Boundary Hydroelectric Project (FERC No. 2144)

Study 14
Assessment of Factors Affecting Aquatic Productivity in Tributary Habitats
Final Report

Prepared for
Seattle City Light

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March 2009

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1 INTRODUCTION

Study 14, Assessment of Factors Affecting Aquatic Productivity in Tributary Habitats, is being conducted in support of the relicensing of the Seattle City Light's (SCL) Boundary Hydroelectric Project (Project), Federal Energy Regulatory Commission (FERC) No. 2144, as identified in the Revised Study Plan (RSP; SCL 2007). The RSP was submitted by SCL on February 14, 2007, and approved by the FERC in its Study Plan Determination letter dated March 15, 2007. This is the final report describing the field efforts and analyses and represents the completion of the study.

Tributary streams contribute to river or reservoir systems by providing physical support as a source of nutrients, sediment, large woody debris (LWD), and water. In addition, they support biological processes by providing refuge, foraging areas, and recruitment habitat to fish residing within the tributaries year-round (termed resident or fluvial fish), as well as to any fish that may migrate between the reservoir and tributary streams (termed adfluvial) during their life cycle. As such, the health of fluvial and adfluvial salmonid populations within the Project area might depend to some degree on tributary streams that provide those physical and biological needs.

Study 14 evaluates tributary areas upstream from the tributary deltas within the Project area. Potential effects from Project operations related to tributary deltas are evaluated in the Study 8, Sediment Transport and Boundary Reservoir Tributary Delta Habitats Final Report (SCL 2009a) and Study 9, Fish Distribution, Timing and Abundance Study Final Report (SCL 2009b). Results of studies 8 and 9 provide an understanding of the effects of Project operations on the habitat in the tributary deltas, the connectivity between Boundary Reservoir and its tributaries, and the potential movement of fish between the tributaries and the reservoir.

Although the operation of Boundary Dam results in fluctuations in water surface elevation that may cause changes in tributary delta conditions, the tributaries upstream of the deltas do not experience any effects from Project operations. The information collected and presented in this report will provide a greater understanding of both tributary habitat conditions (outside of any potential effects of Project operations) and the ability of those tributaries to help sustain populations of native salmonids. This information will also be useful in identifying locations where factors limiting aquatic productivity can be modified through human intervention to improve habitat conditions. These opportunities can be given consideration within the broader relicensing analysis as potential measures to offset impacts to aquatic resources and native salmonid habitats that may be associated with Project operations or other basin activities.

At a broad scale, Boundary Reservoir tributaries provide habitat for salmonid populations that exhibit either adfluvial or fluvial life history traits. Compared to other reservoir systems in the region, such as Box Canyon, Waneta, and Seven Mile, Boundary Reservoir tributaries offer modest adfluvial habitat (tributary habitat connected to the reservoir). The relatively small watershed sizes, presence of natural barriers, high stream gradients, and basin hydrology in these tributaries all contribute to the amount of habitat available for salmonid populations, regardless of life history traits. However, salmonid populations reside in the majority of Boundary Reservoir tributaries (SCL 2007) and are found throughout most drainages, both above and below barriers. In addition, native salmonids inhabiting Boundary Reservoir may utilize habitat available in the tributaries (SCL 2007); however, naturally occurring and human placed barriers may prevent upstream migration in some tributaries.

Limiting factors have been defined as “conditions that limit the ability of habitat to fully sustain populations of salmon” (Salmon Recovery Act codified as Revised Code of Washington [RCW] 77.85 in the 1998 Washington State Legislative Engrossed Substitute House Bill 2496). Study 14 focuses on assessing limiting factors, or factors that affect productivity, in tributaries of the Project area. This will, in turn, identify those factors that affect the tributaries’ ability to help sustain populations of native salmonids.

Several limiting factors have been identified in recent studies (Andonaegui 2003) that may have contributed to the decline of native salmonid populations in the Pend Oreille River and its tributaries: habitat degradation, fish passage barriers, and competition with non-native fish species. In addition, available habitat that could sustain native salmonids may be limited to holding pools in tributary streams, pockets of cooler water in the vicinity of tributary mouths, and areas of groundwater influence along the shoreline of the mainstem Pend Oreille River. These conditions make it difficult for native salmonids to compete with non-native species that are more resilient to variations in water temperature.

For example, bull trout, a native fish listed under the Endangered Species Act (ESA) as “threatened,” is known to exist in the Pend Oreille River, but at low population levels. As noted above, habitat degradation, changes in the natural flow regime, and competition with other species have been associated with the decline of bull trout populations in the Pend Oreille River and its tributaries (Andonaegui 2003). Although bull trout have been observed in a few tributaries between Albeni Falls Dam and Boundary Dam in recent years, no known healthy populations appear to exist (USFWS 2005). Also, no bull trout were captured during Study 9 sampling of the Boundary Reservoir and lower tributary or delta regions in 2007 or 2008. Andonaegui (2003) concluded that with the fragmentation of habitat caused by impassable dams on the Pend Oreille River, such as Box Canyon and Boundary dams, suitable rearing habitat for juvenile bull trout could only be found in the tributaries. However, Andonaegui (2003) also noted that access by bull trout to those tributaries may be restricted by natural and artificial barriers, as well as degraded conditions, such as high water temperatures and lack of thermal refugia, that result in less than suitable habitat (R2 Resource Consultants 1998; McLellan 2001).

Bull trout distribution and abundance is thought to be positively correlated with availability of pools and complex cover such as LWD (Reiman and McIntyre 1993; Jakober 1995; MBTSG 1998 as cited in USFWS 2005). The land use activities occurring in the vicinity of the Boundary Reservoir and its tributaries likely contribute to a reduction in the number of pools and quantity of LWD in the system. For instance, timber harvesting reduces both the amount of LWD supplied to streams and the riparian canopy, which provides shade. Timber harvest can also promote the destabilization of banks, resulting in sediment sloughing into streams. The removal of woody material from streams following timber harvest reduces pool frequency, quality, and channel complexity (Bisson et al. 1987; House and Boehne 1987), thus reducing the amount of viable habitat available to native salmonids. In addition, available literature also suggests that habitat alteration and degradation as a result of forest management practices, hydroelectric development and operations, water supply development, flood control, livestock grazing, and road construction have affected fish populations within the Project area (WDFW 1998; USFWS 2005). Interbreeding, which produces sterile offspring, and competition for habitat and food resources with non-native fish species, such as brook trout, have been further suggested as a serious threat to native salmonids (Andonaegui 2003).

Studies have shown that resident westslope cutthroat trout are found in numerous tributary streams to the Boundary Reservoir (POSRT 2005; SCL 2009b). The widespread introduction of hatchery cutthroat trout since the early 1900s has expanded their range within Washington State, and hybridization of wild and hatchery stocks is considered a threat to wild cutthroat trout populations (50 Code of Federal Regulations [CFR] Part 17). It is also thought that genetic diversity within the cutthroat trout population decreased from historic levels following the construction of multiple dams on the Pend Oreille River (Scholz 2000 in Wydoski and Whitney 2003), at which time fluvial stocks of cutthroat trout were apparently unable to adapt to an adfluvial life history and disappeared from many of the watersheds (C. Vail, WDFW, personal communication, 2004 as cited in POSRT 2005).

Twenty-eight tributaries were identified in the RSP (SCL 2007) as providing between 0 and 5 miles of adfluvial habitat associated directly with Boundary Reservoir. The watersheds comprising these 28 tributaries provide areas of habitat utilization, or potential utilization, for native salmonids and other fish species. This study was designed to inventory available information and data sources about physical habitats and fish populations of the 28 tributaries. From these sources, an initial list of factors affecting productivity was developed. Critical gaps or needs for additional information were identified in 2007 and field collection of these data was completed in 2008. The additional information obtained through field collection was incorporated and the initial list of factors affecting productivity was refined. In addition, factors affecting productivity were evaluated in 2008 to determine if they may be modified through human intervention.

The following sections address each phase of the study objectives and tasks, including compiling information, developing a list of productivity factors, identifying data gaps, finalizing a limiting factors matrix, and evaluating factors affecting tributary productivity.

2 STUDY OBJECTIVES

The primary goal of Study 14, as defined in the RSP, was to compile information on the hydrology, water quality, fish habitat, fish presence and abundance, and migration barriers to determine factors affecting tributary productivity. This information was used to evaluate the feasibility of modifying those factors through human intervention and identify key tributary areas where the productivity of native salmonids may benefit from potential habitat protection or enhancement opportunities.

Specific objectives of the study were to:

- Inventory information on physical habitats and fish in Boundary Reservoir tributaries.
- Evaluate factors affecting tributary productivity.

3 STUDY AREA

The study area included only streams that drain directly into Boundary Reservoir (Table 3.0-1). These streams were grouped by watersheds that comprise watershed administrative units (WAUs) defined by the Washington State Department of Natural Resources (DNR). Those streams that either drain directly into Boundary Reservoir or into a WAU connected to a Boundary Reservoir tributary are located within four WAUs: Slate Creek WAU, Sullivan Creek WAU, Harvey Creek WAU, and Box Canyon WAU (Figure 3.0-1). Within each of these four WAUs reside multiple creeks (Table 3.0-2) potentially providing habitats utilized by native salmonids and other fish species.

Distances upstream from tributary stream mouths are designated in river miles (RM), whereas the location where a tributary enters Boundary Reservoir is designated in Project river miles (PRM) and indicates the approximate distance from the Pend Oreille River mouth to the tributary mouth.

Table 3.0-1. Project river mile designations of tributaries draining into Boundary Reservoir.

Watershed Administrative Unit (WAU)	Tributary Name	Side of Pend Oreille River (West Bank / East Bank)	Project River Mile (PRM) Designation
Slate Creek	**Boundary Dam**		17.0
Slate Creek	Unnamed No. 1	EB	17.2
Slate Creek	Pewee Creek	WB	17.9
Slate Creek	Unnamed No. 2	WB	17.9
Slate Creek	Lime Creek	EB	19.0
Slate Creek	Everett Creek	WB	21.9
Slate Creek	Whiskey Gulch	WB	21.9
Slate Creek	Slate Creek	EB	22.2
Slate Creek	Three Mile Creek	EB	24.3
Slate Creek	Beaver Creek	WB	24.3
Slate Creek	Unnamed No. 3	WB	25.4
Slate Creek	Flume Creek	WB	25.8
Sullivan Creek	Sullivan Creek	EB	26.9
Box Canyon	Unnamed No. 4	WB	27.1
Box Canyon	Linton Creek	WB	28.1
Box Canyon	Unnamed No. 5	WB	28.9
Box Canyon	Unnamed No. 6	WB	29.2
Box Canyon	Pocahontas Creek	EB	29.4
Box Canyon	Unnamed No. 7	WB	29.6
Box Canyon	Unnamed No. 8	WB	30.1
Box Canyon	Wolf Creek	EB	30.3
Box Canyon	Sweet Creek	WB	30.9
Box Canyon	Unnamed No. 9	EB	31.1
Box Canyon	Sand Creek	EB	31.7
Box Canyon	Lost Creek	WB	32.2
Box Canyon	Unnamed No. 10	WB	33.5
Box Canyon	Unnamed No. 11	WB	33.6
Box Canyon	Unnamed No. 12	WB	34.0
Box Canyon	Unnamed No. 13	WB	34.3
Box Canyon	**Box Canyon Dam**		34.5

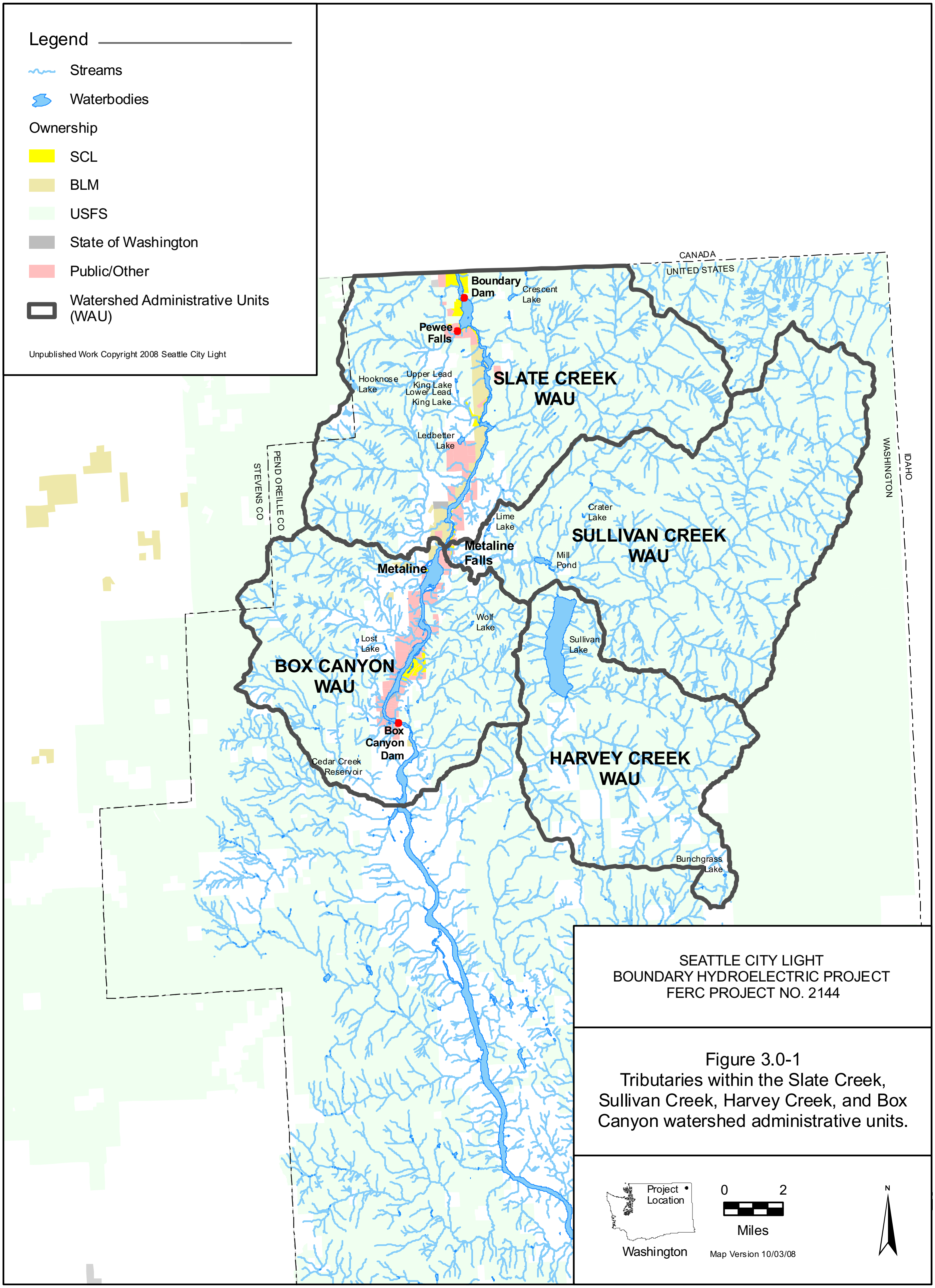

Figure 3.0-1
Tributaries within the Slate Creek, Sullivan Creek, Harvey Creek, and Box Canyon watershed administrative units.

Table 3.0-2. Confluence river mile designations within Boundary Reservoir tributaries.

Tributary/Creek/Waterbody Name	River Mile (RM) Designation
Slate Creek WAU	
Pewee Creek	
Fence Creek	1.1
Slate Creek	
Slumber Creek	2.0
Uncas Gulch	2.75
Styx Creek	4.9
South Fork Slate Creek	6.2
North Fork Slate Creek	6.2
Flume Creek	
South Fork Flume Creek	1.1
Middle Fork Flume Creek	3.3
Sullivan Creek WAU	
Sullivan Creek	
North Fork Sullivan Creek	2.35
Elk Creek	3.7
Outlet Creek	5.3
Pass Creek	8.9
Stony Creek	11.6
Kinyon Creek	12.65
Copper Creek	13.35
Gypsy Creek	13.8
Leola Creek	17.6
Leola Creek	
Deemer Creek	0.32
Harvey Creek WAU	
Outlet Creek	
Sullivan Lake	0.5
Sullivan Lake	
Noisy Creek	3.8
Harvey Creek	4.0
Harvey Creek	
Middle Fork Harvey Creek	10.0
Middle Fork Harvey Creek	
North Fork Harvey Creek	0.5
Box Canyon WAU	
Sweet Creek	
Lunch Creek	1.5

3.1. Slate Creek WAU

Eleven of the 28 tributaries identified in the RSP are in the Slate Creek WAU (Figure 3.1-1). The Slate Creek WAU is located in the northeastern corner of Washington State, in Pend Oreille County (Figure 3.0-1). Slate Creek flows into the Boundary Reservoir reach of the Pend Oreille River at PRM 22.2 and includes the Pewee, Lime, Everett, Whiskey Gulch, Slate, Threemile, Beaver, and Flume creek drainages. Table 3.0-1 identifies the river mile where each of the drainages enters Slate Creek. Andonaegui (2003) documented that the Slate Creek WAU drainage encompassed approximately 189.4 square kilometers (73.1 square miles); however, this was prior to revised WAU boundaries designated by the DNR in 2007. Based on the Geographic Information System (GIS) layers available from the DNR (2007), the Slate Creek WAU drainage size is 247.1 square kilometers (95.4 square miles).

Slate Creek has four main tributaries and two forks: Slumber Creek, Uncas Gulch, Styx Creek, an unnamed creek, and North and South Fork Slate Creek (Figure 3.1-1). The majority of the Slate Creek WAU falls within the Colville National Forest (CNF), with a small section in the eastern portion of the WAU within the Salmo-Priest Wilderness. There is a small amount of privately owned land in the WAU, located adjacent to the Pend Oreille River, north of Metaline Falls. Additionally, a few privately owned, 40-acre timber holdings exist in the Slate Creek drainage. Literature on the geology and hydrology of Slate Creek WAU is limited; however, published information suggests that lead and zinc have been mined in the area (USFS 1998; Andonaegui 2003). In a large portion of the WAU, the bedrock is overlain by younger materials such as glacial drift, glacial till, glacial outwash, alluvium, and volcanic ash. Some of the alluvial and outwash material can be quite sandy (USFS 1998).

Within the Slate Creek WAU, the historic relative abundance and distribution of bull trout is not known. Bull trout have been observed at the mouth of Slate Creek (Andonaegui 2003), but no observations of bull trout upstream of the mouth have been documented. The U.S. Fish and Wildlife Service (USFWS) has designated 0.15 mile of Slate Creek, from the confluence with the Pend Oreille River upstream, as "Critical Habitat" (Federal Register 2005). Within the Pend Oreille River Core Area, Slate Creek was identified as being able to support a local population of bull trout with a numeric recovery goal for migratory adults of 25 to 75 fish (USFWS 2002). To obtain this goal it will be necessary to ensure that the productivity of aquatic habitat in Slate Creek is optimal.

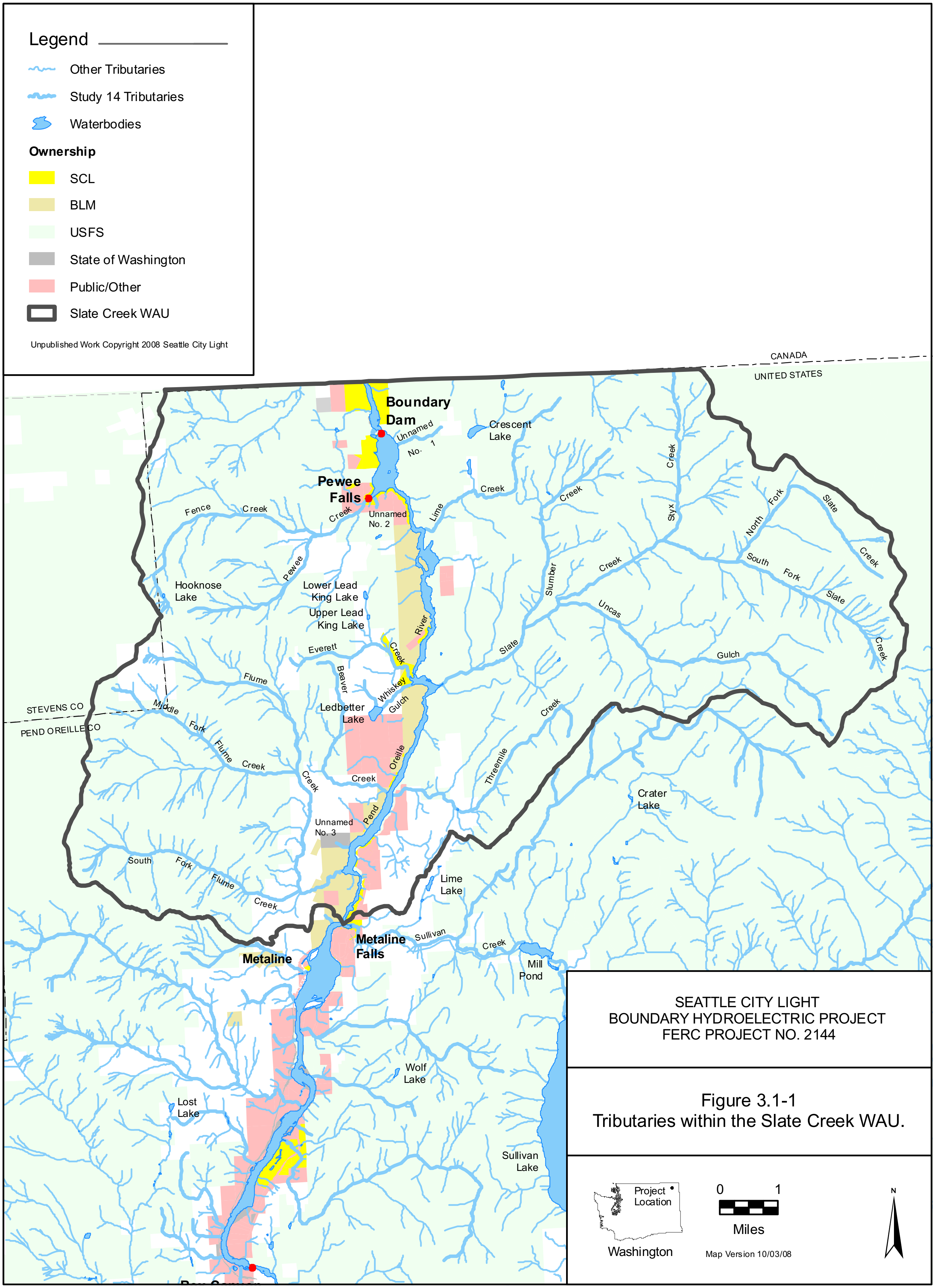

Figure 3.1-1
Tributaries within the Slate Creek WAU.

3.2. Sullivan Creek WAU

Sullivan Creek is one of the 28 tributaries identified in the RSP (Figure 3.2-1). The Sullivan Creek WAU is located in the northeastern part of Washington State, within Pend Oreille County (Figure 3.0-1). Within the Sullivan Creek WAU, the U.S. Forest Service (USFS) manages 97.4 percent of the drainage, with 25.3 percent of it located within the Salmo-Priest Wilderness (USFS 1996; Andonaegui 2003). Sullivan Creek flows 21.4 miles westerly and enters the Pend Oreille River at PRM 26.9, near the town of Metaline Falls (Figure 3.2-1). North Fork Sullivan, Elk, Outlet, Pass, Stony, Kinyon, Copper, Gypsy, and Leola creeks are the primary contributing drainages to the Sullivan Creek WAU (Table 3.0-2).

Available literature from various sources (CES 1996; USFS 1996; Andonaegui 2003; and DNR 2007) suggests slight differences in the estimated size of the Sullivan Creek WAU. Based on available GIS layers from the DNR (2007), and for the purpose of this study, the Sullivan Creek WAU basin size is estimated to be 235.7 square kilometers (91 square miles). The average annual precipitation over the WAU is about 40 inches (CES 1996). The system is snowpack dominated, and spring runoff is the major channel-forming hydrologic event (USFS 1996).

The cultural history of the Sullivan Creek drainage area is rich in many ways. Literature suggests that the Sullivan Creek drainage has historically been utilized, to some extent, by people since the end of the last ice age. Archaeological evidence uncovered at the north end of Sullivan Lake confirmed human presence in the area for at least 3,000 years (Andonaegui 2003). The Sullivan Creek drainage, with its abundant plant and animal resources, was traditionally used by the Kalispell people to hunt and gather food.

The town of Metaline was established in the 1800s as a mining camp in support of gold mining activities largely on Sullivan Creek and was the earliest community to be established in Pend Oreille County. Currently, residential development within the drainage is very limited. The Sullivan Creek watershed is accessed by Sullivan Lake Road, which follows the west shore of Sullivan Lake. A network of USFS roads (233.7 total miles) and approximately 4.4 miles of private roads provide access to other areas of the Sullivan Creek drainage (USFS 1996).

Two dams are present within the Sullivan Creek WAU, with a third dam controlling flow released from the Harvey Creek WAU into Sullivan Creek (Table 3.2-1). The first dam is located in North Fork Sullivan Creek. The North Fork Sullivan Creek mouth is located at RM 2.35 on Sullivan Creek. Upstream from the mouth at RM 0.25 is the North Fork Sullivan Creek Dam, which provides water to the town of Metaline Falls. Between the confluence of North Fork Sullivan Creek and Outlet Creek is Mill Pond Dam (RM 3.25). Outlet Creek is 0.5 mile long and is the outlet of Sullivan Lake, which is located in the Harvey Creek WAU (Figure 3.0-1).

Near the mouth of Sullivan Creek, two bull trout have been documented (Andonaegui 2003). Local agency biologists, studies on resident fish stock status, and surveys conducted throughout the tributary suggests there is suitable habitat to support populations of native salmonids throughout the Sullivan Creek watershed (R2 Resource Consultants 1998; McLellan 2001; Andonaegui 2003). In 2005 the USFWS designated the lower 0.66 mile of Sullivan Creek as "Critical Habitat" (Federal Register 2005). Within the Pend Oreille River Core Area, Sullivan

Creek was identified as being able to support a local population of bull trout with a numeric recovery goal for migratory adults of 600 to 850 fish (USFWS 2002). To obtain this goal it will be necessary to ensure that the productivity of aquatic habitat in Sullivan Creek is optimal.

Table 3.2-1. Dams within the Sullivan Creek and Harvey Creek WAUs.

Dam Name	Tributary/ Creek Name	River Mile Designation	Hydraulic Height (feet)	Year Built	Jurisdictional Agency	Licensee/ Operator	Fish Passage Facilities
Mill Pond Dam	Sullivan Creek	3.25	55	1923	FERC	POPUD	No
Sullivan Lake Dam	Outlet Creek	0.5	29	1931	FERC	POPUD	No
North Fork Sullivan Creek Dam	North Fork Sullivan Creek	0.25 on North Fork Sullivan Creek	13.1	late 1950s	NA	POPUD	No

Notes:
NA – not applicable
POPUD – Pend Oreille Public Utility District

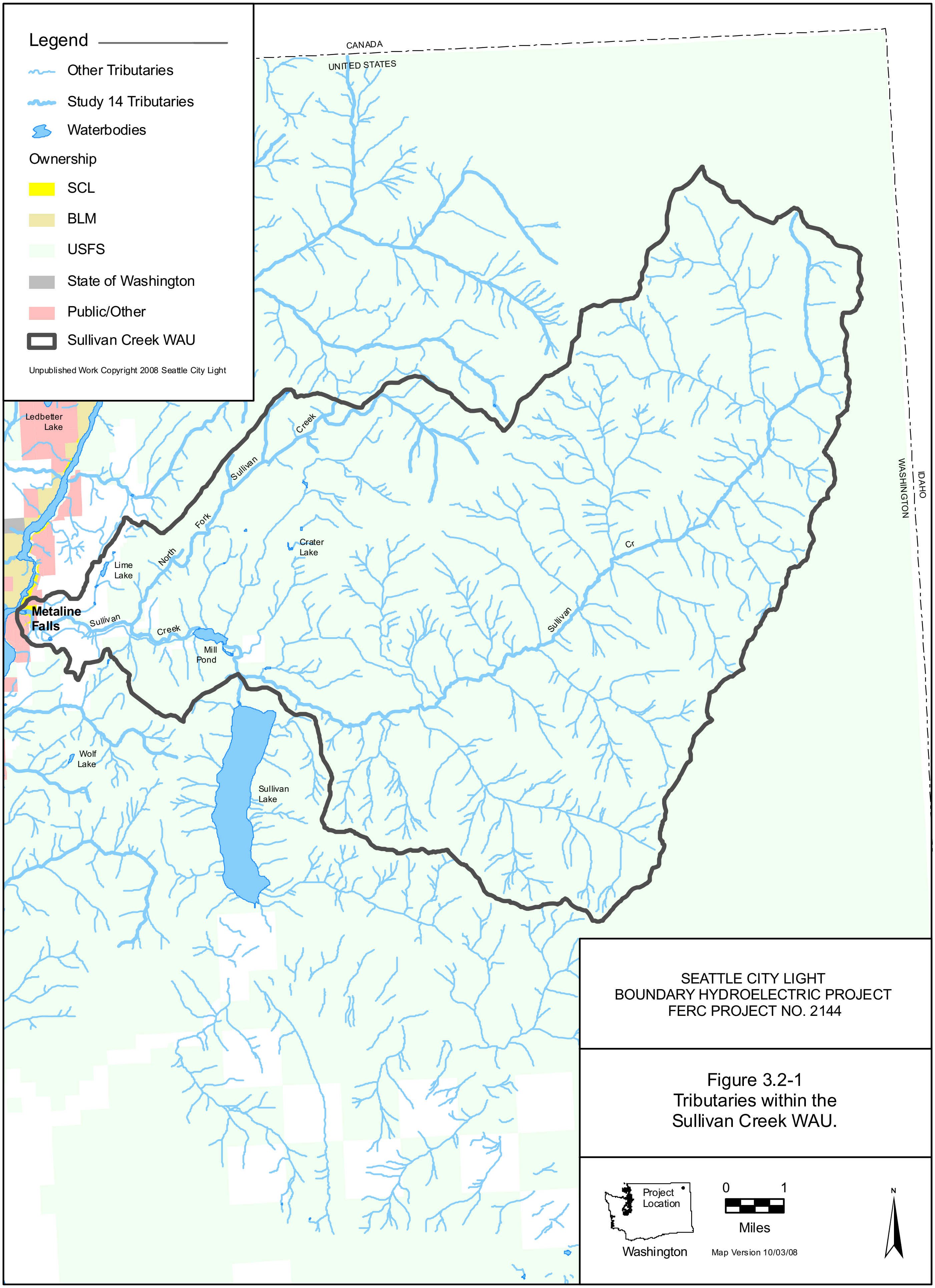

Figure 3.2-1
Tributaries within the
Sullivan Creek WAU.

3.3. Harvey Creek WAU

No tributaries within the Harvey Creek WAU are specifically identified in the RSP. Nevertheless, the entire Harvey Creek WAU drainage flows into Sullivan Lake, which ultimately drains into the Sullivan Creek WAU.

As with the other WAUs located in the study area, the Harvey Creek WAU is located in the northeastern corner of Washington State, in Pend Oreille County, just south of Sullivan Creek WAU (Figures 3.0-1 and 3.3-1). The Harvey Creek WAU is estimated to encompass approximately 138.4 square kilometers (51.5 square miles). Harvey Creek originates at the peaks of Monumental and Salmon mountains, primarily consists of a middle and north fork (Table 3.0-2), and flows approximately 15 miles north-northwesterly from its headwaters before flowing into Sullivan Lake, a natural lake (Andonaegui 2003). In 1931, Sullivan Lake Dam was built at the outlet of the lake (Table 3.2-1), which increased the holding capacity of Sullivan Lake (Andonaegui 2003). Outlet Creek, located on the edges of the Harvey Creek WAU and the Sullivan Creek WAU, flows out of Sullivan Lake at Sullivan Lake Dam and converges with Sullivan Creek at RM 5.3. In the vicinity of the Sullivan Creek/Outlet Creek confluence, there are about nine residences and a small store on private land (Andonaegui 2003).

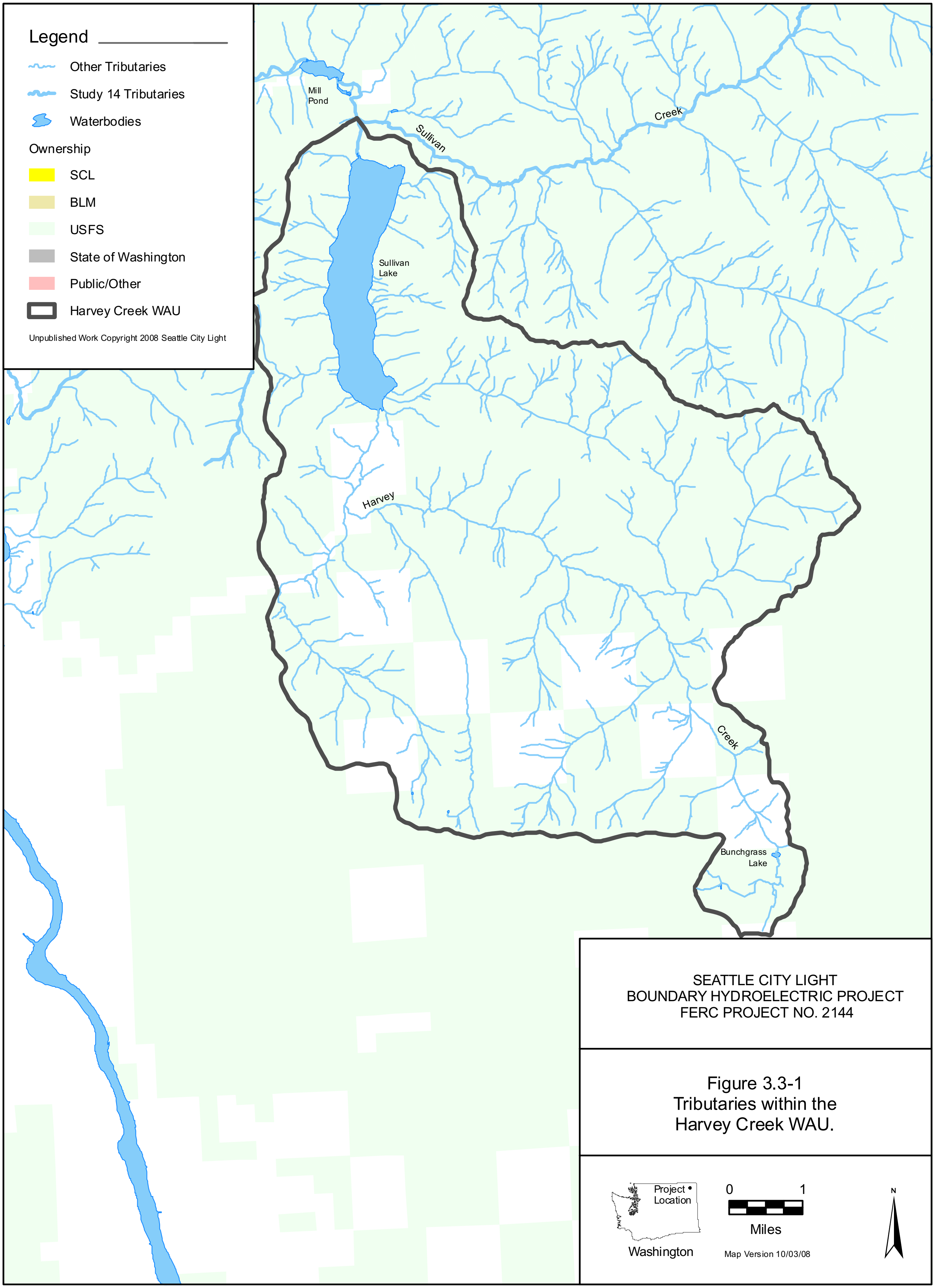

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Figure 3.3-1
Tributaries within the
Harvey Creek WAU.

3.4. Box Canyon WAU

Sixteen of the 28 tributaries identified in the RSP are in the Box Canyon WAU (Figure 3.4-1). The Box Canyon WAU is located in northeastern Washington State, just south of the Slate Creek WAU, in Pend Oreille County (Figure 3.0-1). In 2006, the DNR reassessed many of the state's watersheds and, as a result, renamed Box Canyon WAU to Cedar Creek WAU. Due to the recent nature of the renaming, most of the available literature regarding this WAU refers to it as Box Canyon WAU; therefore, it will be referred to as the Box Canyon WAU for the purpose of this study.

The Box Canyon WAU includes the Sweet and Sand creek drainages, which flow into the Boundary Reservoir reach of the Pend Oreille River at PRM 30.9 and 31.7, respectively (Table 3.0-1). The WAU area is approximately 227.3 square kilometers (87.8 square miles) and encompasses several tributaries that flow into the Pend Oreille River, including Linton, Pocahontas, Wolf, Sweet, Sand, Lost, and 10 unnamed creeks (Table 3.0-1) identified in the RSP.

Within the Box Canyon WAU, Sweet Creek and Sand Creek are the largest tributaries with watershed areas of 28.7 square kilometers (11.1 square miles) and 21.2 square kilometers (8.2 square miles), respectively. Lunch Creek, defined as a tributary to Sweet Creek for the purpose of this study, converges with Sweet Creek at RM 1.5 (Table 3.0-2). At least 50 percent of the Sweet Creek drainage is located on privately-owned property; however, a portion of it is located on National Forest System (NFS) lands (Figure 3.4-1). Within the CNF boundary there are no roads, and management of the area focuses on semi-primitive, non-motorized recreation (USFS 1999a).

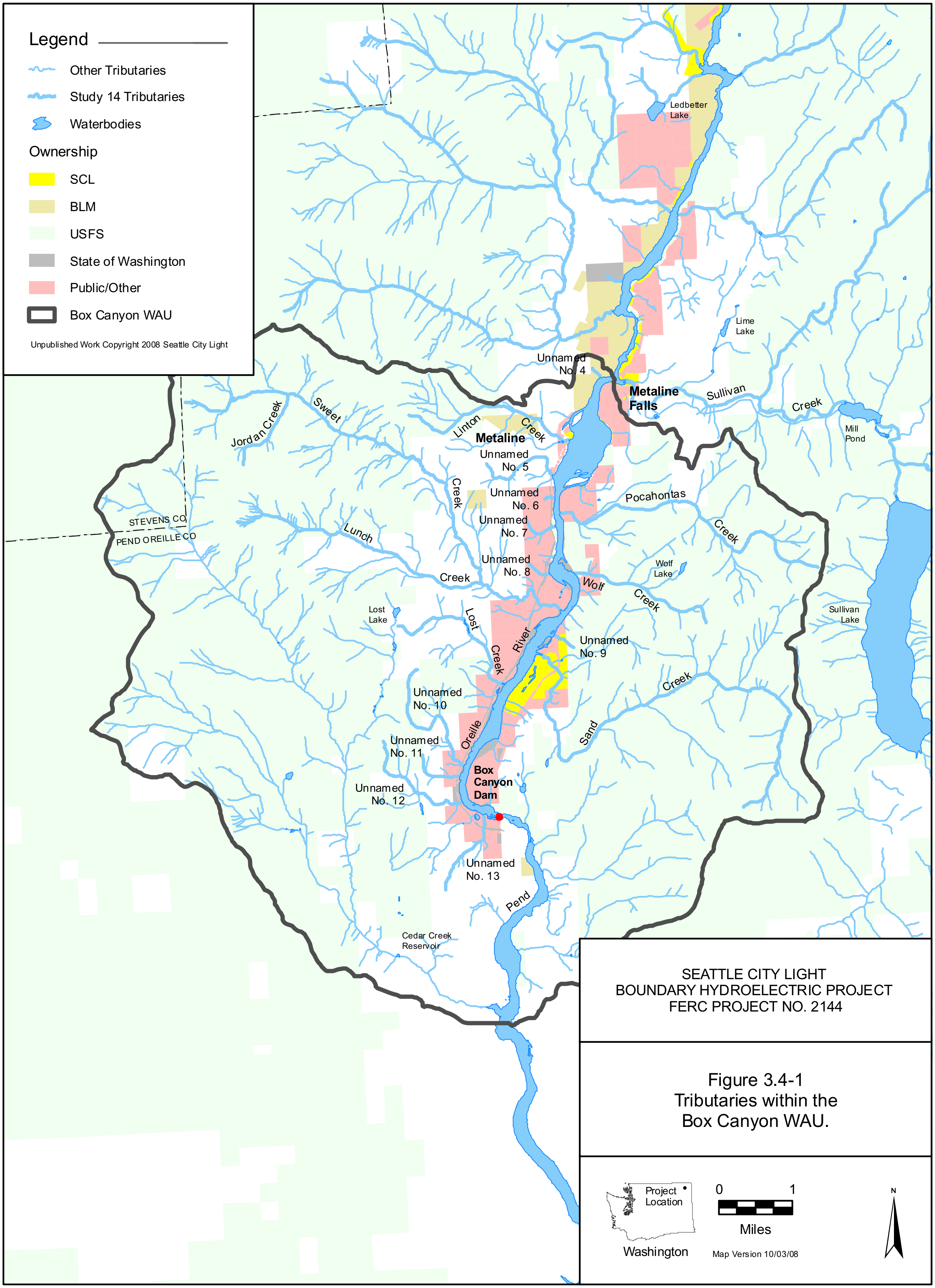

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Figure 3.4-1
Tributaries within the
Box Canyon WAU.

4 METHODS

The following five tasks were identified for the study in the RSP:

- Review and compile available information (Task 1).
- Develop a list of productivity factors (Task 2).
- Develop a draft limiting factors matrix (LFM) (Task 3).
- Identify data gaps and critical data caps necessary to fill through field surveys (Task 4).
- Finalize the draft LFM, develop a list of protection and enhancement opportunities from the field surveys and the finalized LFM, and rank the list of opportunities based on the general feasibility regarding whether those limiting factors can be changed through human intervention (Task 5).

The first four tasks identified in the RSP were completed in 2007. The last task identified in the RSP was completed in 2008. The methods for each task are provided in the following sections.

4.1. Review and Compile Available Information

Available hydrology, water quality, fish habitat, fish presence and abundance, and migration barrier information for tributaries draining to Boundary Reservoir was obtained from the following sources:

- Andonaegui (2003)
- Cascade Environmental Services (1996)
- Connor et al. (2005)
- Entrix (2001, 2002)
- McLellan (2001)
- R2 Resource Consultants (1998)
- Terrapin Environmental (2000)
- USFS (1996)
- USFS (1998)
- USFS (2005)

Only content specific to each of the tributaries draining into Boundary Reservoir was extracted from these sources. Information was organized based on its tributary name and content, and then grouped within respective WAUs for discussion purposes. Specifically, content available on the following topics was reviewed and compiled from information sources for Boundary Reservoir tributaries:

- Migration barriers (natural and artificial)
- Riparian conditions
- Channel conditions (streambank condition, floodplain connectivity, channel stability)
- Habitat elements (channel substrate [embeddedness and fines], LWD, pool frequency and quality, pool depth, wetted width)
- Water quality (7-day maximum temperature)

- Water quantity (discharge, changes in flow regime, gradient)
- Native and non-native fish species

The format, method, content, and evaluation utilized by Andonaegui (2003) provided information and a template to follow for this study. The limiting factors evaluation by Andonaegui (2003), which presents bull trout limiting factors, was the primary template used to organize and review available information.

The SMART database (USFS 2005) provided information from sampling points or reaches for creeks flowing through CNF land. Information from the SMART database was used to address data gaps for tributaries lacking information from other literature sources.

The review of all available relevant information from the previously listed sources was completed in September 2007; any additional information obtained after September 2007 was assessed for inclusion in this report. After reviewing and compiling all available relevant information from the previously listed sources for the tributaries identified as draining into Boundary Reservoir, criteria were developed to identify those tributaries possessing major factors limiting productivity that could be addressed through human intervention. These criteria are discussed in the next section.

4.2. Stream Categorization and Productivity Factors

This task had two purposes: 1) to narrow the selection of streams to only evaluate those that have potential to provide benefits to native salmonids, primarily adfluvial populations, through human intervention if habitat or other conditions could be improved; and 2) to identify productivity factors and their status within the selected tributaries.

In 2007, criteria were developed to categorize streams into three levels of opportunity: primary (areas with high opportunity), secondary (areas with some opportunity), and excluded from evaluation (areas with little to no opportunity). The descriptions in Table 4.2-1 outline the criteria used and the logic behind each of the criteria.

Table 4.2-1. Stream level of opportunity categorization and criteria.

Category	Criteria	Reason
Primary	Adfluvial habitat greater than 250 feet and watershed area is more than 1 square mile.	Streams of this size, at a minimum, have the greatest potential to influence Boundary Reservoir native adfluvial fish resources, and, therefore, if a limiting factor can be improved through human intervention, it may be considered as an opportunity. These streams have both a moderate to large basin to help increase flow and increase overall habitat quality in the reaches accessible to adfluvial fish with the ability to enhance more life stages and sizes of adfluvial species, as well the potential to enhance native fish species.
Secondary	Containing either a watershed area greater than 1 square mile or adfluvial habitat length greater than 250 feet. If a tributary meets either of these criteria, and a natural barrier at the mouth is present and native salmonid species are known to occur in the basin, it will be included.	The larger basins, without adfluvial habitat, may be worth evaluating further because there may be potential for watershed improvements that could enhance native salmonid species populations. The smaller basins, with adfluvial habitat length greater than 250 feet, may have some potential for human-aided improvement, possibly improving available habitat for Boundary Reservoir native species. They are not considered prime streams because of the low amount of drainage area limiting overall habitat, and/or limited adfluvial stream length, restricting the potential to benefit adfluvial habitat through human intervention. Tributaries that have natural barriers occurring at the mouth, but have native salmonids known to be present in the basin, are included because these creeks may have opportunities to improve aquatic habitat without the need to supplement existing populations.
Excluded	Less than 1 square mile and less than 250 feet adfluvial habitat. Has a natural barrier occurring at the mouth of the tributary and no native salmonid populations	These streams, because of their small size and very limited adfluvial habitat, have a low potential to benefit either adfluvial or resident trout under existing conditions, or with any human intervention to current conditions.

After tributaries were categorized by level of opportunity, data tables were created for primary tributaries with available information on migration barriers, riparian conditions, channel conditions and dynamics, habitat elements, water quality, water quantity, and fish species. No data tables were created for the secondary or excluded tributaries.

The data tables created for the primary tributaries were compared to salmonid habitat rating standards for identifying preliminary factors limiting productivity in primary tributaries. Specifically, the bull trout habitat rating criteria for Water Resource Inventory Area (WRIA) 62 (Andonaegui 2003) were used to assist in identifying preliminary limiting factors in primary tributaries. In addition, the Washington Conservation Commission (WCC) WRIA habitat limiting factors ratings standards (Smith 2005)[1] were cross-referenced with the bull trout habitat rating criteria to assess the comparability with Washington State standards.

Based on the results from comparing the data tables to the bull trout rating criteria, and assessing the limiting factors reported by Andonaegui (2003) for the identified primary tributaries, a draft limiting factors matrix was developed. After the draft limiting factors matrix had been developed for the primary tributaries, a limiting factors matrix for the secondary tributaries was developed from the limiting factors matrix reported by Andonaegui (2003).

4.3. Draft Limiting Factors Matrix

Limiting factors are "conditions that limit the ability of habitat to fully sustain populations of salmon," as defined in the Salmon Recovery Act (RCW 77.85).

Within RCW 77.85, salmon are defined as "all members of the family Salmonidae which are capable of self-sustaining, natural production." RCW 77.85 directed state and local government agencies, tribes, and other personnel with appropriate expertise, within each WRIA, to act as a technical advisory group (TAG) to study and identify limiting factors for salmonids. The studies in each WRIA focused on evaluating factors limiting the productivity of native biota in streams and rivers. In general, information was organized by productivity level into categories, and this information was displayed in the form of a matrix (see Andonaegui 2003 and Smith 2005). Types of categories used include poor quality habitat (not properly functioning), fair habitat (at risk), and good quality habitat (properly functioning). These categories provide a classification structure for prioritizing which streams and rivers require the greatest attention in order to address factors limiting aquatic productivity for native species.

In 2007, the first step in creating a draft LFM for the primary tributaries was to compare the data tables (described in Section 4.2) to the bull trout habitat rating criteria. Limiting factors identified in this first step were used to update the bull trout limiting factors matrix for WRIA 62 reported in Andonaegui (2003) for the primary tributaries. The final step was to compare these results to other efforts focused on assessing habitat productivity in these tributaries (Table 4.3-1). Specifically, the limiting factors results from the Northwest Power and Conservation Council (NPCC 2005; see Appendix 1) and the Pend Oreille Salmonid Recovery Team (POSRT 2005; see Appendix 2) were used to reinforce the evaluation and identification of limiting factors determined from the primary tributary data tables and from the Andonaegui (2003; Appendix 3) bull trout limiting factors matrix. The limiting factors matrix for secondary tributaries (see Appendix 4) was developed in a similar fashion, except the preliminary matrix was derived exclusively from Andonaegui (2003) without any updates from data tables.

[1] The WCC habitat limiting factors ratings standards were only used for cross-reference purposes, and not specifically used to evaluate Boundary Reservoir tributaries. As the WCC criteria are used by the state of Washington to evaluate limiting factors throughout the state, it was necessary to assess these standards with the criteria used in Andonaegui (2003).

Table 4.3-1. Other major sources used for Boundary Reservoir tributary information.

Tributary, Watershed Drainage, or Waterbody Name	Individual Bull Trout Observation only (WCC mapping)	Resident Fish Stock Status Project (WDFW)	WRIA 62 Bull Trout Limiting Factors (Andonaegui 2003)	Subbasin Planning Report (NPCC 2005)	Pend Oreille Salmonid Recovery Team (POSRT 2005)	Contains USFWS Critical Habitat
Pewee Creek		X		X	X	
Lime Creek		X		X	X	
Slate Creek		X	X	X	X	X
Flume Creek		X	X	X	X	
Threemile Creek				X	X	
Sullivan Creek	X (only below Mill Pond)	X	X	X	X	X
Sullivan Creek tributaries			X	X	X	
Sullivan Lake			X	X	X	
Sullivan Lake tributaries			X	X	X	
Pocahontas Creek				X	X	
Sweet Creek	X (only below the falls at RM 0.6)	X	X	X	X	
Sand Creek		X	X	X	X	

Notes:
NPCC – Northwest Power and Conservation Council
POSRT – Pend Oreille Salmonid Recovery Team
WCC – Washington Conservation Commission
WDFW – Washington Department of Fish and Wildlife
WRIA – Water Resource Inventory Area
USFWS – U.S. Fish and Wildlife Service

4.4. Identification of Data Gaps and Proposed Data Collection Areas for 2008

In 2007, data gaps were identified by reviewing information, organizing available information into the primary tributaries data sheets, determining factors limiting the productivity of native species, and developing the primary and secondary tributaries limiting factors matrices. Each method described in the previous sections (4.1 through 4.3) provided a mechanism to identify data gaps. Identified data gaps for each of the categories in the limiting factors matrices were noted in the appropriate matrix and documented. Data gaps identified in Andonaegui (2003) and by the CNF (Shuhda 2007) were also included.

Although a data gap in the limiting factors matrices may describe an incomplete evaluation of aquatic conditions for a particular tributary, not all data gaps were deemed critical for determining which areas may be improved through human intervention for streams of interest relative to the Project. To determine which data gaps for the primary and secondary tributaries were critical to address, the following decision criteria were developed. A data gap was considered critical to address if:

- It was from a primary tributary.
- It was related to restoration goals identified by regional groups.
- It was related to a stream section with adfluvial habitat for Boundary Reservoir.
- It occurred in a tributary that has been identified as a priority by the POSRT (2005) or the CNF (Shuhda 2007).

Addressing the data gap(s) or surveying the area would help to determine whether modification through human intervention is necessary, and if intervention actions would benefit adfluvial and native trout. Although only primary tributaries moved forward through this assessment methodology, it does not imply that only the primary streams would potentially benefit from modification through human intervention. Rather, the primary tributaries are those that met the criteria used in this assessment.

In 2007, data gaps considered critical to address were identified and a list of field and office tasks was developed. These tasks included 1) conducting field surveys to collect site-specific data and other information necessary to finalize the limiting factors matrix, and 2) determining the feasibility of protecting habitat for segments identified in 2007. Based on the results from these tasks and the finalized LFM, a prioritized list of protection and enhancement opportunities was developed. These identified field and office tasks, and the methodology used to develop them, are described below.

4.5. 2008 Tasks to Fill Critical Data Gaps and Identify Protection and Enhancement Opportunities

The 2008 tasks were identified during 2007. The intent of the 2008 tasks was to fill critical data gaps and identify enhancement opportunities that would address factors limiting aquatic productivity in Styx, Slumber, Sullivan, Linton, Pocahontas, and Sweet creeks (see Figure 4.5-1). In addition, field tasks were intended to collect site-specific data and other information necessary to evaluate and rank any identified protection and enhancement opportunities. Field surveys in these creeks were conducted during May and July 2008. Three types of field surveys were conducted in each of the creeks: culvert assessments, habitat evaluations, and geomorphic assessments. In addition, a reconnaissance-level road survey was conducted on Sullivan Lake Road along Sullivan Creek.

In 2007, segments in Slate, Sullivan, and Sweet creeks (see Figure 4.5-1) were identified as areas with potential protection opportunities. To determine the feasibility of protecting habitat for these identified segments, a number of office tasks were conducted in 2008 (e.g., phone calls, e-mails, documentation, review of pertinent Web sites, and evaluation of GIS layers to determine property ownership and applicable conservation easement/acquisition procedures).

The field surveys for each creek are detailed in Sections 4.5.1 and 4.5.2. Section 4.5.3 provides methods used to determine the feasibility of protecting habitat for segments of Slate, Sullivan, and Sweet creeks.

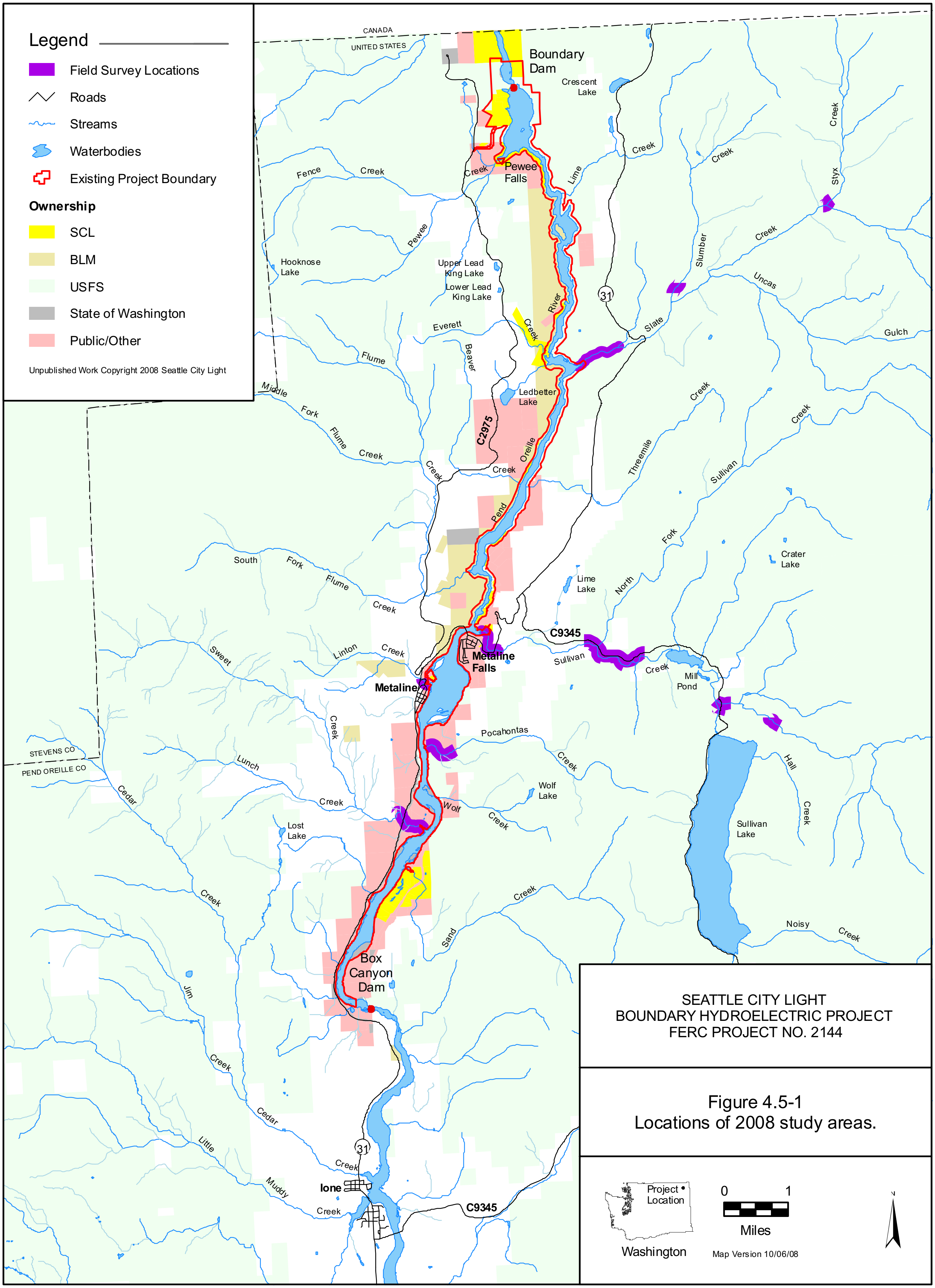

Figure 4.5-1
Locations of 2008 study areas.

4.5.1. Overview of Field Tasks for Each Creek

Six tributary creeks were surveyed in 2008 to evaluate culverts, fish habitat, and/or geomorphic conditions within the creeks:

- Slumber Creek (tributary to Slate Creek)
- Styx Creek (tributary to Slate Creek)
- Sullivan Creek
- Linton Creek
- Pocahontas Creek
- Sweet Creek

A habitat and culvert survey was conducted in Pocahontas Creek in May 2008. The timing of this survey was selected to ensure that water was present in the stream at the time of the survey, because Pocahontas Creek is known to dewater from July to September.

Preliminary observations were also made of Linton Creek in May. However, due to water levels and flood conditions within Metaline Park (Figure 4.5-2), the stream could not be surveyed.

In July 2008, culvert assessments, habitat surveys, and geomorphic evaluations in Styx, Slumber, Sweet, and Linton creeks were completed. The geomorphic and habitat reconnaissance-level survey of Sullivan Creek was also completed in July.

In addition, a road survey was conducted along Sullivan Creek Road in May 2008 as part of the Sullivan Creek studies. During this survey, flows were nearly at bankfull capacity (Figure 4.5-3). This provided a good opportunity to examine bankfull channel dimensions, channel-reach conditions in the climax of processes, and off-channel areas that would be available to fish for overwintering habitat.

Figure 4.5-2. High water and backwatering of Linton Creek resulting in flood conditions within Metaline Park.

Figure 4.5-3. Sullivan Creek at nearly bankfull capacity.

4.5.1.1. Culvert and Habitat Surveys

The primary goal of culvert and habitat surveys was to evaluate habitat conditions adjacent to culverts and to determine whether culvert replacement/ improvement would increase access to productive habitat.

All culverts were surveyed and evaluated to determine passage barrier mechanisms using protocols and criteria provided by the Washington Department of Fish and Wildlife (WDFW) (2000). The evaluation was used to determine if the culvert presented a problem based on slope, water velocity, outfall drop, water depth within the culvert, or other features. Each culvert was initially evaluated for suitability of fish passage with the Level A Barrier Analysis criteria (WDFW 2000) and, if subsequently considered a passage barrier, with the Level B Analysis Spreadsheet for Barrier Assessments, available from WDFW (2001).

Habitat data collection methodologies were based on Peck et al. (2003) and Bain and Stevenson (1999). Based on the data collected under each methodology, metrics were calculated and reported. Calculation of each metric was based on the information available in each of the data collection documents (i.e., Peck et al. 2003; Bain and Stevenson 1999). Specific habitat evaluation activities entailed measuring the thalweg (i.e., the deepest part of the channel), channel slope (using a hand level), wetted width (using a tape measure), LWD, substrate counts, and channel cover. Additional measurements, such as a cross-sectional survey of the bankfull channel (including bankfull width and depth), bank cover, bank angles, bank erosion, substrate embeddedness, percent fines present, and habitat types (e.g., pool, riffle, glide) were also made.

The combined data collection methods and associated metrics were used to provide necessary information to document the quality of habitat available, to evaluate factors limiting aquatic productivity, to update the draft LFM developed during the 2007 efforts, and to determine if habitat characteristics could be improved.

4.5.1.2. Geomorphic Surveys

The primary goals of these survey activities were to document geomorphic and habitat conditions through a reconnaissance survey and identify any potential habitat improvement opportunities. Geomorphic survey methods and classification were based on those described in DNR (1997), Montgomery and Buffington (1997), Rosgen (1996), Peck et al. (2003), Bain and Stevenson (1999), and Harrelson et al. (1994). A spreadsheet available from the Ohio Department of Natural Resources (Mecklenburg 2006) was used to calculate and graph data obtained through the geomorphic survey.

4.5.1.3. Road Survey

The road survey was only done between RM 2.3 and 3.25 of Sullivan Creek because this is the primary section where the road is encroaching and confining Sullivan Creek. Additional information regarding the methodology used to determine where road segments are encroaching and confining the creek is described in detail below. The primary goal of this survey was to evaluate the influence of road segments on Sullivan Creek and determine any potential locations where the road could be relocated, obliterated, and/or reconstructed. The survey was also conducted to determine creek access points, potential survey segments that demonstrated distinct channel-reach morphology, and potential reaches that could provide opportunities to enhance conditions limiting aquatic productivity. Road survey protocols, forms, information, and methods used to determine the road segments that were surveyed, the data that were collected, and the hydrologic connectivity of segments to Sullivan Creek were based on those described in the USFS roads analysis (USFS 1999b); Study 1, Erosion Study Final Report (SCL 2009c); and CNF (2005).

4.5.2. Specific Field Tasks for Each Creek

4.5.2.1. Slumber Creek (Tributary to Slate Creek; RM 2.0)—Culvert, Habitat, and Geomorphic Survey

Within Slumber Creek, at approximately RM 0.2 (see Figure 4.5-1), culvert barrier dimensions were measured and habitat conditions 150 meters (m) (492 feet) upstream and downstream of the culvert were evaluated to characterize the habitat available from culvert replacement/ modifications.

4.5.2.2. Styx Creek (Tributary to Slate Creek; RM 4.9)—Culvert, Habitat, and Geomorphic Survey

Within Styx Creek, at approximately RM 0.1 (see Figure 4.5-1), culvert barrier dimensions were measured and habitat conditions 150 m (492 feet) upstream and downstream of the culvert were evaluated to determine the habitat available from culvert replacement/modifications.

4.5.2.3. Sullivan Creek (PRM 26.9)—Geomorphic and Habitat Reconnaissance Survey

Fluvial geomorphic conditions of Sullivan Creek downstream of Mill Pond (RM 3.25) were evaluated and potential opportunities for sediment control/retention and/or habitat enhancement measures were identified.

The information reviewed in 2007 suggested that in some areas, erosion may be supplying large amounts of sediment to the stream and other areas may experience a deficit of sediment due to trapping of bed material load in Mill Pond. Therefore, areas of high erosion were identified based on the protocols listed in Section 4.5.1. The information was used to decide whether control of erosion would be beneficial on both a local and larger reach scale. In addition, opportunities to increase the retention of desirable sediment sizes within portions of Sullivan Creek, through utilizing LWD or other enhancement measures, were identified. The field reconnaissance of Sullivan Creek in 2008 was done to characterize the overall fluvial geomorphic conditions and key physical processes affecting current conditions. Stream reaches were surveyed to assess channel conditions, classify channel-reach morphology, and evaluate potential responses to any identified enhancement opportunities.

Sullivan Creek downstream of Mill Pond was divided into reaches based on major gradient breaks, similar habitats, and channel-reach morphology determined from U.S. Geological Survey (USGS) topographic maps, aerial photographs, geologic/soils maps, and observations made during the Sullivan Creek road segment survey. A longitudinal profile was developed, from the mouth (RM 0.0) to where Forest Service Road 22 crosses Sullivan Creek (RM 5.95).

Recent aerial photographs dated 2006 were obtained from ArcGIS Map Services (ESRI 2008). Utilizing the longitudinal profile, aerial photographs, and observations made during the Sullivan Creek road segment survey, three reaches (reach 1, 2, and 3) downstream of Mill Pond Dam were identified to possess gradients, similar habitats, and channel-reach morphology that would adequately represent geomorphic and habitat conditions in Sullivan Creek. In addition, these three reaches were identified as possessing the highest opportunity to improve factors limiting aquatic productivity through enhancement actions. Reaches 1, 2, and 3 are located at RM 0.47, 2.30, and 2.74 (see Figure 4.5-1), respectively.

Within each of the three reaches, the following were recorded:

- Dominant bed material size
- Representative bank materials
- Presence or absence of suitable spawning substrate for native salmonids
- Typical substrate conditions (as characterized by a Wolman pebble count)
- Dominant bed form
- Sediment sources
- Roughness elements
- Vertical and lateral geologic controls
- LWD tallies
- Habitat units
- Channel-reach morphology
- Average bankfull width and depth
- Wetted width and depth
- Valley confinement
- Riparian conditions throughout each reach

In addition, a longitudinal survey was conducted in reach 3, and two cross-sections, one in a pool and one in riffle, were also surveyed. Flood-prone area, bankfull width and depth, and wetted width and depth were determined for each cross section. This detailed survey was done because this reach was determined to have a high potential for improving factors limiting aquatic productivity. All data collected in each of the reaches were based on the protocols reported in Section 4.5.1.

In summary, habitat and stream bank conditions and processes dominating the morphology and influencing aquatic habitat conditions of identified reaches in Sullivan Creek downstream of Mill Pond Dam were observed, documented, and photographed. Results and conclusions were developed from the geomorphic and habitat field reconnaissance, including the identification of potential opportunities for sediment control/retention and/or habitat enhancement measures.

To further assist in assessing channel conditions in Sullivan Creek and potential responses to any identified enhancement opportunities that would be implemented downstream of Mill Pond Dam, reaches upstream of Mill Pond Dam in Sullivan Creek and Outlet Creek were also surveyed (reaches 4, 5, and 6). Two reaches in Sullivan Creek and one reach in Outlet Creek were identified from the longitudinal profile, aerial photographs, and during the survey of Sullivan Lake Road. The three surveyed reaches located upstream of Mill Pond are located at RM 4.66 and 5.65 in Sullivan Creek, and tributary RM 0.16 for Outlet Creek (see Figure 4.5-1).

Data from the three reaches upstream of Mill Pond (reaches 4 through 6) were collected using the same protocols as for the data collected downstream of Mill Pond Dam. This information was collected to compare habitat, stream bank conditions, and processes dominating the morphology in portions of Sullivan Creek not influenced by trapping of bed material load in Mill Pond.

Outlet Creek was also surveyed for comparison of habitat and stream bank conditions to data collected downstream of Mill Pond Dam because only Sullivan Lake flow releases have influenced conditions in this reach. The Outlet Creek survey was also conducted to document types of habitat and channels available throughout the Sullivan Creek watershed, including those outside of the mainstem. In addition, the information from surveying upstream of Mill Pond aided in identifying potential opportunities for sediment control/retention and/or habitat enhancement measures downstream of Mill Pond Dam based on a comparison to upstream conditions.

4.5.2.4. Sullivan Creek (PRM 26.9)—Reconnaissance-level Road Survey

Sullivan Lake Road, from RM 2.3 to 3.25 (Mill Pond Dam), was surveyed for locations where road segments could potentially be relocated, obliterated, and/or reconstructed to improve habitat. Specific activities entailed identifying road segments that confine and are hydrologically connected to Sullivan Creek, and documenting these locations via Global Positioning System points, aerial photographs, road mileage, and photographs.

To determine where road segments are encroaching and confining Sullivan Creek, a stream buffer of 120 m (394 feet) was created in ArcGIS around Sullivan Creek and those road segments within the buffer were surveyed. This method of using a stream buffer to determine which road segments are encroaching and hydrologically connected to Sullivan Creek is based on those methods described in Section 4.5.1. The road survey included the following:

- Measuring the cut and fill slope angles of the road segment
- Identifying whether slopes were cut, fill, or natural
- Documenting the shape and orientation of the road surface
- Measuring the width of the road surface
- Documenting stream crossings
- Identifying any road maintenance issues
- Documenting the length of road segment surveyed
- Documenting the length of road segment directly connected (i.e., connected to the stream bank) to Sullivan Creek or other water bodies along the road

4.5.2.5. Linton Creek (PRM 28.1)—Culvert, Habitat, and Geomorphic Survey

Three culverts located downstream of Highway 31 (see Figure 4.5-1) were evaluated to determine whether the culverts were barriers to fish passage and whether the habitat upstream was of high quality. Thirteen culverts that are fish passage barriers from the mouth of Linton Creek (RM 0.0) to RM 1.0 were identified from literature reviewed during the 2007. Although the 2007 efforts determined that data gaps for Linton Creek were not critical to fill, data were collected as part of the 2008 field tasks because Linton Creek was identified in Studies 8 and 9 (SCL 2009a and 2009b) as potentially providing thermal refugia to Boundary Reservoir salmonids.

The surveys in Linton Creek entailed measuring the dimensions of the three culverts downstream of Highway 31 and photograph documenting the stream conditions upstream and downstream of these culverts. In addition, a longitudinal profile of creek segments immediately downstream of each culvert was also developed to demonstrate the conditions downstream from the three culverts.

As part of Study 8 efforts, pressure transducers used for measuring water level and temperature were placed throughout the creek's delta. The available data from the upstream location were obtained and the 7-day average maximum daily temperature was calculated for the creek.

4.5.2.6. Pocahontas Creek (PRM 29.4)—Culvert, Habitat, and Geomorphic Survey

Culvert barrier dimensions at approximately tributary RM 0.34 (see Figure 4.5-1) were measured. In addition, habitat conditions 150 m (492 feet) upstream and downstream of the culvert were evaluated to determine the habitat available from culvert modifications/ replacement.

Pocahontas Creek from RM 0.0 (the mouth) to approximately RM 0.6 (approximate distance of 966 m [3,168 feet]) was also evaluated. Information was collected throughout this section of the creek by recording observations and photograph documenting habitat and stream bank conditions. In addition to these efforts, photographs of the mouth of Pocahontas Creek were taken in September and November 2007 and April through July 2008 to document if flows were present.

As part of Study 8 efforts, pressure transducers used for measuring water level and temperature were placed throughout the creek's delta. The available data from the upstream location was obtained and the 7-day average maximum daily temperature was calculated for the creek.

4.5.2.7. Sweet/Lunch Creek (PRM 30.9)—Culvert, Habitat, and Geomorphic Survey

Culvert barrier dimensions at approximately RM 0.5 (see Figure 4.5-1) were measured and habitat conditions 170 m (558 feet) upstream and downstream of the culvert were evaluated to determine the potential habitat available from culvert modifications.

In addition, from RM 0.0 (the mouth) to approximately RM 0.6 (approximate distance of 966 m [3,168 feet]) was evaluated. Information was collected throughout this section of Sweet Creek by recording observations and photograph documenting habitat and stream bank conditions.

As part of Study 8 efforts, pressure transducers used for measuring water level and temperature were placed throughout the creek's delta. The available data from the upstream location were obtained and the 7-day average maximum daily temperature was calculated for the creek.

4.5.3. Habitat Protection Assessment

As part of the 2008 efforts to identify protection and enhancement opportunities, a feasibility study was conducted to evaluate the potential for protecting habitat in specific segments of Slate Creek, Sullivan Creek, and Sweet Creek (see Figure 4.5-1). These segments were identified during the 2007 Study 14 efforts. Through this feasibility study, appropriate land segments and property ownership along those segments were reviewed.

The areas considered for protection encompassed all property adjacent to the riparian corridor within 91.4 m (300 feet) on either stream bank within specific lengths of stream segments. Specific stream segments were identified during the 2007 Study 14 efforts, namely, RM 0.0 to 0.75, 0.0 to 0.66, 0.0 to 0.5 for Slate, Sullivan, and Sweet creeks, respectively. These specific stream segments were identified as high priority habitats in 2007 and considered of exceptional importance for native salmonids in the Boundary Reservoir system.

As a result of the 2007 efforts, it was necessary to evaluate the current level of protection (e.g., property ownership and land status) for each stream segment as part of the 2008 Study 14 efforts. To determine the current level of protection, the SCL-approved property ownership layer and stream layer were added into ArcGIS. A stream buffer of 91.4 m (300 feet) on either stream bank was created in ArcGIS for the identified stream segment, and the property owner was identified. Based on these identified property owners, an evaluation of the viable options for protecting habitat on these lands was conducted for the areas of these three creeks. Relevant information was obtained about the USFS land designation in the Slate Creek evaluated area. For the Sullivan Creek evaluated area, the evaluation as identified during the 2007 efforts was intended to go from RM 0.0 to RM 0.66. However, the approved SCL property ownership layer did not extend beyond RM 0.47 and therefore only RM 0.0 to 0.47 was included in the evaluated area. For Sweet Creek, property ownership and land status between RM 0.0 to 0.5 was identified and included in the evaluated area.

After the evaluated area and property ownership had been identified, an Internet search was completed that assessed the options available to public and private landowners and whether the proposed segments of land met the criteria required for each option based on ownership. Following the initial Internet search, direct contact via e-mail and phone was made with the U.S. Department of Agriculture (USDA) Farm Services Agency, DNR, WDFW, the Nature Conservancy, the Land Trust Alliance, and the Inland Northwest Land Trust to obtain further information and to ascertain procedures for protecting habitat.

4.6. Finalized Limiting Factors Matrix

In 2008, field surveys (Section 4.5) were conducted to collect data necessary to update the 2007 draft LFM for primary tributaries, specifically those tributaries surveyed as part of the 2008 field activities, and to identify enhancement opportunities that would improve aquatic conditions. The data were first collected in the field, analyzed based on the applicable methods for each protocol, and then summarized into data tables. These summarized data tables were then compared to the WRIA 62 Pend Oreille bull trout habitat rating criteria from Andonaegui (2003) (see Appendix 3) to update the factors limiting productivity for each of the surveyed creeks. This process of comparing summarized data from the 2008 field surveys to the criteria in Appendix 3 resulted in a finalized LFM. The finalized LFM was then used with field-identified locations of habitat and geomorphic improvement opportunities to determine types of enhancement actions that would address factors limiting aquatic productivity.

4.7. Identification of Enhancement Opportunities to Address Factors Limiting Aquatic Productivity

The finalized LFM and field-identified locations of habitat and geomorphic improvement opportunities were used to determine the types of enhancement actions that would address factors limiting aquatic productivity. Specifically, the results from field data were used to update the draft LFM and identify what type of actions would potentially address each limiting factor. Using all data and information, specific types of enhancement opportunities were developed and then compared to current scientific knowledge on fish species and geomorphic responses to each specific type of action. A relative rating for each opportunity was thus developed. Each opportunity was also rated based on several important factors, including the following:

- Property ownership in the immediate vicinity
- Current and potential habitat conditions
- Potential gain in habitat quantity, scale of action (e.g., length of stream treated, size of area planted, length of stream made available)
- General ranges of costs for the type of action, the amount of effort (e.g., earth moving, site access)
- Professional judgment based on the field surveys of each creek and experience monitoring, developing, and evaluating enhancement projects

From these ratings and overviews of priority factors, a rank of high, medium, or low was assigned to each opportunity. This resulted in a list of enhancement opportunities across the surveyed streams at specific reaches and/or locations. The enhancement opportunities are based on identifying actions that address the factors limiting aquatic productivity at each location. Although enhancement opportunities were identified for each of these locations within primary tributaries, this is not to imply that these locations are the only enhancement opportunities in tributaries draining into Boundary Reservoir. Rather, these tributaries are those that met the criteria used in this assessment. Other enhancement opportunities likely exist in both the primary and secondary tributaries. However, the methodology utilized in this study determined those tributaries with the highest potential to address factors limiting aquatic productivity at each location and provided a thorough approach to the identification of opportunities.

5 RESULTS

In 2007, available information on important physical, chemical, and biological conditions of the tributaries was compiled and reviewed, with an initial focus on all tributaries draining directly into Boundary Reservoir as opposed to those sections of tributaries that are retained behind dams. Specifically, the drainage upstream of Mill Pond Dam in the Sullivan Creek WAU and the entire drainage of the Harvey Creek WAU were considered secondary streams because Mill Pond Dam and Sullivan Lake Dam are complete barriers to fish passage, which currently limit these areas to resident fish production. Consequently, documentation of the habitat conditions within the Sullivan Creek drainage upstream of Mill Pond Dam and the Harvey Creek WAU is limited in this report.

