

United States  
Department of  
Agriculture

Forest Service

October 2017

# Still Creek Watershed Restoration Completion Report

**Mt. Hood National Forest  
Zigzag Ranger District**



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## SUMMARY

Between 2012 and 2017, the Mt. Hood National Forest and its partners performed extensive restoration work within the Still Creek 6<sup>th</sup> field watershed. Restoring the health of Still Creek watershed is vital to recover healthy populations of threatened and endangered fish and wildlife species and has been named a priority by both the US Forest Service and the Sandy River Basin Partners. Total investments in the watershed amounted to nearly \$2.2 million dollars and have resulted in significant improvements in habitat quality, water quality, and ecosystem function. Restoration was guided by the Still Creek Watershed Restoration Action Plan (WRAP) (USDA 2011), which identified 19 essential projects to be completed in-stream, within the riparian zone, and at the watershed scale. The stated goals of the 2012 Still Creek Watershed Restoration Action Plan (WRAP) were as follows:

**Goal 1:** Restore natural watershed processes, including riparian function, in-channel habitat, road-related impacts, and eradication of invasive plants to recover/improve production of ESA listed salmon and steelhead.

**Goal 2:** Improve water quality in Still Creek by improving riparian forest health through additional shading to surface waters and through a reduction in sediment delivery from road-related impacts.

**Goal 3:** Provide education engagement opportunities for summer home owners/private landowners/general public to learn about watershed restoration.

**Goal 4:** Provide jobs to local contractors, material suppliers, sport fishing industry.

**Goal 5:** Maintain and strengthen partnership between the Mt. Hood national forest, coalition of Sandy River Basin Partners, summer home owners and private landowners.

This document describes each of the outcomes for 19 essential projects described in the Still Creek WRAP. In summary, in-stream restoration actions impacted over 8 miles of the Still Creek main channel and an estimated 185 acres of floodplain habitat. Additional restoration projects occurred throughout the watershed and led to significant improvements in riparian health and decreases in chronic delivery of sediment and contaminants into Still Creek and its tributaries. Major restoration accomplishments include the following:

- The placement of 2,300 pieces of large wood throughout the Still Creek main channel and floodplain
- The creation of 240 log jam structures throughout the Still Creek main channel and floodplain
- The reconnection of 6.5 miles of side channels to the main channel
- The removal of barriers providing access to 3.15 miles of habitat for migrating salmonids
- The restoration of native riparian vegetation and species composition at 23 riparian rehabilitation sites
- The eradication of invasive plants from multiple sites throughout the basin
- The rehabilitation of 19 dispersed camping recreation sites in the riparian reserve
- The replacement of 5 culverts
- The replacement or upgrade of 18 septic systems connected with the recreation residence program
- The rehabilitation of 6 miles of ditch line on Road 2612 in the riparian reserve
- The removal of seven direct water intake structures from Still Creek and replacement with five wells
- The enhancement of 8.3 miles of stream with marine derived nutrients
- The installment of 30 sediment control structures along US Highway 26 and Oregon State Highway 173
- The resurfacing of 9.1 miles of Road 2612

The result of this work benefits endangered salmon and steelhead in the Still Creek watershed, as well as the Sandy River Basin as a whole. The main purpose of this document is to provide an overview of restoration actions and related monitoring completed within the Still Creek watershed. This document is split into four main sections:

**Section I. Introduction and Background** provides an overview of the Still Creek watershed, restoration partnerships, and planning framework behind restoration activity.

**Section II. In-stream Restoration Actions** provides detail regarding in-stream restoration work and summarizes the results of in-stream habitat surveys performed before and after restoration.

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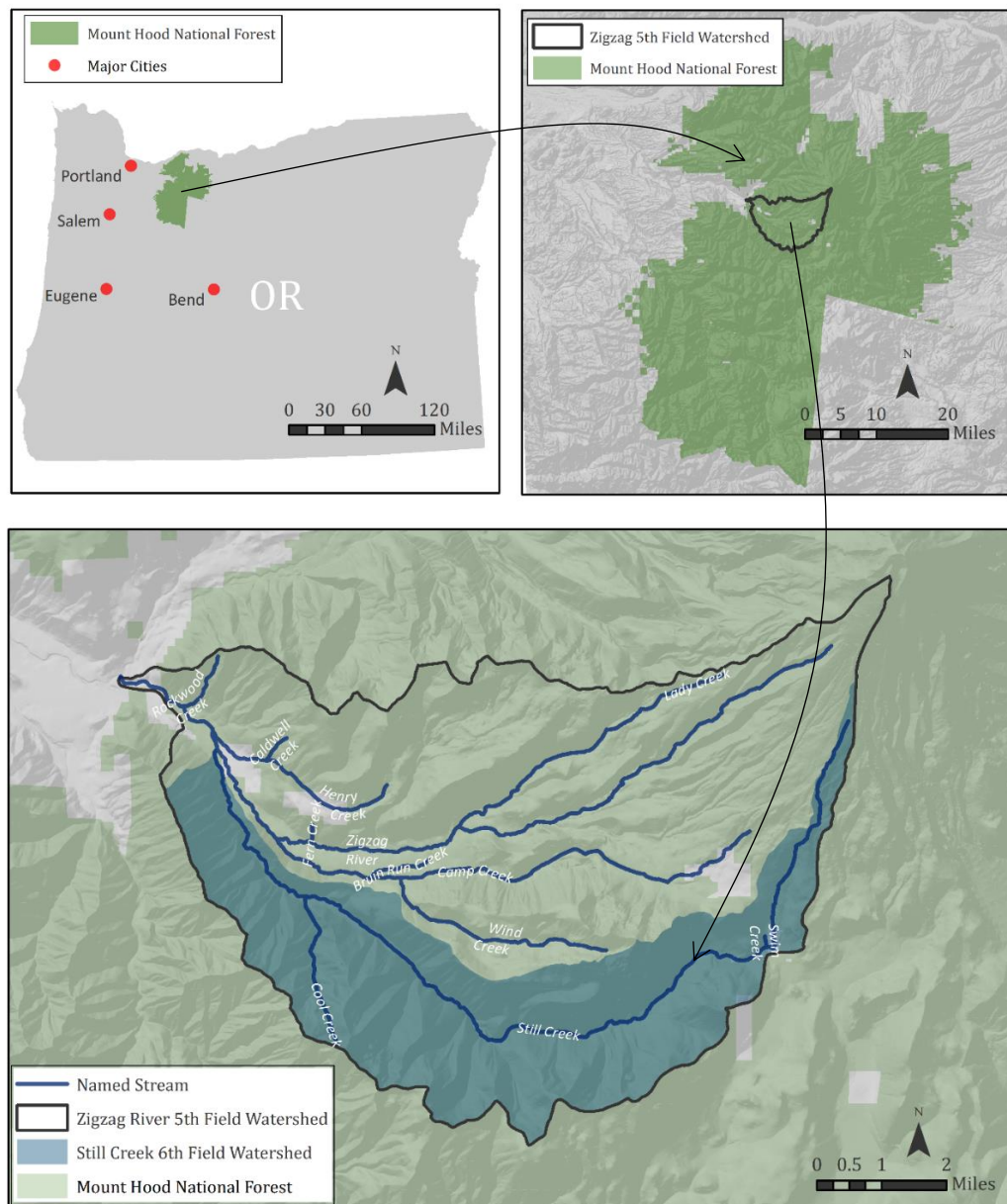
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## SECTION I. INTRODUCTION AND BACKGROUND

Still Creek is a 6<sup>th</sup> field watershed located within the Zigzag River 5<sup>th</sup> field watershed (Figure 1), itself a part of the Sandy River 4<sup>th</sup> field watershed. The Sandy River basin historically supported salmon and steelhead populations numbering in the tens of thousands, but these numbers have significantly declined in the last century (Taylor 1998). Aside from the Salmon River, Still Creek provides the highest densities of spawning and rearing habitat for salmonids in the Sandy River basin (USDA 2011). In particular, Still Creek supports several species of anadromous salmonids listed Threatened under the Endangered Species Act (ESA), including spring Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), and winter steelhead (*Oncorhynchus mykiss*). The watershed also supports resident rainbow trout (*Oncorhynchus mykiss*), resident and anadromous forms of coastal cutthroat trout (*Oncorhynchus clarkii*), dace (*Rhinichthys spp.*), mountain whitefish, (*Prosopium williamsoni*) and sculpin (*Cottidae spp.*) (USDA 2011).



**Figure 1.** The location of Still Creek 6th field watershed within the Zigzag 5th field watershed, the Mount Hood National Forest, and the State of Oregon.

The Zigzag watershed includes habitat for several "species of concern," all of which are tied to the Endangered Species Act, National Forest Management Act (NFMA) regulations, or Forest Service policy, including both the spotted owl (*Strix occidentalis caurina*) and Cope's giant salamander (*Dicamptodon copei*). The watershed also supports several sensitive plants on the Regional Forester's Sensitive Species List, including ground cedar (*Lycopodium complanatum*) and fir clubmoss (*Huperzia spp.*) (USDA 2011).

The Still Creek watershed is approximately 14,412 acres in size. Still Creek originates below the Palmer Glacier and a series of springs on Mt. Hood's west side and is fed by year-round snowpack that exists at the highest elevations (USDA 1995). About 98.3% of the watershed is located within National Forest Land. The watershed is a popular area for hiking, fishing, and camping, and receives a significant number of tourists from the nearby Portland Metropolitan Area. U.S. Highway 26, a major arterial route between Portland and central Oregon, dissects and serves as a primary access to the watershed. Private lands within the watershed include parts of the communities of Government Camp, Rhododendron, and the Faubion/Zigzag areas. Additionally, 129 recreational residences line the lowest 3 miles of the stream.

For a more complete characterization of the Still Creek watershed, see the 2011 Still Creek Watershed Restoration Action Plan (USDA 2011).

## Partnership History

Restoration activities in Still Creek are tiered within the restoration partnerships and planning of the greater Sandy River basin. In the late 1990's, the listing of several anadromous salmon and steelhead native to the Sandy River basin under the Endangered Species Act (ESA) spurred entities in the basin to come together in a collaborative manner and to form the Sandy River Basin Partnership (SRBP) in 1999. The original partnership included the City of Portland, Portland General Electric (PGE), the National Marine Fisheries Service (NMFS), the Oregon Department of Fish and Wildlife (ODFW), the U.S. Fish and Wildlife Service (USFWS), and the U.S. Forest Service (USFS). The SRBP has since grown to include 14 partners<sup>1</sup>.

In 2004, the partners established the Sandy River Basin Working Group (SRBWG) tasked with prioritizing restoration initiatives throughout the basin. The SRBWG adopted an anchor habitat approach, which prioritizes restoration of relatively intact riverine habitats that support specific life history stages of salmon and steelhead to a greater extent than the stream system at large (Frissell 1994). These anchor habitats also act as important refugia during adverse environmental conditions (Frissell 1998). The SRBWG identified key anchor habitats throughout the basin, and identified the lower portions of Still Creek as anchor habitat for Chinook salmon, coho salmon, and winter steelhead (SRBWG 2006).

To leverage resources and coordinate restoration benefitting anadromous salmonids, the SRBWG completed the Sandy River Aquatic Habitat Restoration Strategy in 2007 (SRBWG 2007). The aquatic habitat restoration strategy for the Sandy River basin established geographic priority areas and a hierarchical framework for directing future investments toward high priority restoration needs. The document identified the main-stem of the Sandy River, the Salmon River, and Still Creek as top restoration priorities.

## Forest Service Planning Framework

The restoration initiatives outlined in this report relate to USFS planning frameworks dating back to the Northwest Forest Plan Aquatic Conservation Strategy (ACS) (USDA and USDI 1994). Under the ACS, the USFS completed a watershed analysis of the Zigzag 5<sup>th</sup> field watershed, including the Still Creek sub-watershed, in 1995 (USDA 1995) and updated in 2004 (USDA 2004). The watershed analysis identified restoration opportunities at the watershed scale that support broad ecosystem management objectives described in the Northwest Forest Plan. The 2005 Region 6 Aquatic Restoration Strategy (USDA 2005; updated USDA 2008) provided direction for including watershed restoration into forest plans and prompted the completion of the 2007 Sandy River Basin Aquatic Restoration Plan (SRBWG 2006, SRBWG 2007).

In 2010, the Forest Service's Watershed Condition Framework (WCF) (USDA 2010) provided a more comprehensive approach for restoration of watersheds on National Forest land and required each forest to identify priority watersheds through a "condition class" scoring method. The WCF process identified Still Creek as a priority watershed on Mt. Hood National Forest and required the completion of the 2011 Still Creek Watershed Restoration Action Plan (WRAP). The

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<sup>1</sup> The Sandy River Basin Partners: Clackamas County, Columbia Land Trust, METRO, Multnomah County, National Marine Fisheries Service, The Nature Conservancy, Northwest Steelheaders, Oregon Department of Fish and Wildlife, Portland Water Bureau, Sandy River Basin Watershed Council, The Freshwater Trust, USDA, Mt. Hood National Forest, USDI, Bureau of Land Management, and Western Rivers Conservancy.



WRAP tiered to the broader 2007 Sandy River Basin Restoration Strategy as well as to the 1995 Zigzag River Watershed Analysis (USDA 1995), and provided greater detail regarding essential projects, timelines, costs, and partners. The WRAP is focused on improving metrics associated with the condition class rating outlined in the WCF. Additional detail regarding targets, project areas, implementation, and projected restoration costs were compiled in the 2013 Still Creek Rehabilitation Project document (USDA 2013).

## Essential Projects

The Still Creek WRAP (USDA 2011) identified 19 essential projects for restoration in Still Creek (Table 1). Sections II and III of this report are structured around these 19 essential projects, which are broadly split into two categories: in-stream restoration projects (essential projects SC-1 to SC-8; CC-1) and watershed restoration projects (essential projects SC-9 to SC-18). In-stream restoration projects pertain to in-stream and floodplain habitat work along the main channel and floodplain of Still Creek in nine distinct project areas. Watershed restoration projects pertain to projects aimed at rehabilitating the riparian zone and mitigating impacts from roads to increase water quality.

**Table 1.** Essential projects, separated into in-stream restoration projects and watershed-scale restoration projects.

<b>In-Stream Restoration Projects</b>		
<i>Essential Project</i>	<i>Project Area</i>	<i>Description</i>
SC-1	The Cabins	Increase complexity and floodplain connectivity
SC-2	The Straights	Increase complexity and floodplain connectivity
SC-3	The Compression	Increase complexity and floodplain connectivity
SC-4	Mars Attacks	Increase river complexity and protect road prism.
SC-5	The Elder Growth	Increase complexity and floodplain connectivity
SC-6	The Pumpkin Patch	Increase complexity and floodplain connectivity
SC-7	The Canyon	Increase complexity and floodplain connectivity
SC-8	Headwaters Nirvana	Reduce entrenchment and increase complexity
CC-1	Cool Creek Confluence	Adjust five log weirs to increase fish passage
<b>Watershed Restoration Projects</b>		
<i>Essential Project</i>	<i>Project Name</i>	<i>Description</i>
SC-9	Riparian Rehabilitation	Thin alder and conifer stands to release dominant conifers; plant variety of conifers
SC-10	Invasive Plant Removal	Conduct rapid response invasive plant removal by hand pulling
SC-11	Campsite Rehabilitation	Rehabilitate riparian conditions at dispersed campsites reducing sediment input
SC-12	FS Road 2612 Culverts	Replace undersized culverts on FS-2612 to reduce fine sediment inputs
SC-13	West Leg Road	Replace culverts and rehabilitate ditch line
SC-14	Cool Creek Tract Water Withdrawals	Replace direct water intakes in Still Creek with wells
SC-15	Recreational Residence Septic Replacement	Replace open septic systems with approved closed systems
SC-16	Marine Derived Nutrient Enhancement	Enhance marine-derived nutrients in Still Creek with surplus hatchery salmon
SC-17	US Highway 26 Sediment Traps	Install sediment traps along Highway 26 and Oregon State Highway 173
SC-18	Road 2612 Surface Enhancement	Spot rock Road-2612 to minimize chronic sediment transport

Note: SC = Still Creek; CC = Cool Creek

## Funding

The 2011 Still Creek WRAP identified nearly 3.7 million dollars of investment over a 5-year period to improve the 6th field watershed to a higher condition class. Nearly 71% of the estimated costs were for in-stream restoration while the remaining 29% was for water quality, riparian, and road improvements (USDA 2011). The Zigzag Ranger District recognized that a majority of the funding and in-kind contributions for restoration were going to come directly from Sandy River Basin Partners. Instream restoration actions were to be completed in close collaboration with The Freshwater Trust, BLM, Sandy River Basin Watershed Council, Oregon Department of Fish and Wildlife (ODFW), and Portland Water Bureau (PWB). The Forest Service and Oregon Department of Transportation would need to collaborate on the US Highway 26 sediment issues. The Zigzag Ranger District has a long history of partnering with ODFW and PWB when it comes to monitoring in the Sandy River Basin. It was also recognized that the cabin owners in the recreational residence program were going to take the lead as part of their special use permit in improving water quality issues in Still Creek.

## SECTION II. IN-STREAM RESTORATION ACTIONS | Essential Projects SC-1 through CC-1

This section of the report describes in-stream restoration actions. The first several sections outline in-stream objectives, in-stream monitoring, and the results of in-stream habitat surveys as they pertain to each objective. Following are nine sections providing narratives and maps for each in-stream restoration project area.

In-stream restoration work occurred between river mile 0 (RM 0.00) (at the confluence with the Zigzag River) to river mile 8.01 (RM 8.01) between the summers of 2012 and 2017. Restoration activities on the main stem of Still Creek were split into eight project areas based on stream characteristics, history, and restoration needs (Figure 2). The eight project areas are named as follows: the Cabins (RM 0-3.14), the Straights (RM 3.14-3.42), the Compression (RM 3.42-3.19), Mars Attacks (RM 3.91-4.10), the Elder Growth (RM 4.10-4.41), the Pumpkin Patch (RM 4.41-5.00), the Canyon (RM 5.00-6.51), and Headwaters Nirvana (RM 6.51-8.01). General characteristics for each project area can be found in Table 2. A ninth project area, the Cool Creek Confluence (essential project CC-1), is located on the lower 0.65 miles of Still Creek's largest tributary, Cool Creek. Key in-stream restoration accomplishments included the addition of 2,300 pieces of large wood debris to the stream, the creation of 240 log jams, the reconnection of 6.5 miles of side channel habitat, and the formation of 62 main channel pools. Additionally, the removal of 5 log weirs in Cool Creek opened 0.65 miles of previously unavailable habitat to migrating salmonids.

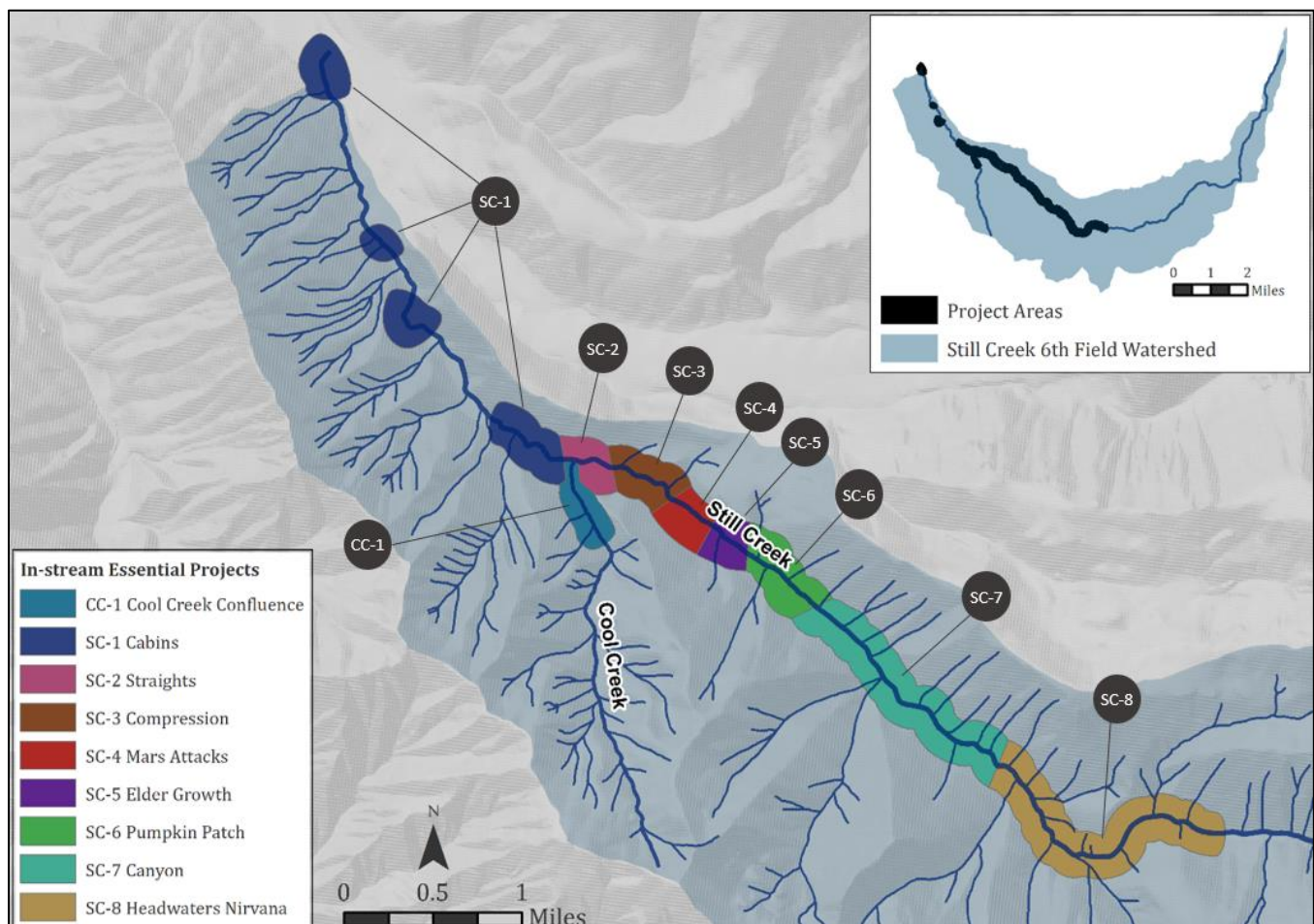


Figure 2. Still Creek restoration project areas (RM 0 – 8.01).

**Table 2.** Project Area characteristics.

Project Area	Cabins <sup>A</sup>	Straights	Compression	Mars Attacks	Elder Growth	Pumpkin Patch	Canyon	Headwaters Nirvana
River Miles (rm)	0.0 - 3.14	3.14 - 3.42	3.42 - 3.91	3.91 - 4.10	4.10 - 4.41	4.41 - 5.0	5.0 - 6.51	6.51 - 8.01
Channel Length (mi)	1.19	0.28	0.49	0.19	0.31	0.59	1.51	1.5
Floodplain Size (acres)	28.5	11.8	21.8	7.9	7.4	20.2	28.3	30.8
Elevation Min. (ft)	1717	1810	1869	1955	1976	2031	2112	2444
Elevation Max. (ft)	1810	1869	1955	1976	2031	2112	2444	2824
Elevation Change (ft)	93	59	86	21	55	81	332	380
Valley Length (ft)	5089	1180	2315	1076	1228	2730	7496	8372

<sup>A</sup>The Cabins project area is split into 3 sub-project areas split between RM 0 and 3.14; all data only represent the 1.19 miles which received restoration treatment.

## Key Partnerships

The Sandy River Basin Partners (SBRP) were instrumental in prioritizing and funding in-stream restoration projects within the Sandy River basin and giving direction to the types of restoration activities that would give the most benefit to threatened salmonids in Still Creek. The Freshwater Trust, BLM, and the Sandy River Basin Watershed Council (SRBWC) secured funds through the Oregon Watershed Enhancement Board (OWEB), Ecotrust's Whole Watershed Restoration Initiative (WWRI), Portland Water Bureau Habitat Conservation Plan grants, National Forest Foundation Matching Awards and Treasured Landscapes grants, National Fish and Wildlife Foundation, Secured Schools Title II funds, and FS Challenge Cost Share grants. In-kind contributions from partners were critical to the success of restoration in Still Creek. In-kind contributions included partners such as Oregon Department of Transportation, Wilderness Volunteers, Mazamas, Farline Bridge Inc., and Clackamas County. Funding for pre- and post-project monitoring funding was secured through the Portland Water Bureau and Portland General Electric (PGE) and in collaboration with The Freshwater Trust and ODFW. The Forest Service contracted the USDA TEAMS Enterprise Unit for completing the designs of all instream and riparian rehabilitation projects. Partners from ODFW, U.S. Fish and Wildlife (USFWS), the National Oceanic and Atmospheric Administration (NOAA), the BLM, Portland Metro, the Nature Conservancy (TNC), The Freshwater Trust, the Sandy River Basin Watershed Council, the PWB and Forest Service staff from other National Forests have actively reviewed the designs for all instream and riparian habitat restoration projects.

## Objectives

Though specific restoration actions varied for each project area, in-stream restoration actions were guided by three objectives: (1) increase large woody debris (LWD), (2) enhance aquatic habitat, and (3) restore floodplain connectivity (USDA 2013). Each objective was then further subdivided into specific targets, outlined below:

### Objective 1. Increase Large Woody Debris

*Objective 1a:* Increase main channel key LWD pieces to 80 pieces per river mile for all project areas to meet standards set by the Columbia River Basin Anadromous Fish Policy and Implementation Guide (PIG) (USDA 1991). Key pieces of LWD are defined as pieces of LWD with a minimum length of 50 feet and a minimum diameter of 24" at 50 feet from the largest end.

*Objective 1b:* Increase main channel key LWD pieces to 106 pieces per river mile for all project areas, according to the Mt. Hood National Forest Land and Resource Management Plan (LRMP) (USDA 1990). Key pieces of LWD are defined as pieces of LWD with a minimum length of 50 feet and a minimum diameter of 24" at 50 feet from the largest end.

