APPENDIX A

Lower Libby Creek
Stream Habitat Assessment
River Mile 0 to 1.4

Survey: September 2011

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1 Introduction

Libby Creek is located in Okanogan County, Washington. It is a tributary to the Methow River that enters the Methow at river mile (RM) 26.5, near the unincorporated community of Carlton. A habitat survey was conducted along lower Libby Creek from RM 0 to approximately RM 1.4 on September 22 and 23, 2011 (Figure 1). There is no streamflow data available for Libby Creek; however, an average annual flow of 18 cfs has been estimated by WDFW (2011). On the Twisp River, a larger Methow tributary located further upstream in the basin, streamflow during the survey period ranged between 60 to 63 cfs (USGS Gage #12448998).

The objective of the Habitat Assessment is to characterize the habitat quantity and quality for salmonid species native to Libby Creek by quantifying in-channel morphologic features, qualitatively describing riparian conditions, and identifying anthropogenic features influencing aquatic habitat. This information is used to inform potential restoration/preservation actions and will provide a baseline for evaluating future habitat trends and for measuring the effectiveness of restoration efforts.

Spring Chinook, summer Chinook, reintroduced coho, summer steelhead, rainbow trout, bull trout, and westslope cutthroat trout are salmonid species found throughout the Methow Valley that potentially utilize Libby Creek for some portion of their life history. Libby Creek was given an “average” score for fish status and utilization in a recent Columbia River Instream Atlas Report for the Methow Basin (WDFW 2011). In this report, seven fish stocks limit their utilization to juvenile rearing only. One exception to this utilization is summer steelhead, which use Libby Creek for spawning, juvenile migration, and juvenile and adult rearing (WDFW 2011). Throughout the Methow Basin, wild summer steelhead currently sustain themselves only at a threshold population size (NW Councils 2004). Steelhead were listed as Endangered under the ESA on August 18, 1997 but were upgraded to Threatened on January 5, 2006.

In general, fish habitat in lower Libby Creek is limited by anthropogenic impacts including road building, land clearing, agriculture, and development. These activities have resulted in channel confinement, bank armoring, channel simplification, and reduced quantities of large woody debris (LWD). The results of this assessment highlight habitat deficiencies by reach and are intended to provide information for establishing objectives and performance targets to guide restoration and preservation activities.

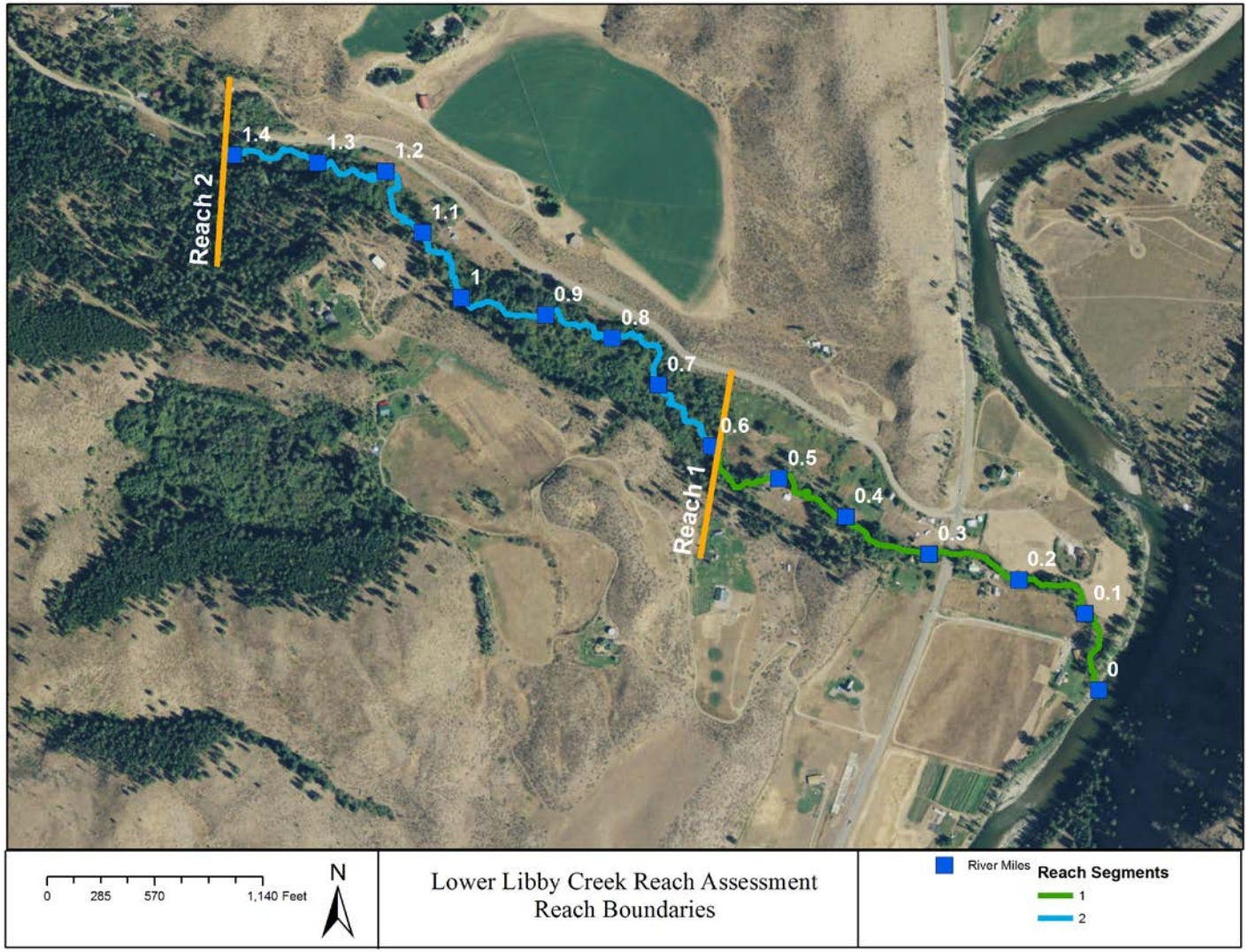


Figure 1. Locator map of the Habitat Assessment area showing the habitat survey reaches used in the assessment.

2 Methods

Two geomorphic reaches have been delineated as part of the reach assessment. These same reaches were used for both the stream habitat assessment and geomorphology assessment to maintain consistency for this and future inventories. Data collected in this survey is intended to compliment preexisting data for the Methow Basin.

Field methods for the habitat survey used the USFS Region 6 Level II Stream Survey Protocol Version 2.6 (USDA Forest Service 2006). A modification was made to the protocol with respect to the nth unit measurement frequency. The protocol indicates that nth unit measurements should occur at no less than a 10% sampling frequency with a minimum of 10 nth unit samples of each unit type per reach. Due to long habitat units relative to reach length, this would have required the measurement of more nth units than was possible given time constraints. As a compromise, the minimum nth unit sampling frequency was increased to 20% with no minimum number of nth units per reach.

Following the Level II Stream Survey Protocol, we compared the ocular (visual) estimates of wetted width performed for every unit with the measured values at nth units in order to determine if correction of the ocular estimates was necessary. The average difference between the actual and ocular values was 3.1 feet. As a result, ocular estimates were not corrected and are considered generally accurate to within +/- 5 feet.

Visual (ocular) estimates of bed sediment composition (considered a “forest option” in the USFS protocol) were recorded for every fast water unit (i.e. riffles and glides). Wolman (1952) pebble counts were recorded at 2 representative riffles per reach. Riparian vegetation was quantified by percent total of riparian inner zones and riparian outer zones for each unit. Additionally, the length of unstable banks were visually estimated for every unit in the study area.

3 Summary of Results

This section summarizes the results across both reaches. Detailed reach summaries with reach-specific results are included in Section 5.

3.2 Channel Morphology

Lower Libby Creek reaches were dominated by pool-riffle morphology. Channel bed substrate consisted primarily of gravel and cobble, with a high frequency of sand. Boulders and bedrock were rarely observed.

Bankfull widths did not vary substantially between stream reaches but did decrease in the downstream direction. This may be attributed to a large degree of artificial channel confinement that affects stream width in scattered locations throughout the study area. Mean bankfull widths were 27.8 feet (stdev 8.3ft). Bankfull depths varied only slightly between reaches. Mean bankfull depth was 2.3 feet (stdev 0.3ft). Mean floodprone widths for Reach 1 and 2 ranged from 174 to 206 feet.

3.3 Habitat Unit Composition

Riffles were the dominant habitat unit type, making up 80% of the total habitat area. Pools and glides comprised approximately 12% and 8% of the total habitat area, respectively. Side-channel habitat was less than 0.5% of the survey area (Figure 2).

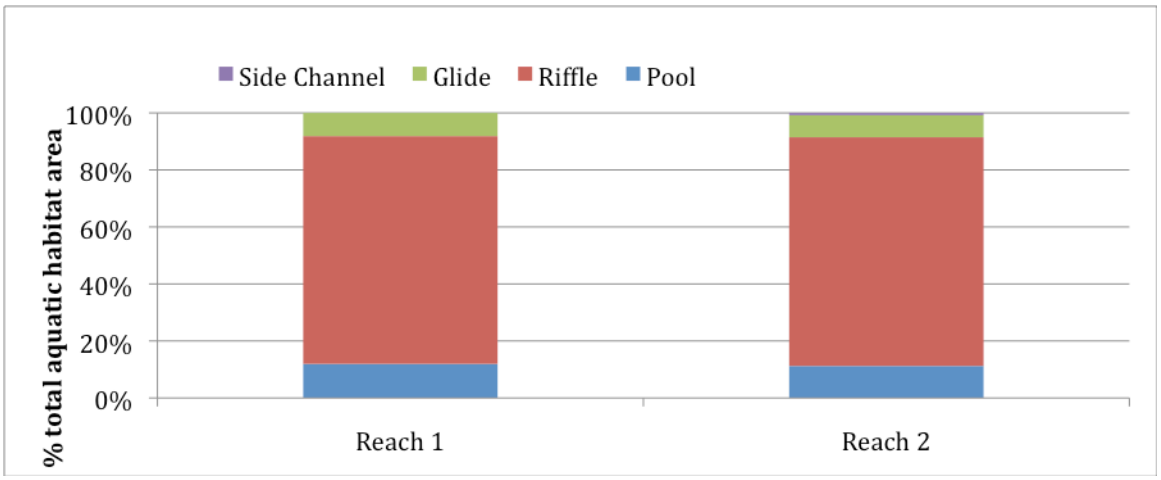


Figure 2. Proportion of habitat types in Reaches 1 and 2 in lower Libby Creek.