The following sections present the final results of this study, discussed by task.

5.1. Review and Compile Available Information

In 2007, information gathered from compiling and reviewing sources for tributaries draining to Boundary Reservoir, excluding the drainage upstream of Mill Pond Dam in Sullivan Creek and the Harvey Creek WAU, resulted in a wide range of data. The majority of this information was from surveys and biological evaluations that occurred in the 1990s, and between 2000 and 2005. This information facilitated the development of a list of productivity factors for Boundary Reservoir tributaries (Section 5.2).

5.2. Stream Categorization and Productivity Factors

In 2007, the information obtained from compiling and reviewing sources was catalogued into several categories affecting productivity including barriers, riparian conditions, channel conditions and dynamics, habitat elements, water quality, water quantity and characteristics, and fish species present for the primary tributaries (see Appendix 5). Subsequently, the catalogued information was organized by WAU and tributary within a WAU, respectively, and provided a detailed list of productivity factors. A data table for Boundary Reservoir primary tributaries (see Appendix 6) was created to develop a summary of the aquatic conditions in primary tributaries.

In 2007, all Boundary Reservoir tributaries, including the Sullivan Creek drainage upstream of Mill Pond Dam and the Harvey Creek WAU, were categorized as primary, secondary, or excluded (see Section 4.2) to determine levels of opportunity within these areas (Table 5.2-1). Although the Sullivan Creek drainage upstream of Mill Pond Dam and the Harvey Creek WAU were not key areas of focus during development of the list of productivity factors, information needed to determine if these areas were primary, secondary, or excluded was obtained from McLellan (2001), Andonaegui (2003), and WDFW SalmonScape (2007).

Table 5.2-1. Determination of primary, secondary, and excluded tributaries.

WAU	Tributary Name	Watershed Area (mi^2)	Length of Adfluvial Habitat (ft)	Natural Barrier at Mouth	Gradient (%)	Discharge[8] (m^3/s) (ft^3/s)	Native Species[8]	Level of Opportunity
Slate Creek	Lime Creek	2.9	6,746[2]		6[2]	0.08 (2.83)	DG	Primary
Slate Creek	Slate Creek	32.3	3,474[2]		6.3[2]	0.31 (10.95)	BT (near mouth); CT	Primary
Slate Creek	Flume Creek	19.3	1,056[2]		7[2]	0.05 to 0.25 (1.77 to 8.83)	CT	Primary
Sullivan Creek	Sullivan Creek WAU	91	21,729[2]		3[2]	7.1 (250.73)	BT; CT; MWF	See all Sullivan Creek opportunities following
Sullivan Creek	Sullivan below Mill Pond Dam	21	21,729[2]		1 to 10[2]	1.4 to 56.6 (49.44 to 1,998.81)	BT; CT; MWF	Primary
Sullivan Creek	N.Fk.Sullivan	10.1	0[3]		2.2[7]	0.04 (1.41)	CT	Primary
Box Canyon	Linton Creek	2.1	19,159[1]		0.3 to 56.4[1]	DG	DG	Primary
Box Canyon	Pocahontas Creek	3.9	16,480[1]		1.5 to 26.9[1]	DG	CT	Primary
Box Canyon	Sweet Creek\Lunch Creek	11.1	2,659[2]		5 to 12[2]	0.15 (5.30)	BT; CT; MWF	Primary
Box Canyon	Sand Creek	8.2	1,320[2]		7[2]	0.01 to 0.02 (0.35 to 0.71)	CT; MWF	Primary
Slate Creek	Pewee Creek	10.4	0[2]	Yes	7 to 9[2]	0.01 (0.35)	CT	Secondary
Slate Creek	Everett Creek	2.2	60[1]		>20 after 60 ft[1]	DG	DG	Secondary
Slate Creek	Whiskey Gulch	<1	547[1]		>20 after 547 ft[1]	DG	DG	Secondary
Sullivan Creek	Sullivan above Outlet Creek	70	0[4]		1.5 to 4[2]	1.2 (42.38)	CT; MWF	Secondary
Harvey Creek	Harvey Creek WAU (Outlet Creek)	51.5	0[4]		0.8 to 60.2[1]	0.3 to 34 (1.06 to 1,200.70)	CT; MWF	Secondary
Box Canyon	Unnamed No. 6	<1	955[1]		>20 after 955 ft[1]	DG	DG	Secondary
Box Canyon	Wolf Creek	1.6	236[1]		16.5[1]	DG	DG	Secondary

Table 5.2-1, **continued…**

WAU	Tributary Name	Watershed Area (mi^2)	Length of Adfluvial Habitat (ft)	Natural Barrier at Mouth	Gradient (%)	Discharge[8] (m^3/s) (ft^3/s)	Native Species[8]	Level of Opportunity
Box Canyon	Lost Creek	1.2	165[1]		8.6[1]	DG	CT	Secondary
Box Canyon	Unnamed No. 13	1.7	<100[5]		>20 after 100 ft[1]	DG	DG	Secondary
Slate Creek	Unnamed No. 1	<1	82[1]		>20 after 82 ft[1]	DG	DG	Exclude
Slate Creek	Unnamed No. 2	<1	129[1]		>20 after 129 ft[1]	DG	DG	Exclude
Slate Creek	Beaver Creek	1.8	0[2]	Yes	12.7[1]	DG	DG	Exclude
Slate Creek	Threemile Creek	4.9	0[2]	Yes	10.5[1]	DG	None	Exclude
Slate Creek	Unnamed No. 3	<1	58[1]		>20 after 58 ft[1]	DG	DG	Exclude
Box Canyon	Unnamed No. 4	<1	77[1]		>20 after 77 ft[1]	DG	DG	Exclude
Box Canyon	Unnamed No. 5	<1	130[1]		>20 after 130 ft[1]	DG	DG	Exclude
Box Canyon	Unnamed No. 7	<1	53[1]		>20 after 53 ft[1]	DG	DG	Exclude
Box Canyon	Unnamed No. 8	<1	66[1]		>20 after 66 ft[1]	DG	DG	Exclude
Box Canyon	Unnamed No. 9	<1	67[1]		>20 after 67 ft[1]	DG	DG	Exclude
Box Canyon	Unnamed No. 10	<1	99[1]		>20 after 99 ft[1]	DG	DG	Exclude
Box Canyon	Unnamed No. 11	<1	78[1]		>20 after 78 ft[1]	DG	DG	Exclude
Box Canyon	Unnamed No. 12	<1	<100[6]		>20 after 102 ft[1]	DG	DG	Exclude

Notes:

DG – Data Gap; CT – Cutthroat Trout; BT – Bull Trout; MWF – Mountain Whitefish; m^3/s – cubic meter per second; m^2 – square mile; ft^3/s – cubic feet per second

1 The length of adfluvial habitat and the gradient were determined from the WDFW SalmonScape (2007) as the distance from the mouth of the stream up to a gradient greater than 20 percent.

2 The length of adfluvial habitat is based on the distance from the mouth of the stream to the lowermost migration barrier reported in McLellan (2001) and/or Andonaegui (2003). Gradients were based on information reported in McLellan (2001) and/or Andonaegui (2003).

3 North Fork Sullivan Creek would be secondary, based on the criteria. However, because there is a culvert at the mouth limiting adfluvial habitat length, there is potential to increase the length to 1,056 feet by removing a culvert at the mouth. Therefore, it was determined to be a Primary Tributary evaluated for factors limiting productivity of native salmonids. In addition, North Fork Sullivan Creek is located in the Sullivan Creek drainage downstream of Mill Pond Dam.

4 Because there is a dam located at Mill Pond Dam (RM 3.25), no adfluvial habitat is available.

5 Based on a site visit in September 2007, the outlet of the culvert which the tributary flows was blocked by riprap, although seepage flow was observed. The length of adfluvial habitat was estimated as less than 100 linear feet of stream (Fullerton 2007).

6 Based on a site visit in September 2007, a culvert perched higher than 15 feet was observed near the reservoir margin. The length of adfluvial habitat was estimated as less than 100 linear feet of stream (Fullerton 2007).

7 Determined from Conner et al. (2005).

8 Determined from McLellan (2001) and Andonaegui (2003).

Tributary streams play an integral part in the conditions of river or reservoir systems by contributing nutrients, sediment, LWD, and water. In addition, tributary streams support biological processes by providing food and refuge habitat to adfluvial and resident fish populations such as bull trout, westslope cutthroat trout, and mountain whitefish. Due to the connections between native salmonids, tributaries, and river or reservoir systems, it is important that the streams draining into Boundary Reservoir be capable of providing physical and biological conditions that assist in maintaining healthy salmonid populations.

Andonaegui (2003) stated that artificial structures, habitat degradation, high water temperatures, changes in the natural flow regime, and species competition have been associated with the decline of bull trout populations in the Pend Oreille River and its tributaries. Based on reviewing available information sources, it was determined that these same factors are potential conditions limiting overall aquatic productivity in Boundary Reservoir primary tributaries.

The following discussion, which is presented by WAU, summarizes the general status of productivity factors for many of the streams in each of the WAUs. The emphasis of the discussion is on primary tributaries because these are the water bodies with the greatest potential for human interventions that would supply the most benefit to mainly adfluvial salmonids. The Harvey WAU is not presented here because no primary streams are present in that region and the area has limited potential as adfluvial habitat. In addition, it is upstream of several dams and potential barriers to upstream fish migration. A complete summary of the productivity factors and their status by streams within the Slate Creek, Sullivan Creek, and Box Canyon WAUs, including all tributaries, is presented in Appendix 5.

5.2.1. Slate Creek WAU

Based on available literature reviewed in 2007, natural waterfalls, cascades, chutes, culverts, and other potential barriers within tributaries of the Slate Creek WAU were determined to be present in Slate, Slumber, Styx, Pewee, Threemile, Beaver, Lime, Everett, Whiskey Gulch, Flume, and South Fork Flume creeks (see Appendix 7 and Figure 5.2-1.). Most of the barriers within the Slate Creek WAU primary tributaries occur naturally (see Appendix 5). Although the Slate Creek WAU barriers are mostly waterfalls, cascades, and chutes, in the Slate Creek and Flume Creek watersheds culverts are present, offering potential areas where upstream connectivity for resident populations of native cutthroat trout could be restored.

A vertical waterfall near the mouth of Flume Creek is a fish passage barrier (McLellan 2001; R2 Resource Consultants 1998; Andonaegui 2003; WDFW SalmonScape 2007). Farther upstream from the vertical waterfall is a culvert that is a potential fish passage barrier. Although barriers are present in Flume Creek, local agency biologists, studies on resident fish stock status, and surveys that were conducted throughout the Flume Creek tributary suggest there are suitable habitat characteristics for resident trout upstream of the waterfall barrier or adfluvial trout downstream of the barrier (R2 Resource Consultants 1998; McLellan 2001; Andonaegui 2003).

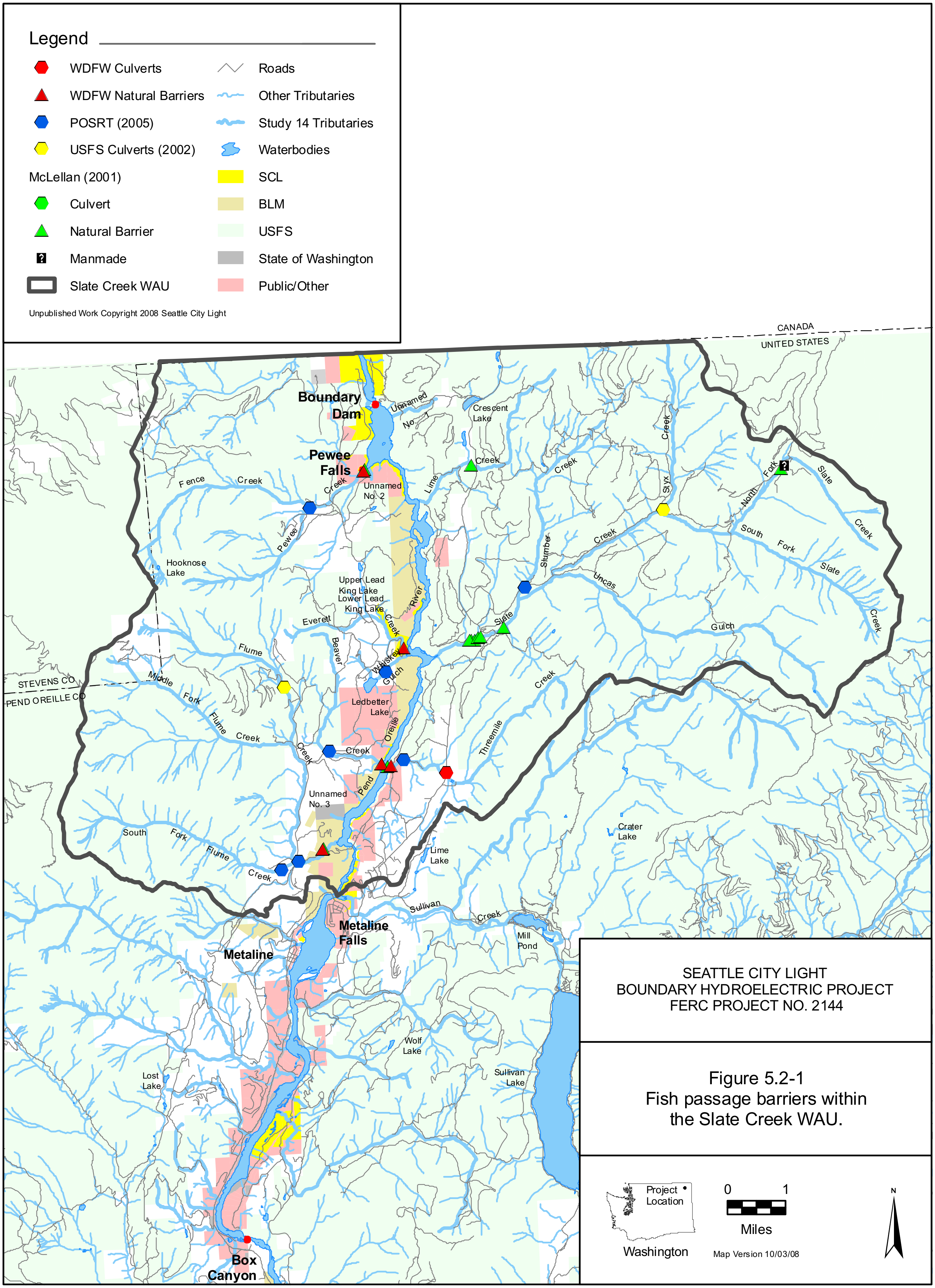

Figure 5.2-1
Fish passage barriers within the Slate Creek WAU.

Past reviews and surveys that had been done suggest that there is suitable habitat for resident or adfluvial trout throughout the Slate Creek watershed (R2 Resource Consultants 1998; McLellan 2001; Andonaegui 2003) (see Appendix 5). In 2005, 0.15 mile of Slate Creek, from the confluence with the Pend Oreille River upstream, was designated as "Critical Habitat" for bull trout by the USFWS (Federal Register 2005).

Overall, within the Slate Creek tributary, available spawning and rearing habitat for bull and cutthroat trout residing in Boundary Reservoir is limited to the stretch from RM 0.0 to an impassable cascade at RM 0.75 (Shuhda 2007). Cutthroat trout were documented as well-distributed throughout the drainage, and successful reproduction was occurring as indicated by the presence of young-of-the-year (USFS 1998) (see Appendix 5). Cutthroat trout were collected between May and June 2007 during a fyke net survey at the mouth of Sand Creek (SCL 2009b). However, Young et al. (2004) suggested that cutthroat trout in Slate Creek had significant genetic influence from hatchery fish stocked during the middle of the 20th century.

Throughout the Slate Creek WAU, the riparian vegetation is intact and continuous with few road crossings; provides adequate shade, detritus, and LWD for future recruitment; and is composed of species reflecting a natural community (USFS 1998, 1999c; Andonaegui 2003) (see Appendix 5). Entrix (2002) reported that riparian harvest and catastrophic wildfires have reduced the availability of LWD, but riparian areas currently contain sufficient large trees to provide for future recruitment. For the Slate Creek WAU, in-stream LWD exceeded 20 pieces per mile for all surveyed reaches (USFS 1999c; Andonaegui 2003).

The WAU primarily consists of V- and U-shaped narrow valley forms (Rosgen A and B channel types) (USFS 1998; Andonaegui 2003) (see Appendix 5). Braiding due to collections of LWD provides some off-channel habitat in side channels and along stream margins (Andonaegui 2003). However, because many of the channels in the WAU are high-gradient streams, they do not contain large amounts of off-channel habitat (USFS 1998; Andonaegui 2003). In a 1998 study of the Slate Creek watershed, the USFS (1998) concluded that past management activities had not resulted in conditions where flows, both peak and low, produced adverse impacts on the watersheds.

5.2.2. Sullivan Creek WAU

Based on available literature reviewed in 2007, natural waterfalls, cascades, chutes, culverts, and dams within the Sullivan Creek WAU were determined to be located in North Fork Sullivan Creek and in the mainstem of Sullivan Creek downstream of, at, and upstream of RM 3.25 (see Appendix 5 and 7 and Figure 5.2-2.). The Sullivan Creek hydroelectric project has been reported as having a limiting effect on bull and cutthroat trout in the WAU (Shuhda 2007). In 2005, the POSRT documented significant fish passage barriers as a bull trout habitat limiting factor in the Sullivan Creek drainage.

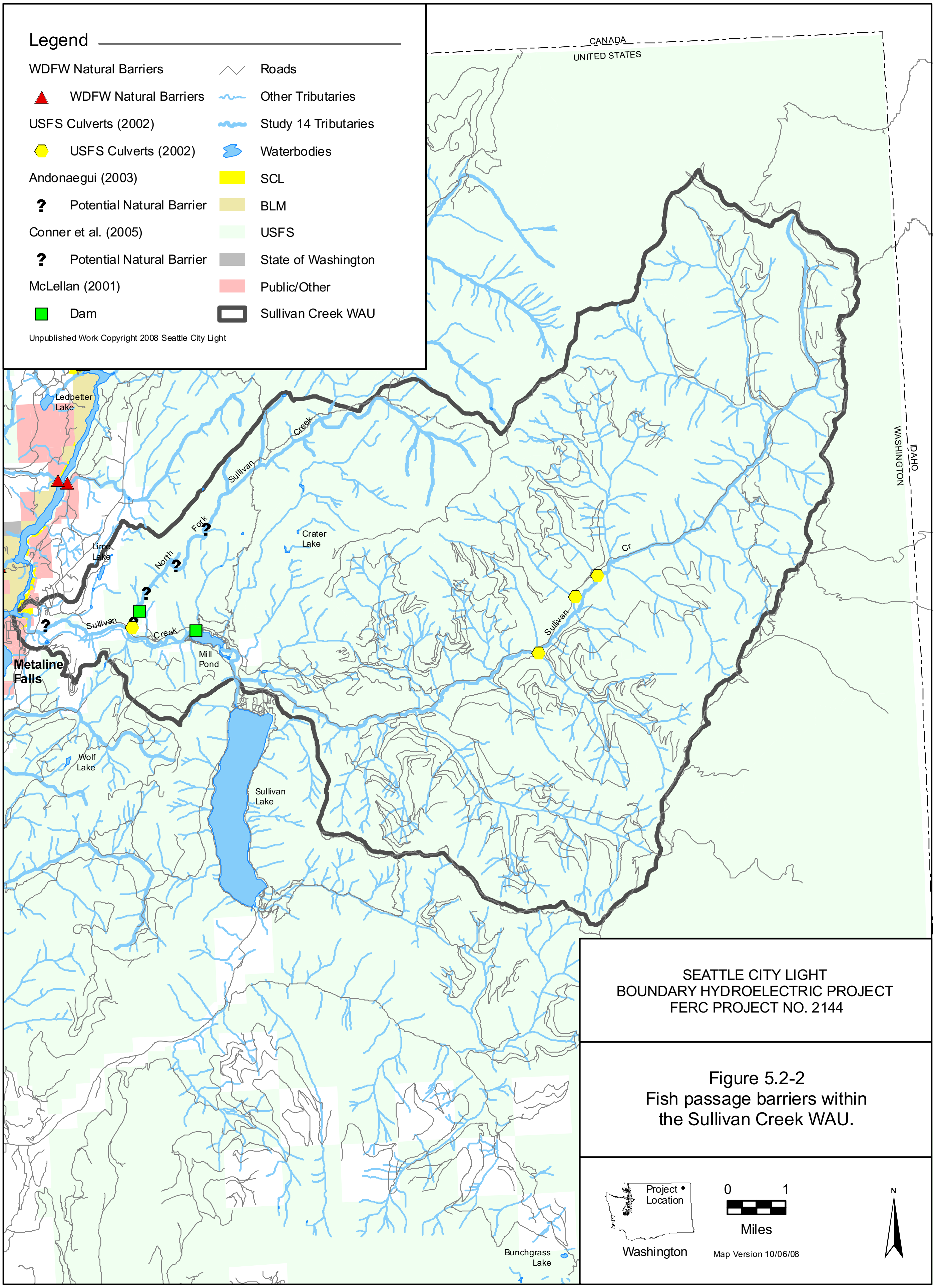

Figure 5.2-2
Fish passage barriers within the Sullivan Creek WAU.

Within the North Fork Sullivan Creek drainage, a culvert at the mouth is a barrier to fish passage. Natural barriers are present upstream from the culvert, as well as the North Fork Sullivan Creek Dam at RM 2.35. Although barriers to fish passage are present, both the undisturbed habitat and the presence of a genetically distinct stock of cutthroat trout in the drainage make this tributary to Sullivan Creek unique (see Appendix 5). Conner et al. (2005) described North Fork Sullivan Creek as one of the most undisturbed streams in the lower Pend Oreille watershed.

Past reviews and surveys suggest there is suitable habitat to support populations of native salmonids throughout the Sullivan Creek watershed (R2 Resource Consultants 1998; McLellan 2001; Andonaegui 2003) (see Appendix 5). In 2005, 0.66 mile of Sullivan Creek, from the confluence with the Pend Oreille River upstream, was designated as "Critical Habitat" for bull trout. Throughout the Sullivan Creek watershed only two bull trout were detected prior to 2003, each below the uppermost natural cascades and chutes that occur near RM 0.65 on Sullivan Creek, upstream from the confluence with the Pend Oreille River (RM 0.0) (Andonaegui 2003). In September 2007, during a snorkel survey being conducted under Study 9 (SCL 2009b), an unidentified char, possibly a bull trout, was observed in lower Sullivan Creek.

There has been no confirmation of bull trout presence in Sullivan Creek. Cutthroat trout, rainbow trout, brook trout, brown trout, and mountain whitefish have all been observed in Sullivan Creek downstream from Mill Pond Dam (Appendix 5). In North Fork Sullivan Creek, the westslope cutthroat trout population was indicated as a distinct genetic stock (Shaklee and Young 2000 as cited in Connor et al. 2005), with no hybridization and no record of past stocking (Appendix 5). From snorkel surveys conducted in 2000, Sullivan Creek had the lowest fish densities, compared to all other tributaries (McLellan 2001). However, of the tributaries surveyed (Slate, Sullivan, Sand, Flume, Sweet, Lunch, Pewee, and Lime creeks), Sullivan Creek had the greatest diversity observed (seven species) (McLellan 2001). McLellan (2001) suggested the low fish densities in Sullivan Creek may have been a result of poor habitat, indicated by low densities of LWD and pool habitats, and/or high angling pressure (see Appendix 5). Overall, spawning and rearing habitat for bull and cutthroat trout from Boundary Reservoir is limited to the stream reach downstream of Mill Pond Dam (RM 3.25).

Historically, the riparian areas along the mainstem of Sullivan Creek have been harvested and have roads located within some of the riparian areas (USFS 1999d). Entrix (2002) reported that aquatic habitat had been most influenced by historic timber harvest, especially clearcutting of riparian areas, road building, fires, and dispersed recreation (see Appendix 5). The USFS (1996) reported that by the mid-1980s, road density was between 1.7 and 2.0 miles per square mile. In addition, the USFS (1999d) stated that the majority of the road system was inside riparian areas, and portions of the riparian areas had been replaced by forest and county road systems, which reduced the amount of riparian areas from historic levels.

Of approximately 234 miles of road within the Sullivan Creek WAU, nearly 46 miles are within 61 meters (200 feet) of streams, with Sullivan Creek Road open and adjacent to Sullivan Creek for most of its length (Entrix 2002). Overall, adequate shade, detritus, and LWD are provided by the riparian area for the Sullivan Creek WAU (Andonaegui 2003).

Above bankfull flow, streambanks have high vegetative cover and well-established riparian communities (Andonaegui 2003); USFS (1996) described the banks along Sullivan Creek as “generally in pretty stable condition.” The primary erosional process throughout the drainage is landslides, and the channel is deeply entrenched and confined as it cuts through a rock canyon (USFS 1996; Andonaegui 2003). Sections of Sullivan Creek downstream and continuing upstream from Mill Pond Dam are historically prone to landslide activity (USFS 1996; Andonaegui 2003). The POSRT (2005) concluded embedded substrate/sedimentation was a bull trout habitat limiting factor.

Throughout the Sullivan Creek drainage, channels primarily comprise narrow V- or U-shaped valley forms (Rosgen A and B channel types) and do not and did not historically have many oxbows, backwater habitat, and ponds (USFS 1996; Andonaegui 2003) (see Appendix 5). Although lacking off-channel habitat, the Sullivan Creek WAU does have some stream margins that provide shallow water habitat and some side-channel habitat resulting from accumulated complexes of LWD forming bars and initiating channel braiding (USFS 1999d; Andonaegui 2003).

5.2.3. Box Canyon WAU

Based on available literature reviewed in 2007, natural waterfalls, cascades, chutes, culverts, and other potential barriers within tributaries of the Box Canyon WAU were determined to be located in Linton, Pocahontas, Wolf, Sweet, Lunch, Sand, Lost, and 13 unnamed creeks (see Appendix 7 and Figure 5.2-3.). Nearly 1.5 miles of Linton Creek are blocked by culverts that are fish passage barriers. A culvert barrier in the lower stream section of Pocahontas Creek is a fish passage barrier (POSRT 2005). In Sweet Creek, a road crossing at State Highway 31 has been described as a velocity barrier to fish passage (Andonaegui 2003; WDFW SalmonScape 2007). However, as Andonaegui (2003) reports, and as documented in McLellan (2001), an adult bull trout was observed between the culvert and a waterfall barrier located upstream of the culvert. In addition, upstream of State Highway 31, juvenile whitefish had been observed, indicating some degree of passage (C. Vail 2002 as cited in Andonaegui 2003).

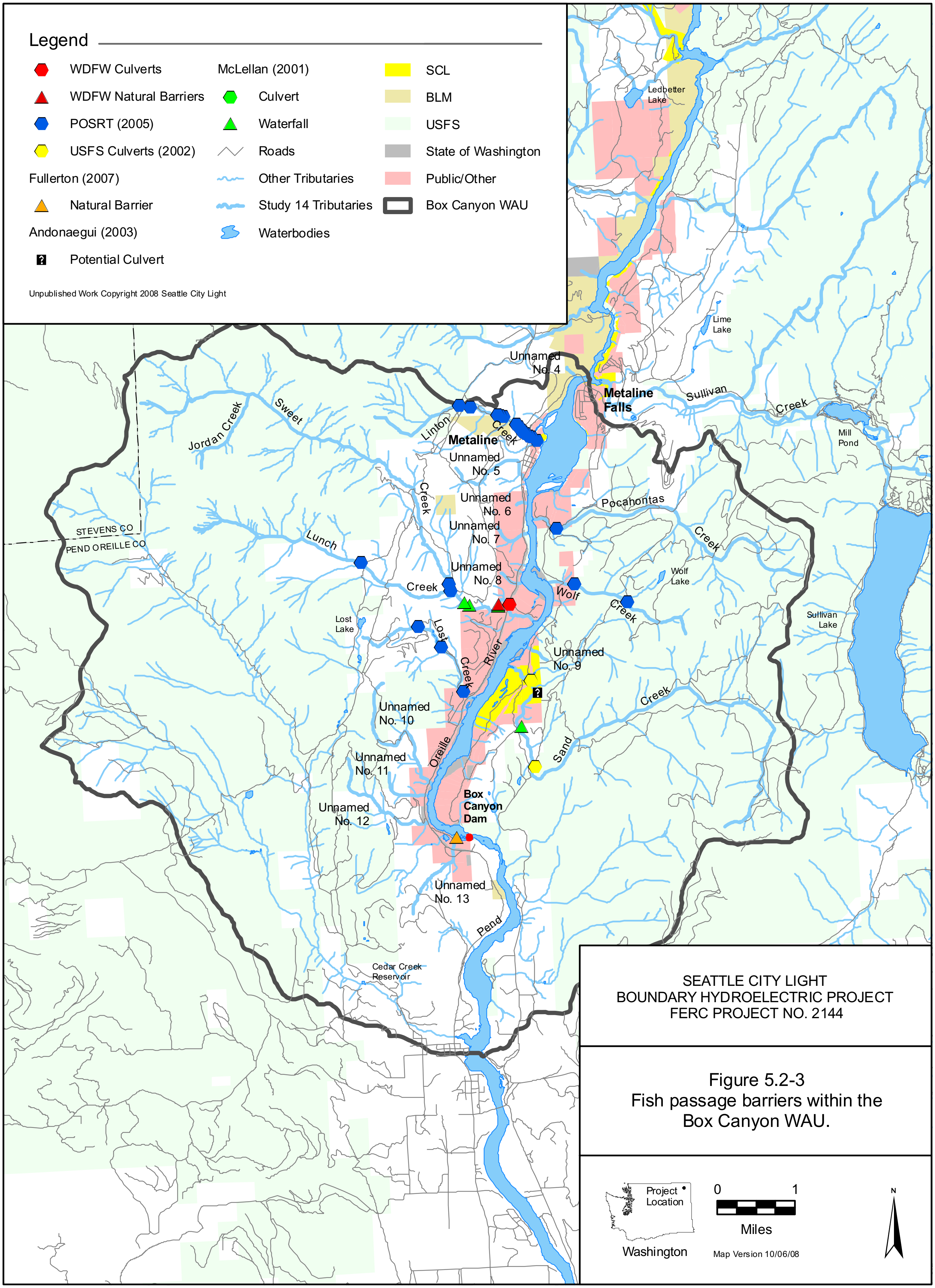

Figure 5.2-3
Fish passage barriers within the Box Canyon WAU.

Reviews and surveys suggest the Box Canyon WAU has suitable habitat characteristics for resident or adfluvial trout (R2 Resource Consultants 1998; McLellan 2001; Andonaegui 2003). Bull trout, cutthroat trout, and mountain whitefish have all been documented as present in the lower sections of the drainage, and cutthroat trout have been documented in the upper section of the drainage (see Appendix 5). R2 Resource Consultants (1998) indicated that potential spawning and rearing habitat for adfluvial salmonids is available below the waterfall barrier in Sweet Creek located at RM 0.6. In addition, Shuhda (2007) noted that available spawning and rearing habitat for bull and cutthroat trout in Boundary Reservoir is limited to the area downstream of the falls barrier.

R2 Resource Consultants (1998) identified a limited amount of spawning and rearing habitat for salmonids below a fish passage barrier in the lower portion of Sand Creek. Andonaegui (2003) documented that limited "suitable" bull trout habitat was identified by the TAG for Sand Creek. In addition, within the watershed, existing habitat had been modified by human activities (Andonaegui 2003). However, instream habitat in Sand Creek was documented as fair to good and complex enough to provide refuge for all life stages of cutthroat trout present in the drainage (USFS 1999e; Andonaegui 2003). Shuhda (2007) noted that available spawning and rearing habitat for bull and cutthroat trout in Boundary Reservoir is limited to the stretch from RM 0.0 to an impassable culvert near RM 0.25 in Sand Creek.

5.3. Draft Limiting Factors Matrix

The draft LFM was developed in 2007 prior to any site-specific field activities that occurred in 2008. In 2007, the status of productivity factors potentially limiting native salmonid populations in Boundary Reservoir tributaries was put in the form of a matrix that categorized the factors as poor quality habitat (not properly functioning), fair habitat (at risk), and good quality habitat (properly functioning). This draft LFM was used to identify data gaps and determine areas limiting aquatic productivity.

A list of tributaries that had the greatest opportunity to be modified through human intervention is shown in Table 5.2-1. These tributaries are identified as "primary" in Table 5.2-1. Based on available information reviewed (see Sections 5.2.1 through 5.2.3), limiting conditions by productivity factor were identified in the draft LFM (see Appendix 8). A matrix was also developed for secondary tributaries using the same methods as for the draft LFM (see Appendix 4).

To evaluate which conditions limit the ability of habitat to fully sustain populations of salmonids, the available information was compared to habitat rating criteria from Andonaegui (2003) (see Appendix 3) and Smith (2005) (see Appendix 9). The categories in these habitat rating criteria comprise, in general, the following:

- Access to spawning and rearing habitat
- Riparian condition
- Channel conditions
- Habitat elements
- Water quality
- Water quantity
- Species competition

In 2007, the draft primary and secondary tributaries LFM facilitated the evaluation of factors limiting aquatic productivity that can be modified through human intervention, and assisted in determining data gaps for the primary and secondary tributaries.

5.4. 2007 Identification of Data Gaps and Proposed Data Collection Areas for 2008

In 2007, data gaps were identified as described in Section 4.4. By using the primary and secondary tributary matrices, data gaps and partial data gaps were noted. A preliminary list of data gaps was then developed for primary tributaries (see Table 5.4-1). As discussed in Section 5.4.1, priority areas for potential habitat improvements, as noted by regional groups, were identified next for consideration to further refine the preliminary list of data gaps. Finally, as discussed in Section 5.4.2, a list of locations where data could be collected in 2008, based on the streams and reaches where critical data gaps were determined to exist, was developed. This determination of critical data gaps and the development of a list of locations where data could be collected in 2008 were based on the criteria described in Section 4.4. The predominant data gaps for the secondary tributaries are identified in Appendix 4.

Table 5.4-1. Identified data gaps in 2007 for the Slate Creek, Sullivan Creek, and Box Canyon WAUs.

Creek Name	Data Gap
Slate Creek WAU	
Styx Creek	• Dimensions of the barrier listed in the Barrier Inventory for Boundary Reservoir tributaries (see Appendix 7). Specifically, the length of the culvert at RM 0.1.
North Fork Slate Creek	• Dimensions of the barrier listed in the Barrier Inventory for Boundary Reservoir tributaries (see Appendix 7). Specifically, McLellan (2001) reported an artificial barrier in North Fork Slate Creek; however, information regarding the barrier is not available.
Flume Creek	• Dimensions of the barriers listed in the Barrier Inventory for Boundary Reservoir tributaries (see Appendix 7). Specifically, the culvert lengths at RM 1.0 and 4.75. • Information on floodplain connectivity and available off-channel habitat is lacking.
South Fork Flume Creek	• Dimensions of the barrier listed in the Barrier Inventory for Boundary Reservoir tributaries (see Appendix 7). Specifically, the culvert height and length at RM 0.3. • Information on riparian conditions, channel connectivity and dynamics, available off-channel habitat, and changes in the flow regime is needed to evaluate factors limiting productivity in South Fork Flume Creek. • Andonaegui (2003) reports that within Flume Creek "instream temperatures are not available for winter months when bull trout eggs are incubating (December – June 28)." Further evaluation and analysis of habitat attribute data (other than barriers, instream temperature, and brook trout competition) are necessary (Andonaegui 2003).
Middle Fork Flume Creek	• Surveys of channel connectivity and dynamics and available off-channel habitat need to be conducted to evaluate factors limiting productivity in Middle Fork Flume Creek.

Table 5.4-1, continued…

Creek Name	Data Gap
Sullivan Creek WAU	
Sullivan Creek	• It is uncertain the extent to which human-induced activities like past timber harvest, road construction, channel straightening and bank armoring, and alteration to bedload and LWD transport by the dams are contributing to habitat degradation in Sullivan Creek. A channel migration zone study may be needed (Andonaegui 2003). • Placer gold mining should be evaluated to determine if restrictions or elimination of this activity could improve habitat conditions for bull trout (POPUD 1/29/03 final draft report review comments, March 2003 as cited in Andonaegui [2003]).
	• Regarding habitat for bull and cutthroat trout in Boundary Reservoir, there is a possibility that within the lower sections of Sullivan Creek the fluctuations in flows caused by release from Sullivan Lake Dam may result in redds becoming dewatered before emergence. Based on this information from Tom Shuhda (2007), the extent to which redds become dewatered before emergence (October through December) is a data gap. • The effect of Sullivan Lake on warming inflow to Sullivan Creek during the summer has not been determined (Shuhda 2007).
North Fork Sullivan Creek	• Dimensions of the barrier listed in the Barrier Inventory for Boundary Reservoir tributaries (see Appendix 7). Specifically, the culvert height, length, and gradient at RM 0.0. • Streambank conditions in North Fork Sullivan Creek have not been evaluated.
Box Canyon WAU	
Linton Creek	• Dimensions of the barriers listed in the Barrier Inventory for Boundary Reservoir tributaries (see Appendix 7) for Linton Creek. • Data are not available to evaluate channel conditions and dynamics, habitat elements, water quality, water quantity, and species competition throughout Linton Creek. The POSRT has identified 13 culverts between RM 0.18 and 1.1. Available habitat downstream, throughout, and upstream of these barriers is not known, and therefore is a data gap in identifying conditions limiting productivity in Linton Creek. • Linton Creek had not been surveyed to determine bull trout presence or absence and habitat suitability (Andonaegui 2003). However, recent surveys in 2008 found no bull trout.
Pocahontas Creek	• Dimensions of the barrier listed in the Barrier Inventory for Boundary Reservoir tributaries (see Appendix 7). Specifically, the culvert height, length, and gradient at RM 0.34. • Information on streambank conditions in Pocahontas Creek is not available.
Sweet Creek	• Dimensions of the barriers listed in the Barrier Inventory for Boundary Reservoir tributaries (see Appendix 7) for Sweet Creek. • Data are not available to evaluate channel conditions and dynamics.
Lunch Creek	• Dimensions of the barrier listed in the Barrier Inventory for Boundary Reservoir tributaries (see Appendix 7) for Lunch Creek. • Data are not available to evaluate channel conditions and dynamics, channel substrate, or available off-channel habitat.
Sand Creek	• Dimensions of the barrier listed in the Barrier Inventory for Boundary Reservoir tributaries (see Appendix 7). Specifically, the culvert height, length, and gradient at RM 0.0.

5.4.1. Priorities in Boundary Reservoir Tributaries

In 2007, not all data gaps identified were critical to determining locations where it was necessary to collect additional information in 2008. Although data gaps were identified and reported in Table 5.4-1, this information had to be screened for data gaps that were critical to fill in order to evaluate areas where factors limiting aquatic productivity could potentially be improved. Priority areas as identified by regional groups were considered as part of the screening process.

Table 5.4-2 provides the POSRT (2005) priorities and the CNF (Shuhda 2007) priorities as they relate to Boundary Reservoir tributaries. The POSRT (2005) identifies the Slate Creek Subbasin and the Sullivan and Harvey Creek WAUs as high priorities within WRIA 62 (see Appendix 10). Shuhda (2007) provided a list of tributaries draining into Boundary Reservoir that have the highest potential for providing bull and cutthroat trout habitat. These organizations' priorities were utilized following the criteria described in Section 4.4.

Table 5.4-2. Priorities identified by POSRT and CNF.

Creek Name	Priorities	
	POSRT	**CNF**
Slate Creek	The POSRT (2005) identified the removal of non-native fish species (brook, brown, and rainbow trout) and the replacement or removal of culverts which have been identified as fish passage barriers throughout the Slate Creek subbasin as high priorities.	Slate Creek between RM 0.0 and 0.75 is the only habitat available to bull trout in this watershed and is therefore high priority habitat (Shuhda 2007). For cutthroat trout upstream from barriers, the area upstream of RM 0.75 on Slate Creek is priority cutthroat habitat.
Sullivan Creek	The POSRT (2005) identified the following improvements to salmonid habitat within the Sullivan Creek drainage: the removal of Mill Pond Dam; restoring the upstream channel to proper form and function; restoring fish passage at Sullivan Lake Dam; removing non-native fish species (brook, brown, and rainbow trout), except kokanee; relocating, obliterating, and/or reconstructing road segments which are contributing sediment to the stream; installing engineered log jams above Mill Pond Dam; stabilizing slopes below Mill Pond Dam; and restoring habitat complexity.	Shuhda (2007) noted that between RM 0.0 and 3.25 in Sullivan Creek is the longest section of available habitat to fish in Boundary Reservoir, and is therefore high priority habitat. He further noted that if Mill Pond Dam and/or Sullivan Lake Dam are removed or if fish passage is provided at these locations, then all of Sullivan Creek and the Harvey Creek drainage would become high priority habitats. For cutthroat trout upstream from barriers, Sullivan Creek above Mill Pond Dam, Sullivan Lake, and throughout the Harvey Creek WAU are areas of high priority habitats.
Sweet Creek	—	Sweet Creek between RM 0.0 and 0.5 was identified as available habitat that has been utilized by bull trout (Shuhda 2007), and is therefore priority habitat.
Flume Creek and Pocahontas Creek	—	For bull trout, Flume Creek and Pocahontas Creek were also identified as high priority tributaries draining into Boundary Reservoir (Shuhda 2007).

Notes:
CNF – Colville National Forest
POSRT – Pend Oreille Salmonid Recovery Team

5.4.2. Critical Data Gaps and Tasks for 2008

In 2007, critical data gaps were identified by screening all the identified data gaps (Table 5.4-1), considering priority areas as identified above (Table 5.4-2), and applying the decision criteria described in Section 4.4. In addition to determining critical data gaps by utilizing all the identified data gaps, the critical data gaps were determined based on the need to evaluate locations where factors limiting aquatic productivity can be potentially modified through human intervention. Although the critical data gaps were those identified through the study process, this does not imply that only these critical data gaps are at locations where enhancement opportunities may address factors limiting aquatic productivity. Rather, these critical data gaps are those that met the criteria used in this assessment (see Section 4.4).

Information is provided in Table 5.4-3 that describes high priority tasks (next steps), identified in 2007, which were intended to address critical data gaps. Slate, Slumber, Styx, Flume, Sullivan, Pocahontas, and Sweet creeks were all identified as priority areas with specific data gaps and stream segments where aquatic productivity could potentially be modified through human intervention. Of these creeks, only the data gaps for Flume Creek were not deemed necessary to fill through data collection tasks planned for 2008 because of the limited amount of current and potential habitat available and the extensive actions that would be necessary to potentially modify productivity.

Table 5.4-3. Critical data gaps identified in 2007.

Creek Name	Critical Data Gap
Slate Creek WAU	
Slate Creek	Between RM 0.0 and 0.75 is the only habitat available to bull trout in this watershed. There is a lack of information on the level of protection for this stream segment of Slate Creek.
Slumber Creek	The amount of quality habitat that would be available by removing the culvert at RM 0.2 is not known.
Styx Creek	Dimensions of the barrier listed in the Barrier Inventory for Boundary Reservoir tributaries (see Appendix 7) are not known. Specifically, the length of the culvert at RM 0.1 and the amount of quality habitat that would be available by removing the culvert is not known.
Sullivan Creek WAU	
Sullivan Creek	Between RM 0.0 and 0.66 is listed as critical habitat available to bull trout in this watershed. There is a lack of information on the level of protection for this stream segment of Sullivan Creek.
	Sources of coarse and fine sediment to the stream below Mill Pond and the geomorphic conditions affecting sediment storage and transport are poorly understood. The locations where sediment control or enhancement may be possible are not known.
Box Canyon WAU	
Pocahontas Creek	Dimensions of the barrier listed in the Barrier Inventory for Boundary Reservoir tributaries (see Appendix 7) are not known. The amount of quality habitat that would be available by removing the culvert is not known.
Sweet Creek	Between RM 0.0 and 0.5 is habitat available to bull trout in this watershed. In addition, bull trout have been observed using this area. There is a lack of information on the level of protection for this stream segment of Sweet Creek.
	Dimensions of the barrier listed in the Barrier Inventory for Boundary Reservoir tributaries (see Appendix 7) are not known. The amount of quality habitat that would be available by removing the culvert is not known. In addition, there is a data gap for channel conditions and dynamics and habitat elements between RM 0.0 and 0.6.

The tasks listed in Table 5.4-4 were undertaken in 2008 to address the data gaps identified in Table 5.4-3.

Table 5.4-4. Tasks identified in 2007 that were completed in 2008.

Stream Name and Task Location	2008 Tasks	Modification Benefit
Slate Creek WAU		
Slate Creek (PRM 26.9)		
RM 0.0 - 0.75	Evaluate the feasibility of protecting habitat in this segment of Slate Creek. • This is an office task. • Utilize phone calls, e-mails, documentation, Web sites, and GIS layers to determine property ownership, property tax value, existing USFS land designation (current forest plans), and applicable conservation easement/acquisition procedure.	Protection of critical habitat
Slumber Creek (RM 2.0)		
RM 0.2	Evaluate habitat in Slumber Creek upstream and downstream of the culvert to determine the extent of habitat that would be available under culvert modifications; evaluate potential culvert modifications. • This is a field task • Habitat assessment will entail surveying 150 to 500 m (492 to 1,640 feet) downstream and between 150 to 500 m (492 and 1,640 feet) upstream of the culvert by measuring the thalweg, slope, wetted width, LWD, substrate, and channel cover. • Culvert assessment will entail measuring the dimensions and slope of the barrier.	Potentially ≥ 1,584 feet of cutthroat habitat
Styx Creek (RM 4.9)		
RM 0.1	Evaluate habitat in Styx Creek upstream and downstream of the culvert to determine the extent of habitat that would be available under culvert modifications; evaluate potential culvert modifications. • This is a field task. • Habitat assessment will entail surveying 150 to 500 m (492 to 1,640 feet) downstream and 150 to 500 m (492 and 1,640 feet) upstream of the culvert by measuring the thalweg, slope, wetted width, LWD, substrate, and channel cover. • Culvert assessment will entail measuring the dimensions and slope of the barrier.	Potentially ≥ 10,032 feet of cutthroat habitat
Sullivan Creek WAU		
Sullivan Creek (PRM 26.9)		
RM 0.0 - 0.66	Evaluate the feasibility of protecting habitat in this segment of Sullivan Creek. • This is an office task. • Utilize phone calls, e-mails, documentation, Web sites, and GIS layers to determine property ownership, property tax value, existing USFS land designation (current forest plans), and conservation easement/acquisition procedure.	Protection of critical habitat

Table 5.4-4, continued…

Stream Name and Task Location	2008 Tasks	Modification Benefit
Sullivan Creek (PRM 26.9)		
RM 0.0 - 3.25	Evaluate the fluvial geomorphic conditions of Sullivan Creek downstream of Mill Pond and identify potential opportunities for sediment control or enhancement measures between RM 0.0 and 3.25. • Activities include both office and field tasks. • Perform a geomorphic field reconnaissance of Sullivan Creek downstream of Mill Pond to characterize the overall geomorphic condition and the key processes contributing to the current condition. Of particular emphasis will be the sediment balance and influence of the trapping of upstream sediments in Mill Pond as well as opportunities for potential sediment control or enhancement measures. • Characterize the dominant bed material size, representative bank materials, and the presence or absence of suitable spawning substrate in this segment of Sullivan Creek. Vertical and lateral geologic controls are to be identified. In addition, 6 to 10 pebble counts will be performed to characterize typical substrate conditions. No pebble counts are required in the tributary delta as this information has been collected as part of Study 8. • In support of the geomorphic field reconnaissance, a profile of Sullivan Creek from RM 0.00 to 3.25 will be developed from the best available topographic mapping and review of current and historical aerial photographs. • Results and conclusions will be documented from the geomorphic field reconnaissance, including the identification of potential opportunities for sediment control or enhancement measures and increased habitat complexity.	Improve sediment recruitment, storage and transport processes; increase habitat complexity
Sullivan Creek (PRM 26.9)		
RM 2.8 - 3.25	Evaluate locations where road segments can be relocated, obliterated, and/or reconstructed. • Activities include both office and field tasks. • Stream segments where road segments encroach on Sullivan Creek will be identified and documented through aerial photographs, available literature, phone calls, and field surveys. • Road segment measurements from field surveys will entail sideslope angle on both sides of the road segment, length of road segment encroaching on Sullivan Creek, and description of road type.	Improve sediment recruitment, storage and transport processes
Box Canyon WAU		
Pocahontas Creek (PRM 29.4)		
RM 0.34	Evaluate barrier dimensions and habitat upstream and downstream of the culvert to determine the extent of habitat that would be available under culvert modifications; evaluate potential culvert modifications. • This is a field task. • Habitat assessment will entail surveying 150 to 500 m (492 to 1,640 feet) downstream and 150 to 500 m (492 to 1,640 feet) upstream of the culvert by measuring the thalweg, slope, wetted width, LWD, substrate, and channel cover. • Culvert assessment will entail measuring the dimensions and slope of the barrier.	Provide upstream access to fish in Boundary Reservoir

Table 5.4-4, continued…

Stream Name and Task Location	2008 Tasks	Modification Benefit
Pocahontas Creek (PRM 29.4)		
RM 0.0 - 0.6	Evaluate habitat conditions and determine streambank conditions, focused on the stretch between RM 0.0 and approximately RM 0.6, to learn which, if any, modifications can be identified to improve habitat conditions. • This is a field task. • The entire length (RM 0.0 to 0.6) will be walked and observations on the creeks condition will be documented. • Habitat and streambank assessment will entail surveying 150 to 500 m (492 to 1,640 feet) of Pocahontas Creek collecting thalweg, slope, wetted width, LWD, substrate, channel cover, and stream bank measurements.	Information on habitat quality, accessibility, and stream bank conditions is unknown, therefore modification type and benefit are not known
Sweet Creek (PRM 30.9)		
RM 0.0 - 0.5	Evaluate the feasibility of protecting habitat in this segment of Sweet Creek. • This is an office task. • Utilize phone calls, e-mails, documentation, Web sites, and GIS layers to determine property ownership, property tax value, existing USFS land designation (current forest plans), and conservation easement/acquisition procedure.	Protection of critical habitat
Sweet Creek (PRM 30.9)		
RM 0.0 - 0.6	Evaluate channel conditions and dynamics between RM 0.0 and 0.6 to learn which, if any, modifications can be identified to improve habitat conditions. • This is a field task. • The entire length (RM 0.0 to 0.6) will be walked and observations on the creeks condition will be documented. • Streambank condition, floodplain connectivity, and channel stability measurements will entail surveying two cross-sections, each in a riffle.	Information on stream bank condition, floodplain connectivity, and channel stability is unknown, therefore modification type and benefit are not known
Sweet Creek (PRM 30.9)		
RM 0.5	Evaluate barrier dimensions and habitat in Sweet Creek upstream and downstream of the culvert to determine the extent of habitat that would be available under culvert modifications; evaluate potential culvert modifications. • This is a field task. • Habitat assessment will entail surveying 150 to 500 m (492 to 1,640 feet) downstream and 150 to 500 m (492 to 1,640 feet) upstream of the culvert by measuring the thalweg, slope, wetted width, LWD, substrate, and channel cover. • Culvert assessment will entail measuring the dimensions and slope of the barrier.	Provide upstream access to fish in Boundary Reservoir

5.5. 2008 Tasks to Fill Critical Data Gaps and Identify Protection and Enhancement Opportunities Results

This section provides a brief overview of the tasks identified in Table 5.4-4, specific field results from the field tasks for each creek, specific enhancement opportunities, and results from the habitat protection assessment.

5.5.1. Overview of Field Tasks for Each Creek

As described in Section 4.5 and Table 5.4-4, six tributary creeks were surveyed in 2008, in general to evaluate culverts, fish habitat, and fluvial geomorphic conditions within the creeks. In addition, a road survey was also conducted along portions of Sullivan Creek. These survey activities were done to fill critical data gaps, update the draft LFM, and identify and rank any enhancement opportunities.

The following sections include the results of the 2008 field efforts and consist of a description of survey results, photographs, relevant maps, and an overview of conditions determined from the survey activities. Complete results from the 2008 surveys, including culvert dimensions, stream habitat conditions, fluvial geomorphic conditions, and road status (depending on the specific site), are presented in Appendix 11. In addition, based on the results from the surveys of culverts in Slumber, Styx, Linton, Pocahontas, and Sweet creeks in 2008, Appendix 7 (Barrier Inventory for Boundary Reservoir Tributaries) was updated and is provided as Appendix 12. A summary data table (Appendix 13) was developed for each creek from the 2008 field survey results (Appendix 11). These summary data tables (Appendix 13) for each creek were developed and used to finalize the LFM.

5.5.2. Results from Specific Field Tasks for Each Creek

5.5.2.1. Slumber Creek (Tributary to Slate Creek)

The culvert located at tributary RM 0.20 and aquatic conditions upstream and downstream of the culvert were surveyed as part of the 2008 field activities (Figures 5.5-1 and 5.5-2). Based on the WDFW (2001) Level B assessment, the culvert was determined to be a barrier to fish passage because it does not satisfy the Washington Administrative Code (WAC) criteria (Appendix 11).

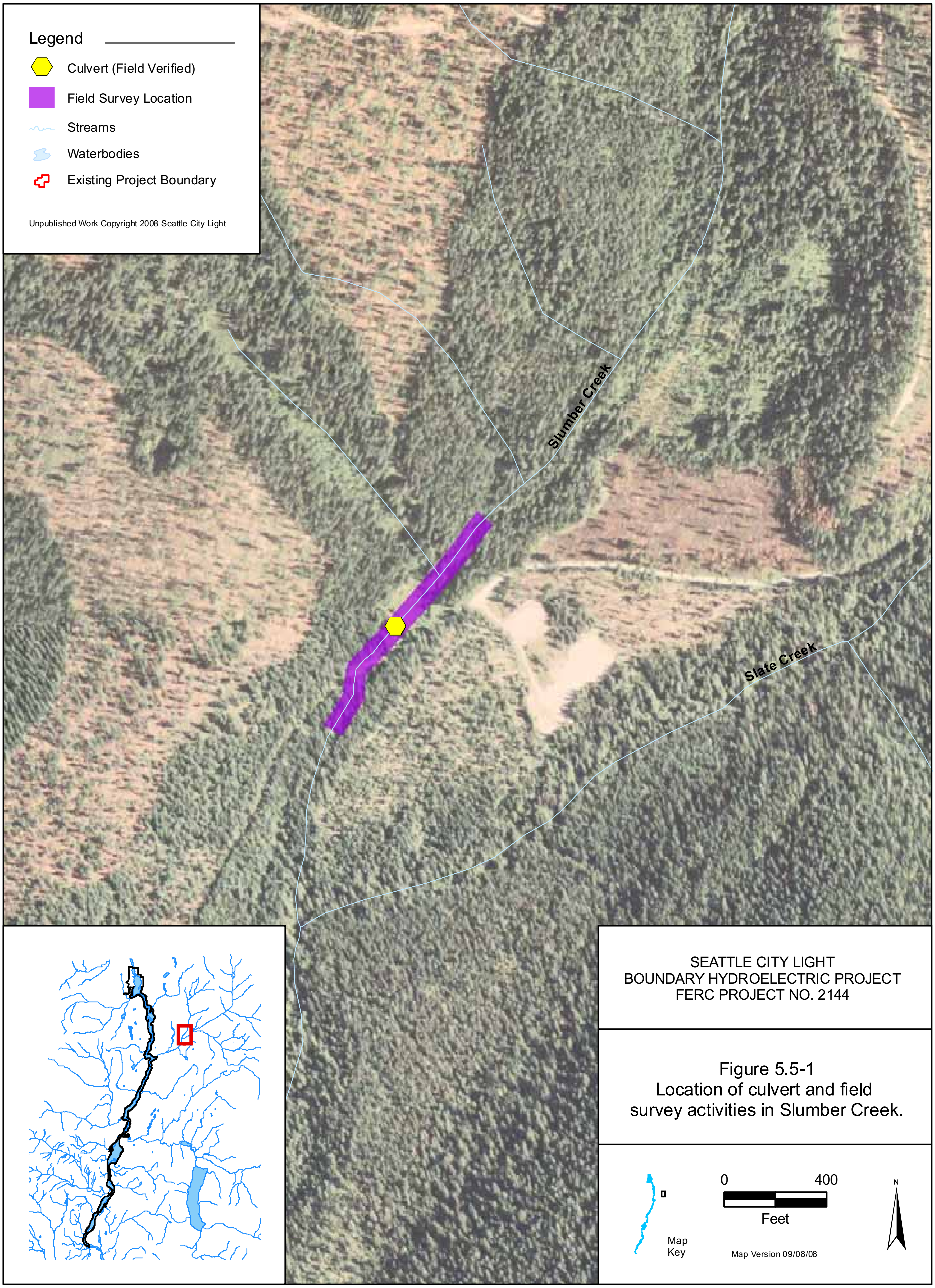

Figure 5.5-1
Location of culvert and field survey activities in Slumber Creek.

Figure 5.5-2. Culvert located on Slumber Creek at RM 0.34.

The survey results demonstrate that the habitat located upstream of the culvert is slightly more suitable fish habitat than that found downstream because the mean residual pool depth, mean thalweg depth, and volume of LWD were all greater upstream than downstream. Most notably, the volume of LWD downstream of the culvert was lower than the quantity upstream (Figure 5.5-3). Although the condition of the riparian corridor was slightly better downstream, the difference between upstream and downstream was fairly small and not enough to affect the overall assessment.

Figure 5.5-3. LWD found in upstream portion of survey reach on Slumber Creek.

Based on the survey, the channel substrate was found to be not properly functioning, mainly due to substrate embeddedness greater than 50 percent both upstream and downstream of the culvert. The median particle size (D50) upstream and downstream of the culvert was fine gravel, measured at 8 millimeters (mm) during a single Wolman pebble count conducted in a riffle downstream of the culvert. Substrate within the sampled riffle consisted of predominantly fine gravel, with some sand, cobble, and silt. The percentages of fine material and bank erosion were higher downstream than upstream, whereas substrate embeddedness was greater upstream of the culvert. In addition, channel stability within Slumber Creek was considered to be good.

Based on the survey results presented in Appendix 11 and summarized in Appendix 13, replacement of the culvert would benefit resident fish species by providing access to 0.5 kilometer (0.3 mile) of suitable habitat upstream of the culvert. Additional benefit may be gained by the installation of LWD in the downstream portion of the creek. Overall, replacement of this culvert is considered only medium in rank compared to other enhancement opportunities.

5.5.2.2. Styx Creek (Tributary to Slate Creek)

The culvert located at tributary RM 0.10 and aquatic conditions upstream and downstream of the culvert were surveyed as part of the 2008 field activities (Figures 5.5-4 and 5.5-5). Based on the WDFW (2001) Level B assessment, the culvert was determined to be a barrier to fish passage because the culvert does not satisfy the WAC criteria (Appendix 11).

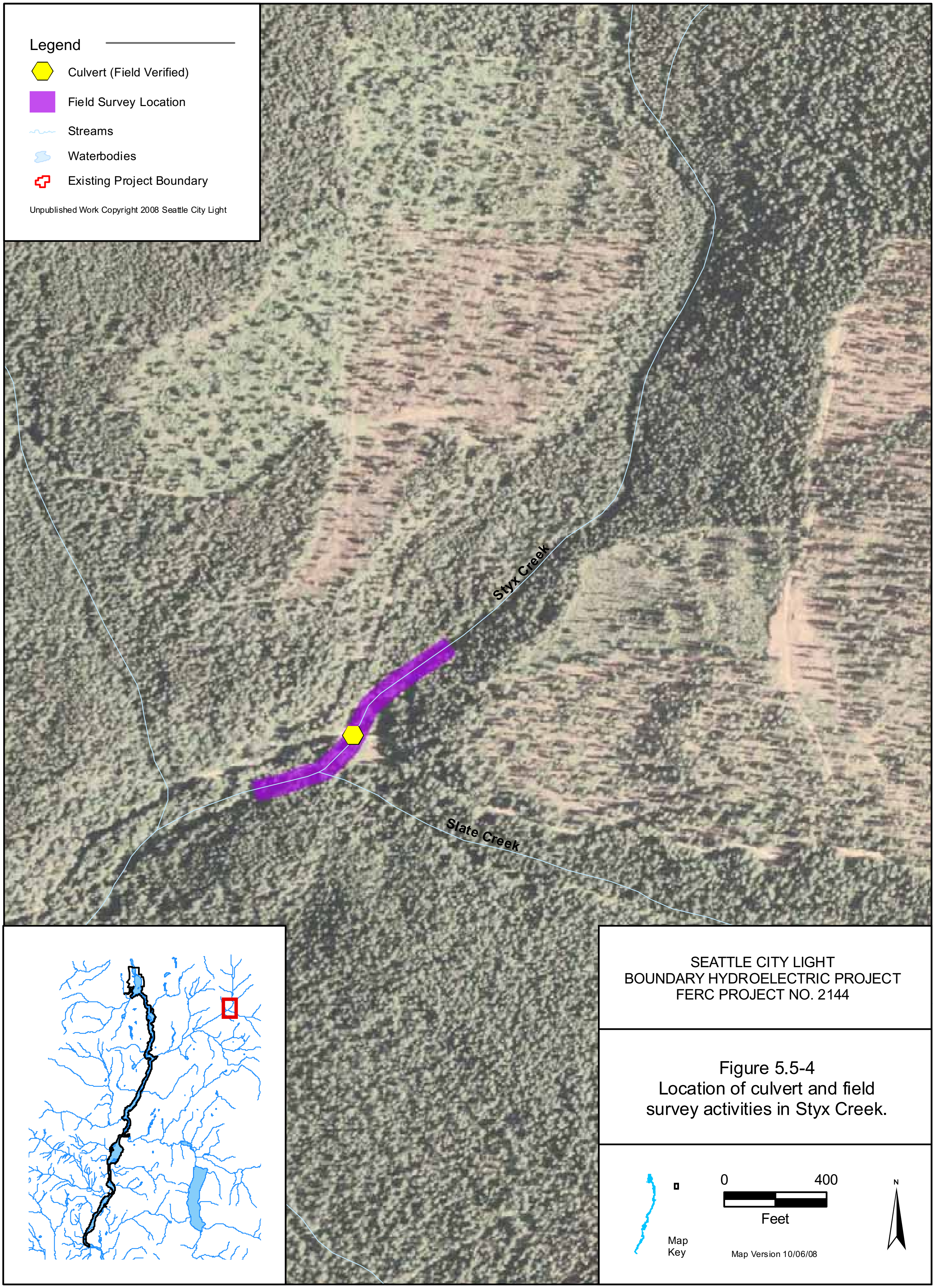

Figure 5.5-4
Location of culvert and field survey activities in Styx Creek.

Figure 5.5-5. Culvert located at RM 0.10 on Styx Creek.

The data from the survey suggest that habitat conditions downstream of the culvert may provide greater channel complexity and water depth than in the upstream section. Riffle comprised most of the habitat both downstream and upstream of the culvert. However, mean residual pool depth, mean thalweg depth, volume of LWD, and riparian structure and cover were all found to be greater downstream of the culvert than upstream. Notably, the LWD in Styx Creek was determined to be 161 pieces per mile, which far exceeds the >20 pieces per mile necessary to classify the LWD in this stream as properly functioning (Figure 5.5-6).

Figure 5.5-6. LWD found in Styx Creek.

The channel substrate within Styx Creek was found to be properly functioning due to the small levels of embeddedness and fine material (Figure 5.5-7). However, the percentages of fine material and bank erosion were found to be greater in the downstream section of Styx Creek. Both the D50 and substrate embeddedness were found to be fairly similar downstream and upstream of the culvert, whereas the average bank angle was found to be lower in the downstream section than in the upstream section. Based on a Wolman pebble count conducted in a riffle downstream of the culvert, substrate within the sampled riffle was predominantly gravel (D50 of 31 mm), with cobbles and sand. However, the channel stability was considered to be fair.

Figure 5.5-7. Channel substrate downstream of the culvert in Styx Creek (photograph taken near confluence with Slate Creek).

Overall, the habitat evaluation of Styx Creek suggests that replacement of the culvert would be beneficial for providing fish passage to approximately 3.1 kilometers (1.9 miles) of stream. However, the habitat above the culvert is fairly similar in quality to that below the culvert; as such, replacement of this culvert is considered only medium in rank compared to other enhancement opportunities.

5.5.2.3. Sullivan Creek

This section presents a summary of the results from the surveys conducted on and near Sullivan Creek, including the road survey, as described earlier in Section 4.5.2.3.

5.5.2.3.1. Fluvial Geomorphic Field Survey

Several factors have affected the geomorphic conditions throughout the Sullivan Creek watershed. Three reaches were surveyed downstream of Mill Pond Dam to characterize these conditions and to provide information for potential habitat enhancement projects. To further assist in this effort, reaches upstream of Mill Pond Dam in Sullivan Creek and Outlet Creek were also surveyed (reaches 4, 5, and 6). The details of the geomorphic conditions are presented in Appendix 11.

In the region downstream of Mill Pond, these factors include partial confinement of the creek by Sullivan Lake Road, altered sediment transport processes, altered hydrology due to the release of water from Sullivan Lake Dam, channel straightening activities, and removal and lack of LWD. These factors have resulted in predominantly plane-bed morphology through most reaches downstream of Mill Pond Dam (Figure 5.5-8).

Upstream of Mill Pond Dam, channel-reaches in Sullivan Creek also exhibit plane-bed morphology (Figure 5.5-9) due to channel straightening activities and removal and lack of LWD (see Appendix 11). The locations of the surveyed reaches, upstream and downstream of Mill Pond Dam, are illustrated in Figures 5.5-10 and 5.5-11.

Figure 5.5-8. Typical plane-bed morphology in Sullivan Creek downstream of Mill Pond Dam.

Figure 5.5-9. Typical plane-bed morphology in Sullivan Creek upstream of Mill Pond Dam.

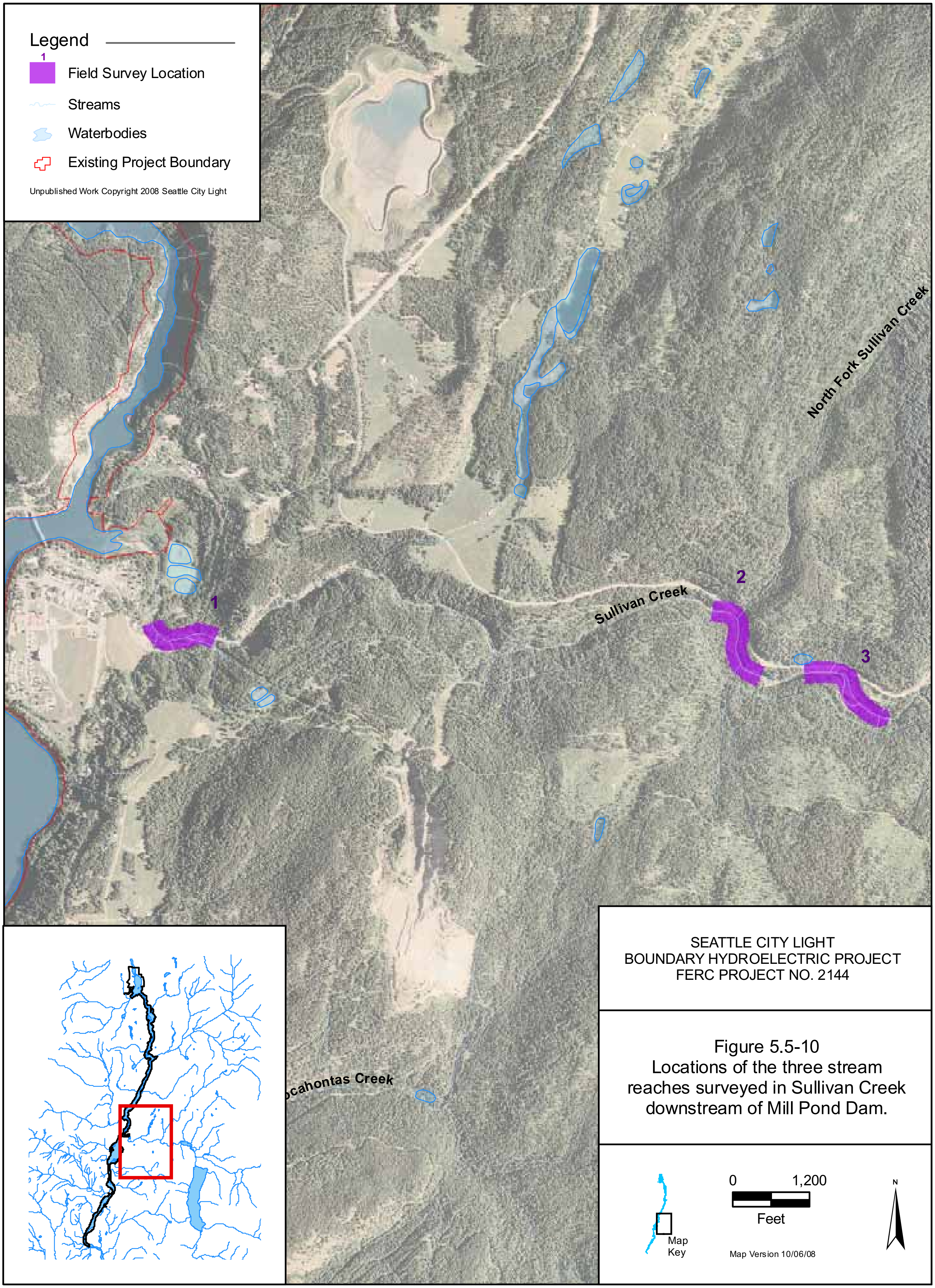

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Figure 5.5-10
Locations of the three stream reaches surveyed in Sullivan Creek downstream of Mill Pond Dam.

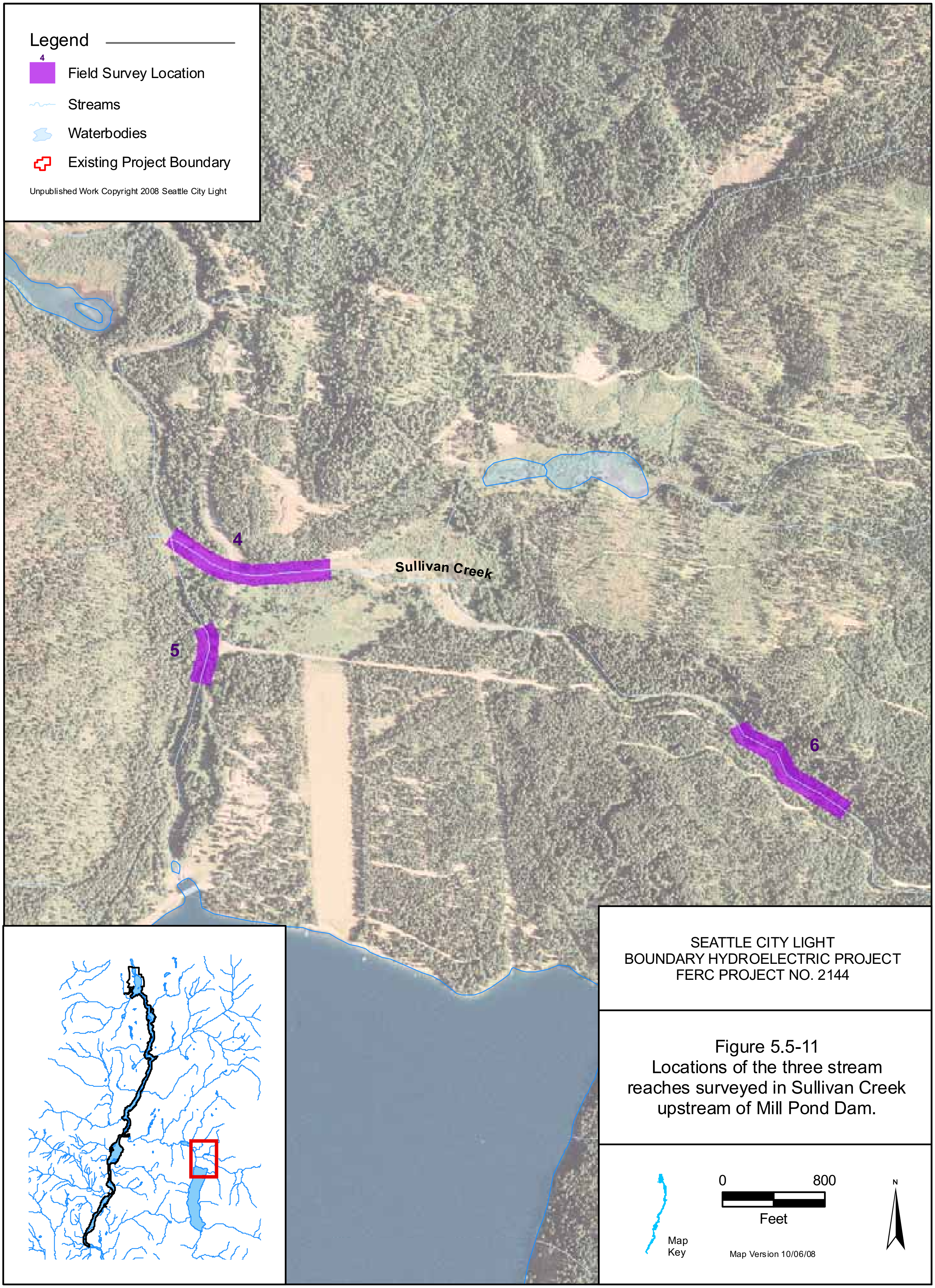

Figure 5.5-11
Locations of the three stream reaches surveyed in Sullivan Creek upstream of Mill Pond Dam.

5.5.2.3.2. Field Survey Results from Downstream of Mill Pond Dam

Channel conditions were fairly similar among the three reaches. The reaches exhibited similar slope (average 1.5 to 2.6 percent), bankfull width (average 19.3 m [63.3 feet] to 21.5 m [70.5 feet]), substrate size (D50 for reaches 1, 2, and 3 were 77, 140, and 180 mm, respectively) and composition (typically cobble), and bed form (plane). Various past and current human activities have affected the conditions of the channel. In reach 1, the stream morphology has been influenced by suction dredge mining, the Highway 31 Bridge, the powerhouse (Figure 5.5-12), and riprap placed along the left bank in portions downstream from the Highway 31 Bridge. The stream morphology in reaches 2 and 3 has been influenced by the location of Sullivan Lake Road and riprap placed in the creek along portions of these road segments. In addition, the historic removal (USFS 1996) and current lack of LWD has contributed to current channel-reach conditions.

Figure 5.5-12. Sullivan Creek near the powerhouse.

These reaches predominantly comprised plane-bed morphology with armored beds, where riffles and rapids were dominant. Pools were rare throughout the reaches, and limited side channels were present in reaches 2 and 3. LWD was also infrequent, with the exception of a log jam in reach 3 (Figure 5.5-13) and few additional log jams between reaches 2 and 3. Overall altered sediment transport processes, channel straightening activities, the location of Sullivan Lake Road, and removal of LWD have resulted in primarily poor fish habitat in Sullivan Creek. However, if complexity and forcing elements (e.g., LWD and boulders) were added to these reaches, forced pool-riffle morphology would probably exist which is more likely the appropriate geomorphic state.

Figure 5.5-13. Log jam present in reach 3, with left bank terrace behind log jam.

Riparian conditions consisted of young (< 40 years) to moderate age (40–80 years) trees of mixed or coniferous forest along the banks of these reaches. However, stretches within these reaches lack vegetation (Figure 5.5-14) and may benefit from plantings (Appendix 11). Some road erosion in reach 3 (see Section 5.5.2.3.5, Sullivan Lake Road Survey) may benefit from riparian vegetation and channel roughening elements that would promote the development of a riparian bench. In addition, placement of structures (e.g. LWD, engineered log jams [ELJs], boulders) along portions of the road in reach 3 may aid in encouraging channel migration toward a left bank terrace that is present, dissipating flood-flow energy, and enhancing the complexity of the channel in this reach.

Figure 5.5-14. Stream and riparian conditions in reach 1.

