Boundary Hydroelectric Project (FERC No. 2144)

Study No. 10

Large Woody Debris Management Study

Final Report

Prepared for
Seattle City Light

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Study No. 10: Large Woody Debris Management Study
Final Report
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1 INTRODUCTION

Study No. 10, Large Woody Debris (LWD) Management Study, is being conducted in support of the relicensing of the Boundary Hydroelectric Project (Project), Federal Energy Regulatory Commission (FERC) No. 2144, as identified in the Revised Study Plan (RSP; SCL 2007) submitted by Seattle City Light (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 for the 2007 study efforts of the LWD Management Study.

The role of woody debris in reservoirs has not been extensively documented, but in general wood in reservoirs and river systems increases habitat complexity and cover for fish and may serve as a source for nutrients (Bjornn and Reiser 1991). Submerged wood has been shown to provide habitat for some species, such as suckers and shiners (Moring et al. 1986, Negus 1987, Moring et al. 1989), but use by salmonids in reservoirs has not been thoroughly documented. Submerged wood has been documented to be a colonization substrate for periphyton and macroinvertebrates, and these macroinvertebrates serve as a food source for salmonids (O'Neal 2000). Northcote and Atagi (1997) suggest that removal of wood from a reservoir would have negative effects on the growth potential of kokanee and rainbow trout.

Floating wood in reservoirs has been shown to attract juvenile warm water species, but may also be related to higher concentrations of predators (Helfman 1979). Wood along the shoreline provides improved cover in shallow areas as well as areas for sediment collection and vegetation establishment (Maser and Sedell 1994). Placement of wood at tributary mouths may provide increased cover for adfluvial species moving between the reservoir and tributary habitat (Northocote and Atagi 1997).

2 STUDY OBJECTIVES

The objectives of Study 10 are to quantify the volume, type, and location of large wood within Boundary Reservoir and to evaluate management alternatives to increase the availability of large wood in the reservoir.

3 STUDY AREA

The study area includes the shoreline in the Forebay, Canyon, and Upper Reservoir reaches of Boundary Reservoir from Box Canyon Dam to Boundary Dam, including the Boundary Dam and Box Canyon Dam trash racks (Figure 3.0-1).

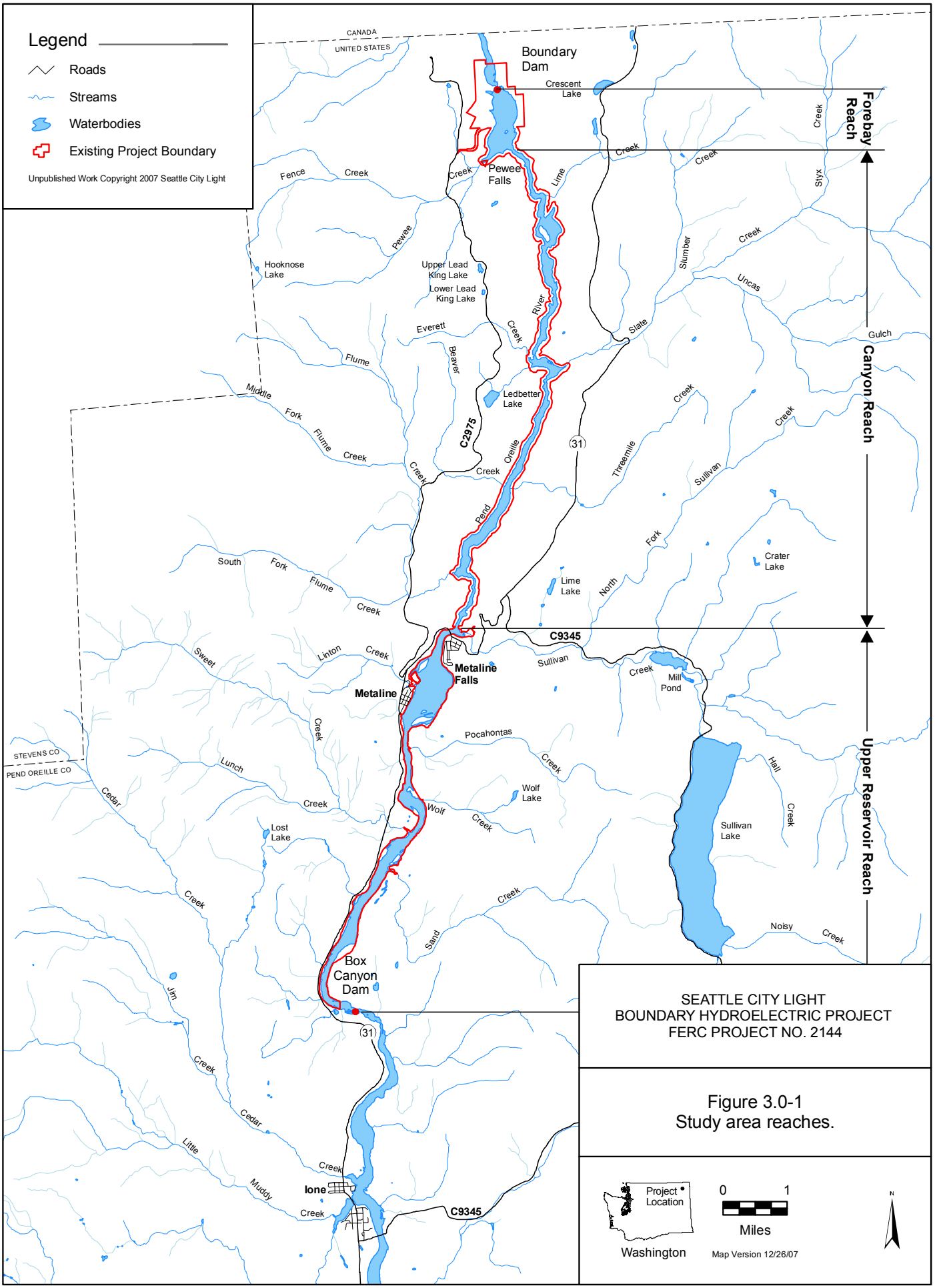


Figure 3.0-1
Study area reaches.

4 METHODS

Five separate tasks were undertaken to address the objectives of the LWD Management Study:

1. Determining current LWD management activities at Boundary Dam
2. Determining current LWD management activities at Box Canyon Dam
3. Mapping the LWD in Boundary Reservoir
4. Quantifying the LWD removed at Boundary Dam trash rack in 2007
5. Developing potential LWD management alternatives for Boundary Reservoir

The study methodology for each task is discussed below.

4.1. Existing LWD Management Activities at Boundary Project

Existing LWD management activities at Boundary Dam were identified using the following steps:

- Contact personnel at the Boundary Project to ascertain the timing and methods of debris removal from the trash rack and other areas in the vicinity of the dam, the volume and number of LWD pieces removed, and the fate of the LWD that was removed.
- Based on information collected, describe LWD management activities at Boundary Project facilities.

Data were collected from the trash rack at Boundary Dam to determine the number of pieces, size class, and volume of LWD removed from the reservoir by SCL during the spring and summer of 2007. Figure 4.1-1 shows photos of the trash rack taken in 2006. Mark Scherf (SCL) identified Ken Maupin, a local contractor responsible for removing wood from the Boundary Dam trash rack as an information source. After being contacted, Mr. Maupin agreed to record information on the number of pieces and volume of wood removed from the trash rack, assigning pieces to the size classes identified in Table 4.1-1. A data sheet was completed, documenting the number and size class of each wood piece removed as well as the number of pieces with attached root wads.

Table 4.1-1. Size classes for LWD.