Pool frequency ranged from 20.1 to 21.5 pools/mile, with mean pool spacing of 16.6 to 19.0 channel widths per pool. Both reaches had nearly identical habitat unit composition, with the exception of two side-channels in Reach 2. Reach 1 had a slightly greater proportion of pool habitat due to the presence of both scour and plunge pools, whereas Reach 2 was dominated by short plunge pools. Reach 2 had a slightly greater number of deep pools, with one residual depth exceeding 3 feet. The majority of the pools throughout the study area were relatively shallow, with residual depths of 1-2 feet (77% of the pools).

Mean wetted width was 14.5 feet (stdev 5.1ft) for the survey area. Mean riffle depths were 0.7 feet (stdev 0.2ft) with mean maximum depths of 1.3 feet (stdev 0.4 ft). Shallow riffle depths can limit adult salmonid passage. Minimum depths of 0.8 feet and 0.6 feet have been reported as necessary to maintain adult Chinook and steelhead passage, respectively (Thompson 1972). However, steelhead adults likely migrate during periods of higher water than was observed during the survey.

Average unit lengths for the three habitat types (pools, riffles, and glides) are presented in Figure 3. Reach 1 had slightly longer pools, as they are predominately scour pools versus the plunge pools that dominate Reach 2. Reach 2 had longer riffles and slightly longer glides.

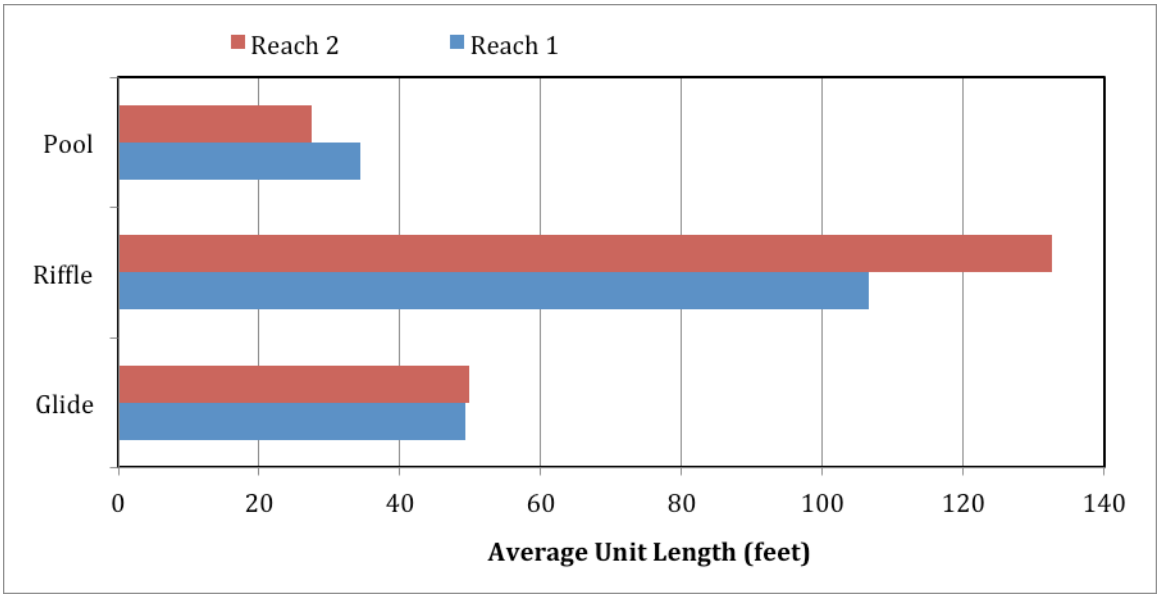


Figure 3. Comparison of average habitat unit lengths for Reaches 1 and 2 in lower Libby Creek.

3.4 Off-Channel Habitat

Side-channel habitat accounted for approximately 0.4% of the surveyed length along the lower 1.4 miles of Libby Creek (Figure 2). A total of 2 wetted side-channels were measured during the survey, both within Reach 2. An abandoned irrigation diversion in Reach 2 was not included in this count, as no active flow was observed at the time of the survey. Reach 2 had one side-channel pool and one side-channel riffle. The side-channel pool occupied a greater area than the side-channel riffle.

Artificial confinement significantly limited off channel habitat in Reach 1, which was at an "unacceptable risk" level based on thresholds from USFWS (1998). Reach 2 was moderately confined by both natural and artificial means. In addition to side-channels, Reach 2 had two groundwater springs (Tributary 1 and 2) and one slope wetland that have the potential to develop into off channel refuge and rearing habitat. Reach 2 is connected to a narrow floodplain for the majority of the reach.

3.5 Large Wood

A total of 268 pieces of wood were counted in lower Libby Creek, with an average of 211 pieces of wood per mile. Of these, 63% of these were "small" pieces with diameters between 6 and 12 inches and lengths greater than 20 feet (Figure 4). Reach 1 had the highest number of "large" pieces per mile (41), compared to 11 large pieces per mile in Reach 2. Large pieces were often stabilizing jams with numerous small, medium, and uncountable (too small) pieces that formed the total volume of complex woody structures. However, there were very few pieces that would meet the criteria for "key" pieces as defined by Schuett-Hames et. al. (1999).

The total number of wood pieces counted was 104 in Reach 1 and 164 in Reach 2. The average

wood frequency in lower Libby Creek (both reaches combined) was 211 pieces/mile. As a reference, median wood loading on "undisturbed" streams of comparable size in the Douglas-Fir/ponderosa pine forest zones in Washington State is 274 pieces/mile (Fox and Bolton 2007). When making these comparisons, it should be noted that the size criteria for large wood used by Fox and Bolton (2007) is based on the WA State Timber Fish & Wildlife criteria, which is smaller (4 inches diameter and 6.6 feet long) than the size criteria used for the USFS Level II surveys (6 inches diameter and 20 feet long).

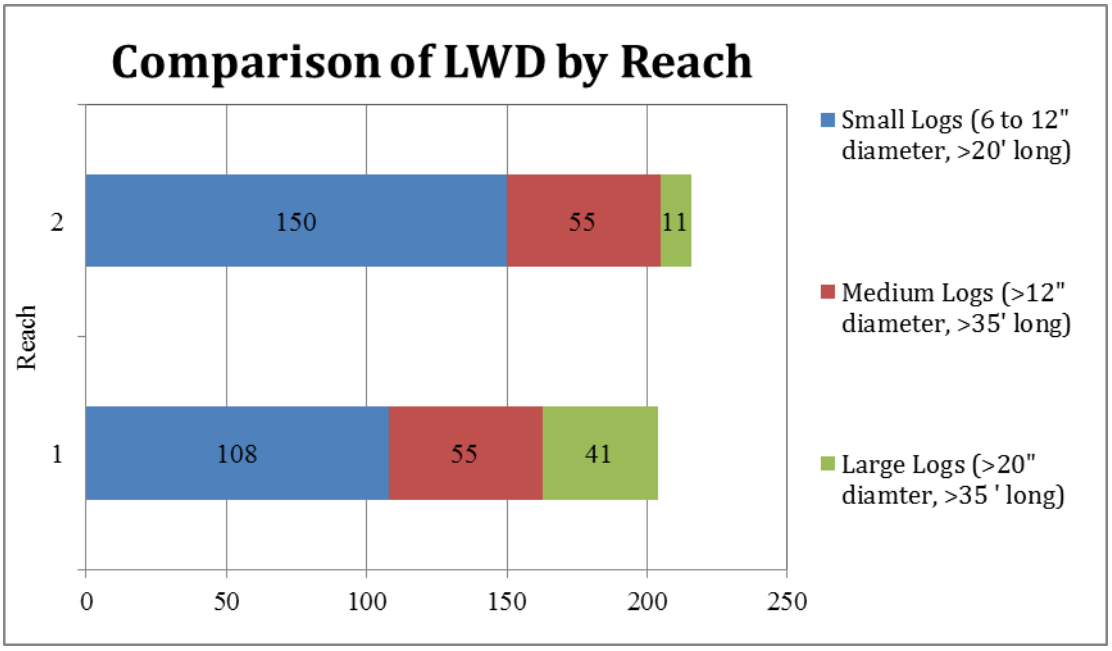


Figure 4. Small and medium/large wood pieces/mile for each reach.

3.6 Substrate and Fine Sediment

Bed substrate was based on ocular estimates at each fast water unit and pebble counts at two representative riffle locations within each of the two reaches. Pebble counts suggested that ocular estimates in Reach 1 slightly underestimated sand and gravel, and slightly underestimated gravel in Reach 2 (Figure 5).

Gravels and cobbles were dominant in lower Libby Creek, with sand a subdominant substrate type (Figure 5 and Figure 6). Boulders were observed infrequently and were more common in riffle habitat towards the upstream end of the survey area. Bedrock was rare and was only observed in two riffles in Reach 2. Generally, Reach 1 had smaller bed substrate than Reach 2.

Sediment measurements indicated that the presence of fine sediment (<2mm) was moderate and on the border of being a concern in the study area. Generally, bed substrate was composed of more than 12% sand.

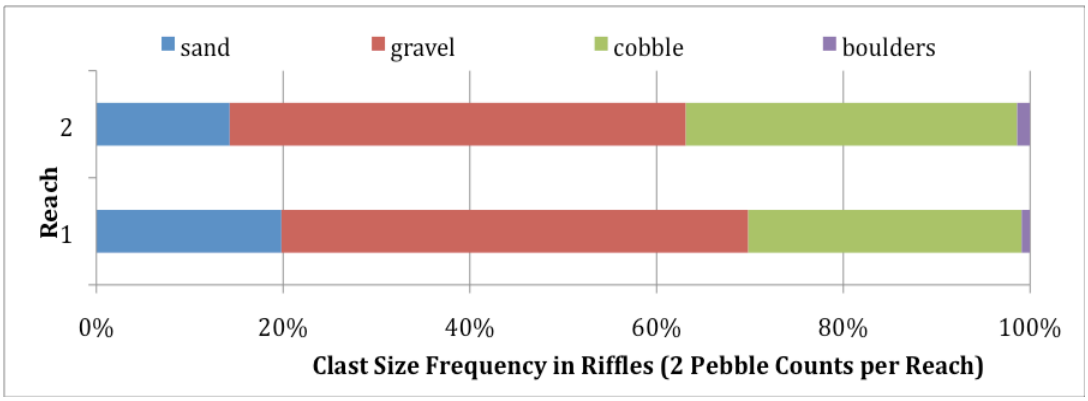


Figure 5. Pebble count classification of substrate by reach for lower Libby Creek (frequency values are derived by pooling the 2 pebble counts per reach).

