Appendix A

Twisp River

Stream Habitat Assessment

River Mile 0 to 7.8

Survey: October 2009

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1 Introduction

The Twisp River is located in Okanogan County, WA. The Twisp River flows into the Methow River near river mile (RM) 41, near the town of Twisp. A habitat survey was conducted along the lower Twisp River from RM 0 to approximately RM 7.8 from October 5 to October 10, 2009 (Figure 1).

The objective of the Habitat Assessment is to characterize the habitat quantity and quality for salmonid species native to the Twisp River 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 salmon, Coho salmon, steelhead trout, rainbow trout, bull trout, and west slope cutthroat trout are native salmonid species to the Twisp River. The lower Twisp River is utilized primarily as a migration corridor for steelhead and spring Chinook salmon, but is also used to some degree for spawning and rearing. Bull trout use the lower Twisp River for migration and rearing (BOR 2008). Spawning, rearing, and adult migration habitat 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 that will be useful for establishing objectives and performance targets to guide restoration and preservation activities.

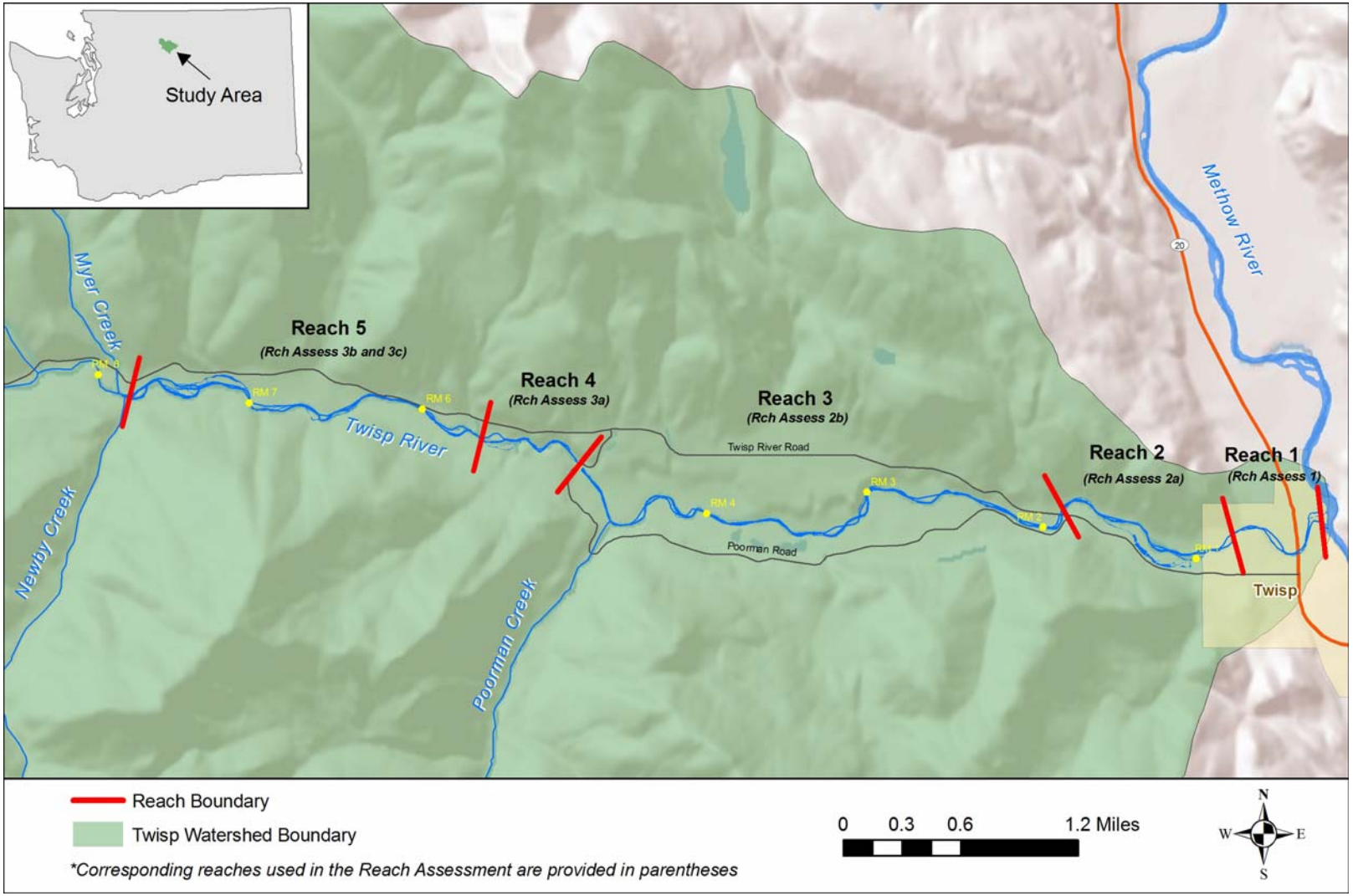


Figure 1. Locator map of the Habitat Assessment area showing the habitat survey reaches used in the assessment. Reaches conform to past habitat surveys to maintain consistency. The relationship to the reach designations used in the Bureau of Reclamation Tributary Assessment (USBR 2008) are provided in parentheses.

2 Methods

Five geomorphic reaches have been previously delineated and used for habitat assessment work in the study area by the Pacific Watershed Institute (PWI 2003) and the U.S. Forest Service (USFS 2001). These same reaches were used for the stream habitat assessment to maintain consistency with these previous efforts. It is important to note, however, that these reaches differ from the reach nomenclature used in the Reach Assessment portion of this report (see Figure 1 for a comparison of reaches).

Field methods for the habitat survey used the USFS Region 6 Level II Stream Survey Protocol Version 2.6 (USFS 2006). A modification was made to the protocol with respect to the n^{th} unit measurement frequency. The protocol indicates that n^{th} unit measurements should occur at no less than a 10% sampling frequency with a minimum of 10 n^{th} 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 n^{th} units than was possible given time constraints. As a compromise, the minimum n^{th} unit sampling frequency was increased to 15% with no minimum number of n^{th} 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 n^{th} units in order to determine if correction of the ocular estimates was necessary. The average difference between the actual and ocular values was 4.8 feet, evenly distributed ab. As a result, ocular estimates were not corrected and are considered generally accurate to within +/- 5 feet.

3 Summary of Results

This section summarizes the results across all five reaches. Detailed reach summaries with reach-specific results are included in Appendix A.

3.1 Channel Morphology

Lower Twisp River reaches are dominated by pool-riffle morphology. Channel bed substrate consists primarily of cobbles and gravel, with a high frequency of boulders in some reaches. Bedrock and sand occur relatively infrequently.

Channel widths do not vary substantially between stream reaches and do not increase in the downstream direction as might be expected (Figure 2). This may be attributed to a large degree of artificial channel confinement that affects stream width in various locations throughout the study area. Mean bankfull widths are 74.4 ft (stdev 17.6). Bankfull depths do not vary substantially among reaches (Figure 3). Median bankfull depths range from 2.8 to 3.3 feet with the largest bankfull depths occurring, on average, in Reaches 2 and 5. Median floodprone widths in reaches 1, 3, 4, and 5 range from 121 to 184 feet (Figure 4). Reach 2 has a wider active floodplain, with a floodprone width of 400 feet.

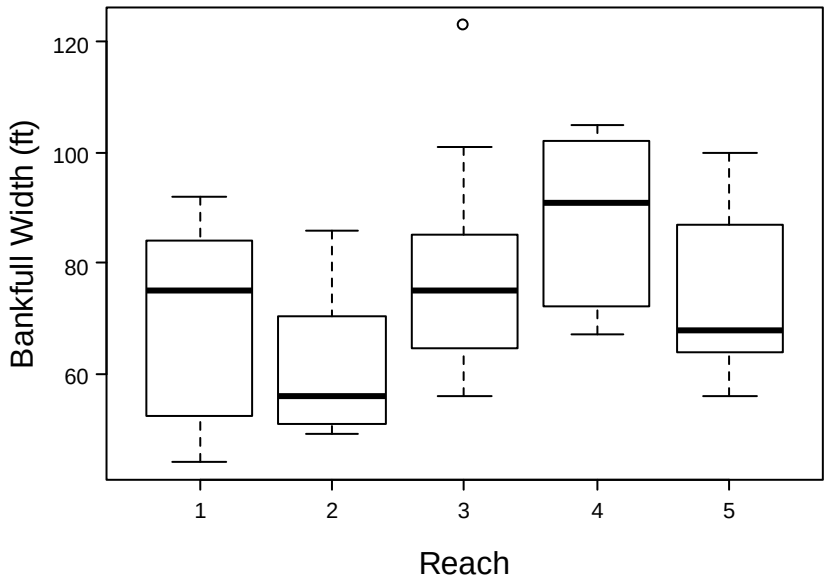


Figure 2. Boxplot of bankfull widths for each reach in feet.

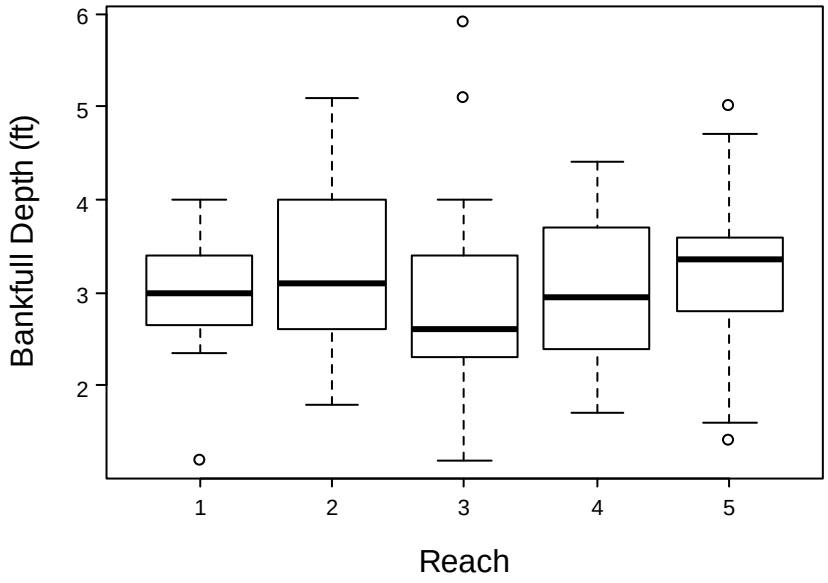


Figure 3. Boxplots of bankfull depths in feet. Each value is an average of three individual measurements taken at each nth riffle unit in each reach.

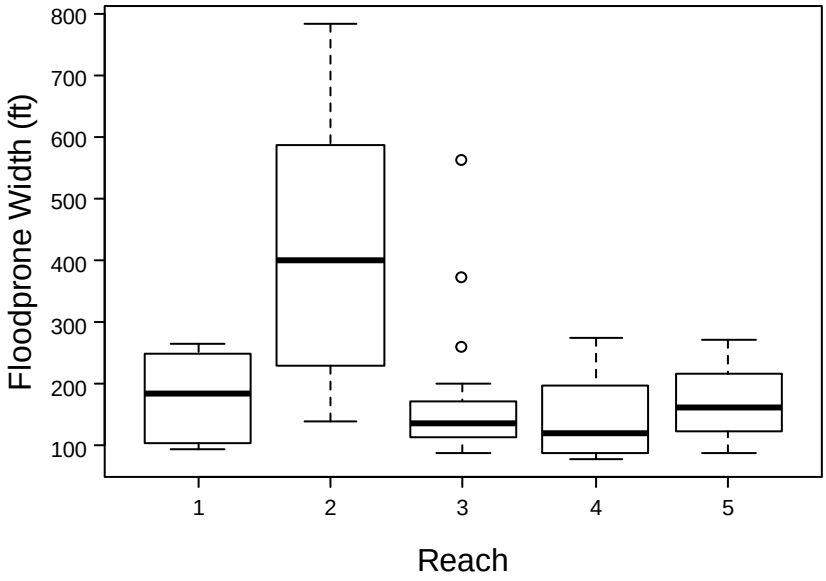


Figure 4. Boxplots of floodprone width in feet.

3.2 Habitat Unit Composition

Riffles are the predominant habitat unit type and make up 51% of the total habitat area. Pools comprise approximately 33% and glides comprise approximately 8% of the total habitat area. The remaining 8% is side channel habitat (Figure 5).

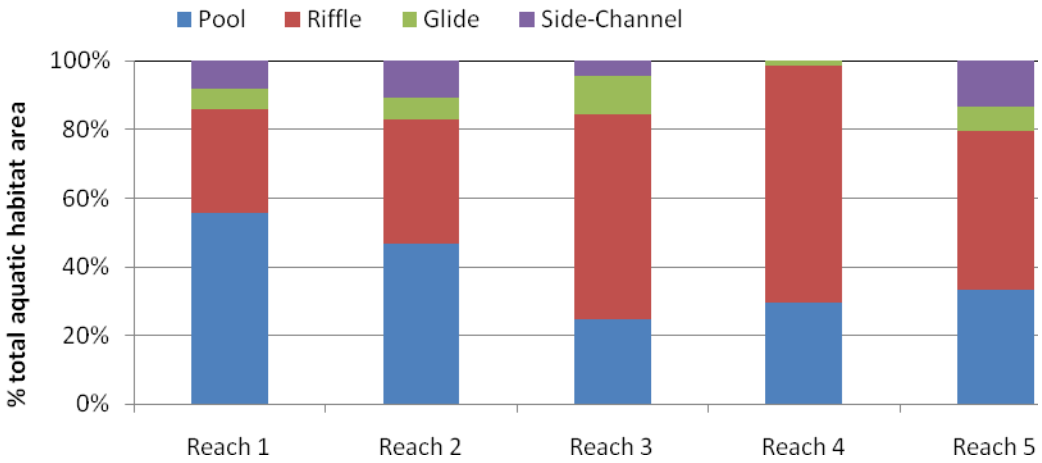


Figure 5. Proportion of habitat types by length in Reaches 1 through 5 on the mainstem Twisp River.

Pool frequency ranges from 8.9 to 23.7 pools/mile, with a mean pool spacing of 305 ft, or a pool approximately every 4 bankfull widths. Reach 1 has the greatest proportion of habitat in pools (56%), although Reach 4 has the greatest number of pools/mile (23.7). Reaches 1 and 2 have the shortest pool spacing (151 ft and 173 ft, respectively). Reach 4 has the greatest number of deep pools (44% of residual depths exceed 3 ft in several pools), owing to its natural confinement and

frequency of bedrock-formed pools. The majority of the pools throughout the study site are relatively shallow, with residual depths of 1-2 ft commonly comprising between one-half to three-quarters of the pools.

Mean wetted widths are 51.3 feet (st. dev. 14.1 ft) and riffles are 5.7 feet wider than pools on average. Mean riffle depths are 0.7 feet (st. dev. 0.1 ft) with mean maximum depths of 1.4 feet (st. dev. 0.3 ft). Minimum depths of 0.8 feet and 0.6 feet have been reported as necessary to maintain Chinook and large trout passage, respectively (Thompson 1972). Shallow riffle depths may limit passage for spring Chinook and steelhead at summer low flow periods; however, many adults will migrate through this area during higher spring or fall flows.

Average unit lengths for the three habitat types (pools, riffles, and glides) are presented in Figure 6. Reaches 1 and 5 have the longest pools. Reaches 3, 4, and 5 have the longest riffles and Reaches 3 and 5 have the longest glides. Reaches 3 and 5 tend to have longer habitat units in general, mostly long riffles and glides.