Diameter Large End	Short Length	Medium Length	Long Length
4 in < 12 in	5 ft < 17 ft	17 < 50 ft	> 50 ft
12 in < 24 in	5 ft < 17 ft	17 < 50 ft	> 50 ft
24 in < 32 in	5 ft < 17 ft	17 < 50 ft	> 50 ft
> 32 in	5 ft < 17 ft	17 < 50 ft	> 50 ft

Source: Peck et al. 2003

May

October

Figure 4.1-1. Photos of Boundary Reservoir trash rack showing high and low levels of wood accumulation during May and October of 2006, respectively.

4.2. Existing LWD Management Activities at Box Canyon Dam

Existing LWD management activities at Box Canyon Dam were identified using the following steps:

- Contact and interview Pend Oreille County Public Utility District (PUD) representatives to identify LWD management activities associated with Box Canyon Dam.
- Discuss timing of debris removal and the volume and type of debris removed at the dam.
- Describe LWD management activities at Box Canyon Dam.

Nathan Jones, Production Manager at Box Canyon Dam, explained the debris removal methods used at Box Canyon Dam. Pat Buckley (PUD) provided information on how LWD has been used in habitat restoration projects in Box Canyon Reservoir.

4.3. LWD Mapping

Mapping of LWD along the Boundary Reservoir shoreline was accomplished in two steps:

1. Examine aerial photographs for LWD locations.
2. Conduct a field survey of the shoreline for existing LWD sites.

Aerial photo interpretation of Boundary Reservoir was used to determine likely locations for LWD measurement and determination of decay class. Aerial photographs taken on August 20, 2005, were examined at a 1:1,000 scale to determine likely locations of LWD within the Boundary Reservoir. Locations of LWD were marked using ArcView Geographic Information Systems (GIS) software. Each location was given a number to identify it on the data layer. The data layers for each area surveyed were then transferred to a Global Positioning System (GPS) unit to locate the points during the field survey.

The entire shoreline of Boundary Reservoir was surveyed from August 20 to 24, 2007. The GPS data layers were used to locate areas with a high probability of LWD deposition. Additionally, the locations of all other observations of LWD were recorded during field surveys. LWD includes all wood from the high water level in the respective region of the reservoir (as designated by vegetation presence, change in slope, or water line marks) to the water level at the time of the survey. The water surface elevation at the Forebay Reach at the time of the survey ranged from 1,977 to 1,993 feet NAVD 88 (1,973 to 1,989 feet NGVD 29[1]). Much of this LWD would not have been observable at higher water levels. Due to low inflow from Box Canyon Dam, there was also significant drawdown in the Upper Reservoir Reach allowing for improved counts of LWD along the shoreline. The water surface elevation at the Box Canyon auxiliary gage ranged from approximately 1,988 to 1,984 feet NAVD 88 (1,984 to 1,980 feet NGVD 29) during the survey period for the Upper Boundary Reservoir. LWD was enumerated approximately from the vegetation line to the visible water depth. The water clarity during the month of August 2007, as measured using a Secchi disk, was generally less than 17 feet (see Study 5, Water Quality Constituent and Productivity Monitoring Interim Report; SCL 2008a).

Each piece of LWD was counted and assigned to a size class using categories defined by Peck et al. (2003) and shown in Table 4.1-1. Where possible, information on decay class of LWD was collected using methods from Robison and Beschta (1990) and Hedman et al. (1996). Table 4.3-1 shows the criteria used for each decay class ranging from I (least decayed) to V (most decayed). The decay class is often related to the length of time that the piece has been in the water; for instance, Decay Class I generally indicates newly recruited LWD.

Table 4.3-1. Decay class criteria.

Decay Class	Bark	Twigs	Texture	Shape	LWD Color
I	Intact	Present	Intact	Round	Original Color
II	Intact	Absent	Intact	Round	Original Color
III	Trace	Absent	Smooth: some surface abrasion	Round	Darkening
IV	Absent	Absent	Abrasion: some holes and openings	Round to oval	Dark
V	Absent	Absent	Vesicular: many holes and openings	Irregular	Dark

Source: Robison and Beschta (1990), Hedman et al. 1996

The location of each piece or group of pieces of LWD was documented using GPS. These points were then overlaid on the aerial photograph composite to show locations of current LWD in Boundary Reservoir and stable locations. Stable areas were defined as areas where LWD remained between the aerial photograph documentation in 2005 and the field surveys in 2007, indicating that the pieces had withstood a high flow period during winter and spring of 2006 and 2007. Stable areas were identified by observations during both the aerial photograph review and

[1] SCL is in the process of converting all Project information from an older elevation datum (National Geodetic Vertical Datum of 1929 [NGVD 29]) to a more recent elevation datum (North American Vertical Datum of 1988 [NAVD 88]). As such, elevations are provided relative to both data throughout this document. The conversion factor between the old and new data is approximately 4 ft (e.g., the crest of the dam is 2,000 feet NGVD 29 and 2,004 feet NAVD 88).

the field mapping at the same locations, and were characterized by a high level of decay in the pieces present. While the decay class alone cannot be used to determine stability (older pieces of LWD may become lodged in the reservoir after significant decay), it does suggest that LWD in a particular location is stable. Stable locations may be good areas to consider placement of future LWD due to their ability to withstand losses during high flows. LWD placed in unstable areas could be dislodged during high flows and be transported downstream, potentially on to the trash rack at Boundary Dam.

GPS files were also uploaded into GIS and a LWD location data layer was created for use in habitat mapping. The elevation of LWD locations was estimated by overlaying the GPS locations on the topography and bathymetry of the Boundary Reservoir using GIS. These elevations can be compared to water surface elevations to predict when a piece of wood will be inundated.

4.4. Quantifying LWD Removal

The number of pieces, the size class, and the volume of wood were recorded during debris removal activities at the Boundary Dam trash rack during spring 2007. The volume of LWD and root wads removed from the rack was calculated using estimated volumes for each size class (Table 4.4-1).

Table 4.4-1. Average volume for LWD by size class.

Diameter Large End[1]	Estimated Volume (ft^3)			
	Length 5 ft < 17 ft	**Length 17 < 50 ft**	**Length > 50 ft**	**Root Wad**
4 in < 12 in	3.1	11.7	26.2	1.7
12 in < 24 inc	16.8	59.2	132.5	8.8
24 in < 32 in	40.6	143.2	320.5	21.4
> 32 in	67.1	236.7	529.9	35.3

Notes:
1 Peck et al. (2003)

4.5. LWD Management Alternatives

LWD management alternatives were developed through discussions with personnel at Box Canyon Dam, review of other studies conducted in support of the relicensing of the Boundary Hydroelectric Project, and discussions with local and regional agency personnel. Agency personnel (Tom Shuhda – U.S. Forest Service [USFS], Karen Honeycutt – USFS, and Kathleen Werr, Pend Oreille Conservation District) were contacted as part of Study 14 (Tributary Habitat Aquatic Productivity Assessment) with respect to potential habitat restoration projects that would improve aquatic habitat in the basin. The Study 14 Interim Report (SCL 2008b) also includes a discussion of the use of LWD for enhancement and restoration efforts in tributaries to Boundary Reservoir. Agency personnel were asked about the following topics: factors limiting bull trout and cutthroat trout in tributaries to Boundary Reservoir, which tributaries had the highest potential for restoration, and where in specific tributaries were the highest priority areas for restoration.

5 RESULTS

This section presents the results of the LWD Management Study.

5.1. Existing LWD Management Activities at the Boundary Project

LWD is removed from the Boundary Dam trash racks using heavy equipment belonging to a contractor. Timber is hauled off site at the discretion of the contractor, and the remaining usable pieces of LWD are cut into firewood for campsites at the Forebay Recreation Area. Unusable wood and trash are transported away by the contractor or burned on site. LWD was removed from the Boundary Dam trash rack twice in 2007, on March 22 and on July 30.