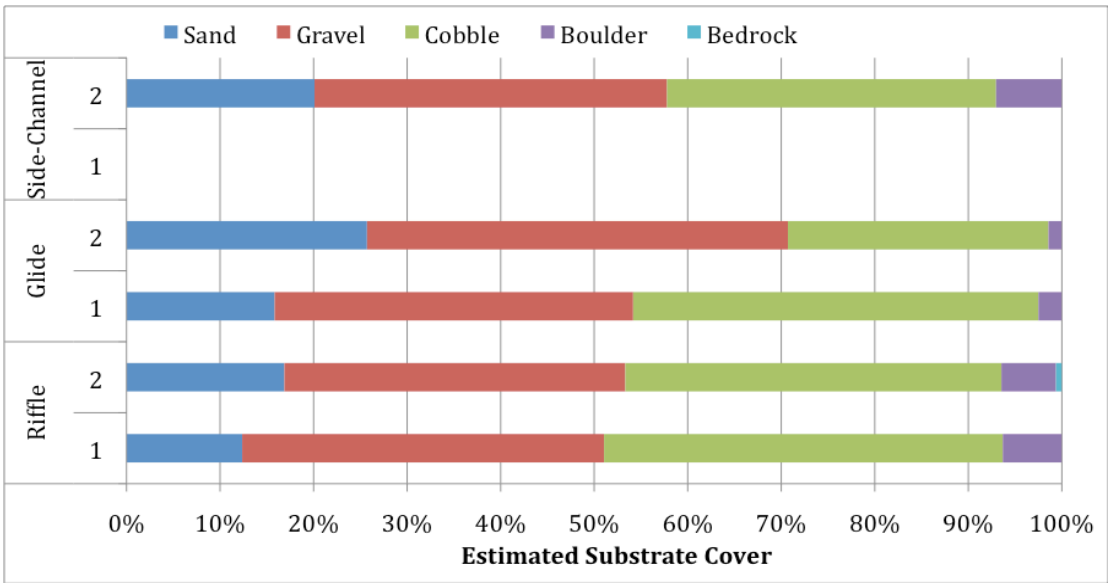


Figure 6. Ocular estimates of substrate by habitat unit type and reach for lower Libby Creek.

3.7 Instability and Disturbance

There was moderate human disturbance to the channel, riparian corridor, and floodplains throughout lower Libby Creek. These alterations are related to past and ongoing land-uses including timber harvest, gravel mining, agricultural use of floodplains, road building, and residential development. Artificial channel confinement in the form of bridges, floodplain fill, irrigation diversions, and bank armoring affects channel and floodplain dynamics within the study area.

Bank instability was present near areas affected by human disturbance and channel confinement.

In total, 7% of the streambanks (373 feet) along Reach 1 were actively eroding. Erosion and instability in this reach has primarily been caused by bank armoring or large wood accumulations that transfer stream energy into streambanks.

Reach 2 bank erosion was higher with a total of 11% of the mainstem streambanks (905 feet) showing signs of active erosion (Figure 7). Erosion in this reach can be attributed to natural conditions as well as land uses including livestock grazing. Eroded areas were characterized by loam soils with fewer instances of cobble banks than was observed in Reach 1.

Bank erosion occurred in all habitat types; however, it was most frequently observed in riffle and glide habitats (Figure 8). In portions of Reach 1, streambank erosion is limited by the presence of riprap armoring near residential development. Plywood riprap lines a small (10 feet) section in Reach 2 near an abandoned irrigation diversion along river-right.

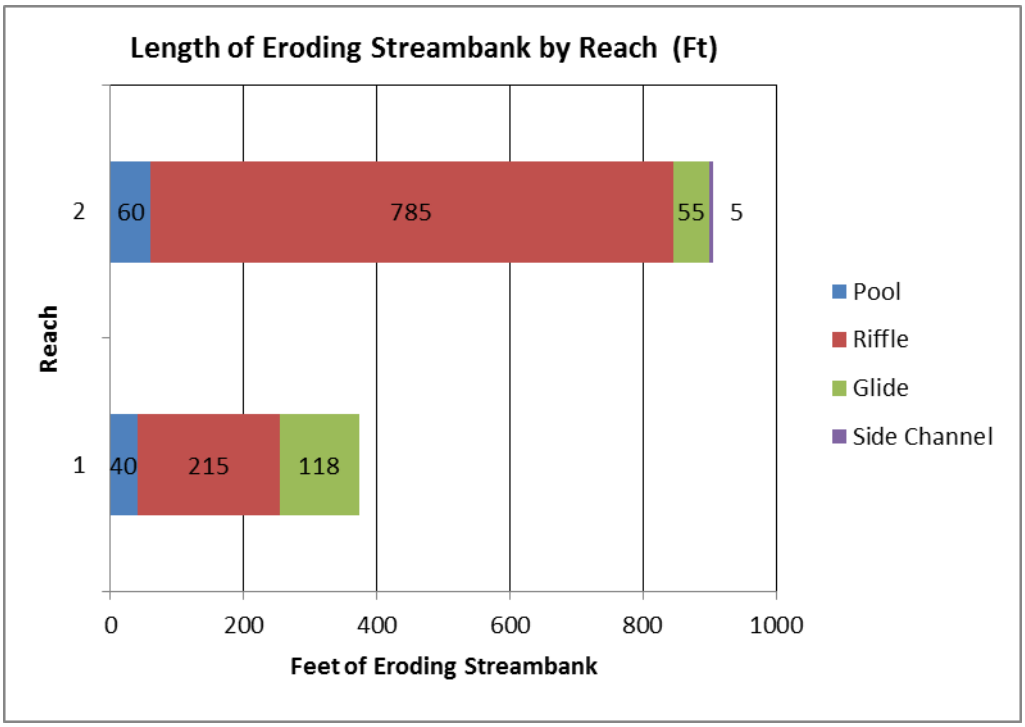


Figure 7. Length of bank erosion by habitat type and reach along lower Libby Creek.

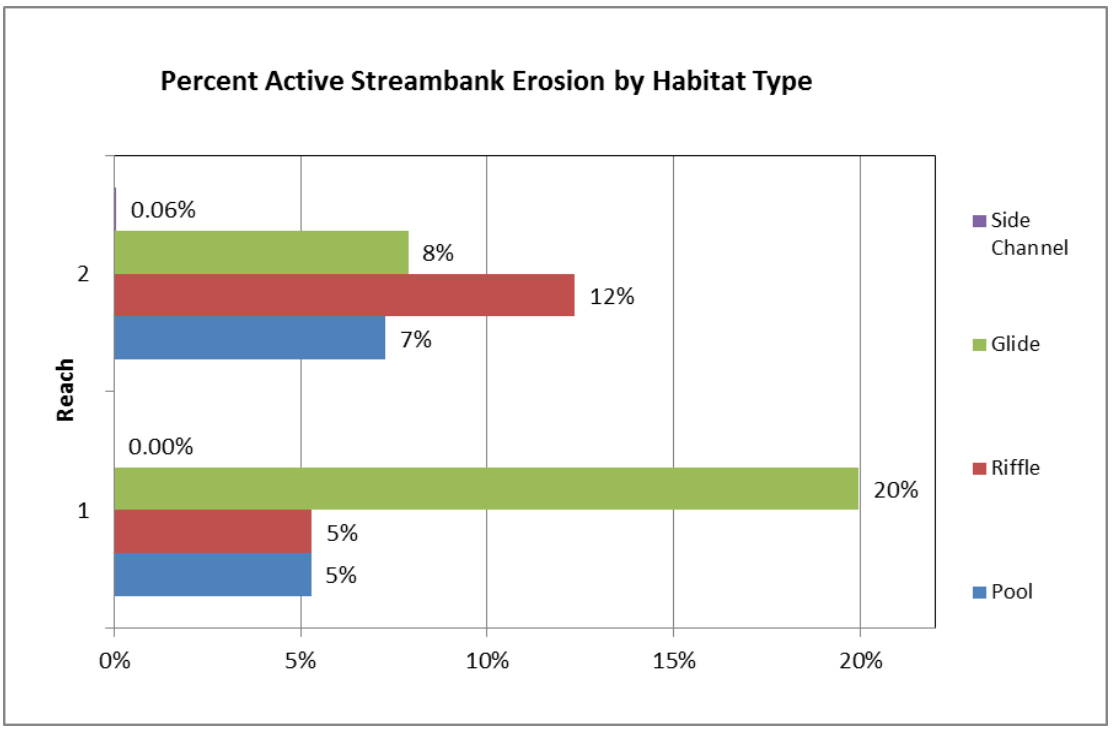


Figure 8. Percent active erosion of each habitat type along lower Libby Creek.

3.8 Fish Passage Barriers

There were no significant fish passage barriers in the study area. Adult passage may be challenging near a series of channel spanning rock weirs in Reach 1 and throughout the entire survey area during periods of low flow. Beaver dams and plunge pools throughout both reaches have the potential to challenge upstream migration for juvenile fish.

3.9 Riparian Corridor

Survey methods dictate defining a dominant size class of vegetation (e.g. large trees, small trees, shrubs, etc) for the inner and outer zones, then defining the dominant species observed in the over and understory within both the inner and outer zones.

Riparian inner zones were typically dominated by small trees (54% of units) or shrubs (27% of units); large trees were dominant in only 12% of units (Figure 9). Outer zones were typically dominated by shrubs (48%) or grass/forbs (26%). Small trees dominated 16% and large trees dominated only 10% of units. Many of the outer zones were within areas that had been cleared for agricultural or residential uses.

The species composition of riparian areas was dominated by deciduous species (Figure 10). The inner zone understory was typically dogwood or grass/forbs. The inner zone overstory was typically either cottonwood, dogwood, alder, or birch. The outer zone understory was typically grass/forbs but the overstory varied considerably.