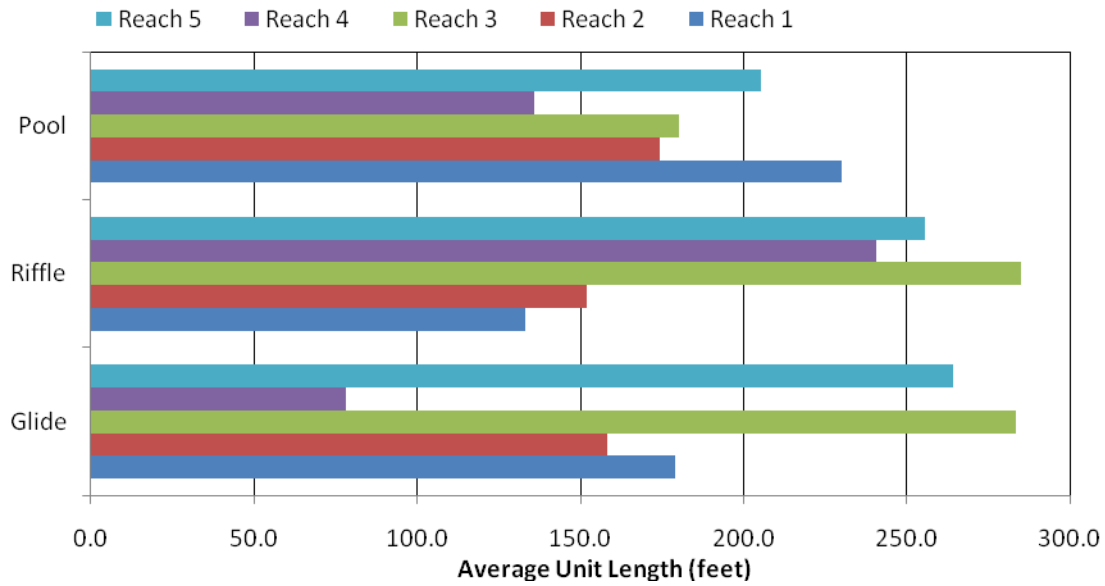


Figure 6. Comparison of average habitat unit lengths for Reaches 1-5 in the mainstem Twisp River.

3.3 Off-Channel Habitat

Side-channel habitat accounts for approximately 8% of the surveyed length along the lower 7.8 miles of the Twisp River (Figure 5). A total of 35 wetted side-channel habitat units were measured during the survey. Reach 5 has the greatest amount of side-channel habitat and Reach 4 has no side-channel habitat. The irrigation diversion and return flow in Reach 5 was considered a side-channel because of active flow during the survey. The diversion into the coho acclimation ponds in Reach 2 was also considered a side-channel during the survey.

Reaches 3 and 5 contained the greatest number of side-channel habitat units, with 8 and 15 side-channels, respectively. Side-channel pools were larger in area for Reaches 2 and 5 and greater in

depth for Reaches 1 and 2. Side-channel pools occupied a greater area than side-channel riffles in Reaches 1-3.

Natural confinement as well as artificial confinement caused by hydromodifications limit side-channel habitat throughout the study area. Natural confinement limits side-channels in Reach 4. In reaches 1, 2, 3, and 5, there are areas where roads, bank armoring, levees, and channel/floodplain filling have reduced the abundance and connectivity of side-channels and off-channel habitat.

3.4 Large Wood

An average of 104 pieces of wood per mile were counted in the Twisp River; 81% of these were "small" pieces with diameters between 6 and 12 inches and lengths greater than 20 feet (Figure 7). Reaches 2 and 5 had the highest number of "large" pieces per mile (6 and 7, respectively), and overall these two reaches also contained the highest frequencies of LWD at 116 and 165 pieces per mile, respectively. The number of pieces per mile in each reach ranged from 65 to 165.

Median wood loading on "undisturbed" streams of comparable size and type in the region is 274 pieces/mile and the 25th percentile is 80 pieces/mile (Fox and Bolton 2007). The average wood frequency in the lower Twisp River (all reaches combined) is 104 pieces/mile, which is well below the median but exceeds the 25th percentile.

Figure 7. Small and medium/large wood pieces/mile for each reach.

3.5 Substrate and Fine Sediment

Bed substrate is based on ocular estimates at each habitat unit and pebble counts at two representative locations within each of the five reaches. The ocular estimates and pebble counts closely agree with percent coverage of gravel, cobble, and boulder. In general, bed substrate in the lower Twisp River is gravel, cobble, and boulder with smaller amounts of bedrock and sand

(Figure 8 and Figure 9). Generally, more sand and boulders are found in the upstream reaches and a greater proportion of the substrate is gravels in the downstream reaches.

Sediment measurements indicate that the presence of fine sediment is low and an excess of fine sediment (<2mm) does not appear to be a significant concern in the study area. Sand accounts for less than 12% of the bed in mainstem habitat units and bed substrate was not considered to be embedded. Side-channels contained a greater abundance of fine sediments, ranging from 5% to 45% sand or fines.

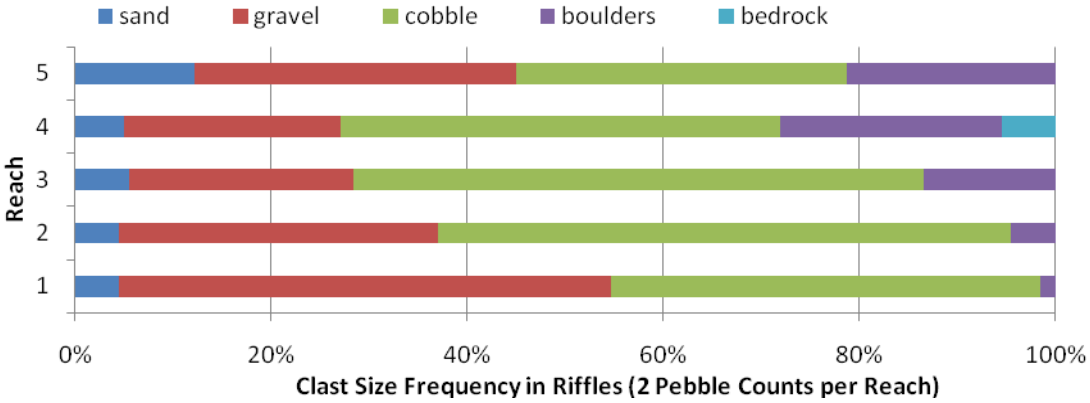


Figure 8. Pebble count classification of substrate by habitat unit type and reach for the Twisp River.

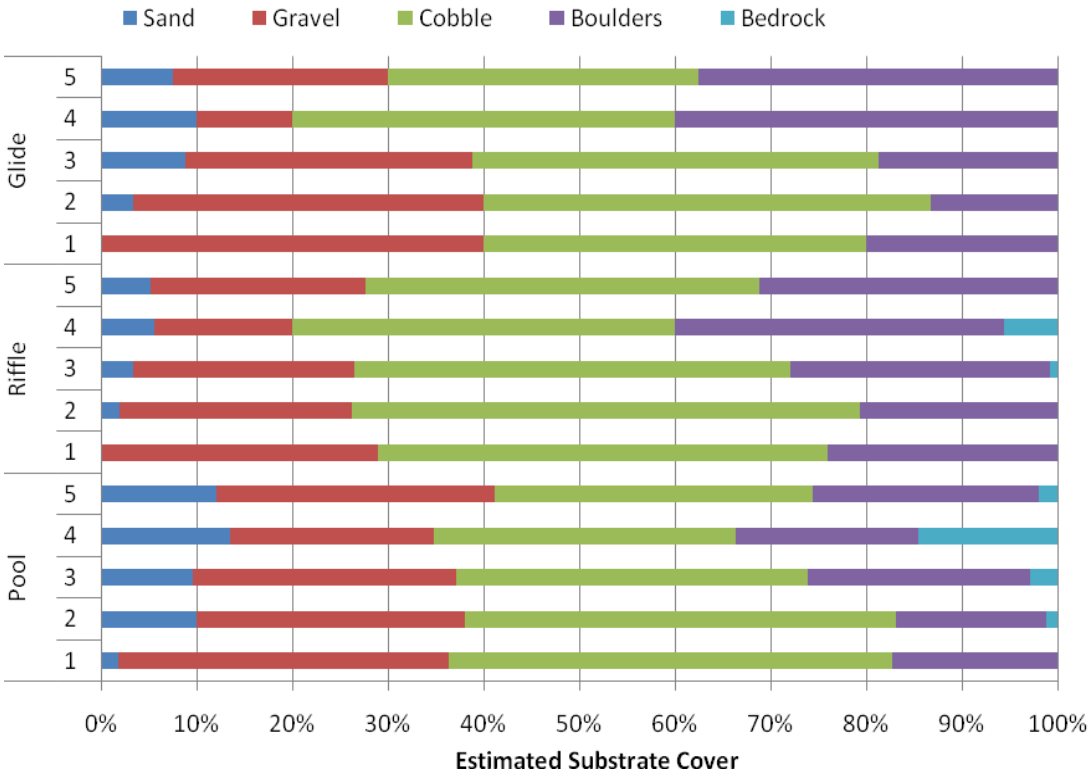


Figure 9. Ocular estimates of substrate by habitat unit type and reach for the Twisp River.

3.6 Instability and Disturbance

There has been significant human alteration along portions of the channel, riparian zone, and floodplain throughout the study area. These alterations are related to past and ongoing land-uses in the lower Twisp River Valley, including timber harvest, gravel mining, agriculture, road building, and residential development. Artificial channel confinement in the form of bridges, floodplain fill, levees, and bank armoring affects channel and floodplain dynamics in many areas. Reach 1, which flows through the town of Twisp, has the greatest proportion of hydromodifications that alter channel and floodplain processes. The other 4 reaches have moderate amounts of human disturbance, except for Reach 4, which has relatively little disturbance as a result of natural valley confinement.

On average, only 3% of the streambanks along the lower 7.8 miles of the Twisp River are actively eroding. The greatest amount of bank erosion was observed in Reach 2, where an average of 7% of the mainstem streambanks displayed active erosion. The other four reaches contained only 2% to 3% bank erosion overall.

Bank erosion occurs in all habitat unit types (Figure 10). Ninety percent of the river-left bank along Reach 2 was eroding, but overall, the lower Twisp does not exhibit excessive erosion. In some areas, streambank erosion is prevented by riprap and boulder weirs.

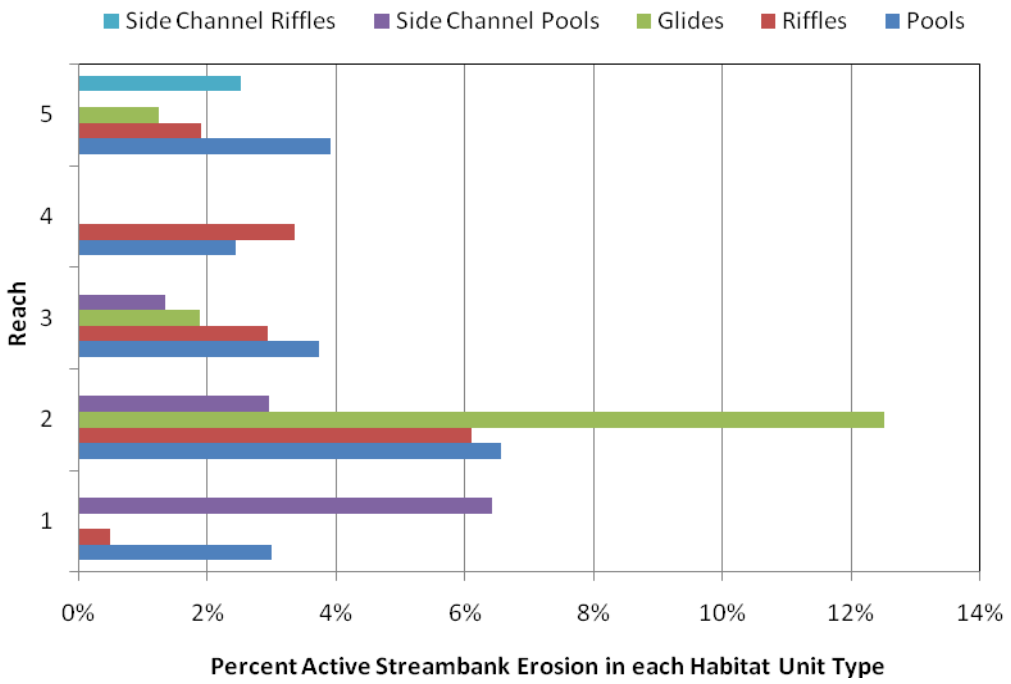


Figure 10. Percent active streambank erosion in each habitat unit type.

3.7 Fish Passage Barriers

There are no significant fish passage barriers in the study area. The adult weir near RM 7.25 may provide a barrier for upstream migrating juveniles under some conditions. A small-head concrete diversion dam at the irrigation diversion near RM 7.4 may limit passage in the river-left side-channel. Low flows, especially during low water years and times of high irrigation diversion, may impact adult fish passage in some areas.

3.8 Riparian Corridor

The inner riparian zones are typically dominated by small trees (76% of measured units); large trees are dominant in 24% of units (Figure 11). Inner zone overstories are almost all hardwoods (95%) (Figure 13) and cottonwood is the dominant overstory species. The understory is mostly hardwood (85%) and exhibits greater species diversity than the overstory; species include river birch, alder, quaking aspen, chokecherry, red-osier dogwood, and willows.

The majority of the riparian outer zones (i.e. floodplain areas) are dominated by large trees (60%), although a significant portion (38%) are dominated by small trees and a few (2%) are dominated by grass/forbs (Figure 12). The outer zone overstory is typically dominated by either conifers (53%) or hardwoods (45%) (Figure 13). The outer zone understory is mostly grass/forbs (53%), although hardwoods (33%) and conifers (12%) also dominate in some areas (Figure 13).

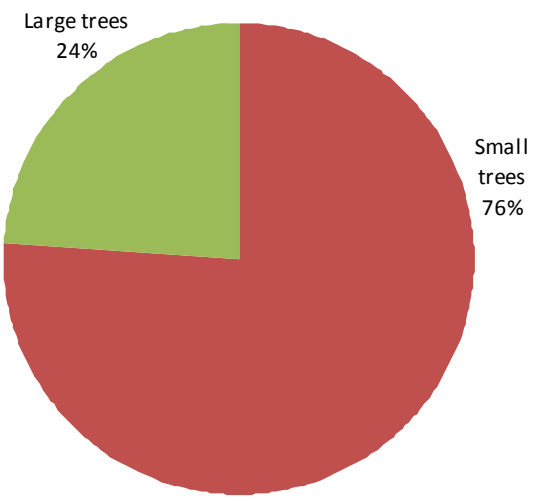


Figure 11. Distribution of the dominant size class category for the riparian inner zones, all reaches combined.

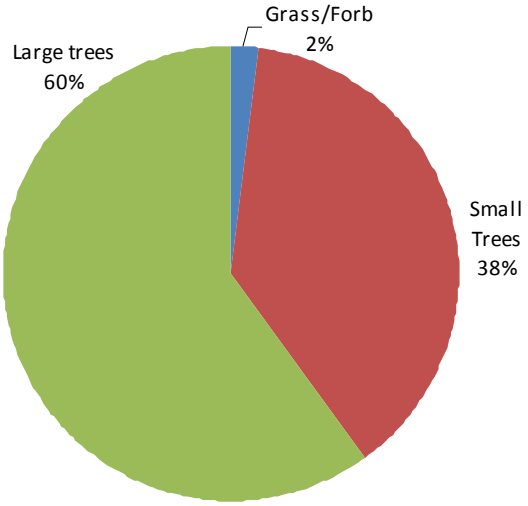


Figure 12. Distribution of the dominant size class category for the riparian outer zones, all reaches combined.

