CHAPTER 4: EAST FORK LEWIS RIVER BASIN – HABITAT ASSESSMENT

Survey on Rock Creek (upper) in the East Fork Lewis River Basin – October 2004

Prepared for

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January 2005

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Acknowledgments

The authors would like to thank the Lower Columbia Fish Recovery Board and staff including Jeff Breckel, Melody Tereski, Gary Wade, Phil Trask, and Lorie Clark. Clark County staff including Rod Swanson, Ron Wierenga, and Dan Kaler provided invaluable data, field assistance, technical review, and other information. Thanks also to those who assisted with the field data collection effort, including Kathryn Arendt and Caryn Ackerman. We thank the landowners who provided access to their property for field surveys. Dan Rawding (WDFW) and Randy Sweet (LCFRB board member) provided valuable information and reviewed portions of the document. Thanks also to the staff of R2 Resource Consultants who we closely collaborated with throughout this project.

4.1 Basin-Specific Methodology

4.1.1 Hydromodification Assessment

The hydromodifications assessment for the lower East Fork Lewis River consists of four individual analyses. The first is a quantification of land-use disturbance throughout the lower river valley bottom. The second is an identification of specific hydromodifications that alter geomorphic processes in the lower river corridor. The third analysis looks at how the availability of channel margin habitat types for salmonids has changed over the years as a result of disturbance. The fourth investigation looks at how the channel migration zone has changed since pre-settlement conditions. The methodologies used for these four analyses are discussed below.

4.1.1.1 Valley Bottom Disturbance

The extent of land-use disturbance in the lower East Fork Lewis River Valley was recorded in order to assess potential impacts to aquatic habitat and to assist in the identification of preservation and restoration efforts. The lower East Fork valley bottom was used as the primary area for analysis. The valley bottom is defined as the area extending between the base of the valley wall on either side of the stream from the mouth to the Lower Rock Creek (LW Rock Creek) confluence at river mile 16.1. The valley bottom essentially equates to the area of Holocene alluvium deposited by the East Fork Lewis River since the last ice age. The valley bottom was delineated as a polygon in a GIS using LiDAR generated 2 foot interval contours. The toe of the valley wall was easily identified as a significant break in topographical slope.

Valley bottom disturbance was classified into 8 categories using high resolution (6 inch pixel resolution) digital aerial photos and information from field surveys. Polygons of disturbance types were digitized in a GIS to facilitate mapping and the quantification of the extent of disturbed areas. The categories and their definitions are as follows:

1. Agriculture – crop or pasture land
2. Cleared – cleared areas not currently under active uses but that are subject to development
3. Open space – disturbed land (diked, drained, cleared) that is unlikely to be developed because of location and/or County, State, or Columbia Land Trust ownership
4. Industrial / Mining – includes the Storedahl Daybreak mining operations site, the Clark County maintenance facility (RM 9.4), and the airstrip (RM 6.4)
5. Public Park – areas within Paradise Point State Park, Daybreak County Park, or Lewisville County Park
6. Residential – areas in rural residential or suburban residential uses, including yards and sparsely forested residential lots
7. Highway Crossings – highway crossings of the valley bottom including fill and bridges (I-5, La Center Bridge, Daybreak Bridge, Lewisville Bridge)
8. Natural – areas that are: a) currently forested, or b) non-forest areas (i.e. wetlands) that do not contain significant disturbance other than invasive species.

4.1.1.2 Hydromodifications

For the purposes of this analysis, hydromodifications refer to anthropogenic modifications that impact the natural geomorphic processes of the stream channel, floodplain, or channel migration zone. The hydromodifications in the lower East Fork include dredging, bridges, roads, fill, levees, mining operations, residential development, and armored banks. Invasive species are also included due to their impact on native riparian vegetation, which potentially influences bank stability and wood recruitment processes.

Hydromodifications were mapped along the lower East Fork from the mouth to LW Rock Creek (RM 16.1). Identification of hydromodifications was conducted using remote sensing and field surveys. Hydromodifications were digitized in a GIS using year 2002 high resolution (6 inch pixel resolution) digital color aerial photographs provided by Clark County. The SSHIAP (WA Dept. of Fish & Wildlife – Salmon and Steelhead Habitat Inventory and Assessment Program) hydromodifications data layers, which consist of point, line, and polygon coverages, were used as a base for the assessment. Field surveys of hydromodifications occurred jointly with the boat-based stream habitat surveys conducted on the lower East Fork from Lewisville Park to the mouth. The locations of some hydromodifications were recorded with a hand-held GPS unit in areas where tree canopy limited the accuracy of aerial photo interpretation. For some hydromodifications, including armored banks and levees, field surveys provided the best source of information. For other hydromodifications, including roads and residential development, aerial photographs provided the most detail. Hydromodifications were classified according to the methodology developed by SSHIAP (2001). New data layers were created in a format that can be used to easily update the existing SSHIAP data layers.

The lineal extent of hydromodifications was quantified along EDT reaches. The lineal length of stream is considered affected if either bank contains the hydromodification. Thus, if only one side of an entire reach has bank armoring, then the reach would be considered 100% armored. For the purposes of this analysis, hydromodifications were grouped into the following categories:

1. Armored – hardened banks (i.e. riprap) serving as a geomorphic control.
2. Avulsed – portion of stream channel avulsed into Ridgefield Pits. Mile 9 pit avulsion not included.
3. Artificial Confinement – channel confinement created by levees, roadways, or bridges.
4. Cleared/Developed – includes cropland, pastureland, rural residential land, lawn, and cleared but undeveloped land.
5. Channel Incision – includes the extent of channel incision associated with the Ridgefield Pit avulsions.
6. Invasive Species Dominated – streambanks where invasive species are the dominant vegetation type. Species include primarily Scotch Broom (*Cytisus scoparius*), Japanese knotweed (*Polygonum cuspidatum*), reed canary Grass (*Phalaris arundinacea*), and Himalayan blackberry (*Rubus discolor*).

4.1.1.3 Channel Margin Habitat

This analysis looks at the change in the type of channel margin habitat in the lower East Fork Lewis River between 1939, 1955, and 2002. The study area consists of the lower mainstem East Fork Lewis, plus any connected side channels or off-channel areas, from the mouth to the LW Rock Creek confluence at river mile 16.1. Aerial photo series from 1939, 1955, and 2002 were used for the assessment. The 1955 and 2002 photos were obtained from Clark County and the 1939 photos were obtained from the US Army Corps of Engineers. The 2002 photos were high resolution (6 inch pixel resolution) digital color aerial photos that had been orthorectified and georeferenced. The 1955 photos had been georeferenced by Clark County but had not been previously orthorectified. The 1939 photos were neither orthorectified nor georeferenced. The 1939 photos were spatially aligned using the georeferencing function in ArcMap™, which provides coarse scale orthorectification. Each of these years contained complete coverage of the study area except for small portions of the 1939 photos, where information was extrapolated from adjacent areas with photo coverage. The wetted surface of the stream and connected off-channels were digitized in a GIS for each of the photo series. Individual polygons were created for each of three primary channel types including main channels, side channels, and back channels. Side channels were defined as secondary channels with flowing water separated from the main flow by islands. Back channels were defined as connected off-channel areas with little to no flow velocities. Back channels included floodplain sloughs, abandoned side channels, alcoves, and connected streamside gravel pits.

The amount and type of habitat was quantified for each reach and for each of the three periods in order to facilitate comparisons between years and between reaches. This information showed trends in channel margin habitat type and helped to identify areas for potential restoration of back channels and side channels.

4.1.1.4 Channel Migration Zone Assessment

This assessment estimates the historical and current extent of the valley floor that is accessible to the lower mainstem channel though meander migration and stream channel avulsions. This area is typically termed the Channel Migration Zone (CMZ). Comparison of the historical and current CMZ helps to determine the degree of human alteration to geomorphic stream channel processes and can provide useful information for identifying stream restoration opportunities.

The delineation of the historical and current CMZ for the lower Lewis was conducted primarily using remote sensing data and involved making a number of assumptions regarding channel migration potential. The CMZ boundaries were determined for the purposes of this analysis and are not intended to be used for regulatory purposes. The historical and current CMZ was delineated from the LW Rock Creek confluence (RM 16.1) to Mason Creek (RM 5.7). Downstream of Mason Creek, the stream is low gradient and tidally influenced. The low sediment transport capacity in this lower segment makes channel migration infrequent and the stream channel appears to have remained relatively stable in its current location over the historical record. Channel and floodplain modifications dating to the late 1800’s have likely contributed to this stability. Because of the early channel modifications and the lack of channel movement documented in the historical record, channel migration zones were not delineated for the lowest 4 mainstem reaches. Over a period of centuries, the stream has likely migrated across the entire valley floor in these reaches; channel movement is now limited by bridges, fill, levees, and bank armoring.

Historical CMZ delineation

In order to estimate the historical extent of the channel migration zone, three methods were employed. First, the widest extent of channel margin locations were mapped using historical maps and photos. These included General Land Office (GLO) survey maps from 1853, a USGS quad map from a 1910 survey, a USACE map from 1935, and aerial photos from 1939, 1955, 1978, and 2002. These were all georeferenced in a GIS if not already registered. Channel margins were digitized in ArcMap™ for all except the 1978 photos. The survey data from 1853 and 1910 was of relatively poor quality, with stream margins intercepting the valley wall in several locations. The CMZ in these areas was edited to conform to the base of the valley wall. In some valley bottom areas not occupied by the stream channel in the historical record, valley floor features such as low floodplain terraces and floodplain depressions suggested past channel location or the potential for future channel occupation. In these locations, the second and third methods of CMZ delineation were employed. These are discussed below.

The second method involved using the aerial photo record to extend the CMZ based on floodplain features. These features primarily included the area within the meander belt-width and extending laterally to include low terraces with meander scroll scars. Low terraces were defined as being less than approximately 10 feet above the elevation of the active channel surface. LiDAR contours overlayed on the high resolution 2002 photos were used in conjunction with older aerial photos to identify the low terraces subject to channel occupation. Method three was used in conjunction with this qualitative approach in some areas as described below.

The third method was to identify the CMZ on higher floodplain terraces not commonly occupied by flood flows, but where active channel movement is occurring (progressive meander migration). In these areas, estimated annual meander migration rates were used to assist in CMZ delineation. The potential extent of migration over a time period of 170 years was used. This is based on the estimated time it would take to grow large wood that would be functional in this system using the criteria specified in the WFPB Forest Practices Board Manual for CMZ delineation (WFPB 2001). Functional large wood can be estimated as wood with a diameter breast height (dbh) of at least one half the reach averaged bankfull channel depth (WFPB 2001), which was approximately 2 meters for reaches 5 through 8. Using a dbh of 1m and a tree diameter growth rate of a quarter inch per year (0.6 cm/yr) yielded a time period of 170 years. The migration rate of a meander upstream of Daybreak Bridge was estimated at 7 feet/year based on comparison of 1939 and 2002 photos. This is similar to the 6 ft/yr rate determined by WEST Consultants and reported in the Storedahl Mine HCP (Sweet et al. 2003) for the river between mile 9 and 10. Six feet per year at 170 years is 1,020 feet; this estimate was used for areas between river mile 9 and 11. Migration rates between river mile 7 and 9 were also estimated by WEST. The average of the estimates reported in the HCP for these reaches is approximately 20 feet/year (not including one 100 ft/yr measure). Twenty feet per year at 170 years is 3,400 feet; this estimate was used between river mile 7 and 9.

Current CMZ delineation

The current CMZ represents the valley floor area that is accessible to channel movement under current conditions. This area was delineated by taking the portion of the historical CMZ that is not constrained by hydromodifications. Hydromodifications used to delineate the current CMZ included features that pose a significant geomorphic control such that they serve to limit lateral channel movement or avulsions. These include levees of significant size, armored banks, well-established roadways, bridges, and areas in uses that would be actively protected during flood events, such as residential development and industrial areas. The current CMZ was delineated on high resolution 2002 digital aerial photos in a GIS. The SSHIAP hydromodification data layers, which were field checked and updated as part of this assessment, were used to assist with CMZ delineation. The FEMA Flood Insurance Rate Map (FIRM) was also used as a reference. The FIRM map denotes the regulatory "floodway", which is the area in which floodplain encroachment would raise the level of the base flood (100 year event) more than one foot in elevation (FEMA 2002). The floodway encompasses the area of the deepest and swiftest flow and was therefore assumed to represent the limit of channel migration in areas where the impact of a particular hydromodification was unknown.

The geomorphic controls used to delineate the current CMZ were evaluated qualitatively and it should be noted that they may not serve to limit channel migration under all conditions. Where feasible, these geomorphic controls may present opportunities for restoration of natural channel migration processes.

4.1.2 Riparian Assessment

The Riparian assessment for the East Fork Lewis River contains five primary analyses. The first is an aerial photograph assessment of large woody debris recruitment potential along all East Fork Basin stream reaches (EDT reaches). The second is an aerial photograph assessment of stream shading conditions for all of the reaches. The third task involved field surveys of riparian conditions in selected reaches in order to field check aerial photo measures and to be used in additional analysis. The fourth task compared field shading information and modeled historical shade conditions to estimate changes to shade and stream temperatures. The fifth task compared riparian assessment results to riparian scores used in the EDT and IWA models.

4.1.2.1 Large Woody Debris Recruitment

Riparian conditions, including categorization of vegetation species type, tree size and density were determined via remote assessment of aerial photographs to estimate large woody debris (LWD) recruitment potential along EDT reaches in the East Fork Lewis Basin. The approach followed the Washington Watershed Analysis guidelines (WFPB 1997). Riparian conditions were assessed using digital aerial photographs with a pixel resolution of 6" and 24". The photographs were taken in early April 2002 prior to deciduous tree leafing. GIS layers of East Fork Lewis water bodies and EDT reaches, obtained from SSHIAP, were edited to line up with the high resolution aerial photographs. These corrected GIS layers were used to generate riparian buffer polygons which extended 100 ft. from each stream bank.

The riparian buffer zone along each EDT reach was split into riparian condition units (RCUs) by dominant vegetation type, tree size and tree density.

Riparian condition codes were as follows:

Vegetation Type:

C =	Conifer	(>70% conifer)
D =	Deciduous	(>70% hardwood)
M =	Mixed	(all other cases)
*	Grass	(>90% grass)
*	Unvegetated	(>90% unvegetated)

*Categories assumed to have no LWD recruitment potential

Tree Size:

S =	Small	(< 12 “ dbh)
M =	Medium	(>12 and < 20 “ dbh)
L =	Large	(>20 “ dbh)

Tree Density:

S =	Sparse	(< 1/3 of ground visible on aerial photos)
D =	Dense	(all other cases)

Each RCU was classified according to its LWD recruitment potential rating as shown in Table 4. 1 and Figure 4. 1. The recruitment potential rating describes the likelihood that the riparian zone will provide functional LWD to the stream in the near term (e.g., a conifer-dominated riparian zone that contains medium-sized trees and is densely stocked (CMD), will have a high likelihood of providing functional LWD to the stream). Condition codes were assigned to a LWD recruitment potential rating of high, moderate or low according to the WFPB guidelines (1997). An overall LWD recruitment rating was assigned to each EDT reach based on a weighted average of the ratings across RCUs within the EDT reach. Ratings of high, medium, and low were assigned values of 3, 2, and 1, respectively, and averaged across RCUs with weights equal to the surface area of the RCU. For example, based on the proportion of each LWD recruitment potential rating by riparian buffer surface area (Table 4. 2), the Manley Creek EDT reach was determined by the following equation:

$$\textbf{LWD recruitment potential} = (3 * .16) + (2 * .19) + (1 * .02) + (0 * .63) = 0.87$$

Overall ratings were rounded to the nearest rating code, thus LWD recruitment potential was classified as low for the Manley Creek EDT reach.

Table 4. 1.Categorical LWD recruitment ratings assigned based on vegetation type, tree size, and tree density scores. From WFPB (1997).

Rating	Riparian Condition Code
High	HSS, HSD, MSS, MSD, CSS, CSD, HMS, HLS
Moderate	HMD, MMS, CMS, CLS, HLD, MLS
Low	CMD, MMD, MLD, CLD

Table 4. 2. Proportion of the Manley Creek EDT reach riparian buffer surface area categorized as having high, moderate, low, and no LWD recruitment potential.

Rating	High	Moderate	Low	None
Code	3	2	1	0
Proportion	0.16	0.19	0.02	0.63

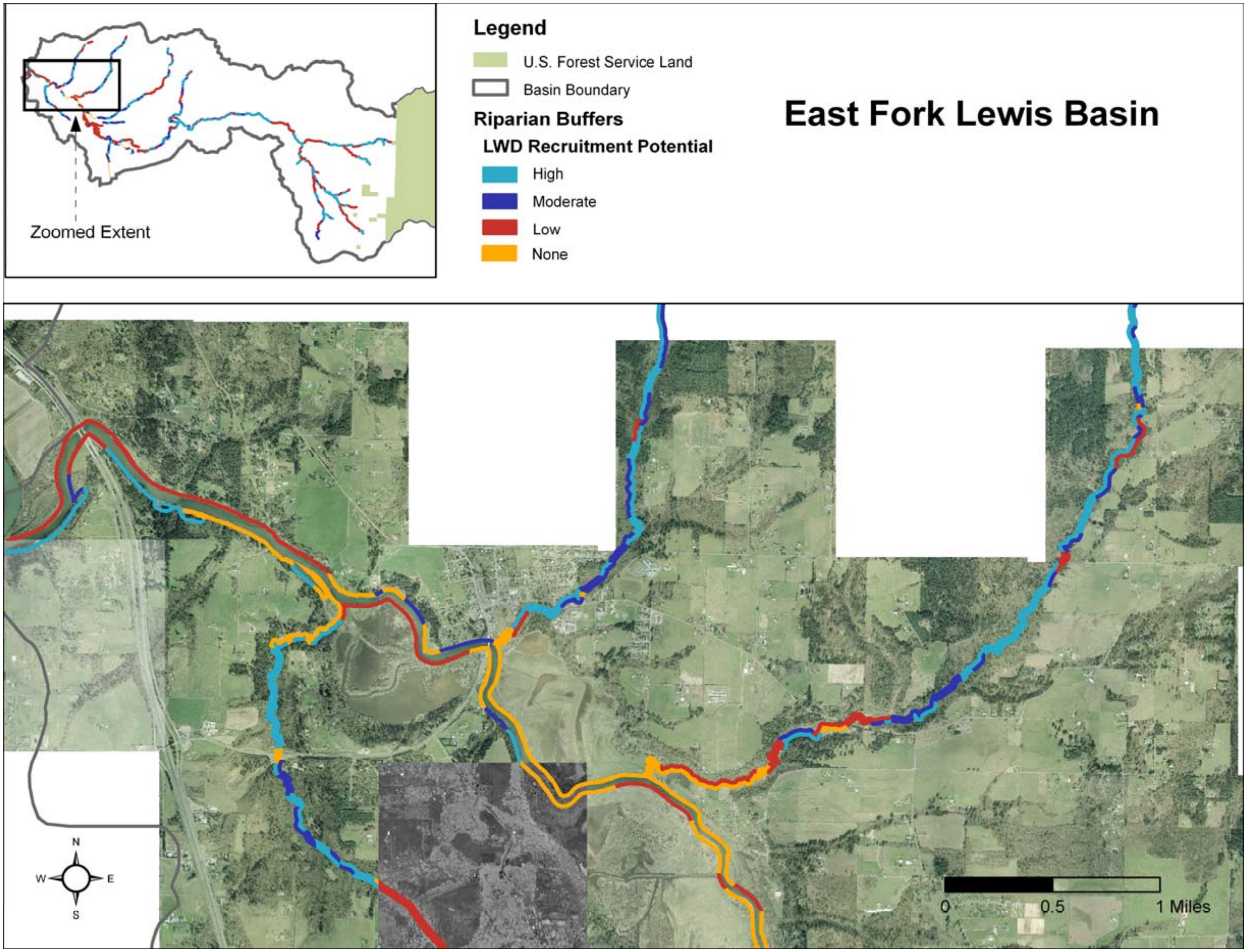

Figure 4. 1. Example of RCUs that have been assigned a LWD recruitment potential rating.

4.1.2.2 Aerial photograph shade assessment

An index of stream visibility from aerial photographs was used to estimate the amount of shade provided by canopy cover along East Fork Lewis EDT reaches. The approach follows the Washington Watershed Analysis guidelines (WFPB 1997). Categorical shade ratings are shown in Table 4. 3.

Table 4. 3. Categorical shade ratings and index of corresponding stream visibility.

Code	Percent Shade	Criteria
5	> 90%	Stream surface not visible on aerial photos
4	70-90%	Stream surface slightly visible or patches
3	40-70%	Stream surface visible but banks are not
2	20-40%	Stream surface and banks visible at times
1	0 - 20%	Stream surface and banks visible

4.1.2.3 Field Verification

VTS

View-to-Sky (VTS) is the fraction of a hemisphere, centered over the stream that is unobstructed by either vegetation or topography. VTS was collected during stream surveys in order to provide field verification to the aerial photo riparian assessment and to be used in modeling change between historical and current shade and temperature conditions. View-to-sky angles were measured at each n^{th} unit (see habitat survey methods section 4.1.3) encountered during stream surveys by estimating the angle to the top of shade producing vegetation on each bank from mid-channel using a hand-held clinometer.

Riparian Zone Width

The inner and outer riparian zone widths were estimated during field surveys, but were not analyzed or reported. It was determined that estimation of the zone widths was too subjective of a parameter to estimate reliably, and reporting those results would be misleading.

4.1.2.4 VTS Modeling

Changes in view-to-sky angles and 7-Day maximum temperatures from pre-settlement conditions were estimated in each reach where field surveys were conducted. Coupled with the temperature elevation screen (Sullivan et al. 1990 as adopted by Washington Forest Practice Board rule), VTS calculations from field survey data can be used to estimate potential stream temperatures per the Washington State DNR Watershed Analysis guidelines (Washington Forest Practices Board 1997).

Pre-settlement vegetative height was assumed to be 150 feet for all reaches with the exception of EF Lewis 1-6B, Dean Creek, and McCormick Creek. Vegetative height in these lower watershed reaches was assumed to be 75 ft. The 150 ft assumption was based on the expected height of a mature conifer in Western Washington. In those reaches where vegetative height was 75 feet, it was assumed that the riparian vegetation was primarily hardwoods which tend to be dominant in lower river watersheds. The mature height of these species is considerably smaller than western Washington conifers.

Change for both VTS and temperature were assigned qualitative impact ratings of low, moderate and high. Those ratings were based on criteria defined in Table 4. 4.

Table 4. 4. Categorical impact ratings assigned based on VTS and temperature change scores.

Rating	Change in VTS (angle in degrees)	Change in Temperature ºC
Low	<+15	<+1
Moderate	+15-35	+1-3
High	>+35	>+3

4.1.2.5 Comparison to EDT and IWA Scores

The riparian function of reaches of the East Fork Lewis was determined using results from aerial photo analysis, and when possible, field observations from stream surveys. The results were compared to values assigned under EDT patient conditions, and the Integrated Watershed Analysis (IWA) impairment ratings.

According to the EDT attribute guidelines, healthy riparian areas dissipate flood energy, moderate drought, store surface waters, recharge groundwater supplies, moderate water temperatures by providing shade, regulate energy inputs, and reduce erosion. Healthy riparian areas also provide large-sized wood structure. EDT ratings are made between 0 and 4 with 0 representing healthy riparian areas, and 4 representing complete severage of floodplain linkages.

Riparian function ratings have been assigned to each EDT reach by WDFW as part of the Lower Columbia River Subbasin planning process. Rationale used to assign ratings were as follows: riparian zones with mature conifers were rated 0.0-1.0 depending on density of large trees and bank stability. Riparian zones with deciduous trees were rated 1.5, and those with brush and few trees were rated as 2.0. For a rating to exceed 2.0, disturbances in the riparian zone needed to be present (LCFRB 2004).

We used these same rationale to assign EDT riparian function scores based on air photo analysis and field survey data. Exceptions to these rationale were made in the East Fork Lewis reaches 1-6B, and the lowest reach of mainstem tributaries downstream of Mill Creek because the riparian zones of these reaches were likely historically dominated by deciduous overstory. In these reaches, the riparian function rating was based on results of the VTS analysis. Reaches where there was no change from historical VTS conditions were rated 0. Reaches of low impact were rated 1, reaches of moderate impact were rated 1.5, and reaches of high impact were rated 2.0.

In this exercise, any disturbance including armoring, avulsion, artificial confinement, incision, and presence of invasive species was taken into account when determining the extent that riparian function has been degraded. The magnitude of riparian disturbance affects the riparian zone was taken into account when assigning EDT scores. Disturbances were only incorporated into the riparian function rating in reaches that were surveyed in the field. In reaches not surveyed, the shade rating from GIS analysis (Table 4. 19) was used as a surrogate for the disturbance level as the second part of determining the riparian function rating. Low shade ratings were assumed to represent increased disturbance levels. In summary, our assignment of a riparian function rating is two part: one based on vegetation type, and a second based on disturbance levels, which was inferred from shade level in reaches not field surveyed.

The IWA riparian component, which was applied to the East Fork Lewis Basin as part of the Lower Columbia Subbasin Planning (LCFRB 2004), rated riparian conditions as impaired, moderately impaired, or functional within subwatersheds (7^{th} field HUCs) in the East Fork Basin. Riparian zone condition is evaluated using a data layer developed following the methods of Lunetta et al. (1997). The data layer describes the proportion of streamside buffer acreage by vegetation class, based on the intersection of LANDSAT TM 1993 data layer with a 30 meter buffer polygon around 1:24,000 SSHIAP stream segments. Functionality or impairment of riparian vegetation is based on the proportion of total buffer area in five vegetation classes including: 1) late seral vegetation, 2) mid seral vegetation, 3) early seral vegetation, 4) other forested lands, clear cuts, brush, young deciduous forests, and 5) non-forested lands including rock, snowfield, urban areas, and agricultural land. The proportion of riparian buffer within these vegetation classes is compared to accepted and newly defined thresholds in order to assign an impairment rating (LCFRB 2004).

4.1.3 Stream Habitat Assessment

Stream reaches were surveyed throughout the East Fork Lewis River Basin between September 27 and October 14, 2004. A total of 40.7 km of stream were surveyed including 27.5 km in the mainstem East Fork Lewis and 13.2 km in tributaries to the East Fork (Figure 4. 2). Surveys in the mainstem lower East Fork Lewis (below Lucia Falls) were conducted via boat, and all others were done on foot. A modified version of the USFS Region 6 Level II Stream Survey Protocol was used for the survey (USFS 1999). General survey methodologies are explained in the introduction and methods chapter (Chapter 1).

There were several modifications to the survey protocol made specifically for the East Fork Lewis Basin surveys. In other basins, maximum depth was not estimated in surveys conducted via boat. In the East Fork Lewis, maximum depths were measured up to 5.0 m in depth. Units deeper than that were called “>5 m”. Secondly, *at least* one pebble count was conducted in each reach where it was safe to do so. In some reaches in the mainstem East Fork, the current was too swift and water too deep to permit a pebble count. Pebble counts were only conducted in pool tailouts with one exception. In LW Rock Creek, an additional pebble count was conducted in a riffle. Minimum depths were not measured in each unit, and average bankfull depth was not estimated. Maximum bankfull depth was visually approximated in every n^{th} unit. Additional information was collected at n^{th} units for at least 10 units per reach, and for at least 10% of each unit type. Finally, the inner riparian zone width was estimated during field surveys, but was not reported. It was determined that estimation of the inner riparian zone width was too subjective of a parameter to estimate reliably, and reporting those results would be misleading.

The identification of habitat unit types differed somewhat from the USFS Level II habitat survey methodology. The habitat unit designations that were used for this project included pool, riffle, glide, beaver pond, and culvert. The designation of habitat type was determined from visible inspection and the dimensions of each habitat type were measured using a hip chain or laser range finder. In order to have greater applicability to the habitat unit types used in the EDT model, the substrate characteristics in riffles were designated. EDT distinguishes between small cobble riffles and large cobble riffles, a distinction that affects the amount of assumed spawning use of the riffles in the model. Whereas we did not call out separate habitat types for small vs. large cobble riffles, we did estimate the percentage of small cobbles (<5 inch diameter) vs. large cobbles (>5 inch diameter) in each riffle. This information can be used to split out riffle types for modeling purposes.

Several EDT reaches were split because stream surveys, aerial photo analysis, and LiDAR stream contour analysis indicated that habitat within portions of the reach were substantially different. Those sub-divided reaches are denoted differently from the original reach name by adding an "A" or "B" to the end of the reach name with "A" indicating the downstream portion of the original reach, and "B" the upstream portion. The partitioned reaches and their boundaries are listed in Table 4. 5.

Table 4. 5. EDT reaches partitioned based on substantial changes in habitat within the reach.

New Reach	Description
EF Lewis 6_A	Dean Creek to head of abandoned channel upstream of Ridgfield gravel pits
EF Lewis 6_B	Head of abandoned channel to Mill Creek
EF Lewis 8_A	Mill Creek to Lewisville Bridge
EF Lewis 8_B	Lewisville Bridge to Rock Creek
McCormick Creek_A	Mouth to County Property Boundary (0.5 miles)
McCormick Creek_B	County Property Boundary to first blocking culvert
Lockwood Creek_A	Mouth to Leigh Property (0.75 miles)
Lockwood Creek_B	Downstream end of Leigh Property to fishtrap1
Dean Creek_A	Mouth to J.A. Moore Road (0.9 miles)
Dean Creek_B	J.A. Moore Road to blocking culvert

Survey sites were selected based on a stratified subsampling procedure. Reaches within the East Fork Lewis were grouped into both tiers and gradient/width categories. The subsampling design required that 50% of the total length of Tier 1 reaches be sampled, 20% of Tier 2 reaches, and 10% of Tier 3 and 4 reaches. Likewise, 10% of each of the gradient/width categores needed to be sampled. All of the site selection criteria were fulfilled with the exception of one (Table 4. 7). We did not sample 10% of the moderate-narrow (MN) gradient/width category because permission could not be secured in sufficient survey sites to do so. Additionally, the survey protocol specified that no reach less than 0.8 km in length would be surveyed. Two surveys in the East Fork Lewis Basin were only 0.7 km long because land access permission denials prevented surveying beyond either end of the reaches. East Fork Lewis reach 7 was not surveyed because the reach no longer exists. The reach was 140m long, but migration of the East Fork Lewis mainstem caused that reach to be encompassed by reach 8A.

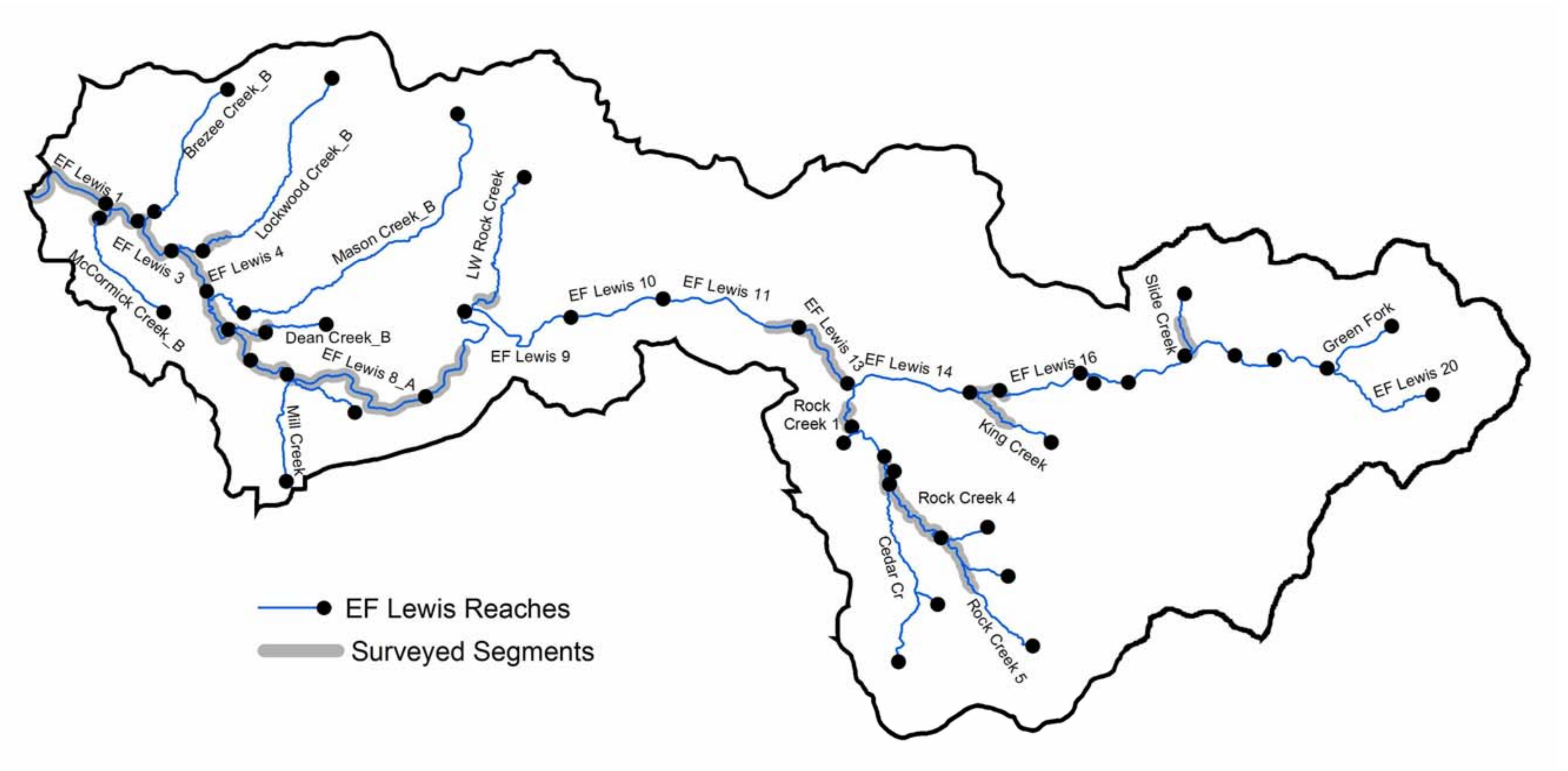

Figure 4. 2. Reaches surveyed in the East Fork Lewis Basin as part of the Stream Habitat Assessment.

Table 4. 6. Summary of reaches surveyed within the East Fork Lewis including gradient/width category and tier.

Surveyed Reach	Grad/Width[1]	Tier[2]	Survey Length (km)	EDT Length (km)	% of EDT Reach Surveyed
EF Lewis 1	LW	2	3.7	3.7	100%
EF Lewis 2	LW	3	1.5	1.5	100%
EF Lewis 3	LW	2	2.0	2.0	100%
EF Lewis 4	LW	1	2.0	2.0	100%
EF Lewis 5	LW	1	2.5	2.5	100%
EF Lewis 6A	LW	1	1.6	1.6	100%
EF Lewis 6B	LW	1	1.6	1.6	100%
EF Lewis 8A	LW	1	5.9	5.9	100%
EF Lewis 8B	LW	1	2.3	5.1	45%
EF Lewis 11	LW	2	1.3	5.1	25%
EF Lewis 13	MW	1	2.1	2.7	78%
EF Lewis 15	MW	1	1.0	1.0	100%
McCormick Creek_A	MN	2	0.9	0.9	100%
Lockwood Creek_B	MN	2	1.0	8.9	11%
Dean Creek_A	MN	3	0.7	1.5	47%
LW Rock Creek	MN	2	0.7	6.6	11%
Rock Creek 1	MM	1	1.1	2.0	55%
Rock Creek 3	MM	1	1.2	1.2	100%
Rock Creek 4	MM	1	2.6	3.4	76%
Rock Creek 5	HM	3	2.0	5.4	37%
King Creek	HN	3	1.8	3.8	47%
Slide Creek	HM	2	1.2	2.4	50%

1. *LW = low gradient and wide; MW = moderate gradient and wide; MN = moderate gradient and narrow; MM = moderate gradient and moderately wide; HM = high gradient and moderately wide; HN = high gradient and narrow. Gradient: low = <1%, moderate = 1-3%, high = >3%. Width: narrow = <5.1m, moderate = 5.1-14.6 m, high = >14.6m.*
2. *From Subbasin/Recovery planning (LCFRB 2004)*

Table 4. 7. Survey results in relation to site selection requirements.

Gradient/Width	Km Needed[1]	Km Surveyed	Tier	Km Needed[2]	Km Surveyed
HM	1.4	3.2	Tier 1	22.5	24.7
HN	0.4	1.8	Tier 2	9.8	10.7
LW	4.5	24.9	Tier 3&4	5.4	5.9
MM	2.2	5.0			
MN	5.1	3.3			
MW	1.1	3.5			

1. *River Km needed to satisfy criteria of 10% of category sampled*
2. *River Km needed to satisfy criteria of 50% of Tier 1, 20% of Tier 2, and 10% of Tier 3 and 4 sampled*

4.1.4 Sediment Sources

There are several objectives for the sediment assessment conducted within the East Fork Lewis Basin. First is a general characterization of sediment supply conditions and associated land-uses that may be impacting aquatic habitat in East Fork Basin stream reaches. Second is the identification of potential project opportunities related to sediment supply conditions. Potential projects include preserving areas with functioning sediment supply conditions and restoring areas with the potential to contribute excessive fine sediment to stream channels. Another objective is to compare assessed sediment conditions to other sediment related assessments that have been conducted in the East Fork Basin including Ecosystem Diagnosis & Treatment (EDT) and the Integrated Watershed Assessment (IWA); both of which were used as part of recent Lower Columbia Subbasin and Recovery Planning (LCFRB 2004). These objectives were accomplished by employing both office-based and field-based analyses as described in the general methods section (Chapter 1) and the basin-specific methods described below. The results of these assessments are discussed for individual areas of the basin as outlined in the results section (Section 4.2.4).

4.1.4.1 Office-Based Analyses

A number of information sources, including maps, aerial photos, and previous assessments, were used to characterize sediment supply conditions throughout the East Fork Lewis Basin. The GIS layers that were consulted in this effort include the WDNR digital geology layer (WDNR 2003), the WDNR soils layer (WDNR 2000), the WDNR roads layer (WDNR 1996), and a hillshaded digital elevation model. Year 2002 high resolution (6 inch and 24 inch pixel resolution) color digital aerial photographs provided by Clark County were used to characterize land-uses and potential sediment source areas. Longitudinal profiles were created for the mainstem East Fork and all major tributaries using a 2-foot contour topographical GIS layer (provided by Clark County) created from LiDAR data. Grain-size distributions were plotted from field surveyed pebble count data.

4.1.4.2 Field Data Collection

Site visits were made in the East Fork Lewis Basin to identify potential sediment source areas and restoration opportunities. These surveys occurred in late September and early October, 2004. The lower mainstem East Fork from Lewisville Park to the mouth was surveyed by boat in conjunction with the stream habitat surveys in order to identify channel-derived sediment sources and restoration opportunities. Hillslope areas in the middle and upper basin, including the Rock Creek Basin, were surveyed by road. Areas with landscape conditions that suggested potential sediment impairment, such as high road densities, clear-cut timber harvest, and new residential development, were targeted for site visits. Field visits focused on the non-federal portion of the basin. A greater emphasis was placed on areas contributing directly to reaches identified as high priority for salmon (*Oncorhynchus sp.*) and steelhead (*O. mykiss*) (Tier 1) in the Lower Columbia Subbasin and Recovery Plan (LCFRB 2004). Information from aerial photo interpretation of land-uses and potential mass wasting sites was used to assist in identifying site visit locations. Information obtained from these site visits was used in conjunction with other data sources (i.e. remote sensing data, existing sediment information, and field sediment sampling) to characterize general sediment conditions and potential restoration and preservation opportunities throughout the basin.

The field sediment sampling for the East Fork Lewis Basin followed the methods described in the general introduction and methods section (Chapter 1) with a few exceptions. First, the reaches initially selected for pebble count and embeddedness sampling using the screen developed for all the basins were adjusted to compliment the stream habitat survey locations and to satisfy other criteria, such as placing an emphasis on assessing sediment conditions in the non-federal portion of the basin. A comparison between the reaches initially selected and those actually surveyed is presented in Table 4. 8. A rationale is provided where the actual sample locations deviate from the initial sample site selections. Overall, more reaches were surveyed and more samples were collected than were identified in the initial screen. In most reaches, at least 2 pebble counts were taken per reach and embeddedness ratings were made for every habitat unit surveyed. A few of the EDT Reaches were split into sub-reaches because of dramatic geomorphic differences as described in the stream habitat section (Section 4.1.3). In the lower mainstem East Fork reaches that were split, pebble counts and embeddedness surveys were conducted in each of the sub-reaches. This additional detail is not included in Table 4. 8.

Table 4. 8. Comparison of sediment sampling reaches selected through application of initial site selection screen and reaches where actual sediment sampling occurred.

	Initial Sample Site Selection[1]		Actual Sample Location[2]		
EDT Reach[3]	Pebble Count & Embeddedness	Embeddedness Only	Pebble Count & Embeddedness	Embeddedness Only	Rationale / Comment
EF Lewis 1			Y		Habitat survey reach
EF Lewis 2		Y	Y		Habitat survey reach
EF Lewis 3		Y	Y		Habitat survey reach
EF Lewis 4	Y		Y		Habitat survey reach
EF Lewis 5	Y		Y		Habitat survey reach
EF Lewis 6	Y		Y		Habitat survey reach
EF Lewis 7		Y			Reach no longer exists
EF Lewis 8	Y		Y		Habitat survey reach
EF Lewis 9		Y			Represented by EF Lewis 8 & 11
EF Lewis 10	Y				Represented by EF Lewis 8 & 11
EF Lewis 11				Y	Habitat survey reach
EF Lewis 12					
EF Lewis 13			Y		Habitat survey reach
EF Lewis 14		Y			Represented by EF Lewis 13 & 15
EF Lewis 15		Y		Y	Habitat survey reach
EF Lewis 16	Y				Represented by EF Lewis 13 & 15
EF Lewis 17		Y			Low priority because USFS land
EF Lewis 18		Y			Low priority because USFS land
EF Lewis 19A		Y			Low priority because USFS land
EF Lewis 19B					
EF Lewis 19C					
EF Lewis 20					
Brezee Creek					
Cedar Creek					
Cold Creek					
Copper Creek	Y				Represented by King Creek
Coyote Creek					
Dean Creek			Y		Habitat survey reach
Green Fork	Y				Low priority because USFS land
King Creek			Y		Habitat survey reach
Lockwood Creek			Y		Habitat survey reach
LW Rock Creek		Y	Y		Habitat survey reach
Manley Creek		Y		Y	Site visit separate from hab. surveys
Mason Creek					
McCormick Creek				Y	Habitat survey reach
Mill Creek	Y		Y		Site visit separate from hab. surveys
Rock Creek 1	Y		Y		Habitat survey reach
Rock Creek 2					
Rock Creek 3	Y		Y		Habitat survey reach
Rock Creek 4	Y		Y		Habitat survey reach

EDT Reach[3]	Initial Sample Site Selection[1]		Actual Sample Location[2]		Rationale / Comment
	Pebble Count & Embeddedness	Embeddedness Only	Pebble Count & Embeddedness	Embeddedness Only	
Rock Creek 5			Y		Habitat survey reach
Slide Creek	Y		Y		Habitat survey reach
unnamed LB trib					
unnamed RB trib1					
unnamed RB trib2					

[1]based on sample site selection criteria described in general methods section (Chapter 1).
[2]sample locations adjusted based on habitat survey locations and other factors described in the Rationale column
[3]some reaches were divided into sub-reaches as described in Section 4.1.3. This additional detail is not included in the table

The other deviation from the general methods pertains to the area within the stream channel in which pebble counts and embeddedness samples were taken. As opposed to identifying specific depositional areas for pebble count sampling, pebble counts were always taken in pool tail-outs. This method was employed primarily to make sure that the samples were taken at consistent locations by the stream survey crew. It also ensured that samples across the basin were reasonably comparable. These surveys also allowed for inferences regarding sediment conditions in areas frequently utilized for salmon and steelhead spawning (pool tail-outs). Visual embeddedness ratings were taken in every habitat unit surveyed, and for pools, embeddedness was estimated in the tail-out for the reasons stated above for pebble counts.

4.1.4.3 Data Integration

Sediment conditions were discussed in the following areas of the East Fork Lewis Basin: 1) Headwaters (USFS ownership), 2) Rock Creek Basin, 3) Upper North-Side Tributaries, 4) Lower East Fork Basin Tributaries, 5) Middle Mainstem East Fork Reaches, and 6) Lower Mainstem East Fork Reaches. Each section begins with a general description of sediment conditions based on the available information sources. Field sampled sediment data, including grain size distributions, embeddedness ratings, and percent fines are compared to geologic conditions, stream morphology, and land-uses occurring in the stream corridor and on the hillslopes. In each area in the basin, sediment conditions are compared to existing sediment information in the EDT and IWA analyses. A section on sediment-related restoration and preservation opportunities is also included in each basin area. The discussion of potential projects focuses on areas where fine sediment sources could be reduced, areas where sediment dynamics may limit the success of instream restoration efforts, and areas where gravel supplementation could benefit habitat or where it should be avoided.

4.2 Results

4.2.1 Hydromodification Assessment

4.2.1.1 Setting

Overview of valley bottom conditions

The East Fork Lewis River downstream of Lewisville Park (RM 13) flows through a flat valley bottom comprised of alluvial sediments laid down by the river since the last ice age (10,000 years before present) (Figure 4. 3). Stream gradients range from 0.5% in the vicinity of Lewisville Park to nearly 0.0% at the confluence with the Lewis River. The valley bottom ranges in width from 0.1 to 0.9 miles across. The valley bottom is at its widest between river miles 4 (near La Center) and 10 (near Daybreak Bridge). The river is moderately confined by valley walls between the LW Rock Creek confluence (RM 16.1) and Lewisville Bridge (RM 13). Below Lewisville Bridge and down to tidal influence (Mason Creek, RM 5.7), the stream is unconfined within a flat alluvial floodplain, although in places the stream is actively eroding the valley wall sediments. These reaches take on a meandering profile, with side channels, abandoned oxbows, and backwater channels. The historical record of channel locations, which dates back over 100 years, reveals that the course of the river has changed on numerous occasions through lateral channel migration and stream channel avulsions. The stream lies adjacent to floodplain terraces of varying elevations. These terraces contain scars of past main channel and floodplain overflow channel locations. Below Daybreak Bridge (RM 10), the gradient of the channel flattens considerably and creates a dynamically shifting channel planform as the river continually adjusts to its deposited sediment load. This dynamic channel shifting zone extends down to tidal influence. The historical record indicates that over the past couple of hundred years, the channel has migrated across as much as 80% of the valley bottom width between Daybreak Bridge (RM 10) and Dean Creek (RM 7.2). Below Mason Creek (RM 5.7) the river is influenced by tides and backwater from the Lewis and Columbia Rivers. The gradient approaches zero from here to the mouth. Channel and terrace sediments are comprised of sand and silt. The river is moderately confined by valley walls from River Mile 1.5 to the mouth.

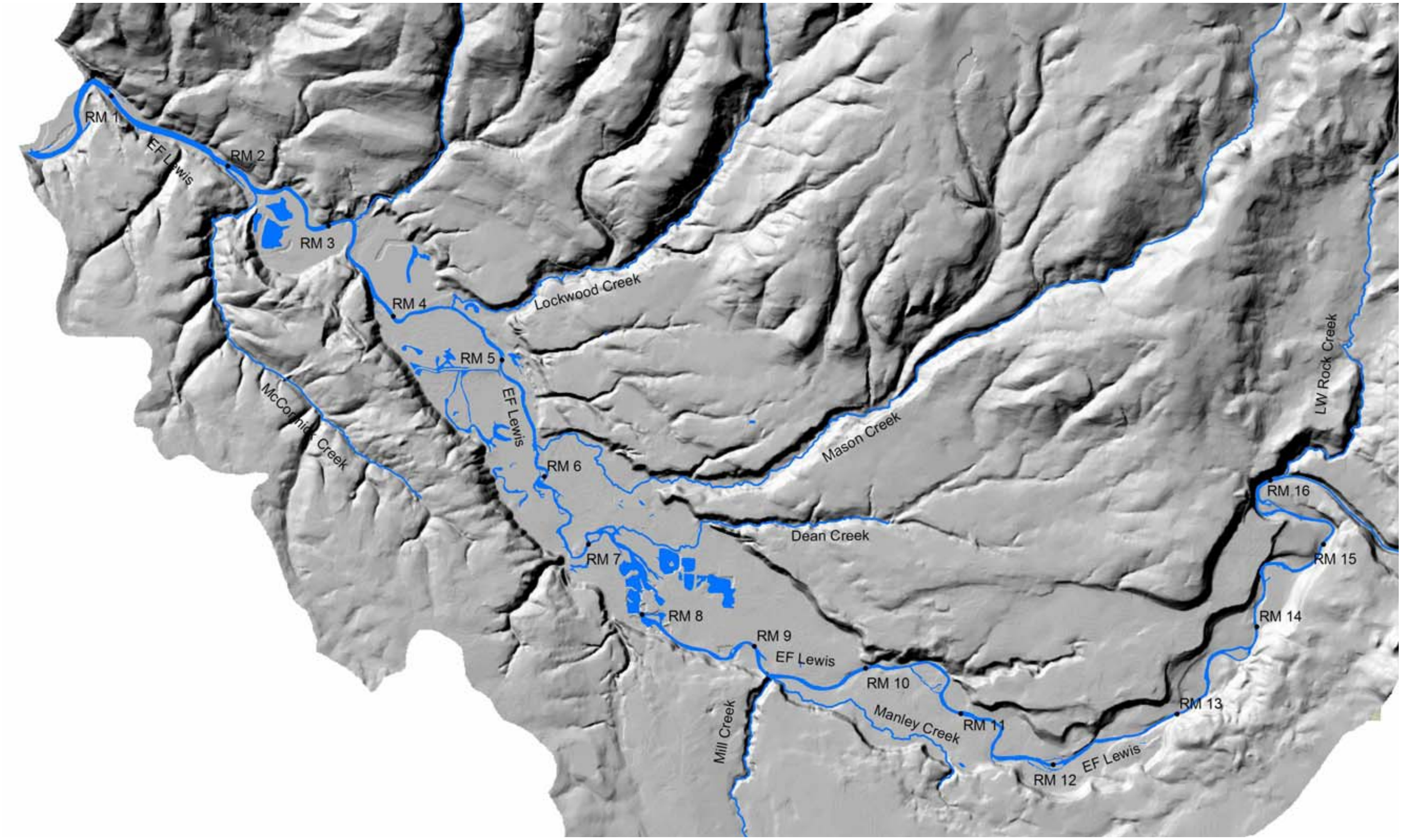

Figure 4. 3. Hillshaded relief map showing the topography of the lower East Fork Lewis River valley bottom. Tributary streams and open water areas are included. River Miles (RM) are displayed for reference.

The following sections describe historical and current conditions of the lower river valley bottom beginning upstream and working downstream:

Upper portion (river mile 16 – 9.5)

Historically, the riparian corridor between RM 16 and 13 was heavily forested with conifers. Riparian forests along the upper reaches were harvested in the early 1900s, with recent clear-cut harvest activity visible on aerial photos from 1939. The area is now mostly forested, even portions within private rural residential uses. Lewisville County Park, which lies just upstream of Lewisville Bridge, occupies the north bank between river mile 13 and 14.3. The park is mostly forested although there are riparian impacts including paved trails, playing fields, and armored streambanks.

Between RM 13 and 9.5, the historical river corridor would have been a gallery forest with patches of even aged hardwoods and conifers reflecting flood disturbance and shifting channel locations. The high terraces would be dominated by mature conifers. Currently, rural residences and agriculture have the most impact on the stream corridor in this area, with residential and agricultural uses extending across the broad floodplain terraces. These terraces were initially put into agricultural production in the early 1900s. Clearing for residential development has occurred in recent years and will likely continue. Lawns extend to the stream in many places. Invasive species are common on river banks and riparian areas, sometimes dominating native vegetation. The most common invasives are reed canary grass (*Phalaris arundinacea*), Japanese knotweed (*Polygonum cuspidatium*), Scotch Broom (*Cytisus scoparius*), and Himalayan blackberry (*Rubus discolor*). Channel modifications in order to protect private property from flood damage have occurred near river mile 11.5, where a 1967 Corps of Engineers "Emergency Flood Control" project improved a levee and rip-rapped bank (USACE 1967), effectively ceasing natural lateral channel migration at this location. There are now houses and lawns adjacent to the stream in this area. Aerial photos from 1939 show evidence of active gravel mining through gravel bar scalping near river mile 10.8. This practice appears to have been terminated by 1955. A migrating meander bend near this location (RM 10.9) is eroding a low terrace on the south bank; a process that may be accelerated due to a lack of bank vegetation. On the north bank between river mile 10.4 to 10.7 there is active erosion of the high valley wall terrace comprised of the fine-grained Troutdale Formation sediments (see Section 4.2.4.1 and Figure 4. 28); this is a natural process. Gravel mining through gravel bar scalping is visible near river mile 10.2 (current site of Daybreak Park) in the 1939 photos. Daybreak Bridge at river mile 10.2 confines the river to its present location. Downstream of the bridge, private property on the north bank has been protected through riprap though it is well vegetated in many places and not continuous. The south bank from river mile 9.8 to 9.5 consists of an actively eroding low terrace with no streambank stability provided by riparian vegetation. This area is owned by the Columbia Land Trust and has good restoration potential

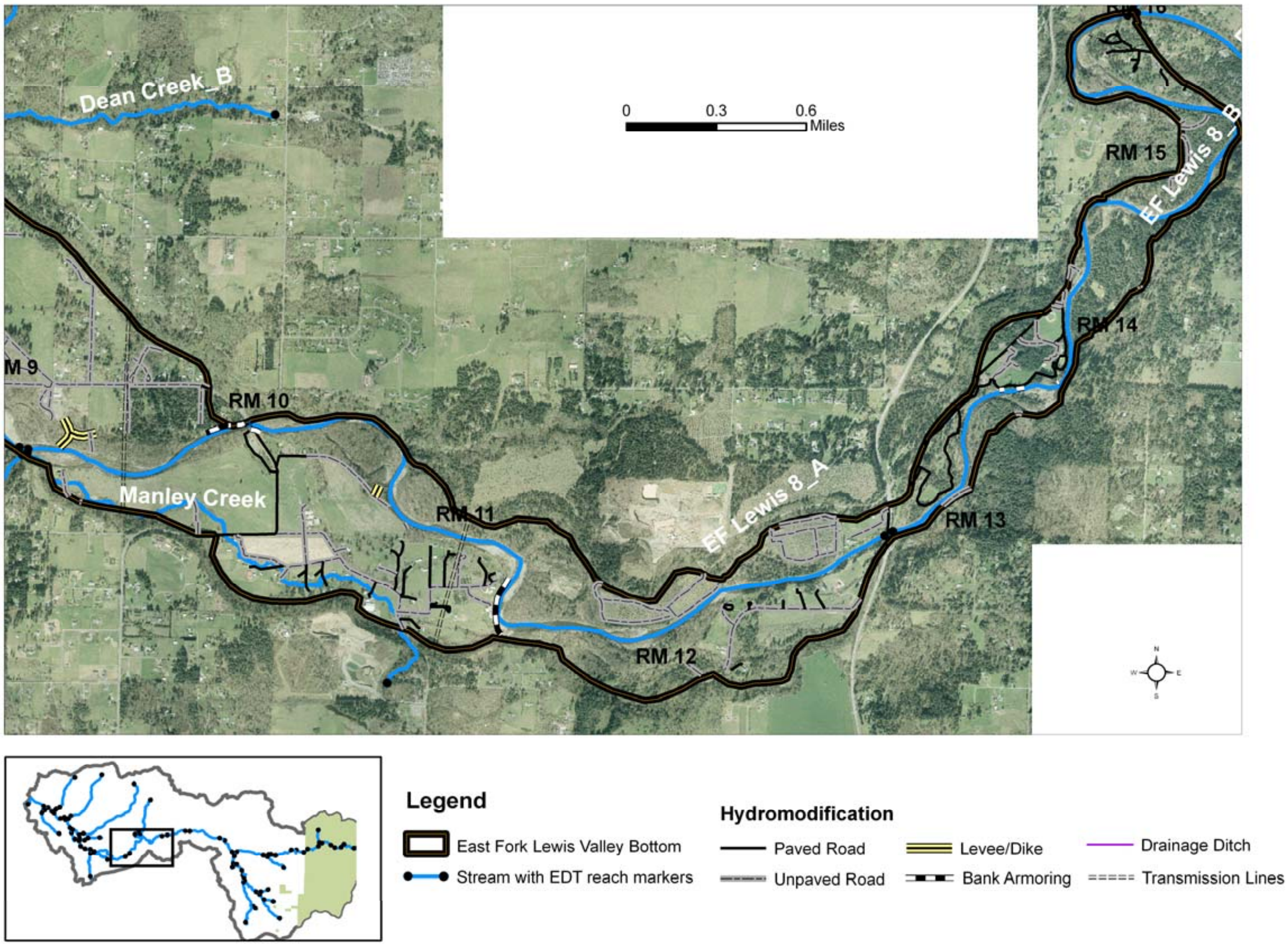

Figure 4. 4. Aerial photograph (April 2002) of the lower East Fork Lewis River from river mile 9 to 15 showing hydromodifications.

Middle Portion (river mile 9.5 – 5.7)

Historically, the river between river mile 9.5 and 5.7 was a meandering and avulsing stream with low floodplain terraces that were frequently inundated by the river. Riparian vegetation would have reflected this dynamic planform, with interspersed patches of even-aged hardwoods reflecting channel movement and flood disturbance. Abandoned oxbows and other frequently inundated areas would have supported wetland vegetation as opposed to hardwoods. Coniferous forests would only have occupied the higher terraces free from frequent flood disturbance. General Land Office (GLO) surveys conducted in 1853 described the valley bottom between RM 7 and 8 as "low brushy bottoms subject to inundation. From 1 to 5 feet deep soil first rate sandy loam. Timber ash…. alder, willow, fir, crabapple and all burned and dead." In fact, all the survey notes consulted throughout the lower river valley noted that the vegetation was all or mostly "burnt and dead" with considerable fallen timber. It is possible that this area was regularly burned by Native Americans to facilitate travel, hunting, and foraging. The survey notes also mention crossing multiple sloughs throughout the valley bottom and the accompanying survey map shows what appears to be a braided channel planform between RM 7 and 8. A network of interconnected sloughs can be seen in the valley bottom northwest of the Dean Creek confluence in the 1939 aerial photos. A 1922 Corps of Engineers topographical quad map created from 1910 surveys actually lists a nearby valley bottom community by the name of "Sloughton".

The current condition of these reaches reflect more than a century of intensive human alteration including agricultural development, residential development, and gravel mining. This portion of the river has also received the most intensive assessment as a result of the effects of gravel mining and proposed future gravel mining operations in the area (see Collins 1997, Norman et al. 1998, Sweet et al. 2003, WEST Consultants 1996).

From river mile 9.5 to 8, there are remnant levees on the north bank that limit channel movement and floodplain connection. These levees protect the Clark County maintenance facility and a pair of old gravel mining ponds. Aerial photos show that gravel mining in the form of gravel bar scalping was occurring as early as 1939. Evidence of active gravel mining can be seen in the 1939 photos near the current County maintenance facility north of the Mill Creek confluence. Evidence of gravel mining can also be seen in the Ridgefield Pits area. The river shifted position to the south in 1995 between river mile 9 and 8.5 as a result of avulsion into a streamside gravel pit (the "Mile 9" Pit) (Norman et. al. 1998). The river is now eroding the 80-100 foot high bank of the south valley wall that is composed of erodable sediments. Rock filled wire basket gabions have been placed at the toe of this wall in an effort to curb erosion, presumably to protect private residences on the bluff above (Figure 4. 5); however, these gabions appear to be experiencing undermining by scour.

Figure 4. 5. Rock filled wire basket gabions protecting toe of eroding streambank at river mile 8.7 on the East Fork Lewis River. Photo taken September 2004

Below river mile 8.5, the river enters the Ridgefield Pits through which the river avulsed into in November 1996, abandoning approximately 3,200 lineal feet of riverine habitat (Norman et al. 1998). The avulsion also initiated channel downcutting (incision) that has extended upstream of the avulsed reach (Norman et al. 1998). Approximately 3,300 feet of the stream now flows through the slow moving and deep pits. Because of the depth of the pits, which are believed to approach 10 meters at their deepest, the river is effectively locked into its current position until the pits fill enough for the stream to be able to once again resume lateral migration. Even though recovery of the pits can be seen in the upstream end as the pits fill with alluvium, full filling of the pits is expected to take decades (Sweet et al. 2003). In the meantime, recruitment of spawning gravels to downstream reaches may be limited. River banks and riparian areas along the avulsed reach are comprised nearly entirely of invasive species although measures have been taken in an attempt to eradicate invasives and reestablish native riparian vegetation.

Below the Dean Creek confluence (RM 7.2) and down to Mason Creek (RM 5.7), the stream resumes its meandering character, with recent channel shifting evident in several locations. Side channels and backwater areas are common. Within the last couple of years, a chum spawning channel has been created in this reach adjacent to the grass airstrip. Lateral migration is limited in a number of areas in this reach because of armored banks (riprap) (Figure 4. 6). Private property on the north bank, including the airstrip, may limit the potential for full restoration of channel migration processes.

Figure 4. 6. Riprap bank protecting the airstrip on the lower mainstem East Fork Lewis River. Photo taken September 2004.

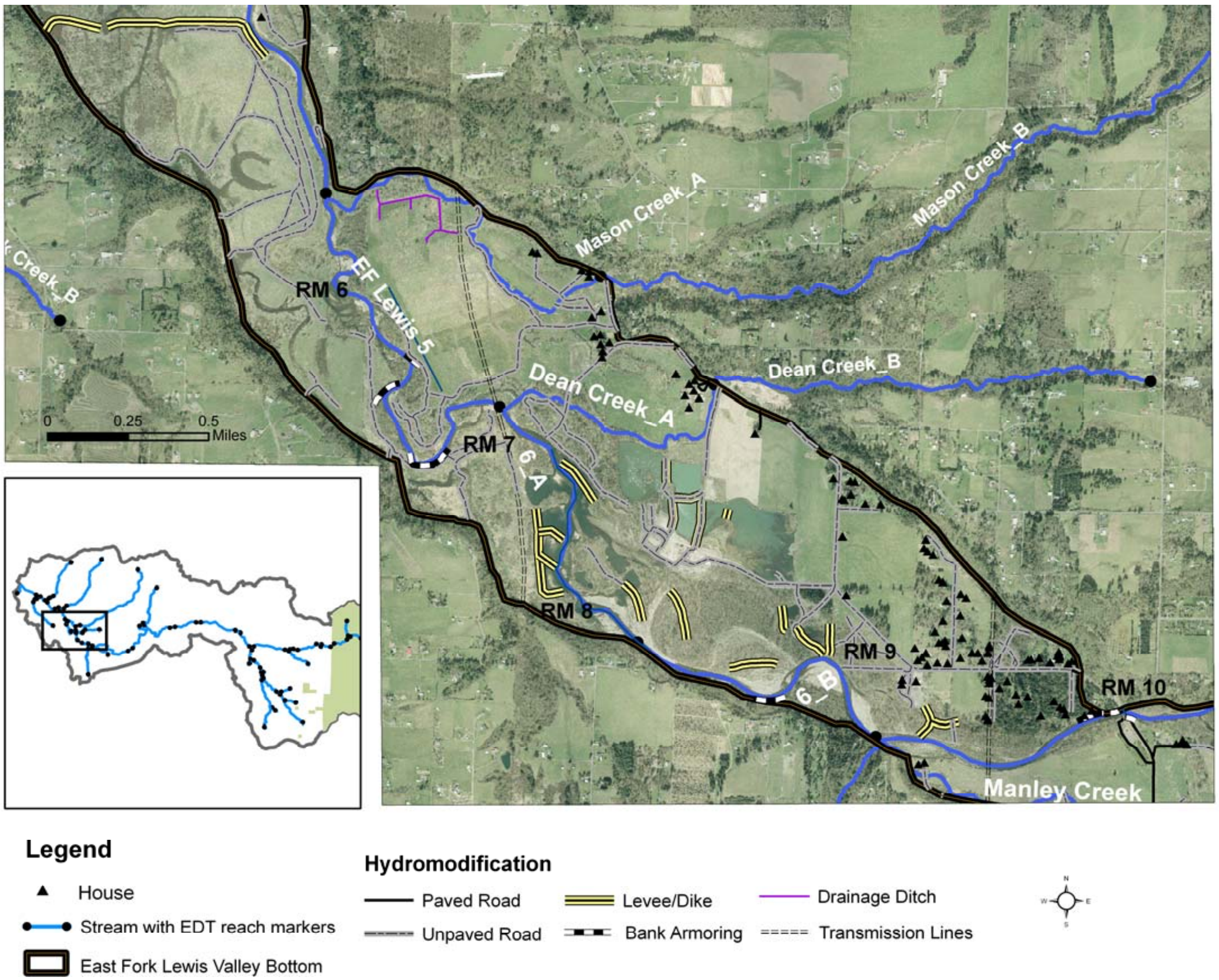

Figure 4. 7. Aerial photograph (April 2002) of the lower East Fork Lewis River from river mile 5 to 10 showing hydromodifications.

<u>Lower Portion (river mile 5.7 – 0)</u>

The river enters tidal influence around Mason Creek (RM 5.7). From here to the mouth, the gradient is nearly flat. Channel and floodplain terrace sediments are sand or finer. There are virtually no coarse substrates suitable for salmon (*Oncorhynchus sp.*) spawning, except for maybe a few small areas located at tributary confluences. On the 1853 GLO survey maps, the lower valley floor was mapped as a "low rich bottom subject to inundation". The flat topography and frequent inundation of the floodplain favored emergent wetland vegetation such as cattails and sedges, although ash and willow are recorded in the historical survey notes for some areas. The off-channel wetland complex south of the river west of La Center Bridge is composed of large ash trees that likely pre-date Euro-American settlement. Historically, these lower reaches and their interconnected off-channel sloughs likely provided important juvenile salmonid rearing habitat.

The current condition of the lower river has been shaped by channel modifications for river navigation, flood control, agriculture, and highway bridges. Some of the earliest uses of the lower East Fork were for travel and log transport on a water route from La Center (then known as "Timmen's Landing") to Portland, OR. The first steamboat trip went up the East Fork to La Center in 1870 (V.C. 12-27-1928). A log flume was present along the lower 3 miles of Brezee Creek as early as 1893. The flume emptied into the East Fork and the logs were floated to mills in Portland (V.I. 3-15-1893). Low water conditions at certain times of the year made boat and log transport difficult and there were therefore many discussions regarding improving the lower river for navigation. In 1895, the Chief of Engineers recommended deepening the East Fork from the mouth to La Center (V.I. 3-13-1895). In 1913, the US Army Corps of Engineers (USACE) authorized the maintenance of a 50 foot wide and 4 foot deep channel from the mouth to La Center (USACE 1990). This authorization was terminated in 1926 (House Document No. 467, 1926). The USACE has no records of actual dredging projects, but dredging and clearing likely occurred by local governments or local business owners with an interest in maintaining river navigation. These river deepening projects, as well as known river deepening on the mainstem Lewis, may have caused channel incision in the lower East Fork, thus reducing the degree of floodplain connectivity. Furthermore, clearing and snagging likely reduced large wood quantities in these reaches.

The other major modifications that have occurred in the lower river include floodplain draining and the construction of levees and bridges. Floodplain draining is evident from ditching north and south of the river between Mason Creek and La Center. Ditching appears to have reduced the extent of inundated off-channel wetland habitat that may have historically provided habitat to aquatic and terrestrial species. The largest levees are the levee south of the river near mile 5 and the La Center Levee, which lies adjacent to the river between river mile 4.5 and 3.2. These levees limit floodplain connections, channel migration, and off-channel habitat potential. The levees do not, however, prevent large floods from inundating the entire valley bottom. A Bridge at La Center replaced ferry service there in 1883. The current bridge, and its associated fill south of the river, currently locks the channel against the north valley wall. Early survey maps suggest that the fill is located in an area where a large side channel branched off south from the mainstem just upstream of present day La Center. The I-5 Bridge crosses the East Fork at river mile 0.8 at Paradise Point State Park. The bridge and the park may slightly prevent channel migration to the south but they are located in an area where the river is naturally confined by steep valley walls.

Although there has been a high degree of alteration of the lower river, these reaches have also narrowly escaped several significant modifications since the time of settlement. In 1883, the citizens of Vancouver voted down a lock and dam on the East Fork that would have made navigation possible all year (V.I. 11-8-1883). In 1935, the Vancouver City Council abandoned an idea for a hydropower facility on the East Fork (V.C. 6-18-1935). In 1958, there was significant discussion of an 800 acre recreational lake that would have been created from a dam at Eddy Rock, which is located between La Center and the I-5 Bridge (V.C. 8-13-1958).

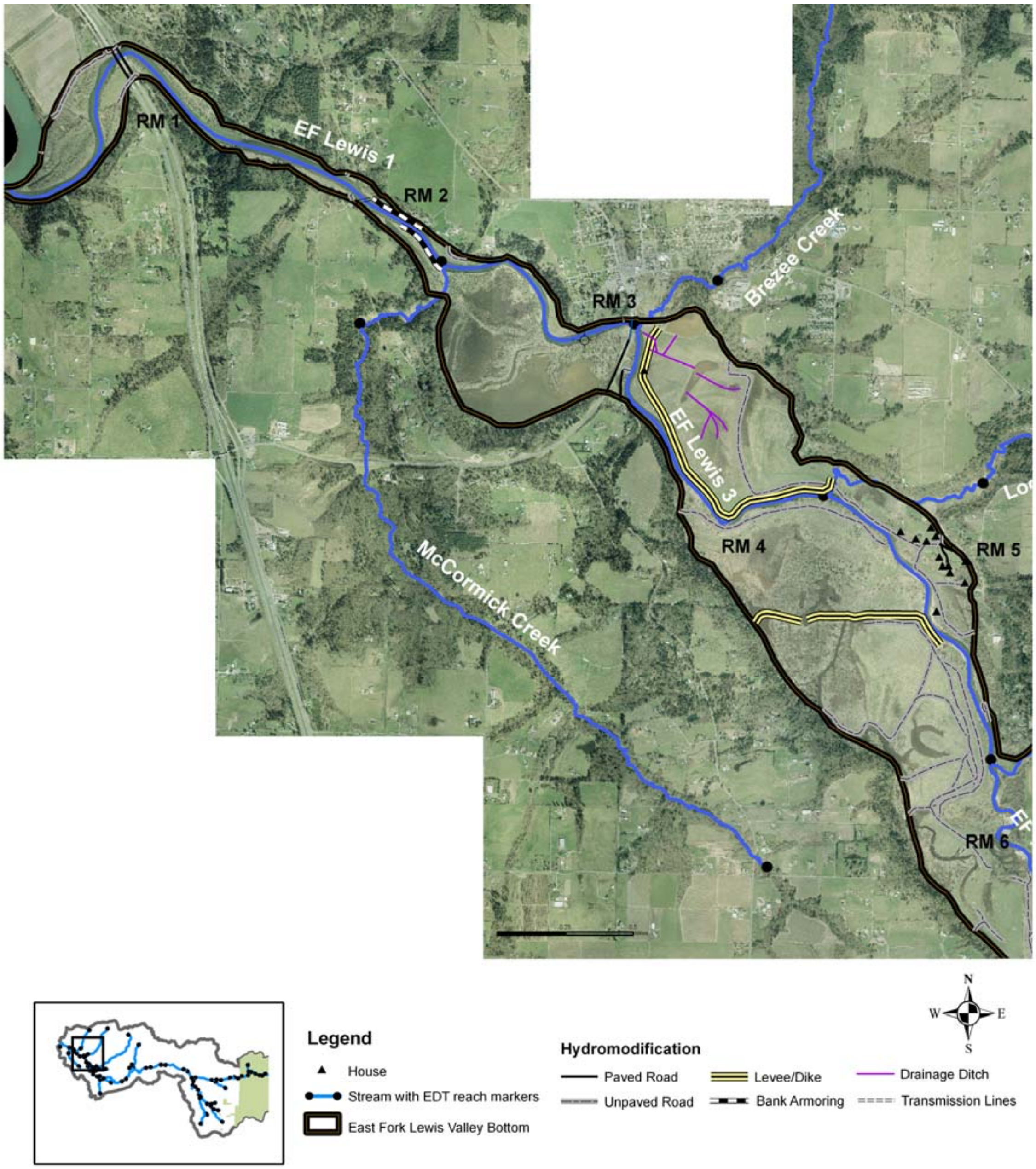

Figure 4. 8. Aerial photograph (April 2002) of the lower East Fork Lewis River from river mile 0 to 5 showing hydromodifications.

4.2.1.2 Valley Bottom Disturbance

For the purposes of this analysis the lower river valley bottom is defined as the area between the base of the valley wall on either side of the stream from the mouth to the LW Rock Creek confluence at river mile 16.1 (Figure 4. 3). The total extent of the lower river valley bottom covers approximately 3,400 acres. Although the entire valley bottom has been altered to some degree by human activity over the past 150 years, nearly 70% is currently either in relatively natural vegetation conditions (e.g. forested) or is disturbed but is protected from additional development (Open Space in Table 4. 9 & Figure 4. 9). The large amount of land in natural vegetation and/or protected conditions is largely attributable to Clark County land ownership, which comprises approximately 1,058 acres, or 31% of the valley bottom. The State of Washington and the Columbia Land Trust each own approximately 2% of the valley bottom acreage. Approximately 11% of the valley bottom is in pasture or crop production and 10% is in residential uses. Only 3% is currently used for mining but that will increase with the proposed expansion of mining operations (see Sweet et al. 2003).

