area) was mobile on a more regular basis.

Previous sediment budget. As part of the Stream Channel Morphology and Aquatic Habitat Study (WTS-3) (PacifiCorp and Cowlitz PUD 2004), a sediment input budget was calculated for the lower Lewis River (between Merwin Dam and the downstream end of Eagle Island) and Cedar Creek. Potential sources of sediment inputs evaluated were soil creep, landslides, and road surface erosion. This analysis calculated that 6,590 tons of sediment enter the Lewis River and 1,560 tons enter Cedar Creek each year (Table 11). These inputs are primarily driven by management-related activities, principally landslides from clearcuts and roads. For the Lewis River, 20% of this material was estimated to be sand and gravel and the rest was silt/clay. For Cedar Creek, the sand and gravel fraction was estimated at 40%. This analysis does not account for bed and bank erosion within the river channel. Bed and bank erosion were not included because rates of bank erosion could not be determined from the aerial photo record.

Table 11. Sediment inputs (in tons/year) to the Lewis River from Merwin Dam to the Downstream End of Eagle Island (Adapted from PacifiCorp and Cowlitz PUD 2004).

Sediment Input	Lewis River from Merwin Dam to Eagle Island (32 sq mi; excluding Cedar Creek)	Cedar Creek
Soil creep	310	480
"Background" landslides (clearcuts>50 years old)	500	630
Management-related landslides (roads & recent clearcuts)	5,740	300
Road surface erosion	40	150
Total (tons)	6,590	1,560

Estimate of sediment contributed to Eagle Island Reach. A planning-level estimate of potential coarse sediment (sand to cobbles) contribution to the Eagle Island reach was developed in order to help evaluate the potential longevity of restoration alternatives. This evaluation used the previous sediment budget information from the Channel Morphology report (PacifiCorp and Cowlitz PUD 2004), which is discussed above, and added in an estimate of sediment contributed from bank erosion within the river upstream of Eagle Island.

The estimate of bank erosion was made by estimating the volume of material eroded by the river at three main areas upstream of Eagle Island over the period of the historical photo record (1938 to present). The three areas include the following: 1) the north bank at RM 12.4 (as much as 250 feet of lateral channel migration between 1938 and 1951), 2) the north (west) bank at RM 13.5 (as much as 330 feet of lateral channel migration between 1951 and present), and 3) the south bank at RM 14 (as much as 100 feet of lateral channel migration between 1938 and 1970). The other significant area of erosion was also located at RM 12.4 where the stream channel avulsed through a gravel pit in the 1960s but this area was not included due to the human-induced nature of the erosion and because gravel mining removed much of the material in the avulsion area. There were no other areas where significant portions of bank erosion could be identified between the upstream end of Eagle Island and Merwin Dam.

Volume estimates were made by calculating the areal extent of erosion and multiplying this by the estimated depth of material, which was determined using elevations of the contemporary bank lines obtained from LiDAR data (and assuming a river depth of 2 feet during the LiDAR flight). The total volume estimate was divided by 73 years (1938 to 2011) to obtain an estimate of the annual volume of material recruited by the river. This estimate came to approximately 7,600 cubic yards per year.

Approximately 800 cubic yards per year was added to the estimate based on the sand and gravel fraction from hillslope and tributary sources obtained from the Channel Morphology report (PacifiCorp and Cowlitz PUD 2004) and assuming a standard material density of 2.9 grams/cm^3 (density of basalt) to convert tons (reported in the study report) to cubic yards. This resulted in a final estimate of approximately 8,400 cubic yards per year. This analysis does not consider vertical erosion of the bed (i.e. incision) or changes in the amount of deposition/storage within the channel. This analysis should be viewed as only a rough approximation; however, it does suggest that the material contributed from bank erosion likely makes up a much greater portion of the coarse sediment input than material delivered from hillslope and tributary sources. This corresponds to what one would expect in a large low gradient alluvial river. The estimate also provides a very high end approximation of the amount of material that could potentially be made available to the Eagle Island reach over time, which could contribute to the on-going trend of bar development at the top of the island. In this context, it can be used to develop order-of-magnitude estimates of how long it might take for natural replacement of material that is excavated as part of restoration alternatives. This information can be used to estimate the potential need for long-term maintenance dredging following restoration actions.

RESTORATION ALTERNATIVES

ALTERNATIVES DEVELOPMENT AND ANALYSIS

Overview. Alternative development has occurred as an iterative process where potential actions have been modeled as scenarios in the 2D model. These are then evaluated according to how well they help accomplish the objectives and how they might function with respect to geomorphic and sediment transport considerations. Through this process, various alternatives and sub-alternatives have been developed. These are discussed in the alternative sections that follow.

As described previously, the primary restoration target is to achieve relatively equal flow split between the North and South Channels. This condition was prevalent since the late 1960s and began to deviate at least as early as the 1980s and extending until present time. One of the causes and consequences of flow shifting has been the development of gravel bars within the North Channel and at the upstream end of the island. Iterative model runs and various scenario combinations have looked at manipulating (removing or modifying) these bars and also adjusting channel widths and depths. Through these investigations, it has become apparent that the primary driving factor of North Channel abandonment is a smaller width (active channel and floodplain) compared to the South Channel.

Summary of alternatives that were evaluated. The first alternative includes manipulating the mid-channel bar(s) upstream of Eagle Island at the North Channel inlet. Two sub-alternatives were developed that involve manipulation of the upstream bar(s). One of those sub-alternatives also includes reducing the height of the riffle at the upstream end of the North Channel.

The second alternative includes construction of side-channels within the North Channel that would potentially serve a dual purpose of increasing channel capacity/width as well as creating fish habitat. Two different side-channel sub-alternatives were developed.

The third alternative includes an aggressive approach to increasing the width of the upper portion of the North Channel and extending this down to the first major bend in the river. Three sub-alternatives were developed as part of this alternative. The sub-alternatives include various combinations and extents of width expansion and bar removal or modification.

In summary, the following types of actions were evaluated as part of the restoration alternatives:

- Removing bar material at head of island
- Reducing elevation of riffle at head of North Channel
- Creating side-channels within the North Channel
- Increasing channel width in portions of the North Channel

Development of the preferred alternative. The initial three concept alternatives were reviewed by the TOG at the January 24, 2013 meeting where it was decided to move forward with a variation of the first alternative (Alternative A). The preliminary design of the preferred alternative was reviewed by the TOG at the March 6, 2013 meeting and was further revised based on TOG input and additional modeling and analysis in order to develop the final (90%) design. Design revisions are described in more detail under the Preferred Alternative section below.

Notes on the use of wood placements. Placement of wood, either log jams or cover wood, has been considered as part of the design process; however, it has not been the focus of the modeling effort. It is clear from the modeling conducted so far that placement of wood alone will not provide the desired flow split conditions since the flow split is governed by much larger scale changes to sediment deposition and channel geometry that have been occurring over the past several decades. Nevertheless, the use of wood could assist with maintaining scour conditions within the North Channel over time following initial bedform manipulation. Placement of wood or log jams would also provide habitat benefits for salmonids.

However, placement of wood must be weighed against long-term channel stability, river use, and boater safety. The North Fork Lewis River experiences heavy recreational boat use, including motorized jet boats, canoes, kayaks and other floating craft. As such, wood placed for habitat usage must consider safety concerns related to boat use. The manipulation of bar forms typically includes adjustment of those bar forms through natural flood related processes. Over time, adjustments of the channel margins associated with manipulated bar forms is reduced, especially as vegetation becomes established. If wood is placed at the margins of manipulated, unvegetated bar forms, gravel along the channel margins may mobilize and result in a submerged or partially submerged log jam that would be a significant boating hazard.

An additional consideration is that placement of large log jams would likely not meet Federal Emergency Management Agency (FEMA) requirements without also needing to increase the flow area to compensate for the impacts of log jam placements. The North Fork Lewis River is a FEMA-regulated floodplain and increases in the Base Flood Elevations (BFE) that impact structures are not permitted. Because structures are located on the riverbank throughout the Eagle Island reach, woody debris roughness elements need to be accompanied by increases in flow conveyance area to avoid increasing the BFE. Increasing flow conveyance area is achieved through additional excavation of river bed or bank gravels to offset the cross sectional conveyance area occupied by wood placements. The final design, which does not include wood placements, aimed at balancing cut and fill volumes. However, hydraulic modeling of the BFE indicated that of the approximately 60,000 cubic yards excavated from the channel, only approximately 50,000 cubic yards could be placed back in the channel to avoid impacts to adjacent structures. The 10,000 cubic yard difference must be disposed of above the 100-year floodplain to meet FEMA requirements. Additions of wood to the project result in additional volumes of excavated material that must be disposed of above the 100-year floodplain.

Alternative A – Bed Manipulation at Head of Island

Alternative A includes manipulating the mid-channel bar(s) at the head of Eagle Island to encourage flow into the North Channel. There are two sub-alternatives. Alternative A1 includes near full removal of the mid-channel bar upstream of the island, reduction of the riffle crest elevation adjacent to the Island Boat Ramp, and placing a bar on river left. Alternative A2 includes partial removal of the mid-channel bar upstream of the island and placement of a bar on river-left upstream of the island. Figure 16, Figure 17, and Figure 18 display topography, in meters, of existing conditions, Alternative A1, and Alternative A2, respectively.

Flow splits for Alternatives A1 and A2 were developed through the use of observation arcs drawn across the North Channel and South Channel (Figure 19). The flow splits provide for an evaluation of the effectiveness of various alternatives in increasing flows in the North Channel. Results are included in Table 12. The observation arcs were drawn from high elevation points across the channels approximately perpendicular to flow to obtain an estimate of flow in each channel. As such, they cross the grid (shown in black) at a diagonal. The diagonal crossing of the grid causes slight calculation and rounding errors that can be observed in the table below. However, this method still provides a measurement of relative effectiveness despite the slight calculation and rounding errors.

In all three alternatives, stream power is used as a measure of where deposition is likely to occur and the long-term effectiveness of alternatives to increase flows in the North Channel. Areas with lower stream power are more prone to deposition. Results, by sub-alternative, are provided for stream power for the 2-year recurrence interval in Figure 20, Figure 21, and Figure 22.