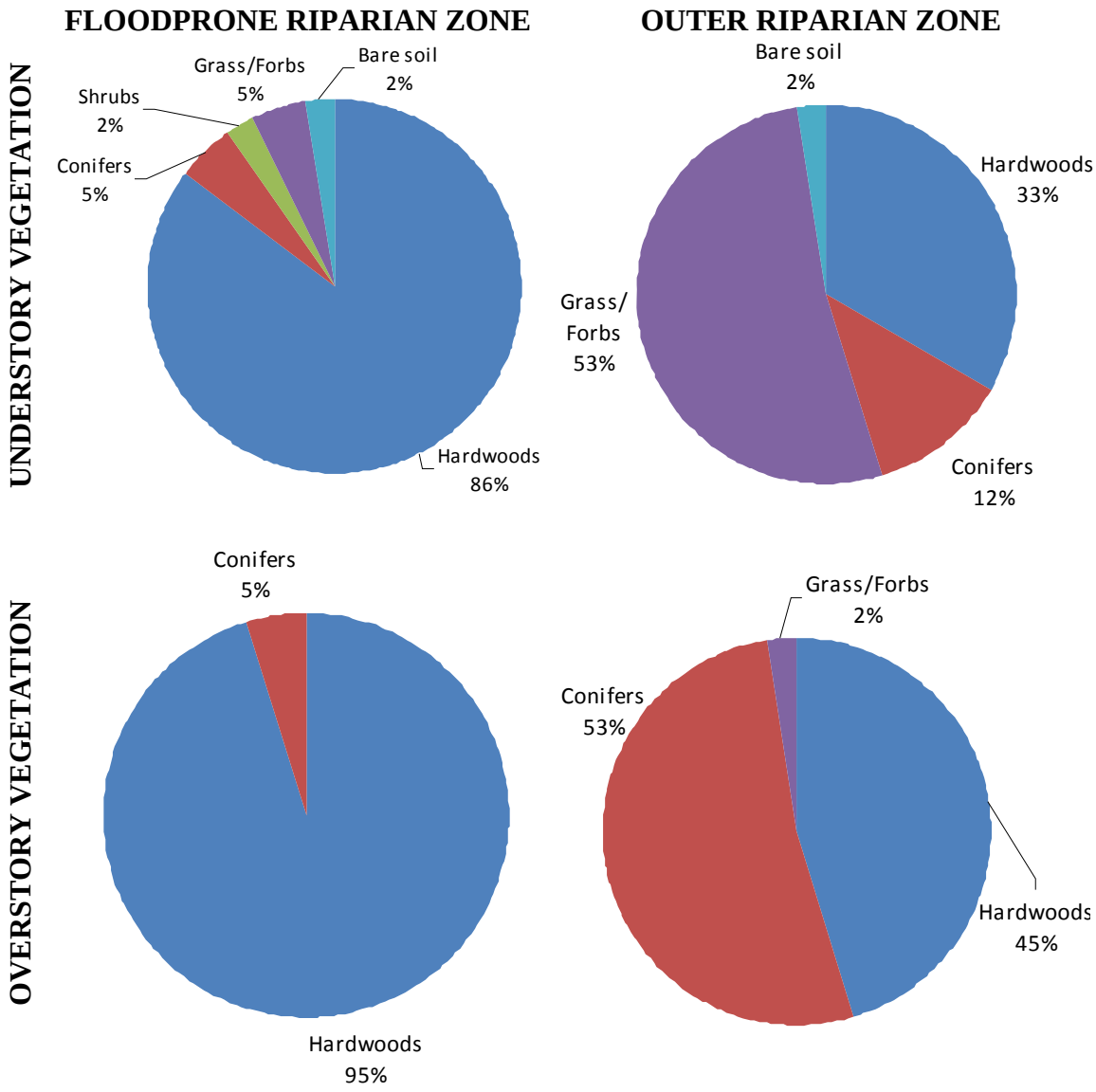


Figure 13. Proportions of vegetation cover types in the riparian zone along the lower 7.8 miles of the Twisp River.

Table 1. Twisp River Data Summary: RM 0 to RM 7.8.

		Total	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Reach Mileage Boundaries (based USBR mileage locations)		0 - 7.8	0 - 0.7	0.7 - 1.9	1.9 - 5.0	5.0 - 5.6	5.6 - 7.8
Channel Morphology			Pool-riffle	Pool-riffle	Pool-riffle	Pool-riffle	Pool-riffle
Slope							
Average (USFS 2001)		1.2%	1.2%	0.6%	1.0%	1.7%	1.3%
Wetted Width (ft)							
Pool							
	Mean	45.6	34.7	46.2	48.4	43.9	47.6
	Median	45.0	35.0	45.0	45.5	42.0	47.0
	StDev	10.4	11.2	12.0	7.4	13.0	8.2
Riffle							
	Mean	51.3	36.5	43.0	56.6	60.2	51.6
	Median	51.0	31.0	41.0	56.0	60.0	48.0
	StDev	14.1	18.4	15.2	10.5	8.6	11.1
Glide							
	Mean	47.3	50.0	43.0	49.0	35.0	50.5
	Median	47.5	50.0	45.0	47.5	35.0	50.5
	StDev	10.5	n=1	13.9	9.9	n=1	10.4
Water Depth (ft)							
Pool Maximum Depth (ft)							
	Mean	2.9	2.7	2.8	3.1	3.6	2.7
	Median	2.5	2.4	2.5	2.8	3.2	2.3
	StDev	1.1	0.9	0.8	1.1	1.4	1.2
Pool Residual Depth (ft)							
	Mean	2.1	2.0	2.0	2.2	2.8	1.9
	Median	1.8	1.7	1.7	1.9	2.4	1.5
	StDev	1.1	0.9	0.9	1.1	1.4	1.1
Maximum Riffle Depth							
	Mean	1.4	1.2	1.2	1.4	1.6	1.6
	Median	1.3	1.1	1.2	1.3	1.6	1.5
	StDev	0.3	0.1	0.2	0.3	0.4	0.3
Average Riffle Depth							
	Mean	0.7	0.7	0.8	0.7	0.8	0.8
	Median	0.7	0.7	0.7	0.7	0.8	0.8
	StDev	0.1	0.1	0.2	0.1	0.1	0.1

	Total	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Reach Mileage Boundaries (based USBR mileage locations)	0 - 7.8	0 - 0.7	0.7 - 1.9	1.9 - 5.0	5.0 - 5.6	5.6 - 7.8
Maximum Glide Depth						
Mean	1.6	1.1	1.4	1.6	2.0	1.8
Median	1.6	1.1	1.5	1.6	2.0	1.8
StDev	0.2	n=1	0.1	0.2	n=1	0.1
Average Glide Depth						
Mean	1.0	0.8	1.1	0.9	1.2	1.1
Median	1.0	0.8	1.0	0.9	1.2	1.1
StDev	0.2	n=1	0.2	0.1	n=1	0.1
Bankfull Characteristics						
Width (ft)						
Mean	74.4	69.5	62.0	76.9	88.0	73.7
StDev	17.6	20.5	15.2	17.8	15.7	14.6
Depth (ft) Averaged over 3 depth measurements						
Mean	3.0	3.0	3.2	2.8	3.0	3.3
StDev	0.6	0.3	0.6	0.7	0.4	0.5
Maximum Depth (ft)						
Mean	3.7	3.5	3.9	3.6	3.7	4.0
StDev	0.9	0.5	1.0	1.1	0.7	0.7
Width:Depth Ratio						
Mean	25.9	23.9	20.6	29.2	30.5	22.8
StDev	9.4	7.8	9.6	10.8	8.2	6.1
Floodprone Width (ft)						
Mean	212	178	422	180	147	167
StDev	160	80	254	129	76	57
Habitat Area %						
Pool	33%	56%	47%	25%	29%	33%
Riffle	51%	30%	36%	60%	69%	46%
Glide	8%	6%	6%	11%	1%	7%
Side Channel	8%	8%	11%	4%	0%	13%
Pools						
Pools per mile	11.5	15.7	15.2	8.9	23.7	10.5
Residual Depth (% of pools)						
Pools< 1 ft	4%	9%	6%	0%	0%	8%
Pools 1-2 ft	57%	45%	65%	57%	33%	64%
Pools 2-3 ft	17%	36%	12%	14%	22%	12%
Pools > 3 ft	22%	9%	18%	29%	44%	16%
Riffle:Pool Ratio	1.1	0.9	0.9	1.3	1.0	1.0

	Total	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Reach Mileage Boundaries (based USBR mileage locations)	0 - 7.8	0 - 0.7	0.7 - 1.9	1.9 - 5.0	5.0 - 5.6	5.6 - 7.8
Mean Pool Spacing	305	151	173	460	280	298
Mean Pool Spacing/Mean Bankfull Width	4	2	3	6	3	4
Large Wood						
Total Number Pieces						
Small (6 in x 20 ft)	659	41	96	184	29	309
Medium (12 in x 35 ft)	132	8	27	17	4	76
Large (20 in by 35 ft)	23	2	7	5	3	6
Number of Pieces/Mile						
Small (6 in x 20 ft)	85	59	86	58	76	130
Medium (12 in x 35 ft)	17	11	24	5	11	32
Large (20 in by 35 ft)	3	3	6	2	8	3
Bank Erosion (% eroding banks)						
Mainstem	3%	2%	7%	3%	3%	3%
Pool	4%	3%	7%	4%	2%	4%
Riffle	3%	0%	6%	3%	3%	2%
Glide	3%	0%	13%	2%	0%	1%
Side Channel Pools	4%	6%	3%	1%	0%	0%
Side Channel Riffles	2%	0%	0%	0%	0%	3%
Substrate (Ocular Estimate)						
Total						
% Sand	9%	2%	7%	7%	10%	15%
% Gravel	27%	34%	29%	27%	17%	26%
% Cobble	40%	45%	47%	41%	36%	34%
% Boulder	22%	20%	16%	23%	28%	25%
% Bedrock	2%	0%	1%	1%	10%	1%
Pool						
% Sand	9%	2%	10%	10%	13%	12%
% Gravel	28%	35%	28%	28%	21%	29%
% Cobble	39%	46%	45%	37%	31%	33%
% Boulder	20%	17%	16%	23%	19%	24%
% Bedrock	4%	0%	1%	3%	15%	2%
Riffle						
% Sand	3%	0%	2%	3%	6%	5%
% Gravel	23%	29%	24%	23%	14%	22%
% Cobble	45%	47%	53%	45%	40%	41%
% Boulder	27%	24%	21%	27%	34%	31%
% Bedrock	1%	0%	0%	1%	6%	0%

		Total	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Reach Mileage Boundaries (based USBR mileage locations)		0 - 7.8	0 - 0.7	0.7 - 1.9	1.9 - 5.0	5.0 - 5.6	5.6 - 7.8
Glide							
	% Sand	6%	0%	3%	9%	10%	8%
	% Gravel	28%	40%	37%	30%	10%	23%
	% Cobble	40%	40%	47%	43%	40%	33%
	% Boulder	26%	20%	13%	19%	40%	38%
	% Bedrock	0%	0%	0%	0%	0%	0%
Side Channel Pools							
	% Sand	17%	5%	15%	12%	-	27%
	% Gravel	40%	55%	43%	47%	-	29%
	% Cobble	33%	35%	33%	35%	-	30%
	% Boulder	9%	5%	5%	7%	-	14%
	% Bedrock	1%	0%	5%	0%	-	0%
Side Channel Riffles							
	% Sand	27%	5%	10%	5%	-	45%
	% Gravel	31%	30%	30%	30%	-	32%
	% Cobble	29%	40%	60%	45%	-	15%
	% Boulder	13%	25%	0%	20%	-	8%
	% Bedrock	0%	0%	0%	0%	-	0%
Pebble Count (*Riffle*)							
	% Sand	6%	4%	5%	5%	5%	12%
	% Gravel	32%	50%	33%	23%	22%	33%
	% Cobble	48%	44%	59%	58%	45%	34%
	% Boulder	13%	1%	5%	13%	23%	21%
	% Bedrock	1%	0%	0%	0%	5%	0%
Vegetation (% of sampled units)							
Riparian Inner Zone							
	Small trees	76%	80%	86%	73%	100%	56%
	Large trees	24%	20%	14%	27%	-	44%
	Hardwoods	95%	100%	100%	100%	100%	78%
	Conifers	5%	-	-	-	-	22%
Riparian Outer Zone							
	Grass/Forb	2%	-	-	-	-	11%
	Small Trees	38%	-	71%	47%	17%	33%
	Large trees	60%	100%	29%	53%	83%	56%
	Hardwoods	45%	20%	100%	60%	-	22%
	Conifers	53%	80%	-	40%	100%	67%

4 References

Fox, M.J. and S.M. Bolton. 2007. A regional and geomorphic reference for quantities and volumes of instream wood in unmanaged forested basins of Washington State. North American Journal of Fisheries Management 27:342-359.

Franklin, JF, and CT Dyrness. 1973. Natural vegetation of Oregon and Washington. US Forest Service General Technical Report PNW-8.

Thompson, K. E. 1972. Determining stream flows for fish life: Proceedings of the Instream Flow Requirement Workshop, March 15-16, 1972, Portland, Oreg.: Pacific Northwest River Basins Commission, p. 31-50.

US Bureau of Reclamation (USBR). 2008. Methow Subbasin Geomorphic Assessment (including 19 technical appendices). February 2008. Prepared by Technical Service Center, Sedimentation and River Hydraulics Group, Denver, Colorado in cooperation with Pacific Northwest Regional Office, Boise, Idaho and Methow Field Station, Winthrop, Washington.

USDA Forest Service (USFS). 2001. Twisp River Stream Survey Report. Okanaogan-Wenatchee National Forest, Methow Valley Ranger District.

USDA Forest Service (USFS). 2006., U.S. Department of Agriculture, Forest Service [USDA FS]. 2006. Stream inventory handbook: levels 1 and 2. Region 6 version 2.6. Portland, OR: Pacific Northwest Region.

Wolman, MG. 1954. A method of sampling coarse river-bed material: Transactions of the American Geophysical Union (EOS) 35:951-956.

ATTACHMENT A STREAM HABITAT REACH REPORTS

Table of Contents

A-1 REACH 1 (same as Reach Assessment Reach 1)

Location: River mile 0 to River mile 0.7

Survey Date: October 5, 2009

Survey Crew: Robin Jenkinson and Emily Plummer (Inter-Fluve)

A-1.1 Reach Overview

Reach 1 is located on the Twisp River alluvial fan as it enters the broad Methow River Valley. The reach extends from RM 0 to RM 0.7 and flows through the town of Twisp, WA. There is considerable development and human infrastructure in the reach, including houses, commercial development, parks, roadways, bank armoring, and levees (see aerial photo in Figure 3).

In the past, Native American camps of greater than 200 teepees used this confluence area, as well as a fish hatchery (Figure 1 and Figure 2). Today, the Twisp City Park borders the river on the river-right bank, which is hardened with riprap.

Figure 1. Fish hatchery located near the Twisp River – Methow River confluence at the turn of the 19th-20th centuries.

Figure 2. Native American camps at the Twisp River – Methow River confluence in 1927.

Figure 3. Reach 1 habitat unit composition map.

A-1.2 Channel Morphology

Reach 1 is located on the Twisp River alluvial fan as it enters the broad Methow River Valley. The reach is low gradient (1.2%) and the valley is unconfined. The channel itself is artificially confined due to human alterations. The channel type is pool-riffle. There is a deep, bedrock-formed pool in the Methow River just upstream of the Twisp confluence (Figure 1Figure 4). At the confluence, the Twisp River flows across a broad cobble and boulder delta (Figure 5). Small cottonwoods and willows grow in some locations on this alluvial deposit and occasional LWD is located throughout the delta.

The historical natural depositional environment in this reach has been impacted by development in and around the town of Twisp, including bank armoring, roadways, bridges, and associated channel incision and constraints on lateral channel dynamics. Due to artificial confinement, bed material is transported more readily through the upper portion of this reach than would have been expected under historical conditions.

Figure 4. View looking upstream on the Methow River from the Twisp River confluence (October 2009).

Figure 5. Looking upstream on the Twisp River from the confluence with the Methow River (October 2009).

A-1.3 Habitat Unit Composition

Reach 1 consists of 56% pools, 30% riffles, 6% glides, and 8% side-channels (Figure 6 and Figure 7). Pool frequency is 15.7 pools/mile or 1 pool every 2 bankfull widths. This was the tightest pool spacing of all the reaches in the survey. Average residual pool depth is 2.0 feet. Average maximum pool depth is 2.7 feet.