Judging from past development trends observed from the historical aerial photo record, agricultural and forest land will continue to be converted to rural residential or suburban residential uses as population in the region continues to grow. Developable forest and agricultural land, especially parcels adjacent to the river, are good opportunities for land acquisition or purchase of conservation easements. The large amount of disturbed land owned by the County, the State, and CLT provides great opportunities for stream corridor, floodplain, wetland, and channel migration corridor restoration.

Table 4. 9. Areal extent of valley bottom land use and disturbance.

Land Use Type	Acres	Percent of Valley Bottom
Natural Vegetation[1]	1375	40%
County or State Park	95	3%
Open Space[3]	927	27%
Agriculture	381	11%
Industrial / Mining	112	3%
Residential	356	10%
Bridges & Associated Fill	13	0.4%
Cleared & Subject to Development[2]	179	5%
Total	**3439**	**100%**

[1]Natural Vegetation = Areas without significant visible anthropogenic disturbance to natural vegetation (i.e. forested, grasslands, or wetland habitat). May contain invasive species and hydromodifications.

[2]Cleared & Subject to Development = Disturbed areas (i.e. cleared of natural vegetation) without current use but subject to development. The bulk of this comprises the Storedahl Daybreak Mine expansion area.

[3]Open Space = Disturbed land (diked, drained, cleared) that is unlikely to be developed because of location and/or County, State, or Columbia Land Trust ownership.

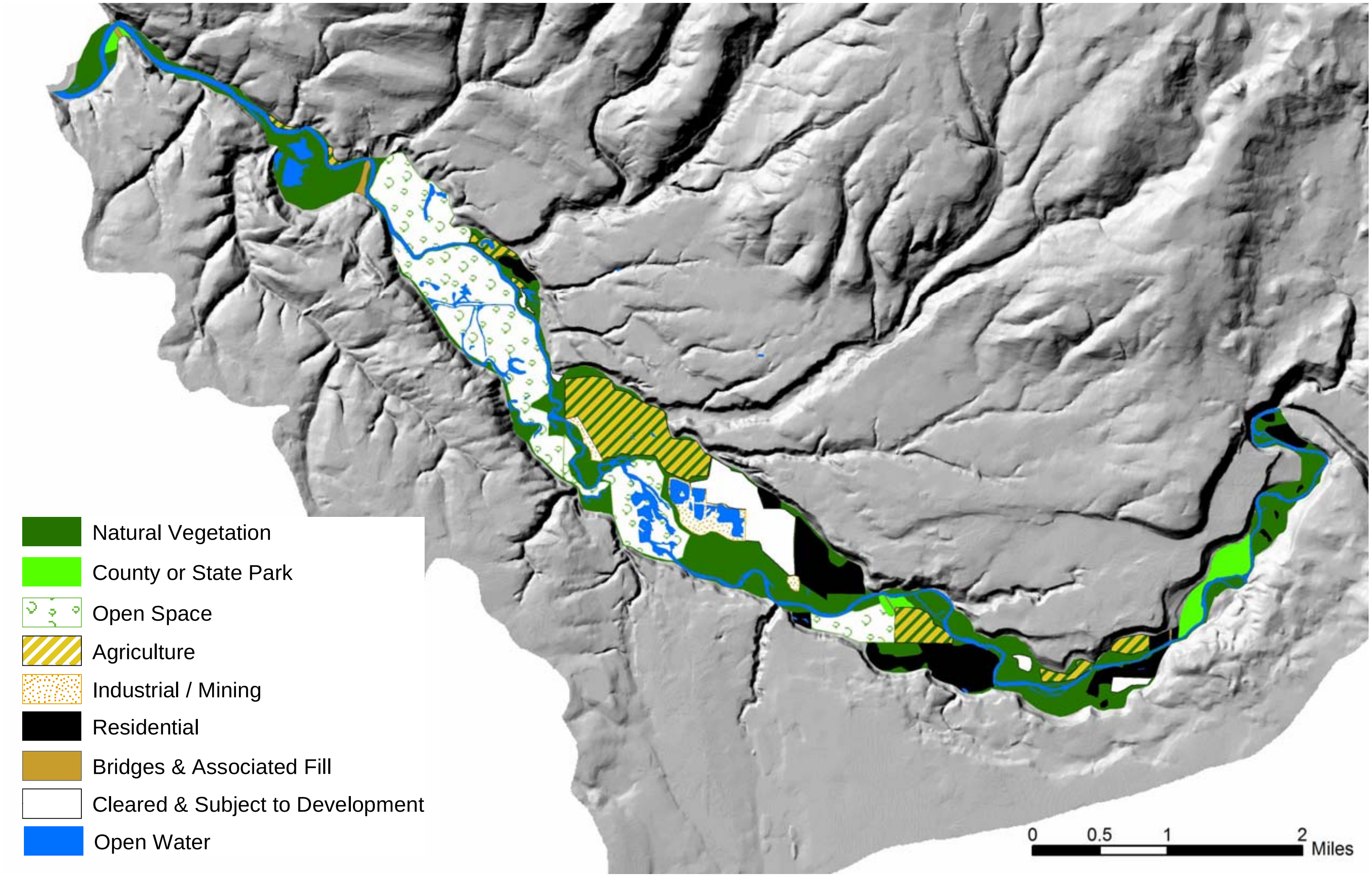

Figure 4. 9. Valley bottom land-use / disturbance in the lower mainstem East Fork Lewis River. See Table 4. 9 for definitions of disturbance and land-use types.

4.2.1.3 Hydromodifications

For the purposes of this analysis, hydromodifications refer to anthropogenic modifications that impact the natural geomorphic processes of the stream channel, floodplain, or channel migration zone. The hydromodifications in the lower East Fork include dredging, bridges, roads, fill, levees, mining operations, residential development, and armored banks. Invasive species are also included due to their impact on native riparian vegetation, which potentially influences bank stability and wood recruitment processes.

The extent of artificial confinement created by bridges, fill, roads, and levees is a concern in the lower East Fork. Although only 13% of the entire lower river is artificially confined, confinement makes up a very large percentage of some reaches (Table 4. 10) and confinement can impact adjacent un-confined reaches through affects on channel migration processes and stream channel incision. Channel incision (downcutting) may be increased in confined channels as a result of increased shear stress on the channel bed when flood flows are confined within the channel. The greatest amount of artificial confinement exists on EDT reaches 3, 4, and 6A. Reaches 3 and 4 are confined by stream adjacent levees. These levees are located on Clark County land and may provide good opportunities for removal, which would improve floodplain connectivity and the potential for formation of off-channel rearing habitat. Reach 6A is confined as a result of avulsion into the Ridgefield Pits. This reach may be difficult to restore; waiting until the pits fill with sediment may be the only viable option. Old levees between river mile 8.5 and 9.5 (Reach 6B and 8A) do not serve to directly confine the channel although they do limit the potential for lateral channel migration. These levees may be providing limited protection of property, including the Clark County maintenance facility north of the Mill Creek confluence. These levees are located on Clark County land. There may be opportunities here for levee removal or, where property is at risk, levee set-backs.

Roads and bridges serve to confine channels in several locations. The I-5 Bridge (RM 0.8), the La Center Bridge (RM 3.2), the Daybreak Bridge (RM 10.2), and the Lewisville Bridge (RM 13) all constrict the channel to some degree. The southern approach to the La Center Bridge sits on approximately one quarter mile of fill that has severed the floodplain valley floor at this location. The southern approach to the Daybreak Bridge also lies on fill that serves to lock the channel at its current location against the north side valley wall. The Lewisville and I-5 Bridges have less impact.

Bank armoring is a concern along the lower river. Bank armoring makes up 10% or greater of reaches 1, 5, and 6B. Bank armoring in reach 5 is of the most concern because of its relatively large affect on channel migration processes. These armored banks also offer the greatest restoration opportunity because they are located on Clark County lands. Bank armoring at river mile 11.5 in reach 8A serves to limit natural channel migration; however, the armoring also protects streamside residences and thus offers little restoration opportunity apart from incorporating vegetation. Bank armoring in other areas, including along Lewisville Park, could benefit from incorporating vegetation to increase cover, shade, and habitat complexity.

Much of the lower river has been cleared and/or developed for agricultural or residential uses. These uses have reduced native riparian vegetation; impacting bank stability, shade, and wood recruitment processes. Landowner education, financial incentives, and land acquisition can be used to restore riparian vegetation on residential and farmed lands. Much of the cleared land is former crop or pasture land that is no longer farmed but that remains in a disturbed condition overrun by invasive species. Re-establishing native riparian vegetation is a priority in these areas and there is great opportunity because of the large amount of Clark County ownership.

Table 4. 10. Lineal extent of hyrdomofications and other related impacts along reaches of the lower mainstem East Fork Lewis River. The lineal length of stream is considered affected if either bank contains the hydromodification. Thus, if only one side of an entire reach has bank armoring, then the reach would be considered 100% armored.

EDT Reach	Reach Length (mi)	Armored[1]	Avulsed[2]	Artificial Confinement[3]	Cleared/ Developed[4]	Channel Incision[5]	Invasive Species Dominated[6]
EF Lewis 1	2.3	16%	0%	8%	37%	0%	46%
EF Lewis 2	0.9	0%	0%	6%	85%	0%	100%
EF Lewis 3	1.3	0%	0%	99%	98%	0%	100%
EF Lewis 4	1.3	0%	0%	29%	100%	0%	99%
EF Lewis 5	1.6	18%	0%	0%	45%	0%	58%
EF Lewis 6A	1.0	0%	78%	31%	81%	93%	100%
EF Lewis 6B	1.0	10%	0%	0%	0%	0%	0%
EF Lewis 8A	3.7	6%	0%	1%	69%	0%	40%
EF Lewis 8B	3.2	2%	0%	3%	35%	0%	4%
Totals	16.1	6%	5%	13%	58%	6%	50%

[1]Armored = Hardened banks (i.e. riprap) serving as a geomorphic control.

[2]Avulsed = Portion of stream channel avulsed into Ridgefield Pits. Mile 9 pit avulsion not included.

[3]Artificial Confinement = Confined by levees, roadways, or bridges.

[4]Cleared/Developed = Includes cropland, pastureland, rural residential land, lawn, and cleared but undeveloped land.

[5]Channel Incision = Includes extent of channel incision associated with Ridgefield Pit avulsions. Does not include the assumed channel incision in reaches 1 through 4 due to the difficulty in quantifying the degree of incision.

[6]Invasive Species Dominated = Streambanks where invasive species are the dominant vegetation type. Species include primarily Scotch Broom, Japanese knotweed, reed canary grass, and Himalayan blackberry.

4.2.1.4 Channel Margin Habitat

This analysis looks at the change in the type of channel margin between 1939, 1955, and 2002. It should be noted that the 1939 and 1955 aerial photos do not reflect unmanaged conditions. Channel modifications, including dredging, bridges, and gravel mining had already occurred prior to the 1930s. This analysis provides information on trends in channel margin habitat due to changing land and river uses since the 1930s. These trends can be used to make inferences of expected future trends and potential restoration opportunities.

The availability of backwater channel and side channel habitat has varied since the 1930s and 1950s. In general, the quantity of side channel and back channel habitat (per reach) was similar in 1939 and 1955 but varied considerably between these dates and 2002. This is due to different stages of stream channel recovery and degradation during these periods. Gravel mining in the form of gravel bar scalping and floodplain mining is evident in several reaches in the 1939 photos. Some of this activity is also visible in the 1955 photos though most of it is confined to the area around Mill Creek. More recent mining activity has been located between Dean Creek and Mill Creek, where avulsions have impacted the channel types.

In East Fork reaches 1 and 2, backwater habitat has decreased somewhat since 1939 (Table 4. 11). This is mostly related to the loss of connected off-channel wetland habitat in the large wetland complex southwest of La Center. There has been virtually no change in backwater and side-channel habitat in reaches 3 and 4, largely because land-use conditions have not changed dramatically in these areas. In reach 5 there has been an increase in both side channel and back channel habitat since 1939 and 1955. This may be due partly to channel movement during the 1996 and 1997 floods and from sediment contributions from the Ridgefield Pit avulsion in 1996. Reach 6A has experienced a decrease in side channel habitat and an increase in back channel habitat as a result of the Ridgefield Pit avulsions which created a large amount of backwater habitat at the expense of side channel and main channel habitat. There has been a decrease in both side channel and back channel habitat in reach 6B. This may be related to the 1995 avulsion into a gravel pit near river mile 9 or could also be related to upstream channel incision following the 1996 Ridgefield Pit avulsion. A high degree of braiding may have been present in the older photos due to gravel mining operations in the area. This may also be a factor in the decrease in side and back channels in Reach 8A. Reach 8A also has experienced residential development and bank armoring that has limited the potential for side channel and back channel formation. Reach 8B remains relatively unchanged since 1939 with respect to the relative abundance of channel margin types.

Side channel and back channel restoration potential varies by reach (Table 4. 11). Reach 2 and 3 contain the best potential for reconnecting off-channel wetland habitat, whereas reach 8A has the greatest potential for restoration or creation of back channels that are hydrologically connected with the river. See section for a detailed explanation of side-channel and back channel restoration opportunities.

Table 4. 11. The areal extent of side channel and backwater channel habitat in relation to the quantity of main channel habitat for two historical periods and the current condition. Potential backwater habitat is included for the current condition.

		1939		1955		Current	
Reach	**Channel Type**	**Meters^2**	**% of Total**	**Meters^2**	**% of Total**	**Meters^2**	**% of Total**
EF Lewis 1	**Total**	**316,796**		**238,798**		**247,445**	
	Main Channel	253,220	80	226,298	95	231,772	94
	Side Channel	0	0	0	0	0	0
	Back Channel	63,575	20	12,500	5	15,673	6
	Potential[1]	0	0	0	0	0	0
EF Lewis 2	**Total**	**95,246**		**61,482**		**67,145**	
	Main Channel	71,548	75	61,482	100	67,145	100
	Side Channel	0	0	0	0	0	0
	Back Channel	23,699	25	0	0	0	0
	Potential[1]	0	0	0	0	216,867	0
EF Lewis 3	**Total**	**82,311**		**79,844**		**86,559**	
	Main Channel	82,311	100	79,354	99	85,220	98
	Side Channel	0	0	0	0	0	0
	Back Channel	0	0	491	1	1,339	2
	Potential[1]	0	0	0	0	52,120	0

Reach	Channel Type	1939 Meters^2	1939 % of Total	1955 Meters^2	1955 % of Total	Current Meters^2	Current % of Total
EF Lewis 4	**Total**	**93,137**		**84,947**		**78,396**	
	Main Channel	89,147	96	82,179	97	77,838	99
	Side Channel	0	0	1,541	2	0	0
	Back Channel	3,990	4	1,227	1	557	1
	Potential[1]	0	0	0	0	0	0
EF Lewis 5	**Total**	**83,317**		**82,778**		**112,588**	
	Main Channel	80,308	96	75,104	91	84,360	75
	Side Channel	3,009	4	4,442	5	18,608	17
	Back Channel	0	0	3,232	0	9,620	9
	Potential[1]	0	0	0	0	4,222	0
EF Lewis 6_A	**Total**	**79,602**		**96,745**		**200,620**	
	Main Channel	50,857	64	68,435	71	95,623	48
	Side Channel	6,551	8	19,432	20	7,609	4
	Back Channel	22,194	28	8,878	9	97,388	49
	Potential[1]	0	0	0	0	9,183	0
EF Lewis 6_B	**Total**	**74,092**		**72,161**		**66,173**	
	Main Channel	62,600	84	59,696	83	62,707	95
	Side Channel	8,328	11	12,465	17	1,084	2
	Back Channel	3,164	4	0	0	2,382	4
	Potential[1]	0	0	0	0	6,840	0
EF Lewis 8_A	**Total**	**270,936**		**233,761**		**240,891**	
	Main Channel	207,397	77	181,897	78	219,758	91
	Side Channel	51,609	19	42,052	18	13,492	6
	Back Channel	11,930	4	9,812	4	7,642	3
	Potential[1]	0	0	0	0	26,059	0
EF Lewis 8_B	**Total**	**162,977**		**162,612**		**181,503**	
	Main Channel	154,106	95	149,488	92	164,000	90
	Side Channel	7,484	5	13,123	8	15,220	8
	Back Channel	1,387	1	0	0	2,283	1
	Potential[1]	0	0	0	0	0	0

[1]Potential refers to the amount of potential backwater (off-channel) habitat that could be reasonably restored or created based on geomorphic considerations such as historical features, presence of relic channels, and topography.

4.2.1.5 Channel Migration Zone Assessment

The historical channel migration zone (CMZ) occupied the majority of the valley floor downstream of river mile 9.5 (Figure 4. 10). Upstream of river mile 9.5, the historical CMZ was not mapped to include some of the higher floodplain terraces except for areas potentially occupied through progressive channel migration (assuming a 170 year time-frame as discussed in the methods section 4.1.1.4). The current CMZ encompasses less of the valley floor along the entire evaluation area as a result of levees, roads, armored banks, fill, bridges, and development. Between Dean Creek and Daybreak Bridge (RM 7.3 – 10.3) the current CMZ approximates the CMZ delineated by WEST Consultants (Sweet et al. 2003) except for at the upstream end (RM 9.3 – 10.3). The current CMZ is smaller than the WEST CMZ on the north bank because of old levees that constrict flood flows. The current CMZ is wider than the WEST CMZ on the south bank because of the potential for progressive channel migration.

Both the historical and current CMZ were plotted in a GIS and change in CMZ area was calculated per EDT reach by splitting the CMZ with a line drawn perpendicular to the valley floor at the reach breaks. The results are presented in Table 4. 12. A total of 53% of the historical CMZ has been lost as a result of hydromodifications. Reach 5 has received the greatest loss (64%) as a result of armored stream banks. This reach also contains some of the greatest restoration potential because of public land ownership and the lack of substantial development of the floodplain. The least amount of impact has occurred in reach 8B (42%), where natural confinement is greater and development is sparse.

Reaches 6A, 6B, and 8A all have experienced nearly a 50% reduction in CMZ area. In the Ridgefield Pit reach (reach 6A), the CMZ is confined by roadways and mining facilities north of the river. Even though the stream is likely confined to its current location until the instream pits fill with sediment, the current CMZ was not assumed to only occupy the current channel because the pits are expected to fill within a matter of decades. The CMZ in reach 6B is constrained on the north side by Bennett Road and the Storedahl Pit Road. There are also old levees north of the river within the mapped CMZ. While these levees were assumed to not limit channel migration during large flood events, they are likely having some influence on channel migration and floodplain connection during smaller return interval floods. They are located mostly on County land and offer good opportunities for removal or set-back.

The CMZ in reach 8A is constrained by the Daybreak Bridge and armored streambanks that are protecting private residential property. Near river mile 9.5 the stream is progressively migrating to the south into a parcel owned by the Columbia Land Trust (CLT). This low terrace may be rapidly eroding in part because of a lack of riparian forest vegetation. Just upstream, the Daybreak Bridge and associated fill have locked the channel against the north valley wall. There is channel migration potential between river mile 10.5 and 11, where there exists active and abandoned side channels. There is another low, unvegetated, and actively eroding low terrace on the south bank at river mile 10.8. Progressive meandering has been halted at the south bank at river mile 11.4 as a result of a riprap bank that is protecting private residences. From here up to Lewisville Bridge there is confinement associated with agricultural and residential development on the north side of the river. Reach 8B is confined by Lewisville Bridge, infrastructure associated with Lewisville Park (including armored streambanks), stream adjacent roadways, and private residences.

Table 4. 12. Degree of CMZ impact along reaches 5-8 in the lower mainstem East Fork Lewis River.

EDT Reach	Historical Acres	Current Acres	Difference (loss)	% Loss
EF Lewis 5	419	152	267	64%
EF Lewis 6A	438	225	213	49%
EF Lewis 6B	335	152	184	55%
EF Lewis 8A	566	282	284	50%
EF Lewis 8B	194	112	82	42%
Totals	1952	923	1030	53%

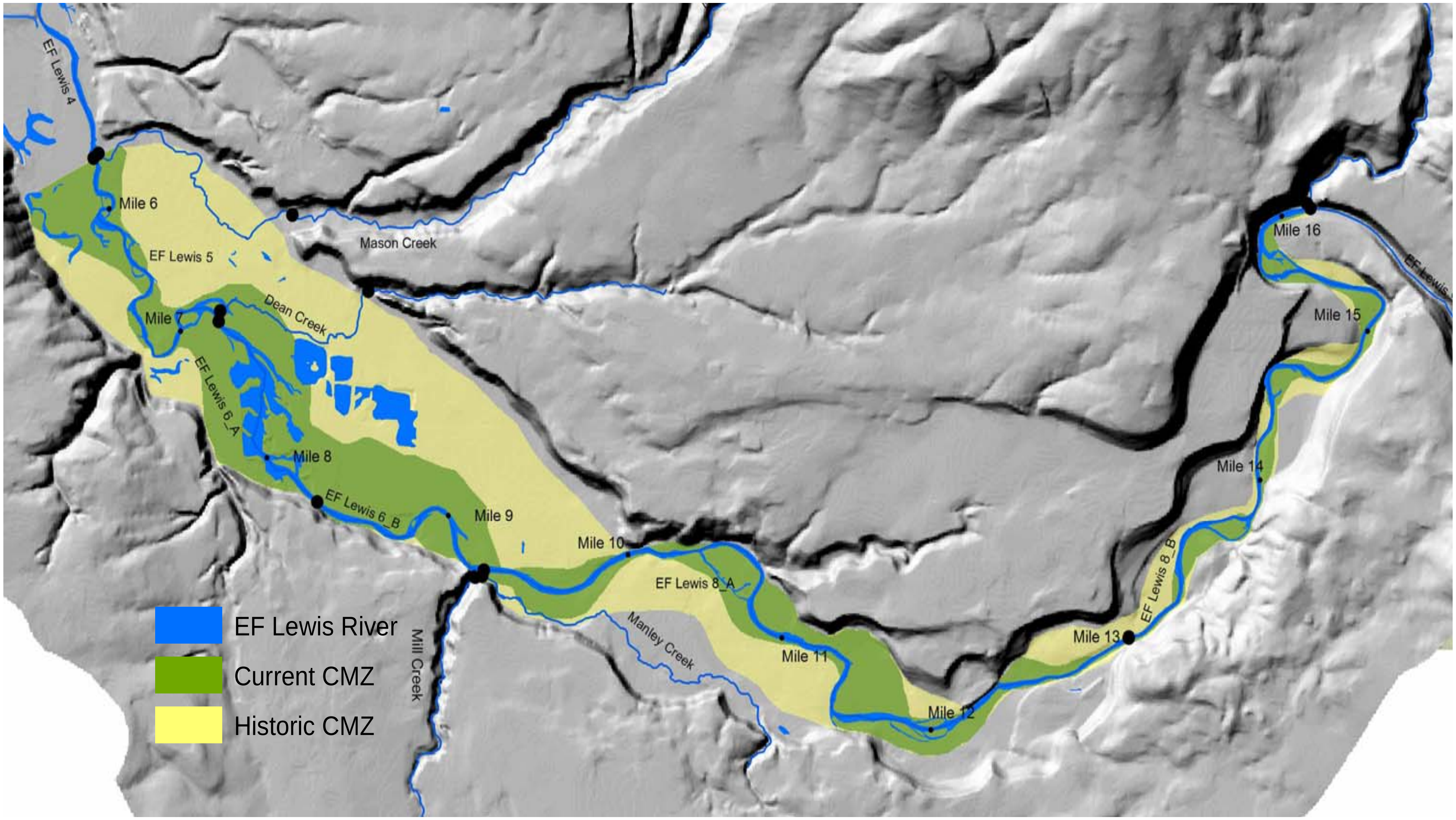

Figure 4. 10. Extent of the historical and current channel migration zone estimated for the lower East Fork Lewis River between LW Rock Creek (river mile 16.1) and Mason Creek (river mile 5.7).

4.2.2 Riparian Assessment

The Riparian Assessment consists of 5 individual assessments: 1) Large woody debris recruitment, 2) Shade determinations from aerial photographs, 3) Field verification, 4) VTS modeling, and 5) Comparison with EDT and IWA ratings. The results for each of these assessments are described below.

4.2.2.1 Large Woody Debris Recruitment

Forty-four EDT reaches in the East Fork Lewis mainstem and tributaries were divided into a total of 774 RCUs during the remote assessment. The number of RCUs was highly variable among EDT reaches, and ranged from 2 to 95 RCUs per reach (mean = 18). The total surface area of riparian zones in the East Fork Lewis Basin (excluding the riparian zone on U.S. Forest Service Land) was 8.55 km^2 over a combined stream length of approximately 140 km.

The most common riparian vegetation type by surface area in the East Fork Lewis Basin was "mixed" conifer and deciduous stands, followed by predominantly deciduous stands, then predominantly conifer stands, and lastly grass and/or no vegetation (Table 4. 13). East Fork Lewis riparian zones were dominated by small and medium sized trees. Large trees were present in 18% of the riparian zone. There were no trees in 12% of the riparian zone (

Table 4. 14). Riparian zones primarily contained densely vegetated stands (65%).

Table 4. 13. Riparian vegetation type in the East Fork Lewis Basin by surface area (km^2).

Vegetation Type	Riparian Zone Surface Area (km^2)	Percent
Mixed	3.61	42%
Deciduous	2.22	26%
Conifer	1.66	19%
Non Forested	1.05	12%
Total	**8.55**	**100%**

Table 4. 14. Riparian tree size rating in the East Fork Lewis Basin by surface area (km^2).

Tree Size	Riparian Zone Surface Area (km^2)	Percent
Large	1.57	18%
Medium	2.55	30%
Small	3.37	39%
Non Forested	1.05	12%
Total	**8.55**	**100%**

Table 4. 15. Riparian stand density in the East Fork Lewis Basin riparian zone by surface area (km^2).

Tree Density	Riparian Zone Surface Area (km^2)	Percent
Dense	5.59	65%
Sparse	1.91	22%
Non Forested	1.05	12%
Total	**8.55**	**100%**

Table 4. 16 shows the proportion of each riparian condition code by surface area across all RCUs in the East Fork Lewis Basin. Condition codes were fairly evenly distributed across all types with the exception of mixed species/medium sized/dense stands (MMD), which comprise ~ 17% of the East Fork Lewis riparian zone (Table 4. 16).

Table 4. 16. Proportion (by surface area) of each riparian condition code across all RCUs. Condition codes are grouped according to their LWD recruitment potential.

Rating	Condition Code	Proportion
High	CLD	4%
	CMD	7%
	MLD	10%
	MMD	17%
Moderate	HLD	1%
	MLS	1%
	CLS	1%
	CMS	3%
	MMS	5%
	HMD	5%
Low	HLS	1%
	CSS	2%
	HMS	2%
	CSD	2%
	MSS	2%
	HSS	6%
	MSD	7%
	HSD	12%
None	NONE	12%

The majority of reaches had moderate LWD recruitment potential (n = 25); 5 had high LWD recruitment potential, 10 had low recruitment potential, and 4 reaches had no LWD recruitment potential (Table 4. 17). The proportion of each vegetation type by EDT reach as determined via remote assessment is shown in Table 4. 18. Lower reaches of the East Fork Lewis mainstem were classified as having low to no LWD recruitment potential. Lower reaches of the East Fork mainstem are tidally influenced and frequently inundated by flooding. Open space and wetlands comprise a significant portion of the riparian zone in these lower reaches. Cattle grazing occurs along some stretches of the lower mainstem. The low rating in East Fork 6_A is related to gravel pit avulsions. Reaches 6B – 8B have low or moderate recruitment potential. These reaches are impacted by agriculture and residential development. Tributaries to these lower reaches such as McCormick, Breeze, Lockwood, and Mason had moderate LWD recruitment potential. Overall, these tributaries are densely vegetated with small trees.

LWD recruitment potential increases to moderate beginning at approximately river mile 12 on the mainstem East Fork. The riparian zone in East Fork mainstem reaches 8B, 10, 11, 13, 14, 16, and 17 is dominated by dense stands of moderately sized conifers. Mixed species stands are also common along these reaches. Riparian stands dominated by hardwoods occur in approximately 20% of the riparian zone along these reaches. Timber harvest has occurred in the vicinity of these reaches and in some places the riparian buffer extends to only 100 feet. The majority of lands adjacent to these reaches have been replanted. East Fork Lewis 12, which is affected by a stream-adjacent-roadway, is rated as low.

Only two mainstem reaches and 3 small tributaries in the upper East Fork were classified as having high LWD recruitment potential (Figure 4. 11). Riparian stands along EF Lewis 9 and 15 are dominated by dense, large and medium conifers and mixed species stands. There is little disturbance to the riparian zone along EF Lewis 9. Timber harvest has occurred up to the 100 foot riparian buffer on EF Lewis 15. Large open spaces remain in recently harvested areas. Other stands immediately adjacent to the conifer-dominated buffer in East Fork Lewis 15 are vegetated with hardwood dominant stands. Copper and Cold Creek and an unnamed tributary were rated as having high LWD recruitment potential.

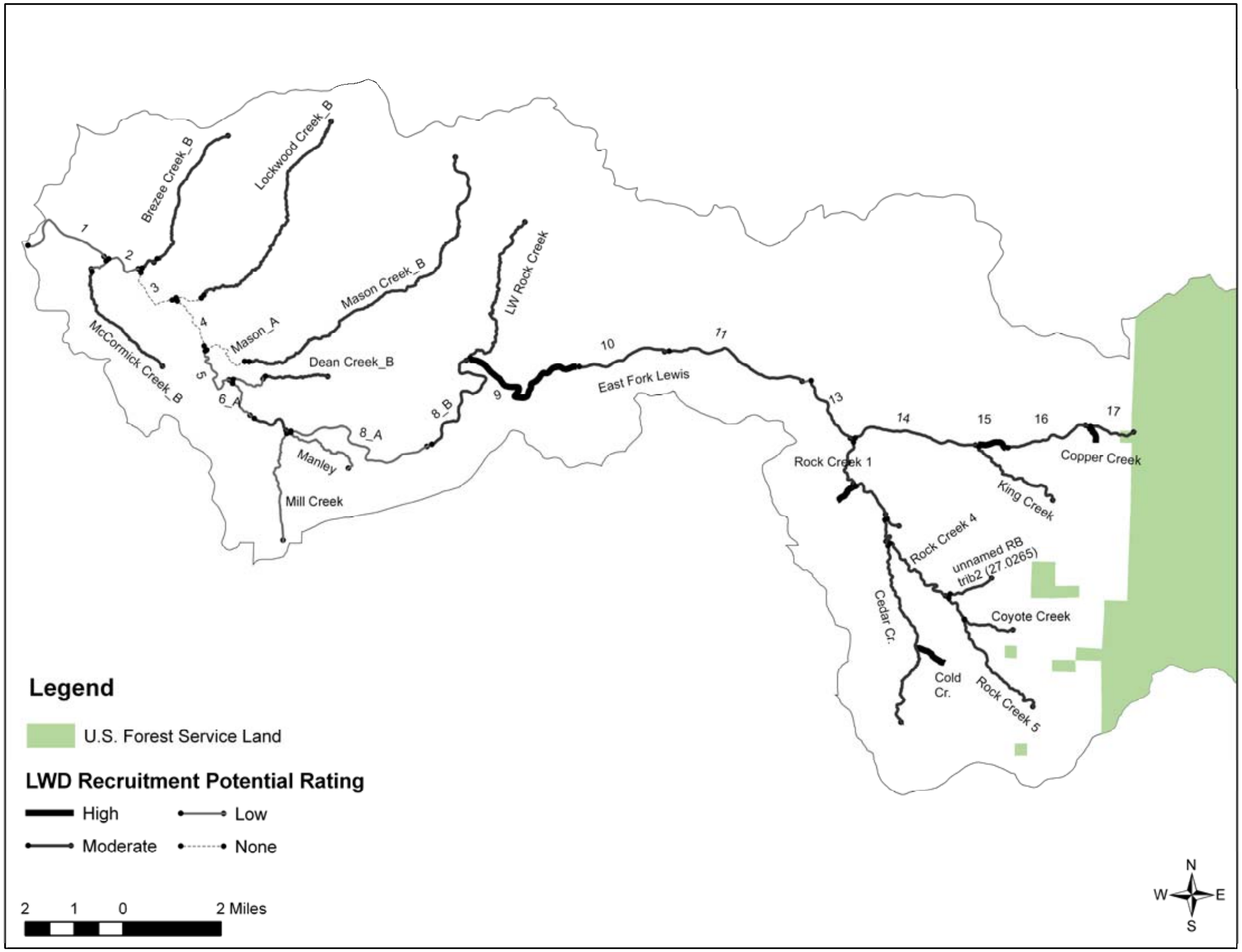

Figure 4. 11. LWD recruitment potential ratings in the East Fork Lewis Basin as determined by remote assessment of aerial photographs.

Table 4. 17. LWD recruitment ratings by EDT reach for the East Fork Lewis Basin.

EDT Reach	Large Woody Debris				
		Proportion of Reach			
	Recruitment Potential	High	Moderate	Low	None
EF Lewis 1	Low	27%	4%	48%	21%
EF Lewis 2	Low	0%	25%	44%	31%
EF Lewis 3	None	7%	6%	5%	82%
EF Lewis 4	None	0%	5%	21%	73%
EF Lewis 5	Low	0%	4%	81%	15%
EF Lewis 6_A	Low	0%	0%	90%	10%
EF Lewis 6_B	Moderate	30%	24%	26%	20%
EF Lewis 8_A	Low	17%	10%	56%	16%
EF Lewis 8_B	Moderate	53%	25%	22%	0%
EF Lewis 9	High	76%	6%	17%	0%
EF Lewis 10	Moderate	47%	32%	19%	2%
EF Lewis 11	Moderate	64%	9%	27%	0%
EF Lewis 12	Low	0%	0%	100%	0%
EF Lewis 13	Moderate	52%	0%	48%	0%
EF Lewis 14	Moderate	52%	2%	46%	0%
EF Lewis 15	High	95%	0%	5%	0%
EF Lewis 16	Moderate	61%	25%	14%	0%
EF Lewis 17	Moderate	33%	14%	53%	0%
King Creek	Moderate	36%	0%	64%	0%
Lockwood Creek_A	None	0%	0%	36%	64%
Lockwood Creek_B	Moderate	47%	34%	16%	2%
LW Rock Creek	Moderate	51%	25%	16%	6%
Manley Creek	Low	16%	18%	2%	63%
Mason Creek_A	None	0%	5%	6%	89%
Mason Creek_B	Moderate	35%	25%	28%	11%
McCormick Creek_A	Low	33%	0%	9%	58%
McCormick Creek_B	Moderate	49%	22%	26%	4%
Mill Creek	Low	35%	14%	11%	40%
Rock Creek 1	Moderate	55%	6%	35%	4%
Rock Creek 2	Moderate	24%	21%	51%	5%
Rock Creek 3	Moderate	37%	35%	28%	0%
Rock Creek 4	Moderate	48%	7%	41%	0%
Rock Creek 5	Moderate	37%	12%	51%	0%
unnamed LB trib	High	100%	0%	0%	0%
unnamed RB trib1	Moderate	27%	13%	60%	0%
unnamed RB trib2	Moderate	29%	38%	33%	0%
Brezee Creek_A	Moderate	56%	0%	16%	28%
Brezee Creek_B	Moderate	39%	29%	22%	10%
Cedar Creek	Moderate	31%	18%	51%	0%
Cold Creek	High	94%	6%	0%	0%
Copper Creek	High	100%	0%	0%	0%
Coyote Creek	Moderate	38%	0%	62%	0%
Dean Creek_A	Low	0%	0%	53%	47%
Dean Creek_B	Moderate	35%	49%	7%	9%

Table 4. 18. Percent of vegetation type by EDT reach in the East Fork Lewis Basin as determined by remote assessment of aerial photographs.

EDT Reach	Vegetation Type				
	Percent of Reach				
	Conifer	Hardwood	Mixed	Grass	Unvegetated
EF Lewis 1	16%	42%	21%	21%	
EF Lewis 2	8%	44%	17%	31%	
EF Lewis 3	7%	5%	6%	82%	
EF Lewis 4		21%	5%	67%	6%
EF Lewis 5		85%		15%	
EF Lewis 6_A		90%		10%	
EF Lewis 6_B		50%	30%		20%
EF Lewis 8_A	7%	56%	21%	11%	6%
EF Lewis 8_B	39%	15%	46%		
EF Lewis 9	50%	1%	49%		
EF Lewis 10	51%	4%	43%		2%
EF Lewis 11	62%	8%	30%		
EF Lewis 12	79%		21%		
EF Lewis 13	29%	29%	41%		
EF Lewis 14	60%	6%	34%		
EF Lewis 15	64%	5%	30%		
EF Lewis 16	54%	5%	41%		
EF Lewis 17	50%	19%	31%		
King Creek		49%	51%		
Lockwood Creek_A		36%		64%	
Lockwood Creek_B	11%	17%	70%	2%	
LW Rock Creek	13%	26%	55%	6%	
Manley Creek	2%	3%	32%	63%	
Mason Creek_A		11%		89%	
Mason Creek_B	6%	24%	58%	6%	5%
McCormick Creek_A	27%	9%	6%	58%	
McCormick Creek_B		24%	72%	4%	0%
Mill Creek	7%	20%	33%	40%	
Rock Creek 1	19%	41%	36%	4%	
Rock Creek 2	35%	21%	38%		5%
Rock Creek 3	52%		48%		
Rock Creek 4	10%	45%	44%		
Rock Creek 5	10%	39%	51%		
unnamed LB trib			100%		
unnamed RB trib1	32%	20%	49%		
unnamed RB trib2		33%	67%		
Brezee Creek_A	22%	16%	34%	28%	
Brezee Creek_B	12%	32%	46%	10%	
Cedar Creek	23%	21%	55%		
Cold Creek	38%	6%	56%		
Copper Creek	70%		30%		
Coyote Creek	36%	3%	61%		
Dean Creek_A		53%		47%	
Dean Creek_B		27%	64%	9%	

4.2.2.2 Shade Determinations from Aerial Photographs

The stream visibility index was applied to all 44 East Fork Lewis Basin EDT reaches. Reaches with low shade occurred in the lower mainstem East Fork and in the lower portion of mainstem tributaries (Figure 4. 12 and Table 4. 19). Lower McCormick and Lockwood Creek had shade ratings in the range of 0 – 20% whereas the upper extent of these creeks were almost entirely shaded (>90%). At approximately river mile 15.5 on the East Fork Lewis mainstem the shade rating increases to 20 – 40% shading. Shade ratings alternate between 20 - 40% shade and 40 - 70% shade up to approximately river mile 30.5 where the shade increases to 70 – 90% (Figure 4. 12).

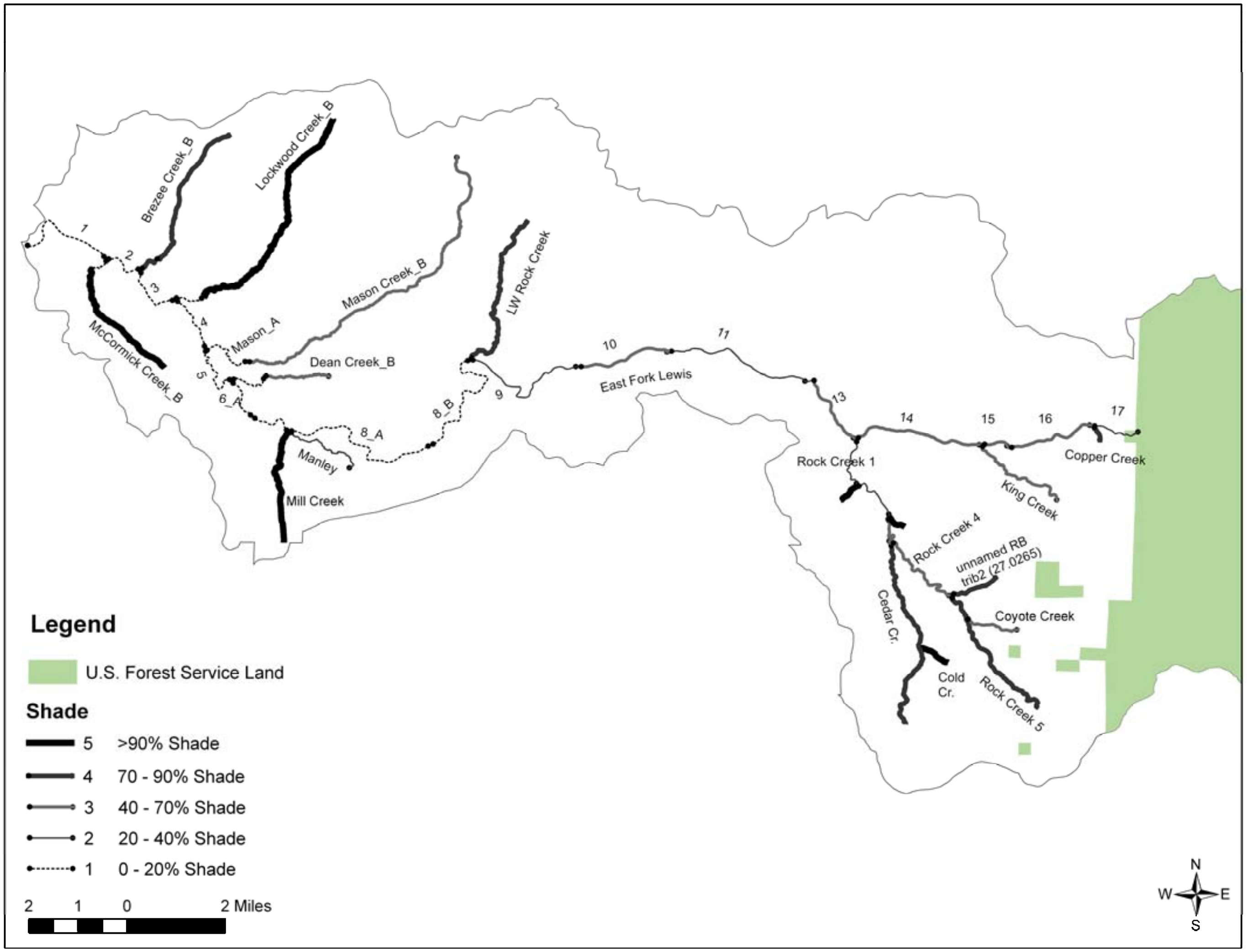

Figure 4. 12.Shade ratings in the East Fork Lewis Basin.

Table 4. 19. Shade ratings from the aerial photograph assessment of East Fork Lewis EDT reaches.

Percent Shade Category				
0 - 20%	**20 - 40%**	**40 - 70%**	**70 - 90%**	**> 90%**
EF Lewis 1	EF Lewis 9	EF Lewis 10	LW Rock Creek	Lockwood Creek_B
EF Lewis 2	EF Lewis 11	EF Lewis 13	Rock Creek 5	McCormick Creek_B
EF Lewis 3	EF Lewis 12	EF Lewis 14	unnamed RB trib2 (27.0265)	Mill Creek
EF Lewis 4	EF Lewis 17	EF Lewis 15	Brezee Creek_A	unnamed LB trib (27.0255?)
EF Lewis 5	Manley Creek	EF Lewis 16	Brezee Creek_B	unnamed RB trib1 (27.0258)
EF Lewis 6_A	Rock Creek 1	King Creek	Cedar Cr. (trib Rock Cr)	Cold Creek
EF Lewis 6_B	Rock Creek 2	Mason Creek_B	Copper Creek	
EF Lewis 8_A		Rock Creek 3		
EF Lewis 8_B		Rock Creek 4		
Lockwood Creek_A		Coyote Creek		
Mason Creek_A		Dean Creek_B		
McCormick Creek_A				
Dean Creek_A				

4.2.2.3 Field Verification

VTS measurements taken during field sampling were used to verify remotely assessed ratings of shading potential. VTS angles are well correlated to shading ratings based on aerial photo analysis. The lowest shade rating is 1, and VTS angles in those reaches ranged from 72-153 degrees. Angles in the shade rating 2 category ranged from 65-70 degrees, and from 33-77 degrees for shade category 3 reaches. The lone category 4 reach had a VTS angle of 11 degrees.

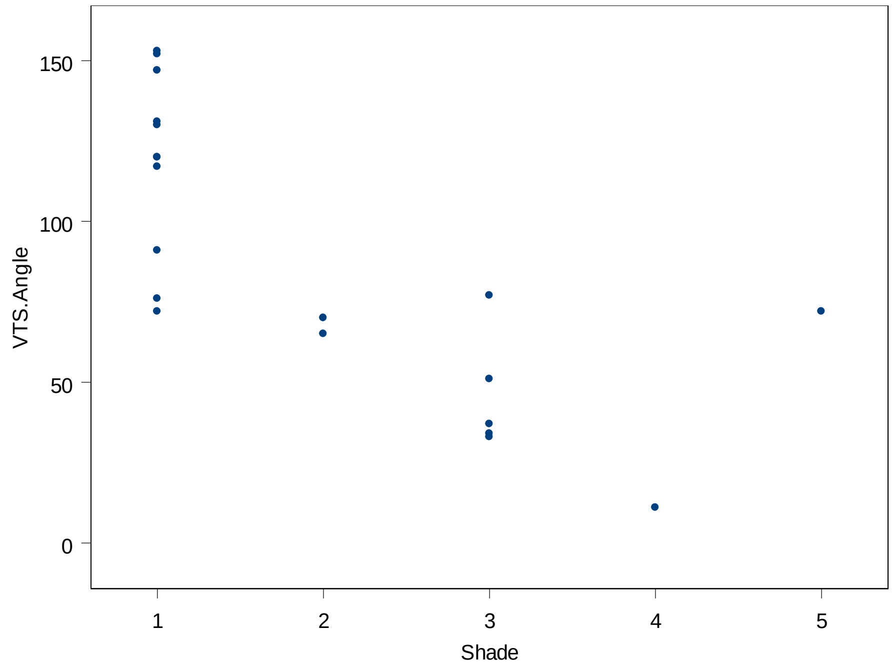

Figure 4. 13. Comparison of VTS angles from field surveys to shading ratings from aerial photo analysis in 20 reaches of the East Fork Lewis basin.

Lockwood Creek_B was the only reach with a category 5 shade rating, the highest rating possible. However, the VTS angle in Lockwood Creek was 72 degrees which would indicate the shade rating should have been between category 1-3. This anomaly can be explained by examining the proportion of the EDT reach that was surveyed. Lockwood Creek_B is approximately 9km long, and the stream survey covered only the lowest 1 km. Field observations and re-examination of aerial photos confirm that riparian shading is vastly different between the surveyed portion of the reach and the unsurveyed portion of the reach. A shade analysis rating of just the surveyed portion of Lockwood Creek_B resulted in an assignment of a 2 rating (20-40% shaded).

The Lockwood Creek_B anomaly brings up an important consideration, that in many instances, the surveyed section of the EDT reach did not encompass the entire reach. This is important because the surveyed portion may not be representative of unsurveyed portions. Lockwood Creek_B is likely to be the most extreme example of this occurrence.

The finding that aerial photo shade ratings correlate with field VTS ratings supports the use of shade ratings in reaches not field surveyed.

4.2.2.4 VTS Modeling

Nearly all of the reaches surveyed have less shade and higher 7-Day maximum temperatures than that estimated for pre-settlement conditions (Table 4. 20). Rock Creek reach 5 showed no change from historical conditions. Six reaches have low impacts from change to VTS, nine have moderate impacts, and seven have high impacts. All of the highly impacted streams are in the lower mainstem East Fork or are tributaries to the lower mainstem. Three of four Rock Creek reaches are in the low impact category along with the two most downstream mainstem East Fork reaches.

Impact ratings for temperature show greater degradation. Only one reach was rated as low impact, ten reaches of moderate impact, and eleven reaches of high impact. Changes were smallest in Rock Creek, King Creek, and the East Fork Lewis reaches 1 and 2. The average temperature increase for East Fork Lewis reaches was 3.1ºC.

Table 4. 20. Change in view-to-sky angle and 7-Day maximum temperature in surveyed reaches of the East Fork Lewis from pre-settlement conditions.

Reach	View-to-Sky Difference (+degrees)	VTS Change Rating	7-Day Max. Temp. Change ºC	Temperature Change Rating
EF Lewis 1	12	Low	1.6	Moderate
EF Lewis 2	11	Low	1.5	Moderate
EF Lewis 3	38	High	5.0	High
EF Lewis 4	24	Moderate	3.2	High
EF Lewis 5	39	High	5.3	High
EF Lewis 6A	35	High	4.7	High
EF Lewis 6B	15	Moderate	2.0	Moderate
EF Lewis 8A	36	High	4.9	High
EF Lewis 8B	28	Moderate	3.7	High
EF Lewis 11	21	Moderate	2.8	Moderate
EF Lewis 13	22	Moderate	3.0	Moderate
EF Lewis 15	15	Moderate	2.1	Moderate
McCormick_A	39	High	5.2	High
Lockwood_B	35	High	4.7	High
Dean_A	33	High	4.4	High
LW Rock	27	Moderate	3.6	High
Rock 1	29	Moderate	3.9	High
Rock 3	9	Low	1.3	Moderate
Rock 4	11	Low	1.5	Moderate
Rock 5	0	Low	0.0	Low
King	10	Low	1.4	Moderate
Slide	18	Moderate	2.4	Moderate

Numerous assumptions were made in this analysis, and as such, the results should be viewed cautiously. The model does not take into account the effects of hillslope or canyon walls on shading. For example, if the stream is confined by a 50 foot bedrock wall with 50 foot tall trees on top, the model assumes the tree height is 100 feet. Under pre-settlement conditions, it regards the vegetative height as 150 ft regardless of the effects of hillslope. Under this assumption, there is only a 50 foot difference in pre and post settlement riparian height, whereas in reality the pre-settlement tree would be atop a 50 foot wall making it 200 feet in total height, and a resultant difference of 100 feet with current conditions. In this way, the model under estimates historical tree heights, and under-estimates impacts on negative changes in view-to-sky angles and temperature change. This has likely occurred in highly confined reaches such as East Fork Lewis reaches 13 and 15 and Rock Creek reach 3, among others.

In addition, the model assumes that temperature influences in each reach are independent of contributing reaches. In some reaches, particularly short reaches, temperature changes may be more dependent upon changes in upstream temperatures than on shading within the reach itself.

4.2.2.5 Comparison to EDT and IWA Scores

EDT ratings based on stream surveys and GIS analysis of aerial photos generally rated riparian function higher (less functional) than previously rated under EDT patient conditions. EDT reaches based on this analysis were rated less functional than previous EDT assignments in 22 reaches, the same in 17 reaches, and more functional in 6 reaches (Table 4. 21). With a few exceptions, the new rating was consistently higher than the EDT rating throughout the mainstem East Fork Lewis and in tributaries to the lower East Fork.

The EDT ratings were also related to the IWA ratings (Table 4. 21). The average EDT rating for "functional" reaches was 1.0 (range 1.0-1.0). In moderately impaired reaches, the average rating was 1.4 (range 0.0-3.0), and in impaired reaches was 2.4 (range 0.5-4.0). Discrepancies between EDT and IWA ratings may be related to a number of factors. First, the IWA ratings are based almost entirely on LandSat generated characterizations of riparian vegetation, which do not have the accuracy of high resolution aerial photo interpretation or field surveys. Second, the IWA ratings reflect conditions averaged throughout an entire subwatershed and may not accurately reflect the more local conditions occurring at the reach scale. And third, the IWA measured riparian conditions on stream reaches present on 1:24,000 scale GIS hydrography layers, which contain many more reaches than those used in the EDT model.

Table 4. 21. Comparision of EDT survey rating of riparian function based on stream surveys to pre-existing EDT rating assignments, and the IWA rating.

Reach	New Rating	EDT Rating	IWA Rating
Surveyed Reaches			
EF Lewis 1	1.5	2	Moderate
EF Lewis 2	2	2	Moderate
EF Lewis 3	3.5	2	Impaired
EF Lewis 4	3	2	Impaired
EF Lewis 5	3	2	Impaired
EF Lewis 6A	4	2	Impaired
EF Lewis 6B	1.5	2	Impaired
EF Lewis 8A	2.5	1	Impaired
EF Lewis 8B	1.5	1	Impaired
EF Lewis 11	1.5	1	Moderate
EF Lewis 13	1.5	1	Moderate
EF Lewis 15	1.5	1	Moderate
McCormick_A	4	1	Impaired
Lockwood_B	2	1	Moderate
Dean_A	4	2	Impaired
LW Rock	2	2	Impaired
Rock 1	1.5	1	Moderate
Rock 3	1	1	Moderate
Rock 4	1.5	1	Moderate
Rock 5	1.5	1	Moderate
King	1.5	1	Moderate
Slide	1	1	Moderate
Unsurveyed Reaches			
EF Lewis 9	1	1	Moderate
EF Lewis 10	1	1	Moderate
EF Lewis 12	1	1	Moderate
EF Lewis 14	1	1	Moderate
EF Lewis 16	1	1	Moderate
EF Lewis 17	1	1	Moderate
Rock 2	1	1	Moderate
Brezee Creek_A	1	1	Impaired
Brezee Creek_B	1	1	Impaired
Cedar Creek (Rock Trib)	1	1	Moderate
Cold Creek	1	1	Functional
Copper Creek	0.5	0	Moderate
Coyote Creek	1	1	Functional
Dean Creek_B	1.5	2	Impaired
Lockwood_A	3	1	Moderate
Manley Creek	2.5	3	Moderate
Mason Creek_A	3	2	Moderate
Mason Creek_B	1.5	2	Moderate
McCormick Creek_B	0.5	1	Impaired
Mill Creek	2	2	Moderate
unnamed LB trib (27.0255?)	0	1	Moderate
unnamed RB trib1 (27.0258)	0.5	1	Moderate
unnamed RB trib2 (27.0265)	0.5	1	Moderate

4.2.3 Stream Habitat Assessment

The results described below represent a general overview of all surveys conducted within the East Fork Lewis Basin. For more detailed information from each survey, please refer to the individual stream survey summaries in Appendix A.

4.2.3.1 Survey Conditions

Flow conditions during surveys were somewhat elevated above late summer low flow conditions, but were far below annual high flow (Figure 4. 14). Flow in the East Fork Lewis near Heisson, Washington ranged from 157-643 cfs during the survey period compared to the mean August (low flow) of 83 cfs. Temperatures recorded via a hand held thermometer throughout the survey period ranged from 9.7-16.1ºC, but typically varied between 11.0-13.0ºC. Visibility was generally excellent with the exception of LW Rock Creek where turbidity inhibited visibility of the substrate. Deep pools and turbulence inhibited visibility in some units in the mainstem East Fork Lewis.

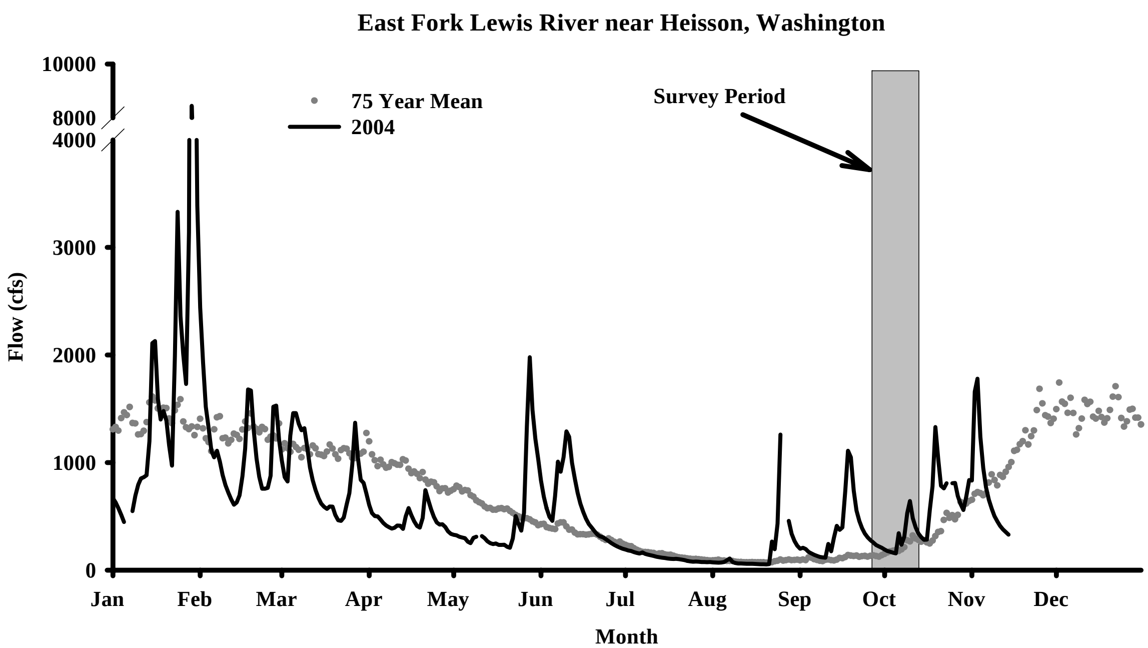

Figure 4. 14. Hydrograph of the East Fork Lewis River near Heisson, Washington displaying the 75 year mean flow and 2004 flow. The 2004 stream survey period is highlighted in gray. USGS gage number 14222500.

4.2.3.2 Channel Morphology

Surveys showed that the mainstem East Fork Lewis reaches have a higher percentage of area in pool habitat than do the tributaries to the East Fork (Table 4. 22). Gradient appears to be related to percent pool with lower gradient reaches having higher percentages of pool. However, the inverse is true of pool frequency. Smaller and higher gradient reaches have more pools per kilometer than do the lower and wider reaches. In the mainstem East Fork, small cobble/gravel riffles are less frequent, and large cobble/boulder riffles are more frequent proceeding upstream. Beaver ponds are present in McCormick, Lockwood, and Dean Creeks. There is a significant amount of side channel habitat in LW Rock Creek and in most of Rock Creek.

Table 4. 22. Unit composition, pool frequency, and side channel presence in surveyed reaches of the East Fork Lewis Basin.

Reach	Gradient (%)	% Pool	Pools/km	% Tailout	% Sm. Cobble/ Gravel Riffle	% Lg Cobble/ Boulder Riffle	% Glide	%Beaver Pond	% Backwater[1]	% Side Channel by length[1]
EF Lewis 1	0.0	*Not Applicable*								
EF Lewis 2	0.0	*Not Applicable*								
EF Lewis 3	0.0	*Not Applicable*								
EF Lewis 4	0.0	*Not Applicable*								
EF Lewis 5	0.3	70	4.4	3	14	1	12	0	9	17
EF Lewis 6A	0.1	30	1.7	5	3	1	2	0	49	4
EF Lewis 6B	0.4	54	4.2	1	28	9	8	0	4	2
EF Lewis 8A	0.4	38	2.2	0	22	29	11	0	3	6
EF Lewis 8B	0.5	39	2.2	0	16	35	10	0	1	8
EF Lewis 11	0.8	50	3.9	2	0	21	27	0	0	0
EF Lewis 13	0.9	34	2.4	2	8	38	18	0	0	0
EF Lewis 15	1.7	58	8.6	3	4	35	0	0	0	0
McCormick Creek_A	0.5	4	4.6	0	1	0	8	87	0	0
Lockwood Creek_B	0.7	47	23.4	2	28	1	1	21	0	1
Dean Creek_A	0.7	16	16.5	1	12	0	19	52	0	0
Lower Rock Creek	2.0	25	15.3	2	21	37	15	0	0	34
Rock Creek 1	1.6	35	8.2	2	9	35	0	0	0	23
Rock Creek 3	1.9	34	8.5	2	15	46	3	0	0	3
Rock Creek 4	1.4	14	9.0	2	27	46	11	0	0	19
Rock Creek 5	2.6	13	9.5	1	10	74	2	0	0	38
King Creek	4.6	25	25.8	2	17	54	2	0	0	12
Slide Creek	3.1	33	25.0	2	6	56	3	0	0	4

1. Values for reaches Lewis 5-8B determined by GIS aerial photo analysis, and may differ slightly from survey results from ground surveys. Side channel rating is by surface area for these reaches.

4.2.3.3 Habitat Features

A summary of important habitat features among the surveyed reaches can be seen in Table 4. 23. Stream sizes were highly variable with average widths ranging from 0.9 m to 59 m and average maximum riffle depths ranging from 0.1 m to 2.0 m. The highest density of LWD was in Rock Creek reach 4 which had 82 pieces per kilometer. Cobble and gravel were the dominant substrate classes, but sand and boulders were the dominant or subdominant classes in several reaches. Cover varied from 2-85% of the reach and view-to-sky angles were typcially related to channel width. Bank instability and disturbance was highly variable between reaches, and was primarily related to land use and geomorphology. Areas with limited development/land use and high amounts of bedrock were more stable than areas with significant development in depositional areas.

In the lower East Fork and lower tributaries, the main disturbance types include hydromodifications such as levees and bridges, residential development, bank armoring, entrenchment, and the Ridgefield gravel pits. The Ridgefield gravel pits have had a substantial influence on the habitat of the affected area in the mainstem East Fork. There are fewer habitat units within the Ridgefield gravel pits and those units are much larger when compared to the East Fork just above and just below the gravel pits (Figure 4. 15). Riffle habitat is significantly lacking and pool frequency is very low. Overall, habitat complexity in the Ridgefield gravel pits is very poor.

Table 4. 23. Important habitat features of surveyed reaches in the East Fork Lewis Basin.

Reach	Gradient (%)	Mean Riffle Width (m)	Mean Max. Riffle Depth (m)	Mean Max. Residual Pool Depth (m)	Pieces LWD/km	Dom. Substrate Size Class[b]	Subcom. Substrate Size Class[2]	% Cover	View to sky angle	% Bank Unstable	% Riparian Disturbed
EF Lewis 1	0.0	59.0[1]	na	na	51	SA	GR	37	131	80	0
EF Lewis 2	0.0	39.0[1]	na	na	2	SA	GR	51	117	70	20
EF Lewis 3	0.0	35.0[1]	na	na	7	SA	GR	52	153	40	95
EF Lewis 4	0.0	36.0[1]	na	na	45	SA	GR	31	130	13	40
EF Lewis 5	0.3	20.3	0.6	1.3	31	CO	GR	15	147	34	8
EF Lewis 6A	0.1	20.7	0.5	>3.5	33	SA	GR	28	152	59	80
EF Lewis 6B	0.4	27.6	0.6	1.2	23	CO	GR	2	120	48	0
EF Lewis 8A	0.4	29.5	0.7	1.3	8	CO	GR	59	91	25	31
EF Lewis 8B	0.5	24.5	1.0	1.7	16	CO	GR	33	120	6	35
EF Lewis 11	0.8	16.8	2.0	1.6	2	CO	BO	85	65	0	17
EF Lewis 13	0.9	24.0	1.8	2.6	5	BO	CO	58	77	0	7
EF Lewis 15	1.7	17.7	0.9	2.3	1	CO	BO	27	51	0	15
McCormick Creek_A	0.5	0.9	0.1	0.4	35	SA	GR	48	76	100	100
Lockwood Creek_B	0.7	5.5	0.3	0.6	35	GR	SA	15	72	22	15
Dean Creek_A	0.7	1.3	0.1	0.4	42	GR	SA	55	72	18	100
Lower Rock Creek	2.0	5.9	0.4	0.5	30	CO	GR	19	57	22	9
Rock Creek 1	1.6	11.3	0.8	1.1	11	CO	GR	35	70	4	0
Rock Creek 3	1.9	10.3	0.5	0.9	21	CO	GR	15	34	5	26
Rock Creek 4	1.4	9.9	0.4	0.8	82	CO	GR	6	37	14	6
Rock Creek 5	2.6	7.8	0.6	0.7	74	CO	GR	23	11	13	7
King Creek	4.6	6.2	0.4	0.5	64	CO	GR	18	33	1	1
Slide Creek	3.1	7.8	0.6	0.6	60	CO	GR	46	42	0	3

1. *Mean wetted channel width. Habitat is entirely tidewater influenced pool/glide.*
2. *SA = sand; GR = gravel; CO = cobble; BO = boulder*

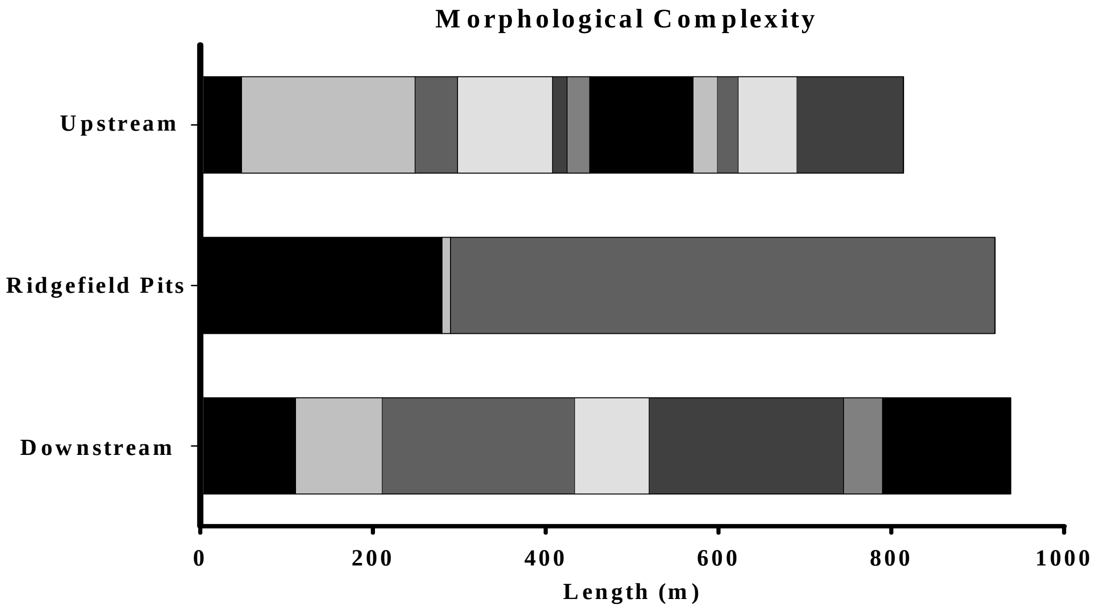

Figure 4. 15. Illustration of morphological complexity in the Ridgefield pits (avulsed reach), and adjacent upstream and downstream sections of the East Fork Lewis River. Each band within the bars represents a distinct habitat unit and its length. In the Ridgefiel Pits reach, two large pools are separated by a short riffle.

4.2.3.4 Comparison to Habitat Standards

Habitat survey data was compared to PFC habitat quality rating criteria that have been developed by NOAA Fisheries (NMFS 1996). Although these ratings may not be appropriate for all channel types and locations, they do provide a general understanding of the quality of habitat within the East Fork with respect to salmon (*Oncorhynchus sp.*). PFC conditions apply the following three ratings: 1) Properly functioning, 2) Functioning at risk, and 3) Not properly functioning. Reaches 1-4 in the mainstem East Fork were not evaluated because it is not appropriate to evaluate habitat in tidewater influenced reaches with these criteria.

Conditions generally did not rate well with reference to the PFC (Table 4. 24). Pool frequency and wood were rated almost entirely “Not properly functioning”. Pool quality, substrate, and bank stability faired somewhat better with several ratings of “Functioning at Risk” and “Properly functioning”. There were no man made barriers encountered, so each reach was rated as “Properly functioning” for barriers. In sum, there are 43 ratings of “Properly functioning”, 16 ratings of “At risk”, and 49 ratings of “Not properly functioning”.

It should be noted that habitat standards such as PFC are developed on a regional basis and achievement of those standards may not be realistic under past or present conditions. For instance, boulder/bedrock transport reaches, such as EF Lewis 13, may have naturally low levels of LWD and would not be expected to meet PFC “Properly functioning” criteria.

Table 4. 24. Comparison of surveyed habitat features to NOAA Fisheries Properly Functioning Condition criteria. NPF = not properly functioning; PF = properly functioning

Reach	Pool Frequency	Pool Quality	LWD	Substrate	Bank Stability	Barriers
EF Lewis 1	*Not Assessed*					
EF Lewis 2	*Not Assessed*					
EF Lewis 3	*Not Assessed*					
EF Lewis 4	*Not Assessed*					
EF Lewis 5	NPF	At Risk	NPF	PF	NPF	PF
EF Lewis 6A	NPF	At Risk	NPF	NPF	NPF	PF
EF Lewis 6B	NPF	At Risk	NPF	PF	NPF	PF
EF Lewis 8A	NPF	At Risk	NPF	PF	NPF	PF
EF Lewis 8B	NPF	At Risk	NPF	PF	PF	PF
EF Lewis 11	NPF	PF	NPF	At Risk	PF	PF
EF Lewis 13	NPF	PF	NPF	At Risk	PF	PF
EF Lewis 15	NPF	PF	NPF	PF	PF	PF
McCormick Creek	NPF	NPF	NPF	NPF	NPF	PF
Lockwood Creek	NPF	NPF	NPF	NPF	NPF	PF
Dean Creek	NPF	NPF	NPF	NPF	At Risk	PF
Lower Rock Creek	NPF	At Risk	NPF	At Risk	NPF	PF
Rock Creek 1	NPF	PF	NPF	PF	PF	PF
Rock Creek 3	NPF	PF	NPF	PF	PF	PF
Rock Creek 4	NPF	PF	NPF	PF	At Risk	PF
Rock Creek 5	NPF	PF	NPF	PF	At Risk	PF
King Creek	At Risk	At Risk	NPF	At Risk	PF	PF
Slide Creek	NPF	PF	NPF	At Risk	PF	PF

4.2.3.5 Comparison to EDT Values

Survey results in each reach were compared to EDT values assigned under patient (current) conditions (Table 4. 25). It is important to note that in many surveys, the surveyed section does not cover the entire EDT reach, so survey observations may not be representative of the entire EDT reach.

Based on the stream surveys, the EDT attribute ratings that are most similar to the EDT patient condition ratings include confinement (hydromodifications), confinement (natural), percent beaver ponds, and percent off-channel habitat. Width ratings based on surveys were about 40% different than patient condition ratings, with survey ratings larger than patient ratings in 15 of 22 reaches. Gradient tended to be lower than rated under patient conditions. Surveys indicated that there are fewer glides, less pool tail-out habitat, more pools, and fewer riffles than assigned under patient conditions. Riparian function, wood, and embeddedness were rated higher (less functional) in the surveys than they are in EDT. More detailed discussion on comparison of EDT attribute ratings based on stream surveys, and previous EDT patient condition ratings are included in reach survey reports.

Table 4. 25. Summary of comparison of EDT patient condition ratings to EDT ratings assigned based on survey results.

	Median	# Observations	
EDT Attribute	**Difference**	**Above EDT**	**Below EDT**
Minimum channel width (%)	40%[1]	15	7
Gradient (%)	60%[1]	7	15
Glides (# of % Pts.)	4.5[2]	5	14
Beaver Ponds (# of % Pts.)	0.0[2]	3	0
Off Channel Habitat (# of % Pts.)	0.0[2]	7	1
Pool Tailouts (# of % Pts.)	4.5[2]	1	21
Primary Pools (# of % Pts.)	12.5[2]	13	9
Small Cobble/Gravel Riffle (# of % Pts.)	5.5[2]	7	9
Large Cobble/Boulder Riffle (# of % Pts.)	5.5[2]	7	11
Confinement – Hydromod. (0-4 score)	0.0[3]	6	1
Confinement – Natural (0-4 score)	0.0[3]	1	7
Riparian Function (0-4 score)	0.5[3]	16	2
Wood (0-4 score)	0.7[3]	13	6
Embeddedness (0-4 score)	0.5[3]	11	5

1. *Percent change in value.*
2. *Change in number of percentage points*
3. *Change in EDT scores which range from 0-4 (0 typcially represents pristine conditions and 4 typically represents disturbed condition, except for natural confinement).*

4.2.4 Sediment Sources

4.2.4.1 Overview

Geologic History of the East Fork Lewis Basin

The uppermost portion of the East Fork Lewis Basin consists primarily of volcanicastic deposits from volcanic activity dating back more than 20 million years ago (Figure 4. 16). More recent glacial sediments (Pleistocene) can be found overlying this material in headwater stream valleys. Andesite flows underlie most of the middle portion of the basin, with glacial material forming floodplain deposits in the Yacolt Valley and in the lower portion of (upper) Rock Creek.

The lower East Fork Lewis, below the lower Rock Creek (LW Rock Creek) confluence, consists primarily of alluvial deposits dating back to the late Miocene (~6 million years ago). In most areas, the deepest alluvial sediments are comprised of the upper and lower Troutdale Formation. The lower Troutdale formation consists of clay, silt, and sand that was laid down across the Portland-Vancouver area in a large lake or estuary in the late Miocene-early Pliocene (>5 million years ago). The upper Troutdale Formation consists primarily of coarse gravel that was laid down as a piedmont fan along the western foot of the Cascades in the late Pliocene or early Pleistocene (approximately 2 million years ago). In the late Pleistocene, an ice tongue extended down the East Fork valley at least as far as Lewisville Park, contributing glacial till and outwash deposits to the lower river valley, which can be seen overlying the deposits of the Troutdale formation in several locations. The Missoula Floods in the Columbia River during the late Pleistocene contributed sediments to the lower East Fork River as part of a broad alluvial fan that extended from the mouth of the Columbia River Gorge. In the vicinity of the East Fork Lewis these deposits consist primarily of sand (Mundorff 1964). Since the last ice age (Holocene – 10,000 years to present) the lower East Fork River has eroded, worked, and deposited these alluvial sediments resulting in broad alluvial terraces. Downstream of Mason Creek, the gradient is insufficient to carry coarse grained material and from here to the mouth the river channel and terraces are composed chiefly of sand or finer material.