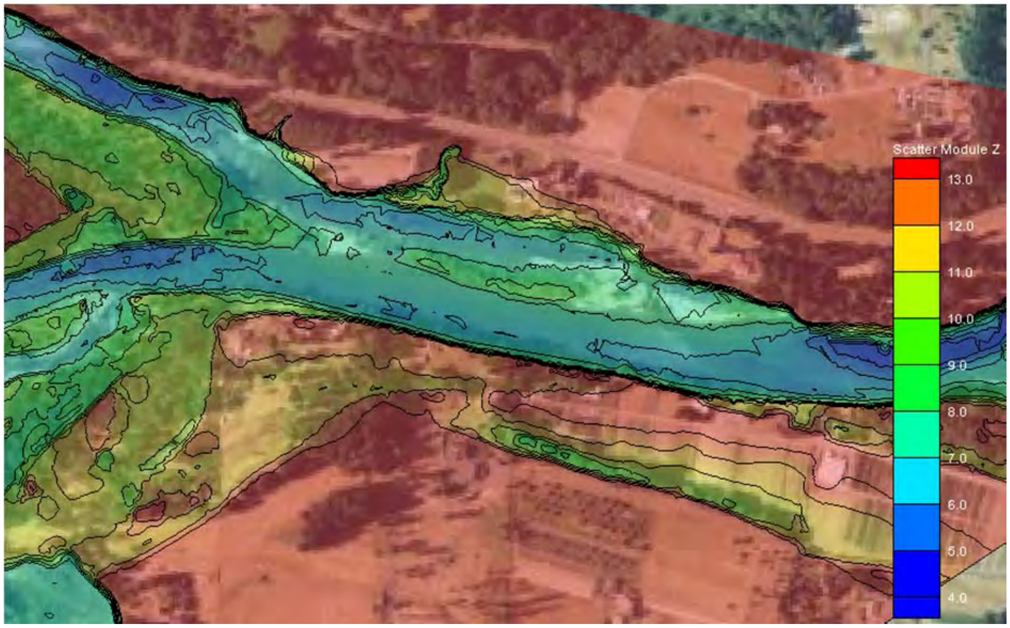

Figure 16. Existing Upstream Bar Topography (m).

Figure 17. Alternative A1 Topography (m).

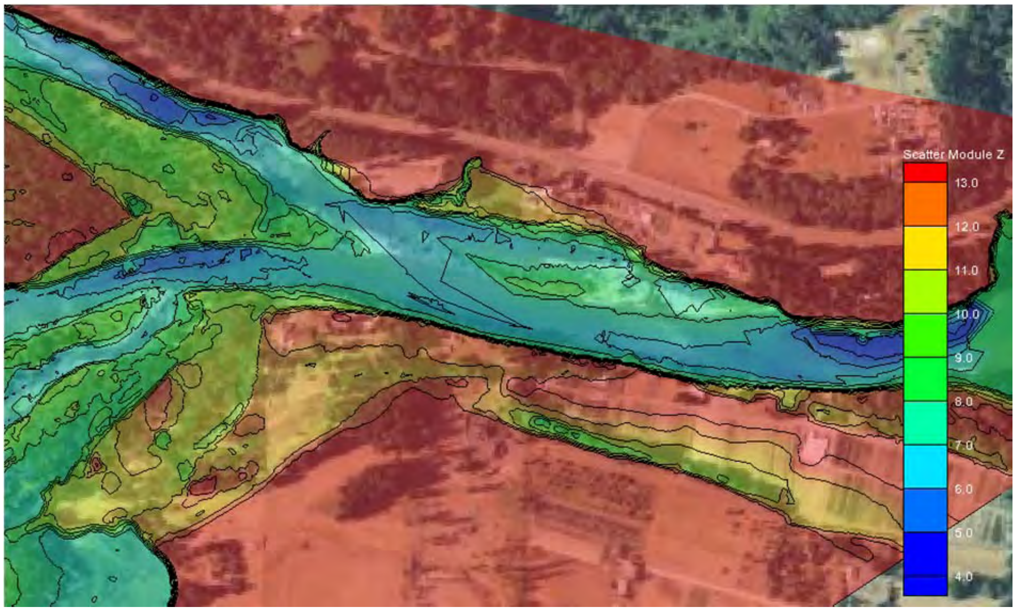

Figure 18. Alternative A2 Topography (m).

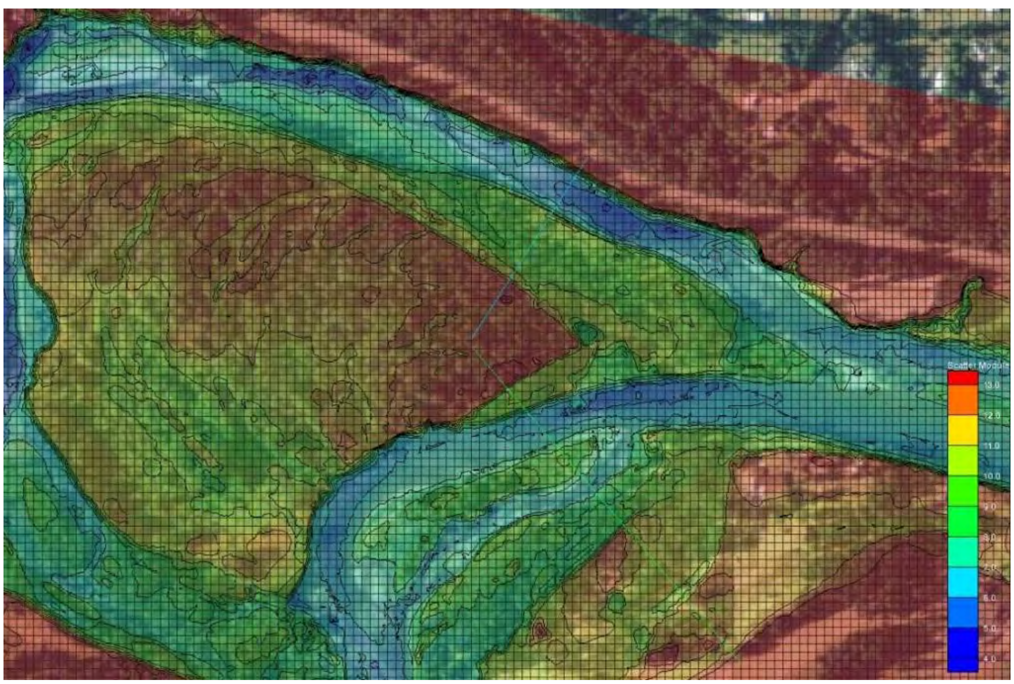

Figure 19. Flow Split Observation Arcs.

Table 12. Flow split conditions (values in cfs) for Alternative A.

	Existing Conditions		Alternative A1		Alternative A2	
	North Channel Flow	South Channel Flow	North Channel Flow	South Channel Flow	North Channel Flow	South Channel Flow
Low Fish Presence Flow	479	1,654	830	1,256	917	1,153
2-Year Flow	9,268	15,325	9,893	14,557	9,437	14,998
10-Year Flow	21,608	43,498	23,378	42,851	22,739	43,218
50-Year Flow	28,496	64,967	28,916	64,625	28,829	64,711
100-Year Flow	29,354	70,165	29,735	69,851	29,587	69,985

Flow splits for Alternative A1 and A2 are increased in the North Channel somewhat for lower flows, but do not substantially increase at higher magnitude flows. The flow splits do not attain the goal of a 50-50 split even at lower flows. As such, the effectiveness of Alternatives A1 and A2 is limited.

Sediment transport characteristics as indicated by stream power shown in Figures 15, 16 and 17. Low stream power values at the inlet of the North Channel do not change substantially from existing conditions. This suggests that maintenance dredging may be required following floods that transport significant sediment volumes. Higher stream power values do result from Alternatives A1 and A2 at the upstream tip of the island, which suggests erosion occurring at that location. The extent and rate of such erosion is unknown.

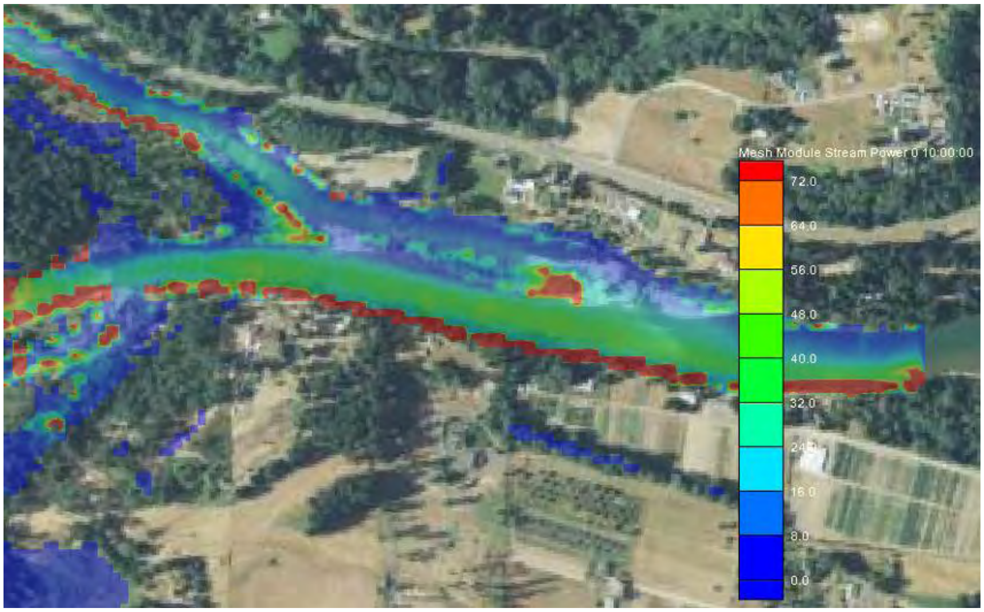

Figure 20. Existing Conditions Q2 Stream Power.

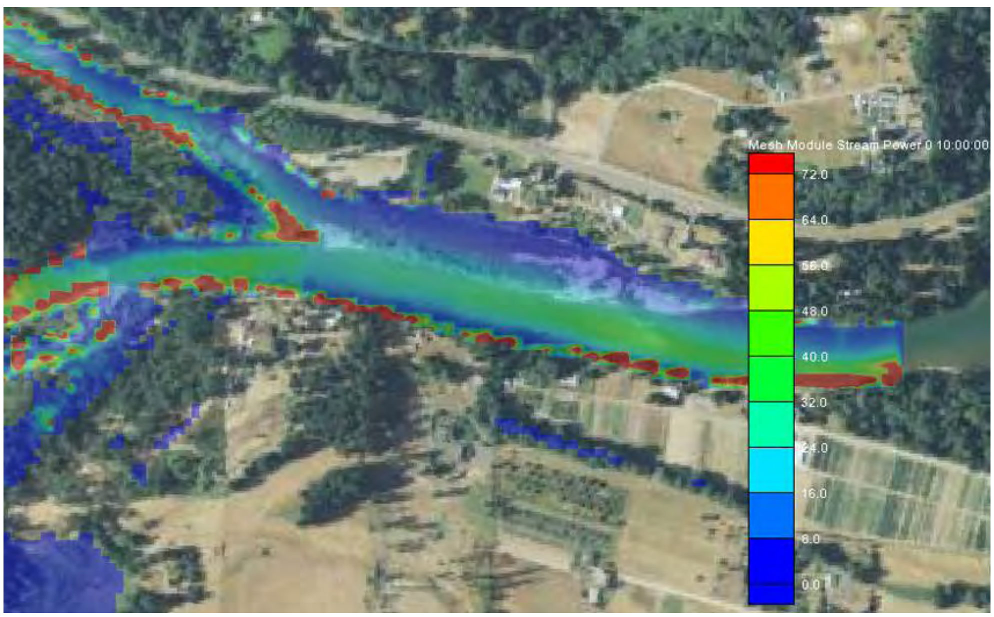

Figure 21. Alternative A1 Q2 Stream Power.