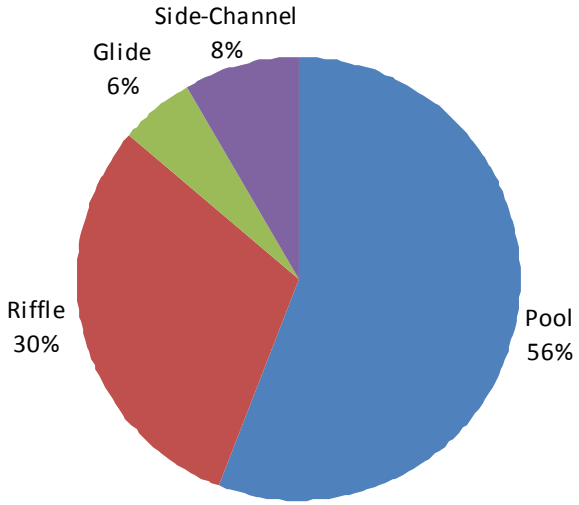


Figure 6. Habitat unit composition for Reach 1.

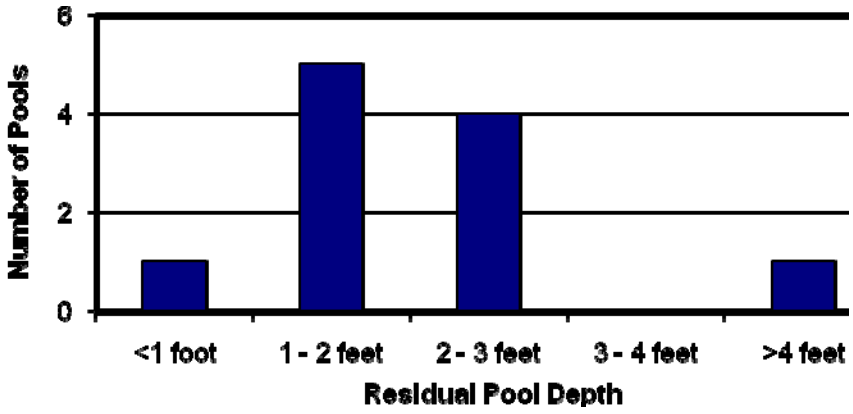


Figure 7. Reach 1 residual pool depths.

A-1.4 Off-Channel Habitat

Four side channels were observed in Reach 1. Two of the side-channels were distributary channels that flowed directly into the Methow River (Figure 8). The downstream 0.2 miles of the reach is a dynamic section of channel and has experienced shifting channel locations of the mainstem Twisp River, Twisp distributary channels, and Methow River channels in the past. Off-channel complexity is high in this section of the river. Off-channel availability in the upstream portion of the reach through the town of Twisp is limited due to artificial confinement, bank armoring, and fill. This area likely had high historical off-channel complexity that has been severely reduced as a result of development and river management.

Figure 8. High-flow distributary side-channel that flows directly into the Methow River at the confluence (October 2009).

A-1.5 Large Woody Debris

LWD plays a moderate role in Reach 1, including sediment sorting, habitat cover, and channel complexity (Table 1and Figure 9). Wood is an important component of pool formation. Large wood frequency is 73 pieces/mile, with "small" pieces comprising 80% of all large woody debris counted in the reach. "Large" wood pieces only accounted for 5% of all large woody debris counted in the reach.

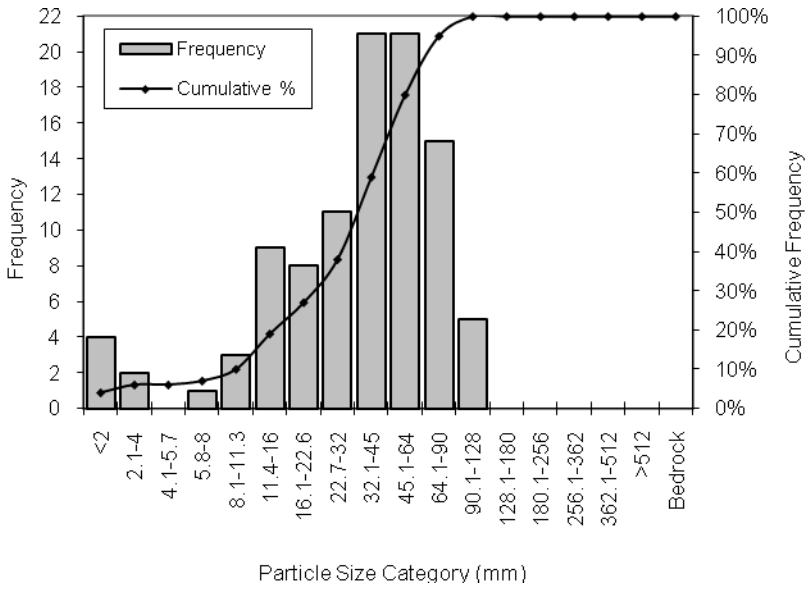
Table 1. Large woody debris quantities in Reach 1.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in by 35 ft)	Total
Number of Pieces	41	8	2	51
Number of Pieces/Mile	59	11	3	73

Figure 9. Large woody debris jam in Reach 1 (October 2009).

A-1.6 Substrate and Fine Sediment

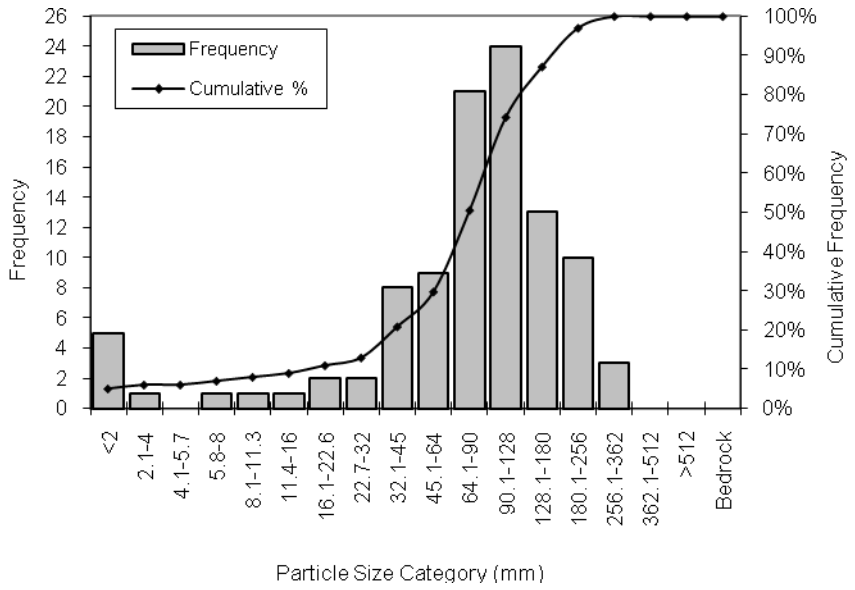
Bed substrate is dominated by gravels and cobbles. Boulders are subdominant. No bedrock was observed during stream surveys. Sand makes up less than 5% of the distribution. The pebble count and size class data are depicted in Figure 10, Figure 11, and Figure 12.



Material	Percent Composition
Sand	4%
Gravel	76%
Cobble	20%
Boulder	0%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	3
D16	14
D50	39
D84	71
D95	90

Figure 10. Grain size distribution and particle size classes from pebble count taken at RM 0.15.



Material	Percent Composition
Sand	5%
Gravel	25%
Cobble	67%
Boulder	3%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	2
D16	37
D50	90
D84	167
D95	240

Figure 11. Grain size distribution and particle size classes from pebble count taken at RM 0.55.

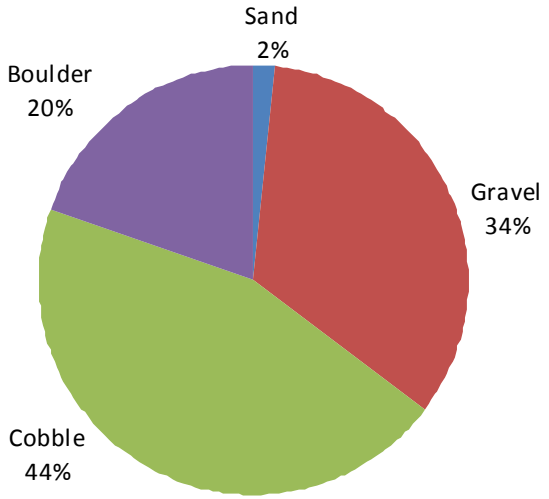


Figure 12. Percent composition of bed substrate based on ocular estimates, Reach 1.

A-1.7 Instability and Disturbance

There has been considerable human alteration to the channel and floodplain throughout Reach 1. Channel straightening, bank armoring, artificial confinement (levees), and incision have reduced dynamic channel adjustments that would have existed historically. The Highway 20 Bridge crosses the reach at RM 0.35. Riprap lines almost the entire river-right (southern) bank of the reach and portions of the river-left bank. Car bodies have also been used in places to provide bank stabilization (Figure 13). Residential development is protected by a levee on the river-right bank from RM 0.4 to 0.8. Houses with lawns and recreational access points occur frequently from RM 0.3 to RM 0.6 (Figure 14).

As a result of widespread bank armoring, actively eroding streambanks are uncommon in Reach 1 and only occur on approximately 165 feet of streambank.

Figure 13. Old car bodies ("detroit riprap") have been incorporated into streambanks in several locations (October 2009).

Figure 14. Residential development within the riparian corridor in Reach 1 (October 2009).

A-1.8 Available Spawning and Rearing Habitat

There is limited spawning and rearing habitat available in Reach 1. Bed substrate is adequately sized but the channel through much of the reach is dynamic and subject to scour and deposition during high flows. There is also potential disruption of spawning beds as a result of recreational access. Pool quantity within the reach is high although the pools generally have shallow residual depths and very little cover. LWD is moderately abundant and there are a number of off-channel rearing areas available.

A-1.9 Fish Passage Barriers

There are no fish passage barriers in Reach 1. Mean riffle thalweg depth is 0.7 feet, just under the 0.8-ft threshold cited for spring Chinook by Thompson (1972). Adult passage may be a concern during very low flow periods.

A-1.10 Riparian Corridor

The forested riparian corridor in Reach 1 is narrow and contains fewer species of trees and shrubs than upstream reaches. The riparian tree canopy is comprised primarily of cottonwood and ponderosa pine. Reed canary grass dominates the floodplain near the confluence.

Small trees are typically dominant within the riparian inner zone (80% of measured units) and nearly all inner zone areas are dominated by hardwoods (Figure 15). Riparian outer zone units are typically dominated by large trees (100% of measured units). Eighty percent of outer zones were dominated by conifers and 20% by hardwoods.

Relatively healthy riparian and floodplain forest vegetation is found downstream of RM 0.2 where active channel dynamics have created a patchwork mosaic of species and stand ages. Reed canary grass, however, is prevalent in this area.

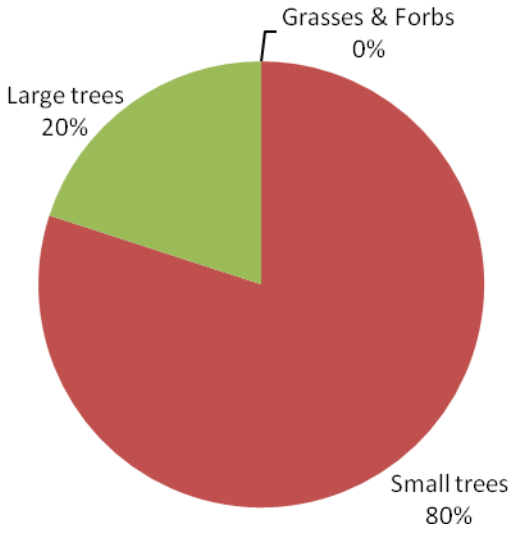


Figure 15. Distribution of the dominant size class category for the riparian inner zone, Reach 1.

A-2 REACH 2 (same as Reach Assessment Reach 2a)

Location: River mile 0.7 to River mile 1.9. *Note: This reach corresponds to BOR Reach 2a (BOR 2008).

Survey Date: October 6, 2009

Survey Crew: Robin Jenkinson and Emily Plummer (Inter-Fluve)

*A staff gage and antenna are located downstream of the Twisp River bridge (RM 1.85) on the river-left bank.

A-2.1 Reach Overview

Reach 2 is located just upstream of the town of Twisp (Figure 17). The reach is low gradient (0.6%) and flows through a moderately confined valley. The reach lies within a more confined valley than adjacent reaches. Land use is rural residential and agriculture. A portion of the floodplain on the south side of the river consists of a series of former gravel ponds that are currently utilized as a salmon acclimation and release facility. There is a levee on the river-right bank and riprap on the river-left bank below the Twisp River Road bridge (Figure 16) that disconnect much of the upstream portion of the reach from the floodplain. Small sections of riprap and push-up levees are located in the downstream portion of the reach but these have a relatively minor effect on channel processes and floodplain connection.

Figure 16. Looking upstream at the Twisp River Road bridge (October 2009). The stream gage is visible on the right.

Figure 17. Reach 2 locator and habitat unit composition map.

A-2.2 Channel Morphology

Reach 2 is a low gradient (0.6%) pool-riffle channel. The reach flows through a moderately confined valley. The channel and floodplain are artificially confined by the Twisp River bridge at the upstream end of the reach. A long right-bank levee and left-bank riprap just downstream of the bridge also disconnect channel and floodplain processes. The downstream portion of the reach (RM 0.7 – 1.4) is impacted by short sections of riprap and push-up levees, but in general is better connected to channel and floodplain processes than the upstream 0.4 miles.

A-2.3 Habitat Unit Composition

Reach 2 consists of 47% pools, 36% riffles, 6% glides, and 11% side-channels (Figure 18 and Figure 19). Pool frequency is 15.2 pools/mile or 1 pool every 3 bankfull widths. Average residual pool depth is 2.0 feet. Average maximum pool depth is 2.8 feet.

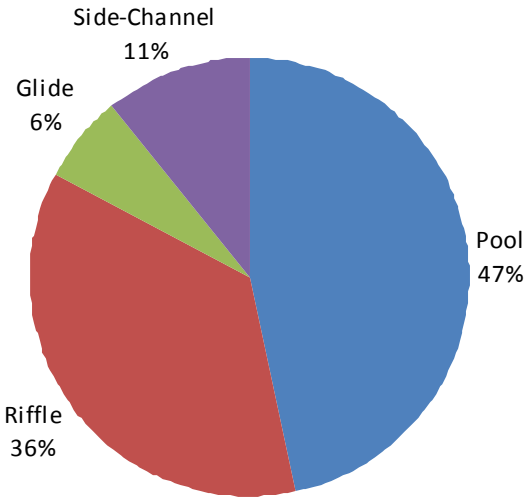


Figure 18. Habitat unit composition for Reach 2.

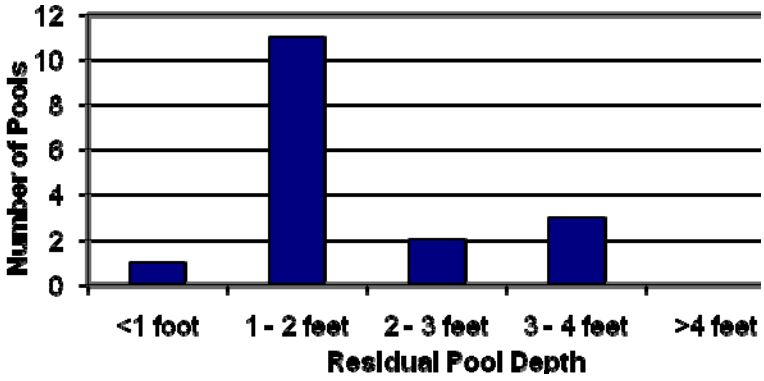


Figure 19. Reach 2 residual pool depths.

A-2.4 Off-Channel Habitat

There are five side-channels in Reach 2. One of the side-channels is a diversion ditch controlled with a headgate at RM 1.3 (Figure 20). This headgate is currently closed and abandoned. In addition to the five side-channels, there is a diversion at RM 1.5 that waters the Methow Salmon Recovery Foundation and Yakama Tribe's coho acclimation ponds located to the south of the main channel. The diversion is a large concrete headgate with a hand-built rock dam used to help divert water (Figure 21). The acclimation ponds are former gravel pits that have been connected to allow for juvenile fish passage through the ponds and out into the mainstem Twisp River. Flow from the ponds enters a side channel at RM 1.0.