Overall, habitat conditions in all three reaches were generally fair to poor for certain fish life stages (see Appendix 11). Depending on the reach, this included limited pool rearing habitat, limited spawning gravel or potential gravel scour, minimal overwinter off-channel habitat, and migration barriers. Enhancement opportunities to improve these habitat conditions are present in each of these reaches. The aquatic habitat conditions in reach 1 could be addressed for approximately 0.5 km (0.3 mile) through riparian plantings, increasing structural complexity, and bank enhancement techniques. Also, adding access to a wetland between reach 2 and 3 may enhance overwinter habitat (see Section 5.5.2.3.5). Reaches 2 and 3 provide an opportunity to address factors limiting aquatic productivity in approximately 1.4 km (0.9 mile) of Sullivan Creek through additions of LWD, ELJs, boulders, and riparian plantings. Overall, enhancement in reaches 1, 2, and 3 would be high in rank compared to other enhancement opportunities.

5.5.2.3.3. Field Survey Results from Upstream of Mill Pond in the Mainstem Sullivan Creek

Generally, habitat conditions in the two reaches (4 and 6) surveyed above Mill Pond Dam were similar to the lower three reaches. The mean slope was also moderate (average 1.2 and 1.5 percent), bankfull widths were slightly less than downstream areas, bankfull depths were greater than reach 3 but similar to reaches 1 and 2, with wetted depth also similar to the lower reaches. Substrate was also similar being cobble dominated. Similar to downstream, channel-reach morphology was primarily plane-bed. Although portions of reach 4 had pool-riffle morphology, the majority of areas were dominated with riffle and rapid habitat. Also similar to the lower reaches, pool habitat was very limited, except where LWD naturally accumulated or had been placed for habitat enhancement (Figure 5.5-15) in portions of reach 4. The occurrence of LWD in reach 4 resulted in both the accumulation of potential spawning gravels and pool formation in proximity to the woody debris. Only one pool was present in reach 6.

Figure 5.5-15. Scour pool resulting from placed LWD in reach 4.

LWD sources were somewhat limited in reaches 4 and 6. The riparian conditions were a mix of young (<40 years) mixed vegetation with a few mature (40–80 years) patches. Upstream sources of woody material were limited because of the presence of Sullivan Dam (for reach 4) and a large log jam retaining LWD upstream of reach 6.

Generally, the overall habitat for specific fish life stages was mostly fair in the reaches, except for good overwintering habitat in reach 4 from side-channel habitat. The limited pool habitat and retention of gravel limited both rearing and spawning. Overall, the habitat conditions were similar to the lower three reaches due primarily to the lack of structure and complexity within these reaches.

5.5.2.3.4. Field Survey Results from Outlet Creek

Outlet Creek (reach 5) was surveyed to characterize other channel conditions in the Sullivan watershed outside of the mainstem channel. Habitat conditions in this smaller channel-reach were generally better than the mainstem conditions. Slope was generally low (range 0.4 to 0.75 percent), with substrate primarily consisting of coarse gravel. However, a greater amount of fines was present in the substrate than in the other reaches measured. Unlike other measured reaches which had few pools, this reach was predominantly pool-riffle morphology. Pools had been formed by past LWD enhancement measures (Figure 5.5-16). Riparian vegetation was primarily young (<40 years) mixed vegetation throughout the reach with similar conditions on both banks. Overall, fish habitat conditions for most life stages were generally fair, including overwintering due to some off-channel habitat, spawning from suitable gravel, and rearing due to the presence of pools. However, high spring flows may scour spawning gravels (e.g., redds) and the presence of Sullivan Lake Dam prevents upstream fish migration.

Figure 5.5-16. Placed LWD in Outlet Creek.

5.5.2.3.5. Sullivan Lake Road Survey

Five road segments were surveyed along Sullivan Lake Road (Table 5.5-1 and Figure 5.5-17) to determine the hydrologic connectivity between the road and Sullivan Creek, the potential effects these segments have on fish habitat and fluvial geomorphic conditions, and the potential for enhancement opportunities that would address locations where the road may be adversely affecting the stream. The details of the road survey are presented in Appendix 11.

No major road issues were determined for any of the segments in the survey. However, some locations had oversteepened fill, sidecasts that were cracked or eroding, and the potential to deliver small amounts of fine sediment and runoff directly to Sullivan Creek. Only segments 3 and 4 are directly connected to Sullivan Creek and may have the greatest effects on habitat conditions in Sullivan Creek.

Table 5.5-1. Distance of road segments surveyed on Sullivan Lake Road.

Road Segment Survey	Approximate Road Mile	Distance
Segment 1	16.1 – 16.0	131.5 m (431.4 ft)
Segment 2	16.0 – 15.8	246.5 m (808.7 ft)
Segment 3	15.8 – 15.6	196.5 m (644.7 ft)
Segment 4	15.6 – 15.1	692.0 m (2270.3 ft)
Segment 5	15.1 – 14.9	193.1 m (633.6 ft)

Segments 3 and 4 are directly connected to the stream for about 318 feet and 260 feet, respectively (Figure 5.5-18). Some riprap has been placed along segment 3 adjacent to the stream to reduce erosion; however, some vegetation is present along the lower portion of the road and stream bank in segment 3. The North Fork Sullivan Creek culvert is within segment 3 (Figure 5.5-19). The culvert is impassable to fish; however, there is a genetically distinct stock of cutthroat trout in this tributary that is separate from other fish in the Sullivan drainage, so this culvert should not be replaced. In segment 4, a wetland is directly connected by a culvert to Sullivan Creek; however, this culvert may not be passable for fish. Replacing this culvert is a low priority because of limited habitat benefits. Habitat conditions along segments 3 and 4 could be improved by decreasing the bank angle and the addition of large boulders and LWD to deflect water, decrease bank erosion, provide some structural complexity, and promote additional growth in the road-side riparian area.

Overall, the steep canyon wall restricts movement of the road away from the stream. In segments 1, 2, and 5 only a few small portions of road in each segment contain sidecasts that were cracked or eroding that could potentially influence the stream below. Road segments 3 and 4 are hydrologically connected to Sullivan Creek and have some potential for habitat enhancement along the connected portion of the stream channel (Appendix 11). Overall, enhancement along road segments 3 and 4 would be high in rank compared to other enhancement opportunities.

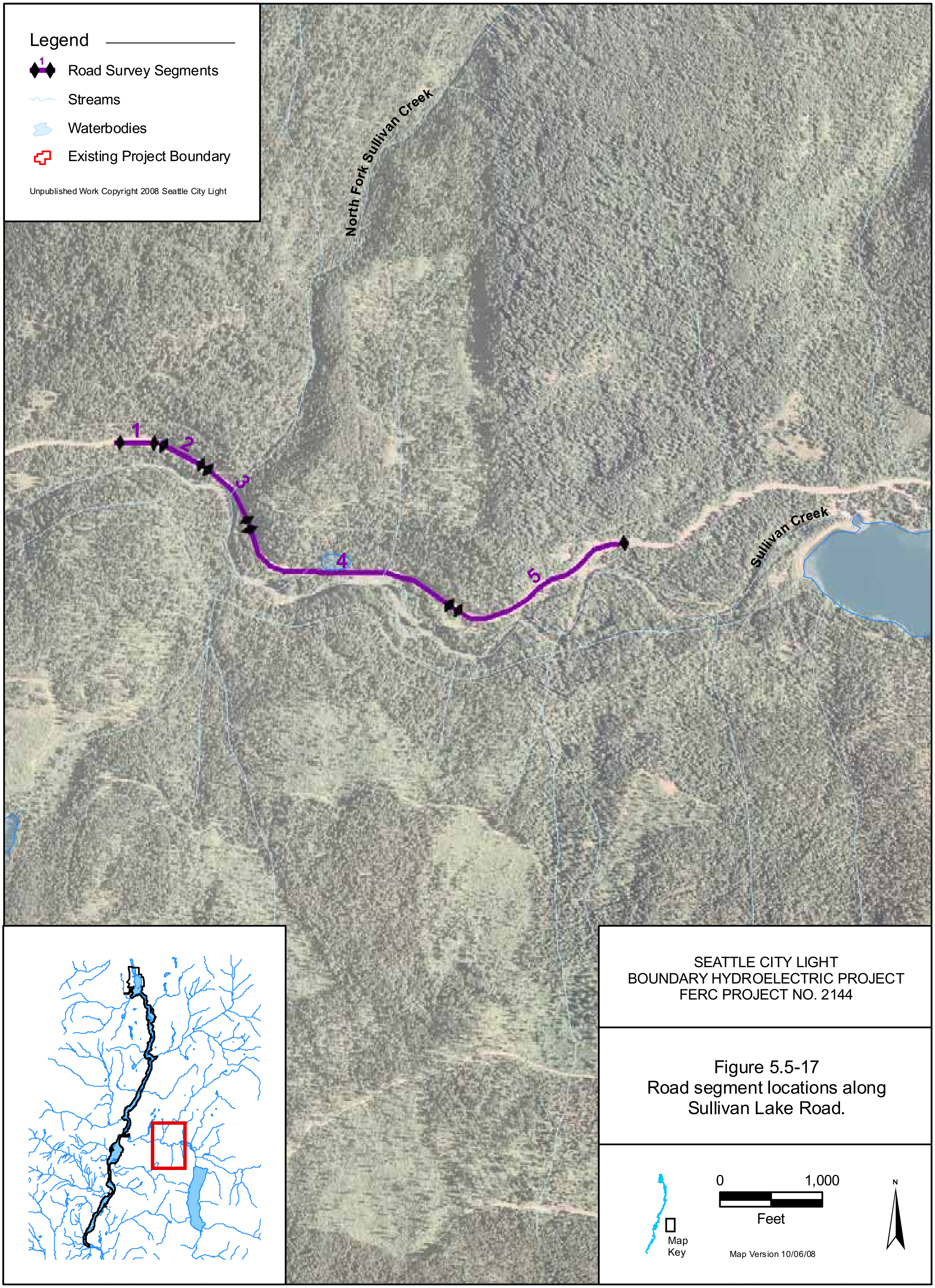

Figure 5.5-17
Road segment locations along Sullivan Lake Road.

Figure 5.5-18. Hydrologic connectivity and riprap along Sullivan Lake Road in Segment 4.

Figure 5.5-19. North Fork of Sullivan Creek culvert at confluence with Sullivan Creek.

5.5.2.4. Linton Creek

Three culverts located on Linton Creek between tributary RM 0.0 and 0.25, and aquatic conditions upstream and downstream of them, were surveyed as part of the field activities (Figures 5.5-20 through 5.5-23). The available information reviewed during 2007 suggested that only three culverts were present between Highway 31 (RM 0.25) and the mouth of Linton Creek (RM 0.0). However, during the survey of Linton Creek, an additional culvert was found immediately downstream from the Highway 31 culvert at RM 0.24. Because time was only available to survey three culverts, it was decided not to survey the Highway 31 culvert, only the three culverts downstream from it (Figure 5.5-20).

The WDFW (2001) Level B assessment revealed that culverts 1.1 and 1.3, located at RM 0.18 and 0.24, respectively, were barriers to fish passage because they do not satisfy the WAC criteria (Appendix 11). The culvert located at RM 0.21 (culvert 1.2) was only evaluated with the Level A Barrier Analysis criteria due to the presence of natural streambed material throughout the culvert. Based on these criteria, culvert 1.2 is not considered a complete barrier to fish passage. However, at the time of the survey, the culvert was nearly filled with debris that may limit some juvenile fish passage.

The survey results demonstrate that the habitat predominantly comprised low gradient riffles (Figures 5.5-24 and 5.5-25), with an average channel slope of 2 percent. Riparian conditions within the survey reach were found to be poor. Stream bank conditions were determined to be fair, whereas LWD within the reach was poor, based on the number of pieces per mile and potential recruitment sources. Pool depth and pool frequency were found to be not properly functioning, but off-channel habitat was classified as fair, due to a wetland connected to Linton Creek upstream from culvert 1.2.

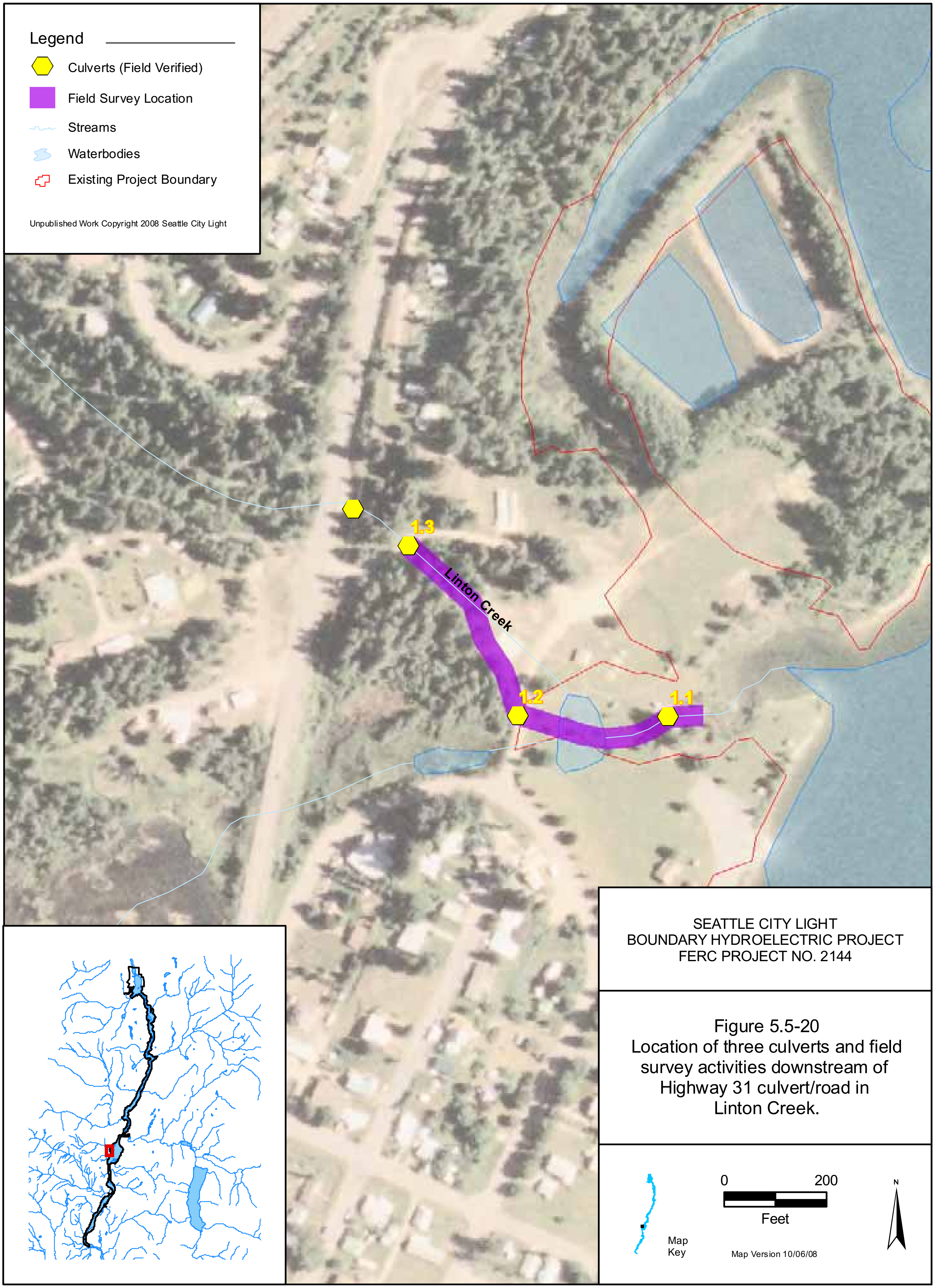

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Figure 5.5-20
Location of three culverts and field survey activities downstream of Highway 31 culvert/road in Linton Creek.

Figure 5.5-21. Outfall of culvert 1.1.

Figure 5.5-22. Outfall of culvert 1.2.

Figure 5.5-23. Outfall of culvert 1.3.

Figure 5.5-24. Stream conditions within lower section of Linton Creek.

Figure 5.5-25. Stream conditions within Linton Creek downstream of culvert 1.3.

The channel substrate condition was found to be fair due to the level of embeddedness and fine material observed. The substrate within the surveyed portion of Linton Creek had a D50 of 18 mm (coarse gravel) and the percentage of fines and embeddedness were both found to be 20 percent (Appendices 11 and 13). However, channel stability was determined to be good and properly functioning, with the exception of an artificial berm downstream of culvert 1.3 on the left bank that prevented any potential channel migration.

To further evaluate the geomorphic and aquatic conditions between each of the three culverts, a longitudinal survey was conducted immediately downstream from each culvert (see Appendix 11). Data collected during those surveys documented that immediately downstream of each culvert is a small pool (plunge pool), transitioning immediately into riffle habitat. The data collected within Linton Creek suggest that fish habitat within the creek was generally poor. Replacement of culvert 1.1 would provide fish passage to habitat upstream; however, the habitat is not of high quality. If passage were provided, additional habitat benefits may be gained by also placing LWD within the creek, planting riparian vegetation, and/or reconstructing the channel. Overall, replacement of the culverts would be low in rank compared to other enhancement opportunities.

5.5.2.5. Pocahontas Creek

Two culverts located at tributary RM 0.34 and aquatic conditions upstream and downstream of the culverts were surveyed as part of the field activities (Figures 5.5-26 and 5.5-27).

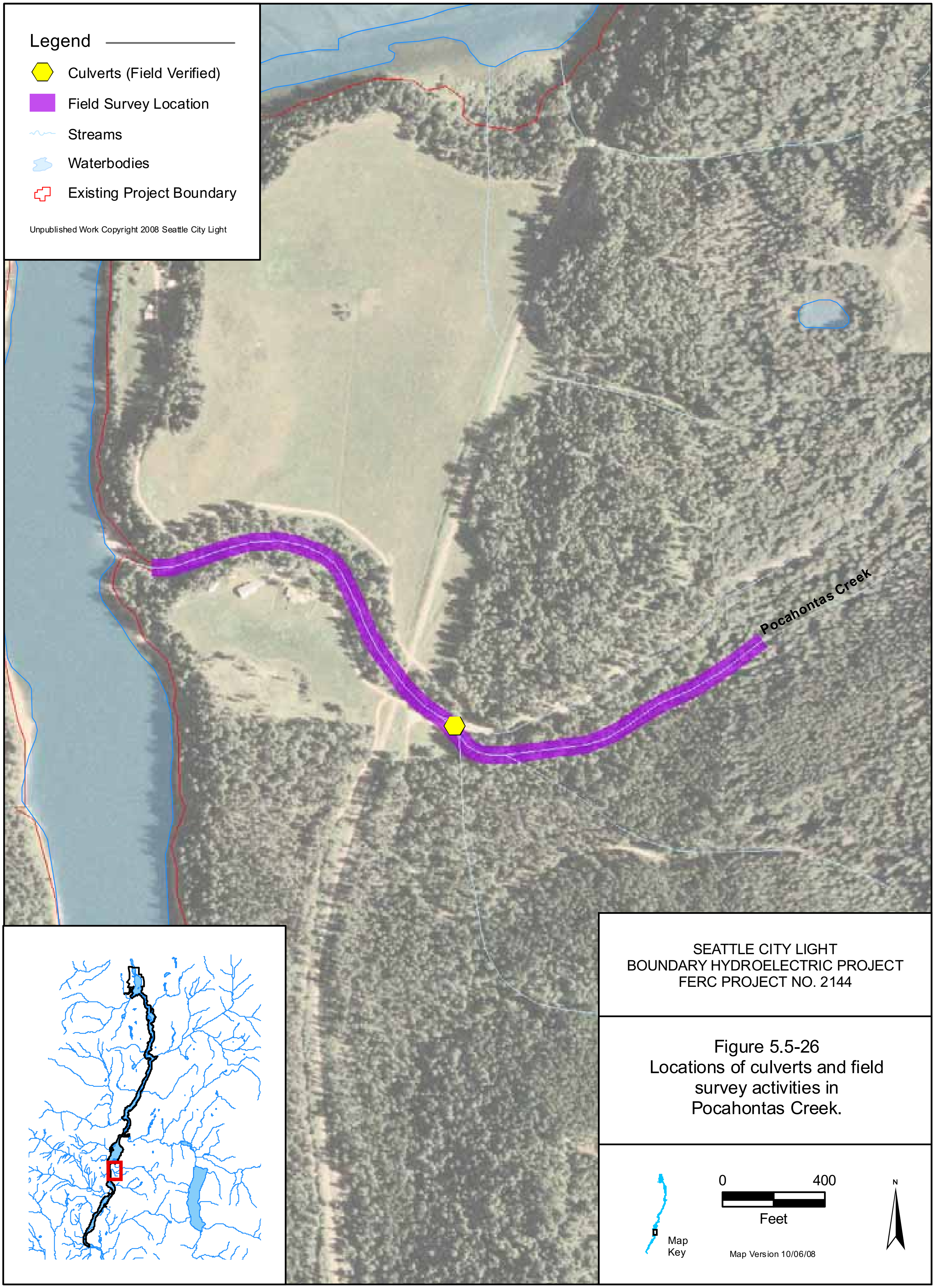

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Figure 5.5-26
Locations of culverts and field survey activities in Pocahontas Creek.

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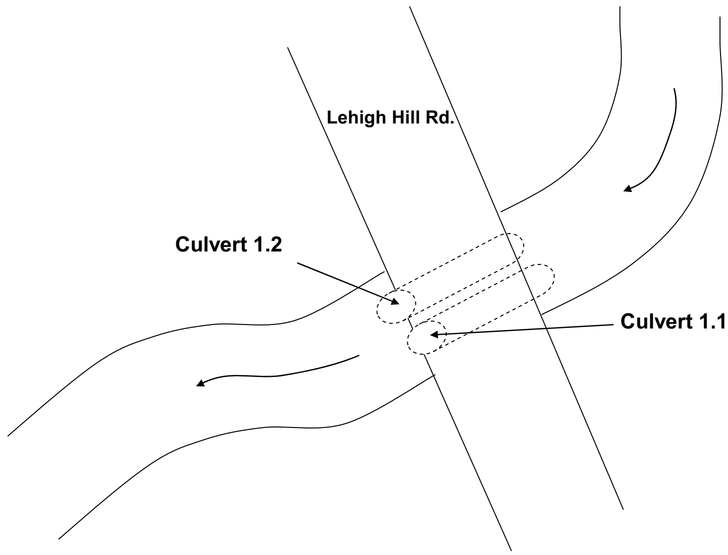

Figure 5.5-27. Locations of culverts 1.1 and 1.2 at Lehigh Hill Road crossing of Pocahontas Creek (RM 0.34).

Based on the WDFW (2001) Level B assessment, the two culverts were determined to be barriers to fish passage because they do not satisfy the WAC criteria (Appendix 11). In addition, at the time of the survey, both culverts were filled with LWD that appeared to further prevent upstream fish passage (Figure 5.5-28).

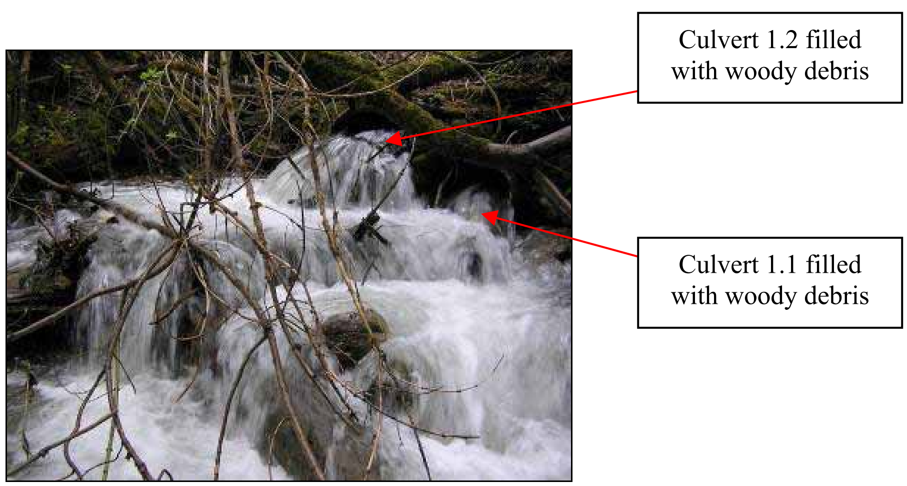

Figure 5.5-28. Pocahontas culverts 1.1 and 1.2 filled with LWD.

Downstream of the two culverts, a falls and a series of step pools were encountered (Figure 5.5-29). A second falls was located upstream of the culverts.

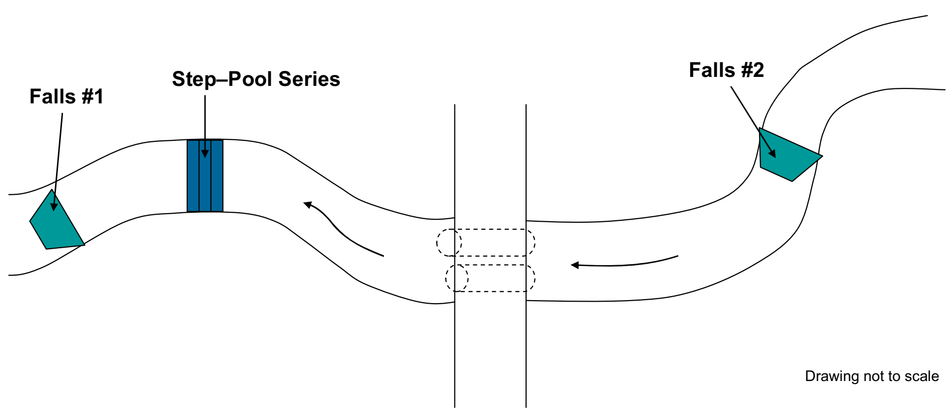

Figure 5.5-29. Location of falls and step pools in Pocahontas Creek.

The downstream falls (Falls #1) (Figure 5.5-30) is not likely a complete fish passage barrier as conditions along the creek margins may facilitate in fish passage under some flows. At high flows, however, the falls may be considered a velocity barrier to certain species and life stages of fish. During the summer months when water levels drop and Pocahontas Creek becomes partially or completely dry, the falls would be considered a barrier to fish passage due to lack of plunge pool depth and/or no water present in the channel. The plunge pool below the falls is small and shallow and appears to flow at a high velocity during high flow events. As a result, it is not likely to provide sufficient juvenile fish passage at high and low flows.

Figure 5.5-30. First falls (Falls #1) encountered in Pocahontas Creek downstream of the culverts.

The step pools encountered downstream of the two culverts and upstream of the first falls includes a series of three steps and pools (Figure 5.5-31). These step pools are not likely a complete fish passage barrier because conditions along the creek margins may facilitate in fish passage under some flows. However, at high flows, the velocity within the step-pool series may serve as a partial barrier to certain species and life stages of fish. All of the pool depths are fairly shallow, ranging from 0.34 to 0.39 m (1.12 to 1.28 feet) at high flows; therefore, reduced flows during the summer months likely result in too little water to allow fish passage above the step-pool series.

Figure 5.5-31. Step-pool series encountered in Pocahontas Creek downstream of the culverts.

A second falls is located upstream from the two culverts (Figure 5.5-32). At 1.2 m (3.9 feet) in height, this falls is not likely a complete fish passage barrier because conditions along the creek margins may facilitate in fish passage under some flows.. During high flows, the falls may be a partial fish passage barrier to certain species and life stages of fish due to high velocity. Similar to the previously described step-pool series and falls (Falls #1), low summer flows may result in a partial fish passage barrier due to low or no plunge pool depth.

Figure 5.5-32. Second falls (Falls #2) encountered in Pocahontas Creek upstream of the culverts.

The survey results demonstrate that upstream and downstream of the two culverts the dominant habitat type was rapids. Mean water surface slope was nearly the same upstream and downstream of the two culverts, at approximately 6 percent. Mean residual pool depth and mean thalweg depth were found to be greater downstream than upstream, but the volume of LWD and streambank cover were greater upstream than downstream. Mean wetted width and three-layer riparian vegetation presence were slightly greater upstream than downstream.

The channel substrate within Pocahontas Creek was found to not be properly functioning. The D50 was slightly greater upstream than downstream. Based on a Wolman pebble count conducted downstream, substrate within the sampled riffle consisted of predominantly gravel (D50 of 8.6 mm), with some boulders, cobbles, and sand. Channel stability within Pocahontas Creek was determined to be fair and may be limiting due to the culverts influence on the stream channel width to depth ratio.

The results of the habitat survey suggest that although there are some differences in specific habitat features between the areas upstream and downstream of the culverts, moderate to high gradient rapids are generally found throughout Pocahontas Creek. Foraging and resting areas are minimal within both sections of the stream, and appropriately sized spawning gravel is lacking in many areas. Therefore, the habitat evaluation of Pocahontas Creek suggests that replacement of the two culverts would be low in rank compared to other enhancement opportunities because it would provide minimal benefit to fish when compared to other tributary habitats in the region.

5.5.2.6. Sweet Creek

The culvert located at tributary RM 0.50 and aquatic conditions upstream and downstream of the culvert was surveyed as part of the field activities (Figure 5.5-33 and 5.5-34). Based on the WDFW (2001) Level B assessment, the culvert was determined to be a barrier to fish passage because the culvert does not satisfy the WAC criteria (Appendix 11).

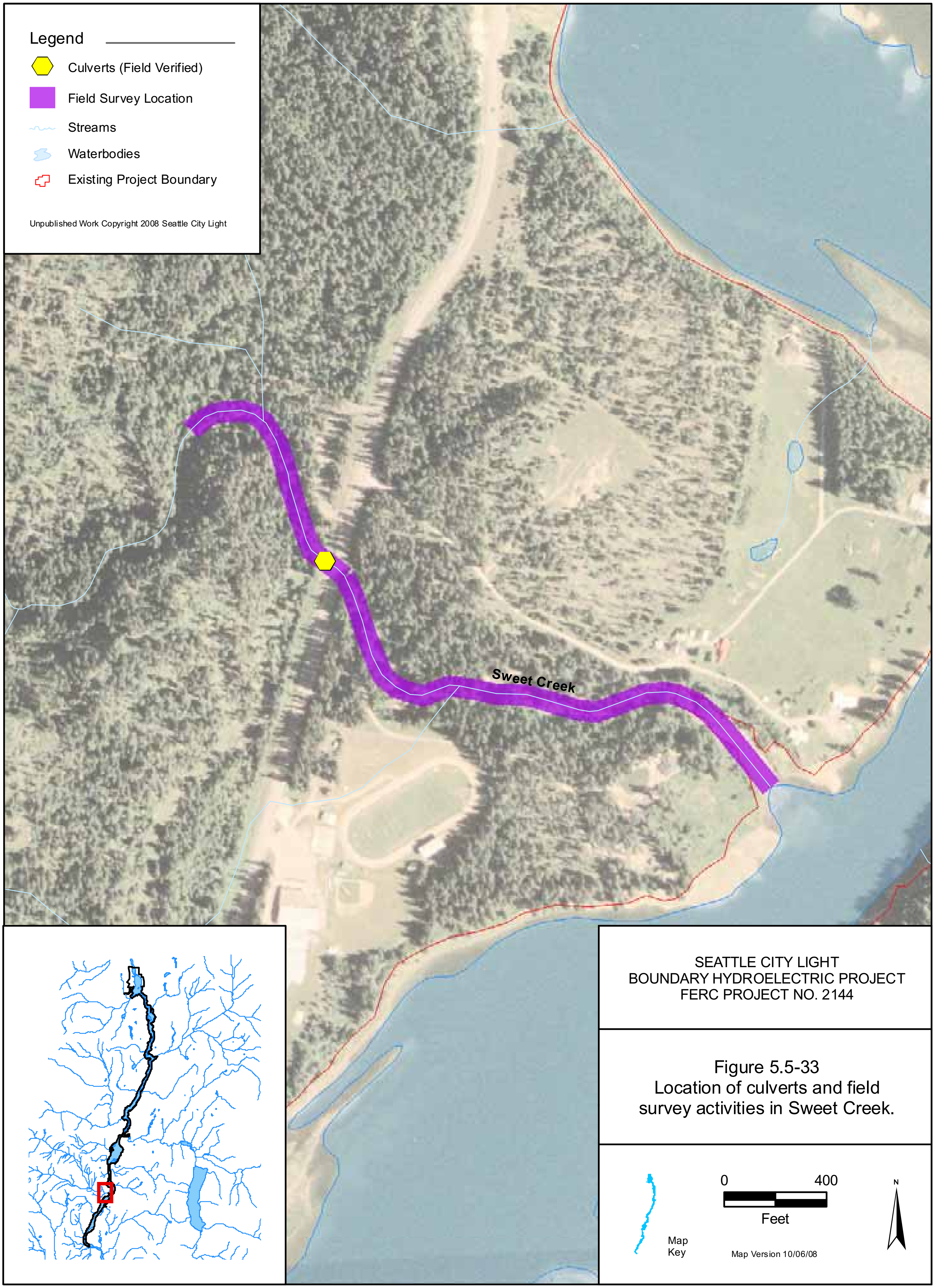

Figure 5.5-33
Location of culverts and field survey activities in Sweet Creek.

Figure 5.5-34. Culvert located at RM 0.50 on Sweet Creek under Highway 31.

Habitat throughout the surveyed portion of Sweet Creek was mostly riffle. Mean water surface slope was found to be the same upstream and downstream of the culvert, at approximately 3 percent. Mean residual pool depth, mean thalweg depth, and volume of LWD were all found to be greater upstream of the culvert than downstream. Riparian and bank vegetation conditions were of high quality in both sections of the creek; however, bank erosion was found to be greater downstream of the culvert.

The channel substrate and channel stability within Sweet Creek were found to be properly functioning. The D50, percentage of fines, and substrate embeddedness in both the area downstream and upstream of the culvert were similar (Figures 5.5-35 and 5.5-36) (Appendix 11). Based on a single Wolman pebble count conducted in a riffle downstream of the culvert, substrate within the sampled riffle consisted of predominantly cobble (D50 of 110 mm).

Figure 5.5-35. Substrate downstream of culvert in Sweet Creek.

Figure 5.5-36. Substrate upstream of culvert in Sweet Creek.

The results of the habitat survey suggest that although there are some minor differences in specific habitat features between the area upstream and downstream of the culvert, low gradient riffle habitat is generally found throughout Sweet Creek. Although the number of LWD pieces per mile within the creek exceeds the criteria to be considered properly functioning, pool frequency is still below the desired level for optimal fish habitat. Replacement of the culvert in Sweet Creek would provide upstream fish passage to approximately 0.10 mile of quality habitat extending from the culvert upstream to the natural falls barrier at RM 0.6 (Figure 5.5-37). In addition, this culvert currently does not allow downstream passage of LWD (pieces were observed jammed against the culvert, retaining spawning-size gravel). Overall, in lieu of replacing the culvert, which would be low in rank compared to other enhancement opportunities, the culvert should be repaired to provide fish passage. Repairing instead of replacing the culvert would provide similar benefits and be high in rank compared to other enhancement opportunities.

Figure 5.5-37. Natural falls barrier located at RM 0.6.

5.5.3. Results from Habitat Protection Evaluation

As described in the methods (Section 4.5.3) and determined during the 2007 study efforts (Table 5.4-3), the feasibility of protecting habitat in Slate, Sullivan, and Sweet creeks was determined to be worth evaluating. The areas considered for protection encompassed all property adjacent to the riparian corridor within 91.4 m (300 feet) on either stream bank within specific lengths of stream segments. This resulted in including complete parcels of land that are unlikely to provide substantial protection to the stream corridor. However, it was not deemed appropriate at this time to decide which portions of land owned by an individual or entity would be available for habitat protection. Instead, entire parcels of lands that were included in each area were considered to have ecological influence on the riparian corridor, and thus the stream, and were therefore included in this analysis. This overestimates the amount of acreage that might be considered for protection; however, determination of what portion of each parcel should be entered into a protective status would be made later. Therefore, the total size of a parcel is used as a basis for future decisions on the exact sizes of property that could potentially be entered into habitat protection.

Specific stream segments evaluated are provided in Table 5.4-3. The specific stream segments of these three streams were identified as high priority habitats (Table 5.4-3) and considered of exceptional importance for native salmonids in the Boundary Reservoir System. During 2007, it was determined to be necessary to evaluate the current level of protection (e.g., property ownership and land status) as part of the 2008 study efforts. The methods used to evaluate the current level of protection and determine habitat protection options are described in Section 4.5.3.

Property owners were identified in ArcGIS and an evaluation of the viable options for placing private and public lands into protective status was conducted for the areas of these three creeks (Figures 5.5-38 through 5.5-40). Based on the stream buffer developed for Slate Creek, the USFS owns all lands surrounding the Slate Creek segment. The total land area considered for habitat protection was 168 acres. Review of the USFS land designation (USFS 2008) within the Slate Creek evaluated area demonstrated that the USFS has designated this area as State Scenic Byway Corridor and Late Successional Reserve.

For Sullivan Creek, the evaluated area identified during the 2007 efforts was intended to extend from RM 0.0 to RM 0.66. However, the available property ownership layer did not extend beyond RM 0.47; therefore, only RM 0.0 to 0.47 was included in the evaluated area. The total land area considered for habitat protection was 1,738.2 acres. Based on the stream buffer developed for Sullivan Creek, the following property owners were identified: City of Metaline Falls (9.6 acres); LeFarge North American Inc. (0.6 acre); Lehigh Portland Cement Co. (0.8 acre); SCL (33.7 acres), Teck Cominco American Inc. (4.2 acres); Pend Oreille Valley Railroad (3.5 acres); and various owners (5.8 acres).

For the Sweet Creek evaluated area, the total land area considered for habitat protection was 80.2 acres. Three private landowners (43.1 acres) and Selkirk School District (37.1 acres) were identified between RM 0.0 and 0.5 (Figure 5.5-40).

From the evaluation, it was determined that habitat protection options include conservation easements, land acquisition, and grants for protection and restoration. Conservation easements and land acquisition options are available to public and private landowners, whereas grant opportunities are generally limited to local and state governments, or private entities working with a local or state government. Further, the acreage, habitat type, and current and past land use are often factors in determining whether a specific parcel of land is eligible for each type of program. An overview of the results of the habitat protection evaluation is summarized below and in Table 5.5-2. Additional information from the evaluation is available in Appendix 14.

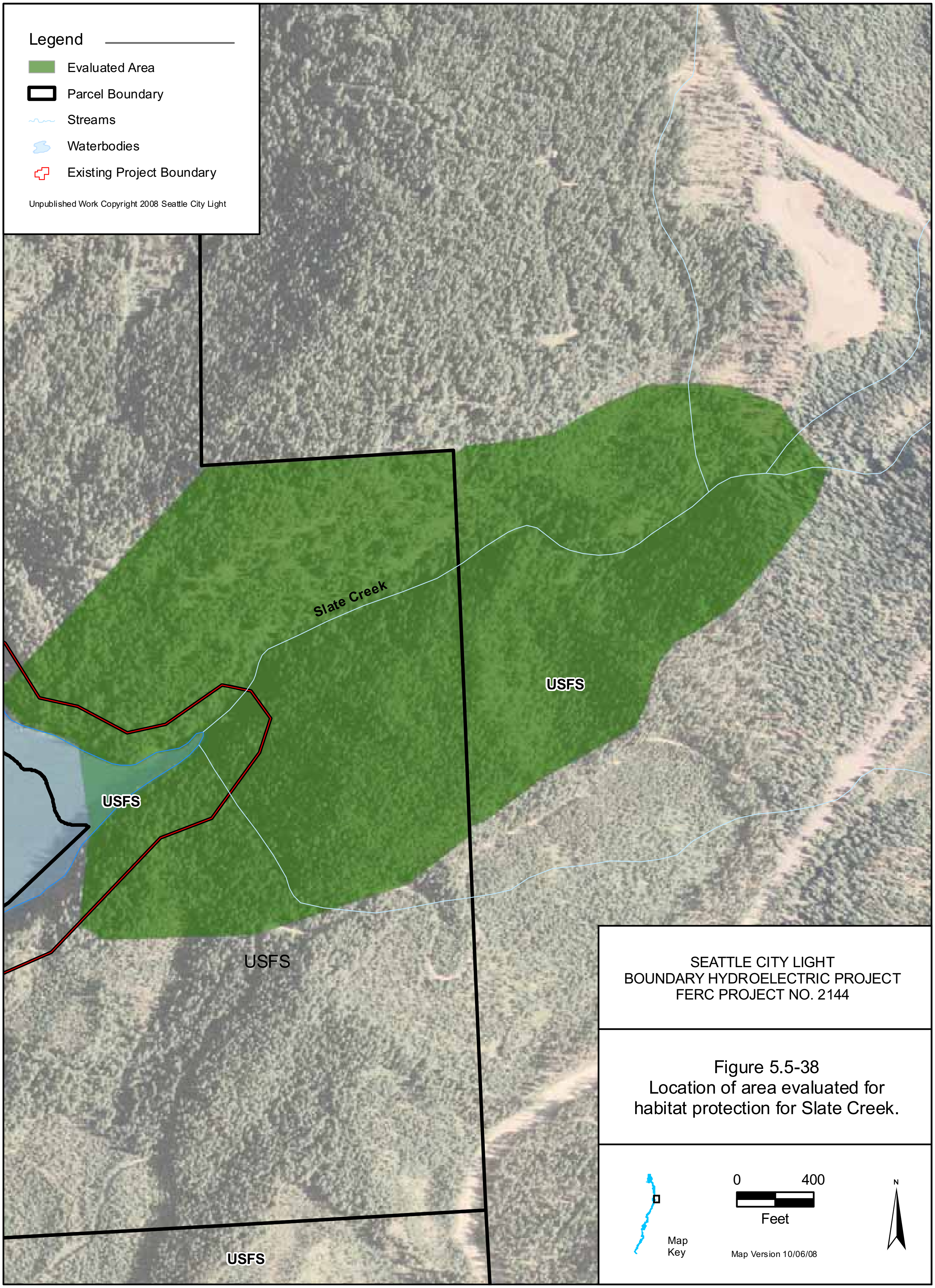

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Figure 5.5-38
Location of area evaluated for habitat protection for Slate Creek.

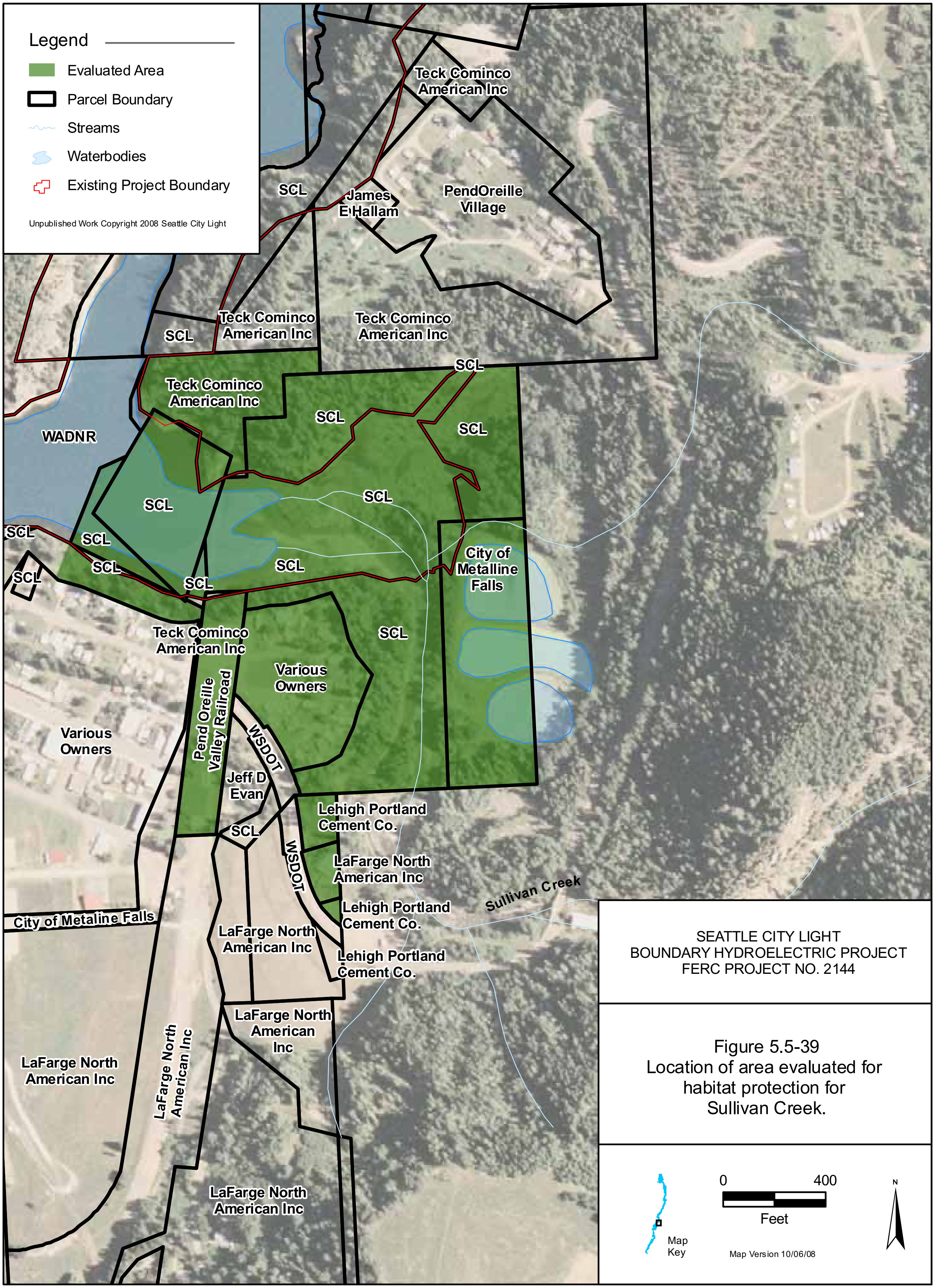

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Figure 5.5-39
Location of area evaluated for habitat protection for Sullivan Creek.

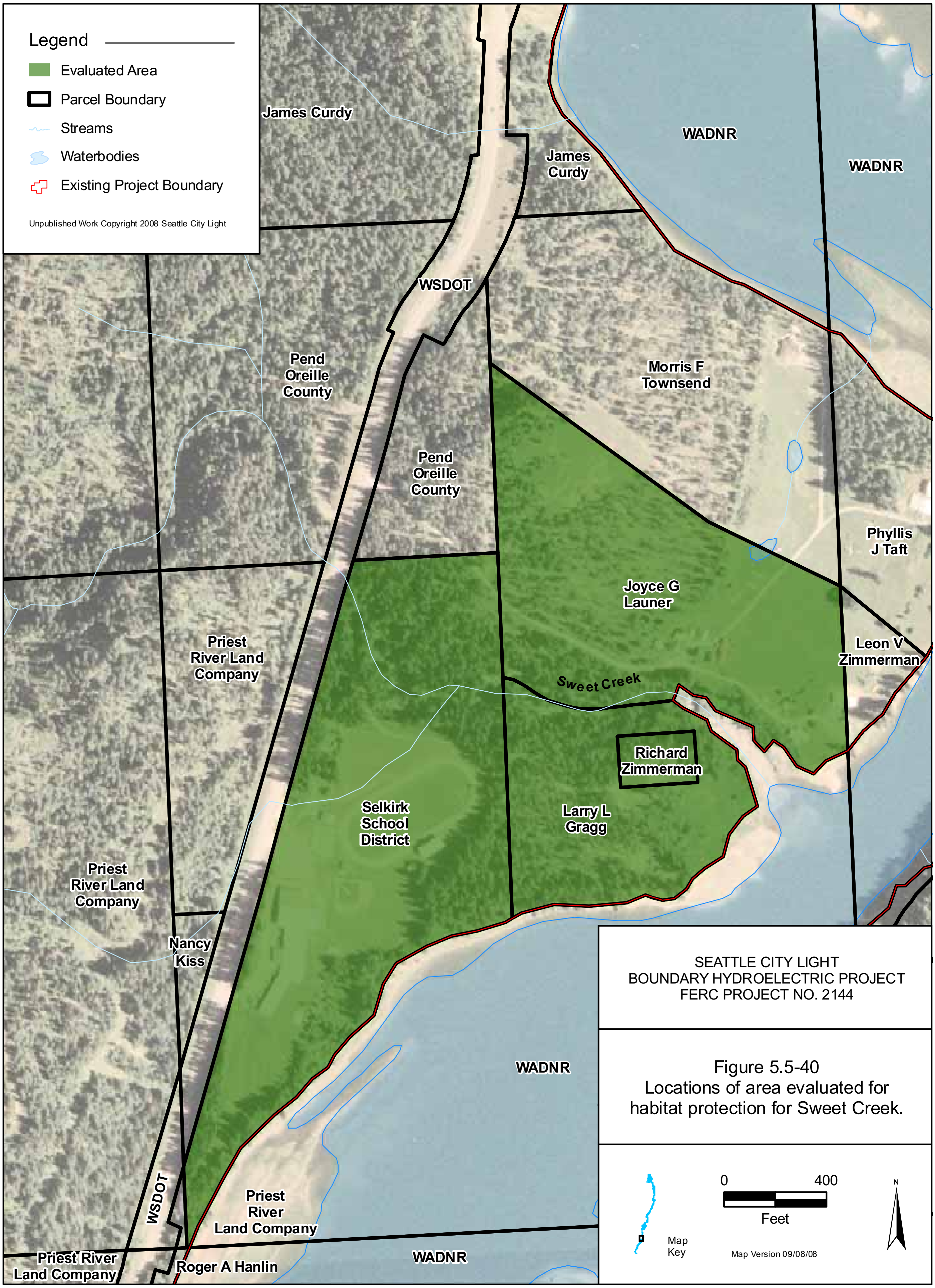

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Figure 5.5-40
Locations of area evaluated for habitat protection for Sweet Creek.

Table 5.5-2. Summary of habitat protection evaluation.

Creek	Property Ownership	Habitat Protection Options	Rank Factors	Rank
Slate Creek RM 0.0 – 0.75	USFS owns all lands surrounding this stream segment. Area evaluated was based on 91.4 m (300 ft) stream buffer. Total evaluated area was 168 ac. Area is designated as State Scenic Byway Corridor and Late Successional Reserve.	Restoration grants such as the Native Fish Habitat Initiative (see Appendix 14 for more information)	Entire area is managed by the USFS. The USFS may be a "willing land manager" (i.e., would potentially agree to implement restoration and habitat improvement projects), but the land use for the area is already designated. However, Forest Plan is currently being updated. Bull trout have been observed at the mouth of Slate Creek, and this segment of stream is the only habitat available to bull trout in this watershed. This area is designated as "Critical Habitat" by USFWS.	Low
Sullivan Creek RM 0.0 – 0.47	Property owners include City of Metaline Falls (9.6 ac); LeFarge North American Inc. (0.6 ac); Lehigh Portland Cement Co. (0.8 ac); SCL (33.7 ac), Teck Cominco American Inc. (4.2 ac); Pend Oreille Valley Railroad (3.5 ac); Various owners (5.8 ac).	Conservation easements; Land acquisition; Restoration Grants (see Appendix 14 for more information).	Contains opportunity to protect potential native salmonid habitat. The lower 0.66 mile is designated as "Critical Habitat." SCL owns land adjacent to Sullivan Creek within the 91.4 m (300 ft) stream buffer. Multiple landowners may make acquiring/protecting land more challenging compared to single ownership. Entire acreage evaluated was 1,738.2 ac.	Medium
Sweet Creek RM (0.0 – 0.5)	Private landowners (43.1; three landowners); Selkirk School District (37.1 acres)	Conservation easements; Land Acquisition; Restoration Grants (see Appendix 14 for more information).	Area has several landowners and it would be difficult to acquire property in cooperation with the number of landowners in the lands adjacent to Sweet Creek. Acreage of 3 or 4 private landowners is too small to be desirable for land trust conservation easement. Entire acreage is 80.2 ac.	Low

5.5.3.1. Conservation Easements

A conservation easement is a legal agreement between a landowner and a land trust or government agency that limits uses of the land in order to protect its environmental resources or conservation values. The land remains in private ownership when placed under a conservation easement. Land restrictions and permanent protections placed on the land remain in place even after an easement donor has sold or given land to others. Individual landowners as well as corporations can donate a conservation easement. Landowners who donate land may be eligible for income tax, estate tax, and federal tax benefits.

The Inland Northwest Land Trust (INLT) is an example of a local nonprofit organization that works in five counties in Washington, including Pend Oreille County, to assist in securing conservation easements and monitoring the terms of the easements. The INLT requires a minimum of 40 acres of land with significant conservation value, such as riparian habitat.

5.5.3.2. Land Acquisition

The Washington State Recreation and Conservation Office (RCO) administers two programs, the Aquatic Lands Enhancement Account (ALEA) and the Washington Wildlife and Recreation Program (WWRP), that provide funding assistance for acquisition, improvement, and protection of designated types of land. The main focus of the ALEA grant program is the acquisition, restoration, or improvement of aquatic lands (lands adjacent to navigable waters) whereas the WWRP has a broader range of land types considered for conservation including areas of critical habitat, natural areas, riparian areas and water access areas. Only local or state governments are eligible to apply for WWRP and ALEA grants (except the Riparian Program of the WWRP in which lead entities are also eligible).

The Land and Water Conservation Fund (LWCF) is a federal fund that provides money to federal, state, and local governments to purchase land, water, and wetlands. Land is acquired from landowners at fair-market value unless the owner chooses to offer the land as a donation or at a lower price. The LWCF funds a matching grant program to assist states in acquiring recreational lands and waters.

5.5.3.3. Habitat Restoration Grants

Many state and federal grant opportunities are available that provide funding for habitat restoration projects. A subset of applicable grant opportunities suitable for land along Slate, Sullivan, and Sweet creeks is discussed below.

The ALEA program and the Salmon Recovery Grant Program are two such grant programs administered through the RCO. As discussed previously, the ALEA is focused on acquisition and restoration of aquatic lands. The Salmon Recovery Grant Program is focused on protection and restoration of salmon habitat. Like the ALEA, the Salmon Recovery Grant Program is open to local and state governments; however, municipal subdivisions, private landowners, and nonprofit organizations are also eligible to apply for Salmon Recovery Grants. Applicants must provide at least 15 percent matching cash or in-kind funds.

The Conservation Reserve Program (CRP), administered by the USDA Farm Service Agency, is another source of funding for privately owned land. The CRP Continuous Sign-Up Program provides participants with rental payments and cost-share assistance in return for participants that plant long-term, resource-conserving vegetation in order to improve the quality of water, control soil erosion, and enhance wildlife habitat. Land suitable for use as a riparian buffer or for similar water quality purposes is eligible for consideration.

The National Fish and Wildlife Foundation offers several grant programs focused on fish conservation. Bring Back the Natives and the Native Fish Habitat Initiative are two of the programs applicable to land in the study area. Bring Back the Natives offers funds for efforts to restore, protect, and enhance native aquatic species to their historic range. The Native Fish Habitat Initiative provides money for projects that protect and restore habitat for native trout and lamprey species.

Lands adjacent to Slate and Sullivan creeks offer the best opportunity for protection of critical habitat, because both of these areas are designated as "Critical Habitat" by the USFWS. Land adjacent to Slate Creek is currently managed by the USFS. Because this land adjacent to Slate Creek is managed by the USFS, specifically as State Scenic Byway Corridors and Lake Successional Forest, there is no potential to consider placing these lands in protected status. Therefore, unless the USFS changes the current land designation for this area as part of the CNF Forest Plan update, currently in progress, the lands adjacent to Slate Creek are considered low rank and not applicable for acquisition or conservation easements.

Multiple property owners are within the evaluated area for Sullivan Creek. Contacting INLT to further investigate the options for acquiring land or placing areas along Sullivan Creek under conservation easements is recommended and is a medium priority, because SCL has substantial land ownership in the evaluated area. Grant programs such as CRP, the WWRP, and the Native Fish Habitat Initiative could be explored for funding of enhancement and protection projects along Sullivan Creek and/or Sweet Creek.

Although the evaluated area for Sweet Creek contains high quality habitat, multiple private land owners in this evaluated area may make the entry of land into protected status challenging and therefore it ranks low compared to placing Sullivan Creek in protected status. Further discussions with the property owners in the evaluated area of Sweet Creek are necessary before any additional evaluation can be made.

5.6. Finalized Limiting Factors Matrix

Data collected during the 2008 field activities were summarized in data tables (see Appendix 13) and used to update the draft LFM (see Appendix 8) for the primary tributaries that were identified during the 2007 study efforts. The finalized LFM Matrix is shown below in Table 5.6-1. Data collected during the field surveys are presented in Section 5.5.2 and in summary data tables (see Appendix 13). These summary tables were used to fill in data gaps that were present in the draft LFM. This was the case with most of the criteria evaluated in Linton Creek, as well as certain criteria in Pocahontas and Sweet creeks. In some creeks, however, such as Sullivan Creek, the field data provided information on creek conditions that varied from what was originally determined from the literature review, thus resulting in specific revisions to the draft LFM.

In five of the creeks surveyed, the draft LFM was revised based on the results from the 2008 field surveys. The matrix was updated to reflect changes in condition status as poor, fair, or good, as well as whether those conditions are considered to be limiting. In Slumber Creek, channel substrate condition was revised from fair to poor and is now considered to be limiting. Off-channel habitat was also updated from good to not applicable, because the gradient was greater than 2 percent, which is outside of the criteria range provided for off-channel habitat (see Appendix 3).

In Styx Creek, channel stability, channel substrate, pool depth, and off-channel habitat were all revised based on quantitative observations. Of those criteria, channel stability and pool depth were both downgraded from good to fair and off-channel habitat was revised to be not applicable, rather than good, because the gradient was greater than 2 percent, which is outside of the criteria range provided for off-channel habitat (see Appendix 3).

Two factors in Sullivan Creek, channel substrate and off-channel habitat, were upgraded to conditions of fair and were changed from limiting to "may be limiting." Channel stability was confirmed to be limiting based on quantitative information.

Eight of the 13 criteria evaluated were updated for Pocahontas Creek. Of the factors revised, approximately half were upgraded, and the others were found to be more degraded than the literature review suggested.

Similar to Pocahontas Creek, 11 of the 13 limiting factors in Sweet Creek were revised as a result of field data collected in 2008. For all criteria except off-channel habitat, conditions were found to be functioning better than the literature suggested. The literature review for off-channel habitat resulted in data that were not in a format comparable with habitat rating criteria, or data were not assessed in a geomorphic context, but were considered to be a limiting condition in the stream. The field survey results from Sweet Creek demonstrated that the gradient was >2 percent, which is outside of the criteria range provided for off-channel habitat (see Appendix 3).

The finalized LFM (Table 5.6-1) facilitated in evaluating factors limiting aquatic productivity. Based on the results from the field surveys (see Section 5.5.2 and Appendix 11), the summarized data tables (see Section 5.5.2 and Appendix 13), and the finalized LFM, enhancement opportunities in the six creeks surveyed during 2008 were identified. These identified enhancement opportunities are focused on addressing factors limiting aquatic productivity.

Table 5.6-1. Finalized matrix of factors limiting productivity of native salmonids in primary tributaries.

Stream Name/Reach	Productivity Factors: Access to Spawning and Rearing		Channel Conditions/Dynamics			Habitat Elements					Water Quality	Water Quantity	Species Competition
	Artificial Structures	Riparian Condition	Streambank Condition	Floodplain Connectivity	Channel Stability	Channel Substrate	LWD	Pool Frequency and Quality	Pool Depth	Off-Channel Habitat	Temperature	Change in Flow Regime	Non-native Fish
SLATE CREEK WAU													
Lime Creek (RM 19.0)													
RM 0.0 - 1.3	G1	√	√	G1	F1	P1	G1	F1	F1	F1	F1	G1	P1
Slate Creek (RM 22.2)													
RM 0.0 - 6.2	G1	F1	G1	G1	F1	F1	G1	G1	G1	G1	G1	G1	P1
Slumber Creek (RM 2.0)													
RM 0.0 - 0.5	P1	G1	G1	G1	G1	P1	G1	G1	G1	NA	G1	G1	P1
Uncas Gulch (RM 2.75)													
RM 0.0 - 2.0	G1	G1	G1	G1	G1	G2	G1	P1	G1	G1	G1	G1	P1
Styx River (RM 4.9)													
RM 0.0 - 2.0	P1	G1	G1	G1	F1	G1	G1	P1	F1	NA	G1	G1	P1
S. Fk. Slate Creek (RM 6.2)													
RM 0.0 - 1.0	G1	G1	G1	G1	G1	G2	G1	G1	G1	G1	G1	G1	P1
N. Fk. Slate Creek (RM 6.2)													
RM 0.0 - 2.5	DG	G1	G1	G1	G1	G2	G1	P1	F1	G1	G1	G1	P1
Flume Creek (RM 25.8)													
RM 0.0 - 4.75	P1	√	G1	DG	√	G1	G1	P1	F1	DG	F1	F1	P1
S. Fk. Flume Creek (RM 1.1)													
RM 0.0 - 0.3	P1	DG	DG	DG	√	G1	√	P1	F1	DG	F1	DG	P1
M. Fk. Flume Creek (RM 3.3)													
RM 0.0 - 0.75	G1	√	DG	DG	√	G1	√	P1	F1	DG	F1	√	P1
SULLIVAN CREEK WAU DOWNSTREAM OF MILL POND DAM (RM 3.25)													
Sullivan Creek (RM 26.9)													
RM 0.0 - 3.25	P1	G1	F1	F1	P1	F1	P1	F1	F1	F1	P1	P1	P1
N. Fk. Sullivan Creek RM (2.35)													
RM 0.0 - headwaters	P1	G1	DG	G1	G1	P1	G1	F1	G1	G1	G1	G1	G1
BOX CANYON WAU													
Linton Creek (RM 28.1)													
RM 0.0 - 1.10	P1	P1	F1	F1	G1	F1	P1	P1	P1	F1	F1	F1	P1
Pocahontas Creek (RM 29.4)													
RM 0.0 - 0.6	P1	F1	F1	G1	F1	P1	G1	P1	P1	NA	F1	F1	P1
Sweet Creek (RM 30.9)													
RM 0.0 - 0.6	P1	F1	F1	G1	G1	G1	G1	G1	F1	NA	F1	G1	P1
Lunch Creek (RM 1.5)													
RM 0.0 - 1.4	P1	√	DG	DG	DG	DG	G1	P1	F1	DG	√	√	P1
Sand Creek (RM 31.7)													
RM 0.0 -1.8	P1	G1	F1	G1	F1	P1	G1	P1	F1	NA	P1	DG	P1

Notes:

P – Average habitat condition considered to be poor (Not Properly Functioning)
F – Average habitat condition considered to be fair (At Risk)
G – Average habitat condition considered to be good (Properly Functioning)
NA – Not Applicable.
√ : 1) data are available but not in a format to allow for ready comparison with Andonaegui (2003) habitat rating criteria, and/or 2) data are not assessed in a geomorphic context.
DG – Data Gap; the stream or reach has not been surveyed or so little information is available that rating the condition was not valid.

1 – Quantitative studies, surveys, or published reports documenting habitat condition.
2 – Professional knowledge of the TAG members as reported in Andonaegui (2003)

(green) = Based on available information, conditions are not limiting.
(orange) = Based on available information, conditions may be limiting.
(red) = Based on available information, conditions are limiting.
(white) = No information is available.

5.7. Identified Protection and Enhancement Opportunities to Improve Factors Limiting Productivity in Tributary Streams

The finalized LFM and field-identified locations of habitat and geomorphic improvement opportunities were used to determine types of protection and enhancement activities that would address factors limiting aquatic productivity. Section 4.7 describes the method used to identify and prioritize protection and enhancement opportunities. Table 5.7-1 identifies protection and enhancement opportunities for specific locations, provides a description of priority factors for each location, and provides a priority rating of high, medium, or low for each location. Figure 5.7-1 provides the location for each of the identified protection and enhancement opportunities. The identified enhancement opportunities are recommended actions that address factors limiting aquatic productivity in the six primary creeks identified as having the highest opportunity to be improved through human modifications.

Table 5.7-1. Identified protection and enhancement opportunities ranked high, medium, or low based on priority factors.

Note: These are provisional estimates based on this pre-feasibility study and are not exact specifications for project designs.

Applicable Limiting Factor	Protection Opportunity	Enhancement Benefits	Priority Factors	Priority
SLATE CREEK WAU				
Slate Creek (PRM 22.2)				
RM 0.0 – 0.75				
Not Applicable; Opportunity is intended to protect habitat	Habitat protection for 168 acres from RM 0.0 to 0.75.	Bull trout have been observed at the mouth of Slate Creek. This area is designated as "Critical Habitat" for bull trout by the USFWS.	Entire area is managed by the USFS. Area is already designated. However, Forest Plan is currently being updated. Bull trout have been observed at the mouth of Slate Creek, and this segment of stream is the only habitat available to bull trout in this watershed. This area is considered "Critical Habitat" for bull trout by USFWS. However, the land is managed by the USFS and is already designated; therefore, the opportunity is not applicable.	Low
RM 0.0 – 6.2 and all tributaries				
Non-native fish	Eradicate non-native fish species throughout the drainage and potentially add/introduce native fish (i.e., westslope cutthroat trout or bull trout).	Would decrease competition for habitat and food resources and predation on native fish species. Would potentially increase native fish numbers.	The opportunity would occur throughout the drainage on both private and public property. Mixed results have been reported from other eradication efforts of non-native fish species. Support from the public and agencies may be difficult to obtain. Logistics related to adding/introducing native fish would need to be determined.	Low

Table 5.7-1, continued…

Applicable Limiting Factor	Protection Opportunity	Enhancement Benefits	Priority Factors	Priority
Slate Creek (PRM 22.2)				
Slumber Creek (RM 2.0)				
RM 0.2				
Culvert, riparian conditions, LWD, pool frequency and quality	Replace the culvert located at RM 0.2 and incorporate LWD placement (at least five pieces) and riparian plantings (at least both sides of culvert fill, construction area, and 15 m (49 ft) up and downstream).	Would provide access to over 0.5 km (0.3 mi) of resident trout habitat comparable to resident trout habitat downstream of the culvert at RM 0.2	This enhancement opportunity involves replacing a stream crossing on USFS Road 3155. The road width is 3.60 m (11.81 ft) and the fill depth is 0.48 m (1.57 ft). The culvert is made of corrugated steel and has a span 1.36 m (4.46 ft), a rise of 0.82 m (2.69 ft) and is 5.0 m (16.4 ft) long. Habitat upstream of culvert at RM 0.2 contains higher amounts of LWD and pool habitat. Placement of LWD (at least five pieces) downstream of the improved culvert may provide additional habitat benefits. Riparian plantings (at least both sides of culvert fill, construction area, and 15 m [49 ft] up and downstream) would provide additional shade benefit to the stream corridor. Replacement of the culvert would improve upstream fish passage and facilitate in the downstream transport of LWD.	Medium
Styx Creek (RM 4.9)				
RM 0.1				
Culvert, riparian conditions, LWD, pool frequency and quality	Replace the culvert located at RM 0.1 and incorporate LWD placement (at least five pieces) and riparian plantings (at least both sides of culvert fill, construction area, and 15 m (49 ft) up and downstream).	Would provide access to over 3.1 km (1.9 mi) of resident trout habitat comparable to resident trout habitat downstream of the culvert at RM 0.1	The enhancement opportunity involves replacing a stream crossing on USFS Road 3155. The road width is 3.60 m (11.81 ft) and the fill depth is 0.26 m (0.85 ft). The culvert is made of corrugated steel and has a span of 2.44 m (8.01 ft), a rise of 1.86 m (6.10 ft) and is 18.5 m (60.70 ft) long. Habitat conditions upstream and downstream of the culvert at RM 0.1 are fairly similar. Gradient between 4 and 6 percent does not provide high quality habitat. Placement of LWD structures (at least five pieces) upstream of the improved culvert may provide additional habitat benefits. Riparian plantings (at least both sides of culvert fill, construction area, and 15 m [49 ft] up and downstream) would provide additional shade benefit to the stream corridor. Replacement of the culvert would improve upstream fish passage and facilitate in the downstream transport of LWD.	Medium

Table 5.7-1, continued…

Applicable Limiting Factor	Protection Opportunity	Enhancement Benefits	Priority Factors	Priority
SULLIVAN CREEK WAU				
Sullivan Creek (PRM 26.9)				
RM 0.0 – 0.47				
Not Applicable; Opportunity is intended to protect habitat	Habitat protection from RM 0.0 to 0.47 through Conservation easements; Land acquisition; Restoration Grants. Entire acreage evaluated was 1738.2107.	Contains opportunity to protect potential bull trout habitat. The lower 0.66 mile is designated as "Critical Habitat." SCL owns land adjacent to Sullivan Creek.	Contains opportunity to protect potential bull trout habitat. The lower 0.66 miles is designated as "Critical Habitat." SCL owns land adjacent to Sullivan Creek within the 91.4 m (300 ft) stream buffer. Multiple landowners may make acquiring/protecting land more challenging compared to single ownership. Entire acreage evaluated was 1,738.2. Property owners include City of Metaline Falls (9.6 ac); LeFarge North American Inc. (0.6 ac); Lehigh Portland Cement Co. (0.8 ac); SCL (33.7 ac), Teck Cominco American Inc. (4.2 ac); Pend Oreille Valley Railroad (3.5 ac); various owners (5.8 ac).	Medium
Sullivan Creek (PRM 26.9)				
RM 0.0 – 3.25 and all tributaries; includes Sullivan Creek upstream of Mill Pond Dam				
Non-native fish	Eradicate non-native fish species throughout the drainage and potentially add/introduce native fish (i.e., westslope cutthroat trout or bull trout).	Would decrease competition for habitat and food resources and predation on native fish species. Would potentially increase native fish numbers.	The opportunity would occur throughout the drainage on both private and public property. Mixed results have been reported from other eradication efforts of non-native fish species. Support from the public and agencies may be difficult to obtain. Logistics related to adding/introducing native fish would need to be determined.	Low

Table 5.7-1, continued…

Applicable Limiting Factor	Protection Opportunity	Enhancement Benefits	Priority Factors	Priority
M 0.3 – 0.6				
Riparian condition, streambank condition, LWD, pool frequency and quality, pool depth, temperature	Riparian planting along left bank for 0.5 km (0.3 mi), LWD placement (>15 pieces), large boulder placement (>5), and channel modification for 0.5 km (0.3 mi) in Reach 1 downstream of the Highway 31 bridge.	Would improve habitat and promote riparian buffer along left bank for 0.5 km (0.3 mi), deflect flow from left bank to right bank, dissipate stream energy along left bank, and decrease erosion along left bank. Would contribute to pool formation, retain LWD and sediment, and promote riparian buffer.	The enhancement opportunity occurs downstream from the Highway 31 bridge and private property is along the left bank. LWD and pool habitat are limited in Sullivan Creek. Structures that assist in catching LWD and retaining gravel are lacking. Longevity of placed wood structures, high energy flood flows, and lack of adequate numbers of mature trees along riparian corridor may necessitate additional placement in future years. Currently, there is little to no riparian cover along the left bank. Instream large boulders would create localized scour holes and provide structures that are lacking. Instream boulders placed along the left bank would provide increased bank stability. The opportunity would promote a riparian buffer along left bank. Over time, as the riparian corridor develops, the opportunity would assist in maintaining cool stream temperature and provide future recruitment of LWD. Maintenance of riparian planting and continued plantings in future years may be necessary. Private property owners along left bank and potential influence to ponds on left bank and downstream along right bank must be evaluated. Enhancement opportunity could potentially protect downstream property owners through bank stabilization techniques. Potential changes in downstream creek orientation must be considered and modeled. Continued suction dredge mining activities in this reach could influence habitat conditions.	Medium
Riparian condition, streambank condition, temperature	Riparian planting along left bank for 0.31 km (0.19 mi) in Reach 1 downstream of the Highway 31 bridge.	Would promote riparian buffer along left bank for 0.31 km (0.19 mi) and, over time, decrease stream temperature and provide future recruitment of LWD.	The enhancement opportunity occurs downstream from the Highway 31 bridge and private property is along the left bank. Currently, there is little to no riparian cover along the left bank. The opportunity promotes a riparian buffer along left bank. Over time, as the riparian corridor develops the opportunity would assist in decreasing stream temperature and provide future recruitment of LWD. Private property owner along left bank has ponds and interest in opportunity would need to be evaluated. Maintenance of riparian planting and continued plantings in future years may be necessary.	High

Table 5.7-1, continued…

Applicable Limiting Factor	Protection Opportunity	Enhancement Benefits	Priority Factors	Priority
RM 2.30 – 2.70				
Floodplain connectivity, channel stability, channel substrate, LWD, pool frequency and quality, pool depth	Engineered Log Jams (ELJs) constructed (≥ 3), placement of large boulders (>5), channel modifications (reach), and riparian plantings (reach) in Reach 2 and along Road Segment 3.	The opportunity would be improve approximately 0.6 km (0.4 mi) of resident trout habitat. Would deflect water from right bank and Road Segment 3 to left bank, decrease bank erosion on right bank, provide instream structure, decrease width to depth ratio, and promote riparian buffer along right bank. Would contribute to pool formation, catch LWD, retain sediment, and promote riparian buffer. Would increase connection to left bank floodplain and terrace.	The enhancement opportunity would occur along Sullivan Lake Road and in Sullivan Creek in a reach that is surrounded by USFS land. LWD and pool habitat are limited in Sullivan Creek. Structures that assist in retaining LWD and gravel are lacking. Limited longevity of placed wood structures, high energy flood flows, and lack of adequate numbers of mature trees along riparian corridor may necessitate additional placement in future years. Large boulders would create localized scour holes and provide structures that are lacking. The opportunity increases connection to left bank floodplain and terrace and promotes a riparian buffer along right bank. Enhancement opportunity would provide a buffer to Road Segment 3, which is hydrologically connected to Reach 2. Protection of Road Segment 3 and the North Fork Sullivan Creek culvert during implementation of enhancement opportunity would be is critical. Road Segment 3 of Sullivan Lake Road is a major highway and the North Fork Sullivan Creek culvert is major crossing.	High
RM 2.50 – 3.00				
Floodplain connectivity, channel stability, Channel substrate, LWD, pool frequency and quality, pool depth	Engineered Log Jams (ELJs) constructed (≥ 4), placement of large boulders (>5), channel modifications (reach), and riparian plantings (reach) in Reach 3 and along Road Segment 4.	The opportunity would improve approximately 0.76 km (0.47 mi) of resident trout habitat. Would deflect water from right bank and Road Segment 4 to left bank, decrease bank erosion on right bank, provide instream structure, decrease width to depth ratio, and promote riparian buffer along right bank. Would contribute to pool formation, retain LWD and sediment, and promote riparian buffer. Would increase connection to left bank floodplain and terrace.	The enhancement opportunity would occur along Sullivan Lake Road and in a reach of Sullivan Creek that is surrounded by USFS land. LWD and pool habitat are limited in Sullivan Creek. Structures that assist in retaining LWD and retaining gravel are lacking. Longevity of placed wood structures, high energy flood flows, and lack of adequate numbers of mature trees along riparian corridor may necessitate additional placement in future years. Large boulders would create localized scour holes and provide structures that are lacking. The opportunity increases connection to left bank floodplain and terrace and promotes riparian buffer along right bank. Enhancement opportunity would provide a buffer to Road Segment 4, which is hydrologically connected to Reach 3. Protection of Road Segment 4 during implementation of enhancement opportunity would be critical. Road Segment 4 of Sullivan Lake Road is a major highway.	High

Table 5.7-1, continued…

Applicable Limiting Factor	Protection Opportunity	Enhancement Benefits	Priority Factors	Priority
Sullivan Creek (PRM 26.9)				
RM 2.3 – 3.25				
Channel stability, LWD, pool frequency and quality	Decrease bank angle through flow-redirection, structural, and/or biotechnical techniques for 0.14 km (0.09 mi) along the hydrologically connected Road Segment 3.	Thalweg would be maintained along right bank, but opportunity would deflect water from right bank and Road Segment 3 to left bank for 0.14 km (0.09 mi), decrease bank erosion on right bank, provide some structure along right bank, potential to decrease width to depth ratio, and promote riparian buffer along right bank. Would contribute to pool formation along the right bank and promote a riparian buffer.	The enhancement opportunity would occur along Sullivan Lake Road and in a reach of Sullivan Creek that is surrounded by USFS land. The opportunity would deflect flows from right bank, and protect Road Segment 3 while providing some structure along right bank. The effort would also promote a riparian buffer along right bank. Enhancement opportunity would provide a buffer to Road Segment 3, which is hydrologically connected to Reach 2. Protection of Road Segment 3 and the North Fork Sullivan Creek culvert is critical. Road Segment 3 of Sullivan Lake Road is a major highway and the North Fork Sullivan Creek culvert is major crossing.	High
Channel stability, LWD, pool frequency and quality	Decrease bank angle and amount of riprap through flow-redirection, structural, and/or biotechnical techniques for 0.097 km (0.060 mi) along the hydrologically connected Road Segment 4.	Thalweg would be maintained along right bank, but opportunity would deflect water from right bank and Road Segment 4 to left bank for 0.097 km (0.060 mi), decrease bank erosion on right bank, provide some structure along right bank, potential to decrease width to depth ratio, and promote a riparian buffer along right bank. Would contribute to pool formation along the right bank and promotes a riparian buffer.	The enhancement opportunity would occur along Sullivan Lake Road and in a reach of Sullivan Creek that is surrounded by USFS land. The opportunity would deflect flows from right bank, protect Road Segment 4, and provide some structure along right bank. Promotes a riparian buffer along right bank. Enhancement opportunity would provide a buffer to Road Segment 4, which is hydrologically connected to Reach 3. Protection of Road Segment 4 is critical. Road Segment 4 of Sullivan Lake Road is a major highway.	High