### Objective 2. Enhance Aquatic Habitat

*Objective 2a:* Increase main channel pool density to 26 pools per mile to meet PIG standards (USDA 1991). A pool here is defined as a channel spanning feature with a minimum residual pool depth of one foot or greater.

*Objective 2b:* Increase main channel primary pool density to meet LRMP standards (USDA 1991). A primary pool here is defined as a channel spanning feature with a minimum residual pool depth of three feet or greater. This standard specifies that project areas with an average gradient of less than 3% should have one pool every five to seven channel widths; project areas with an average gradient of greater than 3% should have one pool every 3 channel widths. Pool density targets were calculated based on channel widths reported prior to restoration (Table 3).

*Objective 2c:* Increase average residual pool depth to four feet or greater in all project areas. Residual pool depth refers to the maximum depth of the pool minus the depth of the pool tail crest, or the point at which water begins flowing out of the pool. This standard is considered to apply only to primary pools.

**Objective 2d:** Increase spawning habitat by 30% or to 2,000 square yards per river mile. For this report, spawning gravels are considered patches of stream substrate where the dominant gravel size was between 64 mm and 256 mm along the secondary axis.

**Objective 2e:** Increase sinuosity to greater than 1.2 overall and to the targets set per project areas in the Still Creek Rehabilitation Project document (USDA 2013) (Table 3).

**Objective 2f:** Decrease thalweg gradient overall and to the targets set per project areas in the Still Creek Rehabilitation Project document (USDA 2013) (Table 3).

### Objective 3. Restore Floodplain Connectivity

**Objective 3a:** Increase side channel to main channel ratio to greater than 0.4 overall, and increase side channel lengths to match or exceed historic estimates (Table 3).

**Objective 3b:** Increase the two year flow recurrence interval floodplain inundation acreage to greater than 30% above existing conditions in the lower project areas.

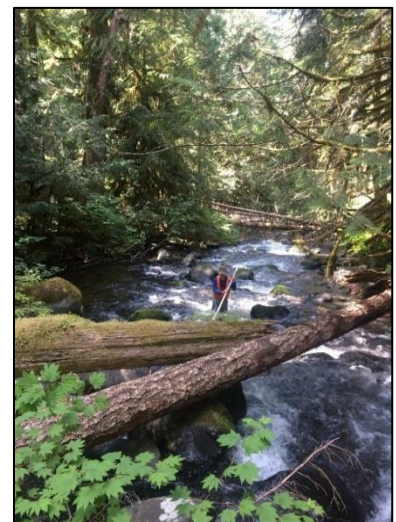
**Objective 3c:** Decrease entrenchment ratios to greater than 3:1 in the lower project areas. Entrenchment ratio is calculated as the ratio of the project area's mean floodprone width to the project area's mean bankfull width.

**Table 3.** Targets defined for each in-stream project area, SC-1 through SC-8.

Objective:	1a	1b	2a	2b	2c	2d	2e	2f	3a	3b	3c
Metric:	Key Piece Density	Key Piece Density	Pool Density	Primary Pool Density	Residual Pool Depth	Spawning Habitat	Sinuosity	Gradient	Side Channel Length	Floodplain Inundation	Entrenchment Ratio
Unit:	Pieces per mile	Pieces per mile	Pools per mile	Pools per mile	Feet	Yards per mile	Channel / Valley Length	Percent	Feet	Acres	Floodprone / Bankfull Width
<i>Cabins</i>	80	106	26	14-20	4	2,000	1.2	1.1	12,144	+30%	3:1
<i>Straights</i>	80	106	26	13-18	4	2,000	1.2	3.3	2,112	+30%	3:1
<i>Compression</i>	80	106	26	17-24	4	2,000	1.2	2.8	3,696	+30%	3:1
<i>Mars Attacks</i>	80	106	26	17-24	4	2,000	1.3	1.8	1,584	+30%	3:1
<i>Elder Growth</i>	80	106	26	16-22	4	2,000	1.2	2.9	2,640	+30%	3:1
<i>Pumpkin Patch</i>	80	106	26	17-23	4	2,000	1.2	2.3	4,752	+30%	3:1
<i>Canyon</i>	80	106	26	36	4	NA	1.2	3.4	2,640	+30%	NA
<i>Headwaters Nirvana</i>	80	106	26	41	4	NA	1.2	3.8	2,640	+30%	NA
<i>Total</i>	80	106	26	16-22	4	NA	1.2	NA	32,208	+30%	NA

## Monitoring Framework

In order to assess the efficacy of restoration work and the completion status of restoration targets, in-stream habitat surveys were completed both before (hereafter, pre restoration surveys) and after (hereafter, post restoration surveys) restoration occurred. Habitat surveys were not completed for the Cool Creek Confluence, and as such, survey results for the Cool Creek Confluence project area are not discussed here. Surveyors followed a USFS Region 6 Level 2 stream survey habitat protocol (USDA 2017) (Figure 3). Pre restoration surveys were completed for all project areas between 2012 and 2017, except for the Compression and Mars Attacks project areas. Unless noted otherwise, pre restoration surveys included measurements for thalweg length, wetted width, pool counts, pool depth, side channel length, bankfull width, and counts of large woody debris. Where possible, data missing from pre restoration surveys were estimated using results from a survey completed of Still Creek in 1996 (USDA 1996) or from the estimates made as part of the Sandy River Basin Ecosystem Diagnosis and Treatment Database (City of Portland 2004). Post restoration surveys were completed for all project areas in the summer of 2017 after the conclusion of restoration actions. Post restoration surveys followed the same protocol as pre restoration surveys, but included additional estimates for spawning gravels, comprehensive side channel surveys, and GPS mapping of all side channel and major log jam structures.



**Figure 3.** Stream surveyor Nik Floyd measures thalweg depth in the Headwaters Nirvana project area.



Due to the limited time period between the conclusion of restoration actions and post restoration surveys, it is important to note that restoration actions have not yet had their full effect as river processes continue to shape the system. The results presented in this report are not intended to provide conclusive statements about the long-term effectiveness of restoration work in Still Creek. Rather, this section of the report is intended to provide a snapshot of Still Creek in its condition following the conclusion of major restoration work, with the assumption that natural river processes will continue to shape the river long into the future.

## Objective 1: Increase Large Woody Debris

**Background** | The Still Creek WRAP noted a lack of large woody debris (LWD) as one of the most significant issues within the Still Creek watershed (USDA 2011). Prior to restoration, lack of large wood led to decreased channel sinuosity, increase channel slope, reduced floodplain roughness, decreased pool densities, reduced off channel habitat, loss of habitat complexity, and limited spawning gravel retention. Dominant tree species within the floodplain have been converted from coniferous to deciduous species as a result of past floods, historic fires, hazard tree removal, and forest clearing. This riparian forest transition has reduced the long term large wood delivery potential along channels within the watershed. Large floods in 1964 and in 1970s scoured channels and swept much of the existing large woody material out of the system. In the aftermath of these floods, the U.S. Army Corps of Engineers, Forest Service, other public agencies, and private individuals removed remaining large logs and boulders from sections of Still Creek. Still Creek key piece levels were particularly low, and failed to meet standards set by the Mount Hood National Forest LRMP at 106 key pieces per river mile (USDA 1990) and the Columbia River Basin Anadromous Fish Passage PIG at 80 key pieces per river mile (USDA 1991).

Restoration actions included the addition of an estimated 2,300 wood pieces throughout the project areas, including at least 300 key pieces of wood. Over 84% of these wood pieces were used to construct approximately 240 log jam structures (Figure 5), designed to promote the deposition and retention of spawning gravels, the formation of slack water and pool habitats, and the reactivation of historic side channels and floodplain habitats. Large wood pieces were sourced from hazard tree removal, debris clean up along highways, forest thinning operations, standing riparian trees, and from debris removal from reservoirs in the Bull Run watershed. Wood was added to the stream either by cabling over standing riparian zone trees directly into the river, flying in wood via helicopter (Figure 4), or dragging trees into the river via skidder through the creation of temporary skid roads.

**Survey Methods** | Survey crews considered all wood pieces exceeding 25 feet in length and 12 inches in diameter as a piece of LWD; any wood piece exceeding 50 feet in length and 24 inches in diameter was considered a key piece. Any structure with 2 or more pieces of LWD touching one another was considered a log jam, and GPS coordinates were taken for all log jams with 4 or more pieces of LWD. Jam data was not collected for pre restoration surveys. Only wood pieces that were partially within the stream's bankfull or were connected to pieces within bankfull were counted. Main channel wood and jam densities were calculated using the same GIS length estimates listed in Table 2, whereas side channel wood and jam densities were calculated using side channel measured thalweg lengths.

**Survey Results** | Post restoration survey crews recorded 2,716 total pieces of LWD, including 472 key pieces, throughout all project areas (Appendix A, Table A1). Approximately 37% (995 pieces) of all wood was recorded within side channel habitats. Pre restoration survey data was incomplete for all project areas making it impossible to fully compare LWD counts before and after restoration work. Despite the missing data, at minimum, survey results revealed an increase in 1,904 pieces of in-stream LWD, including an increase of 305 key pieces, although this data omits wood from several miles of side channel habitat (Table 5). Main channel wood densities were substantially increased across all project areas, with overall wood densities increasing from 90 LWD pieces per river mile to 282 LWD pieces per river mile, and key piece densities increasing from 13 pieces per river mile to 54 pieces per river mile (Figure 6). Pre restoration side channel wood counts were only available for five of eight project areas; however, both LWD and key piece densities increased in all five of these project areas. Overall post restoration side channel wood densities were recorded at 133 pieces of LWD per mile of side channel habitat (Figure 7).

Survey crews recorded a total of 335 jams throughout the project areas, with 194 log jams in the main channel and 141 log jams in side channels. Though pre restoration log jam counts were unavailable, survey crews estimated that 240 log jams were created or improved through recent restoration work. Over 84% of all wood pieces recorded – or 2,295



**Figure 4.** A helicopter delivers a 40' long piece of LWD to Still Creek.

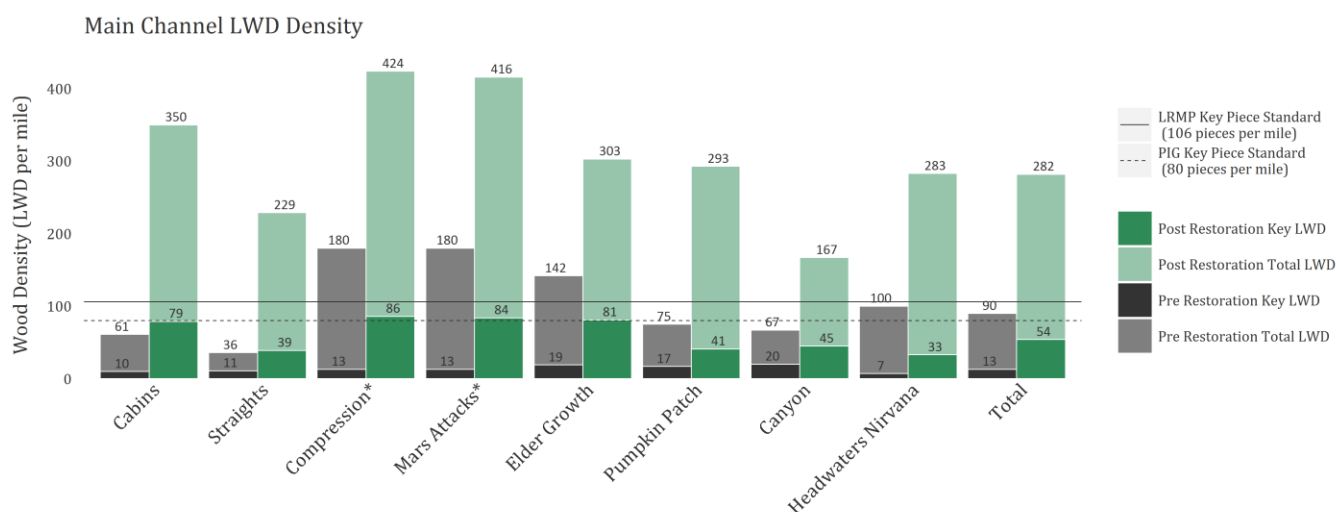


pieces of LWD – were recorded as part of a log jam (Appendix A, Table A1). Main channel jam densities ranged from 25 log jams per river mile in the Straights project area to 51 log jams per river mile in the Compression project area, with an overall jam density of 32 log jams per river mile (Table 4). Side channel log jam densities ranged from 13 jams per mile of side channel habitat in the Headwaters Nirvana project area to 40 jams per mile of side channel habitat in the Straights project area (Table 4).

**Discussion |** While overall key piece densities are still below both PIG (80 pieces per river mile) and LRMP (106 pieces per river mile) standards, the Cabins, Compression, Mars Attacks, and Elder Growth project areas on their own nearly meet, or exceed PIG standards. Similarly, the Compression, Mars Attacks, and Elder Growth project areas are all within approximately 80% of LRMP standard compliance (Figure 6).

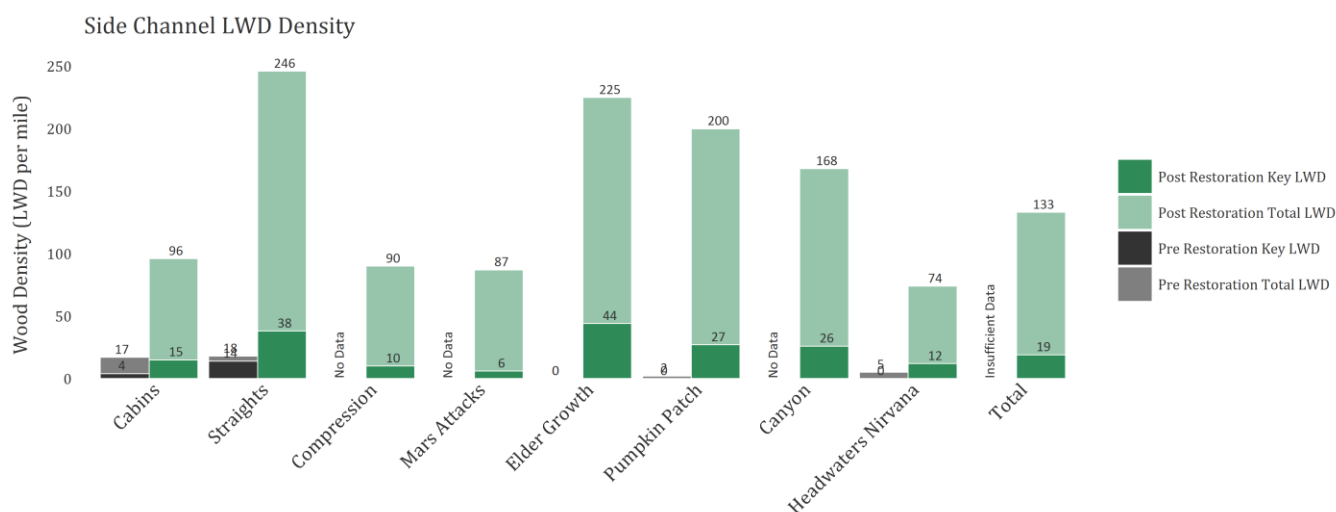


**Figure 5.** An example of a channel spanning restoration log jam in the Cabins project area. Photo is facing upstream.



**Figure 6.** Main channel wood densities compared between pre and post restoration survey data.

\*Pre restoration survey data were unavailable for the Mars Attacks and Compression project areas; data represented here were pulled from the 1996 Still Creek Surveys and the EDT Database.



**Figure 7.** Side channel wood densities compared between pre and post restoration survey data. Insufficient pre restoration data were available to estimate overall pre restoration LWD densities.

The full impact of the placement of LWD will likely not be realized for decades; however, anecdotal evidence suggests that wood additions are already making a positive impact. Survey crews noted the retention and deposition of spawning gravels in and around large wood structures, as well as elevated groundwater tables leading to the reactivation of floodplain groundwater channels. Many large wood structures were placed to promote re-activation of side channel habitats, which increased by nearly 6.5 miles since pre restoration surveys. Furthermore, survey crews reported an increase of 62 main channel pools since pre restoration surveys, the vast majority of which were caused by additions of LWD. Juvenile salmonids were observed utilizing wood structures as early as one week after their construction. Large wood will continue to provide important habitat, promote complex channel dynamics, and recruit additional large woody debris into the future.

**Table 4.** Jam counts, jam densities and percentage of all wood counted located in jams. Numbers in parentheses indicate the subset of jams that were created as a result of restoration work.

Project Area	Jam Count (# Restoration Jams)			Jam Density (jams / mile)		Total Percent Wood in Jams
	Main Channel	Side Channels	Total	Main Channel	Side Channels	
<i>Cabins</i>	34 (27)	28 (21)	63 (46)	28.6	16.6	87.3%
<i>Straights</i>	7 (5)	22 (18)	29 (23)	25.0	39.5	91.0%
<i>Compression</i>	25 (24)	21 (14)	46 (38)	51.0	13.3	78.3%
<i>Mars Attacks</i>	9 (9)	10 (5)	19 (14)	47.4	15.5	89.6%
<i>Elder Growth</i>	10 (9)	13 (12)	23 (21)	32.3	34.0	90.6%
<i>Pumpkin Patch</i>	17 (11)	24 (15)	41 (26)	28.8	19.9	85.0%
<i>Canyon</i>	38 (19)	13 (7)	51 (26)	25.2	18.9	85.0%
<i>Headwaters Nirvana</i>	54 (46)	10 (1)	64 (47)	36.0	13.2	78.1%
<i>Total</i>	194 (150)	141 (93)	335 (240)	32.0	18.8	84.5%

**Table 5.** Total LWD counts compared between pre and post restoration project data. Numbers in parentheses indicate the subset of LWD recorded as key pieces.

Project Area	LWD Counts – Total LWD (Key Pieces)				
	Main Channel		Side Channels		Total LWD Increase
	Pre Restoration	Post Restoration	Pre Restoration	Post Restoration	
<i>Cabins</i>	73 (12)	427 (94)	28 (6)	163 (26)	499 (103)
<i>Straights</i>	10 (3)	64 (11)	10 (8)	137 (21)	181 (21)
<i>Compression</i>	88 <sup>A</sup> (6 <sup>B</sup> )	208 (42)	ND	142 (16)	120 <sup>+</sup> (36 <sup>+</sup> )
<i>Mars Attacks</i>	34 <sup>A</sup> (2 <sup>B</sup> )	79 (16)	ND	56 (4)	135 <sup>+</sup> (14 <sup>+</sup> )
<i>Elder Growth</i>	44 (6)	94 (25)	0 (0)	86 (17)	136 (36)
<i>Pumpkin Patch</i>	44 (10)	173 (24)	3 (0)	241 (32)	367 (46)
<i>Canyon</i>	101 (30)	252 (68)	ND	115 (18)	151 <sup>+</sup> (38 <sup>+</sup> )
<i>Headwaters Nirvana</i>	150 (10)	424 (49)	4 (0)	56 (9)	326 (48)
<i>Total</i>	544 (79)	1721 (329)	45 <sup>+</sup> (14 <sup>+</sup> )	995 (143)	1904 <sup>+</sup> (305 <sup>+</sup> )

<sup>A</sup>Pre restoration LWD count data for the Compression and Mars Attacks project areas are based off of densities from the Sandy River Basin EDT Database (City of Portland 2004). EDT LWD data include wood <12" in diameter, so these data are likely an over-estimate.

<sup>B</sup>Pre restoration key piece data for the Compression and Mars Attacks project areas are based off of densities reported in the 1996 survey data.

<sup>+</sup>Data with a plus sign represent minimum LWD increases when incomplete data were available; actual increase in LWD are almost certainly higher.

## Objective 2: Enhance Aquatic Habitat

**Background |** Pre restoration channel morphology posed a major limiting factor for salmonid reproduction and survival. Low levels of LWD limited pool formation and allowed for moderate channel incision, and pool densities were well below both PIG and LRMP standards. A lack of slow water habitat meant limited resting and foraging habitat for juvenile salmonids and limited resting habitat for migrating salmonids. Pools that were available were generally shallower than the target mean residual pool depth of four feet or greater (USDA 2013). Pools as total percentage of main channel thalweg length were well below the historic estimates of 32.40% (City of Portland 2004).

The lack of LWD and slow water habitats in the stream contributed to low retention levels of gravels, which provide crucial spawning habitat. The Still Creek Final Rehabilitation Plan (USDA 2013) set a target of 2,000 square yards of spawning gravels per river mile for all project areas except for the Canyon and Headwaters Nirvana project areas. Though no pre restoration survey data exist for spawning gravels, it is estimated that spawning gravels were substantially below this target density (USDA 2013).

Moderate channel incision from low levels of LWD and in-channel roughness, as well as historic channel simplification through recreational residential development and road construction, lead to a low sinuosity and a high thalweg gradient. Sinuosity is directly related to the capacity of the main channel to maintain dynamic processes through its migration back and forth across the floodplain, whereas thalweg gradient is indirectly related to the availability of slow water habitats and gravel and sediment depositional areas.

Restoration actions to improve these metrics focused around the addition of LWD outlined in Objective 1. LWD contribute substantially to pool formation, gravel retention, and increased channel complexity. In addition to the addition of LWD placement, two pools were excavated and stabilized with large boulders at sites in the Cabins area.

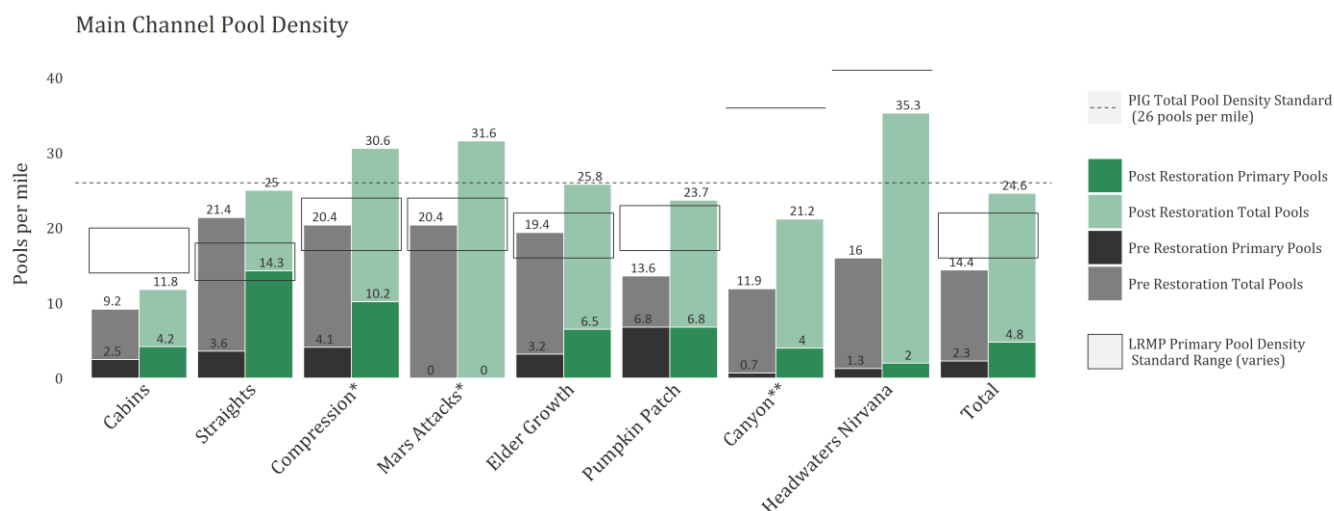
**Survey Methods |** Pools were defined as any channel spanning feature with a minimum residual pool depth of 1 foot or greater in the main channel, and a minimum residual pool depth dependent on bankfull width in side channels (Table 6). Residual pool depths were calculated as the difference between the maximum recorded pool depth and the pool tail crest. In general, only pools with a thalweg length greater than the wetted width were considered; however, all plunge pools were recorded. Primary pools were defined as any pool with a minimum residual pool depth of greater than 3 feet. Survey crews estimated spawning gravel availability in all channel glides, small cobble riffles, and pool tails. Spawning gravels were considered any substrate patches with dominant pebbles measuring between 64 mm and 256 mm along the secondary axis.

Main channel pool densities were calculated by dividing pool counts by channel lengths estimated in GIS (previously presented in Table 2). These GIS derived channel lengths were utilized rather than surveyed lengths to allow direct comparison between pre and post restoration survey data, which differed slightly in measured lengths and may not accurately reflect the changes in pool density. Valley length and project area elevation change were estimated using GIS (Table 2). Sinuosity was calculated as the ratio of the thalweg length to the valley length, and thalweg gradient was calculated as the ratio of elevation change to thalweg lengths. The Compression and Mars Attacks project areas lacked pre restoration survey data, and the Elder Growth project area thalweg length data were incomplete. For these project areas, sinuosity and thalweg gradient estimates were estimated using data derived through GIS.

**Survey Results |** The number of main channel pools recorded throughout all project areas increased from 87 pools, including 14 primary pools, pre restoration to 149 pools, including 29 primary pools, post restoration (Appendix A, Table A1). Main channel pool densities increased from 14.4 pools per river mile and 2.3 primary pools per river mile pre restoration to 24.6 pools per river mile and 4.8 primary pools per river mile post restoration (Figure 8). Pool density increased in all project areas, and primary pool density increased in all project areas except for the Mars Attacks and Pumpkin Patch project areas, which remained the same. The highest post restoration pool density was recorded in the Headwaters Nirvana project area, with 35.3 pools per river mile. The length of pools as a percentage of total thalweg length increased from 12.7% to 20.2% in the main channel. No pre restoration pool data were available for side channels, but surveyors recorded over 301 pools, including 13 primary pools, throughout the surveyed side channel habitats (Appendix A, Table A2). These side channel pools comprised approximately 21.9% of total side channel thalweg length (Table 7).