Figure 20. Headgate on river-left at RM 1.3 (October 2009).

Figure 21. Diversion near RM 1.5 on river-right that sources acclimation ponds (October 2009).

A-2.5 Large Woody Debris

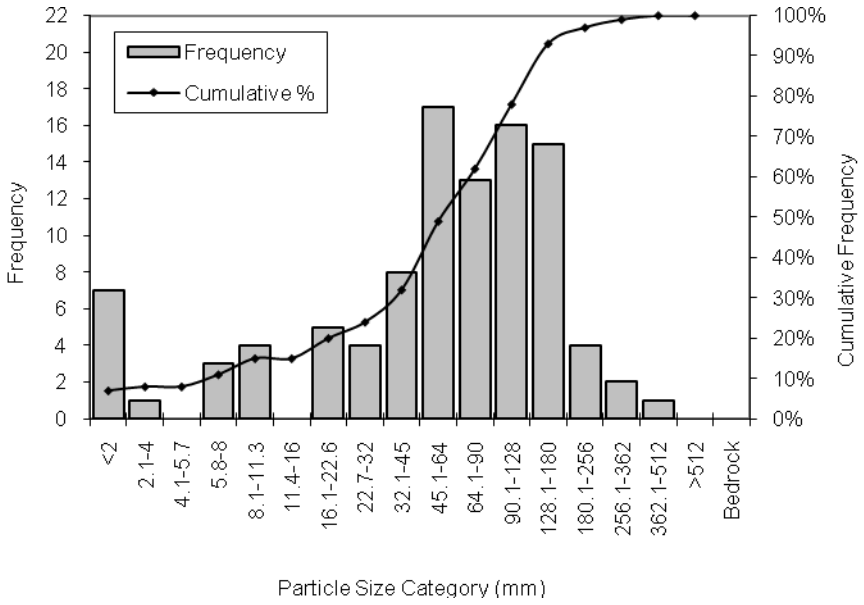
LWD plays an important role in Reach 2, including sediment sorting, habitat cover, and channel complexity. Wood is an important component of pool formation. Large wood frequency is 116 pieces/mile, with "small" pieces comprising 74% of all large wood counted in the reach. "Large" wood pieces only accounted for 5% of all large wood counted in the reach.

Table 2. Large woody debris quantities in Reach 2.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in by 35 ft)	Total
Number of Pieces	96	27	7	130
Number of Pieces/Mile	86	24	6	116

A-2.6 Substrate and Fine Sediment

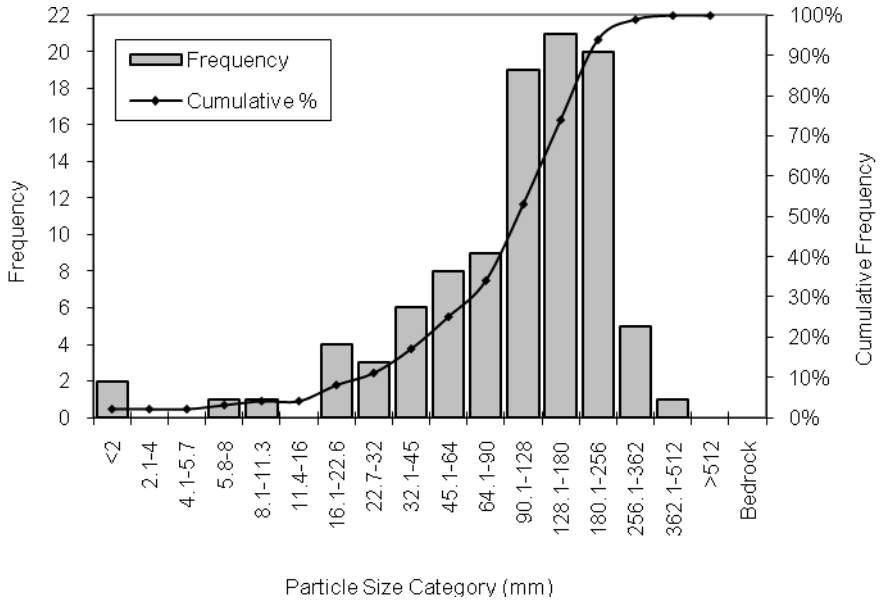
Bed substrate is dominated by gravels and cobbles. Bedrock and boulders are uncommon, although bedrock pools are located near RM 1.4 (Figure 25) and the side-channel at RM 1.7. Sand makes up less than 10% of the distribution. The pebble count and size class data are depicted in Figure 22, Figure 23, and Figure 24.



Material	Percent Composition
Sand	7%
Gravel	42%
Cobble	48%
Boulder	3%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	2
D16	17
D50	66
D84	149
D95	218

Figure 22. Grain size distribution and particle size classes from pebble count taken at RM 0.9.



Material	Percent Composition
Sand	2%
Gravel	23%
Cobble	69%
Boulder	6%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	18
D16	36
D50	122
D84	218
D95	277

Figure 23. Grain size distribution and particle size classes from pebble count taken at RM 1.7.

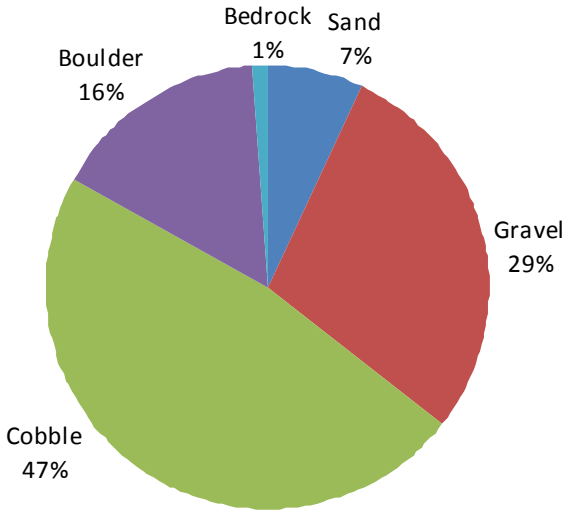


Figure 24. Percent composition of bed substrate based on ocular estimates, Reach 2.

Figure 25. View looking downstream at bedrock pool and boulder vein at RM 1.37 (March 2010).

A-2.7 Instability and Disturbance

Human activities have modified the channel, floodplain, and associated riparian corridor within the reach. The Twisp River bridge constrains channel processes at the upstream end of the reach. A levee extends along the river-right bank below the bridge for 2,000 feet and riprap extends

along river-left for 700 feet (Figure 26). A boulder vein extends out from the river-right bank near RM 1.37 (see Figure 25). A right-bank levee affects side-channel connectivity near RM 1.0. There are other short sections of riprap and push-up levees that affect channel and floodplain processes throughout the reach.

There is active bank erosion in several locations. In some areas, erosion is associated with a lack of a mature streambank vegetation. This is particularly evident on both banks between RM 1.1 and 1.3 (Figure 27).

Washington Department of Fish and Wildlife maintains a smolt trap at RM 1.25. PIT tag antennae are located just downstream of the trap. The coho acclimation ponds are located in the right bank floodplain from RM 1.1 to 1.3. The outlets from these ponds are located near RM 1.0; an observation deck and trails are also located in this area.

Habitat enhancement activities in the reach include constructed log jams along the river-right bank at RM 0.95 and 1.05 and enhancement/construction of a series of bar apex log jams near RM 1.1 (Figure 28).

Figure 26. View looking upstream near RM 1.75 at riprap on river-left bank (March 2010).

Figure 27, View looking downstream at eroding river-left bank and cleared riparian zone near RM 1.15 (March 2010).

Figure 28. Constructed/enhanced bar apex log jam at RM 1.1 (March 2010).

A-2.8 Available Spawning and Rearing Habitat

There is a moderate amount of spawning and rearing habitat available in Reach 2. The dominant substrate in the riffles is cobble (53%) and sub-dominant is gravel (24%). Although steelhead and spring Chinook spawning occurs in this reach, many of the pool tail-out areas consist of large cobbles (> 128 mm) that are larger than the ideal size for Chinook (i.e. 13 – 102 mm) and steelhead (6 – 102 mm) spawning (Bjornn and Reiser 1991). However, the coarse bed provides areas of localized velocity refuge that may be utilized for rearing by juvenile steelhead and resident trout. Pool quantity within the reach is high although the pools generally have shallow residual depths. There are only three pools (6% of reach total) with residual depths greater than 3 feet. LWD is abundant and there are a number of off-channel rearing areas available.

A-2.9 Fish Passage Barriers

There are no fish passage barriers in Reach 2. Mean riffle thalweg depth is 0.8-ft, which meets the minimum threshold depth for passage of spring Chinook (Thompson 1972) and exceeds the threshold for bull trout passage. Adequate flow depths in riffles during summer low flow could be a potential constraint on passage of in-migrating spring Chinook under some conditions.

A-2.10 Riparian Corridor

The presence and width of a forested riparian buffer varies along the reach. Past land clearing for agriculture results in an absence of a forested riparian zone on portions of both sides of the stream between RM 1.1 and 1.3. The remainder of the reach generally has a forested riparian area although riprap and levees affect streambank vegetation in several areas. The stream receives minimal shading from riparian vegetation due to a lack of large trees in the riparian zone and past clearing. Topographic shading may be provided in some locations by the south valley wall.

In the riparian inner zone (near-channel), small trees were the dominant size class (86%) in all measured units (Figure 29), and all of the units were dominated by hardwoods. In the riparian outer zone, 71% of the units were dominated by small trees (Figure 30) and all units were dominated by hardwoods. The most abundant hardwoods in the reach include dogwood, cottonwood, birch, aspen, and chokecherry. There is a greater diversity of riparian vegetation near the downstream end of the reach (Figure 31).

Near-term LWD recruitment potential is low due to a lack of large, mature trees in the riparian area and due to anthropogenic constraints on lateral channel dynamics (e.g. bridge, levees, and riprap). Beaver activity was observed during the survey at several locations.

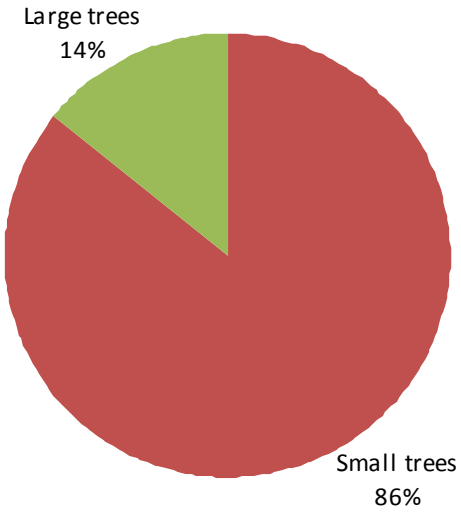


Figure 29. Distribution of the dominant size class category for the riparian inner zones, Reach 2.

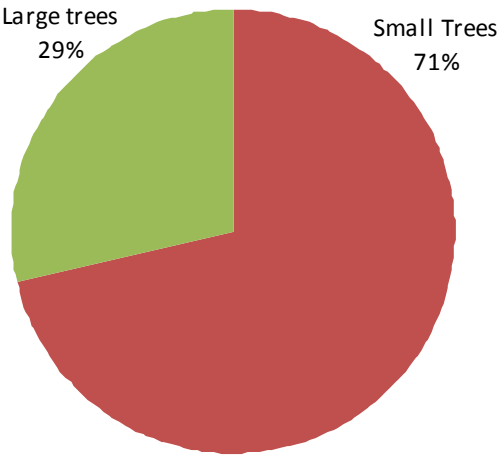


Figure 30. Distribution of the dominant size class category for the riparian outer zones, Reach 2.

Figure 31. Diverse riparian vegetation near downstream end of Reach 2 (October 2009).

A-3 REACH 3 (same as Reach Assessment Reach 2b)

Location: River mile 1.9 to River mile 5.0

Survey Date: October 7 and 8, 2009

Survey Crew: Robin Jenkinson and Emily Plummer (Inter-Fluve)

A-3.1 Reach Overview

Reach 3 extends 3.1 miles upstream from RM 1.9 to the Poorman Creek Cut-off Road Bridge (Figure 32). The reach flows through an unconfined alluvial valley. Levees and riprap banks occur periodically throughout the reach. There are several areas with floodplain wetlands although most have poor surface connection to the main channel. Seven small tributaries enter the channel along the reach including Poorman Creek at RM 4.7. There are also numerous side channels and several springs along the reach. Long, straight, and turbulent riffles are the dominant habitat type. Pools are less frequent in Reach 3 than the other reaches in the study area.

Land use in Reach 3 is predominantly rural residential and agriculture. There are several residences in the floodplain; some with lawns extending to the top of bank. Grazing and watering of livestock also occur in portions of the reach.

Figure 32. Reach 3 – Downstream Portion. Reach locator and habitat unit composition map.

Figure 33. Reach 3 – Upstream Portion. Reach locator and habitat unit composition map.

A-3.2 Channel Morphology

Reach 3 flows within an unconfined alluvial valley. Channel gradient is 1.0%.
The geomorphic low surface is bounded on both sides by glacial terraces. The reach alternates between pool-riffle and plane-bed morphology. Riffles are the dominant habitat unit type. There are many long, uniform riffles with few depositional features.

A-3.3 Habitat Unit Composition

Reach 3 consists of 25% pools, 60% riffles, 11% glides, and 4% side-channels (Figure 34 and Figure 35). Pool frequency is 8.9 pools/mile or 1 pool every 6 bankfull widths. Average residual pool depth is 2.2 feet. Average maximum pool depth is 3.1 feet.

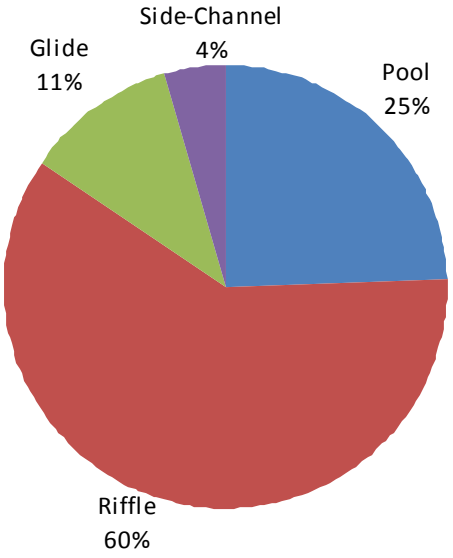


Figure 34. Habitat unit composition, Reach 3.

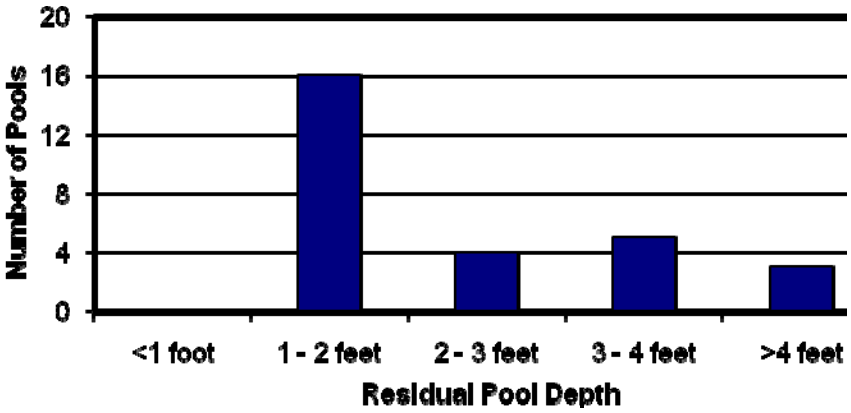


Figure 35. Reach 3 residual pool depths.

A-3.4 Off-Channel Habitat

Eight side channels were observed in Reach 3. One of the side-channels is a diversion ditch controlled with a headgate at RM 4.4 (Figure 36). Approximately half of the side channels were dry or partially dry at the time of the survey.