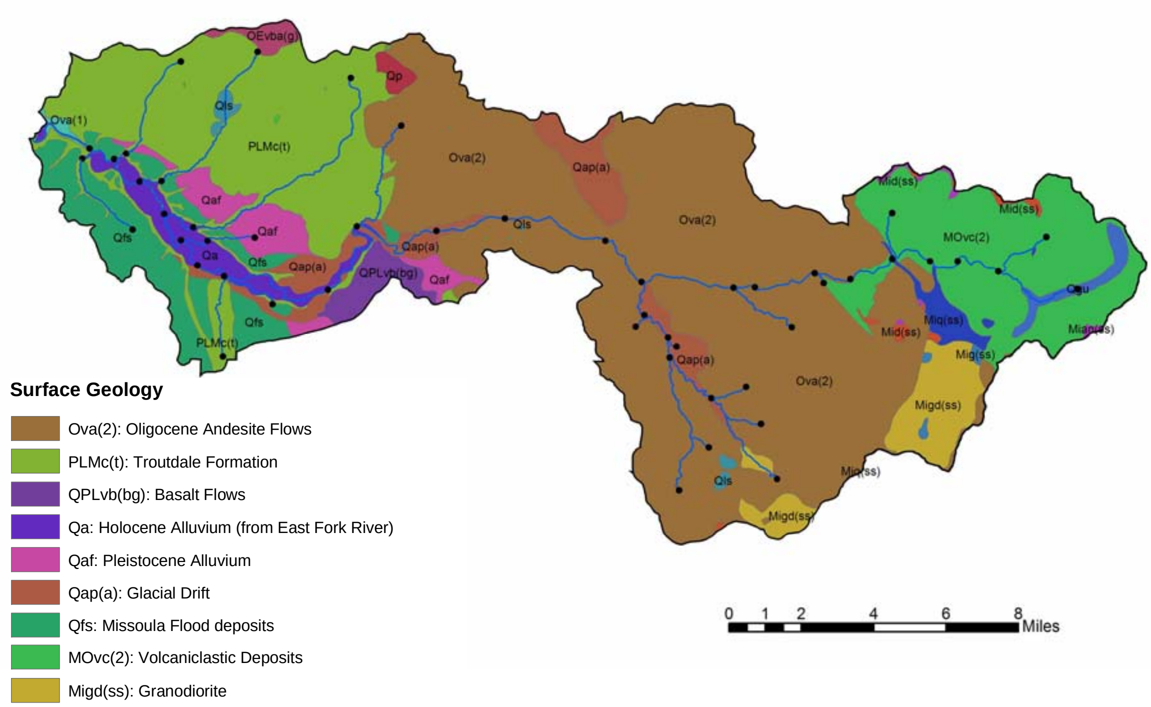

Figure 4. 16. Surficial geology of the EF Lewis Basin. Source: DNR digital geology GIS coverage (WDNR 2003).

<u>Overview of topography, substrate, and erosion characteristics</u>

The headwaters of the East Fork originate above 4000 feet on the westside of the Cascade Crest in western Skamania County. The mainstem headwaters and the headwaters of the Rock Creek Basin are characterized by steep stream valleys with moderately erodable soils (Figure 4. 17 and Figure 4. 18). Stream channels in these upper basins are high gradient and are dominated by sediment source and transport reaches with occasional response reaches located in the mainstem East Fork, Rock Creek, and Cedar Creek. Tributary streams originating from the northern portion of the basin between the Yacolt Creek Basin and the USFS boundary are small, steep, source and transport reaches that originate in private commercial timberlands (Figure 4. 19). Due to intensive harvest practices and high road densities, these streams have the potential for contributing fine sediment to the mainstem. Yacolt Creek originates northwest of Yacolt, WA and courses through a flat valley before entering Big Creek less than a mile from the mainstem East Fork downstream of the Rock Creek confluence. The flat topography of this basin limits the potential for high surface erosion although intensive residential, agricultural, and timber harvest land-uses may create some potential for fine sediment contribution to the mainstem. Fine sediments as well as much of the coarse-grained material (gravel and cobble) that are contributed to the mainstem via Rock Creek, Yacolt Creek, and headwater tributaries are readily transported through the transport reaches in the middle mainstem down to the alluvial reaches below the confluence with LW Rock Creek.

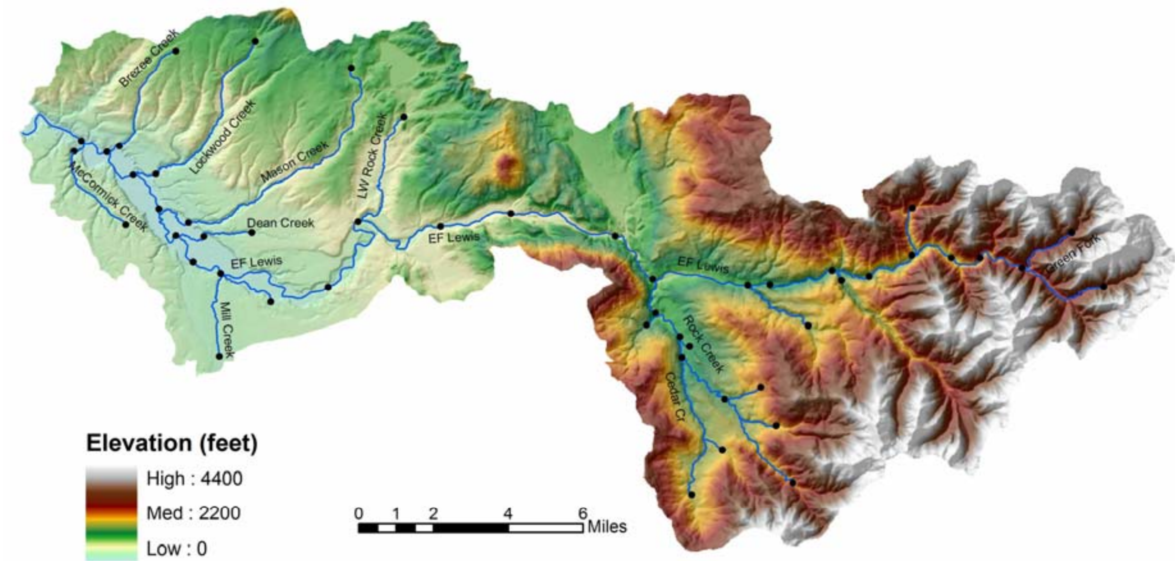

Figure 4. 17. Hillshaded digital elevation model of the East Fork Lewis Basin

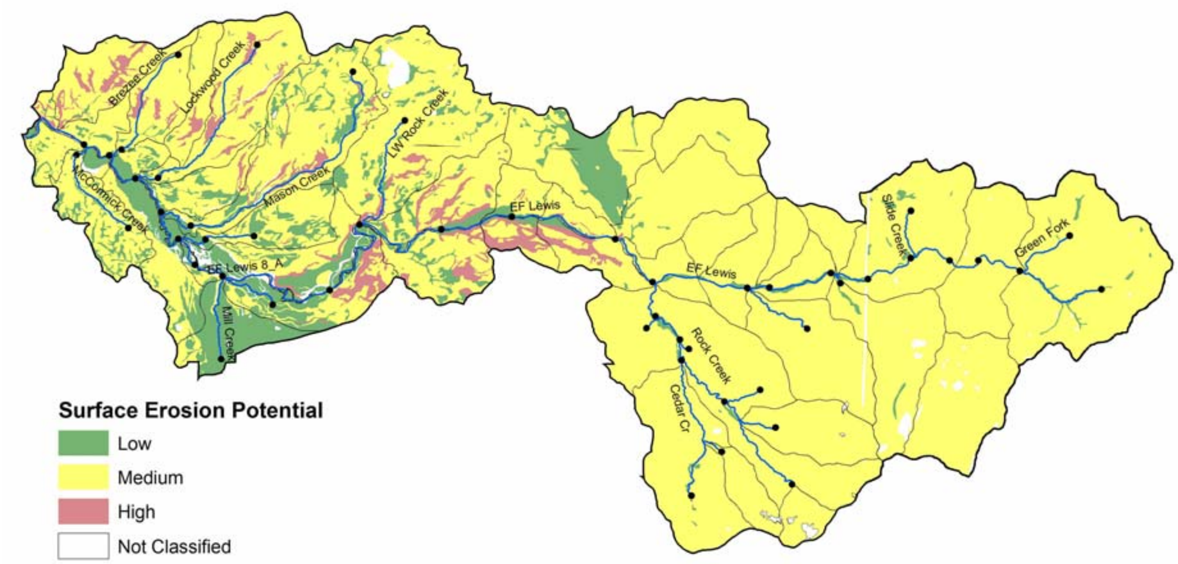

Figure 4. 18. Surface erosion potential (under undisturbed conditions) in the East Fork Lewis Basin. Data is derived from soil erosion rates and topographical slope. Data sources include DNR Clark County soils data and USFS Gifford Pinchot soils data.

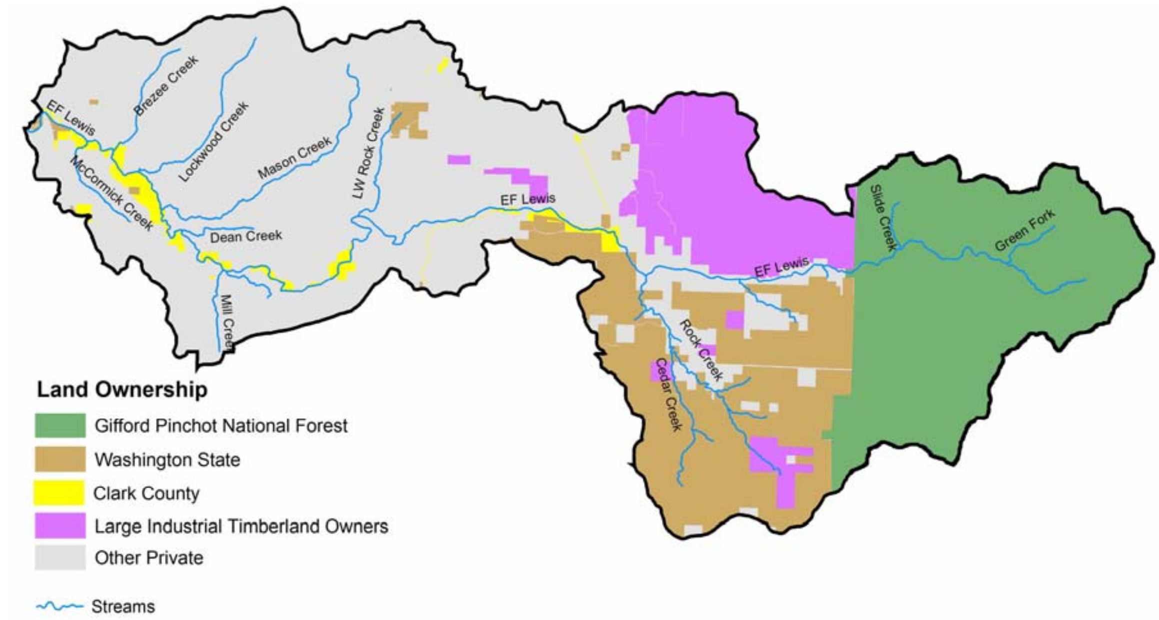

Figure 4. 19. Landownership in the East Fork Lewis Basin.

The middle mainstem reaches between the USFS boundary and LW Rock Creek are bedrock/boulder reaches with high confinement. These reaches are best classified as sediment transport reaches with occasional response segments where spawning sized gravel and cobble accumulates. Grain size distributions indicate that of all the surveyed reaches, these have the coarsest substrates, with approximately 40% of the substrate composed of large boulders or bedrock (Figure 4. 20). Fine sediment quantities are low in these reaches (Table 4. 26), with most of the fines transported downstream to the response reaches below the LW Rock Creek confluence.

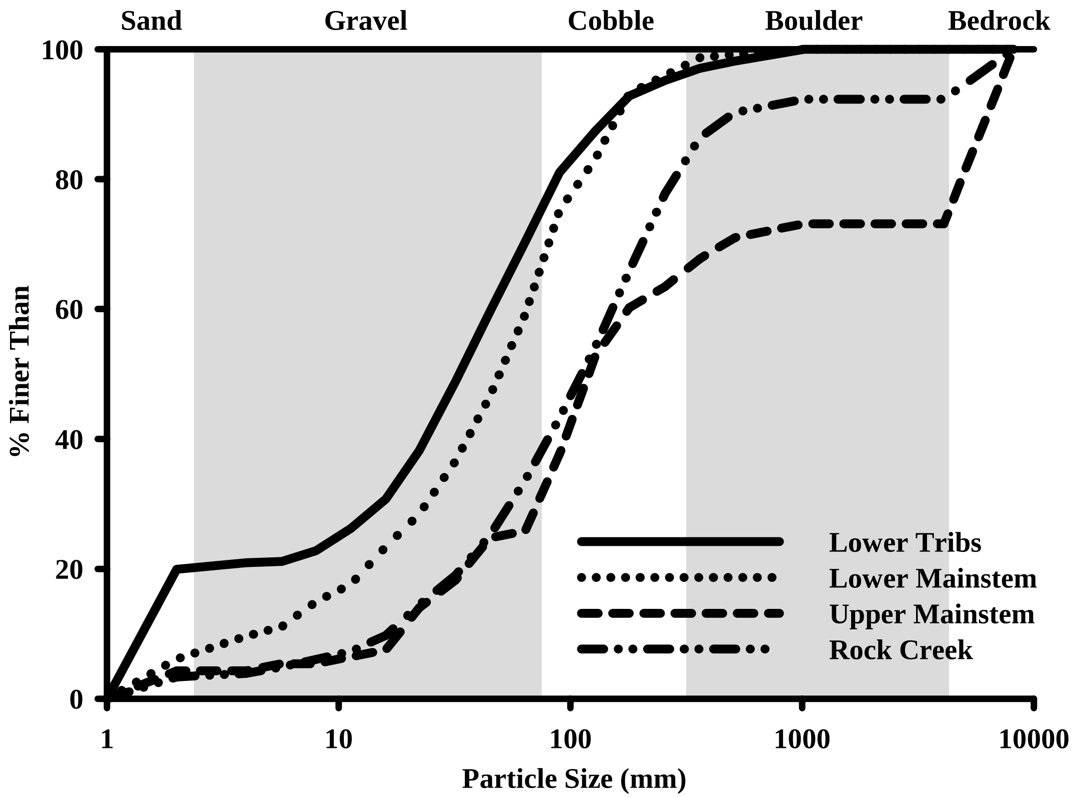

Figure 4. 20. Grain size distributions for surveyed reaches of the East Fork Lewis Basin. Reaches in portions of the basin were averaged in order to observe broad-scale differences in substrate conditions throughout the basin. Grain size distributions are from pebble counts. Grain size distributions for individual reaches can be found in the reach-level habitat summaries (see Appendix A).

Table 4. 26. Summary of field collected sediment data. Additional information can be found in the stream habitat survey reach summaries in Appendix A.

Reach	Upstream/ Downstream	D50 (mm)[1]	D90 (mm)[1]	Percent Sand[2]		Embededdness[4]
				Count[3]	Visual[4]	
EF Lewis 5	--	27.3	77	7	9	<25
EF Lewis 6_A (R. Pits)	--	--	--	--	75	25-50
EF Lewis 6_B	--	77	154	5	6	<25
EF Lewis 8_A	Downstream	54.5	218	6	6	<25
EF Lewis 8_B	Upstream	54.5	218	6	5	<25
EF Lewis 11		--	--	--	5	<25
EF Lewis 13	--	109	Bedrock	4	3	<25
EF Lewis 15	--	--	--	--	7	10-30
McCormick_A	--	--	--	--	94	40-60
Lockwood_B	Downstream	27.3	54.5	18	34	50
Lockwood_B	Upstream	27.3	77	14	34	50
Dean_A	Downstream	6.85	54.5	48	32	25
Dean_A	Upstream	19.3	77	35	32	25
LW Rock	Downstream	109	309	9	4	20
LW Rock	Middle[5]	109	437	5	4	20
LW Rock	Upstream	54.5	768	5	4	20
Rock 1	Downstream	109	768	2	7	10-30
Rock 1	Upstream	154	Bedrock	3	7	10-30
Rock 3	--	109	Bedrock	1	5	10-30
Rock 4	--	109	309	3	9	10-30
Rock 5	Downstream	109	437	7	2	10-30
Rock 5	Upstream	154	309	4	2	10-30
King	Downstream	77	218	5	9	25
King	Upstream	54.5	768	3	9	25
Slide	Upstream	38.5	768	18	9	20-35
Slide	Downstream	54.5	309	1	9	20-35
Mill	--	38.5	154	11	--	25

[1]*pebble counts were assigned to ranges and the midpoint of the range is displayed in this table*
[2]*includes fine sediment <2 mm*
[3]*From Pebble Count*
[4]*Average for entire reach*
[5]*Survey done in a riffle*

The gradient flattens and the river changes character below LW Rock Creek and can be characterized as a low gradient (<1%) alluvial stream from here to the mouth. The portion of the mainstem from LW Rock Creek to Mason Creek is a response reach with pool riffle sequences dominated by fine and medium grained materials (sand to large cobble). Below Mason Creek, the stream is tidally influenced and the gradient approaches zero. The channel and terrace substrate is almost entirely sand and silt from here down to the mouth.

The lower mainstem tributaries originate on the broad rolling plateau created by the Troutdale Formation and Missoula Flood deposits (Figure 4. 16). The streams range in gradient from 0.5% in McCormick Creek to 2.4% in Lockwood Creek (Figure 4. 21). The lower portions of most of these streams, where they flow through the broad valley bottom of the mainstem East Fork, are response reaches with flat slopes and high fine sediment concentrations. Although these watersheds have erodable soils, natural surface erosion potential is moderate due to relatively flat topographical slope. Soil erosion potential has been increased due to residential and agricultural development and may be particularly high as a result of active new residential construction activities.

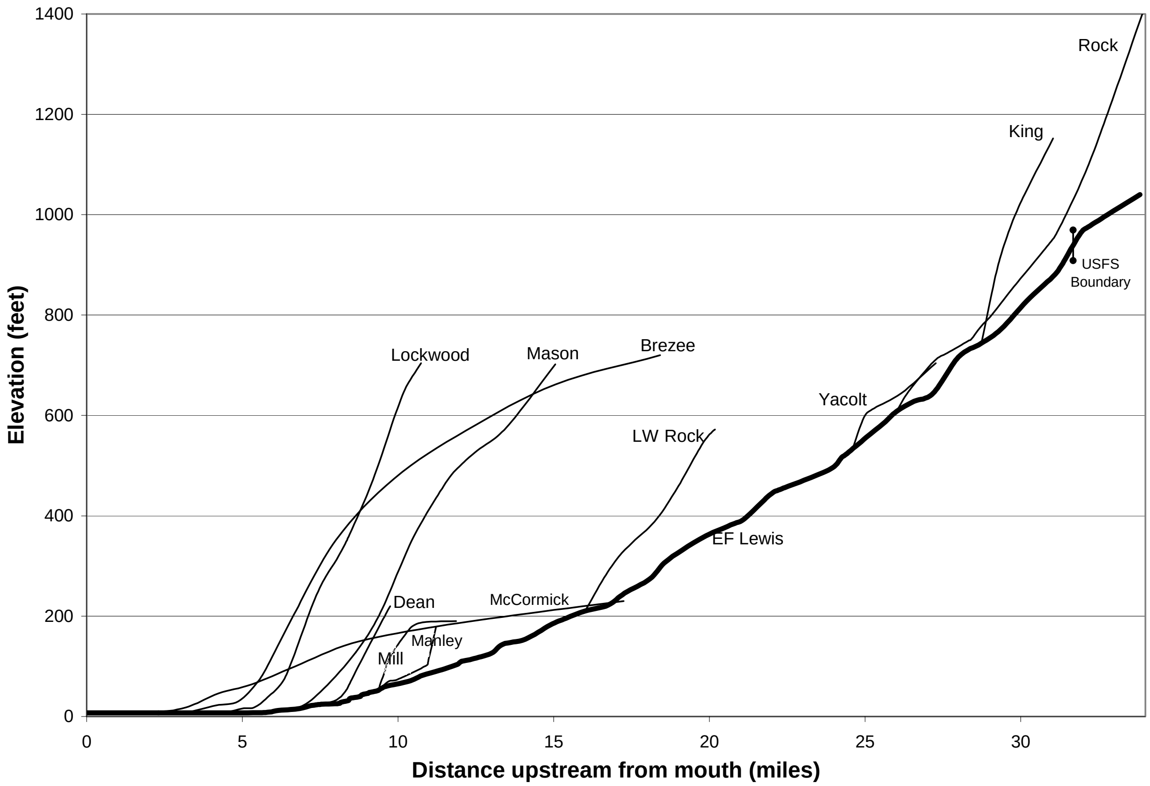

Figure 4. 21. Longitudinal profile of the East Fork Lewis River and major tributaries.

4.2.4.2 Sediment Conditions by Basin Area

<u>Headwaters (Gifford Pinchot National Forest)</u>

The East Fork Lewis Basin assessment focused primarily on the non-federal portion of the basin. Only one field survey (Slide Creek) was conducted within the National Forest and no other site visits or aerial photo interpretation were conducted to identify sediment sources. The Upper East Fork Lewis Watershed Analysis (USFS 1995) characterized general geologic conditions in the upper watershed and identified areas with potentially unstable soil conditions based on geology and land-use. This information, along with the survey results for Slide Creek, is summarized below.

Sediment source and delivery conditions

Surface geology in the upper basin is composed primarily of andesite, volcaniclastic deposits, and granodiorite (Figure 4. 16). Geologic conditions have created considerable mineralization in the Silver Star area, where many valid mining claims are currently held (USFS 1995). The volcaniclastic material shows some weathering but has not developed significant stability problems (USFS 1995). Holocene (last 10,000 years) glacial activity has shaped river valleys and has deposited glacial drift in the headwater valley bottoms (Qgu in Figure 4. 16).

Erosion conditions have been highly impacted by large fires dating back to 1900 that were hot enough to burn all of the duff and change soil characteristics. Surface erosion has decreased as a result of re-growth of forest vegetation, yet surface erosion remains a concern in some areas. Roading has further increased soil erosion potential (USFS 1995). The bulk (over 75%) of the stream channels in the upper basin are sediment source and transport reaches. An analysis of channel conditions using historical aerial photos revealed that reaches of the upper mainstem East Fork and Green Fork Creek went through a period of channel adjustment (narrowing & downcutting) between 1959 and 1979 in response to pulses of fine sediment related to past fires (USFS 1995).

Slide Creek is expected to be typical of many of the larger upper basin tributary streams. Field surveys of Slide Creek revealed that it is a relatively steep (3.5% gradient) step pool channel with pools formed by bedrock steps. As much as 40% of the channel is composed of boulders and bedrock. The USFS rated Slide Creek as having moderate risk of fine sediment input due to roads (USFS 1995). Visual estimates of fine sediment throughout the surveyed reach were less than 10%. One of the two pebble counts, which were conducted in pool tail-outs, measured 18% fines. Embeddedness ratings were moderate, averaging between 20 and 35%.

Fourteen of the 23 upper basin reaches evaluated by the USFS had a moderate or high risk of significant fine sediment impact from roads. Road densities in the upper basin range from 1.9 mi/mi^2 to 3.1 mi/mi^2 with a value of 2.5 mi/mi^2 for the entire USFS portion of the basin (Figure 4. 22). Based on Slide Creek surveys, road densities, and the 1995 Watershed Analysis, fine sediment impacts originating from the national forest can be considered low to moderate. Somewhat elevated fine sediment levels originating from the national forest is consistent with embeddedness estimates in the mainstem East Fork downstream of the USFS boundary (reach 15), in which 30% of the units surveyed were 25-50% embedded. Fine sediments delivered from the upper basin are readily transported through most reaches in the middle mainstem, where natural confinement and velocities are high. These conditions serve to transport fines through these channels and into the low gradient alluvial channels below the confluence with LW Rock Creek.

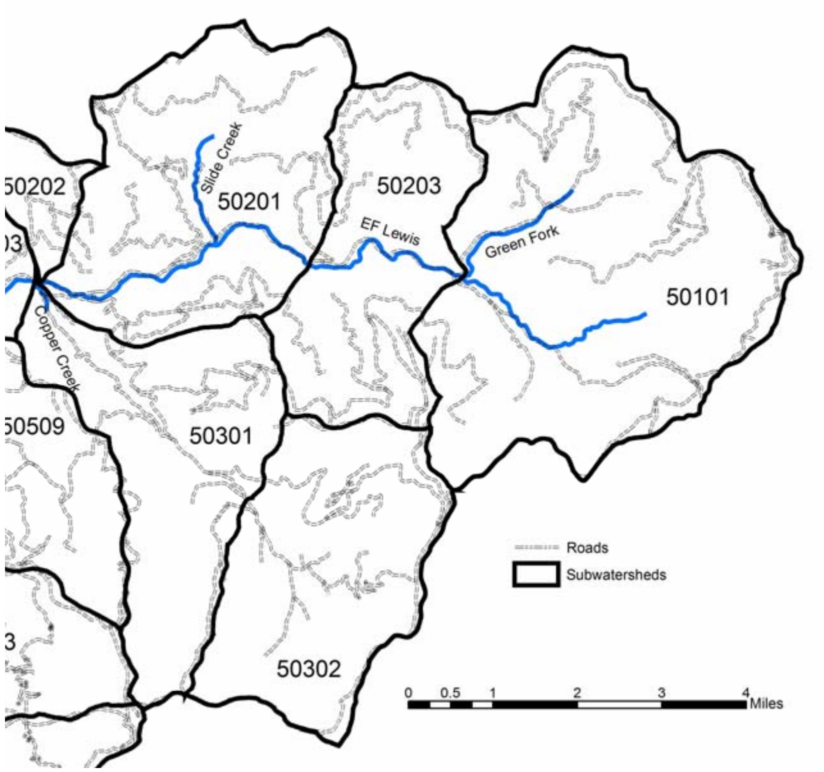

Figure 4. 22. Road network in the USFS portion of the East Fork Lewis Basin.

Comparison to existing assessments

Field surveys, EDT scores, and the IWA compare favorably in the upper East Fork Basin (Table 4. 27). The field survey in Slide Creek yielded an average percent fines of 9%. This is relatively close to the EDT score of 1.7 (12.5%) for Slide Creek, which was obtained through a relationship between road densities and percent fines. The IWA rated sediment supply conditions as moderately impaired in all of the subwatersheds in the upper basin. These ratings reflect moderately high road densities, steep slopes, and moderate natural soil erodability. The IWA ratings fairly represent the EDT scores and survey measures. The field surveys and EDT scores range between approximately 9-15%, which are moderately elevated above typical background fine sediment levels of 6-11% (MBI 2003).

Table 4. 27. Comparison of field surveyed fine sediment quantities, EDT fine sediment scores, and IWA sediment supply condition ratings for the upper East Fork Basin (USFS portion).

Subwatershed	Fine sediment estimated from field surveys[1]	EDT fine sediment ratings ()=categorical score[2]	IWA sediment supply rating (watershed level)
Slide Creek (50201)	9%	12.5% (1.7)	Moderately Impaired
Upper Copper Creek (50302)*	--	--	Moderately Impaired
Upper mainstem (50203)	--	12.5% - 14.5% (1.7– 2)	Moderately Impaired
Headwaters (50101)	--	8.5% - 12% (1 – 1.6)	Moderately Impaired

[1]determined by averaging percent sand (<2mm) from pebble counts and visual observations in all surveyed reaches within subwatershed.

[2]fines for EDT ratings defined as <0.85mm. Fine sediment ratings for EDT were obtained through applying a relationship between road densities and fine sediment developed in the Wind River Basin.

**Lower Copper Creek is covered in the next section (Rock Creek Basin).*

Project opportunities

The primary emphasis in these headwater systems is protection of existing sediment supply conditions. Surface erosion conditions are still improving as forest vegetation continues to mature following large fires since 1900. Although road densities are moderate, there has been very little recent timber harvest, thus reducing surface erosion potential from timber harvest activities. Restoration of hillslope sediment supply conditions would reduce fine sediment inputs to stream channels. The USFS Watershed Analysis recommends silvacultural treatments, road decommissioning, and road weatherization in specific areas of the basin (USFS 1995). This information is the best known source for sediment restoration work in the upper basin.

Rock Creek, King Creek, and Lower Copper Creek Basins

This basin includes Rock Creek (upper) and its tributaries. The watersheds of the small mainstem tributaries of King Creek and Copper Creek (non federal portion) are also included in this discussion as they have similar natural setting and land-use history.

Sediment source and delivery conditions

Surface geology in the basin is andesite (Figure 4. 16), which in general is relatively stable (low erodability). However, steep slopes result in an increased risk of soil erosion and stream channel delivery potential. According to the DNR soil erodability rating, which is based on soil characteristics and slope, the basin has moderate surface erosion potential under natural conditions; only a few flat areas along mainstem Rock and Copper Creeks have low surface erosion potential (Figure 4. 18). Human uses in these basins are dominated by forest practices on state and private timberlands. Road densities are moderately high, ranging from 2.4 mi/mi^2 (Copper Creek Basin) to 3.9 mi/mi^2 (headwaters of Rock Creek) (over 3 mi/mi^2 is generally considered "high"). Due to the high forest road density, surface erosion from roads is expected to be high. Furthermore, the frequency of road crossings over streams increases the risk of routing fine sediments from road surface erosion into drainage ditches and directly into stream channels. Stream road crossing frequencies range from 1.4 crossings/mile of stream in the Coyote Creek Basin to over 3 crossings/mi in the headwaters of Rock Creek. Surface erosion in the basin is also related to clear-cut timber harvests on state and private lands. A site visit of a clear-cut adjacent to Cold Creek revealed that skidding and/or cable yarding has left 10-20% of the cut in bare ground susceptible to erosion. Mass wasting related to roads is also a concern in these basins, especially in the Rock Creek Basin, where road failures have entered directly into anadromous fish bearing stream channels. One of the surveyed failures occurs where the paved Dole Valley Road is adjacent to the mainstem Rock Creek in Reach Rock Creek 4 (Figure 4. 23). Another large failure into a tributary of upper Rock Creek (reach 5) is associated with a forest road within a recent clear-cut.

Figure 4. 23. Landslide from road failure (Dole Valley Road) directly entering Rock Creek.

The steep gradient and natural confinement along much of Rock Creek results in a relatively coarse substrate distribution overall. When compared to other surveyed areas of the East Fork Basin, Rock Creek has some of the coarsest substrate; showing similar bed coarseness as the middle mainstem reaches but containing slightly more gravel and cobble and less bedrock (Figure 4. 20). The median grain size ranges from 109 to 154mm (Table 4. 26). Spawning sized gravel and cobble (10 - 100 mm) comprises approximately 30% of pool tailouts. Despite the observed erosion sites and erosion risk factors in the basin, low quantities of fine sediment (<10% of fines <2mm) were observed on surveyed portions of Rock and King Creeks. Embeddedness was rated between 10% and 30% in all reaches surveyed, indicating a low to moderate concern for embedded substrates. It is likely that the low fines observed during surveys do not accurately represent the amount of fines present following surface runoff events in the winter and spring. Furthermore, fine sediment contributed by mass wasting occurs in pulses and may be difficult to detect during surveys due to its transient presence in the system.

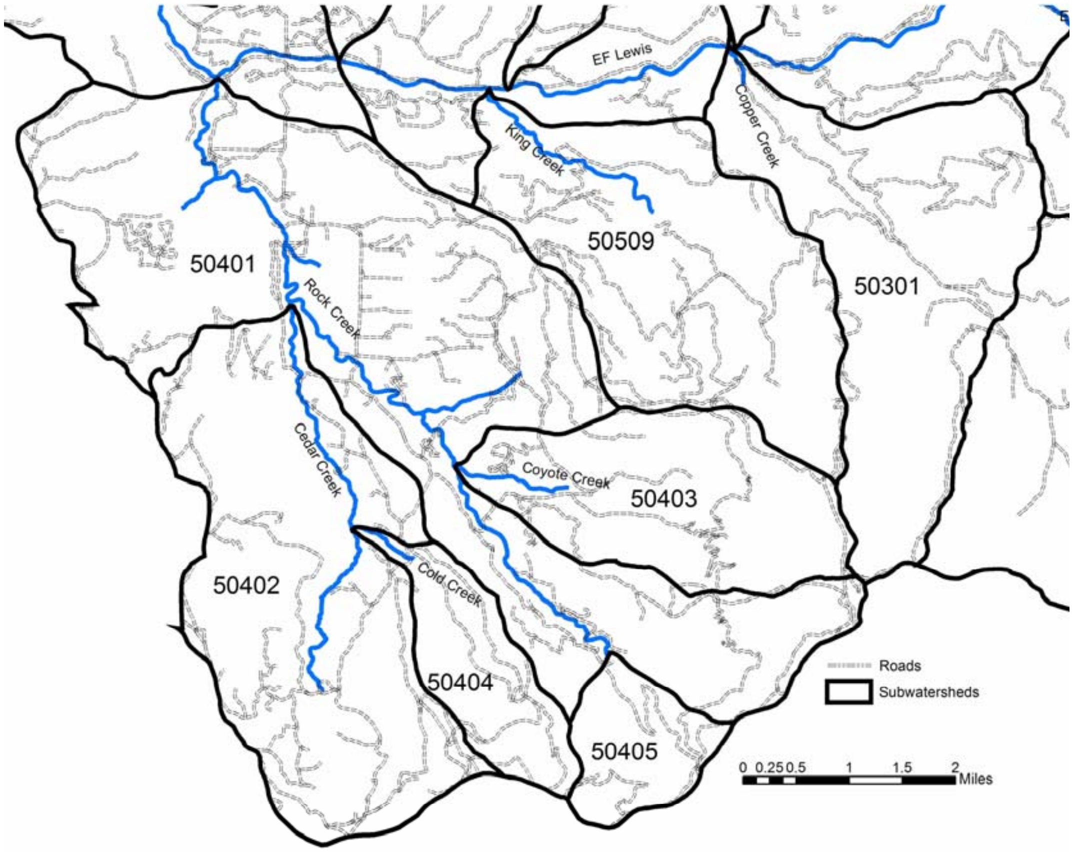

Figure 4. 24. Road network in the Rock Creek, King Creek, and Copper Creek Basins.

Comparison to existing assessments

Fine sediment quantities from field surveys compare moderately well with the EDT scores and the IWA ratings (Table 4. 28). The field survey values are less than the EDT inputs for all reaches surveyed (Rock 1, 3, 4, 5, & King Creek); the differences ranging from 6-9% (using the average of the pebble count and visual estimates). The fine sediment values recorded in the field are low, which is consistent with the IWA functional rating in 4 of the 7 subwatersheds. These measurements and ratings do not appear to reflect the potential influence of erosion sites identified during site visits and aerial photograph interpretation as discussed earlier. The field surveys, conducted during low water periods in the fall, may not accurately characterize fines delivered to stream channels during winter and spring runoff events, which may more directly impact steelhead spawning. Furthermore, many of the fines may be transported through the relatively steep Rock Creek reaches and on into the mainstem East Fork. This explanation may have particular relevance in King Creek, where low fine sediment measures (6.5% fines <2mm) may be related to the steep gradient (4.6%) of the surveyed portion of the reach, despite moderately impaired hillslope sediment delivery conditions.

A few of the IWA functional ratings appear to be borderline moderately impaired. These subwatersheds have road densities just shy of the 3.3 mi/mi^2 threshold used to create the ratings (IWA methods in LCFRB 2004). Apparent inconsistencies between EDT and

IWA are attributable to the borderline IWA ratings and the different attributes considered in the models. EDT fine sediment scores were based solely on road densities whereas the IWA ratings are based on road densities (unsurfaced), topographical slope, and geology. The IWA functional ratings are due to unsurfaced road densities less than 3.3 mi/mi^2, low erodable geology type (andesite), and moderate slopes. Cold Creek and King Creek rate as moderately impaired due to high unsurfaced road density (>3.3 mi/mi^2). Although Copper Creek has low road densities, it rates as moderately impaired due to steeper terrain.

Based on review of the available and somewhat contradictory information, sediment supply conditions are believed to be borderline between functional and moderately impaired for all of these subwatersheds, with in-channel fine sediment loads in the 4-14% range – slightly elevated from typical background levels of 6-11% (MBI 2003). EDT scores may be slightly high in these reaches, especially when considering that EDT defines fine sediment at a smaller size than could be accurately quantified during habitat surveys. Specifying substrate and sediment delivery conditions at a higher resolution would entail more detailed sediment size analyses (i.e. sieve samples) and a watershed scale sediment budget assessment.

Table 4. 28. Comparison of field surveyed fine sediment quantities, EDT fine sediment scores, and IWA sediment supply condition ratings for the Rock Creek, King Creek, and Copper Creek Basins.

Subwatershed	Fine sediment estimated from field surveys[1]	EDT fine sediment ratings ()=categorical score[2]	IWA sediment supply rating (watershed level)
Rock Creek (50401)	4.3%	12.5% (1.7)	Functional
Rock Creek HW (50405)	--	12.5% (1.7)	Functional
Cedar Creek (50402)	--	12.5% (1.7)	Functional
Cold Creek (50404)	--	13% (1.8)	Moderately Impaired
Coyote Creek (50403)	--	12.5% (1.7)	Functional
King Creek (50509)	6.5%	13% (1.8)	Moderately Impaired
Copper Creek (50301)	--	11.5% (1.6)	Moderately Impaired

[1]determined by averaging percent sand (<2mm) from pebble counts and visual observations in all surveyed reaches within subwatershed.

[2]fines for EDT ratings defined as <0.85mm. Fine sediment ratings for EDT were obtained through applying a relationship between road densities and fine sediment developed in the Wind River Basin.

Project opportunities

Both preservation and restoration opportunities exist in the Rock Creek, King Creek, and Copper Creek Basins. The upper subwatershed areas of Cold Creek, Coyote Creek, and Copper Creek have the most intact forest conditions and would be good targets for preservation. Restoration efforts should focus on areas of current mass wasting and surface erosion, including road failures and clear-cut areas noted during site visits. Road maintenance and decommissioning could also yield important benefits, especially in areas where roads traverse steep and unvegetated slopes or are adjacent to watercourses. Improving road drainage and disconnecting road ditches from stream channels may reduce stream sediment delivery in some locations. Additional discussion of hillslope restoration opportunities in these basins can be found in Section 4.3.5.2

Upper North-Side Tributaries

The upper north-side tributaries include the tributaries entering the mainstem from the north between LW Rock Creek and the USFS boundary. From west to east, these streams include Yacolt Creek (tributary to Big Tree Creek) (50505), Big Tree Creek (50504 & 50506), Rogers Creek (50507), Niccolls Creek (50508), and Anaconda Creek (50202). See Figure 4. 25 for subwatershed locations.

Sediment source and delivery conditions

Rogers Creek, Niccolls Creek, and Anaconda Creek are small and relatively steep source and transport streams that originate in private commercial timberlands (Figure 4. 19). The bedrock lithology underlying these basins is andesite, which typically has low erodability. However, steep slopes result in a moderate natural surface erosion potential in these basins (Figure 4. 18). Intensive harvest practices and high road densities (2.8 to 4 mi/mi^2) create the potential for fine sediment contribution to the mainstem East Fork. The Big Tree Creek Basin, which also contains andesite bedrock lithology, has less topographical relief than the smaller mainstem tributaries, yet it still rates as having moderate natural surface erosion potential (Figure 4. 18). This basin, which is located nearly entirely within private commercial timberlands, has received intensive timber harvest over the last decade; road densities and the frequency of road crossings over streams are very high (5.3 mi/mi^2 and 4 crossings/mile of stream, respectively). These conditions increase the potential for fine sediment delivery to stream channels.

Yacolt Creek originates northwest of Yacolt, WA and courses through a flat valley before entering Big Creek less than a mile from the mainstem East Fork. The valley is underlain by glacial drift (Figure 4. 16), which typically has high erodability. Natural surface erosion potential, however, is considered low based on soil types and topographical slope (Figure 4. 18). Erosion potential is likely to be increased over background conditions due to intensive residential, agricultural, and timber harvest land-uses throughout the basin.

There were no stream surveys on any of the upper north side tributaries. These basins received lower priority for sampling because of the very little amount of habitat that is accessible to anadromous fish. The substrate conditions in Rogers, Niccolls, and Anaconda Creeks are assumed to be similar to those in the surveyed portion of King Creek, which has similar topography, geology, and land-use. The Big Tree Creek Basin is expected to have moderate-to-high fine sediment loads as a result of intensive timber harvest and high forest road densities. Yacolt Creek is also expected to have a high percentage of fines. With respect to anadromous salmonids (*Oncorhynchus sp.*), the impact of fines originating in the Big Tree Creek and Yacolt Creek Basins is moderated because of the distance from anadromous fish bearing channels. The impact on resident fish, however, may be considerable.

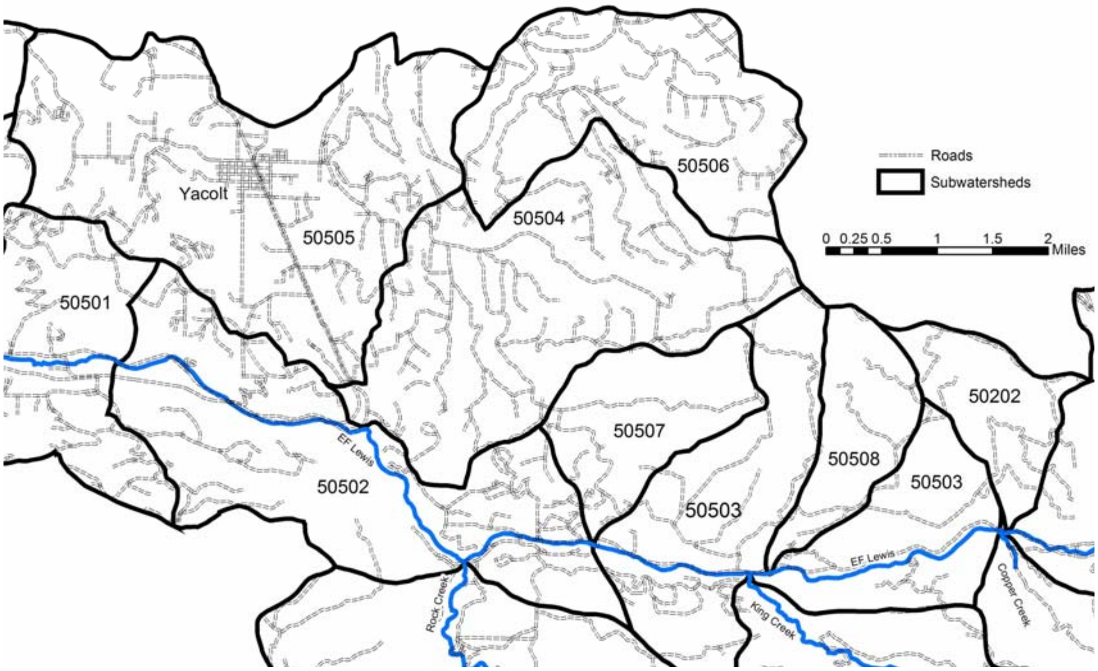

Figure 4. 25. Road network in the upper north-side tributaries basin.

Comparison to existing assessments

Reaches within the upper north side tributaries were not selected for field surveys of sediment conditions. These streams also were not used in the EDT model because of the lack of habitat accessible to anadromous fish. The IWA rated these subwatersheds as moderately impaired with respect to sediment supply, with the exception of Niccolls and Anaconda Creek subwatersheds (50508 & 50202), which were rated as functional. Judging from the available information, these ratings appear to be reasonable. The only exception is the lower portion of Niccolls Creek, where a recent clear-cut harvest on steep slopes has left a narrow riparian buffer (~50 feet). The increased risk of surface erosion in close proximity to the stream may warrant a moderately impaired sediment supply rating in this area.

Project opportunities

The greatest benefits can be gained by first protecting sediment supply conditions in Rogers Creek, Niccolls Creek, Anaconda Creek, and the other small mainstem tributaries between Big Tree Creek and the USFS boundary. These subwatersheds have received less intensive timber harvest than those of the Big Tree Creek and Yacolt Creek Basins. Efforts aimed at reducing fine sediment supply conditions in the upper north side tributaries will benefit resident fish more so than anadromous fish because of a lack of accessible habitat for anadromous species. Preservation and restoration opportunities are discussed further in Section 4.3.4

Lower East Fork Basin Tributaries

The lower river tributary basins include (from east to west) LW Rock Creek, Manley Creek, Mill Creek, Dean Creek, Mason Creek, Lockwood Creek, Brezee Creek, and McCormick Creek.

Sediment source and delivery conditions

The lower tributary basins are located on a rolling plain created by alluvial sediments dating from the late Miocene (> 5 million years ago). The oldest of these is the Troutdale Formation, which consists primarily of fine grained (lower member of formation) and medium grained (upper member of formation) material deposited in an ancient lake/estuary that covered much of the Lower Columbia area. Troutdale Formation sediments underlie most of the northern portion of the lower tributary basins (Figure 4. 16). The southern portion of the basin is underlain primarily by Missoula Flood deposits dating from the Pleistocene (period of ice ages dating back 1.65 million years). There are also other alluvial deposits originating from more localized Pleistocene flood events as well as glacial outwash and till dating from the last ice age. The lower East Fork River valley bottom, through which mainstem tributaries flow, is comprised entirely of alluvium deposited by the “modern” (Holocene) East Fork Lewis River. Sediment conditions in this area are unique and are therefore discussed in a separate section below (Section “Lower Mainstem East Fork Reaches”).

The topography is very flat south of the mainstem East Fork Lewis River, which lies on the broad, flat, alluvial fan created by Missoula Flood deposits. The stream profiles of McCormick, Mill, and Manley Creek are accordingly low gradient (Figure 4. 21). This far from the mouth of the Columbia Gorge, Missoula Flood deposits are composed primarily of sand (Mundorff 1964). The only pebble count conducted on the southern tributaries was on Mill Creek. The count was located in a relatively steep portion of the stream as it cuts through the valley wall of the mainstem East Fork. It therefore does not represent substrate conditions that would be found further upstream on the plateau. The upper portions (plateau) of Mill and McCormick Creek are dominated by fine and medium grained material (sand to gravel). The surveyed portion of Mill reflects moderate inputs of fine sediment from upstream, with 11% sand and 25% embeddedness.

The topography in the tributary basins north of the mainstem is somewhat steeper than the southern portion due to uplift (faulting) and more recent stream valley erosion (Figure 4. 17). The longitudinal profiles of Brezee, Lockwood, Mason, and LW Rock Creek are accordingly steeper than their southern counterparts (Figure 4. 21). Pebble counts in surveyed portions of these streams suggest low (Lockwood Creek) to moderate (LW Rock Creek) coarseness of substrate. Measurements and estimates of percentage fines (<2mm) ranged from 14 to 34% in Lockwood Creek and were 5% or less in the surveyed portion of LW Rock Creek (Table 4. 26).

Background (natural) risk of surface erosion in the lower tributary basins is considered moderate based on soil erodability and topography, with occasional areas of low and high potential (Figure 4. 18). The intensive land-uses in the area, however, significantly increase the risk of surface erosion potential. Because of productive soils and relatively flat topography, the lower basin has experienced intensive agricultural and residential development, as well as some timber harvest in the northern part of the basin. Hillslope surface erosion potential is increased by forest practices, tillage practices, livestock grazing, housing development construction, and land clearing. Mass wasting events on hillslopes are expected to be relatively infrequent due to flat topography; however, there is an increased risk of mass wasting of stream banks in the many areas where riparian vegetation has been removed. Although there is an extensive road network (Figure 4. 26), surface erosion from roads is not a concern because most of the roads are paved. Nevertheless, the increase in the drainage network because of road ditches and the frequency of ditches that empty directly into stream channels increases the efficiency with which hillslope derived fine sediment enters stream channels.

In general, the lower basin tributaries have the finest grain-size distributions in the basin (Figure 4. 20), with generally high percentage fines and high embeddedness ratings (Table 4. 26). Background (natural) erosion conditions combined with intensive land-uses creates a high risk of fine sediment impacts to fish-bearing stream channels.

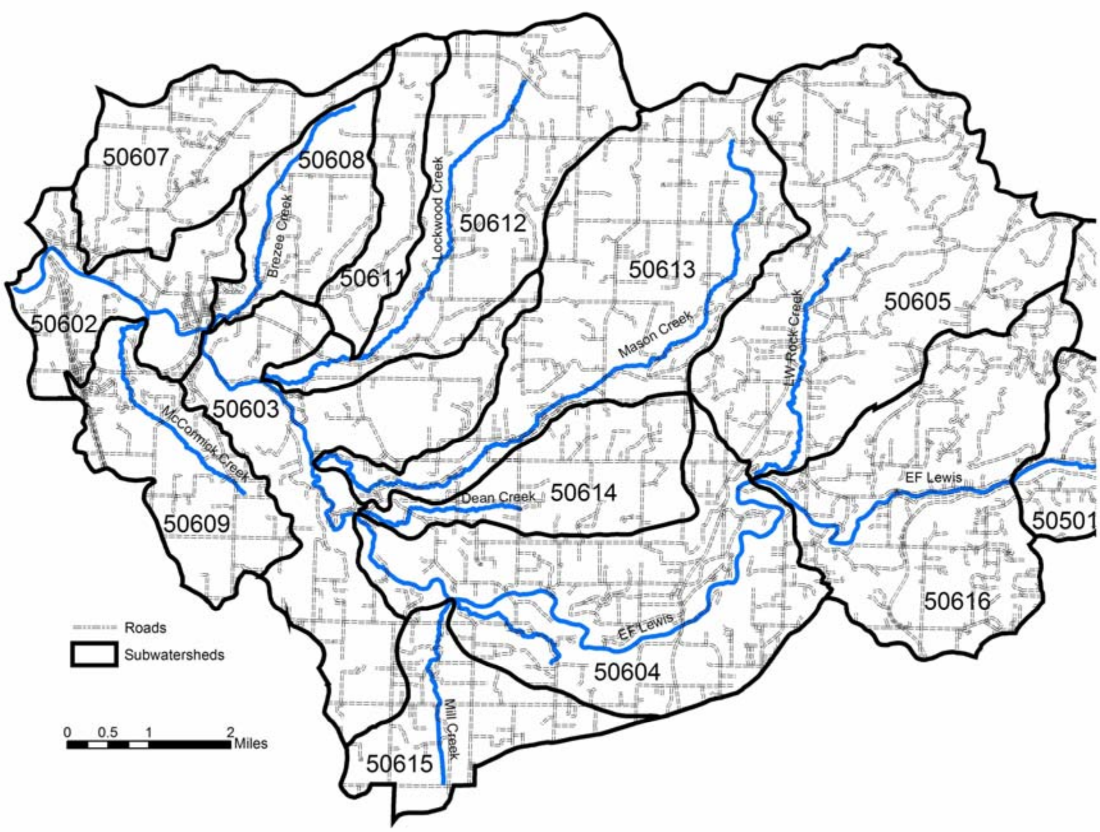

Figure 4. 26. Road network in the Lower East Fork Lewis Basin.

Comparison to existing assessments

The comparisons made between EDT scores and the sediment surveys is complicated by the large differences in sediment conditions in the portions of the streams within the East Fork valley bottom compared to the steeper upstream portions. For this reason, the accuracy of the EDT scores could be substantially improved by splitting the EDT reaches where they enter the valley floor of the East Fork. This is recommended for McCormick

Creek, Brezee Creek, Lockwood Creek, Mason Creek, and Dean Creek. These reaches were divided for the purposes of our assessments. An "A" tagged onto the reach name denotes the portion lying within the East Fork valley bottom.

The valley floor reaches are naturally high in fine sediment owing to their flat gradient. Upstream and adjacent land uses also likely contribute to fine sediment loading. Historically, these reaches likely changed course frequently, adjusting to the changing location of the mainstem East Fork and moving in response to their own sediment loads. McCormick, Brezee, and Lockwood Creek, which are within tidal influence, were likely slough-like, with connected backwater habitats that supported productive juvenile salmonid rearing. These reaches are within the area described as a "low rich bottom subject to inundation" during the 1854 land surveys (for more information see Hydromodifications Section 4.2.1).

The percentage fines (<2mm) recorded in these valley bottom reaches range from 30-38% (Table 4. 29). Therefore, a more accurate EDT score of 4 (>30% fines) is recommended for the East Fork valley bottom segments of McCormick, Brezee, Lockwood, Mason, and Dean Creeks (assuming the EDT reaches are split). The majority of Manley Creek also lies within the valley floor of the East Fork. The majority of the anadromous portion of Manley Creek lies within the East Fork valley bottom and it is very low gradient with many beaver ponds and only occasional patches of spawning sized gravel. Visual surveys of sediment conditions suggest that the EDT scores may be low. Embeddedness within pool tail-outs was rated as 25-50%. Sand sized material makes up greater than 50% of the entire reach and less within riffles (~30%). An EDT score of 3.5 may better represent conditions in this reach.

As for other portions of these tributary streams, the EDT scores differ from the surveyed results in some cases. The Lockwood Creek values differ by less than 7% and therefore appear reasonable. LW Rock field surveys of fine sediment are lower than the EDT scores. This may be partially due to turbid water during the surveys, which made it difficult to measure substrate conditions in any habitat units other than riffles. Considering this limitation, the EDT scores in LW Rock Creek are probably reasonable.

Although Mill Creek surveys noted less fines than that estimated by EDT, the survey was conducted on a relatively steep section as the stream cuts through the valley wall of the mainstem East Fork Lewis. Upstream areas would have a greater percentage of fines.

Although the EDT scores appear reasonable for the non valley floor reaches, the use of road densities to determine these scores may not be appropriate. The relationship between road densities and fine sediment was established in the Wind River Basin where forest land-uses dominate. The lower East Fork tributaries have different land-uses and different topography. It is therefore unlikely that the relative differences in scores between these tributaries are accurate. Effective impervious area may be a better metric in that it would represent the degree of impact related to agricultural and residential development.

The IWA rated all of these subwatersheds as moderately impaired for sediment supply conditions. The intensity of land uses would suggest a greater risk of surface erosion, although the flat topography likely reduces the erosion risk and sediment transport efficiency. The moderately impaired ratings are therefore considered reasonable.

Table 4. 29. Comparison of field surveyed fine sediment quantities, EDT fine sediment scores, and IWA sediment supply condition ratings for the lower East Fork Basin.

Subwatershed	Fine sediment estimated from field surveys[1]	EDT fine sediment ratings ()=categorical score[2]	IWA sediment supply rating (watershed level)
Lockwood Creek A[3] (50612)	--	15.5% (2.1)	Moderately Impaired
Lockwood Creek B (50612)	22%	15.5% (2.1)	Moderately Impaired
Mason Creek A[3] & B (50613)	--	15.5% (2.1)	Moderately Impaired
Dean Creek A[3]	38%	15.5% (2.1)	Moderately Impaired
Dean Creek B (50614)	--	15.5% (2.1)	Moderately Impaired
LW Rock Creek (50605)	6%	15.5% (2.1)	Moderately Impaired
Brezee Creek A[3] & B (50608)	--	16% (2.2)	Moderately Impaired
McCormick Creek A[3]	38%	16% (2.2)	Moderately Impaired
McCormick Creek B (50609)	--	16% (2.2)	Moderately Impaired
Mill Creek (50615)	11%	18% (2.4)	Moderately Impaired
Manley Creek (50604)	30%	18% (2.4)	Moderately Impaired

[1]*determined by averaging percent sand (<2mm) from pebble counts and visual observations in all surveyed reaches within subwatershed.*

[2]*fines for EDT ratings defined as <0.85mm. Fine sediment ratings for EDT were obtained through applying a relationship between road densities and fine sediment developed in the Wind River Basin.*

[3]*an "A" denotes the portion of the stream lying within the valley bottom of the East Fork Lewis River.*

Project opportunities

Sediment conditions are expected to continue to degrade as the lower basin becomes more developed. This is an area of rapid growth owing to flat topography and the proximity to a major metropolitan area. Careful land-use planning and development standards will be necessary to prevent increased sedimentation of stream channels. There is potential for sediment supply restoration efforts including management of agricultural lands, re-forestation of open-space lands, re-configuration of road ditches and stream crossings, and riparian restoration aimed at increasing streambank stability. There may be some opportunity for placement of spawning gravels in select portions of lower mainstem tributaries. Gravel enhancements should focus on areas where the processes that deliver and maintain spawning gravels, such as dynamic channel movement, are unlikely to be restored. Gravel placement should occur in conjunction with structural enhancements such as large wood supplementation in order to reduce scour potential. These opportunities are also discussed in Section 4.3.2.2.

Middle Mainstem East Fork Reaches

This discussion focuses on sediment conditions in the middle mainstem East Fork Lewis (EF Lewis 9 – 17). Hillslope sediment supply conditions throughout the upper basin affect middle mainstem reaches; these conditions have largely been covered in the previous sections. In this section, field surveys in mainstem reaches are compared to the EDT and IWA scores.

Sediment source and delivery conditions

The middle mainstem reaches are primarily composed of confined, high velocity sediment transport reaches. The substrate is generally coarse. Pebble counts were not conducted in the surveyed portions of EF Lewis 11 and 15 because of high velocities and dangerous wading conditions, but observations indicated that substrate was similar in coarseness to the surveyed portion of EF Lewis 13, where a pebble count was performed. This pebble count showed an average D50 of 109mm and a D90 of bedrock. Spawning sized gravels (10-100mm) comprised less than 35% of the substrate. These were some of the coarsest stream reaches surveyed in the basin (Figure 4. 20). The surveyed reaches may not accurately represent substrate conditions in EF Lewis 9, 10, and the downstream portion of EF Lewis 11, which have lower gradients (<1%) than their upstream neighbors. Although the condition of substrate is primarily governed by natural channel morphologies, a lack of instream wood as a result of past fires, timber harvests, and stream clean-outs may be reducing the ability of the channel to store spawning substrate. The average percentage of fines in the surveyed reaches was less than 5%. The percentage of bedrock and boulder is high (>30%) and if one considers the percentage that fines make up of only the spawning sized substrate (minus boulders and bedrock), the percentage fines increases substantially. The presence of fines in spawning substrates is evidenced by embedded substrates (10-30%) in EF Lewis 15 (Table 4. 26). Furthermore, fine sediment is likely more of a problem in EF Lewis 9 – 11, where the gradient drops below 1%. These reaches

Comparison to existing assessments

Observed quantities of fine sediment in the middle mainstem are significantly lower on average than the EDT fine sediment scores for these reaches (Table 4. 30). The field surveys, however, may not be an adequate test of the EDT scores due to the small sample size and the limited location of the surveys. As discussed in the previous section, fines in spawning substrates are likely greater than suggested by the surveys and are probably more of a problem in the unsurveyed reaches of EF Lewis 9, 10, and 11 (downstream portion) because of lower gradient. Nevertheless, the road density and percent fines relationship used to derive the EDT scores may somewhat overestimate percentage fines in these channels because it does not consider channel morphology. This may be more of a concern in reaches 13 – 17, which have greater sediment transport capacity than reaches 9 – 11.

IWA sediment supply ratings correspond well with the EDT scores. The ratings reflect the influence of the upstream contributing basin, which is mostly composed of moderately impaired subwatersheds as discussed in previous sections.

Table 4. 30. Comparison of field surveyed fine sediment quantities, EDT fine sediment scores, and IWA sediment supply condition ratings for the middle mainstem EF Lewis River reaches.

Subwatershed	Fine sediment estimated from field surveys[1]	EDT fine sediment ratings ()=categorical score[2]	IWA sediment supply rating (watershed level)
EF Lewis 9 & 10 (50616)	--	15.5% (2.1)	Moderately Impaired
EF Lewis 11 – 16 (50606, 50503, 50502, 50501)	<5%	13.5% (1.9)	Moderately Impaired
EF Lewis 17 (50201)	--	12.5% (1.7)	Moderately Impaired

[1]*determined by averaging percent sand (<2mm) from pebble counts and visual observations in all surveyed reaches within subwatershed.*

[2]*fines for EDT ratings defined as <0.85mm. Fine sediment ratings for EDT were obtained through applying a relationship between road densities and fine sediment developed in the Wind River Basin.*

Project opportunities

Restoration of sediment conditions in the middle mainstem reaches will come from improvements to the entire upper basin, including the Rock Creek Basin, the headwaters (USFS portion), and the upper north side tributaries. Potential restoration and preservation measures in these areas are discussed in their respective sections and in the project opportunities section (Section 4.3). The 'local' subwatersheds that contain the middle mainstem reaches also have restoration potential. These subwatersheds are primarily impacted by forest practices on private and state lands. The most downstream subwatershed (50616) is also heavily impacted by agriculture and residential development. Road densities range from high (4 mi/mi^2) to very high (5.9 mi/mi^2). As with many areas in the upper basin, the primary restoration opportunities are associated with reducing or improving the forest road network. These reaches do not represent good areas for spawning gravel enhancement. Although spawning gravel quantities are low, the high sediment transport capacity of these channels and the low wood quantities increase the risk of scouring placed gravels out of the stream channels.

Lower Mainstem East Fork Reaches

This discussion focuses on sediment conditions in the lower mainstem East Fork Lewis (EF Lewis 1 – 8). Hillslope sediment supply conditions throughout the basin affect lower mainstem reaches; these conditions have largely been covered in previous sections. In this section, field surveys in mainstem reaches are compared to the EDT and IWA scores. This also discusses channel-derived sediment sources in the lower mainstem alluvial valley, which is a significant source of sediments to the lower river.

Sediment source and delivery conditions

The lower mainstem begins to flatten considerably below the confluence with LW Rock Creek. Gradients from here to the mouth are less than 0.5%. At Mason Creek, the river enters tidal influence and the gradient is virtually zero (Figure 4. 21). The lower river from just downstream of LW Rock Creek to the mouth lies within a broad alluvial valley bottom created from erosion of the river into the layered alluvial sediments of the Troutdale Formation, Pleistocene glacial till, and Missoula Flood deposits (Figure 4. 16). In the last several thousand years, fluvial alluvium worked by the river has been deposited in the valley bottom, creating wide, low elevation floodplain terraces that continue to be eroded and re-created through fluvial processes. The vast majority of the valley bottom is subject to inundation during the largest of floods.

Sediment and substrate conditions in the lower river are affected by: 1) upstream contributing reaches, 2) lower river tributary inputs, and 3) erosion of valley bottom alluvium by the river itself. The first two sources are covered in previous sections. The third source is covered in the following discussion.

Erosion processes in the lower river can be classified into two categories: 1) stream channel avulsions, and 2) stream bank erosion. Both of these serve to recruit sediment into the stream channel. Channel avulsions occur rapidly during high flow events when a side-channel or overflow channel experiences an upstream migrating headcut that 'captures' the main flow of the river once it reaches the mainstem. This results in channel re-alignment and massive re-working of alluvium. Avulsions are a natural process and may be an important component in floodplain and fish habitat creation. Nevertheless, avulsions are often viewed by landowners and river managers as undesirable because of their difficulty to predict, their contribution of sediment to channels, and their potential for damage and loss of property. Avulsions may also be caused by hydromodifications; as is the case with avulsions into gravel pits at river miles 8 and 9 on the East Fork Lewis. The 1996 avulsion into the Ridgefield Pits has reduced overall habitat quality in the reach and has served to artificially lock the river in its current location until the pits fill with alluvium, which will take decades. Restoration efforts in the lower East Fork should focus on eliminating hydromodifications that may artificially increase avulsion potential. Restoration efforts should also work towards eliminating hydromodifications that may be limiting natural avulsion processes. Restoration opportunities related to hydromodifications are covered in the Hydromodifications Section (Section 4.2.1) and the project opportunities section (Section 4.3.1).

The second type of erosion is streambank erosion. As with avulsions, streambank erosion also results in channel re-alignment, yet this process occurs over time through gradual lateral migration of river meanders. There are two general types of eroding streambanks that occur downstream of Lewisville Park. The first of these consists of the low floodplain terraces formed by recent (Holocene) alluvial materials deposited by the East Fork Lewis River. Gradual erosion of these terraces during the process of meander migration is a natural process that has resulted in the shifting channel location that is seen in the historical record. In a few places these terraces are eroding quicker than under pristine conditions due to a lack of vegetated streambanks (Figure 4. 27) and channel modifications that direct or concentrate flows. These sites offer some potential for lessening the degree of erosion through erosion control and re-planting efforts.

The other type of eroding streambanks consist of high banks (20 to 100 feet tall) where the river is adjacent to the valley wall. These banks consist of the high alluvial terraces composed of older geologic material including glacial drift, Missoula Flood deposits, and the fine-grained material of the Troutdale Formation. The highest banks are on the north side of the river upstream of Daybreak Park and on the south side of the river between Daybreak Bridge and the Ridgefield Pits. The high banks upstream of Daybreak Park consist primarily of the lower Troutdale Formation (Figure 4. 28). The high banks further downstream consist of the Troutdale Formation overlain by glacial drift and Pleistocene alluvium (Figure 4. 29 and Figure 4. 30). Active slumping and surface erosion is occurring on most of these high banks though migration of the river into these high terraces occurs much more slowly than into the low fluvial terraces described previously. Nevertheless, houses located at the top of these banks may be at risk of being undermined in coming decades. Rock filled wire basked gabions have been placed under the high bank at river mile 8.7 in attempt to slow the rate of erosion, but these measures appear to be failing as the gabions are undermined by the river. Erosion of these high banks is largely a natural process that has served to broaden the lower river valley bottom over the centuries. The only measures that would effectively prevent continued erosion at these areas include either river re-alignment or large bank armoring and/or deflection structures. These measures are expensive, contain substantial risk, and are not recommended for these areas. Removal of existing hydromodifications may reduce erosion of high banks in a couple of locations.

Figure 4. 27. Erosion of alluvial terrace at downstream end of Reach 8A (RM 9.7). This property has been acquired by the Columbia Land Trust and offers good restoration potential.

Figure 4. 28. Erosion of fine sediment on the high valley wall at river mile 10.6 - upstream of Daybreak Park on the north bank of the East Fork Lewis River.

Figure 4. 29. High bank just downstream of Mill Creek confluence on East Fork Lewis River. Fine grained materials of the Lower Troutdale formation are overlain with glacial sediments and Pleistocene alluvial deposits.

Figure 4. 30. Close-up of the right side of photo in Figure 4. 29, depicting the fine grained material of the Lower Troutdale Formation overlain by alluvium.

Comparison to existing assessments

Field surveys indicate that fine sediment quantities are greater in EF Lewis 3-4 than the EDT scores represent. There are very few coarse substrates in these reaches and the EDT scores should be edited to reflect higher sediment quantities in reaches 3 and 4. In East Fork reaches 5, 6B, 8A, and 8B, surveyed fine sediment was less than EDT suggests. In EF Lewis 6A (avulsed reach) survey scores were much greater than EDT scores. This is as result of the dominance of fine sediments in the gravel pits through which the stream now flows. EDT scores should be updated to reflect the survey ratings.

Table 4. 31. Comparison of field surveyed fine sediment quantities, EDT fine sediment scores, and IWA sediment supply condition ratings for the lower mainstem EF Lewis River reaches.

Subwatershed	Fine sediment estimated from field surveys[1]	EDT fine sediment ratings ()=categorical score[2]	IWA sediment supply rating (watershed level)
EF Lewis 1 & 2	>60%	>30% (4)	Moderately Impaired
EF Lewis 3	>60%	24% (3)	Moderately Impaired
EF Lewis 4	>60%	18% (2.4)	Moderately Impaired
EF Lewis 5	8%	18% (2.4)	Moderately Impaired
EF Lewis 6_A	75%	18% (2.4)	Moderately Impaired
EF Lewis 6_B, 8_A, 8_B	6%	18% (2.4)	Moderately Impaired

[1]determined by averaging percent sand (<2mm) from pebble counts and visual observations in all surveyed reaches within subwatershed.

[2]fines for EDT ratings defined as <0.85mm. Fine sediment ratings for EDT were obtained through applying a relationship between road densities and fine sediment developed in the Wind River Basin.

Project Opportunities

Project opportunities for controlling sediment in the lower mainstem are discussed in detail in the project opportunities section (Section 4.3.1).

4.3 Broad-Scale Preservation and Restoration Opportunities

Broad-scale preservation and restoration opportunities throughout the basin were developed based on the results of the technical assessment, which included assessments of stream habitat, hydromodifications, riparian conditions, and sediment sources. Broad-scale opportunities are discussed below by basin area. These opportunities by no means encompass all of the potential recovery opportunities in the basin, such as those related to nutrients, passage barriers, and water withdrawals, which were not addressed in the technical assessment. This effort has focused chiefly on conditions in the non-federal portion of the basin, so few recommendations are made for the upper portion of the watershed within the Gifford Pinchot National Forest. It should also be noted that the opportunities presented are intended to provide a relatively broad view of the types of activities that could address habitat impairments. In some areas, detail is provided as to the location and type of activities that could be implemented, but in most cases, significant additional assessment will be necessary to determine specific project locations and design. Where more site-specific information was available (i.e. from surveys), finer scale project opportunities were developed. The fine-scale opportunities are presented in Section 4.4.

4.3.1 Lower Mainstem East Fork Lewis

Reaches EF Lewis 1-8 (surveyed reaches include EF Lewis 1-8).

4.3.1.1 Preservation Opportunities

Continue to protect lands within the lower mainstem valley bottom through regulations, land acquisition or conservation easements in order to preserve channel migration zones, floodplains, and off-channel habitat

A considerable amount of the lower East Fork Lewis valley bottom is already within public or land trust ownership. Clark County, which has been obtaining lands for the establishment of a greenbelt along the river, owns approximately 31% of the lower river valley bottom. These land holdings present a great opportunity for restoration of geomorphic processes and native vegetation. Acquiring remaining key parcels would provide the County the ability of restoring channel migration processes throughout much of the lower river. There are limits and challenges to land acquisition efforts due to existing infrastructure already in place, potential resistance from landowners, and potentially high cost. The few priority areas that are listed here are mentioned because of their significance to riverine geomorphic processes and the current lack of prohibitive existing infrastructure determined from site visits and aerial photograph interpretation. The investigators have no knowledge of previous discourse with landowners or of any pertinent economic or social constraints to land acquisition in these areas. Furthermore, the investigators acknowledge that the existence of conservation easements on privately held lands may already be providing adequate protections in some areas. Where they do not currently exist, conservation easements, as opposed to outright acquisition, may be a viable option for protection of ecologically significant lands. There may also be cases where existing regulations provide enough protections to not warrant any further protective measures.

Key parcels in the tidally-influenced area include the area north of the river around river mile 4 and the southern portion of the large wetland complex south of the river just southwest of the La Center Bridge. These parcels may already receive substantial protection because of natural conditions (i.e. frequency of inundation) and regulatory protections.

Acquisition of privately owned parcels located between Mason Creek and Dean Creek could provide great opportunities for restoration of the floodplain and channel migration zone in the lower river. Acquisition in the area north of the Dean Creek confluence may provide an opportunity to restore the connected floodplain slough habitat that is visible on the 1939 aerial photographs. Private parcels to the north of the river have been used for agriculture and a grass airstrip, but there has been no substantial development. Private parcels to the south currently have no active land-uses. This reach has retained its dynamic character in some locations, creating new side and off-channel habitats as it has shifted course over the years. Armored banks currently limit channel migration and protect property along the airstrip and at several locations along the south bank. Land acquisition may provide the opportunity to remove existing bank armoring and allow the river to resume its dynamic character throughout the entire reach. The fate of a recently created salmon spawning channel in this reach would need to be taken into consideration if channel migration processes were to be restored. The FEMA regulatory floodway covers much of this area and existing regulations may therefore already be providing substantial protection.

Between Dean Creek and Mill Creek (RM 7.3 – 9.3), there are many private parcels, many of them owned by gravel mining companies, that will be important for the rehabilitation of this degraded reach. Most of the land acquisition potential is located north of the river in an area proposed for future gravel mining. Proposed mining and rehabilitation efforts are covered in detail in the Storedahl Daybreak Mine HCP (Sweet et al. 2003). The HCP states that once mining and rehabilitation efforts are completed, Storedahl will grant the property to a conservation organization or a government entity for preservation of fish and wildlife habitat into perpetuity.

The rapidly eroding south bank terrace upstream of Daybreak Park at river mile 10.9 is another key area for land acquisition. Acquisition here would facilitate restoration of this unforested and rapidly eroding terrace. The south bank between river mile 11.5 and 12.4 is located in a low floodplain area subject to channel migration. Land acquisition would ensure that the channel migration zone is protected. Acquisition would also facilitate potential restoration of off-channel habitat incorporating the many floodplain sloughs located in the area. The north bank around river mile 12, where the county currently owns a narrow stream buffer, also presents good acquisition potential within the channel migration zone.

4.3.1.2 Restoration Opportunities

Remove hydromodifications along the lower mainstem East Fork Lewis

The hydromodifications with the greatest impact on aquatic habitat in the lower river consist of levees and armored banks. Restoration of these features can range from incorporating vegetation to removing them completely. The feasibility of removing hydromodifications will depend largely on cost and the potential risk to private property resulting from their removal. In cases where levees or armored banks are protecting private property from bank erosion or flooding, there may be some potential for setting back the structures to provide the river as much of its floodplain and channel migration zone as possible. In several areas, the lack of substantial development and County ownership may provide opportunities for removing or setting back hydromodifications. A few potential areas are listed below that are believed to offer good potential for restoration. The Potential projects are described from downstream to upstream. The specific location of the hydromodifications are displayed on maps included in the hydromodifications assessment section 4.2.1.1.