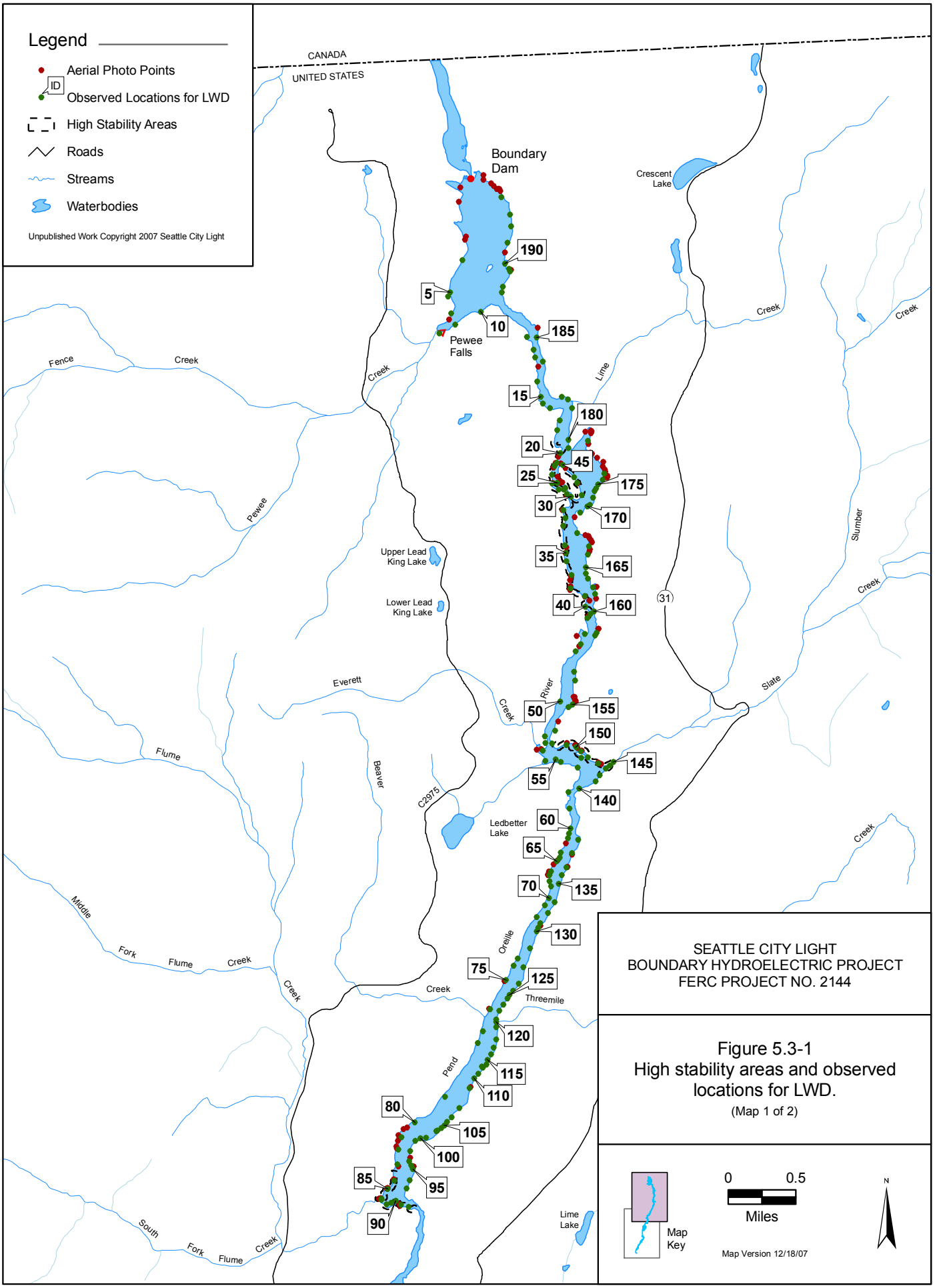
5.2. Existing LWD Management Activities at Box Canyon Dam

Most LWD arrives at Box Canyon Dam during the spring high flows. Much of the LWD passes over the spillway into Boundary Reservoir, but some remains with other debris in the forebay. This LWD is removed with cranes and other machinery. The staff at Box Canyon Dam removes everything, separating the natural material (trees and branches) from the trash. Most large logs are used for firewood. Logs with root wads are stockpiled for future erosion control or potential habitat restoration projects. LWD that is not suitable for other uses is burned. Approximately four to six cords (about 512 to 768 cubic feet) of firewood per year are supplied to the campground from all reservoir sources, including the wood that ends up in the forebay as well as any danger trees that are removed from the shoreline.

The PUD plans to use some of the larger pieces of LWD collected in the forebay for habitat improvement projects in reservoir tributaries and to create ponds for amphibians along the Pend Oreille River (outside of Box Canyon Reservoir).

5.3. LWD Mapping

Figure 5.3-1 shows the high stability areas for LWD and the observed locations of LWD in the Boundary Reservoir in 2007. High stability areas are regions where LWD could be clearly seen in aerial photos and there is overlap (or high concentrations) of both aerial photo points from 2005 and observed points from 2007. These areas are identified as debris concentrations in Figure 5.3-1. LWD maintained its position in these areas throughout two high flow periods, which indicates at least short-term stability, but the long-term stability of these pieces is not known. These more stable areas are likely to provide habitat for fish and for colonization by macroinvertebrates, which serve as a food resource for fish. Figure 5.3-2 shows the volume for each observed location of LWD in Boundary Reservoir. Volumes are also included in Appendix 1, Table A.1-1. Each LWD symbol on the map indicates 1 to 70 actual pieces of LWD. LWD includes all pieces from the high water level in the respective region of the reservoir (as designated by vegetation presence, change in slope, or water line marks) to the water level at the time of the survey. The water surface elevation at the forebay at the time of the survey ranged from 1,977 to 1,993 feet NAVD 88 (1,973 to 1,989 feet NGVD 29). The amount of LWD varied significantly by location, with relatively few locations containing most of the LWD present on the reservoir shore (Figure 5.3-2).