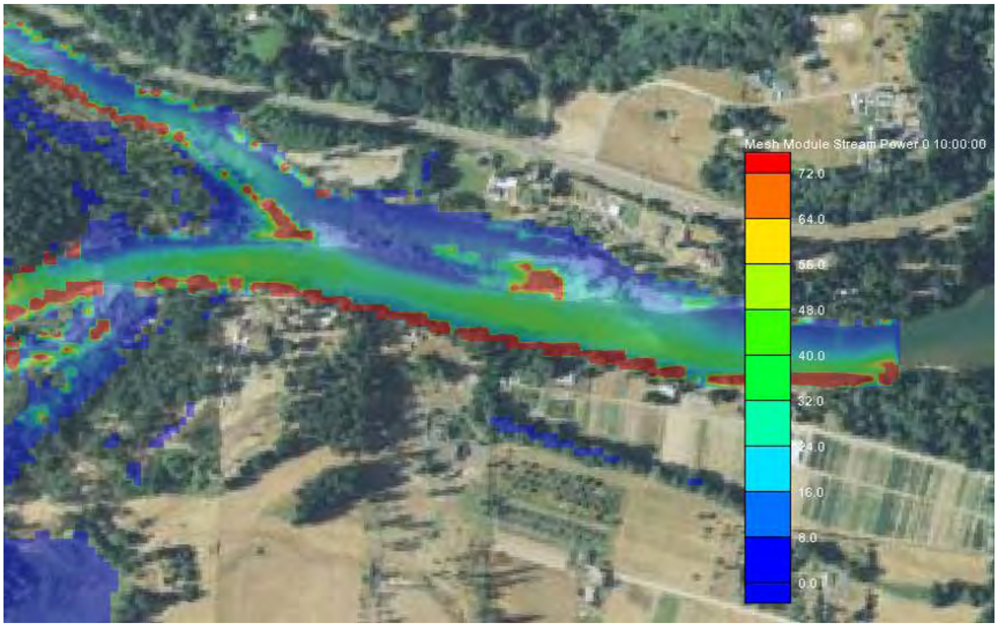

Figure 22. Alternative A2 Q2 Stream Power.

ALTERNATIVE B – SIDE-CHANNEL CREATION IN NORTH CHANNEL

Alternative B includes creating side channels in the North Channel to increase conveyance capacity. Side channels would be created through and around bars that presently appear to reduce conveyance within the North Channel. Two sub-alternatives (B1 and B2) were evaluated. Both sub-alternatives reconnect with the North Channel further downstream where channel width is observed to dramatically increase, especially at higher magnitude floods that may influence channel form. Figure 23, Figure 24, and Figure 25 display topography (in meters) of existing conditions, Alternative B1, and Alternative B2, respectively.

Flow splits at the same observation arcs used for Alternatives A1 and A2 were used to evaluate flow splits for Alternatives B1 and B2. Alternatives B1 and B2 do not significantly affect inflows into the North Channel (Table 13).

Here, stream power is again used as a measure of where deposition is likely to occur and the long-term effectiveness of alternatives to increase flows in the North Channel. Results, by sub-alternative, are provided for stream power for the 2-year recurrence interval in Figure 26, Figure 27, and Figure 28.

Flow splits remain virtually unchanged for Alternatives B1 and B2 when compared to existing conditions. Stream power is also quite similar to exiting conditions. As such, Alternatives B1 and B2 do not appear to be effective in meeting project goals.

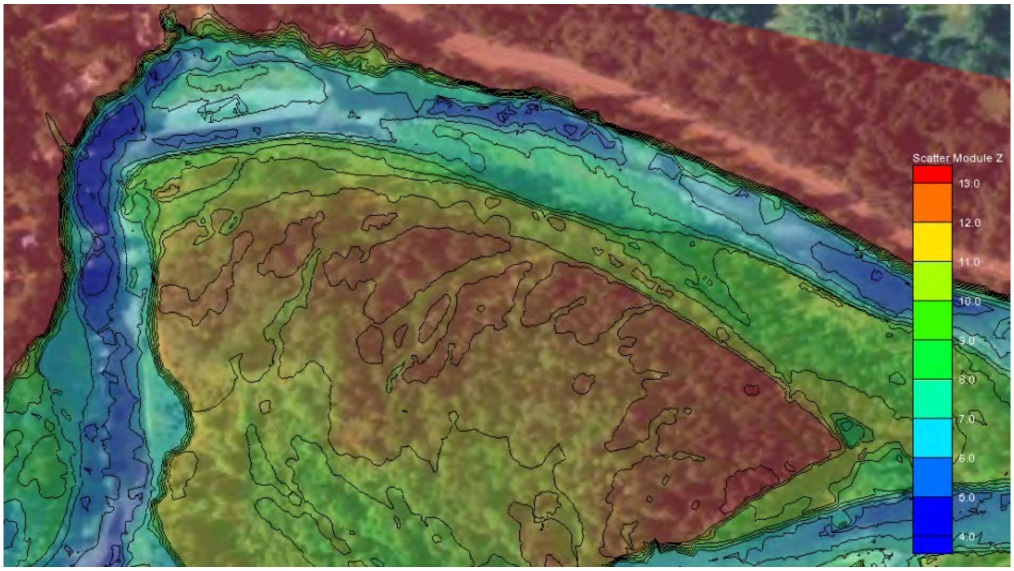

Figure 23. Existing Conditions Topography (m).

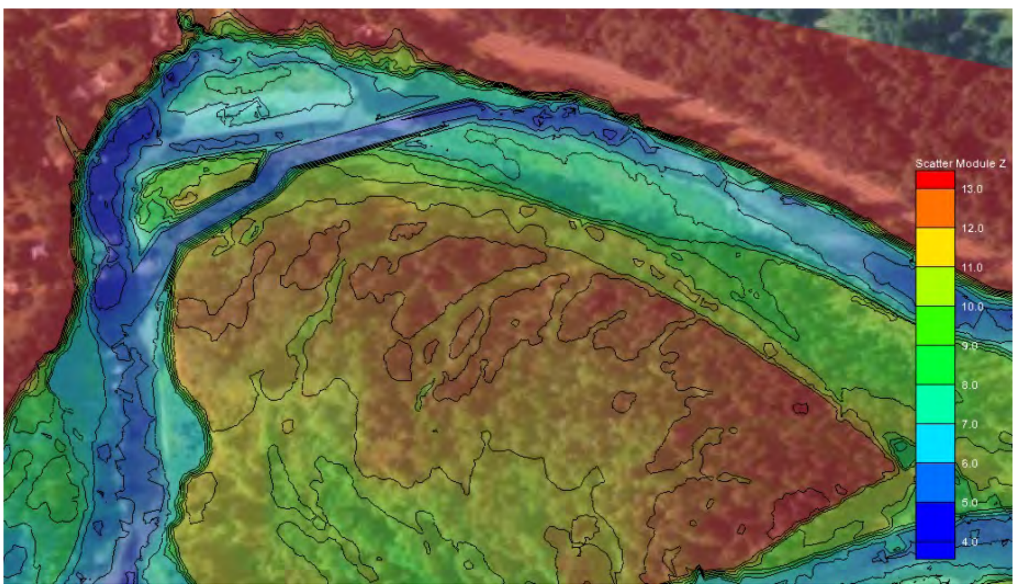

Figure 24. Alternative B1 Topography (m).

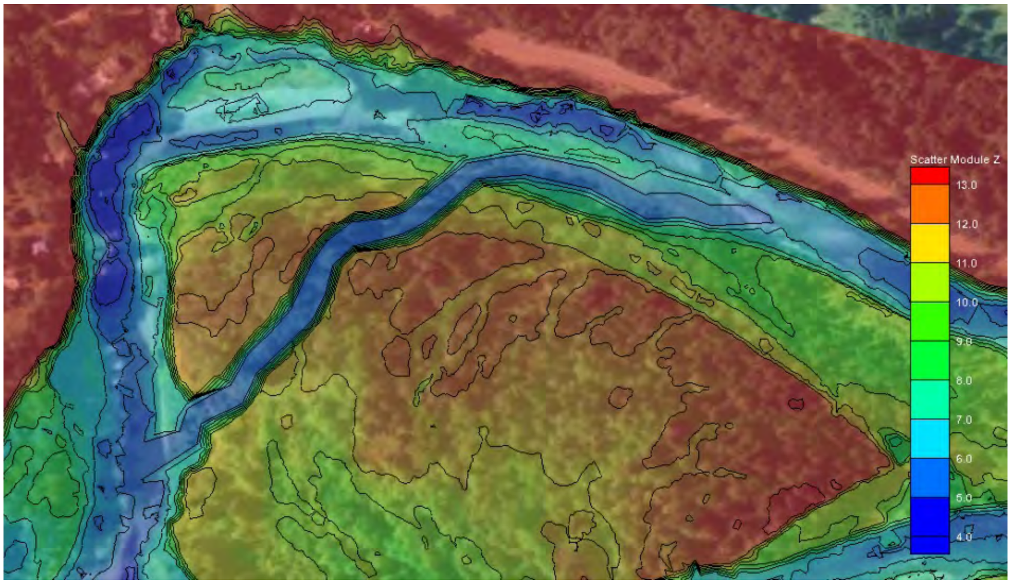

Figure 25. Alternative B2 Topography (m).

Table 13. Flow split conditions (values in cfs) for Alternative B.

	Existing Conditions		Alternative B1		Alternative B2	
	North Channel Flow	South Channel Flow	North Channel Flow	South Channel Flow	North Channel Flow	South Channel Flow
Low Fish Presence Flow	479	1,654	478	1,724	576	1,724
2-Year Flow	9,268	15,325	9,245	15,167	10,013	14,264
10-Year Flow	21,608	43,498	22,812	43,106	23,874	41,907
50-Year Flow	28,496	64,967	28,957	64,460	28,829	64,711
100-Year Flow	29,354	70,165	29,853	69,624	31,357	67,913

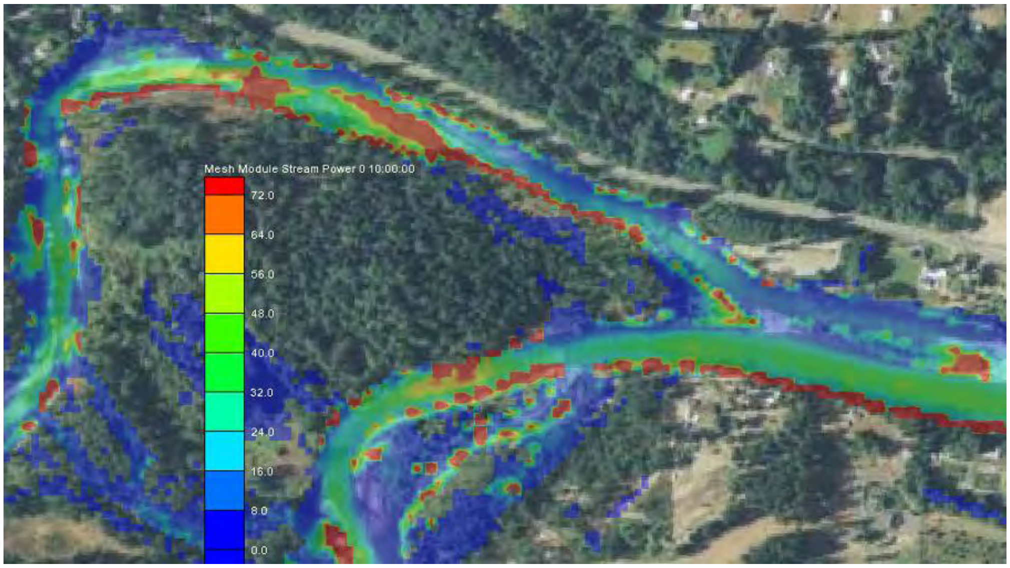

Figure 26. Existing Conditions Q2 Stream Power.