The major hydromodifications in the tidally influenced reaches are riprap near the McCormick Creek confluence, the fill on the southern approach to the La Center Bridge (RM 3.2), the La Center Levee (RM 3.2 – 4.4), and the levee spanning the floodplain south of the river at river mile 5.1. Except for the upstream end of the La Center Levee, Clark County owns the land surrounding these hydromodifications. Any extent to which these features could be removed or set-back would improve the potential for restoration of connected off-channel wetland habitat and would improve floodplain connectivity. Selective breaching of the La Center Levee could increase floodplain connectivity and could be used to facilitate the creation of off-channel habitat.

As mentioned previously, the removal of armored banks (riprap) between Mason Creek and Dean Creek could improve channel migration processes in this reach. Two of the armored banks are located on County land on the south bank between river mile 6.5 and 7 (see Figure 4. 31). These should be considered a high priority for removal. Removal of the riprap bank protecting the grass airstrip would have to be conducted in a cooperative effort with landowners.

The 1996 channel avulsion into the Ridgefield Pits has essentially locked the channel in its current location until the pits fill with sediment. The high walls of the pits are now serving as levees although they are comprised of native material. There may exist viable strategies for speeding recovery of the pits, including caving in the side walls and/or filling the pits with alluvium from the adjacent floodplain. These measures may create other habitat quality concerns (e.g. high temperatures) and may be prohibitively expensive, but they warrant further investigation. It is recognized that there has already been some of this type of work conducted in the area by J.L. Storedahl & Sons and Pacific Rock Environmental Enhancement Group. These efforts involved sloping back the steep banks in the pits, spreading stockpiled soil, scarifying compacted soils, and planting native vegetation (Randy Sweet personal communication, January 2005).

Between the instream pits and Daybreak Bridge there are several old levees located in the floodplain north of the river. These levees are located on County land and in some instances, may be serving to protect property including the County maintenance yard, roadways, and mining facilities at the Daybreak mining site. Field observations suggest that some of these features may have outlived their usefulness yet they continue to limit channel dynamics and floodplain connectivity. A levee on the north bank just upstream of the Mill Creek confluence is acting as a jetty extending into the main channel and may be focusing the flow against the eroding south bank. These structures should be considered a high priority for removal or set-back.

The Daybreak Bridge and associated south-side fill keep the stream channel against the north valley wall. Removal of the fill and extension of the bridge would restore some of the lost channel migration zone. These measures, however, would be very expensive and would jeopardize the Daybreak County Park property. Nevertheless, these measures should be kept in mind for long-term restoration potential.

A small levee on County land on the south bank at river mile 10.8 may be limiting channel migration processes to some degree. This would be an easy levee removal effort. The rip-rapped south bank of the river at river mile 11.5 protects private residential property by halting natural channel migration. Removal of this bank protection would potentially jeopardize several private residences. The most feasible restoration opportunity is to incorporate vegetation and cover components into the riprap bank. Upstream at Lewisville Park there are also several riprap banks that could benefit from the incorporation of vegetation and cover components. The riprap banks along the park may also present opportunities for removing or setting back (burying) bank armoring in order to restore portions of the channel migration zone. These efforts should be explored further.

Figure 4. 31. Rip-rap bank on south bank at RM 6.8.

Reduce severe bank instability at locations along lower mainstem

There are many streambanks along the lower river that are actively eroding fine sediments into stream channels. These are composed of two primary types of eroding banks as described in the sediment section for the lower mainstem (see Section 4.2.4.2). The high eroding banks where the stream is eroding the valley wall are not recommended sites for aggressive erosion control. In the majority of cases, this erosion appears to be a natural process and may be contributing coarse substrate in some areas. In some cases, erosion may be increased over natural conditions because of a lack of vegetated banks, stream incision, and flow obstructions. One potential flow obstruction that may be contributing to high bank erosion is the levee/jetty on the north bank just upstream from Mill Creek. The effect of this obstruction on erosion of the south bank just west of Mill Creek should be further evaluated. In general, control of valley wall erosion would be difficult to accomplish without undertaking extensive engineering measures such as stream channel re-location, bank armoring, or bench terracing of the high banks. Even though such measures have been recommended by previous studies (Dover Habitat Restoration 2003), such strategies should be regarded as a low priority because of their high cost and their potential to further limit channel migration and habitat-forming processes. These aggressive measures should only be employed to protect property where other options, including property acquisition, have been exhausted.

Streambank re-vegetation may help limit erosion of high banks in some cases but will probably not serve to substantially reduce erosion over the long-term. Armoring of the toe of the bank, as has been done with rock filled wire basket gabions along the south bank at river mile 8.7, may reduce bank cutting under most flow conditions, but is at risk of becoming undermined during large events and does little to provide bank complexity.

The other type of eroding banks consists of erosion of the low terraces composed of fluvial alluvium from the East Fork Lewis. This type of erosion is part of the natural process of progressive channel migration but may be exacerbated in some locations because of channel downcutting and lack of bank vegetation. Steep eroding banks of fine material are located throughout the tidally influenced reaches but these should be considered a low priority because of the lack of downstream spawning habitat. Eroding banks between Mason and Dean Creeks may contribute fines to gravels, although the downstream location of these banks also limit their impact to spawning habitat. These banks should be considered a moderate priority for restoration, with restoration of native riparian vegetation as the greatest emphasis. An eroding low terrace on the north bank at river mile 9 should be considered a low priority for restoration because the terrace is forested and the bank contains vegetative cover components. The eroding low terraces at river miles 9.5 and 10.9 should be the highest priority for erosion control (see Figure 4. 32). While these banks may contribute needed coarse substrate to channels, their lack of forest vegetation is accelerating erosion and reducing bank complexity and cover. Initial efforts should focus on reforestation of the terraces with conifers. Bank treatments, such as engineered meander bend log jams, could be installed to bring meander migration rates into more natural conditions and to increase bank complexity and cover.

Figure 4. 32. Rapidly eroding terraces at RM 10.9 (left) and RM 9.5 (right). These rapidly eroding banks present good restoration opportunities.

Create/restore side-channel & off-channel habitats in the lower mainstem East Fork

Restoration of off-channel habitat is a high priority in the lower mainstem East Fork. Off-channel and side-channel habitats provide critical refuge for juvenile coho salmon and often contain groundwater upwelling conditions conducive to chum spawning. Chum and coho salmon populations in the East Fork Lewis have been identified as having low current viability (LCFRB 2004). Rawding et al. (2001) recommend that short-term habitat restoration for chum and coho should focus on construction of off-channel spawning and rearing areas in the lower mainstem.

Side channel and back channel restoration potential varies by reach. Reach 2 and 3 contain the best potential for reconnecting off-channel wetland habitat. There is moderate potential in reach 5; however, this area may have good potential for passive restoration of the CMZ through removal of bank armoring. This passive approach would allow the river to maintain its own off-channel habitat; however, the influence of upstream gravel pit avulsions on channel dynamics needs to be evaluated. The upstream pits will act as sediment traps until the pits fill (Sweet et al. 2003), which may limit channel dynamics and the creation of off-channel and side channel complexes in reach 5. This impact may warrant the development of off-channel habitat in this reach. Potential back water habitat in reach 6_A consists of the downstream end of the abandoned channel from the Ridgefield Pit avulsion and one of the pits themselves. Re-connection of these areas is not recommended because of poor habitat quality and the abundance of backwater habitat already available in this reach. There is some good back channel restoration potential in reach 6_B; however, restoring channel migration processes through setting back levees may be the best approach in this reach. The greatest potential for restoring back channel habitat is in reach 8_A. Restoration of the CMZ is limited in this reach because of existing infrastructure including the Daybreak Bridge, Daybreak Park, and private residential property. Therefore, active restoration or creation of back channels may be appropriate. There are many potential locations for channels, particularly at the downstream end of the inside of meander bends, where relic channels have limited or potential connectivity with the main channel. These projects may only involve re-connection of habitat in some areas but in most areas would require excavation to create a reasonable amount of useable habitat. In areas where channel avulsions through these relic channels would pose a risk to private property, grade control structures could be placed within the channels to prevent headcutting. Potential off-channel restoration sites are depicted in Figure 4. 33.

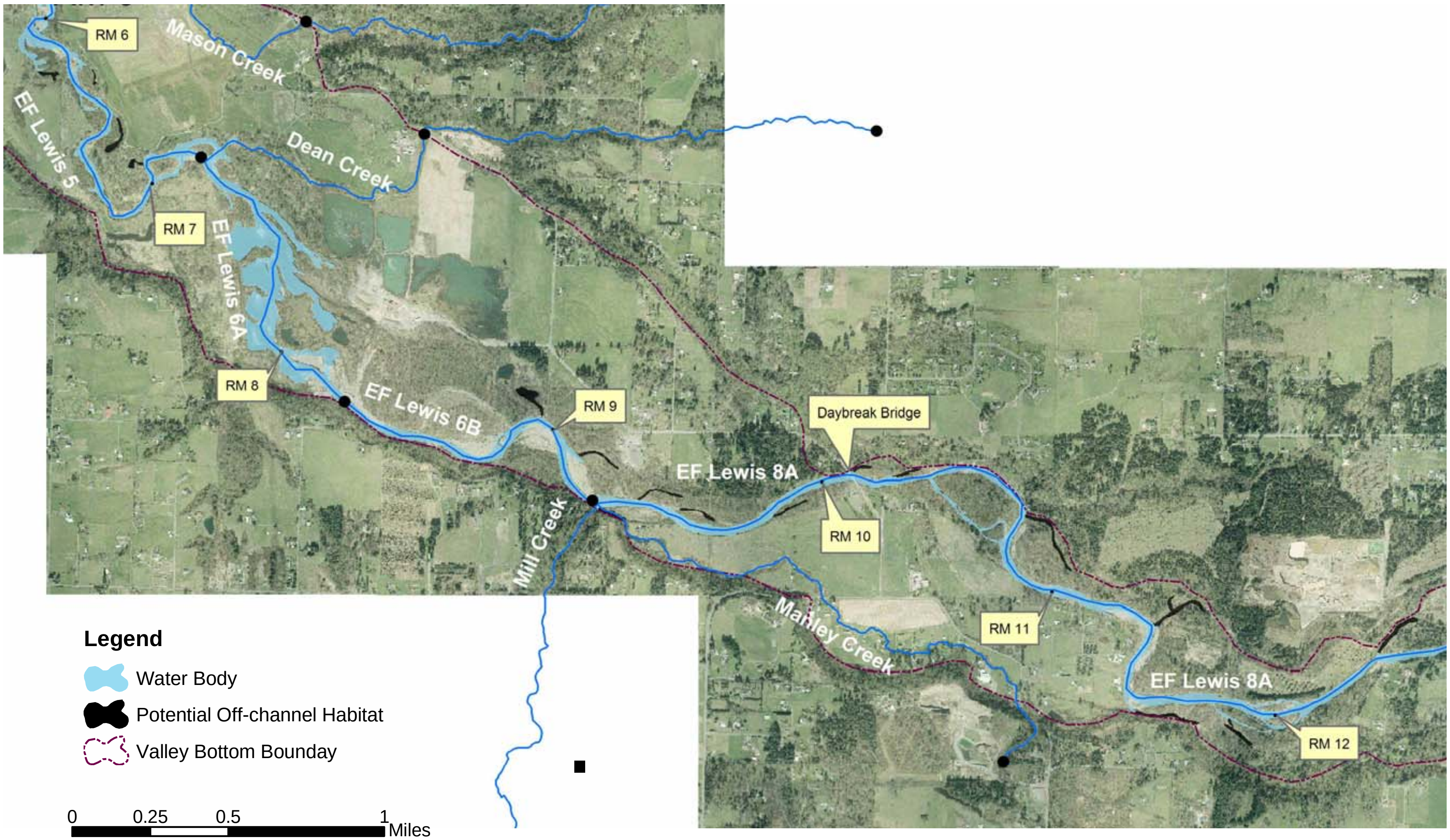

Figure 4. 33. Locations for potential restoration or creation of off-channel salmonid habitat within the lower mainstem East Fork Lewis River.

<u>Riparian forest restoration on lower mainstem East Fork Lewis Reaches</u>

Substantial benefit can be gained by restoring native riparian and floodplain vegetation along the lower mainstem East Fork. East Fork Lewis reaches 1-8A have low to no LWD recruitment potential (exception is reach 6B which has moderate potential). These same reaches have moderate to high temperature impacts from reduced shading.

In EF Lewis 1-6A, grass makes up 10-82% of the riparian vegetation. Reaches 3 and 4 are the worst, with 82% and 67% grass, respectively. Much of that is reed canary grass and other invasives. A major challenge in this effort will be reducing competition from invasive species, including reed canary grass, Himalayan blackberry, Japanese Knotweed, and Scotch Broom (*Cytisus scoparius*).

The tidally-influenced reaches and their associated valley bottom floodplains will present a major challenge for restoration of native vegetation. These areas were historically comprised of emergent wetland vegetation and hydrophilic hardwoods including Oregon ash (*Fraxinus latifolia*) and willow (*Salix spp*), which were commonly noted in the historical survey reports. Although some ash and willow persist in some areas, much of the groundcover is dominated by reed canary grass and will be difficult to eradicate. A few areas along the lower river could benefit from excluding livestock from streambanks. A few areas of streamside pasture are located on the north bank west of La Center between river mile 2 and 3.

There is greater opportunity for successful riparian reforestation upstream of the Mason Creek confluence. Between Mason and Dean Creeks, native hardwoods (willow, cottonwood, and alder) are common along the stream corridor though some streamside areas are devoid of riparian forest and the broader floodplain terrace is mostly non-forested. There appears to be re-vegetation efforts on County land in some areas along the south bank, but there remains restoration opportunities on the north bank and in floodplain areas further removed from the stream channel. Between Dean Creek and the upstream end of the instream gravel pits, there is little riparian or floodplain forest vegetation and the area is dominated by invasive species. During stream surveys of the Ridgefield Pit area, crews were observed spraying Japanese Knotweed. Numerous native riparian plantings were observed as well, although mortality appeared to be close to 50%. Efforts to eradicate invasive species and establish native vegetation should continue; however, success will be difficult to achieve without restoration of natural channel processes in this reach. Reach 6B, which extends from the instream pits to Mill Creek, is in relatively good shape with respect to riparian vegetation and no projects are recommended for this segment. The low eroding terraces on the south bank at river mile 9.5 and 10.9 should be considered high priorities for reforestation. Reforestation efforts at these sites will require consistent maintenance to ensure that invasive species do not overrun tree seedlings. Reforesting these terraces from the stream edge to far back from the channel will increase the chances that as the stream continues to migrate southward it is met with trees that will provide bank stability, shade, and instream LWD.

There are several locations where reforestation of streamside lawns could provide shade, bank stability, and future large wood recruitment benefits. These areas include the south bank from river mile 11 to 11.5, the south bank between mile 12.5 and 13, and the north bank just west of the Lewisville Bridge (RM 12.8). There is also reforestation potential on agricultural land on the north bank around river mile 12.3. Reforestation of these areas would require cooperation with willing landowners. The greatest riparian reforestation opportunity upstream of Lewisville Bridge is at a field on the south bank at river mile 13.3 and at several north bank locations within Lewisville Park.

Restore instream structure to the lower mainstem East Fork Lewis River

Structural enhancements, including primarily the placement of large wood jams, may provide needed habitat complexity in some areas in the lower mainstem. Large wood supplementation projects are best achieved in conjunction with other restoration efforts that have been discussed above, including streambank stabilization, off-channel habitat restoration, and restoration of armored banks.

Large structural restoration projects have been proposed in the lower mainstem East Fork by other investigators (Dover Habitat Restoration 2003). These include channel-spanning grade control structures (cross-vanes) and bank protection structures (J-hook-vanes) that are composed of large rocks and logs. These measures may be appropriate in some locations where protection of property is critical and other options are not possible. However, such approaches should be considered a last resort since they may actually serve to reduce channel- and habitat-forming processes. Large rock of the size needed to effectively provide grade control in the lower mainstem East Fork is far beyond the transport capacity of the stream, therefore creating a geomorphic control on the channel and preventing channel dynamics that are necessary for habitat formation. In general, these approaches should be considered a low priority and their effects should be carefully assessed before implementation.

In general, placement of spawning gravels should be avoided in the main channels in the lower mainstem reaches. Spawning gravels are already relatively abundant with sources coming from upstream and from local channel erosion. The frequent movement of the channel in many locations increases the risk of scour of placed gravels. Gravels should only be placed in areas where channel movement has already been halted through hydromodification and where it can be determined that the gravel placement location or structural elements at the site can protect the gravels from main channel velocities. Gravel placement may be beneficial where it is performed in conjunction with restoration of groundwater fed (hyporheic) back channels designed for salmon spawning. In reach 5, below the Ridgefield Pit avulsion, gravel recruitment from upstream may be eliminated until the instream pits fill. Restoration of channel migration processes through removal of bank armoring at several locations may increase sediment recruitment from streambanks although field surveys indicate that these banks may contain low quantities of coarse material. If further assessment determines that channel migration processes cannot be restored or that gravel quantities will remain critically low even with CMZ restoration (i.e. because of filling of upstream pits), then gravel supplementation could be considered.

4.3.2 Lower Mainstem Tributary Basins

McCormick Creek A & B; Brezee Creek A & B; Lockwood Creek A & B; Mason Creek A & B; Dean Creek A & B, LW Rock Creek (surveyed reaches include McCormick Creek A, Dean Creek A, Lockwood Creek B, and LW Rock Creek)

4.3.2.1 Protection Opportunities

Continue to acquire lands within the lower segments of mainstem tributaries

Land acquisition has provided for potential protection opportunities on some portions of these tributaries where they course through the broad valley bottom of the East Fork Lewis River. The acquired lands include lower McCormick Creek (McCormick Creek_A), lower Brezee Creek (Brezee Creek_A), and lower Manley Creek. These valley bottom segments are owned by Clark County (McCormick and Brezee) and Columbia Land Trust (Manley). The other tributary stream segments lying within the East Fork valley bottom could also benefit from protections offered by land acquisition. Acquiring the bulk of the entire valley bottom could present incredible opportunities for restoration of the historical East Fork Lewis River floodplain, channel migration zone, wetland habitats, and off-channel slough habitat that would support juvenile salmonid rearing. The potential benefits of such broad-scale restoration of the lower East Fork valley bottom places an emphasis on acquisition of additional valley bottom lands, and the focus should be on the lower segments of Lockwood, Mason, and Dean Creeks.

Protect tributary streams and watersheds from the impacts of additional development

Protection measures are also very important for the portions of lower mainstem tributaries lying upstream of the lower East Fork valley bottom that are experiencing rapid changes to land-use. These tributaries lie on a broad rolling terrace formed by Missoula Flood deposits. Erosion potential is mostly moderate based on soil types and topographical slope (see section 4.2.4.2). This area is very conducive to agricultural uses; farming and livestock grazing are widespread throughout. There is also increasing rural residential and suburban development as the Vancouver metropolitan area continues to expand northward. Land-use conversion from rural residential and agricultural uses to high density suburban uses is increasing in many areas, particularly in the southern portion of the basin and near the towns of La Center and Battle Ground. These streams are already significantly degraded in many areas as a result of agriculture, rural residential, and suburban development. Without adequate protections there will be increased impairments to channels, riparian areas, floodplains, and hillslope (upland) processes. The primary avenue for protection is through county growth management and critical areas protections. It is imperative that legal protections are adequate and that they are strictly enforced. Benefits could also be gained by requiring or at least actively encouraging the use of low impact development techniques. Protection of lands through land acquisitions or purchase of conservation easements may be necessary in sensitive areas not adequately protected by County regulations.

4.3.2.2 Restoration Opportunities

Lower East Fork tributary streams have been severely degraded in many areas due to residential, agricultural, and in a few places, timber harvest activities. In some places, restoration opportunities are limited due to the existing level of infrastructure already in place; once lands are developed for residential use they can be very difficult to restore. Most areas, however, present many restoration opportunities. These include passage barrier restoration, riparian forest restoration, reclamation of agriculture and open-space lands, conservation easements on agricultural lands, livestock exclusion, stormwater runoff control, removal of hydromodifications, and invasive species eradication. These opportunities are discussed below.

Riparian forest restoration on lower East Fork tributaries

The next greatest opportunity for restoration of tributary habitat is re-establishment of native riparian forests that have been removed through residential-related clearing (i.e. lawns), agriculture (crops), livestock grazing, and timber harvest. Aerial photo interpretation has indicated that LWD recruitment potential in Lockwood Creek A, McCormick Creek A, and Mill Creek is non-existent or low. Other reaches have moderate potential for LWD recruitment. Based on analysis of stream survey data from McCormick A, Lockwood B, and LW Rock Creek, changes in VTS angles are classified as high to moderate impact. In these three reaches, the 7-Day maximum stream temperatures are an estimated 3.6-5.2ºC higher than under pre-settlement conditions. Re-establishing riparian forest vegetation can help to moderate stream temperatures, provide for bank stability, and provide a source for future inputs of large woody debris. An important component of this is the eradication of invasive species, which chokes many tributary stream segments and often prevents the re-establishment of native vegetation (Figure 4. 34).

Figure 4. 34. Photo looking downstream in Dean Creek showing dominance of invasive vegetation including Reed Canary grass and Himalayan blackberry.

Clearing of native riparian vegetation for lawns and recreational areas has occurred throughout portions of McCormick, Brezee, Lockwood, Mason, Dean, Mill, Manley, and LW Rock Creek. Grasses in these reaches make up as much as 64% of the riparian vegetation. Restoration efforts should first occur along the portions of these stream reaches accessible to anadromous fish. Specific project opportunities will depend on the challenging task of finding willing landowners.

Riparian forests have also been degraded through agricultural practices such as crop production and livestock grazing. In some agricultural areas, riparian buffers are either very narrow or non-existent. Cattle have access to streams in many locations. Restoration opportunities include fencing livestock from riparian areas and establishing riparian buffers to be protected from crop production. Establishing landowner incentives through conservation easements may be necessary to accomplish riparian forest restoration on many agricultural lands. Areas where land is falling out of agricultural production may present opportunities for land acquisition and conversion of lands back to native forest vegetation.

Riparian forests have been degraded in some lower East Fork tributaries through timber harvest impacts. In general, timber harvest impacts are much greater in the upper watershed than in the lower tributaries, yet some instances of riparian harvest have occurred in recent years in the upper portions of Brezee, Mason, Lockwood, and LW Rock Creek. The new Forest Practices regulations are expected to offer protections of riparian forests on private timber lands. Areas that have already been harvested may benefit from replanting efforts. Riparian areas in the small headwater segments of tributary streams may receive less regulatory protections and could be good sites for potential land acquisition or purchase of conservation easements.

Removing hydromodifications in lower East Fork tributaries

Removing hydromodifications in lower East Fork tributaries may be warranted in many cases in order to improve habitat diversity and stream temperature conditions. Field visits and aerial photo analysis has revealed that in many locations, stream morphology has been impacted by channel re-alignment, diversions, small dikes and dams (ponding), and road crossings. Ponding has occurred for aesthetics, livestock watering, and irrigation. These small ponds may be increasing susceptibility to high temperatures, may be limiting fish access to habitats, and may contribute to the impact of non-native fish on native salmonids. Channel modifications including re-alignment and road crossings are likely limiting floodplain function and channel migration processes in many areas. The number of stream crossings per mile in the lower half of the basin range from 1.6 to 3.9, the highest being Mill and Mason Creeks. A detailed assessment of hydromodifications in tributary streams was beyond the scope of this assessment and warrants further investigation for specific impacts and restoration opportunities. Restoration should focus first on the Tier 2 reaches of McCormick Creek, Lockwood Creek, Mill Creek, and LW Rock Creek. Potential activities will rely heavily on finding willing landowners.

Restore instream structure to lower East Fork Tributary Basins

There are many opportunities for restoring instream structure in lower tributary basins. These efforts will primarily involve installation of large woody debris to increase channel complexity and cover. Wood quantities were low on surveyed portions of tributary streams. The riparian assessment identified that LWD recruitment potential was moderate. Wood installation efforts should focus on areas where pool habitat and cover are lacking. There may be some opportunity for placement of spawning gravels in select portions of lower mainstem tributaries. Gravel enhancements should focus on areas where the processes that deliver and maintain spawning gravels, such as dynamic channel movement, are unlikely to be restored. Gravel placement should occur in conjunction with structural enhancements such as large wood supplementation in order to reduce scour potential.

Hillslope restoration of lower East Fork Tributary streams

Hillslope conditions have been degraded throughout the tributary watersheds of the lower East Fork Lewis Basin. These conditions pose a risk to watershed process conditions including runoff processes, sediment delivery, and contaminant transport. The amount of effective impervious area, which is considered a contributor to runoff impairment, is very high throughout these watersheds and the amount of mature forest cover is low. Road densities are also high. Road densities range from 4.8 mi/mi^2 in the Dean Creek subwatershed to 7.7 mi/mi^2 in the lowest mainstem subwatershed. Subwatersheds with road densities greater than 3 mi/mi^2 are generally considered at risk to sediment and runoff impairment. High road densities serve to increase the drainage network, which routes runoff more quickly to stream channels and can therefore increase peak discharges. As a result of impervious surface, road, and vegetation conditions, the Integrated Watershed Assessment (IWA) (conducted as part of Recovery and Subbasin Planning) rated hydrologic conditions "impaired" throughout most of the lower half of the basin (LCFRB 2004). Increased overland runoff can also increase the risk of contaminant delivery to waterways. Runoff from roads, agricultural lands, and residences may contain chemicals used in fertilizers, pesticides, auto fuel, and other sources which can degrade water quality.

The extensive road network, immature or non-existent forest vegetation, soil erodability, and current land-uses have contributed to sediment supply impairment in the lower half of the basin. There currently is a high risk of fine sediment contribution to stream channels. The IWA rated sediment processes as "moderately impaired' throughout these subwatersheds (LCFRB 2004). Stream surveys and site visits measured high amounts of fine sediments (sand and smaller) in Lockwood, Dean, and Mill Creeks. Fine sediments in Dean and Lockwood make up 14-48% of the substrate as compared to most other surveyed reaches that range from 0-15% fine sediment. Gravel/cobble embeddedness was very high in Lockwood Creek, Dean Creek, and McCormick Creek. High fines in the lower (surveyed) sections of McCormick and Dean Creek are due, in part, to natural channel morphology (they are located in the East Fork valley bottom). Based on surveyed conditions in Lockwood and Mill Creek, which are similar in morphology and land-use to all of the other lower East Fork tributaries, it is expected that fine sediment and embeddedness conditions are impaired throughout all of the tributary reaches.

Restoration opportunities for runoff conditions include reducing the area covered by effective impervious surfaces, including paved areas, lawns, and fields. Road ditches could be configured to function as infiltration swales, instead of simply routing stormwater as overland runoff. Stormwater detention facilities may be necessary in areas of high density development. Sediment delivery conditions will benefit from improvement to runoff processes as discussed above. Sediment delivery processes can also be restored through best management practices for agricultural lands including such measures as conservation tillage and crop/grazing rotation. Areas falling out of agricultural production could be targeted for reforestation. Hillslope restoration activities in the lower basin will be difficult due to existing infrastructure and will rely on the cooperation of willing landowners.

Restoration of tributary streams within the East Fork valley bottom

The lower portions of McCormick, Brezee, Lockwood, Mason, Manley, and Dean Creeks that lie within the lower East Fork valley bottom have been impacted by channel re-alignment and confinement and in many areas are entrenched into the alluvial sediments of the East Fork Lewis floodplain. Severe entrenchment was noted in stream surveys of Dean and McCormick Creeks (Figure 4. 35). Past wetland draining, flood control, and clearing for agricultural land has likely been responsible for the entrenched, confined, and denuded condition of these stream segments. Restoration opportunities include removing confining elements such as levees and roads. Grade control to reduce entrenchment may be appropriate in places. Invasive species eradication will be necessary throughout but will be difficult to sustain without restoration of native vegetation and hydrologic processes such as floodplain function and channel migration. Dean Creek is the most impacted of these streams and could benefit greatly from restoration efforts. Lower Dean Creek has been re-aligned by local landowners and is severely entrenched and choked with invasive species. In places, the stream completely disappears under a mat of Himalayan blackberry and reed canary grass. The Storedahl Daybreak Mine Expansion HCP outlines proposed floodplain, riparian, and channel restoration measures on lower Dean Creek (Sweet et al. 2003). Restoration of tributary stream segments within the lower East Fork valley bottom is best conducted in concert with restoration of the entire lower East Fork valley bottom, where great opportunity exists due to existing and potential future land acquisitions.

Figure 4. 35. Photo of mouth of McCormick Creek illustrating severe entrenchment and predominance of reed canary grass. Entrenchment here is approximately 1.7m. Entrenchment drops to 1.0m at upper end of survey.

4.3.3 Middle Mainstem East Fork Lewis River

EF Lewis 9 through EF Lewis 17 (surveyed reaches include EF Reach 11, 13, and 15)

4.3.3.1 Preservation opportunities

Protect riparian corridors and stream channels along the middle mainstem

These reaches lie within a bedrock canyon with naturally limited floodplains and channel migration zones. The primary threats to habitat include riparian degradation from road and housing development that could result in reductions in riparian shade, large wood recruitment, and bank stability. The highway is adjacent to the river in many places and there are riverside homes scattered along these reaches where the topography allows. The presence of the highway allows easy access to these reaches and thus presents a risk of additional encroachment from residential development. Much of the private land along these reaches is small riverside parcels (.25 to 1 acre), many of which have yet to be developed. There currently is active new residential development along these reaches. Due the importance of these reaches for steelhead juvenile rearing, it is imperative that riparian zones are protected from development impacts. The landownership is mostly private lands with Clark County lands and State Lands dominating reach EF Lewis 13 and Clark County land dominating the south bank of reach EF Lewis 11. Adequate application and enforcement of County Critical Areas protections is the primary avenue for protection of privately owned parcels subject to new development. Acquisition of land or purchase of easements would ensure protection of riparian areas.

The most important reaches for protection include the privately owned Tier 1 reaches EF Lewis 9, 10, 12, 15, and 17. Reaches EF Lewis 9 and 10 are already substantially developed but will likely experience continued densification. These reaches are currently dominated by conifers and have moderate to high LWD recruitment potential. Reaches 12 (very short reach), 15 and 17 are less developed but will experience increasing development pressures into the future. Reach 17 is a good candidate for preservation due to good current habitat conditions and lack of substantial development. The Gifford Pinchot National Forest occupies the upstream 30% of this reach.

The next level of importance includes the privately owned Tier 2 reaches EF Lewis 11 and 16. EF Lewis 11 is protected along its south bank by Clark County ownership but will continue to be built upon along the north bank. EF Lewis 16 already has scattered residential development but will continue to be built upon judging from the presence of many small undeveloped parcels.

Reach EF Lewis 13 already receives substantial protection due to County and State lands. EF Lewis 14 is at risk of further development but is lower priority due to its Tier 4 ranking.

Protect hillslope processes in middle mainstem subwatersheds

These subwatersheds represent the transition from the lower basin, which is dominated by mixed uses (agriculture and residential development) to the upper basin, which is dominated by forest land uses. These subwatersheds are therefore likely to receive increasing pressures for land-use conversion as population and development in the lower basin expands eastward. Protection of existing forest land will be very important to sustain existing watershed process conditions.

4.3.3.2 Restoration Opportunities

Reaches EF Lewis 9 through 17 predominantly lie within a bedrock canyon. The primary anthropogenic impacts include residential development of riparian zones, stream adjacent roadways, bank armoring, and invasive species. Wood quantities are low throughout these reaches. LWD densities in surveyed reaches (11, 13, and 15) ranged from 1.0 to 4.3 pieces/km. Wood and spawning substrate was likely reduced by historical splash dam logging and stream clean-outs. LWD recruitment potential in these reaches was mostly rated as moderate, but these reaches may not retain LWD within the active channel because of high flow velocities. Wood quantities were likely naturally lower than "properly functioning condition" thresholds due to channel morphology. Riparian shading is reduced in many areas due to residential development and roads. View-to-sky (VTS) angles have increased moderately by an estimated 15-22% in East Fork Lewis reaches 11, 13, and 15 based upon modeling from stream inventory data. Reduced shade has resulted in an estimated 2.1-3.0 ºC increase in 7-day maximum stream temperatures. Restoration opportunities are discussed within general categories below.

<u>Riparian forest restoration along the middle mainstem East Fork Lewis</u>

There is opportunity for restoration of riparian forests along many of these reaches. These efforts should focus on re-establishing native conifers that will provide future shade and large woody debris. Conifers currently dominate 29-79% of the riparian vegetation in these reaches. Many of the restoration opportunities in the most downstream reaches are on private residential lands. In upstream reaches, restoration opportunities exist on residential parcels as well as on lands in timber harvest use. Reach EF Lewis 9 has opportunities for riparian forest restoration at private residences along the south bank, especially at the downstream end of the reach. EF Lewis 10 has restoration opportunities at private residences throughout the reach. EF Lewis 11 and 12 have intact riparian forests along most of the south bank, except for residential impacts at the downstream end of reach 11. The north bank is highly impacted by the highway that runs adjacent to the river. Riparian forests along EF Lewis 13 are impacted by logging and forest roads. Areas of bank instability noted in the stream surveys are likely related to nearby logging. Riparian forest restoration within a 300 foot riparian corridor would reduce the risk of erosion. EF Lewis 14 through 17 have road, residential, and timber harvest impacts, with restoration opportunities throughout. In general, restoration efforts should focus on the highest tier reaches first and should target areas where vegetation will most likely provide adequate shade and bank stability. Opportunities will ultimately depend on the level of cooperation with local landowners.

Restoration of road impacts and bank armoring along the middle mainstem East Fork Lewis

The objective of this restoration strategy is to reduce impacts related to stream-adjacent roads and bank armoring, which often occur together. Potential actions include road set-back (relocation) and/or incorporation of bio-engineering approaches into armored areas in order to establish vegetation and increase bank habitat complexity. Nearly all of these reaches (EF Lewis 9 – 17) are impacted by stream-adjacent roadways except for EF Lewis 13, where the road does not follow close to the stream. The most impacted reaches are EF Lewis 10 and 11, where the highway is directly adjacent to the stream along much of the north bank and bank armoring is common. In the surveyed portion of reach 11, the road corridor has disturbed 23% of the riparian zone along the north bank. Portions of reaches EF Lewis 14-17 are similarly impacted. Where practical, there should be a consideration of relocating the road out of the riparian corridor, which could be paired with the acquisition of lands between the river and the road. This may not be possible in many areas due to limitations of topography and residential development. The relatively flat topography in EF Lewis 10 may provide an opportunity for road re-location to further north of the river. The railroad corridor, which follows along much of the river (but is generally outside the riparian corridor) along EF Lewis 10-12 and which is owned by Clark County, could be considered for a new road location in some areas. In general, restoration efforts should focus on the highest tier reaches first but opportunities will ultimately depend on other factors including land ownership, road re-location options, and the level of armoring.

Invasive species eradication along the middle mainstem East Fork Lewis

Most of these reaches are dominated by native riparian vegetation, however, the presence of invasive species in disturbed areas is not uncommon. Whereas invasives may provide bank stability and shade in some instances, they may also limit the establishment of native riparian vegetation that may provide more substantial shade, bank stability, and large woody debris recruitment into the future. The most common invasives along these reaches are reed canary grass (*Phalaris arundinacea*), Japanese knotweed (*Polygonum cuspidatum*), and Himalayan blackberry (*Rubus discolor*). They occur most frequently in areas that have been disturbed by residential development, roadways/bank armoring, and logging. Stream surveys along reaches EF Lewis 11, 13, and 15 noted invasive species associated with these types of disturbances, especially where the road is adjacent to the river along the north bank of EF Lewis 11.

Restoration of hillslope processes in the middle mainstem subwatersheds

The subwatersheds that contain the middle mainstem reaches have hillslope restoration potential. These subwatersheds are primarily impacted by forest practices on private and state lands. The most downstream subwatershed (50616 – see sediment section 4.2228224.1.1228652 for map of subwatersheds with ID numbers) is also heavily impacted by agriculture and residential development. Road densities range from high (4 mi/mi^2 in 50503) to very high (5.9 mi/mi^2 in 50616). As with many areas in the upper basin, the primary restoration opportunities are associated with reducing or improving the forest road network.

4.3.4 Upper North Side Tributary Basins

Yacolt Creek, Big Tree Creek, Rogers Creek, Niccolls Creek, Anaconda Creek (no surveyed reaches).

4.3.4.1 Preservation Opportunities

Protect riparian corridors and stream channels in upper north side tributaries

Riparian corridors and stream channels in upper north side tributaries have received intensive management from various land-uses including residential development, agriculture, and timber harvest. Land-use conditions and topography are unique in the Yacolt Creek Basin when compared to other upper north side tributaries. The Yacolt Basin has relatively flat topography suitable for agriculture and residential development. These land-uses exert pressures on Yacolt Basin stream corridors, whereas forest practices dominate the other tributaries. These basins will receive less emphasis for stream corridor restoration activities because of the lack of anadromous fish access. Nevertheless, protecting stream corridors from further impairment will be necessary to protect resident fish habitat and potential effects of riparian conditions on downstream reaches (i.e. temperature and LWD). Adequate application and enforcement of County Critical Areas protections is the primary avenue for protection of privately owned parcels subject to new development, which is of most concern in the Yacolt Basin.

Protect hillslope processes in Rogers, Niccolls, and Anaconda Creek subwatersheds

These small upper north side tributary subwatersheds feed directly into mainstem East Fork reaches that are important for steelhead production. These small basins are located within private commercial timberlands but forest vegetation is relatively intact, especially in higher elevations. Protection of these forests, which lie within the rain-on-snow zone, is important in order to preserve existing sediment supply and runoff processes. Forest Practices Rules are expected to offer substantial protections but may not fully protect against the influence of clear-cut harvests on soil erosion and runoff.

4.3.4.2 Restoration Opportunities

Riparian forest restoration on upper north side tributaries

Riparian restoration in these tributaries will receive less attention because of the lack of anadromous species. Nevertheless, riparian restoration would yield important benefits for resident fish and wildlife species and could have some downstream benefits to anadromous fish with respect to temperature and large wood recruitment.

Restoration of hillslope processes in the upper north side tributary basins

Forest practices as well as agriculture and residential development have impacted hillslope processes in these basins. All of these basins, except for Yacolt Creek, are underlain by andesite deposits and have relatively steep slopes, making them moderately susceptible to erosion. The Yacolt Creek Valley is comprised of glacial drift, which is typically highly erodable, although the flat topographical slope moderates erosion potential. The greatest impact to watershed processes has occurred on private commercial timberland in the Big Tree Creek Basin. This area suffers from immature forest stands and high road densities (>5 mi/mi^2). The area does not contribute directly to anadromous fish bearing waters but likely has some sediment and peak flow effects on downstream anadromous reaches. This area could benefit greatly from road obliteration and limits to area of clear-cut harvests, especially in the rain-on-snow zone, which covers much of the area.

4.3.5 Rock Creek, King Creek, and Copper Creek Basins

(surveyed reaches include portions of Rock 1, 3, 4 and 5 and King Creek)

4.3.5.1 Protection Opportunities

Protect riparian corridors and stream channels in the Rock Creek, King Creek, and Copper Creek Basins

Land ownership along Rock Creek reaches 1-4 is about half state land and half private lands. Land ownership along the remaining reaches is mostly state land and therefore already receives significant protections from land-use conversions and intensive timber harvests. There are impacts related to scattered residential development primarily along Rock Creek reaches 2 and 4 although increased residential development along Rock Creek reaches 1-4 is expected to occur based on proximity to Dole Valley Road, current landownership, and parcel sizes, many of which are divided parcels ranging from 2 to 20 acres. For these reasons, and the Tier 1 rating of Rock Creek 1-4, these reaches represent the most important preservation opportunity. In areas that remain in timber harvest uses into the foreseeable future, riparian harvest limits required by Forest Practices Rules are expected to protect riparian function. On privately owned parcels subject to land use conversion and new development, protection of riparian function will depend on adequate application and enforcement of County Critical Areas protections. Acquisition of land or purchase of easements would ensure protection of riparian areas.

Stream corridors in King and Copper Creeks are largely in forest lands where Forest Practices Rules and State timber land management are expected to provide protection of riparian corridors. The portions of these streams lying within private lands are likely to experience pressure for conversion to residential uses in the future. Adequate application and enforcement of County Critical Areas protections is the primary avenue for protection of privately owned parcels subject to new development. Voluntary land acquisition or purchase of conservation easements would ensure protection of riparian areas.

Protect hillslope conditions in Cedar Creek and Rock Creek headwaters

The headwater subwatersheds of Cedar Creek and Rock Creek are mostly located within State timber lands. These areas have been heavily harvested in the past but there are areas of intact forests with relatively little impacts from the road network. The topography is steep and surface erosion potential is moderate based on slope and soils. Additional clear-cut timber harvest on steep slopes would increase the risk of surface erosion and mass wasting. The subwatersheds with the best conditions with respect to hydrology and sediment processes are the upper Cedar Creek subwatershed (50402) and the Coyote Creek subwatershed (50403) (LCFRB 2004). The Cold Creek subwatershed also has relatively intact forests with the exception of a recent clearcut harvest adjacent to Cold Creek itself. Forest Practices on State timber lands are managed through a Habitat Conservation Plan. The HCP requires protection of hillslope processes through road management and harvest requirements. The HCP is expected to offer protection to runoff and sediment supply processes.

4.3.5.2 Restoration Opportunities

Stream corridors in the Rock Creek, King Creek, and Copper Creek Basins are primarily impacted by timber harvest practices and stream-adjacent roadways, with minor impacts related to residential development along Rock Creek reaches 2 and 4. The restoration opportunities primarily include riparian forest restoration, large wood supplementation, and bank stabilization associated with stream-adjacent roadways. These categories of restoration opportunities are discussed below.

Riparian forest restoration in the Rock Creek, King Creek, and Copper Creek Basins

Stream surveys indicate that riparian forests along Rock Creek (and likely in tributary reaches as well) and King Creek are composed primarily of young conifers and hardwoods. These conditions are reflected in the low wood counts and low pool percentages. The riparian assessment indicated a potential risk of temperature impairment in Rock Creek 1. Past forest fires, including large burns in the early 1900s, have limited the existence of old-growth forest conditions. More recent timber harvests over the past few decades have served to further reduce the presence of mature conifers. Based on the riparian assessment, the potential for recruitment of LWD into Rock and King Creeks is moderate. Riparian forest restoration is expected to occur passively over time as a result of more restrictive riparian harvest limits implemented as part of the new Forest Practices Rules. Some riparian areas may benefit from conifer planting and possibly from hardwood-to-conifer conversion through patch cutting of riparian hardwoods and conifer planting. Aerial photo analysis confirms the abundance of hardwoods, with 3 of 5 Rock Creek reaches, as well as King Creek, all being hardwood dominated. Copper Creek riparian zones are 70% conifer, and 30% mixed hardwoods/conifers. Stream surveys and aerial photo interpretation indicated that in some areas clear-cut harvests have occurred to within 100 feet of the stream, leaving narrow buffers comprised mostly of young alders. Stream segments with this condition include the west bank of reach Rock Creek 4, the west bank of lower Cedar Creek, and upper Rock Creek 5. Such areas are good candidates for riparian forest replanting if they have not been planted already. These instances also emphasize the importance of adequate application and enforcement of Forest Practices Rules. A few areas impacted by rural residential development may offer opportunities for riparian forest restoration and invasive species eradication. The areas with the greatest impacts occur near the boundary of Rock Creek 1 and 2, along the upstream portion of Rock Creek 2, and in Rock Creek 4 just downstream of the Dole Valley Road crossing. A specific opportunity for riparian forest restoration on King Creek is an area of recent near-stream logging along the most downstream 200 meters of stream. These efforts would require cooperation with willing landowners.

Structural Enhancement in Rock Creek, King Creek, and Copper Creek Basins

Large wood quantities are low throughout the surveyed reaches of Rock Creek, especially in reaches one and three, and are expected to be similarly low throughout most of the Rock Creek Basin. Large wood quantities are also low (64 pieces/km) in the surveyed section of King Creek. Copper Creek was not surveyed but likely has similar levels of woody debris. Historical fires and past logging are likely the primary causes of the lack of large wood. Stream clean-outs, which occurred throughout the region in the 1970s, may also have removed accumulations of wood in stream channels. Large wood recruitment potential, while increasing, is currently moderate due to the predominance of young conifers and riparian hardwood species. Large wood supplementation may be appropriate in areas with low wood quantities, low riparian recruitment potential, and a lack of adequate pool habitat. Occasional functioning wood pieces, like one in King Creek shown in Figure 4. 36, provide evidence of the potential benefit of large wood for creating pool habitat, increasing cover, and storing sediments. Surveyed segments of Rock Creek reaches 4 and 5 have lower percent pool and lower primary pool frequency than Rock Creek 1 and 3 (Rock Creek 2 was not surveyed). The Tier 1 rating of Rock Creek 4 suggests that restoration of habitat complexity within this reach may provide the greatest benefit to fish populations, primarily steelhead.

These reaches do not represent good areas for adding spawning gravels. For one, conditions with respect to spawning gravel availability are relatively good already. Furthermore, the abundance of sediment transport channels and the low wood quantities increase the risk of scouring placed gravels out of the stream channels. The most effective method of increasing gravel availability in these streams would be to increase large wood accumulations that trap and sort spawning gravels.

Figure 4. 36. Photo of conifer felled by beavers creating a plunge pool and storing spawning size substrate above (King Creek).

Bank stabilization / road relocation in Rock Creek Basin reaches

Forest roads and the Dole Valley Road run adjacent to stream channels in several locations and impact bank stability and riparian vegetation. Stream surveys indicated riparian impacts from a logging road along the west bank of reach Rock Creek 3 and riparian impacts from Dole Valley Road along reach Rock Creek 4 and 5. There is a large slide that resulted from the failure of Dole Valley Road in reach Rock Creek 4 just upstream of the Dole Valley Road crossing (Figure 4. 37). This slide is actively eroding directly into Rock Creek. Restoration of bank stability at this location will likely require the relocation of the road further away from the stream bank. Another large landslide related to a road failure is located near the upstream end of Rock Creek 5 where the upper Dole Valley Road crosses a west bank tributary to Rock Creek. On reach Rock Creek 3, a forest road is impacting riparian shade conditions along the west bank. The road, which appears to be no longer in use, may offer a good opportunity for road obliteration and re-establishment of vegetation at the site.

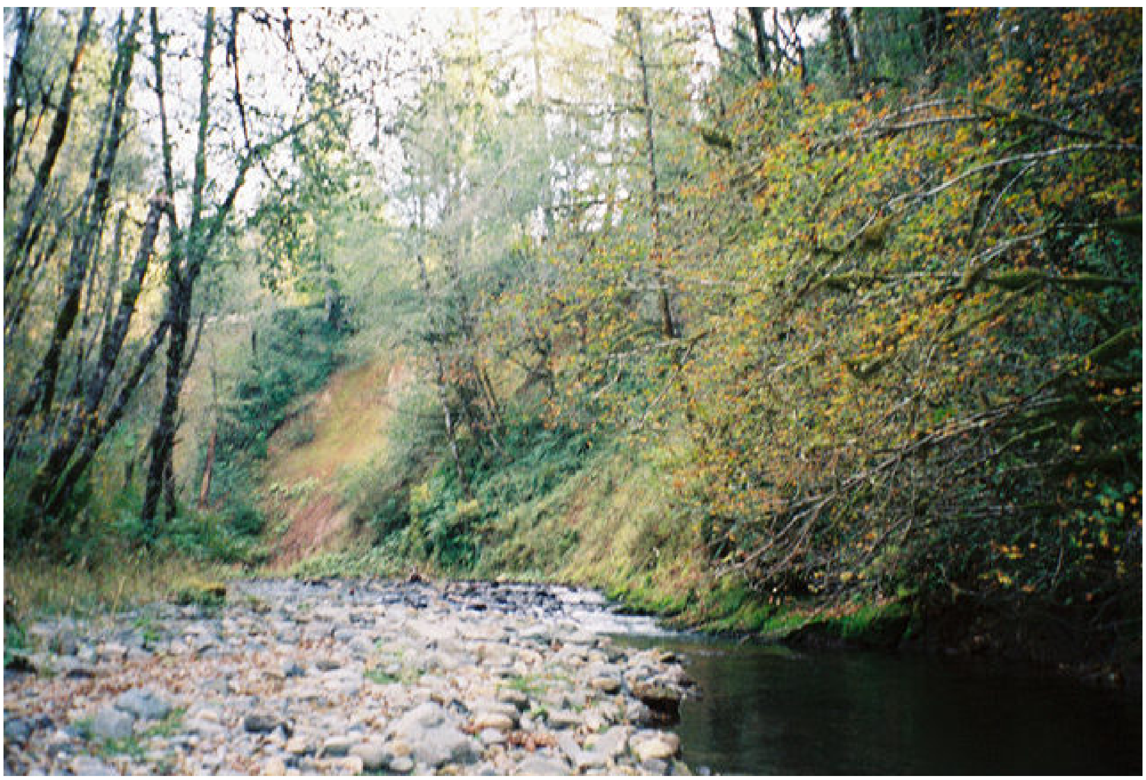

Figure 4. 37. Looking upstream at a road related landslide (left) on Rock Creek upstream of the Dole Valley Road crossing. The slide is the result of the failure of the Dole Valley Road bed and is actively contributing fine and coarse material to Rock Creek.

Restoration of hillslope processes in the Rock Creek, King Creek, and Copper Creek Basins

The Rock Creek Basin has moderate to high road densities (1.9 mi/mi^2 to 3.9 mi/mi^2) and moderate to high stream crossing frequencies (1.4 to 3.1 mi/mi of stream). Forest road crossings over streams can result in the direct transport of road and hillslope surface erosion to stream channels. Field and aerial photo interpretation revealed that there are areas with clear-cut harvests and high road densities in the Rock Creek Basin that could benefit from road obliteration. These areas include the large cut along upper mainstem Rock Creek (reach Rock Creek 5) and cuts along Cedar Creek and Cold Creek (Cedar Creek tributary). Road failures within the upper Rock Creek harvest unit have delivered sediments through mass wasting. Field surveys revealed that a recent harvest unit on State land adjacent to Cold Creek contains significant scarified bare ground that is likely contributing sediments to Cold Creek through surface erosion. Other harvest units and forest roads/skid trails adjacent to Rock Creek 3, 4 and lower Cedar Creek are in close proximity to the stream. Based on observations at other harvest units, these are likely to be sources of fine sediment through surface erosion and mass wasting. The King Creek Basin also has high road densities (3.5 mi/mi^2). Road obliteration could yield important benefits to sediment supply conditions.

4.3.6 Upper East Fork Lewis Basin (USFS portion)

EF Lewis 18-21; Slide Creek, Green Fork Creek (Surveyed reaches include Slide Creek)

This project was focused primarily on non-federal lands within the East Fork Basin. For this reason, field and remote sensing assessments were not conducted extensively in the upper Basin. The following restoration and preservation opportunities reflect information obtained during habitat surveys of Slide Creek and brief consultation of available GIS data.

4.3.6.1 Protection Opportunities

Timber land management in the national forest is guided by the prescriptions of the 1994 Northwest Forest Plan and its Aquatic Conservation Strategy, which offers aggressive protections to stream corridors. As long as these policies are continued, they are expected to provide adequate protections to stream corridors and hillslope processes.

4.3.6.2 Restoration Opportunities

Basin lithology is composed primarily of andesite and volcaniclastic deposits. Natural soil erosion potential is moderate but erosion rates have increased due to the effects of past fires, timber harvest, and roads. The upper basin has moderate to high road densities (1.9 mi/mi^2 to 3.1 mi/mi^2) that may serve to impair sediment supply and peak flow conditions, especially since much of the upper basin lies within the rain-on-snow zone. Road obliteration could yield important benefits to sediment supply and runoff conditions that affect important downstream reaches.

The only field survey conducted within the national forest was on Slide Creek. These surveys indicated that the riparian area of Slide Creek is largely intact. Reductions in shading from pre-settlement conditions, and their associated temperature effects were rated as moderate. There may be some riparian forest restoration opportunity where a logging road impacts vegetation in places. An instream restoration project was conducted there in 1999. Wood quantities in Slide Creek are below standards for Proper Functioning Conditions despite wood placement projects by the USFS. The Upper East Fork Lewis Watershed Analysis (USFS 1995) identifies specific limiting factors in the entire upper East Fork Basin, including elevated stream temperatures, low LWD quantities, lack of pool availability, and unstable areas. The analysis recommends specific areas for hillslope, riparian, and channel restoration.

4.3.7 Entire East Fork Lewis Basin

All reaches (all surveyed reaches)

4.3.7.1 Restoration Opportunities

East Fork Lewis Watershed Clean-Up

Stream surveys indicated that there is opportunity to improve the East Fork Lewis watershed through clean-up of instream and riparian areas. Specific examples of clean-up opportunities include a large culvert within the active channel in King Creek, approximately 900m upstream from the mouth. In LW Rock Creek, there is a large tire mass consisting of 50+ tires, also within the stream channel. Dean Creek has an accumulation of pressure treated lumber and other fencing materials acting as a small jam, near the upstream end of the stream survey reach. In the mainstem East Fork Lewis just downstream of Daybreak Bridge (~RM 10), there are large sections of concrete that should be removed (Figure 4. 38). Trash and road debris can be found in numerous areas of high recreational use or where roads run adjacent to the stream. In general, surveyed reaches within the basin were relatively free of garbage or debris. While the need for clean-up may be limited, this restoration project is a relatively inexpensive way to improve watershed health, and involve local residents in a beneficial process.

Figure 4. 38. Sections of concrete in mainstem EF Lewis River just downstream of Daybreak Bridge.

4.3.8 Prioritization of Broad-Scale Opportunities

A coarse-scale project prioritization was conducted for project opportunities developed as part of the East Fork Lewis Basin Assessment. Protection related projects received the highest priority rating (Very High) with the belief that preventing further degradation is more effective than attempting restoration in the future. The next greatest priority (High) was given to project types that aim to restore processes such as hillslope sediment and flow conditions, channel migration processes, or riparian function. Medium priority were given to project types that entail active restoration that has a high probability of success and addresses known critical needs of East Fork salmon and steelhead populations. Low priority ratings were given to the remainder of projects. The upper north side tributaries received a rating one step lower for each project type because the majority of the basin area does not contribute directly to streams that received a high priority (Tier 1 or 2 reaches) for salmon and steelhead populations assessed as part of lower Columbia Subbasin and Recovery Planning (LCFRB 2004).

Table 4. 32. Coarse-scale project prioritization for potential preservation and restoration project types developed as part of the East Fork Lewis Basin Assessment. See the descriptions above for detailed discussions of each of the restoration/preservation categories listed in the table.

Area and Project Type	Priority Category
Middle Mainstem East Fork Lewis	
Protect riparian corridors and stream channels along the middle mainstem	Very High
Protect hillslope processes in middle mainstem subwatersheds	Very High
Riparian forest restoration along the middle mainstem East Fork Lewis	Medium
Restoration of road impacts and bank armoring along the middle mainstem East Fork Lewis	Medium
Invasive species eradication along the middle mainstem East Fork Lewis	Medium
Restoration of hillslope processes in the middle mainstem subwatersheds	High
Upper North Side Tributary Basins	
Protect riparian corridors and stream channels in upper north side tributaries	High
Protect hillslope processes in Rogers, Niccolls, and Anaconda Creek subwatersheds	High
Riparian forest restoration on upper north side tributaries	Low
Restoration of hillslope processes in the upper north side tributary basins	Medium
Lower Mainstem East Fork Lewis	
Continue to protect lands within the lower mainstem valley bottom through regulations, land acquisition or conservation easements in order to preserve channel migration zones, floodplains, and off-channel habitat	Very High
Remove hydromodifications along the lower mainstem East Fork Lewis	High
Reduce severe bank instability at locations along lower mainstem	Medium
Create or restore side-channel and off-channel habitats	Medium
Riparian forest restoration on lower mainstem East Fork Lewis Reaches	High
Restore instream structure to the lower mainstem East Fork Lewis River	Low
Lower Mainstem Tributary Basins	
Continue to acquire lands within the lower segments of mainstem tributaries	Very High

Area and Project Type	**Priority Category**
Protect tributary streams and watersheds from the impacts of additional development	Very High
Riparian forest restoration on lower East Fork tributaries	Medium
Removing hydromodifications in lower East Fork tributaries	Medium
Restore instream structure to lower East Fork Tributary Basins	Medium
Hillslope restoration of lower East Fork Tributary streams	High
Restoration of tributary streams within the East Fork valley bottom	Medium
Rock Creek, King Creek, and Copper Creek Basins	
Protect riparian corridors and stream channels in the Rock Creek, King Creek, and Copper Creek Basins	Very High
Protect hillslope conditions in Cedar Creek and Rock Creek headwaters	Very High
Riparian forest restoration in the Rock Creek, King Creek, and Copper Creek Basins	High
Large wood supplementation in Rock Creek, King Creek, and Copper Creek Basins	Medium
Bank stabilization / road relocation in Rock Creek Basin reaches	Medium
Restoration of hillslope processes in the Rock Creek, King Creek, and Copper Creek Basins	High
Entire East Fork Lewis Basin	
East Fork Lewis Watershed Clean-Up	Low

4.4 Fine-Scale Preservation and Restoration Opportunities

The previous section discussed many potential restoration and preservation opportunities within broad project-type categories and within various geographic areas in the East Fork Lewis River Basin. In contrast, this section highlights only the subset of those opportunities that are believed to offer the greatest benefit to recovery of ecosystem processes and anadromous fish habitat. These specific opportunities are limited to those observed during field and aerial photograph surveys and do not include potential projects in non-surveyed portions of the basin. The opportunities are listed in order of general priority. Prioritization is based on first emphasizing preservation, followed by restoration of ecosystem processes, and then active (e.g. structural) habitat restoration. Consideration was also given to the importance of the habitat to fish; information that has been obtained from recent Recovery and Subbasin Planning Assessments that prioritized areas and factors for recovery (LCFRB 2004).

1. <u>Protect channel migration zone: mainstem EF Lewis from Mason Creek to Lewisville Bridge (RM 5.7 – 13)</u>
   Avoid the construction of hydromodifications that would constrain the river in any particular location. Also, refrain from implementing stream "restoration" techniques that limit natural channel dynamics, except where absolutely necessary to protect property. Protecting the channel migration zone may require purchase of property or easements at remaining private parcels within the lower river corridor/valley bottom. There has already been significant progress regarding land acquisition in this area. Continuing with these efforts will provide a unique opportunity for restoration/protection of channel migration processes.

2. <u>Protect riparian forests: lower Rock Creek (RM 0 – 7)</u>
   These reaches are characterized by state forest land interspersed with private forest land and private residential properties. Private parcels are clustered near the mouth (RM 0 – 0.5), between RM 1 and RM 2.5, and around the Dole Valley Road Crossing. Judging from current parcel sizes and residential development patterns, these private lands are becoming increasingly subject to land-use conversion from forest land to residential land, which carries with it the potential for negatively impacting riparian function in these biologically important reaches. For the larger parcels that have not been divided, the greatest opportunity for protection may be land acquisition or the purchase of conservation easements. Protection measures could also include establishing minimum lot sizes, requiring tree retention during development, and limiting clearing and grading practices.

3. <u>Protect riparian forests: mainstem EF Lewis from LW Rock Creek to USFS Boundary (RM 16.1 – 33)</u>
   Riparian forests along these reaches are subject to impairment related to increasing residential development of shoreline properties. Judging from current

parcel sizes, ease of access to major roadways, and past development patterns, this is an area of future potential residential growth, especially for vacation homes for people in the nearby Portland/Vancouver metropolitan area. Protection measures may include property acquisition, purchase of conservation easements, or regulations that establish minimum lot sizes, require tree retention, or that limit clearing and grading practices. Large lots in excess of 5 acres that may be subject to subdivision should receive the greatest emphasis for purchase or establishment of conservation easements. Large lots are scattered throughout these reaches. On lots that have already been subdivided, such as those near RM 30-31, regulations that protect riparian function may be the only viable alternative for protection. It is recognized that a significant portion of the shoreline properties in these reaches have already been acquired by Clark County as part of their greenbelt program; these effective protection efforts should be continued.

4. <u>Remove levees: mainstem EF Lewis River (north bank RM 8.3 – 9.5).</u>
   There are 5 or 6 old levees within the floodplain that affect floodplain function and channel dynamics. The specific locations can be seen in Figure 4. 7. Removal of these levees will partially restore channel migration processes in this reach and may also alleviate the rapid erosion of the high bank on the south side of the river at RM 9.2 (near Mill Creek confluence). The levees are all located on Clark County land. The most upstream levee system may be protecting the Clark County maintenance facility. These levees could be set back closer to the facility or the facility could be relocated further from the river. A couple levees are likely reducing the potential of channel avulsion into the two old Clark County gravel mining pits at RM 8.9. In this case, restoring long term channel dynamics likely outweighs the potential negative impacts of avulsion into these pits. In order to address flood hazard concerns from levee removal, a set-back levee system could be created along J.A. Moore Road and the Storedahl Pit Road; an option that should only be considered if the current roadway does not already provide adequate protection.

5. <u>Remove rip-rap banks: mainstem EF Lewis River (south bank RM 6.5 – 7, north bank RM 6.4)</u>
   There are at least three separate sections of rip-rap streambanks between Mason and Dean Creeks. Two are located on Clark County land on the south bank between RM 6.5 and 7. Another one is located along the north bank adjacent to the grass airstrip at RM 6.4. Removal of bank armoring at these locations would help to restore natural channel migration processes. Removal of the south bank armoring would appear to be very feasible considering the public land ownership and the lack of at-risk property. Removal of the north bank armoring may jeopardize the private airstrip and would have to be conducted in a cooperative effort with willing landowners.

6. <u>Streambank stabilization, riparian re-forestation, and cover enhancement: mainstem EF Lewis River (south bank RM 9.5 and RM 10.9).</u>
   This consists of two potential projects of similar character; one at RM 9.5 on the south bank between Mill Creek and Daybreak Park, and one along the south bank

at RM 10.9. Both sites consist of long eroding low floodplain terraces that are devoid of native riparian vegetation. The downstream bank is 500 meters long and the upstream bank is 200 meters long. See Figure 4. 32 for a picture. Restoration efforts should focus on reforestation and on providing bio-engineered bank protections aimed at re-establishing natural rates of channel migration. Bank protections should consist of large wood accumulations that will slow bank erosion, create lateral scour pools, and provide cover for aquatic species. The objective should be to reduce progressive meander migration in order to allow the maturation of native forest vegetation that will eventually provide bank stability, shade, and large wood recruitment. The objective should not be to constrain the river in its current location using non-native materials (e.g. large rock).

7. Create/restore off-channel spawning and rearing habitat: mainstem EF Lewis River (Mason Creek to Dean Creek: RM 5.7 – 7.3 and above Ridgefield Pits to Lewisville Bridge: RM 9 – 13) – see Figure 4. 33 for specific locations.
   Increase the availability of off-channel spawning and rearing habitat through improving connectivity to existing habitat and/or excavating new habitat in suitable locations. There are several areas where there is good potential for creation of off-channel habitat within these reaches. Specific locations are listed in Figure 4. 33. Many of the potential restoration sites are either abandoned side channels or historical channel locations where further excavation would connect with hyporheic flow to create upwelling conditions conducive to spawning (especially for chum). The potential restoration sites also include existing inundated sloughs that could be further excavated and connected to the mainstem to provide slow water winter rearing habitat for juvenile salmonids (especially coho). Off-channel habitats would also benefit from the placement of large wood to increase cover and complexity. Most of the potential restoration sites would benefit from eradication of invasive species and re-establishment of native riparian vegetation.

8. Reduce mass wasting related to roads: Rock Creek basin
   There are several locations where roads have resulted in mass failures directly entering stream channels. These include a large slide that resulted from the failure of Dole Valley Road in reach Rock Creek 4 just upstream of the Dole Valley Road crossing. This slide is actively eroding directly into Rock Creek. Successful restoration of this bank failure will likely require the relocation of the road further away from the stream bank. Another large landslide related to a road failure is located near the upstream end of Rock Creek 5 where the upper Dole Valley Road crosses a west bank tributary to Rock Creek.

9. Remove levee: mainstem EF Lewis River (south bank RM 10.8).
   This small levee, which is located on Clark County land, likely only moderately impairs floodplain and channel migration processes. Nevertheless, it is considered high priority because of feasibility considerations including public landownership and good access. The location of this levee can be seen in Figure 4. 4.

10. <u>Stream channel and riparian restoration; lower Dean Creek (RM 0 – 1).</u>
    Lower Dean Creek is highly impaired due to entrenchment, past channel re-alignment, invasive species, riparian forest degradation, and adjacent gravel mining operations. There is significant restoration opportunity. Re-establishing natural channel morphology through grade control and re-meandering should be considered in the segment immediately downstream of J.A. Moore Road, which has been straightened and channelized. The narrow riparian buffer should be extended to protect the riparian area from livestock grazing and other agricultural uses. Fine sediment contribution could be reduced by addressing runoff from adjacent crops, reducing sediment contribution from gravel pits, and also ensuring that excessive fines are not being contributed from what appears to be a small-scale mining operation just upstream of J.A. Moore Road. There appears to be an existing supply of gravels indicating that grade control for gravel retention may be successful, however, fine sediment inputs need to be reduced before spawning gravel enhancement can be successful. Large wood placements could enhance cover and habitat diversity. Re-establishing native riparian vegetation should be considered a priority. Some or all of these recommended activities are likely to be conducted by J.L. Storedahl & Sons, Inc. in accordance with the Storedahl Daybreak Mine Expansion HCP, which outlines proposed floodplain, riparian, and channel restoration measures on lower Dean Creek (Sweet et al. 2003).

11. <u>Stream channel and riparian restoration: lower Lockwood Creek (RM 0 – 1).</u>
    Lower Lockwood Creek is entrenched, dominated by invasive species, lacks riparian cover, lacks instream structure, and has embedded substrates. Potential restoration opportunities include riparian re-forestation, large wood placement, and grade control to reduce entrenchment. A large off-channel wetland area is located on the right bank (descending) that is currently isolated from the channel due to entrenchment. Grade control, combined with excavation of bank material in a few locations, could provide connectivity with this off-channel habitat. More detailed investigations should be conducted to determine the sources of fine sediment that are creating high embeddedness levels. Bank stabilization through bio-engineering approaches would reduce the contribution of fines from eroding streambanks within the reach.

12. <u>Riparian forest restoration: lower mainstem East Fork Lewis (Mason Creek to Dean Creek, RM 5.7 – 7.3).</u>
    Restore native riparian vegetation through invasive species eradication and tree planting. There are several locations on the north and south banks where reforestation opportunity exists. Much of this land is owned by Clark County and therefore presents good restoration opportunity. Restoration efforts may already by underway in some of these locations.

13. <u>Riparian restoration of private residences: lower mainstem East Fork Lewis (various locations).</u>
    Restore native riparian vegetation through invasive species eradication and tree planting. These sites are located on private residences where native riparian forest vegetation has been replaced by non-native vegetation or lawn. Restoration will

require cooperation from willing landowners. Locations include the south bank from RM 11 to 11.5; the south bank from RM 12.5 – 13; and the north bank at RM 12.8.

14. <u>Stream channel and riparian restoration: LW Rock Creek (RM 0 – 0.7).</u>
The lower portion of LW Rock Creek could benefit from LWD enhancement. Large wood placements would enhance pool habitat, cover, and facilitate the creation of side-channels and backwater habitat. Large wood could also be used to provide grade control and roughness in order to trap spawning gravels. Spawning gravel retention measures (i.e. grade control) are likely to be successful as there appears to be a good supply of gravels and embeddedness levels are relatively low. Portions of the lower reach that are impacted by residential-related clearing could benefit from riparian re-vegetation. There is opportunity for invasive species eradication throughout. There is a large tire mass within the surveyed portion of the reach that should be removed.

15. <u>Stream channel and riparian restoration: lower McCormick Creek (RM 0 – 0.5).</u>
Lower McCormick Creek is severely entrenched and is choked with invasive species. Restoration opportunities include reducing entrenchment through channel grade control and eradication of invasive species. There is good opportunity for riparian reforestation with native conifers upstream of the zone of frequent inundation from the mainstem East Fork. There is also opportunity to enhance the connection with off-channel slough and wetland habitat, especially on the east bank 100 meters upstream from the mouth where a large off-channel slough enters the creek.

16. <u>Riparian forest restoration: lower King Creek (lower 200 meters)</u>
Reforest area of recent clear-cut logging near stream at downstream 200 meters in order to provide shade, bank stability, and a future source of large woody debris recruitment. This area is privately owned.

17. <u>Riparian forest restoration: Rock Creek Basin (various locations)</u>
There are opportunities for reforestation of residential parcels at the boundary of Rock Creek 1 and 2 (RM 1.2); at the upstream portion of Rock Creek 2 (RM 2.3); and in Rock Creek 4 just downstream of the Dole Valley Road crossing. Opportunities for reforestation of harvested areas include Rock Creek 4 (west bank RM 4.2); lower Cedar Creek (west bank RM 0.3-0.8); and upper Rock Creek 5 (RM 7-8). Reforestation with native tree species will enhance bank stability, shade, and future large wood recruitment.

18. <u>Riparian forest restoration: middle mainstem East Fork Lewis (various locations).</u>
There are various opportunities for riparian forest restoration between LW Rock Creek (RM 16) and the USFS boundary (RM 33). Areas with restoration potential are located in the following locations: south bank EF Lewis 9, especially at the downstream end of the reach (residential impacts); throughout EF Lewis 10 (residential impacts); downtream end of reach 11 (residential impacts); throughout EF Lewis 13 (logging and forest roads); throughout EF Lewis 14 – 17

(road, residential, and timber harvest impacts). In general, restoration efforts should focus on the highest tier reaches first and should target areas where vegetation will most likely provide adequate shade and bank stability. Opportunities will ultimately depend on the level of cooperation with local landowners.

19. <u>Remove levee: mainstem EF Lewis River (north bank RM 3.2 – 4.4).</u>
    This is the long La Center levee that can be seen in Figure 4. 8. Removal of this levee system would restore connectivity of the river with floodplain wetlands and could present opportunities for re-establishing off channel slough habitat for juvenile salmonid rearing. Whereas this levee does not currently prevent floodplain inundation in large floods, it does limit floodplain inundation for moderate flow events. Restoring frequent inundation of the floodplain wetlands would enhance habitat for terrestrial and wetland species. This project is considered high priority partly because of feasibility considerations. Much of the levee is within Clark County ownership and there would appear to be relatively low flood risk to property. There is also good potential biological benefit of increased floodplain function and creation of connected off-channel rearing habitat.

20. <u>Remove levee: mainstem EF Lewis River (south bank RM 5.1).</u>
    This levee runs perpendicular to the river at approximately RM 5.1 and serves to bisect the south bank floodplain. The greatest benefit of removing this levee would be to enhance floodplain habitat for terrestrial and wetland species and to increase floodplain hydrologic function. It is considered a high priority primarily because of feasibility considerations. The entire levee system is on Washington State or Clark County land and appears to provide little or no protection of property. Removal of the levee may also be as simple as re-placing the levee material into the adjacent ditch from which it was originally excavated.

21. <u>Incorporate vegetative cover components into rip-rap bank: mainstem EF Lewis River (RM 11.5).</u>
    This 300 meter long rip-rap bank on the south side of the river currently protects residential development that is in close proximity to the river. Removal of the rip-rap is likely to be infeasible because of the potential impact of channel migration to private residences. There are opportunities, however, to incorporate vegetation and cover components into the existing rip-rap. Activities would include interplanting willows (e.g. brush bundles), cottonwoods, and alders into the rip-rap in order to provide shade and cover. Large wood pieces could be anchored into the rip-rap to create lateral scour pools and to provide in-stream cover.

22. <u>Incorporate vegetative cover components into rip-rap banks and riparian restoration: mainstem EF Lewis River (Lewisville Park, RM 13.6 – 13.9).</u>
    There are 2 to 3 segments of rip-rap streambanks on the north bank along Lewisville Park between RM 13.6 and 13.9. Removal of the rip-rap may be infeasible because of the potential impact to the county park due to channel migration. There are opportunities, however, to incorporate vegetation and cover

components into the existing rip-rap. Activities would include inter-planting willows (e.g. brush bundles), cottonwoods, and alders into the rip-rap in order to provide shade and cover. Large wood pieces could be anchored into the rip-rap to create lateral scour pools and to provide in-stream cover. There is a paved pathway adjacent to these armored banks that limits the development of riparian forest vegetation that could provide shade and large wood recruitment. Setting bank this pathway and planting native conifers should be considered.

23. <u>Structural enhancement via large wood placement: Rock Creek (Rock Creek 1-4).</u>
    Add accumulations of large wood in pool forming formations in order to enhance pool frequency, gravel retention, and cover. Rock Creek 1 and 3 have very low wood quantities (Rock 2 was not surveyed). Comparably, Rock Creek 4 has more wood but very low pool availability.

24. <u>Enhance rip-rapped banks / road relocation: middle mainstem East Fork Lewis north bank from Heisson to USFS boundary (RM 19 – 33).</u>
    The road is adjacent to the river in several locations. Many of these areas contain rip-rapped banks with little riparian forest vegetation. Some locations may allow for road-relocation, especially where the topography is flat or where the railroad grade may offer an alternate location. Rip-rapped banks can be enhanced by inter-planting willows (e.g. brush bundles), cottonwoods, and alders into the rip-rap in order to provide shade and cover. Large wood pieces could be anchored into the rip-rap to create lateral scour pools and to provide in-stream cover.