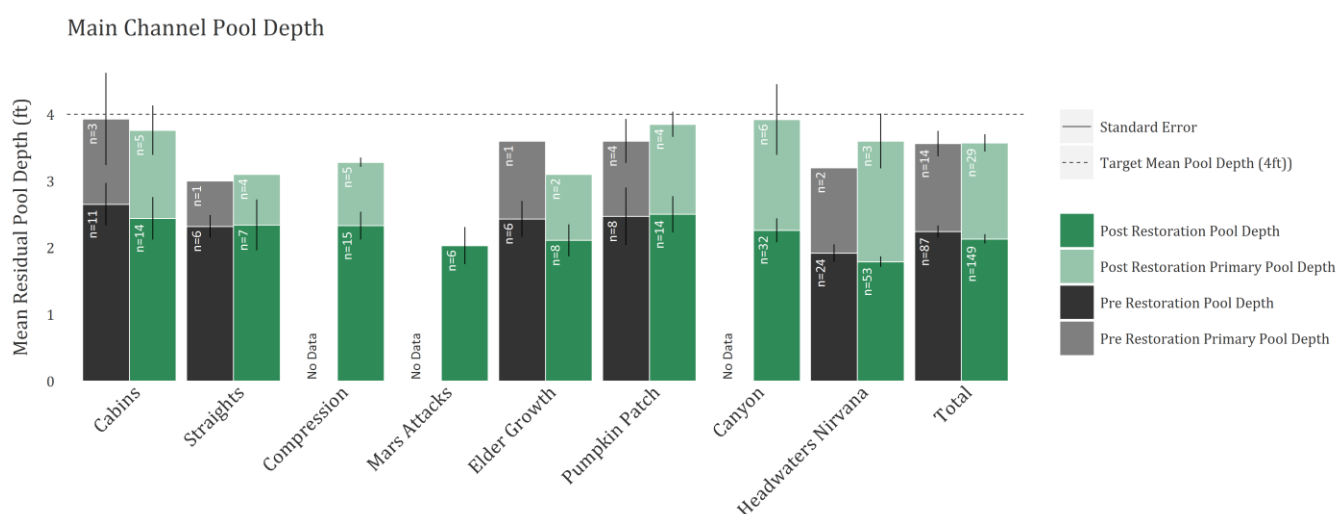
**Table 6.** Side Channel minimum residual pool depths based on bankfull width to qualify a pool.

Bankfull Width (ft)	Minimum Residual Pool Depth
> 0 to 8	0.32
8-16	0.66
16-33	0.82
>33	1



**Figure 8.** Main channel pool densities compared between pre and post restoration survey data. LRMP pool density standards are based on bankfull widths from pre restoration data.

\*Pre restoration survey data were unavailable for the Compression and Mars Attacks project areas; data represented here are estimates based on the average values of surrounding project areas.  
 \*\*Pre restoration primary pool data were unavailable for Canyon project area; data represented here is an estimate based on pool densities in the most similar project area, Headwaters Nirvana.



**Figure 9.** Main channel mean residual pool depths, number of pools observed (n), and standard error of the mean. Overlapping error bars are typically interpreted to mean no significant difference between means.

Mean residual pool depth saw no significant change before and after restoration, with mean residual pool depth measured at 2.2 feet pre restoration and 2.1 feet post restoration. Likewise, mean primary residual pool depth remained at 3.6 feet between pre and post restoration surveys (Figure 9).

No pre restoration data exist for spawning gravel densities; however, the Still Creek Final Rehabilitation Plan (USDA 2013) estimated that gravel densities were below the recommended 2,000 square yards per mile. Post restoration spawning gravel densities ranged from 338 square yards per river mile in the Canyon project area to 2,942 square yards per river mile in the Mars Attacks project area. The average spawning gravel density for the lower project areas (RM 0.00 to 5.00), for which the target densities were set, were measured at 2,106 square yards per mile (Table 8).

Only incomplete data were available to estimate pre restoration thalweg length, but through a combination of field surveys and GIS, pre restoration main channel thalweg length was estimated at 33,172 feet over all project areas (Appendix A, Table A5). Post restoration thalweg length was measured at 32,816 feet over all project areas. This

corresponded to an overall sinuosity of 1.12 in the pre restoration survey data and 1.11 in the post restoration survey data (Table 8). Likewise, overall thalweg gradient remained roughly unchanged for most project areas, with pre restoration overall thalweg gradient measured at 3.3% and post restoration overall thalweg gradient measured at 3.4%. Some exceptions to this are the Straights project area, which saw an increase in sinuosity from 1.29 to 1.39 and a decrease in thalweg gradient from 3.9% to 3.6%, and the Mars Attacks project area, which saw an increase in sinuosity from 1.09 to 1.18 and a decrease in thalweg gradient from 1.8% to 1.6% (Table 8).

**Table 7.** Percentage of channel length comprised of pools, compared between pre restoration and post restoration data, and main channels and side channels.

Project Area	Main Channel		Side Channels	
	Pre Restoration	Post Restoration	Pre Restoration	Post Restoration
Cabins	16.64%	17.67%	No Data	28.44%
Straights	28.99%	27.78%	No Data	7.14%
Compression	15.9% <sup>A</sup>	34.09%	No Data	16.40%
Mars Attacks	15.9% <sup>A</sup>	18.37%	No Data	25.91%
Elder Growth	16.35%	28.23%	No Data	13.73%
Pumpkin Patch	10.97%	28.80%	No Data	30.01%
Canyon	11.66%	14.29%	No Data	19.70%
Headwaters Nirvana	8.09%	17.88%	No Data	19.63%
Total	12.67%	20.19%	No Data	21.92%
Historic <sup>B</sup>	32.40%		No Data	

<sup>A</sup>Compression and Mars Attacks pre restoration values were derived from the Sandy River Basin EDT database (City of Portland 2004).

<sup>B</sup>Historic estimates are for percent of wetted area rather than length.

**Table 8.** Post restoration spawning gravels, sinuosity, and thalweg gradient compared to targets.

Project Area	Spawning Gravels (yards / mile)		Sinuosity			Thalweg Gradient		
	Post Restoration	Target	Pre Restoration	Post Restoration	Target	Pre Restoration*	Post Restoration	Target
Cabins	2,541.2	2,000	1.11	1.14	1.2	1.6%	1.6%	1.1%
Straights	2689.3	2,000	1.29	1.39	1.2	3.9%	3.6%	3.3%
Compression	2446.9	2,000	1.12 <sup>B</sup>	1.07	1.2	3.3% <sup>B</sup>	3.5%	2.8%
Mars Attacks	2942.1	2,000	1.09 <sup>B</sup>	1.18	1.3	1.8% <sup>B</sup>	1.6%	1.8%
Elder Growth	1116.1	2,000	1.05 <sup>B</sup>	1.15	1.2	4.3% <sup>B</sup>	3.9%	2.9%
Pumpkin Patch	920.3	2,000	1.19	1.14	1.2	2.5%	2.6%	2.3%
Canyon	337.7	NA	1.12	1.08	1.2	4.0%	4.1%	3.4%
Headwaters Nirvana	616.0	NA	1.11	1.08	1.2	4.1%	4.2%	3.8%
Total	2106.2 <sup>A</sup>	2,000 <sup>A</sup>	1.12	1.11	1.2	3.3%	3.4%	NA

<sup>A</sup>Total gravel density and targets do not include the Canyon or Headwaters Nirvana project areas, as specified in the Still Creek Final Rehabilitation Plan.

**Discussion |** Six out of eight project areas (Straights, Compression, Mars Attacks, Elder Growth, Pumpkin Patch, and Headwaters Nirvana) nearly meet or exceed the PIG pool density standard of 26 pools per river mile, and overall pool density fell just short of the PIG standard at 24.6 pools per river mile. While only the Straights project area currently meets LRMP standards for primary pool density, deep pools take time and scour from flood events to form. Three five year flood events have occurred in the Sandy River basin since the beginning of restoration in 2012 (USGS 2017) and have begun this process; however, the restoration structures have yet to interact with a major flood event. Only 2 pools were directly created with an excavator, and the increase in the number of pools observed indicates that natural watershed processes are already promoting pool formation.

The length of pools as a percentage of total main channel thalweg length also increased for all project areas except for the Straights, which saw a moderate decrease. This indicates that the amount of resting habitat available for fish is increasing as a result of restoration actions. Estimates from the Ecosystem Diagnosis and Treatment Database (City of



Portland 2004) suggest that historic levels of main channel pool habitat as a percentage of total thalweg length were near 32.4%. While Still Creek is still below this level, the trend indicates that total pool habitat is on the rise. No pre restoration data exist for side channel pools; however, very few of the side channels surveyed existed prior to restoration; as such, the majority of pools surveyed within side channels represent newly accessible pools. If this is considered, then the overall pool habitat within side channels increased by up to 301 pools representing over 8,500 linear feet of pool habitat (Appendix A, Table A2).

While there was no change in mean residual pool depth, there is evidence of pool deepening between pre and post restoration surveys. The two deepest pools pre restoration were measured at a residual pool depth of 5.2 feet and 4.3 feet, whereas the two deepest post restoration pools were measured at 7.2 feet and 6.1 feet. Both of these pools were formed by natural scour rather than artificially forming these depths via a log dam or excavation. The unchanged mean is likely due to the formation of a significant number of shallower pools throughout the project areas. It is expected that winter floods will continue to interact with placed wood structures to create new pools and to deepen existing pools (Figure 10).

Between RM 0.00-5.00, post restoration spawning gravel density exceeded the 2,000 square yard per river mile target at 2,105.8 square yards per river mile. Without detailed pre restoration data, it is difficult to conclusively state that these gravels were a result of recent restoration activity. However, anecdotal evidence provided in survey crew notes suggested that multiple log structures were promoting retention and deposition of gravels. The Elder Growth and Pumpkin Patch project areas still remain below target spawning gravel densities, but it is likely that gravels will continue to accumulate with additional winter flood cycles.

Sinuosity and thalweg gradient are difficult to compare pre and post restoration because of the lack of accurate thalweg length data for some project areas makes it impossible to accurately determine these metrics. Sinuosity and thalweg gradient measurements derived using GIS prior to restoration provide only rough estimates. The roughness of these estimates likely explain why in four out of eight project area, sinuosity decreased and thalweg gradient increased. Regardless, post restoration data show that overall sinuosity and thalweg gradient are still not at target levels. This is not surprising, given that these metrics can be expected to change only with significant changes in main channel morphology – a process that may take decades unless a major flood event occurs. However, the Straights project area sinuosity did increase to a point that it now meets the target sinuosity of 1.2.

### Objective 3: Restore Floodplain Connectivity

**Background |** Prior to restoration, the greatest single limiting factor for salmonid production in Still Creek was the lack of isolated side channels and off channel habitats (SRBWG 2007). Historically, Still Creek had an estimated 6 miles of side channels, which provided critical habitat to several life history stages of anadromous fish. High quality side channel habitat with LWD jams and single pieces provide cover, refugia, feeding grounds, and spawning areas for juvenile and adult fish.

Naturally, in-stream LWD promotes complex floodplain habitats by forcing water onto the floodplain. Historic berms, dikes, revetments, channel cleanouts, and large wood removal disconnected the stream from its historic side channels, particularly in the Cabins Reach. Additionally, channelization and large wood removal following the 1964 flood event led to the incision of the main stem channel and isolation of side channels, which became inaccessible to native fish. Most remaining side channel fish habitat had been simplified by the removal of large wood as well as conversion of riparian stands from a multi-layered over-story dominated by conifers to simple, single thread channels dominated by hardwood over-stories or open areas with fewer conifer components. Estimates within the EDT database suggested that prior to restoration over 25% of the main channel within project areas was confined to a single channel due to man-made hydro-modifications (City of Portland 2004).



*Figure 10. A pool forms behind a log jam structure in the upper Cabins project area. The photos are facing downstream.*



**Figure 11.** A newly excavated side channel and a placed log jam structure in the Straights project area, before and after restoration. The photos are facing downstream.

In order to restore floodplain connectivity, the Still Creek Rehabilitation Plan (USDA 2013) set a target to increase side channel lengths to historic levels (Table 10) and to decrease entrenchment from a 1:1 to a 3:1 ratio. Additionally, the restoration plan set a target to increase the two year flow recurrence interval floodplain inundation acreage to greater than 30% above pre restoration conditions in the lower project areas (RM 0.00 to 5.00).

Restoration actions included the addition of main channel large wood structures to direct water onto the floodplain and the removal of debris and dikes isolating floodplain habitats. Furthermore, excavators partially or fully dug out approximately 4,000 feet of side channels spread throughout the project areas. Log jams were strategically located to aggrade the stream bed through sediment and gravel deposition, and to raise the ground water table to promote the reactivation of floodplain ground water channels. To improve floodplain roughness and enhance the quality of side channel habitat, at least 950 pieces of large wood, including 130 key pieces, were placed throughout the Still Creek floodplain, and an estimated 93 log jams were constructed throughout the floodplain.

**Methods |** Survey crews recorded side channel thalweg lengths for all side channels with evidence of recent scour. Pre restoration side channel data were unavailable for the Compression, Mars Attacks, and Canyon project areas, and only partial data were available for the Straights and Elder Growth project areas. Surveyors recorded GPS tracks for every side channel measured. In addition, survey crews measured main channel bankfull widths and floodprone widths to be used to calculate entrenchment ratio. Note that

a higher entrenchment ratio value indicates lower levels of entrenchment.

The side channel to main channel ratio was calculated by dividing the side channel length by the main channel length using main channel GIS length estimates (Table 2). Entrenchment was calculated by dividing mean floodprone widths by mean bankfull widths for each project area and were compared to estimates of potential entrenchment made in USDA 2013. Bankfull widths were measured in the field, while floodprone widths were estimated in GIS. Percent confinement was calculated in GIS by measuring the total length of the main channel where all water was confined solely to the main channel.

**Survey Results |** The total length of side channel recorded increased from an estimated 1 mile prior to restoration to nearly 7.5 miles (39,585 feet) after restoration. Similarly, the ratio of side channel length to main channel length increased from an estimated 0.2 side channel miles per river mile prior to restoration to 1.2 side channel miles per river mile after restoration (Figure 13).

Though pre restoration entrenchment ratios were unavailable, post restoration entrenchment ratios for all of the lower project areas (RM 0.00 to 5.00) were near the range of potential values estimated using GIS. The most entrenched project area was the Canyon, with an entrenchment ratio ranging from 1.9 to 2.6. The least entrenched project areas was the Pumpkin Patch, with an entrenchment ratio of range of 8.3 to 9.2.

GIS analysis revealed that 41.4% of the total project areas were confined, ranging from 0.0% confinement in the Mars Attacks project area to 66.1% confinement in the Canyon project area. Though direct data on flood inundation areas are not currently available, an estimated 156.7 acres of floodplain habitat were impacted by restoration activities, 97.6 acres of which were in the lower project areas.

**Discussion |** Following restoration, surveyors recorded nearly 7.5 miles of side channel habitat. All project areas at least doubled side channel habitats, and all project areas except for the Cabins and the Elder Growth now exceed estimated historic lengths of side channels. Entrenchment for all project areas



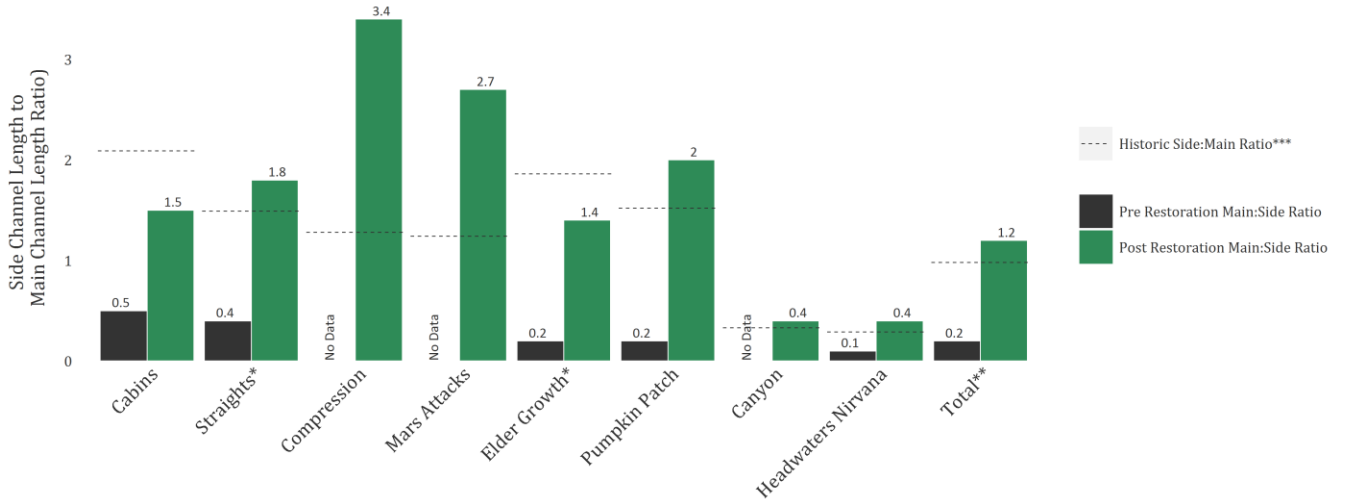
**Figure 12.** A constructed log jam forces water onto the river right floodplain in the Compression project area. Photo is facing downstream.

tended to be within the range of potential values estimated by USDA 2013, indicating that the system has adequate access to the floodplain. The Canyon and Headwaters Nirvana project areas remain with entrenchment ratios that tend to be less than 3:1; however, these areas are expected to have high entrenchment given their steep valley characteristics and their Rosgen Channel classification (Rosgen 1994).

No pre restoration data exist regarding confinement, but post restoration estimates made using GIS suggest that confinement levels are near what should be expected given the Rosgen stream type classifications for each project area (Rosgen 1994). Confinement is a measure of the level of disconnection between the main channel and side channel habitats. Some level of confinement is natural in stream systems, and confinement tends to increase with thalweg gradient. The Cabins project area remains more confined than expected due to the large number of remaining revetments and dikes from recreational residences that cannot be altered in the lower portion of the project area.

Though flood inundation data are not available, low channel confinement, low entrenchment, and reactivation of historic side channels indicate that restoration activities increased flood inundation zones.

The low quality of side channels prior to restoration was noted as an issue in the Still Creek WRAP due to low levels of floodplain LWD (USDA 2011). As previously presented, over 141 log jams (Table 4), including 93 created by restoration, and 995 pieces of LWD (Table 5) were recorded across all side channels. Additionally, surveyors counted over 301 individual pools on floodplains comprising 21.9% of all side channel habitat (Appendix A, Table A2). These indicators suggest that both side channel quantity and habitat quality were markedly improved.



**Figure 13.** Side Channel length to main channel length ratios compared between pre and post restoration survey data.

\*Pre restoration survey data were incomplete for the Straights and Elder Growth project areas side channels; data represented here are likely an under-estimate.

\*\*Because of the missing data, pre restoration totals represent an average weighted by project area length of available data.

\*\*\*Historic side channel to main channel ratios are based on estimated side channel lengths provided in the 2012 Still Creek Rehabilitation Project Plan (TEAMS 2012).

**Table 9.** Estimated confinement compared with expected levels of confinement given Rosgen channel types for each project area (Rosgen 1994), and estimated entrenchment ratios compared with potential entrenchment.

Project Area	Confinement			Entrenchment	
	%Confined	Rosgen Channel Type	Expected Confinement	Entrenchment Range	Entrenchment Potential Range
<i>Cabins</i>	32.0%	C	Low	3.3 - 5.9	3.0 - 5.4
<i>Straights</i>	21.2%	A-B	Moderate to High	4.3 - 5.0	4.3 - 5.0
<i>Compression</i>	0.6%	B	Moderate	2.2 - 6.8	2.3 - 7.2
<i>Mars Attacks</i>	0.0%	B	Moderate	3.1 - 4.2 <sup>A</sup>	3.0 - 4.5
<i>Elder Growth</i>	29.2%	B	Moderate	4.4 - 4.6	5.1 - 5.3
<i>Pumpkin Patch</i>	10.8%	B	Moderate	8.3 - 9.2	10.7 - 11.8
<i>Canyon</i>	66.1%	A-B	Moderate to High	1.9 - 2.6	2.2 - 2.9
<i>Headwaters Nirvana</i>	64.0%	A-B	Moderate to High	2.0 - 2.9	2.4 - 3.5
<i>Total</i>	41.4%	NA	NA	NA	NA

<sup>A</sup>No bankfull data were available to calculate entrenchment ratios for Mars Attacks; entrenchment ratios were determined by estimating bankfull widths of the surrounding project areas, the Compression and the Elder Growth.

**Table 10.** Total side channel lengths compared before and after restoration.

Project Area	Side Channel Length (ft)			
	Historic	Pre Restoration	Post Restoration	Increase
<i>Cabins</i>	12,144	2,661	8,921	6,260
<i>Straights</i>	2,112	617	2,941	2,324
<i>Compression</i>	3,696	No Data	8,337	No Data
<i>Mars Attacks</i>	1,584	No Data	3,400	No Data
<i>Elder Growth</i>	2,640	317 <sup>+</sup>	2,017	1,700
<i>Pumpkin Patch</i>	4,752	670 <sup>+</sup>	6,352	5,682
<i>Canyon</i>	2,640	No Data	3,624	No Data
<i>Headwaters Nirvana</i>	2,640	1,202	3,993	2,791
<i>Total</i>	32,208	No Data	39,585	No Data

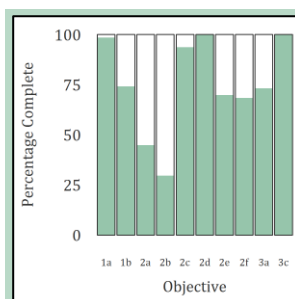
<sup>+</sup>Data with a plus sign represent minimum LWD increases when incomplete data were available; actual increase in LWD are almost certainly higher.



## Essential Project SC-1 | the Cabins

**Background** | The Cabins project area is a low gradient depositional reach and contains the lowest average stream thalweg gradient of any of the project areas. The area is named for the 129 recreational resident cabins along this section of the river, including many cabins situated on the floodplain. Prior to restoration, the area was characterized by low levels of downed woody debris as a result of poor riparian conditions and LWD removal. Without significant LWD, natural stream pinch points and a history of dike construction and channel straightening lead to increased lateral stream channel migration and avulsion rates, stream bank instability, and terrace erosion. These processes threatened several cabins within the channel migration zone. Restoration outcomes for the Cabins project area were to restore floodplain resilience, maximize pool quantity and quality, and increase off-channel rearing and spawning habitat.

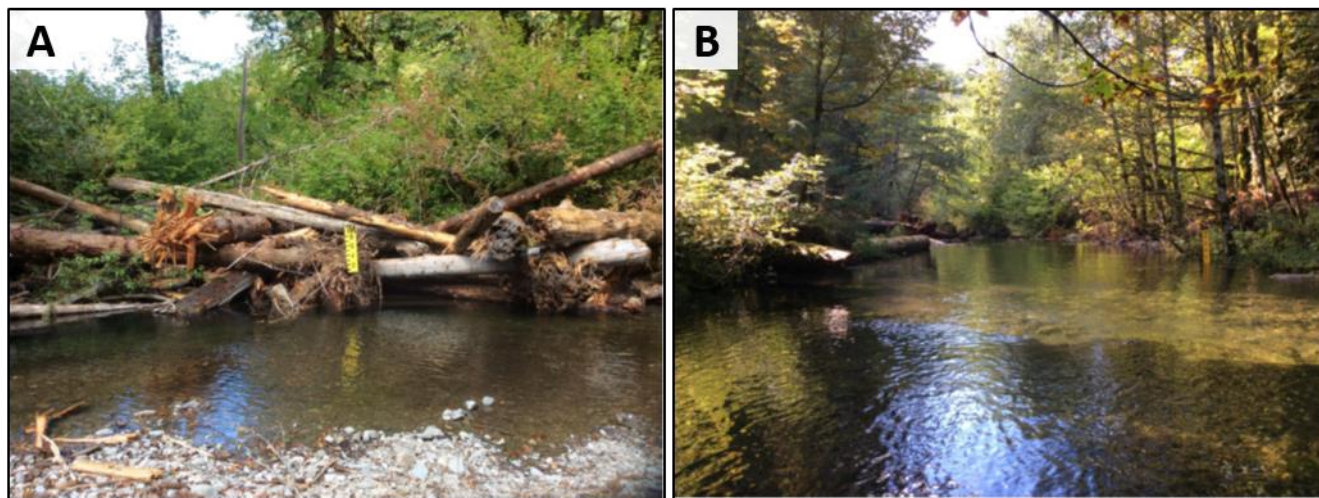
**Actions** | Restoration of the Cabins Reach occurred in three areas spread through the reach: from the Still Creek mouth to RM 0.24 (lower Cabins), from RM 1.78 to RM 2.09 (middle Cabins), and from RM 2.66 to the upstream end (RM 3.14) of the project area (upper Cabins). Work was performed on the lower Cabins in 2016; in the middle Cabins in 2016 and 2017; and in the upper Cabins in 2014 and 2017. Between the three sections, excavators dug two new pools, constructed one 1,100 foot long side channel that re-routed approximately 10% of the river onto the Middle Cabins floodplain, removed riprap and dikes to reactivate a 700 foot long historic side channel and re-activate a large floodplain area in the upper Cabins, added nearly 480 pieces of large woody debris to the main channel and side channels, and constructed or created 45 log jams (Figure 14). An additional log jam was created just downstream of the Road 2620 bridge, outside of the listed project areas. In total, an estimated 28.5 acres of floodplain habitat were restored.