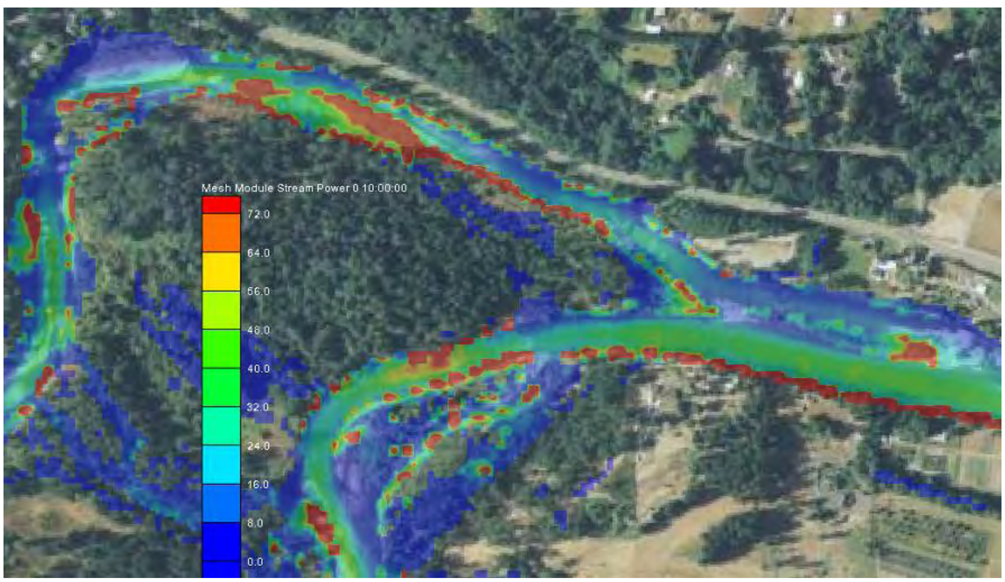

Figure 27. Alternative B1, Q2 Stream Power.

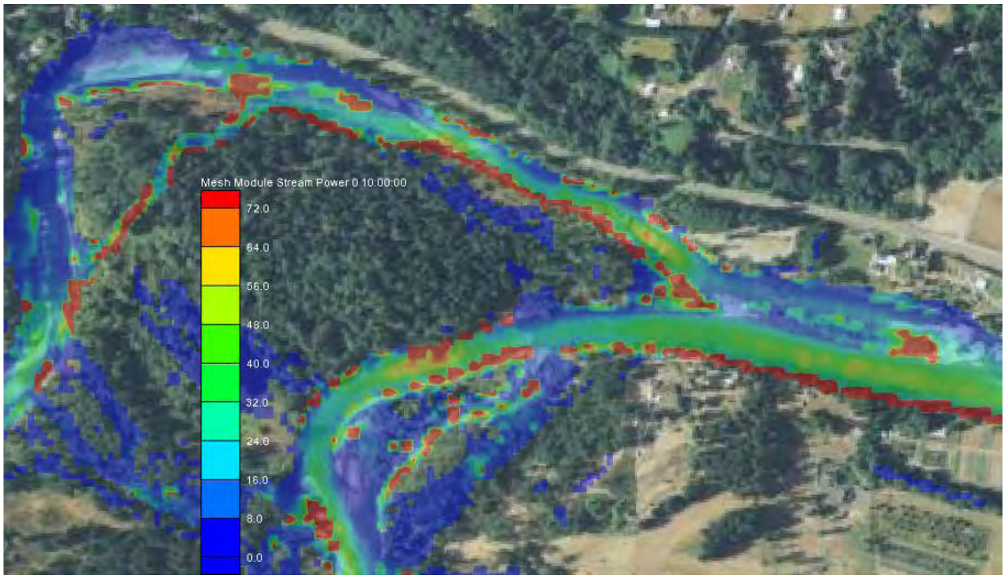

Figure 28. Alternative B2, Q2 Stream Power.

ALTERNATIVE C –NORTH CHANNEL EXPANSION

Alternative C results from recognizing that the North Channel has reduced width compared to the South Channel. The width of the upstream end of the North Channel (from its inlet until it abuts Lewis River Road) has been continually decreasing throughout the photo record. Width does not increase in the North Channel until after it turns south, diverging from Lewis River Road. Three sub-alternatives (C1, C2, and C3) were evaluated. All sub-alternatives expand the North Channel from its inlet, through the upstream end of the channel, and extend to where channel width is observed to dramatically increase, especially at higher magnitude floods that may influence channel form. Figure 29, Figure 30, Figure 31, and Figure 32 display topography, in meters, of existing conditions, Alternative C1, Alternative C2, and Alternative C3, respectively.

Flow splits at the same observation arcs used for Alternatives A and B were used to evaluate flow splits for Alternatives C1, C2, and C3, and are displayed in Table 14. Alternative C1 dramatically changes low flows in the North Channel. Alternative C1’s influence on flow splits is reduced as flow magnitude increases. Alternative C2 realizes a close to 50 -50 split in flows between the North and South channels at low flow, but its influence diminishes at higher flows as with Alternative C1. Although Alternative C3 increases flow into the North Channel, it does not appear as effective as Alternatives C1 and C2.

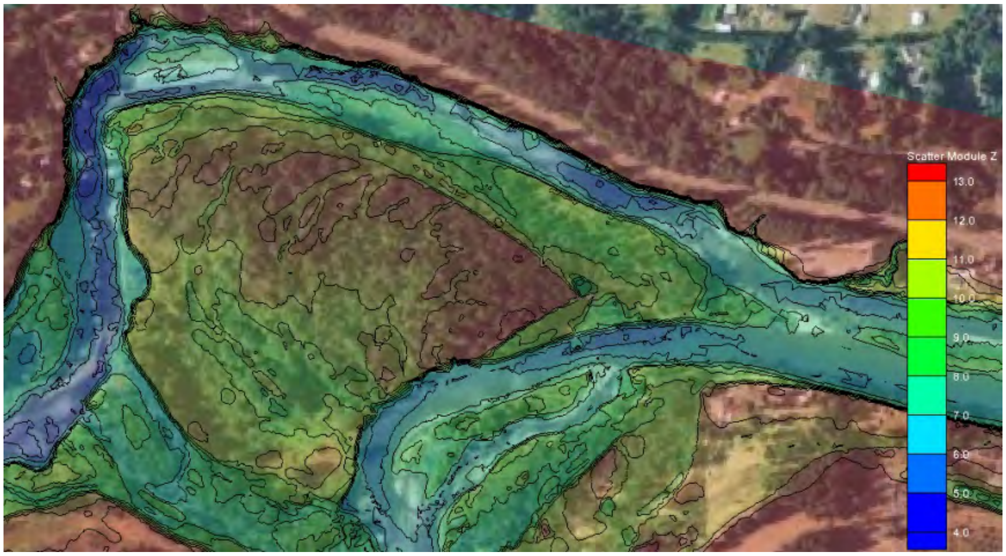

Figure 29. Existing Conditions Topography (m)

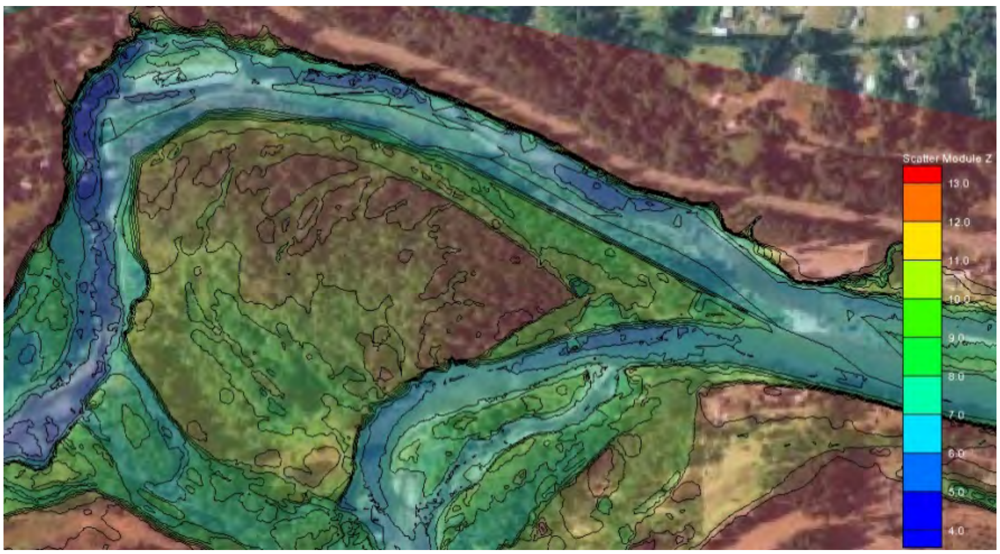

Figure 30. Alternative C1, Topography (m)

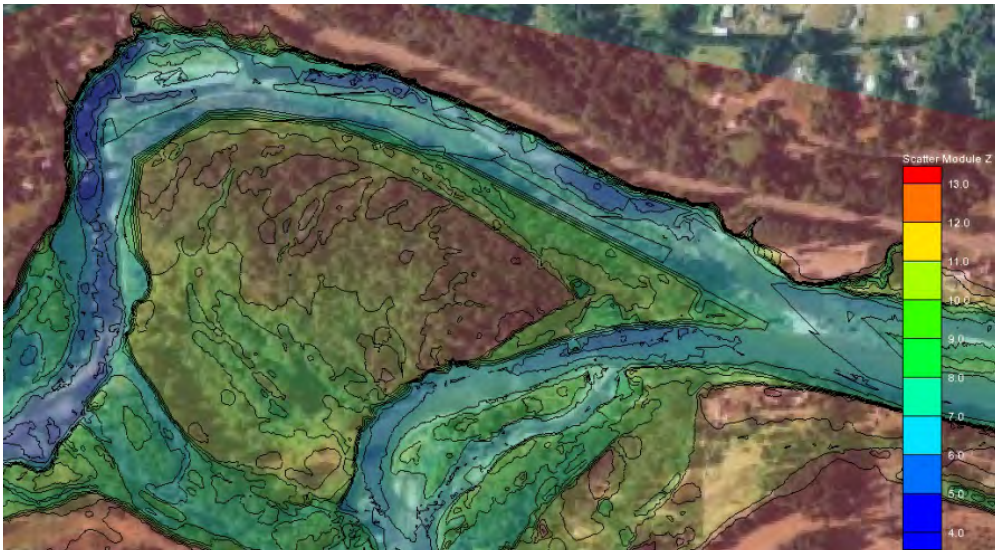

Figure 31. Alternative C2, Topography (m)