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Appendix 4.A.

Stream Survey Reports

4.A.1. East Fork Lewis River below Lower Rock Creek

4.A.1.1. Introduction

The East Fork Lewis River is located in Clark and Skamania Counties and joins the Lewis River near Lewis River RKm 6 (RM 4). This report presents findings from stream surveys on the East Fork Lewis River below lower Rock Creek (LW Rock Creek) (RKm 25.8) (RM 16.1) in EDT reaches 1-8 (Figure 4. 39). East Fork Lewis reach 7 was not surveyed because the reach no longer exists. Previously, reach 7 was a short reach (140m) that extended from Mill Creek upstream to Manley Creek. Recent channel changes related to migration of the mainstem have resulted in Manley Creek entering an abandoned back channel that empties into the mainstem at the same location as Mill Creek, thus eliminating reach 7. EDT reaches 6 and 8 were subdivided because of significant changes in channel morphology and habitat conditions observed within each reach. Subdivided reaches are denoted as 6A and 6B, and 8A and 8B. Reach boundaries for reaches 1-8B are listed in Table 4. 33. A total of 23.1 kilometers of river were surveyed, representing 89% of EDT reaches 1-8B. Each reach was surveyed in its entirety with the exception of reach 8B of which 45% was surveyed. The survey reaches are located between the mouth of the East Fork Lewis and RKm 23.1 (RM 14.4) (Lewisville Park). Stream surveys were conducted via boat using a modified version of the USFS Region 6 Level II Stream Survey Protocol (See Chapter 1). Surveys were performed from September 27-29, 2004. Temperatures recorded throughout the survey period ranged from 12.8 to 16.1ºC.

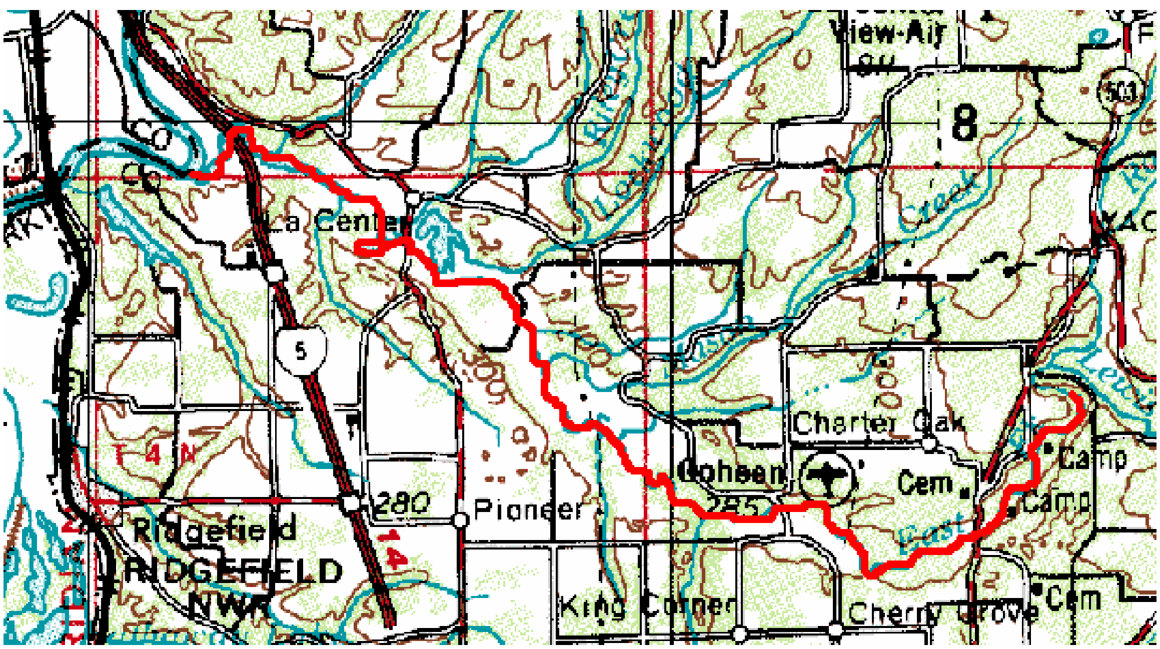


Figure 4. 39. Topographic map of the East Fork Lewis River highlighting the stream survey area. Survey length is 23.1 kilometers.

Table 4. 33. Reach boundaries of surveyed reaches in the East Fork Lewis River below LW Rock Creek.

Reach	Downstream Boundary	Upstream Boundary	Reach Length [km (mile)]
1	Lewis River	McCormick Creek	3.7 (2.3)
2	McCormick Creek	Brezee Creek	1.5 (0.9)
3	Brezee Creek	Lockwood Creek	2.0 (1.2)
4	Lockwood Creek	Mason Creek	2.0 (1.2)
5	Mason Creek	Dean Creek	2.5 (1.6)
6A	Dean Creek	Head of abandoned channel upstream of gravel pits	1.6 (1.0)
6B	Head of abandoned channel upstream of gravel pits	Mill Creek	1.6 (1.0)
8A	Manley Creek	Lewisville Bridge	5.9 (3.7)
8B	Lewisville Bridge	Rock Creek	5.1 (3.2)

4.A.1.2. Channel Morphology

The East Fork Lewis River reaches 1-4 are tidewater influenced. These reaches are low gradient depositional areas. Habitat types were difficult to classify in these reaches because standard morphological unit definitions do not apply well. These reaches have many qualities of glide habitat but they also have deep pools with residual depth. The pools do not have tailouts but rather slow transitions into glides. The habitat throughout these reaches was estimated as 10% pool and 90% glide (Figure 4. 40). Reaches 6A-8B are slightly higher gradient and are pool-riffle morphology (Montgomery and Buffington 1999). Reach 5 is a transitional reach between the pool-riffle morphology of reaches 6A-8B and the tidewater habitat of reaches 1-4. Reach 5 is primarily pool habitat. Reach 6A currently flows through the Ridgefield Pits, which are abandoned gravel pits that the stream avulsed into in November 1996. This reach consists primarily of backwater pools created by the pits and the historical main channel (Figure 4. 42). These units are not likely to function in the same manner as typical pools or backwater pools. The pools are very deep (>5m), they contain low amounts of cover, and they make up a disproportionate amount of the surface area of the reach. Their characteristics are not consistent with other pools (primary pools or backwater pools) within the lower East Fork Lewis. The characteristics of this reach in comparison to upstream and downstream reaches is discussed further in section 4.4.1.1 (Instability & Disturbance). Reaches 6B-8B are similar to each other with respect to the proportion of pool and riffle habitat types. Among riffles, large cobble/boulder riffles become less common and small cobble/gravel more common proceeding downstream. Fall Chinook were occasionally observed spawning throughout reaches 5-8B.

Figure 4. 40. Photo of the lower East Fork Lewis River. This type of habitat is typical of the tidally influenced reaches (EF Lewis 1-4). Photo taken September 2004.

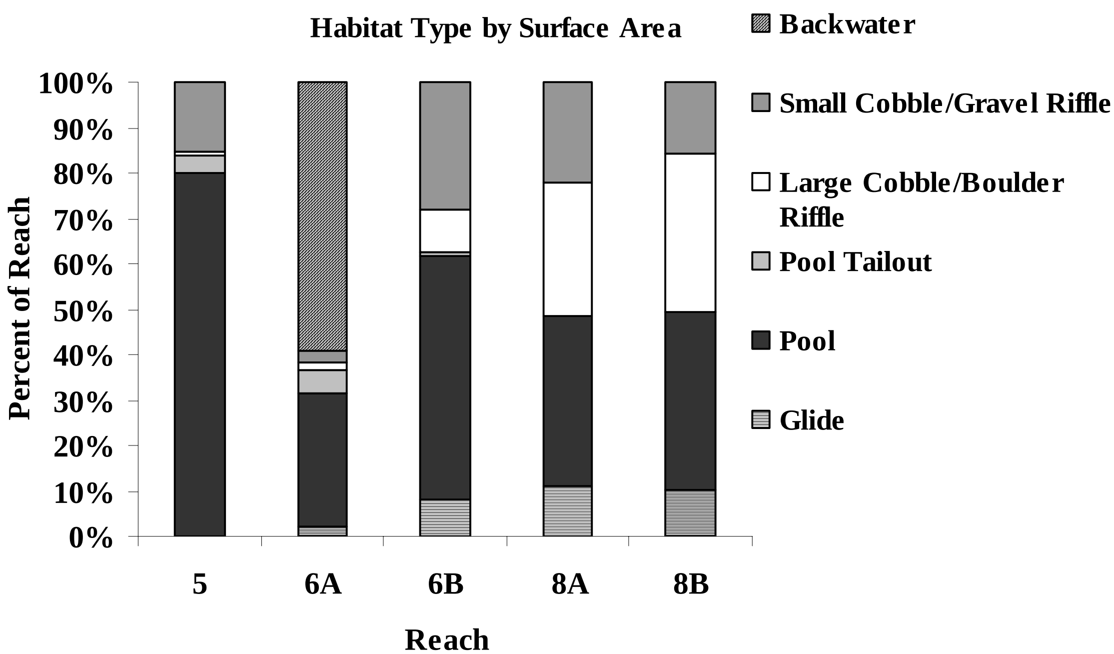


Figure 4. 41. Unit composition by percent surface area of the surveyed reaches of the East Fork Lewis River below LW Rock Creek. Reaches 1-4 not included because they are entirely pool/glide type habitat.

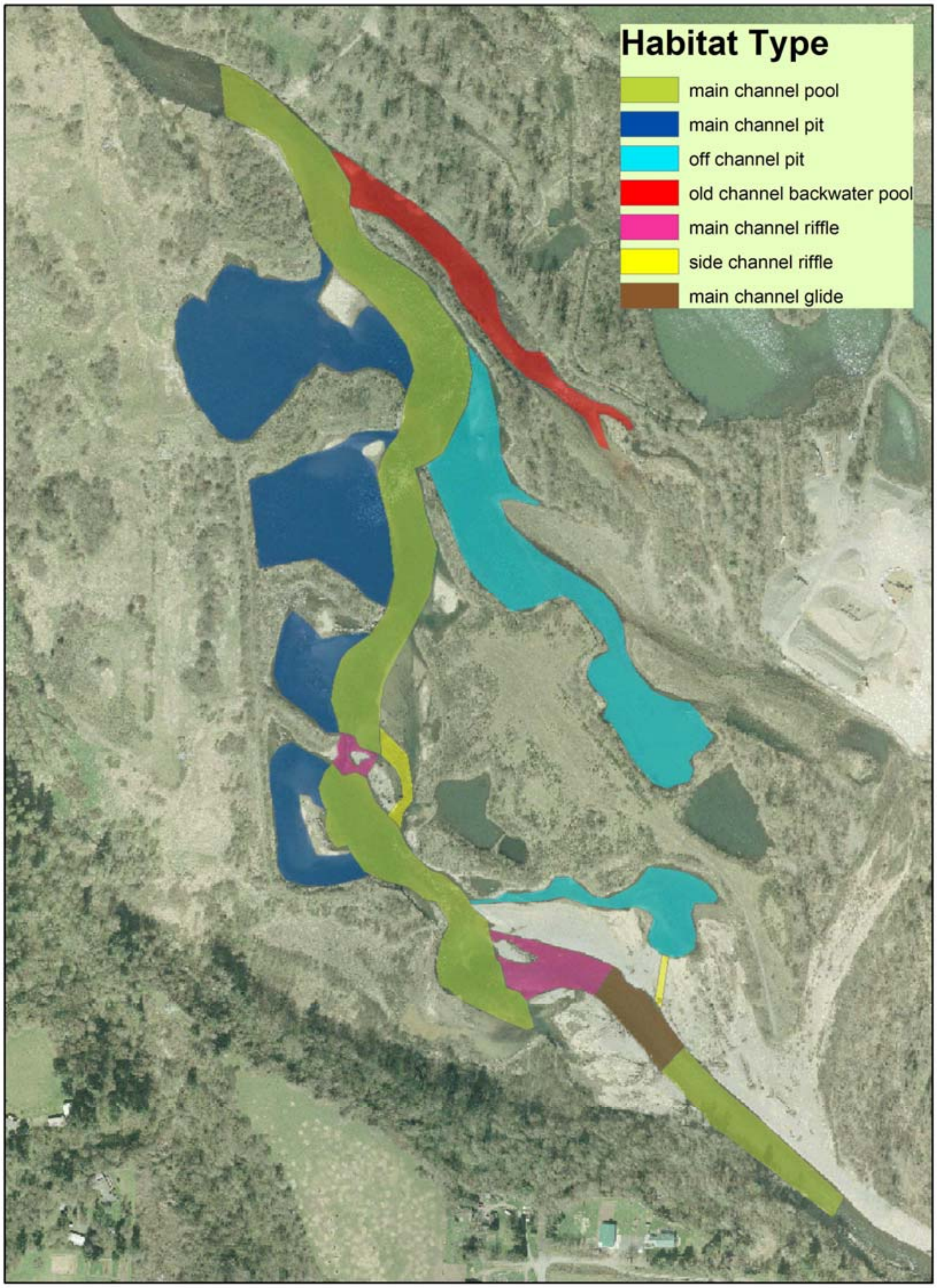


Figure 4. 42. Aerial photograph of East Fork Lewis reach 6A (Ridgefield Pit avulsion). The reach is parsed into different habitat types denoted by different colors.

The East Fork Lewis River in reaches 1-8B is low gradient (<0.5% slope). The lower reaches are naturally unconfined but are artificially confined by hydromodifications in places. Mean widths range from 25m to 59m and average maximum pool depth ranges from 1.6m to greater than 5.0m (Table 4. 34). Several pools are greater than 5.0m in depth (our survey equipment did not allow for depth measurements greater than 5.0m). A majority of the pools are primary (mainstem) pools but pool frequencies are low. Side channel area ranges from 0-17%. Side channel area was estimated via GIS aerial photo analysis (see Section 4.2.1.4).

Table 4. 34. Average channel morphology characteristics of surveyed sections of the East Fork Lewis River.

Reach	Mean Gradient (%) [1]	Mean Riffle Width (m)	Mean active chanl. Width (m)	Mean Max. Riffle Depth (m)	Mean Residual Pool Depth (m)	Mean Max. Pool Depth (m)	Pool per km.	Primary pools (>1.0m deep) per km.	Side channel by area (%)[3]
1	0.0	59.0 [2]	65.0	na	na	>5	na	na	0
2	0.0	39.0 [2]	52.0	na	na	3.1	na	na	0
3	0.0	35.0 [2]	42.0	na	na	2.7	na	na	0
4	0.0	36.0 [2]	43.0	na	na	3.0	na	na	0
5	0.29	20.3	36.1	0.6	1.3	1.8	4.4	4.0	17
6A	0.12	20.7	84.0	0.5	>3.5	>5.0	1.7	1.7	4
6B	0.42	27.6	48.6	0.6	1.2	1.6	4.2	4.2	2
8A	0.38	29.5	47.0	0.7	1.3	1.9	2.2	2.2	6
8B	0.51	24.5	35.0	1.0	1.7	2.3	2.2	2.2	8

1. *Based on LiDAR contours*
2. *Mean wetted channel width. Habitat is entirely tidewater influenced pool/glide.*
3. *Dry or wetted side channels.*

4.A.1.3. Wood

Wood availability is limited in the lower East Fork Lewis. Reaches 1 and 4-6A have the greatest amounts of wood with 31-51 pieces/km. Reaches 2-3 and 6B-8B have only 2-23 pieces/km. Several root wads and jams are present but their densities are low (Table 4. 35).

Table 4. 35. Size and density of wood, jams, and root wads in surveyed sections of the East Fork Lewis River.

Wood Category	1	2	3	4	5	6A	6B	8A	8B
Small Pieces/km[1]	33	0	2	22	13	13	6	4	8
Medium Pieces/km[2]	15	2	3	13	14	15	11	2	6
Large Pieces/km[3]	3	0	2	10	4	5	6	2	2
Jams/km[4]	0	0	0	1	1	0	1	0	0
Root wads/km[5]	0	0	0	0	0	0	1	0	0

[1] *10-20 cm diameter; >2 m long*
[2] *20-50 cm diameter; >2 m long*
[3] *>50 cm diameter; >2 m long*
[4] *>10 pieces in accumulation*
[5] *>2 m long*

4.A.1.4. Substrate

Characterization of substrate based on visual observation showed that substrate size increases moving upstream (Figure 4. 43 and Figure 4. 44). The data from pools should be viewed with some caution because the substrate in the deepest portion of some pools could not be seen, so substrate calls were made where the substrate was visible. This may have caused some bias in pool substrate estimates. In reaches 1-4, sand is the dominant substrate class making up 60% of the substrate or greater. In reaches 5-8B, gravel and cobble are the dominant substrate classes with cobble becoming progressively more dominant in each reach progressing upstream. The proportion of boulders increases and gravel decreases moving upstream. The exception is reach 6A where the high amount of fines in the Ridgefield Pits results in fines as the dominant substrate type in pools (Figure 4. 43). Along the margins of the main pools and backwater habitat, the substrate is primarily sand and silt with a dune-ripple channel bottom. No riffles are present in reaches 1-4. Grain sizes for each category are listed in Table 4. 36.

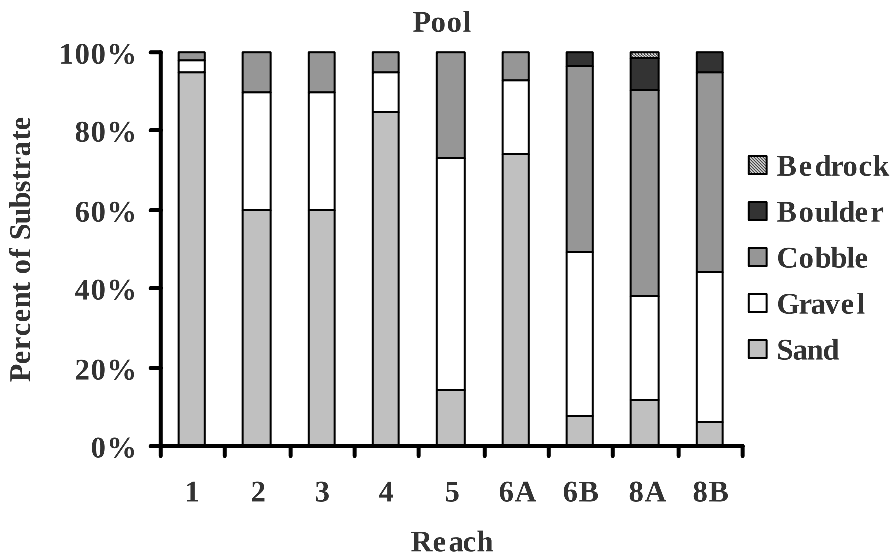


Figure 4. 43. Substrate size class composition in pools in surveyed reaches of the East Fork Lewis below LW Rock Creek. The values for reach 6A include the backwater units in the Ridgefield Pits.

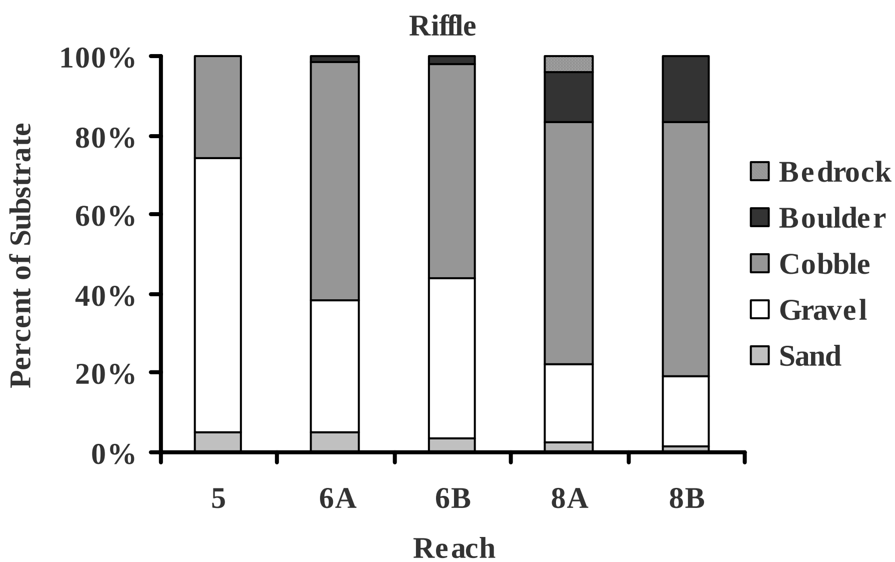


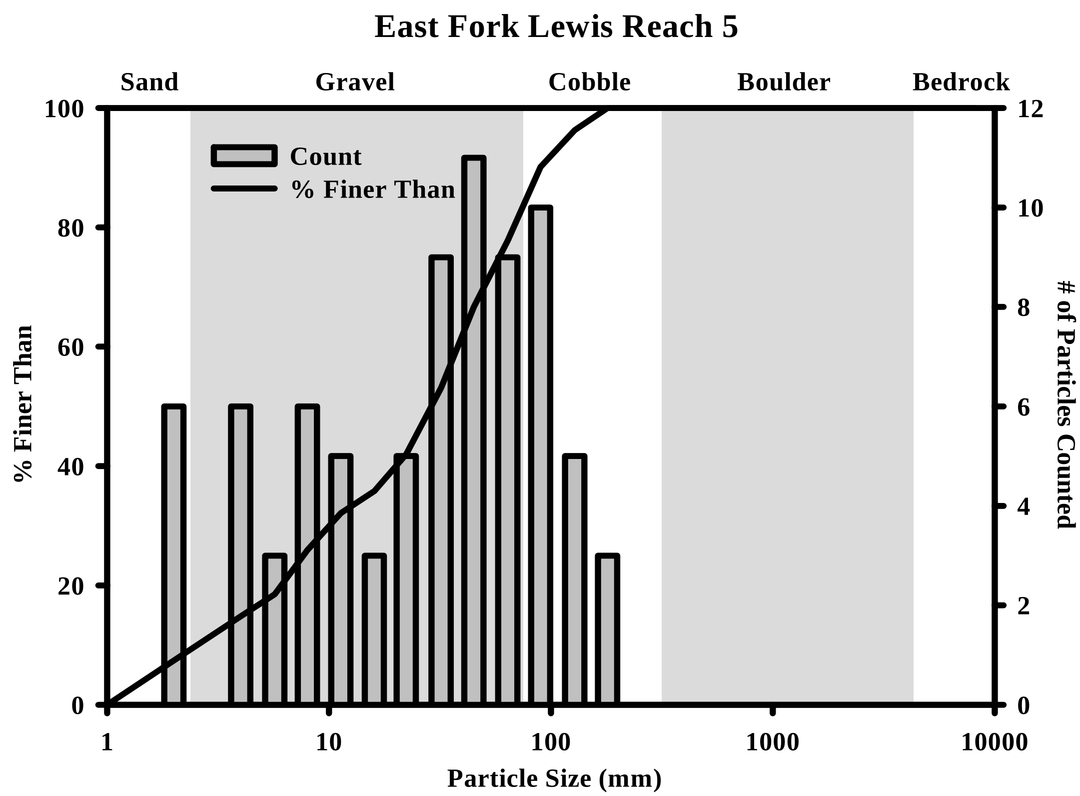
Figure 4. 44. Substrate size class composition in riffles in surveyed reaches of the East Fork Lewis below LW Rock Creek.

Table 4. 36. Grain size ranges for substrate size categories used in visual observations and pebble counts.

Category	Grain Size Range (mm)
Sand	< 2
Gravel	2 – 64
Cobble	64 – 256
Boulder	256 – 4096
Bedrock	>4096

Embeddedness was rated in riffles, glides, and pool tailouts in each unit according to four categories (0-25%, 25-50%, 50-75%, and 75-100%). Embeddedness was not rated in reaches 1-4 because those reaches had no riffles or pool tailouts and were composed almost entirely of fines. In reaches 5-8B, 98% of all units were rated as having low embeddedness (0-25%). In the Ridgefield Pits area (avulsed reach), the gravel and cobble that is available is embedded 25-50%.

Pebble counts were conducted within reaches 5, 6, and 8. Pebble counts showed that the dominant particle sizes in pool tailouts are large gravel and cobble. The median size class for the reach 5 count was 22.6-32 mm and for reach 6 was 64-90mm. The median class in both units of reach 8 was 45-64 mm. Sand made up 5-7% of each of the pebble counts. Boulders were present in the reach 8 counts but not in the reach 5 and 6 counts.



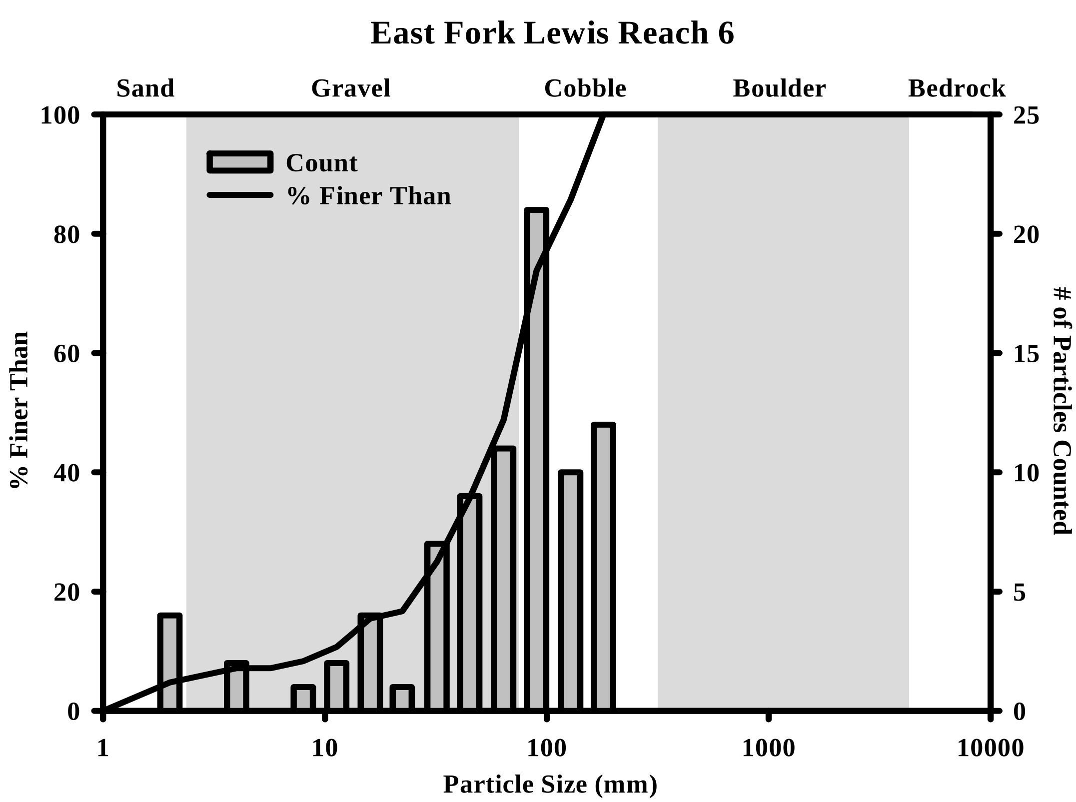
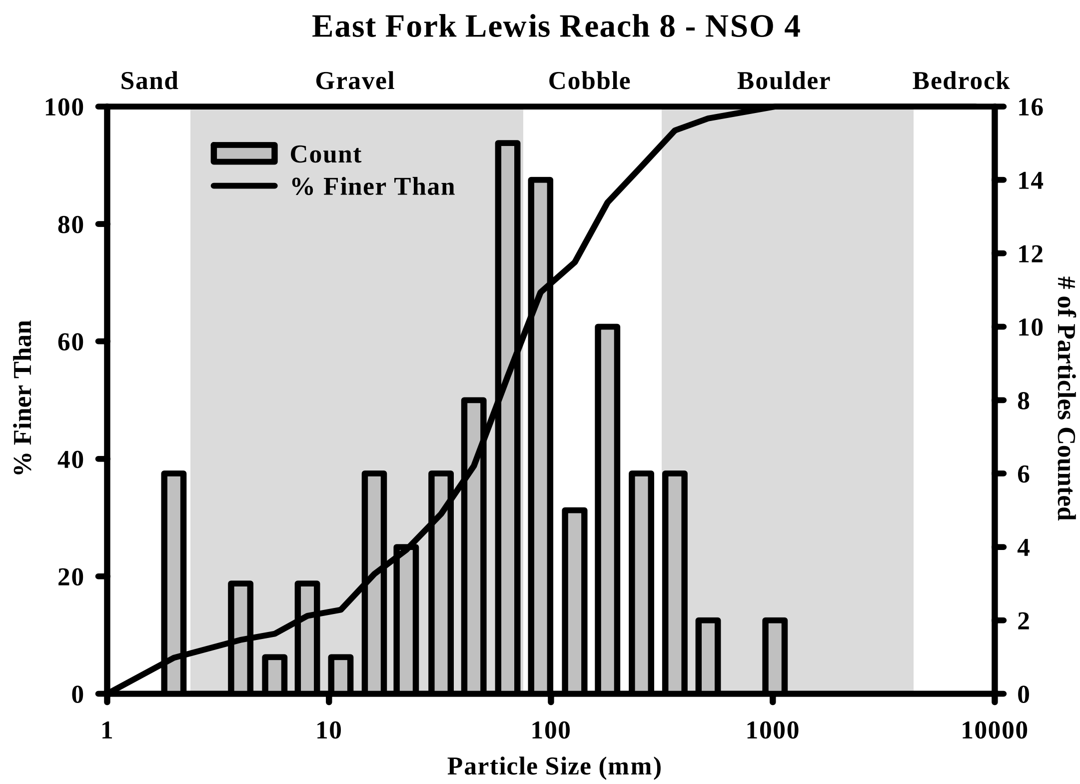


Figure 4. 45. Grain size distribution based on pebble counts in the East Fork Lewis reaches 5 and 6.



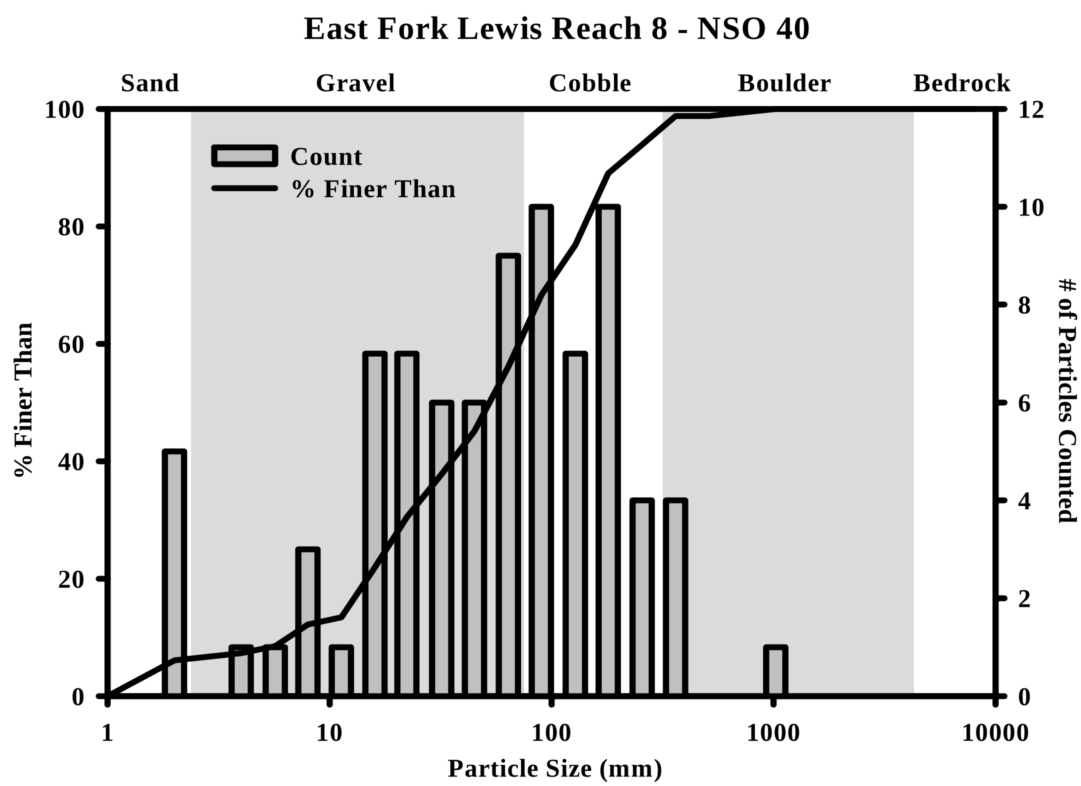


Figure 4. 46. Grain size distribution based on pebble counts in the East Fork Lewis reach 8. NSO 40 is downstream of NSO 4.

4.A.1.5. Cover

Cover in the East Fork Lewis is primarily provided by depth and substrate. Large woody debris and overhanging cover provide negligible amounts of cover and undercut banks do not provide any cover. Depth provides cover for over 0-50% of the surface area with the greatest amount in reaches two and three. Substrate provides cover for over 7-10% of the habitat in reaches 8A and 8B (Table 4. 37).

Table 4. 37. Presence of cover within the surveyed portions of the lower East Fork Lewis River. Cover is measured as the percent of the surface area of the reach.

Cover Type	1	2	3	4	5	6A	6B	8A	8B
LWD	0	0	0	1	0	1	2	0	0
Undercut Bank	0	0	0	0	0	0	0	0	0
Overhanging Cover	0	1	2	0	2	1	0	3	0
Depth > 1m	37	50	50	30	13	26	0	49	23
Substrate (Velocity cover)	0	0	0	0	0	0	0	7	10

4.A.1.6. Riparian

The mean view to sky angle in the lower East Fork Lewis ranges from 91-153 degrees (Table 4. 38). Stream shade is the greatest in reach 8A and is least in reaches 3 and 6A. Shade is limited because of the width of both the river and the valley bottom. The dominant vegetation varied by reach and by bank. In the lower four reaches, grasses and forbs make up a great portion of the riparian habitat. In general, there is an increasing frequency of mature hardwoods, mature conifers, and mixed hardwoods/conifers as one progresses upstream (Figure 4. 47).

Table 4. 38. Riparian shade characteristics in surveyed sections of the East Fork Lewis River. Data presented as proceeding downstream.

Parameter	1	2	3	4	5	6A	6B	8A	8B
Mean distance to vegetation – left bank (m)	101	40	27	15	50	111	30	18	25
Mean left bank canopy angle (degrees)	21	27	4	25	14	19	45	46	27
Mean distance to vegetation – right bank (m)	41	37	15	80	45	144	94	23	44
Mean right bank canopy angle (degrees)	28	36	23	25	19	9	15	43	33
Mean view to sky (degrees)	131	117	153	130	147	152	120	91	120

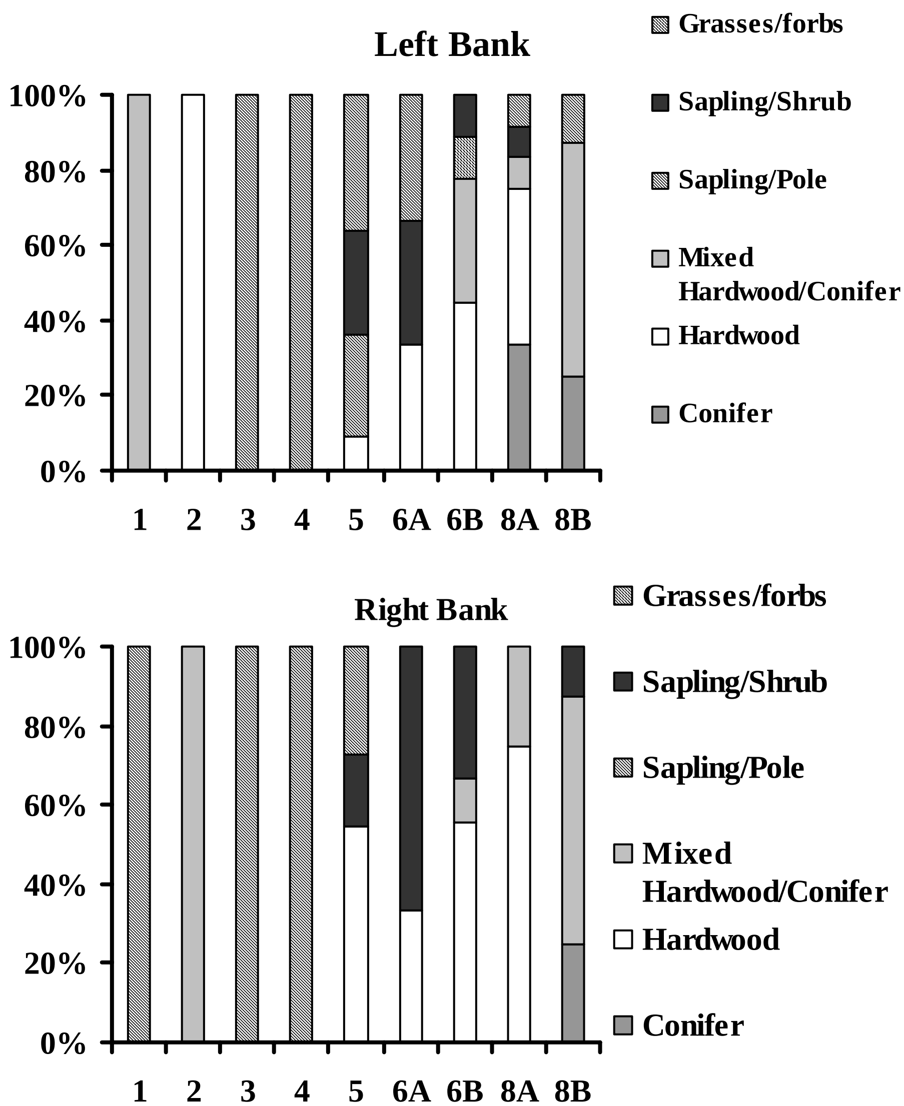


Figure 4. 47. Vegetation type by percentage of units observed. Data presented as proceeding downstream.

4.4.1.1 Instability & Disturbance

There is a significant amount of bank instability in the lower East Fork Lewis, especially in the lower three reaches (Table 4. 39). In many areas, instability and disturbance is related to land use practices such as grazing, residential development, and hydromodifications. Habitat conditions related to hydromodifications are also covered in the Hydromodifications section (Section 4.2.1).

The lower three reaches have exposed and unstable banks, which are likely related to channel incision. Instability is lowest in reaches 4 and 8B. See Figure 4. 48 for a typical example of bank instability in the lower East Fork Lewis River.

Table 4. 39. Bank instability and disturbance of surveyed sections of the East Fork Lewis River. Data presented as proceeding downstream.

Parameter	1	2	3	4	5	6A	6B	8A	8B
Left bank instability (%)	80	80	80	10	29	43	67	25	3
Right bank instability (%)	80	60	0	15	38	75	28	24	9
Left bank disturbance (%)	0	20	90	0	9	--[1]	0	55	11
Right bank disturbance (%)	0	20	100	80	7	--[1]	0	7	59

1. *See discussion on effects of gravel pits on reach 6A.*

Figure 4. 48. Photo of eroding streambank in reach 8A (RM 9.7).

The degree to which land-use or channel disturbances affect the river varies from reach to reach. The major disturbances include the Ridgefield gravel pits, levees, streamside residential development, bank armoring, bridge crossings, cattle grazing, and the spread of invasive species in the riparian zone.

One of the greatest disturbances in the lower East Fork Lewis is the 1996 avulsion into the Ridgefield Pits, which have been incorporated into the main channel, abandoning 3,400 feet of spawning and rearing habitat (Norman et al. 1998). An analysis was undertaken to attempt to quantify changes in stream habitat availability resulting from the gravel pit avulsions. In the analysis, the portion of the stream encompassing the gravel pits was compared to similar lengths of river habitat immediately upstream and downstream of the pits. Filling of the pits since the 1996 avulsion has improved channel habitat in the upstream 320 meters of the avulsed reach; this segment was therefore not considered to be within the area currently affected by gravel pits. The length of habitat currently affected by the pits is 920m. An approximately equal length of habitat both upstream and downstream of the pits was evaluated in an attempt to identify changes to the habitat resulting from the pits. The assumption is that the upstream and downstream habitat would be representative of the gravel pit affected area prior to the avulsion.

The most notable difference between the Ridgefield Pits and upstream and downstream areas is the difference in morphological complexity. There are three main channel units within the Ridgefield Pits (two very large pools and one 10m riffle) compared to 11 units in the upstream reach and 7 in the downstream reach (Figure 4. 49). Pool spacing is an important factor in fall Chinook (*Oncorhynchus tshawytscha*) production. Increased pool frequency is positively correlated with increased Chinook spawning densities (Hayman et al. 1996). Pool frequency in the downstream area was nearly three times greater than in the gravel pit section. Pool frequency in the upstream area was similar to that in the gravel pit section because of the presence of glides in the upstream segment. Perhaps a better indicator of overall habitat complexity is the frequency of individual habitat units, which is illustrated by Figure 4. 49. Habitat unit frequency is four times greater in the downstream segment than in the pits segment and 2 times greater in the upstream segment than in the pits segment.

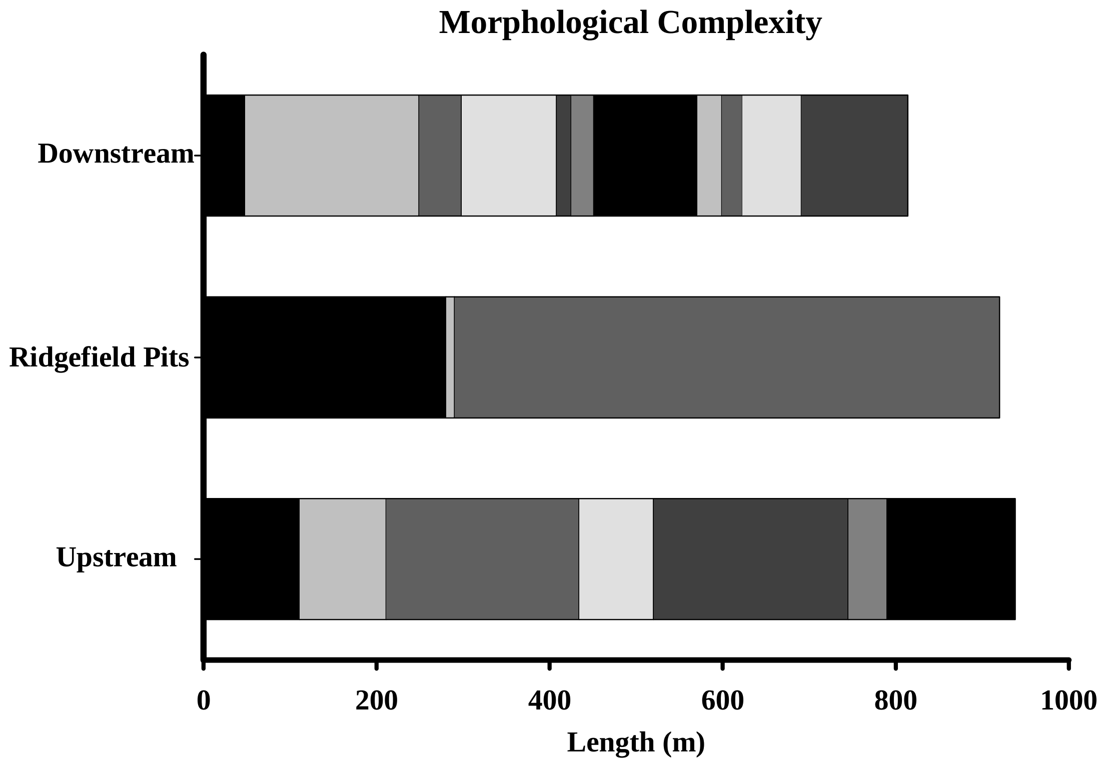


Figure 4. 49. Illustration of morphological complexity in the Ridgefield pits and adjacent upstream and downstream sections of the East Fork Lewis River. Each band within the bars represents a distinct main channel habitat unit and its length.

The size of pools in the Ridgefield pits is much greater than the pools in adjacent areas; however, as percent of total wetted surface, the pit segment has a lower percentage of main channel pool habitat than upstream and downstream segments. Large pools such as those present in the Ridgefield pits are not well suited for juvenile rearing. Huntington (1997) presents data from the Bull Run River in Oregon that demonstrates that counts of juvenile steelhead in large pools (2,500 m^2) were no greater than counts in smaller pools (<380 m^2). Cramer (2001) reasoned that the findings of Huntington (1997) were based on the preference of juveniles for the heads and tails of pools rather than the calm mid-water sections. This reasoning was based on similar findings with Chinook in the Sandy River, Oregon.

Riffle availability is distinctly different with greater than 10 times the amount of riffle habitat available outside the pits than inside. Riffle availability is important to rearing of juvenile salmonids (*Oncorhynchus sp.*) because riffles are the primary production areas for the drift invertebrates upon which juvenile salmonids feed (Rader 1997; Waters

1962). In fact, Waters (1962) found that at least 60% of the stream in his study needed to be comprised of riffles in order to generate the abundance of *Baetis* mayflies consumed in pools. Only 2% of habitat in the Ridgefield pits is riffle.

The Ridgefield Pits are extremely deep in comparison to adjacent river sections (Table 4. 40). The depth of the pits has been estimated at 10m (Sweet et al. 2003), whereas the maximum depth measured in units within areas immediately upstream and downstream of the pits is 2.4m. Although the pits create abundant backwater habitat, there is little cover and little shallow water habitat. The pits section is 5.5 times wider than the upstream or downstream sections. Wood density within the Ridgefield section is similar to the upstream and greater than the downstream sections (Table 4. 40).

Table 4. 40. Parameter values in the Ridgefield pits and adjacent upstream and downstream areas.

Parameter	Downstream	Ridgefield Pits	Upstream
Length	814m	920m	938m
% Pool[1]	56%	34%	43%
Pool Frequency (#/km)	6.1	2.1	2.1
Habitat Unit Frequency	13.5	3.3	7.5
Max. Pool Depth (m)	2.4	10.0	1.7
% Riffle	33%	2%	25%
% Backwater	0%	64%	0%
Wetted Width	25	140	23
Wood Density (#/km)[2]	14.7	27.2	33.0

1. *"Pool" habitat does not include backwater.*
2. *LWD counts include small, medium, and large pieces as defined in section 4.A.1.3.*

4.A.1.7. Comparison to Habitat Standards

Numerous standards for rating the quality of salmonid habitat have been developed. Data collected in this survey were rated via two sets of standards applicable to basins of southwest Washington. The Washington Conservation Commission (WCC) established a set of standards to identify factors limiting salmonid production throughout the state. Standards applicable to western Washington were used here. Habitat features in surveyed reaches of the East Fork Lewis were also compared to the NOAA Fisheries Properly Functioning Condition (PFC) standards. Only standards applicable to data collected were incorporated. Reaches 1-4 were not included because the habitat quality standards are not as applicable to these tidally influenced reaches.

The available amount of pool surface area in reaches 5 and 6B was rated as "Good" under the WCC criteria (Table 4. 41). Reaches 8A and 8B were rated as "Fair" and reach 6A was rated as "Poor". Pool frequency was rated as "Not Properly Functioning" and Pool Quality was rated as "At Risk" for all of the reaches. LWD is below criteria guidelines, and with the exception of Reach 8B, streambank stability is rated as "Poor". There were no artificial barriers on the surveyed reaches, so the barriers criterion was rated favorably.

Table 4. 41. East Fork Lewis habitat feature ratings according to regional salmonid habitat quality standards. Gray shaded cells indicate that no standard is available. PF = properly functioning; NPF = not properly functioning.

Parameter	Reach 5 WCC[1]	Reach 5 PFC[2]	Reach 6A WCC[1]	Reach 6A PFC[2]	Reach 6B WCC[1]	Reach 6B PFC[2]	Reach 8A WCC[1]	Reach 8A PFC[2]	Reach 8B WCC[1]	Reach 8B PFC[2]
% Pool by Surface Area	Good		Poor		Good		Fair		Fair	
Pool Frequency		NPF		NPF		NPF		NPF		NPF
Pool Quality		At Risk		At Risk		At Risk		At Risk		At Risk
LWD		NPF		NPF		NPF		NPF		NPF
Substrate		PF		NPF		PF		PF		PF
Streambank Stability	Poor	NPF	Poor	NPF	Poor	NPF	Poor	NPF	Good	PF
Barriers	Good	PF	Good	PF	Good	PF	Good	PF	Good	PF

1. *Available ratings: good; fair; poor*
2. *Available ratings: properly functioning; at risk; not properly functioning*

4.A.1.8. Comparison to EDT Values

Habitat types were difficult to classify in reaches one through four because standard morphological unit definitions do not apply. These reaches are tidewater influenced and are mostly glide-like, although there are areas of deep pools with residual depth. The pools do not have distinct tailouts, but rather slow transitions into glides. Embeddedness was rated as zero in reaches 1-4 because EDT specifies that in reaches where gravels and cobble do not exist, that the reach should be rated zero. Cobble and gravel are extremely limited in these depositional reaches.

Most attributes varied slightly between the patient ratings and the survey based ratings (Table 4. 42). The river is wider near the mouth and narrower near La Center than represented in the patient condition ratings. Riparian function is less favorable based on surveyed ratings than under patient ratings. In reaches 5-8B, there are significant differences in the availability of pool and riffle habitat than what was estimated for EDT.

Table 4. 42. EDT Patient scores assigned to the lower East Fork Lewis and EDT scores based on 2004 stream survey results for categories relevant to data collected. The gradient is for the entire EDT reach, not just the surveyed section.

Category	Reach 1		Reach 2		Reach 3		Reach 4		Reach 5	
	EDT	Survey	EDT	Survey	EDT	Survey	EDT	Survey	EDT	Survey
Channel width – minimum (m)	34.1	59.0	34.1	39.0	34.1	35.0	34.1	36.0	34.1	20.0
Gradient %	0.1	0.0	0.0	0.0	0.3	0.0	0.6	0.0	0.3	0.3
Confinement – hydromodifications	1	1	2	2	2	3	2	2	1	1
Confinement – natural	0	0	0	0	3	0	0	0	0	0
Habitat Type – Glides	94%	90%	94%	90%	94%	90%	94%	90%	17%	12%
Habitat Type – Beaver ponds	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Habitat Type – off-channel habitat factor	0%	9%	0%	0%	0%	2%	0%	1%	0%	6%
Habitat Type – pool tailouts	1%	0%	1%	0%	1%	0%	1%	1%	7%	3%
Habitat Type – primary pools	5%	10%	5%	10%	5%	10%	5%	10%	38%	73%
Habitat Type – small cobble/gravel riffles	0%	0%	0%	0%	0%	0%	0%	0%	34%	14%
Habitat Type – Large cobble/bldr riffles	0%	0%	0%	0%	0%	0%	0%	0%	3%	1%
Riparian Function	2	1.5	2	2	2	3.5	2	3	2	3
Wood	3	2.6	3	4	3	3.6	3	2	3	2.4
Embeddedness	3	0	3	0	2.5	0	2.5	0	0.9	0.9

Category	**Reach 6A**		**Reach 6B**		**Reach 8A**		**Reach 8B**	
	EDT	**Survey**	**EDT**	**Survey**	**EDT**	**Survey**	**EDT**	**Survey**
Channel width – minimum (m)	34.1	137	34.1	27.6	27.4	29.5	27.4	24.5
Gradient %	0.2	0.1	0.2	0.4	0.4	0.4	0.4	0.5
Confinement – hydromodific ations	1	3	1	1	1	1	1	1
Confinement – natural	0	0	0	0	1	0	1	1
Habitat Type – Glides	20%	2%	20%	8%	14%	11%	14%	10%
Habitat Type – Beaver ponds	0%	0%	0%	0%	0%	0%	0%	0%
Habitat Type – off-channel habitat factor	0%	59%	0%	0%	0%	3%	0%	1%
Habitat Type – pool tailouts	7%	5%	7%	1%	7%	0%	7%	0%
Habitat Type – primary pools	38%	30%	38%	54%	60%	38%	60%	39%
Habitat Type – small cobble/gravel riffles	34%	3%	34%	28%	1%	22%	1%	16%
Habitat Type – Large cobble/bldr riffles	3%	1%	3%	9%	11%	29%	11%	35%
Riparian Function	2	4	2	1.5	1	2.5	1	1.5
Wood	3	3.6	3	3.9	3	4	3	3.4
Embeddedness	0.9	2.0	0.9	0.9	0.9	0.9	0.9	0.9

4.A.1.9. Potential Areas of Restoration

Potential areas of restoration in the lower East Fork Lewis are discussed in section 4.3.1 of this report.

4.A.2. East Fork Lewis River above Lucia Falls

4.A.2.1. Introduction

This report presents findings from stream surveys on the East Fork Lewis River above Lucia Falls (RM 21) (RKm 33.8), in EDT reaches 11, 13, and 15 (Figure 4. 50). A total of 4.4 kilometers (2.7 miles) of river were surveyed representing 51% of EDT reaches 11, 13 and 15. The respective percentages surveyed by reach are 25%, 78%, and 100%. The survey reaches are located between RKm 37.7 (RM 23.4) and RKm 47.6 (RM 29.6) (Horseshoe Falls). Stream surveys were conducted on foot using a modified version of the USFS Region 6 Level II Stream Survey Protocol (USFS 1999). Surveys were performed from October 12-13, 2004. Temperature location, dates, and times are shown in Table 4. 43.

Land use and ownership within the surveyed areas is primarily industrial or state timber land with some residential and county park land. A highway runs along the right descending bank throughout the three reaches. There are sections where houses are present between the road and river. The left bank is almost exclusively timber land.

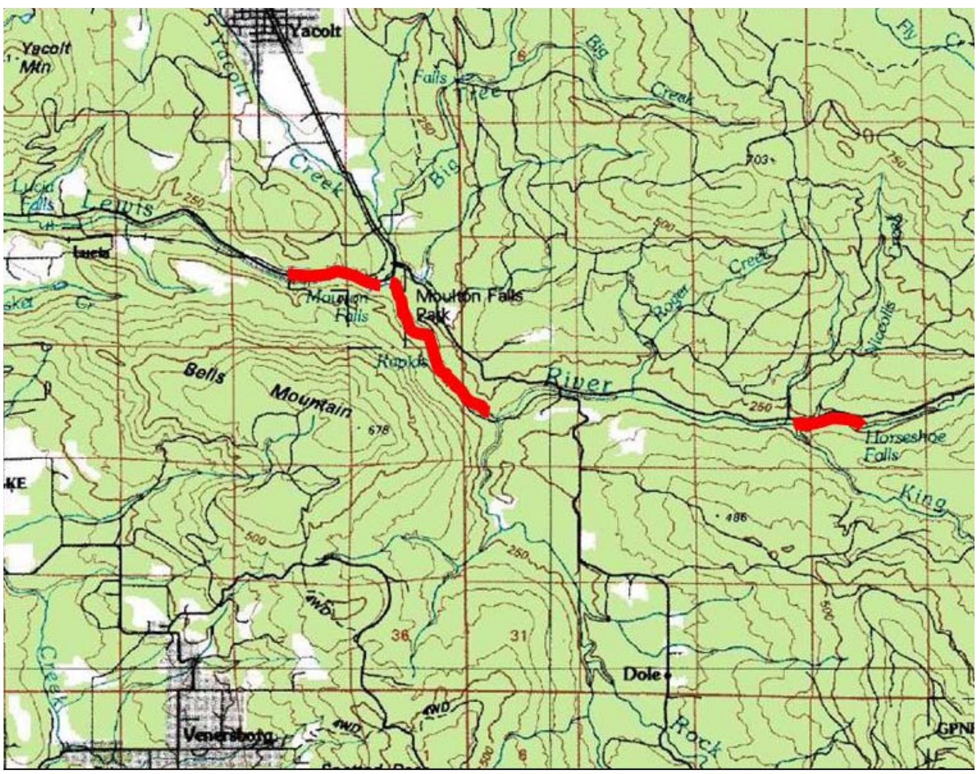


Figure 4. 50. USGS topographic map of the East Fork Lewis River, highlighting the stream survey area. Combined length of surveys is 4.8 kilometers.

Table 4. 43. Temperatures recorded in the East Fork Lewis River during stream surveys.

Reach	Date	Time	Temperature ºC
11	10/12	16:00	11.1
13	10/13	9:00	10.0
13	10/13	13:30	11.1
15	No temperature reading		

4.A.2.2. Channel Morphology

The East Fork Lewis River reaches 11-13 are comprised primarily of pools. Large cobble/boulder riffles and glides are also prominent habitat types. There is no small cobble/gravel riffle habitat in reach 11 and no glide habitat in reach 15. Some of the riffles in reaches 11 and 13 are rapids. The East Fork Lewis reaches 11, 13, and 15 are primarily boulder/bedrock reaches with areas of step-pool and plane-bed morphologies (Montgomery and Buffington 1998).

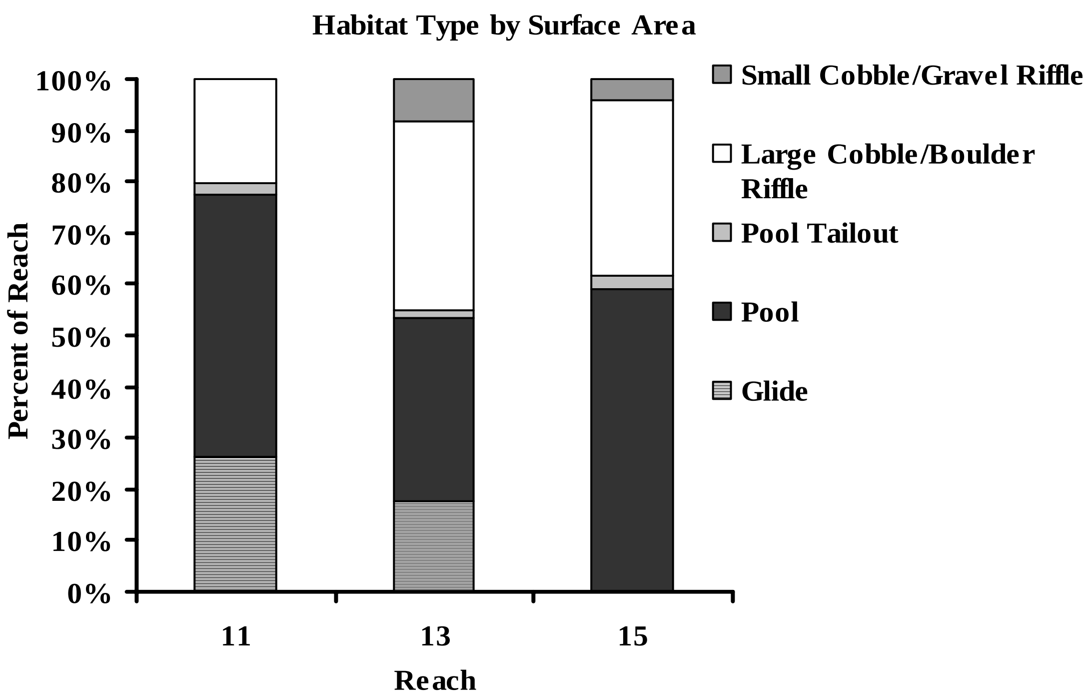


Figure 4. 51. Unit composition by percent surface area of the surveyed reaches of the East Fork Lewis River above Lucia Falls.

Figure 4. 52. Photo of the East Fork Lewis River reach 13.

The East Fork Lewis River in reaches 11, 13, and 15 is moderate gradient (0.8 – 1.7%) and is confined in many places by bedrock walls or steep valley walls. Mean widths range from 16.8m to 24.0m and average riffle depth ranges from 0.9m to 2.4m (Table 4. 44). Pools are most frequent in reach 15 and all of the pools are greater than 1.0m deep. The confinement of the reaches inhibits the formation of side channels.

Table 4. 44. Average channel morphology characteristics of surveyed sections of the East Fork Lewis River above Lucia Falls.

Parameter	Reach 11	Reach 13	Reach 15
Mean gradient[1]	0.84	0.94	1.72
Mean riffle wetted width (m)	16.8	24.0	17.7
Mean active channel width (m)	22.4	30.6	19.5
Mean maximum riffle depth[2] (m)	2.0	1.8	0.9
Mean residual pool depth[2] (m)	1.6	2.6	2.3
Mean maximum pool depth[2] (m)	2.5	3.3	2.8
Pools per kilometer	3.9	2.9	8.6
Primary pools (>1.0m deep) per kilometer	3.9	2.9	8.6
% of Length with side channel[3]	0	0	0

1. *As determined from LiDAR contours.*
2. *Approximation. Some units were too deep to measure maximum depth so estimates were made. These values likely underestimate actual depths.*
3. *Dry or wetted side channels.*

4.A.2.3. Wood

Wood availability is very low in each of the three reaches. Reach 13 has the greatest wood availability with a total of 4.3 pieces of LWD per kilometer (Table 4. 45). Only one jam and one rootwad are present among all three reaches.

Table 4. 45. Size and density of wood, jams, and root wads in the surveyed section of the East Fork Lewis River.

Wood Category	Reach 11	Reach 13	Reach 15
Small Pieces[1]	0.0	1.4	0.0
Medium Pieces[2]	0.8	1.9	1.0
Large Pieces[3]	0.8	1.0	0.0
Jams[4]	0.0	0.4	0.0
Root wads[5]	0.0	0.4	0.0

1. *10-20 cm diameter; >2 m long*
2. *20-50 cm diameter; >2 m long*
3. *>50 cm diameter; >2 m long*
4. *>10 pieces in accumulation*
5. *>2 m long*

4.A.2.4. Substrate

Characterization of substrate based on visual observation showed that the dominant substrate class in pools is cobble in reaches 11 and 15 and boulders in reach 13 (Figure 4. 53). The data from pools should be viewed with some caution because the substrate in the deepest portion of many pools could not be seen, so substrate calls were made where the substrate was visible. This may have caused some bias in pool substrate estimates. In riffles, boulders are the dominant substrate class in reaches 11 and 13. Cobble is the dominant size class in riffles in reach 15 (Figure 4. 54). Sand makes up less than 10% of the substrate in either pools or riffles, but is greatest in pools. There is a significant bedrock presence in all three reaches. Grain sizes for each substrate category are listed in Table 4. 46.

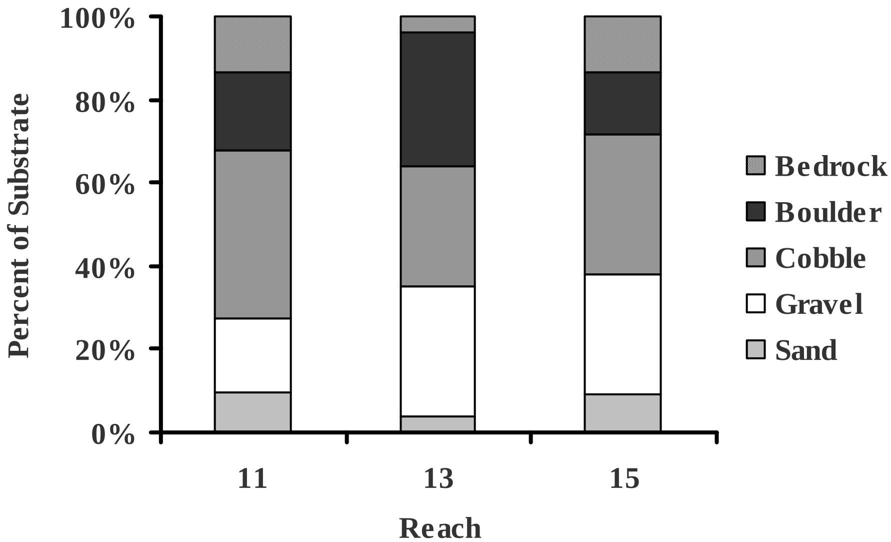


Figure 4. 53. Substrate size class composition in pools in surveyed reaches of the East Fork Lewis above Lucia Falls.

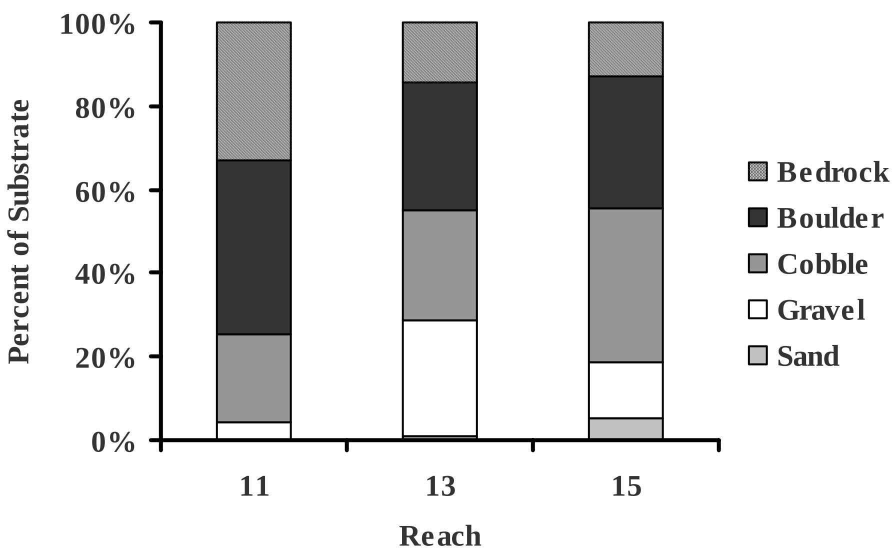


Figure 4. 54. Substrate size class composition in riffles in surveyed reaches of the East Fork Lewis above Lucia Falls.

Table 4. 46. Grain size ranges for substrate size categories used in visual observations and pebble counts.

Category	Grain Size Range (mm)
Sand	< 2
Gravel	2 – 64
Cobble	64 – 256
Boulder	256 – 4096
Bedrock	>4096

Embeddedness was rated in each unit according to four categories (0-25%, 25-50%, 50-75%, and 75-100%). Embeddedness was estimated in riffles, glides, and pool tailouts. Embeddedness in each of the reaches of the East Fork Lewis is generally rated low (0-25%) though some units in reach 15 are classified as 25-50% embedded (Figure 4. 55).

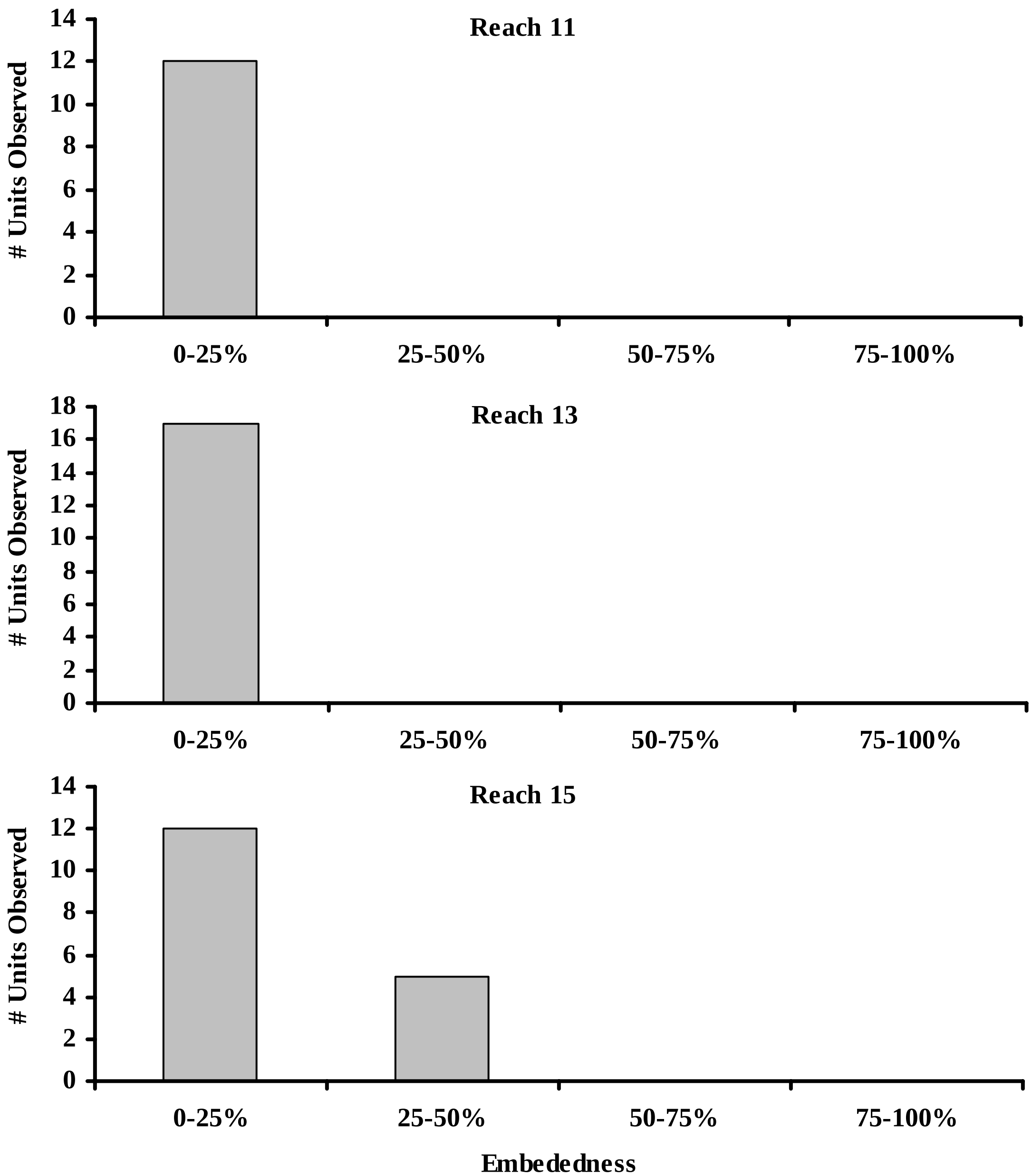


Figure 4. 55. Frequency of embeddedness ratings in surveyed reaches of the middle mainstem East Fork Lewis River.

The only pebble count conducted within these three reaches was in reach 13. Generally, it was not safe to conduct pebble counts in the tail-out of pools in these reaches. The tail of NSO 2 in reach 13 was broad and shallow allowing the opportunity to conduct a count. It is important to note that because of these factors, this unit may not be representative of other pools within these reaches. The most frequently selected size category was bedrock and the most selected size class was cobble. The median size category was 64-90mm. Sand made up four percent of the particles selected.

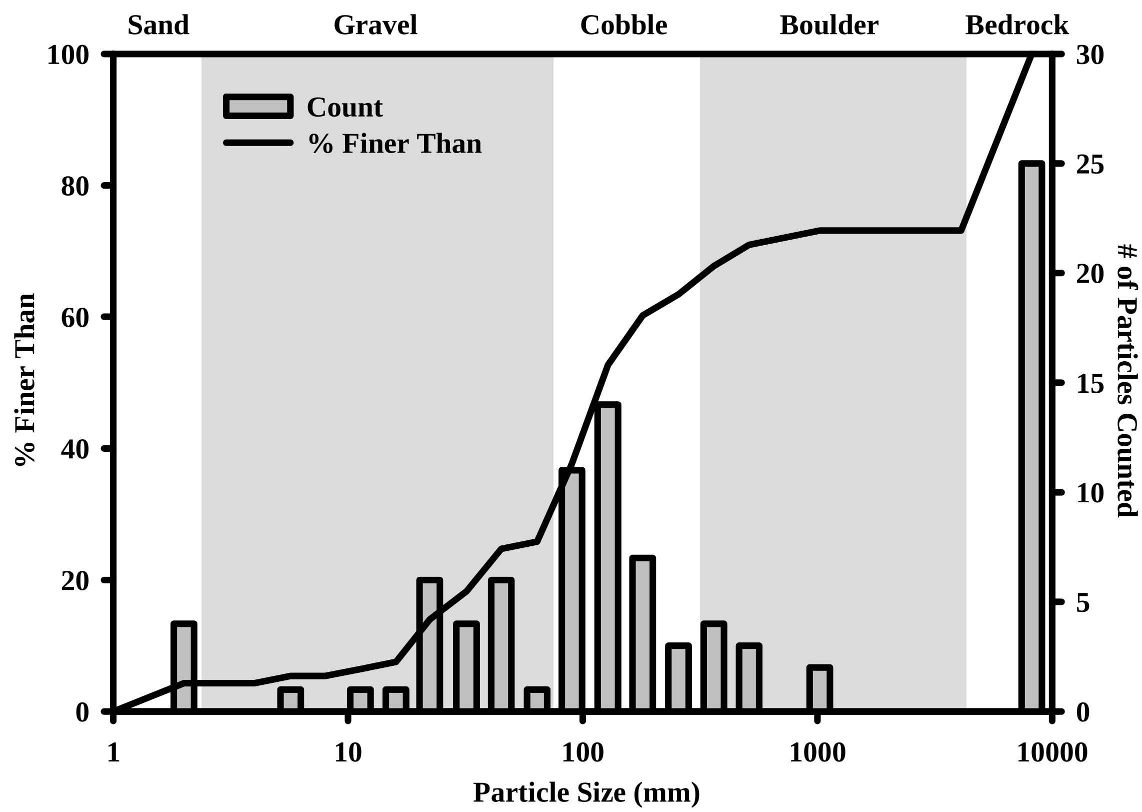


Figure 4. 56. Grain size distribution based on pebble counts in the East Fork Lewis reach 13.