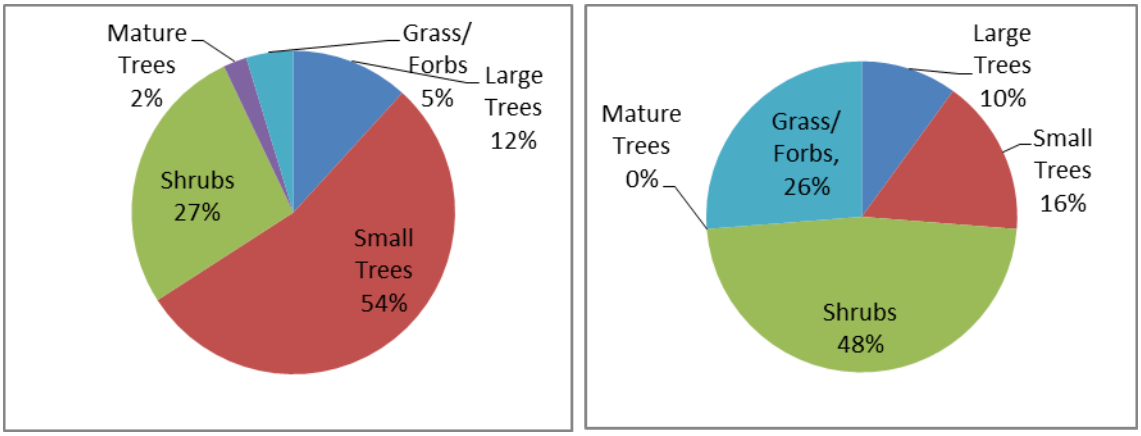


Figure 9. Libby Creek Inner Zone Distribution (left) and Outer Zone Distribution (right) of the dominant diameter class category for the riparian zones in lower Libby Creek (RM 0.0 to RM 1.3).

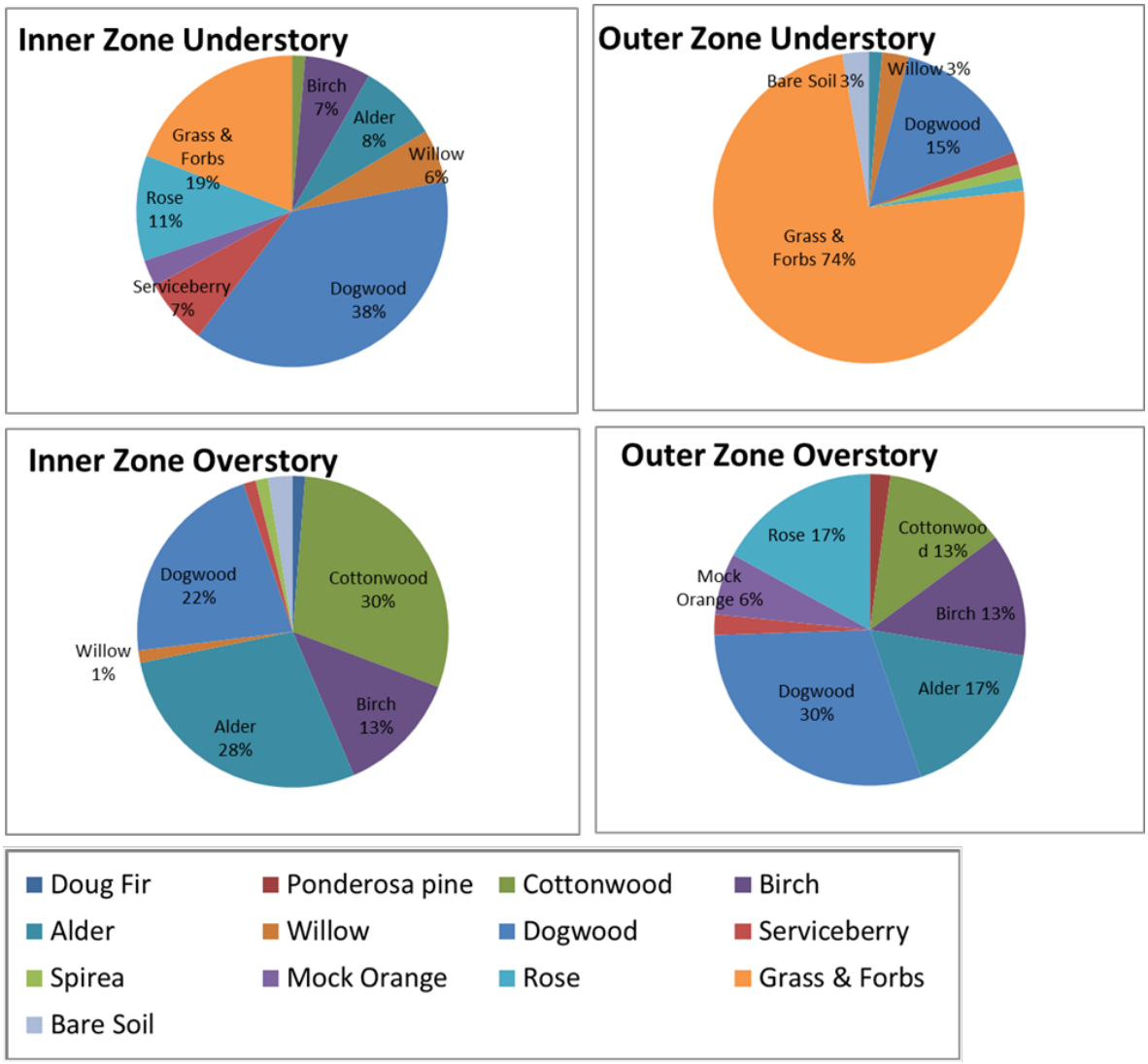


Figure 10. Proportions of vegetation cover in lower Libby Creek. The dominant species of grasses and forbs were not determined, however curly dock, Canada thistle, burdock, slough sedge, nettles and reed canary grass were observed.

4 Summary Data Tables

Libby Creek Data Summary: RM 0 to RM 1.4.

		Total	**Reach 1**	**Reach 2**
Reach Mileage Boundaries		0 – 1.4	0 – 0.6	0.6 – 1.4
Channel Morphology			Pool-riffle	Pool-riffle
Slope			2.11%	2.95%
Wetted Width (ft)				
Pool				
	Mean	15.4	14.8	15.8
	Median	15.5	16.0	15.0
	StDev	5.5	5.2	5.9
Riffle				
	Mean	15.0	16.8	13.6
	Median	14.0	16.0	12.5
	StDev	4.6	4.6	4.1
Glide				
	Mean	12.4	12.8	12.0
	Median	11.0	13.0	11.0
	StDev	4.5	5.5	3.8
Water Depth (ft)				
Pool Maximum Depth (ft)				
	Mean	2.4	2.4	2.5
	Median	2.3	2.3	2.3
	StDev	0.5	0.4	0.6
Pool Residual Depth (ft)				
	Mean	1.6	1.4	1.7
	Median	1.5	1.2	1.6
	StDev	0.6	0.5	0.6
Maximum Riffle Depth				
	Mean	1.3	1.2	1.4
	Median	1.2	1.1	1.3
	StDev	0.4	0.4	0.5
Average Riffle Depth				
	Mean	0.7	0.7	0.6
	Median	0.6	0.7	0.6
	StDev	0.2	0.2	0.2

Reach Mileage Boundaries		**Total** 0 – 1.4	**Reach 1** 0 – 0.6	**Reach 2** 0.6 – 1.4
Maximum Glide Depth				
	Mean	1.7	1.8	1.7
	Median	1.8	1.8	1.8
	StDev	0.3	0.2	0.3
Average Glide Depth				
	Mean	0.9	0.9	0.9
	Median	0.9	1.0	0.9
	StDev	0.2	0.2	0.1
Bankfull Characteristics				
Width (ft)				
	Mean	27.8	22.6	31.6
	StDev	8.3	8.6	6.0
Depth (ft) Averaged over 3 depth measurements				
	Mean	2.3	2.2	2.3
	StDev	0.3	0.3	0.3
Maximum Depth (ft)				
	Mean	3.0	2.8	3.2
	StDev	0.6	0.3	0.7
Width:Depth Ratio				
	Mean	12.6	10.5	14.1
	StDev	4.4	4.1	4.2
Floodprone Width (ft)				
	Mean	192.5	174	205.7
	StDev	110.5	138.5	95.4
Habitat Area %				
Pool		12%	12%	11%
Riffle		80%	80%	80%
Glide		8%	8%	8%
Side Channel		0%	0%	1%
Pools				
Pools per Mile		20.7	21.5	20.1
Residual Depth (% of pools)				
	Pools < 1 ft	4%	9%	0%
	Pools 1-2 ft	77%	73%	80%
	Pools 2-3 ft	15%	18%	13%
	Pools > 3 ft	4%	0%	7%
Riffle:Pool Ratio		1.7	1.7	1.6

Reach Mileage Boundaries		**Total** 0 – 1.4	**Reach 1** 0 – 0.6	**Reach 2** 0.6 – 1.4
Mean Pool Spacing (channel widths per pool)		17.9	16.6	19.0
Large Wood				
Number Pieces				
	Totals	268	104	164
	Small (6 in x 20 ft)	169	55	114
	Medium (12 in x 35 ft)	70	28	42
	Large (20 in by 35 ft)	29	21	8
Number of Pieces/Mile				
	Totals	211	204	216
	Small (6 in x 20 ft)	258	108	150
	Medium (12 in x 35 ft)	110	55	55
	Large (20 in by 35 ft)	52	41	11
Bank Erosion (% eroding banks)				
	Totals	10%	7%	11%
	Pool	6%	5%	7%
	Riffle	10%	5%	12%
	Glide	13%	20%	8%
	Side Channel Pools	0%		0%
	Side Channel Riffles	0%		0%
Substrate (Ocular Estimate)				
Total				
	% Sand	17%	13%	19%
	% Gravel	38%	39%	38%
	% Cobble	40%	43%	37%
	% Boulder	5%	5%	5%
	% Bedrock	0%	0%	1%
Riffle				
	% Sand	15%	12%	17%
	% Gravel	37%	39%	36%
	% Cobble	41%	43%	40%
	% Boulder	6%	6%	6%
	% Bedrock	0%	0%	1%
Glide				
	% Sand	21%	16%	26%
	% Gravel	42%	38%	45%
	% Cobble	35%	43%	28%
	% Boulder	2%	3%	1%