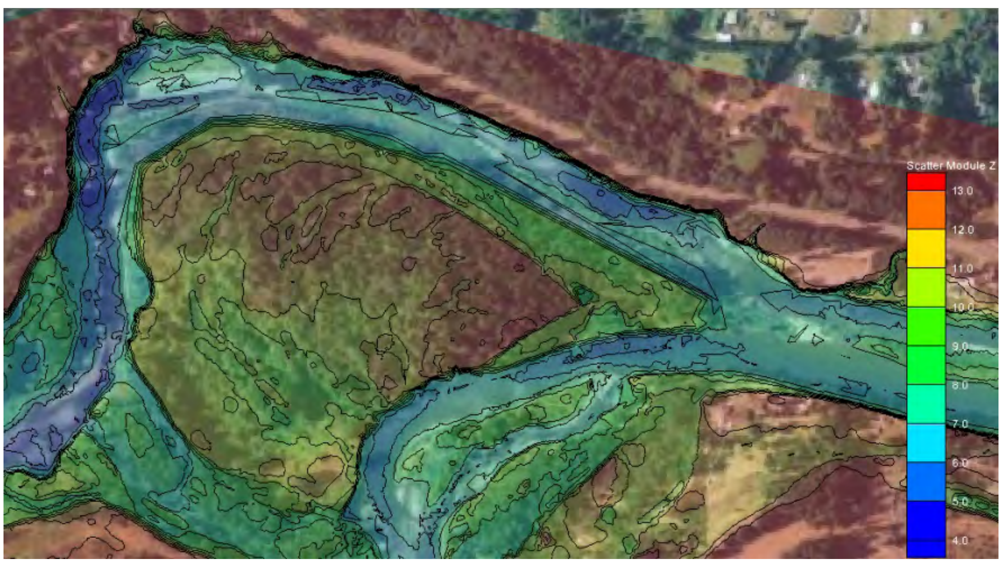

Figure 32. Alternative C3 Topography (m)

Table 14. Flow split conditions (values in cfs) for Alternative C.

	Existing Conditions		Alternative C1		Alternative C2		Alternative C3	
	North Channel Flow	South Channel Flow	North Channel Flow	South Channel Flow	North Channel Flow	South Channel Flow	North Channel Flow	South Channel Flow
Low Fish Presence Flow	479	1,654	1,665	461	987	1,158	703	1,354
2-Year Flow	9,268	15,325	12,383	11,892	11,218	13,374	11,218	12,182
10-Year Flow	21,608	43,498	28,972	36,994	27,566	38,565	28,881	39,002
50-Year Flow	28,496	64,967	36,471	57,211	35,411	58,394	35,227	58,835
100-Year Flow	29,354	70,165	37,365	61,782	36,217	63,009	35,762	63,810

Again, stream power is used as a measure of where deposition is likely to occur and the long-term effectiveness of alternatives to increase flows in the North Channel. Results, by sub-alternative, are provided for stream power for the 2-year recurrence interval in Figure 34, Figure 35, and Figure 36.

Stream power values suggest that deposition could occur at the inlet of the North Channel for all Alternatives C1, C2, and C3. As such, maintenance dredging may be required following floods that transport significant sediment volumes. The extent and rate of deposition is unknown.

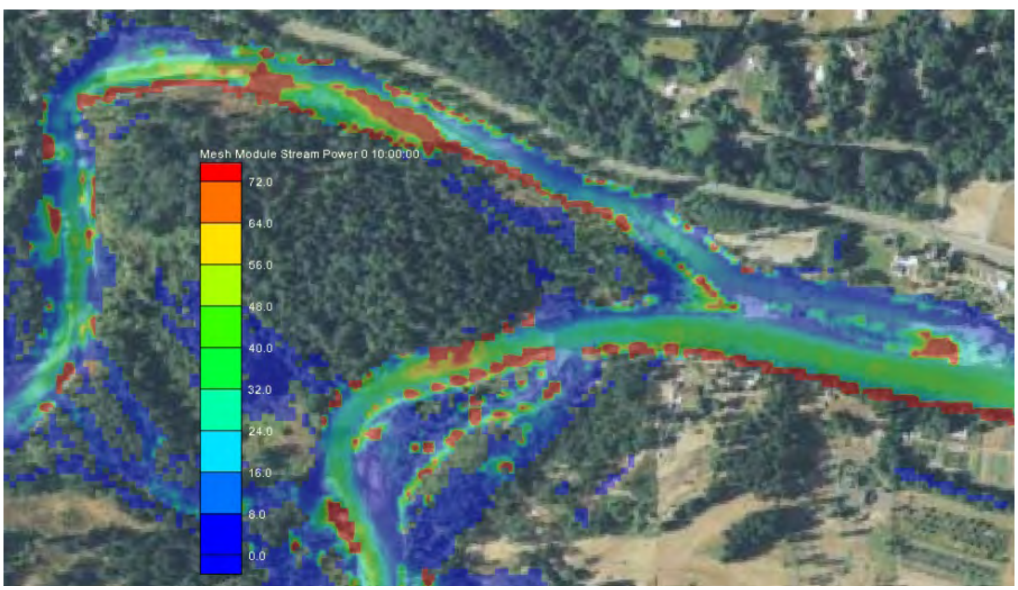

Figure 33. Existing Conditions Q2 Stream Power

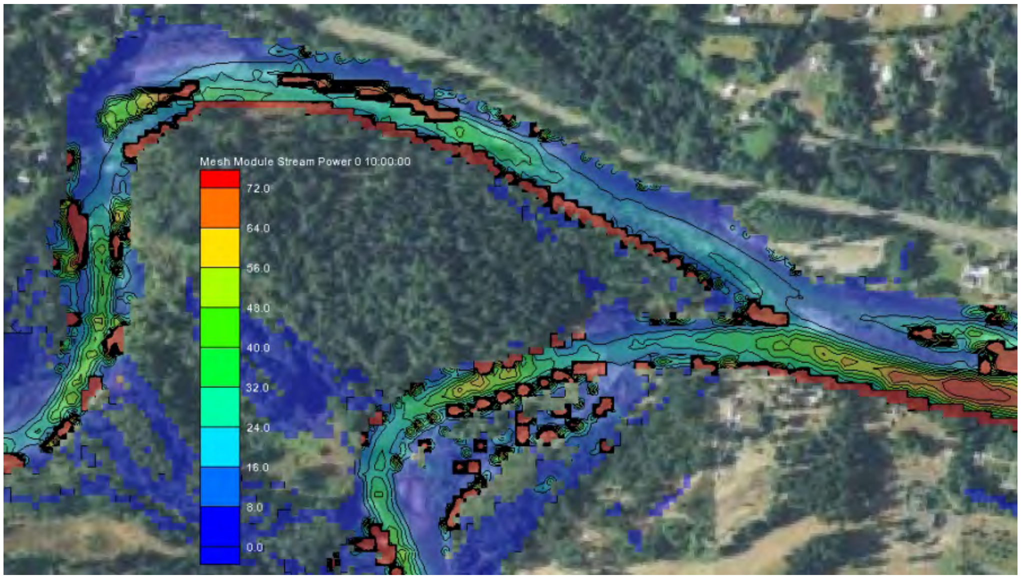

Figure 34. Alternative C1 Q2 Stream Power

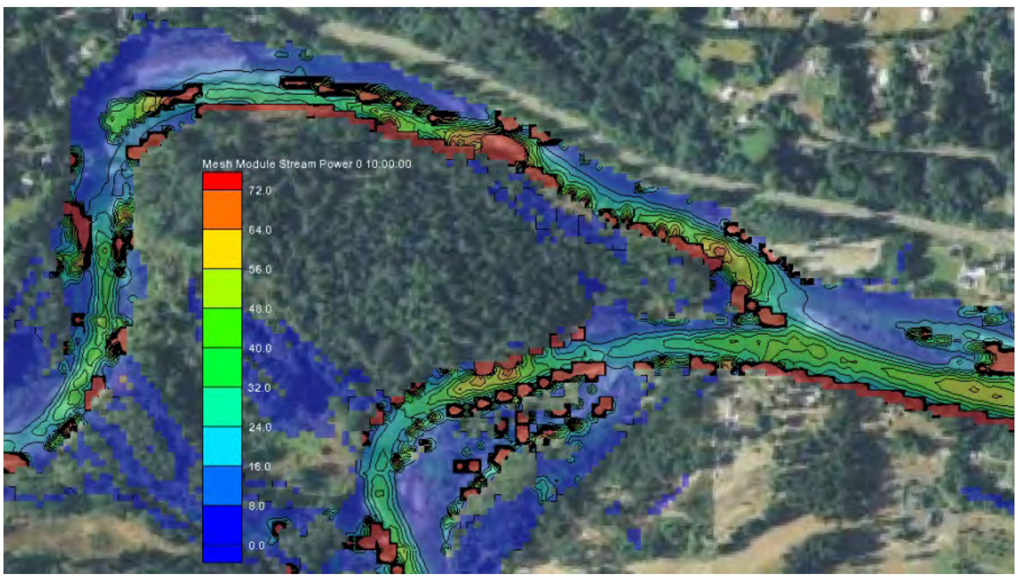

Figure 35. Alternative C2 Q2 Stream Power

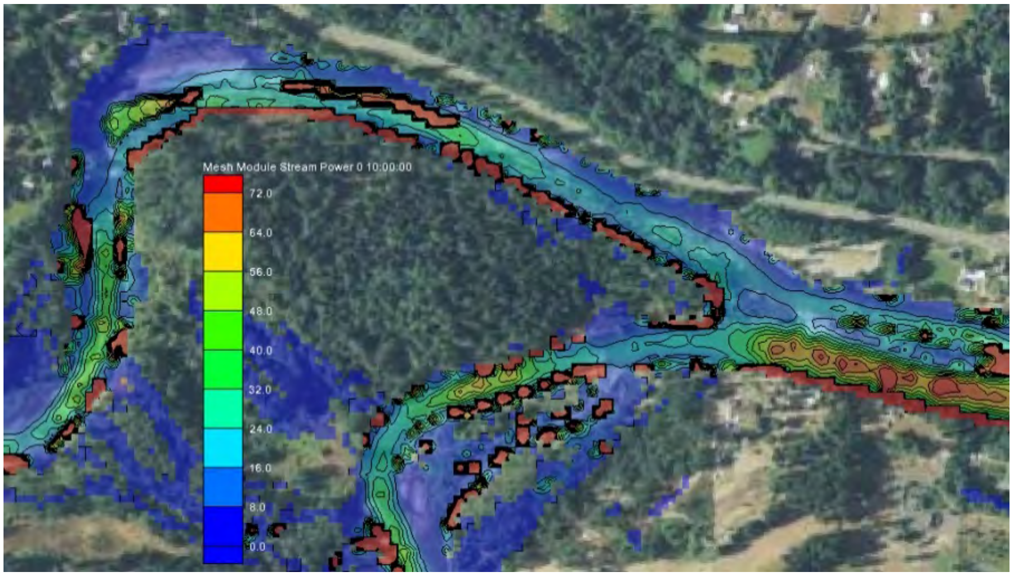

Figure 36. Alternative C3 Q2 Stream Power

PREFERRED ALTERNATIVE

Background on selection of preferred alternative. All alternatives were presented at the January 24, 2013 TOG meeting. There was considerable discussion by the group regarding the alternatives and what approach was most appropriate to carry forward to the design phase. In the end, it was agreed to move forward with a variation of Alternative A, with the acknowledgement that target fish use flows would be achieved but that long-term channel maintenance flows might not be achieved. A component that was added to Alternative A was 'habitat optimization', which would utilize the 2D model to determine the bed configuration that would provide the greatest amount of suitable habitat for juvenile Chinook rearing.