4.A.2.5. Cover

Cover is provided in the East Fork Lewis by depth and substrate. Large woody debris, undercut banks, and overhanging vegetation do not provide significant cover. Depth provides cover over 12-76% of the surface area with the greatest amount in reach 11 and the least in reach 15. Velocity breaks from substrate cover 9-22% of the habitat with the most in reach 13 and the least in reach 11. Reach 11 has the highest cover availability of the three reaches at 85%, while reach 15 has the least at 27% (Table 4. 47).

Table 4. 47. Presence of cover within the surveyed portion of the middle mainstem East Fork Lewis River. Cover is measured as percent surface area of the surveyed reach.

Cover Type	Reach 11	Reach 13	Reach 15
LWD	0	0	0
Undercut Bank	0	0	0
Overhanging Cover	0	0	0
Depth > 1m	76	36	12
Substrate (Velocity cover)	9	22	15

4.A.2.6. Riparian

The mean view to sky angle in Rock Creek ranges from 51-77 degrees (Table 4. 48). Shading is the greatest in the most confined reach and the reach with no road along the bank (Reach 13). The dominant overstory vegetation varied by reach and by bank. Conifers were present on both banks in all three reaches. Hardwoods were present on the left bank in reaches 11 and 13 and on the right bank in reaches 13 and 15. Mixed conifers/hardwoods were present everywhere except in reach 13 on the left bank (Figure 4. 57).

Table 4. 48. Riparian shading characteristics in the surveyed sections of the middle mainstem East Fork Lewis River. The data is presented as proceeding downstream.

Parameter	Reach 11	Reach 13	Reach 15
Mean distance to vegetation – left bank (m)	29	38	13
Mean left bank canopy angle (degrees)	55	43	69
Mean distance to vegetation – right bank (m)	30	16	17
Mean right bank canopy angle (degrees)	60	60	60
Mean view to sky (degrees)	65	77	51

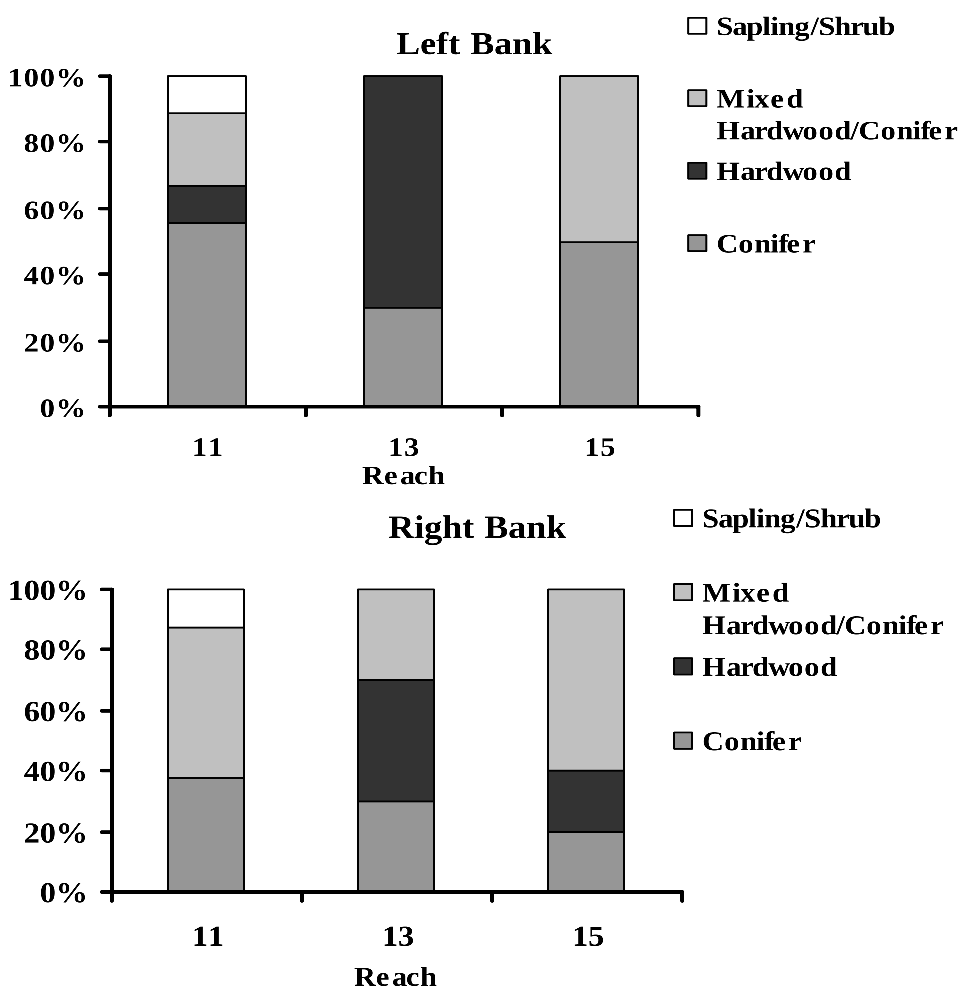


Figure 4. 57. Vegetation type by percentage of units observed. Data presented as proceeding downstream.

4.A.2.7. Instability & Disturbance

There is no bank instability in the surveyed portions of reaches 11, 13, and 15 (Table 4. 49). Each of the reaches is buffered to a significant degree against instability by bedrock walls.

The riparian zones of each of the reaches are slightly or moderately disturbed. Reach 11 suffers the greatest disturbance from a road following the right bank and a hiking/biking trail along the left bank. The road follows near enough to the river for a couple hundred meters that the right bank is armored by rip-rap. Reach 11 is also disturbed by invasive vegetation. Both reed canary grass (*Phalaris arundinacea*) and Japanese knotweed (*Polygonum cuspidatium*) are present in the riparian area. Reach 13 is disturbed along the lowest section by the same road and hiking trail as along reach 11. There is also a county park along the right bank at the lower end of the reach. Reach 15 is disturbed by a highway and residences along the right bank and clear-cut timber harvest on the left bank.

Table 4. 49. Bank instability and disturbance of the surveyed sections of the middle mainstem East Fork Lewis River. Data presented as proceeding downstream.

Parameter	Reach 11	Reach 13	Reach 15
Left bank instability (%)	0	0	0
Right bank instability (%)	0	0	0
Left bank disturbance (%)	10	7	12
Right bank disturbance (%)	23	7	17

4.A.2.8. Comparison to Habitat Standards

Numerous standards for rating the quality of salmonid (*Oncorhynchus sp.*) habitat have been developed. Data collected in this survey were rated via two sets of standards applicable to basins of southwest Washington. The Washington Conservation Commission (WCC) established a set of standards to identify factors limiting salmonid production throughout the state. Standards applicable to western Washington were used here. Habitat features in surveyed reaches of the East Fork Lewis were also compared to the NOAA Fisheries Properly Functioning Condition (PFC) standards. Only standards applicable to data collected were incorporated.

The available amount of pool surface area in reaches 11 and 15 is rated as “good” under the WCC criteria (Table 4. 50). Percent pool in reach 13 is rated as “fair”. Pool frequency is rated as “Not Properly Functioning” for the three reaches but pool quality is rated as “Properly Functioning.” Substrate was rated as “At Risk” in reaches 11 and 13 because neither cobble nor gravel are the dominant substrate (boulders are dominant). Streambank stability is rated favorably for all three reaches.

Table 4. 50. East Fork Lewis habitat feature ratings under regional salmonid habitat quality standards. Gray shaded cells indicate that no standard is available. PF = properly functioning; NPF = not properly functioning.

Parameter	Reach 11 WCC[1]	Reach 11 PFC[2]	Reach 13 WCC[1]	Reach 13 PFC[2]	Reach 15 WCC[1]	Reach 15 PFC[2]
% Pool by Surface Area	Good		Fair		Good	
Pool Frequency		NPF		NPF		NPF
Pool Quality		PF		PF		PF
LWD		NPF		NPF		NPF
Substrate		At Risk		At Risk		PF
Streambank Stability	Good	PF	Good	PF	Good	PF
Barriers	Good	PF	Good	PF	Good	PF

1. Available ratings: good; fair; poor
2. Available ratings: properly functioning; at risk; not properly functioning

4.A.2.9. Comparison to EDT Values

EDT patient scores are generally consistent with scores assigned based on survey results. An important difference is the breakdown of habitat units. In reach 11 there are more glides and less pool tailout habitat than represented by the EDT patient scores. In reaches 13 and 15 there is more riffle habitat and less pool habitat than assigned by EDT (Table 4. 51).

Table 4. 51. EDT Patient scores assigned to the lower East Fork Lewis River and EDT scores based on 2004 stream survey results for categories relevant to data collected. Gradient is for the entire EDT reach, not just the surveyed section.

Category	EDT Patient Score	Score from Survey
Reach 11		
Channel width – minimum (m)	20.4	16.8
Gradient %	0.7	0.7
Confinement – hydromodifications	0	1
Confinement – natural	3	4
Habitat Type – Glides	6%	27%
Habitat Type – Beaver ponds	0%	0%
Habitat Type – off-channel habitat factor	0%	0%
Habitat Type – pool tailouts	17%	2%
Habitat Type – primary pools	53%	52%
Habitat Type – small cobble/gravel riffles	0%	0%
Habitat Type – Large cobble/boulder riffles	24%	21%
Riparian Function	1	1.5
Wood	4	4
Embeddedness	0.8	0.8
Reach 13	**EDT Patient Score**	**Score from Survey**
Channel width – minimum (m)	17.7	24.0
Gradient %	1.1	1.2
Confinement – hydromodifications	0	0
Confinement – natural	4	4
Habitat Type – Glides	8%	18%
Habitat Type – Beaver ponds	0%	0%
Habitat Type – off-channel habitat factor	0%	0%
Habitat Type – pool tailouts	5%	2%
Habitat Type – primary pools	18%	36%
Habitat Type – small cobble/gravel riffles	0%	8%
Habitat Type – Large cobble/boulder riffles	69%	38%
Riparian Function	1	1.5
Wood	4	4
Embeddedness	0.8	0.8
Reach 15	**EDT Patient Score**	**Score from Survey**
Channel width – minimum (m)	17.1	17.7
Gradient %	1.1	1.7
Confinement – hydromodifications	0	0
Confinement – natural	4	4
Habitat Type – Glides	5%	0%
Habitat Type – Beaver ponds	0%	0%
Habitat Type – off-channel habitat factor	0%	0%
Habitat Type – pool tailouts	5%	3%
Habitat Type – primary pools	37%	61%
Habitat Type – small cobble/gravel riffles	5%	4%
Habitat Type – Large cobble/boulder riffles	48%	35%
Riparian Function	1	1.5
Wood	3	4
Embeddedness	0.8	1.1

4.A.2.10. Potential Areas of Restoration

Potential restoration opportunities in the East Fork Lewis above Lucia falls are discussed in section 4.3.3 of this report.

4.A.3. McCormick Creek

4.A.3.1. Introduction

McCormick Creek is located in Clark County approximately 1.5 km west of the town of La Center, WA and enters the East Fork Lewis at RKm 3.7 (RM 2.3). McCormick Creek was surveyed on October 8 from the mouth upstream 0.9 km, representing 22% of the EDT McCormick Creek reach (Figure 4. 58). A modified version of the USFS Region 6 Level II Stream Survey Protocol was used for the survey (USFS 1999). A stream temperature of 13.6°C was recorded at 09:30 AM. Clark County owns the property along the survey reach and land-use is unmanaged grassland and timber.

The McCormick Creek EDT reach was split into two reaches because stream surveys, aerial photo analysis, and LiDAR stream contour analysis indicated that channel morphology and vegetation were substantially different between the lower portion of the stream that lies within the mainstem East Fork valley bottom and the upstream portion. The sub-divided reaches are denoted differently from the original reach name by adding an "A" or "B" to the end of the reach name with "A" indicating the downstream portion of the original reach and "B" the upstream portion. This survey was conducted in McCormick Creek_A, and the survey area accounts for 100% of the reach.

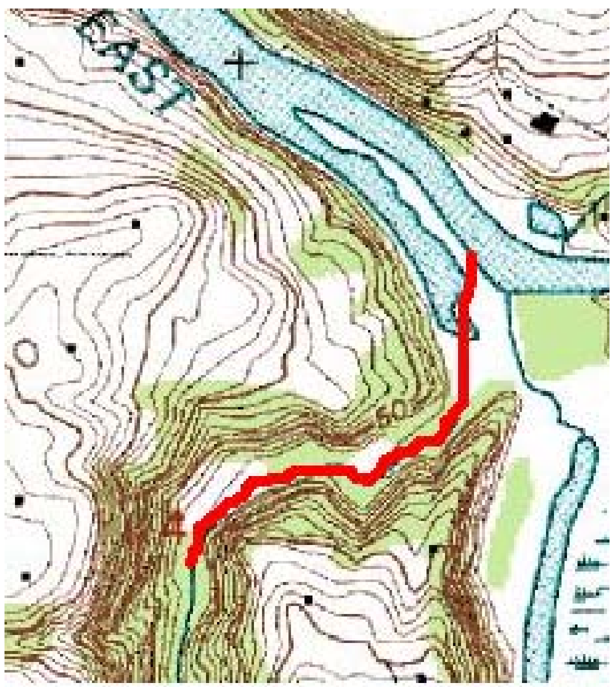


Figure 4. 58. USGS topographic map of McCormick Creek highlighting the stream survey area. Survey length is 0.9 kilometers. The stream channel no longer enters the East Fork Lewis as depicted by the USGS map, which shows the stream entering the large back channel. The highlighted survey area more accurately reflects the location of the stream, which bypasses the back channel and enters the main channel of the East Fork Lewis directly.

4.A.3.2. Channel Morphology

McCormick Creek is comprised primarily of slow-water habitat with 91% of habitat classified as either beaver ponds or pools, with beaver ponds the dominant habitat type (Figure 4. 59). There are no large cobble/boulder riffle habitat types within the survey area. Beaver ponds dominate the lower portion but near the upstream end the stream begins to transition to a pool-riffle morphology. Lower McCormick Creek is tidally influenced.

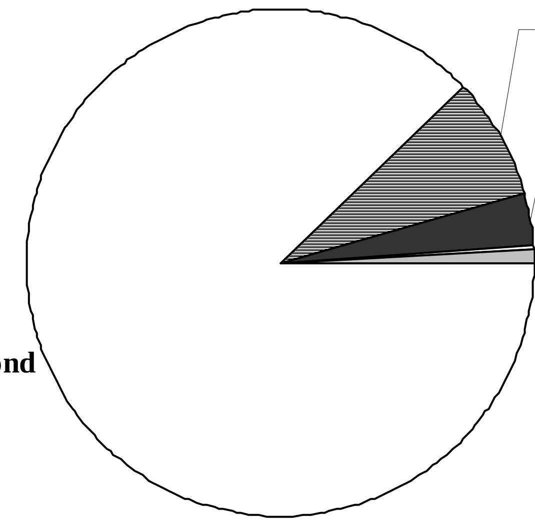


Figure 4. 59. Unit composition by percent surface area of the surveyed section of McCormick Creek.

McCormick Creek is very low gradient and lies within an unconfined valley. The stream is entrenched within its floodplain. The mean wetted width in riffles is only 0.9m. There is little water and the wetted depth is very shallow, consequently few deep pools are available (Table 4. 52).

Table 4. 52. Average channel morphology characteristics of surveyed section of McCormick Creek.

Parameter	Reach Value
Mean gradient[1]	0.5
Mean riffle wetted width (m)	0.9
Mean active channel width (m)	2.7
Mean maximum riffle depth (m)	0.1
Mean residual pool depth (m)	0.4
Mean maximum pool depth (m)	0.5
Mean maximum beaver pond depth (m)	0.9
Pools per kilometer[2]	4.6
Primary pools (>1.0m deep) per kilometer[2]	0.0
% of Length with side channel[3]	0

1. *As determined from LiDAR contours.*
2. *Does not include beaver ponds*
3. *Dry or wetted side channels.*

4.A.3.3. Wood

There are 35 pieces of LWD per kilometer in the surveyed section of McCormick Creek. A majority of those are small pieces (Table 4. 53). Most of the wood is within the beaver ponds where it provides cover. The beaver dams are constructed mainly of accumulations of small woody debris that are not large enough to be counted as LWD. Few trees are available in the riparian area for future wood recruitment. There is a significant amount of downed wood within the valley that spans the stream but is perched above the active channel due to entrenchment (Figure 4. 60). Branches from these fallen trees reach into the stream but most are too small to qualify as LWD. These branches do provide some overhead cover.

Table 4. 53. Size and density of wood, jams, and root wads in the surveyed section of McCormick Creek.

Wood Category	Definition	# Per Kilometer
Small Pieces	10-20 cm diameter; >2 m long	24
Medium Pieces	20-50 cm diameter; >2 m long	9
Large Pieces	>50 cm diameter; >2 m long	2
Jams	>10 pieces in accumulation	0
Root wads	>2 m long	0

Figure 4. 60. Photo of a tree that has fallen but is perched above the active channel due to the entrenchment of the stream.

4.A.3.4. Substrate

Characterization of substrate based on visual observation showed that the dominant and sub-dominant substrate classes in pools are sand and gravel, respectively, while in pools, gravel is dominant and sand is subdominant. Substrate in the beaver ponds is entirely sand. No boulders or bedrock are present in the survey area and cobble presence is negligible (Table 4. 54). Grain sizes for each category are listed in Table 4. 54.

Table 4. 54. Grain size ranges for substrate size categories used in visual observations and pebble counts.

Category	Grain Size Range (mm)
Sand	< 2
Gravel	2 – 64
Cobble	64 – 256
Boulder	256 – 4096
Bedrock	>4096

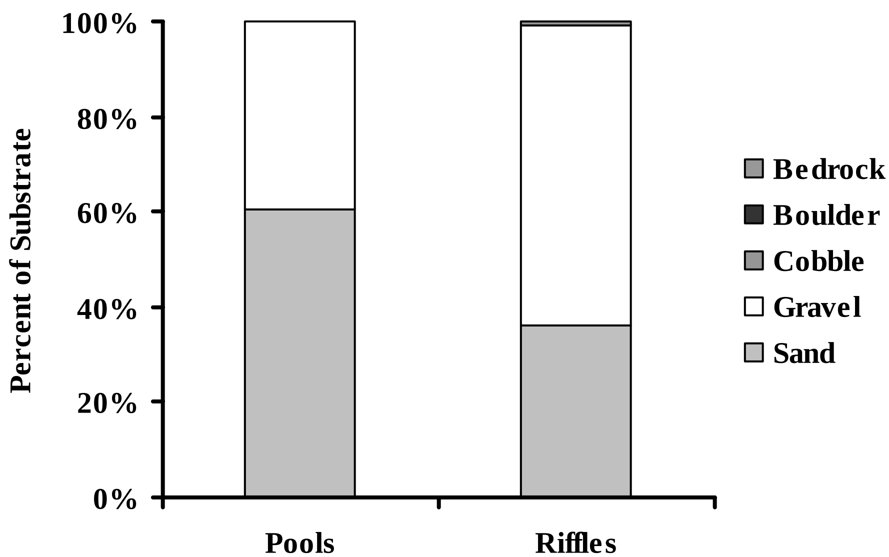


Figure 4. 61. Substrate size class composition in pools and riffles in the surveyed section of McCormick Creek.

Embeddedness was rated in each unit according to four categories (0-25%, 25-50%, 50-75%, and 75-100%). Embeddedness was estimated in riffles and pool tailouts where gravel or cobble were present. Embeddedness was rated in only 13 units and ratings among the embeddedness categories were relatively evenly spread. The median rating is 50-75%. This reach is a very low gradient depositional zone that would be expected to have a high level of embeddedness under natural conditions.

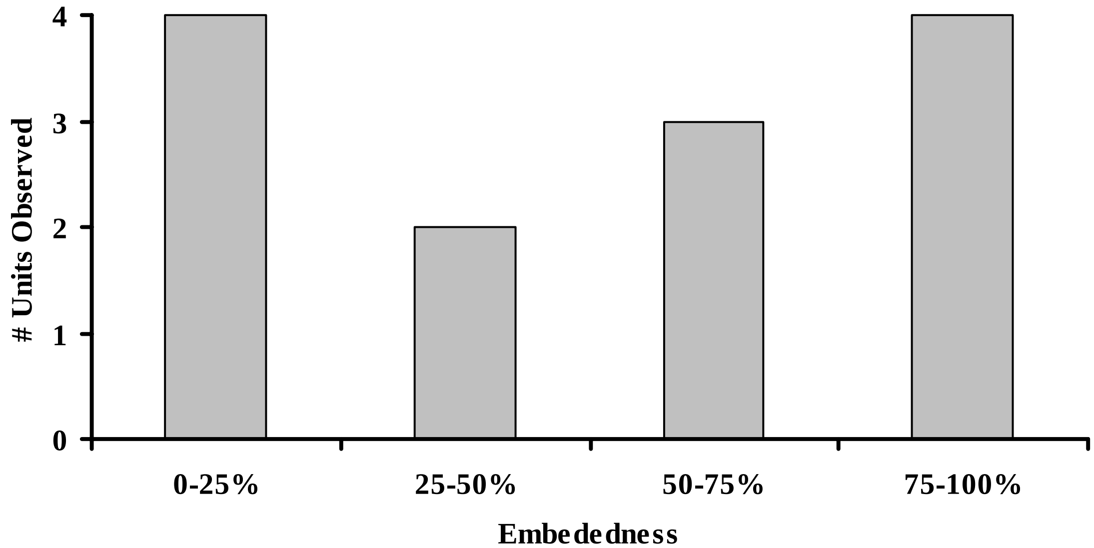


Figure 4. 62. Frequency of embeddedness ratings in the surveyed section of McCormick Creek.

No pebble counts were conducted in McCormick Creek because few pools are available and tailouts are not well defined.

4.A.3.5. Cover

Cover is provided in McCormick Creek primarily by overhanging cover. McCormick Creek is very narrow and entrenched. Trees have fallen and are perched above the stream but the branches hang into the stream and provide overhead cover (see Figure 4. 60). Cover is provided by depth in the beaver ponds (Table 4. 55).

Table 4. 55. Presence of cover within the surveyed portion of McCormick Creek; measured as percent of surface area of stream unit covered.

Cover Type	Average % Cover Provided
LWD	0
Undercut Bank	0
Overhanging Cover	41
Depth > 1m	7
Substrate (Velocity cover)	0

4.A.3.6. Riparian

The surveyed section of McCormick Creek has a view to sky angle (VTS) of 76 degrees (Table 4. 56). The dominant shading vegetation is mixed hardwoods and conifers at the edges of the valley. The valley bottom is dominated by reed canary grass (*Phalaris arundinacea*) with occasional shrubs and Oregon ash (*Fraxinus latifolia*) trees. In some instances the dominant shading vegetation is the reed canary grass at the top of the bank of the entrenched stream. The overstory at the edges of the valley was considered the primary shade producer.

The dominant vegetation on the left bank is grasses and forbs, predominantly reed canary grass. Mixed hardwoods and conifers are present but most of them are greater than 35m from the stream. The right bank is nearer to the valley wall and a mix of hardwoods and conifers make up the dominant vegetation type. The valley bottom between the stream channel and valley wall is dominated by grasses (Table 4. 56). Figure 4. 64 represents riparian vegetation typical of the surveyed section of McCormick Creek.

Table 4. 56. Riparian shading characteristics in the surveyed section of McCormick Creek. Data presented as proceeding downstream.

Parameter	Result
Mean distance to vegetation – left bank (m)	32
Mean left bank canopy angle (degrees)	52
Mean distance to vegetation – right bank (m)	24
Mean right bank canopy angle (degrees)	52
Mean view to sky (degrees)	76

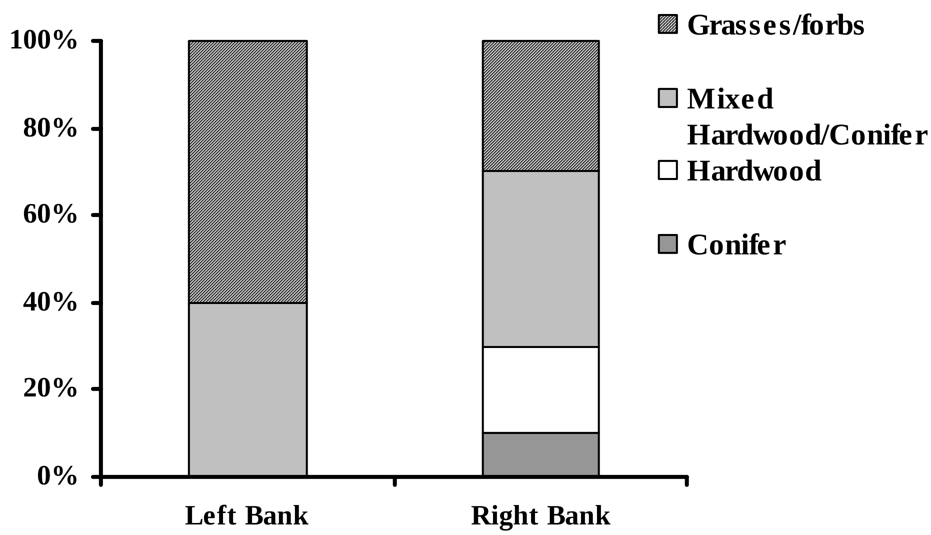


Figure 4. 63. Dominant vegetation type by percentage of units observed. Data presented as proceeding downstream.

Figure 4. 64. Photo looking upstream at the McCormick Creek valley. Notice the dominance of grasses on the valley bottom and mixed hardwoods and conifers beginning at the valley walls.

4.A.3.7. Instability & Disturbance

Bank instability in the surveyed section of McCormick Creek is essentially 100% on both banks. Reed canary grass is acting as a stabilizer to some extent but entrenchment of the stream has resulted in exposure of loose soil on both banks throughout. In multiple locations the instability of the bank has resulted in bank slumping sometimes creating small dams of earthen material. Entrenchment depth varies from 1.7m near the mouth of the creek to 1.0m near the upstream end of the survey (Figure 4. 65). The riparian zones on both banks are nearly 100% impacted from entrenchment and/or invasive species (Table 4. 57). There is no development in the reach.

Table 4. 57. Bank instability and disturbance of the surveyed section of McCormick Creek. Data presented as proceeding downstream.

Parameter	Result	Comment
Left bank instability (%)	100	
Right bank instability (%)	100	
Left bank disturbance (%)	100	Invasive vegetation; entrenchment
Right bank disturbance (%)	100	Invasive vegetation; entrenchment

Figure 4. 65. Photo of mouth of McCormick Creek illustrating severe entrenchment and dominance of reed canary grass. Entrenchment here is approximately 1.7m. Entrenchment drops to 1.0m at the upper end of the survey.

4.A.3.8. Other Observations

There is a washed out culvert in the stream within the first unit measuring 1.0m in diameter and 3-4m in length. The culvert runs parallel to the flow and is not acting as a barrier though the stream flows both through and around it. In addition to the invasive plants mentioned earlier, *Spirea* and duckweed (*Lemnacea*) were also observed. When gravel substrate was encountered near the upstream end of the survey, there was an abundance of tiny snails of unidentified species. Eleven beaver dams are present in the reach. Some beaver dams, which reach as high as 0.65 meters, may limit adult fish passage. The shallow depth below the dams may prevent salmonids from gaining enough thrust to jump the dams (Figure 4. 66). At low flow, there is probably not enough water for a salmon or steelhead to move upstream far enough to reach the dams.

Figure 4. 66. Typical beaver dam in McCormick Creek. Dam height above wetted surface is 0.4m.

4.A.3.9. Comparison to Habitat Standards

Numerous standards for rating the quality of salmonid habitat have been developed. Data collected in this survey were rated via two sets of standards applicable to basins of southwest Washington. The Washington Conservation Commission (WCC) established a set of standards to identify factors limiting salmonid production throughout the state. Standards applicable to western Washington were used here. McCormick Creek habitat features were also compared to the NOAA Fisheries Properly Functioning Condition (PFC) standards. Only standards applicable to data collected were incorporated.

McCormick Creek performed poorly when rated under the WCC and PFC criteria (Table 4. 58). Each of the parameters with the exception of barriers received the lowest rating under each criteria evaluated. There are few pools, few pieces of functional large woody debris, embedded substrate, and highly unstable banks.

Table 4. 58. McCormick Creek habitat feature ratings according to regional salmonid habitat quality standards. Gray shaded cells indicate that no standard is available.

Parameter	WCC[1]	PFC[2]
% Pool by Surface Area	Poor	
Pool Frequency	Poor	Not Properly Functioning
Pool Quality		Not Properly Functioning
LWD	Poor	Not Properly Functioning
Substrate		Not Properly Functioning
Streambank Stability	Poor	Not Properly Functioning
Barriers	Good	Properly Functioning

1. *Available ratings: good; fair; poor*
2. *Available ratings: properly functioning; at risk; not properly functioning*

4.A.3.10. Comparison to EDT Values

EDT patient scores differ from the scores assigned based on survey results. It is important to consider that the surveyed section of McCormick Creek only represents 22% of the EDT reach. The habitat above the survey reach is likely significantly different than that within the survey reach due to differences in stream morphology. Specifically, the upstream gradient is higher and the valley is more confined, suggesting a greater proportion of pool-riffle habitat, a lower amount of main channel beaver pond habitat, and more gravels and cobbles.

In the surveyed section, there are far fewer glides and more beaver ponds than the EDT score represents. Both confinement from hydromodifications and riparian function are rated higher than assigned by EDT based on survey observations of severe entrenchment. Natural confinement is rated lower than EDT patient conditions since the survey area is largely unconfined. Embeddedness was rated as zero because EDT attribute designation criteria state that reaches where gravel and cobble substrate do not exist, embeddedness should be rated zero. Neither gravel nor cobble are present throughout most of the surveyed reach.

Table 4. 59. EDT Patient scores assigned to McCormick Creek and EDT scores based on 2004 stream survey results for categories relevant to data collected.

Category	EDT Patient Score	Score from Survey[1]
Channel width – minimum (m)	3.0	0.9
Gradient	1.3	0.5
Confinement – hydromodifications	0	4
Confinement – natural	4	0
Habitat Type – Glides	39%	8%
Habitat Type – Beaver ponds	0%	87%
Habitat Type – off-channel habitat factor	0%	0%
Habitat Type – pool tailouts	8%	0%
Habitat Type – primary pools	32%	4%
Habitat Type – small cobble/gravel riffles	16%	1%
Habitat Type – Large cobble/boulder riffles	5%	0%
Riparian Function	1	4
Wood	3	4
Embeddedness	0.9	0

[1] *It is important to note that the survey represents only 22% of the entire EDT reach and conditions in the non-surveyed portion of the reach differ substantially from the surveyed portion.*

4.A.3.11. Potential Areas of Restoration

There is restoration opportunity in lower McCormick Creek. The stream has been isolated from its floodplain via entrenchment and as a result riparian function is impaired. There is little potential for wood recruitment since the only overstory is sparse ash. Entrenchment has resulted in unstable banks. Pool and wood availability are low although there is a high proportion of beaver ponds. Considering the gradient, this reach has probably always been a depositional area for fine sediments from both McCormick Creek and the East Fork Lewis River. Potential restoration efforts should focus on reducing entrenchment, eradicating invasive species, re-establishing native riparian vegetation, and adding complexity and cover. Restoration opportunities of lower mainstem East Fork tributaries that lie within the mainstem valley bottom are discussed further in Section 4.3.2.

4.A.4. Lockwood Creek

4.A.4.1. Introduction

Lockwood Creek is located in Clark County approximately 1.5km southwest of the town of La Center, WA and enters the East Fork Lewis at RKm 7.2 (RM 4.5). Lockwood Creek was surveyed on October 11 from RKm 1.3 to 2.2 (RM 0.8 to 1.3) representing 10% of the EDT Lockwood Creek reach (Figure 4. 67). A modified version of the USFS Region 6 Level II Stream Survey Protocol was used for the survey (USFS 1999). A single temperature of 11.4°C was recorded at 11:15 AM.

The Lockwood Creek EDT reach was split into two reaches because stream surveys, aerial photo analysis, and LiDAR stream contour analysis indicated that habitat within portions of the reach were substantially different. The sub-divided reaches are denoted differently from the original reach name by adding an "A" or "B" to the end of the reach name with "A" indicating the downstream portion of the original reach and "B" the upstream portion. This survey was conducted in Lockwood Creek_B, and the survey area accounts for 11% of the reach.

Landownership within the survey reach is private rural residential. Land use within the stream valley is mostly unmanaged, with some small scale agriculture and timber uses. There is one residence near the stream at the upstream end of the surveyed segment.

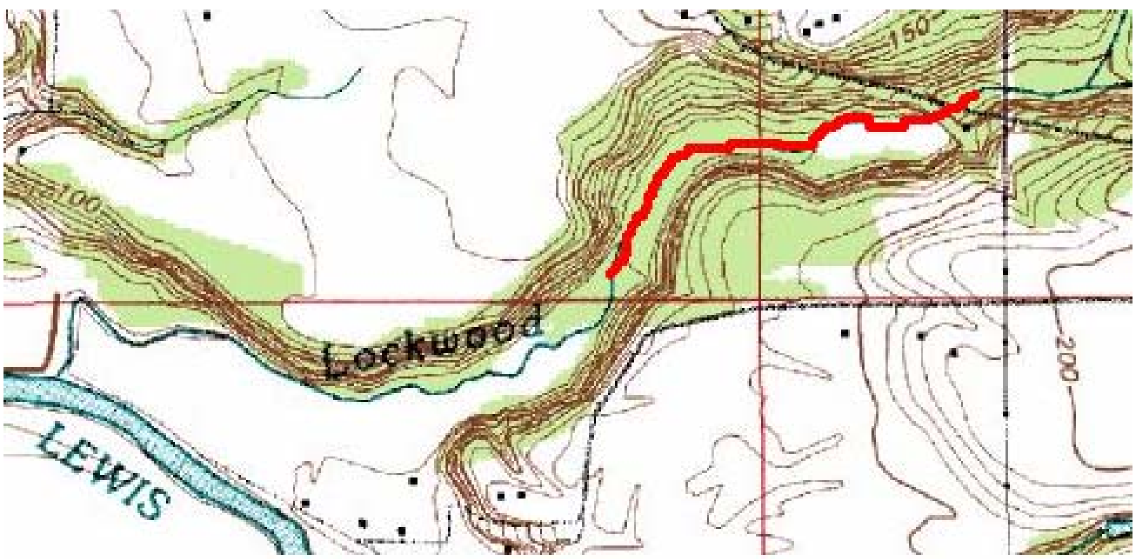


Figure 4. 67. USGS topographic map of Lockwood Creek highlighting the stream survey area. Survey length is 1.0 kilometer.

4.A.4.2. Channel Morphology

Lockwood Creek is comprised primarily of pools with a significant amount of small gravel/cobble riffles and beaver ponds (Figure 4. 68). A majority of the surveyed portion of Lockwood Creek has a pool-riffle morphology (Montgomery and Buffington, 1998). The downstream end of the survey area is dominated by beaver ponds. Upstream of the beaver ponds there are clearly defined pools and riffles.

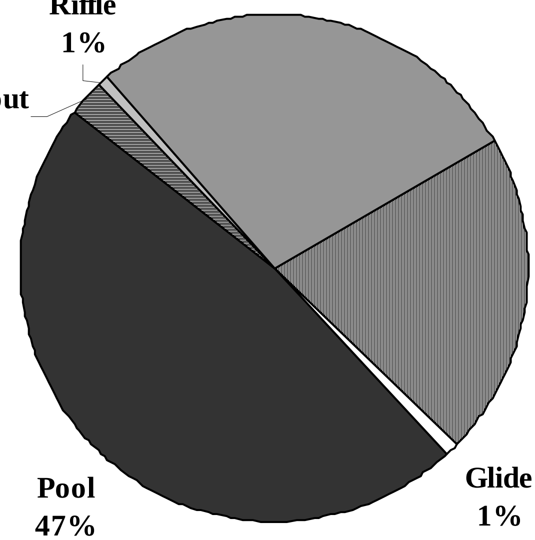


Figure 4. 68. Unit composition by percent surface area of the surveyed section of Lockwood Creek.

Lockwood Creek is low gradient and unconfined throughout the survey area, though it has undergone some entrenchment that may be related to anthropogenic influences. The valley bottom maintains a broad wetland that probably historically received overflow from Lockwood Creek on an annual basis. With the current entrenchment, the wetland is likely inundated less frequently than historically. The wetland may have functioned as an important over-winter rearing area in the past. Riffles are shallow and average 5.5m wide. There are 23.4 pools per kilometer, but few of those are greater than 1m deep (Table 4. 60).

Table 4. 60. Average channel morphology characteristics of the surveyed section of Lockwood Creek.

Parameter	Reach 1 Value
Mean gradient[1]	0.7
Mean riffle wetted width (m)	5.5
Mean active channel width (m)	7.1
Mean maximum riffle depth (m)	0.3
Mean residual pool depth (m)	0.6
Mean maximum pool depth (m)	0.8
Pools per kilometer	23.4
Primary pools (>1.0m deep) per kilometer	2.9
% of Length with side channel[2]	1

1. *As determined from LiDAR contours.*
2. *Dry or wetted side channels.*

4.A.4.3. Wood

There were 35 pieces of LWD per kilometer in the surveyed section of Lockwood Creek. Small pieces made up the largest portion among size classes, followed by medium and then large pieces. There were 1 jam and 1 rootwad per kilometer (Table 4. 61).

Table 4. 61. Size and density of wood, jams, and root wads in the surveyed section of Lockwood Creek.

Wood Category	Definition	# Per Kilometer
Small Pieces	10-20 cm diameter; >2 m long	19
Medium Pieces	20-50 cm diameter; >2 m long	11
Large Pieces	>50 cm diameter; >2 m long	5
Jams	>10 pieces in accumulation	1
Root wads	>2 m long	1

4.A.4.4. Substrate

Characterization of substrate based on visual observation showed that the dominant and subdominant substrate classes in pools is gravel and sand, respectively. The same is true in riffles, except the percentage of substrate as gravel is greater (Figure 4. 69). Sand makes up 38% of the substrate in pools and 18% of the substrate in riffles. Grain sizes for each category are listed in Table 4. 62.

Table 4. 62. Grain size ranges for substrate size categories used in visual observations and pebble counts.

Category	Grain Size Range (mm)
Sand	< 2
Gravel	2 – 64
Cobble	64 – 256
Boulder	256 – 4096
Bedrock	>4096

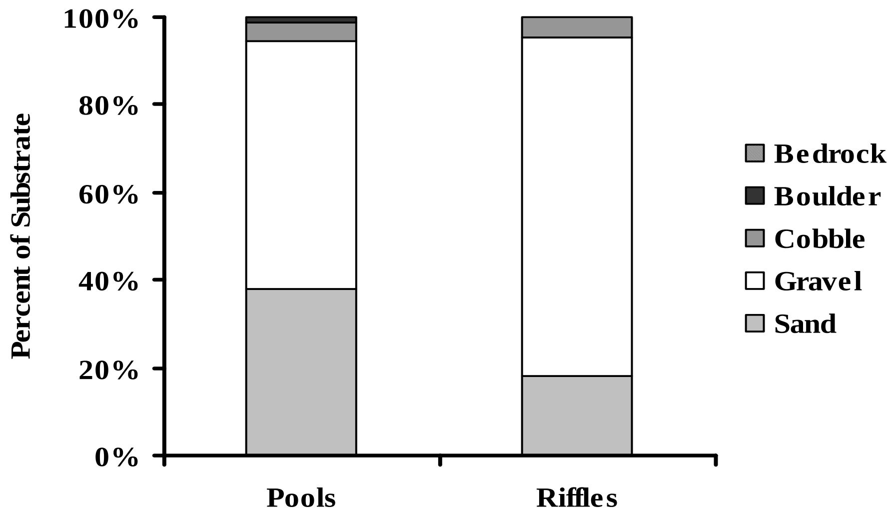


Figure 4. 69. Substrate size class composition in pools and riffles in the surveyed section of Lockwood Creek.

Embeddedness was rated in each unit according to four categories (0-25%, 25-50%, 50-75%, and 75-100%). Embeddedness was estimated in riffles, glides, and pool tailouts. Forty-six percent of embeddedness ratings in Lockwood Creek fall within the 50-75% category and an additional 41% are in the 25-50% category (Figure 4. 70). Embeddedness for the entire reach averaged about 50%. Figure 4. 71 is a photo showing the typical level of embeddedness in Lockwood Creek.

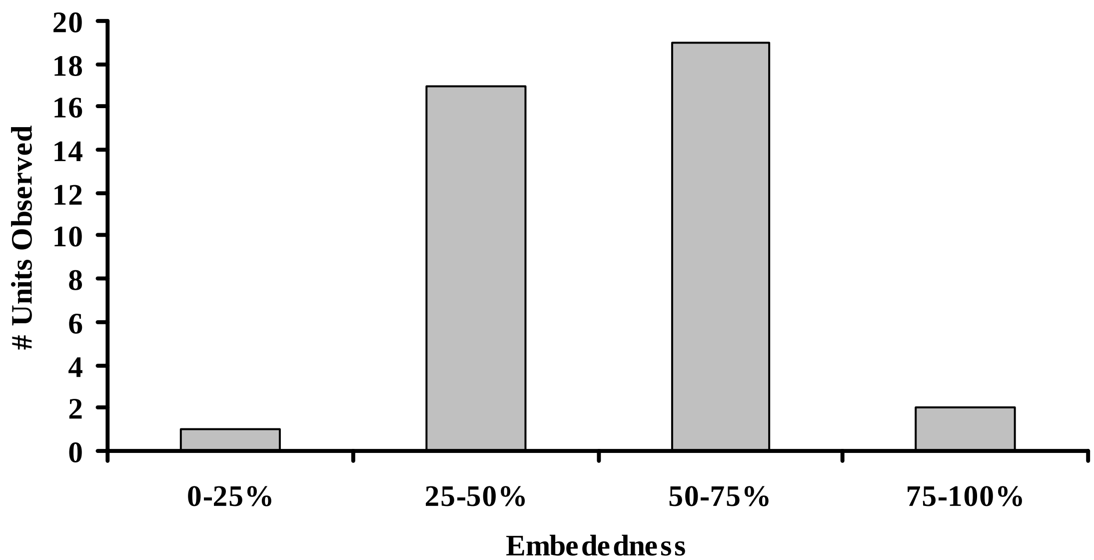


Figure 4. 70. Frequency of embeddedness ratings in the surveyed section of Lockwood Creek.

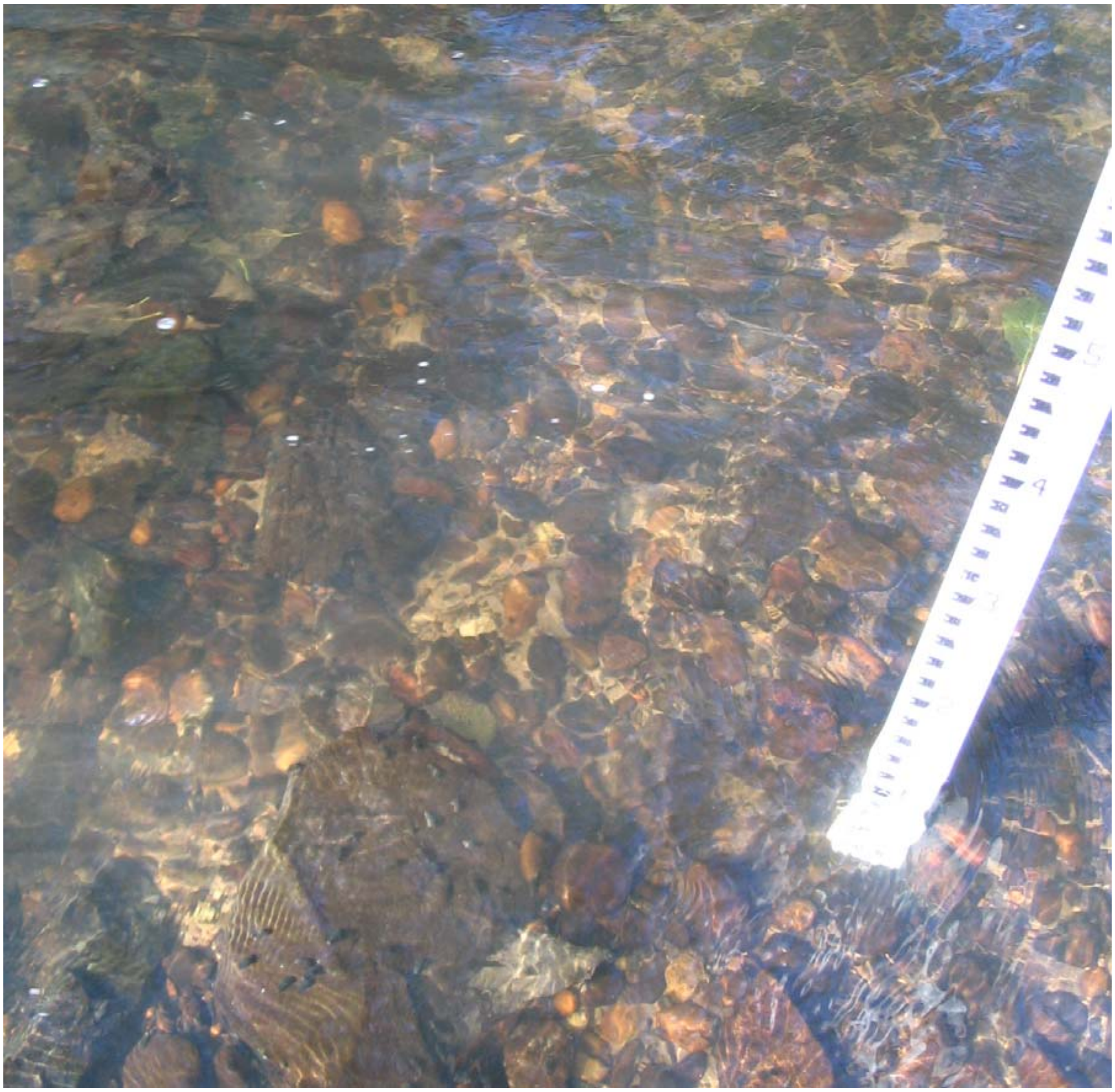
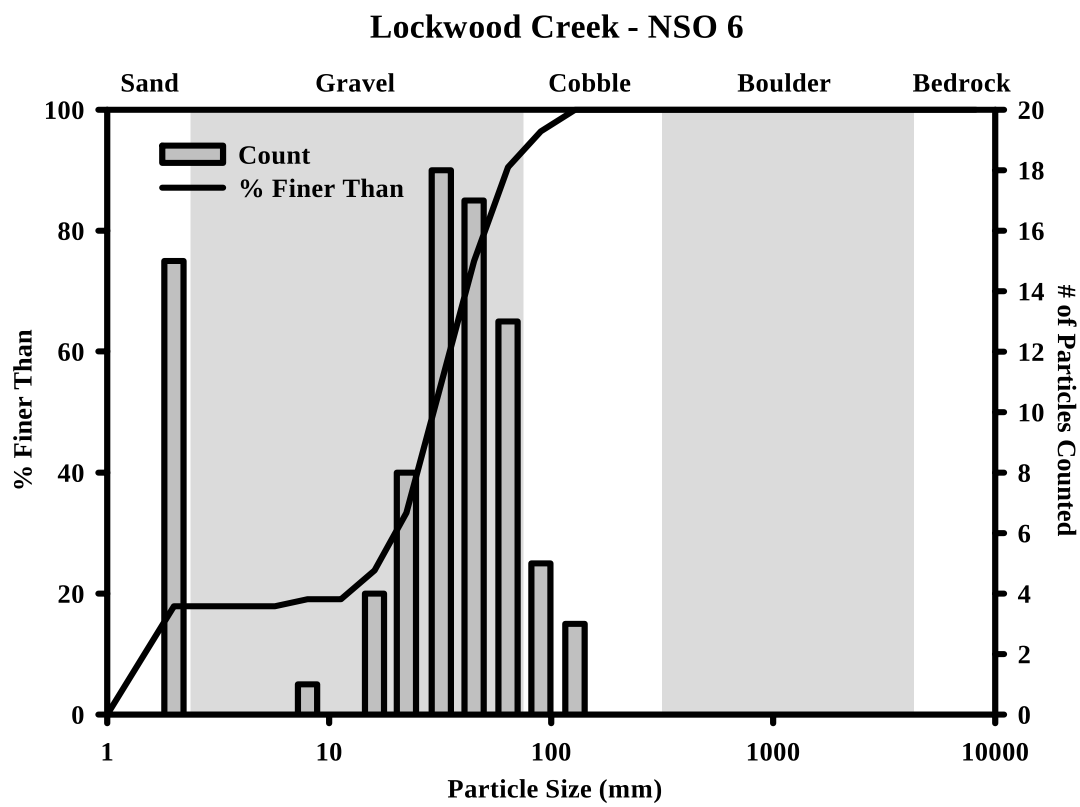


Figure 4. 71. Photo of substrate in Lockwood Creek showing gravel and cobble substrate embedded with sand.

Pebble counts were conducted in the tailouts of two pools within the survey area. In the upstream unit (NSO 30), the most frequent size category recorded was 64-90mm, though gravel was the dominant substrate class with 67% of particles counted (Figure 4. 72). In NSO 6, the dominant size category was 22.6-32mm and the dominant substrate class was gravel. The median size category in both counts was 22.6-32mm. In NSO 30, 14% of particles were in the sand category and in NSO 6, 18% were in the sand category. There were no boulder or bedrock in either pebble count.



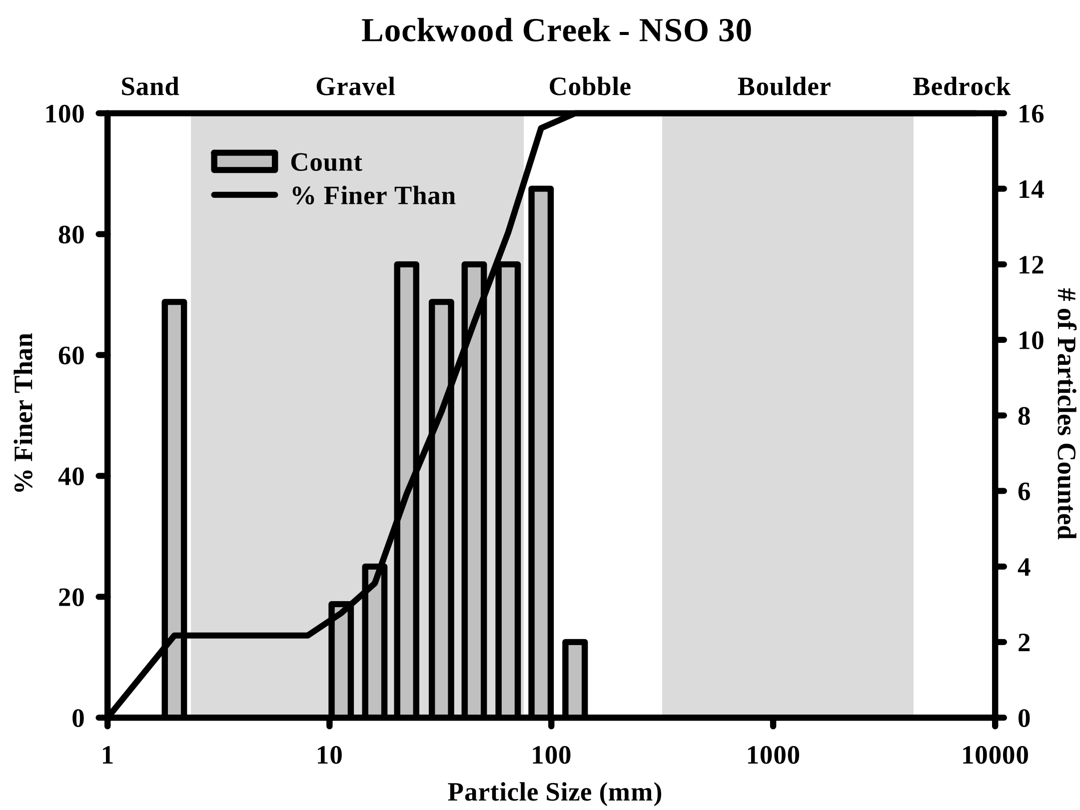


Figure 4. 72. Grain size distribution based on pebble counts in two pool tailouts in Lockwood Creek.

4.A.4.5. Cover

There is little cover available in Lockwood Creek. Cover is provided by LWD, undercut banks, overhanging cover, and depth, although total average cover only comprises 15% of the area. The dominant cover form is overhanging vegetation (Table 4. 63).

Table 4. 63. Presence of cover within the surveyed portion of Lockwood Creek. Measured as percent of surface area of stream unit covered.

Cover Type	Average % Cover Provided
LWD	2
Undercut Bank	2
Overhanging Cover	7
Depth > 1m	4
Substrate (Velocity cover)	0

4.A.4.6. Riparian

Lockwood Creek has a mean view to sky angle of 72 degrees in the survey area (Table 4. 64). The wide and wet valley inhibits the growth of a nearby overstory along much of the right bank. This results in a generally open canopy. The dominant vegetative overstory within the riparian zone is different between the two banks. The left bank is roughly 50% hardwood and mixed hardwood/conifer. The remaining dominant vegetation are shrubs and grasses. On the left bank, slightly over 60% of the dominant riparian vegetation is saplings, shrubs, and grasses (Figure 4. 73).

Table 4. 64. Riparian shading characteristics in the surveyed section of Lockwood Creek. Data presented as proceeding downstream.

Parameter	Result
Mean distance to vegetation – left bank (m)	41
Mean left bank canopy angle (degrees)	49
Mean distance to vegetation – right bank (m)	23
Mean right bank canopy angle (degrees)	59
Mean view to sky (degrees)	72

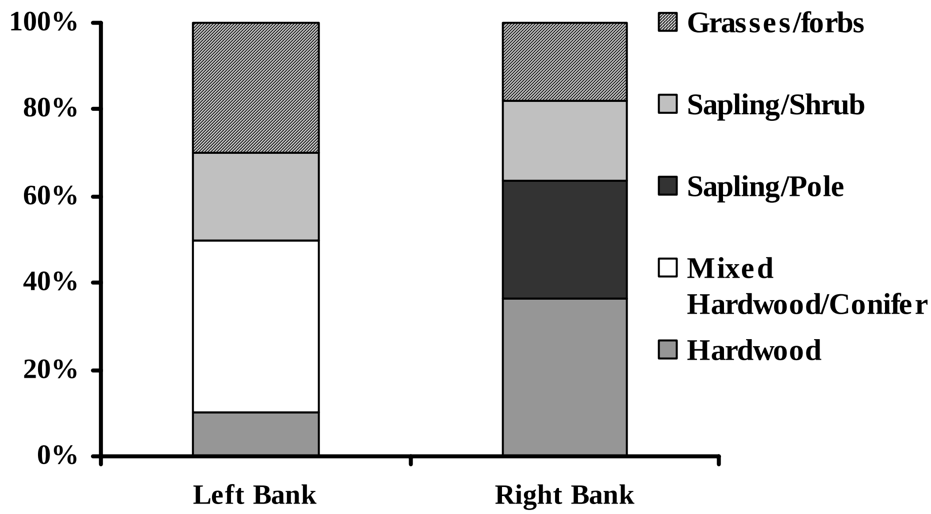


Figure 4. 73. Vegetation type by percentage of units observed. Data presented as proceeding downstream.

4.A.4.7. Instability & Disturbance

There is substantial bank instability in the surveyed section of Lockwood Creek (Table 4. 65). The stream has entrenched itself throughout much of the survey area and in the process has exposed erodible surfaces on both banks, especially in the lower end of the survey area. The primary disturbance is a residence at the upper end of the survey reach and the stream crossing of County Road 42. Associated with the County Road 42 culvert is an apparent culvert passage improvement structure. This was considered a disturbance, though it likely represents and improvement over previous conditions. See "Other Observations" for more detail on this structure. Entrenchment was not quantified but was present throughout most of the survey area and impacted roughly 50% of the survey area.

Table 4. 65. Bank instability and disturbance of the surveyed section of Lockwood Creek. Data presented as proceeding downstream.

Parameter	Result	Comment
Left bank instability (%)	18	
Right bank instability (%)	25	
Left bank disturbance (%)	19	Residence; culvert improvement; road
Right bank disturbance (%)	11	Road; culvert improvement

4.A.4.8. Other Observations

The lower 279m of the survey is made up of two beaver ponds. In this section, the stream is entrenched by 0.6m and the dominant vegetation is reed canary grass (*Phalaris arundinacea*), Himalayan blackberry (*Rubus discolor*), Stinging Nettle (*Urtica dioica*), ash (*Fraxinus sp.*), and dogwood (*Cornus sp.*). Upstream, the invasive vegetation policeman's helmet (*Impatiens glandulifera*) was observed. Four Chinook salmon (*Oncorhynchus tshawytscha*) were seen during the survey. They were in two sets of pairs, were in spawning colors, and at least one was adipose fin-clipped.

Near the upper end of the survey, just downstream of the County Road 42 culvert, some habitat modification has been done in an apparent attempt to facilitate passage through the culvert. A series of 5 weirs over a 22m span elevate the stream bed so that there is no step into the highway culvert (Figure 4. 74). The stream here is reinforced on each bank with rip rap.

Figure 4. 74. Set of weirs set up to improve passage through the County Road 42 culvert. Note rip rap on both banks.

4.A.4.9. Comparison to Habitat Standards

Numerous standards for rating the quality of salmonid habitat have been developed. Data collected in this survey were rated via two sets of standards applicable to basins of southwest Washington. The Washington Conservation Commission (WCC) established a set of standards to identify factors limiting salmonid production throughout the state. Standards applicable to western Washington were used here. Lockwood Creek habitat features were also compared to the NOAA Fisheries Properly Functioning Condition (PFC) standards. Only standards applicable to data collected were incorporated.

Lockwood Creek is rated poorly in all circumstances with the exception of pool frequency and barriers (Table 4. 66). While pool surface area is rated as fair, both criteria determined that the pools are spaced too far apart and are not of sufficient quality. There is too little wood, embeddedness is too high, and the streambanks are too unstable.

Table 4. 66. Lockwood Creek habitat feature ratings under regional salmonid habitat quality standards. Gray shaded cells indicate that no standard is available.

Parameter	WCC[1]	PFC[2]
% Pool by Surface Area	Fair	
Pool Frequency	Poor	Not Properly Functioning
Pool Quality		At Risk
LWD		Not Properly Functioning
Substrate		Not Properly Functioning
Streambank Stability	Poor	Not Properly Functioning
Barriers	Good	Properly Functioning

1. *Available ratings: good; fair; poor*
2. *Available ratings: properly functioning; at risk; not properly functioning*

4.A.4.10. Comparison to EDT Values

EDT patient scores differed from scores assigned based on survey results. EDT patient scores for habitat types are greatly different from habitat types observed during surveys. Surveys showed there are more pools, riffles, and beaver ponds and less glides than incorporated into EDT. Confinement by hydromodification is rated as 2.7 based on surveys because about 50% of the survey area is entrenched. This shows a greater impact than accounted for in EDT. The valley is very wide, often greater than 4 times the active channel width, so the natural confinement is rated as a 1, which is more unconfined than accounted for in EDT. Riparian function is rated as 2.5 because the stream is entrenched for 50% of the surveyed length. Very little large wood is present, resulting in the rating from the survey to be lower than the EDT patient score. The EDT patient score for embeddedness is much less than that determined from survey results (Table 4. 67).

Table 4. 67. EDT Patient scores assigned to Lockwood Creek and EDT scores based on 2004 stream survey results for categories relevant to data collected. Gradient is for entire Lockwood Creek reach B as determined from LiDAR contours.

Category	EDT Patient Score	Score from Survey
Channel width – minimum (m)	3.4	5.5
Gradient %	1.7	2.4
Confinement – hydromodifications	1	2.7
Confinement – natural	3	1
Habitat Type – Glides	39%	1%
Habitat Type – Beaver ponds	0%	21%
Habitat Type – off-channel habitat factor	0%	0%
Habitat Type – pool tailouts	8%	2%
Habitat Type – primary pools	32%	47%
Habitat Type – small cobble/gravel riffles	16%	28%
Habitat Type – Large cobble/boulder riffles	5%	1%
Riparian Function	1	2
Wood	3	3.8
Embeddedness	0.8	2.5

4.A.4.11. Potential Areas of Restoration

Much of the surveyed area of Lockwood Creek is entrenched. Along the right descending bank, where the valley is broad, there is a significant lowland/wetland area. This area is characterized by vegetation including skunk cabbage, horsetail, cattails, reed canary grass, and alder (Figure 4. 75). Historically, this area was probably frequently inundated and provided important winter rearing habitat. Currently, the entrenchment of Lockwood Creek prevents it from reaching this area in all but the highest flows.

There is significant presence of invasive vegetative species in Lockwood Creek. Reed canary grass is the dominant invasive, but policeman's helmet is also present. Restoration opportunities in lower mainstem tributary streams are discussed further in Section 4.3.2.

Figure 4. 75. Photo of wetland area off the right bank along the surveyed section of Lockwood Creek.

4.A.5. Dean Creek

4.A.5.1. Introduction

Dean Creek is located in Clark County. Dean Creek enters the East Fork Lewis at river kilometer 11.8 (RM 7.3), approximately 5 km (3 miles) southeast of the town of La Center, WA. Dean Creek was surveyed on October 14 from the intersection with J. A. Moore Road downstream 0.7km, representing 20% of the EDT Dean Creek reach (Figure 4. 76). A modified version of the USFS Region 6 Level II Stream Survey Protocol was used for the survey (USFS 1999). One temperature was recorded during the survey at 09:30 of 12.2°C.

The Dean Creek EDT reach was split into two reaches because stream surveys, aerial photo analysis, and LiDAR stream contour analysis indicated that habitat within portions of the reach were substantially different. The sub-divided reaches are denoted differently from the original reach name by adding an "A" or "B" to the end of the reach name with "A" indicating the downstream portion of the original reach, and "B" the upstream portion. This survey was conducted in Dean Creek_A, and the survey area accounts for 47% of the reach.

Landownership within the survey reach is private agricultural and industrial. The right descending bank is entirely in farmland and the left descending bank is owned by Storedahl & Sons (Daybreak Mine), though much of the land is under agricultural usage.

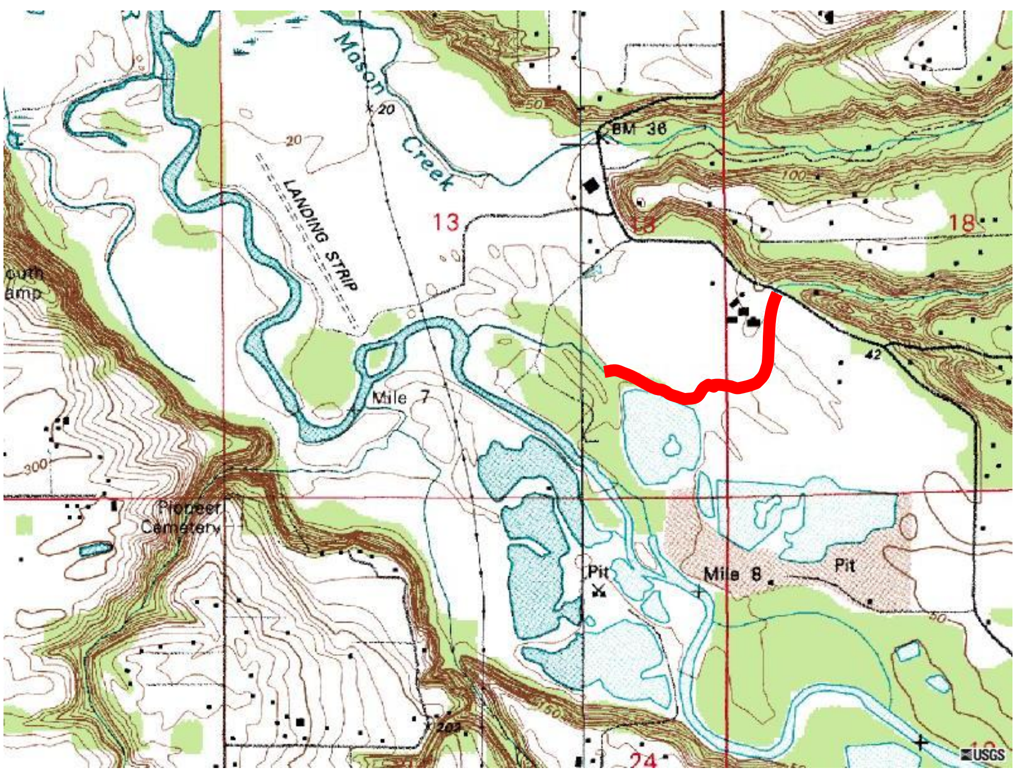


Figure 4. 76. USGS topographic map of Dean Creek highlighting the stream survey area. Survey length is 0.7 kilometers.

4.A.5.2. Channel Morphology

Dean Creek is comprised primarily of slow-water habitat with 68% of habitat classified as either beaver ponds or pools, with beaver ponds as the dominant habitat type (Figure 4. 77). There is no large cobble/boulder riffle habitat within the survey area. The upstream portion of the survey area is pool-riffle morphology (Montgomery and Buffington 1998), transitioning downstream into a series of beaver ponds.

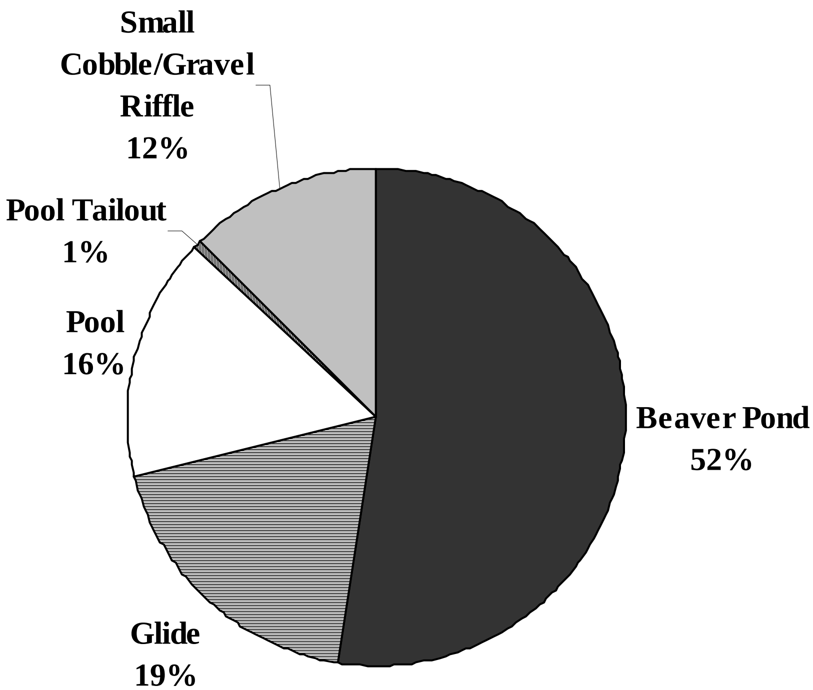


Figure 4. 77. Unit composition by percent surface area of the surveyed section of Dean Creek.

Dean Creek is low gradient and is within an unconfined valley. The stream itself has downcut into the streambed leaving itself entrenched. The upstream end of the survey area has been manually channelized as indicated by severe entrenchment and a lack of stream sinuosity. The mean wetted width in Dean Creek riffles is only 1.3m. The wetted depth is very shallow, and consequently few deep pools are available (Table 4. 68).

Table 4. 68. Average channel morphology characteristics of surveyed section of Dean Creek.

Parameter	Reach Value
Mean gradient[1]	0.7
Mean riffle wetted width (m)	1.3
Mean active channel width (m)	3.3
Mean maximum riffle depth (m)	0.1
Mean residual pool depth (m)	0.4
Mean maximum pool depth (m)	0.5
Mean maximum beaver pond depth (m)	1.5
Pools per kilometer[2]	16.5
Primary pools (>1.0m deep) per kilometer[2]	1.4
% of Length with side channel[3]	0

1. *As determined using LiDAR.*
2. *Does not include beaver ponds*
3. *Dry or wetted side channels.*

4.A.5.3. Wood

There are 42 pieces of LWD per kilometer in the surveyed section of Dean Creek. A majority of those are small pieces (Table 4. 69). Much of the wood is concentrated in the lower end of the survey area where the beaver ponds are. Very few trees are available in the riparian area for future wood recruitment.

Table 4. 69. Size and density of wood, jams, and root wads in surveyed section of Dean Creek.

Wood Category	Definition	# Per Kilometer
Small Pieces	10-20 cm diameter; >2 m long	26
Medium Pieces	20-50 cm diameter; >2 m long	15
Large Pieces	>50 cm diameter; >2 m long	1
Jams	>10 pieces in accumulation	1
Root wads	>2 m long	3

4.A.5.4. Substrate

Characterization of substrate based on visual observation showed that the dominant and sub-dominant substrate classes in pools are sand and gravel, respectively. In riffles, gravel is dominant while sand is subdominant. Substrate in the beaver ponds is entirely sand. Small amounts of cobble are present in both pools and riffles, but there are no boulders or bedrock (Figure 4. 78). Grain sizes for each category are listed in Table 4. 70.

Table 4. 70. Grain size ranges for substrate size categories used in visual observations and pebble counts.

Category	Grain Size Range (mm)
Sand	< 2
Gravel	2 – 64
Cobble	64 – 256
Boulder	256 – 4096
Bedrock	>4096

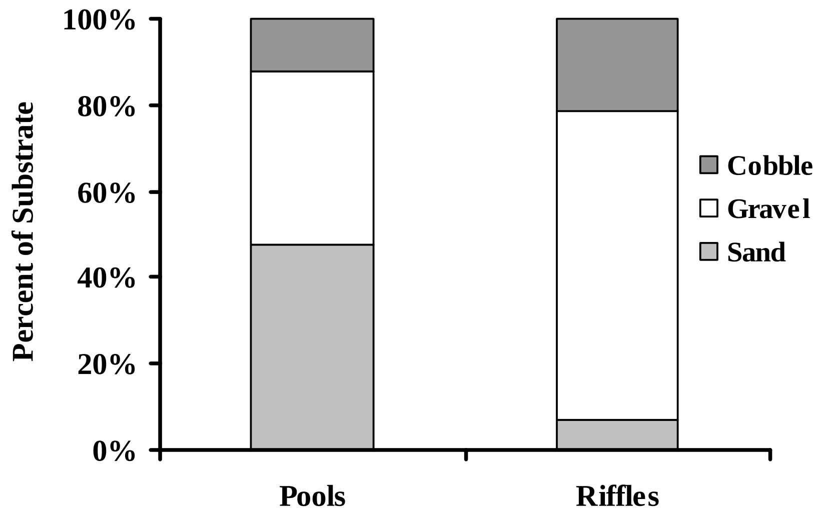


Figure 4. 78. Substrate size class composition in pools and riffles in surveyed section of Dean Creek.

Embeddedness was rated in each unit according to four categories (0-25%, 25-50%, 50-75%, and 75-100%). Embeddedness was estimated in riffles, glides, and pool tailouts. Embeddedness was not estimated in units without gravel or cobble substrate. Forty-nine percent of embeddedness ratings in Dean Creek fall within the 0-25% category, though some units are as much as 75-100% embedded (Figure 4. 79). Embeddedness increased progressively downstream. Averaging all observations indicates that embeddedness for the survey area in its entirety is near 25%.