Reach Mileage Boundaries		**Total** 0 – 1.4	**Reach 1** 0 – 0.6	**Reach 2** 0.6 – 1.4
	% Bedrock	0%	0%	0%
Side Channel Pools				
	% Sand	10%		10%
	% Gravel	35%		35%
	% Cobble	45%		45%
	% Boulder	10%		10%
	% Bedrock	0%		0%
Side Channel Riffles				
	% Sand	30%		30%
	% Gravel	40%		40%
	% Cobble	25%		25%
	% Boulder	5%		5%
	% Bedrock	0%		0%
Riffle Pebble Count (*2 pebble counts per reach*)				
	% Sand	17%	20%	14%
	% Gravel	49%	50%	49%
	% Cobble	32%	29%	35%
	% Boulder	1%	1%	1%
	% Bedrock	0%	0%	0%
Vegetation (% of sampled units)				
Riparian Inner Zone				
	Grass/Forbs	5%	3%	6%
	Shrubs	27%	25%	29%
	Small trees	54%	56%	53%
	Large trees	12%	11%	12%
	Mature Trees	2%	6%	0%
Riparian Outer Zone				
	Grass/Forbs	26%	34%	19%
	Shrubs	48%	54%	43%
	Small trees	16%	6%	26%
	Large trees	10%	6%	13%
	Mature Trees	0%	0%	0%

5 Reach Reports

5.2 Reach 1

Location: River mile 0 to River mile 0.6

Survey Date: September 22, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

*A staff gage and PIT Tag antenna are located upstream of the Hwy 153 Bridge (RM 0.3).

5.2.1 Reach Overview

Reach 1 is located on the Libby Creek alluvial fan as it enters the lower Methow River valley. The confluence with the Methow River is on the river-right bank at RM 26.5. The reach extends from Libby Creek RM 0 to RM 0.6, flowing under Highway 153 and through residential, agricultural and livestock grazing lands. There is considerable habitat alteration and human infrastructure in the reach, including houses, hobby farms, horse fords, roads, bank armoring, and grade control structures (rock weirs) (Figure 11 and Figure 12). These alterations have confined Reach 1 to a narrow riparian corridor with little canopy cover and no off-channel habitat.

Figure 11. Bank armoring and scour along lower Libby Creek (September 2011).

Figure 12. Habitat alteration and channel confinement at the Hwy 153 Bridge (RM 0.3).

5.2.2 Channel Morphology

Reach 1 is located on the Libby Creek alluvial fan as it enters the lower Methow River valley. Just upstream of the confluence, Libby Creek forks into a short braided riffle that flows out of a beaver-dammed pool (Figure 13 and Figure 14). Young willows grow along the alluvial deposit with small woody debris accumulating throughout the delta.

The reach has a moderate gradient (2.11%) and the valley is moderately confined by residential and agricultural land uses. The stream itself is channelized and artificially confined due to human alterations. The channel type is pool-riffle.

The historical natural depositional environment in this reach has been impacted by development in and around the agricultural community of Carlton, including bank armoring, roadways, and bridges. Due to artificial confinement, bed material is transported more readily through this reach than would have been expected under historical conditions.

Figure 13. Confluence of Libby Creek looking downstream towards the Methow River. Young willows are growing along the alluvial deposits (September 2011).

Figure 14. Looking upstream from the mouth of Libby Creek at a beaver-dammed pool (September 2011).

5.2.3 Habitat Unit Composition

Reach 1 consisted of 12% pools, 80% riffles, 8% glides, and 0% side-channels (Figure 15 and Figure 16). Pool frequency was 21.5 pools per mile, with mean pool spacing of 16.6 channel widths per pool. Reach 1 had slightly more pools per mile than Reach 2. Reach 1 would be

considered "functioning at risk" with respect to pool spacing based on USFWS (1998). Average residual pool depth was 1.4 feet. Average maximum pool depth was 2.4 feet. Scour pools were the dominant pool type (e.g. Figure 17).

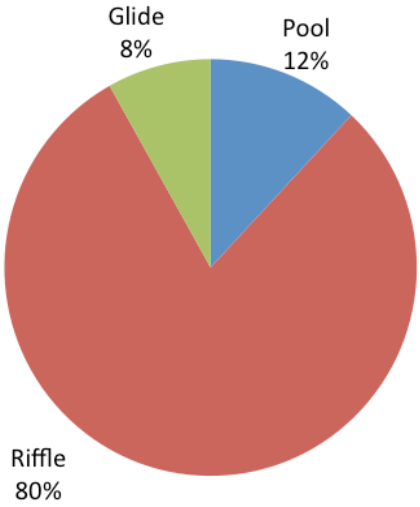


Figure 15. Habitat unit composition for Reach 1.

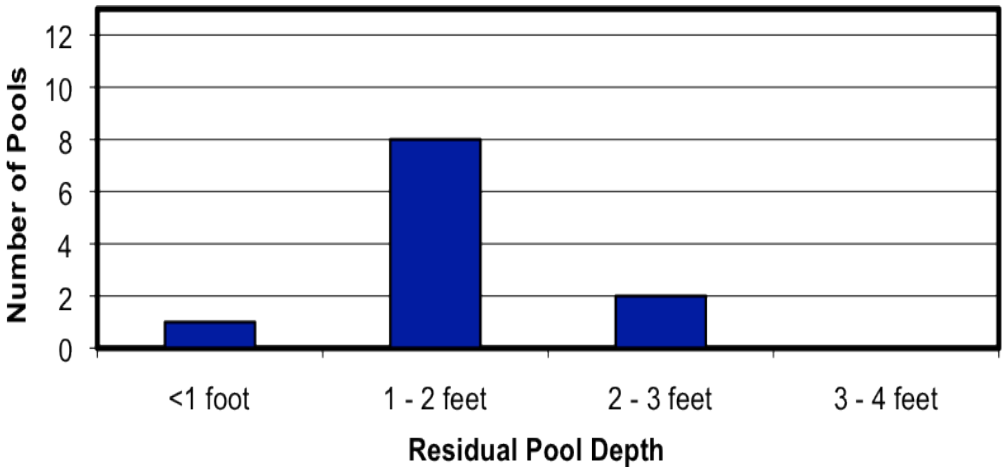


Figure 16. Reach 1 residual pool depths.

Figure 17. Scour pool near the mouth of Libby Creek. This is a representative slow water unit (pool) observed in Reach 1 (September 2011).

5.2.4 Off-Channel Habitat

No side channels were observed in Reach 1. Artificial confinement, bank armoring, and fill prevent access to off-channel and floodplain habitats. Reach 1 likely had high historical off-channel complexity that has been severely reduced as a result of land uses.

5.2.5 Large Woody Debris

Wood plays a moderate role in Reach 1, including sediment sorting, habitat cover, and channel complexity (Table 1 and Figure 18). The number of LWD pieces in Reach 1 was higher than in Reach 2. LWD frequency was 104 pieces/mile, with "large" pieces comprising 20% of all LWD in the reach. "Medium" wood pieces accounted for 27% of all LWD in the reach, and "small" pieces accounted for 53%. Black cottonwood is the most abundant species of LWD. Wood quantities averaged 204 pieces per mile in Reach 1, less than the recommended quantities of 274 pieces/mile for median wood loading in unmanaged stream systems of comparable size and type (Fox and Bolton 2007). When making these comparisons, it should be noted that the size criteria for large wood used by Fox and Bolton (2007) is based on the WA State Timber Fish & Wildlife criteria, which is smaller (4 inches diameter and 6.6 feet long) than the size criteria used for the USFS Level II surveys (6 inches diameter and 20 feet long).

The potential for woody debris recruitment is limited in this reach due to bank armoring that limits lateral erosion, past riparian clearing, and use of chicken wire to protect riparian trees from beaver activity.

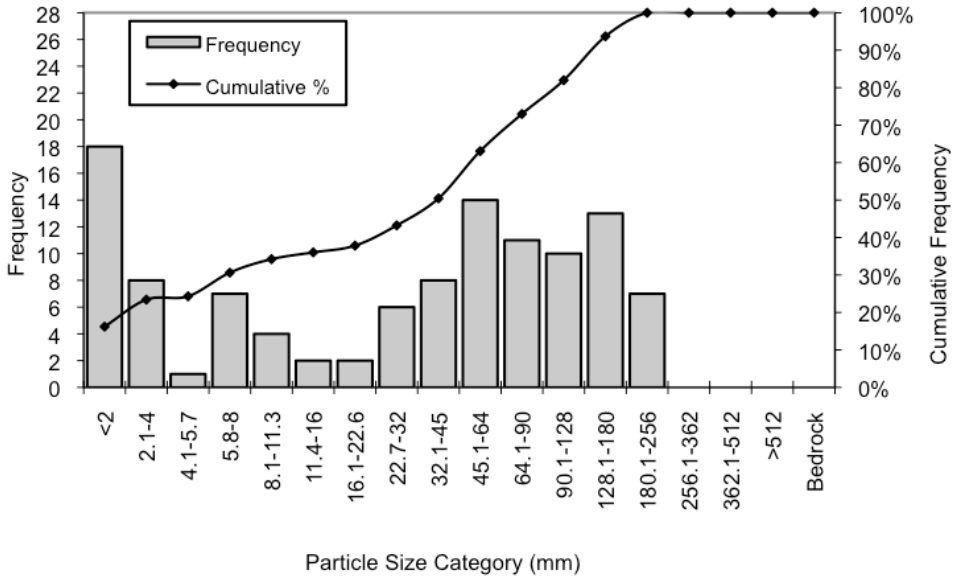
Table 1. Large woody debris quantities in Reach 1.

Reach 1	Small (6 in x 20 ft)	Medium (12in x 35 ft)	Large (20in x 35 ft)	Total
Number of Pieces	55	28	21	104
Number of Pieces/Mile	108	55	41	204

Figure 18. Large woody debris jam in Reach 1 (September 2011).