With the habitat optimization criterion added to the preferred alternative, it became necessary to use the fish preference criteria (see IFIM Study sub-section under the Fisheries Studies and Trends Section) in conjunction with model iterations in order to create a grading plan that achieved hydraulic and floodway objectives but also maximized habitat suitability to the extent possible. Based on the information in Table 6, the following habitat optimization criteria were used: Velocity = 0 – 1.5 ft/s and Depth = 0 – 4 ft.

The alternatives analysis considered a low fish presence flow, but it was decided that habitat optimization should be based on average flow conditions during the rearing period. Thus, the 50% exceedance flow for the last 10 years of record between mid-February and the end of June was calculated to evaluate fish optimization criteria. The average 50% exceedance flow for this period came to 4,644 cfs (rounded to nearest 500 = 4,500 cfs). In addition to habitat optimization, the design was modified to satisfy multiple objectives, including improving flow to the North Channel, achieving an approximate cut and fill balance, and avoiding rise of the 100-year flood.

A draft (preliminary) design of the preferred alternative was developed and reviewed by the TOG at the March 6, 2013 meeting. Based on TOG input and additional modeling and analysis, the design was further refined for the final (90%) design submittal. One of the primary changes between the draft and final is the necessary removal of approximately 10,000 cubic yards of material that will be disposed of above the 100-year floodplain instead of back in the channel as part of the bed reconfiguration. Although it was desirable to achieve a cut and fill balance, the removal of this material is necessary in order to achieve a no-rise condition at the 100-year flood (FEMA requirement).

Description of preferred alternative. The final design includes removing the mid-channel bar upstream of Eagle Island and creating gravel bars on each side of the channel by relocating the mid-channel bar material. The preferred alternative topography/bathymetry is displayed in Figure 37 (in meters). The design includes excavation of approximately 60,000 cubic yards from the mid-channel bar and placement of approximately 50,000 cubic yards of new bar material on the margins. The remaining 10,000 cubic yards of material is necessary to remove from the channel in order to obtain a no-rise condition of the 100-year flood elevation. This material will be transported to a disposal site on Eagle Island that is above the 100-year floodplain elevation.

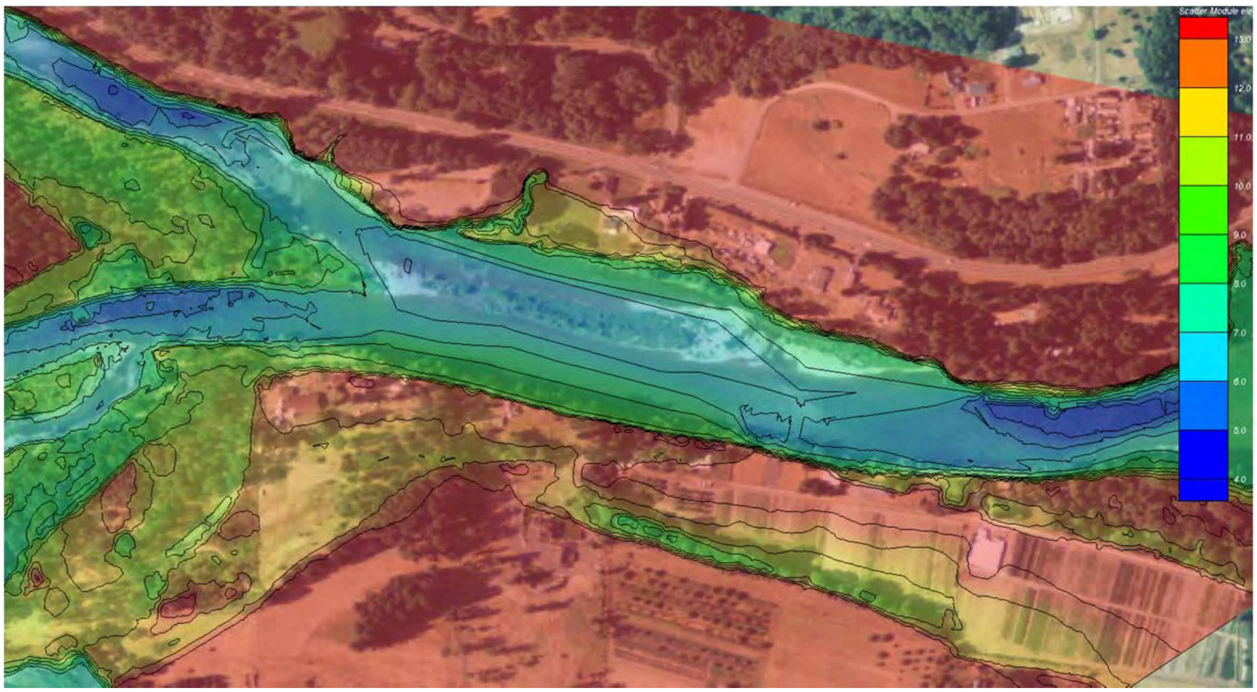

Figure 37. Preferred Alternative Topography/Bathymetry(meters).

Placing gravel bars on both sides of the channel improved flow and sediment transport characteristics compared to previous versions of Alternative A. Table 15 provides flow split information around the island at modeled flows in cfs. Figure 38 and Figure 39 display stream power at the 2-year recurrence interval for existing and proposed conditions, respectively. Flow and sediment transport characteristics for the preferred alternative are improved beyond existing conditions. Higher stream power in the mid-channel area just prior to the flow split suggests that, compared to existing conditions, this area will be much more effective at transporting bed material through this area as opposed to resulting in bed material deposition.

Table 15. Preferred Alternative Flow Splits (cfs).

	Existing Conditions		Preferred Alternative	
	North Channel Flow	South Channel Flow	North Channel Flow	South Channel Flow
Low Fish Presence	479	1,654	874	1,200
Ave. Fish Presence	1,343	3,517	1,870	2,893
2-Year Flow	9,268	15,325	9,940	14,413
10-Year Flow	21,608	43,498	24,765	41,519
50-Year Flow	28,496	64,967	30,978	63,024
100-Year Flow	29,354	70,165	31,806	68,136

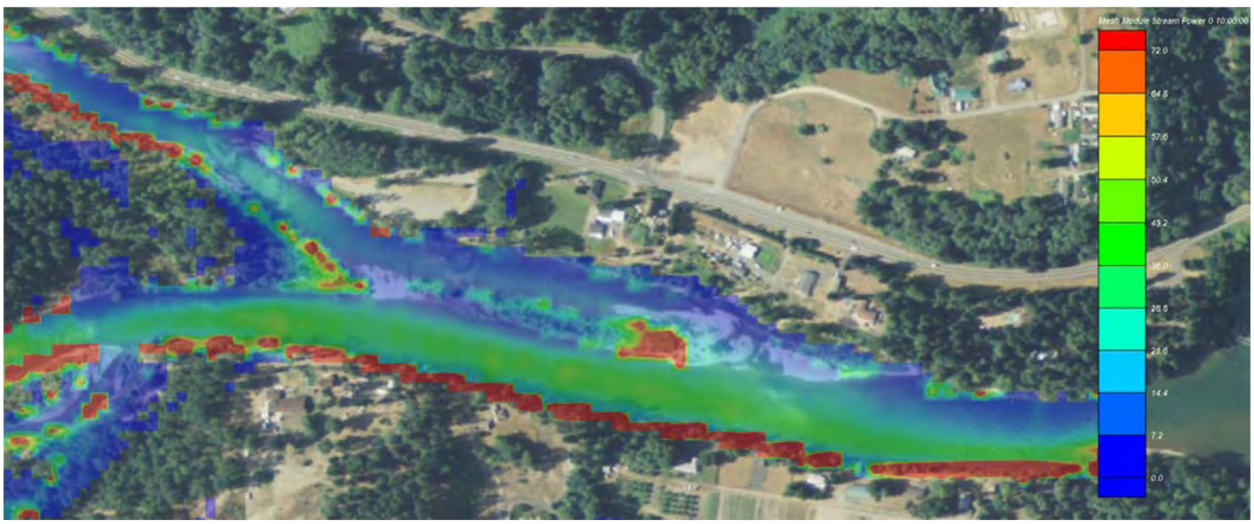

Figure 38. Existing Conditions Q2 Stream Power.

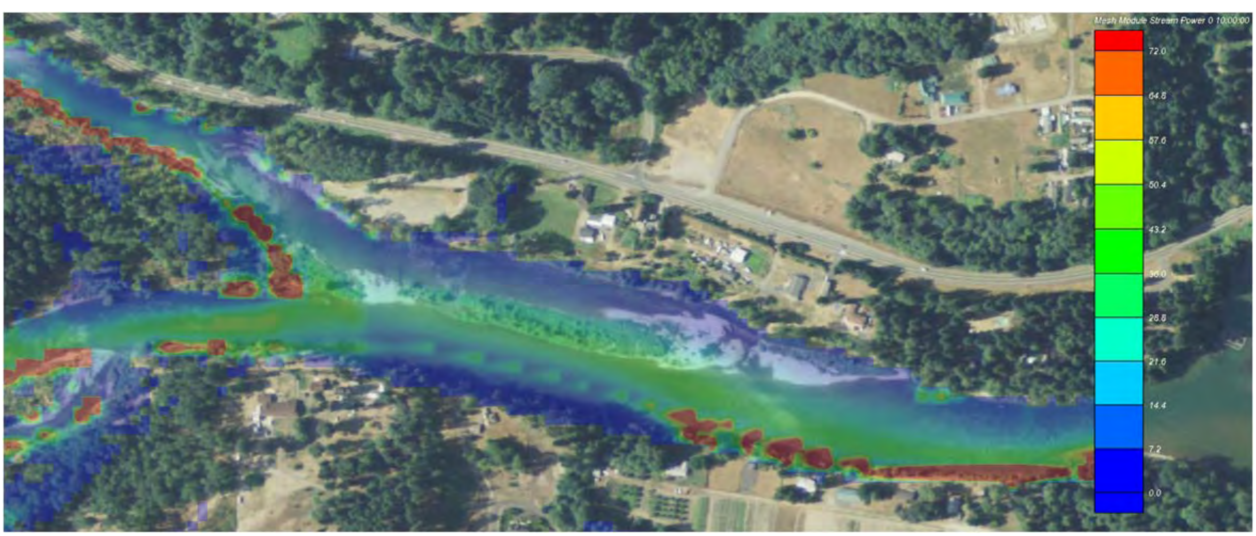

Figure 39. Preferred Alternative Q2 Stream Power.