Table 5.7-1, continued…

Applicable Limiting Factor	Protection Opportunity	Enhancement Benefits	Priority Factors	Priority
Culvert	Replace the culvert located in Road Segment 4.	Would provide connectivity and fish species access to a 3157 m^2 (33982 ft^2) wetland that would function as additional off-channel habitat. Wetland drains through the culvert to a wetland that is hydrologically connected to Sullivan Creek.	The opportunity occurs in Road Segment 4 on Sullivan Lake Road. Currently, the culvert fills with water during high flows. No detailed culvert evaluation was completed, but it was assumed that at high flows and low flows the culvert is a barrier to fish passage. The outfall of the culvert is damaged. Replacing this culvert would increase the hydrologic connectivity between the wetland and Sullivan Creek and provide additional off-channel habitat for fish species. The culvert is under Sullivan Lake Road, which is a major highway. Replacement of the culvert would take considerable effort and expense.	Low
BOX CANYON WAU				
Linton Creek (PRM 28.1)				
RM 0.0 – 0.21				
Riparian condition, Streambank condition, Temperature	Riparian planting for 0.34 km (0.21 mi) along Linton Creek.	Would promote a riparian buffer along banks for 0.34 km (0.21 mi) and over time, decrease stream temperature and provide future recruitment of LWD.	The opportunity occurs in Metaline Park. Currently, there is little to no riparian cover along the banks. Opportunity would promote riparian buffer along banks. Over time, as the riparian corridor develops the opportunity would assist in maintaining cool stream temperature and provide future recruitment of LWD.	High
Linton Creek (PRM 28.1)				
RM 0.18				
Culvert	Replace or remove the culvert located at RM 0.18.	Would provide access to at least 0.048 km (0.03 mi) and potentially 0.097 km (0.06 mi) of adfluvial habitat. Replacement would also facilitate in transporting LWD downstream of the culvert to the delta.	The opportunity occurs in Metaline Park. The stream crossing at RM 0.18 functions as a berm when flooding conditions occur. The road/path width is 3.69 m (12.1 ft) and fill depth is 2.02 m (6.64 ft). The culvert is made of corrugated steel and has a span of 0.79 m (2.59 ft), a rise of 0.76 m (2.49 ft) and is 12.0 m (39.4 ft) long. The habitat between RM 0.18 and 0.21 provides limited spawning or rearing habitat. Although the culvert at RM 0.21 is not a complete barrier to fish passage, due to size of the culvert, debris clogs the culvert at RM 0.21 and upstream passage may be limited at times. Assuming the culvert at RM 0.21 is replaced or consistently cleared of debris, the wetland and stream segment immediately upstream from the culvert would provide rearing habitat and some spawning habitat.	Low

Table 5.7-1, continued…

Applicable Limiting Factor	Protection Opportunity	Enhancement Benefits	Priority Factors	Priority
Linton Creek (PRM 28.1)				
RM 0.21				
Culvert	Replace (or consistently clear) the culvert located at RM 0.21.	Replacement of the culvert would improve upstream passage for 0.048 km (0.03 mi) at all flows. Replacement would also facilitate in transporting LWD downstream of the culvert.	The opportunity occurs in Metaline Park. The culvert at RM 0.21 is not a complete barrier to fish passage. However, due to the size of the culvert, debris fills the inside of the culvert at RM 0.21 and upstream passage may be limited at times. Assuming the culvert at RM 0.21 is either replaced or consistently cleared of debris, the wetland and stream segment immediately upstream from the culvert would provide rearing habitat and some spawning habitat. The road width is 4.3 m (14.1 ft) and fill depth is 0.62 m (2.04 ft). The culvert is made of corrugated steel and has a span of 1.01 m (3.31 ft), a rise of 0.87 m (2.85 ft) with streambed material throughout, and is 9.7 m (31.8 ft) long. If the culvert replacement at RM 0.18 is implemented, then either replacement or consistent clearing of debris in this culvert increase in priority.	Low
Linton Creek (PRM 28.1)				
RM 0.24				
Culvert	Replace the culvert located at RM 0.24.	Would provide access to over 0.016 km (0.01 mi) of adfluvial habitat. Replacement would also facilitate in transporting LWD downstream of the culvert.	The opportunity occurs within the Metaline Park. The road width is 4.7 m (15.4 ft) and fill depth is 7.0 m (23.0 ft). The culvert is made of corrugated steel and has a span of 1.10 m (3.61 ft), a rise of 1.12 m (3.67 ft), and is 40.5 m (132.9 ft) long. The stream crossing is 7.0 m (23.0 ft) above the culvert. Replacement of the culvert would take considerable effort and expense. The habitat from the culvert to 0.016 km (0.01 mi) upstream of the culvert provides low levels of suitable spawning and rearing habitat.	Low

Table 5.7-1, continued…

Applicable Limiting Factor	Protection Opportunity	Enhancement Benefits	Priority Factors	Priority
Linton Creek (PRM 28.1)				
RM 0.0 – 0.24				
Culverts, Riparian condition, Streambank condition, Floodplain connectivity, Channel stability, Channel substrate, LWD, Pool frequency and quality, pool depth, Off-channel habitat, Temperature	Replace all culverts, reconstruct channel, place LWD (>20), place gravel (numerous locations), and conduct riparian planting opportunity between RM 0.0 and 0.24	Would address nearly all factors limiting aquatic productivity between RM 0.0 and 0.24.	The opportunity occurs within the Metaline Park. The enhancement opportunity would take considerable effort and expense. Public support, changes in park aesthetics, location and access to current structures, boat launch, and parking area would be large factors that would need to be considered. Current aquatic conditions are poor and the opportunity would assist in addressing the factors limiting productivity. Flooding conditions in the park that currently occur and due to opportunity would need to be modeled. If the culvert at RM 0.18 is replaced the priority for this opportunity would increase.	Low
Pocahontas Creek (PRM 29.4)				
RM 0.34				
Culverts	Replace the two culverts located at RM 0.34.	Would provide access to over 4.4 km (2.7 mi) of adfluvial habitat that is comparable to adfluvial habitat downstream of the culvert at RM 0.34.	The enhancement opportunity involves improving two culverts on a County Road (Lehigh Hill Rd) that provides access to private properties in the area. The road width is 5.50 m (18.04 ft) and fill depth is 3.56 m (11.68 ft). The two culverts (1.1 and 1.2) are made of corrugated steel and have a span of 0.46 m (1.51 ft) and 0.58 m (1.90 ft), a rise of 0.43 m (1.41 ft) and 0.52 m (1.71 ft), and are 8.25 m (27.07 ft) and 8.25 m (27.07 ft) long, respectively. Falls and steps downstream of culvert at RM 0.34 may limit upstream access. Natural features such as stream gradient (6 percent), waterfalls, a series of step-pools, and dewatering during summer months limit the availability of quality habitat.	Low

Table 5.7-1, continued…

Applicable Limiting Factor	Protection Opportunity	Enhancement Benefits	Priority Factors	Priority
Sweet Creek (PRM 30.9)				
RM 0.0 – 0.5				
Not Applicable; Opportunity is intended to protect habitat	Habitat protection from RM 0.0 to 0.5 through Conservation Easements; Land Acquisition; Restoration Grants	Would provide protection of habitat where bull trout have been observed. Sweet Creek contains high quality habitat.	Area has several landowners and it would be difficult to acquire property in cooperation with the number of landowners in the lands adjacent to Sweet Creek. Acreage of 3 or 4 private landowners is too small to be desirable for land trust conservation easement. Entire acreage is 80.2 ac. Private landowners (43.1 acres; 3 landowners); Selkirk School District (37.1 acres).	Low
Sweet Creek (PRM 30.9)				
RM 0.0 – headwaters and all tributaries				
Non-native fish	Eradicate non-native fish species throughout the drainage and potentially add/introduce native fish (i.e., westslope cutthroat trout or bull trout).	Would decrease competition for habitat and food resources and predation on native fish species. Would potentially increase native fish numbers.	The opportunity would occur throughout the drainage on both private and public property. Mixed results have been reported from other eradication efforts of non-native fish species. Support from the public and agencies may be difficult to obtain. Logistics related to adding/introducing native fish would need to be determined.	Low
RM 0.4 – 0.5				
Streambank condition, LWD	Placement of LWD (>10) jams with channel spanning key pieces (>5) of LWD and perform bank reshaping at LWD locations within 170 m (557.7 ft) downstream of the Highway 31 culvert at RM 0.5.	The LWD jams with channel spanning key pieces of LWD would increase habitat complexity and retain gravel. Would improve habitat for 0.16 km (0.10 mi).	The Highway 31 culvert at RM 0.5 prevents LWD from being transported downstream. For 170 m (557.7 ft) downstream of the culvert, the addition of LWD would create additional pools and retain spawning size gravel. Throughout Sweet Creek at locations where channel spanning LWD is present, side channels, off-channel habitats, and/or pools have been created. Beyond 170 m (557.7 ft) downstream of the culvert, LWD is available and future recruitment potential of LWD from the riparian zone is adequate. Property is downstream from the Highway 31 culvert maintained by WSDOT. Stream is along Selkirk High School property.	Medium
Riparian condition, streambank condition	Conifer planting along right bank on upper terrace adjacent to Selkirk High School football field and track for approximately 0.29 acres.	Would promote riparian corridor connectivity along high right bank for approximately 0.29 acre.	The opportunity would be implemented on the upper terrace adjacent to the Selkirk High School football field and track. Opportunity would provide riparian corridor connectivity and, if the creek continues to migrate towards the right bank, the planted conifers would be a source of LWD in future years.	Low

Table 5.7-1, continued…

Applicable Limiting Factor	Protection Opportunity	Enhancement Benefits	Priority Factors	Priority
Sweet Creek (PRM 30.9)				
RM 0.5				
Culvert	Replace the culvert located at RM 0.5.	Would provide access to over 0.16 km (0.1 mi) of adfluvial habitat containing off-channel habitats, some spawning habitat, and habitat that is similar in quality to the adfluvial habitat downstream of the culvert at RM 0.5.	The culvert is under Highway 31, which is maintained by WSDOT. Property surrounding it is owned by Pend Oreille County, Selkirk School District, and private ownership downstream. The road width is 7.27 m (23.85 ft) and fill depth is 2.03 m (6.66 ft). The culvert is made of cast-in-place concrete and has a span of 2.43 m (7.97 ft), a rise of 3.60 m (11.81 ft), and is 18.3 m (60.04 ft) long. Removal or replacement of the culvert would take considerable effort and expense due to its location. The waterfall at RM 0.6 is a complete fish passage barrier and limits the amount of available adfluvial habitat that would be provided by implementing this opportunity. The habitat upstream of culvert is similar in quality to the adfluvial habitat downstream of the culvert. The culvert limits the amount of woody material transported downstream. Replacement would assist in increasing the amount of woody material transported downstream and provide fish passage at all flows. If the culvert design consists of a natural stream bottom and the width is appropriately sized, no clearing of debris inside or upstream of the culvert would likely be necessary. Culvert outfall and velocity are barriers to fish passage. Velocity must be considered if current culvert replaced.	Low

Table 5.7-1, continued…

Applicable Limiting Factor	Protection Opportunity	Enhancement Benefits	Priority Factors	Priority
Culvert	Improve the culvert located at RM 0.5.	Would provide access to 0.16 km (0.1 mi) of adfluvial habitat containing off-channel habitats, some spawning habitat, and habitat that is similar in quality to the adfluvial habitat downstream of the culvert at RM 0.5.	The culvert is under Highway 31, which is maintained by WSDOT. Property surrounding it is owned by Pend Oreille County, Selkirk School District, and private ownership downstream. The road width is 7.27 m (23.85 ft) and fill depth is 2.03 m (6.66 ft). The culvert is made of cast-in-place concrete and has a span of 2.43 m (7.97 ft), a rise of 3.60 m (11.81 ft), and is 18.3 m (60.04 ft) long. The outfall drop is 0.60 m (1.97 ft). Improvement through adding baffles, weirs, and/or aprons on the downstream end would facilitate upstream fish passage. The waterfall at RM 0.6 is a complete passage barrier and limits the amount of available adfluvial habitat that would be provided by implementing this opportunity. The habitat upstream of culvert is similar in quality to the adfluvial habitat downstream of the culvert. Improvement would not increase the amount of woody material transported downstream. Consistent clearing of debris in and upstream of the culvert would be needed to ensure fish passage at all flows. Cleared debris could be placed downstream of the culvert. Culvert outfall and velocity are barriers to fish passage. Velocity must be considered if current culvert replaced, and improvements inside culvert would also be necessary.	High

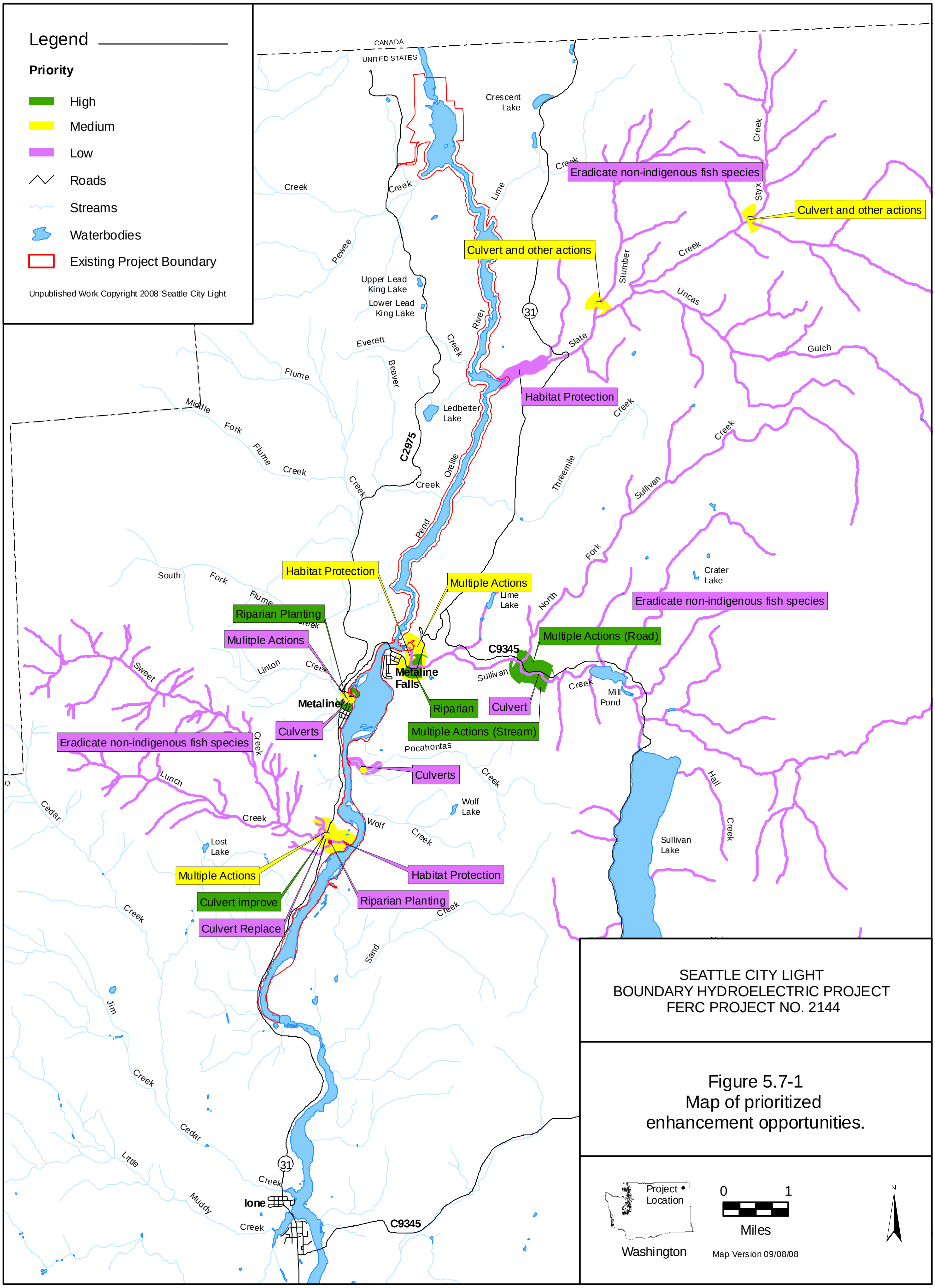

Figure 5.7-1
Map of prioritized enhancement opportunities.

6 CONCLUSIONS

Study 14 assessed limiting factors, or factors that affect productivity, in tributaries of the Project area. This assessment was done to identify those factors that affect the tributaries' ability to sustain populations of native salmonids. There are no effects related to Project operations on the tributaries upstream of the deltas. Any potential effects from Project operations related to the tributary deltas are evaluated in Study 8 (SCL 2009a).

The specific objectives of Study 14 were to:

- Inventory information on physical habitats and fish in Boundary Reservoir tributaries.
- Evaluate factors affecting tributary productivity.

The following five tasks were identified for the study in the RSP:

- Review and compile available information (Task 1).
- Develop a list of productivity factors (Task 2).
- Develop a draft limiting factors matrix (LFM) (Task 3).
- Identify data gaps and critical data caps necessary to fill through field surveys (Task 4).
- Finalize the draft LFM, develop a list of protection and enhancement opportunities from the field surveys and the finalized LFM, and rank the list of opportunities based on the general feasibility regarding whether those limiting factors can be changed through human intervention (Task 5).

These objectives have been addressed and the tasks have been completed. The information presented in this report identifies potential protection and enhancement opportunities intended to improve factors limiting aquatic productivity in tributaries draining into Boundary Reservoir.

On a broad scale, tributaries draining into Boundary Reservoir provide habitat for salmonid populations that exhibit either adfluvial or fluvial (resident) life history traits. The relatively small watershed sizes, presence of natural barriers, high stream gradients, and basin hydrology in these tributaries all contribute to the amount of high quality habitat available for salmonid populations, regardless of life history traits. However, salmonid populations inhabit the majority of Boundary Reservoir tributaries. In addition, native salmonids inhabiting Boundary Reservoir may utilize habitat available in the tributaries.

Twenty-eight tributaries draining into Boundary Reservoir were reviewed through the Study 14 efforts. The 28 tributaries are, in general, high gradient streams that have historically been altered in some form through anthropogenic activities.

Out of the 28 tributaries, 8 were identified as primary tributaries that provide the best opportunity to address factors limiting aquatic productivity through human intervention. Six of those 8 tributaries were identified as priority streams with critical data gaps. These critical data gaps were addressed in 2008. The six priority streams were:

- Slumber Creek (tributary to Slate Creek)
- Styx Creek (tributary to Slate Creek)

- Sullivan Creek
- Linton Creek
- Pocahontas Creek
- Sweet Creek

Field surveys of these six tributaries suggested that Sullivan Creek and Sweet Creek provide the best available existing habitat for salmonid populations that exhibit either adfluvial or fluvial life history traits because they are relatively larger than other Boundary Reservoir tributaries and have favorable fluvial geomorphic characteristics, known salmonid use, and a longer length of adfluvial habitat.

Specific potential enhancement opportunities that could address factors limiting aquatic productivity through human intervention were identified for the six priority tributaries in the study. These opportunities are summarized in Table 6.0-1.

In addition to the habitat evaluations, specific areas of Sullivan and Sweet creeks were also evaluated for potential habitat protection. Options include conservation easements, land acquisition, and habitat restoration grants. Land adjacent to Slate Creek was also evaluated for potential habitat protection. However, because the USFS currently manages these lands, they were considered low rank and not applicable for protection.

Implementation of the specific enhancement opportunities identified in this study is anticipated to improve the factors affecting aquatic productivity, reach-scale river morphology, and aquatic habitat for native salmonid species. Although the identified opportunities would generally improve limiting factors, pre- and/or post-monitoring of potential enhancement and protection opportunities would be needed to measure the response of both fish species and fluvial geomorphic processes in the six priority tributaries.

Last, it is important to note that other opportunities could potentially be identified in any of the priority tributaries, and also likely in the secondary streams. However, efforts were focused on identifying the selected enhancement and protection opportunities determined through the evaluation process described in this study. In addition, because of the relatively small watershed sizes, presence of natural barriers, high stream gradients, and basin hydrology in these tributaries, and the number of streams, reaches, and sites that could be looked at that may not contain opportunities as beneficial as others, the selected enhancement and protection opportunities were those that surfaced with the highest potential to address factors limiting aquatic productivity through the process identified in the study.

Table 6.0-1. Summary of opportunities within the tributary streams.

Stream	Habitat Protection	Non-native Fish Eradication[1]	Culvert Modification	LWD Placement	Riparian Plantings	Boulder Placement	ELJ	Channel Modification	Flow Redirection	Gravel Placement
Slate Creek										
RM 0.0-0.75	L									
RM 0.0-6.2		L								
Slumber Creek										
RM 0.2			M	M	M					
Styx Creek										
RM 0.1			M	M	M					
Sullivan Creek										
RM 0.0-0.66	M									
RM 0.0-3.25		L								
RM 0.3-0.6				M	M, H	M		M		
RM 2.30-2.70					H	H	H	H		
RM 2.50-3.00					H	H	H	H		
RM 2.3-3.25			L						H, H	
Linton Creek										
RM 0.0-0.21					H					
RM 0.18			L							
RM 0.21			L							
RM 0.24			L							
RM 0.0-0.24			L	L	L			L		L
Pocahontas Creek										
RM 0.34			L, L							
Sweet Creek										
RM 0.0-0.50	L									
RM 0.0-headwaters		L								
Rm 0.4-0.5				M	L			M		
RM 0.5			L, H							

Notes:
L – opportunity of low priority exists; M – opportunity of medium priority exists; H – opportunity of high priority exists; LWD – large woody debris; ELJ – engineered log jam
1 Includes identifying locations of eradication and the potential addition/introduction of native fish (i.e., westslope cutthroat trout or bull trout)

7 VARIANCES FROM FERC-APPROVED STUDY PLAN AND PROPOSED MODIFICATIONS

The work products for this study included an electronic database containing the available information from Boundary Reservoir tributaries on hydrology, water quality, fish habitat, fish presence and abundance, channel morphology, riparian conditions, and migration barriers. SCL determined on June 13, 2007, that for simplicity no electronic database was required and instead a table would be put together, which would fully meet the needs of the study and supersede what is described in the RSP. This information is provided in tables within Appendices 6, 7, 12, and 13. In addition, an extensive list of productivity factors by creek names is in Appendix 5.

There were no other variances from, or proposed modifications to, the RSP.

8 REFERENCES

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Appendix 1: Northwest Power and Conservation Council Subbasin Planning (2005)

Table A.1-1. Ranking of reaches with the largest deviation from the reference habitat conditions for bull trout in the Pend Oreille Subbasin.

Reach Name	Reach Rank	Reach Score	Riparian Condition	Channel stability	Habitat Diversity	Fine sediment	High Flow	Low Flow	Oxygen	Low Temperature	High Temperature	Pollutants	Obstructions
Lower Sullivan Creek	4	0.5	2	2	5	9	5	5	10	10	1	5	4
Lower Harvey Creek	15	0.3	2	2	1	4	6	6	8	8	8	8	4
Lower Sand Creek	26	0.3	2	4	2	1	4	4	9	9	4	9	8
Pass Creek	35	0.2	1	1	4	1	5	5	8	8	5	8	8
Middle Sullivan Creek	39	0.2	1	4	1	1	4	4	8	8	4	8	8
Upper Sullivan Creek	57	0.2	2	4	1	2	4	4	7	7	7	7	7
Sweet/Lunch Creek	68	0.1	1	3	3	1	5	5	8	8	5	8	8
Middle Harvey Creek	68	0.1	1	2	2	2	2	2	7	7	7	7	7
Sullivan Lake	73	0.1	6	2	2	2	1	6	8	8	8	8	5
North and Middle Fork Harvey Creek	74	0.1	1	1	1	1	1	1	7	7	7	7	7
Slate Creek	87	0.1	2	2	2	1	2	2	7	7	7	7	7
Deemer/Leola Creek	93	0.1	1	1	1	1	1	1	7	7	7	7	7
Gypsy Creek	93	0.1	1	1	1	1	1	1	7	7	7	7	7

Note:
The table is based on Qualitative Habitat Assessment (QHA) results, the number of reaches and watersheds that currently contain bull trout has decreased by 57 percent from historic numbers. Historically there were 98 of 167 delineated reaches and watersheds within the Pend Oreille Subbasin that supported bull trout. Currently, that number has dropped by 56 reaches to only 42 reaches and watersheds supporting bull trout.

A reach rank equal to 1 has the greatest deviation from reference condition in comparison to other reaches. Reach scores range from 0 to 1, with 1 having the greatest deviation from reference. Values associated with each habitat attribute range from 1 to11; a value of 1 indicates a habitat attribute having the greatest deviation from reference compared to the other attributes within that reach. In some cases multiple habitat attributes have a value of 1 indicating all attributes equally deviate the most from the reference.

Table A.1-2. Ranking of streams whose habitat is most similar to the reference condition for bull trout in the Pend Oreille Subbasin in comparison to other reaches.

Reach Name	Reach Rank	Reach Score	Riparian Condition	Channel stability	Habitat Diversity	Fine sediment	High Flow	Low Flow	Oxygen	Low Temperature	High Temperature	Pollutants	Obstructions
Slate Creek	8	-0.84	5	5	5	10	5	5	1	1	1	1	11
Lower Sullivan Creek	29	-0.5	8	8	4	3	4	4	1	1	10	4	11
Sweet/Lunch Creek	41	-0.32	8	5	7	8	6	3	1	10	3	1	10

Note:
The table is based on Qualitative Habitat Assessment (QHA) results, the number of reaches and watersheds that currently contain bull trout has decreased by 57 percent from historic numbers. Historically there were 98 of 167 delineated reaches and watersheds within the Pend Oreille Subbasin that supported bull trout. Currently, that number has dropped by 56 reaches to only 42 reaches and watersheds supporting bull trout.

A reach rank equal to 1 reveals the reach with current conditions most similar to reference conditions in comparison to other reaches. Reach score ranges from 0 to -1, with -1 having the least deviation from reference. Values associated with each habitat attribute range from 1 to 11; a value of 1 indicates a habitat attribute being most similar to the reference compared to the other attributes within that reach. In some cases multiple habitat attributes have a value of 1 indicating all attributes are equally the most similar to the reference

Table A.1-3. Ranking of reaches with the largest deviation from the reference habitat conditions for westslope cutthroat in the Pend Oreille Subbasin.

Reach Name	**Reach Rank**	**Reach Score**	**Riparian Condition**	**Channel stability**	**Habitat Diversity**	**Fine sediment**	**High Flow**	**Low Flow**	**Oxygen**	**Low Temperature**	**High Temperature**	**Pollutants**	**Obstructions**
Lower Sullivan Creek	5	0.5	2	2	5	9	5	5	10	10	1	5	4
Lower Harvey Creek	20	0.3	2	2	1	4	6	6	8	8	8	8	4
Lower Sand Creek	39	0.3	2	4	2	1	4	4	9	9	4	9	8
Pass Creek	48	0.2	1	1	4	1	5	5	8	8	5	8	8
Upper Sand Creek	48	0.2	3	4	2	1	4	4	8	8	4	8	8
Middle Sullivan Creek	56	0.2	1	4	1	1	4	4	8	8	4	8	8
Upper Sullivan Creek	77	0.2	2	4	1	2	4	4	7	7	7	7	7
Sweet/Lunch Creek	89	0.1	1	3	3	1	5	5	8	8	5	8	8
Middle Harvey Creek	89	0.1	1	2	2	2	2	2	7	7	7	7	7
Flume Creek	95	0.1	1	3	3	1	5	5	8	8	5	8	11
Sullivan Lake	95	0.1	6	2	2	2	1	6	8	8	8	8	5
North and Middle Fork Harvey Creek	97	0.1	1	1	1	1	1	1	7	7	7	7	7
Pocahontas Creek	99	0.1	2	2	2	1	5	5	8	8	5	8	11
Threemile Creek	103	0.1	1	1	1	1	6	6	6	6	1	6	6
Peewee/Russian Creek	103	0.1	1	1	1	1	5	5	7	7	7	7	7
Slate Creek	115	0.1	2	2	2	1	2	2	7	7	7	7	7
Deemer/Leola Creek	120	0.1	1	1	1	1	1	1	7	7	7	7	7
Gypsy Creek	120	0.1	1	1	1	1	1	1	7	7	7	7	7
Lime Creek	122	0.1	1	1	1	1	5	5	8	8	5	8	11
North Fork Sullivan Creek	123	0.0	2	2	2	2	2	2	2	2	2	2	1

Note:
A reach rank equal to 1 has the greatest deviation from reference condition in comparison to other reaches. Reach scores range from 0 to 1, with 1 having the greatest deviation from reference. Values associated with each habitat attribute range from 1 to 11; a value of 1 indicates a habitat attribute having the greatest deviation from reference compared to the other attributes within that reach. In some cases multiple habitat attributes have a value of 1 indicating all attributes equally deviate the most from the reference.

Table A.1-4. Ranking of streams whose habitat is most similar to the reference condition for westslope cutthroat trout in the Pend Oreille Subbasin in comparison to other reaches.

Reach Name	Reach Rank	Reach Score	Riparian Condition	Channel stability	Habitat Diversity	Fine sediment	High Flow	Low Flow	Oxygen	Low Temperature	High Temperature	Pollutants	Obstructions
North Fork Sullivan Creek	7	-0.86	1	1	1	1	1	1	1	10	1	1	11
Deemer/Leola Creek	8	-0.86	4	4	4	4	4	4	1	11	1	1	10
Gypsy Creek	8	-0.86	4	4	4	4	4	4	1	11	1	1	10
South Fork Lost Creek	10	-0.84	6	7	7	7	1	1	1	11	1	1	10
Slate Creek	21	-0.8	5	5	4	5	1	5	1	11	5	1	10
North and Middle Fork Harvey Creek	24	-0.79	4	4	4	4	4	4	1	11	1	1	10
Sullivan Lake	25	-0.78	4	6	6	6	9	4	1	10	1	1	10
Middle Harvey Creek	26	-0.78	6	6	6	10	3	3	1	10	3	1	9
Pocahontas Creek	26	-0.78	10	6	6	9	1	1	1	10	4	4	8
Peewee/Russian Creek	34	-0.75	6	6	6	6	4	4	1	10	1	1	11
Upper Sullivan Creek	36	-0.74	8	4	10	8	4	4	1	10	1	1	7
Sweet/Lunch Creek	51	-0.72	8	3	3	8	5	5	1	11	5	1	8
Middle Sullivan Creek	59	-0.7	8	3	8	8	3	3	1	8	3	1	7
Pass Creek	63	-0.69	8	8	7	8	3	3	1	8	3	1	6
Upper Sand Creek	63	-0.69	8	3	9	11	3	3	1	9	3	1	7
Lower Sand Creek	73	-0.66	7	3	7	11	3	3	1	7	3	1	7
Lower Harvey Creek	90	-0.61	8	8	10	6	4	4	1	6	1	1	11
Lower Sullivan Creek	109	-0.45	8	8	3	2	3	3	1	3	10	3	11

Note:
A reach rank equal to 1 reveals the reach with current conditions most similar to reference conditions in comparison to other reaches. Reach score ranges from 0 to -1, with -1 having the least deviation from reference. Values associated with each habitat attribute range from 1 to 11, a value of 1 indicates a habitat attribute being most similar to the reference compared to the other attributes within that reach. In some cases multiple habitat attributes have a value of 1 indicating all attributes are equally the most similar to the reference.

Table A.1-5. Reaches where mountain whitefish are no longer present and corresponding rank for the degree of habitat deviation from reference conditions.

Reach Name	Reach Rank	Reach Score	Riparian Condition	Channel stability	Habitat Diversity	Fine sediment	High Flow	Low Flow	Oxygen	Low Temperature	High Temperature	Pollutants	Obstructions
Lower Sullivan Creek	3	0.3	9	2	7	7	3	6	10	10	5	3	1
Lower Harvey Creek	6	0.2	7	3	4	1	5	6	8	8	8	8	1
Lower Sand Creek	11	0.2	7	4	2	1	2	5	9	9	7	9	5
Pass Creek	18	0.2	6	2	4	1	3	5	8	8	6	8	8
Sullivan Lake	36	0.1	7	3	5	2	1	6	8	8	8	8	4
Middle Harvey Creek	42	0.1	6	3	5	1	1	4	7	7	7	7	7
Sweet/Lunch Creek	44	0.1	5	2	3	1	3	6	8	8	7	8	8
North and Middle Fork Harvey Creek	45	0.1	5	2	4	1	6	6	6	6	6	6	3
Pocahontas Creek	48	0.1	6	2	3	1	3	5	8	8	6	8	11
Threemile Creek	52	0.1	5	2	3	1	6	6	6	6	3	6	6
Slate Creek	54	0.1	6	3	5	1	2	4	7	7	7	7	7
Lime Creek	61	0.0	6	2	3	1	3	5	8	8	6	8	11

Note:
It should be noted in 2003 (after information had been collected for the QHA), WDFW captured mountain whitefish in an adfluvial trap in lower Harvey Creek (WDFW, unpublished data 2003). Reach rank refers to the degree of habitat change from reference to present conditions, 1 = greatest habitat alteration.

Table A.1-6. Ranking of streams whose habitat is most similar to the reference condition for mountain whitefish in the Pend Oreille Subbasin in comparison to other reaches.

Reach Name	Reach Rank	Reach Score	Riparian Condition	Channel stability	Habitat Diversity	Fine sediment	High Flow	Low Flow	Oxygen	Low Temperature	High Temperature	Pollutants	Obstructions
Sullivan Lake	7	-0.6	11	6	10	3	4	5	1	7	7	1	7
Middle Sullivan Creek	12	-0.57	11	5	10	6	3	6	1	6	9	1	4
Sweet/Lunch Creek	17	-0.56	10	6	9	4	3	5	1	7	8	1	11
Lower Sullivan Creek	22	-0.38	10	8	7	2	3	6	1	3	9	3	11

Note:
A reach rank equal to 1 reveals the reach with current conditions most similar to reference conditions in comparison to other reaches. Reach score ranges from 0 to -1, with -1 having the least deviation from reference. Values associated with each habitat attribute range from 1 to 11, a value of 1 indicates a habitat attribute being most similar to the reference compared to the other attributes within that reach. In some cases multiple habitat attributes have a value of 1 indicating all attributes are equally the most similar to the reference.

Table A.1-7. Ranking of reaches with the largest deviation from the reference habitat conditions for kokanee in the Pend Oreille Subbasin.

Reach Name	Reach Rank	Reach Score	Riparian Condition	Channel stability	Habitat Diversity	Fine sediment	High Flow	Low Flow	Oxygen	Low Temperature	High Temperature	Pollutants	Obstructions
Lower Harvey Creek	5	0.2	7	1	4	2	5	5	7	7	7	7	2
Sullivan Lake	15	0.1	7	2	5	2	1	5	7	7	7	7	4

Note:
A reach rank equal to 1 has the greatest deviation from reference condition in comparison to other reaches. Reach scores range from 0 to 1, with 1 having the greatest deviation from reference. Values associated with each habitat attribute range from 1 to 11, a value of 1 indicates a habitat attribute having the greatest deviation from reference compared to the other attributes within that reach. In some cases multiple habitat attributes have a value of 1 indicating all attributes equally deviate the most from the reference.

Table A.1-8. Ranking of streams whose habitat is most similar to the reference condition for kokanee in the Pend Oreille Subbasin in comparison to other reaches.

Reach Name	**Reach Rank**	**Reach Score**	**Riparian Condition**	**Channel stability**	**Habitat Diversity**	**Fine sediment**	**High Flow**	**Low Flow**	**Oxygen**	**Low Temperature**	**High Temperature**	**Pollutants**	**Obstructions**
Sullivan Lake	3	-0.65	11	5	9	5	7	4	1	1	10	1	8
Lower Harvey Creek	13	-0.54	11	7	10	6	4	4	1	1	8	1	9

Note:
A reach rank equal to 1 reveals the reach with current conditions most similar to reference conditions in comparison to other reaches. Reach score ranges from 0 to -1, with -1 having the least deviation from reference. Values associated with each habitat attribute range from 1 to 11, a value of 1 indicates a habitat attribute being most similar to the reference compared to the other attributes within that reach. In some cases multiple habitat attributes have a value of 1 indicating all attributes are equally the most similar to the reference.

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Appendix 2: Pend Oreille Salmon Recovery Team (2005) Limiting Factors Evaluation

Table A.2-1. Results from the POSRT (2005) WRIA 62 limiting factors evaluation.

Summary of Bull Trout Limiting Factors by Subbasin				**HABITAT LIMITING FACTORS and PRIORITY** Numbered boxes indicate limiting factor presence and priority, with "1" being a higher priority limiting factor in that subbasin than "10". Unless otherwise indicated, all data is from the WRIA 62 Habitat Limiting Factors Report for Bull Trout (Andonaegui 2003). Pink shaded boxes denote limiting factors which are undocumented but are suspected by the Technical Advisory Group (TAG).														
Subbasin	**POLE[1] Priority**	**USFWS Critical Habitat**	**LF Habitat Types**	**Degraded riparian habitat**	**Embedded substrate/sedimentation**	**Channel complexity lacking**	**Degraded pool habitat**	**Altered channel morphology**	**Stream channel instability**	**Elevated stream temperature**	**Other water quality problem**	**Significant fish passage barriers**	**Other fish passage barriers**	**Non-native species competition**	**Development pressure**	**High road density**	**Dewatering**	**Undetermined – Data Lacking**
Slate	High	No	Suitable										2[2]	1				
Sullivan	High	**Yes**	Recoverable Suitable		6		5	3		4		2		1				7

Notes:
1 Pend Oreille Lead Entity
2 DNR internal data

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Appendix 3: Bull Trout Habitat Rating Criteria from Andonaegui (2003)

Table A.3-1. WRIA 62 Pend Oreille bull trout habitat rating criteria from Andonaegui (2003).

Habitat Factor	Parameter/Unit	Channel Type	Poor (Not Properly Functioning)	Fair (At Risk)	Good (Properly Functioning)	Source
Access to Spawning and Rearing Habitat						
Artificial Structures (i.e. culverts, dams, dikes)	Man-made physical barriers (address subsurface flows or dewatering where they impede fish passage under water quality attributes)	All	Man-made barriers present in reaches do not allow upstream and /or downstream fish passage at a range of flows.	Man-made barriers present in the reach do not allow upstream and/or downstream fish passage at base/low flows.	Man-made barriers present in the reach allow upstream and downstream fish passage at all flows.	USFWS Guidelines
Riparian Condition						
Riparian Condition	Riparian Habitat Conservation Areas (RHCAs): Riparian corridors, wetlands, intermittent headwater streams, and other areas where proper ecological functioning is crucial to maintenance of the stream's water, sediment, woody debris and nutrient delivery systems (definition taken from INFISH)	All – Eastside	Riparian areas are fragmented, poorly connected, or provide inadequate protection of habitats for sensitive aquatic species (<70% intact, refugia does not occur), and adequately buffer impacts on rangelands; percent similarity of riparian vegetation to the potential natural community/composition is <25%.	Moderate loss of connectivity or function (shade, LWD recruitment, etc.) of riparian areas, or incomplete protection of habitats and refugia for sensitive aquatic species (≈ 70-80% intact) and adequately buffers impacts on rangelands: percent similarity of riparian vegetation to the potential natural community/composition is 25-50% or better.	The riparian areas provide adequate shade, LWD recruitment, and habitat protection and connectivity in subwatersheds, and buffers or includes known refugia for sensitive aquatic species (>80% intact) and adequately buffers impacts on rangelands: percent similarity of riparian vegetation to the potential natural community/composition is >50%.	USFWS Guidelines
Channel Conditions/Dynamics						
Streambank Condition	% of stream reach in stable condition	All - Eastside	<50% of any stream reach has ≥90% stability	50–80% of any stream reach has ≥90% stability	>80% of any stream reach has ≥90% stability	USFWS Guidelines

Table A.3-1, continued…

Habitat Factor	Parameter/Unit	Channel Type	Poor (Not Properly Functioning)	Fair (At Risk)	Good (Properly Functioning)	Source
Floodplain Connectivity	Stream and off-channel habitat length with lost floodplain connectivity due to incision, roads, dikes, flood protection, or other	All – Eastside	Severe reduction in hydrologic connectivity between off channel, wetland, floodplain and riparian areas; wetlands extent drastically reduced and riparian vegetation/success on altered significantly.	Reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function and riparian vegetation/succession.	Off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession.	USFWS Guidelines
Channel Stability		All	W/D or Entrenchment ratio is inappropriate for geomorphologically correct Rosgen stream type	W/D or Entrenchment ratio is increasing/decreasing beyond range of acceptable for geomorphologically correct Rosgen stream type	W/D and Entrenchment ratio is appropriate for geomorphologically correct Rosgen stream type	TAG 2002 criteria and Rosgen 1996
Habitat Elements						
Channel Substrate	Substrate condition as it relates to rearing habitat and spawning and incubation habitat, including but not limited to, the degree of substrate embeddedness, substrate mobility, and percent fines.	All – Eastside	>30% embeddedness (rearing) or >17% fines <0.85mm (spawning/incubation)	20 – 30% embeddedness (rearing) or 12 - 17% fines <0.85mm (spawning/incubation)	<20% embeddedness (rearing) or <12% fines <0.85mm (spawning/incubation)	USFWS Guidelines
Large Woody Debris	Pieces/mile that are >12” in diameter and >35 ft. in length with at least one end of piece within the OHWL (Ordinary High Water Line); also adequate sources of woody debris are available for both long and short-term recruitment	All – Eastside	Current levels are not at those desired values for “Good/Properly Functioning”, and potential sources of woody debris for short and /or long term recruitment are lacking	Current values are being maintained at minimum levels desired for “Good/Functioning Appropriately”, but potential sources for long-term woody debris recruitment are lacking to maintain these minimum values	Current values are being maintained at greater than >20 pieces/mile, >12” in diameter and >35” ft. in length.	USFWS Guidelines

Table A.3-1, continued…

Habitat Factor	Parameter/Unit	Channel Type	Poor (Not Properly Functioning)	Fair (At Risk)	Good (Properly Functioning)	Source
Habitat Elements						
Pool Frequency and Quality	% wetted channel surface area comprising pools	All	Pool frequency is considerably lower than values desired for “good/properly functioning”; also cover/temperature is inadequate, and there has been a major reduction of pool volume by fine sediment.	Pool frequency is similar to values in “good/ properly functioning” but pools have inadequate cover/temperature and /or there has been a moderate reduction of pool volume by fine sediment.	Pool frequency in a reach closely approximates: Wetted Width (ft) — # Pools/ mile 0–5 — 39 5-10 — 60 10-15 — 48 15-20 — 39 20-30 — 23 30-35 — 18 35-40 — 10 40-65 — 9 65-100 — 4 (can use formula: pools/ mile = 5,280/ wetted channel width ÷ # channel widths per pool	USFWS Guidelines
Pool Depth	Pools >1 meter	Streams >3m in wetted width	No pools	few pools	many pools present	USFWS Guidelines
Off-channel Habitat	Area within the channel migration zone which is also accessible during peak flow events.	Reaches with average gradient <2%	Reach has no ponds, oxbows, backwaters, or other off-channel areas	Reach has some ponds, oxbows, backwaters, and other off-channel areas with cover; but side-channel areas are generally high energy areas	Reach has many ponds, oxbows, backwaters, and other off-channel areas with cover; and side-channels are low energy areas	USFWS Guidelines

Table A.3-1, continued…

Habitat Factor	Parameter/Unit	Channel Type	Poor (Not Properly Functioning)	Fair (At Risk)	Good (Properly Functioning)	Source
Water Quality						
Temperature	degrees Celsius/ degrees Fahrenheit	All	7-day average maximum temperature in a reach during the following life history stages: • >15°C/ >59°F (rearing) • <4°C or >10°C/ <39°F or >50°F (spawning) • <1°C or >6°C/ <34°F or >43ºF (incubation) also temperatures in areas used by adults during migration regularly exceed 15ºC/59ºF (thermal barriers present)	7-day average maximum temperature in a reach during the following life history stages: • <4°C or 13-15ºC/ <39°F or 55º-59ºF (rearing) • <4°C or 10°C/ <39°F or 50°F (spawning) • <2°C or 6°C/ <36°F or 43ºF (incubation) also temperatures in areas used by adults during migration sometimes exceed 15ºC/59ºF	7-day average maximum temperature in a reach during the following life history stages: • 4°-12ºC/ 39°-54ºF (rearing) • 4° - 9ºC/ 39°-48°F (spawning) • 2°-5°C/ 36°-41ºF (incubation) also temperatures do not exceed 15ºC/59ºF in areas used by adults during migration (no thermal barriers)	USFWS Guidelines
Water Quantity						
Change in Flow Regime	Change in Peak/Base Flows	All	Pronounced changes in peak flow, base flow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography	Some evidence of altered peak flow, base flow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography	Watershed hydrograph indicates peak flow, base flow and flow timing characteristics comparable to an undisturbed watershed of similar size, geology and geography	USFWS Guidelines
Species Competition						
Non-indigenous fish species	Presence/ Absence	All	Present in the drainage	Present in an adjacent drainage and have access to the drainage	Absent in the drainage and there is not opportunity for access to the drainage	TAG 2002 criteria

Appendix 4: Secondary Tributaries Limiting Factors Matrix

Table A.4-1. Secondary tributaries limiting factors matrix.

	Access to Spawning and Rearing		Channel Conditions/Dynamics			Habitat Elements					Water Quality	Water Quantity	Species Competition
Stream Name	Artificial Structures	Riparian Condition	Streambank Condition	Floodplain Connectivity	Channel Stability	Channel Substrate	LWD	Pool Frequency and Quality	Pool Depth	Off-Channel Habitat	Temperature	Change in Flow Regime	Non-indigenous Fish
SLATE CREEK WAU													
Pewee Creek (RM 17.9)													
RM 0.0 - 1.3	P1	P1	DG	DG	P1	P1	G1	P1	DG	DG	G1	√	P1
Fence Creek (RM 1.1)													
RM 0.0 - 0.31	G1	DG	DG	DG	DG	DG	DG	P1	F1	DG	G1	√	P1
Everett Creek (RM 21.9)													
RM 0.0 - 1.2	P1	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
Whiskey Gulch (RM 21.9)													
RM 0.0 - 0.6	P1	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
SULLIVAN CREEK WAU UPSTREAM OF MILL POND DAM (RM 3.25)													
Sullivan Creek (RM 26.9)													
RM 3.25 - ?/headwaters	P1	F1	F1	G1	√	√	P1	P1	F1	NA	F1	F1	P1
Elk Creek (RM 3.7)													
RM 0.0 - 0.58	P1	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
Outlet Creek (RM 5.3)													
RM 0.0 - 0.5	G1	F2	F2	DG	DG	F2	DG	G1	G1	DG	DG	P1	P1
Pass Creek (RM 8.9)													
RM 0.0 - headwaters	G1	√	DG	DG	√	√	DG	G1	G1	DG	√	√	F1
Stony Creek (RM 11.6)													
RM 0.0 - 0.04	P1	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
Kinyon Creek (RM 12.65)													
RM 0.0 - 0.27	P1	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
Copper Creek (RM 13.35)													
RM 0.0 - 0.05	P1	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
Gypsy Creek (RM 13.8)													
RM 0.0 - 2.0	G1	√	DG	DG	√	√	DG	G1	G1	DG	√	√	P1
Leola Creek (RM 17.6)													
RM 0.0 - 3.0	G1	G1	G1	G1	F1	DG	G1	F1	G1	G1	√	√	F1
Deemer Creek (RM 0.32)													
RM 0.0 - 2.0	G1	√	G1	√	F1	DG	G1	P1	P1	G1	√	√	P1
HARVEY CREEK WAU													
Sullivan Lake (RM 0.5)													
RM 0.0 - 4.0/length of lake	P1	F1	G1	G1	NA	NA	DG	NA	NA	NA	√	P1	P1
Noisy Creek (RM 3.8/Lk. Sullivan inlet)													
RM 0.0 - ?	G1	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
Harvey Creek (RM 4.0/Lk. Sullivan inlet)													
RM 0.0 - headwaters	G1	F1	F1	√	G1	√	F1	P1	P1	NA	F1	√	P2
M. Fk. Harvey Creek (RM 10.0)													
RM 0.0 - 1.5	G1	√	F1	√	G1	√	G1	P1	F1	NA	√	√	F1
N. Fk. Harvey Creek (RM 0.5)													
RM 0.0 -2.3/headwaters	G1	√	F1	√	G1	√	G1	P1	P1	NA	√	√	F1

Table A.4-1, continued…

Stream Name	Access to Spawning and Rearing		Channel Conditions/Dynamics			Habitat Elements					Water Quality	Water Quantity	Species Competition
	Artificial Structures	Riparian Condition	Streambank Condition	Floodplain Connectivity	Channel Stability	Channel Substrate	LWD	Pool Frequency and Quality	Pool Depth	Off-Channel Habitat	Temperature	Change in Flow Regime	Non-indigenous Fish
BOX CANYON WAU													
Unnamed No. 6 (RM 29.2)													
RM 0.0 - 0.18	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
Wolf Creek (RM 30.3)													
RM 0.0 - 1.21	P1	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
Lost Creek (RM 32.2)													
RM 0.0 - 1.41	P1	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
Unnamed No. 13 (RM 34.3)													
RM 0.0 -0.02	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG

Notes:

P – Average habitat condition considered to be poor (Not Properly Functioning)
F – Average habitat condition considered to be fair (At Risk)
G – Average habitat condition considered to be good (Properly Functioning)
NA – Not Applicable.

1 – Quantitative studies, surveys, or published reports documenting habitat condition.
2 – Professional knowledge of the TAG members as reported in Andonaegui (2003)

Green = Based on available information, conditions are not limiting.
Orange = Based on available information, conditions may be limiting.
Red = Based on available information, conditions are limiting.
White = No information is available.

√ : 1) data are available from reports, the NPCC (2005), and/or POSRT (2005), but not in a format to allow for ready comparison with Andonaegui (2003) habitat rating criteria, and/or 2) data are not assessed in a geomorphic context.

DG = Data Gap; the stream or reach has not been surveyed or so little information is available that rating the condition was not valid.

Appendix 5: List of Productivity Factors

A.5.1SLATE CREEK WAU

A.5.1.1 Pewee Creek

Barrier

A naturally occurring 50 meter (165 ft) vertical waterfall at the mouth of Pewee Creek is a barrier to fish passage, making the creek disconnected from Boundary Reservoir (McLellan 2001; Andonaegui 2003; WDFW SalmonScape 2007). Approximately upstream from RM 1.2 there is a fish passage barrier (POSRT 2005).

Habitat Elements

Channel Substrate: In surveying sites within two reaches of Pewee Creek conducted in 2000, McLellan (2001) reported the dominant substrate boulder for the upper reach and rubble for the lower reach. However, for the entire Pewee Creek watershed McLellan (2001) reported rubble as the dominant substrate.

LWD: McLellan (2001) conducted habitat surveys within two reaches on Pewee Creek and based on data available from the report, there was a mean of 290 pieces of LWD per mile.

Pool Frequency and Quality: McLellan (2001) conducted habitat surveys within two reaches on Pewee Creek, and reported 21 large pools per mile for the upstream reach and zero large pools per mile for the downstream reach. The downstream reach started at approximately RM 0.31 and went upstream to approximately RM 0.62. The upstream reach went from approximately RM 0.62 to the confluence of Pewee Creek and Fence Creek (approximately RM 1.1 on Pewee Creek).

Pool Depth: McLellan (2001) reported no information for mean pool width, maximum depth, and residual depth for two reaches surveyed on Pewee Creek.

Wetted Width: McLellan (2001) reported the average wetted width was 2.8 m (9.2 ft) in 2000 from surveys of three stream reaches.

Water Quality

Temperature: In a water temperature study conducted in Boundary Reservoir by R2 Resource Consultants (1998), cool water refugia were available for salmonids during August and September at the confluence of the creek and the reservoir. However, the cool water zone was relatively small in size, but well defined (R2 Resource Consultants 1998; Andonaegui 2003). Based on the data available from the McLellan (2001) report the 7-day average maximum temperature for Pewee Creek at its mouth was 11.8ºC (53.24ºF) between August 6 and August 12, 2000.

Water Quantity and Characteristics

McLellan (2001) determined the discharge on September 25, 2000, to be 0.01 m^3/s (0.35 ft^3/s) at the mouth of Pewee Creek. The mean gradient from two reaches surveyed on Pewee Creek was 7 percent, and in Fence Creek, a tributary draining into Pewee Creek, the gradient was 9 percent (McLellan 2001). Entrix (2002) reported the maximum flow recorded as 0.0 m^3/s (0.4 ft^3/s).

Fish Species

Cutthroat Trout: Cutthroat trout density in Pewee Creek was 1 fish/100 m^2 based on sites within two 500 m (1,640.4 ft) reaches surveyed in 2000 (McLellan 2001). However, cutthroat trout were not observed during snorkel surveys in the reach between the confluence of Fence and Pewee creeks (approximately RM 1.1) and downstream to approximately RM 0.62 (McLellan 2001). Eastern brook trout were the only other fish species observed during the survey and were found in both surveyed reaches on Pewee Creek (McLellan 2001).

Brook Trout: Eastern brook trout density in Pewee Creek was 1 fish/100 m^2 based on sites within two 500 m (1,640.4 ft) reaches surveyed in 2000 (McLellan 2001). Cutthroat trout were the only other fish species observed during the survey (McLellan 2001).

A.5.1.2 Fence Creek

Habitat Elements:

Channel Substrate: In surveying sites within a 500 m (1,640.4 ft) reach of Fence Creek conducted in 2000, McLellan (2001) reported the dominant substrate as cobble.

LWD: McLellan (2001) conducted habitat surveys within a reach on Fence Creek and documented 402 pieces of LWD per mile.

Pool Frequency and Quality: McLellan (2001) conducted habitat surveys within a reach on Fence Creek and reported a mean of 31 large pools per mile.

Pool Depth: McLellan (2001) conducted habitat surveys within a reach on Fence Creek and determined the mean width, maximum depth, and residual depth for the reach was 2.6 m (8.5 ft), 43 centimeters (cm) (16.9 inches [in]), and 10 cm (3.9 in), respectively.

Water Quantity and Characteristics

The gradient from one reach surveyed on Fence Creek was 9 percent (McLellan 2001).

Fish Species

Cutthroat Trout: Cutthroat trout density in Fence Creek was 1 fish/100 m^2 based on sites within a 500 m (1,640.4 ft) reach surveyed in 2000 (McLellan 2001). Eastern brook trout were the only other fish species observed during the survey (McLellan 2001).

Brook Trout: Eastern brook trout density in Fence Creek was 1 fish/100 m^2 based on sites within a 500 m (1,640.4 ft) reach surveyed in 2000 (McLellan 2001). Cutthroat trout were the only other fish species observed during the survey (McLellan 2001).

A.5.1.3 Lime Creek

Barriers

Lime Creek goes subsurface for approximately 100 m (330 ft) at RM 1.3, downstream of the Lake Lucerne tributary and State Highway 31 (McLellan 2001; Andonaegui 2003).

Channel Conditions and Dynamics

Floodplain Connectivity: The USFS (2005) SMART database documents braiding, off-channel areas, and beaver activity in the comments for Lime Creek.

Channel Stability: The USFS (2005) SMART database reports the entrenchment ration between 2.0 and 3.9.

Habitat Elements

Channel Substrate: The USFS (1998) reported embeddedness was greater than 35 percent and attributed the condition of substrate in Lime Creek to the drainage occurring in area of decomposed limestone (USFS 1998). In habitat surveys conducted in 2000, McLellan (2001) reported the dominant substrate as gravel.

LWD: McLellan (2001) conducted habitat surveys within four reaches on Lime Creek and documented a mean of 772 pieces of LWD per mile.

Pool Frequency and Quality: McLellan (2001) conducted habitat surveys within four reaches on Lime Creek and determined the dominant habitat type was riffle (60 percent). Although riffle was reported as the dominant habitat type, McLellan (2001) reported a mean of 47 large pools per mile.

Pool Depth: McLellan (2001) conducted habitat surveys within four reaches on Lime Creek and determined the mean width, maximum depth, and residual depth for two of the four reaches was 4.0 m (13.1 ft), 38 cm (15.0 in), and 24 cm (9.4 in), respectively.

Off-Channel Habitat: The USFS (2005) documents braiding, off-channel areas, and beaver activity in the comments for Lime Creek.

Wetted Width: McLellan (2001) reported the average wetted width was 3.1 m (10.2 ft) in 2000 from surveys of four stream reaches.

Water Quality

Temperature: Instream summer time water temperatures naturally exceeded the tolerance level for bull trout fry and juveniles (T. Shuhda, USFS, email comm., 2003 as cited in Andonaegui 2003). The USFS (1998) documents temperatures in Lime Creek as high as 15ºC (59ºF) during the summer and attributed these summer temperatures to warm water input from Lake Lucerne. Using data reported by McLellan (2001) from monitoring water temperature 1,340 times with a thermograph between June 28 and October 27, 2000, the 7-day average maximum temperature was 11.6ºC (52.88ºF) between August 6 and August 12, 2000. The CNF Total Maximum Daily Load (TMDL) (Ecology 2005) reported Lime Creek as unlisted impaired under section 303(d) of the Clean Water Act for temperature in 1998.

Water Quantity and Characteristics

McLellan (2001) determined the discharge on September 26, 2000, to be 0.08 m^3/s (2.83 ft^3/s), and noted the creek went subsurface approximately 100 m downstream of State Highway 31. The mean gradient from four reaches surveyed on Lime Creek was 6 percent (McLellan 2001). Entrix (2002) reported the maximum flow recorded as 0.2 m^3/s (5.3 ft^3/s). The CNF TMDL (Ecology 2005) reported average July – August flow to be 0.02 m^3/s (0.76 ft^3/s).

Fish Species

Brook Trout: A sustaining population of eastern brook trout was documented in Lime Creek (USFS 1998). In snorkel surveys conducted in 2000 on four reaches in Lime Creek, McLellan (2001) reported eastern brook trout as the only fish species observed. No fish were observed upstream of approximately RM 1.3 (McLellan 2001). However, McLellan (2001) reported that the mean density of brook trout for the three reaches where brook trout were present was 5 fish/100 m^2.

A.5.1.4 Everett Creek

Barrier

Approximately at RM 0.16 of Everett Creek there is a potential waterfall barrier (WDFW SalmonScape 2007). At approximately RM 1.2 there is a culvert listed in the WDFW GIS layers; however, it is noted that the crossing was abandoned (WDFW SalmonScape 2007).

Water Quantity and Characteristics

The mean gradient was greater than 20 percent after 18.3 m (60 ft) upstream from the confluence with Boundary Reservoir (RM 0.0) (R2 Resource Consultants 1996; WDFW SalmonScape 2007).

A.5.1.5 Whiskey Gulch

Barrier

Approximately at RM 0.60 on Whiskey Gulch there is a fish passage barrier (POSRT 2005).

Water Quantity and Characteristics

The mean gradient was greater than 20 percent after 166.7 m (547 ft) upstream from the confluence with Boundary Reservoir (RM 0.0) (R2 Resource Consultants 1996; WDFW SalmonScape 2007).

A.5.1.6 Slate Creek

Barrier

A survey of Slate Creek in 1997 by R2 Resource Consultants provided information that no fish passage barriers existed in the creek, although portions of the creek have several steep gradients which could limit passage by small salmonids under some streamflow conditions (R2 Resource Consultants 1998; Andonaegui 2003). The USFS (1999b) reported that there are no known artificial fish passage barriers in the Slate Creek WAU, but did identify a series of cascades at RM 0.75 that could limit passage under some streamflow conditions. However, McLellan (2001) reported that a series of natural falls, cascades, and chutes are a complete barrier to fish passage. Based on maps and written descriptions from McLellan (2001), the series of natural falls, cascades, and chutes starts approximately at RM 0.75 and continues upstream for 800 meters (m) (2,624.7 ft). Moving in an upstream direction, the first waterfall (near RM 0.75) was 6.0 m (19.7 ft) high, the second waterfall was 4.0 m (13.1 ft) high, the third waterfall was 5.0 m (16.4 ft) high, the fourth waterfall was 2.8 m (9.2 ft) high, and the chute was 30 m (98.4 ft) long, 2.0 m (6.7 ft) wide, and had a gradient of 38 percent with uninterrupted flow (McLellan 2001). The differences between the conditions reported by McLellan (2001) and those from R2 Resource Consultants (1998) and USFS (1999b) require further evaluation to determine under what flow conditions portions of Slate Creek limit upstream passage to fish species utilizing the drainage. McLellan (2001) identifies an additional waterfall (3.0 m [9.8 ft]) and chute (10 m [32.8 ft] long, 1 m [3.3 ft] wide, gradient of 24 percent) as a fish passage barrier in Slate Creek (near RM 1.5), approximately 400 m (1,312.3 ft) upstream from the State Highway 31 bridge.

Riparian Conditions

Alder, alder/dogwood, and conifer/alder are the primary riparian vegetation communities documented for Slate Creek (USFS 1998; Andonaegui 2003). R2 Resource Consultants (1998) documented a shaded riparian corridor in Slate Creek, based on observed temperatures.

Channel Conditions and Dynamics

Streambank Condition: Of the stream reaches surveyed on USFS land in 1991 and 1997, the majority of the reaches had greater than 90 percent stability (USFS 1999b; Andonaegui 2003).

Habitat Elements

Channel Substrate: Based on reaches surveyed in 1991 and 1997 by the USFS, cobble and gravel were determined to be the dominant substrate with embeddedness less than 35 percent (USFS 1998; Andonaegui 2003). R2 Resource Consultants (1998) reported a mean of 6 percent for surface fines from surveys in Slate Creek. McLellan (2001) reported the dominant substrate type was cobble and boulder with a mean embeddedness of 6 percent based on sites surveyed in seven reaches on Slate Creek.

LWD: For the nine stream reaches surveyed by the USFS in Slate Creek, 210, 142, 201, 234, 154, 187, 161, 137, and 128 pieces of LWD per mile were documented (USFS 1998). In the nine stream reaches surveyed on Slate Creek, the USFS (1998) reports that LWD is the primary source of instream cover. McLellan (2001) conducted habitat surveys in sites within seven reaches on Slate Creek and based on data available from the report, there was a mean of 635 pieces of LWD per mile.

Pool Frequency and Quality: Nine stream reaches were surveyed in Slate Creek by the USFS and 24, 26, 22, 10, 17, 19, 23, and 20 pools per mile documented (USFS 1998). McLellan (2001) conducted habitat surveys at sites within seven reaches on Slate Creek and reported a mean of 38 large pools per mile. However, McLellan (2001) reported that riffles were the dominant habitat type for Slate Creek.

Pool Depth: Based on observations during snorkel surveys, there were negligible amounts of fine sediment in pool substrate (USFS 1999b; Andonaegui 2003). McLellan (2001) conducted habitat surveys at sites within seven reaches on Slate Creek and the mean width, maximum depth, and residual depth for the combined reaches was 3.8 m (12.4 ft), 53 cm (20.9 in), and 36.1 cm (14.2 in), respectively. On average in Slate Creek, pool depths have been documented to range between 0.8 and 1.1 m (2.5 and 3.5 ft) and provide suitable overwintering habitat (Andonaegui 2003).

Wetted Width: Based on data available from the McLellan (2001) survey of seven stream reaches on Slate Creek, the average wetted width was 6.3 m (20.7 ft).

Water Quality

Temperature Near RM 0.0: In a water temperature study conducted in Boundary Reservoir by R2 Resource Consultants (1998), cool water refugia were available for salmonids during August and September at the confluence of the creek and the reservoir. However, the cool water zone was relatively small in size, but well defined (R2 Resource Consultants 1998; Andonaegui 2003). The USFS (1998) documents temperatures in Slate Creek and its tributaries reaching 10ºC (50ºF) during the summer. Based on limited data from the USFS (1999b) reported by Andonaegui (2003), during the summer months and into the spawning period for bull trout water temperatures were consistently between 7 and 9ºC (44 and 48ºF). Andonaegui (2003) describes that the information available from the USFS (1999b) was "insufficient to determine the 7-day average maximum temperature in Slate Creek and its tributaries." However, of the data that were available, spot temperatures taken during surveys were determined to be within the acceptable bull trout ranges for spawning and rearing and assumed accessible for incubation (USFS 1999b; Andonaegui 2003). Andonaegui (2003) goes on to state that there are inconsistencies between the data provided to SCL by R2 Resource Consultants (1998) and the data reported by the USFS (1999b). R2 Resource Consultants (1998) recorded water temperatures at the mouth of Slate Creek (RM 0.0) using thermographs in 1996 and again from late July through early November 1997. At the mouth of Slate Creek the maximum water temperature recorded was 15.4ºC (59.7ºF) on August 5 and 6, 1997 (R2 Resource Consultants 1998). The 7-day average maximum temperature at the mouth of Slate Creek in the study by R2 Resource Consultants (1998) was 14.6ºC (58.3ºF) between August 1 and 7, 1997. McLellan (2001) measured the temperature of lower Slate Creek between June 28 and October 17, 2000, and determined the maximum temperature to be 13.34ºC (56.0ºF) on August 8 and 9, and the minimum temperature to be 2.80ºC (37.0ºF) on October 6. Using data reported by McLellan (2001), the 7-day average maximum temperature in lower Slate Creek was 13.1ºC (55.58ºF) between August 6 and August 12, 2000.

Temperature Near RM 2.6: R2 Resource Consultants (1998) recorded water temperatures near the confluence of Uncas Gulch and Slate Creek (approximately RM 2.6 on Slate Creek) using thermographs in 1996 and again from late July through early November 1997. The 7-day average maximum temperature for the period of record on Slate Creek was 11.7ºC (53.06ºF) between August 1 and 7, 1997 (R2 Resource Consultants 1998).

Water Quantity and Characteristics

At the mouth of Slate Creek (RM 0.0) the discharge was 0.31 m^3/s (10.95 ft^3/s) on July 31, 2000 (McLellan 2001). The mean gradient from seven reaches surveyed on Slate Creek was 6.3 percent (McLellan 2001). Entrix (2002) reported the maximum flow recorded as 0.3 m^3/s (11.0 ft^3/s).

Fish Species

Bull Trout: In 1998 the USFS documented that near the mouth of Slate Creek (RM 0.0) bull trout had been captured in 1994, 1995, and 1997 (USFS 1998 and 1999b). Five bull trout were captured using hook-and-line near the confluence of Slate Creek and Boundary Reservoir from 1994 and 1995 by USFS and WDFW biologists (R2 Resource Consultants 1998; Andonaegui 2003). Between 1996 and 1997, R2 Resource Consultants captured one bull trout near the confluence of Slate Creek and Boundary Reservoir (RM 0.0) during a 2-year fish sampling survey of the reservoir and its tributaries (R2 Resource Consultants 1998; Andonaegui 2003). R2 Resource Consultants (1998) documented that the USFS observed possible bull trout hybrids in the middle and upper reaches of Slate Creek.

Cutthroat Trout: Westslope cutthroat trout were found in Slate Creek (USFS 1998). Cutthroat trout were observed at sites in nine reaches on Slate Creek and North Fork Slate Creek at a mean density of 4 fish/100 m^2 (McLellan 2001). Cutthroat trout were observed in all of the reaches during snorkel surveys conducted in 2000, except the uppermost reach in North Fork Slate Creek (McLellan 2001).

Rainbow Trout: Rainbow trout were found in Slate Creek and, based on documentation of surveys provided by the USFS (1998), successful reproduction had been occurring (USFS 1998). Electrofishing conducted the next day after snorkel surveys in 1997 resulted in no rainbow trout captured in Slate Creek (R2 Resource Consultants 1998). Rainbow trout were only observed at one site out of nine reaches surveyed on Slate Creek and North Fork Slate Creek at a mean density of less than 1 fish/100 m^2 (McLellan 2001). In the study by McLellan (2001), rainbow trout were only observed in a single reach located upstream from the mouth of Slate Creek (RM 0.0).

Brook Trout: Brook trout were stocked in Slate Creek in 1981 (USFS 1998). In addition, earlier stocking of brook trout in Slate Creek prior to 1981 most likely occurred (USFS 1998; Andonaegui 2003). Brook trout have been observed during surveys in Slate Creek (R2 Resource Consultants 1998; McLellan 2001; Andonaegui 2003). In snorkel surveys conducted in 2000 at sites within nine reaches on Slate Creek and North Fork Slate Creek, McLellan (2001) reported eastern brook trout at a mean density of 1 fish/100 m^2 for the combined reaches. Within the stretch of Slate Creek between RM 0.0 and 0.75, brook trout can be found in this habitat competing for food and habitat, and interbreeding with bull trout (Shuhda 2007).

Brown Trout: During electrofishing surveys conducted the next day after snorkel surveys in 1997, no brown trout were observed in Slate Creek (R2 Resource Consultants 1998).

A.5.1.7 Slumber Creek

Barrier

Within Slumber Creek, upstream (RM 0.2) from the confluence with Slate Creek (RM 0.0) is a culvert, 2.4 m (8 ft) high and 5.2 m (17 ft) long, that is a complete barrier to fish passage (USFS 2002; Andonaegui 2003; POSRT 2005). At RM 2.3 Slumber Creek has been documented to dewater in August (see Appendix 1).

Riparian Conditions

A conifer/alder community is the dominant riparian vegetation documented for Slumber Creek (USFS 1998). Stream cover greater than 30 percent was reported in the USFS (2005) SMART database.

Channel Conditions and Dynamics

Channel Stability: The USFS (2005) SMART database reports the entrenchment ration between 1.7 and 2.0.

Habitat Elements

Channel Substrate: The present condition of substrate in Slumber Creek has been attributed to the drainage occurring in area of decomposed limestone (USFS 1998). Based on reaches surveyed in 1991 and 1997 by the USFS, cobble, gravel and sand were determined to be the dominant substrate with embeddedness greater than 35 percent (USFS 1998; Andonaegui 2003).

Within two reaches surveyed by the USFS (1999b), percent fines were between 40 and 90 percent.

LWD: Two stream reaches were surveyed by the USFS in Slumber Creek, and 155 and 167 pieces of LWD per mile were documented (USFS 1998; USFS 2005). In the two stream reaches surveyed of Slumber Creek the USFS (1998) reports that LWD is the primary source of instream cover.

Pool Frequency and Quality: The USFS conducted two stream reach surveys in Slumber Creek and determined there were 33 and 56 pools per mile in each of the surveyed reaches (USFS 1998; USFS 2005).

Pool Depth: In Slumber Creek pool depths have been documented to range between 0.61 and 0.91 m (2 and 3 ft) and provide suitable overwintering habitat (Andonaegui 2003). Based on observations during snorkel surveys, there were negligible amounts of fine sediment in pool substrate (USFS 1999b; Andonaegui 2003).

Wetted Width: Based on data available in the USFS (2005) SMART database, the average wetted width was 2.3 m (7.4 ft) in 2000 during surveys of Slumber Creek.

Fish Species

Cutthroat Trout: Westslope cutthroat trout were found in fish surveys of Slumber Creek (USFS 1998).

Brook Trout: Eastern brook trout were found in fish surveys of Slumber Creek (USFS 1998). Brook trout were stocked in Slumber Creek in 1981 (USFS 1998). However, earlier stocking of brook trout in Slumber Creek prior to 1981 most likely occurred (USFS 1998; Andonaegui 2003).

A.5.1.8 Uncas Gulch

Riparian Conditions

A conifer/alder and conifer/forb riparian vegetation community is documented for Uncas Gulch (USFS 1998).

Habitat Elements

Channel Substrate: The dominant substrates in the reaches surveyed in 1991 and 1997 by the USFS were cobble, gravel, and sand with embeddedness less than 35 percent (USFS 1998; Andonaegui 2003).

LWD: Three stream reaches were surveyed by the USFS in Uncas Gulch, and 218, 138, and 44 pieces of LWD per mile were documented in the reaches (USFS 1998). In the three stream reaches surveyed of Uncas Gulch the USFS (1998) reports that LWD is the primary source of instream cover.

Pool Frequency and Quality: Surveys conducted by the USFS resulted in documentation of 17, 22, and 10 pools per mile in three stream reaches surveyed (USFS 1998).

Pool Depth: Within Uncas Gulch pool depths range between 0.61 and 0.91 m (2 and 3 ft) and provide suitable overwintering habitat (Andonaegui 2003). Based on observations during snorkel surveys, there were negligible amounts of fine sediment in pool substrate (USFS 1999b; Andonaegui 2003).

Wetted Width: Based on data available in the USFS (2005) SMART database, the average wetted width was 4.1 m (13.3 ft) in 2000 during surveys of Uncas Gulch.

Fish Species

Cutthroat Trout: Westslope cutthroat trout were found in fish surveys of Uncas Gulch (USFS 1998).

Brook Trout: Eastern brook trout were found in fish surveys of Uncas Gulch (USFS 1998).

A.5.1.9 Styx Creek

Barrier

Within Styx Creek, upstream from the confluence of Styx Creek and South Fork Slate Creek (RM 0.10 on Styx Creek) the culvert, 3.96 m (13 ft) high, at USFS Road 3155 is a fish passage barrier (USFS 2002; Andonaegui 2003).

Riparian Conditions

A conifer/alder and conifer/forb riparian vegetation community is documented for Styx Creek (USFS 1998).

Habitat Elements

Channel Substrate: Determined from reaches surveyed in 1991 and 1997 by the USFS, the dominant substrates in Styx Creek were cobble, gravel, and sand with embeddedness less than 35 percent (USFS 1998a; Andonaegui 2003).

LWD: The USFS surveyed four stream reaches in Styx Creek and documented 141, 214, 102, and 128 pieces of LWD per mile in the surveyed reaches (USFS 1998). In the four stream reaches surveyed of Styx Creek the USFS (1998) reports that LWD is the primary source of instream cover.

Pool Frequency and Quality: Within the four stream reaches surveyed by the USFS, 4, 4, 11, and 4 pools per mile were documented for each of the surveyed reaches in Styx Creek (USFS 1998).

Pool Depth: Pool depths in Styx Creek range between 0.55 and 0.70 m (1.8 and 2.3 ft) and provide suitable overwintering habitat (Andonaegui 2003). Based on observations during snorkel surveys, there were negligible amounts of fine sediment in pool substrate (USFS 1999b; Andonaegui 2003).

Wetted Width: Based on data available in the USFS (2005) SMART database, the average wetted width was 1.8 m (5.8 ft) in 2000 during surveys of Slumber Creek.

Fish Species

Cutthroat Trout: Westslope cutthroat trout were found in fish surveys of Styx Creek (USFS 1998).

Brook Trout: Eastern brook trout were found in fish surveys of Styx Creek (USFS 1998).

A.5.1.10 North Fork Slate Creek

Barrier

Within the North Fork Slate Creek, located 300 m (984.3 ft) downstream from USFS Road 209 crossing (approximately RM 1.4), McLellan (2001) identifies a chute (27.5 m [90.2 ft] long, 1 m [3.3 ft] wide, with an 18 percent gradient) as a barrier. Upstream of this chute barrier McLellan (2001) provides an artificial barrier point (Figure 5.2-1.). However, McLellan (2001) provides no additional information, barrier dimensions, or reference for this barrier.

Habitat Elements

Channel Substrate: McLellan (2001) reported the dominant substrate types were cobble and boulder with a mean embeddedness of 3 percent based on sites surveyed in two reaches on Slate Creek.

LWD: McLellan (2001) conducted habitat surveys in sites within two reaches on North Fork Slate Creek and based on data available from the report, there was a mean of 604 pieces of LWD per mile.

Pool Frequency and Quality: McLellan (2001) conducted habitat surveys at sites within two reaches on North Fork Slate Creek and reported a mean of 23 large pools per mile.

Pool Depth: McLellan (2001) conducted habitat surveys at sites within two reaches on North Fork Slate Creek and the mean width, maximum depth, and residual depth for the combined reaches were 2.9 m (9.5 ft), 47.5 cm (18.7 in), and 30 cm (11.8 in), respectively.