Legend
Aerial Photo Points
ID
Observed Locations for LWD
High Stability Areas
Roads
Streams
Waterbodies
Unpublished Work Copyright 2007 Seattle City Light
CANADA
UNITED STATES
Boundary Dam
Crescent Lake
Pewee Falls
Upper Lead King Lake
Lower Lead King Lake
Ledbetter Lake
Lime Lake
Fence Creek
Pewee Creek
Lime Creek
Slate Creek
Slumber Creek
Everett Creek
Flume Creek
Beaver Creek
C2975
Middle Fork Flume Creek
South Fork Flume Creek
Pend Oreille River
Threemile Creek
31
190
5
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BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure 5.3-1
High stability areas and observed locations for LWD.
(Map 1 of 2)
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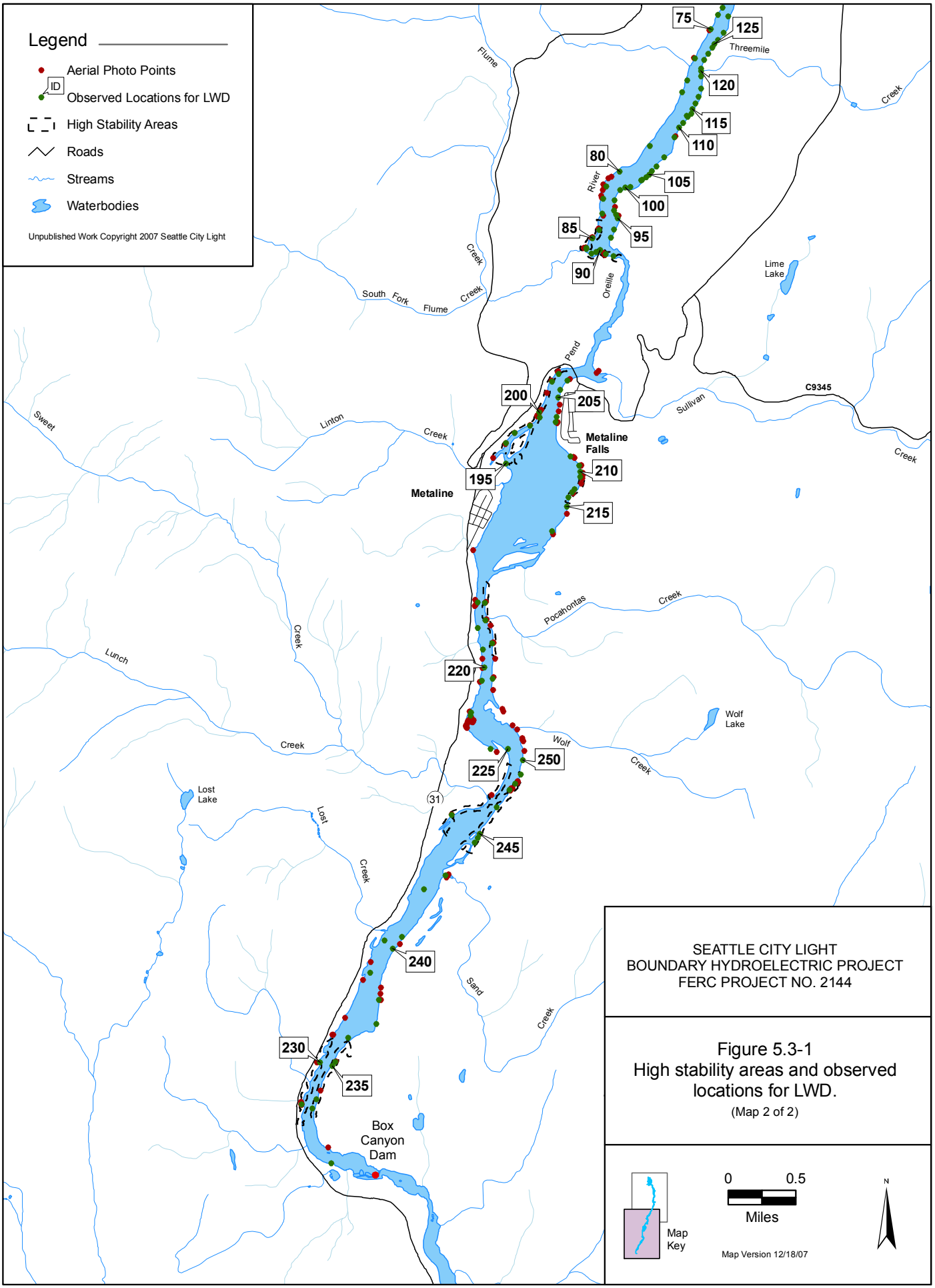

Figure 5.3-1
High stability areas and observed locations for LWD.
(Map 2 of 2)

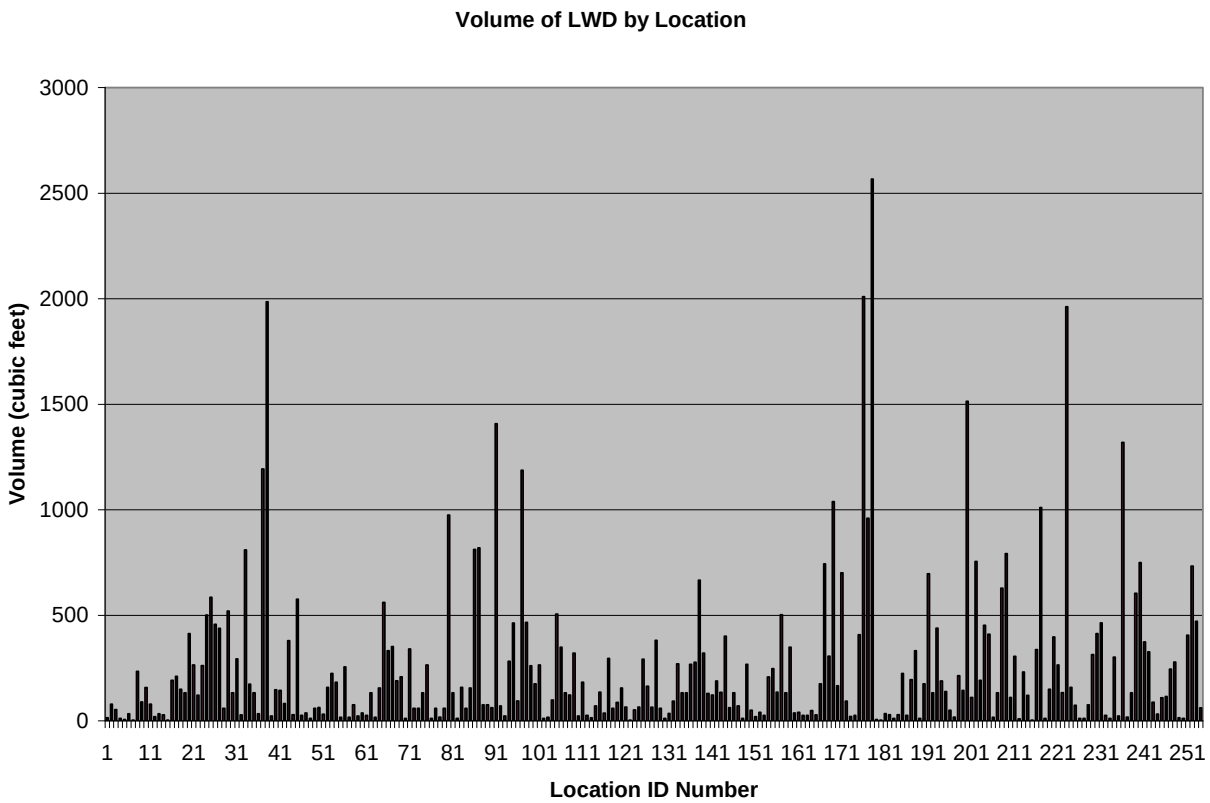

Figure 5.3-2. Volume of LWD by observed location; locations shown in Figure 5.3-1.

Table 5.3-1 shows the total count for each LWD size category. Appendix 1 contains the data with the count and volume by reaches and location. In terms of standards or goals for LWD numbers, the current standards are better suited to smaller streams than large rivers and were not designed to rate levels in reservoirs, but are mentioned here to provide a frame of reference for the number of pieces of LWD observed. The U.S. Fish and Wildlife Service and NOAA Fisheries (NMFS 1996) consider "properly functioning" streams in eastern Washington to have more than 20 pieces of LWD (i.e., greater than 12 inches in diameter and 35 feet in length) per river mile. Fox (2001) has recommended this criterion be revised for eastern Washington.

Table 5.3-1. Total field-mapped LWD counts and volumes.