### BOX 1. CABINS PROJECT OVERVIEW

River Miles: RM 0.00-3.14  
 Surveyed Length: 5,802 feet  
 Year(s) Restored: 2014, 2016-2017  
 Floodplain Area Impacted: 28.5 acres  
 Wood Added: 480 pieces  
 Jams Created: 45 jams  
 Side Channel Improvements: 8,921 feet

<sup>2</sup>See footnote for brief description of objectives for the Cabins

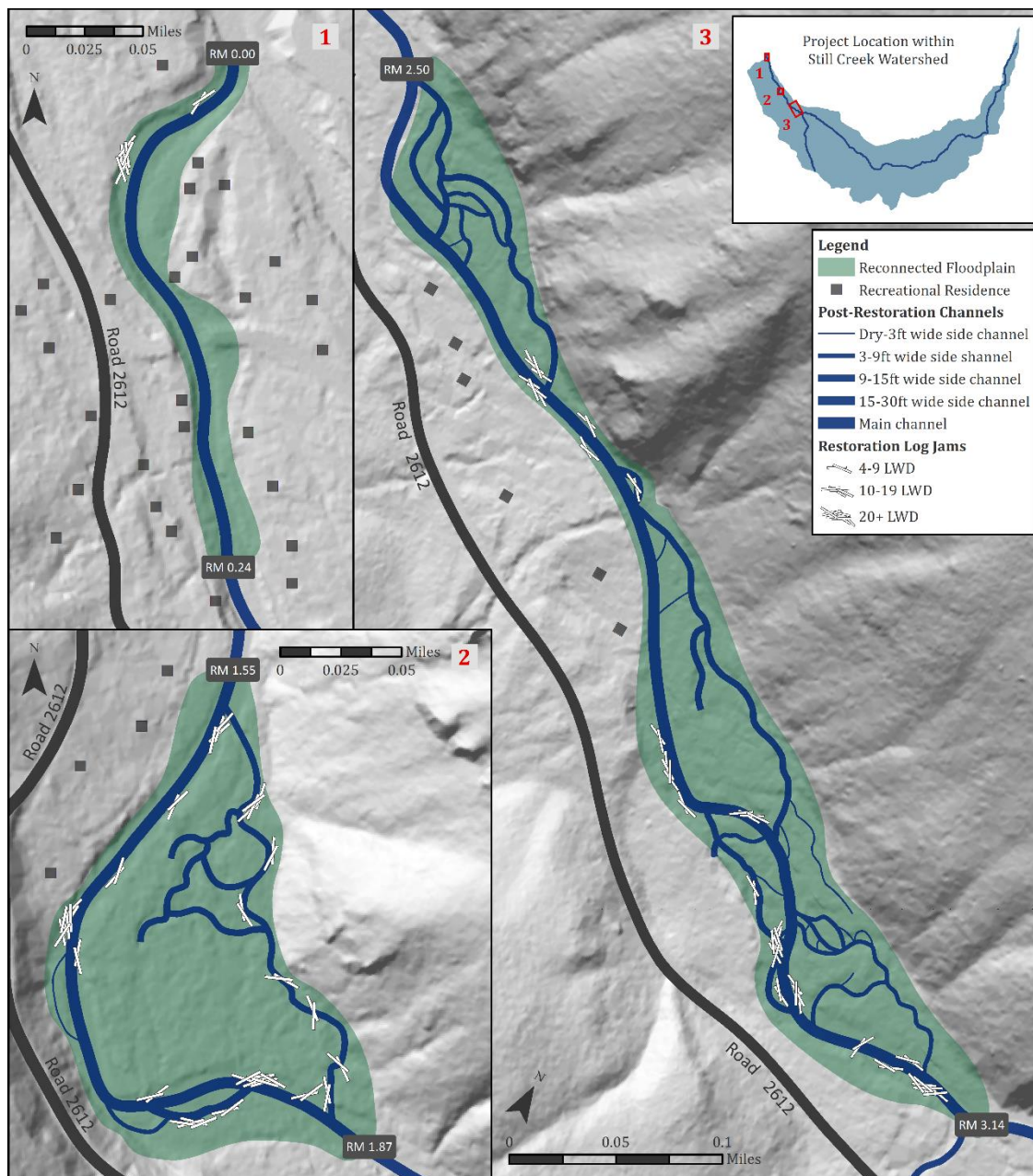


**Figure 14.** (A) A recently placed log jam on river right promotes the formation of a deep water pocket. Photo is facing across the stream, from river left towards river right. (B) A newly formed pool behind a log jam. Prior to restoration, this area had been a fast moving riffle.

Key outcomes for this area were realized with the reactivation or improvement of nearly 1.7 miles of side channel habitat (Figure 15) and the creation of three new pools through LWD additions and excavation. The area now nearly meets (>75% of target), meets, or exceeds five out of ten objectives for which data were available (Box 1)<sup>2</sup>. It is expected that objectives not currently being met will continue to improve as natural river processes continue to create and deepen pools, increase channel sinuosity, and decrease thalweg gradient.

<sup>2</sup>Cabins project area objectives: (1a) Key piece density to 80 pieces/river mile; (1b) Key piece density to 106 pieces/river mile; (2a) Pool density to 26 pools/river mile; (2b) Primary pool density to 14 pools/river mile; (2c) Primary pool depth to 4 feet; (2d) Spawning pool density to 2,000 yd<sup>2</sup>/mile; (2e) Sinuosity to 1.2; (2f) Thalweg gradient 1.1%; (3a) Side channels to 12,144 feet; (3b) Not shown because no data available; (3c) Entrenchment ratio to 3:1





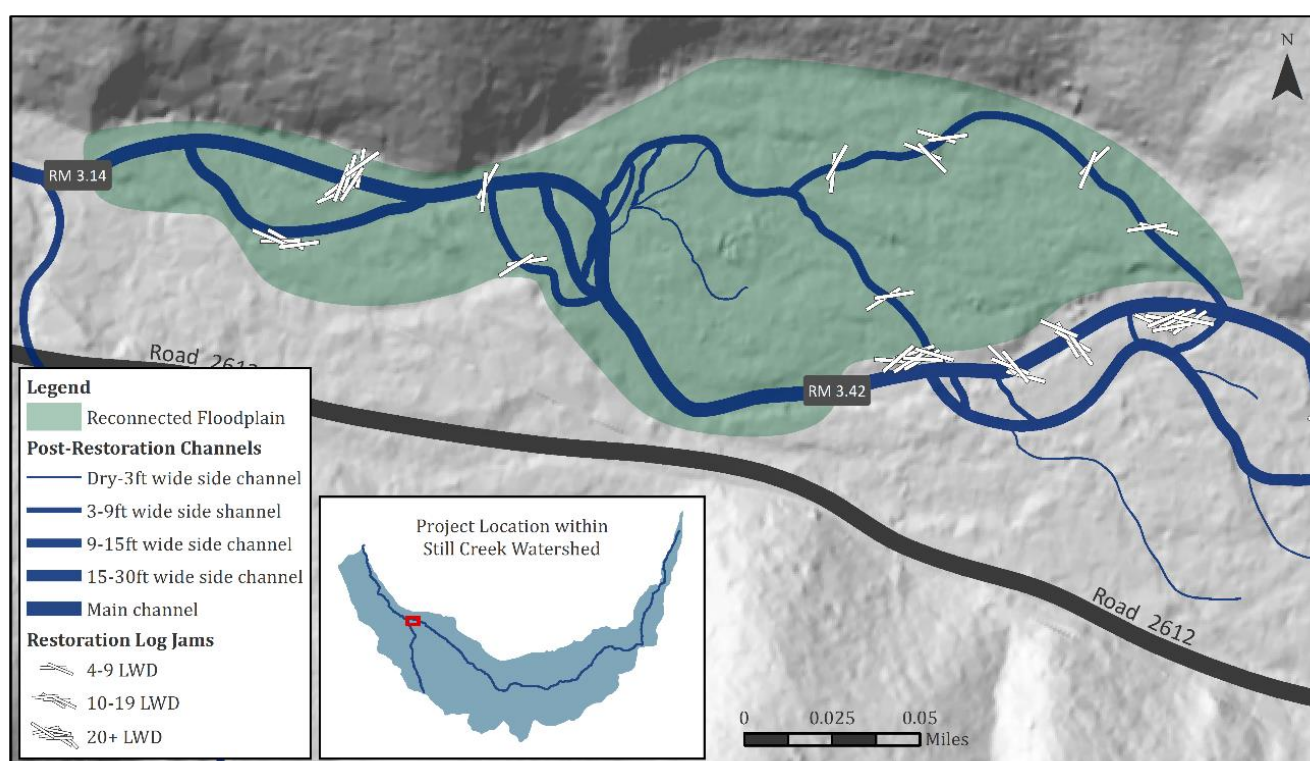
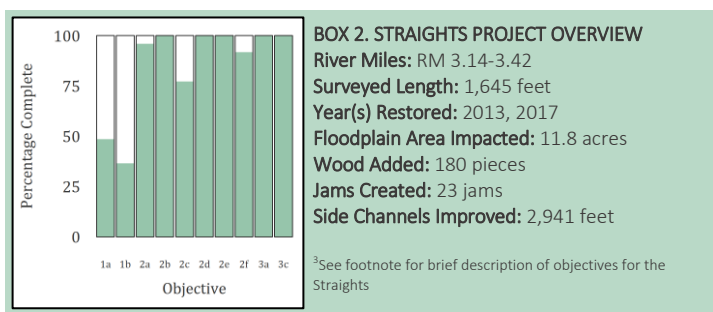
**Figure 15.** The lower (1), middle (2), and upper (3) Cabins project areas and their location within the Still Creek watershed, showing post restoration side channels, estimated active floodplain, and the location of major restoration logjams. Note: only log jams containing 4 or more pieces of LWD are represented on this map.

## Essential Project SC-2 | the Straights

**Background |** Prior to restoration, the Straights project area was characterized by low levels of coarse woody debris and lack of floodplain roughness, which allowed the stream to lose sinuosity and increase thalweg gradient. The low sinuosity and slope allowed for exceedingly long riffles with very few pools for resting area between. Key outcomes for the Straights project area were to increase sinuosity, reduce channel slope, increase floodplain roughness, increase pool densities, increase off channel habitat, and increase spawning gravel retention.

**Actions** | Restoration in the Straights project area occurred in the summers of 2013 and 2017. Approximately 180 pieces of large woody debris were placed in 23 jams both in the main channel and in the side channels of the Straights project area (Figure 16). Excavators removed a berm in the upper portion of the project area to reconnect a nearly 800 foot long historic side channel.

Key outcomes for the area were realized with a sinuosity increase to 1.39 and a reduced thalweg gradient to 3.6%. Floodplain roughness was increased through the addition of 127 pieces of large wood debris to the floodplain, and off channel habitat was increased through the re-activation or improvement of 2,941 feet of side channels. The Straights now has among the highest spawning gravel densities in the Still Creek watershed, with over 2,600 square yards of spawning gravels per river mile. Straights project area now nearly meets (>75% of target), meets, or exceeds eight out of ten objectives for which data are available (Box 2)<sup>3</sup>. The two objectives (1a and 1b) not met pertain to densities of key pieces of LWD; however, all other evidence indicates that current levels are promoting naturally dynamic river processes. In total, an estimated 11.8 acres of floodplain habitat were restored.



**Figure 16.** The Straights project area and its location within the Still Creek watershed, showing post restoration side channels, estimated active floodplain, and the location of major restoration log jams. Note, only log jams containing 4 or more pieces of LWD are represented on this map.

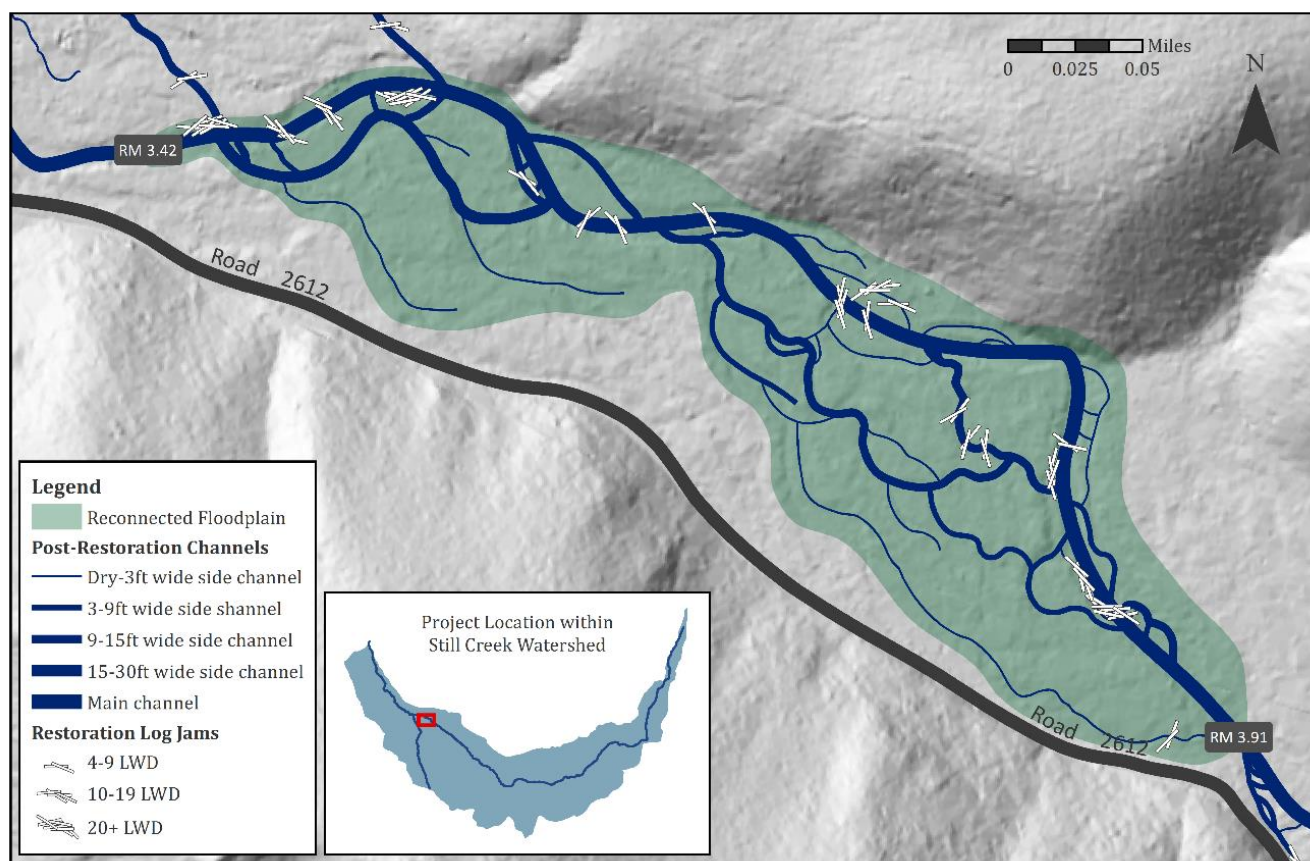
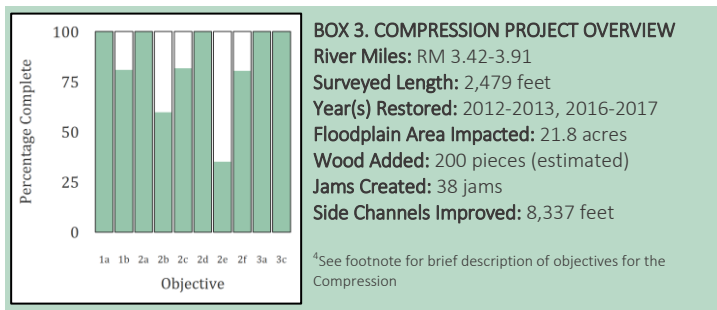
<sup>3</sup>Straights project area objectives: (1a) Key piece density to 80 pieces/river mile; (1b) Key piece density to 106 pieces/river mile; (2a) Pool density to 26 pools/river mile; (2b) Primary pool density to 13 pools/river mile; (2c) Primary pool depth to 4 feet; (2d) Spawning gravels to 2,000 yd<sup>2</sup>/mile; (2e) Sinuosity to 1.2; (2f) Thalweg gradient 3.3%; (3a) Side channels to 2,112 feet; (3b) Not shown because no data available; (3c) Entrenchment ratio to 3:1



## Essential Project SC-3 | the Compression

**Background** | The Compression project area was characterized by a simplified stream channel with few pools, side channels or off channel habitat. Previous habitat enhancement efforts have improved conditions to some degree, however approximately half of previous structures have been dislodged from their original orientation or location and either were rotated parallel to the flow or deposited on the floodplain. Key outcomes for the Compression project area were to reactivate floodplain side channels and alcoves, increase floodplain ground water, increase pool density and volume, and provide additional hiding cover for juvenile fish.

**Actions** | Restoration actions in the Compression project area occurred in the summers of 2012, 2013, 2016, and 2017. Approximately 200 pieces of LWD were placed in 38 jams both in the main channel and in the side channels. Excavators removed a riprap and berms in several locations on the river left floodplain to open an extensive side channel network. In total, an estimated 21.8 acres of floodplain habitat were restored.



**Figure 17.** The Compression project area and its location within the Still Creek watershed, showing post restoration side channels, estimated active floodplain, and the location of major restoration logjams. Note, only log jams containing 4 or more pieces of LWD are represented on this map. Side channels on the floodplain that do not connect to another channel on both ends represent groundwater side channels and their source on the floodplain.

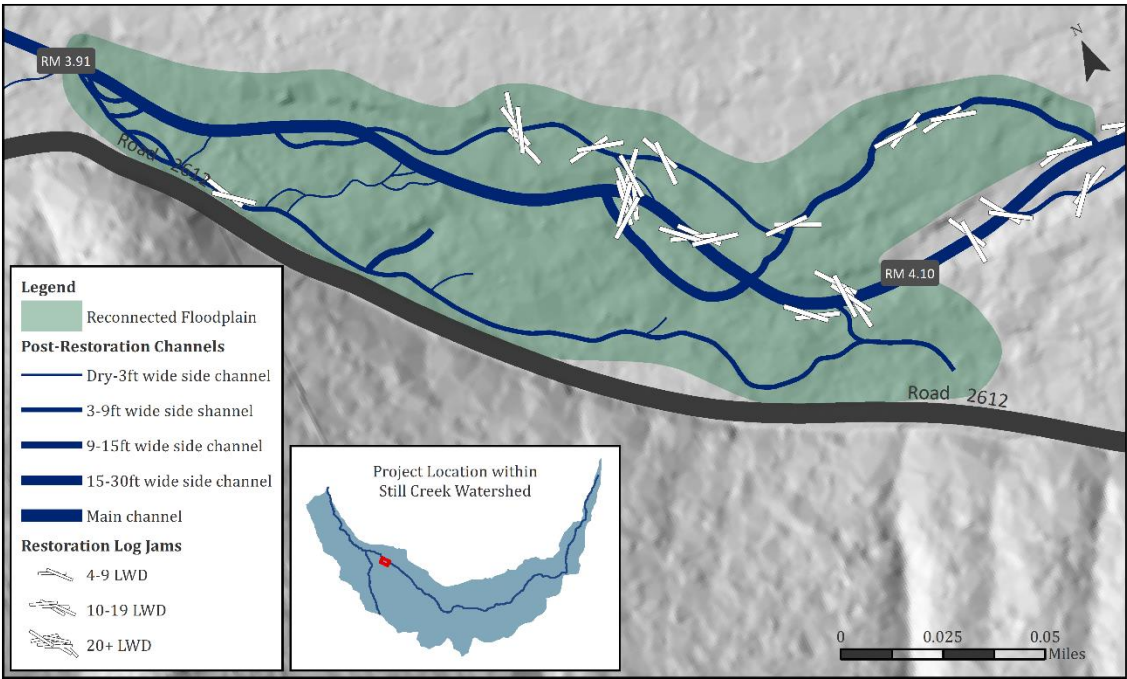
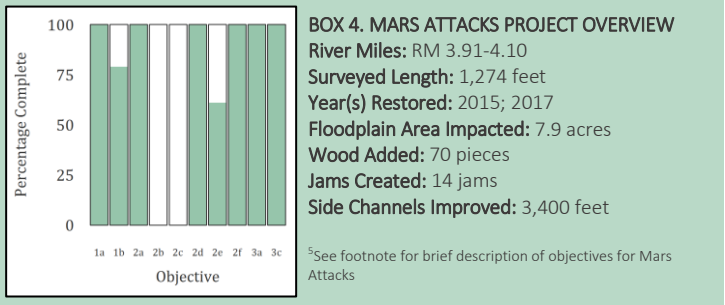
Key outcomes for the area were realized with the creation or improvement of nearly 1.6 miles of side channel habitat. Several side channels were fed entirely by groundwater, indicating that groundwater tables have risen (Figure 17). Five new pools were recorded in the main channel, and numerous additional pools throughout side channels, indicating an increase in both pool density and volume. The addition of large wood and jam structures provide additional hiding

cover for fish. The Compression project area now nearly meets (>75% of target), meets, or exceeds eight out of ten objectives for which data are available (Box 3)<sup>4</sup>. Objectives not met include objective 2a, relating to pool density, and objective 2e, relating to sinuosity. It is expected that both of these processes will continue to improve through time.

Essential Project SC-4 | Mars Attacks

**Background |** The Mars Attacks project area is a relatively complex and dynamic area characterized by low thalweg slope and deposition from the steeper upstream Elder Growth project area. Prior to restoration, floodplain LWD and roughness were extremely low to non-existent, although several channel spanning large wood structures constructed in the mid 1990’s remained. The depositional nature of the reach, poor riparian, and floodplain roughness conditions, channel spanning structures and recent flood events combined to aggrade the reach and pushed the stream laterally to the left bank, cutting a significant side channel into the FS 2612 road prism, threatening the integrity of the road, and increasing sediment transport. Key outcomes for the Mars Attacks project area were to promote natural channel dynamics, protect FS road 2612, and increase habitat complexity.

**Actions |** Restoration actions in the Mars Attacks project area occurred in the summers of 2015 and 2017. Approximately 70 pieces of large woody debris were placed in 14 jams both in the main channel and in the side channels (Figure 18). Several large pieces of wood were placed along the FS 2612 road to protect the road from erosion during winter flooding. In total, an estimated 7.9 acres of floodplain habitat were restored.



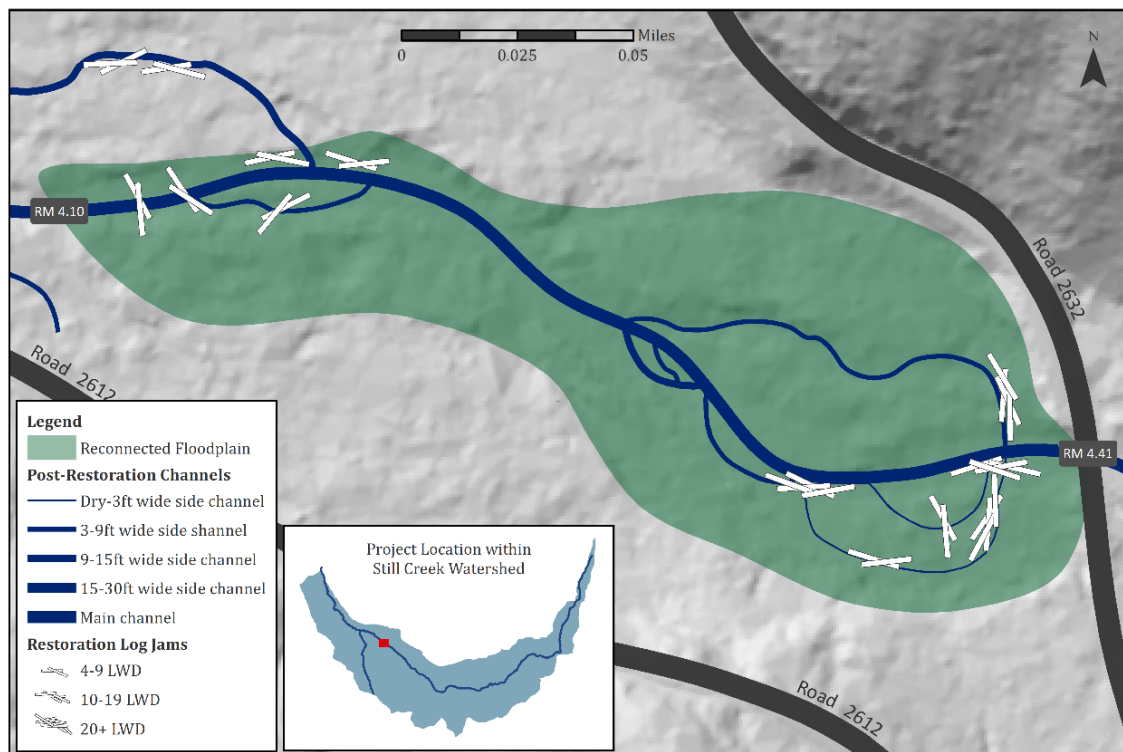
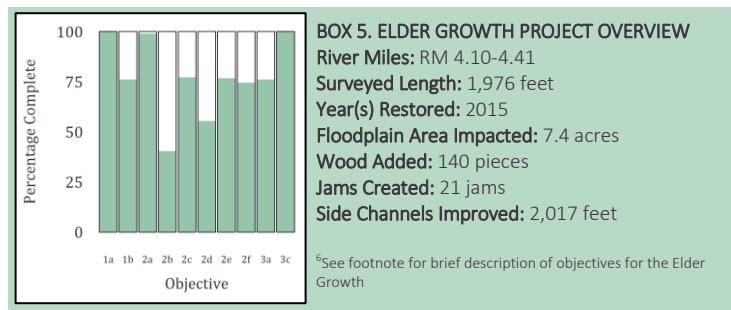
**Figure 18.** The Mars Attacks project area and its location within the Still Creek watershed, showing post restoration side channels, estimated active floodplain, and the location of major restoration logjams. Note, only log jams containing 4 or more pieces of LWD are represented on this map.

<sup>4</sup>Compression project area objectives: (1a) Key piece density to 80 pieces/river mile; (1b) Key piece density to 106 pieces/river mile; (2a) Pool density to 26 pools/river mile; (2b) Primary pool density to 17 pools/river mile; (2c) Primary pool depth to 4 feet; (2d) Spawning gravels to 2,000 yd<sup>3</sup>/mile; (2e) Sinuosity to 1.2; (2f) Thalweg gradient 2.8%; (3a) Side channels to 3,696 feet; (3b) Not shown because no data available; (3c) Entrenchment ratio to 3:1

Key outcomes for the area where realized through the addition of LWD promoting natural channel dynamics. Though wood structures along FS Road 2612 have yet to be tested by winter flooding, it is expected that wood placements will substantially reduce the erosion potential at this site and will protect the integrity of the road. Habitat complexity has been increased through the addition of large wood structures and the reactivation of multiple side channels. The Mars Attacks project area now nearly meets (>75% of target), meets, or exceeds seven out of ten objectives listed for which data are available<sup>5</sup>. Objectives not met include objectives 2b and 2c, which pertain to density and depth of primary pools, respectively. Mars Attacks does not contain primary pools at present; however, it is expected that large wood structures will continue to promote the deepening of existing pools. Objective 2e pertains to sinuosity, which should increase with increased channel roughness and complexity.