Wetted Width: Based on data available from the McLellan (2001) survey of two stream reaches on North Fork Slate Creek, the average wetted width was 3.5 m (11.5 ft).

Water Quality

Temperature Near RM 0.9: McLellan (2001) measured the temperature of North Fork Slate Creek between June 28 and October 17, 2000. Using data reported by McLellan (2001), the 7-day average maximum temperature during the period of record in upper Slate Creek was 9.0ºC (48.2ºF) between August 3 and August 9, 2000.

Water Quantity and Characteristics

The mean gradient from two reaches surveyed on North Fork Slate Creek was 6.5 percent (McLellan 2001).

Fish Species

Cutthroat Trout: Westslope cutthroat trout were found in Slate Creek (USFS 1998). Cutthroat trout were observed at sites in nine reaches on Slate Creek and North Fork Slate Creek at a mean density of 4 fish/100 m^2 (McLellan 2001). Cutthroat trout were observed in all of the reaches during snorkel surveys conducted in 2000, except the uppermost reach in North Fork Slate Creek (McLellan 2001).

Brook Trout: Brook trout were stocked in Slate Creek in 1981 (USFS 1998). In addition, earlier stocking of brook trout in Slate Creek prior to 1981 most likely occurred (USFS 1998; Andonaegui 2003). Brook trout have been observed during surveys in Slate Creek (R2 Resource Consultants 1998; McLellan 2001; Andonaegui 2003). In snorkel surveys conducted in 2000 at sites within nine reaches on Slate Creek and North Fork Slate Creek, McLellan (2001) reported eastern brook trout at a mean density of 1 fish/100 m^2 for the combined reaches. Within the stretch of Slate Creek between RM 0.0 and 0.75, brook trout can be found in this habitat competing for food and habitat, and interbreeding with bull trout (Shuhda 2007).

A.5.1.11 South Fork Slate Creek

Fish Species

Cutthroat Trout: Westslope cutthroat trout were found in fish surveys of South Fork Slate Creek (USFS 1998).

Brook Trout: Eastern brook trout were found in fish surveys of South Fork Slate Creek (USFS 1998).

A.5.1.12 Threemile Creek

Barrier

The naturally occurring falls (5.0 m [16.4 ft] high) at the mouth of Threemile Creek is a barrier to fish passage, making the creek disconnected from Boundary Reservoir (McLellan 2001; Andonaegui 2003; WDFW SalmonScape 2007). The USFS (1998) documents that Threemile

Creek is intermittent and non-fish bearing where the creek flows through National Forest lands. Approximately at RM 0.15 there is a fish passage barrier (POSRT 2005).

Riparian Conditions

A conifer/alder riparian vegetation community is documented for Threemile Creek (USFS 1998).

Habitat Elements

Channel Substrate: Sand and gravels were dominant substrates with embeddedness greater than 35 percent for the reaches surveyed in 1991 and 1997 (USFS 1998). The USFS notes in the 1998 Slate Salmo Watershed Assessment that for the existing geology there was an excessive amount of sand present in Threemile Creek (USFS 1998).

LWD: In Threemile Creek the USFS surveyed two reaches and documented 149 and 518 pieces of LWD per mile for the surveyed reaches (USFS 1998). In the two stream reaches surveyed of Threemile Creek the USFS (1998) reports that LWD is the primary source of instream cover.

Pool Frequency and Quality: In two stream reaches surveyed by the USFS (1998), 20 and 15 pools per mile were documented for each of the surveyed reaches.

Water Quality

Temperature: The USFS (1998) documents temperatures in Threemile Creek reaching 7.2ºC (45ºF) during the summer. McLellan (2001) measured water temperature near the mouth (RM 0.0) of Threemile Creek with a thermograph from June 28 to October 17, 2000. Based on the data available from the McLellan (2001) report, the 7-day average maximum temperature was 10.4ºC (50.72ºF) between August 6 and August 12, 2000.

Water Quantity and Characteristics

The mean gradient was 10.5 percent in the drainage upstream from the natural barrier at the mouth (RM 0.0) (WDFW SalmonScape 2007).

Fish Species

Rainbow Trout: Within the private lands of Threemile Creek a sustaining population of rainbow trout has been documented (USFS 1998). The USFS (1998) reported that Threemile Creek is intermittent and non-fish bearing where the creek flows through National Forest lands.

Brook Trout: Within the private lands of Threemile Creek a sustaining population of eastern brook trout has been documented (USFS 1998; USFS 2005). The USFS (1998) documents that Threemile Creek is intermittent and non-fish-bearing where the creek flows through National Forest lands.

A.5.1.13 Beaver Creek

Barriers

A natural 25.3 m (83 ft) falls at the mouth of Beaver Creek is a fish passage barrier (McLellan 2001; Andonaegui 2003; WDFW SalmonScape 2007). Approximately at RM 1.1 there is a fish passage barrier (POSRT 2005).

Water Quantity and Characteristics

The mean gradient was 12.7 percent in the drainage upstream from the natural barrier at the mouth (RM 0.0) (WDFW SalmonScape 2007).

A.5.1.14 Flume Creek

Barriers

A vertical waterfall that is 13.0 m (43 ft) high is located at RM 0.2 and is a fish passage barrier (McLellan 2001; R2 Resource Consultants 1998; Andonaegui 2003; WDFW SalmonScape 2007). A culvert under the County Road, Boundary Road, at RM 1.0 is a potential fish passage barrier, and was approximately 2.5 m (8.2 ft) above the surface of the plunge pool (McLellan 2001; Andonaegui 2003; POSRT 2005). At RM 4.75 the culvert crossing at the USFS Road 350 is a potential fish passage barrier, as the culvert mouth was 1.5 m (4.9 ft) high and there was no plunge pool below it in 2000 (McLellan 2001; USFS 2002; Andonaegui 2003).

Riparian Conditions

Habitat units surveyed by R2 Resource Consultants (1998) in Flume Creek were found to have a percent cover supplied by overhanging vegetation of 10 percent. In addition, the mean canopy cover was 22 percent (R2 Resource Consultants 1998). Percent of stream channel covered was reported as between 20 and 30 percent in the USFS (2005) SMART database.

Channel Conditions and Dynamics

Streambank Condition: Habitat units surveyed by R2 Resource Consultants (1998) in Flume Creek were found to have an average undercut bank cover of 10.2 percent.

Habitat Elements

Channel Substrate: R2 Resource Consultants (1998) reported a mean of 10 percent for surface fines from surveys in Flume Creek. McLellan (2001) conducted habitat surveys within four reaches on Flume Creek and determined the dominant substrate as cobble.

LWD: McLellan (2001) conducted habitat surveys within four reaches on Flume Creek and documented a mean of 357 pieces of LWD per mile. Within habitat units surveyed throughout

Flume Creek, including the Middle and South Fork, R2 Resource Consultants (1998) found four to six pieces of LWD per habitat unit.

Pool Frequency and Quality: McLellan (2001) conducted habitat surveys within four reaches on Flume Creek and determined the dominant habitat type was riffle (86 percent). Although riffle was reported as the dominant habitat type, McLellan (2001) reported a mean of 19 large pools per mile. The dominant habitat type in Flume Creek is riffle as reported by Andonaegui (2003).

Pool Depth: Average maximum depths for habitat units surveyed throughout Flume Creek, including the Middle and South Forks, were reported to be around 0.5 m (1.5 ft) deep (R2 Resource Consultants 1998). McLellan (2001) conducted habitat surveys within four reaches on Flume Creek and determined the mean width, maximum depth, and residual depth for all four reaches were 2.6 m (8.5 ft), 37cm (14.6 in), and 18 cm (7.1 in), respectively.

Wetted Width: McLellan (2001) reported the average wetted width was 4.5 m (14.8 ft) in 2000 from surveys of four stream reaches.

Water Quality

Temperature at RM 0.0: In a water temperature study conducted in Boundary Reservoir by R2 Resource Consultants, cool-water refugia were available for salmonids during August and September at the confluence of the creek and the reservoir. However, the cool water zone was relatively small in size, but well defined (R2 Resource Consultants 1998; Andonaegui 2003). From August 15 through October 27, 1996, and again from July 25 through November 11, 1997, hourly recordings of water temperatures were collected at the mouth of Flume Creek (RM 0.0) (R2 Resource Consultants 1998). The 7-day average maximum temperature during the period of record was 14.2ºC (57.6ºF) between August 1 and 7, 1997 (R2 Resource Consultants 1998). Between June 28 and October 17, 2000, the water temperature in lower Flume Creek was measured with an electronic thermograph (McLellan 2001). The maximum temperature recorded near RM 0.0 on Flume Creek in 2000 was 14.71ºC (58.46ºF) on July 21 and 29, and the minimum was 3.19ºC (37.74ºF) on October 6 (McLellan 2001; Andonaegui 2003). Based on the data available from the McLellan (2001) report, the 7-day average maximum temperature was 14.3ºC (57.74ºF) between July 31 and August 6, 2000.

Temperature between RM 2.2 and 3.3: From August 15 through October 27, 1996, and again from July 25 through November 11, 1997, hourly recordings of water temperatures were collected between the South and Middle forks of Flume Creek (approximately RM 2.2) (R2 Resource Consultants 1998). The 7-day average maximum temperature during the period of record was 12.6ºC (54.7ºF) between August 24 and 30, 1996 (R2 Resource Consultants 1998). Between June 28 and October 17, 2000, the water temperature in upper Flume Creek (near RM 3.3) was measured with an electronic thermograph (McLellan 2001). The maximum temperature recorded within upper Flume Creek in 2000 was 12.68ºC (54.82ºF) on August 9, and the minimum was 2.88ºC (37.18ºF) on October 6 (McLellan 2001; Andonaegui 2003). Based on the data available from the McLellan (2001) report, the 7-day average maximum temperature for upper Flume Creek was 12.4ºC (54.32ºF) between August 7 and August 13, 2000. The USFS deployed a thermograph at the USFS boundary (approximately RM 3.1) on Flume Creek from

July 24 to September 30, 2002 (Andonaegui 2003). The 7-day average maximum temperature during the period of record at the USFS boundary on Flume Creek was 11.5ºC (52.7ºF) and the maximum temperature was 12.6ºC (54.7ºF) (Honeycutt 2003 as cited in Andonaegui 2003).

Water Quantity and Characteristics

McLellan (2001) determined the discharge on September 6, 2000, to be 0.25 m^3/s (8.83 ft^3/s). The mean gradient from four reaches surveyed on Flume Creek was 7 percent (McLellan 2001). The CNF TMDL (Ecology 2005) reported average flow July between August to be 0.05 m^3/s (1.9 ft^3/s).

Fish Species

Bull Trout: Access to habitat is limited for migratory life history forms of bull trout (Andonaegui 2003). Bull trout have not been detected in Flume Creek from snorkeling and electrofishing surveys (R2 Resource Consultants 1998; USFS 1999a; McLellan 2001; Andonaegui 2003). However, habitat within Flume Creek has been identified as "Suitable" by the TAG (Andonaegui 2003).

Cutthroat Trout: Two cutthroat trout were observed in upper Flume Creek (R2 Resource Consultants 1998). Electrofishing conducted the next day after snorkel surveys in 1997 resulted in no cutthroat trout captured in Flume Creek (R2 Resource Consultants 1998). The POSRT (2005) documents the presence of cutthroat trout in Flume Creek.

Rainbow Trout: Electrofishing conducted the next day after snorkel surveys in 1997 resulted in no rainbow trout captured in Flume Creek (R2 Resource Consultants 1998).

Brook Trout: From day creel surveys conducted on Flume Creek in 1950, 1959, and 1960, brook trout were the only fish captured (WDFW, unpublished data as cited in McLellan 2001). Brook trout have been documented as the dominant fish species in Flume Creek (R2 Resource Consultants 1998; McLellan 2001; Andonaegui 2003). In 1997, during snorkel surveys, Flume Creek was comprised almost exclusively of brook trout (R2 Resource Consultants 1998). During snorkel surveys in 2000, McLellan (2001) reported that brook trout were the only fish species observed (9 fish/100 m^2) throughout Flume Creek. The majority of brook trout (20 fish/100 m^2) were observed between the confluence of the Middle Fork Flume Creek with the mainstem Flume Creek (approximately RM 3.3) and 500 m upstream (1,640.4 ft). However, within the headwaters of Flume Creek (approximately upstream from RM 4.3) no fish were observed (McLellan 2001).

Brown Trout: During electrofishing surveys conducted the next day after snorkel surveys in 1997, no brown trout were observed in Flume Creek (R2 Resource Consultants 1998).

A.5.1.15 South Fork Flume Creek

Barriers

Approximately at RM 0.3 on South Fork Flume Creek there is a potential fish passage barrier (POSRT 2005).

Habitat Elements

Wetted Width: Based on data available in a report by R2 Resource Consultants (1998), the average wetted width was 3.1 m (10.2 ft).

A.5.1.16 Middle Fork Flume Creek

Habitat Elements

Wetted Width: Based on data available in a report by R2 Resource Consultants (1998), the average wetted width was 3.1 m (10.3 ft).

Water Quantity and Characteristics

R2 Resource Consultants (1998) noted that Middle Fork Flume Creek is relatively undisturbed.

Fish Species

Bull Trout: Habitat is documented as relatively undisturbed and containing possible bull x brook trout hybrids (R2 Resource Consultants 1998).

Brook Trout: In the Middle Fork Flume Creek several unusual brook trout phenotypes were observed with markings similar to those observed in brook trout *x* bull trout hybrids (R2 Resource Consultants 1998).

A.5.2SULLIVAN CREEK WAU

A.5.2.1 Sullivan Creek

Barriers

Between RM 0.0 and 2.35: Within the mainstem Sullivan Creek, between RM 0.6 and 0.65, natural cascades and chutes have been documented to potentially prevent fish passage under some stream flow conditions (CES 1996; Andonaegui 2003). However, there is disagreement on the degree to which the cascades and chutes prevent fish passage under all conditions and flows (Andonaegui 2003). CES (1996) evaluated the barriers under multiple flows on various days (September 22, 1994, at 1.4 cubic meters per second [m^3/s] (50 cubic feet per second [ft^3/s]); July 6, 1995, at 5.6 m^3/s [198 ft^3/s]; August 7, 1995, at 2.0 m^3/s [72 ft^3/s]; November 2, 1995, at 5.4 m^3/s [192 ft^3/s]; November 4, 1995, at 9.1 m^3/s [323 ft^3/s]) and determined that passage under

certain flow conditions is possible between RM 0.6 and 0.65. However, CES (1996) did determine that barriers may be a primary factor in the absence of both fluvial and adfluvial populations of bull trout in Sullivan Creek upstream of RM 0.65. McLellan (2001) noted that CES (1996) had determined the cascades and chutes between RM 0.6 and 0.65 as potential barriers. However, McLellan (2001) identified neither of them as barriers in 2000.
At RM 3.25: The Mill Pond Dam at RM 3.25 on the mainstem Sullivan Creek is a complete barrier to fish passage (R2 Resource Consultants 1998; USFS 1999d; McLellan 2001; Andonaegui 2003). The Mill Pond Dam height is 16.8 m (55 ft) (Andonaegui 2003).

Riparian Conditions

Hemlock/wild ginger with thinleaf alder on point bars and other depositional areas described the climax riparian vegetation for the mainstem Sullivan Creek (USFS 1996). The USFS (1996) noted that the existing riparian vegetation contained spruce with some small cedar and hemlock, and a lack of shrubs and herbaceous cover caused a decrease in the duff layer. The lack of shrubs and herbaceous cover were attributed to disperse recreational sites (USFS 1996). The USFS (1996) reported that by the mid-1980s, road density was between 1.7 and 2 miles per square mile. Historically, the riparian areas along main Sullivan Creek have been harvested and have roads located within some of the riparian areas (USFS 1999d). In addition, the USFS (1999d) states that the majority of the road system is inside of riparian areas, and portions of the riparian areas have been replaced by forest and county road systems limiting the total riparian areas from historic levels. However, the USFS (1999d) also states that drainage-wide there are limited road crossings and riparian areas are continuous in nature. The USFS (1999d) concludes that the width of existing riparian buffers may not be adequate to filter all sediments leaving road surfaces, particularly in valley bottoms of the drainage. Habitat units surveyed by R2 Resource Consultants (1998) in Sullivan Creek were found to have a percent cover supplied by overhanging vegetation of 4 percent. In addition, the mean canopy cover was 10 percent (R2 Resource Consultants 1998). Entrix (2002) reported that aquatic habitat has been most influenced by historic timber harvest, especially clearcutting of riparian areas, road building, fires, and dispersed recreation. Of approximately 234 miles of road within the WAU, nearly 46 miles are within 61 m (200 ft) of streams, with Sullivan Creek Road open and adjacent to Sullivan Creek for most of its length (Entrix 2002). Andonaegui (2003) determined that although "the riparian vegetation is not at a climax condition, over 50 percent of the existing vegetation is what would be expected of these conditions." Overall, adequate shade, detritus, and LWD are provided by the riparian area for the Sullivan Creek WAU (Andonaegui 2003). Above bankfull flow there is high vegetative cover (75 percent or greater) and well-established riparian communities (Andonaegui 2003).

Channel Conditions and Dynamics

Streambank Condition: Above bankfull flow, streambanks have high vegetative cover and well-established riparian communities (Andonaegui 2003). The primary erosional process throughout the drainage is landslides (USFS 1996; Andonaegui 2003). Habitat units surveyed by R2 Resource Consultants (1998) in Sullivan Creek were found to have an average undercut bank cover of 3 percent. The channel is deeply entrenched and confined as it cuts through a rock canyon (USFS 1996; Andonaegui 2003). Along some sections of the south side of Sullivan

Creek the bank slopes are unstable due to a closed-box flume that was used to transport water to a power house near the mouth of Sullivan Creek (Andonaegui 2003). The closed-box flume historically, and as recently as 1997, had caused landslides into Sullivan Creek (USFS 1999d; Andonaegui 2003). Sections of Sullivan Creek downstream from and continuing upstream from Mill Pond Dam are historically prone to landslide activity (USFS 1996; Andonaegui 2003). Based on a USFS report in 1996, the banks along Sullivan Creek were documented as "generally in pretty stable condition" (USFS 1996). However, from the confluence of North Fork Sullivan Creek with the mainstem Sullivan Creek (RM 2.35), upstream to Gypsy Creek (RM 13.8), sections of the channel have been straightened (USFS 1996; Andonaegui 2003).

Floodplain Connectivity: Throughout the Sullivan Creek drainage, channels primarily comprise narrow V- or U-shaped valley forms (Rosgen A and B channel types) and do not and did not historically have many oxbows, backwater, and ponds (USFS 1996; Andonaegui 2003). Channels comprising narrow V- or U-shaped valley forms have relatively small floodplains and riparian areas, and lack off-channel habitat and extensive wetlands areas. Although lacking off-channel habitat, the Sullivan Creek WAU does have some stream margins providing shallow water habitat and some side channel habitat resulting from accumulated complexes of woody debris forming bars and initiating channel braiding (USFS 1999d; Andonaegui 2003). The channel is deeply entrenched and confined as it cuts through a rock canyon between RM 0.0 and 2.35 (USFS 1996; Andonaegui 2003).

Channel Stability: The channel has deepened and stabilized, mid-channel bars have generally disappeared, and lateral migration has ceased from the mouth upstream beyond Mill Pond Dam (USFS 1996; Andonaegui 2003). In 1996 the USFS determined that changes in the flow regime and the bed load transport had resulted from the construction of Mill Pond Dam and Sullivan Lake Dam (USFS 1996). However, the USFS (1996) noted that the effect within Sullivan Creek below Mill Pond Dam from the reduced peak spring (channel maintenance) flows and the reduced sediment load is difficult to determine. Instream restoration activities that have occurred in Sullivan Creek, downstream of Sullivan Lake Dam, have been blown out in the past due to flows exceeding 28.3 m^3/s (1,000 ft^3/s) in the spring during high run-off years (POPUD 2003 as cited in Andonaegui 2003). Within Sullivan Creek, channel stability ranges from good to excellent (Wasson 1992 as cited in USFS 1996; Andonaegui 2003). In contrast, the POSRT (2005) documented altered channel morphology as a bull trout habitat limiting factor. The USFS (2005) SMART database documents the entrenchment ration as between 1.1 and 2.0.

Habitat Elements

Channel Substrate between RM 0.0 and 3.25: This section of Sullivan Creek is primarily a bedrock-dominated channel (USFS 1996; Andonaegui 2003). Within this section of Sullivan Creek, flooding and scouring can frequently occur, and spring high flows (exceeding 28.3 m^3/s [1,000 ft^3/s] at times) are likely occurrences when bull trout eggs and alevins are still in the gravel (CES 1996; Andonaegui 2003). In the 1950s and 1960s, Sullivan Creek from RM 0.5 to 2.1 was straightened through the placement of riprap and gabion structures (Andonaegui 2003). The channel-straightening activity may have increased the intensity of flooding and scouring downstream of RM 2.1. However, Andonaegui (2003) reports that substrate is not a limiting factor in Sullivan Creek downstream of Mill Pond Dam (RM 3.25). Bedload material is deficient downstream of Mill Pond Dam (RM 3.25), because all bedload and most suspended sediment are retained behind the dam (USFS 1996; Andonaegui 2003). The USFS (1996) determined that this section of Sullivan Creek is lacking in spawning gravels caused by sediment being retained behind Mill Pond Dam. Regarding the fate of Mill Pond, the USFS (1996) reported that eventually the pond will fill with sediment and become a large wetland. In surveying sites within three reaches of Sullivan Creek downstream of Mill Pond Dam, McLellan (2001) reported the dominant substrate as rubble for two of the reaches and boulder for the other reach. Within this section of Sullivan Creek the scarcity of spawning size material, due to the interception of Mill Pond Dam, is a limiting factor (Shuhda 2007). The USFS (2005) SMART database documents greater than 20 percent fines.

LWD between RM 0.0 and 3.25: Downstream of Mill Pond Dam (RM 3.25) woody debris that creates habitat complexity is generally lacking (CES 1996; Andonaegui 2003). Within the steep-walled canyon in lower Sullivan Creek, LWD has been described as being "flushed" during high winter flows (CES 1996; Andonaegui 2003). Five out of nine reaches surveyed in this section of Sullivan Creek had less than 20 pieces of LWD per mile (USFS 1996; Andonaegui 2003). Sullivan Creek historically had LWD jams, but channel straightening and removal of LWD jams between the 1950s and 1970s, from North Fork Sullivan Creek (RM 2.35) upstream, may have simplified the channel (USFS 1996; Andonaegui 2003). McLellan (2001) conducted habitat surveys at sites within three reaches in lower Sullivan Creek, and based on data available from the 2001 report, there was a mean of 70 pieces of LWD per mile.

Pool Frequency and Quality between RM 0.0 and 3.25: Within Sullivan Creek pools are lacking (USFS 1996; Andonaegui 2003). Bedrock and boulder structure throughout the canyon reach of Sullivan Creek have been documented to create some pools, contribute to hydraulic complexity, and provide overhead cover (CES 1996; Andonaegui 2003). Downstream of the canyon reach (between RM 0.0 and 0.6), riffles, boulder runs, and low-gradient cascades have been documented as the primary habitat unit (CES 1996; Andonaegui 2003). In habitat surveys conducted in 2000 throughout Sullivan Creek, McLellan (2001) reported the dominant habitat type as riffles (69 percent). In three reaches surveyed downstream of RM 3.25, McLellan (2001) reported a mean of 10.4 large pools per mile. The POSRT (2005) documented degraded pool habitat as a bull trout habitat limiting factor.

Pool Depth between RM 0.0 and 3.25: McLellan (2001) conducted habitat surveys in three reaches downstream of RM 3.25. However, only results from two of the surveyed reaches were provided in McLellan (2001). Based on the information provided, the mean width, maximum depth, and residual depth for the two reaches were 15.3 m (50.2 ft), 161 cm (63.4 in), and 100 cm (39.4 in), respectively.

Wetted Width between RM 0.0 and 3.25: The average wetted width was 17.9 m (58.7 ft) in 2000 from surveys conducted of three reaches in lower Sullivan Creek (McLellan 2001).

Water Quality

Temperature at RM 0.0: In a water temperature study conducted in Boundary Reservoir by R2 Resource Consultants, cool water refugia were available for salmonids during August and

September at the confluence of the creek and the reservoir. However, the cool water zone was relatively small in size, but well defined (R2 Resource Consultants 1998, Andonaegui 2003). The Sullivan Lake impoundment modifies water temperatures in lower reaches of Sullivan Creek (R2 Resource Consultants 1998; Andonaegui 2003). From August 15 through October 27, 1996, and again from July 25 through November 11, 1997, hourly recordings of water temperatures were collected at the mouth of Sullivan Creek (R2 Resource Consultants 1998; Andonaegui 2003). The 7-day average maximum temperature during the period of record was 16.9ºC (62.4ºF) between August 24 and 30, 1996 (R2 Resource Consultants 1998; Andonaegui 2003). Throughout the 1997 monitoring period warm water temperatures, measured approximately at RM 1.7 by R2 Resource Consultants (1998), demonstrated the warming effect of Mill Pond Dam on waters discharged from Sullivan Lake and flowing towards the mouth of Sullivan Creek (Andonaegui 2003). During bull trout incubation, rearing, and spawning periods in lower Sullivan Creek the USFS (1999d) calculated the 7-day average maximum temperatures to be 9.6ºC (49.2ºF), 18.3ºC (64.9ºF), and 14.9ºC (58.9ºF), respectively. Between June 28 and October 19, 2000, the water temperature of lower Sullivan Creek (upstream of RM 2.35) was measured with an electronic thermograph (McLellan 2001; Andonaegui 2003). The maximum temperature recorded for lower Sullivan Creek in 2000 was 18.86ºC (66.0ºF) on August 9, and the minimum was 4.93ºC (40.87ºF) on September 23 (McLellan 2001; Andonaegui 2003). The 7-day average maximum temperature during the period of record was 18.2ºC (64.8ºF) between August 8 and August 14, 2000 (McLellan 2001). The USFS deployed a thermograph at the USFS boundary on lower Sullivan Creek from July 24 to October 28, 2002, and determined the 7-day average maximum temperature to be 17.1ºC (62.8ºF) (K. Honeycutt, USFS, email. comm., 2003 as cited in Andonaegui 2003).
Temperature approximately at RM 0.6: Between May 19, 1993, and October 17, 1997, stream temperatures were recorded weekly, and the maximum temperature was 19.7ºC (67.4ºF) recorded in July and August 1994 (CES 1996; Andonaegui 2003). The minimum stream temperature between May 1993 and October 1997 was -4.8ºC (23.3ºF) recorded in February 1994 (CES 1996; Andonaegui 2003). During the stream temperature recording from May 1993 to October 1997, the 7-day average minimum temperature was -1.8ºC (28.8ºF) (January 4 through 10, 1995), and the 7-day average maximum temperature was 24.7ºC (76.4ºF) (July 22 through 29, 1994) (CES 1996; Andonaegui 2003).

Temperature approximately at RM 1.7: The Sullivan Lake impoundment modifies water temperatures in lower reaches of Sullivan Creek (R2 Resource Consultants 1998; Andonaegui 2003). From August 15 through October 27, 1996, and again from July 25 through November 11, 1997, hourly recordings of water temperatures were collected midway between the Lime Lake Road turnoff (approximately RM 1.2) and the North Fork confluence with Sullivan Creek (RM 2.35) (R2 Resource Consultants 1998; Andonaegui 2003). The 7-day average maximum temperature during the period of record was 14.0ºC (57.2ºF) between August 1 and 7, 1997 (R2 Resource Consultants 1998; Andonaegui 2003). Throughout the 1997 monitoring period warm water temperatures, measured approximately at RM 1.7 by R2 Resource Consultants (1998), demonstrated the warming effect of Mill Pond Dam on waters discharged from Sullivan Lake and flowing towards the mouth of Sullivan Creek (Andonaegui 2003). A difference of nearly 6.5ºC (43.7ºF) in the maximum daily temperature was determined between the thermograph stations at the mouth of Sullivan Creek (RM 0.0) and the station at approximately RM 1.7 (R2 Resource Consultants 1998; Andonaegui 2003). The difference of nearly 6.5ºC (43.7ºF) between these two monitoring stations was greater than the differences observed in upper and lower temperature monitoring stations in Slate and Flume creeks (Slate Creek WAU), and Sweet and Sand creeks (Box Canyon WAU) during the same period of record (R2 Resource Consultants 1998; Andonaegui 2003).

Temperature downstream of RM 3.25: During the summer months water temperatures can exceed 16ºC (60.8ºF), with release from Mill Pond Dam increasing water temperature by approximately 0.5 to 1ºC (32.9 to 33.8ºF) (Shuhda 2007). The CNF TMDL (Ecology 2005) reported average July – August flow to be 0.02 m^3/s (0.76 ft^3/s). Pickett (2004) reported that Sullivan Creek required a TMDL. The POSRT (2005) documented elevated stream temperature as a bull trout habitat limiting factor.

Temperature at RM 3.25: Stream temperatures were collected at Mill Pond Dam (RM 3.25) from March 1, 1993 to June 26, 1993, and again from August 13, 1993 to October 17, 1995, and the maximum temperature recorded was 18.9ºC (66.0 ºF) recorded in July 1994 (CES 1996; Andonaegui 2003). The minimum stream temperature during the period of record was -0.8ºC (30.6ºF) recorded in January 1995 (CES 1996; Andonaegui 2003). Throughout both stream temperature recording periods, the 7-day average minimum temperature was -0.5ºC (31.1ºF) (January 2 through 8, 1995), and the 7-day average maximum temperature was 18.3ºC (64.9ºF) (July 24 through 30, 1994) (CES 1996; Andonaegui 2003).

Water Quantity and Characteristics

In the 1950s and 1960s, Sullivan Creek from RM 0.5 to 2.1 was straightened through the placement of riprap and gabion structures (Andonaegui 2003). The channel-straightening activity may have increased the intensity of flooding and scouring downstream of RM 2.1. On August 16, 2000, the discharge was 2.20 m^3/s (77.69 ft^3/s) near the mouth (RM 0.0) of Sullivan Creek (McLellan 2001). Using data from McLellan (2001), the mean channel gradient was calculated to be 2.3 percent based on results from surveys of three stream reaches, ranging between 1 and 4 percent, downstream of RM 3.25. The average stream gradient between North Fork Sullivan Creek (RM 2.35) and Highway 31 has been reported as 4 percent (USFS 1996; McLellan 2001; R2 Resource Consultants 2006), with stream reaches ranging between 4 and 10 percent (USFS 1996). The average annual flow has been reported as 7.1 m^3/s (251.1 ft^3/s) at the mouth of Sullivan Creek (RM 0.0) (Entrix 2002). Entrix (2002) determined that at a point near Metaline Falls (near RM 0.0), monthly average flows are higher in May and June, ranging between 19.4 and 21.7 m^3/s (685.9 and 764.9 ft^3/s), respectively, than throughout the rest of the year. In addition, Entrix (2002) determined that at a point near Metaline Falls (near RM 0.0), minimum flows occurred in both January and February, ranging between 2.3 and 2.1 m^3/s (81.4 and 73.5 ft^3/s), and August and September, ranging between 2.6 and 2.4 m^3/s (91.1 and 85.4 ft^3/s). Baseflows have been measured as low as 1.4 m^3/s (50 ft^3/s), and the maximum flow recorded exceeded 56.6m^3/s (2000 ft^3/s) below Mill Pond Dam as described in a 1996 USFS report of the Sullivan Creek Watershed (Wasson 1992 as cited in USFS 1996). The USFS (1996) noted that the maximum spring run-off flows, downstream of Sullivan Lake Dam, is perhaps half to three quarters the historic levels. Artificial raising and lowering of water levels in Sullivan Lake behind Sullivan Lake Dam have moderated flows from natural levels downstream of Sullivan Lake Dam to the mouth of Sullivan Creek (USFS 1999d; Andonaegui

2003). The Sullivan Lake impoundment alters the flow regime of the lower reaches of Sullivan Creek (R2 Resource Consultants 1998; Andonaegui 2003). Specifically, the manipulation of streamflow through the release of water from Sullivan Lake Dam in the fall (first week of October) changes from between 1.4 and 2.1 m^3/s (50 to 75 ft^3/s) to between 8.5 and 11.3 m^3/s (300 to 400 ft^3/s) in one day within Sullivan Creek between RM 0.0 and 3.25 (Shuhda 2007). These large fluctuations in stream flow, due to the release of water from Sullivan Lake Dam, may drive fry and juvenile fish into the open, making them more susceptible to predation. Although the increase in streamflow during the fall provides access to additional spawning habitat within lower Sullivan Creek, as discharge decreases from approximately 11.3 m^3/s (400 ft^3/s) back to 1.4 m^3/s (50 ft^3/s) between October and December, redds may become dewatered before emergence (Shuhda 2007).

Fish Species

Bull Trout: A biologist for CES in 1993 observed an adult bull trout in approximately 2.4 m (8 ft) of water downstream of a natural chute at RM 0.65 (CES 1996; Andonaegui 2003). However, positive identification of the bull trout through repeated diving at the location was not feasible due to high water velocities, water depth, and turbulence at the location (Blum 2002 as cited in Andonaegui 2003). In 1993 and 1994, no live bull trout were identified between RM 0.0 and RM 3.25 from electrofishing several locations (CES 1996). However, CES (1996) did find one dead female bull trout in proximity to the mouth of Sullivan Creek during the 1993 surveys. In lower Sullivan Creek, downstream of RM 3.25 to the confluence with the Pend Oreille River (RM 0.0), no bull trout were observed during surveys in 1994 and 1995 (CES 1996).

Cutthroat Trout: Cutthroat trout were observed and identified during surveys in 1993, 1994, and 1995 of Sullivan Creek between the mouth (RM 0.0) and Mill Pond Dam (RM 3.25) (CES 1996). From snorkel surveys in Sullivan Creek downstream of Mill Pond Dam, McLellan (2001) found cutthroat trout density to be less than 1 fish/100 m^2.

Rainbow Trout: In Sullivan Creek, rainbow trout were the most common fish species observed during snorkel surveys in 1997 (R2 Resource Consultants 1998). Electrofishing conducted the next day after snorkel surveys in 1997 resulted in an intermediate amount of cutthroat captured in Sullivan Creek (R2 Resource Consultants 1998). Rainbow trout were documented by the USFS (1996) as found only in the mainstem of Sullivan Creek up to the confluence of Rainy Creek (Rainy Creek is beyond the focus study area described for the Sullivan Creek WAU). However, documentation of native redband rainbow trout in the Pend Oreille River system between Albeni Falls and Boundary Dam is limited based on POPUD statements (POPUD 2003 as cited in Andonaegui 2003). From snorkel surveys of 55 sites within 20 stream reaches, McLellan (2001) found rainbow trout density to be less than 1 fish/100 m^2. Rainbow trout were observed in lower Sullivan Creek during surveys in 1993, 1994, and 1995 (CES 1996). From snorkel surveys in Sullivan Creek downstream of Mill Pond Dam, McLellan (2001) found rainbow trout density to be greater than 1 fish/100 m^2. Within the stretch of Sullivan Creek downstream of Mill Pond Dam (RM 3.25), rainbow trout can be found in this habitat competing for food and habitat, and interbreeding with cutthroat trout (Shuhda 2007).

Brook Trout: Brook trout have been observed in Sullivan Creek (R2 Resource Consultants 1998; McLellan 2001; Andonaegui 2003). In the USFS (1996) watershed assessment of Sullivan Creek, eastern brook trout were found throughout Sullivan Creek, spawning and rearing in tributary habitats, with very little spawning occurring in the mainstem of Sullivan Creek. From snorkel surveys of 55 sites within 20 stream reaches, McLellan (2001) found brook trout density to be less than 1 fish/100 m^2. Brook trout were observed between the mouth of Sullivan Creek (RM 0.0) and Mill Pond Dam (RM 3.25) during fish surveys conducted in 1993, 1994, and 1995 (CES 1996; Andonaegui 2003). Brook trout were not observed in Sullivan Creek downstream of Mill Pond Dam (RM 3.25) during snorkel surveys conducted between August 7 and August 16, 2000 (McLellan 2001). Within the stretch of Sullivan Creek downstream of Mill Pond Dam (RM 3.25), brook trout can be found in this habitat competing for food and habitat, and interbreeding with bull trout (Shuhda 2007). R2 Resource Consultants (2006) also reported the presence of brook trout in Sullivan Creek.

Brown Trout: Brown trout were observed in lower Sullivan Creek during surveys conducted in 1993, 1994, and 1995 (CES 1996). Brown trout are known to occur downstream of Mill Pond Dam, though not in the tributaries (T. Shuhda 2002 as cited in Andonaegui 2003). An adfluvial population of brown trout utilizes the Pend Oreille River and spawns in Sullivan Creek downstream of Mill Pond Dam (USFS 1996). However, the lower chutes and cascades at RM 0.6 and 0.65 have been suggested as barriers to fish passage, limiting access to upstream migration (Andonaegui 2003). The USFS (1996) documented that streams in eastern Washington had not been stocked with non-native salmonid fish species since the mid-1980s. Electrofishing conducted the next day after snorkel surveys in 1997 resulted in relative low densities (0.02 fish/m^2) of brown trout at sites surveyed in Sullivan Creek (R2 Resource Consultants 1998). From snorkel surveys in Sullivan Creek downstream of Mill Pond Dam, McLellan (2001) found brown trout density to be less than 1 fish/100 m^2.

Mountain Whitefish: Next to rainbow trout, mountain whitefish was the second most common fish species observed during snorkel surveys of Sullivan Creek in 1997 (R2 Resource Consultants 1998). From snorkel surveys of 55 sites within 20 stream reaches, McLellan (2001) found mountain whitefish density to be less than 1 fish/100 m^2. Mountain whitefish were observed in lower Sullivan Creek during surveys conducted in 1994 and 1995 (CES 1996). From snorkel surveys in Sullivan Creek downstream of Mill Pond Dam, McLellan (2001) found the average mountain whitefish density to be greater than 1 fish/100 m^2.

A.5.2.2 North Fork Sullivan Creek

Barriers

At RM 0.0: The culvert crossing at Sullivan Lake Road (County Road 9345) within the North Fork Sullivan Creek drainage (RM 0.0 of North Fork Sullivan Creek), near the confluence of North Fork Sullivan Creek and Sullivan Creek (RM 0.0 on North Fork Sullivan Creek and RM 2.35 on the mainstem Sullivan Creek), is a fish passage barrier (USFS 2002; Andonaegui 2003). Connor et al. (2005) documented the culvert crossing on Sullivan Lake Road as potential slope and velocity fish passage barrier.

At RM 0.20: In the North Fork Sullivan Creek drainage, upstream of the culvert crossing at Sullivan Lake Road, is a natural falls (RM 0.20) that appears to prevent fish passage (T. Shuhda, USFS, and C. Vail, WDFW, as cited in Andonaegui 2003). Connor et al. (2005) documented the natural falls (RM 0.20) as a series of three falls, between 2 to 4 m (6.6 to 13.1 ft) high, potentially blocking fish passage.

At RM 0.25: The North Fork Sullivan Creek Dam at RM 0.25, which is owned an operated by the Pend Oreille Public Utility District (POPUD) to supply drinking water to the town of Metaline Falls, is a complete fish passage barrier (USFS 1996; Andonaegui 2003; Connor et al. 2005).

At RM 0.60: Connor et al. (2005) document a significant gradient and habitat change 540 m (1,771.7 ft) upstream of the dam (approximately near RM 0.60); however, no information is provided on whether the gradient may limit fish passage.

At RM 1.50: Connor et al. (2005) report that a 2.3 m (7.5 ft) fall and bedrock cascade near RM 1.50 (1,980 m [6,496.1 ft] upstream from the North Fork Sullivan Creek Dam) is potential fish passage barrier.

At RM 2.60: Upstream of RM 2.60, Connor et al. (2005) report two potential fall barriers, one 2.1 m (6.9 ft) high and the other 1.5 m (4.9 ft) high.

Riparian Conditions

The riparian vegetation in North Fork Sullivan Creek has been described as a hemlock/oak/fern association with alders growing on depositional areas and in the North Fork Sullivan Creek channel (USFS 1996). There are no roads and no major human impacts above North Fork Sullivan Creek Dam, and the creek flows through a mature cedar forest with overhead canopy nearly complete (RM 0.25) (Connor et al. 2005).

Channel Conditions and Dynamics

Streambank Condition: Throughout North Fork Sullivan Creek, habitat ranged from high gradient entrenched canyons to wide valleys with sediment laden, braided channels influenced by past beaver activity (Connor et al. 2005).

Floodplain Connectivity: Throughout North Fork Sullivan Creek habitat ranged from high gradient entrenched canyons to wide valleys with sediment-laden, braided channels influenced by past beaver activity (Connor et al. 2005). There are no roads and no major human impacts above North Fork Sullivan Creek Dam (RM 0.25) (Connor et al. 2005).

Channel Stability: Throughout North Fork Sullivan Creek, habitat ranged from high gradient entrenched canyons to wide valleys with sediment-laden, braided channels influenced by past beaver activity (Connor et al. 2005). There are no roads and no major human impacts above North Fork Sullivan Creek Dam (RM 0.25) (Connor et al. 2005).

Habitat Elements

Channel Substrate: Connor et al. (2005) surveyed seven reaches totaling 5.1 km (3.2 mi) in 2003, and determined gravel and cobble were the dominant substrate (42.2 percent and 27.9 percent, respectively) within North Fork Sullivan Creek. In all surveyed reaches in 2003, except the reach downstream of North Fork Sullivan Creek Dam which acts as a sediment trap, substrate embeddedness was relatively high (mean of 69 percent)(Connor et al. 2005).

LWD: Connor et al. (2005) reported that active LWD was abundant, averaging 578 pieces per mile, with many log jams comprising large cedars in the watershed.

Pool Frequency and Quality: Instream habitat in North Fork Sullivan Creek was documented as very diverse with pocket pools and short riffles (USFS 1996). From surveys in 2003, Connor et al. (2005) reported that riffle was the dominant habitat type (58.0 percent of the seven transects surveyed), with pools and runs recorded at 19.0 percent and 23.0 percent, respectively. Connor et al. (2005) went on to report that eight-four primary pools were counted corresponding to 26.6 pools per mile.

Pool Depth: From conducting surveys in seven reaches within North For Sullivan Creek, Connor et al. (2005) found the average length, maximum depth, and residual depths of pools were 3.8 m (12.5 ft), 63.8 cm (25.1 in), and 46.7 cm (18.4 in), respectively.

Off-Channel Habitat: Throughout North Fork Sullivan Creek habitat ranged from high gradient entrenched canyons to wide valleys with sediment-laden, braided channels influenced by past beaver activity (Connor et al. 2005).

Wetted Width: Connor et al. (2005) surveyed seven reaches totaling 5.1 km (3.2 mi) in 2003, and found the mean wetted width was 3.8 m (12.5 ft) and depth 23.7 cm (9.3 in) within North Fork Sullivan Creek.

Water Quality

Temperature: The USFS deployed a thermograph upstream from the confluence of North Fork Sullivan Creek and the mainstem Sullivan Creek at the USFS boundary from July 18 to September 18, 2002, and determined the 7-day average maximum temperature during this period was 11.8ºC (53.2ºF) (K. Honeycutt, USFS, email. comm., 2003 as cited in Andonaegui 2003). McLellan (2001) measured water temperature near the mouth (RM 0.0) of North Fork Sullivan Creek with a thermograph from June 28 to October 19, 2000. Based on the data available from the McLellan (2001) report, the 7-day average maximum temperature was 11.9ºC (53.42ºF) between August 6 and August 12, 2000. Connor et al. (2005) recorded stream temperature hourly between June 19 and October 16, 2003, and determined the 7-day average maximum temperature during this period was 13.0ºC (55.4ºF). The maximum temperature during this period of record was 14.9ºC (58.8ºF) on August 19, and the minimum was 4.8ºC (40.6ºF) on October 15 (Connor et al. 2005).

Water Quantity and Characteristics

The watershed is roadless and borders the Salmo-Priest Wilderness Area, with typical land use practices such as logging, road building, and grazing absent in the drainage (Connor et al. 2005). Connor et al. (2005) documented the mean channel gradient was 2.2 percent, ranging from 0.5 percent to 15.0 percent, from the seven reaches surveyed within North Fork Sullivan Creek in 2003. The North Fork Sullivan Creek has a low flow restriction of 0.06 m^3/s (2 ft^3/s) (Entrix 2002). At the confluence of North Fork Sullivan Creek and the mainstem Sullivan Creek (RM 0.0 on North Fork Sullivan Creek and RM 2.35 on Sullivan Creek), Connor et al. (2005) determined the discharge to be 0.04 m^3/s (1.34 ft^3/s) on September 4, 2003. Located at RM 0.25, North Fork Sullivan Lake Dam is operated as a run-of the-river dam (Andonaegui 2003). At the base of the dam there is an eight-inch pipe, and even during the lowest flows during the summer months water is typically spilling over the dam (Blum 2003 as cited in Andonaegui 2003). Connor et al. (2005) reported that above the North Fork Sullivan Creek Dam there were no major impacts from human development.

Fish Species

Bull Trout: No bull trout have been found in any of the tributaries draining into Sullivan Creek, including North Fork Sullivan Creek (Andonaegui 2003). No bull trout were detected from surveying seven sites in North Fork Sullivan Creek, at least one of which was located upstream of the North Fork Sullivan Creek Dam (RM 0.25) (Blum 2003 as cited in Andonaegui 2003).

Cutthroat Trout: Connor et al. (2005) used electrofishing to sample two 100 m (328.1 ft) reaches in North Fork Sullivan Creek for fish species, and found only cutthroat trout, both above and below the dam (RM 0.25). From electrofishing downstream of the dam, Connor et al. (2005) reported cutthroat trout density was 13.9 fish/100 m^2. The westslope cutthroat trout population present in North Fork Sullivan Creek downstream of RM 0.25 was indicated as a distinct genetic stock, with no hybridization and no record of past stocking (Shaklee and Young 2000 and Gayeski et al. 2001 as cited in Connor et al. 2005). In addition, the stock in North Fork Sullivan Creek were found to be distinct, indicating they exist as reproductively isolated from other stocks occurring in Upper Sullivan Creek (isolated above Mill Pond Dam) (Shaklee and Young 2000 as cited in Connor et al. 2005). Only westslope cutthroat are known to occur upstream of the North Fork Sullivan Creek Dam (CES 1996; Vail 2003 as cited in Andonaegui 2003; USFS 2005). Connor et al. (2005) used electrofishing to sample two 100 m (328.1 ft) reaches in North Fork Sullivan Creek for fish species, and found only cutthroat trout, both above and below the dam (RM 0.25). From the electrofishing survey conducted upstream of the dam, Connor et al. (2005) reported cutthroat trout density was 5.2 fish/100 m^2. Connor et al. (2005) note that conducting electrofishing surveys in reaches farther upstream of the dam was not feasible due to the remote location and steep valley walls with large downed trees. However, while conducting habitat surveys in the reaches farther upstream of the dam, cutthroat trout were observed but were not collected during attempts using hook-and-line sampling (Connor et al. 2005).

A.5.3BOX CANYON WAU

A.5.3.1 Linton Creek

Barriers

Approximately at RMs 0.18, 0.21, 0.25, 0.33, 0.34, 0.38, 0.42, 0.67, 0.71, 0.76, 0.78, 1.07, and 1.10 on Linton Creek there are fish passage barriers (POSRT 2005).

Water Quantity and Characteristics

The gradient in Linton Creek ranges between 0.3 percent in reaches near Boundary Reservoir to 56.4 percent in the headwaters (WDFW SalmonScape 2007).

A.5.3.2 Pocahontas Creek

Barriers

Approximately at RM 0.34 on Pocahontas Creek there is a fish passage barrier (POSRT 2005). During the summer, flows in lower Pocahontas Creek between RM 0.0 and approximately 0.25 are generally subsurface (R2 Resource Consultants 2006; T. Shuhda, USFS, pers. comm., 2005 as cited in R2 Resource Consultants 2006).

Riparian Conditions

In the comments of the USFS (2005) SMART database for the Pocahontas records it is noted that there is a closed cedar canopy.

Channel Conditions and Dynamics

Streambank Condition: In the comments of the USFS (2005) SMART database for the Pocahontas records, it is noted for a number of locations that there are unstable banks and landslides.

Channel Stability: The entrenchment ratio, based on the USFS (2005) SMART database, was 1.3. In the comments of the database for the Pocahontas records, it is noted that the channel is entrenched.

Habitat Elements

Channel Substrate: The percent of fines, based on the USFS (2005) SMART database, was greater than 20 percent.

LWD: Based on data available in the USFS (2005) SMART database, there were 21.4 pieces of LWD per mile.

Pool Frequency and Quality: The amount of pools per mile, based on the USFS (2005) SMART database, was 36.4.

Pool Depth: The pool depth, based on the USFS (2005) SMART database, was 0.61 m (2 ft).

Wetted Width: The mean wetted width, based on the USFS (2005) SMART database, was 1.9 m (6.1 ft).

Water Quantity and Characteristics

During the summer, flows in lower Pocahontas Creek between RM 0.0 and approximately 0.25 are generally subsurface (R2 Resource Consultants 2006; T. Shuhda, USFS, pers. comm., 2005 as cited in R2 Resource Consultants 2006). Stream gradient ranges between 1.5 percent in reaches close to Boundary Reservoir and 26.9 percent in headwater reaches (WDFW SalmonScape 2007).

Fish Species

Cutthroat Trout: The POSRT (2005) documents cutthroat trout as present in Pocahontas Creek.

Rainbow Trout: The POSRT (2005) documents rainbow trout as present.

A.5.3.3 Wolf Creek

Barriers

Approximately at RM 0.35 and 1.21 on Wolf Creek there are fish passage barriers (POSRT 2005).

Water Quantity and Characteristics

The average gradient in Wolf Creek is 16.5 percent (WDFW SalmonScape 2007).

A.5.3.4 Sweet Creek

Barriers

At RM 0.5: A road crossing at State Highway 31 (RM 0.5) is described as a velocity barrier to fish passage (Andonaegui 2003; WDFW SalmonScape 2007). However, as Andonaegui (2003) reports, and as documented in McLellan (2001), an adult bull trout was observed upstream of the culvert and downstream of the first waterfall barrier in 2000. In addition, upstream of State Highway 31 juvenile whitefish had been observed indicating some degree of passage (C. Vail 2002 as cited in Andonaegui 2003). Andonaegui (2003) documents that the barrier at RM 0.5 was listed in the WDFW Salmonid Screening, Habitat Enhancement, and Restoration Division (SSHEAR) database GIS barrier coverage as of November 2002. As of August 2007, the road crossing is still included in the GIS culverts layer available from WDFW SalmonScape (2007).

RM 0.60: From RM 0.6, and continuing upstream 870 m (2854.3 ft), there is a series of four natural waterfalls, 6.0 m (19.7 ft), 6.0 m (19.7 ft), 6.0 m (19.7 ft), and 8.2 m (26.9 ft) high, that are fish passage barriers (McLellan 2001; Andonaegui 2003). Based on the WDFW SalmonScape (2007) GIS barrier layer, only the first natural waterfall is reported (approximately RM 0.6). R2 Resource Consultants (1998) also documented a barrier falls at approximately RM 0.6 on Sweet Creek, but noted that below the falls is potential spawning and rearing habitat for adfluvial salmonids.

RM 1.4: Approximately upstream from RM 1.4 on Sweet Creek there is a potential fish passage barrier (POSRT 2005). Approximately upstream from RM 1.5 on Sweet Creek there is a fish passage barrier (POSRT 2005).

Riparian Conditions

R2 Resource Consultants (1998) documented a well-shaded channel for Sweet Creek. In addition, from surveys of habitat units in Sweet Creek, R2 Resource Consultants (1998) determined the mean canopy cover was 30 percent.

Habitat Elements

Channel Substrate: R2 Resource Consultants (1998) reported a mean of 12 percent for surface fines from surveys in Sweet Creek. The dominant substrate is boulder for Sweet Creek (McLellan 2001; Andonaegui 2003).

LWD: Based on 14 sites in five stream reaches surveyed within Sweet Creek, there was a mean of 290 pieces of LWD per mile (McLellan 2001). R2 Resource Consultants (2006) reported Sweet Creek contains a fair level of LWD (289.7 to 321.9 pieces per mile).

Pool Frequency and Quality: The dominant habitat type is riffle for Sweet Creek (McLellan 2001; Andonaegui 2003). McLellan (2001) reported 27 large pools per mile from surveying 14 sites in five stream reaches of Sweet Creek in 2000. R2 Resource Consultants (2006) reported Sweet Creek contains a fair amount of pools (27.4 to 80.5 pools per mile).

Pool Depth: McLellan (2001) conducted habitat surveys within five reaches of Sweet Creek and determined the mean width, maximum depth, and residual depth for the combined five reaches were 3.7 m (12.1 ft), 52 cm (20.5 in), and 33 cm (13.0 in), respectively.

Wetted Width: McLellan (2001) conducted surveys of five stream reaches in Sweet Creek and reported a mean wetted width of 4.3 m (14.1 ft).

Water Quality

Temperature: From August 15 through October 27, 1996, and again from July 25 through November 11, 1997, hourly recordings of water temperatures were collected just downstream of the State Highway 31 crossing (R2 Resource Consultants 1998). The 7-day average maximum temperature during the period of record was 15.3ºC (59.5ºF) between August 1 and 7, 1997 (R2

Resource Consultants 1998). R2 Resource Consultants (1998) also placed a second water temperature recording station upstream of the State Highway 31 crossing, but there was little difference in temperature between the upper and lower sites. Between June 28 and October 17, 2000, the water temperature downstream of the State Highway 31 crossing in Sweet Creek was measured with an electronic thermograph (McLellan 2001). The maximum temperature recorded within Sweet Creek in 2000 was 15.63ºC (60.13ºF) on August 6, 7, and 9, and the minimum was 2.26ºC (36.07ºF) on October 6 (McLellan 2001). Based on the data available from the McLellan (2001) report, the 7-day average maximum temperature was 15.4ºC (59.7ºF) between August 7 and 13, 2000.

Water Quantity and Characteristics

McLellan (2001) determined the discharge to be 0.15 m^3/s (5.30 ft^3/s) for Sweet Creek on September 11, 2000. From habitat surveys at five stream reaches, McLellan (2001) reported and mean gradient of 5 percent on Sweet Creek.

Fish Species

Bull Trout: Access to habitat is limited for migratory life history forms of bull trout (Andonaegui 2003). However, three bull trout have been documented in the Sweet Creek drainage (Andonaegui 2003). At the mouth of Sweet Creek (RM 0.0), a 20-inch adult bull trout was captured by Bob Peck (WDFW biologist) using a gill net in the fall during the early 1980s (Andonaegui 2003). Again in the fall during the early 1980s, Bob Peck found a dead 34-inch bull trout along the streambank upstream from RM 0.0 (Andonaegui 2003). In 1988, R2 Resource Consultants conducted snorkel surveys on Sweet Creek and no bull trout were observed (USFS 1999c). In the fall of 1997, R2 Resource Consultants again surveyed Sweet Creek using snorkel surveys and did not observe bull trout (R2 Resource Consultants 1998). In the fall of 2000, a 12-inch adult bull trout was observed during a snorkel survey in a plunge pool downstream of the barrier waterfall at RM 0.6, approximately 400 m (1312.3ft) upstream of the State Highway 31 stream crossing (McLellan 2001). Based on the surveys reported in McLellan (2001), bull trout density was less than 1 fish/100 m^2.

Cutthroat Trout: Predominately cutthroat trout were observed in snorkel survey of Sweet Creek in 1997 (R2 Resource Consultants 1998). Electrofishing conducted the next day after snorkel surveys in 1997 resulted in an intermediate density of cutthroat trout captured in Sweet Creek (R2 Resource Consultants 1998). From snorkel surveys conducted in 2000 at 14 sites within five stream reaches, McLellan (2001) reported cutthroat trout density to be 4 fish/100 m^2. Cutthroat trout were collected during June of 2007 in a survey where fyke nets were deployed at the mouth of Sweet Creek intended to collect downstream migrating fish (SCL 2009).

Rainbow Trout: Next to cutthroat trout, rainbow trout were the second most common fish species observed during snorkel surveys of Sweet Creek in 1997 (R2 Resource Consultants 1998). Electrofishing conducted the next day after snorkel surveys in 1997 resulted in an intermediate density of rainbow trout captured in Sweet Creek (R2 Resource Consultants 1998). From snorkel surveys conducted in 2000 at 14 sites within five stream reaches, McLellan (2001) reported rainbow trout density to be 4 fish/100 m^2. Rainbow trout were observed both upstream and downstream of the culvert barrier located at RM 0.5 (McLellan 2001). Within the stretch of Sweet Creek between RM 0.0 and 0.5, rainbow trout can be found competing for food and habitat, and interbreeding with cutthroat trout (Shuhda 2007). A rainbow trout was collected during June 2007 in a survey in which fyke nets were deployed at the mouth of Sweet Creek to collect downstream migrating fish (SCL 2009).

Brook Trout: Within Sweet Creek, brook trout have been known to occur (R2 Resource Consultants 1998; McLellan 2001). Electrofishing conducted the next day after snorkeling surveys in 1997 resulted in relative low densities of brook trout at sites surveyed in Sweet Creek (R2 Resource Consultants 1998). Although densities were relatively low, brook trout were observed both downstream and upstream of the waterfalls that start at RM 0.6 and continue upstream for 870 m (2854.3 feet) (R2 Resource Consultants 1998). From snorkel surveys conducted in 2000 at 14 sites within five stream reaches, McLellan (2001) reported brook trout density to be 1 fish/100 m^2. Again, brook trout were observed both downstream and upstream of the waterfalls that start at RM 0.6 (2854.3 ft) (McLellan 2001). These waterfalls are barriers to fish passage (see above Barriers, RM 0.60). Within the stretch of Sweet Creek between RM 0.0 and 0.5, brook trout can be found in this habitat competing for food and habitat, and interbreeding with bull trout (Shuhda 2007).

Brown Trout: Electrofishing conducted the next day after snorkel surveys in 1997 resulted in relative low densities (0.02 fish/m^2) of brown trout at sites surveyed in Sweet Creek (R2 Resource Consultants 1998). From snorkel surveys conducted in 2000 at 14 sites within five stream reaches, McLellan (2001) reported brown trout density to be less than 1 fish/100 m^2. Brown trout were collected during June 2007 in a survey in which fyke nets were deployed at the mouth of Sweet Creek to collect downstream migrating fish (SCL 2009).

Mountain Whitefish: From snorkel surveys conducted in 2000 at 14 sites within five stream reaches, McLellan (2001) reported a single mountain whitefish (less than 1 fish/100 m^2) was observed.

A.5.3.5 Lunch Creek

Barriers

Approximately upstream from RM 1.4 on Lunch Creek there is a potential fish passage barrier (POSRT 2005).

Habitat Elements

Channel Substrate: The dominant substrate is rubble for Lunch Creek (McLellan 2001).

LWD: Based on three stream reaches surveyed within Lunch Creek, there was a mean of 338 pieces of LWD per mile (McLellan 2001).

Pool Frequency and Quality: The dominant habitat type is riffle for Lunch Creek (McLellan 2001). McLellan (2001) reported 12 large pools per mile from surveying three stream reaches of Lunch Creek in 2000.

Pool Depth: McLellan (2001) conducted habitat surveys within three reaches of Lunch Creek and determined the mean width, maximum depth, and residual depth for the combined three reaches were 2.9 m (9.5 ft), 46 cm (18.1 in), and 29 cm (11.4 in), respectively.

Wetted Width: The mean wetted width, based on surveys of three stream reaches conducted in 2000 on Lunch Creek, was 3.5 m (11.5 ft).

Water Quality

Temperature: McLellan (2001) reported mean values of water temperature from surveys conducted in three stream reaches on Lunch Creek. The mean water temperature for all three reaches was 8ºC (44.6ºF), but the 7-day average maximum temperature was not able to be calculated from the data available.

Water Quantity and Characteristics

From habitat surveys at three stream reaches on Lunch Creek, McLellan (2001) reported a mean gradient of 12 percent.

Fish Species

Cutthroat Trout: From snorkel surveys conducted in 2000 at seven sites within three stream reaches, McLellan (2001) reported cutthroat trout density to be 2 fish/100 m^2 and cutthroat trout were the only fish species observed.

A.5.3.6 Sand Creek

Barriers

From the confluence of Sand Creek with the Pend Oreille River (RM 0.0) upstream to RM 0.25, portions of the creek have been documented to dewater in September, with water going subsurface (USFS 1999a; Andonaegui 2003). The USFS (1999a) noted that in June 1992 the recorded flow at the mouth was very low for that time of year. In August of 1996, the water depth in all areas of the channel in the lower 0.25 mile of Sand Creek was less 0.3 m (1 ft) deep (R2 Resource Consultants 1998). At RM 0.25, near USFS Road 3669, the culvert (2.0 m [6.6 ft] vertical drop and 75.0 m [246.1 ft] long) under the railroad track is a fish passage barrier at all flows (USFS 1999a; McLellan 2001; Andonaegui 2003). Andonaegui (2003) documents a culvert at RM 0.5 as a fish passage barrier, but the culvert is not listed in barriers spreadsheet provided in the report (see Appendix 1). A natural waterfall barrier (5.0 m [16.4 ft] vertical) occurs at RM 1.25 offering limited access to habitat for migratory life history forms of bull trout (McLellan 2001; Andonaegui 2003). At RM 1.8 in Sand Creek there is a culvert, 4.2 m (13.94 ft) high and 15.7 m (51.6 ft) long, at the USFS Road 3310160 creek crossing preventing fish passage (USFS 2002; Andonaegui 2003).

Riparian Conditions

Most of the largest components of the riparian stands along Sand Creek have been removed by wildfires and past harvest (USFS 1999a). However, the USFS (1999a) notes in the report that species expected of the natural riparian community comprised the current vegetation species composition. With the exception of several road crossings and portions of old road located within the RHCA (Riparian Habitat Conservation Area), the riparian areas are continuous in nature (USFS 1999a). In 1999 the USFS documented that upstream of RM 2.0 there was approximately 0.75 mile of road system located inside of the riparian areas (USFS 1999a). Of the 0.75 mile of road system in riparian areas, 0.5 mile is not maintained and closed to vehicular traffic, and 0.25 mile is maintained, but only when there is damage to the road (USFS 1999a). The 0.25 mile of road system that is maintained is being overgrown, but is kept open through public utilization of the road (USFS 1999a). The USFS (1999a) reported the riparian areas existing along the main channel as functioning and hydrologically linked to Sand Creek. In surveys of habitat units in Sand Creek, R2 Resource Consultants (1998) determined the mean canopy cover was 37 percent.

Channel Conditions and Dynamics

Streambank Condition: Habitat units surveyed by R2 Resource Consultants (1998) in Sand Creek were found to have an average undercut bank cover of 9.6 percent. Ground cover for the streambanks was less than 25 percent along two reaches and between 51 and 75 percent at two other reaches surveyed on USFS land (USFS 1999a). In addition, the USFS (1999a) states that on two reaches surveyed within private lands, streambank cover was less than 25 percent. The USFS (1999a) documents that the quality of refugia for native salmonids is fair to good, but there was a problem with streambank stability and embeddedness throughout the system. Andonaegui (2003) describes the streambank condition as fair in Sand Creek (USFS 2002f and Honeycutt 2003 as cited in Andonaegui 2003).

Floodplain Connectivity: The valley form is V-shaped with low to moderate sideslopes and narrow floodplains along Sand Creek (USFS 1999a). The USFS (1999a) reported the riparian areas existing along the main channel as functioning and hydrologically linked to Sand Creek.

Channel Stability: The USFS (1999a) reported a problem primarily with streambank stability and embeddedness of the streambed substrate throughout the system. Channel stability has been reported as fair in Sand Creek (K. Honeycutt, USFS, email. comm., 2003 as cited in Andonaegui 2003).

Habitat Elements

Channel Substrate: R2 Resource Consultants (1998) reported a mean of 30 percent for surface fines from surveys in Sand Creek. Five out six reaches surveyed by the USFS (1999a) had embeddedness levels of greater than 35 percent. Sand was determined to be the dominant substrate material, with gravel as the subdominant material in one out four reaches surveyed (USFS 1999a). The other three reaches surveyed for sediment had gravel as the dominant substrate (USFS 1999a). The streambanks have sand as the dominant substrate, and natural erosion is expected (USFS 1999a). In the USFS (1999a) report on Sand Creek, the level of embeddedness and the natural rates of bank erosion are attributed to the lack of streambank cover. Boulder, sand, and cobble were found as the dominant substrates in five reaches surveyed in 2000 (McLellan 2001). However, McLellan (2001) determined sand was the dominant substrate for Sand Creek.

LWD: Within all reaches surveyed and reported by the USFS (1999a), LWD exceeded 20 pieces per mile. Based on 12 sites in five reaches surveyed within Sand Creek, there was a mean of 579 pieces of LWD per mile (McLellan 2001).

Pool Frequency and Quality: The USFS (1999a) reported that the number of pools per mile on all surveyed reach was lower than what would be expected (listed as 60 pools per mile by the Andonaegui [2003]) for a stream with an average wetted width of 3.7 m (12 ft). In addition, the USFS (1999a) reported that sand was the dominant substrate in pools, which appeared to be moderately reducing pool volume. Based on review of the USFS SMART database (2005), for six reaches surveyed in 1992, pools per mile ranged from nearly 14 to over 24. Based on surveys conducted in 2000 of five reaches within Sand Creek, a mean of 29 large pools per mile was reported (McLellan 2001). However, McLellan (2001) documented that riffles were the dominant habitat type (69 percent) for the sites surveyed within the five reaches on Sand Creek.

Pool Depth: McLellan (2001) conducted habitat surveys within five reaches on Sand Creek and determined the mean width, maximum depth, and residual depth for the combined five reaches were 2.5 m (8.2 ft), 34 cm (13.4 in), and 20 cm (7.9 in), respectively. Andonaegui (2003) reported pool depth as fair (K. Honeycutt, USFS, email. comm., 2003 as cited in Andonaegui 2003).

Off-Channel Habitat: Of all existing habitat surveyed by the USFS (1999a), approximately 1 percent is off-channel habitat resulting from the channel braiding around debris jams. In addition, beaver dams and ponds are frequent in Sand Creek (USFS 1999a).

Wetted Width: McLellan (2001) conducted surveys of five stream reaches on Sand Creek and reported a mean wetted width of 2.1 m (6.9 ft).

Water Quality

Temperature: The USFS (1999a) reports that "sporadic" water temperature data are available for Sand Creek. In 1979, a Forest Hydrologist collected water temperature data, and crews collecting physical habitat as part of electroshocking (1992) and snorkeling (1997) inventories in Sand Creek also collected water temperature data (USFS 1999a). During a two week period in July of 1992, temperatures in Sand Creek ranged from 11ºC (52ºF) to 14ºC (58ºF) (USFS 1999a). In the upper portion of Sand Creek water temperature was recorded at 12.5ºC (55ºF) on August 15, 1997 (USFS 1999a). In the lower portion of Sand Creek the highest temperature recorded was 14ºC (58ºF) during the month of July. The lowest temperature recorded for Sand Creek was 5ºC (41ºF) in May of 1979 (USFS 1999a). The USFS (1999a) notes that the based on the limited available data it was not possible to determine a 7-day average maximum temperature. Also due to the lack of data available, the USFS (1999a) was not able to determine whether water temperatures were suitable for bull trout spawning and incubation. However, for bull trout rearing the USFS (1999a) notes there are more tolerable temperatures in the upper headwaters with more marginal water temperatures in lower Sand Creek. From August 15 through October 27, 1996, and again from July 25 through November 11, 1997, hourly recordings of water temperatures were collected near the mouth of Sand Creek (RM 0.0) (R2 Resource Consultants 1998). The lower reach of Sand Creek is braided with water flowing through a delta area containing porous streambed with subsurface flows (R2 Resource Consultants 1998; Andonaegui 2003). Due to this braiding in the lower reach, Sand Creek was dewatered soon after placement of the thermograph (R2 Resource Consultants 1998; Andonaegui 2003). By 1997 the thermograph was replaced at the mouth of Sand Creek and recorded water temperature throughout the entire monitoring period (R2 Resource Consultants 1998). The 7-day average maximum temperature during the period of record was 15.9ºC (60.6ºF) between August 1 and 7, 1997 (R2 Resource Consultants 1998). Between June 28 and October 19, 2000, the water temperature at the mouth of Sand Creek was measured with an electronic thermograph (McLellan 2001). The maximum temperature recorded within Sand Creek in 2000 was 16.26ºC (62ºF) on August 23, and the minimum was 2.53ºC (36.5ºF) on October 6 (McLellan 2001; Andonaegui 2003). Based on the data available in the McLellan (2001) report, the 7-day average maximum temperature was calculated and determined to be 14.5ºC (58.1ºF) between August 7 and 13, 2000, at the mouth of Sand Creek.

Water Quantity and Characteristics

There are no undisturbed watersheds of similar nature to evaluate changes in the flow regime within the Sand Creek drainage (USFS 1999a). In the USFS (1999a) biological evaluation of the Wolf Creek Timber Sale, it was believed that within the watershed the high density of roads (2.9 miles per square mile), located primarily outside of the RHCA, and the low level of acreage in harvested openings (9.4 percent), may not have a noticeable effect on the natural flow regime. However, the USFS (1999a) documented that there was not enough information available for this determination. The USFS (1999a) reported that the flow at the mouth of Sand Creek on June 3, 1992, was 0.02 m^3/s (0.83 ft^3/s), and noted that this was very low for that time of year. In the lower reach of Sand Creek the channel is braided with water running through a delta area containing porous stream bed with subsurface flows (Andonaegui 2003). R2 Resource Consultants (1998) estimated the flow in the lower 0.25 miles of Sand Creek during August 1996 to be less than 0.03 m^3/s (1 ft^3/s), with no channel areas exceeding 0.3 m (1 ft) deep. No information is available on whether the dewatering in the lower reach of Sand Creek is a natural condition or related to human impacts in the drainage (Andonaegui 2003). On September 7, 2000, McLellan (2001) determined the discharge to be 0.01 m^3/s (0.35 ft^3/s) for Sand Creek at the mouth (RM 0.0). The mean gradient from five reaches surveyed on Sand Creek was 7 percent (McLellan 2001).

Fish Species

<u>Bull Trout:</u> Access to habitat is limited for migratory life history forms of bull trout (Andonaegui 2003). Bull trout have not been detected in Sand Creek from snorkeling and electrofishing surveys (R2 Resource Consultants 1998; USFS 1999a; McLellan 2001;

Andonaegui 2003). However, habitat within Sand Creek has been identified as "Suitable" by the TAG (Andonaegui 2003).

<u>Cutthroat Trout:</u> During electroshocking and snorkeling surveys along the fish-bearing segments of Sand Creek, the USFS (1999a) documented that westslope cutthroat trout fry, juveniles, and adults were observed. Cutthroat trout were observed during snorkel surveys of Sand Creek in 1997 (R2 Resource Consultants 1998). Electrofishing conducted the next day after snorkel surveys in 1997 resulted in an intermediate density of cutthroat trout captured in Sand Creek (R2 Resource Consultants 1998). From snorkel surveys conducted in 2000 of sites within five reaches on Sand Creek, McLellan (2001) reported a mean of 2 fish/100 m^2. Cutthroat trout were collected between May and June of 2007 in a survey where fyke nets were deployed at the mouth of Sand Creek intended to collect downstream migrating fish (SCL 2009).

<u>Rainbow Trout:</u> During electroshocking and snorkeling surveys along the fish-bearing segments of Sand Creek, the USFS (1999a) documented that rainbow trout fry, juveniles, and adults were observed. Rainbow *x* cutthroat trout hybrids and rainbow trout were observed during a snorkel survey of Sand Creek in 1997 (R2 Resource Consultants 1998). Electrofishing conducted the next day after snorkel surveys in 1997 resulted in a high density of rainbow trout captured in Sand Creek (R2 Resource Consultants 1998). From snorkel surveys conducted in tributaries draining into Boundary Reservoir in 2000, Sand Creek had the highest fish densities of rainbow trout, compared to all other tributaries, of 11 fish/100 m^2 (McLellan 2001). Within the stretch of Sand Creek between RM 0.0 and 0.25, rainbow trout can be found in this habitat competing for food and habitat, and interbreeding with cutthroat trout (Shuhda 2007). Rainbow trout were collected between May and June 2007 in a survey in which fyke nets were deployed at the mouth of Sand Creek to collect downstream migrating fish (SCL 2009).

<u>Brook Trout:</u> The USFS (1999a) observed a few eastern brook trout in the stream below a culvert approximately at RM 0.3 and was not able to determine if reproduction was occurring. During a snorkel survey in 1997, R2 Resource Consultants (1998) identified brook trout throughout Sand Creek. However, electrofishing conducted the next day after snorkel surveys in 1997, resulted in relative low densities of brook trout at sites surveyed in Sand Creek (R2 Resource Consultants 1998). In surveys conducted in 2000, McLellan (2001) did not observe any brook trout in five reaches. However, within the stretch of Sand Creek between RM 0.0 and 0.25, brook trout have been found in this habitat competing for food and habitat, and interbreeding with bull trout (Shuhda 2007).

<u>Brown Trout:</u> Electrofishing conducted the next day after snorkel surveys in 1997 resulted in relative low densities (0.02 fish/m^2) of brown trout at sites surveyed in Sand Creek (R2 Resource Consultants 1998). In surveys conducted in 2000, McLellan (2001) did not observe any brown trout in five reaches. Brown trout were collected between May and June of 2007 in a survey in which fyke nets were deployed at the mouth of Sand Creek to collect downstream migrating fish (SCL 2009).

<u>Mountain Whitefish:</u> In surveys conducted in 2000, McLellan (2001) did not observe any mountain whitefish in five reaches. However, the POSRT (2005) documents mountain whitefish present in Sand Creek.

A.5.3.7 Lost Creek

Barriers

Approximately at RM 0.16, 0.92, and 1.41 on Lost Creek there are potential fish passage barriers (POSRT 2005).

Water Quantity and Characteristics

The average gradient in Lost Creek is 8.6 percent (WDFW SalmonScape 2007).

Fish Species

Cutthroat Trout: R2 Resource Consultants (2006) reported the presence of cutthroat trout in Lost Creek.

A.5.3.8 Unnamed No. 13

Barriers

During a March 2007 site visit as part of the Boundary Reservoir Project (FERC No. 2144) relicensing process, a natural fish migration barrier more than 4.6 m (15 ft) high was observed (Fullerton 2007).

Water Quantity and Characteristics

The gradient is greater than 20 percent approximately 30.5 m (100 ft) upstream from the confluence with Boundary Reservoir (RM 0.0) (WDFW SalmonScape 2007).

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Appendix 6: 2007 Spreadsheet of Data from Primary Tributaries

Table A.6-1. Migration barrier and channel condition and dynamic information for primary tributaries draining into Boundary Reservoir.

Tributary Name	Creek Name	Access to Spawning and Rearing		Riparian Condition	Channel Conditions/Dynamics		
		Artificial Barrier	Natural Barrier		Streambank Condition	Floodplain Connectivity	Channel Stability
SLATE CREEK WAU							
Lime Creek (RM 19.0)	Lime Creek Mainstem						
	RM 0.0 - 1.3	None	Yes	DG	DG	Connected	Acceptable
Slate Creek (RM 22.2)	Slate Creek Mainstem						
	RM 0.0 - 6.2	None	Yes	Adequate	>90% stability	Connected	Appropriate
	Slumber Creek (RM 2.0)						
	RM 0.0 - 2.3	Yes	Yes	Adequate	↑	↑	Appropriate
	Uncas Gulch (RM 2.75)						
	RM 0.0 - 2.0	None	None	Adequate	↑	↑	Appropriate
	Styx Creek (RM 4.9)						
	RM 0.0 - 2.0	Yes	None	Adequate	↑	↑	Appropriate
	S. Fk. Slate Creek (RM 6.2)						
	RM 0.0 - 1.0	None	None	Adequate	↑	↑	Appropriate
	N. Fk. Slate Creek (RM 6.2)						
	RM 0.0 - 2.5	?	Yes	Adequate	↑	↑	Appropriate
Flume Creek (RM 25.8)	Flume Creek Mainstem						
	RM 0.0 - 4.75	Yes	Yes	DG	DG	DG	DG
	S. Fk. Flume Creek (RM 1.1)						
	RM 0.0 - 0.3	Yes	None	DG	DG	DG	DG
	M. Fk. Flume Creek (RM 3.3)						
	RM 0.0 - 0.75	None	None	DG	DG	DG	DG
SULLIVAN CREEK WAU DOWNSTREAM OF MILL POND DAM (RM 3.25)							
Sullivan Creek (RM 26.9)	Sullivan Creek Mainstem						
	RM 0.0 - 3.25	Yes	?	Adequate	50 to 80% stable	Stream margins	Appropriate
	N. Fk. Sullivan Creek (RM 2.35)						
	RM 0.0 - headwaters	Yes	?	Adequate	DG	Connected	Appropriate

Table A.6-1, continued...