Diameter Large End	Count at Length 5 ft < 17 ft	Estimated Volume (ft^3)	Count at Length 17 ft < 50 ft	Estimated Volume (ft^3)	Count at Length > 50 ft	Estimated Volume (ft^3)	Total Count	Total Volume (ft^3)
4 in < 12 in	289	905	506	5,910	171	4,475	966	**11,290**
12 in < 24 in	125	2,098	180	10,651	197	26,097	502	**38,846**
24 in < 32 in	11	442	16	2,291	30	9,616	57	**12,349**
> 32 in	5	336	0	0	1	529	6	**865**
Grand Total	430	3,781	702	18,852	399	40,717	1,531	**63,350**

For the 17.5 miles of Boundary Reservoir, 424 pieces of LWD exceeded the diameter criterion and were longer than 17 feet, or about 24 pieces per mile, which exceeds the "properly functioning" criterion. However, the amount of LWD varied substantially among the reaches, with densities being much higher in the Canyon and Forebay reaches than in the Upper Reservoir Reach (Table 5.3-2). In some parts of the reservoir, LWD levels were below the "properly functioning" level; however, the criterion was developed for free-flowing rivers and is not necessarily applicable to reservoirs.

Table 5.3-2. Density of LWD counts and volumes by reach.

Reach	Reach Length (miles)	Per Mile of Reservoir Length		
		Estimated Number of NOAA[1] size pieces	Number of All Pieces	Estimated Volume (ft^3) of All Pieces
Forebay	1.0	22	80	2,881
Canyon	8.9	33	118	4,706
Upper Reservoir	7.6	15	53	2,881

Note:
1 See NMFS (1996)

Rivers and reservoirs have different hydrologic patterns and seasonal fluctuation patterns that affect how and whether LWD is retained in a system and the function of the LWD that is retained. In natural river systems in the Pacific Northwest, flows change significantly with seasons and LWD is carried in and out of the system at high flows, generally in the winter or spring. The LWD that lodges in the river can provide velocity refuges in the form of backwater habitat for fish use during high flows. LWD can also promote scour of deeper pools and the creation of side channels if pieces remain stable and interact with moving water and mobile substrate. In a reservoir system, velocities are generally greatly reduced, as are seasonal fluctuations caused by high flows. In Boundary Reservoir, daily fluctuations of the water level may make some pieces of LWD unavailable for fish use for a substantial period of the year. Additionally, LWD does not generally promote scour in Boundary Reservoir due to low water velocities and relatively stable substrate.

Some sections of the Boundary Reservoir shoreline contained stumps remaining from past timber harvest prior to the reservoir establishment. These stumps were included in the counts as LWD greater than 12 inches in diameter and 5 feet or less in length. A total of 141 stumps were observed, which is 8 percent of the total number of pieces of LWD in the reservoir (Table 5.3-1). Stumps provide some aquatic habitat benefit, but not the level of cover complexity provided by an exposed root wad.

The average decay state of LWD in the reservoir was moderate (classes 2 and 3), indicating that residence time and movement are moderate (Figure 5.3-3). Approximately 75 percent of the LWD was moderately decayed.

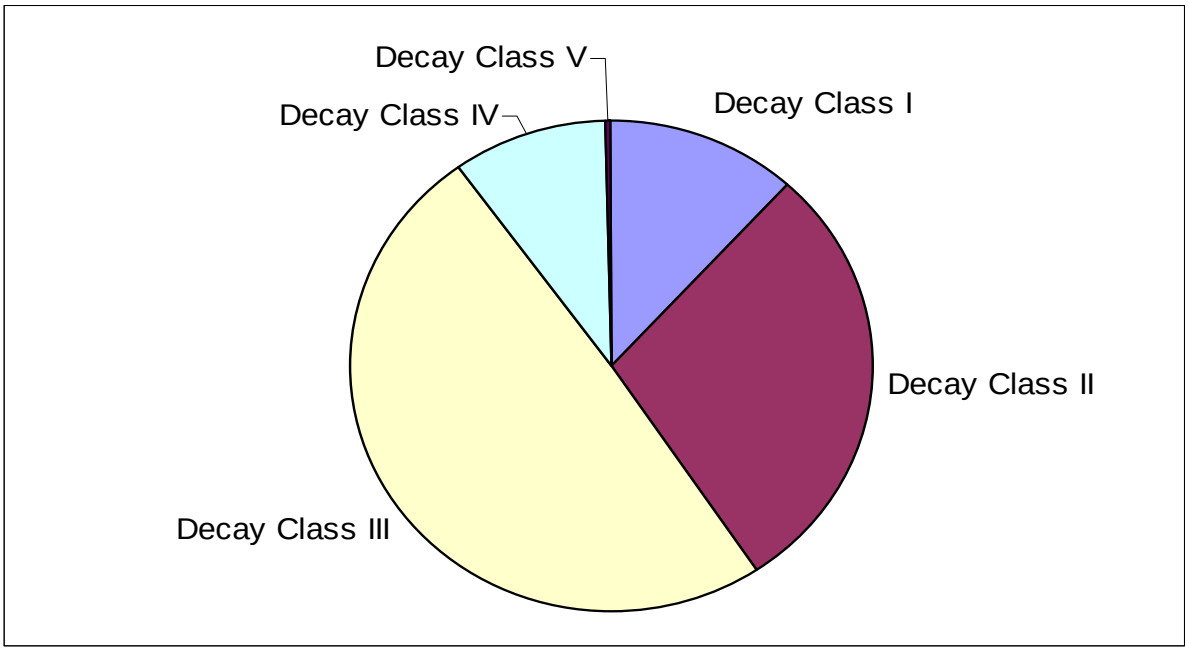

Figure 5.3-3. Decay class of wood within Boundary Reservoir.

Figure 5.3-4 shows the elevation in feet (NAVD 88) of each LWD location as mapped. The elevation information can be used to determine at what water elevation LWD pieces would be submerged. The Compilation of Hydrologic Data for Boundary Reservoir (R2 Resource Consultants 2006) identifies the 50 percent exceedance for the period from 1987 to 2004 for water surface elevations in the Boundary forebay and at Box Canyon Dam. In the forebay, the 50 percent exceedance is 1,990 feet NAVD 88 (1,986 feet NGVD 29) and at Box Canyon Dam it is 1,993 feet NGVD 88 (1,989 feet NGVD 29). The 90 percent exceedance is 1,984 feet NGVD 88 (1,980 feet NGVD 29) at the forebay and 1,990 feet NAVD 88 (1,986 feet NGVD 29) at Box Canyon Dam (R2 Resource Consultants 2006).