5.2.6 Substrate and Fine Sediment

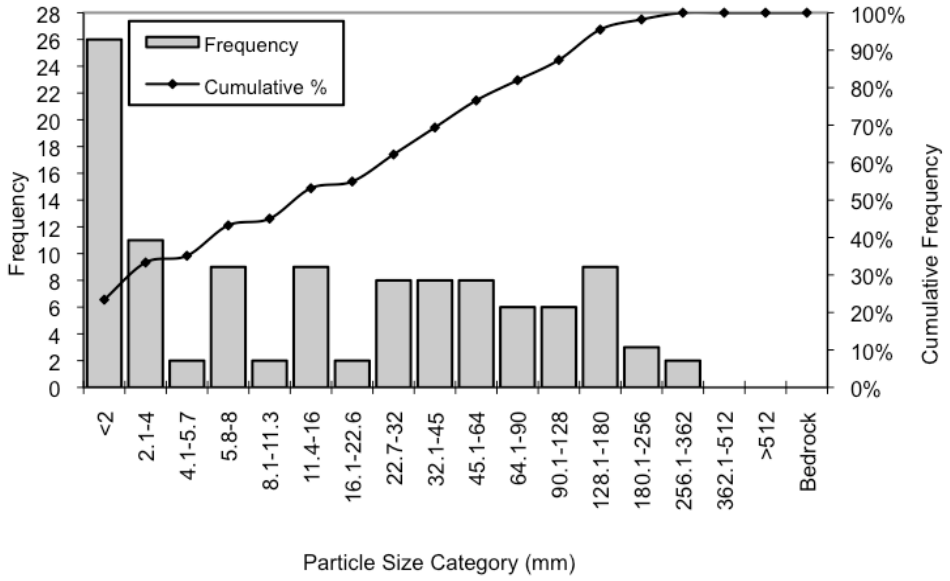
Bed substrate was dominated by gravels and cobbles. Sand was subdominant. No bedrock was observed in Reach 1 and boulders made up no greater than 5% of the distribution. Percent fines (<2mm) were relatively high (13-23%) based on the ocular estimates and pebble counts. Reach 1 would be considered "functioning at risk" with respect to fines in gravel (near areas of spawning and incubation) based on USFWS (1998). The pebble count and size class data are depicted in Figure 19, Figure 20, and Figure 21.



Material	Percent Composition
Sand	16%
Gravel	47%
Cobble	37%
Boulder	0%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	2
D50	44
D84	137
D95	196

Figure 19. Grain size distribution and particle size classes from pebble count taken at RM 0.22.



Material	Percent Composition
Sand	23%
Gravel	53%
Cobble	22%
Boulder	2%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	<2
D50	14
D84	104
D95	177

Figure 20. Grain size distribution and particle size classes from pebble count taken at RM 0.46.

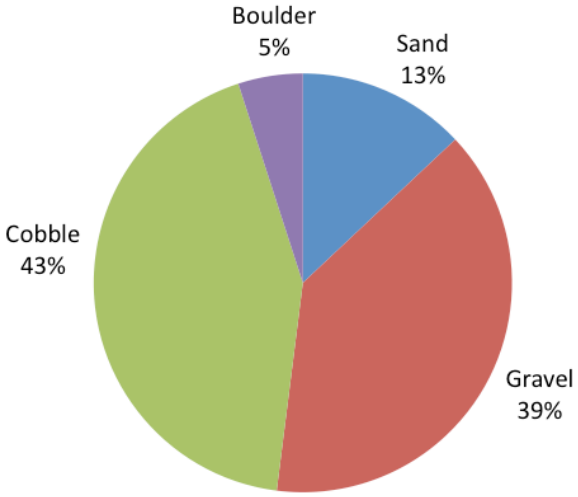


Figure 21. Percent composition of bed substrate based on ocular estimates, Reach 1.

5.2.7 Instability and Disturbance

Human activities have modified the channel, floodplain and riparian corridor in Reach 1. Erosion was minimal, with 7% (373 feet total) of actively eroding streambank measured along both banks (Figure 22). Floodplain connectivity and natural channel processes, including lateral channel dynamics, were limited by residential development, agricultural practices, and bank armoring (Figure 23).

Hwy 153 crosses Libby Creek at RM 0.3. The bridge abutments and adjacent riprap confine the channel, limit meandering, increase water velocities, and contribute to channel incision.

In some areas, bank erosion was associated with a lack of riparian vegetation due to livestock grazing (RM 0.3) and residential development (RM 0.5) (Figure 24). Riparian plantings would help provide natural stability to streambanks and floodplain areas.

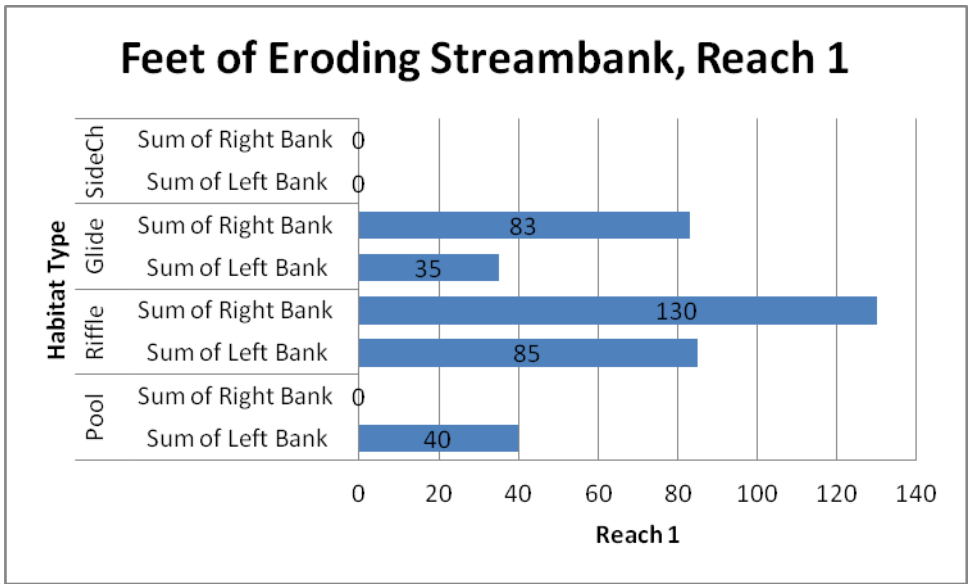


Figure 22. Lineal distance of erosion (above the bankfull channel) according to left or right bank and habitat unit type in Reach 1.

Figure 23. Riprap armoring limits floodplain connectivity and lateral channel dynamics near RM 0.3, Reach 1 (September 2011).

Figure 24. Vegetation clearing and development in the riparian zone near RM 0.5, Reach 1 (September 2011).

5.2.8 Available Spawning and Rearing Habitat

There was minimal spawning and moderate rearing habitat available in Reach 1. Bed substrate was adequately sized, with riffles having 39% gravel and 41% cobble. Gravels and cobbles were embedded with fines in many potential spawning riffles (Figure 25).

Pool quantity and quality was below "functioning adequately" conditions (USFWS 1998) with the reach having shallow residual depths and no pools with residual depths greater than 3 feet.

Canopy cover and riparian vegetation was sparse and limited to a narrow corridor. LWD was below acceptable levels and the short and long-term recruitment potential for woody debris is lacking.

Steelhead and trout primarily use this reach as a migration corridor to access upstream habitat closer to the Okanogan National Forest boundary. WDFW collects PIT (Passive Integrated Transponder) tag data from steelhead and other salmonids migrating through Reach 1 (Bob Jateff, WDFW, personal communication, Oct. 19, 2011). An instream PIT tag detection antenna is located at RM 0.3, just upstream from the Hwy 153 Bridge (Figure 26).

Figure 25. Riffle habitat in Reach 1 with sparse canopy cover and embedded substrate (September 2011).

Figure 26. Instream PIT tag detection antenna in Lower Libby Creek at RM 0.3 (September 2011).

5.2.9 Fish Passage Barriers

Adult passage may be a concern during low flow periods. Mean riffle thalweg depth was 0.7 feet, just under the 0.8-ft threshold cited for spring Chinook by Thompson (1972). A small beaver dam, just upstream of the confluence with the Methow River (Figure 3), may act as a

migration barrier during times of low flow. The beaver dam had a 2-ft difference in water surface elevation that could hinder upstream migration during the summer and fall. At approximately RM 0.35, several channel spanning rock weirs that protect a river-right home and horse ford may prevent the upstream colonization of juvenile fish at times of very low flow (Figure 17).

Figure 27. Rock weirs (located at RM 0.35) may prevent upstream colonization by juvenile fish during low water years (September 2011).

5.2.10 Riparian Corridor

The riparian corridor in Reach 1 was forested, with less diversity of trees and shrubs than upstream reaches. The riparian canopy was comprised primarily of cottonwoods with a smaller amount of young ponderosa pines. Willows were abundant along the streambanks and on cobble bars near the mouth. Shrubs and other herbaceous plants were dominant on the floodplain terrace extending beyond the inner riparian zone.

Small trees were typically dominant within the riparian inner zone (56% of measured units) (Figure 28) and nearly all inner zone areas were dominated by hardwood species including alder, cottonwood, and birch. Riparian outer zone units were typically dominated by shrubs (54% of measured units) including rose, willow, mock orange, and serviceberry. Grass, forbs and other herbaceous plants were abundant throughout the outer zone (34%).

Near the mouth of Libby Creek, mature cottonwoods dominate the riparian zone and understory vegetation was sparse (Figure 29). The riparian overstory in the upper portion of Reach 1 was dominated by small trees (including alder, birch, and cottonwood), yet some areas lack substantial overstory vegetation aside from dense thickets of red-osier dogwood (12-20 ft tall). In other sections, small alders were dominant, providing valuable stream shade and future woody

debris. The floodplain terraces in Reach 1 were primarily unmanaged pasture lands sparsely vegetated with hardwood shrubs or herbaceous vegetation.