Tributary Name	Creek Name	Access to Spawning and Rearing		Riparian Condition	Channel Conditions/Dynamics		
		Artificial Barrier	Natural Barrier		Streambank Condition	Floodplain Connectivity	Channel Stability
BOX CANYON WAU							
Linton Creek (RM 28.1)	Linton Creek Mainstem						
	RM 0.0 - 1.10	Yes	None	DG	DG	DG	DG
Pocahontas Creek (RM 29.4)	Pocahontas Creek Mainstem						
	RM 0.0 - 0.6	Yes	Yes	DG	DG	Connected	Inappropriate
Sweet Creek (RM 30.9)	Sweet Creek Mainstem						
	RM 0.0 - 1.5	Yes	Yes	DG	DG	DG	DG
	Lunch Creek (RM 1.5)						
	RM 0.0 - 1.4	Yes	None	DG	DG	DG	DG
Sand Creek (RM 31.7)	Sand Creek						
	RM 0.0 - 1.8	Yes	Yes	Adequate	50 to 80% stability	Connected	Appropriate

Notes:
↑ – Limited data were available and not in a format that was similar to other reported data; and/or data are not assessed in a geomorphic context.
Data from tributaries under the same Tributary Name and/or WAU will be used in evaluating limiting factors.
? – Conflicting data and/or lack of data provided in order to determine value.
DG – Data Gap; the stream has not been surveyed; or so little information is available that reporting data would not provide insight into evaluating conditions limiting tributary productivity.
Adequate – provides shade, LWD recruitment, and habitat protection and connectivity.
Connected – Hydrologically linked to off-channel areas.
Acceptable – W/D or entrenchment ratio is beyond range for geomorphologically correct Rosgen stream type.
Appropriate – W/D and Entrenchment is appropriate for geomorphologically correct Rosgen stream type.
Inappropriate – W/D or Entrenchment ratio is inappropriate for geomorphologically correct Rosgen type.

Table A.6-2. Habitat information for primary tributaries draining into Boundary Reservoir.

Tributary Name	Creek Name	Habitat					
		Channel Substrate	LWD (pieces per mile)	Pool Frequency (pools per mile)	Pool Depth (m)	Off-Channel Habitat	Wetted Width (m)
SLATE CREEK WAU							
Lime Creek (RM 19.0)	Lime Creek Mainstem						
	RM 0.0 - 1.3	>35% embeddedness	772	47	0.38	Some	3.1
Slate Creek (RM 22.2)	Slate Creek Mainstem						
	RM 0.0 - 6.2	5 to <35% embeddedness & 5% fines	635	38	0.8 to 1.1	Some	6.3
	Slumber Creek (RM 2.0)						
	RM 0.0 - 2.3	>35% embeddedness & 30 to 40% fines	155 to 167	33 to 56	0.61 to 0.91	Some	7.4
	Uncas Gulch (RM 2.75)						
	RM 0.0 - 2.0	<35% embeddednes	44 to 218	10 to 22	0.61 to 0.91	Some	4.1
	Styx Creek (RM 4.9)						
	RM 0.0 - 2.0	<35% embeddedness	102 to 214	4 to 11	0.55 to 0.70	Some	1.8
	S. Fk. Slate Creek (RM 6.2)						

Table A.6-2, continued...

Tributary Name	Creek Name	Habitat					
		Channel Substrate	**LWD** (pieces per mile)	**Pool Frequency** (pools per mile)	**Pool Depth** (m)	**Off-Channel Habitat**	**Wetted Width** (m)
	RM 0.0 - 1.0	5 to <35% embeddedness	↑	↑	↑	Some	↑
	N. Fk. Slate Creek (RM 6.2)						
	RM 0.0 - 2.5	5 to <35% embeddedness	604	23	0.5	Some	3.5
Flume Creek (RM 25.8)	Flume Creek Mainstem						
	RM 0.0 - 4.75	10% fines	357	19	0.37 to 0.5	DG	4.5
	S. Fk. Flume Creek (RM 1.1)						
	RM 0.0 - 0.3	↑	↑	↑	0.5	DG	3.1
	M. Fk. Flume Creek (RM 3.3)						
	RM 0.0 - 0.75	↑	↑	↑	0.5	DG	3.1
SULLIVAN CREEK WAU DOWNSTREAM OF MILL POND DAM (RM 3.25)							
Sullivan Creek (RM 26.9)	Sullivan Creek Mainstem						
	RM 0.0 - RM 3.25	>20% fines	<20 to 70	10.4	0.8 to 1.61	Stream Margins	17.9
	N. Fk. Sullivan Creek (RM 2.35)						
	RM 0.0 - headwaters	69% embeddedness	578	26.6	0.64	Some	3.8
BOX CANYON WAU							
Linton Creek (RM 28.1)	Linton Creek Mainstem						
	RM 0.0 - 1.10	DG	DG	DG	DG	DG	DG
Pocahontas Creek (RM 29.4)	Pocahontas Creek Mainstem						
	RM 0.0 - 0.6	>20% fines	21.4	36.4	0.61	Some	1.9

Table A.6-2, continued...

Tributary Name	Creek Name	Habitat					
		Channel Substrate	LWD (pieces per mile)	Pool Frequency (pools per mile)	Pool Depth (m)	Off-Channel Habitat	Wetted Width (m)
Sweet Creek (RM 30.9)	Sweet Creek Mainstem						
	RM 0.0 - 1.5	12% surface fines	289.7 to 321.9	27 to 80.5	0.52	DG	4.3
	Lunch Creek (RM 1.5)						
	RM 0.0 - 1.4	DG	338	12	0.46	DG	3.5
Sand Creek (RM 31.7)	Sand Creek						
	RM 0.0 - 1.8	>35% embeddedness and 30% fines	579	14 to 29	0.34	Some	2.1

Notes:
↑ – Limited data were available and not in a format that was similar to other reported data; and/or data are not assessed in a geomorphic context.
Data from tributaries under the same Tributary Name and/or WAU will be used in evaluating limiting factors.
DG – Data Gap; the stream has not been surveyed; or so little information is available that reporting data would not provide insight into evaluating conditions limiting tributary productivity.

Table A.6-3. Water quality, water quantity, native species, and species competition and hybrids information for Primary Tributaries draining into Boundary Reservoir.

Tributary Name	Creek Name	Water Quality 7-day Average Maximum Temperature (°C)	Water Quantity Changes in Flow Regime	Native Species Present	Species Competition & Hybrids	
					Non-indigenous Fish	Hybrids
SLATE CREEK WAU						
Lime Creek (RM 19.0)	Lime Creek Mainstem					
	RM 0.0 - 1.3	11.6	↑	None	BK	None
Slate Creek (RM 22.2)	Slate Creek Mainstem					
	RM 0.0 - 6.2	13.1 to 14.6	Comparable	BT (near mouth); CT	BK; RB	BT x BK
	Slumber Creek (RM 2.0)					
	RM 0.0 - 2.3	↑	Comparable	CT	BK	None
	Uncas Gulch (RM 2.75)					
	RM 0.0 - 2.0	11.7	Comparable	CT	BK	None
	Styx Creek (RM 4.9)					
	RM 0.0 - 2.0	↑	Comparable	CT	BK	None
	S. Fk. Slate Creek (RM 6.2)					
	RM 0.0 - 1.0	↑	Comparable	CT	BK	None
	N. Fk. Slate Creek (RM 6.2)					
	RM 0.0 - 2.5	9	Comparable	CT	BK	None
Flume Creek (RM 25.8)	Flume Creek Mainstem					
	RM 0.0 - 4.75	12.4 to 14.3	DG	CT	BK	None
	S. Fk. Flume Creek (RM 1.1)					
	RM 0.0 - 0.3	↑	DG	↑	↑	None
	M. Fk. Flume Creek (RM 3.3)					
	RM 0.0 - 0.75	11.5 to 12.6	Comparable	↑	↑	BT x BK

Table A.6-3, continued...

Tributary Name	Creek Name	Water Quality 7-day Average Maximum Temperature (°C)	Water Quantity Changes in Flow Regime	Native Species Present	Species Competition & Hybrids	
					Non-indigenous Fish	Hybrids
SULLIVAN CREEK WAU DOWNSTREAM OF MILL POND DAM (RM 3.25)						
Sullivan Creek (RM 26.9)	Sullivan Creek Mainstem					
	RM 0.0 - RM 3.25	9.6 to 24.7; majority >14.9	Pronounced	BT; CT; MWF	BK; GBT; RB	BT x BK; CT x RB
	N. Fk. Sullivan Creek (RM 2.35)					
	RM 0.0 - headwaters	11.9 - 13.0	Comparable	CT; distinct stock	None	None
BOX CANYON WAU						
Linton Creek (RM 28.1)	Linton Creek Mainstem					
	RM 0.0 - 1.10	DG	DG	DG	DG	DG
Pocahontas Creek (RM 29.4)	Pocahontas Creek Mainstem					
	RM 0.0 - 0.6	DG	DG	CT	RB	DG
Sweet Creek (RM 30.9)	Sweet Creek Mainstem					
	RM 0.0 - 1.5	15.4	DG	BT; CT; MWF	BK; GBT; RB	BT x BK; CT x RB
	Lunch Creek (RM 1.5)					
	RM 0.0 - 1.4	↑	DG	CT	↑	↑
Sand Creek (RM 31.7)	Sand Creek					
	RM 0.0 - 1.8	14.5 to 15.9	DG	CT; MWF	BK; GBT; RB	BT x BK; CT x RB

Notes:
↑ – Limited data were available and not in a format that was similar to other reported data; and/or data are not assessed in a geomorphic context.
Data from tributaries under the same Tributary Name and/or WAU will be used in evaluating limiting factors.
DG – Data Gap; the stream has not been surveyed; or so little information is available that reporting data would not provide insight into evaluating conditions limiting tributary productivity.
Comparable – watershed hydrography indicates an undisturbed watershed of similar size, geology and geography.
Pronounced – watershed hydrography indicates changes relative to an undisturbed watershed of similar size, geology and geography.
BT – Bull trout; CT – Cutthroat trout; MWF – Mountain whitefish; BK – Brook trout; GBT – Brown trout; RB – Rainbow trout

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Appendix 7: 2007 Barrier Inventory for Boundary Reservoir Tributaries

Table A.7-1. 2007 results from evaluating all available literature sources and available GIS layers on fish migration barriers occurring in tributaries draining into Boundary Reservoir.

Tributary Name	Tributary/Creek Name	Barrier Location (RM)	Barrier Type	Height (m)	Length (m)	Gradient (%)	Comments	Source
SLATE CREEK WAU								
Pewee Creek (RM 17.9)	Pewee Creek Mainstem	0.0	Waterfall	50	N/A			McLellan (2001)
	Pewee Creek Mainstem	1.2	Culvert	DG	DG			POSRT (2005)
Lime Creek (RM 19.0)	Lime Creek Mainstem	1.3	Dewatering	N/A	100			McLellan (2001)
Everett Creek (RM 21.9)	Everett Creek Mainstem	0.16	Waterfall	DG	DG		Potential barrier	WDFW SalmonScape (2007)
	Everett Creek Mainstem	1.20	Culvert	DG	DG		Potentially abandoned	WDFW SalmonScape (2007)
Whiskey Gulch (RM 21.9)	Whiskey Gulch Mainstem	0.6	Culvert	DG	DG			POSRT (2005)
Slate Creek (RM 22.2)	Slate Creek Mainstem	0.75	Natural Series	2.8 to 6.0	800	38		McLellan (2001)
	Slate Creek Mainstem	1.5	Natural Series	3	10	24		McLellan (2001)
	Slumber Creek (RM 2.0)	0.2	Culvert	2.4	5.2	0.03		USFS Culvert Database (2002)
	Slumber Creek (RM 2.0)	2.3	Dewatering	N/A	N/A			Andonaegui (2003)
	Styx River (RM 4.9)	0.1	Culvert	3.96	DG	0.1		USFS Culvert Database (2002)
	N. Fk. Slate Creek (RM 6.2)	1.4	Natural Series	DG	27.5	18		McLellan (2001)
	N. Fk. Slate Creek (RM 6.2)	1.5	Manmade	DG	DG	DG	Questionable	McLellan (2001)
Threemile Creek (RM 24.3)	Threemile Mainstem	0	Waterfall	5	N/A			McLellan (2001)
	Threemile Mainstem	0.15	Culvert	DG	DG			POSRT (2005)
Beaver Creek (RM 24.3)	Beaver Creek Mainstem	0	Waterfall	25.3	N/A			McLellan (2001)
	Beaver Creek Mainstem	1.1	Culvert	DG	DG			POSRT (2005)
Flume Creek (RM 25.8)	Flume Creek Mainstem	0.20	Waterfall	13	N/A			McLellan (2001)
	Flume Creek Mainstem	1.0	Culvert	2.5	DG			McLellan (2001)
	Flume Creek Mainstem	4.75	Culvert	1.5	DG			McLellan (2001)
	S. Fk. Flume Creek (RM 1.1)	0.3	Culvert	DG	DG			POSRT (2005)
SULLIVAN CREEK WAU								
Sullivan Creek (RM 26.9)	Sullivan Creek Mainstem	0.6	Natural Series				Questionable	CES (1996)
	Sullivan Creek Mainstem	3.25	DAM	16.8	N/A	N/A	Mill Pond Dam	R2 Resource Consultants (1998)
	North Fork Sullivan Creek (RM 2.35)	0.0	Culvert	DG	DG	DG		USFS Culvert Database (2002)
	North Fork Sullivan Creek (RM 2.35)	0.2	Natural Series	2 to 4	DG	DG		USFS Culvert Database (2002)
	North Fork Sullivan Creek (RM 2.35)	0.6	Gradient	DG	DG	DG		Connor et al. (2005)
	North Fork Sullivan Creek (RM 2.35)	1.5	Natural Series	2.3	DG	DG		Connor et al. (2005)
	North Fork Sullivan Creek (RM 2.35)	2.6	Two Waterfalls	2.1 and 1.5	DG	DG		Connor et al. (2005)
	Elk Creek (RM 3.7)	0.58	DG	DG	DG	DG	No information provided	WDFW SalmonScape (2007)
	Stony Creek (RM 11.6)	0.04	Culvert	3.9	15.2	0.03	Questionable	USFS Culvert Database (2002)
	Kinyon Creek (RM 12.65)	0.27	Culvert	3.5	12.8	0.05		USFS Culvert Database (2002)
	Copper Creek (RM 13.35)	0.05	Culvert	DG	DG	DG		USFS Culvert Database (2002)

Table A.7-1, continued…

Tributary Name	Tributary/Creek Name	Barrier Location (RM)	Barrier Type	Height (m)	Length (m)	Gradient (%)	Comments	Source
BOX CANYON WAU								
Linton Creek (RM 28.1)	Linton Creek Mainstem	0.18	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.21	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.25	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.33	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.24	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.38	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.42	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.67	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.71	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.76	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.78	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	1.07	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	1.1	Culvert	DG	DG	DG		POSRT (2005)
Pocahontas Creek (RM 29.4)	Pocahontas Creek Mainstem	0.0 to 0.25	Dewatering	N/A	402	N/A		R2 Resource Consultants (2006)
	Pocahontas Creek Mainstem	0.34	Culvert	DG	DG	DG		POSRT (2005)
Wolf Creek (RM 30.3)	Wolf Creek Mainstem	0.35	Culvert	DG	DG	DG		POSRT (2005)
	Wolf Creek Mainstem	1.21	Culvert	DG	DG	DG		POSRT (2005)
Sweet Creek (RM 30.9)	Sweet Creek Mainstem	0.5	Culvert	2.59	19.5	DG	Problem is velocity	WDFW SalmonScape (2007)
	Sweet Creek Mainstem	0.6	Natural Series	6 to 8.2	870	DG		McLellan (2001)
	Sweet Creek Mainstem	1.4	Culvert	DG	DG	DG		POSRT (2005)
	Sweet Creek Mainstem	1.5	Culvert	DG	DG	DG		POSRT (2005)
	Lunch Creek (RM 1.5)	1.4	Culvert	DG	DG	DG		POSRT (2005)
Sand Creek (RM 31.6)	Sand Creek Mainstem	0.0 to 0.25	Dewatering	N/A	402.3	N/A		Andonaegui (2003)
	Sand Creek Mainstem	0.25	Culvert	2	75	DG		McLellan (2001)
	Sand Creek Mainstem	0.5	Culvert	DG	DG	DG	No information provided	Andonaegui (2003)
	Sand Creek Mainstem	1.25	Waterfall	5	N/A	N/A		McLellan (2001)
	Sand Creek Mainstem	1.8	Culvert	4.2	15.7	0.03		USFS Culvert Database (2002)
Lost Creek (RM 31.6)	Lost Creek Mainstem	0.16	Culvert	DG	DG	DG		POSRT (2005)
	Lost Creek Mainstem	0.92	Culvert	DG	DG	DG		POSRT (2005)
	Lost Creek Mainstem	1.41	Culvert	DG	DG	DG		POSRT (2005)
Unnamed No. 13	Unnamed No. 13 Mainstem	**0.18**	**Natural**	**>4.6**	**DG**	**DG**		**B. Fullerton, TT EC Inc., pers. Comm., 2007)**

Appendix 8: Draft Limiting Factors Matrix

Table A.8-1. 2007 draft matrix of factors limiting productivity of native salmonids in primary tributaries.

Stream Name/Reach	Productivity Factors												
	Access to Spawning and Rearing		Channel Conditions/Dynamics			Habitat Elements					Water Quality	Water Quantity	Species Competition
	Artificial Structures	Riparian Condition	Streambank Condition	Floodplain Connectivity	Channel Stability	Channel Substrate	LWD	Pool Frequency and Quality	Pool Depth	Off-Channel Habitat	Temperature	Change in Flow Regime	Non-indigenous Fish
SLATE CREEK WAU													
Lime Creek (RM 19.0)													
RM 0.0 - 1.3	G1	√	√	G1	F1	P1	G1	F1	F1	F1	F1	G1	P1
Slate Creek (RM 22.2)													
RM 0.0 - 6.2	G1	F1	G1	G1	F1	F1	G1	G1	G1	G1	G1	G1	P1
Slumber Creek (RM 2.0)													
RM 0.0 - 0.5	P1	G1	G1	G1	G1	F1	G1	G1	G1	G1	G1	G1	P1
Uncas Gulch (RM 2.75)													
RM 0.0 - 2.0	G1	G1	G1	G1	G1	G2	G1	P1	G1	G1	G1	G1	P1
Styx River (RM 4.9)													
RM 0.0 - 2.0	P1	G1	G1	G1	G1	G2	G1	P1	G1	G1	G1	G1	P1
S. Fk. Slate Creek (RM 6.2)													
RM 0.0 - 1.0	G1	G1	G1	G1	G1	G2	G1	G1	G1	G1	G1	G1	P1
N. Fk. Slate Creek (RM 6.2)													
RM 0.0 - 2.5	DG	G1	G1	G1	G1	G2	G1	P1	F1	G1	G1	G1	P1
Flume Creek (RM 25.8)													
RM 0.0 - 4.75	P1	√	G1	DG	√	G1	G1	P1	F1	DG	F1	F1	P1
S. Fk. Flume Creek (RM 1.1)													
RM 0.0 - 0.3	P1	DG	DG	DG	√	G1	√	P1	F1	DG	F1	DG	P1
M. Fk. Flume Creek (RM 3.3)													
RM 0.0 - 0.75	G1	√	DG	DG	√	G1	√	P1	F1	DG	F1	√	P1
SULLIVAN CREEK WAU DOWNSTREAM OF MILL POND DAM (RM 3.25)													
Sullivan Creek (RM 26.9)													
RM 0.0 - 3.25	P1	G1	F1	G1	√	P1	P1	F1	F1	NA	P1	P1	P1
N. Fk. Sullivan Creek RM (2.35)													
RM 0.0 - headwaters	P1	G1	DG	G1	G1	P1	G1	F1	G1	G1	G1	G1	G1
BOX CANYON WAU													
Linton Creek (RM 28.1)													
RM 0.0 - 1.10	P1	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
Pocahontas Creek (RM 29.4)													
RM 0.0 - 0.6	P1	√	DG	G1	P1	P1	F1	P1	F1	F1	√	√	P1
Sweet Creek (RM 30.9)													
RM 0.0 - 0.6	P1	√	DG	DG	√	P1	G1	G1	F1	√	P1	√	P1
Lunch Creek (RM 1.5)													
RM 0.0 - 1.4	P1	√	DG	DG	DG	DG	G1	P1	F1	DG	√	√	P1
Sand Creek (RM 31.7)													
RM 0.0 -1.8	P1	G1	F1	G1	F1	P1	G1	P1	F1	NA	P1	DG	P1

Notes:
P – Average habitat condition considered to be poor (Not Properly Functioning)
F – Average habitat condition considered to be fair (At Risk)
G – Average habitat condition considered to be good (Properly Functioning)
NA – Not Applicable.
√ : 1) data is available but not in a format to allow for ready comparison with Andonaegui (2003) habitat rating criteria, and/or 2) data is not assessed in a geomorphic context.
DG – Data Gap; the stream or reach has not been surveyed or so little information is available that rating the condition was not valid.

1 – Quantitative studies, surveys, or published reports documenting habitat condition.
2 – Professional knowledge of the TAG members as reported in Andonaegui (2003)

(green) = Based on available information, conditions are not limiting.
(orange) = Based on available information, conditions may be limiting.
(red) = Based on available information, conditions are limiting.
(white) = No information is available.

Appendix 9: Washington Conservation Commission Salmonid Habitat Rating Criteria (Smith 2005)

Table A.9-1. Salmonid habitat rating criteria from Smith (2005).

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Access and Passage						
Artificial Barriers	% known/potential habitat blocked by artificial barriers	All	>20%	10-20%	<10%	WCC
Floodplains						
Floodplain Connectivity	Stream and off-channel habitat length with lost floodplain connectivity due to incision, roads, dikes, flood protection, or other	<1% gradient	>50%	10-50%	<10%	WCC
Loss of Floodplain Habitat	Lost wetted area	<1% gradient	>66%	33-66%	<33%	WCC
Channel Conditions						
Fine Sediment	Fines < 0.85 mm in spawning gravel	All – Westside	>17%	11-17%	≤11%	WSP/WSA/ NMFS/Hood Canal
	Fines < 0.85 mm in spawning gravel	All – Eastside	>20%	11-20%	≤11%	NMFS

Table A.9-1, continued...

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Large Woody Debris	pieces/m channel length	≤ 4% gradient, <15 m wide (Westside only)	<0.2	0.2-0.4	>0.4	Hood Canal/Skagit
	or use Watershed Analysis piece and key piece standards listed below when data are available					
	pieces/channel width	<20 m wide	<1	1-2	2-4	WSP/WSA
	key pieces/channel width*	<10 m wide (Westside only)	<0.15	0.15-0.30	>0.30	WSP/WSA
	key pieces/channel width*	10-20 m wide (Westside only)	<0.20	0.20-0.50	>0.50	WSP/WSA
	* Minimum size to qualify as a key piece:	BFW (m)	Diameter (m)	Length (m)		
		0-5	0.4	8		
		6-10	0.55	10		
		11-15	0.65	18		
		16-20	0.7	24		
Percent Pool	% pool, by surface area	<2% gradient, <15 m wide	<40%	40-55%	>55%	WSP/WSA
	% pool, by surface area	2-5% gradient, <15 m wide	<30%	30-40%	>40%	WSP/WSA
	% pool, by surface area	>5% gradient, <15 m wide	<20%	20-30%	>30%	WSP/WSA
	% pool, by surface area	>15 m	<35%	35-50%	>50%	Hood Canal
Pool Frequency	channel widths per pool	<15 m	>4	2-4	<2	WSP/WSA
	channel widths per pool	>15 m	-	-	chann width / pools/mile / cw/pool 50' / 26 / 4.1 75' / 23 / 3.1 100' / 18 / 2.9	NMFS

Table A.9-1, continued...

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Pool Quality	pools >1 m deep with good cover and cool water	All	No deep pools and inadequate cover or temperature, major reduction of pool volume by sediment	Few deep pools or inadequate cover or temperature, moderate reduction of pool volume by sediment	Sufficient deep pools	NMFS/WSP/ WSA
Streambank Stability	% of banks not actively eroding	All	<80% stable	80-90% stable	>90% stable	NMFS/WSP
Sediment Input						
Sediment Supply	$m^3/km^2/yr$	All	>100 or exceeds natural rate*	-	<100 or does not exceed natural rate*	Skagit
*Note: this rate is highly variable in natural conditions						
Mass Wasting		All	Significant increase over natural levels for mass wasting events that deliver to stream	-	No increase over natural levels for mass wasting events that deliver to stream	WSA
Road Density	mi/mi^2	All	>3 with many valley bottom roads	2-3 with some valley bottom roads	<2 with no valley bottom roads	NMFS

Table A.9-1, continued...

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
			or use results from Watershed Analysis where available			
Riparian Zones						
Riparian Condition	riparian buffer width (measured out horizontally from the channel migration zone on each side of the stream) Riparian composition	Type 1-3 and untyped salmonid streams >5’ wide	<75’ or <50% of site potential tree height (whichever is greater) OR Dominated by hardwoods, shrubs, or non-native species (<30% conifer) unless these species were dominant historically.or non-native species (<30% conifer) unless these species were dominant historically.	75’-150’ or 50-100% of site potential tree height (whichever is greater) AND Dominated by conifers or a mix of conifers and hardwoods (≥30% conifer) of any age unless hardwoods were dominant historically.	>150’ or site potential tree height (whichever is greater) AND Dominated by mature conifers (≥70% conifer) unless hardwoods were dominant historically	WCC/WSP
	• buffer width • riparian composition	Type 4 and untyped perennial streams <5’ wide	<50’ with same composition as above	50’-100’ with same composition as above	>100’ with same composition as above	WCC/WSP
	• buffer width • riparian composition	Type 5 and all other untyped streams	<25’ with same composition as above	25’-50’ with same composition as above	>50’ with same composition as above	WCC/WSP
Water Quality						
Temperature	degrees Celsius	All	>15.6° C (spawning) >17.8° C (migration and rearing)	14-15.6° C (spawning) 14-17.8° C (migration and rearing)	10-14° C (degree)	NMFS
Dissolved Oxygen	mg/L	All	<6	6-8	>8	ManTech

Table A.9-1, continued...

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Hydrology						
Flow	hydrologic maturity	All	<60% of watershed with forest stands aged 25 years or more	-	>60% of watershed with forest stands aged 25 years or more	WSP/Hood Canal
	or use results from Watershed Analysis where available					
	% impervious surface	Lowlands basin	>10%	3-10%	≤3%	Skagit

<u>Notes:</u>
BFW – bankfull width
NMFS – National Marine Fisheries Service
Skagit – Skagit Watershed Council Protection and Restoration Strategy (1998)
WCC – Washington Conservation Commission
WSA – Watershed Analysis Manual, v. 4.0 (1997), Washington Forest Practices Board
WSP – Wild Salmon Policy (Washington Department of Fish and Wildlife)

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Appendix 10: POSRT (2005) Priority Subbasins and Actions

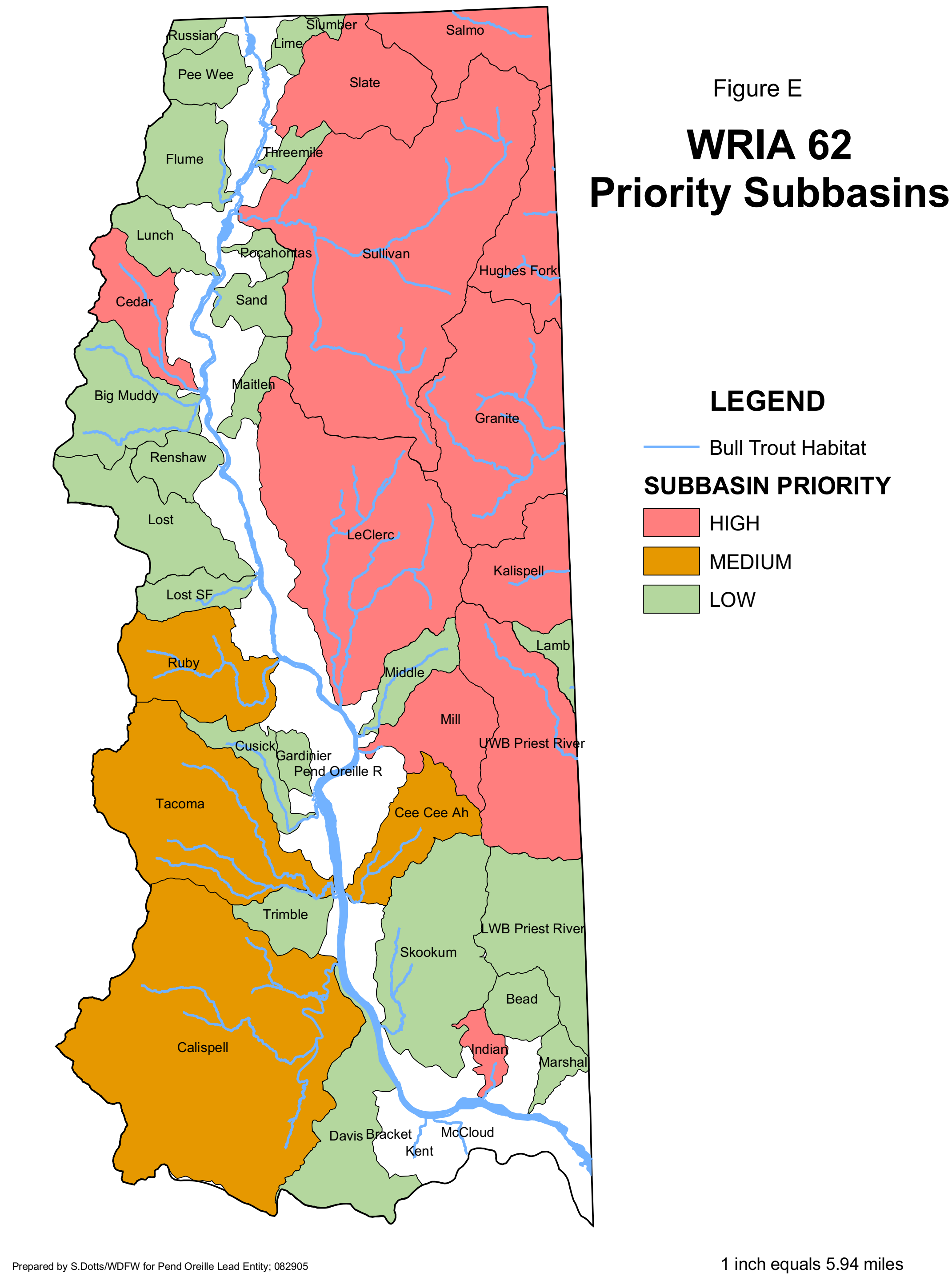

Figure A.10-1. Priorities and actions map for WRIA 62 Subbasins identified by the POSRT (2005). The figure illustrates all priorities identified in WRIA 62. Subsequent information in Appendix 10 will only focus on Boundary Reservoir tributaries.

Table A.10-1. Priorities and actions for subbasins identified as "High" priorities by the POSRT (2005) for Boundary Reservoir tributaries.

Reach[1]	Species	Habitat Type Addressed	Project Type[2]	Actions/Need	Action Priority	LF[4] Priority	Rationale	Community Support[5]	Project Status
SLATE SUBBASIN – High Priority Area #5 (Figure A.10-2)									
Slate Creek (subbasin-wide)	Bull trout (threatened) WCT	Spawning Rearing	R	Remove non-native fish species (brook, brown and rainbow trout)	1	1	Non-native brook trout hybridize with bull trout and complete for habitat and resources; non-native rainbow trout hybridize with native WCT trout and complete for habitat and resources with both WCT and bull trout. Brown trout compete for habitat and resources with both WCT and bull trout and are predators on these two species as well.	Low	Out of Scope
Slate Creek (subbasin-wide)	WCT	Migration	R	Replace or remove culverts which have been identified as fish passage barriers	2	2	These barriers prevent migration of WCT.	Moderate	See Appendix E in POSRT (2005)
SULLIVAN SUBBASIN – High Priority Area #7 (Figure A.10-3)									
Sullivan Creek (RM 3.25)	Bull trout (threatened) WCT	Migration	R	Remove Mill Pond Dam and restore upstream channel to proper form and function	1	2,4	This barrier blocks access to 28 miles salmonid habitat.	Low	Unfunded
Outlet Creek (RM 0.5)	Bull trout (threatened) WCT	Migration	R	Restore fish passage at Sullivan Lake Dam	2	2	This barrier blocks access to 16 miles and 1,251 acres (Sullivan Lake) of salmonid habitat.	Moderate	Unfunded

Table A.10-1, continued…

Reach[1]	Species	Habitat Type Addressed	Project Type[2]	Actions/Need	Action Priority	LF[4] Priority	Rationale	Community Support[5]	Project Status
Sullivan Creek (subbasin-wide)	Bull trout (threatened) WCT	Spawning Rearing	R	Remove non-native fish species (brook, brown and rainbow trout), except kokanee	3	1	Non-native brook trout hybridize with bull trout and complete for habitat and resources; non-native rainbow trout hybridize with native WCT trout and complete for habitat and resources with both WCT and bull trout Brown trout compete for habitat and resources with both WCT and bull trout and are predators on these two species as well.. Kokanee are an important recreational fish in Sullivan Lake, which do not negatively impact bull trout populations and provide forage.	Moderate	Out of Scope
Sullivan Creek (RM 2.8-3.2) Pass Creek (RM 2.6-5.1)	Bull trout (threatened) WCT	Spawning Rearing	R	Relocate, obliterate, and/or reconstruct road segments which are contributing sediment to streams	4	6	Excessive soil input into streams can limit winter rearing and spawning habitat through the filling of pools and interstitial spaces within gravels and cobbles.	Low	Unfunded

Table A.10-1, continued…

Reach[1]	Species	Habitat Type Addressed	Project Type[2]	Actions/Need	Action Priority	LF[4] Priority	Rationale	Community Support[5]	Project Status
Sullivan Creek (RM 3.75-5.25)	Bull trout (threatened) WCT	Spawning Rearing	R	Install engineered log jams above Mill Pond Dam	5	3,5	This section of Sullivan Creek lacks habitat complexity, particularly in the amount of instream wood needed for cover.	Moderate	Unfunded
Sullivan Creek (RM 0-3.25)	Bull trout (threatened) WCT	Spawning Rearing	R	Stabilize slopes below Mill Pond Dam	6	3	Steep slopes with drainage problems are a periodic source of fine sediment that degrades downstream spawning and rearing habitat.	Moderate	Unfunded
Sullivan Lake (RM 0.5 of Outlet Creek)	Bull trout (threatened)	Spawning Rearing Migration	A	Determine the biological effects of current and alternative management of lake water levels on bull trout life histories above and below the dam	7	7	Existing unnatural flow regime in lower Sullivan Creek, lack of littoral area in Sullivan Lake and possibly aggradation of lower Harvey Creek are results of present hydroelectric project (i.e., Sullivan Lake Dam). This is a critical data gap.	Moderate	Unfunded
Sullivan Lake	Pygmy whitefish	Spawning Rearing	A	Assess habitat factors limiting pygmy whitefish in lake	8	7	Pygmy whitefish are a state "sensitive" species and long term viability needs to be assured to keep it from being listed under ESA. This is a critical data gap.	MIR	Unfunded

Table A.10-1, continued…

Reach[1]	Species	Habitat Type Addressed	Project Type[2]	Actions/Need	Action Priority	LF[4] Priority	Rationale	Community Support[5]	Project Status
Sullivan Creek (Subbasin-wide)	Bull trout (threatened) WCT	Spawning Rearing	R	Restore habitat complexity	9	3,5,6	Upper Sullivan Creek had extensive riparian harvest and wood pulled out of the steam in the 1960-70s. Lower Sullivan Creek lacks spawning material and instream wood due to interception by Mill Pond Dam. Habitat complexity must be improved to provide appropriate spawning and rearing habitat for bull trout and other salmonids.	Moderate	Partially Funded (POPUD)

Notes:
1 River miles are estimated.
2 A = Assessment Project; R = Restoration Project
3 A sequential prioritization of action/need within subbasin
4 LF = Limiting Factor (see corresponding figure for limiting factor description)
5 Values for Community Support
POPUD – Pend Oreille Public Utility District
WCT – westslope cutthroat trout

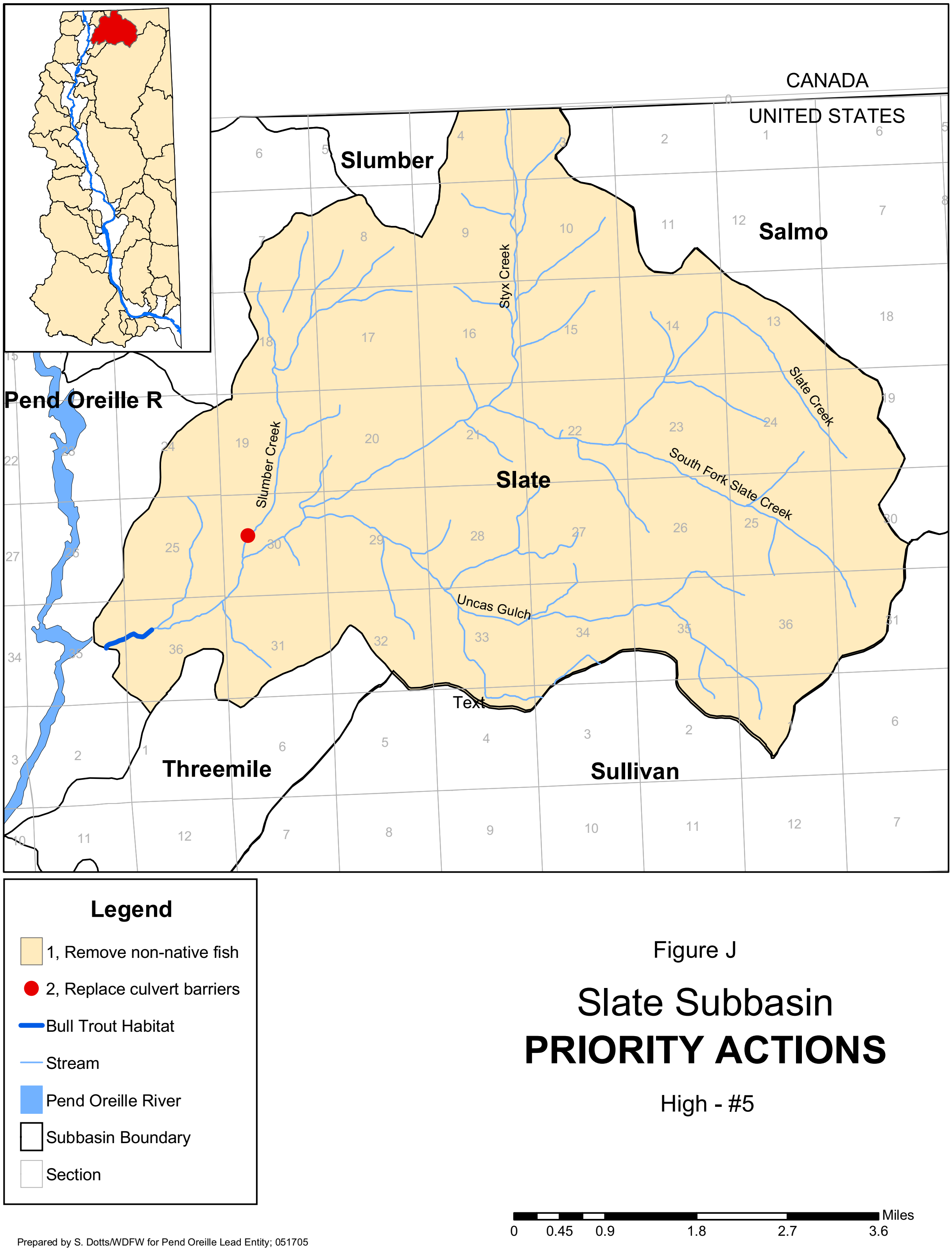

Figure A.10-2. Map of priority actions for the Slate Subbasin identified by the POSRT (2005). Priorities are documented in Table A.10-1.

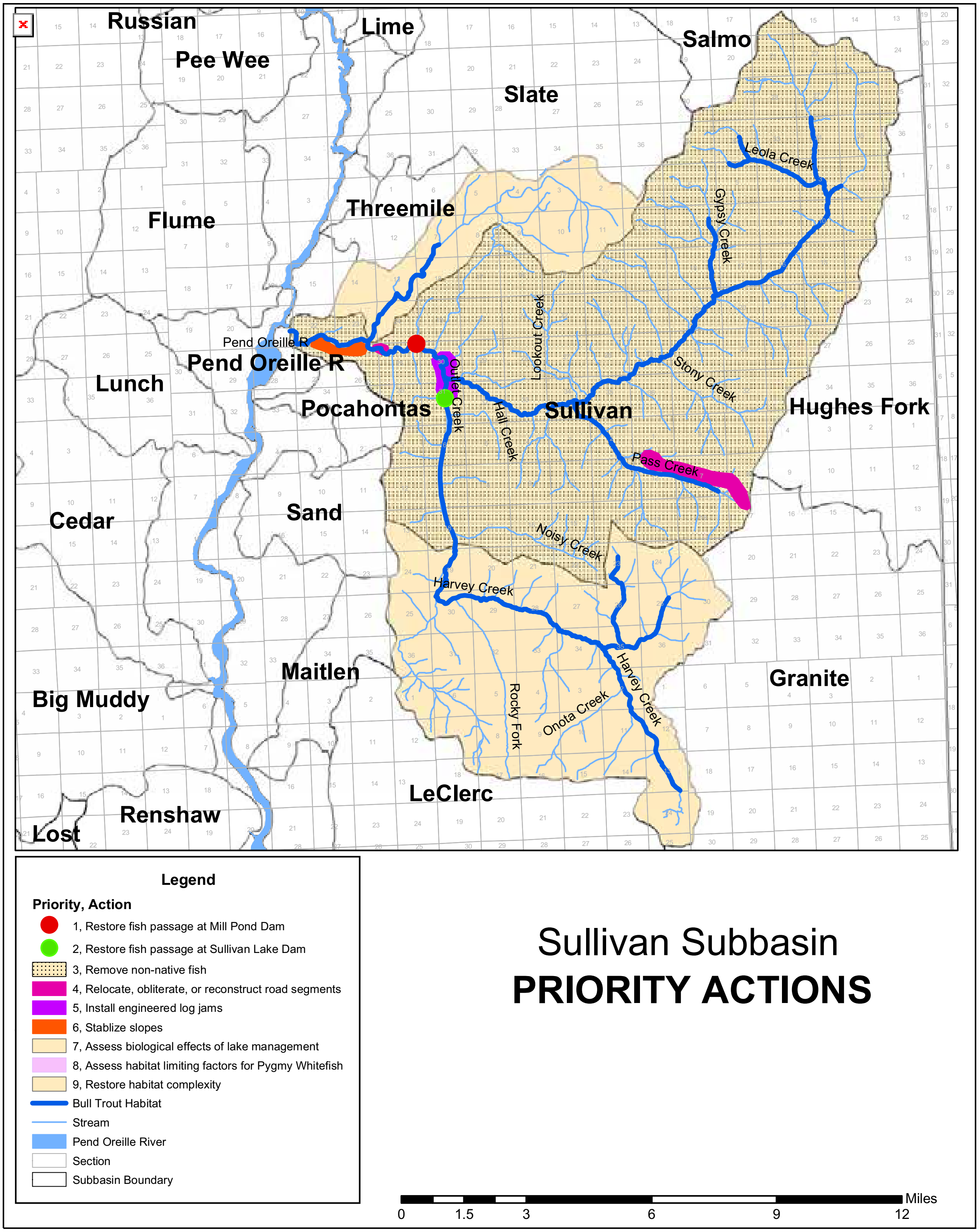

Figure A.10-3. Map of priority actions for the Slate Subbasin identified by the POSRT (2005). Priorities are documented in Table A.10-1.

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Appendix 11: Results from the 2008 Field Assessments of Tributary Creeks

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List of Tables

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A.11.1 SLUMBER CREEK (TRIBUTARY TO SLATE CREEK)

Table A.11.1-1. Slumber Creek culvert dimensions.

Feature	Culvert 1.1
Culvert Material	Corrugated Steel
Span	1.36 m (4.46 ft)
Rise	0.82 m (2.69 ft)
Water Depth in Culvert	0.13 m (0.43 ft)
Outfall Drop	0.00 m (0.00 ft)
Length	5.0 m (16.4 ft)
Slope	0.7%
Road Width	3.60 m (11.81 ft)
Fill Depth	0.48 m (1.57 ft)

Table A.11.1-2. Results from habitat survey downstream of culvert on Slumber Creek.

Mean Residual Pool Depth	Mean Thalweg Depth	Mean Water Surface Slope (%)	Mean Wetted Width	Volume of LWD	Dominant Habitat Type	3-Layer Riparian Vegetation Presence (%)	Riparian Cover Along Bank (0 -17)[1]	Percent Fines (%)	D50 (mm)	Embeddness (%)	Streambank Cover Value (1 - ≥ 4)[2]	Avg Bank Angle (°)[3]	Bank Erosion (%)
5.9 cm (2.3 in)	21.1 cm (8.3 in)	3	1.7 m (5.6 ft)	8.1 m^3 (286.0 ft^3)	Riffle	87.5	16.3	20	6.4	73.3	4	110	25.8

Notes:

1 Values are between 0 and 17 with 0 representing no bank cover and 17 representing complete bank cover.

2 A value of 4 is a good rating for total cover. Good is defined in Bain and Stevenson (1999) as most of the streambank surfaces are covered by vegetation or rocky material the size of pebbles and larger. Areas not covered by vegetation are protected by materials that will limit erosion at high streamflows.

3 An average bank angle between 90° and 135° indicates steeply sloping shorelines, as defined in Bain and Stevenson (1999).

Table A.11.1-3. Results from reach-scale habitat survey upstream of culvert on Slumber Creek.

Mean Residual Pool Depth	Mean Thalweg Depth	Mean Water Surface Slope (%)	Mean Wetted Width	Volume of LWD	Dominant Habitat Type	3-Layer Riparian Vegetation Presence (%)	Mean Canopy Density Along Bank (0 -17)[1]	Percent Fines (%)	D50 (mm)	Embeddness (%)	Streambank Cover Value (1 - ≥ 4)[2]	Average Bank Angle (°)[3]	Bank Erosion (%)
12.6 cm (5.0 in)	30.6 cm (12.0 in)	3	2.4 m (7.9 ft)	17.3 m^3 (610.9 ft^3)	Pool	75	16	6.7	6	78.8	4	118	20.8

Notes:
1 Values are between 0 and 17 with 0 representing no bank cover and 17 representing complete bank cover.
2 A value of 4 is a good rating for total cover. Good is defined in Bain and Stevenson (1999) as most of the streambank surfaces are covered by vegetation or rocky material the size of pebbles and larger. Areas not covered by vegetation are protected by materials that will limit erosion at high streamflows.
3 An average bank angle between 90° and 135° indicates steeply sloping shorelines, as defined in Bain and Stevenson (1999).

Table A.11.1-4. Results from the Level B Assessment of the culvert on Slumber Creek.

Fish Passage Barrier Assessment and Prioritization Manual - 2.3 Barrier Analysis
Level B Spreadsheet; Version: Excel 97, Metric Units
Updated: May 30, 2001

Site Information			**Source Worksheet**
Stream:	Slumber Creek		Hydrology
Site ID:	Slumber Creek		"
Sequencer:	1.1		"

Hydrology

Hydrology Method Selected:	Ordinary High Water Method		Hydrology
Elevation of Ordinary High Water:	29.5		X Section

Downstream Channel Cross Section

	TopLB	ToeLB	Bed1	Bed2	Bed3	ToeRB	TopRB	Source Worksheet
								X Section
Station:	0	0.35	1.05	1.65	2.2	2.9	4.55	"
Elev:	29.61	29.16	29.2	29.21	29.21	29.24	29.5	"

DS Control Water Surface Elevation:	29.314			X Section
Water Surface Elevation 50 ft. (15.24 m) DS:	29.014			"
Manning's "n" for channel	0.03			"
Cross Section Water Surface Elevation at Wfp:	29.504			"
Culvert Length:	5.00	m		Round
Maximum Velocity:	1.22	mps	(WAC criteria)	
Minimum Water Depth:	0.30	m	(WAC criteria)	
Maximum Hydrualic Drop in Fishway:	0.30	m	(WAC criteria)	
Culvert Type:	Round Culvert			X Section

Culvert Analysis

Round Culvert Diamter (m):	1.36	Round
Manning's n for culvert:	0.0240	"
Culvert Length (m):	5.00	"
U/S Invert Elevation:	29.28	"
D/S/ Invert Elelvation:	29.24	"
Normal Flow Depth (m):	0.883	"
Culvert Slope (m/m):	0.0072	"
Velocity w/o backwater (mps):	1.89	"
Water Surface Elevation at DS end of culvert:	29.50	"
Flow Depth at DS end of culvert:	0.00	"
Culvert Influenced by Backwater:	No	"
Outlet Submerged:	No	"
Length Submerged (m):	0.00	"
Backwater Length Plus Submerged Length (m):	0.00	"
Maximum Velocity in Culvert (mps):	0.00	"
Minimum Depth in Culvert (m):	0.00	"

Summary of Analysis

1. High Fish Passage Design Flow, Qfp was determined by the **Ordinary High Water Method.**

Qfp = 1.88 cms

2. Next the culvert was analyzed at Qfp without backwater.

Max. Velocity (w/o backwater) =	**1.89**	**mps**	**Does not satisfy WAC criteria.**
Min. Depth (w/o backwater) =	**0.88**	**m**	**Satisfies WAC criteria.**

Velocity does not satisfy WAC criteria, check backwater

3. Finally, the backwater condition was analyzed.

Is the culvert influenced by backwater?	**No**	
Is the culvert outlet submerged?	**No**	**0.00 m of culvert submerged**

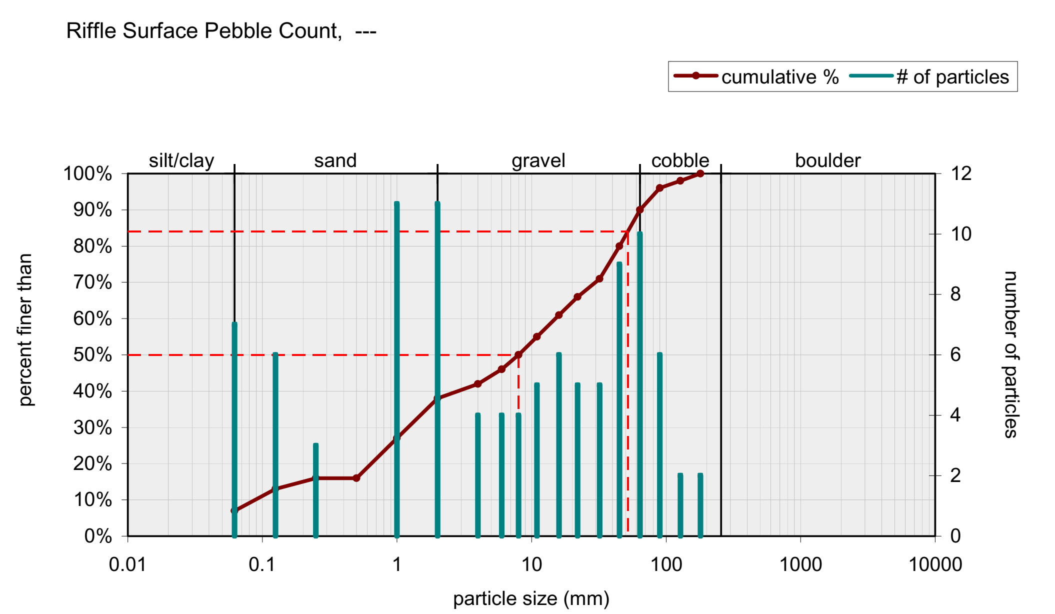
Max. Velocity (w/ backwater) =	**0.00**	**mps**	**Satisfies WAC criteria.**
Min. Depth (w/ backwater) =	**0.00**	**m**	**Does not satisfy WAC criteria.**

4. The Final Answer…

The culvert does not satisfy WAC criteria.
The culvert is a barrier.

Table A.11.1-5. Geomorphic survey results for Slumber Creek.

Bankfull Width	Mean Bankfull Depth	Bankfull Cross-Sectional Area	Width/Depth Ratio	Maximum Bankfull Depth	Width of Flood-Prone Area	Entrench-ment Ratio	D50	Channel Slope	Channel Sinuosity
1.9 m (6.2 ft)	0.21 m (0.69 ft)	0.4 m^2 (4.3 ft^2)	8.9	0.3 m (1.0 ft)	2.8 m (9.2 ft)	1.5	8 mm	3%	1.07



Size (mm)	
D16	0.5
D35	1.7
D50	8
D65	21
D84	52
D95	85

Size Distribution	
mean	5.1
dispersion	11.3
skewness	-0.14

Type	
silt/clay	7%
sand	31%
gravel	52%
cobble	10%
boulder	0%

Figure A.11.1-1. Riffle surface pebble count results for Slumber Creek.

A.11.2 STYX CREEK (TRIBUTARY TO SLATE CREEK)

Table A.11.2-1. Styx Creek culvert dimensions.

Feature	Culvert 1.1
Culvert Material	Corrugated Steel
Span	2.44 m (8.01 ft)
Rise	1.86 m (6.10 ft)
Water Depth in Culvert	0.11 m (0.36 ft)
Outfall Drop	0.17 m (0.56 ft)
Length	18.5 m (60.70 ft)
Slope	6.5%
Road Width	3.60 m (11.81 ft)
Fill Depth	0.26 m (0.85 ft)

Table A.11.2-2. Results from habitat survey downstream of culvert on Styx Creek.

Mean Residual Pool Depth	Mean Thalweg Depth	Mean Water Surface Slope (%)	Mean Wetted Width	Volume of LWD	Dominant Habitat Type	Three-Layer Riparian Vegetation Presence (%)	Riparian Cover Along Bank (0 -17)[1]	Percent Fines (%)	D50 (mm)	Embeddness (%)	Streambank Cover Value (1 - > 4)[2]	Average Bank Angle (°)[3]	Bank Erosion (%)
8.6 cm (2.3 in)	26.4 cm (10.4 in)	6	3.7 m (12.1 ft)	16.1 m^3 (568.6 ft^3)	Riffle	100	17	6.7	27	25	> 4	111	16.7

Notes:
1 Values are between 0 and 17 with 0 representing no bank cover and 17 representing complete bank cover.
2 A value of > 4 is an excellent rating for total cover. Excellent is defined in Bain and Stevenson (1999) as nearly all of the streambank is covered by vegetation in vigorous condition or by boulders and cobble.
3 An average bank angle between 90° and 135° indicates steeply sloping shorelines, as defined in Bain and Stevenson (1999).

Table A.11.2-3. Results from reach-scale habitat survey upstream of culvert.

Mean Residual Pool Depth	Mean Thalweg Depth	Mean Water Surface Slope (%)	Mean Wetted Width	Volume of LWD	Dominant Habitat Type	Three-Layer Riparian Vegetation Presence (%)	Mean Canopy Density Along Bank (0 -17)[1]	Percent Fines (%)	D50 (mm)	Embeddness (%)	Streambank Cover Value (1 - > 4)[2]	Average Bank Angle (°)[3]	Bank Erosion (%)
4.6 cm (1.8 in)	20.5 cm (8.1 in)	4	3.0 m (9.8 ft)	9.6 m^3 (339.0 ft^3)	Riffle	62.5	16.4	0	28	26.5	4	160	6.7

Notes:
1 Values are between 0 and 17 with 0 representing no bank cover and 17 representing complete bank cover.
2 A value of 4 is a good rating for total cover. Good is defined in Bain and Stevenson (1999) as most of the streambank surfaces are covered by vegetation or rocky material the size of pebbles and larger. Areas not covered by vegetation are protected by materials that will limit erosion at high streamflows.
3 An average bank angle greater than 135° reflects gently sloping banks, as defined in Bain and Stevenson (1999).

Table A.11.2-4. Results from the Level B Assessment of the culvert on Styx Creek.

Fish Passage Barrier Assessment and Prioritization Manual - 2.3 Barrier Analysis
Level B Spreadsheet; Version: Excel 97, Metric Units
Updated: May 30, 2001

Site Information				**Source Worksheet**
Stream:	Styx Creek			Hydrology
Site ID:	Styx Creek			"
Sequencer:	1.1			"
Hydrology				
Hydrology Method Selected:	Ordinary High Water Method			Hydrology
Elevation of Ordinary High Water:	27.51			X Section

Downstream Channel Cross Section

	TopLB	ToeLB	Bed1	Bed2	Bed3	ToeRB	TopRB	X Section
Station:	0.00	0.19	1.84	2.70	2.87	3.89	4.82	"
Elev:	27.51	27.33	27.24	27.15	27.31	27.30	27.12	"

DS Control Water Surface Elevation:	27.36			X Section
Water Surface Elevation 50 ft. (15.24 m) DS:	26.511			"
Manning's "n" for channel	0.04			"
Cross Section Water Surface Elevation at Wfp:	27.51			"
Culvert Length:	18.50	m		Round
Maximum Velocity:	1.22	mps	(WAC criteria)	
Minimum Water Depth:	0.30	m	(WAC criteria)	
Maximum Hydrualic Drop in Fishway:	0.30	m	(WAC criteria)	
Culvert Type:	Round Culvert			X Section

Culvert Analysis

Round Culvert Diamter (m):	2.44	Round
Manning's n for culvert:	0.0270	"
Culvert Length (m):	18.50	"
U/S Invert Elevation:	28.72	"
D/S/ Invert Elelvation:	27.52	"
Normal Flow Depth (m):	0.427	"
Culvert Slope (m/m):	0.0649	"
Velocity w/o backwater (mps):	3.84	"
Water Surface Elevation at DS end of culvert:	27.51	"
Flow Depth at DS end of culvert:	0.00	"
Culvert Influenced by Backwater:	No	"
Outlet Submerged:	No	"
Length Submerged (m):	0.00	"
Backwater Length Plus Submerged Length (m):	0.00	"
Maximum Velocity in Culvert (mps):	0.00	"
Minimum Depth in Culvert (m):	0.00	"

Summary of Analysis

1. High Fish Passage Design Flow, Qfp was determined by the **Ordinary High Water Method.**

Qfp = 2.11 cms

2. Next the culvert was analyzed at Qfp without backwater.

Max. Velocity (w/o backwater) =	**3.84**	**mps**	**Does not satisfy WAC criteria.**
Min. Depth (w/o backwater) =	**0.43**	**m**	**Satisfies WAC criteria.**

Velocity does not satisfy WAC criteria, check backwater

3. Finally, the backwater condition was analyzed.

Is the culvert influenced by backwater?	**No**	**Culvert is partially backwatered**
Is the culvert outlet submerged?	**No**	**0.00 m of culvert submerged**

The flow conditions are too complex to calculate with this worksheet. Max. velocity and min. depth below are ROUGH ESTIMATES!

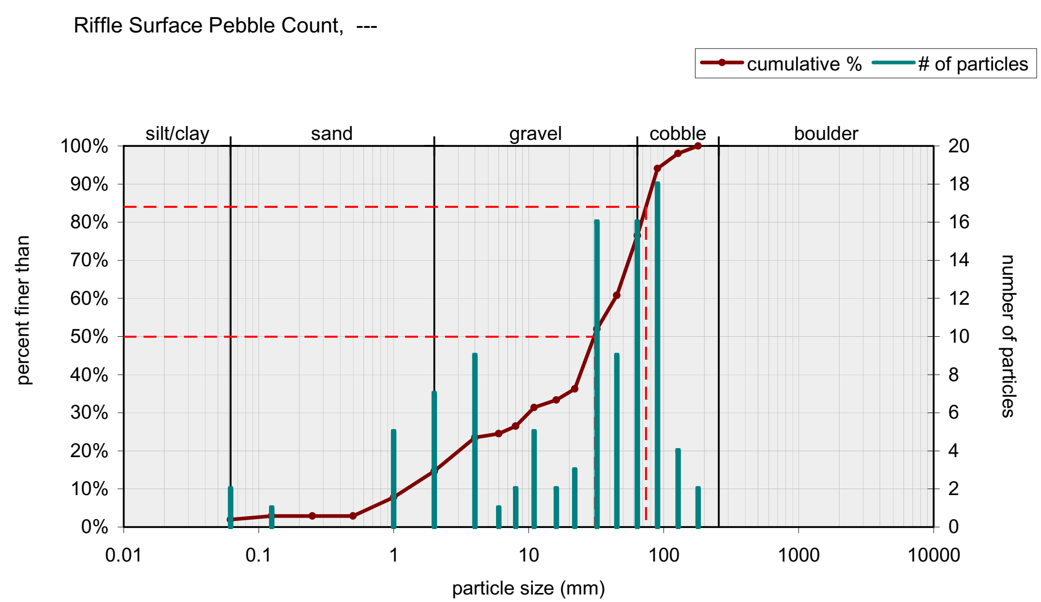
Max. Velocity (w/ backwater) =	**0.00**	**mps**	**Satisfies WAC criteria.**
Min. Depth (w/ backwater) =	**0.00**	**m**	**Does not satisfy WAC criteria.**

4. The Final Answer…

The culvert does not satisfy WAC criteria.
The culvert is a barrier.

Table A.11.2-5. Results of geomorphic survey on Styx Creek.

Bankfull Width	Mean Bankfull Depth	Bankfull Cross-Sectional Area	Width/Depth Ratio	Maximum Bankfull Depth	Width of Flood-Prone Area	Entrench-ment Ratio	D50	Channel Slope	Channel Sinuosity
4.8 m (15.7 ft)	0.20 m (0.66 ft)	1.0 m^2 (10.8 ft^2)	23.5	0.4 m (1.3 ft)	7.9 m (25.9 ft)	1.6	31 mm	6%	1.0



Size (mm)	
D16	2.2
D35	19
D50	31
D65	49
D84	74
D95	97

Size Distribution	
mean	12.8
dispersion	8.2
skewness	-0.31

Type	
silt/clay	2%
sand	13%
gravel	62%
cobble	24%
boulder	0%

Figure A.11.2-1. Riffle surface pebble count results from Styx Creek.

A.11.3 SULLIVAN CREEK

A.11.3.1. Watershed Geomorphology

The underlying geology, within the Sullivan Creek drainage, is metamorphic, mostly metasedimentary (marine metasediments, metaconglornerates, metacarbonate, quartzite and argillites) with rocks that have been folded and sheared by a number of faults (USFS 1996). Valuable mineral deposits (lead, zinc, gold, limestone) can be found in the general area of the Sullivan Creek watershed. Placer gold was mined along Sullivan Creek (USFS 1996), and suction dredge mining as a recreational activity continues. Glacial material generally fills the valley bottoms and many upland slopes (USFS 1996). The soils in the drainage are formed from colluvial bedrock material, glacial material, and volcanic ash (USFS 1996). The primary erosional process throughout the drainage is landslides, and the channel is deeply entrenched and confined as it cuts through a rock canyon (USFS 1996; Andonaegui 2003). Sections of Sullivan Creek downstream and continuing upstream from Mill Pond Dam are historically prone to landslide activity (USFS 1996; Andonaegui 2003). Throughout the Sullivan Creek drainage, channels primarily comprise narrow V- or U-shaped valley forms (Rosgen A and B channel types) and do not and did not historically have many oxbows, backwater habitat, and ponds (USFS 1996; Andonaegui 2003).

The creation of Mill Pond Dam in 1909 altered the natural sediment transport processes in Sullivan Creek by trapping all bedload material behind the dam (USFS 1996). This has created a condition where Sullivan Creek, downstream of Mill Pond Dam (RM 0.0–3.25), is sediment starved (USFS 1996). Therefore, the sediment transport capacity exceeds the sediment supply, which has resulted in a lack of appropriately sized spawning gravel for local trout populations and extensive armoring of the bed surface. Additional information regarding sediment transport processes and the influence Mill Pond Dam has on these processes are described in Study 8.

In Sullivan Creek, maximum flow occurs in May through June, with the minimum flows (baseflow) occurring in the winter due to frozen conditions (USFS 1996). Based on data available from R2 Resource Consultants (2008) report, the minimum average daily inflow of Sullivan Creek to Boundary Dam Reservoir was 0.48 m^3/s (16.9 ft^3/s) (occurring on 2/6/1975) and the maximum average daily inflow was 113.8 m^3/s (4020.0 ft^3/s) (occurring on 6/1/1997). The average annual flow has been reported as 7.1 m^3/s (251.1 ft^3/s) at the mouth of Sullivan Creek (RM 0.0) (Entrix 2002). Downstream of Mill Pond Dam, flooding and scouring can frequently occur, and spring high flows (exceeding 28.3 m^3/s [1,000 ft^3/s] at times) are likely occurrences (CES 1996; Andonaegui 2003) (Figure A.11.3-1).

Figure A.11.3-1. Sullivan Creek at bankfull flow during May survey of Road Segment 4.

In addition to the creation of Mill Pond Dam altering sediment transport processes in Sullivan Creek, altered hydrology due to the release of water from Sullivan Lake Dam, channel straightening activities throughout Sullivan Creek, the location of Sullivan Lake Road along the Creek, and the historic removal of large woody debris (LWD) from the Sullivan Creek drainage have altered the stream morphology (USFS 1996). The results from Road Segments 3 and 4 illustrate the confining influence Sullivan Lake Road has on Sullivan Creek. In Sullivan Creek, at the North Fork Sullivan Creek confluence (RM 2.35 in Sullivan Creek) upstream to Mill Pond Dam (RM 3.25), the USFS (1996) notes that historically the channel was probably pool-riffle morphology. However, the altered sediment transport processes, channel straightening activities, Sullivan Lake Road, and removal of LWD have resulted in a predominately plane-bed morphology (Figures A.11.3-2 and A.11.3-3). The USFS (1996) also notes that these same activities have altered the stream morphology of Sullivan Creek from Mill Pond upstream to Gypsy Creek.

Figure A.11.3-2. Typical plane-bed morphology in Sullivan Creek downstream of Mill Pond Dam.

Figure A.11.3-3. Typical plane-bed morphology in Sullivan Creek upstream from Mill Pond Dam.

To further evaluate the current conditions in Sullivan Creek downstream of Mill Pond Dam (RM 3.25), and determine if there were opportunities to enhance factors limiting aquatic habitat through human intervention, three stream reaches were surveyed (see Figure A.11.3-4 and Table A.11.3-1 below). These reaches were selected by reviewing aerial photographs, developing a longitudinal profile of Sullivan Creek, and performing a field reconnaissance. To investigate the conditions of Sullivan Creek, where not influenced by Mill Pond Dam, three reaches upstream of Mill Pond Dam (RM 3.25) were also surveyed (see Figure A.11.3-4 and Table A.11.3-1 below). Two reaches upstream of Mill Pond Dam were in Sullivan Creek. The other reach was in Outlet Creek, which is the stream channel outflow from Sullivan Lake Dam and is a tributary to Sullivan Creek. The Outlet Creek reach was surveyed to provide information on types of habitat and stream channel conditions available throughout the Sullivan Creek watershed, outside of the mainstem.

Table A.11.3-1. Approximate river mile locations and length of stream reaches surveyed in Sullivan Creek and Outlet Creek.

Reach	River Mile	Reach Length
1 – Sullivan Creek	0.47	340 m (1115.5 ft)
2 – Sullivan Creek	2.30	480 m (1574.8 ft)
3 – Sullivan Creek	2.74	450 m (1476.4 ft)
4 – Sullivan Creek	4.66	320 m (1049.9 ft)
5 – Outlet Creek (Tributary River Mile to Sullivan Creek)	0.16	150 m (492.1 ft)
6 – Sullivan Creek	5.65	294 m (964.6 ft)

The average slope of Sullivan Creek from the mouth (RM 0.0) to Mill Pond Dam (3.25) is 4.3 percent and from the confluence with Outlet Creek to Forest Service Road 22 is 2.3 percent (Figure A.11.3-4 and Table A.11.3-2). The average slope for the three reaches surveyed downstream of Mill Pond Dam is 2.3 percent and for the three reaches surveyed upstream of Mill Pond Dam is 1.3 percent. Although the average slope downstream of Mill Pond Dam is greater than the average slopes upstream, the diagnostic features of plane-bed morphology are exhibited in channel-reaches both up- and downstream of the dam.

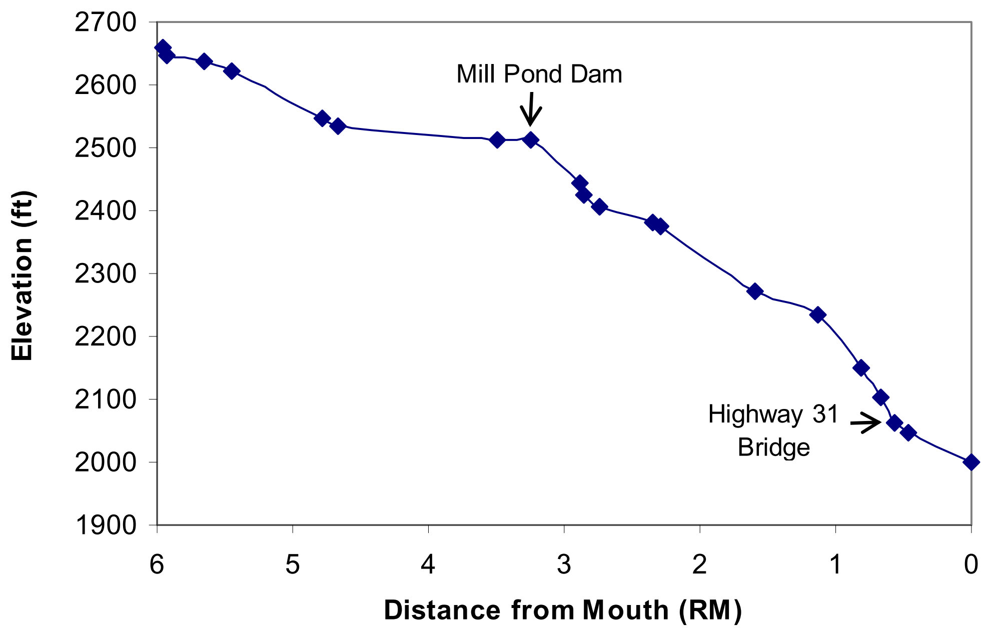


Figure A.11.3-4. Longitudinal profile of Sullivan Creek from the mouth to where Forest Service Road 22 crosses Sullivan Creek.

Table A.11.3-2. Sullivan Creek longitudinal profile data and landmarks.

Distance (RM)	Elevation (ft)	Landmarks
0.00	1,998.82	Sullivan Creek South Bank Established Temporary Control
0.47	2,048	Start of Reach 1
0.57	2,063	Highway 31 Bridge
0.66	2,103	Start of Cascades
0.81	2,151	In canyon of Sullivan Creek
1.13	2,235	In canyon of Sullivan Creek
1.59	2,273	In canyon of Sullivan Creek
2.30	2,374	Start of Reach 2
2.35	2,381	Confluence with North Fork Sullivan
2.74	2,405	Start of Reach 3
2.85	2,426	First major upstream bend
2.88	2,443	Second major upstream bend
3.25	2,511	Mill Pond Dam
3.49	2,514	Center of Mill Pond
4.66	2,533	Confluence with Outlet Creek/Near start of Reach 4
4.78	2,546	Sullivan Lake Road Bridge
5.45	2,623	Entering canyon towards start of Reach 6
5.65	2,639	Start of Reach 6
5.92	2,648	Engineered Log Jam
5.95	2,659	Forest Service Road 22

Historical aerial photographs for Sullivan Creek downstream of Mill Pond dated from 1932 (USFS 2008a) and 1971-1972 (USFS 2008b) were collected at the USFS Newport-Sullivan Lake's Station in Metaline Falls. Recent aerial photographs for Sullivan Creek downstream of Mill Pond dated 2006 were obtained from ArcGIS Map Services (ESRI 2008). Comparison of the 1932, 1971–1972, and 2006 aerial photographs shows the Sullivan Creek channel pattern and road locations remain consistent (red arrows in Figures A.11.3-5 through A.11.3-7 indicate similar locations of channel and road). Small changes in some meander bends are present between 1932, 1971-1972, and 2006, but overall channel pattern remains consistent. In reviewing each of the aerial photographs, the location of Sullivan Lake Road and its connectivity to reaches 2 and 3, surveyed in 2008 (yellow and orange arrows in Figures A.11.3-5 through A.11.3-7), remains fairly similar. Only one major change in the location of Sullivan Lake Road occurs (between 1932 and 1971–1972 indicated by green and brown arrows in Figures A.11.3-5 and A.11.3-6).

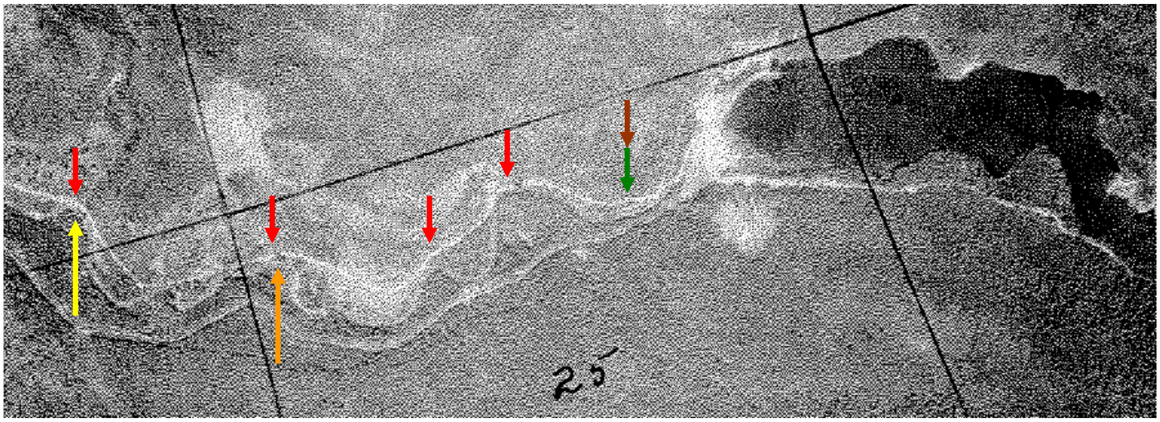


Figure A.11.3-5. Historical aerial photograph of Sullivan Creek downstream of Mill Pond dated 1932. Red arrows indicate similar locations of channel and road. Yellow arrow indicates location of reach 2 surveyed in 2008. Orange arrow indicates location of reach 3 surveyed in 2008. Green arrow indicates location of Sullivan Lake Road in 1932 and brown arrow indicates road in 1971-1972.

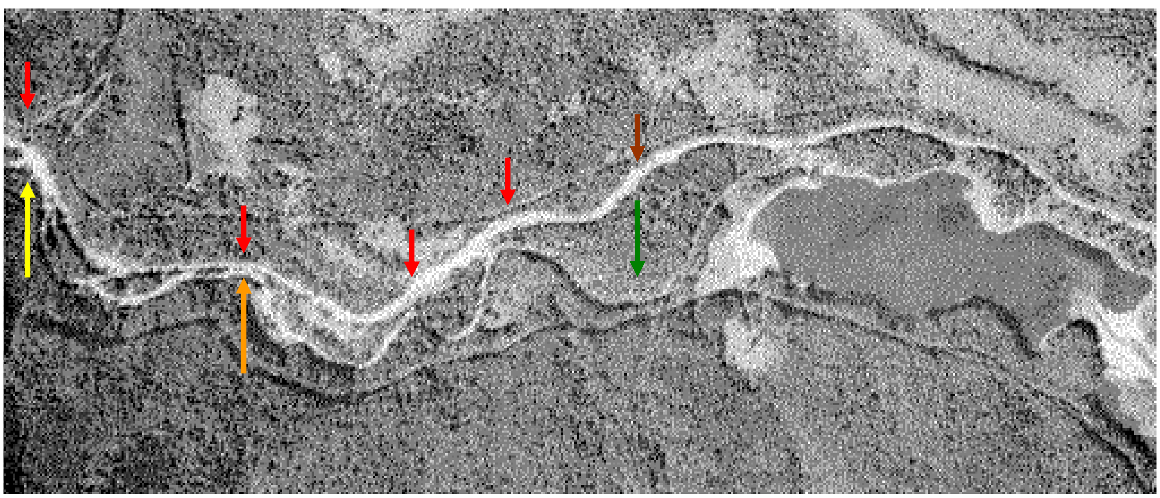


Figure A.11.3-6. Historical aerial photograph of Sullivan Creek downstream of Mill Pond dated 1971-1972. Red arrows indicate similar locations of channel and road. Yellow arrow indicates location of reach 2 surveyed in 2008. Orange arrow indicates location of reach 3 surveyed in 2008. Green arrow indicates location of Sullivan Lake Road in 1932 and brown arrow indicates road in 1971-1972.