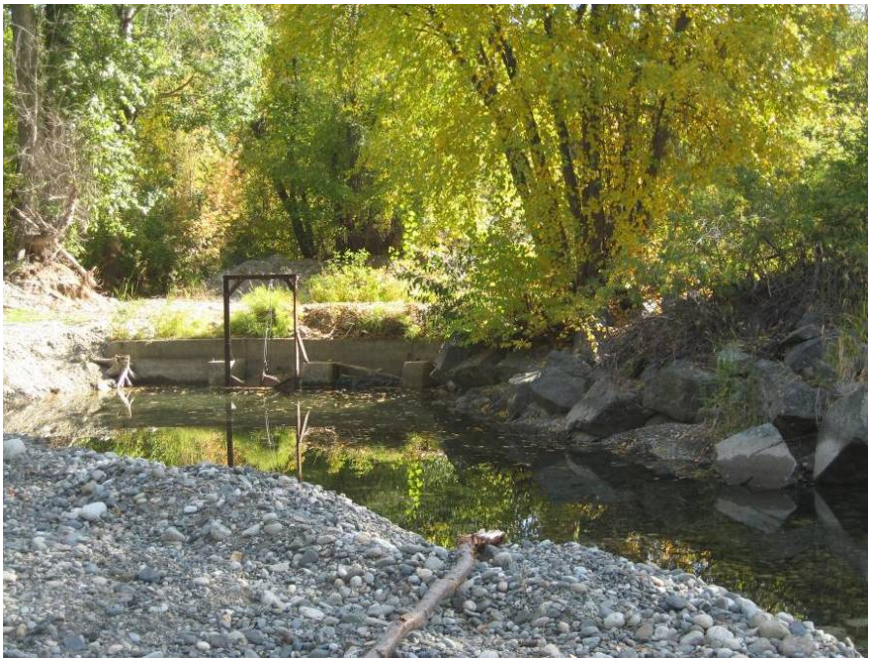


Figure 36. Irrigation diversion and headgate near RM 4.4 (October 2009).

A-3.5 Large Woody Debris

LWD counts were low for Reach 3 compared with the other reaches. Large wood frequency is 65 pieces/mile, with "small" pieces comprising 89% of all LWD counted in the reach. "Large" wood pieces only accounted for 3% of the LWD in the reach.

Beaver activity was observed at several locations along the reach and may contribute to LWD recruitment and channel complexity in some locations.

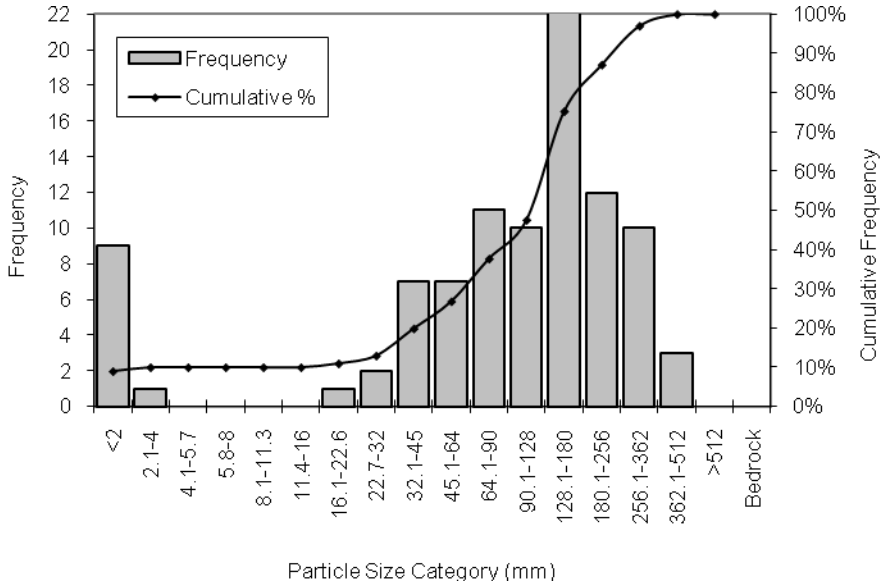
Table 3. Large woody debris quantities in Reach 3.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in by 35 ft)	Total
Number of Pieces	184	17	5	206
Number of Pieces/Mile	58	5	2	65

A-3.6 Substrate and Fine Sediment

Bed substrate is dominated by cobbles, with gravels and boulders sub-dominant. Much of the low-flow channel bed consists of coarse material, with smaller gravels and cobbles in

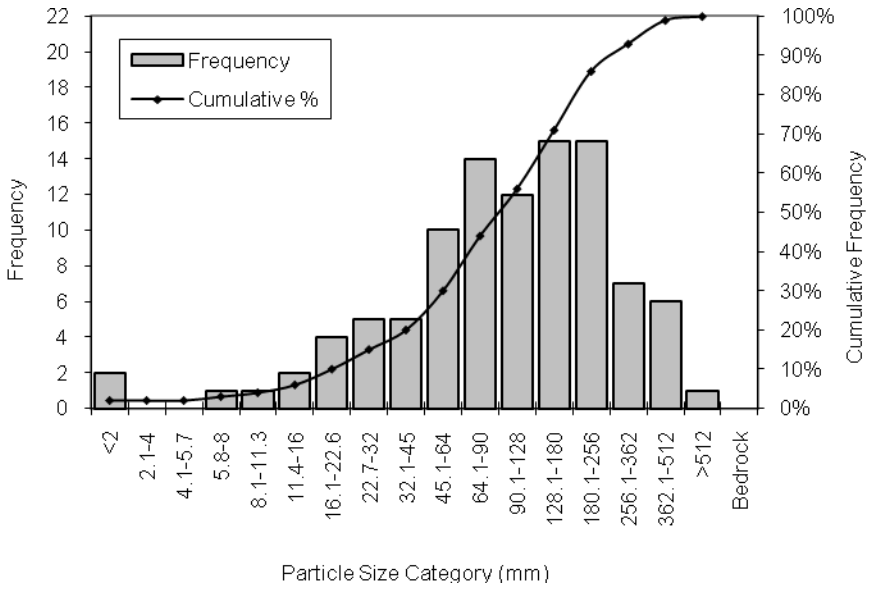
depositional areas. Bedrock is relatively uncommon and was only observed at a few locations along the reach. Sand makes up less than 10% of the grain-size distribution based on pebble count data. The pebble count and size class data are depicted in Figure 37, Figure 38, and Figure 39.



Material	Percent Composition
Sand	9%
Gravel	18%
Cobble	60%
Boulder	13%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	2
D16	38
D50	133
D84	236
D95	260

Figure 37. Grain size distribution and particle size classes from pebble count taken at RM 2.6.



Material	Percent Composition
Sand	2%
Gravel	28%
Cobble	56%
Boulder	14%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	14
D16	35
D50	109
D84	246
D95	412

Figure 38. Grain size distribution and particle size classes from pebble count taken at RM 4.6.

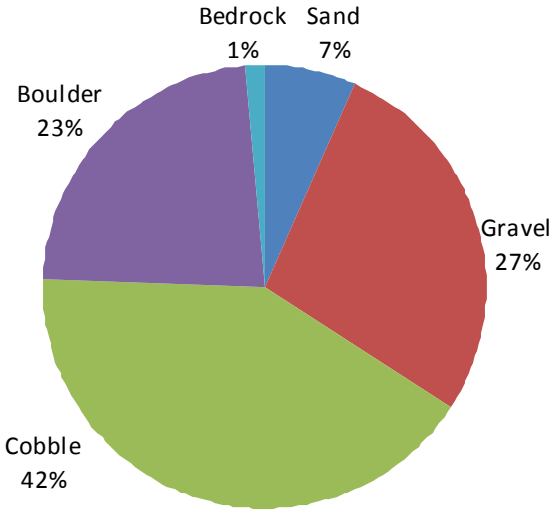


Figure 39. Percent composition of bed substrate based on ocular estimates, Reach 3.

A-3.7 Instability and Disturbance

Levees, riprap, and boulder weirs are used to stabilize banks and control flooding in several locations. Long sections of riprap (>1,000 ft) are located along both banks near RM 2.6. Smaller sections of riprap and levees are located intermittently between RM 4.0 and 4.5. There is 600 feet of riprap along the river-right bank just upstream of the bridge at RM 1.9 where Poorman Creek Road abuts the channel. An old concrete abutment is located just upstream of the Twisp River Road bridge at RM 1.9 (Figure 40).

Culverts discharge into the channel at RM 1.95, RM 2.3, and RM 3.8. The culvert at RM 1.95 discharges flow from the series of abandoned gravel pits (aka "chain of lakes") located along the southern floodplain terrace. This culvert is mostly plugged and was not flowing during surveys in March 2010 (Figure 41). Neither of the other culverts were flowing at the time of the October 2009 survey. Two irrigation pumps are located at RM 2.7, one on the right bank and one on the left bank. Both pumps are screened.

Active bank erosion was also evident in several locations. Bank erosion was associated with clearing of riparian vegetation at several locations between RM 3.2 and 3.5 (Figure 42). There is also considerable erosion of the high glacial terrace near RM 4.6.

There are numerous residences within the floodplain; some with lawns extending to the top of bank and recreational access to the river. Grazing and watering of livestock is also evident along sections of the reach (Figure 43).

Figure 40. Old concrete footing/abutment near RM 1.9 (October 2009).

Figure 41. Culvert (mostly plugged) draining floodplain ponds at RM 1.95 (river-right bank) (March 2010).

Figure 42. Erosion on river-left (north) bank near RM 3.2 (October 2009).

Figure 43. Livestock access to the stream near RM 4.9 (October 2009).

A-3.8 Available Spawning and Rearing Habitat

There is limited spawning and rearing habitat available in Reach 3. The dominant substrate in the riffles is cobble (58%) and sub-dominant is gravel (23%) and boulders (13%). Although the coarse bed is not ideal for spawning, redds were observed during the survey near RM 4.2.

The coarse bed provides areas of localized velocity refuge that may be utilized for rearing by juvenile steelhead and resident trout. Pool quantity within the reach is low and the majority of pools (57%) have a residual depth of less than 2 feet. There are eight pools (28% of the reach total) with residual depths greater than 3 feet. LWD frequency is low.

A-3.9 Fish Passage Barriers

There are no fish passage barriers in Reach 2. Mean riffle thalweg depth is 0.7 feet. The minimum threshold depth for passage by spring Chinook is 0.8 feet (Thompson 1972). Shallow depths during summer low flow could be a potential constraint on passage under some conditions for in-migrating spring Chinook.

A-3.10 Riparian Corridor

The native riparian forest has been affected by roadways, residential uses, bank armoring, and agriculture. In some areas, the vegetated riparian buffer is narrow due to the proximity of the valley wall. Poorman Creek Road, residential uses, and grazing have reduced the width of the riparian corridor in several locations.

In the riparian inner zone, small trees were the dominant size class (73%) in all measured units; large trees made up the remainder (Figure 44). All inner zones were dominated by hardwoods, mostly cottonwoods with smaller amounts of willow, birch, and alder. There is a mature grove of quaking aspens at RM 3.9. In the riparian outer zone, large trees were dominant in 53% of the units and small trees were dominant in 47% (); 60% of units were dominated by hardwoods and 40% were dominated by conifers. Hardwoods in the riparian outer zones were mostly willow, cottonwood, birch, alder, and aspen. Conifers within the reach included ponderosa pine and Douglas fir.

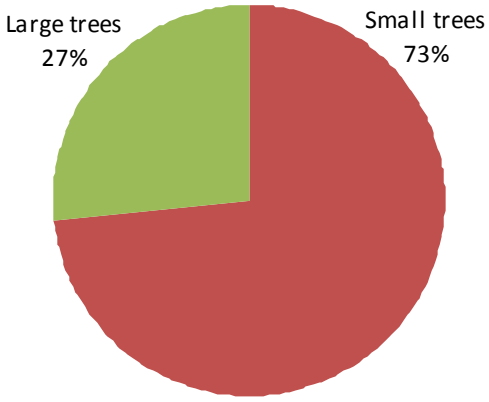


Figure 44. Distribution of the dominant size class category for the riparian inner zones, Reach 3.

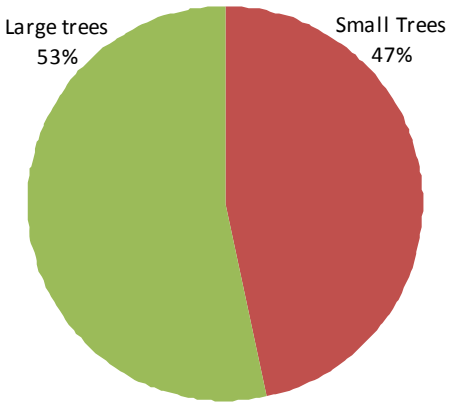


Figure 45. Distribution of the dominant size class category for the riparian outer zones, Reach 3.

A-4 REACH 4 (same as Reach Assessment Reach 3a)

Location: River mile 5.0 to River mile 5.6

Survey Date: October 8, 2009

Survey Crew: Robin Jenkinson and Emily Plummer (Inter-Fluve)

A-4.1 Reach Overview

Reach 4 extends 0.6 miles from Poorman Creek Cut-off Road Bridge upstream to the end of the bedrock gorge (Figure 46). Land use is rural residential and agriculture, although much of the reach has a forested riparian buffer. Most of the homes are located well above the floodplain. A swimming area, trail, and picnic table are located near RM 5.2.

Figure 46. View looking upstream near RM 5.1. Typical bedform with coarse substrate and bedrock outcrops (October 2009).

A-4.2 Channel Morphology

Reach 4 is a transport reach that flows through a deeply entrenched gorge bounded by high glacial terraces and bedrock outcrops. The gradient is low to moderate (1.7%). The valley width and floodprone width are both approximately 150 feet. The reach is pool-riffle, with long, plane-bed riffles and several deep bedrock-formed pools. Hillslope seeps enter the river along the river-left bank near RM 5.2. There is a tributary (waterfall) that enters the river on the river-left bank at RM 5.4.

A-4.3 Habitat Unit Composition

Reach 4 consists of 29% pools, 69% riffles, 2% glides, and 0% side channels (Figure 47 and Figure 48). Pool frequency is 23.7 pools/mile or 1 pool every 3 bankfull widths. Average residual pool depth is 2.8 feet. Average maximum pool depth is 3.6 feet. Most of the pools in the reach are formed by bedrock constrictions at the beds in the river (Figure 49). Most of the riffles form long and uniform plane-bed segments (Figure 50).

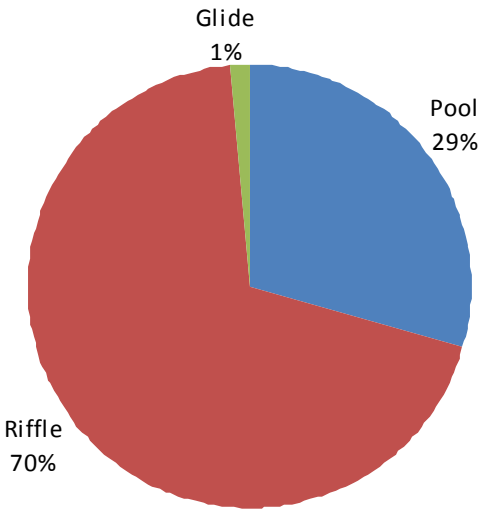


Figure 47. Habitat unit composition, Reach 4.

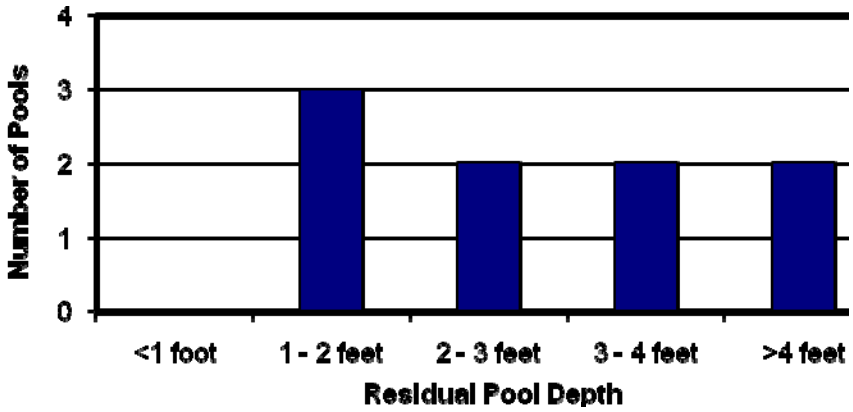


Figure 48. Reach 4 residual pool depths.