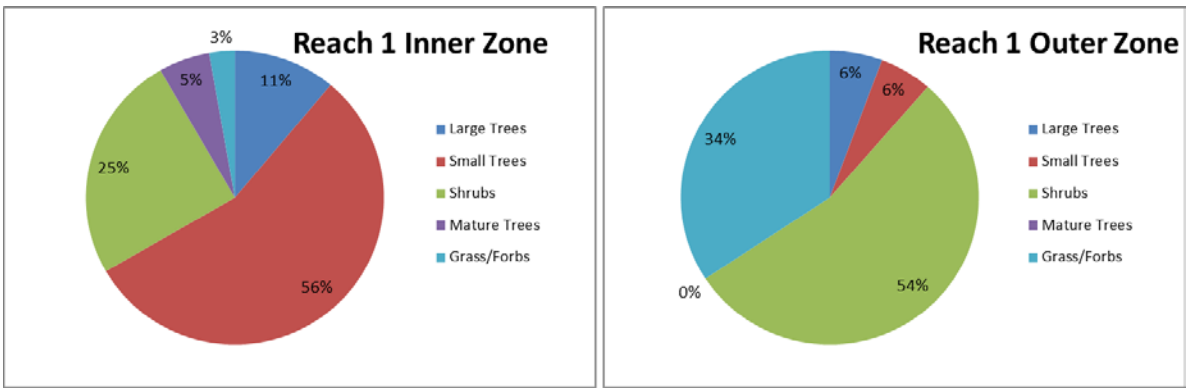


Figure 28. Distribution of vegetation size class categories for the riparian inner and outer zones in Reach 1.

Figure 29. Dominant vegetation observed in Reach 1 near RM 0.2 (September 2011).

5.3 Reach 2

Location: River mile 0.6 to River mile 1.4

Survey Date: September 22 and 23, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

5.3.1 Reach Overview

Reach 2 begins approximately 0.3 RMs upstream of Hwy 153. This section of Libby Creek has a low gradient and is moderately confined between a hillside along the river-right bank and by Libby Creek Road along the left bank. Land use is residential and agriculture. Larger private parcels are more frequent towards the upper end of the reach. Beyond the reach boundary at RM 1.4, Libby Creek flows through Okanogan National Forest lands.

5.3.2 Channel Morphology

Reach 2 is a moderate gradient (2.95%) pool-riffle channel. The reach flows through a moderately confined valley. The channel and floodplain are artificially confined in portions of the reach that lie adjacent to Libby Creek Road and developed lands. Several failed wooden bridges and an abandoned irrigation diversion (right bank at RM 0.7) are located in the reach. The reach is relatively unconstrained and meanders through a narrow floodplain (Figure 30). There are high flow channels, slope wetlands, and beaver activity. Channel gradient increases at RM 1.2 and the dominant habitat type transitions to cascading riffles.

Figure 30. Reach 2 flows through a narrow floodplain and has a greater wood supply than Reach 1. The channel is moderately confined between the right bank hillside (observed in the photo) and a left bank road (September 2011).

5.3.3 Habitat Unit Composition

Reach 2 consisted of 11% pools, 80% riffles, 8% glides, and 1% side-channels (Figure 31). Residual pool depths ranged from 1 to 4 feet (Figure 32). Average residual pool depth was 1.7 feet. Average maximum pool depth was 2.5 feet. Plunge pools formed by channel spanning LWD and/or woody debris jams were the dominant slow water units (e.g. Figure 33). Pool frequency was 20.1 pools per mile, with mean pool spacing of 19.0 channel widths per pool. Reach 2 would be considered "functioning at risk" with respect to pool spacing based on USFWS (1998).

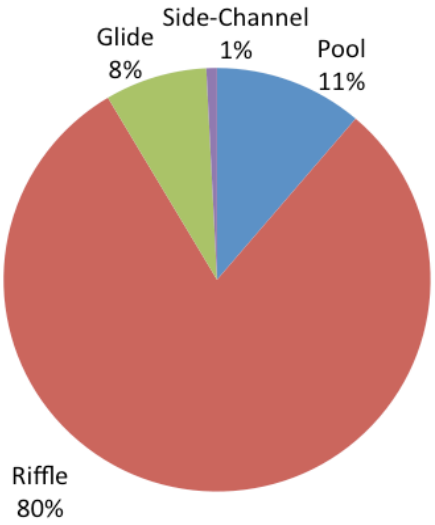


Figure 31. Habitat unit composition for Reach 2.

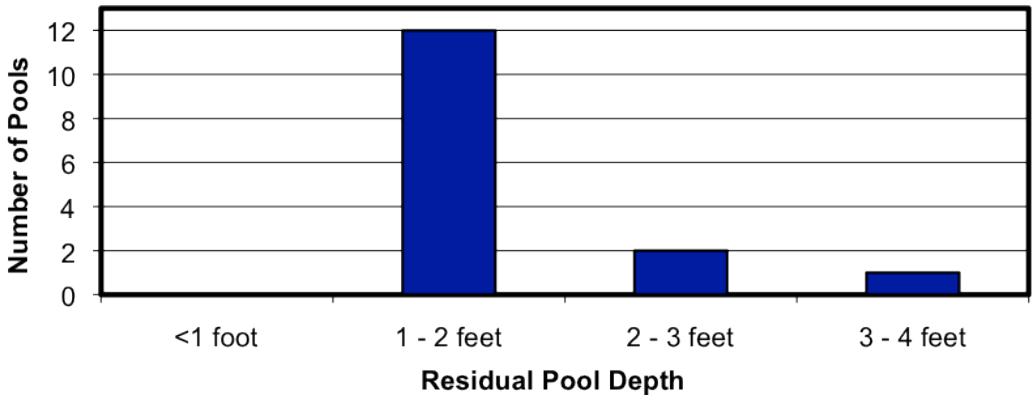


Figure 32. Reach 2 residual pool depths.

Figure 33. Representative plunge pool in Reach 2 (September 2011).

5.3.4 Off-Channel Habitat

There were two side-channels in Reach 2. Both side-channels were short and had collected small LWD along the upstream side of the island separating the unit from the main channel.

In addition to the two side-channels, there was an abandoned irrigation diversion at RM 0.7 along the right bank. The diversion had a large concrete headgate (Figure 34) with a cobble lined channel that had been filled with smaller gravels and fines. The main channel had been armored with plywood at the upstream end of the diversion to protect the closed headgate and channel (Figure 35).

Opposite the abandoned irrigation diversion, and confined between the left bank and Libby Creek Road, was a wetland complex perched on a bench above the main channel. The wetland was currently isolated from the main channel. Further upstream, at RM 0.8 and 1.2, were two separate tributaries that originate from groundwater springs along the river-right hillside (Figure 36). The wetland and one of the tributaries had evidence of beaver activity.

Figure 34. Headgate in an abandoned irrigation diversion at RM 0.7 (September 2011).

Figure 35. Plywood armoring along river-right near the downstream end of Reach 2 (September 2011).

Figure 36. Spring-origin tributary entering the channel from river-right (September 2011).

5.3.5 Large Woody Debris

Instream wood plays a moderate role in Reach 2, including sediment sorting, habitat cover, flood refuge habitat, and channel complexity (Table 2). Wood was an important component of plunge pool formation observed in Reach 2 (Figure 37). Most wood jams were comprised principally of small material that had accumulated behind larger stable pieces. The jams had captured fallen leaves, needles, and other stream detritus, improving habitat cover and providing food for macroinvertebrates and fish.

LWD frequency totaled 164 pieces with 216 pieces/mile and "small" pieces comprising 70% of all LWD counted in the reach. "Large" pieces accounted for only 5% of the LWD. Reach 2 appeared to have adequate LWD recruitment potential due to numerous mature riparian trees within the narrow floodplain (Figure 38).

Table 2. Large woody debris quantities in Reach 2.

Reach 2	Small (6 in x 20 ft)	Medium (12in x 35 ft)	Large (20in x 35 ft)	Total
Number of Pieces	114	42	8	164
Number of Pieces/Mile	150	55	11	216

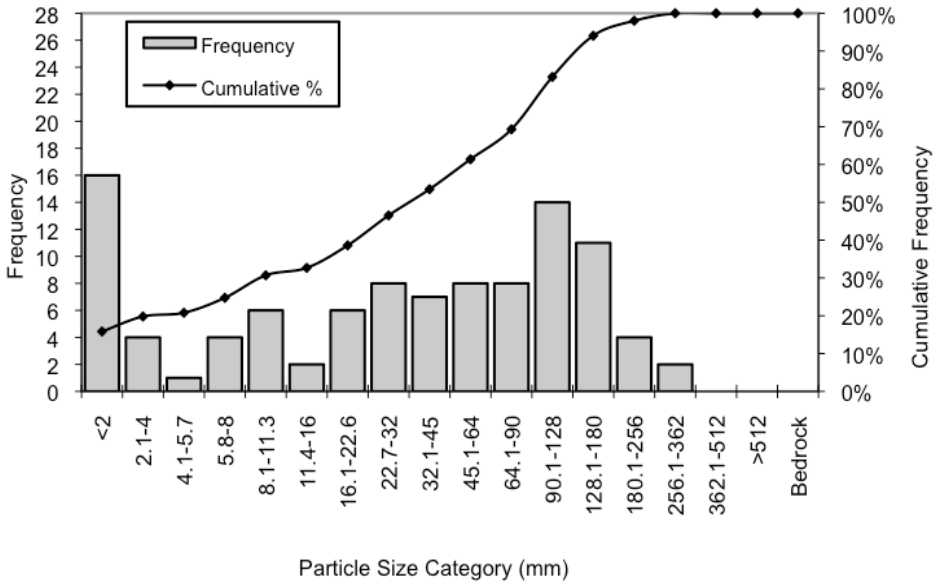
Figure 37. Characteristic plunge pool formed by channel-spanning LWD, Reach 2 (September 2011).

Figure 38. Narrow floodplain with large cottonwoods and high flow channel along river-left (September 2011).

5.3.6 Substrate and Fine Sediment

Bed substrate was dominated by gravels and cobbles. Bedrock and boulders were rare, although large boulders become more prevalent above RM 1.2 (Figure 39). The percentage of fine sediment (<2mm) was relatively high, making up approximately 13-19% of the substrate distribution. Reach 2 would be considered "functioning at risk" with respect to fines in gravel (near areas of spawning and incubation) based on USFWS (1998). The pebble count data and ocular estimates are presented in Figure 40, Figure 41, and Figure 42.