Figure A.11.3-7. Recent aerial photograph for Sullivan Creek downstream of Mill Pond dated 2006. Red arrows indicate similar locations of channel and road. Yellow arrow indicates location of reach 2 surveyed in 2008. Orange arrow indicates location of reach 3 surveyed in 2008.

A.11.3.1.1. Field Survey Results from Downstream of Mill Pond Dam

Results of the field survey of reaches 1, 2, and 3 found channel slope ranged from 0.1 to 6.4 percent. The mean slopes for reaches 1, 2, and 3 were 2.6, 1.7, and 1.5 percent, respectively. Channel dimensions remained fairly consistent among the three reaches. In reach 1, the stream morphology has been influenced by suction dredge mining, the Highway 31 Bridge, the powerhouse, and riprap placed along the left bank in portions downstream from the Highway 31 Bridge. The stream morphology in reaches 2 and 3 has been influenced by the location of Sullivan Lake Road (Figure A.11.3-7) and riprap placed in the creek along portions of these road segments.

Dominant roughness elements for all three reaches were boulders, cobbles, banks, bed forms, and riprap. The D50 for reaches 1, 2, and 3 were 77, 140, and 180 mm (primarily cobble substrate), respectively. Where medium to large boulders (500–2000 mm) were present, pools were scoured. Fine sediments in pools and riffles were between 0 and 25 percent for all three reaches; primarily, they were present locally in sheltered locations, behind obstructions, or in backwater. Other channel and morphological conditions were similar among all three reaches. Fluvial processes, bank erosion, hillslope, and debris flows were the dominate sediment sources with the dominant bed surface pattern of riffles and rapids. Plane-bed morphology and typical armored bed surfaces occurred in these reaches. However, if complexity and forcing elements (e.g., LWD and boulders) were restored to these reaches, forced pool-riffle morphology would most likely form.

Pools throughout the reaches were infrequent and isolated around boulders, logs, and bedrock outcrops. Side channels and off-channel habitats were available in reaches 2 and 3. LWD was infrequent throughout all three reaches. However, in reach 3, a log jam was present and a pool was immediately downstream (Figure A.11.3-8).

Figure A.11.3-8. Log jam present in reach 3. Notice left bank terrace in photo behind log jam.

A detailed survey was conducted in this reach to further investigate this scoured pool, demonstrate in more detail the stream morphology in this reach, and evaluate the potential to modify this reach with structures (e.g., engineered log jams [ELJs] and boulders).

This detailed survey of reach 3 suggests placement of a series of ELJs and large boulders along the right bank of the reach would decrease the channel width to depth ratio, encourage channel migration away from Sullivan Lake Road and towards the right bank terrace, increase pool and quality riffle habitat, and assist in retaining gravel. Although this survey was not conducted in reach 2, the results from this detailed survey in reach 3 are likely applicable to reach 2 because conditions in the two reaches were similar. Implementing a series of ELJs, placing large boulders, constructing appropriately spaced riffles, extending the right bank further into the channel, and planting riparian vegetation along the right bank would assist in enhancing complexity in these two reaches and returning stream morphology to a more appropriate channel type.

Riparian composition primarily consisted of young (< 40 years) mixed vegetation, although reaches 2 and 3 contained coniferous patches that were mature (40–80 years). Active recruitment processes for all three reaches included bankcutting, windthrow, floodplain, and upstream sources. Within reach 1, the left bank riparian corridor, 100 m (328 feet) downstream of Highway 31 Bridge, is lacking any riparian vegetation for 62 m (203 feet) (Figure A.11.3-9). In addition, two small ponds are separated from Sullivan Creek in this section. Riparian plantings, ELJs, large boulders, and bank protection techniques along this left bank downstream from the Highway 31 Bridge in reach 1 would address factors limiting aquatic productivity in this portion of Sullivan Creek.

Figure A.11.3-9. Stream and riparian conditions in reach 1.

The right bank riparian corridor in reach 2, along Sullivan Lake Road at the North Sullivan Creek confluence with Sullivan Creek, is lacking vegetation, and any channel roughness elements that would facilitate in building a riparian corridor. Riparian plantings implemented in conjunction with the series of ELJs, large boulders, riffles, and bank protection techniques described above would address factors limiting aquatic productivity in this portion of Sullivan Creek.

Along the right bank in reach 3, where Sullivan Lake Road runs parallel to Sullivan Creek, the bank is stable, but some erosion occurs at higher flows. Riparian vegetation and channel roughening elements that would promote a riparian bench to develop are lacking along this right bank. The addition of roughness elements (e.g., ELJs and boulders) to the right bank would aid in protecting the bank and road, developing pool habitat, pushing flows from the right bank towards the terrace on the left bank, and decreasing the width-to-depth ratio in this reach.

There is a left bank terrace that extends along the entire reach length. In addition, there is a terrace on the right bank in the upstream extent of the reach. The left bank terrace is stable, with patches of mature (40–80 years) conifers (Figure A.11.3-10 and Figure A.11.3-11). The right bank terrace (Figure A.11.3-12) separates the mainstem Sullivan Creek from a 0.3 m (1 foot) wide side channel (Figure A.11.3-13). The terrace on the right bank of Sullivan Creek is eroding, but maintains young mixed vegetation. A log jam and pool, previously described above, are also present.

The downstream point of the right bank terrace in reach 3 would be the furthest extent into the stream channel that would be appropriate to place structures and develop a right bank riparian corridor. By extending portions of the right bank to this point in the channel, it would provide an adequate area for riparian plantings while maintaining connectivity to the side channel in this reach. In addition, encouraging channel migration towards the left bank terrace would facilitate in dissipating flood-flow energy away from the right bank and Sullivan Lake Road, decreasing the width-to-depth ratio, and encouraging future recruitment of woody debris from the left bank.

Figure A.11.3-10. Terrace along left bank of Reach 3 is in background of photo.

Figure A.11.3-11. Vegetation on terrace along left bank of Reach 3.

Figure A.11.3-12. Right and left bank terraces in reach 3.

Figure A.11.3-13. Side channel on right bank side of right terrace in reach 3.

Survey results and known past actions indicate altered sediment transport processes, channel straightening activities, the location of Sullivan Lake Road, and removal of LWD have resulted in primarily poor fish habitat in Sullivan Creek. The habitat conditions in reach 1 are poor for fish migration, rearing, and overwintering. Spawning gravel is low and there is high potential that any redds would be scoured. Migration and rearing habitat is fair in reach 2, with small pockets of pools available.

Overwintering conditions are not present in reach 2 because there is a lack of off-channel habitat (Figure A.11.3-14). However, upstream of reach 2 and downstream from reach 3 there is an off-channel area that is hydrologically connected to a wetland (see previously discussed Road Segment 4 description of wetland). Similar to reach 1, spawning gravel in reach 2 is fairly absent and during high flows there is high potential that any redds would be scoured. The habitat conditions in reach 3 are fair for migration, rearing, and overwintering, as some pools, side channels, and off-channel habitats are available. Conditions are poor for fish spawning; because appropriate sized gravel is lacking and during high flows, there is high potential that any redds would be scoured.

Figure A.11.3-14. Stream conditions in reach 2.

Although the existing conditions in reaches 1, 2, and 3 are fairly limiting to aquatic productivity, all three reaches provide enhancement opportunities that would be beneficial to both local fish populations and fluvial processes. The aquatic conditions in reach 1 should be addressed through riparian plantings, increasing structural complexity, and bank protection techniques. Reaches 2 and 3 provide a unique opportunity to address factors limiting aquatic productivity in approximately 0.5 miles of Sullivan Creek. This would be accomplished by further developing an enhancement opportunity that would start at the downstream extent of reach 2 and continue up to end of reach 3.

Implementing an enhancement opportunity at this scale would ensure that Sullivan Lake Road is protected due to changes in stream morphology, while maximizing improvement to aquatic habitat. Despite the scale that is addressed through any potential enhancement opportunities, increasing the structural complexity of Sullivan Creek downstream of Mill Pond Dam would assist in improving both aquatic conditions and channel-reach morphology.

A.11.3.1.2. Field Survey Results from Upstream of Mill Pond

Channel slope, upstream of Mill Pond in reaches 4 and 6 of Sullivan Creek, was between 0.6 and 3.2 percent. The mean slopes for reaches 4 and 6 were 1.2 and 1.5 percent, respectively. These channel slopes are similar to those in reaches 2 and 3 downstream of Mill Pond. Mean bankfull width and wetted width were less in reaches 4 and 6 than in the downstream reaches (see Section A.11.3.2, Channel Assessment Summaries). Mean bankfull depth was greater in reaches 4 and 6 than reach 3, but similar to reaches 1 and 2. Wetted depth was similar among all five reaches.

The dominant roughness elements in reaches 4 and 6 were cobble, LWD, bed form, banks, and boulders. Two pebble counts were conducted for reach 4, one downstream and one upstream of the confluence with Outlet Creek. The upstream pebble count was conducted upstream of both the confluence with Outlet Creek and the Sullivan Lake Road Bridge. The D50 for reach 4 downstream was 130 mm and 150 mm upstream. The D50 for reach 6 was 110 mm. The D50 for all five reaches, 1, 2, 3, 4, and 6, was the size of cobbles. Fine sediment levels in pools and riffles were between 0 and 25 percent for both reaches, and primarily were present locally in sheltered locations, behind obstructions, or in backwater.

The dominant sediment sources in both reaches 4 and 5 are fluvial, hillslope, and bank erosion; the dominant bed surface pattern was riffle and rapids. Both reaches 4 and 6 are plane-bed channels. The predominant channel-reach morphologies of reaches 4 and 6 are similar to those of reaches 1, 2, and 3. However, in reach 4, downstream of the Sullivan Lake Road Bridge at the confluence with Outlet Creek, Sullivan Creek is unconfined, with a broad floodplain comprising two side channels. Unlike the plane-bed morphology present in other reaches, this portion of Sullivan Creek in reach 4 displays pool-riffle morphology.

Pieces of LWD had been placed in the portion of reach 4 near the confluence with Outlet Creek. These structures resulted in scoured pools (Figure A.11.3-15). However, pool spacing throughout reach 4 was infrequently spaced and only occurred when forced. Only one pool was present in reach 6. Woody debris was present, but infrequent in both reaches. However, a log jam was present in reach 4 and what appeared as either an ELJ or additions of LWD was present upstream from reach 6. These additions of LWD upstream of reach 6, whether used to construct a log jam or just added as individual pieces, have resulted in a large log jam. The ELJ/placed LWD upstream of reach 6 provided an opportunity to examine channel response to a large log jam in Sullivan Creek.

Figure A.11.3-15. Scour pool resulting from LWD in reach 4.

The pool created on the downstream end of the large log jam was 24.5 m (80.4 feet) long, by 12.8 m (42.0 feet) wide, with a maximum depth of 1.7 m (5.6 feet). The ELJ was approximately

31 m (101.7 feet) long, 26 m (85.3 feet) wide, and 4.3 m (14.1 feet) high (Figure A.11.3-16). At least 15 LWD pieces in the jam appeared to have been placed. The log jam primary functions were pool scour, pool development on the upstream end, and gravel retention. On the upstream end, the large log jam was retaining a 1.15 m (3.77 feet) high, 45 m (147.6 feet) long, and 13.5 m (44.3 feet) wide deposit of gravel (Figure A.11.3-17).

Figure A.11.3-16. Large log jam upstream from reach 6.

Figure A.11.3-17. Gravel stored upstream from large log jam.

Riparian composition along both banks of reach 4 was different than that of reaches 2 and 3. The left bank of reach 4 was primarily composed of young (<40 years) mixed vegetation with a few mature (40–80 years) patches. The composition along the right bank was primarily young deciduous with some herbaceous. These differences in riparian composition between reach 2, 3, and 4 are associated with the floodplain available in reach 4. Active recruitment processes in reach 4 included bankcutting, floodplain, and upstream sources. Riparian composition in reach 6 was similar to the riparian composition along the left banks of reaches 2 and 3. Channel margin vegetation in reach 6 is young (<40 years) and mature (40–80 years) mixed vegetation along both banks. Active recruitment processes included bankcutting, hillslope, and windthrow. No upstream sources are currently available in reach 6 because the large log jam upstream of the reach is retaining the majority of upstream woody debris.

The habitat conditions in reach 4 are fair for fish migration, spawning, and rearing, because there are no upstream blockages in Sullivan Creek, spawning gravel is available in side channels, and a few pools are located downstream of the Sullivan Lake Road Bridge. Overwintering habitat is good due to the presence of the side channels that provide off-channel habitat. The rearing and overwintering habitat in reach 6 is poor. Spawning gravel in reach 6 is fairly absent and during high flows there is high potential that any redds would be scoured. Migration is fair, with no upstream obstructions. These habitat conditions in reaches 4 and 6 are similar to those described for reaches 1, 2, and 3, downstream of Mill Pond Dam. The lack of good quality fish habitat in reaches 1, 2, 3, 4, and 6 represents the absence of structural complexity throughout Sullivan Creek.

A.11.3.1.3. Field Survey Results from Outlet Creek

In addition to surveying reaches 4 and 6 upstream of Mill Pond, a 150 m (492.1 foot) long reach in Outlet Creek was surveyed. The results from the survey of Outlet Creek are presented separately from the other reaches because the morphology and habitat conditions differ from those of Sullivan Creek. Surveying a reach distinctly different from Sullivan Creek provides information on types of habitat and channels available throughout the Sullivan Creek watershed.

Outlet Creek (reach 5) channel dimensions were less than those of the reaches in Sullivan Creek (see Section A.11.3.2). Channel slope in Outlet Creek ranged between 0.4 and 0.7 percent. The dominant roughness elements are bed forms cobbles, banks, and LWD. The D50 in the surveyed reach is 60 mm (coarse gravel). Fine sediment in pools and riffles was between 0 and 25 percent and primarily was present locally in sheltered locations, behind obstructions, or in backwater. However, there was a greater presence of fines in this reach than any of the reaches surveyed in Sullivan Creek. The dominant sediment sources were fluvial and bank erosion, and the dominant bed surface pattern was riffles and glides. The reach is unconfined and is predominantly pool-riffle morphology.

Pools were primarily formed by LWD, and placed LWD was present (Figure A.11.3-18). One placed structure created a 0.54 m (1.8 ft) deep, by 12.0 m (39.4 foot) long, by 5 m (16.4 foot) wide pool. Pool spacing was five channel widths apart. Bank stability, bar stability, and pool scour are the primary LWD functions. Pools and LWD were more prevalent in the surveyed reach of Outlet Creek than any of the reaches surveyed in Sullivan Creek.

Figure A.11.3-18. Placed LWD in Outlet Creek.

Channel margin vegetation comprised young (<40 years) mixed vegetation throughout the reach with similar conditions on both banks. The riparian corridor active recruitment processes included bankcutting, windthrow, and floodplain. Groundcover along both banks was dense and much greater than any of the reaches surveyed in Sullivan Creek. Although channel dimensions were less in Outlet Creek than Sullivan Creek, channel spanning LWD and riparian cover was much greater in reach 5 compared to the other reaches.

The habitat conditions in reach 5 are poor for fish migration because Sullivan Lake Dam is a barrier to fish passage. Spawning gravel is available, and although the release flows from Sullivan Lake Dam may pose a threat to redds, the absence of large amounts of bank erosion and the conditions of the channel and substrate suggested redd scour may be limited. Rearing habitat is fair as there are some pools created from LWD. Overwintering habitat appeared to be fair due to the presence of side channels that provide off-channel habitat. Although habitat conditions in Outlet Creek are primarily fair, as the riparian corridor continues to develop, future recruitment of LWD to this pool-riffle morphology will only improve upon the current conditions.

The data and results from the Sullivan Creek fluvial geomorphic field surveys provide a foundation for identifying reach-scale enhancement opportunities. The plane-bed morphology displayed in the majority of reaches that were surveyed indicate a need for increased complexity and roughening elements, sediment control structures, decreased width-to-depth ratios, bank improvements, and riparian plantings. General types of projects have been identified for reaches 1, 2, and 3. Utilizing the information available from these surveys will assist in developing conceptual designs that will further solidify specific designs, benefits, and costs.

A.11.3.2. Channel Assessments

Table A.11.3-3. Channel assessment summary—reach 1 of Sullivan Creek.

Stream:	Sullivan Creek	WAU:	Sullivan Creek	Observers:	CJ, TG, DP
Reach No:	1	Response Type:	Transport	Date:	7/15/2008
Length Sampled:	340 m (1,115.5 ft)	Total Reach Length:	340 m (1,115.5 ft)	Flow:	medium

Channel Dimensions

Mean bankfull width:	23.3 m (76.4 ft)	Wetted width:	20.8 m (68.2 ft)
Mean bankfull depth:	2.08 m (6.82 ft)	Wetted depth:	0.34 m (1.12 ft)
Valley bottom width:	47.4 m (155.5 ft)	Channel slope:	1 – 6.4% (mean = 2.6%)

Bed Conditions

Throughout the reach bed conditions have been influenced by suction dredge mining, the Highway 31 bridge, and the Power House.
First 162 m (531 ft) of reach: Dominate roughness elements are cobbles, boulders, and banks. Dominate sediment sources are fluvial, bank erosion, and debris flows. Typical slope is 2%. Dominate bed surface pattern was riffles and rapids. Reach is moderately confined. Predominately plane-bed morphology.
Second 178 m (584 ft) of reach: Dominate roughness elements are boulders, banks, cobbles, and steps. Dominate sediment sources are fluvial and debris flows. Typical slope is 4%. Dominate bed surface pattern was riffles and rapids. Reach is moderately confined. A cascade and series of chutes begin 56 m (184 ft) upstream from the end of the reach. Evidence of debris flows at the cascade was observed. Predominately intermediate morphology of riffle step (plane bed – step pool).

Gravel bars

Limited gravel bars present; transverse bars present in first portion of reach.

Channel pattern Sinuous Sinuosity*: 1.2

Pools and pool spacing

Mean residual pool depth was 0.6 m (2.0 ft). Pools were infrequent and isolated around boulders, bedrock, or logs.

Primary LWD Function(s):

Large woody debris (LWD) was infrequent throughout the reach and primarily above the water surface, active at higher flows. LWD functioned were bank stability and small pool scour. Two pieces were greater than 0.7 m (2.3 ft) and thirty-five pieces were greater than 2.4 m (7.9 ft) in length. No log jams were present.

Table A.11.3-3, continued…

Fine Sediment Deposits

% fine sediment in pools: __0-25____%

% fine sediment in riffles: __0-25____% Locally in sheltered locations.

Bank Conditions

Bank Material

Texture: Alluvium/Cobbles, gravel, and sand.
Source: Banks and debris flows.
Sources of protection: Boulders, rip rap, LWD, Highway 31 bridge, Power House, Bedrock
% Bank erosion in reach: 65%
Location description: Along both banks downstream of Highway 31 bridge. Along right bank upstream from the Highway 31 bridge. Debris flow occurred 56 m (184 ft) upstream from end of reach.

Riparian Conditions

Channel margin vegetation: Young (<40 years) mixed vegetation.
Riparian corridor: Riparian composition primarily consisted of young mixed vegetation. Active recruitment processes included bankcutting, windthrow, floodplain, and upstream sources. Left bank riparian corridor, 100 m (328 ft) downstream of Highway 31 bridge, is lacking vegetation for 62 m (203 ft) with nearly no bank cover.

Fish Habitat Quality

Migration:	Low
Spawning gravel (presence and stability):	Low
Rearing habitat:	Low
Overwintering (off-channel):	Low

Table A.11.3-4. Channel assessment summary—reach 2 of Sullivan Creek.

Stream:	Sullivan Creek	WAU:	Sullivan Creek	Observers:	CJ, TG, DP
Reach No:	2	Response Type:	Transport	Date:	7/15/2008
Length Sampled:	480 m (1,574.8 ft)	Total Reach Length:	480 m (1,574.8 ft)	Flow:	medium

Channel Dimensions

Mean bankfull width:	21.5 m (70.5 ft)	Wetted width:	18.0 m (59.1 ft)
Mean bankfull depth:	1.83 m (6.00 ft)	Wetted depth:	0.66 m (2.17 ft)
Valley bottom width:	79.7 m (261.5 ft)	Channel slope:	0.5 – 4% (mean = 1.7%)

Bed Conditions

Dominate roughness elements are boulders, cobbles, steps, bedrock, and bed forms. Some portions of reach have substantial bedrock influence. Where large boulders are present, scour occurs and pools are formed. Dominate sediment sources are fluvial, hillslope, and debris flows. Typical slope is 2.0%. Dominate bed surface pattern was riffles. Rapids were present at locations of bedrock and formed scour pools. Reach is moderately confined. Predominately plane-bed morphology. However, if complexity and forcing elements (e.g., LWD and Boulders) were restored to this reach, a forced pool-riffle morphology would potentially exist.

Gravel bars

Five gravel bars were present in the reach. Gravel bar characteristics include medial, single obstruction (e.g., LWD or Boulders), point, and transverse. Two side channels around transverse bars were present.

Channel pattern Sinuous — Sinuosity*: 1.2

Pools and pool spacing

Mean residual pool depth was 0.8 m (2.6 ft). Pools were infrequent in first 230 m (754.6 ft) and isolated around boulders, logs, and the outfall from the confluence of North Fork Sullivan Creek with Sullivan Creek. Within the second 250 m (820 ft) of the reach, pool spacing was 2.7 channel widths apart. Pool forming factors consisted of smooth bedrock outcrops, banks, boulders, culvert, bed form, and side channels. Approximately 224 m (734.9 ft) upstream from the end of the reach is on off-channel area that is connected to a wetland.

Primary LWD Function(s):

Large woody debris (LWD) was infrequent throughout the reach and primarily above the water surface, active at higher flows. LWD functions were bank stability and limited, small pool scour. Two pieces of LWD in the reach were greater than 0.7 m (2.3 ft) and twenty-eight pieces were greater than 2.4 m (7.9 ft) in length. No log jams were present, although 15 m (49.2 ft) upstream of the end of the reach where three log jams. However, the majority of the pieces in the log jam were less than 0.3 m (0.98 ft) in diameter.

Table A.11.3-4, continued…

Fine Sediment Deposits

% fine sediment in pools: __0-25____% Local accumulation behind obstructions and in slackwater.

% fine sediment in riffles: __0-25____%

Bank Conditions

Bank Material

Texture: Alluvium and Bedrock
Source: Fluvial, banks, hillslope, and debris flows
Sources of protection: Boulders, Rip Rap, LWD, Sullivan Lake Road, Culvert, Bedrock
% Bank erosion in reach: 35%
Location description: Along right bank where non-maintained camping ground is present and along Sullivan Lake Road where the North Fork Sullivan Creek culvert is present. Right bank in this area appears to be fairly stable, but erosion occurs at higher flows. Vegetation is established on some portions of this right bank area, but is generally lacking. Roughness elements would facilitate in protecting bank, developing microscale pool habitat, pushing flows from right bank, and protecting Sullivan Lake Road.

Riparian Conditions

Channel margin vegetation: Young (<40 years) mixed vegetation primarily was present, but some vegetation, including coniferous patches, were mature (40 – 80 years).
Riparian corridor: Riparian composition primarily consisted of young mixed vegetation. Active recruitment processes included bankcutting, windthrow, floodplain, and upstream sources. Right bank riparian corridor, along Sullivan Lake Road at the North Sullivan Creek confluence with Sullivan Creek, is lacking vegetation, and any channel roughness elements that would facilitate in building a riparian corridor.

Fish Habitat Quality

Migration:	Medium
Spawning gravel (presence and stability):	Low
Rearing habitat:	Medium
Overwintering (off-channel):	Low

Table A.11.3-5. Channel assessment summary—reach 3 of Sullivan Creek.

Stream:	Sullivan Creek	WAU:	Sullivan Creek	Observers:	CJ, TG, DP
Reach No:	3	Response Type:	Transport	Date:	7/15/2008
Length Sampled:	450 m (1,476.4 ft)	Total Reach Length:	450 m (1,476.4 ft)	Flow:	medium

Channel Dimensions

Mean bankfull width:	21.3 m (69.9 ft)	Wetted width:	19.3 m (63.3 ft)
Mean bankfull depth:	0.8 m (2.6 ft)	Wetted depth:	0.7 m (2.3 ft)
Valley bottom width:	67.5 m (221.6 ft)	Channel slope:	0.1 – 3.3% (mean = 1.5%)

Bed Conditions

Dominate roughness elements are boulders, cobbles, banks, and bed forms. Where log jam was present, pool was formed. Dominate sediment sources are fluvial, hillslope, and bank erosion. Typical slope is 1.5%. Dominate bed surface pattern was rapids, riffles, and side channels. Reach is moderately confined. Predominately plane-bed morphology. However, if complexity and forcing elements (e.g., LWD and Boulders) were restored to this reach, a forced pool-riffle morphology would potentially exist.

Gravel bars

Three point bars and a transverse gravel bar were present in the reach. Two side channels were present around the bars that provided off-channel habitat and locations that dissipate flood-flow energy.

Channel pattern Sinuous Sinuosity*: 1.2

Pools and pool spacing

Mean residual pool depth was 0.75 m (2.46 ft). Two pools were present, one formed by a log jam on the left bank and the other by bed form. Although two pools were present, pool spacing was infrequent and only occurred when forced by bed form or obstruction. Approximately 265 m (869.4 ft) downstream from the reach is an off-channel area that is connected to a wetland.

Primary LWD Function(s):

Large woody debris (LWD) was infrequent throughout the reach and primarily above the water surface, active at higher flows. LWD functions were bank stability, bar stability, and pool scour. Two pieces of LWD in the reach were greater than 0.7 m (2.3 ft) and thirty-seven pieces were greater than 2.4 m (7.9 ft) in length. One log jam was present, with pieces of the jam still in the active channel that scoured a pool.

Table A.11.3-5, continued…

Fine Sediment Deposits

% fine sediment in riffles: __0-25____%

Bank Conditions

Bank Material

Texture: Alluvium/Boulders, Cobbles, Rip Rap
Source: Fluvial, hillslope, and bank erosion
Sources of protection: Boulders, Rip Rap, LWD, Sullivan Lake Road, Bedrock
% Bank erosion in reach: 45%
Location description: Along right bank where Sullivan Lake Road runs parallel to Sullivan Creek, the bank is stable, but some erosion occurs at higher flows. Vegetation is lacking along this right bank. Roughness elements (e.g., LWD, rootwads, boulders) would facilitate in protecting bank, developing microscale pool habitat, pushing flows from right bank, and protecting Sullivan Lake Road. There are terraces on the left and right banks. The left bank terrace is more stable, with patches of mature (40- 80 years) conifers. The right bank terrace separates the mainstem Sullivan Creek from a 0.3 m (1 ft) wide side channel. The terrace on the right bank of Sullivan Creek is eroding. The section of Sullivan Creek, where there is a terrace on the left and right banks, is where the log jam is present that assisted in scouring the 107 m (351.1 ft) long pool. This area has the potential to develop a series of log jams that encourage channel migration towards the left bank and the terrace on the left bank.

Riparian Conditions

Channel margin vegetation: Young (<40 years) and mature (40 – 80 years) mixed vegetation was present along the left bank. However, on the right bank primarily young mixed vegetation was present.
Riparian corridor: Active recruitment processes included bankcutting, windthrow, and upstream sources. Right bank riparian corridor, along Sullivan Lake Road, is lacking vegetation, and any channel roughness elements that would facilitate in building a riparian corridor.

Fish Habitat Quality

Migration:	Medium
Spawning gravel (presence and stability):	Low
Rearing habitat:	Medium
Overwintering (off-channel):	Medium

Table A.11.3-6. Channel assessment summary—reach 4 of Sullivan Creek.

Stream:	Sullivan Creek	WAU:	Sullivan Creek	Observers:	CJ, TG
Reach No:	4	Response Type:	Transport	Date:	7/16/2008
Length Sampled:	320 m (1,049.9 ft)	Total Reach Length:	320 m (1,049.9 ft)	Flow:	low

Channel Dimensions

Mean bankfull width:	18.4 m (60.4 ft)	Wetted width:	13.3 m (43.6 ft)
Mean bankfull depth:	1.3 m (4.3 ft)	Wetted depth:	0.5 m (1.6 ft)
Valley bottom width:	110.7 m (363.2 ft)	Channel slope:	0.6 – 1.7% (mean = 1.2%)

Bed Conditions

The confluence of Outlet Creek enters Sullivan Creek at 20 m (65.6 ft) upstream from the start of this reach.
Dominate roughness elements are cobble, LWD, bed form, banks, and obstructions. Where LWD was placed or present, pool was formed. Dominate sediment sources are fluvial, hillslope, and bank erosion. Typical slope is 1.2%. Dominate bed surface pattern was riffle. Reach is unconfined. However, the Sullivan Lake Road bridge confines Sullivan Creek from 11 m (36.1 ft). Predominately plane-bed morphology.

Gravel bars

Point, lateral, and medial bars were present in the reach. Two dry side channels were present downstream of the Sullivan Lake Road bridge. These side channels are active at higher flows. At the time of the survey backwater was present at the downstream end of each of the side channels. Gravel bar presence was primarily downstream of the Sullivan Lake Road bridge.

Channel pattern Sinuous — Sinuosity*: 1.1

Pools and pool spacing

Mean residual pool depth was 0.62 m (2.03 ft). Four pools were present, one formed by a placed piece of woody debris. All pools were formed by woody debris, with banks, bedform, or roots of standing trees or stumps also factors. Pool spacing was infrequent and only occurred when forced.

Primary LWD Function(s):

Large woody debris (LWD) was greater downstream of the Sullivan Lake Road bridge, near the confluence with Outlet Creek. A placed piece of LWD was present in Sullivan Creek at the confluence with Outlet Creek. LWD functions were bank stability, bar stability, and pool scour. There were no pieces of LWD in the reach that were greater than 0.7 m (2.3 ft). However, there were twenty pieces that were greater than 2.4 m (7.9 ft) in length. One log jam was present, with pieces of the jam still in the active channel. The primary log jam function was to scour a 19 m (62.3 ft) long pool.

Table A.11.3-6, continued…

Fine Sediment Deposits

% fine sediment in pools: __0-25____% Local accumulation behind obstructions and in slackwater.

% fine sediment in riffles: __0-25____% Locally in sheltered locations.

Bank Conditions

Bank Material

Texture: Alluvium/Boulders, Cobbles, Gravel, and Sand
Source: Fluvial, hillslope, and bank erosion
Sources of protection: Cobbles, Boulders, LWD, Sullivan Lake Road bridge
% Bank erosion in reach: 25%
Location description: Primarily along the left bank of Sullivan Creek, upstream and downstream of the Outlet Creek confluence.

Riparian Conditions

Channel margin vegetation: Riparian composition along the left bank was primarily young (<40 years) mixed vegetation with a few mature (40 – 80 years) patches along the left bank. The composition along the right bank was primarily young deciduous with some herbaceous.
Riparian corridor: Active recruitment processes included bankcutting, floodplain, and upstream sources.

Fish Habitat Quality

Migration:	Medium
Spawning gravel (presence and stability):	Medium
Rearing habitat:	Medium
Overwintering (off-channel):	High

Table A.11.3-7. Channel assessment summary—reach 5 of Outlet Creek.

Stream:	Outlet Creek	WAU:	Sullivan Creek	Observers:	CJ, TG
Reach No:	5	Response Type:	Transport	Date:	7/15/2008
Length Sampled:	150 m (492.1 ft)	Total Reach Length:	293 m (961.3 ft)	Flow:	low

Channel Dimensions

Mean bankfull width:	14.7 m (48.2 ft)	Wetted width:	13.6 m (44.6 ft)
Mean bankfull depth:	0.7 m (2.3 ft)	Wetted depth:	0.2 m (0.7 ft)
Valley bottom width:	78.9 m (258.9 ft)	Channel slope:	0.4 – 0.7%

Bed Conditions

Dominate roughness elements are bed forms cobbles, banks, and LWD. Where LWD was present, pool was formed. Dominate sediment sources are fluvial and bank erosion. Typical slope is 0.7%. Dominate bed surface pattern was riffles and glides. Reach is unconfined. Predominately pool-riffle morphology.

Gravel bars

Four point bars and a transverse gravel bar were present in the reach. Side channels were present around the bars that provided off-channel habitat and locations that dissipate flood-flow energy.

Channel pattern Sinuous Sinuosity*: 1.2

Pools and pool spacing

Mean residual pool depth was 0.34 m (1.11 ft). Pools were primarily formed by LWD. One placed structure created a 0.54 m (1.8 ft) deep, by 12.0 m (39.4 ft) long, by 5 m (16.4 ft) wide pool. Pool spacing was 5 channel widths apart.

Primary LWD Function(s):

Large woody debris (LWD) was present in the active channel in some portions of the reach. LWD functions were bank stability, bar stability, and pool scour. Two pieces of LWD in the reach were greater than 0.7 m (2.3 ft) and thirty-seven pieces were greater than 2.4 m (7.9 ft) in length.

Fine Sediment Deposits

% fine sediment in pools: 0-25 % Local accumulation behind obstructions and in slackwater.

% fine sediment in riffles: 0-25 % Locally in sheltered locations.

Table A.11.3-7, continued…

Bank Conditions

Bank Material

Texture: Alluvium/Cobbles, Gravels, Sand
Source: Fluvial and bank erosion
Sources of protection: LWD, Cobbles, Bed Form
% Bank erosion in reach: 20%
Location description: Small, localized patches of erosion along both banks.

Riparian Conditions

Channel margin vegetation: Young (<40 years) mixed vegetation was present throughout the reach.
Riparian corridor: Active recruitment processes included bankcutting, windthrow, and floodplain.

Fish Habitat Quality

Migration:	Low
Spawning gravel (presence and stability):	High
Rearing habitat:	Medium
Overwintering (off-channel):	Medium

Table A.11.3-8. Channel assessment summary—reach 6 of Sullivan Creek.

Stream:	Sullivan Creek	WAU:	Sullivan Creek	Observers:	CJ, TG
Reach No:	6	Response Type:	Transport	Date:	7/15/2008
Length Sampled:	294 m (964.6 ft)	Total Reach Length:	294 m (964.6 ft)	Flow:	low

Channel Dimensions

Mean bankfull width:	14.5 m (47.6 ft)	Wetted width:	12.4 m (40.7 ft)
Mean bankfull depth:	1.7 m (5.6 ft)	Wetted depth:	0.7 m (2.3 ft)
Valley bottom width:	47.6 m (156.2 ft)	Channel slope:	0.2 – 3.2% (mean = 1.5%)

Bed Conditions

Dominate roughness elements are boulders, cobbles, bedrock, and obstructions. Dominate sediment sources are fluvial, bank erosion, and hillslope. Typical slope is 1.0%. Dominate bed surface pattern was riffles and rapids. Reach is moderately confined. Predominately plane-bed morphology.

Gravel bars

Three semi-active (>50% in floodplain and non-vegetated) point bars were present in the reach.

Channel pattern Sinuous Sinuosity*: 1.2

Pools and pool spacing

There was only one pool in the surveyed reach. The pools maximum depth was 1.9 m (6.2 ft) and was formed by smooth bedrock. Approximately 136 m (446.2 ft) upstream from the end of the reach was a large log jam, potentially engineered. The pool created on the downstream end of the log jam was 24.5 m (80.4 ft) long, by 12.8 m (42.0 ft) wide, with a maximum depth of 1.7 m (5.6 ft).

Primary LWD Function(s):

Large woody debris (LWD) was present in the active channel in some portions of the reach. LWD functions were bank stability and pool scour. No pieces of LWD in the reach were greater than 0.65 m (2.13 ft) and twenty-two pieces were greater than 1.8 m (5.9 ft) in length. Approximately 136 m (446.2 ft) upstream from the end of the reach was an engineered log jam. The log jam was approximately 31 m (101.7 ft) long, 26 m (85.3 ft) wide, and 4.3 m (14.1 ft) high. At least fifteen LWD pieces in the jam appeared to have been placed. The log jam primary functions were pool scour, pool development on the upstream end, and retaining of gravel. On the upstream end the log jam was retaining 1.15 m (3.77 ft) high, 45 m (147.6 ft) long, and 13.5 m (44.3 ft) wide deposit of gravel.

Table A.11.3-8, continued…

Fine Sediment Deposits

% fine sediment in pools: __0-25____% Local accumulation behind obstructions and in slackwater.

% fine sediment in riffles: __0-25____% Locally in sheltered locations.

Bank Conditions

Bank Material

Texture: Alluvium/Bedrock, Boulders, Cobbles, Gravels, Sand, and LWD
Source: Fluvial, hillslope, and bank erosion
Sources of protection: Bedrock, Boulders, Cobbles, Bed Form, and LWD
% Bank erosion in reach: 40%
Location description: Continuously along both banks from 44 m (144.4 ft) and intermittent, independent of channel geometry.

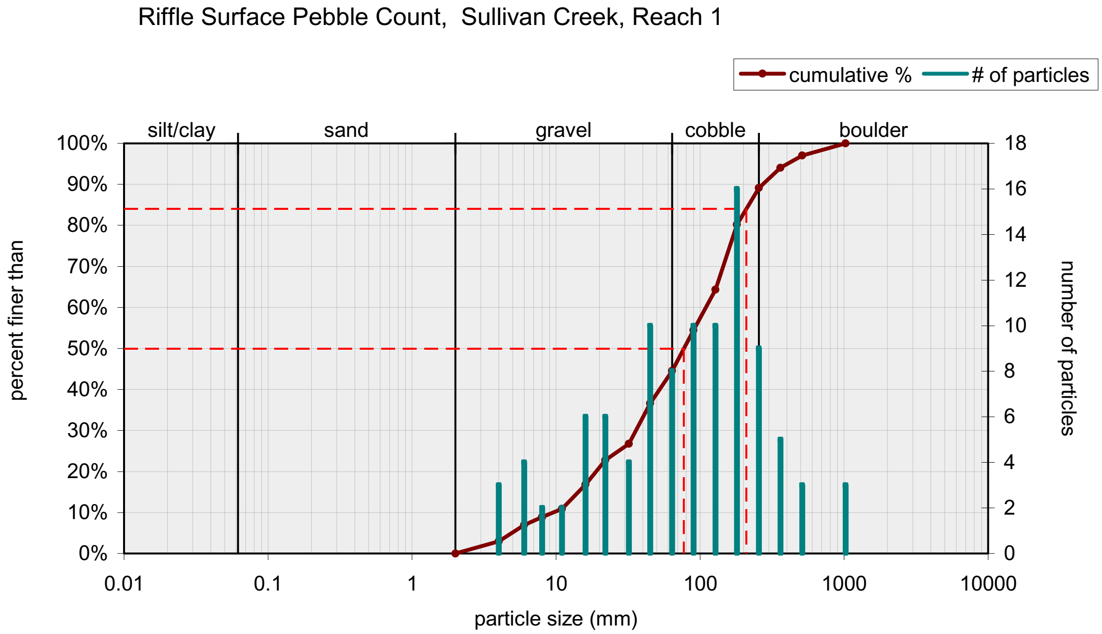
Riparian Conditions

Channel margin vegetation: Young (<40 years) and mature (40 – 80 years) mixed vegetation was present along both banks.
Riparian corridor: Active recruitment processes included bankcutting, windthrow, and floodplain.

Fish Habitat Quality

Migration:	Medium
Spawning gravel (presence and stability):	Low
Rearing habitat:	Low
Overwintering (off-channel):	Low

A.11.3.3. Pebble Counts

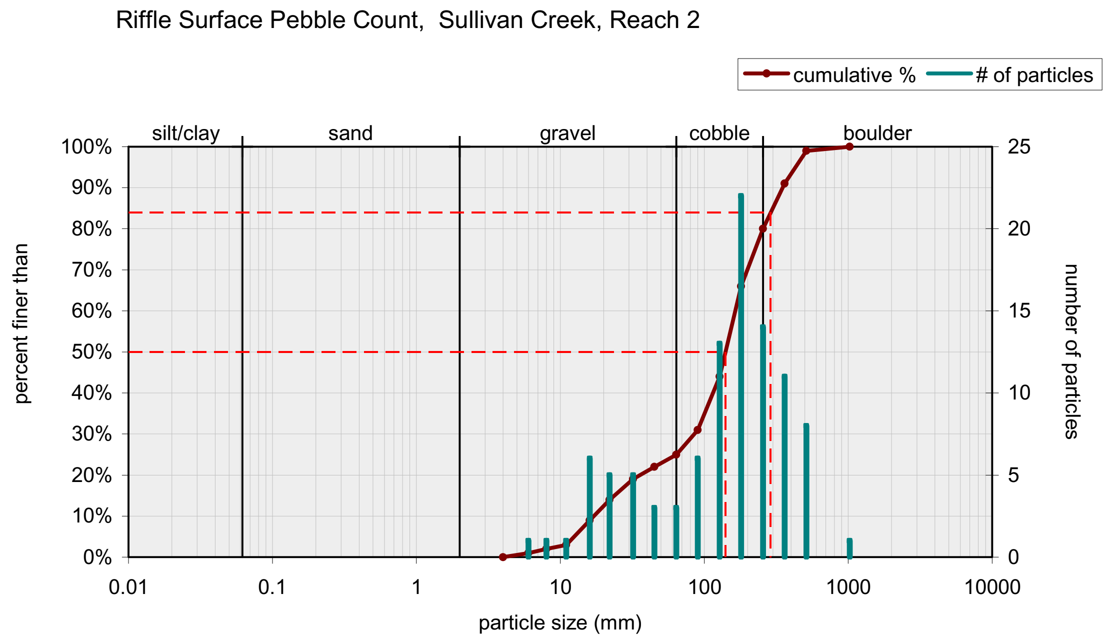


Size (mm)	
D16	15
D35	43
D50	77
D65	130
D84	210
D95	400

Size Distribution	
mean	56.1
dispersion	3.9
skewness	-0.13

Type	
silt/clay	0%
sand	0%
gravel	45%
cobble	45%
boulder	11%

Figure A.11.3-19. Riffle surface pebble count distribution from Sullivan Creek, reach 1.

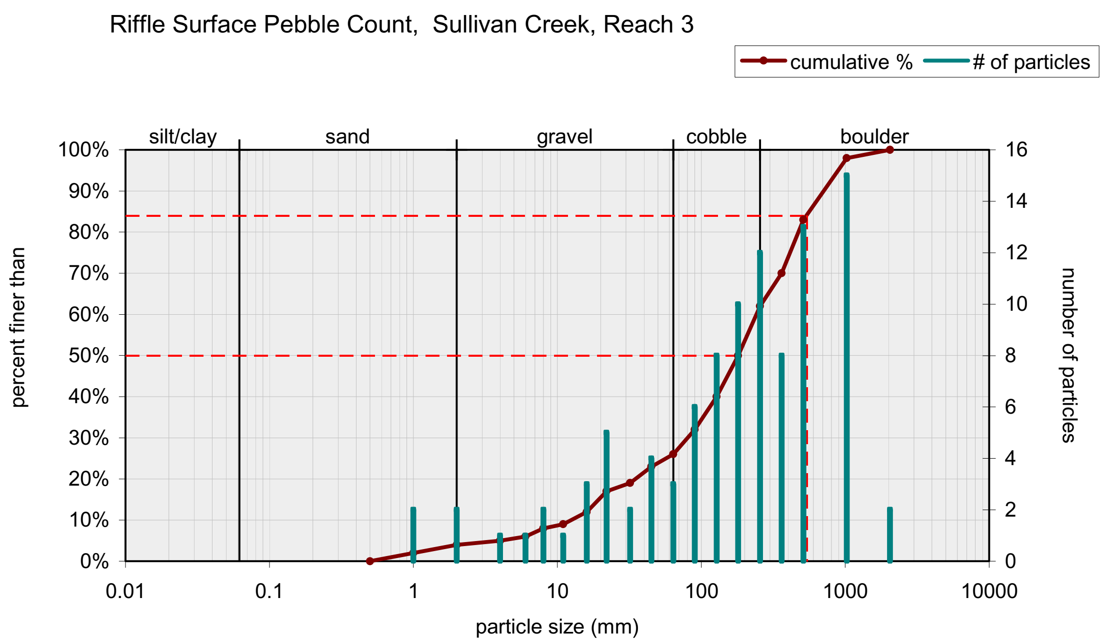


Size (mm)	
D16	26
D35	100
D50	140
D65	180
D84	290
D95	430

Size Distribution	
mean	86.8
dispersion	3.7
skewness	-0.20

Type	
silt/clay	0%
sand	0%
gravel	25%
cobble	55%
boulder	20%

Figure A.11.3-20. Riffle surface pebble count for Sullivan Creek, reach 2.

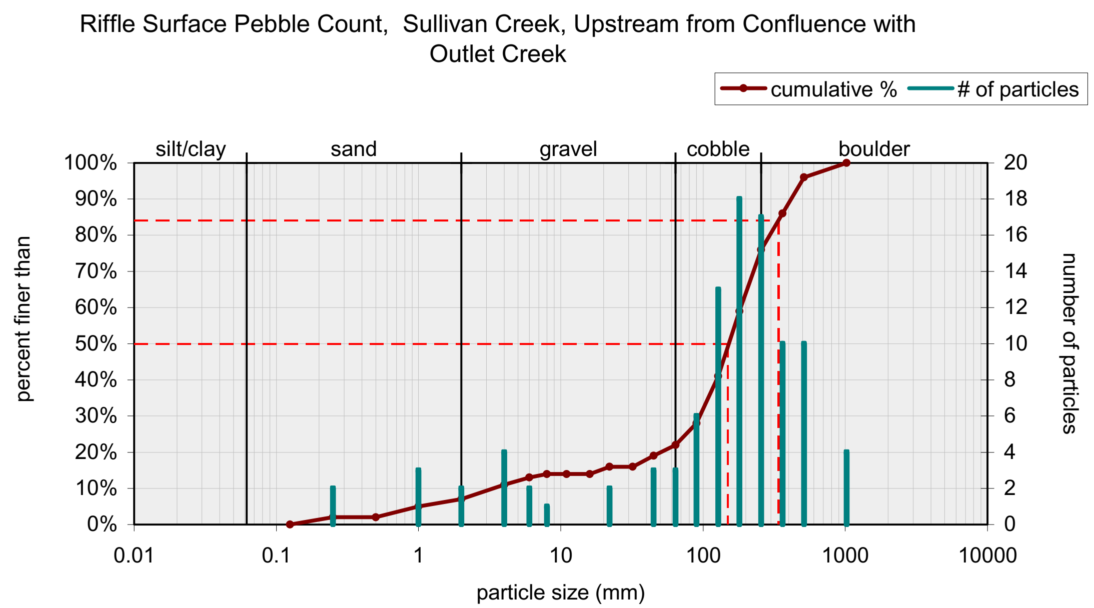


Size (mm)	
D16	21
D35	100
D50	180
D65	290
D84	540
D95	890

Size Distribution	
mean	106.5
dispersion	5.8
skewness	-0.19

Type	
silt/clay	0%
sand	4%
gravel	22%
cobble	36%
boulder	38%

Figure A.11.3-21. Riffle surface pebble count for Sullivan Creek, reach 3.

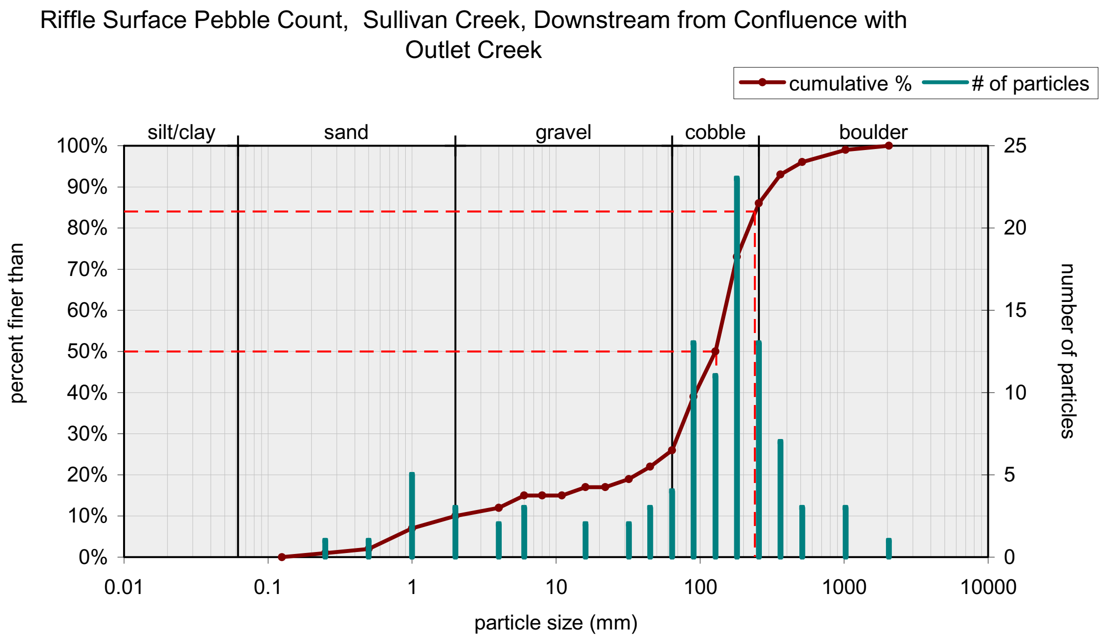


Size (mm)		
D16	32	3.4
D35	110	12
D50	150	17
D65	200	20
D84	340	29
D95	490	39

Size Distribution	
mean	104.3
dispersion	3.5
skewness	-0.16

Type	
silt/clay	0%
sand	7%
gravel	15%
cobble	54%
boulder	24%

Figure A.11.3-22. Riffle surface pebble count for Sullivan Creek, reach 4, upstream of Sullivan Lake Road Bridge and confluence with Outlet Creek.

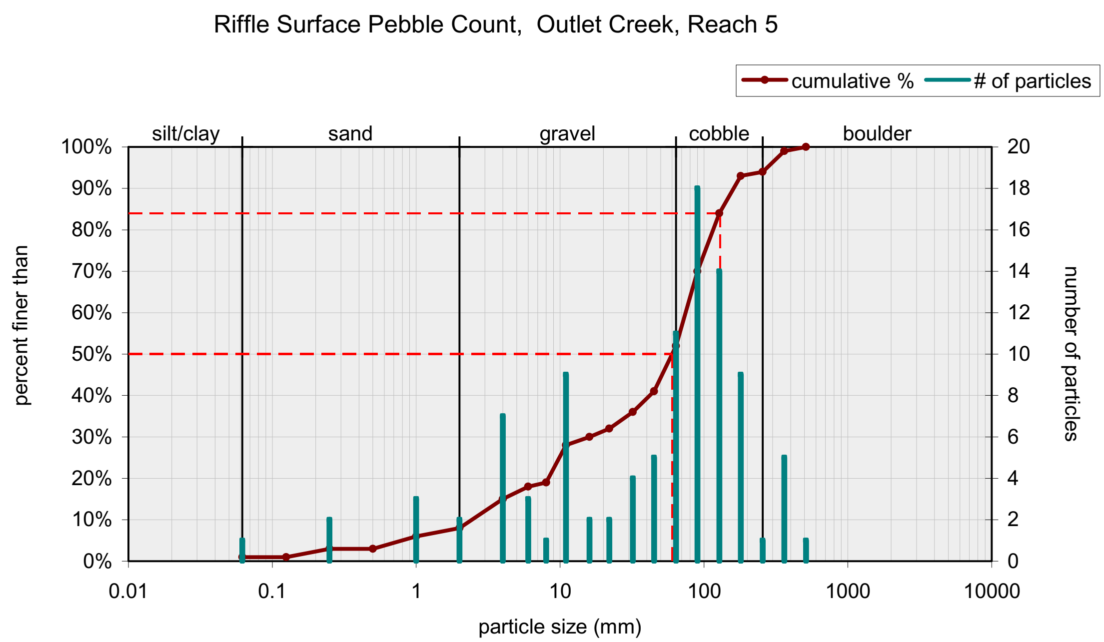


Size (mm)	
D16	13
D35	81
D50	130
D65	160
D84	240
D95	460

Size Distribution	
mean	55.9
dispersion	5.9
skewness	-0.33

Type	
silt/clay	0%
sand	10%
gravel	16%
cobble	60%
boulder	14%

Figure A.11.3-23. Riffle surface pebble count for Sullivan Creek, reach 4, downstream of Sullivan Lake Road Bridge and confluence with Outlet Creek.

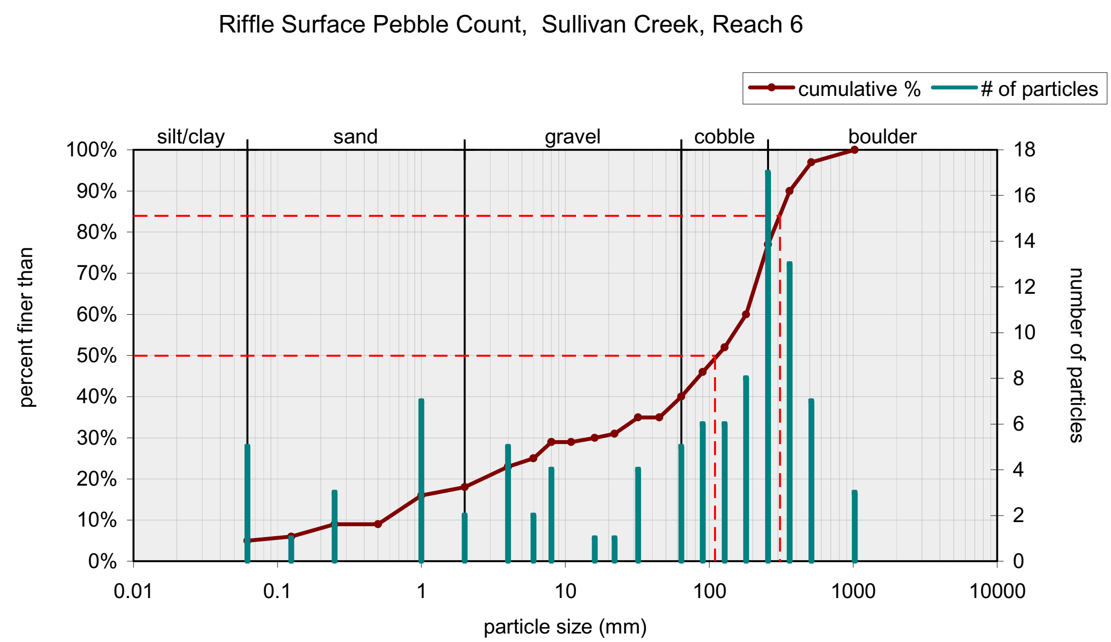


Size (mm)	
D16	4.6
D35	29
D50	60
D65	82
D84	130
D95	270

Size Distribution	
mean	24.5
dispersion	7.6
skewness	-0.32

Type	
silt/clay	1%
sand	7%
gravel	44%
cobble	42%
boulder	6%

Figure A.11.3-24. Riffle surface pebble count distribution from Outlet Creek, reach 5.



Size (mm)	
D16	1
D35	45
D50	110
D65	200
D84	310
D95	460

Size Distribution	
mean	17.6
dispersion	56.4
skewness	-0.50

Type	
silt/clay	5%
sand	13%
gravel	22%
cobble	37%
boulder	23%

Figure A.11.3-25. Riffle pebble count distribution from Sullivan Creek, reach 6.

A.11.3.4. Reach 3—Downstream of Mill Pond Dam

Table A.11.3-9. Summary results from detailed survey of reach 3 in Sullivan Creek.

Summary		
Stream:	Sullivan Creek	
Watershed:	Sullivan Creek	
Location:	Reach 3, Road Segment 4	
Latitude:	48.85758	
Longitude:	-116.67640	
State:	Washington	
County:	USA	
Date:	7.17.2008	
Observers:	Chris James and Tricia Gross	
Channel type:	Plane-bed	
Drainage area (sq.mi.):	91	
notes:	Sullivan Creek Reach 3 within Road Segment 4 was surveyed as a representitive reach of conditions downstream from Mill Pond Dam and to illustrate the locations where log jams could be placed and road connectivity to Sullivan Creek could be improved. Discharge at time of survey, based on cross-section survey, was 134.1 ft^3/s.	
Dimension	bankfull channel typical	
floodplain: width flood prone area (ft)	98.7	
low bank height (ft)	1.6	
riffle-run: x-area bankfull (sq.ft.)	208.3	
width bankfull (ft)	92.9	
mean depth (ft)	2.24	
max depth (ft)	3.8	
hydraulic radius (ft)	2.2	
pool: x-area pool (sq.ft.)	163.4	
width pool (ft)	54.1	
max depth pool (ft)	4.4	
hydraulic radius (ft)	2.9	
dimensionless ratios:	typical	
width depth ratio	41.4	
entrenchment ratio	1.1	
riffle max depth ratio	1.7	
bank height ratio	0.4	
pool area ratio	0.8	
pool width ratio	0.6	
pool max depth ratio	2.0	
hydraulics:	typical	
discharge rate (cfs)	578.5	
channel slope (%)	0.72	
	riffle-run	pool
velocity (ft/s)	2.8	3.5
Froude number	0.33	0.13
shear stress (lbs/sq.ft.)	0.999	1.318
shear velocity (ft/s)	0.718	0.825
stream power (lb/s)	259.9	
unit stream power (lb/ft/s)	2.798	
relative roughness	3.8	
friction factor u/u*	3.9	
threshold grain size (t*=0.06) (mm)	49.1	
Shield's parameter	0.016	

Table A.11.3-9, continued…

Pattern	typical	min	max
meander length (ft)	1551.2	862.0	2014.8
belt width (ft)	242.8	111.4	399.8
amplitude (ft)	393.3	354.2	419.5
radius (ft)	715.9		
arc angle (degrees)	60.0		
stream length (ft)	1663.7		
valley length (ft)	1395.2		
Sinuosity	1.2		
Meander Length Ratio	16.7	9.3	21.7
Meander Width Ratio	2.6	1.2	4.3
Radius Ratio	7.7	---	---
Profile	typical	min	max
pool-pool spacing (ft)	170.6	14.4	193.6
riffle length (ft)	255.1	223.1	287.1
pool length (ft)	209.8	68.6	351.1
run length (ft)	274.6	54.1	474.1
glide length (ft)	---	---	---
channel slope (%)	0.72		
riffle slope (%)	0.355	0.35	0.36
pool slope (%)	0.0834	0.0068	0.16
run slope (%)	1.97	1.1	3.3
glide slope (%)	---	---	---
measured valley slope (%)	1.2		
valley slope from sinuosity (%)	0.9		
Riffle Length Ratio	3.7	3.2	4.1
Pool Length Ratio	3	1	5.1
Run Length Ratio	4	0.8	6.8
Glide Length Ratio	---	---	---
Riffle Slope Ratio	0.5	0.5	0.5
Pool Slope Ratio	0.1	0	0.2
Run Slope Ratio	2.7	1.5	4.6
Glide Slope Ratio	---	---	---
Pool Spacing Ratio	2.5	0.2	2.8
Channel Materials	Riffle Surface		
D16 (mm)	21		
D35 (mm)	100		
D50 (mm)	180		
D65 (mm)	290		
D84 (mm)	540		
D95 (mm)	890		
mean (mm)	106.5		
dispersion	5.8		
skewness	-0.2		
Shape Factor	0.43		
% Silt/Clay	0%		
% Sand	4%		
% Gravel	22%		
% Cobble	36%		
% Boulder	38%		
% Bedrock			
% Clay Hardpan			
% Detritus/Wood			
% Artificial			
Largest Mobile (mm)	192		

Table A.11.3-9, continued…

Channel Materials	
Largest Mobile	192
Shape Factor	0.43
Bed Surface D16	21
Bed Surface D35	100
Bed Surface D50	180
Bed Surface D65	290
Bed Surface D84	540
Bed Surface D95	890
Bed Surface mean	106.5
Bed Surface dispersion	5.8
Bed Surface skewness	-0.192
Bed Surface % Silt/Clay	0%
Bed Surface % Sand	4%
Bed Surface % Gravel	22%
Bed Surface % Cobble	36%
Bed Surface % Boulder	38%

Table A.11.3-9, continued…

Profile	
pool-pool spacing	170.6
pool-pool spacing min	14.44
pool-pool spacing max	193.57
riffle length	255.1
riffle length min	223.1
riffle length max	287.07
pool length	209.8
pool length min	68.57
pool length max	351.05
run length	274.6
run length min	54.13
run length max	474.08
glide length	---
glide length min	---
glide length max	---
channel slope (%)	0.72
riffle slope (%)	0.355
riffle slope (%) min	0.35
riffle slope (%) max	0.36
pool slope (%)	0.0834
pool slope (%) min	0.0068
pool slope (%) max	0.16
run slope (%)	1.97
run slope (%) min	1.1
run slope (%) max	3.3
glide slope (%)	---
glide slope (%) min	---
glide slope (%) max	---
measured valley slope (%)	1.2
valley slope from sinuosity (%)	0.86
Riffle Length Ratio	3.7
Riffle Length Ratio min	3.2
Riffle Length Ratio max	4.1
Pool Length Ratio	3
Pool Length Ratio min	1
Pool Length Ratio max	5.1
Run Length Ratio	4
Run Length Ratio min	0.8
Run Length Ratio max	6.8
Glide Length Ratio	---
Glide Length Ratio min	---
Glide Length Ratio max	---
Riffle Slope Ratio	0.5
Riffle Slope Ratio min	0.5
Riffle Slope Ratio max	0.5
Pool Slope Ratio	0.1
Pool Slope Ratio min	0
Pool Slope Ratio max	0.2
Run Slope Ratio	2.7
Run Slope Ratio min	1.5
Run Slope Ratio max	4.6
Glide Slope Ratio	---
Glide Slope Ratio min	---
Glide Slope Ratio max	---
Pool Spacing Ratio	2.5
Pool Spacing Ratio min	0.2
Pool Spacing Ratio max	2.8

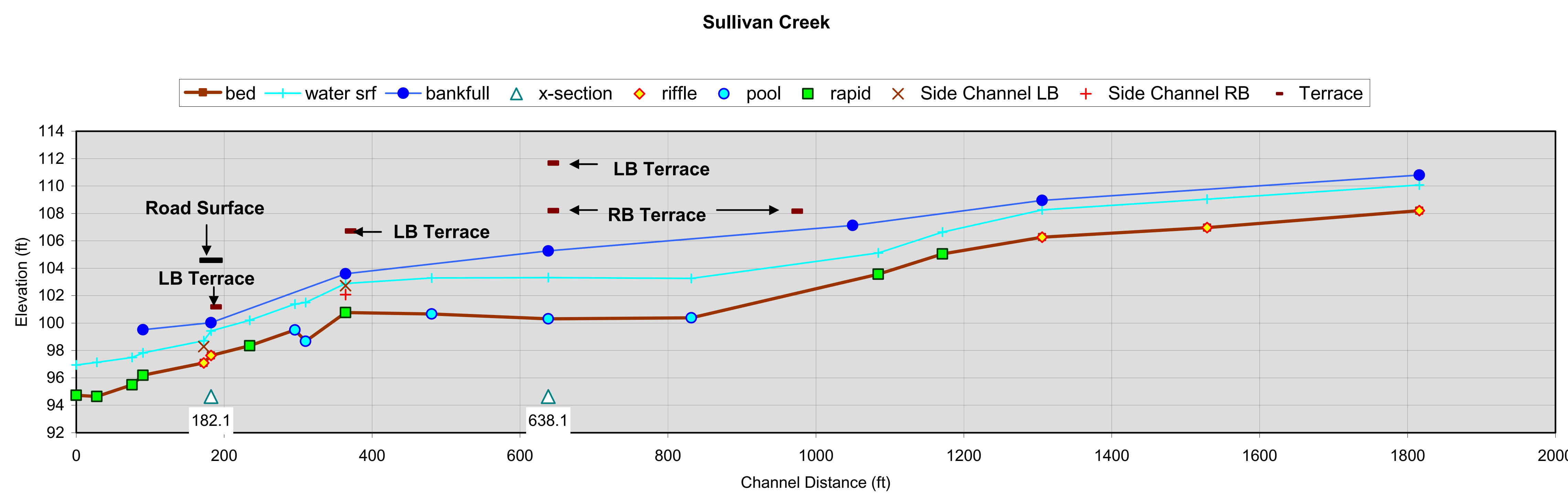
Table A.11.3-9, continued…

Pattern	
meander length	1551.2
meander length min	862.0
meander length max	2014.8
belt width	242.8
belt width min	111.4
belt width max	399.8
amplitude	393.3
amplitude min	354.2
amplitude max	419.5
radius	715.9
radius min	---
radius max	---
arc angle (degrees)	60.0
arc angle (degrees) min	---
arc angle (degrees) max	---
stream length	1663.7
valley length	1395.2
Sinuosity	1.2
Meander Width Ratio	2.6
Meander Width Ratio min	1.2
Meander Width Ratio max	4.3
Meander Length Ratio	16.7
Meander Length Ratio min	9.3
Meander Length Ratio max	21.7
Radius Ratio	7.7
Radius Ratio min	---
Radius Ratio max	---
Floodplain	
width flood prone area	98.7
width flood prone area min	---
width flood prone area max	---
low bank height	1.6
low bank height min	---
low bank height max	---
entrenchment ratio	1.1
entrenchment ratio min	---
entrenchment ratio max	---
bank height ratio	0.4
bank height ratio min	---
bank height ratio max	---

Table A.11.3-9, continued…

Bankfull Channel Dimensions	
x-area bankfull	208.3
x-area bankfull min	---
x-area bankfull max	---
width bankfull	92.9
width bankfull min	---
width bankfull max	---
mean depth	2.24
mean depth min	---
mean depth max	---
max depth	3.8
max depth min	---
max depth max	---
hydraulic radius	2.2
x-area pool	163.4
x-area pool min	---
x-area pool max	---
width pool	54.1
width pool min	---
width pool max	---
max depth pool	4.4
max depth pool min	---
max depth pool max	---
hydraulic radius pool	2.9
Width/Depth Ratio	41.4
Width/Depth Ratio min	---
Width/Depth Ratio max	---
Riffle Max Depth Ratio	1.7
Riffle Max Depth Ratio min	---
Riffle Max Depth Ratio max	---
Pool Area Ratio	0.8
Pool Area Ratio min	---
Pool Area Ratio max	---
Pool Width Ratio	0.6
Pool Width Ratio min	---
Pool Width Ratio max	---
Pool Max Depth Ratio	2.0
Pool Max Depth Ratio min	---
Pool Max Depth Ratio max	---
Bankfull Channel Hydraulics:	
discharge rate, Q	578.5
channel slope (%)	0.720
velocity	2.8
velocity (ft/sec) pool	3.5
Froude number	0.328
Froude number pool	0.133
shear stress	0.999
shear stress (lbs/ft sq) pool	1.318
shear velocity	0.718
shear velocity pool	0.825
stream power	259.9
unit stream power	2.798
relative roughness	3.8
relative roughness pool	0.0
friction factor u/u*	3.9
friction factor u/u* pool	0.0
threshold grain size	49.1

Longitudinal Slope Profile

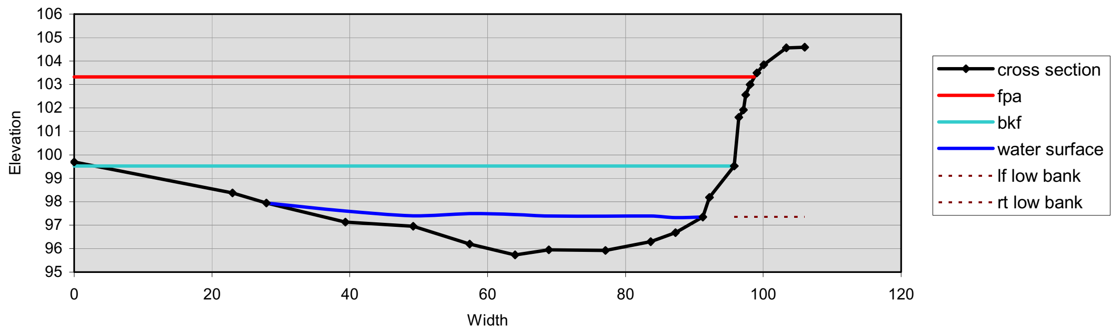


	slope (%)		slope ratio		length (ft)		length ratio		pool-pool spacing (ft)		p-p ratio	
reach	0.72		---		1815.9	(26.2 channel widths)	---		---		---	
riffle	0.355	(0.35 - 0.36)	0.5	(0.5 - 0.5)	255.1	(223.1 - 287.07)	3.7	(3.2 - 4.1)	---		---	
pool	0.0834	(0.0068 - 0.16)	0.1	(0 - 0.2)	209.8	(68.57 - 351.05)	3	(1 - 5.1)	170.6	(14.44 - 193.57)	2.5	(0.2 - 2.8)
rapid	1.97	(1.1 - 3.3)	2.7	(1.5 - 4.6)	274.6	(54.13 - 474.08)	4	(0.8 - 6.8)	---		---	

Figure A.11.3-26. Longitudinal profile of reach 3 in Sullivan Creek. LB is left bank and RB is right bank.

Cross Section 1

1 + 82.09 Sullivan Creek, Riffle



Bankfull Dimensions	
208.3	x-section area (ft.sq.)
92.9	width (ft)
2.2	mean depth (ft)
3.8	max depth (ft)
93.7	wetted parimeter (ft)
2.2	hyd radi (ft)
41.4	width-depth ratio

Flood Dimensions	
98.7	W flood prone area (ft)
1.1	entrenchment ratio
1.6	low bank height (ft)
0.4	low bank height ratio

Materials	
180	D50 Riffle (mm)
540	D84 Riffle (mm)
49	threshold grain size (mm):

Bankfull Flow	
2.8	velocity (ft/s)
578.5	discharge rate (cfs)
0.33	Froude number

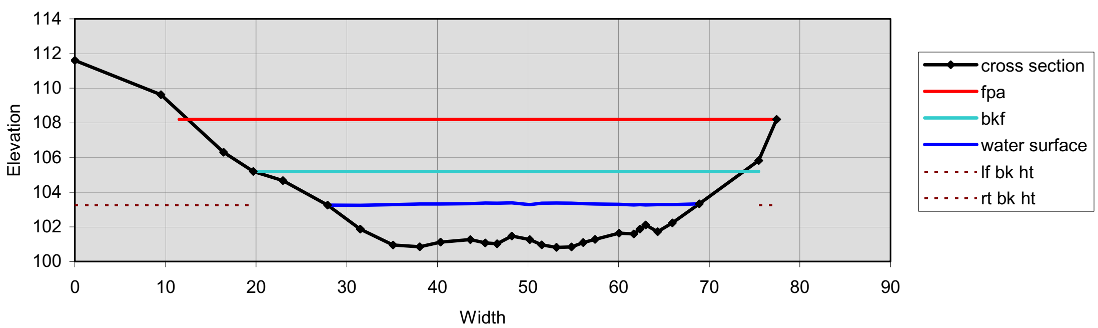
Flow Resistance	
0.078	Manning's roughness
0.54	D'Arcy-Weisbach fric.
3.9	resistance factor u/u*
1.3	relative roughness

Forces & Power	
0.72	channel slope (%)
1.00	shear stress (lb/sq.ft.)
0.72	shear velocity (ft/s)
2.8	unit strm power (lb/ft/s)

Figure A.11.3-27. Cross-section of riffle in reach 3 of Sullivan Creek. FPA is flood-prone area, bkf is bankfull, lf bk ht is left bank height, and rt bk ht is right bank height.

Cross Section 2

6 + 38.12 Sullivan Creek, Pool



Bankfull Dimensions	
163.4	x-section area (ft.sq.)
54.1	width (ft)
3.0	mean depth (ft)
4.4	max depth (ft)
55.7	wetted parimeter (ft)
2.9	hyd radi (ft)
17.9	width-depth ratio

Flood Dimensions	
66.6	W flood prone area (ft)
1.2	entrenchment ratio
2.4	low bank height (ft)
0.6	low bank height ratio

Materials	
180	D50 Riffle (mm)
540	D84 Riffle (mm)
65	threshold grain size (mm):

Bankfull Flow	
3.7	velocity (ft/s)
599.9	discharge rate (cfs)
0.38	Froude number

Flow Resistance	
0.070	Manning's roughness
0.40	D'Arcy-Weisbach fric.
4.5	resistance factor u/u*
1.7	relative roughness

Forces & Power	
0.72	channel slope (%)
1.32	shear stress (lb/sq.ft.)
0.82	shear velocity (ft/s)
5	unit strm power (lb/ft/s)

Figure A.11.3-28. Cross-section of pool in reach 3 of Sullivan Creek. FPA is flood-prone area, bkf is bankfull, lf bk ht is left bank height, and rt bk ht is right bank height.

A.11.3.5. Sullivan Creek—Road Survey Data

A.11.3.5.1. Segment 1

Table A.11.3-10. Data collected from the survey of segment 1.

Metric	Condition
Average Distance to Sullivan Creek	116 m (380.6 ft)
Delivery	Run-off and sediment via road surface and down fill slope to Sullivan Creek
Drainage	Dispersed
Ditch	None
Road Gradient	5 – 10%
Road Width	9.0 LM (29.5 LF)
Road Configuration	Thru Cut
Surfacing	Asphalt
Road Shape	Crowned
Cut Slope Cover Density	30 – 50%
Cut Slope Average Height	1.5 VM (5.0 VF)
Cut Slope Angle	> 70°
Cut Slope Material	Gravel, bedrock, organic soil and material
Cut Slope Structure Issues	Stable cut bank, solid rock
Fill Slope Cover Density	10 – 30%
Fill Slope Average Height	3.0 VM (10.0 VF)
Fill Slope Angle	< 45°
Fill Slope Material	Gravel, sand, fill material
Fill Slope Issues	Sidecast cracking, sidecast erosion
Road Issues	None

Figure A.11.3-29. Photo of segment 1 road, cut, and fill.

Figure A.11.3-30. Photo of segment 1 road, cut, and fill.

Figure A.11.3-31. Photo of segment 1 road, cut, and fill.

Figure A.11.3-32. Photo of segment 1 road surface and shoulder material.

Figure A.11.3-33. Photo of typical cut slope in segment 1.

Figure A.11.3-34. Photo of typical bedrock outcrop on cut slope in segment 1.

A.11.3.5.2. Segment 2

Table A.11.3-11. Data collected from the survey of segment 2.

Metric	Condition
Average Distance to Sullivan Creek	48 m (157.5 ft)
Delivery	Run-off and sediment via road surface and down fill slope to Sullivan Creek
Drainage	Ditchout, natural swale, and dispersed
Ditch	Width is 0.9 LM (3 LF); Depth is < 0.3 LM (< 1 LF); Contains vegetation or rock; Ditch is not eroding
Road Gradient	< 5%
Road Width	9.0 LM (29.5 LF)
Road Configuration	Thru Cut
Surfacing	Asphalt
Road Shape	Sloped away from Sullivan Creek
Cut Slope Cover Density	50 – 70%
Cut Slope Average Height	1.5 VM (5.0 VF)
Cut Slope Angle	> 70°
Cut Slope Material	Gravel, sand, cobble, organic soil and material
Cut Slope Structure Issues	Stable cut bank
Fill Slope Cover Density	70 – 90%
Fill Slope Average Height	1.5 VM (5.0 VF)
Fill Slope Angle	< 45°
Fill Slope Material	Gravel, sand, fill material, and 30 m (98.4 ft) of rip rap
Fill Slope Issues	Potential to deliver, shoulder slope failure, sidecast cracking, sidecast erosion, oversteepened fill in some locations
Road Issues	None

Figure A.11.3-35. Road segment 2 with rip rap used to stabilize fill side of road.

Figure A.11.3-36. Road segment 2 at mile post 16.

Figure A.11.3-37. End of Road segment 2 and approaching North Fork Sullivan Creek (in background of photo). Sullivan Creek is on passenger side of car.

A.11.3.5.3. Segment 3

Table A.11.3-12. Data collected from the survey of segment 3.