## Essential Project SC-5 | the Elder Growth

**Background** | The Elder Growth project area is characterized by a relatively steep gradient (>3%) and a moderately entrenched channel bounded by a mature riparian forest. Due to the relative steepness and entrenchment, LWD less than 80 ft in length tends to become mobilized out of the reach during peak flow events and therefore LWD density and habitat complexity levels are relatively low. Prior to restoration, the Elder Growth floodplain was almost completely devoid of LWD roughness. Key outcomes for the Elder Growth project area were to increase LWD levels, increase habitat complexity, reduce entrenchment, increase floodplain connectivity and off channel habitats, increase slack water habitat and hiding cover, and improve sediment and nutrient retention. In total, an estimated 7.4 acres of floodplain habitat were restored.



**Figure 19.** The Elder Growth project area and its location within the Still Creek watershed, showing post restoration side channels, estimated active floodplain, and the location of major logjams. Note, only log jams containing 4 or more pieces of LWD are represented on this map.

<sup>5</sup>Mars Attacks project area objectives: (1a) Key piece density to 80 pieces/river mile; (1b) Key piece density to 106 pieces/river mile; (2a) Pool density to 26 pools/river mile; (2b) Primary pool density to 17 pools/river mile; (2c) Primary pool depth to 4 feet; (2d) Spawning gravels to 2,000 yd<sup>3</sup>/mile; (2e) Sinuosity to 1.3; (2f) Thalweg gradient 1.8%; (3a) Side channels to 1,584 feet; (3b) Not shown because no data available; (3c) Entrenchment ratio to 3:1



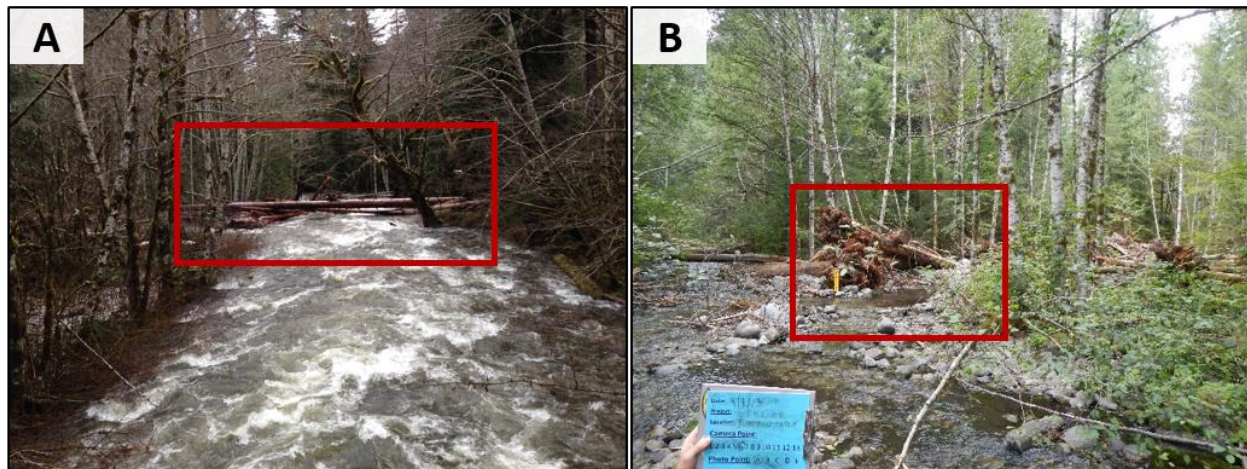
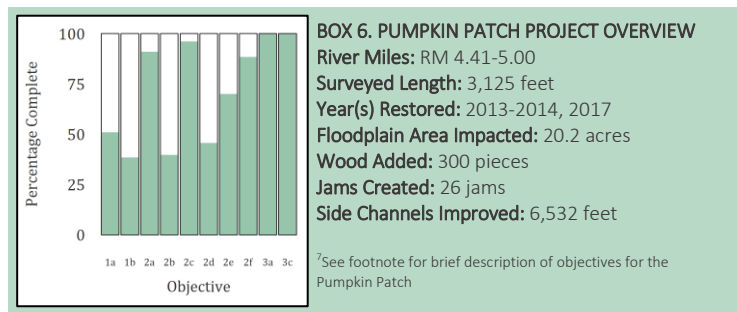
**Actions** | Restoration actions in the Elder Growth project area occurred in the summer of 2015. Approximately 140 pieces of large woody debris were placed in 21 jams both in the main channel and in the side channels (Figure 19).

Key outcomes for the area were realized through the substantial increase in LWD density to nearly 303 pieces of main channel LWD per river mile, and the addition 86 pieces of LWD throughout the floodplain. The addition of LWD has increased habitat complexity and is expected to improve sediment and nutrient retention. The entrenchment ratio now exceeds 4:1 throughout the project area, and floodplain connectivity has been improved through the improvement of over 2,000 feet of side channels. The main channel increased the overall availability of pool habitat as a percentage of total length from 16.4% prior to restoration to 28.2% after restoration. The addition of main channel slow water habitats and the reactivation of side channel habitats has substantially improved the availability of refugia and resting habitats for migrating and juvenile salmonids. The Elder Growth project area now nearly meets (>75% of target), meets, or exceeds eight out of ten objectives for which data are available (Box 5)<sup>6</sup>. Objectives not met include objective 2b (relating to primary pool density) and objective 2d (relating to the availability of spawning gravels). The additions of LWD to the project area are expected to continue to promote pool deepening and creation as well as gravel retention.

## Essential Project SC-6 | the Pumpkin Patch

**Background** | The Pumpkin Patch project area is dominated by late-seral stands of Douglas fir, Hemlock, and red cedar. The area was known to support the high densities of young of the year salmonids. However, there was evidence of severe channel straightening and large wood removal within the project area. This led to a moderately to highly entrenched main channel with an average thalweg slope between two and three percent.

However, the large floodplain historic floodplain area indicated a high potential to decrease entrenchment and improve floodplain connectivity. Previous work in the 1990's added large wood to the upper end of this reach which did aggrade the stream bed elevation and reconnect some of the historic floodplains to some degree, and in recent years several mature old growth trees have fallen into the channel and have contributed significant complexity to the reach. However significant sections of the reach were still cut off from the floodplain. Key outcomes for this area were to reconnect the floodplain to restore off-channel rearing and over-wintering habitat for juvenile salmonids, to increase the quantity and quality of pools within this reach, and to aggrade the main channel.

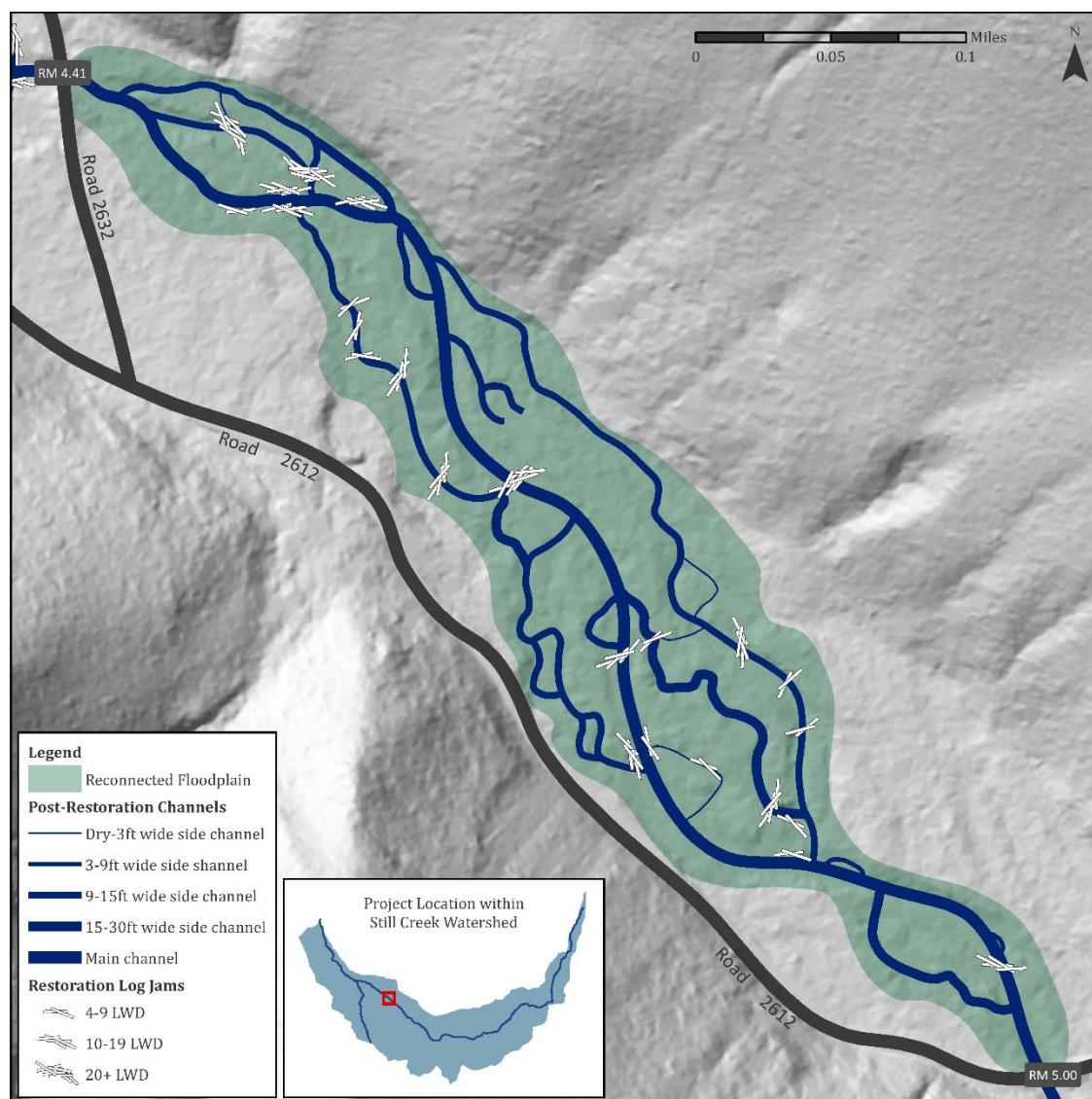


**Figure 20.** (A) A log structure slows winter high flows down the main channel, outlined in red box. Photo is facing downstream. (B) A log structure and removed riprap push water onto the floodplain, outlined in red box. Photo is facing downstream.

<sup>6</sup>Elder Growth project area objectives: (1a) Key piece density to 80 pieces/river mile; (1b) Key piece density to 106 pieces/river mile; (2a) Pool density to 26 pools/river mile; (2b) Primary pool density to 16 pools/river mile; (2c) Primary pool depth to 4 feet; (2d) Spawning gravels to 2,000 yd<sup>3</sup>/mile; (2e) Sinuosity to 1.2; (2f) Thalweg gradient 2.9%; (3a) Side channels to 2,640 feet; (3b) Not shown because no data available; (3c) Entrenchment ratio to 3:1

**Actions** | Restoration in the Pumpkin Patch project area occurred primarily in the summers of 2013, 2014 and 2017. Approximately 300 pieces of LWD were placed in 26 jams (Figure 21) both in the main channel and in the side channels (Figure 20). Berms were removed and log jams installed to guide water into a large 800 foot long side channel, which now contains approximately 20% of the river's flow. In total, an estimated 20.2 acres of floodplain habitat were restored.

Key outcomes for the area were realized through the reconnection or improvement of more than 1.2 miles of side channel habitat, which now provides substantial off-channel and over-wintering habitat for juvenile salmonids. Main channel pool density increased from 13.6 to 23.7 pools per river mile, and the reactivation of the floodplain now provides access to 9 pools counted throughout the floodplain. The Pumpkin Patch project area now nearly meets (>75% of target), meets, or exceeds five out of ten targets listed for the area (Box 6)<sup>7</sup>. Key piece LWD density (objectives 1a and 2a), primary pool density (objective 2b), and spawning gravel densities still remain below target values, but these are all expected to increase with time. Likewise, sinuosity (objective 2e) is still below the target of 1.2. The improvement in this reach are expected to enhance the existing production potential and restore high quality salmonid rearing habitat.



**Figure 21.** The Pumpkin Patch project area and its location within the Still Creek watershed, showing post restoration side channels, estimated active floodplain, and the location of major logjams. Note, only log jams containing 4 or more pieces of LWD are represented on this map.

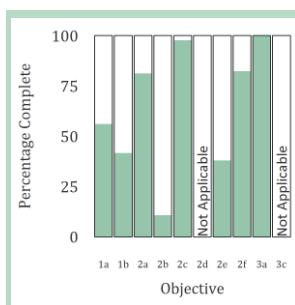
<sup>7</sup>Pumpkin Patch project area objectives: (1a) Key piece density to 80 pieces/river mile; (1b) Key piece density to 106 pieces/river mile; (2a) Pool density to 26 pools/river mile; (2b) Primary pool density to 17 pools/river mile; (2c) Primary pool depth to 4 feet; (2d) Spawning gravels to 2,000 yd<sup>3</sup>/mile; (2e) Sinuosity to 1.2; (2f) Thalweg gradient 2.3%; (3a) Side channels to 4,752 feet; (3b) Not shown because no data available; (3c) Entrenchment ratio to 3:1



## Essential Project SC-7 | the Canyon

**Background** | The Canyon project area is named for its high gradient (>4%) and steep valley characteristics. The area is characterized by later seral riparian forests, natural entrenchment, and a narrow channel migration zone. Prior to restoration, the area contained many long riffles unbroken by pools or other resting habitat and low levels of LWD. Key outcomes for the Canyon project area were to increase habitat complexity and to provide additional slack water resting habitat for migrating and rearing salmonids.

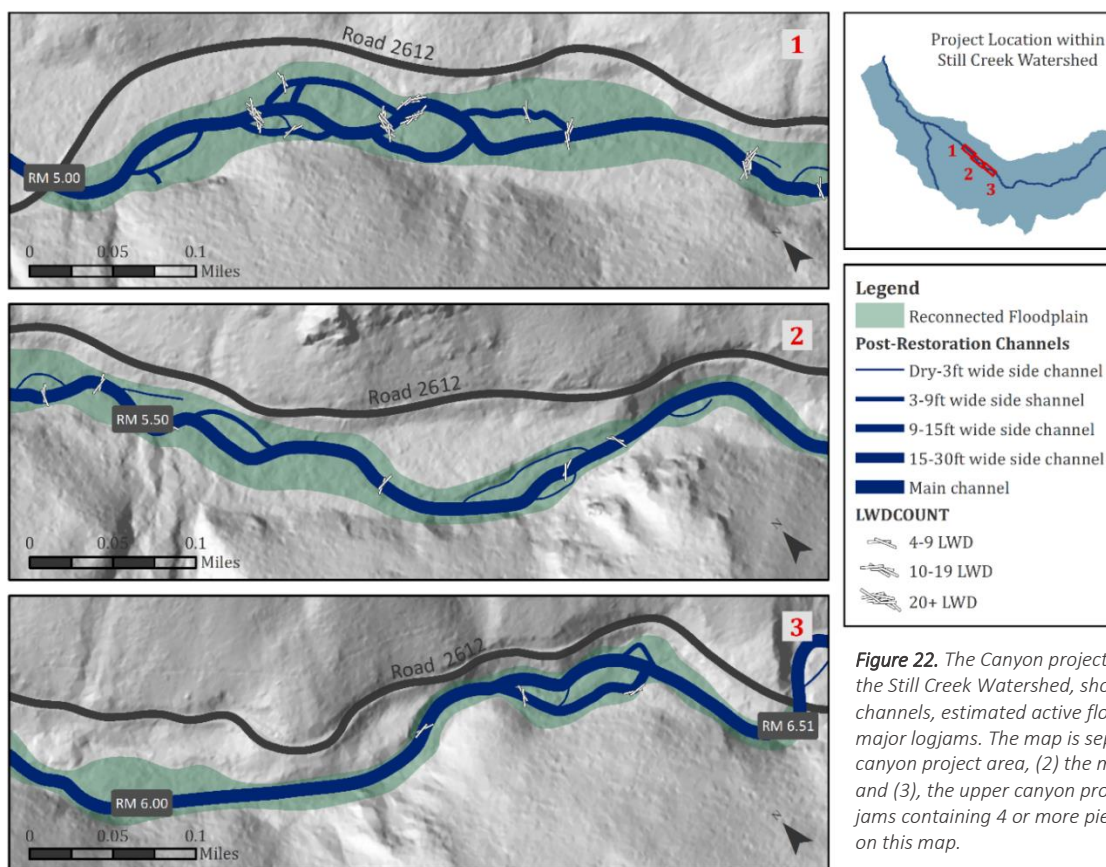
**Actions** | Restoration actions in the Canyon project area occurred between 2016 and 2017. Approximately 50 riparian zone conifers were cabled over into the main channel and side channels, and an additional 265 pieces of LWD were transported by helicopter into the lower portion of the reach. These logs were used to construct a total of 26 jams throughout the project area (Figure 22). In the upper portion of the reach, log jams helped to raise groundwater levels and force water into the limited available floodplain habitat. In the lower portion of the reach, two large side channels 600 and 400 feet long were reactivated, and riprap was removed from an additional 350 foot long side channel. In total, an estimated 28.3 acres of floodplain habitat were impacted.



### BOX 7. THE CANYON PROJECT OVERVIEW

**River Miles:** RM 5.00-6.51  
**Surveyed Length:** 8,070 feet  
**Year(s) Restored:** 2016-2017  
**Floodplain Area Impacted:** 28.3 acres  
**Wood Added:** 315 pieces  
**Jams Created:** 26 jams  
**Side Channels Improved:** 3,624 feet

<sup>a</sup>See footnote for brief description of objectives for the Canyon



**Figure 22.** The Canyon project area and its location within the Still Creek Watershed, showing post-restoration side channels, estimated active floodplain, and the location of major logjams. The map is separated into (1) the lower canyon project area, (2) the middle canyon project area, and (3), the upper canyon project area. Note, only log jams containing 4 or more pieces of LWD are represented on this map.

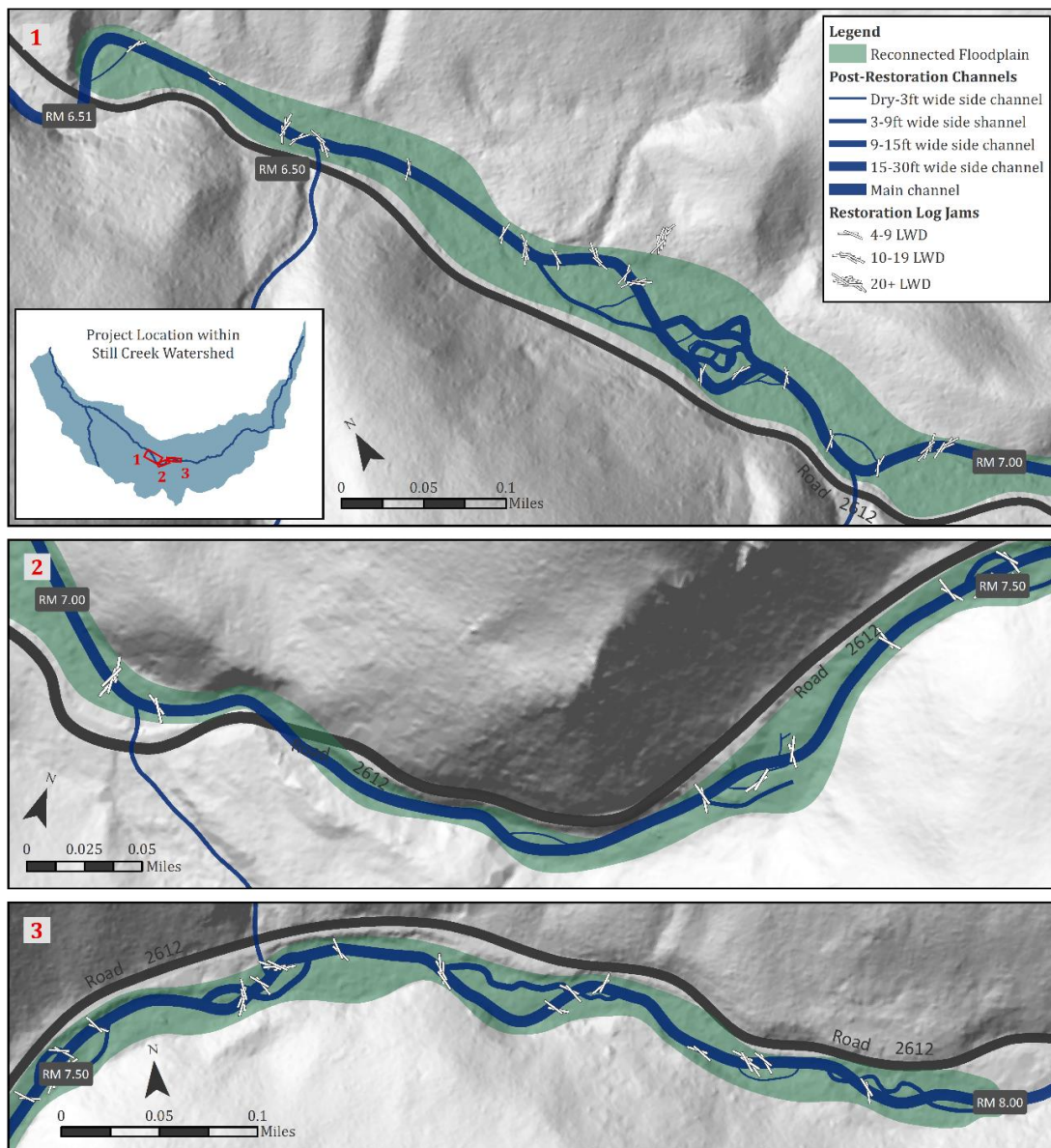
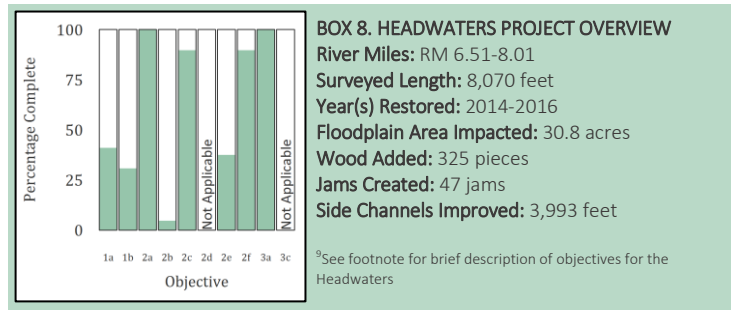
Key outcomes for this area were realized through the addition of substantial LWD to the main channel, increasing complexity and providing additional resting habitat. In total, 3,624 feet of side channels were created or enhanced due to restoration actions, providing much needed off channel habitat in this high gradient area. The Canyon project area now nearly meets (>75% of target), meets, or exceeds five out of nine targets applicable to the area (Box 7)<sup>8</sup>. Wood

<sup>8</sup> Canyon project area objectives: (1a) Key piece density to 80 pieces/river mile; (1b) Key piece density to 106 pieces/river mile; (2a) Pool density to 26 pools/river mile; (2b) Primary pool density to 36 pools/river mile; (2c) Primary pool depth to 4 feet; (2d) No standard; (2e) Sinuosity to 1.2; (2f) Thalweg gradient 3.4%; (3a) Side channels to 2,640 feet; (3b) Not shown because no data available; (3c) No standard

densities (objective 1a and 1b), primary pool densities (objective 2b), and sinuosity (objective 2e) are still below target values, but are expected to improve with time.

## Essential Project SC-8 | Headwaters Nirvana

**Background |** Similar to the Canyon project area, the Headwaters Nirvana project area has a relatively steep gradient with an average channel thalweg slope greater than four percent with riparian areas dominated by late seral conifers. Prior to restoration, several natural large wood accumulations had formed within the reach; however LWD densities were still low relative to reference conditions. Key outcomes for the Headwaters Nirvana project area were to increase habitat complexity and provide slack water resting habitat.



**Figure 23.** The lower (1), middle (2), and upper (3) portions of the headwaters Nirvana project area and their location within the Still Creek watershed, showing post restoration side channels, estimated active floodplain, and the location of major logjams. Note, only log jams containing 4 or more pieces of LWD are represented on this map.



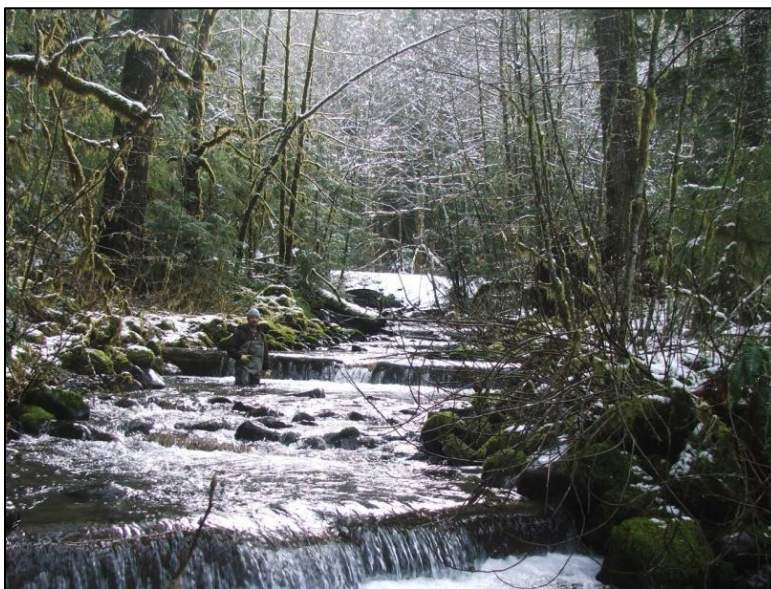
**Actions** | Restoration actions in the Headwaters Nirvana project area occurred in 2014, 2015, and 2016. Approximately 220 riparian zone conifers were cabled over into the main channel and side channels with another 115 logs cabled in via a skidder winch line and blocks. The cabled over trees and logs created 47 log jams and helped to reactive the limited available side channel habitats (Figure 23). In total, an estimated 30.8 acres of floodplain habitat were impacted.