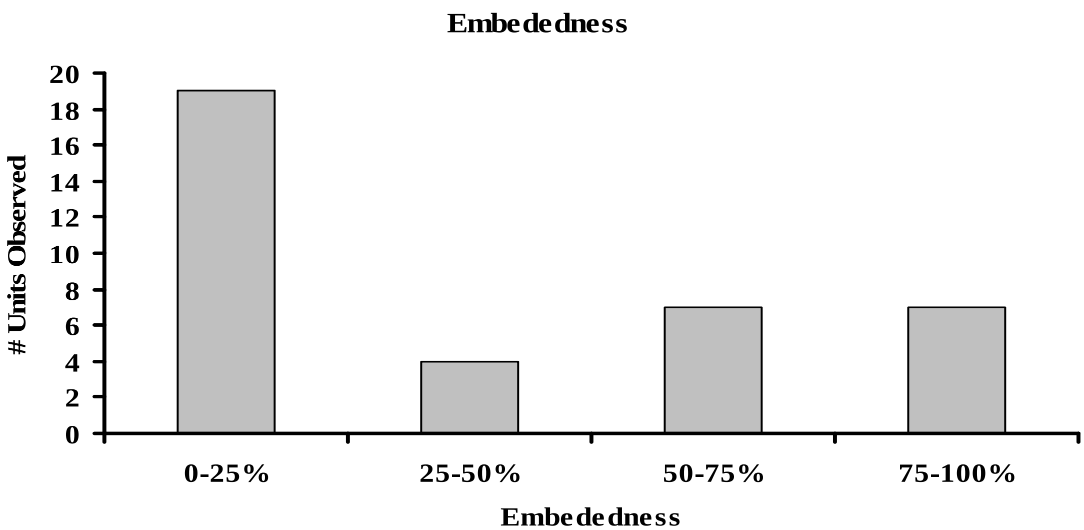
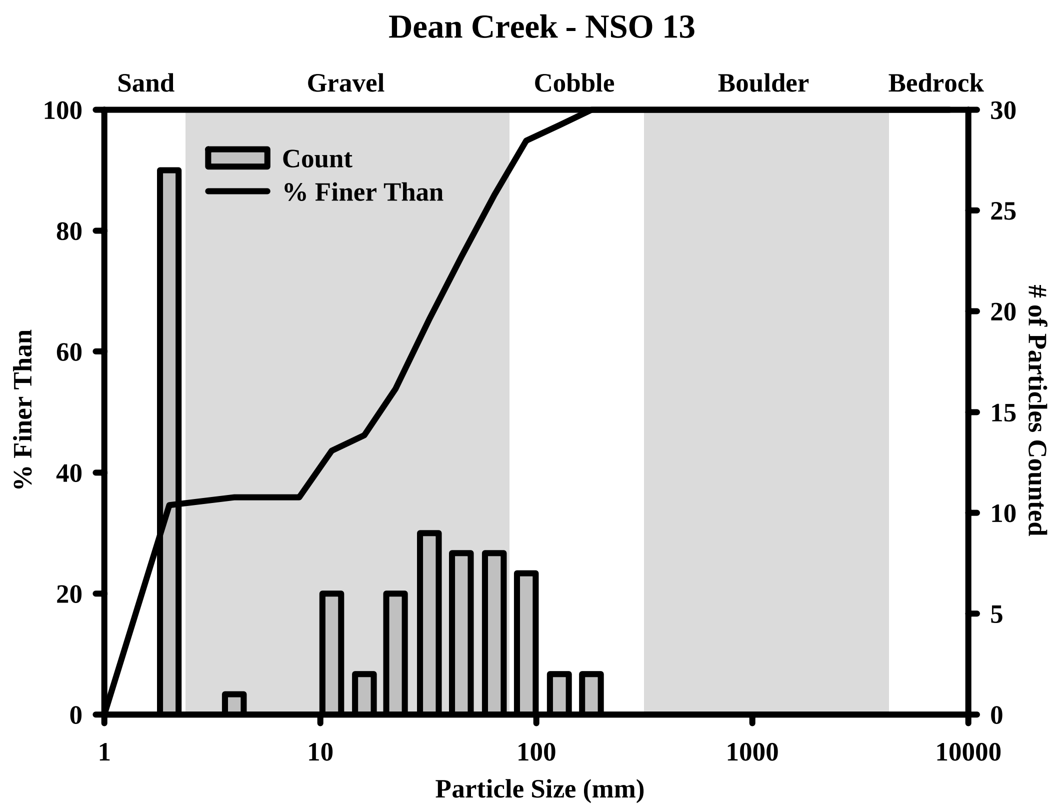


Figure 4. 79. Frequency of embededness ratings in surveyed sections of Dean Creek.

Pebble counts were conducted in the tailouts of two pools within the survey area. In both units sand is the dominant particle size group (Figure 4. 80). Grain sizes are slightly finer in the downstream unit (NSO 37) with 48% sand, than in the upstream unit (NSO 13) which has 35% sand. The median size category in NSO 37 is 5.7-8mm, and in NSO 13 is 16-22.6mm. The largest particle counted in either count is in the 128-180mm category. Aside from the sand, particle sizes in both units were favorable for salmonid spawning.



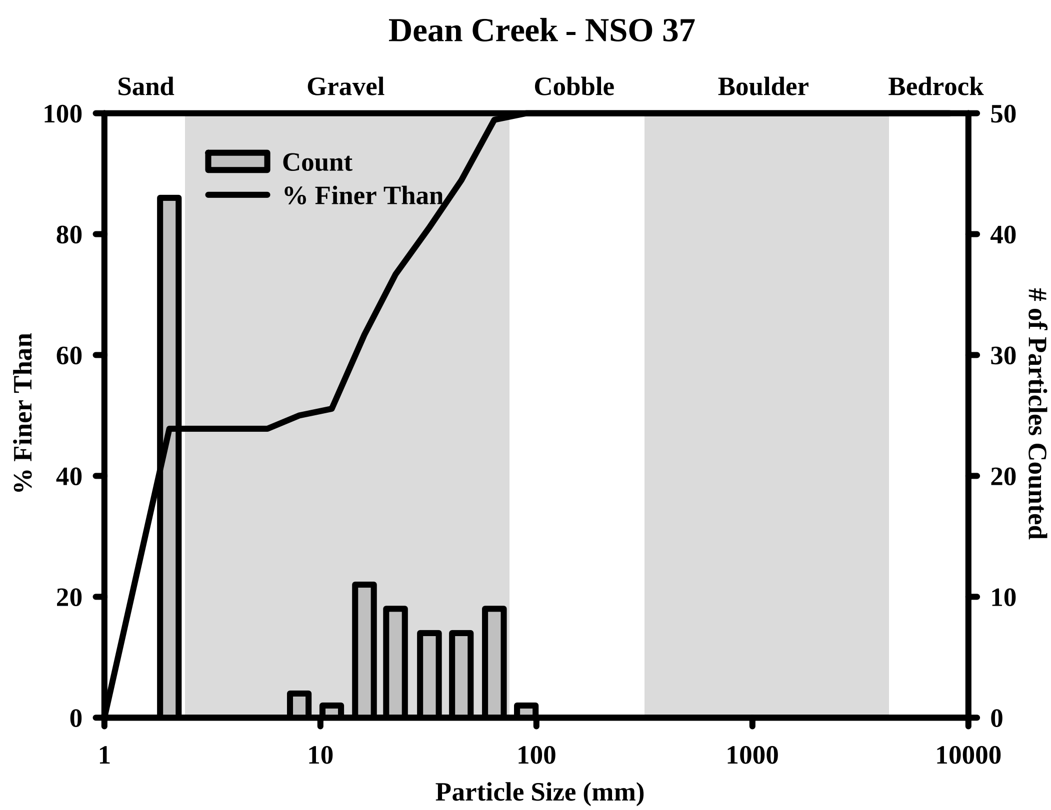


Figure 4. 80. Grain size distribution based on pebble counts in two pool tailouts in Dean Creek.

4.A.5.5. Cover

Cover is provided in Dean Creek primarily by overhanging vegetation. Dean Creek is very narrow, and is crowded by Himalayan blackberry (*Rubus discolor*) and reed canary grass (*Phalaris arundinacea*)to the point that they occasionally cover the wetted channel completely. Cover is provided by depth in the beaver ponds. Limited cover from LWD is also available (Table 4. 71).

Table 4. 71. Presence of cover within the surveyed portion of Dean Creek. Measured as percent of surface area of stream unit covered.

Cover Type	Average % Cover Provided
LWD	1
Undercut Bank	0
Overhanging Cover	45
Depth > 1m	9
Substrate (Velocity cover)	0

4.A.5.6. Riparian

The surveyed section of Dean Creek has a view to sky angle (VTS) of 72 degrees (Table 4. 72). The dominant shading vegetation is immediately on the left and right banks in the form of Himalayan blackberry and reed canary grass. The occasional willow, cottonwood, or Oregon ash are also present, especially towards the downstream end of the survey area. Though these hardwoods are present, the shrubs are the dominant vegetation type in all units (Figure 4. 81). Figure 4. 82 shows the typical riparian vegetation of the surveyed section of Dean Creek.

Table 4. 72. Riparian shading characteristics in surveyed section of Dean Creek. Data presented as proceeding downstream.

Parameter	Result
Mean distance to vegetation – left bank (m)	2
Mean left bank canopy angle (degrees)	63
Mean distance to vegetation – right bank (m)	3
Mean right bank canopy angle (degrees)	65
Mean view to sky (degrees)	72

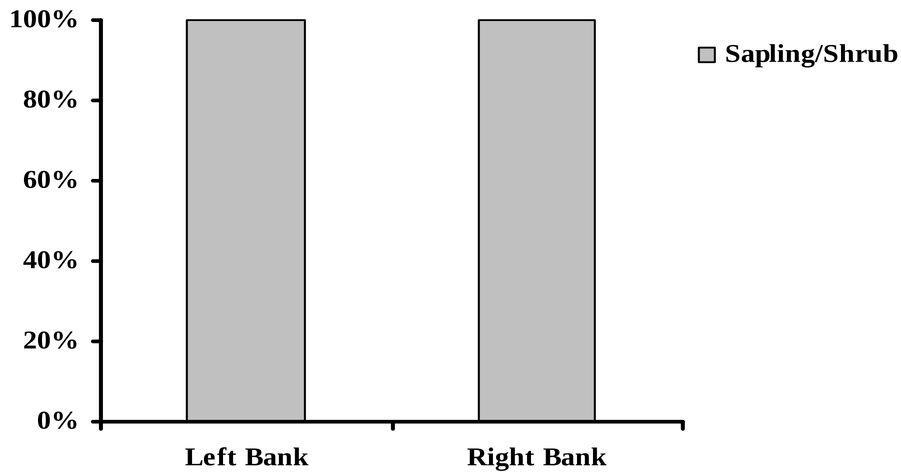


Figure 4. 81. Dominant vegetation type by percentage of units observed. Data presented as proceeding downstream.

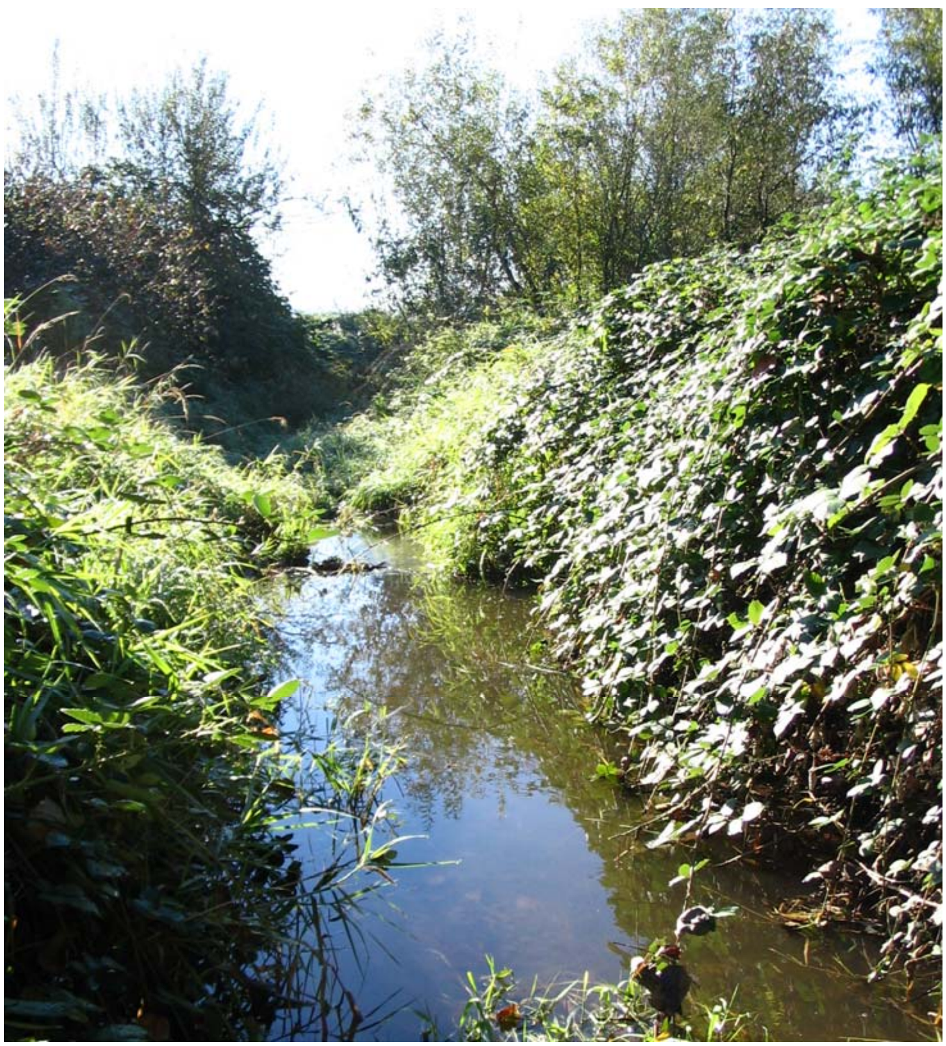


Figure 4. 82. Photo looking downstream in Dean Creek showing typical riparian vegetation and entrenchment.

4.A.5.7. Instability & Disturbance

Bank instability in the surveyed section of Dean Creek averages 17% on the left bank, and 18% on the right bank (Table 4. 73). Entrenchment of the stream has resulted in exposure of loose soil on both banks. Exotic vegetation including reed canary grass and blackberries are stabilizing both banks to some extent. The riparian zone of Dean Creek is 100% disturbed. The stream is channelized, entrenched, choked with exotic vegetation, has little overstory vegetation, and is bordered by agriculture land within approximately 20m of the stream on either side. There are gravel mining pits in the lower portion of the survey area off the left bank. Figure 4. 82 and Figure 4. 83 show the prevalence of exotic vegetation in Dean Creek.

Table 4. 73. Bank instability and disturbance of surveyed section of Dean Creek. Data presented as proceeding downstream.

Parameter	Result	Comment
Left bank instability (%)	17	
Right bank instability (%)	18	
Left bank disturbance (%)	100	Exotic vegetation; entrenchment; agriculture; gravel mining
Right bank disturbance (%)	100	Exotic vegetation; entrenchment; agriculture

Figure 4. 83. Photo showing Dean Creek at the upstream end of the survey. Note the prevalence of reed canary grass and Himalayan blackberry. The stream is flowing underneath the Himalayan blackberry on the right side of the picture.

There is a bridge crossing at the upstream end of the survey area that may be too small for the stream. At the time of the survey, the bridge was only 0.6m above the wetted surface of the stream, and only 0.2m above the bankfull mark. (Figure 4. 84).

Figure 4. 84. Picture of bridge over Dean Creek at the upstream end of the survey area.

4.A.5.8. Other Observations

In some locations, the density of reed canary grass and blackberries completely obstructs the view of the stream (see Figure 4. 83). There are a few short stretches where some willows, ash, or cottonwoods are present that provided shade, and in these sections, the reed canary grass and blackberries are more sparse.

Near the upper end of the survey, pressure treated lumber in accumulation with other fencing materials and some naturally contributed wood form two wood jams. The jams are within a few meters of each other, and in combination pose passage problems at low and moderate flows. In other locations it is likely that at low flow the stream goes sub-surface for short sections, potentially inhibiting passage upstream or downstream.

Both freshwater mussels and duckweed were observed in the lower end of the survey reach.

4.A.5.9. Comparison to Habitat Standards

Numerous standards for rating the quality of salmonid (*Oncorhynchus sp.*) habitat have been developed. Data collected in this survey were rated via two sets of standards applicable to basins of southwest Washington. The Washington Conservation Commission (WCC) established a set of standards to identify factors limiting salmonids production throughout the state. Standards applicable to western Washington were used here. Dean Creek habitat features were also compared to the NOAA Fisheries Properly Functioning Condition (PFC) standards. Only standards applicable to data collected were incorporated.

Dean Creek performed poorly when rated under the WCC and PFC criteria (Table 4. 74). Pool availability, pool frequency, pool quality, wood availability, and substrate each failed the criteria. Streambank stability rated moderately as “Fair” under the WCC, and as “At Risk” under the PFC. The barriers criteria were passed, though the wood jams in the upper survey area have been created partially with man made materials. These jams may be inhibiting passage. Further, flows likely go subsurface in the summer. In the absence of anthropogenic influences on the stream, there may have been sufficient flow to allow upstream and downstream passage throughout the low flow season.

Table 4. 74. Dean Creek habitat feature ratings under regional salmonids habitat quality standards. Gray shaded cells indicate that no standard is available.

Parameter	WCC[1]	PFC[2]
% Pool by Surface Area	Poor	
Pool Frequency	Poor	Not Properly Functioning
Pool Quality		Not Properly Functioning
LWD		Not Properly Functioning
Substrate		Not Properly Functioning
Streambank Stability	Fair	At Risk
Barriers	Good	Properly Functioning

1. *Available ratings: good; fair; poor*
2. *Available ratings: properly functioning; at risk; not properly functioning*

4.A.5.10. Comparison to EDT Values

EDT patient scores are different from scores assigned based on survey results. It is important to consider that the surveyed section of Dean Creek only represents 20% of the EDT reach. The measured channel width is less than that rated by EDT. Survey observations indicate that confinement via hydromodifications affect the entire length of the survey. The upper portion of the survey reach has been channelized, and the entire survey area suffers from entrenchment likely caused by anthropogenic sources. Natural confinement is much less than that rated under EDT patient conditions. Also, habitat type compositions in the stream varied from EDT patient scores, the riparian zone is less functional than scored in EDT, there is less wood available, and embeddedness is higher than rated for the EDT patient condition (Table 4. 75).

Table 4. 75. EDT Patient scores assigned to Dean Creek, and EDT scores based on 2004 stream survey results for categories relevant to data collected. Gradient is for entire EDT reach as determined from LiDAR contours, not just surveyed section.

Category	EDT Patient Score	Score from Survey
Channel width – minimum (m)	2.1	1.3
Gradient %	1.5	0.5
Confinement – hydromodifications	1	4
Confinement – natural	3	0
Habitat Type – Glides	39%	19%
Habitat Type – Beaver ponds	0%	52%
Habitat Type – off-channel habitat factor	0%	0%
Habitat Type – pool tailouts	8%	1%
Habitat Type – primary pools	38%	16%
Habitat Type – small cobble/gravel riffles	16%	12%
Habitat Type – Large cobble/boulder riffles	5%	0%
Riparian Function	2	4
Wood	3	4
Embeddedness	0.8	1.5

4.A.5.11. Potential Areas of Restoration

Dean Creek is a prime candidate for restoration throughout the surveyed area. The stream has been isolated from its floodplain via channelization and entrenchment. Riparian function is greatly reduced and riparian vegetation is primarily reed canary grass and Himalayan blackberry. Little habitat forming wood is present, and channel complexity is almost non-existent. There is little potential for wood recruitment since the only overstory present is sparse cottonwood, willow, and ash. This also presents a problem in ensuring bank stability and minimizing future fine sediment inputs. The existing gravel and cobble substrate is ideally sized for salmonid spawning, but high embededness likely inhibits successful spawning. If spawning could be successful, rearing young may be able to take advantage of the beaver ponds in the lower end of the reach.

4.A.6. LW Rock Creek

4.A.6.1. Introduction

Lower Rock Creek is located in Clark County approximately 6 km north of Battle Ground, and enters the East Fork Lewis at RKm 26 (RM 16.1). Lower Rock Creek was surveyed on October 7 from RKm 0.4 to RKm 1.1 (RM 0.25 to 0.7) representing 11% of the EDT Lower Rock Creek reach (Figure 4. 85). A modified version of the USFS Region 6 Level II Stream Survey Protocol was used for the survey (USFS 1999). A temperature of 12.2°C was recorded at 11:00 AM. Landownership within the survey reach is primarily rural residential. Landuse within the stream valley is mostly unmanaged timber, with agriculture away from the stream.

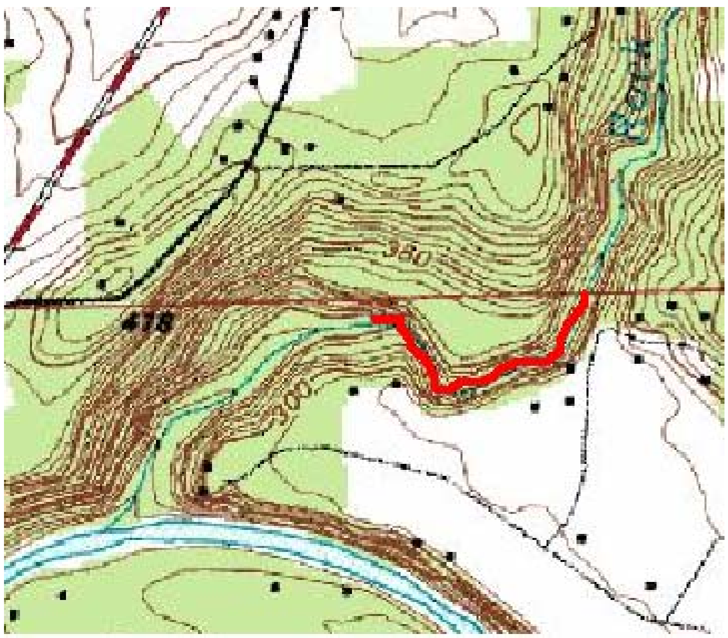


Figure 4. 85. USGS topographic map of Lower Rock Creek, highlighting the stream survey area. Survey length is 0.7 kilometers.

4.A.6.2. Channel Morphology

Large cobble/boulder riffles are the dominant habitat type in Lower Rock Creek with pools as the second most prominent habitat type. Turbidity precluded the ability to classify all riffles into their large cobble/boulder and small cobble/gravel components. Units where the substrate was clearly visible were assumed to be representative of all riffles in the survey area. The surveyed portion of Lower Rock Creek is a pool-riffle reach (Montgomery and Buffington 1998).

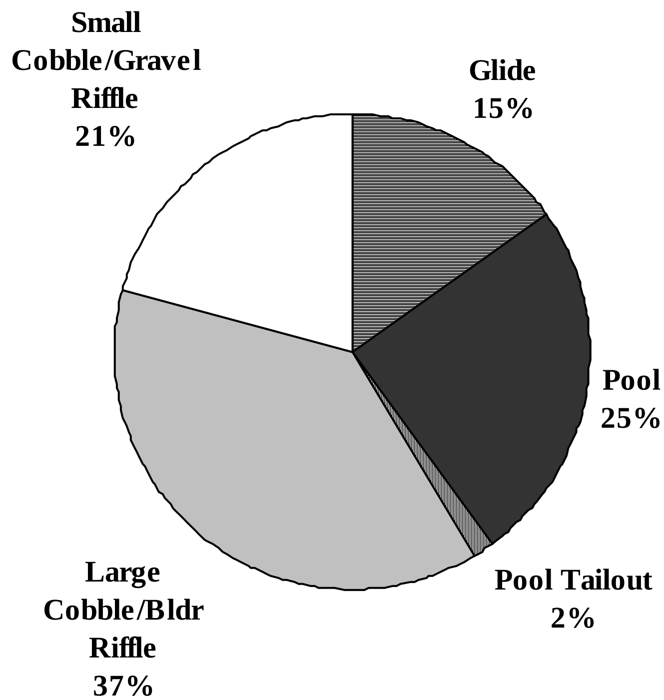


Figure 4. 86. Unit composition by percent surface area of the surveyed section of Lower Rock Creek.

Lower Rock Creek is low-moderate gradient and is moderately confined by the valley hillslope. The average riffle width is 5.9m. There are few pools per kilometer at 15.3, but nearly one-third of those are primary pools. Lower Rock Creek has a significant amount of side channel habitat. Thirty-four percent of the surveyed length is comprised of multiple channels (Table 4. 76).

Table 4. 76. Average channel morphology characteristics of surveyed section of Lower Rock Creek.

Parameter	Reach 1 Value
Mean gradient[1]	2.0
Mean riffle wetted width (m)	5.9
Mean active channel width (m)	6.8
Mean maximum riffle depth (m)	0.4
Mean residual pool depth (m)	0.5
Mean maximum pool depth (m)	0.8
Pools per kilometer	15.3
Primary pools (>1.0m deep) per kilometer	4.6
% of Length with side channel[2]	34

1. *As determined from LiDAR contours.*
2. *Dry or wetted side channels.*

4.A.6.3. Wood

There are 30 pieces of LWD per kilometer in the surveyed section of Lower Rock Creek. A majority of those are small or medium pieces (Table 4. 77). There are also three jams and six rootwads per kilometer.

Table 4. 77. Size and density of wood, jams, and root wads in surveyed section of Lower Rock Creek.

Wood Category	Definition	# Per Kilometer
Small Pieces	10-20 cm diameter; >2 m long	14
Medium Pieces	20-50 cm diameter; >2 m long	14
Large Pieces	>50 cm diameter; >2 m long	2
Jams	>10 pieces in accumulation	3
Root wads	>2 m long	6

4.A.6.4. Substrate

Characterization of substrate based on visual observation showed that the dominant and sub-dominant substrate classes in riffles are cobble and gravel respectively. Substrate could not be evaluated in pools because highly turbid water obscured vision of the substrate. Sand and boulders are present in minor proportions (Figure 4. 87). Grain sizes for each category are listed in Table 4. 78.

Table 4. 78. Grain size ranges for substrate size categories used in visual observations and pebble counts.

Category	Grain Size Range (mm)
Sand	< 2
Gravel	2 – 64
Cobble	64 – 256
Boulder	256 – 4096
Bedrock	>4096

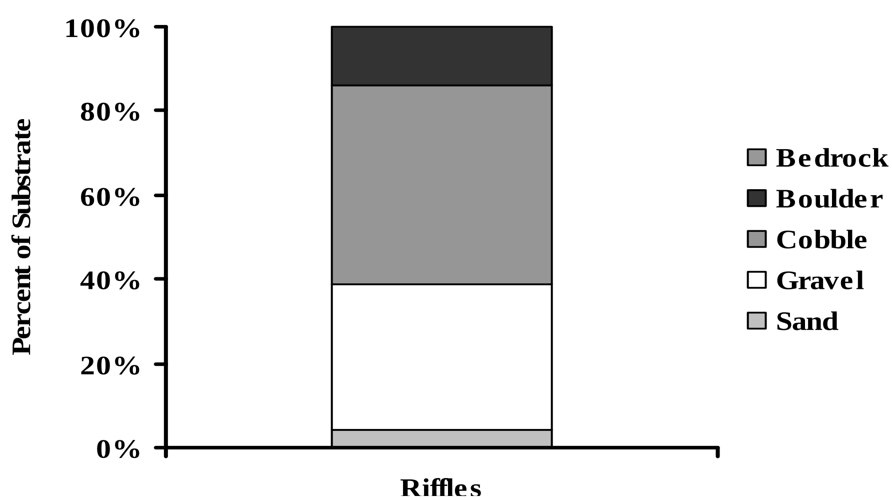


Figure 4. 87. Substrate size class composition in riffles in surveyed section of LW Rock Creek.

Embeddedness was rated in each unit according to four categories (0-25%, 25-50%, 50-75%, and 75-100%). Embeddedness was estimated in riffles, glides, and pool tailouts. All embeddedness ratings in Lower Rock Creek fall within the 0-25% category (Figure 4. 88). Field observations indicate that embeddedness within the reach typically is near 20%.

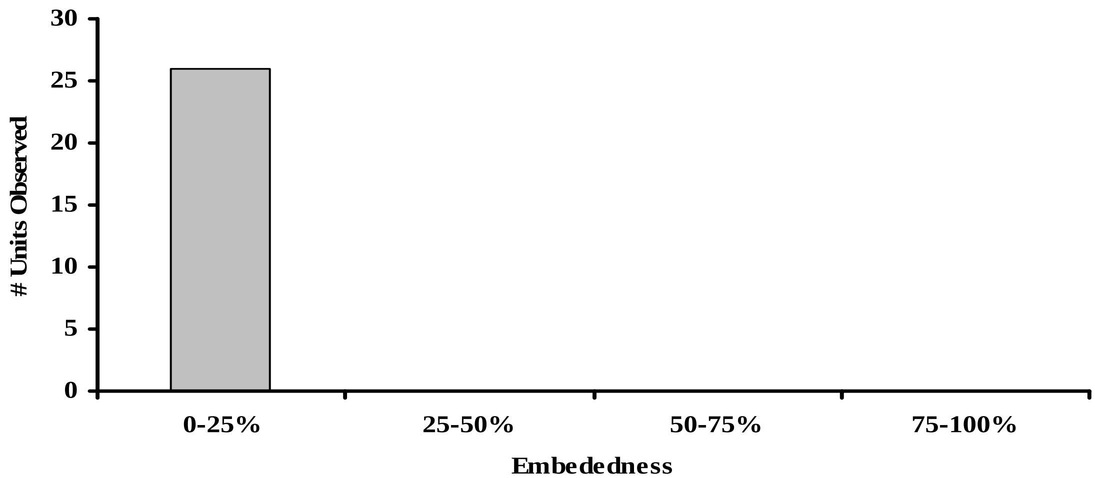


Figure 4. 88. Frequency of embeddedness ratings in surveyed sections of Lower Rock Creek.

Pebble counts were conducted in the tailouts of two pools within the survey area. An additional pebble count was done in a riffle in the middle of the reach since turbidity inhibited visual observation of substrate in some units. The riffle pebble count was done in NSO 10. In the most upstream pool tailout (NSO 1), the most frequent size category selected is 512-1024mm, though gravel is the most dominant substrate class (Figure 4. 89). In the downstream pool tailout (NSO 24), the dominant size category selected is 90-128mm and cobble is the dominant substrate class. In the riffle (NSO 10), the most selected size category is 362-512mm and the dominant substrate class is cobble. In NSOs 1, 10, and 24, sand made up 5%, 5%, and 9% of the substrate respectively. The median size category in the three units is 45-64mm, 90-128mm, and 90-128mm respectively.

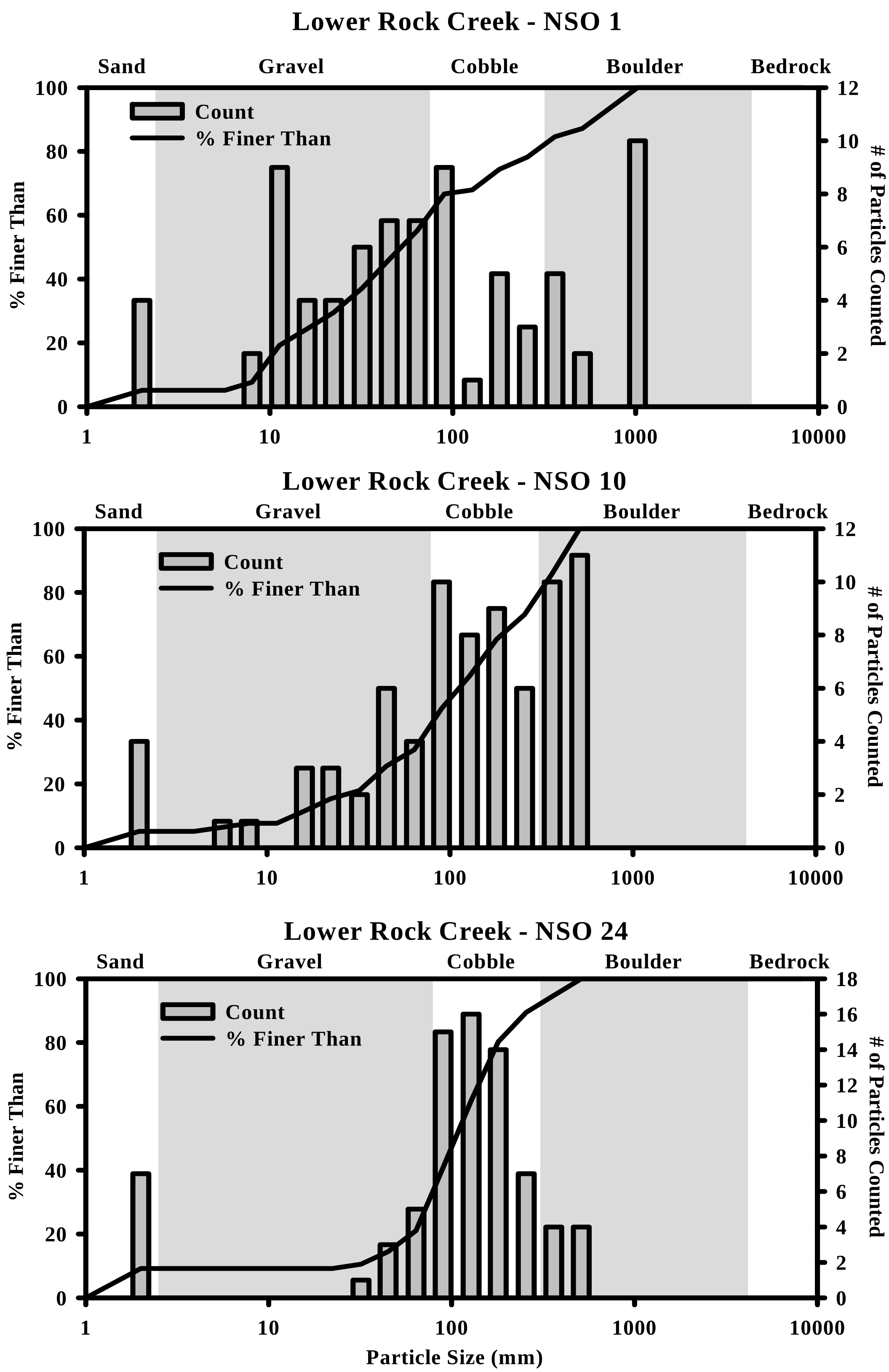


Figure 4. 89. Grain size distribution based on pebble counts in two pool tailouts and a riffle in Lower Rock Creek. NSOs 1 and 24 are pool tailouts. NSO 10 is a riffle.

4.A.6.5. Cover

Cover is provided in Lower Rock Creek in three of the five different cover forms recognized by the protocol including: overhanging cover, depth, and substrate velocity breaks. The dominant cover form is substrate with 11% of the reach having cover provided by boulders and bedrock creating velocity refuge (Table 4. 79). A few pools are deep enough to provide depth cover, and there is a limited amount of overhanging cover. While LWD is present in the reach, it provides negligible amounts of cover.

Table 4. 79. Presence of cover within the surveyed portion of Lower Rock Creek. Measured as percent of surface area of stream unit covered.

Cover Type	Average % Cover Provided
LWD	0
Undercut Bank	0
Overhanging Cover	3
Depth > 1m	5
Substrate (Velocity cover)	11

4.A.6.6. Riparian

Lower Rock Creek is shaded by vegetation on both banks. The mean view to sky angle is 57 degrees (Table 4. 80). Mixed hardwoods and conifers provide the dominant overstory vegetation type through much of the reach though in some places the riparian may be predominantly hardwood or predominantly conifer (Figure 4. 90). A small portion of the right bank is dominated by saplings. The riparian understory is dominated by Himalayan blackberry (*Rubus discolor*) and reed canary grass (*Phalaris arundinacea*). Near one residence, English ivy (*Hedera helix*) was prevelant on a cliff on the left bank.

Table 4. 80. Riparian shading characteristics in surveyed section of Lower Rock Creek. Data presented as proceeding downstream.

Parameter	Result
Mean distance to vegetation – left bank (m)	17
Mean left bank canopy angle (degrees)	60
Mean distance to vegetation – right bank (m)	16
Mean right bank canopy angle (degrees)	63
Mean view to sky (degrees)	57

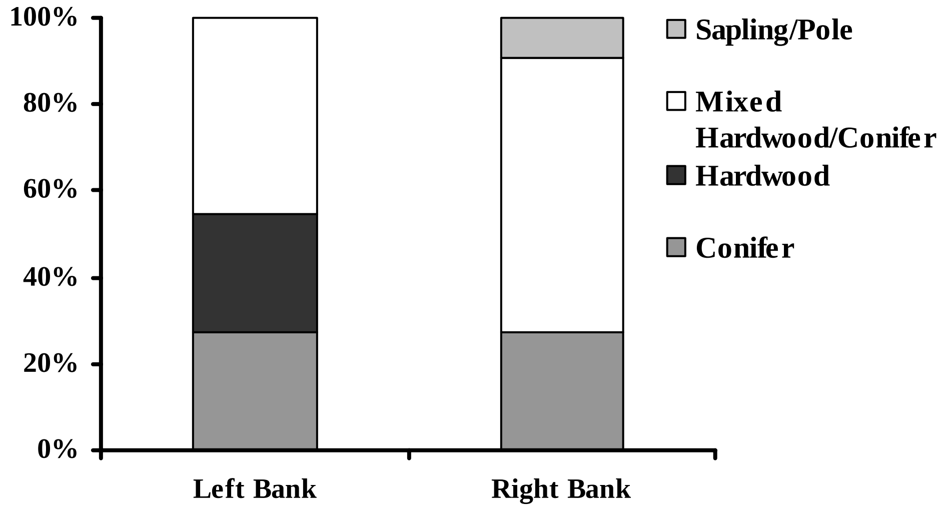


Figure 4. 90. Vegetation type by percentage of units observed. Data presented as proceeding downstream.

4.A.6.7. Instability & Disturbance

There is significant bank instability in Lower Rock Creek (Table 4. 81). As the stream meanders back and forth, the outside banks of the stream show exposed faces of erodible walls with cobble and gravel held amongst fine sediments (Figure 4. 91). In several places, the stream cut into a soft clay/bedrock wall. The left bank riparian zone is disturbed by small scale logging/tree removal in the upstream end of the survey area, residences, and brush clearing in the lower portion of the survey area. There is a 40m long levee near the lower end of the survey along the brush clearing. The levee is 1.5m high. Invasive vegetation is present throughout most of the reach.

Table 4. 81. Bank instability and disturbance of surveyed section of Lower Rock Creek. Data presented as proceeding downstream.

Parameter	Result	Comment
Left bank instability (%)	25	
Right bank instability (%)	18	
Left bank disturbance (%)	17	Logging; residence; brush clearing; levee
Right bank disturbance (%)	0	

Figure 4. 91. Actively eroding bank of Lower Rock Creek contributing fines, gravel and cobble to the stream.

4.A.6.8. Other Observations

A large mass of tires wrapped around a few trees was found in the survey area. The tires were roped together, and it is unclear if they had been dumped near there, or have moved down from farther upstream. It is uncertain how long the tires have been there, but it is likely they have been there for several years. The mass is acting as a large root wad by serving as a scouring agent causing the formation of a large pool just below (Figure 4. 92). The mass has created a 107m long side channel by diverting water at high flows both towards the pool, and also along the opposite side of the mass over the stream floodplain. The side channel is newly forming, but is in a low gradient area with a broad valley floor. The side channel can meander laterally and there is cobble and gravel available in the substrate (Figure 4. 93).

Figure 4. 92. Photo of tire mass in Lower Rock Creek. Mass has formed the pool along the left side of the picture, and an ephemeral side channel off to the right side of the picture.

Figure 4. 93. Lower end of newly forming side channel created by tire mass.

Several live adult coho salmon (*Oncorhynchus kisutch*) were observed during the survey, and one carcass of an unspawned male. The carcass measured 60cm in fork length, was not adipose clipped, and showed no other marks.

4.A.6.9. Comparison to Habitat Standards

Numerous standards for rating the quality of salmonids (*Oncorhynchus sp.*) habitat have been developed. Data collected in this survey were rated via two sets of standards applicable to basins of southwest Washington. The Washington Conservation Commission (WCC) established a set of standards to identify factors limiting salmonids production throughout the state. Standards applicable to western Washington were used here. Lower Rock Creek habitat features were also compared to the NOAA Fisheries Properly Functioning Condition (PFC) standards. Only standards applicable to data collected were incorporated.

The availability and frequency of pools are rated poorly under both criteria (Table 4. 82). Pool quality is rated as “At Risk” under the PFC criterion. LWD density is rated unfavorably under both sets of criteria. Substrate is classified as “At Risk” because embeddedness is 20% for the reach. Greater than 20% of the banks are unstable, so streambank stability is rated as “Poor” and “Not Properly Functioning”. There are no barriers present in the surveyed portion of the reach.

Table 4. 82. Lower Rock Creek habitat feature ratings under regional salmonids habitat quality standards. Gray shaded cells indicate that no standard is available.

Parameter	WCC[1]	PFC[2]
% Pool by Surface Area	Poor	
Pool Frequency	Poor	Not Properly Functioning
Pool Quality		At Risk
LWD		Not Properly Functioning
Substrate		At Risk
Streambank Stability	Poor	Not Properly Functioning
Barriers	Good	Properly Functioning

1. *Available ratings: good; fair; poor*
2. *Available ratings: properly functioning; at risk; not properly functioning*

4.A.6.10. Comparison to EDT Values

EDT patient scores are generally similar to scores assigned based on survey results with the exception of habitat unit type percentages. There is less pool habitat available and more riffles than assigned under EDT patient conditions (Table 4. 83). There are minor differences in riparian function, wood, and embeddedness.

Table 4. 83. EDT Patient scores assigned to Lower Rock Creek, and EDT scores based on 2004 stream survey results for categories relevant to data collected. Gradient is for entire EDT reach as determined from LiDAR contours.

Category	EDT Patient Score	Score from Survey
Channel width – minimum (m)	2.7	5.9
Gradient %	1.7	1.7
Confinement – hydromodifications	1	1
Confinement – natural	3	1.5
Habitat Type – Glides	39%	15%
Habitat Type – Beaver ponds	0%	0%
Habitat Type – off-channel habitat factor	0%	0%
Habitat Type – pool tailouts	8%	2%
Habitat Type – primary pools	32%	25%
Habitat Type – small cobble/gravel riffles	16%	21%
Habitat Type – Large cobble/boulder riffles	5%	37%
Riparian Function	2	2
Wood	3	4
Embeddedness	0.8	1.2

4.A.6.11. Potential Areas of Restoration

Both LWD densities and pool parameters were rated poorly or moderately under the WCC and PFC criteria. Both of these shortfalls could be addressed with the addition of secured LWD in pool forming positions. The potential for natural recruitment of large pieces of wood is low. Most of the riparian zone is dominated by hardwoods, or young conifers though a few mature cedars are present.

There is also a substantial opportunity to take advantage of pre-existing side channels and enhance their function in the stream. Thirty-four percent of the surveyed length consisted of multiple channels. With moderate valley confinement, there is room for channels to move laterally or to create off-channel habitat along the side channels or main channel.

Invasive vegetation is prevalent in the riparian zone. It may be appropriate to take measures to make the habitat less conducive to these invasives by planting trees that will eventually provide an overstory that discourages the growth of plants such as reed canary grass and blackberry. In one short section of the survey where several cedars were located, the blackberry and reed canary grass gave way to ferns, vine maple and salmonberry. Work to improve the riparian zone of the stream may also improve bank instability issues.

4.A.7. Rock Creek

4.A.7.1. Introduction

Rock Creek is located in Clark County about 3km upstream from Moulton Falls on the East Fork Lewis. Rock Creek enters the East Fork Lewis at RKm 42 (RM 26). Rock Creek was surveyed between September 30 and October 12, 2004. Several segments of the stream were surveyed between RKm 0.8 (RM 0.5) and RKm 10.5 (RM 6.5) (Figure 4. 94). These surveys were in EDT reaches 1, 3, 4, & 5. The total survey distance was 6.9 km, representing 58% of the four EDT reaches combined. For the individual reaches, 55%, 100%, 76%, and 37% of the EDT reach was surveyed, respectively. A modified version of the USFS Region 6 Level II Stream Survey Protocol was used for the survey (USFS 1999). Temperature location, dates, and times are shown in Table 4. 84. Land use within the surveyed reaches is primarily managed timberland under private and state ownership. There is also scattered rural residential development within the stream corridor.

Table 4. 84. Temperatures recorded in Rock Creek during stream surveys.

Reach	Date	Time	Temperature ºC
1	10/4	13:45	12.2
1	10/4	17:00	12.2
3	10/1	8:00	11.1
3	10/1	13:00	12.2
4	9/30	9:00	11.1
4	9/30	14:00	13.3
4	9/30	15:30	12.2
5	10/12	9:40	9.7
5	10/12	15:00	11.1

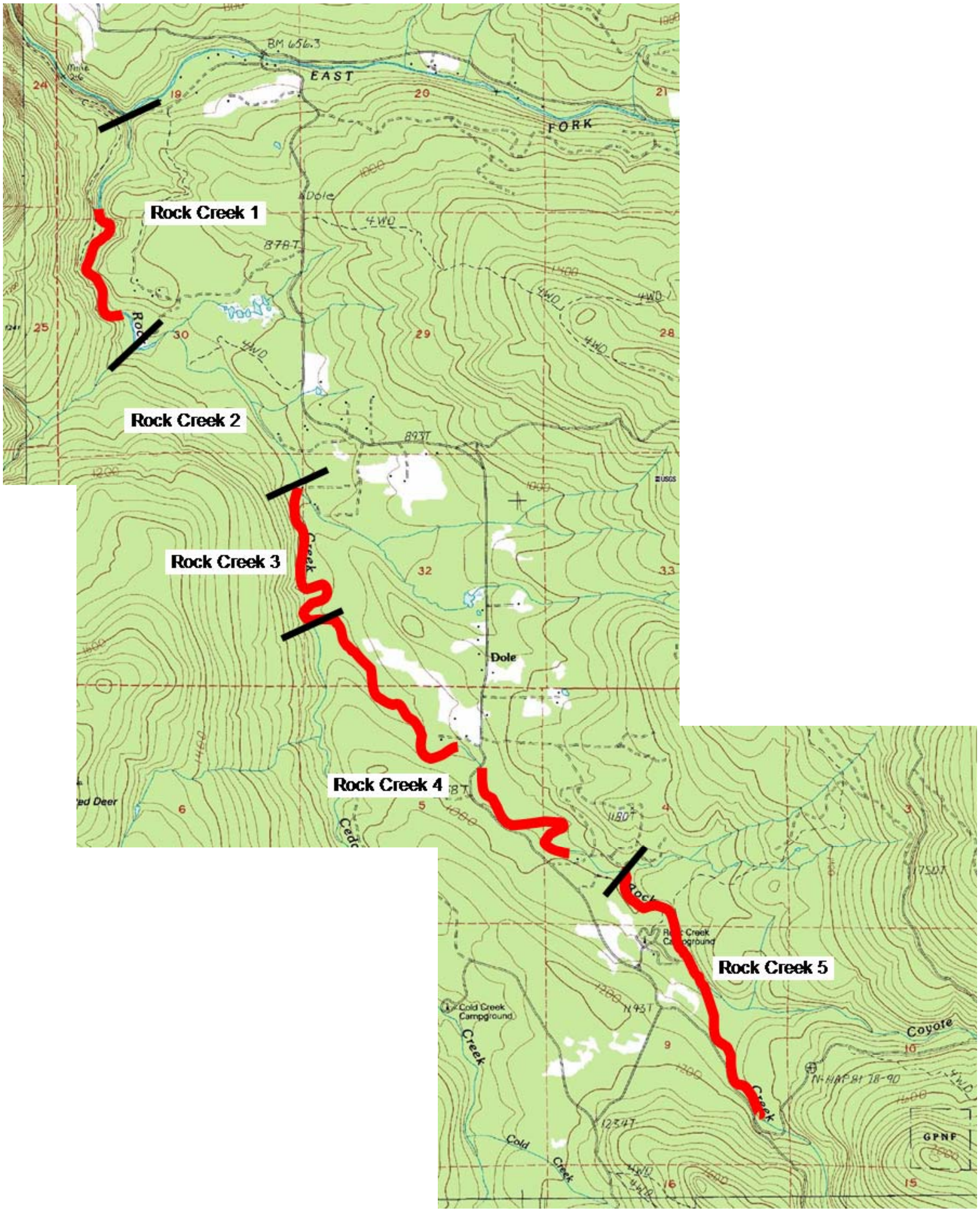


Figure 4. 94. USGS topographic map of Rock Creek highlighting the stream survey area. Survey length totals 7.0 kilometers.

4.A.7.2. Channel Morphology

Rock Creek is comprised primarily of large cobble/boulder riffles with pools as the second most prominent habitat type (Figure 4. 95). There is some variation between reaches. Most notably, there is less large cobble/boulder riffle habitat and more small cobble/gravel riffle habitat in reach four than in the other reaches. Also, there is less pool habitat by surface area in reaches four and five than in reaches one and three. Some of the riffles in reaches one and five are best described as "pocket water" because they are steep and turbulent with numerous boulders which form small pools that are not channel spanning. The surveyed portions of Rock Creek have characteristics of cascade, step-pool, and plane-bed channel morphologies (Montgomery and Buffington, 1998).

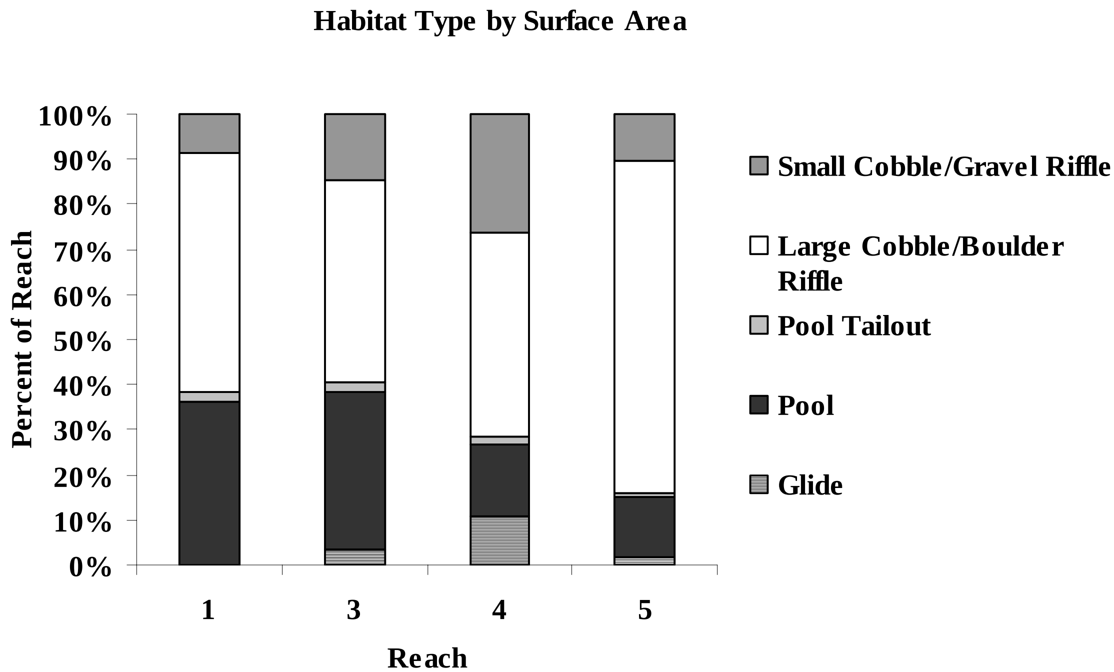


Figure 4. 95. Unit composition by percent surface area of the surveyed reaches of Rock Creek.

Rock Creek is a moderate to high gradient stream and is confined by bedrock and steep valley walls. Much of reach four and short portions of reach five are moderately confined. Mean widths range from 7.8m to 11.3m and average riffle depth ranges from 0.4m to 0.8m (Table 4. 85). Pools become less frequent moving downstream. There are more primary pools in reaches one and three than in four and five. The entrance of Cedar Creek between reaches three and four doubles the volume of water in Rock Creek. Side channels are common throughout Rock Creek with the exception of reach three which is the most confined and least sinuous of the four reaches.

Table 4. 85. Average channel morphology characteristics of surveyed sections of Rock Creek.

Parameter	Reach 1	Reach 3	Reach 4	Reach 5
Mean gradient[1]	1.6	1.9	1.4	2.6
Mean riffle wetted width (m)	11.3	10.3	9.9	7.8
Mean active channel width (m)	14.8	13.4	13.9	9.1
Mean maximum riffle depth (m)	0.8	0.5	0.4	0.6
Mean residual pool depth (m)	1.1	0.9	0.8	0.7
Mean maximum pool depth (m)	1.5	1.2	1.1	1.1
Pools per kilometer	8.2	8.5	9.0	9.5
Primary pools (>1.0m deep) per kilometer	7.3	7.7	5.8	5.0
% of Length with side channel[2]	23	3	19	38

1. *As determined from LiDAR contours.*
2. *Dry or wetted side channels.*

4.A.7.3. Wood

Wood availability differs greatly between the two reaches upstream of Cedar Creek and the two reaches downstream of Cedar Creek. Reaches one and three average 16 pieces/km whereas reaches four and five average 78 pieces/km (Table 4. 86). Riparian stands in the reaches are not drastically different, so the difference in densities is probably a reflection of stream power. The lower two reaches are more confined and carry about twice the water as the upper two reaches because of flow input from Cedar Creek.

Table 4. 86. Size and density of wood, jams, and root wads in the surveyed sections of Rock Creek.

Wood Category	Reach 1	Reach 3	Reach 4	Reach 5
Small Pieces/km[1]	5	7	21	33
Medium Pieces/km[2]	2	11	44	20
Large Pieces/km[3]	4	3	17	21
Jams/km[4]	0	0	1	1
Root wads/km[5]	1	1	na[6]	1

1. *10-20 cm diameter; >2 m long*
2. *20-50 cm diameter; >2 m long*
3. *>50 cm diameter; >2 m long*
4. *>10 pieces in accumulation*
5. *>2 m long*
6. *Rootwad estimate not available for this reach.*

4.A.7.4. Substrate

Characterization of substrate based on visual observation showed that the dominant and sub-dominant substrate classes in pools are cobble and gravel, respectively (Figure 4. 96). The same holds true in riffles except that cobbles make up an even larger proportion of the substrate (Figure 4. 97). Boulders are the next most prominent substrate size category in both pools and riffles. Sand is limited except in pools in reach four where it makes up 14% of the substrate. Grain sizes for each category are listed in Table 4. 87.

There are few differences between reaches. Reach three is higher in cobble than the other reaches. Reach four is highest in boulders. Reaches one and four have a substantial amount of bedrock.

Table 4. 87. Grain size ranges for substrate size categories used in visual observations and pebble counts.

Category	Grain Size Range (mm)
Sand	< 2
Gravel	2 – 64
Cobble	64 – 256
Boulder	256 – 4096
Bedrock	>4096

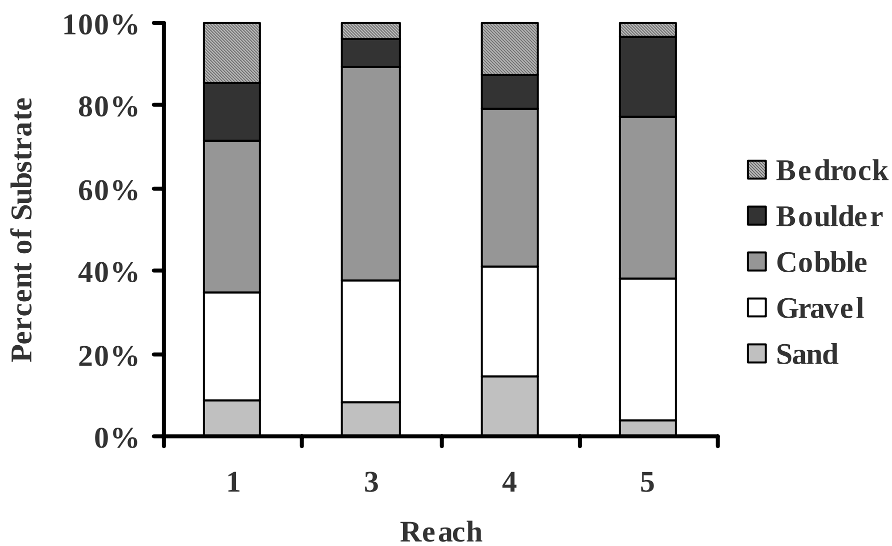


Figure 4. 96. Substrate size class composition in pools in surveyed reaches of Rock Creek.

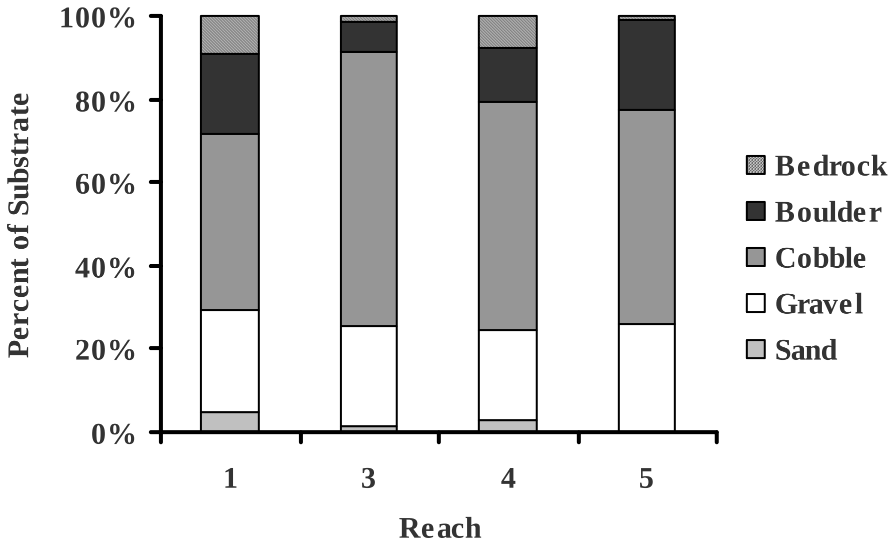


Figure 4. 97. Substrate size class composition in riffles in surveyed reaches of Rock Creek.

Embeddedness was rated in each unit according to four categories (0-25%, 25-50%, 50-75%, and 75-100%). Embeddedness was estimated in riffles, glides, and pool tailouts. Embeddedness in each of the reaches of Rock Creek is generally rated low (0-25%) though some units in reaches three and four are classified as 25-50% embedded (Figure 4. 98). Field observations indicate that embeddedness within Rock Creek is 10-30%.

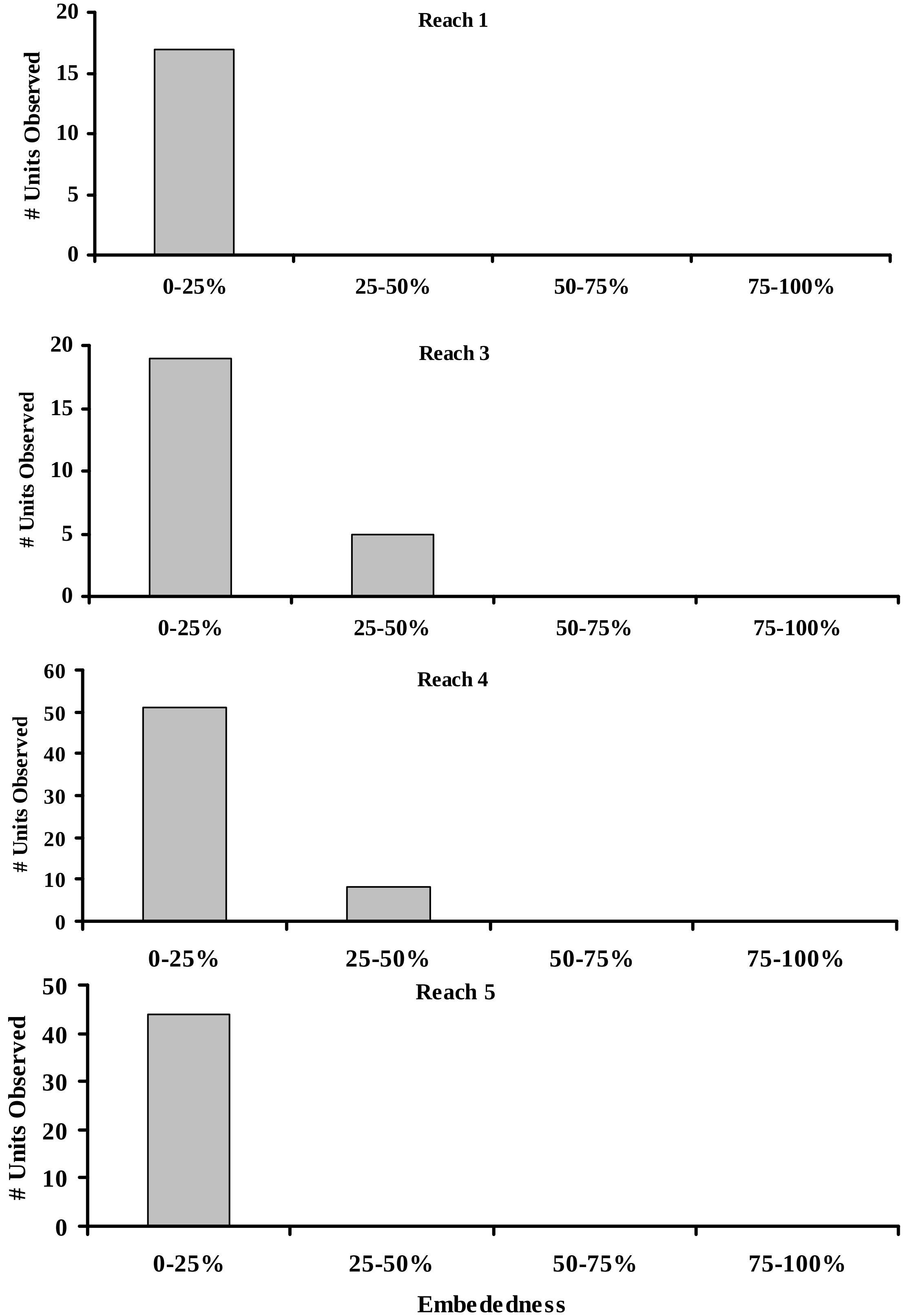


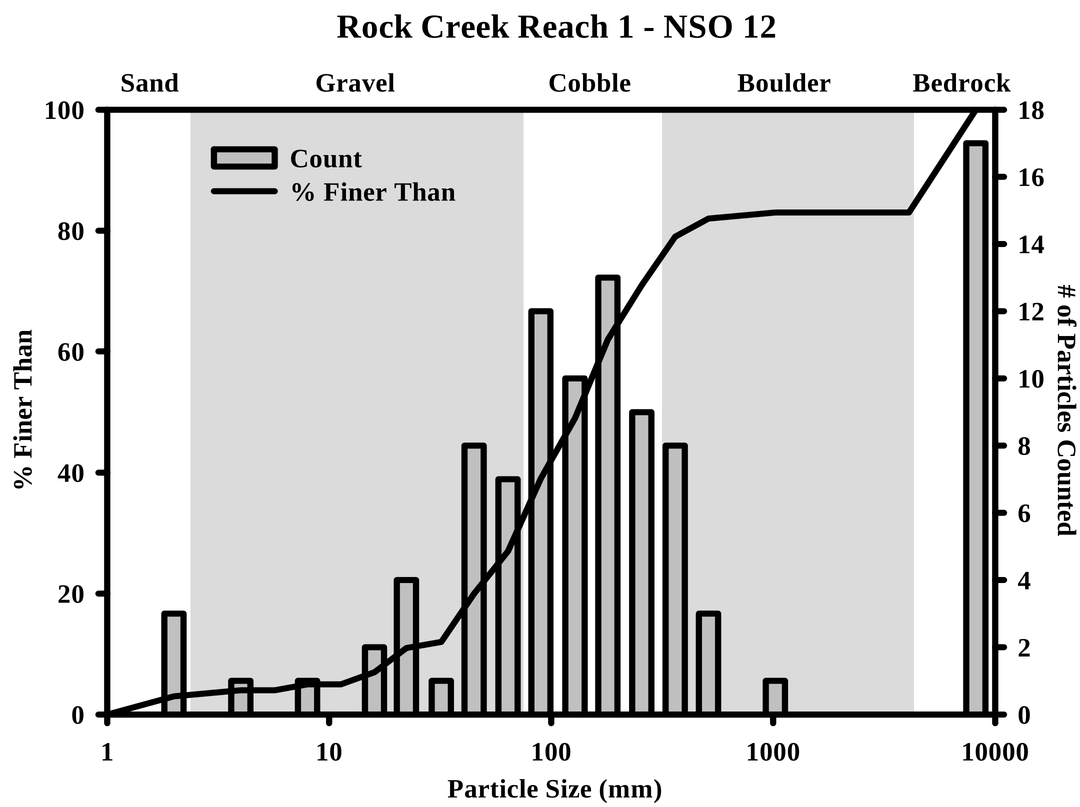
Figure 4. 98. Frequency of embeddedness ratings in surveyed reaches of Rock Creek.

Pebble counts were conducted in pool tailouts within each reach. Two counts were conducted in reaches one and five and one count was conducted in reaches three and four. There is similarity among the pebble counts in the different reaches. The percentage of substrate in sand is consistently low at 7% or less. The dominant size category is consistently cobble and cobble or gravel are always the dominant substrate classes. The two most confined reaches, reaches one and three, also have the greatest portion of bedrock in the pebble counts.

The most frequent size category selected in both units of reach one is 128-180mm and cobble is the most dominant substrate class (Figure 4. 99). Only 3% of particles are sand in NSO 12 and 2% in NSO 16. In NSO 12, the median size category is 128-180mm and in NSO 16 it is 90-128mm.

In reach three, the dominant and median size category is 128-180mm. The dominant substrate class is gravel and only 1% of particles counted are sand. In reach four, 64-90mm is the dominant size category and 90-128mm is the median category. The most prominent substrate class is gravel and 3% of the particles selected are sand (Figure 4. 100).

In the upstream unit of reach five (NSO 10), the dominant size category is 180-256mm. In the downstream unit (NSO 39), two categories, 90-128 and 180-256, were co-dominant. Cobble is the dominant size class in both units. The median size category in NSO 10 is 128-180mm and in NSO 39 is 90-128mm. Sand makes up 4-7% of the substrate in the two units (Figure 4. 101).



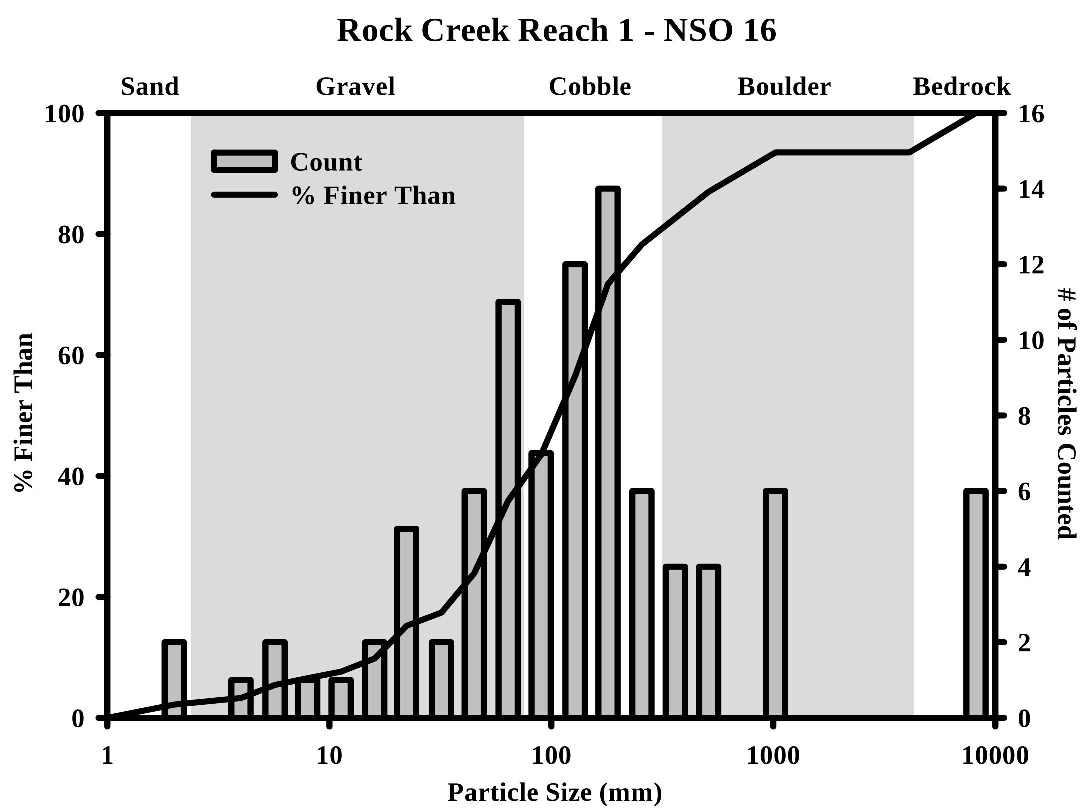


Figure 4. 99. Grain size distribution based on pebble counts in Rock Creek reach 1.

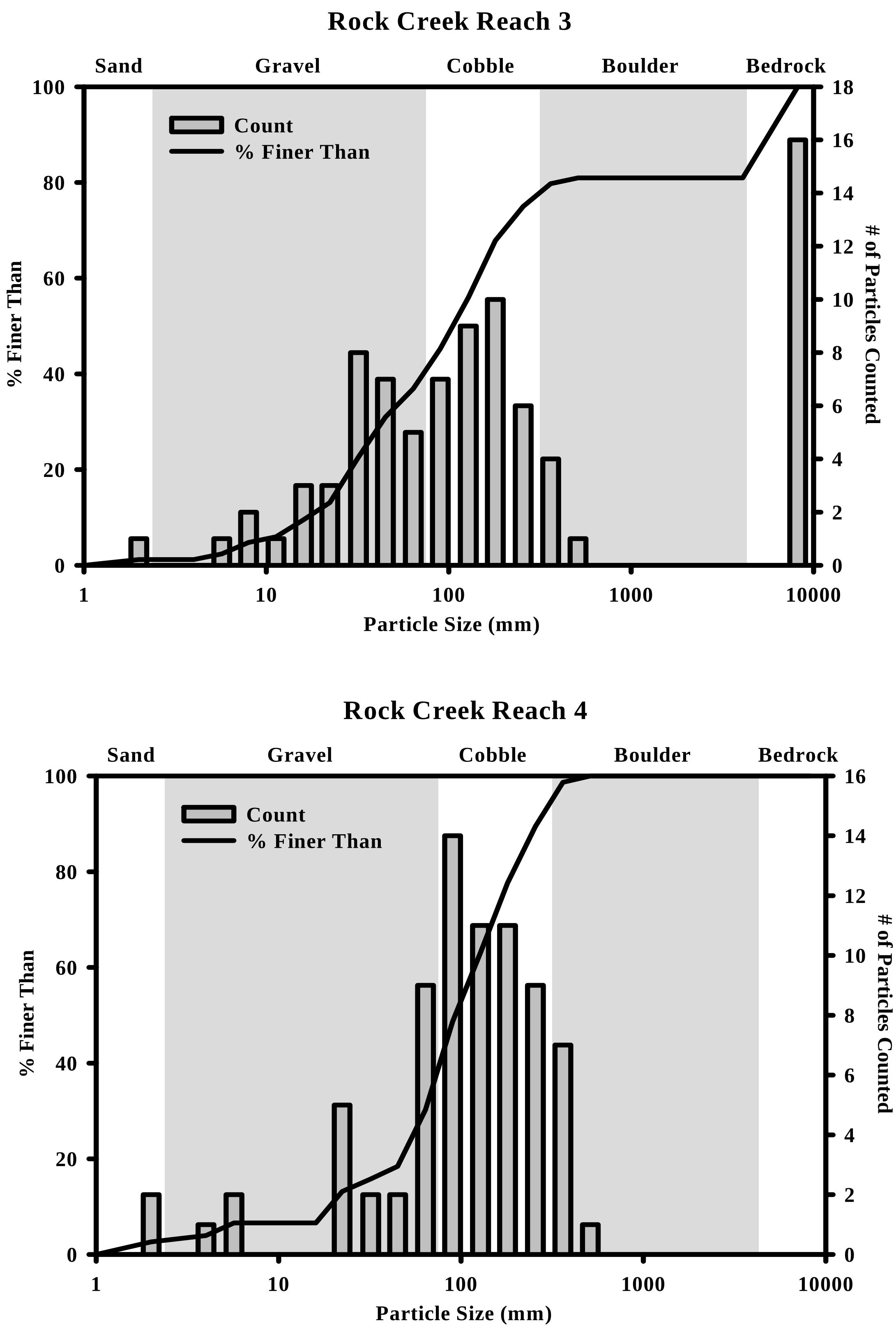
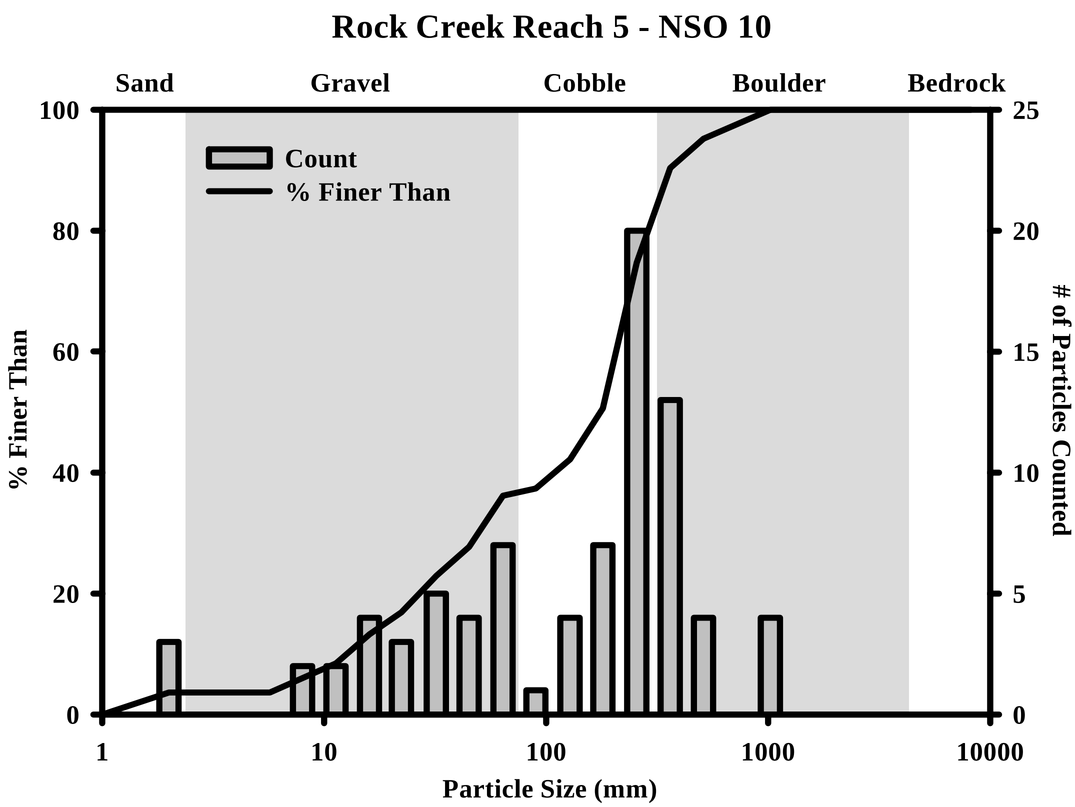


Figure 4. 100. Grain size distribution based on pebble counts in Rock Creek reaches three and four.