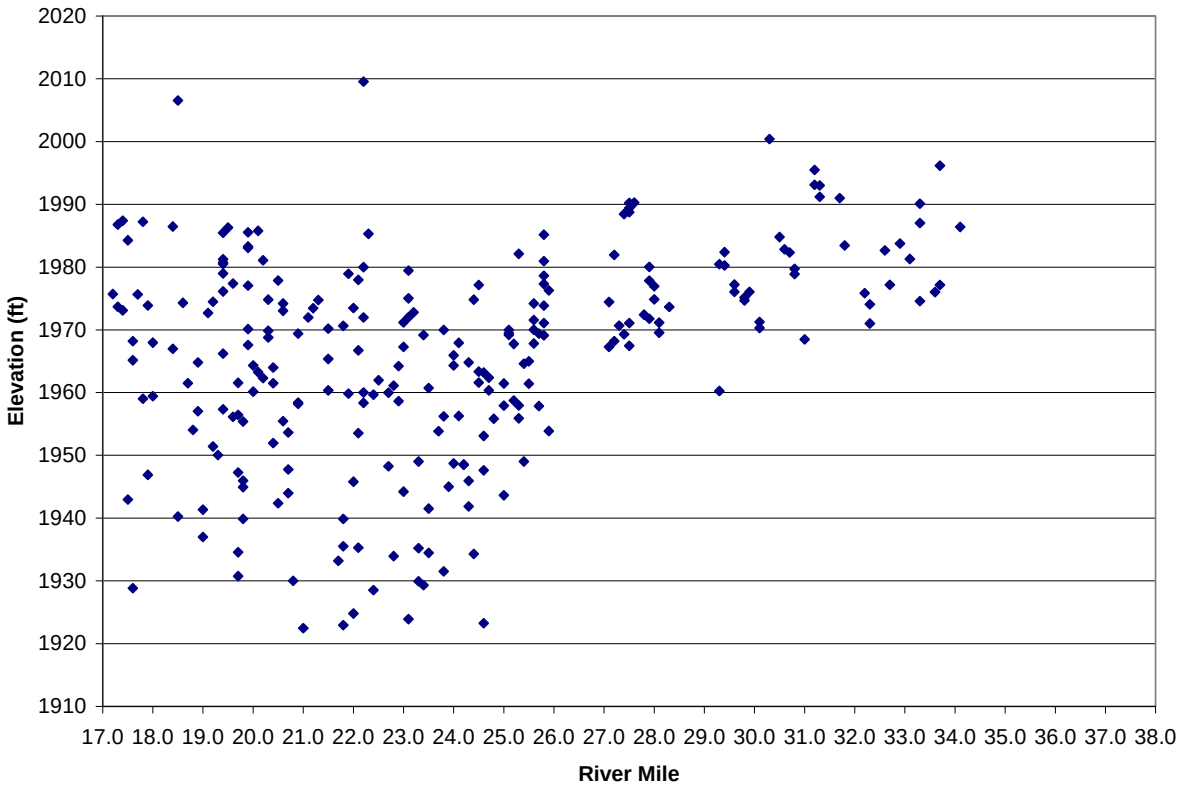

Figure 5.3-4. Mapped elevations of LWD locations by Project river mile; elevations are in feet NAVD 88.

Note: Estimates of elevation are derived from GPS coordinates mapped onto project bathymetry. Accuracy of GPS coordinates was limited in the canyon reaches. Reported LWD elevations in areas of steep topography may be inaccurate due to GPS accuracy limitations. For example, in areas of steep topography elevations can vary from 6 to 39 feet vertically over a distance of 10 feet horizontally.

A review of Figure 5.3-4 shows that most of the LWD in the reservoir was submerged at more than 90 percent of flows from 1987 to 2004. However, it should be noted that there is high variability in the mapped elevations for LWD locations due to inaccuracy in the GPS measurements and the steepness of the bathymetry data. Small differences in location can result in large changes in mapped elevation.

5.4. Quantifying LWD Removal

The quantity of LWD removed at Boundary Dam in 2007 is shown in Tables 5.4-1 and 5.4-2. More LWD was removed early in the season. In March, the greatest number of pieces was in the small size category, while in July there were more pieces in the moderate size categories. A larger percentage of the logs collected in July had root wads attached to them. Root wads are useful in creating habitat features that provide better cover for salmonids and other fish species. Timmons and Garrett (1985) found a significantly higher rate of catch for game fish in a reservoir in areas with stumps and standing timber than in a control area where no LWD was present.

Table 5.4-1. Numbers, size classes, and volume of LWD collected at Boundary Dam trash rack; data collected on March 22, 2007.

Diameter Large End	Count at Length 5 ft < 17 ft	Estimated Volume (ft^3)	Count at Length 17 ft < 50 ft	Estimated Volume (ft^3)	Count at Length > 50 ft	Estimated Volume (ft^3)	Total Count	Total Volume (ft^3)	Total Count with Root Wads	Root Wad Volume (ft^3)
4 in < 12 in	127	398	35	409	2	52	164	**859**	16	27.84
12 in < 24 in	9	151	13	769	6	114	28	**1,035**	11	96.80
24 in < 32 in	0	0	1	143	0	0	1	**143**	0	0
> 32 in	0	0	0	0	0	0	0	**0**	0	0
Grand Total	136	549	49	1,321	8	167	193	**2,037**	27	124.64

Table 5.4-2. Numbers, size classes, and volume of LWD collected at Boundary Dam trash rack; data collected on July 29, 2007.

Diameter Large End	Count at Length 5 ft < 17 ft	Estimated Volume (ft^3)	Count at Length 17 ft < 50 ft	Estimated Volume (ft^3)	Count at Length > 50 ft	Estimated Volume (ft^3)	Total Count	Total Volume (ft^3)	Total Count with Root Wads	Root Wad Volume (ft^3)
4 in < 12 in	3	10	1	12	0	0	4	**22**	1	1.74
12 in < 24 in	1	17	6	355	0	0	7	**372**	4	35.20
24 in < 32 in	1	41	0	0	2	641	3	**682**	2	42.74
> 32 in	0	0	0	0	1	530	1	**530**	1	35.33
Grand Total	5	67	7	367	3	1,171	15	**1,605**	8	115.01

The number of pieces and volume of LWD along shorelines was compared to the quantity of LWD removed during 2007 from the trash rack. The volume of wood removed from the trash rack at Boundary Dam in the two removal events represents 5.4 percent of the total volume of LWD in the reservoir (sum of mapped volume and rack volume). The number of pieces removed from the trash rack represents 12 percent of the total number of pieces (the sum of the number of pieces along the shoreline and the number in the trash rack). However, for the largest size class (>32-inch diameter), which are potentially the most important for a river this size, 38 percent of the volume and 14 percent of the pieces were removed at the rack. However, this is a small sample size and may not be significant. A visual comparison of the distribution of size classes of LWD between that removed from the trash rack and the total LWD along the shoreline in Boundary Reservoir (the sum of the number of pieces along the shoreline and the number in the trash rack) is shown in Figure 5.4-1. A Chi square test ($\alpha = 0.05$) comparing the two distributions showed that they were not the same.

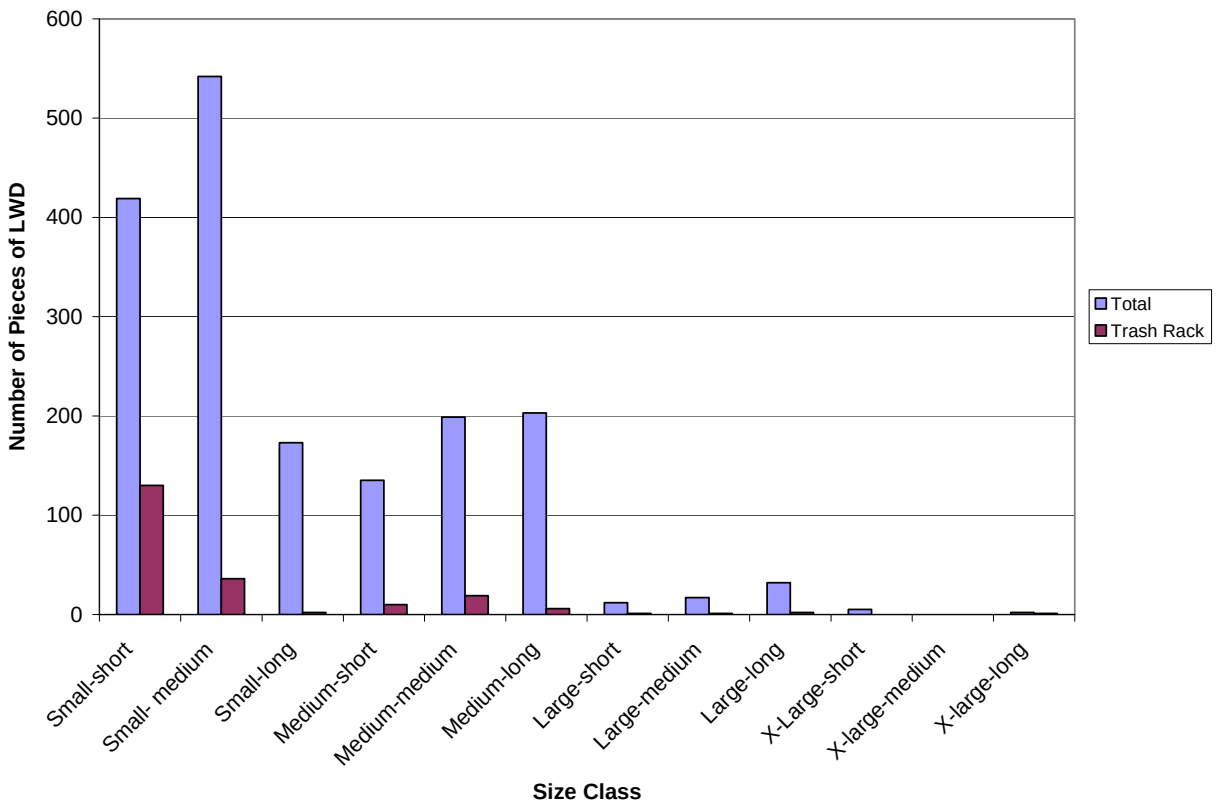

Figure 5.4-1. LWD distributions by size class for total LWD and LWD removed from the Boundary Dam trash rack.