Key outcomes for the area were realized through the substantial accumulations of main channel large wood, which increased habitat complexity and created resting habitat for migrating salmonids. Additionally, wood additions to the stream helped to improve the 3,993 feet of side channels recorded throughout the reach, which provide additional refuge for fish. The Headwaters Nirvana project area now nearly meets (>75% of target), meets, or exceeds five out of nine targets listed for the area (Box 8)<sup>9</sup>. Key piece density (objectives 1a and 1b), primary pool density (objective 2b), and sinuosity (objective 2e) all remain below targets. However, it is assumed that large wood accumulations will continue into the future as restoration wood structures promote the recruitment of additional woody debris, and pools will continue to form as winter floods interact with placed wood. At present, Headwaters Nirvana has the highest pool density of any project area, but is limited only by the availability of deep pools.

## Essential Project CC-1 | the Cool Creek Confluence

**Background** | Cool Creek, the largest tributary to Still Creek, provides year-round habitat for coastal cutthroat trout and resident rainbow trout and provides spawning and rearing habitat for winter steelhead trout and coho salmon. Five log weirs were constructed in 1984 to provide grade controls along the stream portions that were downstream of a culvert on FS Road 2612. Since that time, jump heights had increased to greater than 1.5 feet limiting upstream migration of juvenile salmonids.

**Background** | In 2012, the weirs were altered via a spyder excavator and were replaced with riffles and roughened channel cascades that provide a more natural geomorphology and maximize upstream access for juvenile salmonids (Figure 24). Jump heights were reduced to less than 0.6 feet in height in most cases. The project opened an additional 0.65 miles of habitat to juvenile anadromous fish.



**Figure 24.** Log weirs prior to removal on Cool Creek prevented passage of anadromous salmonids to 0.65 miles of habitat.

<sup>9</sup> Headwaters project area objectives: (1a) Key piece density to 80 pieces/river mile; (1b) Key piece density to 106 pieces/river mile; (2a) Pool density to 26 pools/river mile; (2b) Primary pool density to 41 pools/river mile; (2c) Primary pool depth to 4 feet; (2d) No standard (2e) Sinuosity to 1.2; (2f) Thalweg gradient 3.8%; (3a) Side channels to 2,640 feet; (3b) Not shown because no data available; (3c) No standard

## SECTION III. WATERSHED RESTORATION ACTIONS | Essential Projects SC-9 to SC-18

This portion of the report outlines watershed restoration actions (essential projects SC-9 through SC-18). Watershed restoration projects pertain to projects aimed at rehabilitating the riparian zone, improving fish passage to tributaries, and mitigating impacts from roads and other sources of sediment.

### Essential Project SC-9 | Riparian Rehabilitation

**Key Partners** | This project was completed through the help of various volunteer groups who donated over 3,700 hours of time to the Forest Service. These groups included the Clackamas 4-H, Educational Recreational Adventures, the Mazamas, National Forest Foundation, Sandy River Watershed Council, Timberlake Job Corps, and Wilderness Volunteers.

**Background** | Riparian vegetation is a key piece to a properly functioning riparian area. Healthy, intact riparian areas are critical for controlling water temperature, creating health aquatic habitat, and maintaining stream bank stability. Riparian areas offer essential habitat for threatened salmon and steelhead present in Still Creek at critical stages of their life history. Over time, riparian vegetation (specifically dominant tree species) along Still Creek has been converted from conifer to deciduous species through stand replacing fires, recreational residence activities, and past timber harvest. This has resulted in excessive sediment delivery through unnatural erosion, reduction of stream shade, and reduced instream woody debris. The objective of this project was to restore native riparian vegetation age structure and species composition in both the overstory and the understory canopies along Still Creek.

**Actions** | Between 2012 and 2017, about 13 acres of riparian habitat was restored with native conifers and understory vegetation (Figure 25). Over 2,000 cedars trees were planted along the riparian areas of Still Creek. Approximately 2,000 sword ferns and salmon berries were transplanted into the riparian area. Native grass seed was spread throughout the entire 13 acres of revegetated areas.

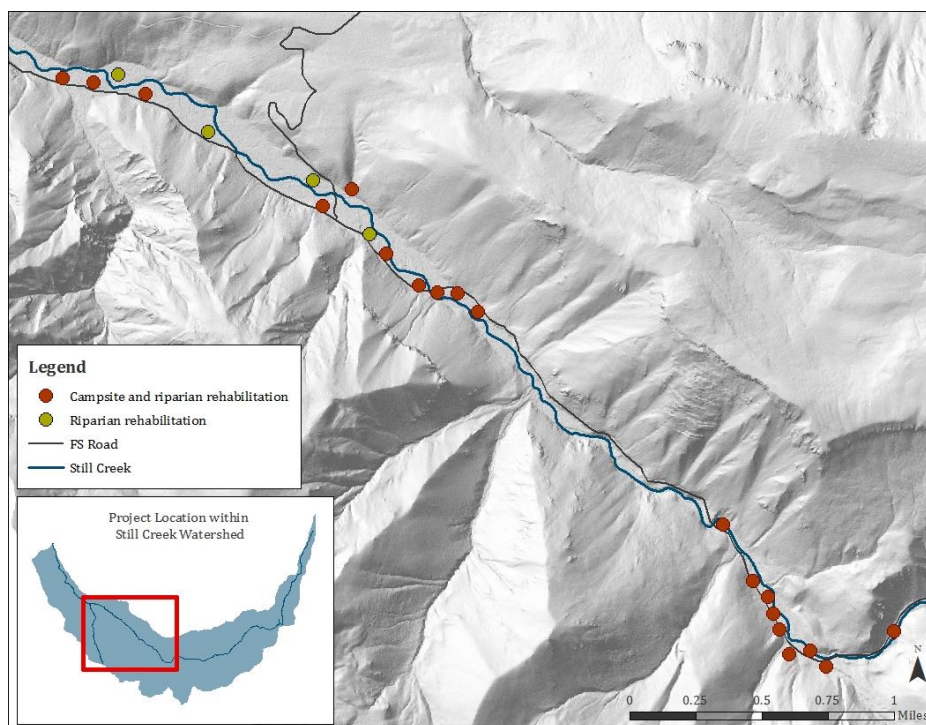


Figure 25. Map of riparian vegetation (essential project SC-9) and campsite rehabilitation (essential project SC-11) sites throughout the Still Creek Watershed.

### Essential Project SC-10 | Invasive plant removal

**Key Partners** | This project was completed through collaboration with the Sandy River Watershed Council and Forest Service recreational residence owners. An estimated 12,000 volunteer hours were donated to this project.

**Background** | Past activities such as logging, road developing, residential development, and recreation have introduced numerous invasive plants to the Still Creek watershed, primarily within the riparian area. Surveys completed in 2004 and 2005, documented invasive weeds such as Japanese knotweed (*Fallopia japonica*), scotch broom (*Cytisus scoparius*), vinca (*Vinca spp.*) and periwinkle (*Vinca spp.*) occurring in small patches occurring sporadically throughout the summer home areas within Still Creek. Additional populations of English Ivy (*Hedera helix*) and English Holly (*Ilex aquifolium*)

were known to be established. While invasive plant levels remain low, a rapid and early response can prevent invasive plants from outgrowing, replacing, and destroying native plants.

**Actions** | Invasive species locations were found by monitoring newly disturbed sites and relying on personnel to report any sightings within the watershed. The US Forest service oversaw hand-pulling of recently established populations of English Ivy and English Holly and spraying of Japanese knotweed with approved herbicide. The rapid response to these invasive species introductions have helped to mitigate further spread throughout the watershed.

### Essential Project SC-11 | Campsite rehabilitation

**Key Partners** | This project was successfully completed through a collaboration with the forest service and the following volunteer groups: Clackamas 4-H, Educational Recreational Adventures, the Mazamas, National Forest Foundation, Sandy River Watershed Council, Timberlake Job Corps, and Wilderness Volunteers.

**Background** | Still Creek watershed is a popular area for outdoor recreation. Over the years, many user-created campsites (also referred to as dispersed campsites) and informal trails have been established within the riparian corridor. Dispersed camping activities severely reduce ground cover, shrubs, and young trees resulting in increased bank erosion and sediment delivery to Still Creek. Heavily compacted areas resulting from dispersed camping also limit the ability for new vegetation to become re-established, further reducing the riparian function. The original goal this project was to reduce the de-vegetated footprint of six user developed campsites by restoring 2.5 acres with native trees and shrubs, and placing downed large wood around the perimeter of these sites.

**Actions** | From 2012 to 2017, 19 de-vegetated dispersed campsites were reduced in size or completely removed, restoring 12.4 acres of floodplain and riparian habitat and exceeding project goals. Excavators and hand tools were used to de-compact soils in camping areas to promote the reestablishment of native vegetation. Native conifers, shrubs, forbs, and grasses were planted to restore the riparian area. Downed logs were added to the sites to increase floodplain roughness and to discourage future use of rehabilitated campsites.

### Essential Project SC-12 | FS Road 2612 culvert replacements

**Key Partners** | The Forest Service independently designed, implemented and funded this essential project. Funding was obtained through Forest Service retained receipts and CMGL funding.

**Background** | FS Road 2612 follows alongside Still Creek for nearly the entire length of the stream, with distances between the road and the stream varying from several feet to a few hundred yards. Multiple small tributaries pass under the road through culverts before joining Still Creek. The FS Road 2612 has a high density of stream crossings, with six to ten culverts per mile of the road. Most of these culverts function properly by allowing high stream discharge to pass natural sediment and wood debris, and most do not create fish other

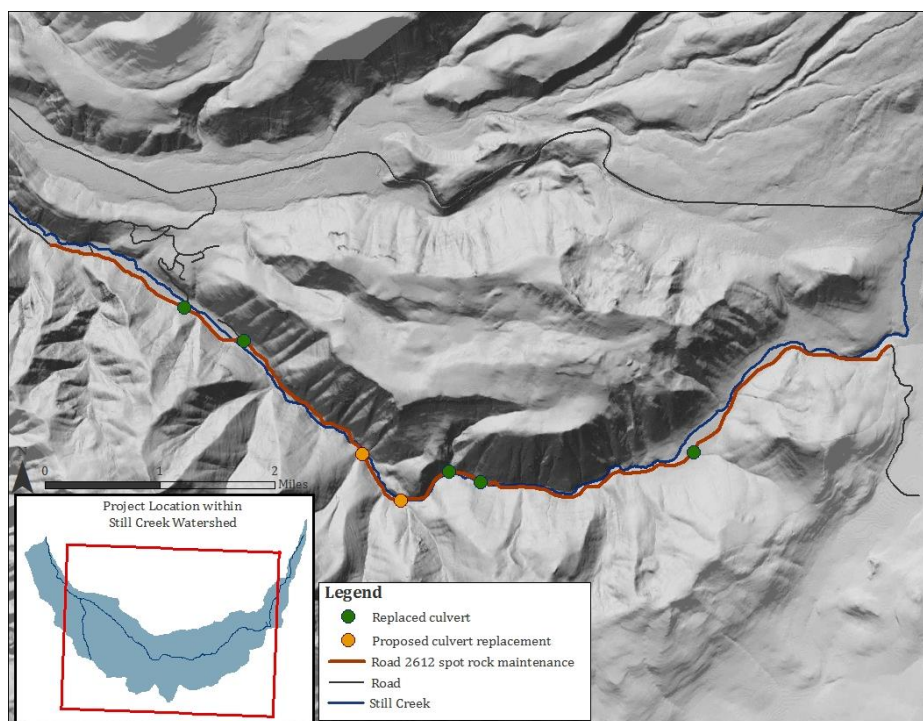


Figure 26. Map of culvert replacement sites throughout the Still Creek Watershed.



aquatic organism passage barriers. However, it was found that seven culverts were not functioning properly and were either contributing to road related sediment entering Still Creek and/or creating aquatic organism passage barriers. The original objective of this project was to replace eight culverts to improve aquatic organism passage and minimize the delivery of road sediment to the stream.

**Actions** | Following a review of culverts along Still Creek Road, it was determined that only 7 culverts were a priority for replacement. As of the writing of this report, five of the seven culverts had been upgraded along FS Road 2612, and plans are in process for the replacement of two additional culverts. Culvert locations were as follows:

**Trib D:** The original site contained two culverts; one 48 inch diameter by 39 foot long culvert, and one 24 inch diameter by 41 foot long culvert. The two were replaced with a single 18 foot wide, open-bottom arched culvert. In addition to reducing sediment transport, the replacement of the Trib D culvert re-opened approximately 2.5 miles of previously blocked tributary habitat to aquatic organism passage.

Two culverts are still needed to be replaced. Trib A and Trib C culverts will require an Aquatic Organism Passage survey and more thorough design before they can be implemented by the planned date of 2018 or 2019. Following culvert replacement, the Forest Service conducted monitoring of the culverts following major storm events. All culvert replacements were found successful throughout post project monitoring.

**Trib H:** The former 18 inch diameter culvert was replaced with a 36 inch diameter culvert.

**Unnamed tributary:** The former 24 inch diameter culvert was replaced with a 36 inch culvert.

**Other:** One road cross drainage culvert was added to increase water conveyance through Still Creek Road and another was replaced.



## Essential Project SC-13 | West Leg Road

**Key Partners** | This project was completed by the US Forest Service with CMLG funding and in collaboration with RLK Company at Timberline Lodge.

**Background** | West Leg Road is located in the headwaters of the Still Creek watershed and was in need of critical road maintenance and repair. The West Leg Road is six miles long and has several stream crossings that are tributaries to Still Creek and potential sources of road sediment. Original restoration plans called for the inspection and possible replacement of multiple culverts along this; however, culvert inspections revealed that all culverts draining the West Leg Road were in good condition and not adversely impacting the Still Creek watershed. Ditch lines along the West Leg Road were in poor condition and required rehabilitation to reduce sediment transport into streams. The goal for this essential project was to rehabilitate the ditch line to reduce sediment transport into Still Creek and tributaries along the West Leg Road.

**Actions** | The Forest Service completed this project by cleaning and rehabilitating the entire six mile length of the West Leg Road ditch lines. Rehabilitation included scraping ditch lines, creating sediment barriers, and removing organic duff from the edge of the road.



## Essential Project 14 | Cool Creek Tract Water Withdrawals

**Key Partners** | The Forest Service collaborated with nine recreational residence owners and Clackamas County to complete this project.

**Background** | Numerous recreational residential cabins of the 25 cabins within the Cool Creek Tract have pumped water for domestic use directly from Still Creek. Water intake structures have been observed near salmon and trout redds. Additionally, larval and juvenile salmonids may inadvertently be drawn into the water intake. The objective for this project was to remove the direct water intakes in Still Creek to protect ESA threatened salmon and steelhead, and to replace intakes by drilling 12 wells that will not adversely impact native fish in Still Creek.

**Actions** | From 2012 to 2017, five wells were dug in place of using direct water intakes to provide water for the Cool Creek Tract residents (Figure 27). Nine direct water intakes were removed from Still Creek due to residences sharing wells with additional waterlines. Well drilling was recorded by the Zigzag Ranger District Permit Administrator and Oregon Water Resources Department. The Forest Service conducted all NEPA analyses, provided resource protection oversight during the construction of the wells, monitored post disturbance sites for erosion, and rehabilitated sites with native vegetation in cooperation with the cabin owner. The cabin owners ensured that private contractors complied with the best management practices that protect aquatic resources and control erosion. Cabin owners also worked with Clackamas County to ensure all permits were acquired and met Clackamas County standards. Although progress was made towards eliminating all water intake structures from Still Creek in the Cool Creek Tract to increase water quality and quantity, there remains five recreational residences currently withdrawing water that need to be addressed.

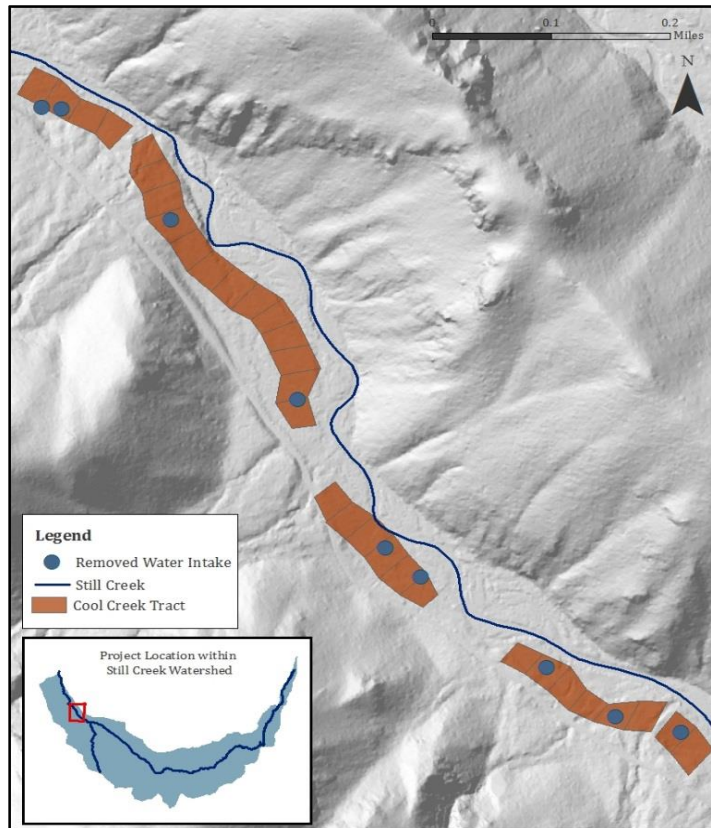


Figure 27. Map of wells drilled between 2011 and 2017 to replace direct water withdrawal intakes for recreational residences.

## Essential Project 15 | Recreational Residence Septic Replacement

**Key Partners** | This project was a success due to collaboration among cabin owners, Clackamas County, the Oregon Department of Environmental Quality (ODEQ), and the Forest Service.

**Background** | There are 129 recreational resident cabins within the Still Creek watershed. Many of these cabins are within the 100-year floodplain and some are on islands surrounded by side channels (USDA 2009). Some of these cabins have open septic systems, which are likely to contribute fecal contaminants to surface and sub-surface water during high flow events. Replacing existing open septic systems with fully sealed systems can alleviate this chronic infusion of waste that occurs during high water events. The objective for this project was to convert a minimum of ten septic systems to closed systems so as to minimize chances for failure during floods and other high water events.

**Actions** | Eighteen septic systems were replaced within the Still Creek, Vine Maple and Cool Creek Tracts between 2012 and 2017 (Figure 28) (Clackamas County 2017). This exceeded the project goals of constructing ten new systems. Replaced septic systems were recorded by the Zigzag Ranger District Permit Administrator and Clackamas County. The new septic systems all met Clackamas County regulations with a 100 foot minimum setback from all perennial streams and a fully contained system with no adverse effects to water quality. The Forest Service conducted all of the NEPA

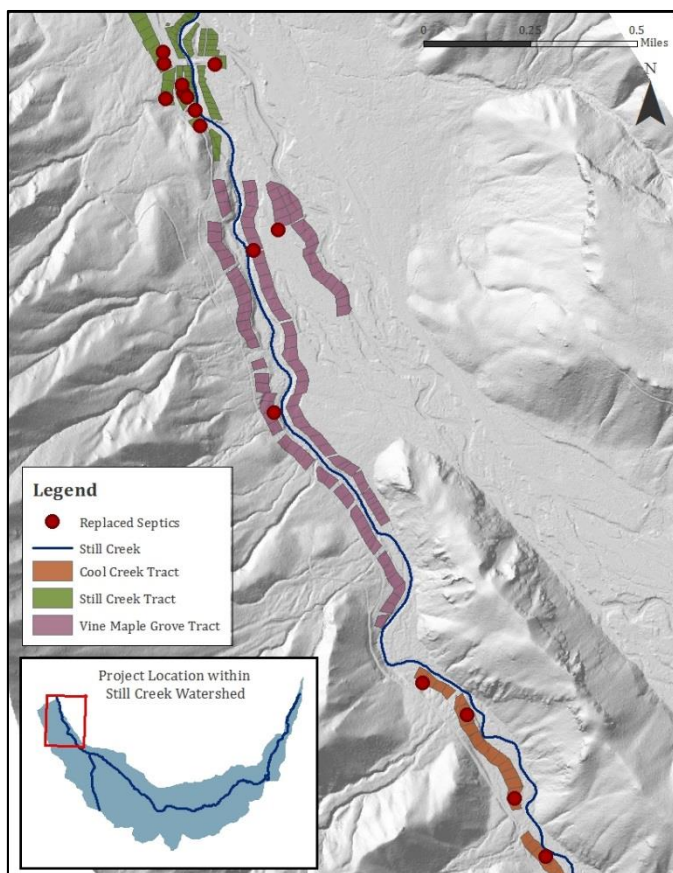


Figure 28. Map of septic systems installed or upgraded from 2012-2017.

analyses, provided resource protection oversight of the construction, and ensured compliance for post disturbance site monitoring completed by the cabin owner. Cabin owners worked with Clackamas County and ODEQ to ensure that all permits were acquired and septic systems meet Clackamas County and ODEQ standards.

Currently, six open septic systems remain within the Cool Creek Tract. During the permit reissuance process, when a cabin owner is transferring or selling a permit to a new owner, permit holders are required by the Forest Service to have their septic system inspected to insure they are functioning correctly. If the system does not meet Clackamas County regulations, new cabin owners are required to install a new septic system. The Forest Service will continue to perform septic system inspection and recommend cabin owners to get replacements prior to future permit reissuance.

## Essential Project 16 | Marine derived nutrient enhancement

**Key Partners** | This project was completed by a collaboration among the Oregon Department of Fish and Wildlife (ODFW), the Sandy River Basin Watershed Council (SRBWC), the Portland Water Bureau (PWB), and the US Forest Service.

**Background** | Suppressed natural runs of salmon and steelhead have reduced the marine derived nutrients in Still Creek. Salmon runs are a mechanism to bring marine derived nutrients upstream into freshwater ecosystems to benefit all trophic levels extending from the stream into the riparian zone. The objective for this project was to enhance the marine-derived nutrients in Still Creek by using surplus hatchery salmon.

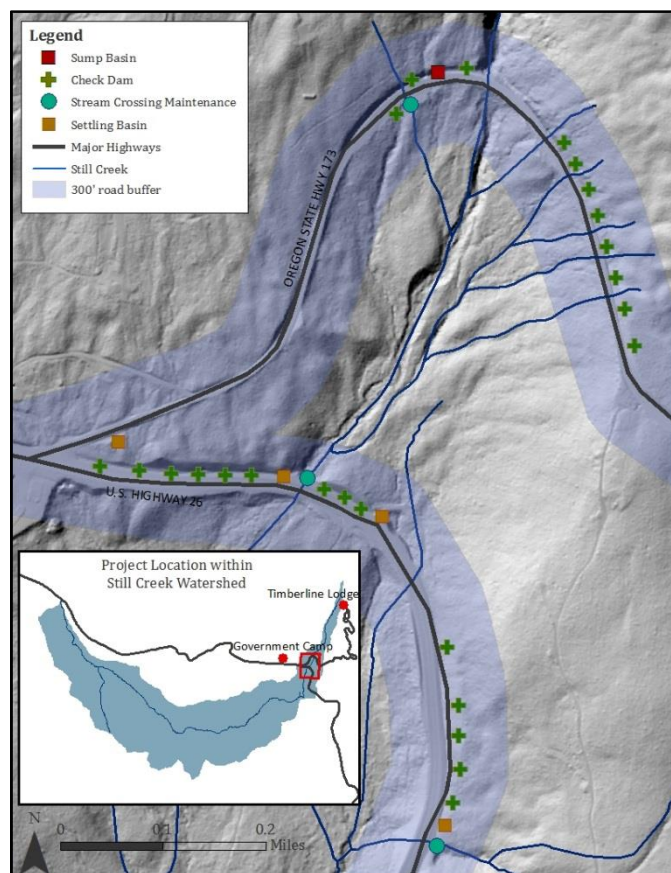
**Actions** | From 2011 to 2017, salmon carcasses have been placed along 8.3 miles of Still Creek annually to increase marine derived nutrients. This project was completed and continues annually through a collaboration among ODFW, Sandy River Watershed Council, Portland Water Bureau, and the FS.



## Essential Project 17 | US Highway 26 sediment traps

**Key Partners** | The Oregon Department of Transportation initiated collaboration with the Forest Service.

**Background** | Conveyance of road-related sediment from US Highway 26 and Oregon State Highway 173 into Still Creek is of mutual concern to the US Forest Service and Oregon Department of Transportation (ODOT). US Highway 26 and Oregon State Highway 173 provide an important commercial and recreational travel route connecting Portland to central Oregon as well as recreational facilities around Mt. Hood. Icy road conditions occur frequently in winter due to the high elevation, high precipitation, and low nightly temperatures. In order to create safer travel conditions, ODOT spreads hundreds of tons of road sand every year onto US Highway 26 and Highway 173 (USDA 1995). As a result, approximately, 328 tons of road sand enter the headwaters of Still Creek each year (USDA 1995). Excessive sediment reduces habitat quality and water quality in aquatic environments by reducing stream bed habitats, reducing fish spawning habitat, increasing contaminants by serving as a vector, and depressing dissolved oxygen levels (Berry et al. 2003).



**Figure 30.** Map showing location of sediment retention or control structures constructed in 2017 by ODOT on U.S. Highway 26 and Oregon State Highway 173 to reduce road related sediment transport into Still Creek.