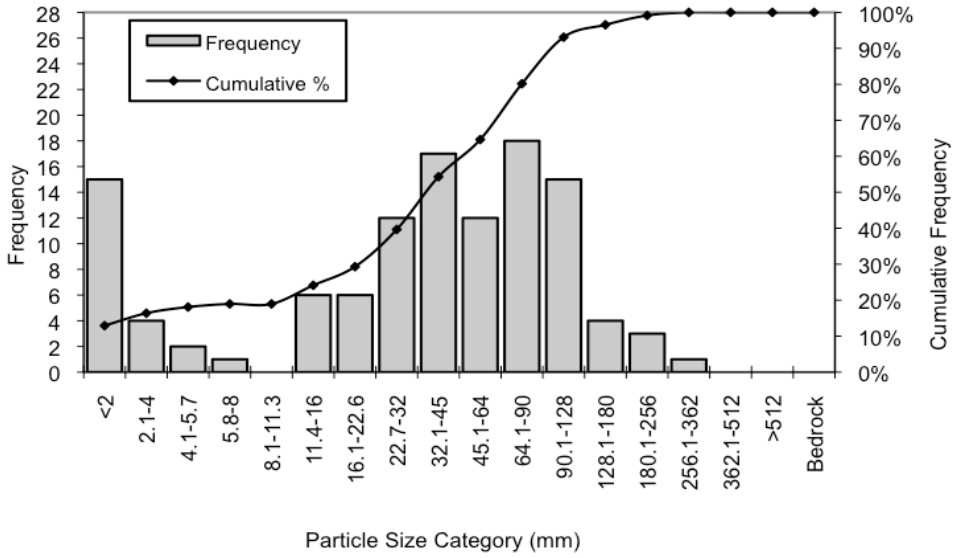
Figure 39. Boulders were observed towards the upstream end of Reach 2 (September 2011).



Material	Percent Composition
Sand	16%
Gravel	46%
Cobble	37%
Boulder	2%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	2
D50	39
D84	132
D95	198

Figure 40. Grain size distribution and particle size classes from pebble count taken at RM 0.7.



Material	Percent Composition
Sand	13%
Gravel	52%
Cobble	34%
Boulder	1%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	4
D50	41
D84	101
D95	157

Figure 41. Grain size distribution and particle size classes from pebble count taken at RM 1.0.

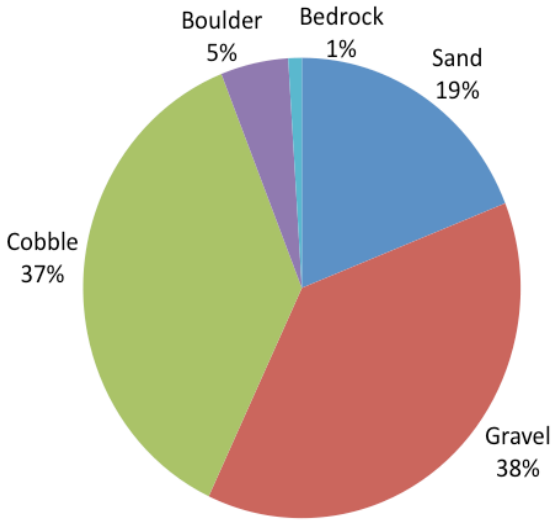


Figure 42. Percent composition of bed substrate based on ocular estimates, Reach 2.

5.3.7 Instability and Disturbance

Human activities have modified the channel, floodplain, and riparian corridor. Although residential development in Reach 2 was less than Reach 1, channel modifications and bank instability were more prevalent in Reach 2. Reach 2 had 905 feet of actively eroding streambank, making up 11% of total reach erosion (Figure 43).

The channel was naturally confined along river-right. Loam soils were exposed in a few incised channel sections (Figure 44). Past land use practices (including logging and road building) may have contributed to these conditions.

There were several small channel-spanning bridges throughout Reach 2; however, most were located above the active channel and did not include bank armoring. A bridge at the upper end of the reach (near RM 1.3) was located downstream of a right bend where riprap and gabions affected channel hydraulics and lateral channel dynamics. There was also a small failed footbridge that had accumulated woody material and created a downstream plunge pool.

A failed irrigation diversion was located at RM 0.7. The channel was likely altered in this area to divert water into the irrigation canal. The system was no longer functional; however, flows continue to be affected by the diversion structure and are causing erosion along the river-right bank.

Livestock grazing along the riparian corridor (Figure 45) has resulted in exposed streambanks that were contributing fine sediment and animal waste during rains and high flow events. Bank vegetation was limited where livestock had access to the stream. Exclusion fencing and riparian plantings would be beneficial in these areas.

A non-functional culvert was located instream near RM 0.7 (Figure 46). This culvert may have been used to drain the slope wetland located within the river-left floodplain bench.

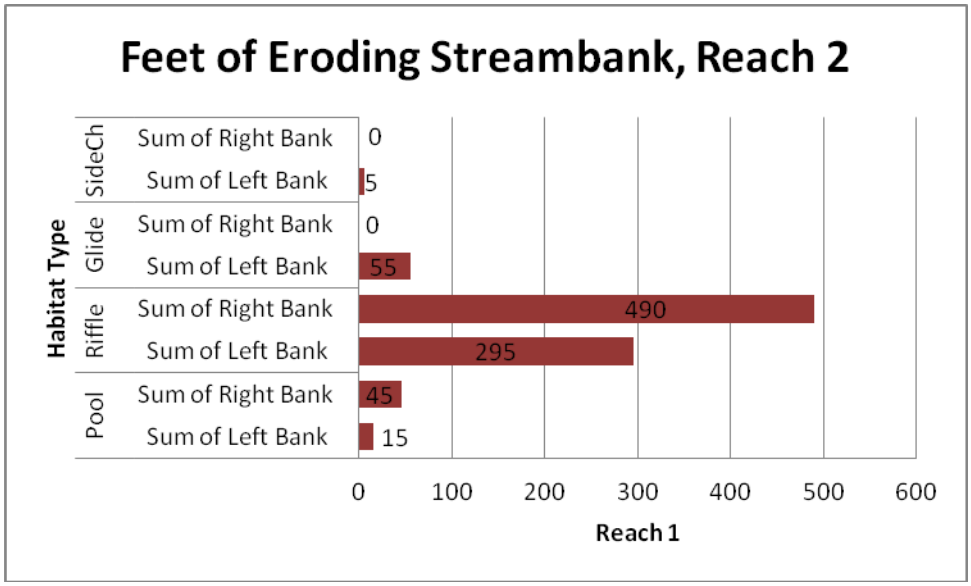


Figure 43. Length of eroding streambank in feet.

Figure 44. Channel incision observed in the upper portion of Reach 2 (September 2011).

Figure 45. Riparian grazing, Reach 2 (September 2011).

Figure 46. Remnant culvert in Reach 2 (September 2011). This culvert may have been used to drain the river-left wetland at RM 0.7.

5.3.8 Available Spawning and Rearing Habitat

A moderate amount of spawning and rearing habitat was available in Reach 2. Cobble was the dominant substrate in riffles (40%) and gravel was sub-dominant (36%). Steelhead spawn

throughout this reach (Figure 47). Many of the pool tail-out areas were composed of gravels and small cobbles that are within the optimum range for spawning steelhead (6 – 102 mm, Bjornn and Reiser 1991). The coarse bed at the upstream end of this reach provides areas of localized velocity refuge that may be utilized for rearing by juvenile steelhead and resident trout.

Pool quantity within the reach was low to moderate and the pools generally had shallow residual depths. There was only one pool with a residual depth greater than 3 feet. Reach 2 pool quantity would be considered below "functioning adequately" conditions based on USFWS (1998).

LWD was below adequate levels but there are good future potential recruitment sources.

Figure 47. Riffle where steelhead spawning has been observed during past spawning surveys (September 2011).

5.3.9 Fish Passage Barriers

There were no fish passage barriers in Reach 2. Several plunge pools have the potential to limit upstream passage for juvenile steelhead and trout during low flow periods. Mean riffle thalweg depth was 0.6 ft, which is below the minimum threshold depth for passage for spring Chinook (Thompson 1972). However, spring snowmelt flows would allow for easy upstream passage by adult summer steelhead.

5.3.10 Riparian Corridor

Reach 2 was generally forested but there continues to be impacts related to past riparian clearing and grazing. Riparian cover was more diverse and provided more stream shade than Reach 1. Hardwoods were more abundant than conifers and included alder, birch, cottonwood, and thickets of red osier dogwood. There were a few ponderosa pines toward the upstream end of the reach. There was also greater diversity of shrubs in Reach 2, which included serviceberry, mock

orange, bald hip rose, Douglas spirea, Columbia hawthorne, and snowberry. Columbia clematis was abundant in areas where the canopy provided filtered or full sunlight. Clematis may impact the growth and vigor of more desirable overstory vegetation due to its abundance and its ability to shade out young seedlings.

In the riparian inner zone (near-channel), small trees were the dominant size class (53%) (Figure 48) and shrubs were sub-dominant (29%). In the riparian outer zone, 43% of the units were dominated by shrubs, including red osier dogwood, hawthorne, spirea, and sagebrush. The stream is naturally confined by the valley wall along river-right, which shades the stream in the afternoon.

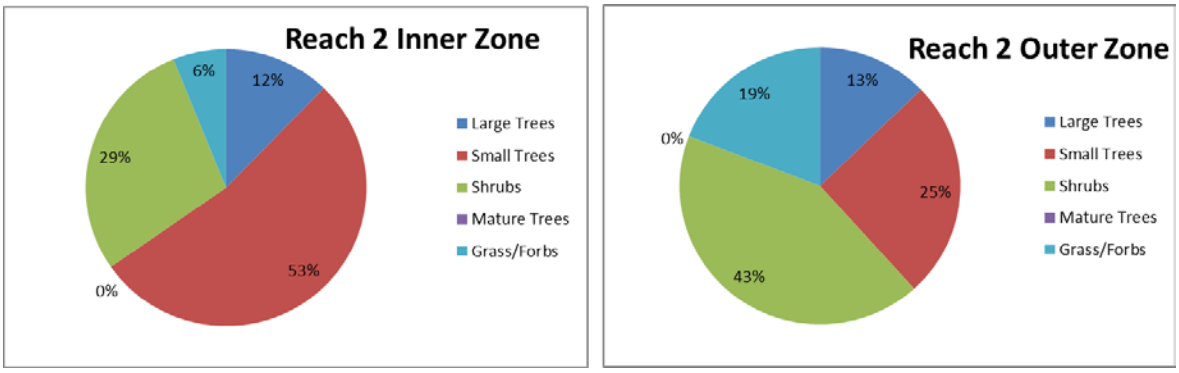


Figure 48. Distribution of vegetation size class categories for the riparian inner and outer zones in Reach 2.

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