The volume of LWD removed from Boundary Dam trash rack was about six times what was removed from the Box Canyon Dam trash rack. The amount of LWD removed from Box Canyon Dam was based on cords of wood produced, and the total volume removed was likely underestimated; however, most of the large pieces, and thus most of the LWD volume, were accounted for. The LWD removed at Boundary Dam in 2007 included 4 pieces that could have been used to enhance aquatic habitat in the mainstem (large diameter and length) and 16 pieces

that could have been used to enhance habitat in tributaries (greater than 24 inches diameter and medium to long length).

Peak spring flow was low in 2007 (54,000 cubic feet per second [cfs]) compared to the recent historical average (since 1980) peak of about 76,000 cfs, which may have reduced the amount of wood reaching the trash rack during the study period relative to what occurs in most years.

5.5. LWD Management Alternatives and Opportunities for Modification by Human Intervention

There are several management alternatives for LWD removed from the trash rack at Boundary Dam.

- **Maintain current management of using the LWD for timber and firewood for campsites.** This strategy benefits campers and may provide a small economic benefit for the removal contractor and local mills through timber production.
- **Pass LWD downstream at Boundary Dam.** Releasing LWD through the sluiceway at the dam's crest could provide a low-cost method of keeping LWD moving through the Pend Oreille system. This action would counteract the dam's disruptive effects on LWD transport in the Pend Oreille River. Disadvantages of this approach include potential increased effort at downstream hydroelectric projects to ensure LWD does not affect operations. There is also a risk that LWD passed over the dam during spill would break apart into smaller, less functional pieces. This alternative would likely require sorting and removing trash from the wood before passing the wood downstream. Trash removal is currently accomplished by the LWD removal contractor, but there could be additional costs if LWD is to be returned to the reservoir to be released through the sluiceway.
- **Improve factors limiting productivity in the mainstem reservoir.** Placing LWD along shorelines in the reservoir in areas where stability appears to be high would have the potential to improve productivity in the reservoir. The action could include the use of anchoring systems to hold individual wood pieces or log jam complexes in place. Information from Study 9, the Fish Distribution, Timing, and Abundance Study, could be used to aid in determining the best locations for LWD placement. The details would need to be determined on a site-specific basis. This strategy would benefit aquatic habitat by increasing cover for fish species, substrate for production of aquatic invertebrates (as a food resource for fish species), and potential use by shorebirds in Boundary Reservoir. Due to reservoir surface fluctuation associated with Project operations and the influence of Metaline Falls as a hydraulic control, LWD placed higher on the shoreline in the lower reservoir may be exposed to longer periods of dewatering than that placed in the upper reservoir. The relative benefits of fish use and the effects of the duration of dewatering would have to be weighed in determining the best location for placement. LWD distribution in the reservoir is patchy (Figure 5.3-2) and areas of low abundance could benefit from LWD placement, provided that the areas are conducive to LWD retention.

- **Improve factors limiting productivity in tributary deltas along the reservoir.** Some tributary deltas have been observed to be areas of relatively high fish use, especially for salmonids, and placement of wood in deltas could improve habitat. One disadvantage of this alternative is the difficulty in securing LWD in sandy tributary deltas; because the sand substrate is unstable during high water events, LWD placed there would likely move in high flows. Another potential disadvantage of this alternative is increased risk of predator concentrations in these delta areas because LWD placement could provide cover for predator species like smallmouth bass.
- **Improve factors limiting productivity farther upstream in tributaries to the reservoir.** This strategy would improve habitat for salmonids that use upstream portions of reservoir tributaries. The disadvantages of this strategy are that downstream movement of wood would be disrupted and wood would be unavailable for use in terrestrial habitats. Potential tributary habitat enhancement opportunities are identified as part of Study 14 (SCL 2008b). LWD placement in tributaries would be considered off-site mitigation in terms of providing benefits to physical habitat in Boundary Reservoir but may also provide benefits to adfluvial fish that spend part of their life cycle in the reservoir and part of their life cycle in tributaries to the reservoir.
- **Use LWD in terrestrial areas along the reservoir to improve small mammal habitat.** Animals that would benefit from the placement of wood in terrestrial habitats have been identified using habitat-species relationships and through wildlife surveys along the Boundary Reservoir (G. Green, Tetra Tech EC, personal communication, December 2007). Several types of animals, including amphibians (e.g., long-toed salamander, Pacific treefrog), reptiles (e.g., rubber boa, common garter snake), birds (e.g., pileated woodpecker, blue grouse) and mammals (e.g., rodents, black bears, raccoons), use downed logs in terrestrial environments for various habitat needs including cover, feeding, and reproduction (Thomas [1979] and G. Green, Tetra Tech EC, personal communication, December 2007).
- **Habitat restoration efforts in the Pend Oreille Basin that have been identified as high priorities for aquatic habitat improvement by the Pend Oreille Salmonid Recovery Team, or as part of the Water Resource Inventory Area (WRIA) 62 sub-basin planning process.** The Pend Oreille Salmonid Recovery Team is involved in ongoing planning to set restoration priorities and could be contacted to determine if there is a need for additional LWD for habitat projects in the basin that would benefit aquatic resources. These projects would be considered off-site mitigation and would not likely directly improve habitat conditions in the Boundary Reservoir.

6 CONCLUSIONS

LWD is currently removed seasonally from the trash racks at both Boundary Dam and Box Canyon Dam. Current management of LWD in both locations is fairly similar, with most LWD converted to firewood for use at public campgrounds. Mapping of LWD along the Boundary Reservoir shoreline indicates that LWD is distributed in concentrated areas throughout the reservoir, and some of these areas have remained stable since 2005. LWD removed from the trash rack in 2007 represents 5.4 percent (by volume) and 12 percent (by number of pieces) of

the total LWD present in the reservoir in 2007. Recommendations for improved management of LWD in Boundary Dam include the following:

- Pass LWD downstream at Boundary Dam.
- Improve factors limiting productivity in the mainstem reservoir.
- Improve factors limiting productivity in tributary deltas along the reservoir.
- Improve factors limiting productivity farther upstream in tributaries to the reservoir.
- Use LWD in terrestrial areas along the reservoir to improve small mammal habitat.
- Employ habitat restoration efforts in the Pend Oreille Basin that have been identified as high priorities for aquatic habitat improvement by the Pend Oreille Salmonid Recovery Team, or as part of the WRIA 62 sub-basin planning process.

7 VARIANCES FROM FERC-APPROVED STUDY PLAN AND PROPOSED MODIFICATIONS

There have been no variances from the RSP for this study and there are no modifications proposed because the LWD mapping task is complete.