**Figure 29.** ODOT and USFS meet to discuss possible sediment trap structures.

The objective of this project was to reduce the conveyance of road-related sediment from US Highway 26 and Oregon State Highway 173 to Still Creek and its tributaries by partnering with ODOT to construct sediment retention basins upstream and downstream of drain culverts and ditches. Sediment retention basins are one method of reducing sediment and pollutant conveyance to streams near roads. Trapping road-related sediment and pollutants before they enter the stream is an effective way to minimize adverse environmental impacts due to roads and increase water quality (Moser 1996). The project addressed the approximately 1.8 miles of US Highway 26 and Oregon State Highway 173 that convey sediment into Still Creek. Still Creek and its tributaries are within 300 feet of the highways for 1.2 miles of the 1.8 miles. There are 12 stream crossings along the project area, nine of which are tributaries to Still Creek, and the remaining three are tributaries to the Salmon River.

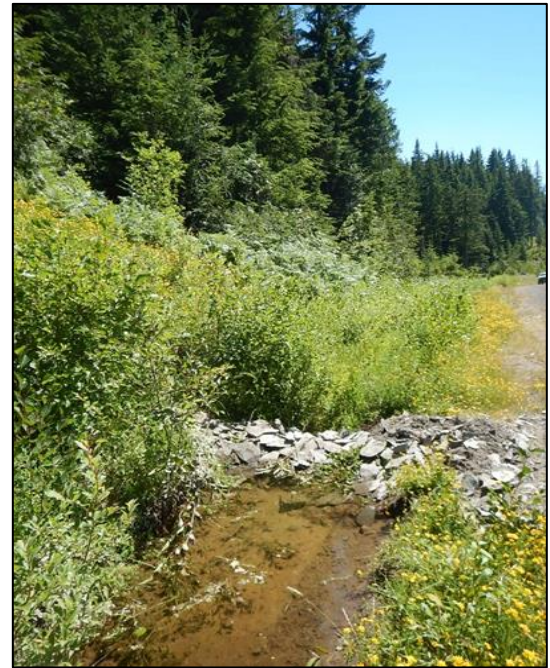
**Actions** | In June and July 2017, the Forest Service and ODOT held office and field meeting to discuss possible sediment barrier solutions that would trap sediment before it reaches Still Creek and its tributaries (Figure 29). Best management practices, barrier and sump construction plans, future work, and routine maintenance schedules were discussed and agreed

upon at the meetings. Sediment retention structure type and implementation locations were collaboratively identified by the Forest Service and ODOT while in the field.

Sediment retention structures were constructed and road maintenance was completed by ODOT on July 20th, 2017 (Figure 31). Cumulatively, two miles of US Highway 26 and Oregon State Highway 173 now have 30 sediment retention barriers that are expected to significantly reduce road-related sediment transport to Still Creek and its tributaries (Figure 30). The following construction and maintenance was completed:

- 25 check dams
- Four settling basins
- One sump basin
- Restructuring and addition of riprap to one stream crossing.
- Addition of retention structures and cleaning of three stream crossing.

Still Creek watershed is expected to have a reduction in road-related sediments being conveyed into streams as a direct result of this project.



*Figure 31. A check dam constructed in 2017 traps sediment along Highway 26.*

## Essential Project 18 | Road 2612 surface enhancement

**Key Partners** | The US Forest Service completed this project independently.

**Background** | The FS Road 2612, which runs nearly the entire length of Still Creek, has numerous tributaries that cross the road through culverts on their route to Still Creek. These tributaries, ditch lines and other cross drains transport road related sediment from the FS Road 2612 directly into Still Creek. Resurfacing roads has been found to significantly reduce road-related sediment into streams. The objective of this project was to resurface FS Road 2612 with spot rock to a minimum of six inch gravel lift to stabilize the road bed and surface, and ultimately reduce sediment transport through ditch lines and culverts

**Actions** | FS Road 2612 was enhanced with gravel throughout the 9.1 miles of road where it is closest to Still Creek. After resurfacing was completed, road storm patrols were performed to ensure that the road was functioning properly.



## SECTION IV. GOAL STATUS | Goals 1 – 5

In addition to improving in-stream habitat and watershed health of the Still Creek watershed, the US Forest Service made it a priority to utilize the restoration of Still Creek to provide opportunities for summer home owners and general public to learn about watershed restoration (goal 3); to provide jobs to local contractors, material suppliers, and the sport fishing industry (goal 4); and to maintain and strengthen partnership between the Mt. Hood National Forest, coalition of Sandy River Basin Partners, summer home owners and private landowners. This section provides a brief description of how each of these goals were accomplished.

### **Goal 1 | Restore natural watershed processes, including riparian function, in-channel habitat, road-related impacts, and eradication of invasive plants to recover/improve production of ESA listed salmon and steelhead.**

The recent work in Still Creek was intended to restore the stream to a dynamic system shaped by natural watershed processes, and this required complementary work both in-stream and out-of-stream. The addition of over 2,300 pieces of large wood to the stream has provided dramatic and rapid improvements in overall habitat quality; however, these structures will truly take effect in the long term as they continuously shape and improve channel and floodplain conditions. Still Creek continues to be limited by its potential for large wood recruitment due to the loss of late-seral coniferous stands throughout much of the watershed. To address this issue, riparian rehabilitation occurred at 23 sites throughout the watershed with the intention of restoring the forest structure to reference conditions in the long term. The removal of invasive plants and campsite rehabilitation ensured that healthy riparian zones remain intact. The significant sediment control measures completed throughout the watershed, including road enhancement, construction of sediment control structures, and culvert replacement, all ensure a reduction in sediment to Still Creek for the foreseeable future. These measures should significantly improve not only the stream's current capacity to support ESA listed salmon and steelhead, but also its long term potential to provide a refuge for resilient salmon and steelhead populations.

### **Goal 2 | Improve water quality in Still Creek by improving riparian forest health through additional shading to surface waters and through a reduction in sediment delivery from road-related impacts.**

Water quality was improved on two fronts: through both a reduction in the potential sources for contaminants to enter the water, as well as through an increase in the overall health of the riparian zone. The replacement of culverts, ditch line rehabilitation, and installment of sediment control structures all limited the overall potential of sediment and other road contaminants to enter the waterway. Similarly, the replacement of 18 aging septic systems supported long-term reductions in fecal contaminants from recreational residences. Restored riparian vegetation and campsite rehabilitation both ensured that healthy riparian zones remain intact and continue to stabilize stream banks and prevent chronic sediment delivery to the stream. Likewise, the addition of marine derived nutrients to the stream not only benefits in-stream fish and macroinvertebrate communities, but supports the long term health of the riparian forest. These measures ensure that water quality in Still Creek will remain of a high enough quality to support healthy populations of salmon and steelhead while benefitting area residents and visitors alike.

### **Goal 3 | Provide education engagement opportunities for summer home owners/private landowners/general public to learn about watershed restoration.**

Restoration within the Still Creek watershed provided many educational engagement opportunities for non-profits, community members, and the general public. From 2012 to 2017, 225 individuals cumulatively donated over 3,700 volunteer hours to restoration within the Still Creek watershed. These 225 individuals, all from diverse organizations, participated in educational outreach with the Forest Service and gained valuable information related to the importance of watershed restoration and protection of native species. Educational outreach opportunities included tree and native vegetation plantings, invasive weed removal, native seed collection, salmon carcass nutrient enrichment, spawning surveys, stream monitoring, and smolt trap monitoring. The following organizations volunteered with the FS to complete restoration within the Still Creek watershed: Educational Recreational Adventures, National Forest Foundation, Salmon Carcass Nutrient Enhancement, Wilderness Volunteers, Sandy River Watershed Council, Mazamas, BARK, Clackamas 4-H, Timberlake Job Corps, Sandy River Basin Watershed Council, and local community members.

#### Goal 4 | Provide jobs to local contractors, material suppliers, sport fishing industry.

The creation of jobs and supporting local economies through restoration work is a priority for the US Forest Service (USDA 2012). One study found that, in Oregon, river and road restoration activities can generate over 20 jobs and \$2.3 million in economic activity for every \$1 million invested (Moseley and Nielsen-Pincus, 2009). Using this estimate, the \$2.2 million invested in the restoration of Still Creek may have generated upwards of \$5.1 million in local economic activity. Specific activities involved the employment of local contractors for road and in-channel work utilizing heavy equipment, such as front-loaders, excavators, dump trucks, bull dozers, helicopters, and log hauling trucks. The Forest Service relied on material suppliers to acquire supplies not readily available on the forest, including culverts, specialized tools, and additional rocks and logs for in-stream restoration. Contracting work involved tree thinning and hauling, and the removal of invasive species.

In addition to jobs created directly by restoration work, the Still Creek restoration projects continue to benefit the local economy by supporting healthy runs of salmon and steelhead. These species provide a fishery that not only employs local guides, but also fuels the local tackle retailers/manufactures, boat manufacturing companies, and numerous other small businesses that depend on angling revenue. Furthermore, restoration work in Still Creek enhances amenities in the Mt. Hood National Forest, which receives over one million visitors each year and supports a large tourism economy including motels, stores, and restaurants.

#### Goal 5 | Maintain and strengthen partnership between the Mt. Hood National Forest, coalition of Sandy River Basin Partners, summer home owners and private landowners.

The Forest Service has a long history of partnerships with federal, state, and local entities. Restoration work in Still Creek was a collaboration with the Mt. Hood National Forest, the Sandy River Basin Partners, contractors, volunteers, recreational residence owners, local businesses, and other organizations. Key partners for planning and implementation included the following:

The Freshwater Trust  
Clackamas County  
Columbia Land Trust  
Portland Metro  
Multnomah County  
National Marine Fisheries Service  
The Nature Conservancy  
Northwest Steelheaders  
Oregon Department of Fish and Wildlife  
Portland Water Bureau  
Sandy River Basin Watershed Council  
Western Rivers Conservancy  
USDA Forest Service  
USDA TEAMS Enterprise Unit  
USDI Bureau of Land Management  
Oregon Parks and Recreation  
East Multnomah County SWCD  
The Clackamas County SWCD  
Oregon Department of Transportation  
The Wilderness Volunteers  
Mazamas  
Portland General Electric



*Figure 32. The Wilderness Volunteers and Mt. Hood National Forest fisheries program staff after a long day of riparian rehabilitation work.*

Working with each of these partners fostered working relationships and human capital that can be applied to future restoration work throughout the Sandy River basin and the Mt. Hood National Forest.

## ACKNOWLEDGEMENTS

We thank Kathryn Arendt, Zigzag RD fish biologist, for leading much of the planning, partnering, development, and implementation of nearly all the restoration actions in the Still Creek 6<sup>th</sup> field watershed. Todd Parker, Zigzag RD hydrologist, was instrumental for much of the planning of the WRAP, BMP monitoring, and implementation oversight for road and water quality improvement projects. We thank Bill Westbrook, Zigzag District Ranger, and Brad Goehring, Mt. Hood Forest Fish Program Manager, for their broad support of restoration and partnerships. Josh Haslitt, Kevin Perkins, Emi Ikeda, Jacob Sleasman, and Haley McDonel completed all of the pre-project stream surveys. Josh Marxen, Forest Road Manager, and Walt Hislop, Forest Engineer, were instrumental in addressing road related sediment issues and AOP projects in the Still Creek 6<sup>th</sup> field watershed. Brian Bair and Greg Robertson from the TEAMS Enterprise Unit, were instrumental in the design and implementation oversight of the instream restoration. Nearly 90% of the funding secured for instream restoration can be directly attributed to Mark McCollister and The Freshwater Trust. Additionally, our ability to partner with Bruce Zoellick, BLM, gained a much greater ability to leverage limited funds for restoration in Still Creek and the Salmon River. Steve Wise and Corrinne Handelman from the Sandy River Basin Watershed Council were critical to our planting, invasive removal, and marine derived nutrient programs on Mt. Hood NF. All of the biological monitoring was completed in close cooperation with Todd Alsbury and Ben Walczak from Oregon Department of Fish and Wildlife and Steve Kucas and Burke Stroebel from Portland Water Bureau. We also thank Jeff Fisher, Monique Leslie, and Hillary Cosentino from The Freshwater Trust for much of the pre- and post-instream restoration monitoring. Tom and Susan Holling with the Wilderness Volunteers were critical to completing much of the final planting and erosion control for the instream restoration projects on Still Creek. We thank Don and Kristy Mench and Bob and Carla Heade for their long term support by volunteering for smolt out-migration monitoring. Finally, we thank Jim McNamee and Will Ewing from the Oregon Department of Transportation in partnering to secure large wood for restoration and cooperating to address sediment issues along our highways.

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## APPENDIX A. DATA TABLES

**Table A1.** Post restoration data for the main channel only, separated by in-stream essential project area.

Variable (Main Channel Only)	Cabins	Straights	Compression	Mars Attacks	Elder Growth	Pumpkin Patch	Canyon	Headwaters Nirvana	Total
Total Thalweg Length (ft)	5,802	1,645	2,479	1,274	1,417	3,125	8,070	9,004	<b>32,816</b>
Pool Thalweg Length (ft)	1,025	457	845	234	400	900	1,153	1,610	<b>6,624</b>
Riffle Thalweg Length (ft)	4,777	1,188	1,634	1,040	1,017	2,225	6,917	7,394	<b>26,192</b>
Percentage Comprised of Pools	17.67%	27.78%	34.09%	18.37%	28.23%	28.80%	14.29%	17.88%	<b>20.19%</b>
Pool Count	14	7	15	6	8	14	32	53	<b>149</b>
Primary Pool Count	5	4	5	0	2	4	6	3	<b>29</b>
Pool Density (pools / river mile)	11.8	25.0	30.6	31.6	25.8	23.7	21.2	35.3	<b>24.6</b>
Primary Pool Density (pools / river mile)	4.2	14.3	10.2	0	6.5	6.8	4.0	2.0	<b>4.8</b>
LRMP Primary Pool Density Standard, Minimum	14	13	17	17	16	17	36	41	<b>16</b>
LRMP Primary Pool Density Standard, Maximum	20	18	24	24	22	23	36	41	<b>22</b>
Mean Pool Depth ± sd (ft)	2.44 ± 1.21	2.34 ± 1.00	2.33 ± 0.83	2.03 ± 0.69	2.11 ± 0.69	2.50 ± 1.00	2.26 ± 1.01	1.79 ± 0.61	<b>2.13 ± 0.88</b>
Mean Primary Pool Depth ± sd (ft)	3.76 ± 0.82	3.10 ± 0.00	3.28 ± 0.16	NA	3.10 ± 0.00	3.85 ± 0.39	3.92 ± 1.29	3.60 ± 0.71	<b>3.57 ± 0.72</b>
Mini Wood Piece Count, Bankfull	147	34	119	44	49	167	179	577	<b>1,316</b>
Small LWD Count, Bankfull	295 <sup>A</sup>	46	130	46	61	113	163	359	<b>1,213</b>
Medium LWD Count, Bankfull	46	9	35	11	18	20	47	38	<b>224</b>
Large LWD Count, Bankfull	41	2	3	0	5	0	10	1	<b>62</b>
Mini Wood Piece Count, out of Bankfull	17	0	49	25	8	59	22	21	<b>201</b>
Small LWD Count, out of Bankfull	38	7	36	17	8	36	21	16	<b>179</b>
Medium LWD Count, out of Bankfull	7	0	4	5	1	4	9	10	<b>40</b>
Large LWD Count, out of Bankfull	0	0	0	0	1	0	2	0	<b>3</b>
Total LWD Count	427	64	208	79	94	173	252	424	<b>1,721</b>
Total Key Piece Count	94	11	42	16	25	24	68	49	<b>329</b>
LWD Density (LWD / river mile)	350	229	424	416	303	293	167	283	<b>282</b>
Key Piece Density (Key piece / river mile)	79	39	86	84	81	41	45	33	<b>54</b>
Jam Count	34	7	25	9	10	17	38	54	<b>194</b>
Restoration Jam Count	27	5	24	9	9	11	19	46	<b>150</b>
Jam Density (Jams / river mile)	28.6	25.0	51.0	47.4	32.3	28.8	25.2	36.0	<b>32.0</b>
LWD in Jams Count	400	61	202	72	90	157	211	348	<b>1,541</b>
Percent Wood in Jams	93.7%	95.3%	97.1%	91.1%	95.7%	90.8%	83.7%	82.1%	<b>89.5%</b>
Total Spawning Gravel Area (yd <sup>2</sup> )	3,024	753	1,199	559	346	543	510	924	<b>7,857</b>
Spawning Gravel Density (yd <sup>2</sup> / river mile)	2541.2	2689.3	2446.9	2942.1	1116.1	920.3	337.7	616.0	<b>2106.2*</b>
Mean Bankfull Width (ft)	54.1	48.0	46.5	45.0	47.8	50.4	46.3	43.8	<b>47.5</b>
Sinuosity	1.14	1.39	1.07	1.18	1.15	1.14	1.08	1.08	<b>1.11</b>
Thalweg Gradient	1.6%	3.6%	3.5%	1.6%	3.9%	2.6%	4.1%	4.2%	<b>3.4%</b>
Percent Confined	32.0%	21.2%	0.6%	0.0%	29.2%	10.8%	66.1%	64.0%	<b>41.40%</b>
Entrenchment Ratio, Minimum	3.3	4.3	2.2	3.1	4.4	8.3	1.9	2.0	<b>1.9</b>
Entrenchment Ratio, Maximum	5.9	5.0	6.8	4.2	4.6	9.2	2.6	2.9	<b>9.2</b>

<sup>A</sup>The Cabins project area included one 11-log restoration jam placed downstream of the road 20 bridge, separate from other restoration work in the lower, middle, and upper cabins project areas. Because this jam was isolated from the remainder of the project area, these 11 logs were not used to calculate wood or jam densities, but were used to record the total amount of LWD placed within the Cabins project area.

**Table A2.** Post restoration data for side channels only, separated by in-stream essential project area.

Variable (Side Channels Only)	Cabins	Straights	Compression	Mars Attacks	Elder Growth	Pumpkin Patch	Canyon	Headwaters Nirvana	Total
Total Thalweg Length (ft)	8,921	2,941	8,337	3,400	2,017	6,352	3,624	3,993	<b>39,585</b>
Pool Thalweg Length (ft)	2,537	210	1,367	881	277	1,906	714	784	<b>8,676</b>
Riffle Thalweg Length (ft)	6,384	2,731	6,970	2,519	1,740	4,446	2,910	3,209	<b>30,909</b>
Percentage Comprised of Pools	28.44%	7.14%	16.40%	25.91%	13.73%	30.01%	19.70%	19.63%	<b>21.92%</b>
Side Channel to Main Channel Ratio	1.5	1.8	3.4	2.7	1.4	2.0	0.4	0.4	<b>1.2</b>
Pool Count	57	7	53	36	9	56	32	51	<b>301</b>
Primary Pool Count	5	2	1	0	1	2	1	1	<b>13</b>
Pool Density (pools / river mile)	33.7	12.6	33.6	55.9	23.6	46.5	46.6	67.4	<b>40.1</b>
Primary Pool Density (pools / river mile)	3.0	3.6	0.6	0.0	2.6	1.7	1.5	1.3	<b>1.7</b>
Mean Pool Depth ± sd (ft)	1.68 ± 0.92	2.32 ± 2.45	1.13 ± 0.53	0.95 ± 0.55	1.47 ± 1.12	1.43 ± 0.66	1.22 ± 0.67	1.09 ± 0.59	<b>1.31 ± 0.80</b>
Mean Primary Pool Depth ± sd (ft)	3.44 ± 0.33	7.20 ± 0.00	3.00 ± 0.00	NA	3.10 ± 0.00	3.44 ± 0.42	3.30 ± 0.00	3.10 ± 0.00	<b>3.64 ± 1.16</b>
Mini Wood Piece Count, Bankfull	191	105	232	98	72	467	187	176	<b>1,528</b>
Small LWD Count, Bankfull	127	110	119	51	68	169	90	46	<b>779</b>
Medium LWD Count, Bankfull	13	13	10	3	11	22	14	8	<b>94</b>
Large LWD Count, Bankfull	13	5	6	1	5	1	2	1	<b>34</b>
Mini Wood Piece Count, out of Bankfull	6	3	7	5	2	101	6	4	<b>134</b>
Small LWD Count, out of Bankfull	10	6	7	1	1	40	7	1	<b>73</b>
Medium LWD Count, out of Bankfull	0	2	0	0	1	9	1	0	<b>13</b>
Large LWD Count, out of Bankfull	0	1	0	0	0	0	1	0	<b>2</b>
Total LWD Count	163	137	142	56	86	241	115	56	<b>995</b>
Total Key Piece Count	26	21	16	4	17	32	18	9	<b>143</b>
LWD Density (LWD / river mile)	96	246	90	87	225	200	168	74	<b>133</b>
Key Piece Density (Key piece / river mile)	15	38	10	6	45	27	26	12	<b>19</b>
Jam Count	28	22	21	10	13	24	13	10	<b>141</b>
Restoration Jam Count	21	18	14	5	12	15	7	1	<b>93</b>
Jam Density (Jams / river mile)	16.6	39.5	13.3	15.5	34.0	19.9	18.9	13.2	<b>18.8</b>
LWD in Jams Count	126	122	72	49	73	195	101	27	<b>765</b>
Percent Wood in Jams	77.3%	89.1%	50.7%	87.5%	84.9%	80.9%	87.8%	48.2%	<b>76.9%</b>
Total Spawning Gravel Area (yd <sup>2</sup> ) <sup>a</sup>	132	235	435	221	70	509	32	278	<b>1,911</b>

<sup>a</sup>Surveyors did not record spawning gravels for all side channels; data presented here represent the total area of spawning gravels recorded and are likely an under-estimate.

**Table A3.** Post restoration data for selected variables for the main channels and side channels combined, separated by in-stream essential project area.

Variable (Main Channel Only)	Cabins	Straights	Compression	Mars Attacks	Elder Growth	Pumpkin Patch	Canyon	Headwaters Nirvana	Total
Pool Count	71	14	68	42	17	70	64	104	450
Primary Pool Count	10	6	6	0	3	6	7	4	42
Mini Wood Piece Count, Bankfull	338	139	351	142	121	634	366	753	2844
Small LWD Count, Bankfull	422 <sup>A</sup>	156	249	97	129	282	253	405	1981
Medium LWD Count, Bankfull	59	22	45	14	29	42	61	46	318
Large LWD Count, Bankfull	54	7	9	1	10	1	12	2	96
Mini Wood Piece Count, out of Bankfull	23	3	56	30	10	160	28	25	335
Small LWD Count, out of Bankfull	48	13	43	18	9	76	28	17	252
Medium LWD Count, out of Bankfull	7	2	4	5	2	13	10	10	53
Large LWD Count, out of Bankfull	0	1	0	0	1	0	3	0	5
Total LWD Count	590	201	350	135	180	414	367	480	2716
Total Key Piece Count	120	32	58	20	42	56	86	58	472
Jam Count	62	29	46	19	23	41	51	64	335
Restoration Jam Count	48	23	38	14	21	26	26	47	243
LWD in Jams Count	515	183	274	121	163	352	312	375	2295
Percent Wood in Jams	87.29%	91.04%	78.29%	89.63%	90.56%	85.02%	85.01%	78.13%	84.50%
Total Spawning Gravel Area (yd <sup>2</sup> ) <sup>B</sup>	3,156	988	1,634	780	416	1,052	542	1,202	9,768

<sup>A</sup>The Cabins project area included one 11-log restoration jam placed downstream of the road 20 bridge, separate from other restoration work in the lower, middle, and upper cabins project areas. Because this jam was isolated from the remainder of the project area, these 11 logs were not used to calculate wood or jam densities, but were used to record the total amount of LWD placed within the Cabins project area.

<sup>B</sup>Surveyors did not record spawning gravels for all side channels; data presented here represent the total area of spawning gravels recorded and are likely an under-estimate.