Figure 49. Deep bedrock-formed pool near RM 5.4 (October 2009).

Figure 50. Typical high gradient riffle near RM 5.3 (October 2009).

A-4.4 Off-Channel Habitat

There are no active low-flow side channels in Reach 4. A high-flow side-channel is located on the river-right between RM 5.4 and 5.6. The side channel had moist pools at the time of the survey and abundant LWD.

A-4.5 Large Woody Debris

LWD frequency is low in Reach 4. LWD frequency is 95 pieces/mile, with "small" pieces comprising 81% of all LWD counted in the reach. "Large" wood pieces only accounted for 8% of the LWD in the reach (Table 4). Wood is likely readily transported through this reach during floods.

Logs are anchored into the right bank with metal rods between RM 5.0 and RM 5.1. One of the logs is anchored in near the Poorman Creek Cut-off Road Bridge. Two additional logs are anchored with cable at RM 5.1, one to the right-bank and one to the left-bank.

Mature riparian timber, the prevalence of large confers in the riparian zone, and steep hillslope topography provides stream shade and LWD recruitment potential. A burned area on the river-left bank near RM 5.2 has the potential to contribute LWD to the channel in the short-term (Figure 51).

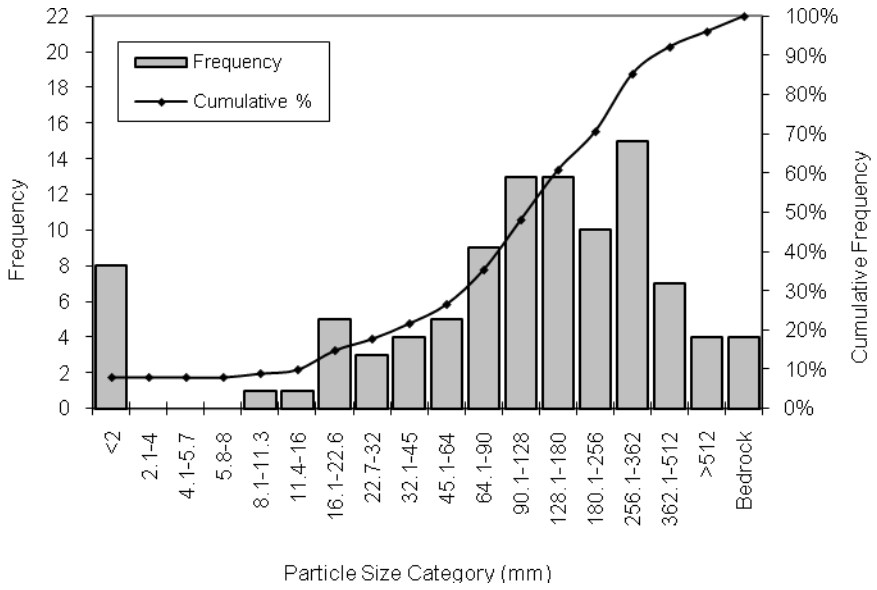
Table 4. Large woody debris quantities in Reach 4.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in by 35 ft)	Total
Number of Pieces	29	4	3	36
Number of Pieces/Mile	76	11	8	95

Figure 51. Burned area near RM 5.2 has the potential to provide short-term LWD recruitment (October 2009).

A-4.6 Substrate and Fine Sediment

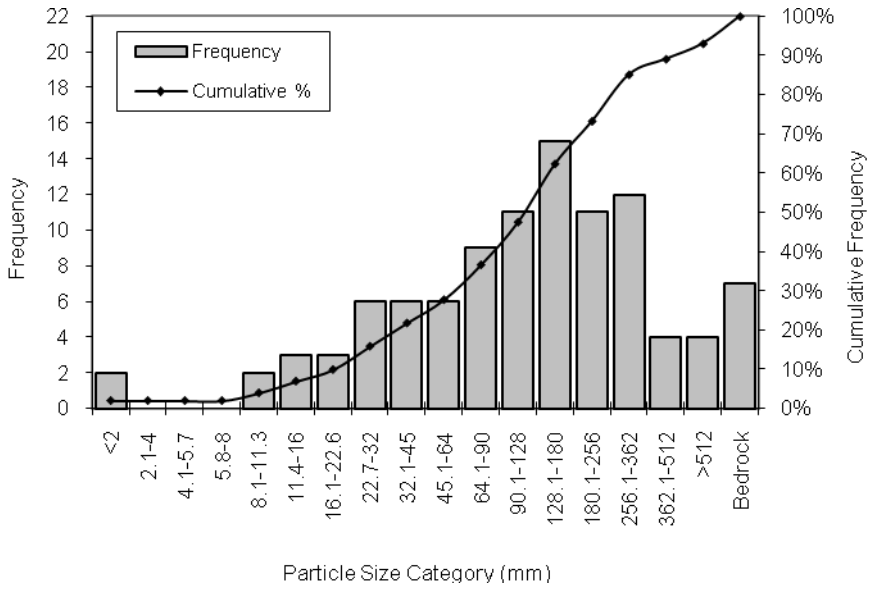
Large cobbles and small boulders are the dominant substrate type throughout the reach. Bedrock is prevalent along the channel margins and in portions of the channel itself, but bedrock consists 10% or less of the total bed composition. Bank erosion at the burned area is a potential source of substrate in the reach (Figure 51). The pebble count data and the results of the ocular substrate measures are depicted in Figure 52, Figure 53, and Figure 54.



Material	Percent Composition
Sand	8%
Gravel	19%
Cobble	44%
Boulder	25%
Bedrock	4%

Size Class	Size percent finer than (mm)
D5	2
D16	27
D50	136
D84	353
D95	883

Figure 52. Grain size distribution and particle size classes from pebble count taken near RM 5.25.



Material	Percent Composition
Sand	2%
Gravel	26%
Cobble	46%
Boulder	20%
Bedrock	7%

Size Class	Size percent finer than (mm)
D5	13
D16	32
D50	137
D84	352
D95	1024

Figure 53. Grain size distribution and particle size classes from pebble count taken at RM 5.38.

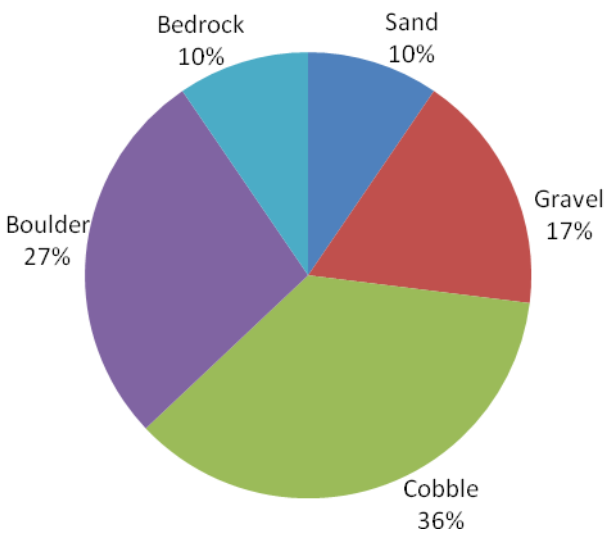


Figure 54. Percent composition of bed substrate based on ocular estimates, Reach 4.

A-4.7 Instability and Disturbance

There are approximately 20 feet of riprap on both banks upstream of the Poorman Cut-off Road Bridge. There are no other significant alterations to channel or floodplain processes in the reach. Human activities mainly consist of recreation access. There is a swimming area, trail, and picnic table on the river-right bank at RM 5.2. Most of the homes are located well above the floodplain.

A-4.8 Available Spawning and Rearing Habitat

There is good spawning and rearing habitat in Reach 4. Although substrate is generally coarse (cobbles and boulders), a few of the long tail-outs at the bedrock-formed pools provide high quality potential for spring Chinook and steelhead spawning. The deep pools also provide good adult holding and juvenile rearing habitat for multiple salmonid species.

The dominant substrate in the riffles is cobble (45%) and sub-dominant is boulders (23%) and gravels (22%). Pool quantity within the reach is much higher in Reach 4 than any of the other reaches, with 23.7 pools per mile compared with 8.9 to 25.7 pools per mile in the other reaches. Twenty-two percent of the pools have a residual depth of less than 2 feet. Forty-four percent have residual depths greater than 3 feet. LWD frequency is moderate compared to the other reaches. Pools provide most of the protection and cover within the reach.

A-4.9 Fish Passage Barriers

There are no fish passage barriers in Reach 4. Mean riffle thalweg depth is 0.8 feet, which is the minimum threshold depth for passage of spring Chinook (Thompson 1972). Flow depths in some years may present passage limitations for Chinook.

A-4.10 Riparian Corridor

The riparian area is generally in good condition due to the steep slopes and limited access to streambanks (Figure 56). A recent burned area was located within the riparian zone and adjacent hillslope near RM 5.2 (Figure 51).

In the riparian inner zone, small trees were the dominant size class (100%) in all measured units, and all units were dominated by hardwoods, mostly cottonwoods, alder, and dogwood. In the riparian outer zone, large trees were dominant in the majority of units (83%), followed by small trees (17%) (Figure 55). All of the measured outer zones were dominated by conifers, primarily ponderosa pine.

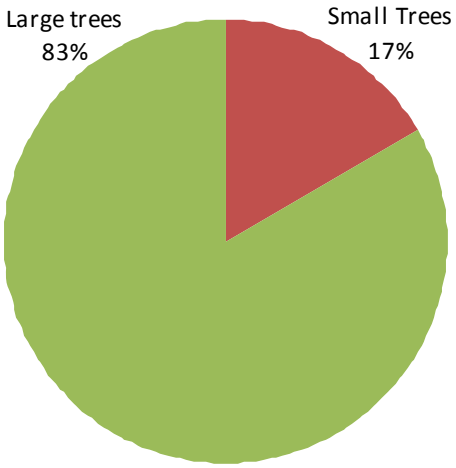


Figure 55. Distribution of the dominant size class category for the riparian outer zones, Reach 4.

Figure 56. Mature conifers in the riparian area near RM 5.1 (October 2009).

A-5 REACH 5 (same as Reach Assessment Reach 3b and 3c)

Location: River mile 5.6 to River mile 7.8

Survey Date: October 8-10, 2009

Survey Crew: Robin Jenkinson and Emily Plummer (Inter-Fluve)

* A staff gage is located at RM 6.6. The gage read 0.8 feet at the time of the survey.

A-5.1 Reach Overview

Reach 5 extends from the bedrock gorge upstream 2.1 miles to Newby Creek (Figure 57 and Figure 58). The reach is low gradient and flows through a wide, moderately confined valley. Development of the floodplain is primarily agricultural and rural residential and includes land clearing, irrigation diversions, and levees to protect against erosion and flooding. The Twisp River Road parallels the reach to the north. There are screened irrigation diversions at two locations: (1) near RM 7.4 on the north bank (Twisp River Power and Irrigation Ditch) and (2) near RM 6.4 on the south bank. There is also a fish weir that is operated seasonally at RM 7.25.

Figure 57. Reach 5 – Downstream Portion. Reach locator and habitat unit composition map.

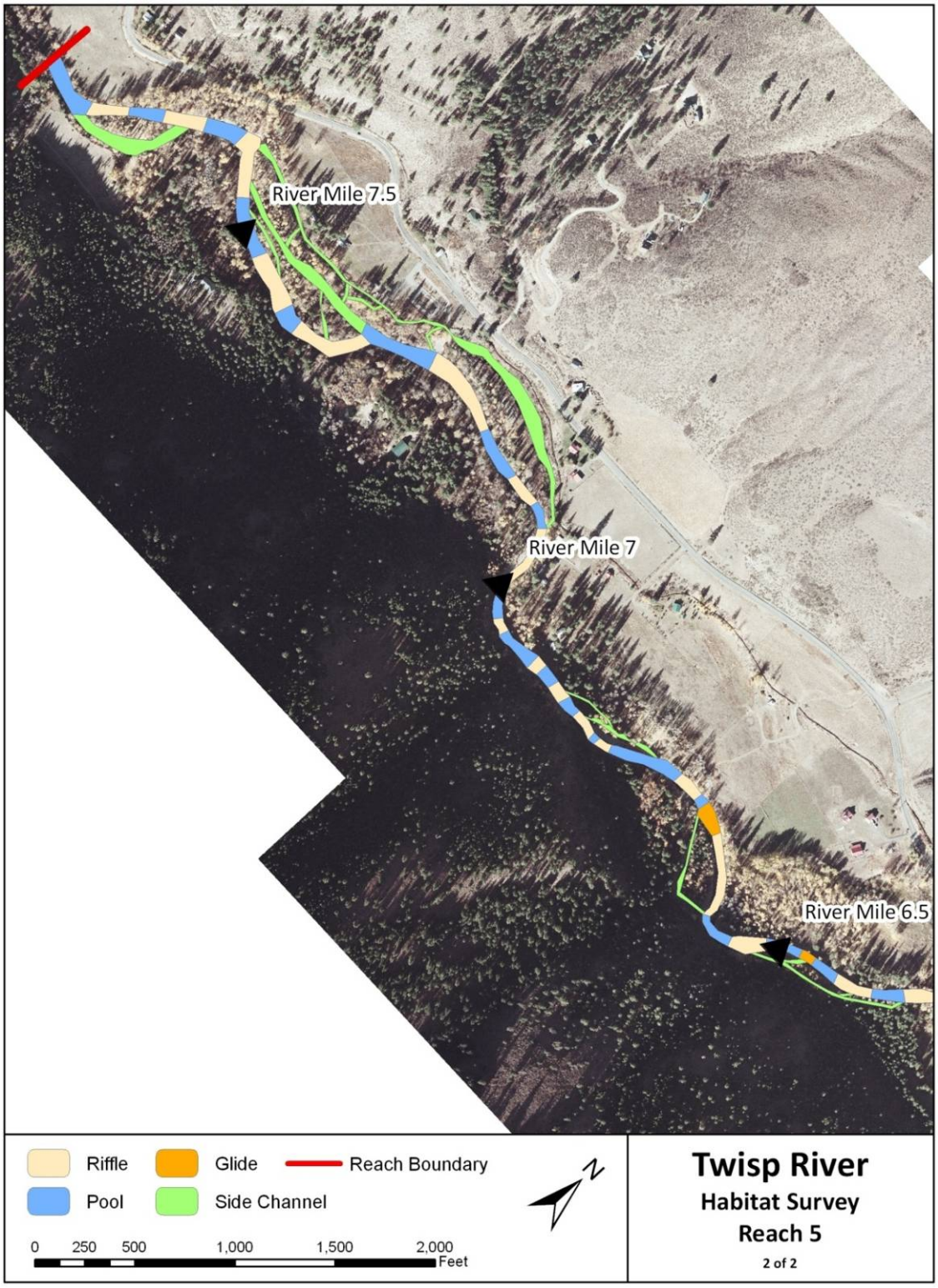


Figure 58. Reach 5 – Upstream Portion. Reach locator and habitat unit composition map.

A-5.2 Channel Morphology

Reach 5 is low gradient (1.3%) and flows through a wide, moderately confined valley. The reach is mostly pool-riffle with several multiple-thread sections with side-channels. Several long plane-bed sections are located within the reach (Figure 60). The reach is bounded by glacial terraces and tributary alluvial fan deposits. There is generally good connectivity with floodplains with the exception of several locations where levees, bank armoring, bridges, and/or floodplain fill have artificially confined channels and have limited floodplain connections.

Figure 59. View looking upstream at a long plane-bed section near RM 6.3 (October 2009).

A-5.3 Habitat Unit Composition

Reach 5 consists of 34% pools, 46% riffles, 7% glides, and 13% side-channels (Figure 60 and Figure 61). Pool frequency is 10.5 pools/mile or 1 pool every 4 bankfull widths. Average residual pool depth is 1.9 feet. Average maximum pool depth is 2.7 feet.