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Appendix 1. LWD Counts and Volumes by Location

Table A.1-1 provides the actual counts and volumes observed by Boundary Reservoir Reach and location during the LWD survey on Boundary Reservoir.

Table A.1-1. LWD counts and volumes by reach and location.

Reach	LWD Location	Total Count	Total Volume (ft^3)
Forebay	1	2	15
Forebay	2	3	79
Forebay	3	4	53
Forebay	4	1	12
Forebay	5	2	6
Forebay	6	2	34
Forebay	7	1	3
Forebay	8	16	234
Forebay	9	5	89
Forebay	10	6	158
Canyon	11	3	79
Canyon	12	2	20
Canyon	13	2	34
Canyon	14	2	28
Canyon	15	1	3
Canyon	16	2	192
Canyon	17	14	211
Canyon	18	5	150
Canyon	19	1	132
Canyon	20	9	414
Canyon	21	2	265
Canyon	22	3	121
Canyon	23	3	262
Canyon	24	6	502
Canyon	25	3	585
Canyon	26	4	457
Canyon	27	6	438
Canyon	28	1	59
Canyon	29	7	521
Canyon	30	1	132
Canyon	31	4	294
Canyon	32	2	28
Canyon	33	11	810
Canyon	34	4	173
Canyon	35	1	132
Canyon	36	2	34
Canyon	37	15	1,194
Canyon	38	33	1,985
Canyon	39	2	23
Canyon	40	3	147
Canyon	41	2	144
Canyon	42	3	83

Table A.1-1, continued…

Reach	LWD Location	Total Count	Total Volume (ft^3)
Canyon	43	8	380
Canyon	44	2	29
Canyon	45	28	576
Canyon	46	1	26
Canyon	47	2	38
Canyon	48	1	12
Canyon	49	1	59
Canyon	50	5	64
Canyon	51	3	32
Canyon	52	2	159
Canyon	53	7	224
Canyon	54	6	182
Canyon	55	1	17
Canyon	56	7	255
Canyon	57	1	17
Canyon	58	2	76
Canyon	59	2	23
Canyon	60	2	38
Canyon	61	1	26
Canyon	62	4	133
Canyon	63	1	17
Canyon	64	4	156
Canyon	65	7	561
Canyon	66	2	332
Canyon	67	13	352
Canyon	68	8	190
Canyon	69	3	208
Canyon	70	1	12
Canyon	71	4	341
Canyon	72	1	59
Canyon	73	1	59
Canyon	74	1	132
Canyon	75	2	265
Canyon	76	1	12
Canyon	77	1	59
Canyon	78	3	18
Canyon	79	1	59
Canyon	80	12	975
Canyon	81	1	132
Canyon	82	1	12
Canyon	83	2	159
Canyon	84	1	59
Canyon	85	3	156
Canyon	86	8	812
Canyon	87	18	820
Canyon	88	2	76
Canyon	89	2	76

Table A.1-1, continued…

Reach	LWD Location	Total Count	Total Volume (ft^3)
Canyon	90	2	62
Canyon	91	18	1,408
Canyon	92	2	71
Canyon	93	2	23
Canyon	94	13	282
Canyon	95	25	464
Canyon	96	4	94
Canyon	97	46	1,187
Canyon	98	17	466
Canyon	99	11	261
Canyon	100	3	175
Canyon	101	2	265
Canyon	102	1	12
Canyon	103	1	17
Canyon	104	5	99
Canyon	105	15	506
Canyon	106	3	349
Canyon	107	1	132
Canyon	108	10	123
Canyon	109	1	321
Canyon	110	2	23
Canyon	111	6	182
Canyon	112	1	26
Canyon	113	2	15
Canyon	114	7	71
Canyon	115	2	136
Canyon	116	6	36
Canyon	117	7	296
Canyon	118	1	59
Canyon	119	7	88
Canyon	120	3	156
Canyon	121	3	65
Canyon	122	1	3
Canyon	123	2	52
Canyon	124	3	65
Canyon	125	5	291
Canyon	126	4	164
Canyon	127	5	64
Canyon	128	10	381
Canyon	129	1	59
Canyon	130	1	12
Canyon	131	3	35
Canyon	132	5	94
Canyon	133	9	270
Canyon	134	1	132
Canyon	135	1	132
Canyon	136	4	268

Table A.1-1, continued…

Reach	LWD Location	Total Count	Total Volume (ft^3)
Canyon	137	6	277
Canyon	138	13	667
Canyon	139	1	321
Canyon	140	3	130
Canyon	141	6	123
Canyon	142	4	189
Canyon	143	5	135
Canyon	144	13	400
Canyon	145	2	62
Canyon	146	1	132
Canyon	147	2	71
Canyon	148	1	12
Canyon	149	3	268
Canyon	150	3	50
Canyon	151	2	20
Canyon	152	3	40
Canyon	153	1	26
Canyon	154	11	207
Canyon	155	5	247
Canyon	156	2	136
Canyon	157	7	503
Canyon	158	1	132
Canyon	159	7	349
Canyon	160	2	38
Canyon	161	3	41
Canyon	162	1	26
Canyon	163	1	26
Canyon	164	4	48
Canyon	165	2	28
Canyon	166	8	176
Canyon	167	20	744
Canyon	168	10	307
Canyon	169	46	1,039
Canyon	170	9	166
Canyon	171	22	701
Canyon	172	5	93
Canyon	173	4	21
Canyon	174	1	26
Canyon	175	12	408
Canyon	176	70	2,009
Canyon	177	12	959
Canyon	178	60	2,567
Canyon	179	2	6
Canyon	180	1	3
Canyon	181	4	35
Canyon	182	2	29
Canyon	183	1	12

Table A.1-1, continued…

Reach	LWD Location	Total Count	Total Volume (ft^3)
Canyon	184	2	29
Canyon	185	7	224
Forebay	186	1	26
Forebay	187	3	195
Forebay	188	2	332
Forebay	189	1	12
Forebay	190	3	175
Forebay	191	12	697
Forebay	192	1	132
Forebay	193	11	439
Forebay	194	4	189
Upper	195	3	139
Upper	196	3	50
Upper	197	3	18
Upper	198	3	214
Upper	199	2	144
Upper	200	40	1,514
Upper	201	6	111
Upper	202	14	755
Upper	203	2	192
Upper	204	2	453
Upper	205	4	410
Upper	206	1	17
Upper	207	1	132
Upper	208	10	628
Upper	209	9	792
Upper	210	5	111
Upper	211	6	305
Upper	212	3	9
Upper	213	10	231
Upper	214	5	120
Upper	215	1	3
Upper	216	2	337
Upper	217	28	1,010
Upper	218	1	12
Upper	219	2	149
Upper	220	3	397
Upper	221	2	265
Upper	222	9	134
Upper	223	62	1,961
Upper	224	4	159
Upper	225	6	73
Upper	226	1	12
Upper	227	1	12
Upper	228	2	76
Upper	229	8	314
Upper	230	4	413

Table A.1-1, continued…

Reach	LWD Location	Total Count	Total Volume (ft^3)
Upper	231	3	465
Upper	232	1	26
Upper	233	1	12
Upper	234	12	302
Upper	235	3	23
Upper	236	18	1,319
Upper	237	3	18
Upper	238	1	132
Upper	239	4	604
Upper	240	11	749
Upper	241	13	374
Upper	242	3	327
Upper	243	3	88
Upper	244	3	32
Upper	245	4	109
Upper	246	6	115
Upper	247	14	245
Upper	248	11	278
Upper	249	2	15
Upper	250	1	12
Upper	251	5	406
Upper	252	6	733
Upper	253	5	471
Upper	254	4	61
	TOTAL	**1,539**	**63,354**