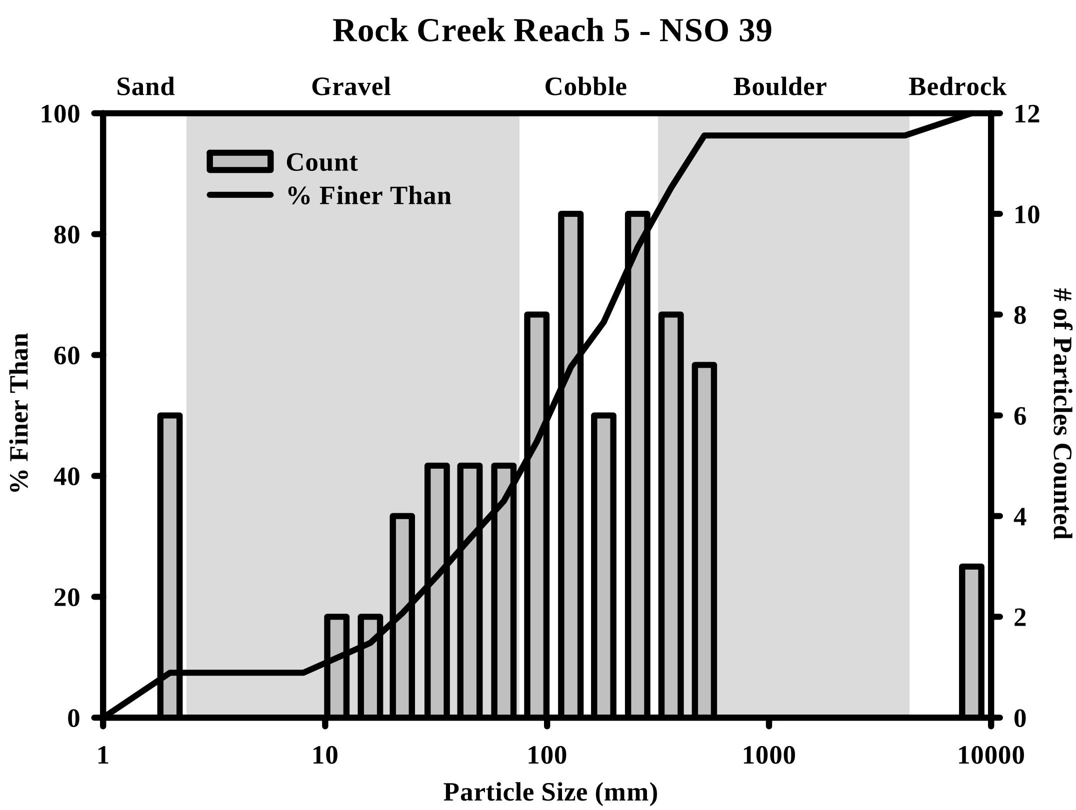


Figure 4. 101. Grain size distribution based on pebble counts in Rock Creek reach five.

4.A.7.5. Cover

Cover is provided in Rock Creek in each of the five different cover forms recognized by the protocol including: LWD, undercut banks, overhanging cover, depth, and substrate velocity breaks. The forms that provide the most cover are depth and substrate. Depth provides cover for over 29% of the surface area in reach one. Velocity breaks from substrate cover 19% of the habitat in reach five and four to six percent in the other reaches (Table 4. 88). Cover provided by LWD, undercut banks, and overhanging cover is negligible. Reach one maintains the most cover at 35%, while reach four maintains the least at 6%.

Table 4. 88. Presence of cover within the surveyed portions of Rock Creek. Cover is measured as percent of surface area.

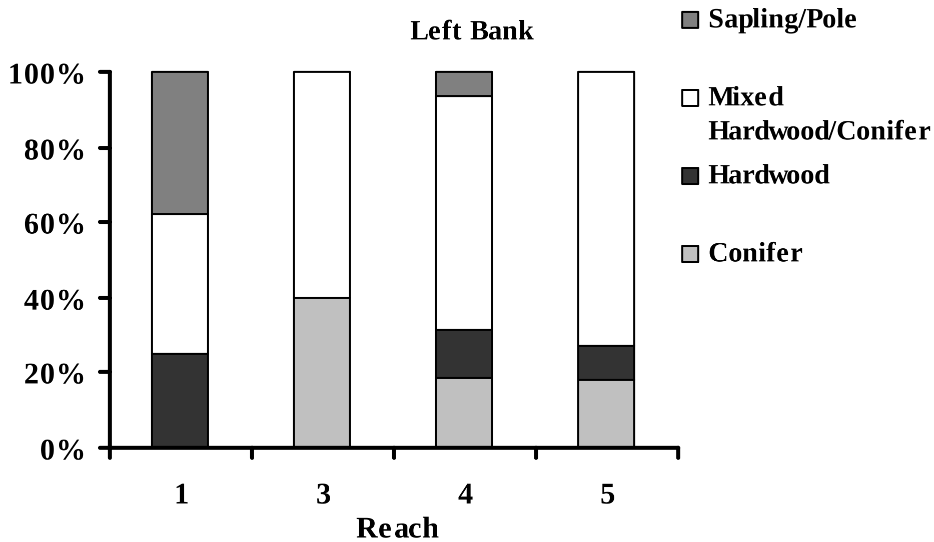
Cover Type	Reach 1	Reach 3	Reach 4	Reach 5
LWD	0	0	1	1
Undercut Bank	0	0	0	1
Overhanging Cover	0	2	0	2
Depth > 1m	29	8	1	0
Substrate (Velocity cover)	6	5	4	19

4.A.7.6. Riparian

The mean view to sky angle in Rock Creek ranges from 11-70 degrees (Table 4. 89). Shading is the greatest in the most upstream reach (Reach 5) and the lowest in the most downstream reach (Reach 1). The dominant overstory vegetation is mature mixed hardwoods and conifers. Conifers alone are the next most dominant followed by hardwoods alone. In reach 1, the sapling/pole vegetation type is co-dominant with mixed stands (Figure 4. 102).

Table 4. 89. Riparian shading characteristics in the surveyed sections of Rock Creek. Data presented as proceeding downstream.

Parameter	Reach 1	Reach 3	Reach 4	Reach 5
Mean distance to vegetation – left bank (m)	13	9	9	8
Mean left bank canopy angle (degrees)	54	74	76	84
Mean distance to vegetation – right bank (m)	16	7	15	8
Mean right bank canopy angle (degrees)	56	72	67	85
Mean view to sky (degrees)	70	34	37	11



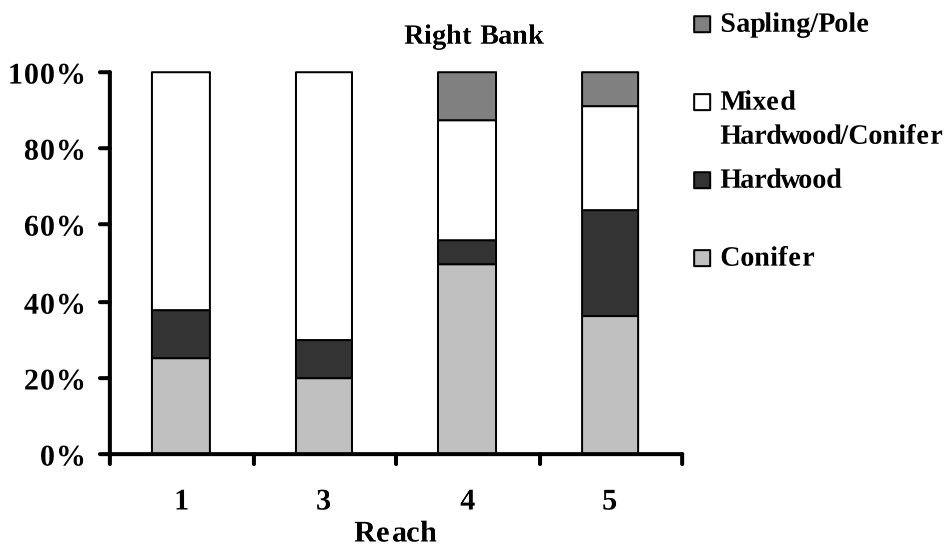


Figure 4. 102. Vegetation type by percentage of units observed. Data presented as proceeding downstream.

4.A.7.7. Instability & Disturbance

There is little bank instability in reaches one and three and moderate amounts in reaches four and five (Table 4. 90). Reaches one and three are buffered against instability by bedrock walls throughout much of the reach. Most of the bank instability in Rock Creek is created by the stream cutting into clay/silt hardpan bedrock walls. These walls crumble and contribute large angular pieces of clay.

Disturbance is greatest in reach three where the left bank (proceeding downstream) has recently been logged and an unmaintained road follows the entire length of the reach. Disturbance throughout the rest of Rock Creek comes primarily from logging activities or roads. There are a few locations where rural residential development has resulted in disturbance through "domestication" of vegetation along the bank, but these incidences are infrequent. Rock Creek campground in reach five has caused some disturbance.

In reach four where Dole Valley Road lies atop a bluff adjacent to the stream, there is a road cut failure directly entering the stream. The failure has contributed a significant amount of cobble and gravel as well as fines to the stream.

Table 4. 90. Bank instability and disturbance of surveyed section of Rock Creek. Data presented as proceeding downstream.

Parameter	Reach 1	Reach 3	Reach 4	Reach 5
Left bank instability (%)	6	9	15	13
Right bank instability (%)	1	0	13	13
Left bank disturbance (%)	0	36	3	10
Right bank disturbance (%)	0	16	8	4

4.A.7.8. Other Observations

In reach one, 190m downstream from the upstream end of the survey, there is a 2.0m bedrock falls. A deep pool at the base of the falls makes the falls passable for steelhead (*Oncorhynchus mykiss*) at most flows. There are several pockets or steps within the falls that would ease passage (Figure 4. 103). A large redd was observed in the tailout of the pool below the falls (Figure 4. 104). It is commonly understood that steelhead are the only anadromous salmonid that pass Lucia Falls, which lies downstream of the mouth of Rock Creek on the mainstem East Fork Lewis. This redd was freshly built and measured 2.5m wide and 3.5m long, indicating that it was built by a Chinook (*Oncorhynchus tshawytscha*). It is possible that unusually high flows in August permitted some Chinook to pass Lucia Falls in 2004.

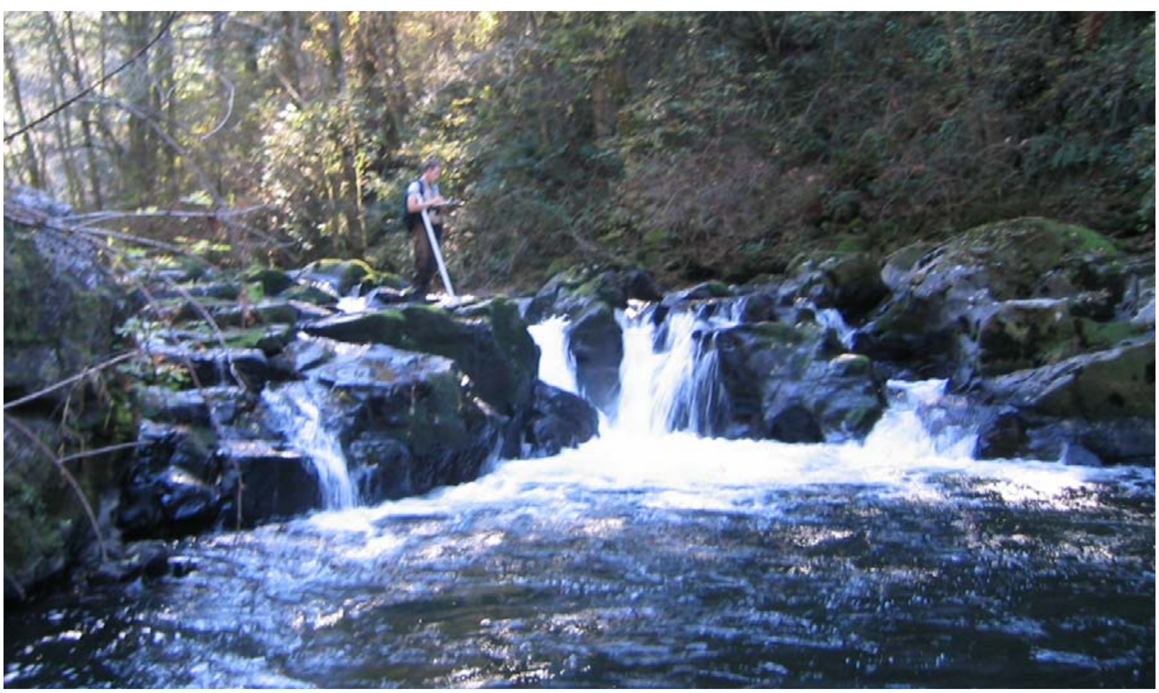


Figure 4. 103. Two meter high falls in Rock Creek reach one between NSOs three and four.

Figure 4. 104. Redd observed in the tailout of the pool below the falls in Rock Creek reach 1. Redd measures 3.5m long and 2.5m wide. Photo taken in October 2004.

4.A.7.9. Comparison to Habitat Standards

Numerous standards for rating the quality of salmonid habitat have been developed. Data collected in this survey were rated via two sets of standards applicable to basins of southwest Washington. The Washington Conservation Commission (WCC) established a set of standards to identify factors limiting salmonid production throughout the state. Standards applicable to western Washington were used here. Rock Creek habitat features were also compared to the NOAA Fisheries Properly Functioning Condition (PFC) standards. Only standards applicable to data collected were incorporated.

Availability of pool parameters were rated poorly under both criteria, but pool quality was rated as “Properly Functioning” under the PFC criterion (Table 4. 91). Density of large woody debris was rated as poor. Substrate was rated as “Properly Functioning”. Streambank stability was rated good for reaches one and three and as fair for reaches four and five. The barrier parameter was rated favorable under all conditions.

Table 4. 91. Rock Creek habitat feature ratings under regional salmonid habitat quality standards. Gray shaded cells indicate that no standard is available. PF = properly functioning; NPF = not properly functioning.

Parameter	Reach 1 WCC[1]	Reach 1 PFC[2]	Reach 3 WCC[1]	Reach 3 PFC[2]	Reach 4 WCC[1]	Reach 4 PFC[2]	Reach 5 WCC[1]	Reach 5 PFC[2]
% Pool by Surface Area	Fair		Fair		Poor		Poor	
Pool Frequency	Poor	NPF	Poor	NPF	Poor	NPF	Poor	NPF
Pool Quality		PF		PF		PF		PF
LWD		NPF		NPF		NPF		NPF
Substrate		PF		PF		PF		PF
Streambank Stability	Good	PF	Good	PF	Fair	At Risk	Fair	At Risk
Barriers	Good	PF	Good	PF	Good	PF	Good	PF

[1.] *Available ratings: good; fair; poor*
[2.] *Available ratings: properly functioning; at risk; not properly functioning*

4.A.7.10. Comparison to EDT Values

EDT patient scores were generally consistent with scores assigned based on survey results. Important differences include width differences in reaches three and four and differences in unit composition. Embeddedness is slightly higher than accounted for under EDT patient conditions (Table 4. 92).

Table 4. 92. EDT Patient scores assigned to Rock Creek and EDT scores based on 2004 stream survey results for categories relevant to data collected.

Category	EDT Patient Score	Score from Survey
Reach 1		
Channel width – minimum (m)	11.3	11.3
Gradient %	2.2	1.8
Confinement – hydromodifications	0	0
Confinement – natural	4	4
Habitat Type – Glides	0	0
Habitat Type – Beaver ponds	0	0
Habitat Type – off-channel habitat factor	0	0
Habitat Type – pool tailouts	11	2
Habitat Type – primary pools	35	37
Habitat Type – small cobble/gravel riffles	27	9
Habitat Type – Large cobble/boulder riffles	27	54
Riparian Function	1	1.5
Wood	3	4
Embeddedness	0.7	0.8
Reach 3	**EDT Patient Score**	**Score from Survey**
Channel width – minimum (m)	11.9	10.3
Gradient %	1.1	1.9
Confinement – hydromodifications	1	0
Confinement – natural	4	4
Habitat Type – Glides	1	3
Habitat Type – Beaver ponds	0	0
Habitat Type – off-channel habitat factor	0	0

Category	EDT Patient Score	Score from Survey
Habitat Type – pool tailouts	8	2
Habitat Type – primary pools	32	36
Habitat Type – small cobble/gravel riffles	20	15
Habitat Type – Large cobble/boulder riffles	39	46
Riparian Function	1	1
Wood	3	3.7
Embeddedness	0.7	1.2
Reach 4	**EDT Patient Score**	**Score from Survey**
Channel width – minimum (m)	7.0	9.9
Gradient %	1.4	1.0
Confinement – hydromodifications	0	0
Confinement – natural	4	4
Habitat Type – Glides	0	11
Habitat Type – Beaver ponds	0	0
Habitat Type – off-channel habitat factor	0	0
Habitat Type – pool tailouts	6	2
Habitat Type – primary pools	30	16
Habitat Type – small cobble/gravel riffles	13	27
Habitat Type – Large cobble/boulder riffles	51	46
Riparian Function	1	1.5
Wood	3	2.4
Embeddedness	0.7	1.1
Reach 5	**EDT Patient Score**	**Score from Survey**
Channel width – minimum (m)	7.0	7.8
Gradient %	3.6	3.1
Confinement – hydromodifications	0	0
Confinement – natural	4	4
Habitat Type – Glides	0	2
Habitat Type – Beaver ponds	0	0
Habitat Type – off-channel habitat factor	0	0
Habitat Type – pool tailouts	6	1
Habitat Type – primary pools	30	14
Habitat Type – small cobble/gravel riffles	13	10
Habitat Type – Large cobble/boulder riffles	51	74
Riparian Function	1	1.5
Wood	3	3
Embeddedness	0.7	0.8

4.A.7.11. Potential Areas of Restoration

The most likely potential for restoration in Rock Creek would be the addition of large woody debris. Current LWD densities are low and the potential for recruitment of large pieces in the near future is also low. Much of the vegetation in the immediate vicinity of the stream is hardwoods and young conifers. Pool availability is low and increases in stable pieces of LWD could help to create additional pool habitat. There is very little development along Rock Creek with the exception of a couple of rural residences that seem to have had little impact on the stream. There is an unmanaged road along reach three and Dole Valley Road along reaches four and five. The Dole Valley Road failure on the south bank upstream of the Dole Valley Road crossing should be addressed through road relocation and revegetation. More information on potential restoration opportunities can be found in the restoration opportunities section (Section 4.3.5).

4.A.8. King Creek

4.A.8.1. Introduction

King Creek enters the East Fork Lewis at RKm 47 (RM 29), approximately 5 km west of the Gifford Pinchot National Forest boundary in eastern Clark County. King Creek was surveyed on October 5 from the mouth upstream 1.8 km representing 47% of the EDT King Creek reach (Figure 4. 105). A modified version of the USFS Region 6 Level II Stream Survey Protocol was used for the survey (USFS 1999). A single temperature of 11°C was recorded at 11:24 AM. Land use along the surveyed portion of King Creek is entirely managed timberland. Some areas within the lower King Creek valley have been recently harvested.

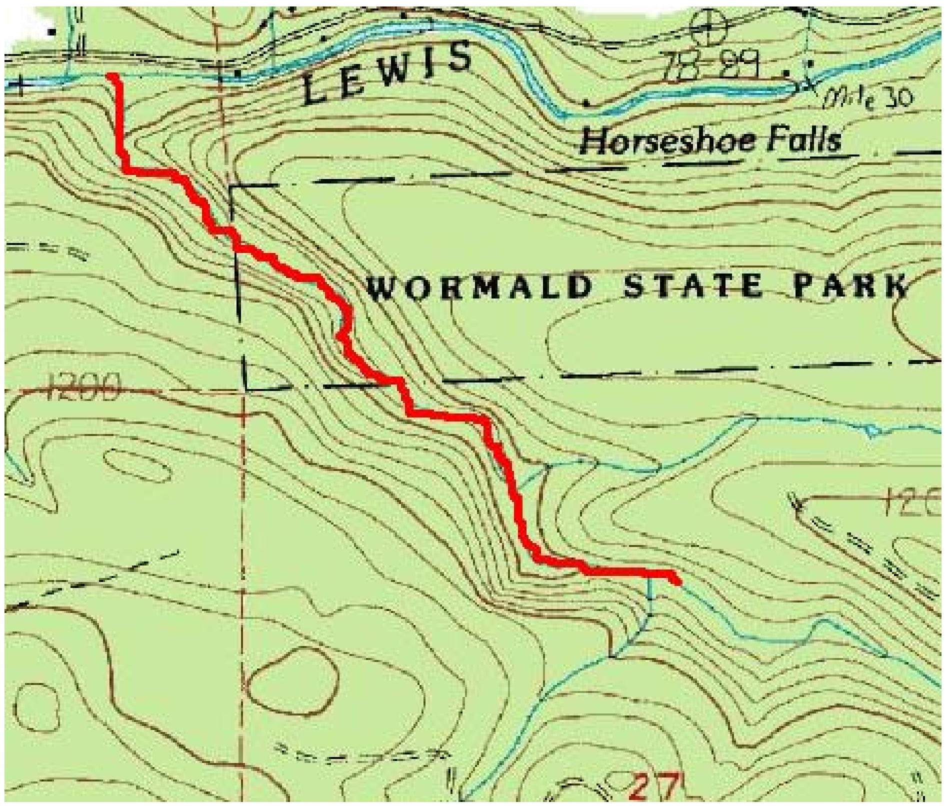


Figure 4. 105. USGS topographic map of King Creek highlighting the stream survey area. Survey length is 1.8 kilometers.

4.A.8.2. Channel Morphology

King Creek is comprised primarily of large cobble/boulder riffles with pools as the second most prominent habitat type (Figure 4. 106). Some units classified as large cobble/boulder riffles are cascades with steep and turbulent sections comprised of small pockets or pools. Field crews estimated that the "pocket-water" riffles may be comprised of as much as 50% pocket-water habitat. The channel type on the surveyed portion of King Creek is best classified as having a step-pool morphology (Montgomery and Buffington, 1998). Pool tailouts are typically short and end abruptly in steps, which minimizes the amount of available spawning habitat within pools. Cobbles in tailouts are frequently too large for spawning and were embedded at 20-30%.

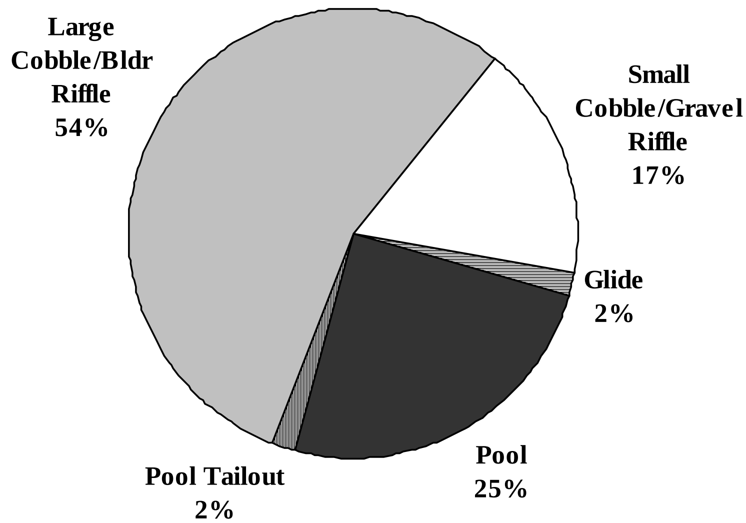


Figure 4. 106. Unit composition by percent surface area of the surveyed section of King Creek.

King Creek is moderate gradient and is moderately confined throughout by the valley wall. The stream is alternately against the east and west valley wall proceeding downstream. The active channel width is two times wider than the wetted width. Twelve percent of the surveyed length is comprised of multiple channels (Table 4. 93).

Table 4. 93. Average channel morphology characteristics of the surveyed section of King Creek.

Parameter	Reach Value
Mean gradient[1]	4.6
Mean riffle wetted width (m)	6.2
Mean active channel width (m)	13.5
Mean maximum riffle depth (m)	0.4
Mean residual pool depth (m)	0.5
Mean maximum pool depth (m)	0.7
Pools per kilometer	25.8
Primary pools (>1.0m deep) per kilometer	3.4
% of Length with side channel[2]	12

1. *As determined from LiDAR contours.*
2. *Dry or wetted side channels.*

4.A.8.3. Wood

There are 64 pieces of LWD per kilometer in the surveyed section of King Creek. Small pieces make up the largest portion among size classes and medium and large pieces are split evenly. There are also 4 jams and one rootwad per kilometer (Table 4. 94).

Table 4. 94. Size and density of wood, jams, and root wads in surveyed section of King Creek.

Wood Category	Definition	# Per Kilometer
Small Pieces	10-20 cm diameter; >2 m long	28
Medium Pieces	20-50 cm diameter; >2 m long	17
Large Pieces	>50 cm diameter; >2 m long	19
Jams	>10 pieces in accumulation	4
Root wads	>2 m long	1

4.A.8.4. Substrate

Characterization of substrate based on visual observation showed that the dominant and sub-dominant substrate classes in pools are gravel and cobble, respectively. Cobble and gravel are the dominant and sub-dominant size classes in riffles, respectively. Bedrock is the least present size category in both unit types (Figure 4. 107). Sand makes up 12% of the substrate in pools and 5% of the substrate in riffles. Grain sizes for each category are listed in Table 4. 95.

Table 4. 95. Grain size ranges for substrate size categories used in visual observations and pebble counts.

Category	Grain Size Range (mm)
Sand	< 2
Gravel	2 – 64
Cobble	64 – 256
Boulder	256 – 4096
Bedrock	>4096

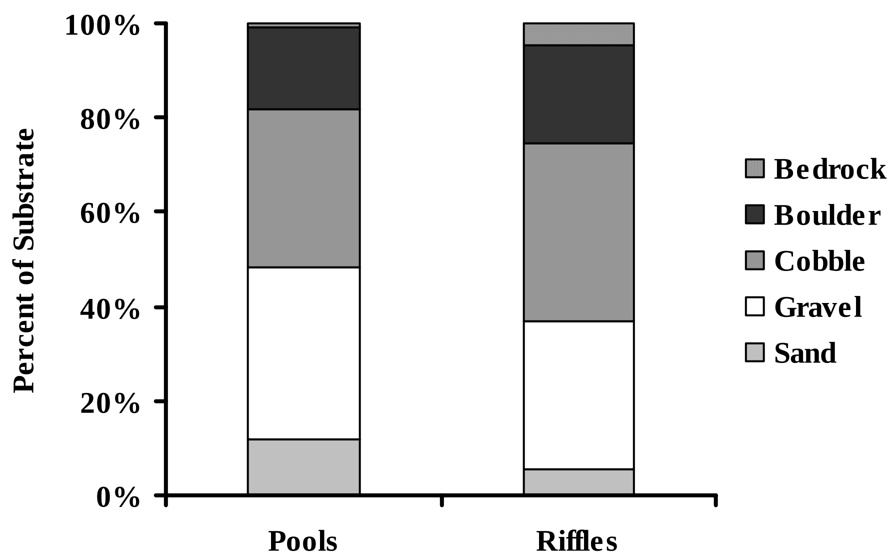


Figure 4. 107. Substrate size class composition in pools and riffles in the surveyed section of King Creek.

Embeddedness was rated in each unit according to four categories (0-25%, 25-50%, 50-75%, and 75-100%). Embeddedness was estimated in riffles, glides, and pool tailouts. Sixty-one percent of embeddedness ratings in King Creek fall within the 0-25% category. The other 39% are within the 25-50% category (Figure 4. 108). Field observations indicate that embeddedness ranges from 20-30%.

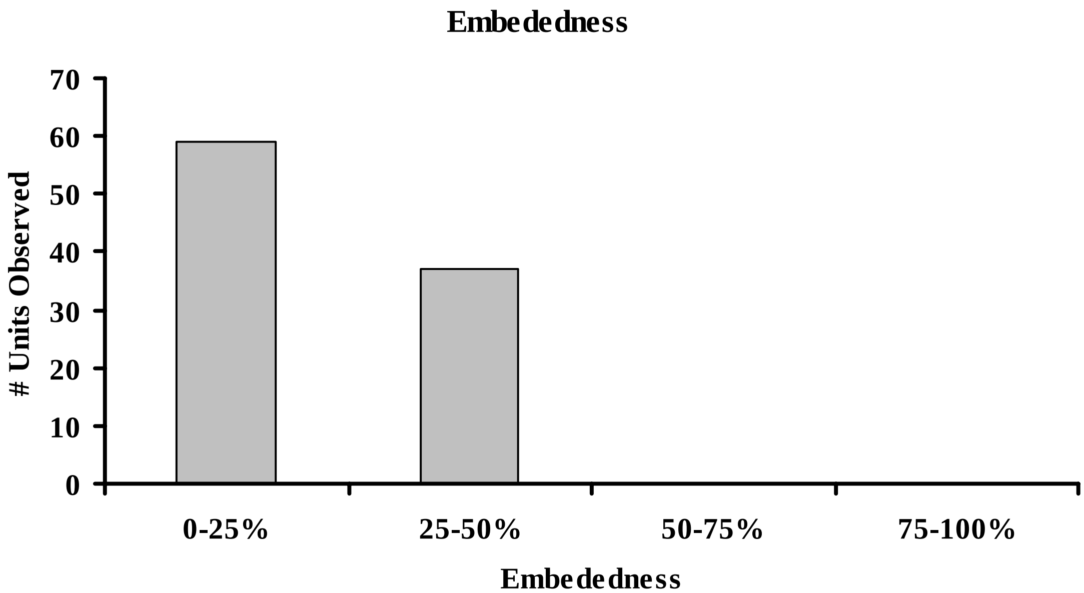
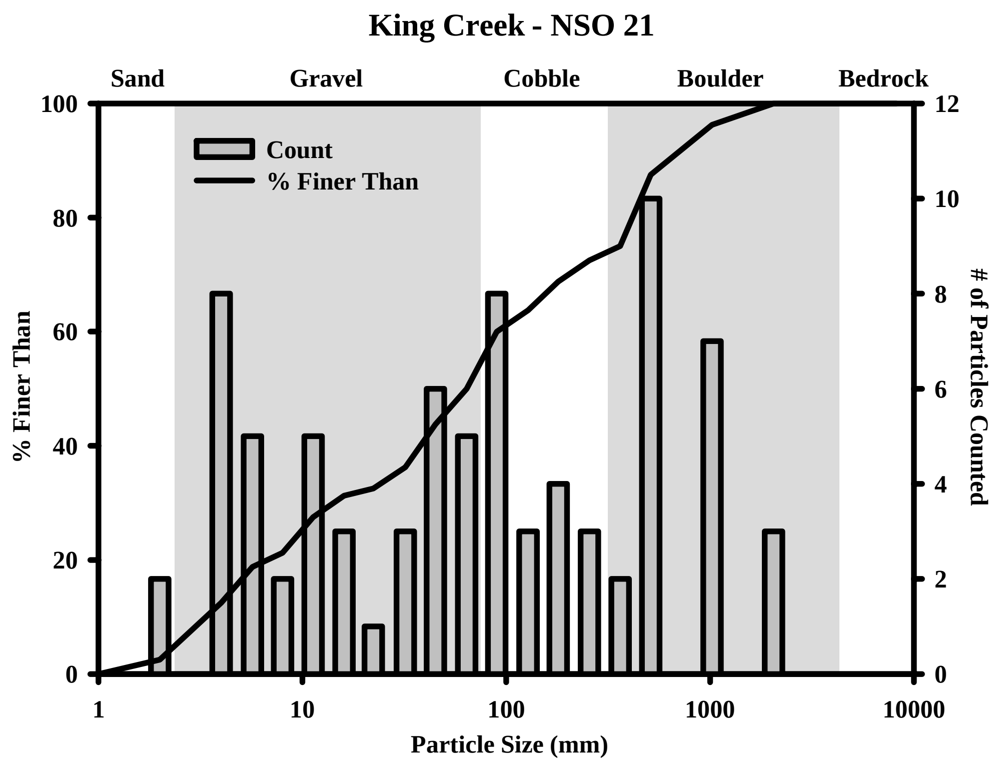


Figure 4. 108. Frequency of embeddedness ratings in surveyed sections of King Creek.

Pebble counts were conducted in the tailouts of two pools within the survey area. In the upper unit (NSO 21), the most frequent size category is 362-512mm, though gravel is the dominant substrate class with 48% of particles (Figure 4. 109). In NSO 51, the dominant size category is 64-90mm and the dominant substrate class is cobble. The median size category in NSO 21 is 45-64mm and in NSO 51 is 64-90mm. In NSO 21, 3% of particles are in the sand category and in NSO 51 only 5% are in the sand category. In NSO 21, there are more fine gravel particles and boulders than in NSO 51.



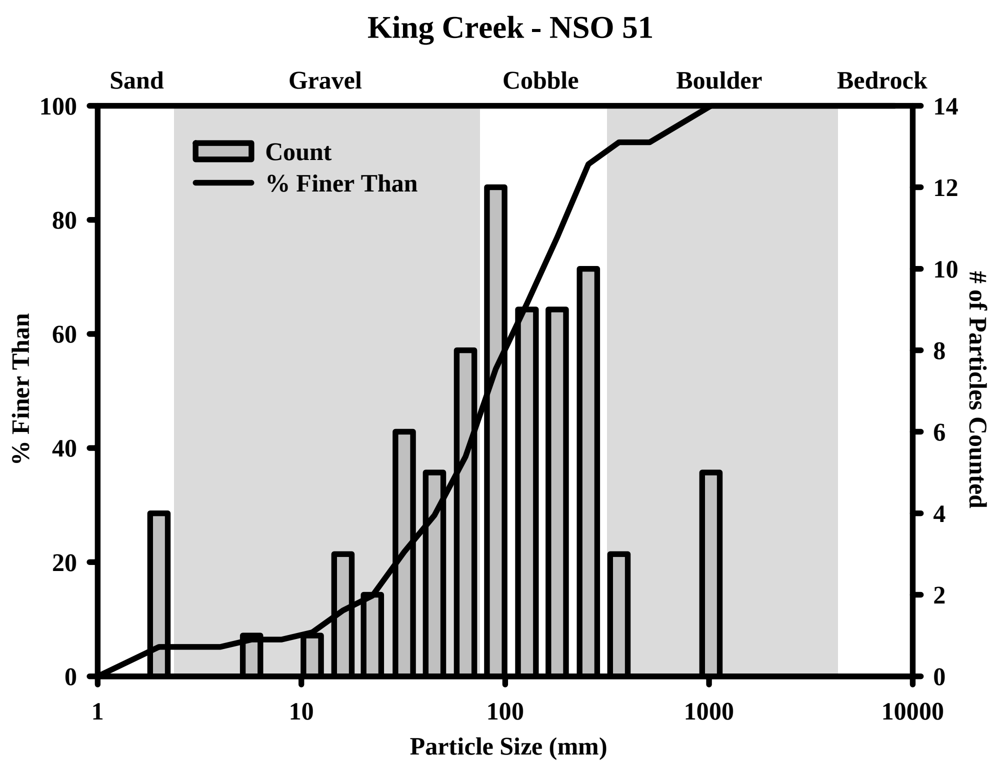


Figure 4. 109. Grain size distribution based on pebble counts in two pool tailouts in King Creek.

4.A.8.5. Cover

Cover is provided in King Creek in four of the five different cover forms recognized by the protocol including: LWD, overhanging cover, depth, and substrate velocity breaks. The dominant cover form is substrate with 11% of the reach having cover provided by boulders creating velocity refuge (Table 4. 96). While LWD is present in fair density throughout the reach, it is not a significant source of cover. Some large pieces act as forming agents and create pools, but many other pieces also are on the wetted margins running parallel to the stream flow and thus do not create significant cover.

Table 4. 96. Presence of cover within the surveyed portion of King Creek. Measured as percent of surface area of stream unit covered.

Cover Type	Average % Cover Provided
LWD	1
Undercut Bank	0
Overhanging Cover	3
Depth > 1m	3
Substrate (Velocity cover)	11

4.A.8.6. Riparian

King Creek is well shaded by vegetation on both banks. The mean view to sky angle is 33 degrees (Table 4. 97). Dominant overstory vegetation is primarily hardwoods in the form of alder, especially on the right bank (Figure 4. 110). Occasionally, conifers, saplings or shrubs made up the dominant overstory. Within 200m of the mouth, logging activity near the left bank has eliminated much of the vegetation providing shade and overstory. Logging activity is occasionally present throughout the reach outside of the 35m riparian zone.

Table 4. 97. Riparian shading characteristics in surveyed section of King Creek. Data presented as proceeding downstream.

Parameter	Result
Mean distance to vegetation – left bank (m)	14
Mean left bank canopy angle (degrees)	70
Mean distance to vegetation – right bank (m)	13
Mean right bank canopy angle (degrees)	77
Mean view to sky (degrees)	33

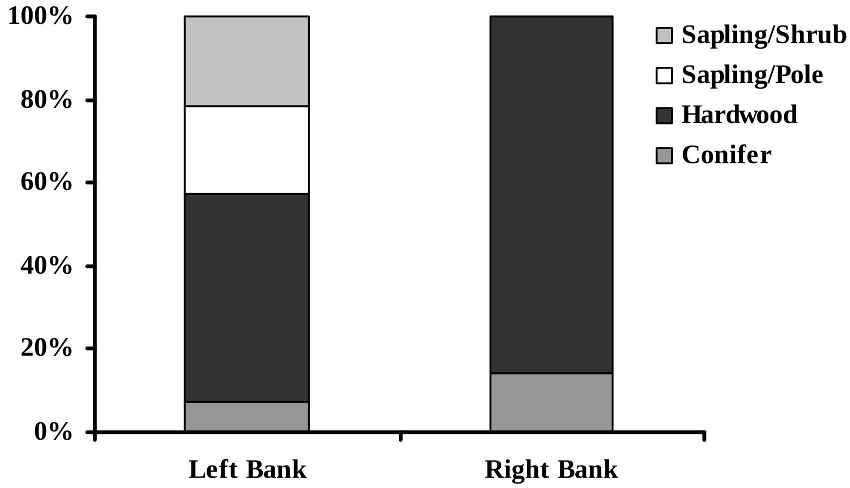


Figure 4. 110. Vegetation type by percentage of units observed. Data presented as proceeding downstream.

4.A.8.7. Instability & Disturbance

There is minimal bank instability in the surveyed section of King Creek and no recent timber harvest throughout most of the riparian zone (Table 4. 98). The only disturbance present is the clear-cut at the lower end of the reach and a primitive road crossing within the logged area. It is unclear if the crossing is currently in use.

Table 4. 98. Bank instability and disturbance of the surveyed section of King Creek. Data presented as proceeding downstream.

Parameter	Result	Comment
Left bank instability (%)	1	
Right bank instability (%)	0	
Left bank disturbance (%)	1	Clear-cut and road crossing at lower end
Right bank disturbance (%)	1	Road crossing at lower end of reach

4.A.8.8. Other Observations

There is a washed out culvert in the stream channel 1000m upstream from the mouth. The culvert measures approximately 1-1.5m in diameter and 8m in length (Figure 4. 111). Its position in the channel currently precludes it from posing any passage issues but future high water events could mobilize it and reposition it in the channel.

Three adult steelhead (*O. mykiss*) and beaver (*Castor canadensis*) activity were seen in the reach. Near one tributary junction, beavers had felled a conifer that spanned the channel and has created a plunge pool below the log, which has held spawning size substrate above the log (Figure 4. 112).

There is a small log jam with large pieces of wood and a falls 190m upstream from the mouth of King Creek. The falls is 2m high and there are large cedar pieces at both the top and the bottom of the falls. On the right side of the falls (ascending) there is an intermediate pool that would assist in passage at moderate or high flows. At low flows this falls may be a barrier or at least would impose a significant passage challenge.

Figure 4. 111. Photo of washed out culvert in the stream channel approximately 1000m from the mouth of King Creek.

Figure 4. 112. Photo of conifer felled by beavers creating a plunge pool and storing spawning size substrate above.

4.A.8.9. Comparison to Habitat Standards

Numerous standards for rating the quality of salmonid (*Oncorhynchus sp.*) habitat have been developed. Data collected in this survey were rated via two sets of standards applicable to basins of southwest Washington. The Washington Conservation Commission (WCC) established a set of standards to identify factors limiting salmonid production throughout the state. Standards applicable to western Washington were used here. King Creek habitat features were also compared to the NOAA Fisheries Properly Functioning Condition (PFC) standards. Only standards applicable to data collected were incorporated.

The availability of surface area of pools was rated as "poor" by the WCC criteria (Table 4. 99). However, it is worth noting that several riffles within this reach were cascades with numerous small and turbulent pocket pools within them. The area and frequency of units surveyed as pools does not account for these pocket water pools. Pool frequency was rated in the middle under both sets of criteria, as was pool quality by the PFC criterion. Substrate was rated as "At risk" by the PFC because embeddedness was usually greater than 20%. Stability and barrier presence were rated favorably under both sets of criteria.

Table 4. 99. King Creek habitat feature ratings under regional salmonid habitat quality standards. Gray shaded cells indicate that no standard is available.

Parameter	WCC[1]	PFC[2]
% Pool by Surface Area	Poor	
Pool Frequency	Fair	At Risk
Pool Quality		At Risk
LWD		Not Properly Functioning
Substrate		At Risk
Streambank Stability	Good	Properly Functioning
Barriers	Good	Properly Functioning

1. *Available ratings: good; fair; poor*
2. *Available ratings: properly functioning; at risk; not properly functioning*

4.A.8.10. Comparison to EDT Values

EDT patient scores were generally similar to scores assigned based on survey results. Important differences include an EDT patient score for small cobble/gravel riffles of 7% whereas surveys showed that 17% of habitat within the reach was small cobble/gravel riffle. Much of this difference was made up in the over-estimation of large cobble/boulder habitat types within EDT. Observed embeddedness was higher than assigned under the EDT patient condition and there was slightly more wood present than assigned under EDT (Table 4. 100).

Table 4. 100. EDT Patient scores assigned to King Creek and EDT scores based on 2004 stream survey results for categories relevant to data collected. Gradient is for entire EDT reach as determined from LiDAR contours, not just surveyed section.

Category	EDT Patient Score	Score from Survey
Channel width – minimum (m)	3.7	6.2
Gradient %	5.6	3.3
Confinement – hydromodifications	0	0
Confinement – natural	4	3.5
Habitat Type – Glides	3%	2%
Habitat Type – Beaver ponds	0%	0%
Habitat Type – off-channel habitat factor	0%	0%
Habitat Type – pool tailouts	3%	2%
Habitat Type – primary pools	21%	25%
Habitat Type – small cobble/gravel riffles	7%	17%
Habitat Type – Large cobble/boulder riffles	66%	54%
Riparian Function	1	1.5
Wood	3	2.7
Embeddedness	0.7	1.5

4.A.8.11. Potential Areas of Restoration

Pool and LWD metrics were rated either moderately or poorly under the WCC and PFC. Where large conifer pieces are present in the stream channel, pools have been formed and substrate stored. However, the riparian zone is predominantly hardwood (see Figure 4. 110). Recent recruitment of LWD has been low and the future potential recruitment of large pieces that may persist and form habitat is low.

Logging within the riparian zone in the lower 200m of stream, as well as the road crossing, may be having detrimental impacts on the lowest section of King Creek. Certainly, vegetative shading has been reduced and the potential exists for increased erosion and bank instability in this section. Within this 200m segment is a major primary pool and a section of braided channels; habitat complexity that is important to protect in this lower segment.

Additionally, removing the washed out culvert within the channel 1000m upstream from the mouth should be considered; however, the culvert is not having any major deleterious effects on stream habitat at this time.

4.A.9. Slide Creek

4.A.9.1. Introduction

Slide Creek is located in Skamania County in the Gifford Pinchot National Forest. The creek enters the East Fork Lewis at RKm 55 (RM 34). Slide Creek was surveyed on October 6 from the mouth upstream 1.2 km representing 50% of the EDT Slide Creek reach (Figure 4. 113). A modified version of the USFS Region 6 Level II Stream Survey Protocol was used for the survey (USFS 1999). Two temperatures were recorded during the survey ranging from 11.4-12.2°C. The Slide Creek Basin is owned entirely by the USFS and land use is managed timberland.

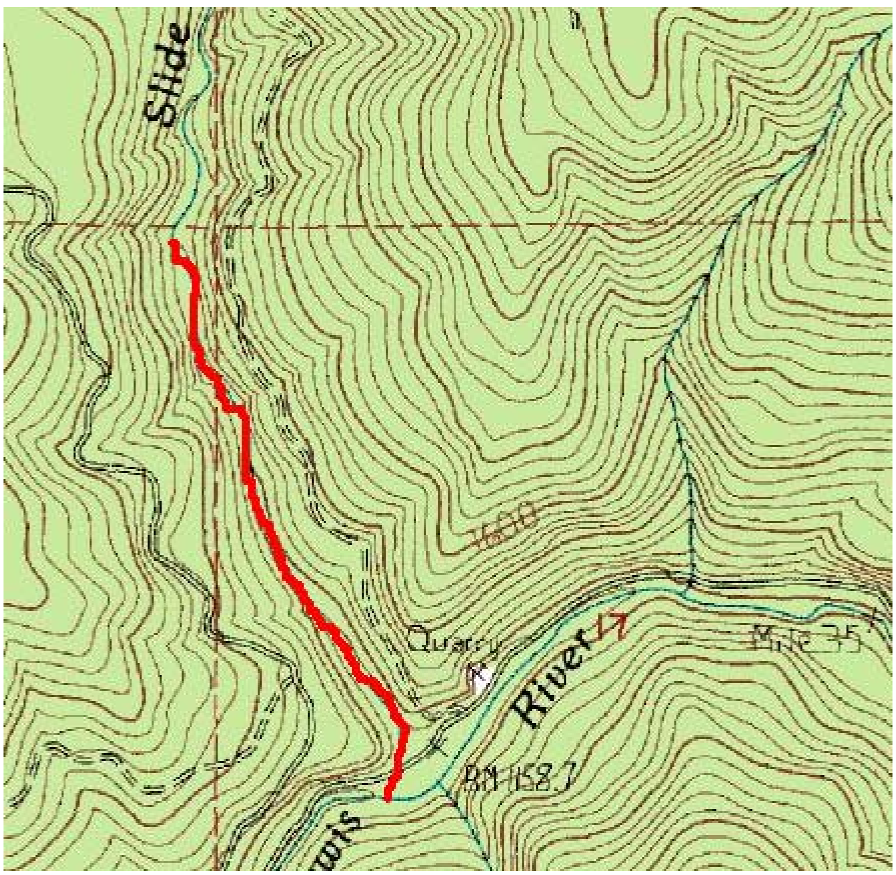


Figure 4. 113. USGS topographic map of Slide Creek highlighting the stream survey area. Survey length is 1.2 kilometers.

4.A.9.2. Channel Morphology

Slide creek is comprised primarily of large cobble/boulder riffles with pools as the second most prominent habitat type (Figure 4. 114). Some units classified as large cobble/boulder riffles are cascades with steep and turbulent sections containing small pockets or pools. The surveyed portion of Slide Creek is best classified as having a step-pool morphology (Montgomery and Buffington, 1998). The existence of at least four pools in the lower 350m of the survey could be partially attributed to stream restoration activities from 1999.

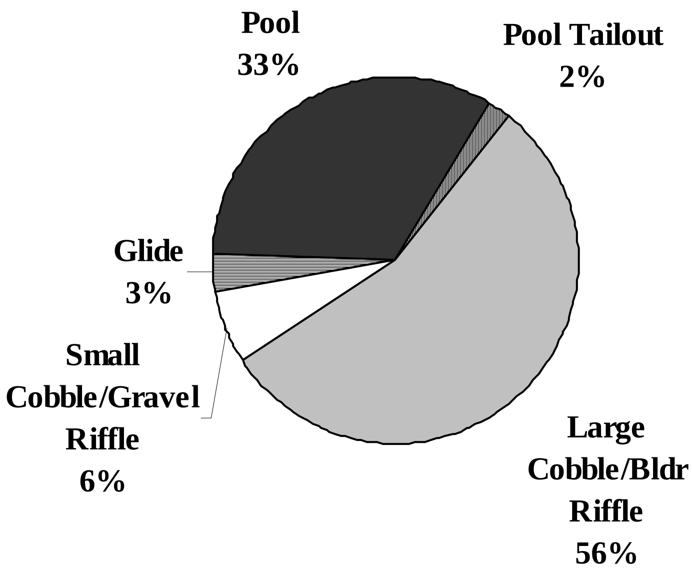


Figure 4. 114. Unit composition by percent surface area of the surveyed section of Slide Creek.

Slide Creek is high gradient and is confined throughout by bedrock and steep valley walls. The active channel width is only 7% greater than the observed wetted width and only 4% of the length surveyed included a secondary channel (Table 4. 101).

Table 4. 101. Average channel morphology characteristics of surveyed section of Slide Creek.

Parameter	Reach Value
Mean gradient[1]	3.1
Mean riffle wetted width (m)	7.8
Mean active channel width (m)	8.4
Mean maximum riffle depth (m)	0.6
Mean residual pool depth (m)	0.6
Mean maximum pool depth (m)	1.0
Pools per kilometer	25.0
Primary pools (>1.0m deep) per kilometer	7.5
% of Length with side channel[2]	4

1. *As determined from LiDAR contours.*
2. *Dry or wetted side channels.*

4.A.9.3. Wood

There are 60 pieces of LWD per kilometer in the surveyed section of Slide Creek. A majority of those are large pieces (Table 4. 102). Approximately 20 of the large pieces were placed during a 1999 stream restoration project; there were no jams and few root wads.

Table 4. 102. Size and density of wood, jams, and root wads in the surveyed section of Slide Creek.

Wood Category	Definition	# Per Kilometer
Small Pieces	10-20 cm diameter; >2 m long	5
Medium Pieces	20-50 cm diameter; >2 m long	14
Large Pieces	>50 cm diameter; >2 m long	41[1]
Jams	>10 pieces in accumulation	0
Root wads	>2 m long	2

[1.] *26 pieces/km of naturally contributed pieces. Other pieces placed during restoration efforts.*

4.A.9.4. Substrate

Characterization of substrate based on visual observation showed that the dominant and sub-dominant substrate classes in pools are gravel and cobble, respectively (Figure 4. 115. Cobble and bedrock are the dominant and sub-dominant size classes in riffles, respectively. Sand is the least present size category in both unit types. In riffles, bedrock comprises approximately 30% of the substrate. Bedrock serves as a hydraulic control in many locations, forming cascades and creating step-pool morphology with sequential pools separated by short bedrock steps (Figure 4. 116). Grain sizes for each category are listed in Table 4. 103.

Table 4. 103. Grain size ranges for substrate size categories used in visual observations and pebble counts.

Category	Grain Size Range (mm)
Sand	< 2
Gravel	2 – 64
Cobble	64 – 256
Boulder	256 – 4096
Bedrock	>4096

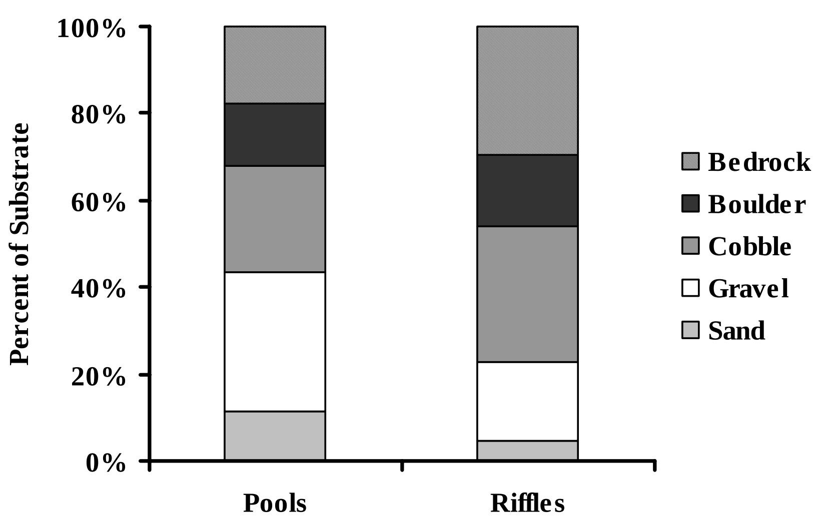


Figure 4. 115. Substrate size class composition in pools and riffles in the surveyed section of Slide Creek.

Figure 4. 116. Photo illustrating presence and function of bedrock typical throughout much of Slide Creek.

Embeddedness was rated in each unit according to four categories (0-25%, 25-50%, 50-75%, and 75-100%). Embeddedness was estimated in riffles, glides, and pool tailouts. Sixty percent of embeddedness ratings in Slide Creek fall within the 25-50% category. The other 40% are within the 0-25% category (Figure 4. 117). Field observations indicate that embeddedness within the reach typically ranges between 20-35%.

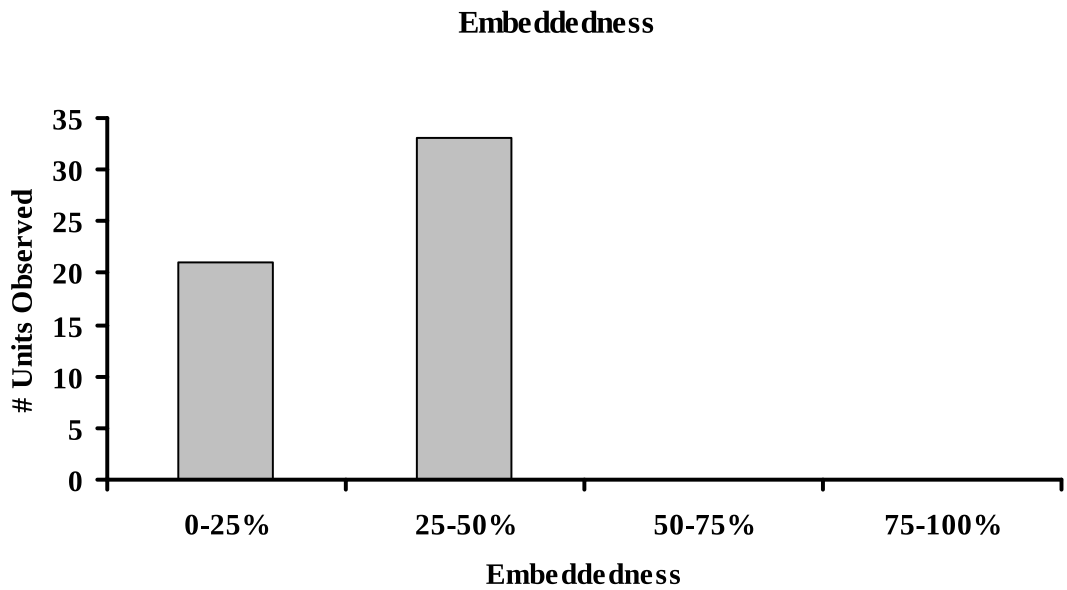
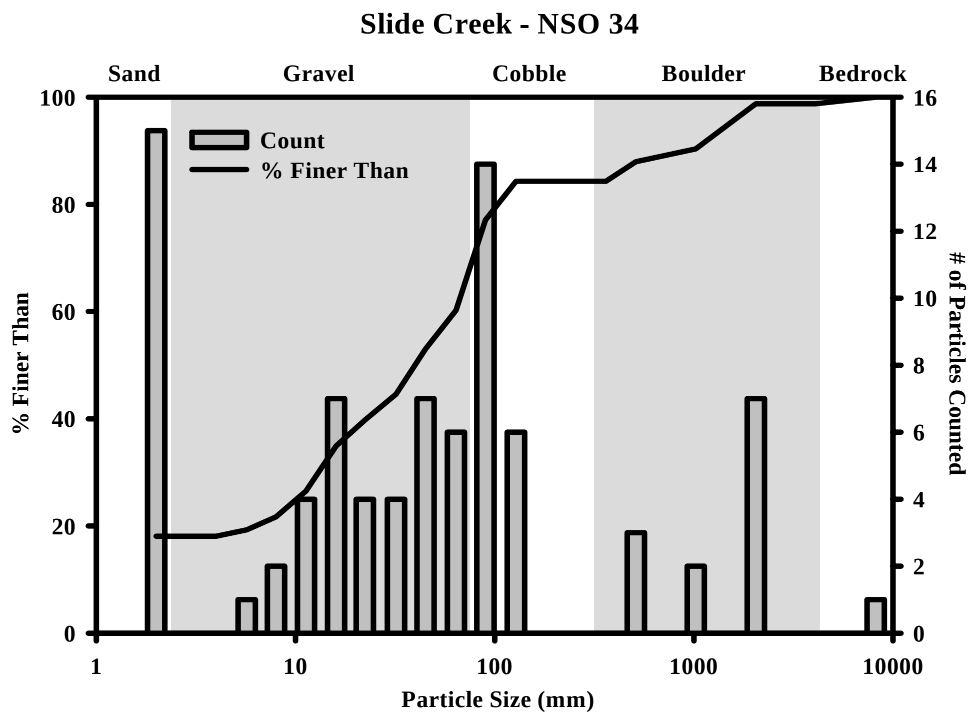


Figure 4. 117. Frequency of embeddedness ratings in the surveyed section of Slide Creek.

Pebble counts were conducted in the tailouts of two pools within the survey area. In the lower unit (NSO 34), the most frequent size category selected was sand, though gravel was the most dominant substrate class (Figure 4. 118). In that same unit, 60% of all particles were gravel size or smaller. In NSO 54, there was a shift to larger particle sizes with more cobble and less sand present. In this unit, 55% of all particles were gravel size or smaller. The median size category in NSO 34 was 32-45mm and in NSO 54 was 45-64mm. In NSO 34, 18% of particles were in the sand category. In NSO 54, only 1% were in the sand category.



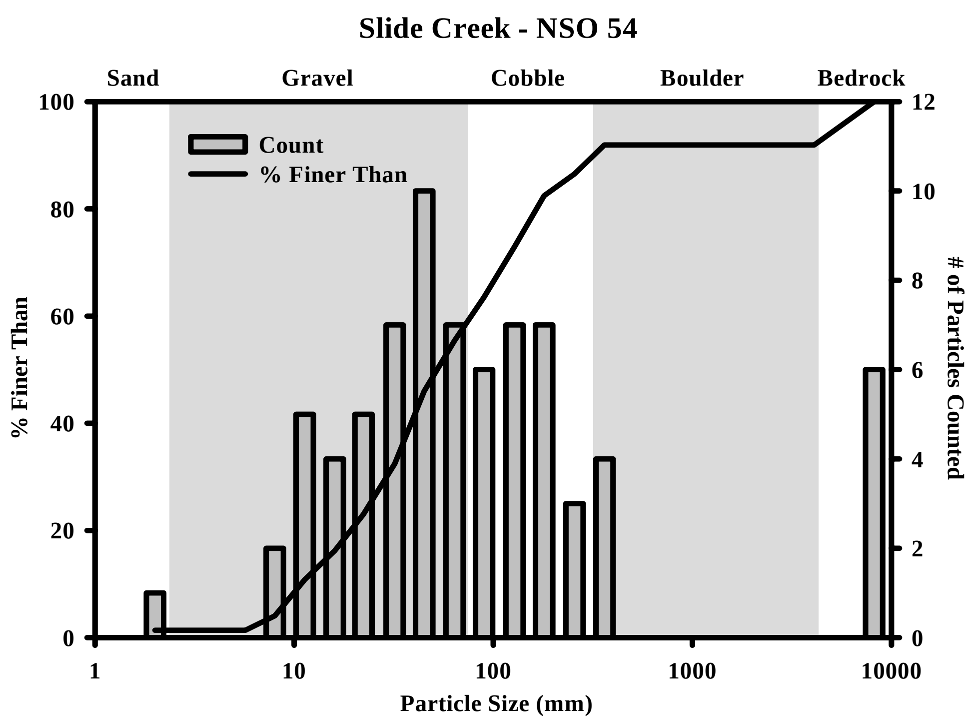


Figure 4. 118. Grain size distribution based on pebble counts in two pool tailouts in Slide Creek.

4.A.9.5. Cover

Cover is provided in Slide Creek in each of the five different cover forms recognized by the protocol including: LWD, undercut banks, overhanging cover, depth, and substrate velocity breaks. The dominant cover form is substrate with 21% of the reach having cover provided by boulders and bedrock creating velocity refuge (Table 4. 104). Depth in pools also is a significant source of cover with several primary pools of adequate depth present within the reach. While LWD is present in fair density throughout the reach, it is not a significant source of cover. Many large pieces act as forming agents and create pools but many other pieces are on the wetted margins running parallel to the stream flow, therefore not providing significant cover.

Table 4. 104. Presence of cover within the surveyed portion of Slide Creek. Cover is measured as the percent of surface area of stream unit.

Cover Type	Average % Cover Provided
LWD	1
Undercut Bank	1
Overhanging Cover	6
Depth > 1m	17
Substrate (Velocity cover)	21

4.A.9.6. Riparian

Slide Creek is well shaded by vegetation on both banks. The mean view to sky angle is 42 degrees (Table 4. 105). Dominant vegetation is either conifers or mixed hardwood and conifers (Figure 4. 119). A small portion of the left bank is dominated by saplings and shrubs where a de-commissioned road follows the stream bank at the lower end of the reach.

Table 4. 105. Riparian shading characteristics in the surveyed section of Slide Creek. Data is presented as proceeding downstream.

Parameter	Result
Mean distance to vegetation – left bank (m)	16
Mean left bank canopy angle (degrees)	68
Mean distance to vegetation – right bank (m)	11
Mean right bank canopy angle (degrees)	70
Mean view to sky (degrees)	42

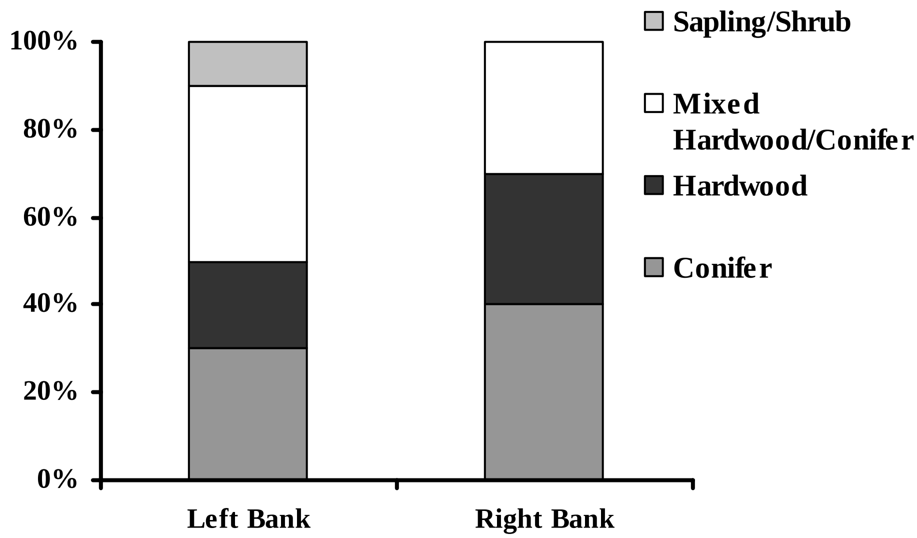


Figure 4. 119. Vegetation type by percentage of units observed. Data presented as proceeding downstream.

4.A.9.7. Instability & Disturbance

There is no bank instability in the surveyed section of Slide Creek and no recent timber harvest within the surveyed reach. Confinement by bedrock throughout much of the reach precludes the existence of bank instability. The only disturbance present is a de-commissioned road following the left bank (proceeding downstream) along the lower portion of the surveyed reach. For the majority of the reach length, the road is outside the 35m riparian zone so the percentage of riparian zone disturbed is low at 6% (Table 4. 106).

Table 4. 106. Bank instability and disturbance of surveyed section of Slide Creek. Data presented as proceeding downstream.

Parameter	Result	Comment
Left bank instability (%)	0	
Right bank instability (%)	0	
Left bank disturbance (%)	6	De-commissioned road
Right bank disturbance (%)	0	

USFS Road 42 crosses Slide Creek 66m upstream from the mouth. There is an open arch culvert measuring 10m in length and 5m in diameter at this road crossing. There are no baffles present. There is a sizeable pool below and inside the culvert changing to a riffle within the culvert. There is a steep, though short, cascade where the pool transitions to a riffle within the culvert (Figure 4. 120). It is not likely the culvert would pose a passage barrier at any flow.

Figure 4. 120. Picture of culvert beneath USFS Road 42, 66m upstream from the mouth of Slide Creek.

4.A.9.8. Other Observations

Beginning 113m from the mouth and continuing for 236m is restoration activity from 1999. In several places large wood was placed numbering between 18 and 22 pieces with at least one large root wad. These pieces were placed as both deflector logs and to hold sediment while creating a downstream scour pool. Several boulders were also placed along the left descending bank in one location where the de-commissioned road draws near to the stream. Restoration appeared to be focused on locations where the road was closest to the stream (Figure 4. 121).

Figure 4. 121. Photo of stream restoration activity in lower Slide Creek (view looking downstream). Note buildup of cobbles and gravels upstream of engineered jam and formation of pools both above and below the jam. The de-commissioned road is approximately 5m off to the left of the picture.

4.A.9.9. Comparison to Habitat Standards

Numerous standards for rating the quality of salmonid (*Oncorhynchus sp.*) habitat have been developed. Data collected in this survey were rated via two sets of standards applicable to basins of southwest Washington. The Washington Conservation Commission (WCC) established a set of standards to identify factors limiting salmonid production throughout the state. Standards applicable to western Washington were used here. Slide Creek habitat features were also compared to the NOAA Fisheries Properly Functioning Condition (PFC) standards. Only standards applicable to data collected were incorporated.

The availability and frequency of pools are rated poorly under both criteria (Table 4. 107). However, it is worth noting that several riffles within this reach are cascades that have numerous small and turbulent pocket pools within them. The area and frequency of units surveyed as pools does not account for these pocket water pools. LWD density is rated unfavorably under both sets of criteria and substrate was rated as “not properly functioning” due to moderate embeddedness levels. Stability and barrier presence are both rated favorably under both sets of criteria.

Table 4. 107. Slide Creek habitat feature ratings under regional salmonid habitat quality standards. Gray shaded cells indicate that no standard is available.

Parameter	WCC[1]	PFC[2]
% Pool by Surface Area	Fair	
Pool Frequency	Poor	Not Properly Functioning
Pool Quality		Properly Functioning
LWD		Not Properly Functioning
Substrate		At Risk
Streambank Stability	Good	Properly Functioning
Barriers	Good	Properly Functioning

1. *Available ratings: good; fair; poor*
2. *Available ratings: properly functioning; at risk; not properly functioning*

4.A.9.10. Comparison to EDT Values

EDT patient scores are generally similar to scores assigned based on survey results. Important differences include a minimum width greater than the EDT patient score and higher embeddedness than the EDT patient score (Table 4. 108). Other minor differences include more pool habitat and less riffle than the EDT patient score.

Table 4. 108. EDT Patient scores assigned to Slide Creek and EDT scores based on 2004 stream survey results for categories relevant to data collected. Gradient is for the entire EDT reach based on LiDAR contours.

Category	EDT Patient Score	Score from Survey
Channel width – minimum (m)	4.5	7.8
Gradient %	9.0	3.5
Confinement – hydromodifications	0	0
Confinement – natural	4	4
Habitat Type – Glides	3%	3%
Habitat Type – Beaver ponds	0%	0%
Habitat Type – off-channel habitat factor	0%	0%
Habitat Type – pool tailouts	3%	2%
Habitat Type – primary pools	21%	32%
Habitat Type – small cobble/gravel riffles	7%	7%
Habitat Type – Large cobble/boulder riffles	66%	56%
Riparian Function	1	1
Wood	3	2.8
Embeddedness	0.7	1.6

4.A.9.11. Potential Areas of Restoration

Both LWD densities and pool frequency are rated as “poor” under the WCC criteria and “not properly functioning” under the PFC criteria. Both of these shortfalls could be addressed with the addition of secured LWD in pool forming positions. Restoration activities of 1999 not only increased the LWD density of the surveyed section by 33%, but also formed primary pools and helped to store spawning gravels (Figure 4. 121). Natural retention of wood in Slide Creek may be low because of high gradient and confinement. The creek may therefore not be expected to meet the WCC and PFC standards even under pristine conditions. Additional discussion of project opportunities for Slide Creek and the remainder of the upper basin can be found in Section 4.3.6 .

Appendix 4.B.

Update of SSHIAP Hydromodifications GIS Coverages

Introduction

This appendix includes background information and metadata for GIS coverages to be used for editing SSHIAP hydromodifications GIS coverages. The GIS coverages to be used for updating the SSHIAP coverages have been provided to the Lower Columbia Fish Recovery Board as part of this project.

Background

As part of the watershed and habitat assessment for the East Fork Lewis River Basin conducted for the Lower Columbia Fish Recovery Board (LCFRB), SP Cramer & Associates has made recommendations for edits to the SSHIAP (WDFW – Salmon and Steelhead Habitat Inventory and Assessment Program) hydromodifications GIS coverages. The SSHIAP coverages consist of a point, a line, and a polygon coverage for WRIA 27. The recommended edits are focused only within the vicinity of the lower mainstem East Fork Lewis River valley bottom from the mouth to river mile 16 (confluence with lower Rock Creek). Sources for the recommended edits include field surveys, aerial photograph analysis, information from other studies, and existing GIS coverages, including LiDAR contours provided by Clark County. High resolution (6 inch pixel size) digital color orthophotos from 2002 were particularly useful for this analysis. These were provided by Clark County. The recommendations have been provided in the form of GIS coverages to the LCFRB. It is under the discretion and responsibility of SSHIAP to update their coverages to reflect the recommended changes. The content of these coverages is discussed below.

Shapefile descriptions and event tables

The recommended edits are provided in the form of 2 shapefiles for each file type (point, line, polygon), resulting in 6 shapefiles overall. For each of the SSHIAP files, one shapefile contains only those features that are recommended for *deletion* from the existing SSHIAP coverage and the second shapefile contains only features that are recommended for *addition* to the SSHIAP coverage.

The *additions* shapefiles are the following:

1. East_Fork_Hydromod_Additions_(pnt) – recommended additions to SSHIAP Hydromodifications point coverage
2. East_Fork_Hydromod_Additions_(line) – recommended additions to SSHIAP Hydromodifications line coverage
3. East_Fork_Hydromod_Additions_(poly) – recommended additions to SSHIAP Hydromodifications polygon coverage

The *additions* shapefiles have 4 fields that have been added to them. All of the existing fields are also retained although most of these have been left for SSHIAP personnel to complete according to their protocol. The only existing fields that are edited are the "comments" field, which includes any relevant information on the feature, and the "HMOD" field, which contains the SSHIAP HMOD ID code. The 4 fields that have been added to the *additions* shapefiles are listed below with their explanation:

Field Name	Format	Description
LCFRB_code	10 digit integer	R2 summary code. A simplified form of the HMOD ID code.
LCFRBsourc	20 digit text	Name of firm (in this case, all are "SP Cramer & Assoc.")
LCFRBsrcID	10 digit integer	Code of firm - 1 for R2, 2 for SP Cramer & Assoc.
EDT_Reach	20 digit text	Name of EDT Reach that is closest to the feature
FieldChk	2 digit text	Y for yes, N for no for whether the feature was field checked.

The *deletions* shapefiles are the following:

4. East_Fork_Hydromod_Deletions_(pnt) – recommended deletions to SSHIAP Hydromodifications point coverage
5. East_Fork_Hydromod_ Deletions _(line) – recommended deletions to SSHIAP Hydromodifications line coverage
6. East_Fork_Hydromod_ Deletions _(poly) – recommended deletions to SSHIAP Hydromodifications polygon coverage

The *deletions* shapefiles have 3 fields that have been added to them. All of the existing fields are also retained although most of these have been left for SSHIAP personnel to complete according to their protocol. The only existing fields that are edited are the "comments" field, which includes any relevant information on the feature. The 3 fields that have been added to the *deletions* shapefiles are listed below with their explanation:

Field Name	Format	Description
LCFRB_Notes	20 digit text	This just says "delete" for every feature
LCFRBsourc	20 digit text	Name of firm (in this case, all are "SP Cramer & Assoc.")
LCFRBsrcID	10 digit integer	Code of firm - 1 for R2, 2 for SP Cramer & Assoc.

Projection Information

All shapefiles are in Washington Stateplane South – NAD 1927 – Feet

Summary

In many instances, the recommended edits are simply a higher resolution delineation of existing features in the SSHIAP coverages. In these cases, the existing feature is recommended for deletion and a new feature is recommended for addition in its place. In other cases, entirely new features are recommended for addition or entire features are recommended for deletion. Where applicable, the source of the information (e.g. field surveys, aerial photos) is indicated in the comments field. The following table gives a summary of the number of features included in each shapefile.

Shapefile Name	Number of features
East_Fork_Hydromod_Additions_(pnt)	18
East_Fork_Hydromod_Additions_(line)	91
East_Fork_Hydromod_Additions_(poly)	13
East_Fork_Hydromod_Deletions_(pnt)	4
East_Fork_Hydromod_Deletions_(line)	88
East_Fork_Hydromod_Deletions_(poly)	13