**Table A4.** Variables derived by GIS, separated by in-stream essential project area.

Variable	Cabins	Straights	Compression	Mars Attacks	Elder Growth	Pumpkin Patch	Canyon	Headwaters Nirvana	Total
River Mile, Downstream	0	3.14	3.42	3.91	4.1	4.41	5	6.51	0
River Mile, Upstream	3.14	3.42	3.91	4.1	4.41	5	6.51	8.01	8.01
Elevation, Downstream (ft)	1,717	1,810	1,869	1,955	1,976	2,031	2,112	2,444	1,717
Elevation, Upstream (ft)	1,810	1,869	1,955	1,976	2,031	2,112	2,444	2,824	2,824
Elevation Change (ft)	93	59	86	21	55	81	332	380	1,107
GIS Estimated Length	1.19	0.28	0.49	0.19	0.31	0.59	1.51	1.5	6.06
Valley Length (ft)	5,089	1,180	2,315	1,076	1,228	2,730	7,496	8,372	29,496
Minimum Floodprone Width (ft)	177	206	102	139	209	417	90	86	86
Maximum Floodprone Width (ft)	317	241	318	191	219	464	121	126	464
Floodplain Impacted (Acres)	28.5	11.8	21.8	7.9	7.4	20.2	28.3	30.8	156.7



**Table A5.** Pre restoration data for the main channel only, separated by in-stream essential project area.

Variable (Main Channel Only)	Cabins	Straights	Compression	Mars Attacks	Elder Growth	Pumpkin Patch	Canyon	Headwaters Nirvana	Total
Total Thalweg Length (ft)	5,665	1,528	2,587 <sup>A</sup>	1,177 <sup>A</sup>	1,290 <sup>A</sup>	3237	8,385	9,303	<b>33,172</b>
Pool Thalweg Length (ft)	943	443	411 <sup>B</sup>	187 <sup>B</sup>	211 <sup>B</sup>	355	978	752	<b>4,280</b>
Riffle Thalweg Length (ft)	4,722	1,085	2,176 <sup>B</sup>	990 <sup>B</sup>	1,079 <sup>B</sup>	2,882	7,407	8,551	<b>28,892</b>
Percentage Comprised of Pools	16.65%	28.99%	15.8% <sup>C</sup>	15.8% <sup>C</sup>	16.36% <sup>C</sup>	10.97%	11.66%	8.08%	<b>12.90%</b>
Pool Count	11	6	10 <sup>B</sup>	4 <sup>B</sup>	6	8	18	24	<b>87</b>
Primary Pool Count	3	1	2 <sup>B</sup>	0 <sup>B</sup>	1	4	1 <sup>B</sup>	2	<b>14</b>
Pool Density (pools / river mile)	9.2	21.4	20.4	21.1	19.4	13.6	11.9	16.0	<b>14.4</b>
Primary Pool Density (pools / river mile)	2.5	3.6	4.1	0.0	3.2	6.8	0.7	1.3	<b>2.3</b>
Mean Pool Depth ± sd (ft)	2.65 ± 1.06	2.32 ± 0.43	No Data	No Data	2.43 ± 0.66	2.47 ± 1.22	No Data	1.92 ± 0.62	<b>2.24 ± 0.83</b>
Mean Primary Pool Depth ± sd (ft)	3.93 ± 1.19	3.00 ± 0.00	No Data	No Data	3.60 ± 0.00	3.60 ± 0.66	No Data	3.20 ± 0.00	<b>3.56 ± 0.72</b>
Small LWD Count	61	7	82 <sup>D</sup>	32 <sup>D</sup>	38	34	71	140	<b>465</b>
Medium LWD Count	10	2	6 <sup>E</sup>	2 <sup>E</sup>	6	9	24	7	<b>66</b>
Large LWD Count	2	1	0 <sup>E</sup>	0 <sup>E</sup>	0	1	6	3	<b>13</b>
Total LWD Count	73	10	88	34	44	44	101	150	<b>544</b>
Total Key Piece Count	12	3	6	2	6	10	30	10	<b>79</b>
LWD Density (LWD / river mile)	61	36	180 <sup>D</sup>	180 <sup>D</sup>	142	75	67	100	<b>90</b>
Key Piece Density (Key piece / river mile)	10	11	13 <sup>E</sup>	13 <sup>E</sup>	19	17	20	7	<b>13</b>
Sinuosity	1.11	1.29	1.12	1.09	1.05	1.19	1.12	1.11	<b>1.12</b>
Thalweg Gradient	1.6%	3.9%	3.3%	1.8%	4.3%	2.5%	4.0%	4.1%	<b>3.3%</b>

<sup>A</sup>Accurate surveyed thalweg length data were unavailable; values here were derived from estimates made in GIS.

<sup>B</sup>Accurate surveyed pool and riffle length data were unavailable; values here represent the percentage of thalweg length as pools estimated in the EDT database multiplied by the total thalweg length.

<sup>C</sup>Percentage of thalweg comprised of pools are based on estimates made in the Sandy River Basin EDT Database (City of Portland 2004).

<sup>D</sup>Pre restoration survey wood data unavailable; data represented here were derived based on wood density estimates from the Sandy River Basin EDT Database (City of Portland 2004).

<sup>E</sup>Pre restoration key piece data unavailable; data represented here were based on wood density estimates from the 1996 Still Creek surveys (USDA 1996).

**Table A6.** Pre restoration data for side channels only, separated by in-stream essential project area.

Variable (Side Channels Only)	Cabins	Straights	Compression	Mars Attacks	Elder Growth	Pumpkin Patch	Canyon	Headwater Nirvana	Total
Total Thalweg Length (ft)	2,661	617	No Data	No Data	317 <sup>+</sup>	670 <sup>+</sup>	No Data	1,202	<b>5,467<sup>+</sup></b>
Side Channel to Main Channel Ratio	0.5	0.4	No Data	No Data	0.2 <sup>+</sup>	0.2 <sup>+</sup>	No Data	0.1	<b>0.2<sup>+</sup></b>
Small LWD Count	22	2	No Data	No Data	0	3	No Data	4	<b>31<sup>+</sup></b>
Medium LWD Count	4	6	No Data	No Data	0	0	No Data	0	<b>10<sup>+</sup></b>
Large LWD Count	2	2	No Data	No Data	0	0	No Data	0	<b>4<sup>+</sup></b>
Total LWD Count	28	10	No Data	No Data	0	3	No Data	4	<b>45<sup>+</sup></b>
LWD Density (LWD / river mile)	17	18	No Data	No Data	0	3	No Data	5	<b>No Data</b>
Key Piece Density (Key piece / river mile)	4	14	No Data	No Data	0	0	No Data	0	<b>No Data</b>

<sup>+</sup>Because of significant amounts of missing pre restoration survey data, all values with a + sign represent minimum values based on available survey data; true values were likely higher.

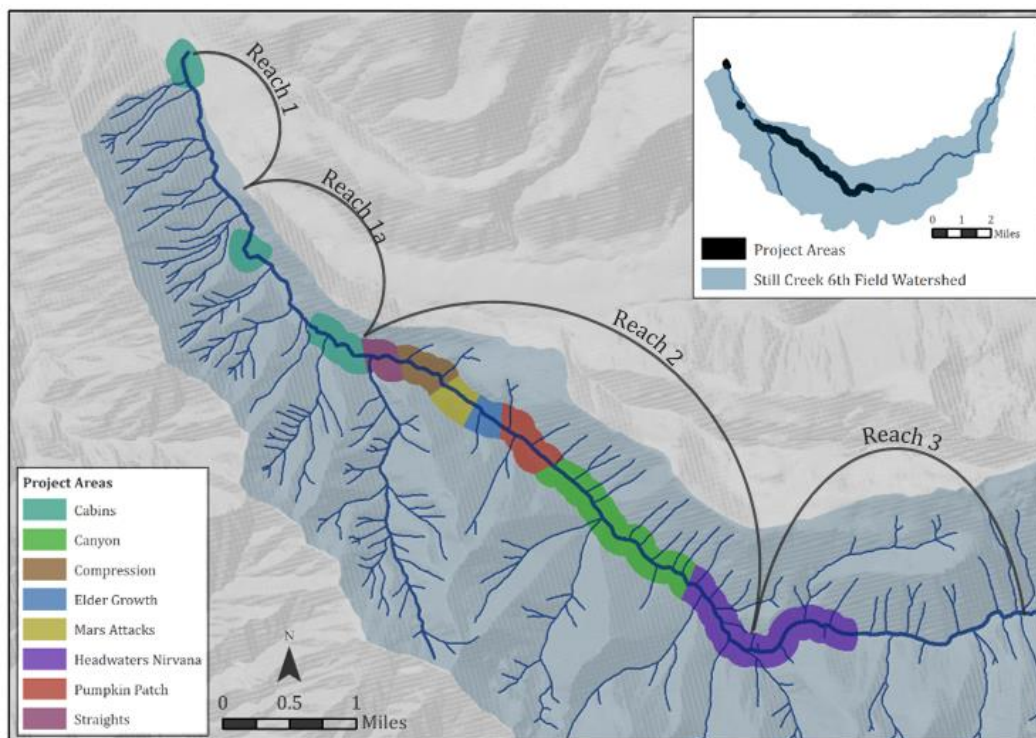
## APPENDIX B. EDT RESTORATION TARGETS

### Background

Included as part of the 2004 Zigzag Watershed Analysis update (USDA 2004), a basin-wide analysis was completed using the Ecosystem Diagnosis and Treatment Model (EDT). Initial analysis was completed by Mobrand Biometrics first in 2002 and updated in 2004 for the entire Sandy River basin, including Still Creek. The model was populated with stream survey data from Forest Service Level 2 stream surveys, ODFW physical habitat surveys, and BLM aquatic surveys. The assessment compared current versus historical habitat conditions and identified factors limiting salmon and steelhead production. Additionally, the model provided a prescription for key restoration targets to improve limiting habitat factors. The following description of EDT is an excerpt from the Mobrand Biometrics website (<http://www.mobrand.com/edt.htm>):

*"The Ecosystem Diagnosis and Treatment (EDT) is a species habitat-relationship model developed for anadromous and resident salmonids. It has been developed over a number of years primarily by state, tribal, local and private interests in the Pacific Northwest. This type of model links habitat characteristics to biological features of fish and wildlife species. In practice, EDT is a process for assembling and organizing watershed information as a basis for development and implementation of recovery and management plans. It is based on the premise that restoration of specific species will primarily involve restoration of their ecosystems. EDT provides a detailed depiction of the environment and an assessment of that environment with regard to performance of fish and wildlife populations. Environment includes physical habitat features as well as biological interactions such as predation and competition. Reach specific data for 46 parameters are loaded into the model for both existing (Patent) condition and historic (Template) conditions, based on range of natural variation. Model outputs allow for interpretation of variance between existing and historic conditions and cumulative adverse impacts to target juvenile salmonids. Cumulative impacts are tallied as fish move downstream through other reaches to the Columbia River, Pacific Ocean and then as they return as adults."*

The EDT assessment separated the watershed into 6 reaches. Parts of four of these reaches were included in the recent Still Creek restoration projects, including all of Reach 2 (Figure B1). The purpose of this section is to outline the restoration targets defined by the EDT analysis and to assess how recent restoration of Still Creek has helped to accomplish these targets.



**Figure B1.** Map showing Still Creek main channel project areas and the four EDT reaches to which they belong.

**Table B1.** Restoration prescription from the 2004 Sandy River Basin EDT (City of Portland 2004).

Reach	Length (mi)	Length Treated (mi)	Attribute	Prescription	Progress
Reach 1	1.0	0.24	Confinement	Remove 2688 feet of riprap or levees.	Confinement restored to natural levels
			Pool Habitat	Create 38,261 ft <sup>2</sup> of pools habitat.	Created 4,762 ft <sup>2</sup> of pool habitat
			Large Wood*	Increase large wood by 2,673 pieces.	Increased wood by 92 pieces
			Riparian Function (%)	Add 37% to riparian function score.	No Data
Reach 1a	2.2	0.95	Confinement	Remove 5,766 feet of riprap or levees.	Confinement restored to natural levels
			Pool Habitat	Create 2,024 ft <sup>2</sup> of pool habitat.	Lost 3,022 ft <sup>2</sup> of pool habitat
			Glide Habitat	Create 2,024 ft <sup>2</sup> of glides.	Created 12,994 ft <sup>2</sup> of glide habitat
			Large Wood*	Increase large wood by 2,228 pieces.	Increased wood by 693 pieces
			Riparian Function (%)	Add 37% to riparian function score.	No Data
Reach 2	4.1	4.10	Confinement	Remove 10,761 feet of riprap or levees.	Confinement restored to natural levels
			Pool Tail Habitat	Create 110,414 ft <sup>2</sup> of pool habitat.	Created 50,917 ft <sup>2</sup> of pool habitat
			Large Wood*	Increase large wood by 4,157 pieces.	Increased wood by 3,550 pieces
			Riparian Function (%)	Add 17% to riparian function score.	No Data
Reach 3	2.1	0.77	Confinement	Remove 5,545 feet of riprap or levees.	Confinement restored to natural levels
			Large Wood*	Increase large wood by 2,946 pieces.	Increased wood by 436 pieces
			Riparian Function (%)	Add 37% to riparian function score.	No Data

\*The EDT database considers large wood pieces to be any piece exceeding 7 feet in length in 4 inches in diameter at 7 feet from the widest end.

Key actions for Still Creek restoration identified in the EDT analysis included: decreasing stream confinement; increasing the available pool (including pools and pool tails) and glide habitat; increasing the amount of large wood within the system; and improving riparian function. Riparian function is a metric designed to represent the quality of linkages between river and floodplain habitat, and is scored from 0% (non-functioning linkages) to 100% (fully functioning linkages). Specific targets for each of the reaches addressed or partially addressed by the Still Creek WRAP are listed in Table B1. Restoration actions to address these issues included the addition of 2,300 pieces of large wood throughout all reaches, the creation of 240 log jams, and the removal of riprap and levees to reopen historic side channel habitats.

## Methods

Data on the historic condition of Still Creek where derived from the Sandy River EDT Database (City of Portland 2004), which was acquired from partners at the Portland Water Bureau. Pre restoration data were collected through stream surveys; where pre restoration data were missing, estimates from the EDT database were utilized. All post restoration data were acquired through in-stream habitat surveys.

Pre restoration surveys included measurements for pool wetted area and total channel wetted area. Pre restoration glide data were not collected, estimates were derived from the EDT database (City of Portland 2004). Post restoration surveys included measurements for pool wetted area, glide wetted area, and total channel area, as well as estimates for the total percentage of main channel confined to a single channel. Pools were defined as any channel spanning feature with a residual pool depth of 1 foot or greater. Though data were collected for both main and side channel habitats, data represented here are only representative of the main channel.

Wood counts were performed both before and after restoration to include four size classes: mini pieces (at least 7ft length x 4in width), small pieces (at least 25ft length x 12in width), medium pieces (at least 50ft length x 24in width), and large pieces (at least 50ft length x 36 in width). Because pre restoration wood counts did not include the mini size class, pre restoration wood count data were estimated using data from the EDT database (City of Portland 2004). Though the EDT database contained pre restoration wood estimates for the entire reach, these counts were linearly scaled to only represent treated areas.

All historic estimates, and all pre restoration data for confinement and riparian function were derived from the EDT database (City of Portland 2004). Post restoration confinement was calculated as the ratio of average reach bankfull width to average valley floodprone width. No riparian function scores were calculated post restoration.

Estimates for changes between pre and post restoration pool and glide habitat were performed by comparing the pre restoration percentage of total wetted area represented by each habitat type to the post restoration percentage of total wetted area represented by each habitat type. The difference in pre and post restoration percentages was then used to



multiply the total measured post restoration wetted area. This approach was utilized because direct comparisons of pre and post restoration wetted area were impossible due to differences in stream flows each year; survey data from years with high stream flows provide much larger habitat area estimates than low stream flow years, making wetted area comparisons inaccurate. The approach utilized here allows for comparison between years with different stream flows and provides at least a rough estimate of changes in pool and glide habitat areas.

## Results

Pool habitat increased in all reaches except for Reach 1a, where pool habitat decreased by approximately 2%, or an estimated 3,022 ft<sup>2</sup>. Pool habitat as a percentage of total area was below historic estimates for each reach. Changes in glide habitat were only estimated for Reach 1a because this is the only reach that was prescribed an increase in glide habitat. Glide habitat increased by 8.6%, or 12,994 ft<sup>2</sup> compared with pre restoration estimates from the EDT database. Glide habitat now exceeds historic estimates. Wood was increased in all reaches, with an estimated increase of 92 pieces in Reach 1; 693 pieces in Reach 1a; 3,550 pieces in Reach 2; and 436 pieces in Reach 3. Overall wood counts are still below historic estimates for all reaches, but Reach 2 is within 87% of this target (Table B2).

Post project confinement data suggested that confinement levels tended to fall within the historic levels expected for each reach. Reach 1 values ranged from 3.3 to 5.9; Reach 1a ranged from 3.3 to 5.9; Reach 2 ranged from 1.9 to 9.2; and Reach 3 ranged from 2.0 to 2.9 (Table B3).

**Table B2.** Comparison between historic estimates, pre restoration survey results, and post restoration survey results for metrics related to EDT targets. Confinement results are presented in Table B3. Note that values presented here are adjusted to reflect only treated areas, not entire EDT reaches.

Reach	Surveyed Area <sup>A</sup>	Attribute	Historic	Pre Restoration	Post Restoration	Change
Reach 1	54,738ft <sup>2</sup>	Pool Habitat	27.0%	4.9%	13.6%	+8.7% (+4,762 ft <sup>2</sup> ) <sup>C</sup>
		Large Wood (# pieces)	644	14 <sup>B</sup>	106	+92 pieces
		Riparian Function Score	0	2	ND	ND
Reach 1a	151,095ft <sup>2</sup>	Pool Habitat	48.6%	19.4%	17.4%	-2.0% (-3,022 ft <sup>2</sup> ) <sup>C</sup>
		Glide Habitat	8.5%	8.1% <sup>B</sup>	16.7%	+8.6% (+12,994ft <sup>2</sup> ) <sup>C</sup>
		Large Wood (# pieces)	1,140	140 <sup>B</sup>	833	+693 pieces
		Riparian Function Score	0	2	ND	ND
Reach 2	707,176ft <sup>2</sup>	Pool Habitat	32.40%	12.3%	19.5%	+7.2% (+50,917ft <sup>2</sup> ) <sup>C</sup>
		Large Wood (# pieces)	4,920	738 <sup>B</sup>	4,288	+3,550 pieces
		Riparian Function Score	0	1	ND	ND
Reach 3	156,490ft <sup>2</sup>	Large Wood (# pieces)	1,271	191 <sup>B</sup>	627	+436 pieces
		Riparian Function Score	0	2	ND	ND

<sup>A</sup>Surveyed areas reflect the total wetted area measured in post restoration stream surveys.

<sup>B</sup>Pre restoration data were unavailable for these metrics. Values here reflect estimates from the EDT database (City of Portland 2004).

<sup>C</sup>Changes in habitat area were calculated by multiplying the percentage change of total habitat area by the post restoration surveyed area.

## Discussion

Restoration plans did not fully cover EDT Reach 1, Reach 1a, or Reach 3; only Reach 2 was treated in its entirety. Regardless, significant progress was made towards accomplishing each of the targets set by the EDT analysis. In total, an increase of 4,771 pieces of wood were recorded between pre restoration estimates and post restoration surveys. Still, an additional 2,581 pieces of wood are needed to meet targets in Reach 1; 1,535 pieces of wood to meet targets in Reach 1a; 807 pieces of wood to meet targets in Reach 2; and 2,510 pieces of wood to meet targets in Reach 3. It is important to note that the 2,300 wood pieces added to the stream through in-stream restoration work were mostly in the small, medium, or large size classes. Additional wood noted in survey data can be accounted for by mini size class wood pieces being actively recruited into placed log jams; it is expected that wood counts will continue to increase as restoration wood structures continue to trap additional wood pieces.

Pool habitat was created in all reaches except for Reach 1a; however losses here were relatively minor (-3,022 ft<sup>2</sup>) when compared with gains in pool habitat in other reaches (+55,679 ft<sup>2</sup>). Furthermore, some of these changes in pool

**Table B3.** Post project confinement ratio compared with estimated historic confinement (City of Portland 2004).

	Historic Confinement	Post Project Confinement
Reach 1	2 - >4	3.3-5.9
Reach 1a	>4	3.3-5.9
Reach 2	2-4	1.9-9.2
Reach 3	<2 - 4	2.0-2.9

habitat in Reach 2 may be due to the substantial increases in available glide habitat, which nearly doubled to 12,994ft<sup>2</sup>. No project area has yet met targets for pool habitat created; however, Reach 1a has exceeded targets set for the creation of additional glide habitat. It is expected the pool area will continue to increase over all reaches as the interaction of wood pieces with additional winter flood cycles promotes pool scour and deepening.

Pre restoration estimates from the EDT database (City of Portland 2004) suggested that approximately 25% of Reaches 1, 1a, 2, and 3 were confined due to unnatural man made hydro-modifications such as construction of dikes, levees, revetments, and stream straightening. The EDT analysis prescribed the removal of 24,760 feet of levees throughout all three reaches. Though exact data regarding the bank feet of levees and riprap removed were not recorded, excavators addressed this issue at key locations within Reaches 1a and Reach 2. Virtually all man-made obstructions to floodplain connectivity were removed, approximately 7.5 miles of side channel habitat were created or enhanced, and approximately 185 acres of floodplain habitat were improved. Post restoration confinement ratios indicate that channel confinement is now within the historic range for all reaches. Reach 2 remains slightly more confined than expected (the minimum value is 1.9, compared with the historic value of 2.0); however, the most confined sections occur in the Canyon project area, which has limited room for improvement.

## **Conclusion**

Though restoration targets were not met for all reaches, Reach 2 can be considered largely complete for several reasons: (a) the entire reach was treated, and (b) wood structures are expected to continue to increase pool area and wood recruitment. Reaches 1, 1a, and 3 require additional restoration actions to meet targets prescribed by the EDT analysis.

## APPENDIX C. PHOTO POINTS

The Mount Hood National Forest's partners at The Freshwater Trust took the lead on providing photo documentation for restoration actions. Photo points were taken both before and after restoration at key locations throughout the restoration project areas. In general, photos were taken within one month before, and one month after, restoration. This portion of the report presents a selected number of photos that emphasize the creation of wood structures, the opening of side channels, and the formation of pools.



### Cabins Project Area

*Figure C1. Constructed jam on river right in the Cabins project area. The photos are taken looking across the main channel.*



### Cabins Project Area

*Figure C2. Enhanced large wood structure in the Cabins project area. The photos are taken looking across the main channel.*





Pre Restoration - July 2017



Post Restoration - September 2017

#### Cabins Project Area

*Figure C3. Newly excavated side channel inlet re-activating a large floodplain area in the Middle Cabins project area. The photos are taken facing downstream.*



Pre Restoration - July 2013



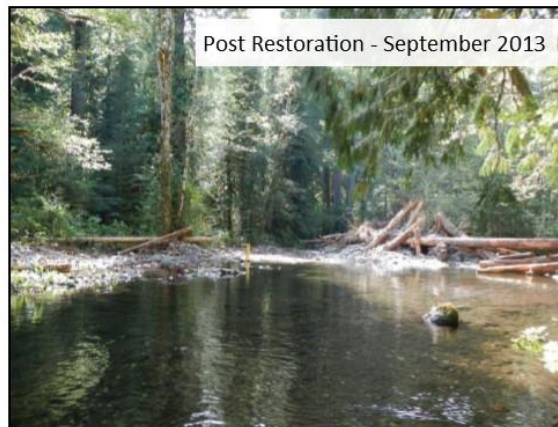
Post Restoration - September 2013

#### Straights Project Area

*Figure C4. Channel spanning jam restoration structure in the Straights project area, before and after restoration. The photos are facing upstream.*



Pre Restoration - July 2013



Post Restoration - September 2013

#### Straights Project Area

*Figure C5. Channel spanning jam restoration structure in the Straights project area, before and after restoration. The photos are facing downstream.*





Pre Restoration - July 2013



Post Restoration - September 2013

#### Compression Project Area

*Figure C6. Restoration jam created in the Compression project area constructed in 2015. The photos are taken looking up-stream.*



Pre Restoration - July 2013



Post Restoration - September 2013

#### Compression Project Area

*Figure C7. Reactivated side channel in the Compression project area. The photos are taken looking downstream.*



Pre Restoration - July 2015



Post Restoration - September 2015

#### Mars Attacks Project Area

*Figure C8. Restoration jam and excavated side channel created in the Mars Attacks project area constructed in 2015. The photos are taken looking upstream.*





Pre Restoration - July 2015



Post Restoration - September 2015

#### Mars Attacks Project Area

*Figure C9. Restoration jam and excavated side channel created in the Mars Attacks project area constructed in 2015. The photos are taken looking downstream.*



Pre Restoration - July 2015



Post Restoration - September 2015

#### Elder Growth Project Area

*Figure C10. Restoration jam created in the Elder Growth project area constructed in 2015. The photos are taken looking downstream.*



Pre Restoration - July 2015



Post Restoration - September 2015

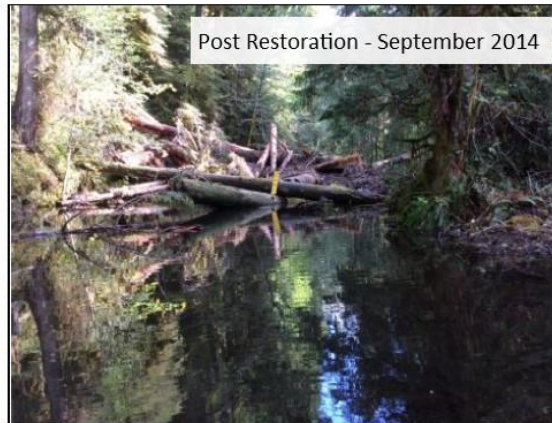
#### Elder Growth Project Area

*Figure C11. Restoration jam created in the Elder Growth project area constructed in 2015. The photos are taken looking downstream.*





Pre Restoration - July 2014



Post Restoration - September 2014

#### Pumpkin Patch Project Area

*Figure C12. Enhanced log jam in the Pumpkin Patch project area. The photos are taken looking upstream.*



Pre Restoration - July 2014



Post Restoration - September 2014

#### Pumpkin Patch Project Area

*Figure C13. Reactivated side channel in the Pumpkin Patch project area. The photos are taken looking upstream.*



Pre Restoration - July 2014



Post Restoration - September 2014

#### Pumpkin Patch Project Area

*Figure C14. Reactivated side channel in the Pumpkin Patch project area. The photos are taken looking downstream.*





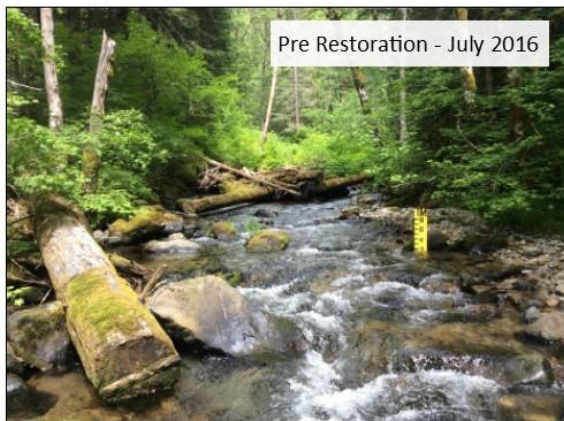
Pre Restoration - July 2017



Post Restoration - September 2017

#### Canyon Project Area

*Figure C15* Reactivated side channel, island jam, and rehabilitated dispersed camping site in the Canyons project area. The photos are taken looking downstream.



Pre Restoration - July 2016



Post Restoration - September 2016

#### Headwaters Nirvana Project Area

*Figure C16.* Trees cabled over in the Headwaters Nirvana project area. The photos are taken looking upstream.



Pre Restoration - July 2016



Post Restoration - September 2016

#### Headwaters Nirvana Project Area

*Figure C17.* A jam formed as a result of cabled over trees in the Headwaters Nirvana project area. The photos are taken looking downstream.