The preferred alternative also provides desirable depths and velocities along channel margins at the average fish presence flows. The proposed bed configuration was obtained by optimizing habitat within the fish preference ranges while also accomplishing the other objectives mentioned previously. Figure 40 and Figure 41 provide flow depth in feet at the average fish presence flow (4,500 cfs). Flow depths are over 4 feet in the center of the channel, but are optimal along the channel margins. Figure 42 and Figure 43 provide flow velocity in feet per second at the average fish presence flow (4,500 cfs).

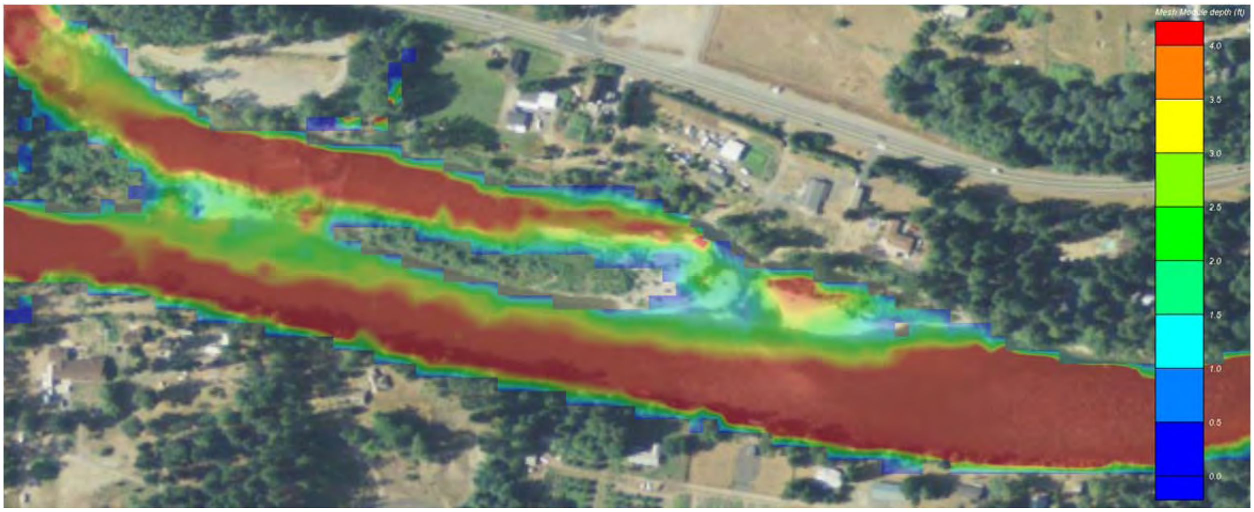

Figure 40. Existing Conditions, Average Fish Presence Flow Depth (ft).

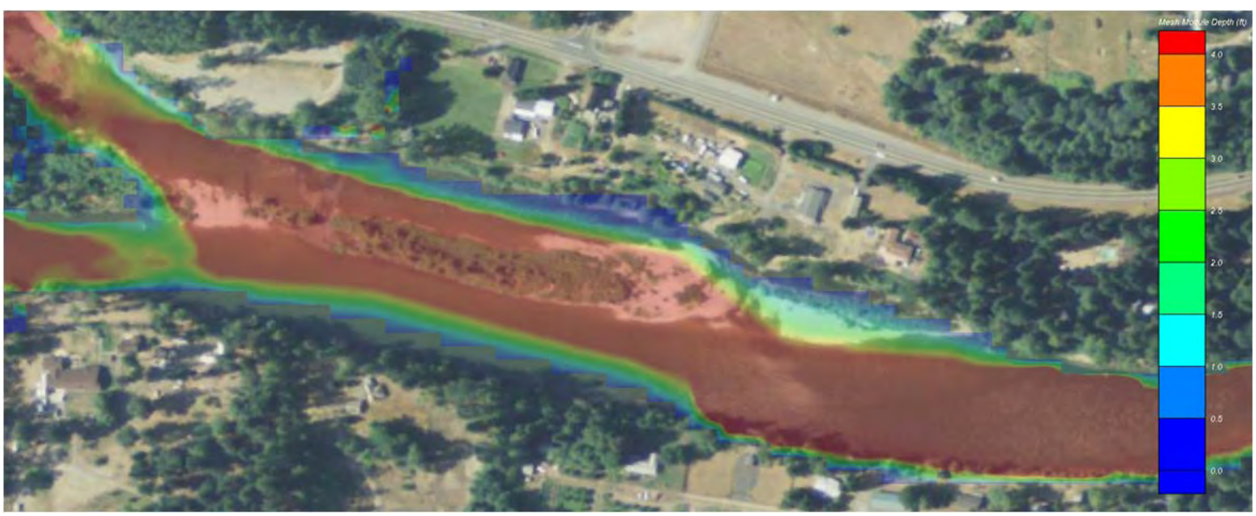

Figure 41. Preferred Alternative, Average Fish Presence Flow Depth (ft).

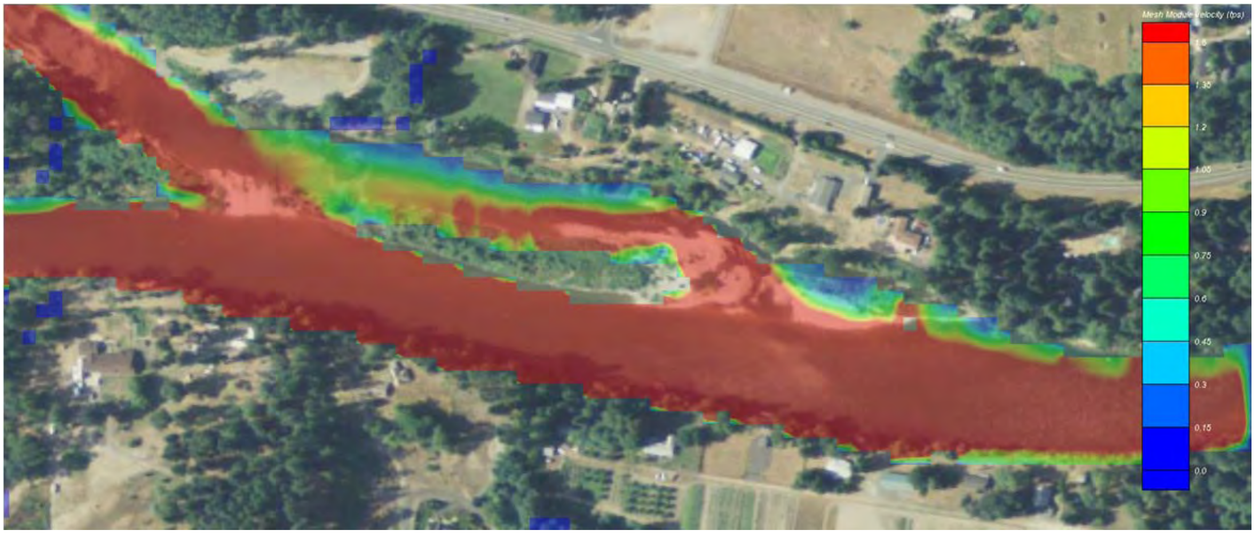

Figure 42. Existing Conditions, Average Fish Presence Flow Velocity (ft/s).

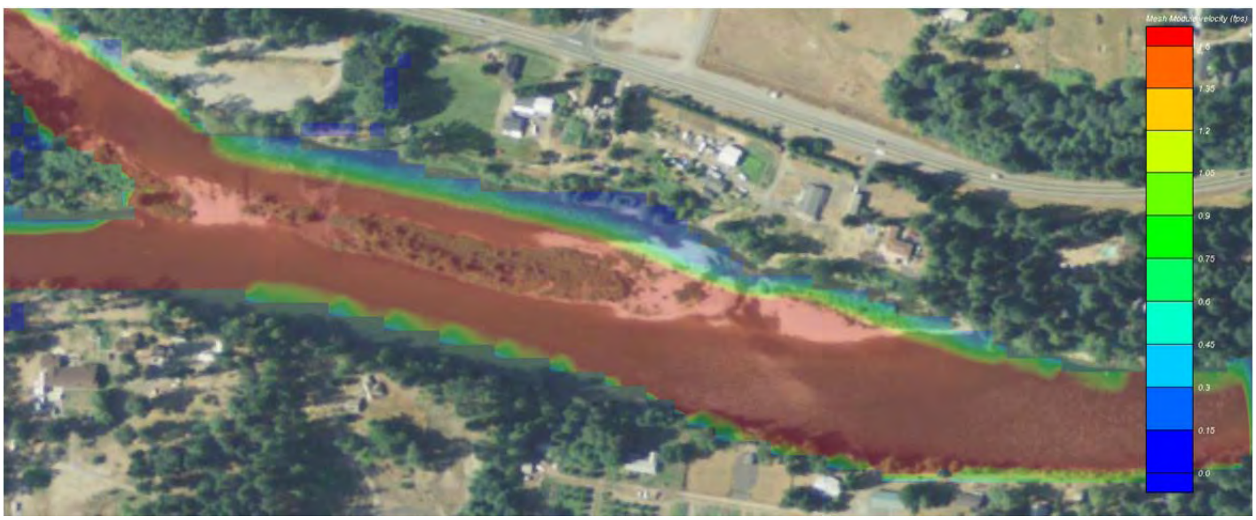

Figure 43. Preferred Alternative, Average Fish Presence Flow Velocity (ft/s).

Removal of reed canary grass. An additional component of the preferred alternative includes addressing reed canary grass colonization on gravel bars within the North Channel. Reed canary grass colonization is an issue that was discussed at the TOG meetings and is a condition that has been observed by WDFW fish biologists to have worsened over time. The increased extent of colonization of gravel bar surfaces has also been observed in the aerial photo record (see Geomorphology section). This vegetation encroachment serves to artificially stabilize streambed material and adds to channel roughness, factors that may be contributing to the narrowing and loss of hydraulic capacity of the North Channel over time. As part of the preferred alternative, reed canary grass will be removed from the two primary gravel bars (one on river-left and one mid-channel) located in the North Channel just upstream of the sharp left bend in the channel. This material will be removed using a hydraulic excavator and will be transported to a disposal site on Eagle Island. See plans for details.

Proposed conditions flood hydraulics. A 1-dimensional HEC-RAS model was developed to evaluate the Base Flood Elevation (BFE), which corresponds to a 100-year return frequency. The BFE evaluation was performed to evaluate if the proposed project increases risk of flooding structures, as required by the Federal Emergency Management Agency (FEMA). FEMA readily accepts HEC-RAS hydraulic model evaluations, and does not currently accept TUFLOW model (2-dimensional model) output. The HEC-RAS model evaluation involves comparing proposed conditions to existing conditions to evaluate water surface elevations at the BFE. In order to achieve a no-rise condition at the BFE, 10,000 cubic yards of material will be removed from the channel and disposed of in an upland location above the 100-year floodplain elevation. See the design plans for more information.