Metric	Condition
Average Distance to Sullivan Creek	The majority of segment 3 is directly connected to the Sullivan Creek streambank.
Delivery	Direct delivery to Sullivan Creek
Drainage	Culvert, natural swale, sag point, and dispersed
Ditch	Width is 0.3 LM (1 LF); Depth is < 0.3 LM (< 1 LF); Contains vegetation or rock; Ditch is not eroding
Road Gradient	< 5%
Road Width	9.0 LM (29.5 LF)
Road Configuration	Thru fill and Thru Cut (only for 48 LM (157.5 LF))
Surfacing	Asphalt
Road Shape	Sloped towards Sullivan Creek
Cut Slope Cover Density	70 – 90%
Cut Slope Average Height	1.5 VM (5.0 VF)
Cut Slope Angle	> 70°
Cut Slope Material	Gravel, sand, cobble, organic soil and material
Cut Slope Structure Issues	Stable cut bank, raveling large and fine materials, and slumping in a few locations
Fill Slope Cover Density	30 – 50%
Fill Slope Average Height	3.0 VM (10.0 VF)
Fill Slope Angle	45 – 50°
Fill Slope Material	Boulders, gravel, sand, and fill material
Fill Slope Issues	Potential to deliver, shoulder slope failure, sidecast erosion, oversteepend fill along Sullivan Creek
Road Issues	None

Figure A.11.3-38. Road segment 3 that is directly connected to Sullivan Creek.

Figure A.11.3-39. Sullivan Creek bank that is connected to road segment 3.

Figure A.11.3-40. North Fork Sullivan Creek culvert that is under road segment 3.

Figure A.11.3-41. County road that departs from road segment 3 and heads up North Fork Sullivan Creek.

Figure A.11.3-42. Non-maintained campground that is between road segment 3 and Sullivan Creek.

Figure A.11.3-43. Grass land in road segment 3.

Table A.11.3-13. Data collected for the North Fork Sullivan Creek culvert.

Metric	Condition
Purpose	Stream Crossing
Inlet	OK
Outfall Drop	None
Type of Culvert	Corrugated Steel
Outlet Features	Armored
Future Plug Potential	Medium
Inlet Blockage	None
Outlet Blockage	None
Prescription Urgency	None
Culvert Condition Issues	None
Culvert Function Issues	Culvert is a fish passage barrier
Prescription	None
Comments	Culvert is a fish passage barrier. However, the cutthroat trout population in North Fork Sullivan Creek is a distinct genetic stock and therefore the culvert should not be replaced. Culvert structure appeared to function adequately at high and low flows.

A.11.3.5.4. Segment 4

Table A.11.3-14. Data collected from the survey of segment 4.

Metric	Condition
Average Distance to Sullivan Creek	segment 4 is directly connected to 79 LM (259.2 LF) of wetland on both the left and right side of the road. This wetland is directly connected to Sullivan Creek. segment 4 is directly connected to 97 LM (318.2 LF) of Sullivan Creek. The remaining length of segment 4 is on a terrace of Sullivan Creek that is on average 72.9 LM (239.1 LF) away from the Creek.
Delivery	Direct delivery to Sullivan Creek for 176 LM (577.4 LF) while the remaining 516 LM (1692.9 LF) are not directly connected, but run-off and sediment via road surface may be delivered to Sullivan Creek.
Drainage	Culvert, ditchout, natural swale, and dispersed
Ditch	Width is 0.6 LM (2 LF); Depth is 0.3 – 0.6 LM (1 – 2 LF); Contains vegetation or rock; Ditch is not eroding
Road Gradient	< 5%
Road Width	9.0 LM (29.5 LF)
Road Configuration	Thru fill and Full Bench
Surfacing	Asphalt
Road Shape	Crowned
Cut Slope Cover Density	70 – 90%
Cut Slope Average Height	0.8 VM (2.5 VF)
Cut Slope Angle	50 – 70°
Cut Slope Material	Gravel, sand, and organic soil and material
Cut Slope Structure Issues	Stable cut bank, solid rock, and raveling large materials
Fill Slope Cover Density	50 – 70%
Fill Slope Average Height	0.8 VM (2.5 VF)
Fill Slope Angle	< 45°
Fill Slope Material	Gravel, sand, rip rap, hydric soils, and organic soil and material
Fill Slope Issues	Potential to deliver, oversteepend fill, culvert fill failing, soft fill on shoulder, shoulder slope failure, perched landing, and sidecast erosion.
Road Issues	Road crosses wetland and is directly connected to Sullivan Creek with rip rap used to protect road.

Figure A.11.3-44. Photo taken in road segment 4. Sullivan Creek off-channel area (right side in photo) in road segment 4.

Figure A.11.3-45. Photo taken in road segment 4. Culvert submerged in Sullivan Creek off-channel area in road segment 4.

Figure A.11.3-46. Wetland that is connected via ac culvert to the Sullivan Creek off-channel area in road segment 4.

Figure A.11.3-47. Landing in road segment 4. Road segment 4 is directly connected to Sullivan Creek in this portion of the road segment.

Figure A.11.3-48. Rip rap that has been placed in Sullivan Creek along road segment 4.

Table A.11.3-15. Data collected for the culvert connecting the wetland.

Metric	Condition
Purpose	Stream Crossing
Inlet	OK
Outfall Drop	Bottom of culvert is buried in fine sediments
Type of Culvert	Corrugated Steel
Outlet Features	Buried in fine sediments
Future Plug Potential	High
Inlet Blockage	0 – 25%
Outlet Blockage	75 – 100% of outlet was backwatered from high flows in Sullivan Creek
Prescription Urgency	Low
Culvert Condition Issues	Outfall damaged
Culvert Function Issues	Culvert full of water and high flows undermine culvert
Prescription	Repair/install bottomless arch culvert
Comments	Culvert should be replaced with bottomless arch culvert to provide connectivity between wetlands and off-channel habitat for fish species.

A.11.3.5.5. Segment 5

Table A.11.3-16. Data collected from the survey of segment 5.

Metric	Condition
Average Distance to Sullivan Creek	64.5 LM (211.6 LF)
Delivery	Run-off and sediment via road surface and down fill slope to Sullivan Creek
Drainage	Ditchout and dispersed
Ditch	Width is 0.9 LM (3 LF); Depth is < 0.3 LM (< 1 LF); Contains vegetation or rock; Ditch is not eroding
Road Gradient	10 – 15%
Road Width	9.0 LM (29.5 LF)
Road Configuration	Thru Cut and Full Bench
Surfacing	Asphalt
Road Shape	Sloped away from Sullivan Creek
Cut Slope Cover Density	30 – 50%
Cut Slope Average Height	3.0 VM (10.0 VF)
Cut Slope Angle	> 70°
Cut Slope Material	Gravel, sand, cobble, organic soil and material
Cut Slope Structure Issues	Raveling large and fine materials, and slumping
Fill Slope Cover Density	50 – 70%
Fill Slope Average Height	3.0 VM (10.0 VF)
Fill Slope Angle	45 – 50°
Fill Slope Material	Gravel, sand, rip rap, and fill material
Fill Slope Issues	Oversteepend fill, shoulder slope failure, sidecast cracking, sidecast erosion, and placed rip rap
Road Issues	None

Figure A.11.3-49. Cut slope in road segment 5.

Figure A.11.3-50. Start of road segment 5.

Figure A.11.3-51. Road barrier in road segment 5.

Figure A.11.3-52. From road segment 5 looking down from barrier (previous photo) towards Sullivan Creek.

Figure A.11.3-53. Placed rip rap material below barrier (see photo above) in road segment 5.

A.11.4 LINTON CREEK

Table A.11.4-1. Dimensions of culverts surveyed in Linton Creek.

Feature	Culvert 1.1	Culvert 1.2	Culvert 1.3
Culvert Material	Corrugated Steel	Corrugated Steel	Corrugated Steel
Span	0.79 m (2.59 ft)	1.01 m (3.31 ft)	1.10 m (3.61 ft)
Rise	0.76 m (2.49 ft)	0.87 m (2.85 ft)	1.12 m (3.67 ft)
Water Depth in Culvert	0.17 m (0.56 ft)	0.20 m (0.66 ft)	0.10 m (0.33ft)
Outfall Drop	0.74 m (2.43 ft)	0 m (0 ft)	1.08 m (3.54 ft)
Length	12.0 m (39.4 ft)	9.7 m (31.8 ft)	40.5 m (132.9 ft)
Slope	4.5%	1.5%	2.5%
Road Width	3.69 m (12.1 ft)	4.3 m (14.1 ft)	4.7 m (15.4 ft)
Fill Depth	2.02 m (6.64 ft)	0.62 m (2.04 ft)	7.0 m (23.0 ft)

Table A.11.4-2. Results from habitat survey of Linton Creek.

Mean Residual Pool Depth	Mean Thalweg Depth	Mean Water Surface Slope (%)	Mean Wetted Width	Volume of LWD	Dominant Habitat Type	Riparian Cover Along Bank (0 -17)[1]	Percent Fines (%)	D50 (mm)	Embeddness (%)	Streambank Cover Value (1 - ≥ 4)[2]	Average Bank Angle (°)[3]	Bank Erosion (%)
7.1 cm (2.8 in)	19.0 cm (7.5 in)	2.3	3.2 m (10.6 ft)	1.2 m^3 (42.4 ft^3)	Riffle	8.5	20	18	20	3	125	35

Notes:

1 Values are between 0 and 17 with 0 representing no bank cover and 17 representing complete bank cover.

2 A value of 3 is a fair rating for total cover. Fair is defined in Bain and Stevenson (1999) as a substantial portion of the streambank surface is not covered by vegetation or rocky material. These areas have a poor resistance to erosion.

3 An average bank angle between 90° and 135° indicates steeply sloping shorelines, as defined in Bain and Stevenson (1999).

Table A.11.4-3. Results from the Level B Assessment of culvert 1.1 on Linton Creek.

Fish Passage Barrier Assessment and Prioritization Manual - 2.3 Barrier Analysis
Level B Spreadsheet; Version: Excel 97, Metric Units
Updated: May 30, 2001

Site Information									**Source Worksheet**
Stream:	Linton Creek								Hydrology
Site ID:	Linton Creek								"
Sequencer:	1.1								"
Hydrology									
Hydrology Method Selected:	Ordinary High Water Method								Hydrology
Elevation of Ordinary High Water:	608.55								X Section
Downstream Channel Cross Section									
	TopLB	**ToeLB**	**Bed1**	**Bed2**	**Bed3**	**ToeRB**	**TopRB**		X Section
Station:	0.00	0.47	0.91	2.73	4.09	5.02	6.45		"
Elev:	608.487	608.271	608.314	608.418	608.349	608.259	608.421		"

DS Control Water Surface Elevation:	608.421			X Section
Water Surface Elevation 50 ft. (15.24 m) DS:	608.046			"
Manning's "n" for channel	0.04			"
Cross Section Water Surface Elevation at Wfp:	608.55			"
Culvert Length:	12.00	m		Round
Maximum Velocity:	1.22	mps	(WAC criteria)	
Minimum Water Depth:	0.30	m	(WAC criteria)	
Maximum Hydrualic Drop in Fishway:	0.30	m	(WAC criteria)	
Culvert Type:	Round Culvert			X Section
Culvert Analysis				
Round Culvert Diamter (m):	0.79			Round
Manning's n for culvert:	0.0240			"
Culvert Length (m):	12.00			"
U/S Invert Elevation:	609.57			"
D/S/ Invert Elelvation:	609.03			"
Normal Flow Depth (m):	0.75			"
Culvert Slope (m/m):	0.0453			"
Velocity w/o backwater (mps):	3.28			"
Water Surface Elevation at DS end of culvert:	608.55			"
Flow Depth at DS end of culvert:	0.00			"
Culvert Influenced by Backwater:	No			"
Outlet Submerged:	No			"
Length Submerged (m):	0.00			"
Backwater Length Plus Submerged Length (m):	0.00			"
Maximum Velocity in Culvert (mps):	0.00			"
Minimum Depth in Culvert (m):	0.00			"

Summary of Analysis

1. High Fish Passage Design Flow, Qfp was determined by the **Ordinary High Water Method.**
Qfp = 1.97 cms

2. Next the culvert was analyzed at Qfp without backwater.

Max. Velocity (w/o backwater) =	**3.28**	**mps**	**Does not satisfy WAC criteria.**
Min. Depth (w/o backwater) =	**0.75**	**m**	**Satisfies WAC criteria.**

Velocity does not satisfy WAC criteria, check backwater

3. Finally, the backwater condition was analyzed.

Is the culvert influenced by backwater?	**No**		
Is the culvert outlet submerged?	**No**		**0.00 m of culvert submerged**

The flow conditions are too complex to calculate with this worksheet. Max. velocity and min. depth below are ROUGH ESTIMATES!

Max. Velocity (w/ backwater) =	**0.00**	**mps**	**Satisfies WAC criteria.**
Min. Depth (w/ backwater) =	**0.00**	**m**	**Does not satisfy WAC criteria.**

4. The Final Answer…
The culvert does not satisfy WAC criteria.

Table A.11.4-4. Results from the Level B Assessment of culvert 1.3 on Linton Creek.

Fish Passage Barrier Assessment and Prioritization Manual - 2.3 Barrier Analysis
Level B Spreadsheet; Version: Excel 97, Metric Units
Updated: May 30, 2001

Site Information								**Source Worksheet**
Stream:	Linton Creek							Hydrology
Site ID:	Linton Creek							"
Sequencer:	1.3							"
Hydrology								
Hydrology Method Selected:	Ordinary High Water Method							Hydrology
Elevation of Ordinary High Water:	616.03							X Section
Downstream Channel Cross Section								
	TopLB	**ToeLB**	**Bed1**	**Bed2**	**Bed3**	**ToeRB**	**TopRB**	X Section
Station:	0.00	0.39	0.78	1.49	2.05	2.45	2.72	"
Elev:	616.031	615.171	615.580	615.568	615.519	615.421	615.854	"

DS Control Water Surface Elevation:	615.427			X Section
Water Surface Elevation 50 ft. (15.24 m) DS:	615.068			"
Manning's "n" for channel	0.04			"
Cross Section Water Surface Elevation at Wfp:	616.031			"
Culvert Length:	40.50	m		Round
Maximum Velocity:	0.91	mps	(WAC criteria)	
Minimum Water Depth:	0.30	m	(WAC criteria)	
Maximum Hydrualic Drop in Fishway:	0.30	m	(WAC criteria)	
Culvert Type:	Round Culvert			X Section
Culvert Analysis				
Round Culvert Diamter (m):	1.1			Round
Manning's n for culvert:	0.0240			"
Culvert Length (m):	40.50			"
U/S Invert Elevation:	617.51			"
D/S/ Invert Elelvation:	616.51			"
Normal Flow Depth (m):	1.034			"
Culvert Slope (m/m):	0.0249			"
Velocity w/o backwater (mps):	3.05			"
Water Surface Elevation at DS end of culvert:	616.03			"
Flow Depth at DS end of culvert:	0.00			"
Culvert Influenced by Backwater:	No			"
Outlet Submerged:	No			"
Length Submerged (m):	0.00			"
Backwater Length Plus Submerged Length (m):	0.00			"
Maximum Velocity in Culvert (mps):	0.00			"
Minimum Depth in Culvert (m):	0.00			"

Summary of Analysis

1. High Fish Passage Design Flow, Qfp was determined by the **Ordinary High Water Method.**

Qfp = 2.94 cms

2. Next the culvert was analyzed at Qfp without backwater.

Max. Velocity (w/o backwater) =	**3.05**	**mps**	**Does not satisfy WAC criteria.**
Min. Depth (w/o backwater) =	**1.03**	**m**	**Satisfies WAC criteria.**

Velocity does not satisfy WAC criteria, check backwater

3. Finally, the backwater condition was analyzed.

Is the culvert influenced by backwater?	**No**	
Is the culvert outlet submerged?	**No**	**0.00 m of culvert submerged**

The flow conditions are too complex to calculate with this worksheet. Max. velocity and min. depth below are ROUGH ESTIMATES!

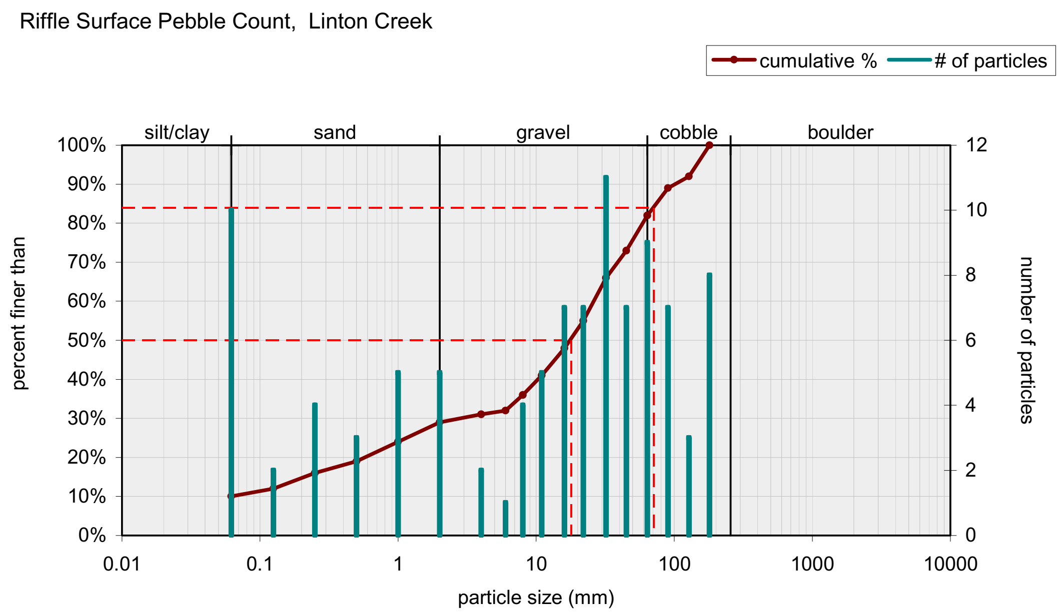
Max. Velocity (w/ backwater) =	**0.00**	**mps**	**Satisfies WAC criteria.**
Min. Depth (w/ backwater) =	**0.00**	**m**	**Does not satisfy WAC criteria.**

4. The Final Answer…

The culvert does not satisfy WAC criteria.
The culvert is a barrier.

Table A.11.4-5. Results of geomorphic survey of Linton Creek.

Bankfull Width	Mean Bankfull Depth	Bankfull Cross-Sectional Area	Width/Depth Ratio	Maximum Bankfull Depth	Width of Flood-Prone Area	Entrench-ment Ratio	D50	Channel Slope	Channel Sinuosity
8.1 m (26.6 ft)	0.9 m (3.0 ft)	7.3 m^2 (78.6 ft^2)	9.0	1.2 m (3.9 ft)	9.1 m (29.9 ft)	1.1	18 mm	2%	1.1



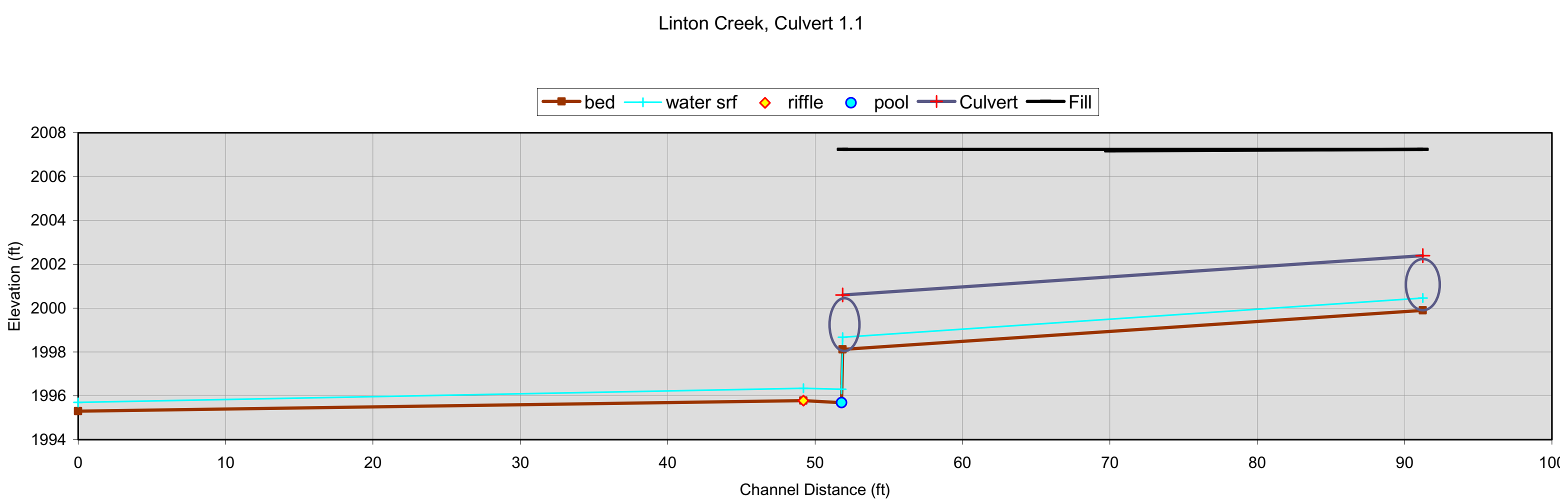
Size (mm)	
D16	0.25
D35	7.4
D50	18
D65	31
D84	71
D95	150

Size Distribution	
mean	4.2
dispersion	38.0
skewness	-0.40

Type	
silt/clay	10%
sand	19%
gravel	53%
cobble	18%
boulder	0%

Figure A.11.4-1. Riffle surface pebble count results from Linton Creek.

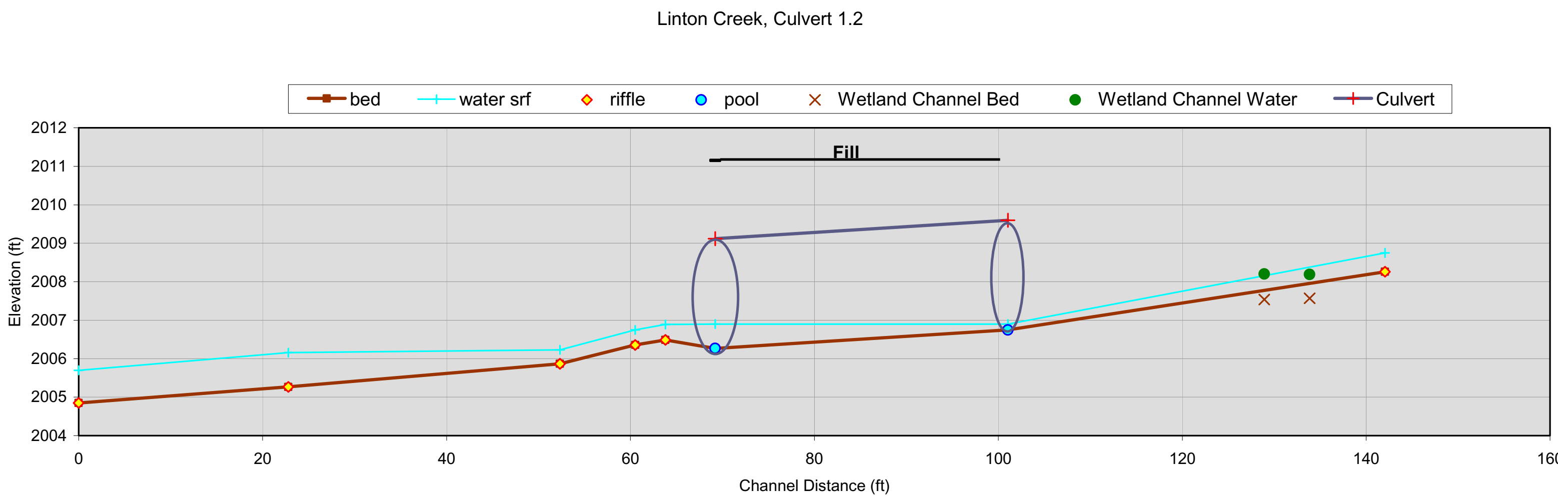
Longitudinal Slope Profile p



	slope (%)	slope ratio	length (ft)	length ratio	pool-pool spacing (ft)	p-p ratio
reach	2	---	91.2 (33.8 channel widths)	---	---	---
riffle	1.7	0.9	49.2	18.2	---	---
pool	1	0.5	2.6	1	---	---

Figure A.11.4-2. Longitudinal profile of stream segment downstream from culvert 1.1.

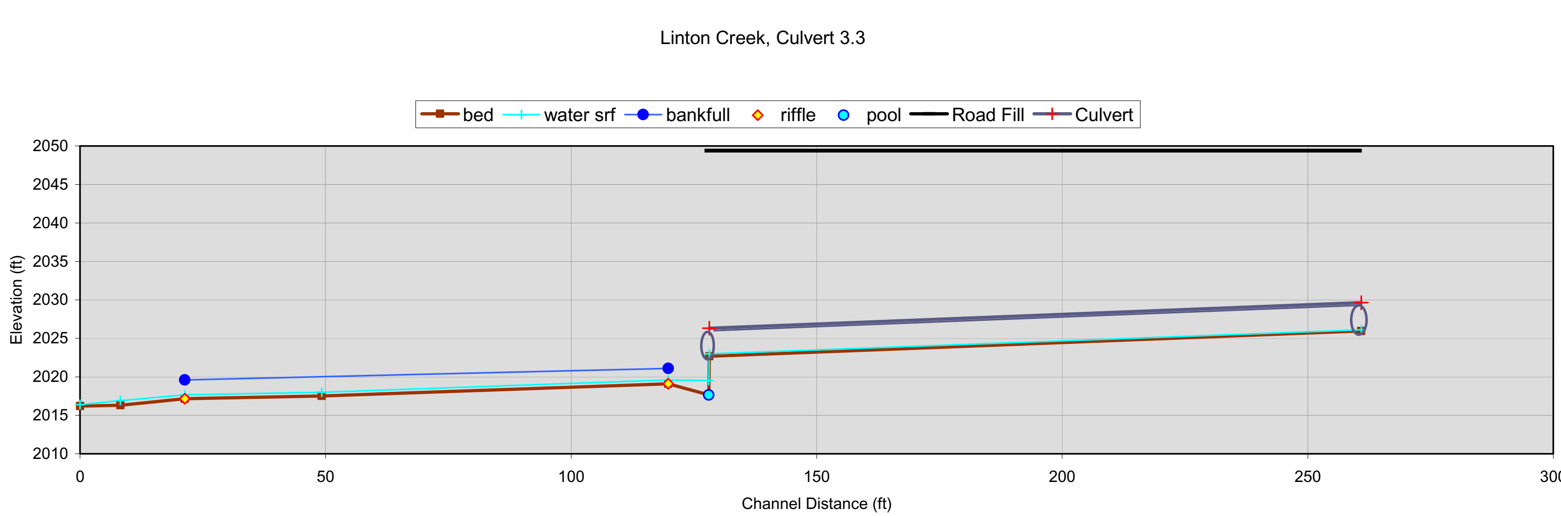
Longitudinal Slope Profile p



	slope (%)	slope ratio	length (ft)	length ratio	pool-pool spacing (ft)	p-p ratio
reach	2.1	---	142.1 (52.6 channel widths)	---	---	---
riffle	3.1 (1.7 - 4.5)	1.5 (0.8 - 2.1)	52.4 (41.01 - 63.81)	19.4 (15.2 - 23.6)	---	---
pool	0.0094	0	31.8 (0 - 41)	11.8 (--- - 15.2)	31.8	11.8

Figure A.11.4-3. Longitudinal profile of stream segment downstream from culvert 1.2. Streambed material was throughout the culvert with woody debris slash potentially limiting upstream passage by juvenile fish.

Longitudinal Slope Profile



	slope (%)	slope ratio	length (ft)	length ratio	pool-pool spacing (ft)	p-p ratio
reach	2.4	---	260.9 (96.6 channel widths)	---	---	---
riffle	3.95 (2 - 5.9)	1.6 (0.8 - 2.5)	59.9 (21.32 - 98.43)	22.2 (7.9 - 36.5)	---	---
pool	0.85	0.4	8.3	3.1	---	---

Figure A.11.4-4. Longitudinal profile of stream segment downstream from culvert 1.3. The Highway 31 culvert is 17.5 m (57.4 ft) upstream from Culvert 1.3.

A.11.5 POCAHONTAS CREEK

Table A.11.5-1. Dimensions of Pocahontas Creek culverts.

Feature	Culvert 1.1	Culvert 1.2
Culvert Material	Corrugated Steel	Corrugated Steel
Span	0.46 m (1.51 ft)	0.58 m (1.90 ft)
Rise	0.43 m (1.41 ft)	0.52 m (1.71 ft)
Water Depth in Culvert	0.28 m (0.92 ft)	0.37m (1.21 ft)
Outfall Drop	0.03 m (0.10 ft)	0.07 m (0.23 ft)
Length	8.25 m (27.07 ft)	8.25 m (27.07 ft)
Slope	8.9%	5.9%
Road Width	5.5 m (18.04 ft)	5.5m (18.04 ft)
Fill Depth	3.56 m (11.68 ft)	3.56 m (11.68 ft)

Table A.11.5-2. Dimensions of falls and step pool features in Pocahontas Creek.

Habitat Feature	Height (m)	Width (m)	Max. Plunge Pool Depth (m)	Plunge Pool Length (m)
Falls #1	1.78	5.7	0.4	0.7
Step pool series				
Downstream	0.72	3.2	0.39	1.0
Mid	1.24	2.5	0.34	1.0
Upstream	2.70	2.8	0.35	4.1
Falls #2	1.2	3.2	0.66	0.4

Table A.11.5-3. Results from habitat survey downstream of culvert on Pocahontas Creek.

Mean Residual Pool Depth	Mean Thalweg Depth	Mean Water Surface Slope (%)	Mean Wetted Width	Volume of LWD	Dominant Habitat Type	Three-Layer Riparian Vegetation Presence (%)	Riparian Cover Along Bank (0 -17)[1]	Percent Fines (%)	D50 (mm)	Embeddness (%)	Streambank Cover Value (1 - ≥ 4)[2]	Average Bank Angle (°)[3]	Bank Erosion (%)
6.4 cm (2.5 in)	30.4 cm (12.0 in)	6	2.2 m (6.6 ft)	3.8 m^3 (134.2 ft^3)	Rapid	91.7	16.7	8	5.5	51.3	4	107	48.5

Notes:
1 Values are between 0 and 17 with 0 representing no bank cover and 17 representing complete bank cover.
2 A value of 4 is a good rating for total cover. Good is defined in Bain and Stevenson (1999) as most of the streambank surfaces are covered by vegetation or rocky material the size of pebbles and larger. Areas not covered by vegetation are protected by materials that will limit erosion at high streamflows.
3 An average bank angle between 90° and 135° indicates steeply sloping shorelines, as defined in Bain and Stevenson (1999).

Table A.11.5-4. Results from reach-scale habitat survey upstream of culvert on Pocahontas Creek.

Mean Residual Pool Depth	Mean Thalweg Depth	Mean Water Surface Slope (%)	Mean Wetted Width	Volume of LWD	Dominant Habitat Type	Three-Layer Riparian Vegetation Presence (%)	Mean Canopy Density Along Bank (0 -17)[1]	Percent Fines (%)	D50 (mm)	Embeddness (%)	Streambank Cover Value (1 - ≥ 4)[2]	Average Bank Angle (°)[3]	Bank Erosion (%)
2.8 cm (1.1 in)	26.8 cm (10.6 in)	6	2.8 m (9.2 ft)	10.1 m^3 (356.7 ft^3)	Rapid	100	15.4	10	7.5	59.4	≥ 4	106	23.3

Notes:
1 Values are between 0 and 17 with 0 representing no bank cover and 17 representing complete bank cover.
2 A value of ≥4 is an excellent rating for total cover. Excellent is defined in Bain and Stevenson (1999) as nearly all of the streambank is covered by vegetation in vigorous condition or by boulders and cobble.
3 An average bank angle between 90° and 135° indicates steeply sloping shorelines, as defined in Bain and Stevenson (1999).

Table A.11.5-5. Results from the Level B Assessment of culvert 1.1 on Pocahontas Creek.

Fish Passage Barrier Assessment and Prioritization Manual - 2.3 Barrier Analysis
Level B Spreadsheet; Version: Excel 97, Metric Units
Updated: May 30, 2001

Site Information				**Source Worksheet**
Stream:	Pocahontas Creek			Hydrology
Site ID:	POC			"
Sequencer:	1.1			"
Hydrology				
Hydrology Method Selected:	Ordinary High Water Method			Hydrology
Elevation of Ordinary High Water:	25.63			X Section

Downstream Channel Cross Section

	TopLB	ToeLB	Bed1	Bed2	Bed3	ToeRB	TopRB	Source Worksheet
								X Section
Station:	0.00	0.35	1.05	1.65	2.20	2.90	4.55	"
Elev:	26.17	25.55	25.53	25.53	25.47	25.56	26.81	"

DS Control Water Surface Elevation:	25.69			X Section
Water Surface Elevation 50 ft. (15.24 m) DS:	24.99			"
Manning's "n" for channel	0.04			"
Cross Section Water Surface Elevation at Wfp:	25.63			"
Culvert Length:	8.25	m		Round
Maximum Velocity:	1.22	mps	(WAC criteria)	
Minimum Water Depth:	0.30	m	(WAC criteria)	
Maximum Hydrualic Drop in Fishway:	0.30	m	(WAC criteria)	
Culvert Type:	Round Culvert			X Section

Culvert Analysis

Round Culvert Diamter (m):	0.46	Round
Manning's n for culvert:	0.0240	"
Culvert Length (m):	8.25	"
U/S Invert Elevation:	26.8	"
D/S/ Invert Elelvation:	26.18	"
Normal Flow Depth (m):	0.305	"
Culvert Slope (m/m):	0.752	"
Velocity w/o backwater (mps):	2.97	"
Water Surface Elevation at DS end of culvert:	25.63	"
Flow Depth at DS end of culvert:	0.00	"
Culvert Influenced by Backwater:	No	"
Outlet Submerged:	No	"
Length Submerged (m):	0.00	"
Backwater Length Plus Submerged Length (m):	0.00	"
Maximum Velocity in Culvert (mps):	0.00	"
Minimum Depth in Culvert (m):	0.00	"

Summary of Analysis

1. High Fish Passage Design Flow, Qfp was determined by the **Ordinary High Water Method.**
   Qfp = 0.35 cms

2. Next the culvert was analyzed at Qfp without backwater.

Max. Velocity (w/o backwater) =	**2.97 mps**	**Does not satisfy WAC criteria.**
Min. Depth (w/o backwater) =	**0.31 m**	**Satisfies WAC criteria.**

Velocity does not satisfy WAC criteria, check backwater

3. Finally, the backwater condition was analyzed.

Is the culvert influenced by backwater?	**No**	**Culvert is partially backwatered**
Is the culvert outlet submerged?	**No**	**0.00 m of culvert submerged**

The flow conditions are too complex to calculate with this worksheet. Max. velocity and min. depth below are ROUGH ESTIMATES!

Max. Velocity (w/ backwater) =	**0.00 mps**	**Satisfies WAC criteria.**
Min. Depth (w/ backwater) =	**0.00 m**	**Does not satisfy WAC criteria.**

4. The Final Answer…
   The culvert does not satisfy WAC criteria.
   The culvert is a barrier.

Table A.11.5-6. Results from the Level B Assessment of culvert 1.2 on Pocahontas Creek.

Fish Passage Barrier Assessment and Prioritization Manual - 2.3 Barrier Analysis
Level B Spreadsheet; Version: Excel 97, Metric Units
Updated: May 30, 2001

Site Information			**Source Worksheet**
Stream:	Pocahontas Creek		Hydrology
Site ID:	POC		"
Sequencer:	1.2		"
Hydrology			
Hydrology Method Selected:	Ordinary High Water Method		Hydrology
Elevation of Ordinary High Water:	25.63		X Section
Downstream Channel Cross Section			

	TopLB	ToeLB	Bed1	Bed2	Bed3	ToeRB	TopRB	Source Worksheet
Station:	0.00	0.35	1.05	1.65	2.20	2.90	4.55	X Section "
Elev:	26.17	25.55	25.53	25.53	25.47	25.56	26.81	"

DS Control Water Surface Elevation:	25.69			X Section
Water Surface Elevation 50 ft. (15.24 m) DS:	24.99			"
Manning's "n" for channel	0.04			"
Cross Section Water Surface Elevation at Wfp:	25.63			"
Culvert Length:	8.25	m		Round
Maximum Velocity:	1.22	mps	(WAC criteria)	
Minimum Water Depth:	0.30	m	(WAC criteria)	
Maximum Hydrualic Drop in Fishway:	0.30	m	(WAC criteria)	
Culvert Type:	Round Culvert			X Section
Culvert Analysis				
Round Culvert Diamter (m):	0.58			Round
Manning's n for culvert:	0.0240			"
Culvert Length (m):	8.25			"
U/S Invert Elevation:	26.74			"
D/S/ Invert Elelvation:	26.25			"
Normal Flow Depth (m):	0.28			"
Culvert Slope (m/m):	0.0594			"
Velocity w/o backwater (mps):	2.74			"
Water Surface Elevation at DS end of culvert:	25.63			"
Flow Depth at DS end of culvert:	0.00			"
Culvert Influenced by Backwater:	No			"
Outlet Submerged:	No			"
Length Submerged (m):	0.00			"
Backwater Length Plus Submerged Length (m):	0.00			"
Maximum Velocity in Culvert (mps):	0.00			"
Minimum Depth in Culvert (m):	0.00			"

Summary of Analysis

1. High Fish Passage Design Flow, Qfp was determined by the **Ordinary High Water Method.**

Qfp = 0.35 cms

2. Next the culvert was analyzed at Qfp without backwater.

Max. Velocity (w/o backwater) =	**2.74**	**mps**	**Does not satisfy WAC criteria.**
Min. Depth (w/o backwater) =	**0.28**	**m**	**Satisfies WAC criteria.**

Velocity does not satisfy WAC criteria, check backwater

3. Finally, the backwater condition was analyzed.

Is the culvert influenced by backwater?	**No**	**Culvert is partially backwatered**
Is the culvert outlet submerged?	**No**	**0.00 m of culvert submerged**

The flow conditions are too complex to calculate with this worksheet. Max. velocity and min. depth below are ROUGH ESTIMATES!

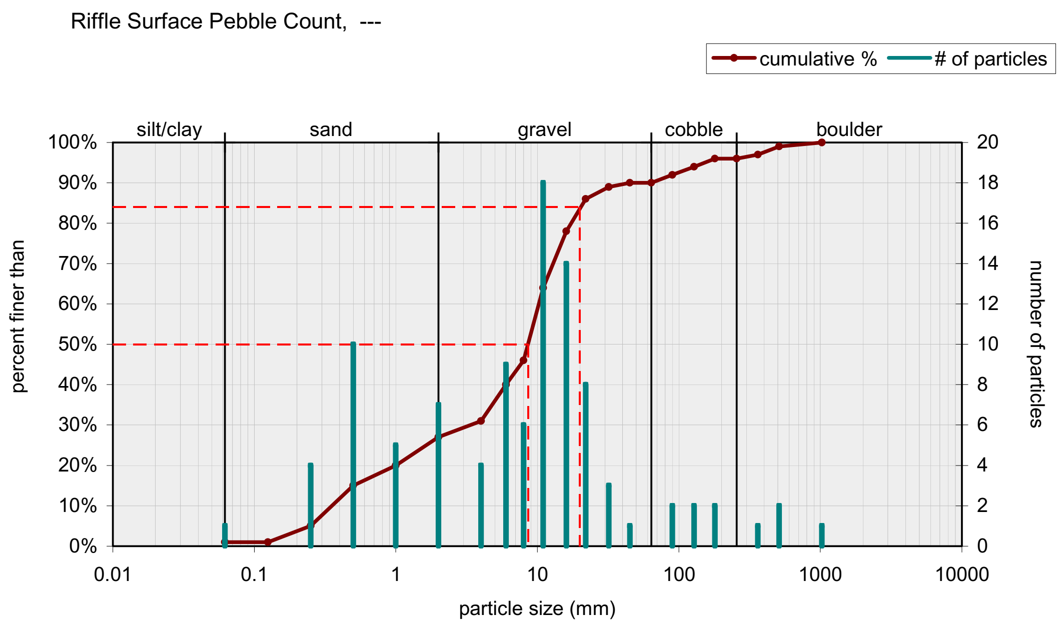
Max. Velocity (w/ backwater) =	**0.00**	**mps**	**Satisfies WAC criteria.**
Min. Depth (w/ backwater) =	**0.00**	**m**	**Does not satisfy WAC criteria.**

4. The Final Answer…

The culvert does not satisfy WAC criteria.
The culvert is a barrier.

Table A.11.5-7. Results of geomorphic survey on Pocahontas Creek.

Bankfull Width	Mean Bankfull Depth	Bankfull Cross-Sectional Area	Width/Depth Ratio	Maximum Bankfull Depth	Width of Flood-Prone Area	Entrench-ment Ratio	D50	Channel Slope	Channel Sinuosity
4.2 m (13.8 ft)	0.5 m (1.6 ft)	2.0 m^2 (21.5 ft^2)	8.4	0.7 m (2.3 ft)	10.6 m (34.8 ft)	2.5	8.6 mm	6%	1.1



Size (mm)	
D16	0.57
D35	4.8
D50	8.6
D65	11
D84	20
D95	150

Size Distribution	
mean	3.4
dispersion	8.7
skewness	-0.33

Type	
silt/clay	1%
sand	26%
gravel	63%
cobble	6%
boulder	4%

Figure A.11.5-1. Riffle surface pebble count results from Pocahontas Creek.

A.11.6 SWEET CREEK

Table A.11.6-1. Sweet Creek culvert dimensions.

Dimension	Culvert 1.1
Culvert Material	Cast-in-place Concrete
Span	2.43 m (7.97 ft)
Rise	3.60 m (11.81 ft)
Water Depth in Culvert	0.07 m (0.23 ft)
Outfall Drop	0.60 m (1.97 ft)
Length	18.3 m (60.04 ft)
Slope	2.7%
Road Width	7.27 m (23.85 ft)
Fill Depth	2.03 m (6.66 ft)

Table A.11.6-2. Results from habitat survey downstream of culvert on Sweet Creek.

Mean Residual Pool Depth	Mean Thalweg Depth	Mean Water Surface Slope (%)	Mean Wetted Width	Volume of LWD	Dominant Habitat Type	Three-Layer Riparian Vegetation Presence (%)	Riparian Cover Along Bank (0 -17)[1]	Percent Fines (%)	D50 (mm)	Embeddness (%)	Streambank Cover Value (1 -> 4)[2]	Average Bank Angle (°)[3]	Bank Erosion (%)
5.6 cm (2.2 in)	31.9 cm (12.6 in)	3	10.0 m (32.8 ft)	10.8 m^3 (381.4 ft^3)	Riffle	100	16.2	2	101	18.3	> 4	108	35.3

Notes:
1 Values are between 0 and 17 with 0 representing no bank cover and 17 representing complete bank cover.
2 A value of > 4 is an excellent rating for total cover. Excellent is defined in Bain and Stevenson (1999) as nearly all of the streambank is covered by vegetation in vigorous condition or by boulders and cobble.
3 An average bank angle between 90° and 135° indicates steeply sloping shorelines, as defined in Bain and Stevenson (1999).

Table A.11.6-3. Results from reach-scale habitat survey upstream of culvert on Sweet Creek.

Mean Residual Pool Depth	Mean Thalweg Depth	Mean Water Surface Slope (%)	Mean Wetted Width	Volume of LWD	Dominant Habitat Type	Three-Layer Riparian Vegetation Presence (%)	Mean Canopy Density Along Bank (0 -17)[1]	Percent Fines (%)	D50 (mm)	Embeddness (%)	Streambank Cover Value (1 - > 4)[2]	Average Bank Angle (°)[3]	Bank Erosion (%)
8.7 cm (3.4 in)	34.0 cm (13.4 in)	3	5.4 m (17.7 ft)	15.5 m^3 (547.4 ft^3)	Riffle	100	16.4	2	100	14.7	> 4	105	26.5

Notes:

1 Values are between 0 and 17 with 0 representing no bank cover and 17 representing complete bank cover.

2 A value of > 4 is an excellent rating for total cover. Excellent is defined in Bain and Stevenson (1999) as nearly all of the streambank is covered by vegetation in vigorous condition or by boulders and cobble.

3 An average bank angle between 90° and 135° indicates steeply sloping shorelines, as defined in Bain and Stevenson (1999).

Table A.11.6-4. Results from the Level B Assessment of the culvert on Sweet Creek.

Fish Passage Barrier Assessment and Prioritization Manual - 2.3 Barrier Analysis
Level B Spreadsheet; Version: Excel 97, Metric Units
Updated: May 30, 2001

Site Information				**Source Worksheet**
Stream:	Sweet Creek			Hydrology
Site ID:	Sweet Creek			"
Sequencer:	1.1			"
Hydrology				
Hydrology Method Selected:	Ordinary High Water Method			Hydrology
Elevation of Ordinary High Water:	24.35			X Section

Downstream Channel Cross Section

	TopLB	ToeLB	Bed1	Bed2	Bed3	ToeRB	TopRB	X Section
Station:	0.00	0.74	2.53	4.43	6.96	7.95	8.22	"
Elev:	24.076	23.969	23.863	23.893	23.814	23.805	23.899	"

DS Control Water Surface Elevation:	23.988			X Section
Water Surface Elevation 50 ft. (15.24 m) DS:	23.15			"
Manning's "n" for channel	0.04			"
Cross Section Water Surface Elevation at Wfp:	24.345			"
Culvert Length:	18.30	m		Box
Maximum Velocity:	1.22	mps	(WAC criteria)	
Minimum Water Depth:	0.30	m	(WAC criteria)	
Maximum Hydrualic Drop in Fishway:	0.30	m	(WAC criteria)	
Culvert Type:	Box Culvert			X Section

Culvert Analysis

Box Culvert Span (m):	2.43	Box
Box Culvert Rise (m):	3.60	"
Manning's n for culvert:	0.0140	"
Culvert Length:	18.30	
U/S Invert Elevation:	25.26	"
D/S/ Invert Elelvation:	24.77	"
Normal Flow Depth (m):	0.9095	"
Culvert Slope (m/m):	0.0269	"
Velocity w/o backwater (mps):	7.56	"
Water Surface Elevation at DS end of culvert:	24.35	"
Flow Depth at DS end of culvert:	-0.43	"
Culvert Influenced by Backwater:	No	"
Outlet Submerged:	No	"
Length Submerged (m):	0.00	"
Backwater Length Plus Submerged Length (m):	0.00	"
Maximum Velocity in Culvert (mps):	0.00	"
Minimum Depth in Culvert (m):	0.00	"

Summary of Analysis

1. High Fish Passage Design Flow, Qfp was determined by the **Ordinary High Water Method.**
Qfp = 16.70 cms

2. Next the culvert was analyzed at Qfp without backwater.
Max. Velocity (w/o backwater) = 7.56 mps Does not satisfy WAC criteria.
Min. Depth (w/o backwater) = 0.91 m Satisfies WAC criteria.

Velocity does not satisfy WAC criteria, check backwater

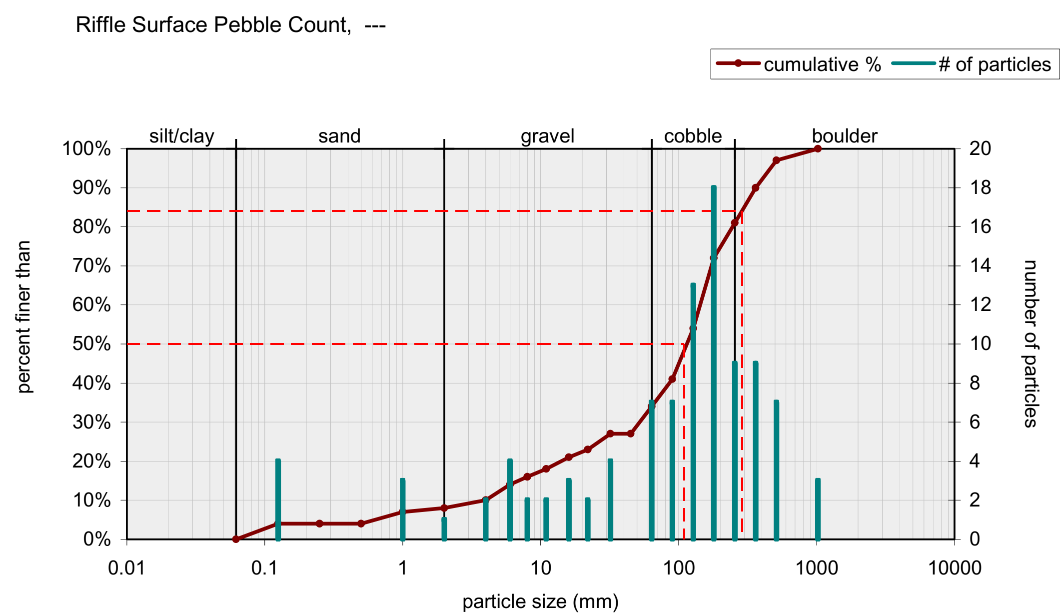
3. Finally, the backwater condition was analyzed.
Is the culvert influenced by backwater? No
Is the culvert outlet submerged? No 0.00 m of culvert submerged

Max. Velocity (w/ backwater) = 0.00 mps Satisfies WAC criteria.
Min. Depth (w/ backwater) = 0.00 m Does not satisfy WAC criteria.

4. The Final Answer…
The culvert does not satisfy WAC criteria.
The culvert is a barrier.

Table A.11.6-5. Geomorphic survey results for Sweet Creek.

Bankfull Width	Mean Bankfull Depth	Bankfull Cross-Sectional Area	Width/Depth Ratio	Maximum Bankfull Depth	Width of Flood-Prone Area	Entrench-ment Ratio	D50	Channel Slope	Channel Sinuosity
11.3 m (37.1 ft)	0.57 m (1.87 ft)	6.4 m^2 (68.9 ft^2)	19.8	0.8 m (2.6 ft)	14.1 m (46.3 ft)	1.2	110 mm	3.3%	1.4



Size (mm)	
D16	8
D35	67
D50	110
D65	160
D84	290
D95	460

Size Distribution	
mean	48.2
dispersion	8.2
skewness	-0.29

Type	
silt/clay	0%
sand	8%
gravel	26%
cobble	47%
boulder	19%

Figure A.11.6-1. Riffle surface pebble count results for Sweet Creek.

A.11.7 REFERENCES

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Appendix 12: 2008 Updated Barrier Inventory for Boundary Reservoir Tributaries

Table A.12-1. 2008 updated barrier results from field surveys and 2007 results from evaluating all available literature sources and available GIS layers on fish migration barriers occurring in tributaries draining into Boundary Reservoir.

Tributary Name	Tributary/Creek Name	Barrier Location (RM)	Barrier Type	Height (m)	Length (m)	Gradient (%)	Comments	Source
SLATE CREEK WAU								
Pewee Creek (RM 17.9)	Pewee Creek Mainstem	0.0	Waterfall	50	N/A			McLellan (2001)
	Pewee Creek Mainstem	1.2	Culvert	DG	DG			POSRT (2005)
Lime Creek (RM 19.0)	Lime Creek Mainstem	1.3	Dewatering	N/A	100			McLellan (2001)
Everett Creek (RM 21.9)	Everett Creek Mainstem	0.16	Waterfall	DG	DG		Potential barrier	WDFW SalmonScape (2007)
	Everett Creek Mainstem	1.20	Culvert	DG	DG		Potentially abandoned	WDFW SalmonScape (2007)
Whiskey Gulch (RM 21.9)	Whiskey Gulch Mainstem	0.6	Culvert	DG	DG			POSRT (2005)
Slate Creek (RM 22.2)	Slate Creek Mainstem	0.75	Natural Series	2.8 to 6.0	800	38		McLellan (2001)
	Slate Creek Mainstem	1.5	Natural Series	3	10	24		McLellan (2001)
	Slumber Creek (RM 2.0)	0.2	Culvert	0.82	5.0	0.7	2008 field verified	Study No. 14 2008 field verified
	Slumber Creek (RM 2.0)	2.3	Dewatering	N/A	N/A			Andonaegui (2003)
	Styx River (RM 4.9)	0.1	Culvert	1.86	18.5	6.5	2008 field verified	Study No. 14 2008 field verified
	N. Fk. Slate Creek (RM 6.2)	1.4	Natural Series	DG	27.5	18		McLellan (2001)
	N. Fk. Slate Creek (RM 6.2)	1.5	Manmade	DG	DG	DG	Questionable	McLellan (2001)
Threemile Creek (RM 24.3)	Threemile Mainstem	0	Waterfall	5	N/A			McLellan (2001)
	Threemile Mainstem	0.15	Culvert	DG	DG			POSRT (2005)
Beaver Creek (RM 24.3)	Beaver Creek Mainstem	0	Waterfall	25.3	N/A			McLellan (2001)
	Beaver Creek Mainstem	1.1	Culvert	DG	DG			POSRT (2005)
Flume Creek (RM 25.8)	Flume Creek Mainstem	0.20	Waterfall	13	N/A			McLellan (2001)
	Flume Creek Mainstem	1.0	Culvert	2.5	DG			McLellan (2001)
	Flume Creek Mainstem	4.75	Culvert	1.5	DG			McLellan (2001)
	S. Fk. Flume Creek (RM 1.1)	0.3	Culvert	DG	DG			POSRT (2005)
SULLIVAN CREEK WAU								
Sullivan Creek (RM 26.9)	Sullivan Creek Mainstem	0.6	Natural Series				Questionable	CES (1996)
	Sullivan Creek Mainstem	3.25	DAM	16.8	N/A	N/A	Mill Pond Dam	R2 Resource Consultants (1998)
	North Fork Sullivan Creek (RM 2.35)	0.0	Culvert	DG	DG	DG		USFS Culvert Database (2002)
	North Fork Sullivan Creek (RM 2.35)	0.2	Natural Series	2 to 4	DG	DG		USFS Culvert Database (2002)
	North Fork Sullivan Creek (RM 2.35)	0.6	Gradient	DG	DG	DG		Connor et al. (2005)
	North Fork Sullivan Creek (RM 2.35)	1.5	Natural Series	2.3	DG	DG		Connor et al. (2005)
	North Fork Sullivan Creek (RM 2.35)	2.6	Two Waterfalls	2.1 and 1.5	DG	DG		Connor et al. (2005)
	Elk Creek (RM 3.7)	0.58	DG	DG	DG	DG	No information provided	WDFW SalmonScape (2007)
	Stony Creek (RM 11.6)	0.04	Culvert	3.9	15.2	0.03	Questionable	USFS Culvert Database (2002)
	Kinyon Creek (RM 12.65)	0.27	Culvert	3.5	12.8	0.05		USFS Culvert Database (2002)
	Copper Creek (RM 13.35)	0.05	Culvert	DG	DG	DG		USFS Culvert Database (2002)

Table A.12-1, continued…

Tributary Name	Tributary/Creek Name	Barrier Location (RM)	Barrier Type	Height (m)	Length (m)	Gradient (%)	Comments	Source
BOX CANYON WAU								
Linton Creek (RM 28.1)	Linton Creek Mainstem	0.18	Culvert	0.76	12.0	4.5	Culvert 1.1; 2008 field verified	POSRT (2005), Study No. 14 2008 field verified
	Linton Creek Mainstem	0.21	Culvert	0.87	9.7	1.5	Culvert 1.2; 2008 field verified	POSRT (2005), Study No. 14 2008 field verified
	Linton Creek Mainstem	0.24	Culvert	1.12	40.5	2.5	Culvert 1.3; 2008 field verified	POSRT (2005), Study No. 14 2008 field verified
	Linton Creek Mainstem	0.25	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.33	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.38	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.42	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.67	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.71	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.76	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	0.78	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	1.07	Culvert	DG	DG	DG		POSRT (2005)
	Linton Creek Mainstem	1.1	Culvert	DG	DG	DG		POSRT (2005)
Pocahontas Creek (RM 29.4)	Pocahontas Creek Mainstem	0.0 to 0.25	Dewatering	N/A	402	N/A	2008 field verified	R2 Resource Consultants (2006), Study No. 14 2008 field verified
	Pocahontas Creek Mainstem	0.34	Culvert	0.43	8.25	8.9	Culvert 1.1; 2008 field verified	POSRT (2005), Study No. 14 2008 field verified
	Pocahontas Creek Mainstem	0.34	Culvert	0.52	8.25	5.9	Culvert 1.2; 2008 field verified	Study No. 14 2008 field verified
Wolf Creek (RM 30.3)	Wolf Creek Mainstem	0.35	Culvert	DG	DG	DG		POSRT (2005)
	Wolf Creek Mainstem	1.21	Culvert	DG	DG	DG		POSRT (2005)
Sweet Creek (RM 30.9)	Sweet Creek Mainstem	0.5	Culvert	3.60	18.3	2.7	Problem is velocity (WDFW 2007); Problem is also outfall drop (Study No. 14 field verified)	WDFW SalmonScape (2007), Study No. 14 2008 field verified
	Sweet Creek Mainstem	0.6	Natural Series	6 to 8.2	870	N/A		McLellan (2001), Study No. 14 2008 field verified
	Sweet Creek Mainstem	1.4	Culvert	DG	DG	DG		POSRT (2005)
	Sweet Creek Mainstem	1.5	Culvert	DG	DG	DG		POSRT (2005)
	Lunch Creek (RM 1.5)	1.4	Culvert	DG	DG	DG		POSRT (2005)
Sand Creek (RM 31.6)	Sand Creek Mainstem	0.0 to 0.25	Dewatering	N/A	402.3	N/A		Andonaegui (2003)
	Sand Creek Mainstem	0.25	Culvert	2	75	DG		McLellan (2001)
	Sand Creek Mainstem	0.5	Culvert	DG	DG	DG	No information provided	Andonaegui (2003)
	Sand Creek Mainstem	1.25	Waterfall	5	N/A	N/A		McLellan (2001)
	Sand Creek Mainstem	1.8	Culvert	4.2	15.7	0.03		USFS Culvert Database (2002)
Lost Creek (RM 31.6)	Lost Creek Mainstem	0.16	Culvert	DG	DG	DG		POSRT (2005)
	Lost Creek Mainstem	0.92	Culvert	DG	DG	DG		POSRT (2005)
	Lost Creek Mainstem	1.41	Culvert	DG	DG	DG		POSRT (2005)
Unnamed No. 13	Unnamed No. 13 Mainstem	0.18	Natural	>4.6	DG	DG		Fullerton (2007)

Notes:
DG – data gap
N/A – not applicable

Appendix 13: Summary Data Tables for 2008

Table A.13-1. Migration barriers, channel conditions, and dynamic summary data table for Slumber Creek.

Tributary Name	Creek Name	Access to Spawning and Rearing		Riparian Condition	Channel Conditions/Dynamics		
		Artificial Barrier	Natural Barrier		Streambank Condition	Floodplain Connectivity	Channel Stability
SLATE CREEK WAU							
Slate Creek (RM 22.2)	Slumber Creek (RM 2.0)						
	RM 0.0 - 2.3	Yes	No	Adequate	>80% of any stream reach has >90% stability	Stream margins	Acceptable

Definitions:
Adequate – provides shade, LWD recruitment, and habitat protection and connectivity.
Acceptable – a stream with width/depth ratio and entrenchment ratio that is considered at risk in terms of channel stability in the limiting factors matrix.

Table A.13-2. Habitat summary data table for Slumber Creek.

Tributary Name	Creek Name	Habitat					
		Channel Substrate	LWD (pieces per mile)	Pool Frequency (pools per mile)	Pool Depth (m)	Off-Channel Habitat	Wetted Width (m)
SLATE CREEK WAU							
Slate Creek (RM 22.2)	Slumber Creek (RM 2.0)						
	RM 0.0 - 2.3	>50% embeddedness & 5 - 20% fines	143	53	0.31	NA - gradient >2%	2.1

Table A.13-3. Water quality, water quantity, native species, species competition, and hybrids summary data table for Slumber Creek.

Tributary Name	Creek Name	Water Quality	Water Quantity	Native Species	Species Competition & Hybrids	
		7-day average maximum temperature (°C)	Changes in Flow Regime	Present	Non-indigenous Fish	Hybrids
SLATE CREEK WAU						
Slate Creek (RM 22.2)	Slumber Creek (RM 2.0)					
	RM 0.0 - 2.3	11.7 to 14.6	Comparable	CT	BK	None

Definitions:

Comparable – watershed hydrography indicates an undisturbed watershed of similar size, geology and geography.

BT – Bull trout; CT – Cutthroat trout; MWF – Mountain whitefish; BK – Brook trout; GBT – Brown trout; RB – Rainbow trout

Table A.13-4. Migration barriers, channel conditions, and dynamic summary data table for Styx Creek.

Tributary Name	Creek Name	Access to Spawning a and Rearing		Riparian Condition	Channel Conditions/Dynamics		
		Artificial Barrier	Natural Barrier		Streambank Condition	Floodplain Connectivity	Channel Stability
SLATE CREEK WAU							
Slate Creek (RM 22.2)	Styx Creek (RM 4.9)						
	RM 0.0 - 2.0	Yes	No	Adequate	>80% of any stream reach has >90% stability	Stream margins	Acceptable

Definitions:
Adequate – provides shade, LWD recruitment, and habitat protection and connectivity.
Acceptable – a stream with width/depth ratio and entrenchment ratio that is considered at risk in terms of channel stability in the limiting factors matrix.

Table A.13-5. Habitat summary data table for Styx Creek.

Tributary Name	Creek Name	Habitat					
		Channel Substrate	LWD (pieces per mile)	Pool Frequency (pools per mile)	Pool Depth (m)	Off-Channel Habitat	Wetted Width (m)
SLATE CREEK WAU							
Slate Creek (RM 22.2)	Styx Creek (RM 4.9)						
	RM 0.0 - 2.0	20 - 30% embeddedness & < 10% fines	161	17	0.40	NA - gradient >2%	3.4

Table A.13-6. Water quality, water quantity, native species, species competition, and hybrids summary data table for Styx Creek.

		Water Quality	Water Quantity	Native Species	Species Competition & Hybrids	
Tributary Name	Creek Name	7-day average maximum temperature (°C)	Changes in Flow Regime	Present	Non-indigenous Fish	Hybrids
SLATE CREEK WAU						
Slate Creek (RM 22.2)	Styx Creek (RM 4.9)					
	RM 0.0 - 2.0	9 to 14.6	Comparable	CT	BK	None

Definitions:

Comparable – watershed hydrography indicates an undisturbed watershed of similar size, geology and geography.

BT – Bull trout; CT – Cutthroat trout; MWF – Mountain whitefish; BK – Brook trout; GBT – Brown trout; RB – Rainbow trout

Table A.13-7. Migration barriers, channel conditions, and dynamic information for Sullivan Creek.

Tributary Name	Creek Name	Access to Spawning and Rearing		Riparian Condition	Channel Conditions/Dynamics		
		Artificial Barrier	Natural Barrier		Streambank Condition	Floodplain Connectivity	Channel Stability
SULLIVAN CREEK WAU DOWNSTREAM OF MILL POND DAM (RM 3.25)							
Sullivan Creek (RM 26.9)	Sullivan Creek Mainstem						
	RM 0.0 - 3.25	Yes	?	Adequate	50-80% has >90% stability	Reduced	Inappropriate

<u>Definitions:</u>

Adequate – provides shade, LWD recruitment, and habitat protection and connectivity.

Reduced – Reduced connectivity to linkage to floodplains and riparian areas.

Inappropriate – a stream with width/depth ratio and entrenchment ratio that is considered no properly functioning in terms of channel stability in the limiting factors matrix.

Table A.13-8. Habitat information for Sullivan Creek.

Tributary Name	Creek Name	Habitat					
		Channel Substrate	LWD (pieces per mile)	Pool Frequency (pools per mile)	Pool Depth (m)	Off-Channel Habitat	Wetted Width (m)
SULLIVAN CREEK WAU DOWNSTREAM OF MILL POND DAM (RM 3.25)							
Sullivan Creek (RM 26.9)	Sullivan Creek Mainstem						
	RM 0.0 - 3.25	<20% embeddedness & <12% fines	<20 to 70	10.9	0.8 to 1.61	Some off-channel areas	19.4

Table A.13-9. Water quality, water quantity, native species, species competition, and hybrids information for Sullivan Creek.

		Water Quality	Water Quantity	Native Species	Species Competition & Hybrids	
Tributary Name	Creek Name	7-day average maximum temperature (°C)	Changes in Flow Regime	Present	Non-indigenous Fish	Hybrids
SULLIVAN CREEK WAU DOWNSTREAM OF MILL POND DAM (RM 3.25)						
Sullivan Creek (RM 26.9)	Sullivan Creek Mainstem					
	RM 0.0 - 3.25	9.6 to 24.7; majority >14.9; 10.6 – 20[a];	Pronounced	BT; CT; MWF	BK; GBT; RB	BT x BK; CT x RB

Definitions:

Pronounced – watershed hydrography indicates changes relative to an undisturbed watershed of similar size, geology and geography.

BT – Bull trout; CT – Cutthroat trout; MWF – Mountain whitefish; BK – Brook trout; GBT – Brown trout; RB – Rainbow trout

[a] From 2007 data collected as part of Study 8 Sediment Transport and Boundary Reservoir Tributary Delta Habitats.

Table A.13-10. Migration barriers, channel conditions, and dynamic summary data table for Linton Creek.

Tributary Name	Creek Name	Access to Spawning and Rearing		Riparian Condition	Channel Conditions/Dynamics		
		Artificial Barrier	Natural Barrier		Streambank Condition	Floodplain Connectivity	Channel Stability
BOX CANYON WAU							
Linton Creek (RM 28.1)	Linton Creek Mainstem						
	RM 0.0 – 0.25	Yes	No	Inadequate	50-80% has >90% stability	Reduced	Appropriate

Definitions:

Inadequate – Riparian areas are fragmented, poorly connected, or provide inadequate protection of habitats.

Reduced – linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced.

Appropriate – a stream with width/depth ratio and entrenchment ratio that is considered properly functioning in terms of channel stability in the limiting factors matrix.

Table A.13-11. Habitat summary data table for Linton Creek.

Tributary Name	Creek Name	Habitat					
		Channel Substrate	LWD (pieces per mile)	Pool Frequency (pools per mile)	Pool Depth (m)	Off-Channel Habitat	Wetted Width (m)
BOX CANYON WAU							
Linton Creek (RM 28.1)	Linton Creek Mainstem						
	RM 0.0 – 0.25	20% embeddedness & 20% fines	12	12	0.29	Fair	2.5

Definitions:

Fair – Some ponds, oxbows, backwaters, and other off-channel areas are present.

Table A.13-12. Water quality, water quantity, native species, species competition, and hybrids summary data table for Linton Creek.

		Water Quality	Water Quantity	Native Species	Species Competition & Hybrids	
Tributary Name	**Creek Name**	**7-day average maximum temperature (°C)**	**Changes in Flow Regime**	**Present[b]**	**Non-indigenous Fish[b]**	**Hybrids[b]**
BOX CANYON WAU						
Linton Creek (RM 28.1)	Linton Creek Mainstem					
	RM 0.0 – 0.25	7.4 – 13.7[a]	Altered	CT	BK, GBT, RB	None

Definitions:

Altered – Some evidence of altered peak flow, base flow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography.

BT – Bull trout; CT – Cutthroat trout; MWF – Mountain whitefish; BK – Brook trout; GBT – Brown trout; RB – Rainbow trout

[a] Data used to calculate the 7-day average maximum temperature are from Seattle City Light (SCL) 2008. Study 8 – Sediment Transport and Boundary Reservoir Tributary Delta Habitats Interim Study Report for the Boundary Hydroelectric Project (FERC No. 2144). Prepared by Tetra Tech and Thomas R. Payne and Associates. March.

[b] Data from SCL. 2009. Study 9 – Fish Distribution, Timing, and Abundance Study Final Report for Boundary Hydroelectric Project (FERC No. 2144). Prepared by Terrapin Environmental and Golder Associates. March.

Table A.13-13. Migration barriers, channel conditions, and channel dynamics summary data table for Pocahontas Creek.

Tributary Name	Creek Name	Access to Spawning and Rearing		Riparian Condition	Channel Conditions/Dynamics		
		Artificial Barrier	Natural Barrier		Streambank Condition	Floodplain Connectivity	Channel Stability
BOX CANYON WAU							
Pocahontas Creek (RM 29.4)	Pocahontas Creek Mainstem						
	RM 0.0 - 0.6	Yes	Yes	Adequate	50-80% has >90% stability	Stream margins	Acceptable

Definitions:
Adequate – provides shade, LWD recruitment, and habitat protection and connectivity.
Acceptable – a stream with width/depth ratio and entrenchment ratio that is considered at risk in terms of channel stability in the limiting factors matrix.

Table A.13-14. Habitat summary data table for Pocahontas Creek.

Tributary Name	Creek Name	Habitat					
		Channel Substrate	LWD (pieces per mile)	Pool Frequency (pools per mile)	Pool Depth (m)	Off-Channel Habitat	Wetted Width (m)
BOX CANYON WAU							
Pocahontas Creek (RM 29.4)	Pocahontas Creek Mainstem						
	RM 0.0 - 0.6	>50% embeddedness	36.7	33.3	0.52	NA - gradient >2%	2.5

Table A.13-15. Water quality, water quantity, native species, species competition, and hybrids summary data table for Pocahontas Creek.

Tributary Name	Creek Name	Water Quality	Water Quantity	Native Species	Species Competition & Hybrids	
		7-day average maximum temperature (°C)	Changes in Flow Regime	Present	Non-indigenous Fish	Hybrids
BOX CANYON WAU						
Pocahontas Creek (RM 29.4)	Pocahontas Creek Mainstem					
	RM 0.0 - 0.6	7.7-13.4 ˚C	Comparable	CT	RB	DG

Definitions:
Comparable – watershed hydrography is comparable to an undisturbed watershed of similar size, geology and geography.
BT – Bull trout; CT – Cutthroat trout; MWF – Mountain whitefish; BK – Brook trout; GBT – Brown trout; RB – Rainbow trout
DG – data gap
Note: Water quality temperature information originated from Study 8 (SCL 2009) data.

Table A.13-16. Migration barriers, channel conditions, and dynamic summary data table for Sweet Creek.

Tributary Name	Creek Name	Access to Spawning and Rearing		Riparian Condition	Channel Conditions/Dynamics		
		Artificial Barrier	Natural Barrier		Streambank Condition	Floodplain Connectivity	Channel Stability
BOX CANYON WAU							
Sweet Creek (RM 30.9)	Sweet Creek Mainstem						
	RM 0.0 – 0.6	Yes	Yes	Adequate	50 - 80% of any stream reach has >90% stability	Connected	Appropriate

Definitions:

Adequate – provides shade, LWD recruitment, and habitat protection and connectivity.

Connected – Hydrologically linked to off-channel areas.

Appropriate – a stream with width/depth ratio and entrenchment ratio that is considered properly functioning in terms of channel stability in the limiting factors matrix.

Table A.13-17. Habitat summary data table for Sweet Creek.

Tributary Name	Creek Name	Habitat					
		Channel Substrate	LWD (pieces per mile)	Pool Frequency (pools per mile)	Pool Depth (m)	Off-Channel Habitat	Wetted Width (m)
BOX CANYON WAU							
Sweet Creek (RM 30.9)	Sweet Creek Mainstem						
	RM 0.0 – 0.6	<20% embeddedness & < 5% fines	234.7	26.8	0.60	NA - gradient >2%; off-channel areas present	7.7

Table A.13-18. Water quality, water quantity, native species, species competition, and hybrids summary data table for Sweet Creek.

		Water Quality	Water Quantity	Native Species	Species Competition & Hybrids	
Tributary Name	**Creek Name**	**7-day average maximum temperature (°C)**	**Changes in Flow Regime**	**Present[a]**	**Non-indigenous Fish[a]**	**Hybrids[a]**
BOX CANYON WAU						
Sweet Creek (RM 30.9)	Sweet Creek Mainstem					
	RM 0.0 – 0.6	3.2 to 15.4; 12.1 during rearing in 2007	Comparable	BT; CT; MWF	BK; GBT; RB	BT x BK; CT x RB

Definitions:

Comparable – watershed hydrography indicates an undisturbed watershed of similar size, geology and geography.

BT – Bull trout; CT – Cutthroat trout; MWF – Mountain whitefish; BK – Brook trout; GBT – Brown trout; RB – Rainbow trout

[a] Data from Study 9 final report (SCL 2009).

Appendix 14: Additional Information from the Habitat Protection Evaluation

Table A.14-1. Options available for placing land into areas of protected habitat.

Agency	Program	Applicable To	Website	Comments
Conservation Easements / Incentive Programs				
Inland Northwest Land Trust	Conservation easement	Private landowners (including corporations)	www.inlandnwlandtrust.org	Income tax and estate tax benefits; MIN SIZE = 40 acres- particularly interested in forest, wetlands and riparian habitat.
Land Trust Alliance	Conservation easement	Private landowners	http://www.landtrustalliance.org/	
Land Acquisition				
Bureau of Land Management (BLM), National Park Service (NPS), US Fish and Wildlife Service (USFWS), and US Forest Service (USFS)	Land and Water Conservation Fund	Public and private land	http://www.nps.gov/ncrc/programs/lwcf/ http://www.fs.fed.us/land/staff/LWCF	Principal source of land acquisition for federal agencies and provides a matching program for state land acquisition.
The Trust for Public Land	Land acquisitions (Sometimes Conservation easements)	Public and private landowners	http://www.tpl.org/	The Trust for Public Land (TPL) is a national, nonprofit, land conservation organization that conserves land for people to enjoy as parks, community gardens, historic sites, rural lands, and other natural places, ensuring livable communities for generations to come.
Grants				
EPA	Five Star Restoration Grant Program		http://www.epa.gov/owow/wetlands/restore /5star/	The Five Star Restoration Program brings together students, conservation corps, other youth organizations, citizen groups, corporations, landowners and government agencies to provide environmental education through projects that restore streambanks and wetlands. The program provides challenge grants, technical support, and opportunities for information exchange to enable community-based restoration projects.

Table A.14-1, continued…

Agency	Program	Applicable To	Website	Comments
Recreation and Conservation Funding Board (RCFB)	Aquatic Lands Enhancement Account	Local and state government	http://www.rco.wa.gov/rcfb/grants/alea.htm	Only local and state governments: grants for purchase, improvement, or protection of aquatic lands. (Federal agencies and private entities can seek partnership with eligible entity); Must be located on lands adjoining a water body that meets the definition of navigable.
	Washington Wildlife and Recreation Program	Local and state agencies	http://www.rco.wa.gov/rcfb/grants/wwrp.htm	Funding assistance for a range of land conservation and parks and recreation development including: Acquisition of water access, critical habitat, natural areas, riparian protection.
Salmon Recovery Funding Board (SRFB)	Salmon Recovery Grant Program	Municipal subdivisions; private landowners; tribal governments; state agencies; nonprofit organizations	http://www.rco.wa.gov/srfb/board/board.htm	Must entail protection and restoring habitats. Applicants must provide at least 15% matching funds in cash or in-kind:
US Department of Agriculture – Farm Service Agency (FSA)	CRP – Continuous Signup	Private landowners	http://www.nrcs.usda.gov/programs/CRP/ http://www.fsa.usda.gov/FSA/newsReleases?area=newsroom&subject=landing&topic=pfs&newstype=prfactsheet&type=detail&item=pf_20060601_consv_en_crpcsup06.html	Eligible land includes certain marginal pastureland that is enrolled in the Water Bank Program or suitable for use as a riparian buffer or for similar water quality purposes. Talked with Randy Primmer, County Executive Director, FSA – Service Center Office, Spokane County Farm Service Agency, (509) 924-7350

Table A.14-1, continued…

Agency	Program	Applicable To	Website	Comments
The National Fish and Wildlife Foundation	Bring Back the Natives	Nonprofit organizations; universities; Native American tribes; and local, state, and federal agencies	http://www.nfwf.org/AM/Template.cfm?Section=Fish_Conservation2&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=8196	The BBN program seeks projects that initiate partnerships with private landowners, demonstrate successful collaborative efforts, address watershed health issues that would lead to restoring, protecting, and enhancing habitats and are key to restoring, protecting, and enhancing native aquatic species and their migration corridors, promote stewardship on private lands, and that can demonstrate a 2:1 non-federal to federal match.
	Native Fish Habitat Initiative		http://www.nfwf.org/AM/Template.cfm?Section=Fish_Conservation2&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=7044	The Foundation and the Service are seeking on-the-ground projects that will result in habitat conservation, protection, restoration, or management actions that benefit native trout such as coastal cutthroat, westslope cutthroat, Yellowstone cutthroat, Lahontan cutthroat, Bonneville cutthroat, bull trout, and redband trout, along with Pacific lamprey and other native lamprey species.

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