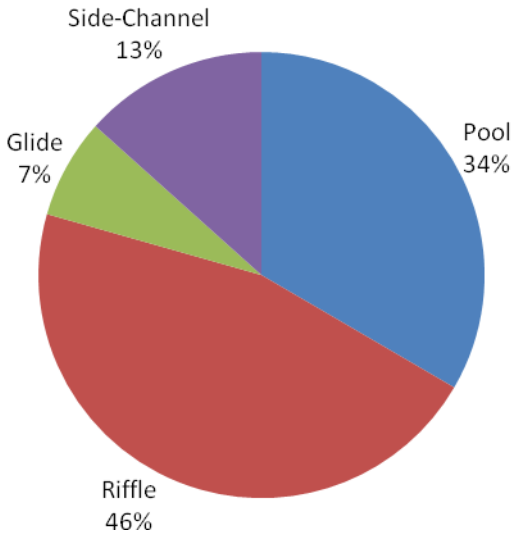


Figure 60. Habitat unit composition, Reach 5.

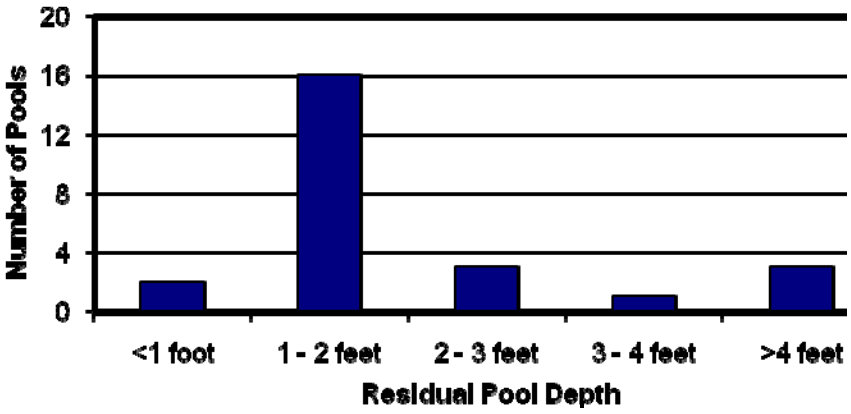


Figure 61. Reach 5 residual pool depths.

A-5.4 Off-Channel Habitat

Reach 5 has the greatest amount of side-channel habitat of all the reaches in the study area. Fifteen side channels were observed in Reach 5, which accounts for 13% of the habitat area in the reach. Several of these side-channels were only partially flowing at the time of the survey. Two of the side channels (RM 6.5 and 7.6) are irrigation diversions with return flow to the river. Several of the side-channels are not active at summer low-flow periods. There are floodplain wetlands to the north of the main channel near RM 6.3 that have limited or no connectivity to the main channel during low flow periods.

A-5.5 Large Woody Debris

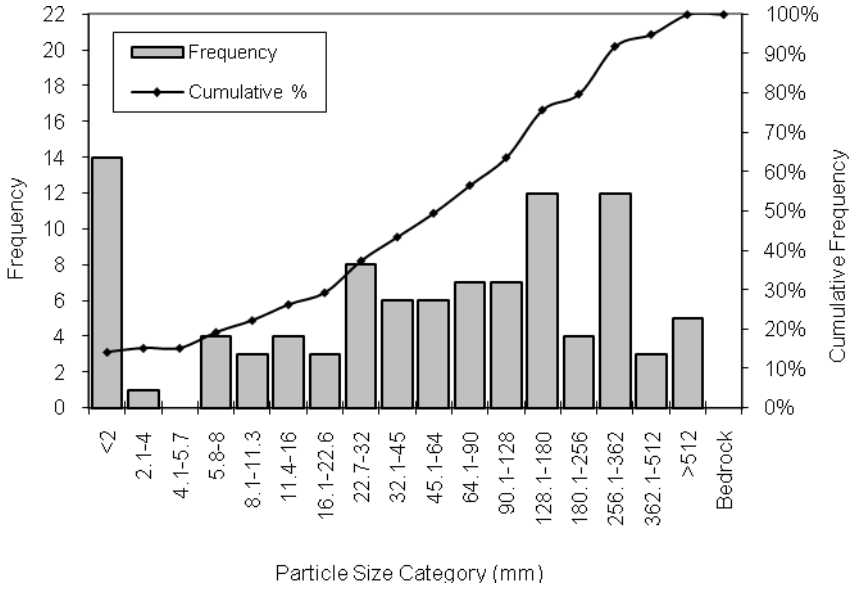
LWD quantities are high for Reach 5 compared to other reaches in the study area. LWD frequency is 165 pieces/mile, with "small" pieces comprising 79% of all LWD counted in the reach (Table 5). "Large" wood pieces are relatively scarce and only account for 2% of the LWD in the reach.

Table 5. Large woody debris quantities in Reach 5.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in by 35 ft)	Total
Number of Pieces	309	76	6	391
Number of Pieces/Mile	130	32	3	165

A-5.6 Substrate and Fine Sediment

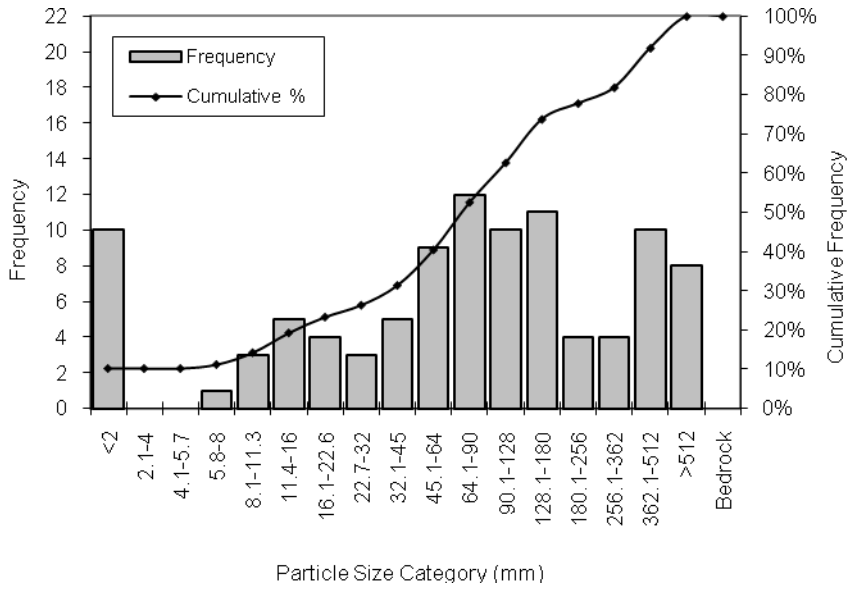
Bed substrate is dominated by gravels and cobbles, with boulders sub-dominant. Bedrock is relatively uncommon although bedrock outcrops were observed at a few locations along the reach. Sand, which is more common in Reach 5 than in other reaches, comprises up to 15% of the distribution. The pebble count and size class data are depicted in Figure 62, Figure 63, and Figure 64.



Material	Percent Composition
Sand	14%
Gravel	35%
Cobble	30%
Boulder	20%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	2
D16	6
D50	66
D84	991
D95	512

Figure 62. Grain size distribution and particle size classes from pebble count taken at RM 5.6.



Material	Percent Composition
Sand	10%
Gravel	30%
Cobble	37%
Boulder	22%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	2
D16	26
D50	85
D84	394
D95	707

Figure 63. Grain size distribution and particle size classes from pebble count taken at RM 7.65.

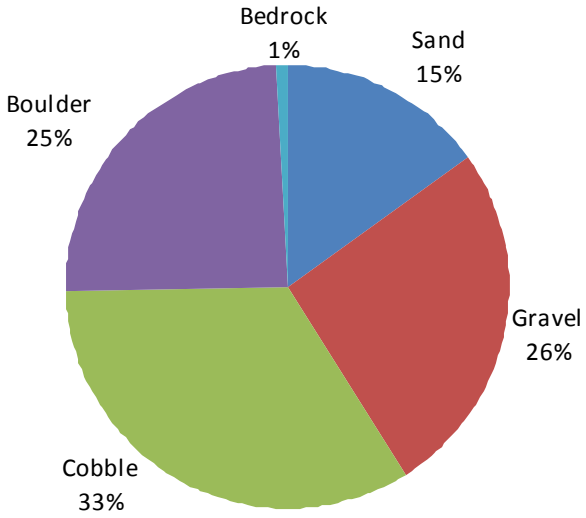


Figure 64. Percent composition of bed substrate based on ocular estimates, Reach 5.

A-5.7 Instability and Disturbance

Human activities have modified the channel, floodplain, and associated riparian corridor within the reach. The primary elements of disturbance to the channel include riprap, levees, road embankments, and irrigation diversions. The two areas of greatest impact are where the Twisp River Road abuts the channel for approximately 1,600 feet near RM 6.1 and near RM 7.2 where a private bridge, fish weir, levee, and diversion canal constrain channel processes. Other shorter sections of levee and riprap are located throughout the reach. Two private bridges cross the river, one at RM 6.1 and another at RM 7.15.

Land use is rural residential and agriculture. There are several private residences located within the floodplain or on adjacent terraces (Figure 65); many of these areas have streambanks protected with riprap. There is cleared pasture land at several locations, including a long section along the south bank from RM 5.8 to 6.3, where there is only a narrow forested riparian buffer (less than 50 feet in most locations) (Figure 66).

Active bank erosion is evident along the reach, often associated with land clearing for agriculture, residential uses, or roadways. Active erosion of the glacial terrace also occurs in several places, including at RM 6.9 and RM 6.55 (Figure 67).

Figure 65. House adjacent to main channel near RM 6.75 (October 2009).

Figure 66. View looking upstream at the narrow forested buffer separating the main channel from pasture land near RM 5.9 (October 2009).

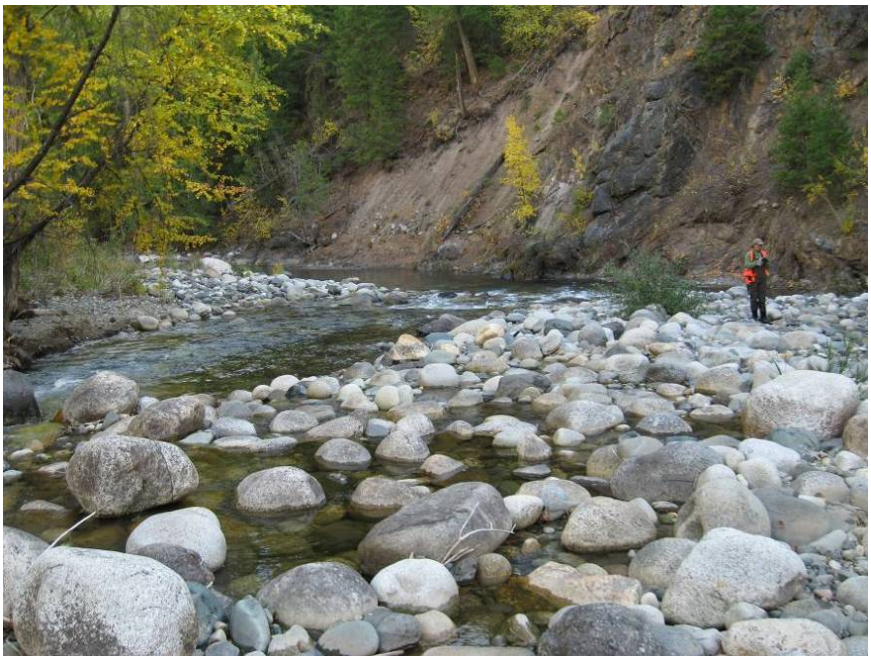


Figure 67. Exposure of bedrock and erosion of glacial material near RM 6.55 (October 2009).

A-5.8 Available Spawning and Rearing Habitat

There is moderate spawning and rearing habitat available in Reach 5. The dominant substrates are cobbles and gravels; boulders are sub-dominant. Although steelhead and spring Chinook spawning occurs in this reach, many of the riffle and pool tail-out areas consist of large cobbles (> 128 mm) that are larger than the ideal size for Chinook (i.e. 13 – 102 mm) and steelhead (6 – 102 mm) spawning (Bjornn and Reiser 1991). However, the coarse bed provides areas of localized velocity refuge that may be utilized for rearing by juvenile steelhead and resident trout.

Pool quantity within the reach is low and the majority of pools (72%) have a residual depth of less than 2 feet. There are three pools (12% of the reach total) with residual depths greater than 3 feet. LWD cover is relatively abundant along the reach.

A-5.9 Fish Passage Barriers

Fish passage is mostly unrestricted in Reach 5. Mean riffle thalweg depth is 0.8 feet, which meets the minimum threshold depth for passage of spring Chinook (Thompson 1972) and exceeds the threshold for bull trout passage. The absence of adequate flow depths in riffles during summer low flow could be a potential concern in very dry years.

The fish weir at RM 7.25 likely presents a passage barrier for upstream migration juveniles during low flows (Figure 68). A 2.5-ft tall concrete dam located just downstream of the irrigation diversion on a side-channel at RM 7.6 may limit fish passage, especially during summer low flow periods (Figure 69).

Figure 68. Adult fish weir at RM 7.25 (October 2009).

Figure 69. Concrete diversion weir at RM 7.6 used to divert flow into an irrigation canal (October 2009).

A-5.10 Riparian Corridor

The presence and width of a forested riparian buffer varies within the reach. Past land clearing for agriculture and the Twisp River Road embankment results in a narrow forested riparian buffer (less than 50 feet wide) on portions of the right and left banks between RM 5.8 and RM 6.2. There are other areas of localized clearing of riparian vegetation due primarily to residential uses.

Most of the riparian inner zones are dominated by small trees (56%) (Figure 70), and mostly consist of hardwoods (78% hardwood; 22% conifer). Cottonwoods, alder, and dogwood are the most prevalent inner zone species. The majority of riparian outer zones are dominated by large trees (56%), followed by small trees (33%) and grass/forbs (11%) (Figure 71). Conifers are the dominant tree in outer zones (22% hardwood; 67% conifer). Outer zones include ponderosa pine, cottonwoods, shrubs, and grasses (i.e. pasture and lawns).

The level of stream shade provided by the riparian canopy varies throughout the reach. Topographic shading is provided by the steep southern valley wall in the middle portion of the reach (RM 6.4 – 7.0).

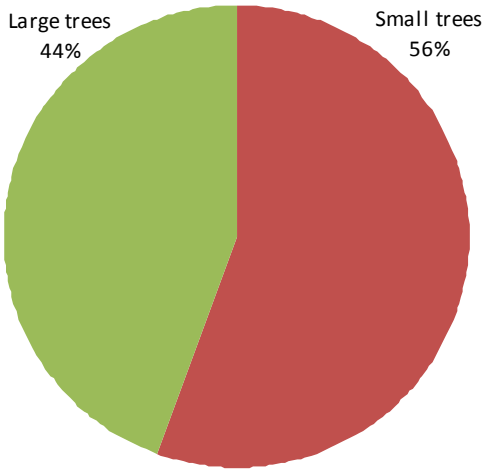


Figure 70. Distribution of the dominant size class category for the riparian inner zones, Reach 5.

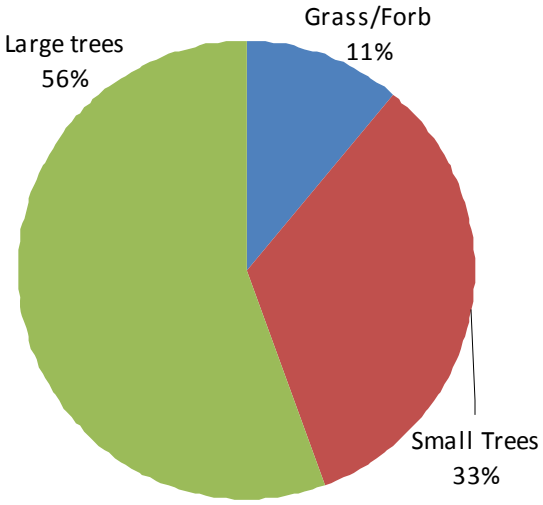


Figure 71. Distribution of the dominant size class category for the riparian outer zones, Reach 5.