Use of large wood for habitat and stability. During the TOG meetings, the use of large wood to assist with scouring at the entrance of the channel and to enhance fish habitat was recommended. Large wood is not included in the preferred alternative design at this time since channel boundary adjustments are expected to occur to some degree during high flow periods following implementation. With the high level of boat traffic on the river, it is advised that boundary adjustment be allowed to occur prior to wood placements to avoid stranding wood in the navigation channel and creating a potential boating hazard. As such, it is recommended that wood placements be evaluated after the project has been exposed to at least one bed-mobilizing flood event (i.e. 2-5 year recurrence interval flood).

Over time, it is expected that a portion of the placed material will be transported downstream as part of natural streambed transport processes. This is expected to most likely occur along the river-left bank where stream energy is highest and where the existing thalweg of the channel is located. The use of wood "vanes" was considered in order to increase the stability of this material. The vanes would be constructed of piling-ballasted logs extending perpendicularly out from the river-left bank and buried within the placed gravel bar material in order to provide stability. These would provide some internal rigid structure to the constructed gravel bar. The spacing of the vanes would range from 100-200 feet and anywhere from 5 to 20 vanes would be constructed, with a primary focus on the upstream end of the constructed bar where stream energy is highest. Due to a number of factors, including the quantity of wood material that would be required to provide adequate stability and the risk of vanes becoming exposed and providing a boating hazard, this treatment was not incorporated into the 90% design. Further analysis, as well as risk assessment conducted in coordination with river recreational users, is needed before incorporating the use of vanes. However, if risks can be sufficiently addressed and added costs justified, this treatment could be incorporated into the final (100%) designs.

Conclusions and Response to Key Questions

This section is formatted as a response to key questions that this project has attempted to address. These questions are intended to summarize the analysis and the design and to address questions and concerns raised by members of the TOG that were discussed at meetings and other communications throughout the design effort.

What are the trends in channel shifting and what is likely to happen in the future? The geomorphic analysis indicates measureable trends in channel shifting from the North Channel to the South Channel since the 1940s. Prior to that, patterns in flow are less clear, primarily due to human alterations to the channel and the legacy effects of the 1933 flood, both of which affect conditions seen on the 1938 photo series. We do know, however, that the channel was in a single-thread alignment in 1854, which was the date of the first known surveys of the area (Government Land Office surveys). The flow split of the channels was approximately 57% North Channel and 43% South Channel in 1948 and in recent years is closer to 40% North Channel and 60% South Channel (see Figure 5). The current flow split may have deviated even further since the latest aerial photos based on flow measurements taken as part of this study in June 2012 (35% North Channel; 65% South Channel). There has also been significant channel narrowing in both the North and South Channels over the course of the aerial photo record. This is likely related to the flood regime (lack of large scouring floods in recent years) and to vegetation encroachment. Vegetation encroachment (primarily shrubs and reed canary grass) has occurred as a result of the lack of scouring flows and due to elevated summer flows due to minimum flow requirements of the hydrosystem license.

Channel shifting appears to be related to numerous factors and is likely related ultimately to overall less capacity in the North Channel due to a narrower channel and floodplain area than what is found in the South Channel. This condition may be related to past floodplain gravel mining near the top of the South Channel as well as more resistant boundary conditions (i.e. bedrock) within portions of the North Channel that prevent widening. We believe that deposition of gravel bars within the North Channel and at the top of the island are primarily symptoms (as opposed to causes) of this underlying condition, but have nevertheless further contributed to channel shifting as part of a feedback loop where channel capacity is further constrained by sediment deposition in the North Channel.

The bed configuration at the top of the island at the flow split has also changed over time due to the development of the mid-channel bar and vegetation establishment. This bar reduces the connectivity of the North Channel to the main channel, especially at low flows where only a few shallow cross-over channels convey surface flow into the North Channel (see Figure 7).

Future trends are difficult to predict although we can make some inferences based on our analysis. Based on historical trends, the North Channel has gone from conveying 57% of the flow in 1948 to as little as 31% of the flow in 2012. If this trend continues, we could see the North Channel convey 20% of the flow by 2050. In this scenario, surface flow connectivity into the North Channel during low flow periods could be at risk of shutting off completely. There is, however, considerable uncertainty with respect to future trends. This is a dynamic area where shifting of lateral channel position and split flow conditions has changed over the past 150 years. These dynamics will likely continue, but likely to a lesser degree due to hydro-regulation and the associated vegetation encroachment and reduction in flood peaks.

What would be lost in terms of fish production and habitat conditions if no action is taken?
Continued shifting of flow from the North to South Channels could potentially reduce or eliminate (for some flow conditions) habitat and associated fish production in the North Channel. Juvenile salmonid sampling by WDFW since the early 1980s indicates that the North Channel has been a major producer of juvenile salmonids in the lower Lewis River. The North Channel has the second highest catch amounts of the five areas in the lower river, historically comprising nearly a quarter of the total catch on average. Over time, loss of this highly used rearing area could have a significant impact on fish production at the population scale. Since the early 1980s, there has been a general declining trend in the total catch amounts in the North Channel compared to the other areas (Figure 12), which is possibly related to the reduction of flow in the North Channel. An important consideration is that the WDFW salmonid sampling is not conducted with the intent of comparing fish use of habitat areas over time, which increases the uncertainty in the conclusions derived from these data for this purpose. Another line of evidence of fish production and habitat trends comes

from the personal experience and observations by WDFW field biologists who have worked on the river sampling juvenile and adult salmonids for decades. These observations suggest there have been detrimental alterations to habitat and fish production as a result of bar development and vegetation encroachment at the top of the island and within the North Channel. If historical trends continue, total fish production could be affected.

What would be gained from restoration actions (i.e. the preferred alternative)? The primary benefit of restoration actions would be to ensure that habitat conditions and fish use of the North Channel do not continue to decline (as discussed above). The actual habitat ***gain*** from restoration actions is harder to quantify. The greatest gain in habitat would likely be related to the direct improvement in attraction flows into the North Channel at the top of the island, which would increase the likelihood of juvenile fish entering the North Channel, although little is known about the specific effects of sediment deposition on fish movement patterns. The preferred alternative would essentially turn back the clock and create conditions at the top of the island that are more similar to conditions in the 1950s, where flow split more evenly into the North and South Channels and there was not the large mid-channel bar that now restricts flows (see comparisons of 1970 and 2012 conditions in Table 4 and Figure 7). Additional flow in the North Channel would also increase the amount of wetted margin habitat in the North Channel and would likely scour channel margins and reduce the degree of vegetation encroachment.

What alternatives were evaluated and what is the preferred alternative? Three alternatives were originally evaluated as part of the conceptual design phase of the project. Each of the three alternatives also included at least one or more sub-alternatives that included variations of the alternative. Details of the sub-alternatives and discussion regarding the rationale behind the alternatives are included in the Alternatives Development and Analysis section of the report. Based on input from the TOG and further modeling and analysis, a variation of Alternative A was selected as the Preferred Alternative. The original conceptual alternatives and the final preferred alternative the described below:

Alternative A: Removing and re-configuring the bar material at the top end of Eagle Island and at the upstream end of the North Channel

Alternative B: Construction of side-channels within the North Channel in order to increase channel hydraulic capacity and sediment conveyance and to create diverse fish habitat

Alternative C: Increasing the width of the North Channel to increase channel hydraulic capacity and sediment conveyance

Preferred Alternative: Removing approximately 60,000 cubic yards of material at the mid-channel bar at the top of the island and placing this material along the adjacent channel margins (north and south sides). Material would be placed as gradually sloping gravel banks in order to maximize juvenile Chinook rearing habitat. To achieve a no-rise condition at the 100-year flood (FEMA requirement), a portion (approximately 10,000 cubic yards) of the removed bar material would need to be re-located to a disposal site on Eagle Island above the 100-year floodplain. Reed canary grass that has encroached on bars within the North Channel will also be removed. Design drawings are included in the final planset. Further coordination with adjacent landowners, permitting agencies, and river recreational users will need to occur prior to moving forward with implementation of the preferred alternative.

What is the long-term sustainability of the project? The design was configured to increase stream flow and stream energy entering the North Channel to the extent possible in order to increase flow in the North Channel and to reduce the rate of sediment deposition at the mid-channel bar area. The hydraulic model, however, is only accurate in predicting conditions immediately following project construction. Channel changes will undoubtedly occur in the years following construction and these changes will affect flow and sediment dynamics.

The mid-channel bar area is a naturally depositional area that has experienced increasing sediment deposition since at least the past 75 years and this trend will likely continue at least to some degree due to large-scale governing influences on sediment and flow dynamics. Hydraulic analysis has indicated that hydraulic capacity and sediment conveyance in the North Channel is lower than in the South Channel due largely to a narrower channel width, which is likely influenced by geology (i.e. presence of more resistant boundary conditions), past land-uses, and vegetation encroachment. The preferred alternative does not address the underlying channel width issue, which would be a much larger-scale [and prohibitively expensive] project, but would likely be the most sustainable solution over the long-term. Based on TOG input, the preferred alternative instead addresses the sediment deposition issue at the top of the island, with the acknowledgement that future maintenance of new sediment deposition may be necessary.

The longevity of the preferred alternative, and thus the number of years until maintenance would be required, is difficult to predict; but inferences can be made based on the analysis. The rough sediment input estimate for the river between Eagle Island and Merwin Dam (see sub-section in the Sediment Sources and Dynamics section) resulted in an estimate of coarse bedload (sand to cobbles) delivery to the river of 8,400 cubic yards per year, on average. Most of this material would be expected to be stored near the source areas within the river upstream of Eagle Island, as can be seen in the photo record. If we make a very conservative (large) estimate and assume that half of this material enters the Eagle Island area, **and** is deposited at the top of the island, then it would take 14 years to re-form the bar that is excavated (60,000 cubic yards). This is likely a conservative estimate because most of the material would be stored upstream and much of the material entering the area would be carried further downstream. Another approach to estimating project longevity is to look at how long it has taken for the current mid-channel bar to form. The preferred alternative will essentially be dialing the clock back to the configuration that was present at the top of the island in the 1950s. Using this approach, re-deposition to current conditions could take as long as 60 years. Using the average of these two approaches results in a predicted longevity of 35-40 years. Ultimately, however, the occurrences of floods and erosional events, which are impossible to predict, will determine project longevity and the need for long-term maintenance.

What are the next steps? The next step is to consult with other stakeholders to determine the best means for moving the project forward. These stakeholders include local landowners, river users, permitting agency personnel, and potential funding sources. Some of these stakeholders have already been involved in the project via the technical group (TOG). Local landowners and river users may be affected by components of the project and it will be necessary to obtain their support and/or address any potential concerns they may have with the designs. It will also be necessary to obtain assurances from permitting agency personnel that the project can be constructed as designed and still meet permit requirements. Initial drafts of the permit applications are completed and the permitting process could be initiated at any time. Potential funding sources will also need to be identified and any necessary partners brought on board. Prior to implementation, the 90% designs will be amended as necessary based on input obtained during this process.

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Appendix A, B and 90% Designs available upon

appropriate approval from PacifiCorp