Upper Green River
Baseline Habitat Monitoring
2005 / 2006

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1. INTRODUCTION

Habitat alteration and/or loss have contributed to large-scale declines in the number and geographic distribution of both resident and anadromous fish inhabiting the Pacific Northwest (Nehlsen et al. 1991; Weitkamp et al. 1995; Johnson et al. 1999). In general, headwater tributaries have been impacted by forest practices and lower tributaries and mainstem rivers have been impacted by agriculture and/or urbanization. Diking for flood control, draining and filling of freshwater and estuarine wetlands, and sedimentation due to forest practices and urban development are cited as problems throughout Puget Sound Area (WDFW et al. 1994). Blockages by dams, water diversions, and shifts in flow regime due to hydroelectric development and flood control projects are major habitat problems in some basins. The Puget Sound Salmon Stock Review Group provided an extensive review of habitat conditions for several of the salmonid stocks in Puget Sound and concluded that reductions in habitat capacity and quality have contributed to escapement problems for Puget Sound Chinook, citing evidence of curtailment of tributary and mainstem habitat due to dams, and losses of slough and side-channel habitat due to diking, dredging, and hydromodification (Cramer et al. 1999).

The Green River basin has experienced many of the impacts noted above. Land and water use activities including logging, agriculture, urbanization, municipal and industrial water use, and flood control have all affected processes controlling the flow of water, sediment, energy and nutrients through the basin. These processes govern the underlying production potential of the system and directly influence fish and their habitat. As a consequence, many natural features of the Green River's aquatic habitats have been compromised, reduced or lost. The U.S. Army Corps of Engineers (USACE) Seattle District and their local sponsors are currently implementing two large projects in the Green River basin near Seattle, Washington – the Howard Hanson Dam (HHD) Additional Storage Project (AWSP) and the Green-Duwamish Ecosystem Restoration Project (GD-ERP). The AWSP is a dual-purpose water supply and ecosystem restoration project with Tacoma Public Utilities as the local sponsor. The AWSP includes construction of a downstream fish passage facility at HHD and a suite of habitat restoration and mitigation projects in the upper and middle Green River. Upstream transport of adult salmonids is to be accomplished by a trap and haul facility constructed by Tacoma Public Utilities at the Tacoma Headworks Dam.

The U.S. Army Corps of Engineers completed construction of HHD at River Mile RM 64.5 on the Green River in 1962. The project is currently operated to provide fall and winter flood control and summer low flow augmentation for fish resources. In 1989, the USACE began

studies to determine if HHD could be used to meet municipal and individual water supply needs as part of an AWSP. The AWSP was subject to extensive agency review and a collaborative decision making process involving the National Marine Fisheries Service, U.S. Fish and Wildlife Service, Washington State Department of Ecology, Washington Department of Fish and Wildlife, Tacoma Public Utilities and the Muckleshoot Indian Tribe. This process resulted in a phased adaptive management plan that provides early outputs of water supply and restoration benefits with an opportunity to review and adjust the project as experience is gained. Key elements of the AWSP restoration and mitigation program include experimentation, monitoring and data analysis followed by adjustment of management and operation practices in response to knowledge gained through the monitoring process.

The USACE is currently developing an integrated monitoring program to evaluate the effects of the various parts of the AWSP. This includes both reach scale and site-specific monitoring of the upper Green River and tributaries to Eagle Gorge Reservoir. Reach scale monitoring in the upper Green River and reservoir tributaries will be used to evaluate the effectiveness of the upper watershed habitat mitigation and restoration projects and document that mitigation objectives are achieved. Specific objectives include creation of 8,000 ft^2 of pool area in the North Fork Green River and 72,000 ft^2 of pool area in the mainstem Green River. Follow-up monitoring will occur at 5-year intervals to verify that objectives are being met. Site-specific monitoring will focus on documenting the performance and effectiveness of the individual habitat projects, and is beyond the scope of this study. The project life is 50 years. It is therefore likely that habitat projects will be replaced periodically. Reach scale and site specific monitoring is designed to determine when this project replacement is required and which project types are most effective at achieving the desired habitat. Details regarding habitat project design can be found in the Green River Fish Habitat Mitigation and Restoration Design Documentation Report (USACE 2005).

Reach scale monitoring utilizes extensive, low intensity surveys to document the spatial distribution, location, types and general physical characteristics of habitat units and other important habitat features such as large woody debris (LWD). Documenting the number and spacing of pools, the frequency and distribution of LWD, and general substrate conditions over the entire study reach provides a means of determining whether restoration programs are achieving the desired goals for the entire study area, (e.g., increasing the number of large pools). Reach scale monitoring is generally conducted using one of two approaches: semi-quantitative habitat mapping of the entire study reach, or more quantitative subsampling of representative segments that are then extrapolated to the entire study reach. Low intensity mapping of the entire reach was determined to be the preferred for large rivers, such as the Green River. In large rivers, individual habitat units may be thousands of feet-long. Representative reaches of even a

mile or more in length may contain only a few habitat units, and alteration of any individual unit by a localized event (e.g., bank failure or breaking up of a LWD jam) can profoundly influence estimates of overall habitat conditions if extrapolated to the reach as a whole.

This study outlines the baseline habitat monitoring of instream habitat within the upper Green River between approximately River Mile (RM) 69 (head of existing Howard Hanson Reservoir at 1,147 ft. elevation) and approximately RM 86 (High Trestle Bridge), tributaries to the upper mainstem including Smay and Sunday Creek, and tributaries to Eagle Gorge Reservoir including: North Fork Green River; Gale Creek; Charley Creek; McDonald Creek; Cottonwood Creek; and Piling Creek. In addition, Signani Slough, an off channel restoration area downstream of Howard Hanson Reservoir, was also surveyed.

2. ENVIRONMENTAL SETTING

The Green River drains an area of 484 square miles located in the southern part of King County Washington. The mainstem Green River flows north and west for approximately 84 miles from its headwaters in the Cascade mountains. At RM 11 the Green River is joined by the Black River to form the Duwamish River before emptying into Puget Sound at Elliott Bay.

Historically, Lake Washington and Lake Sammamish, the Cedar River and the Green and White River all drained to the Duwamish River, forming one of the largest basins in Puget Sound, with a drainage area of 1,639 mi^2. Beginning in 1906, a series of natural and man-made events resulted in the separation of the Duwamish basin into three separate and smaller basins: the Lake Washington Basin (663 mi^2), which includes Lakes Washington and Sammamish and the Cedar River basin; the White River (494 mi^2); and the Green River (484 mi^2). A large flood in 1906 formed a log jam that blocked the confluence of the Green and White Rivers and shifted the majority of the White River flow south into the Puyallup River. Through channelization efforts authorized by the State Legislature in 1909, this shift was made permanent, and the former White River channel was filled. In 1912, a public improvement district diverted the Cedar River into Lake Washington to maintain the elevation of the lake once the Ship Canal was completed, further reducing the drainage area of the Green River basin.

The Green River watershed can effectively be subdivided into three subbasins. The upper Green River extends from the headwaters to Tacoma's Headworks Diversion Dam at River Mile 61.0, which is located 3.5 miles downstream of HHD. The Tacoma Headworks diversion dam currently blocks the upstream migration of anadromous salmonids. The middle Green River includes areas draining to the mainstem between the Tacoma Headworks and the confluence with Soos Creek near Auburn at RM 33.8. The lower Green River continues to the confluence with the Black River at RM 11, which is the upstream extent of the estuary. The baseline habitat monitoring described in this report focused on the upper Green River, hereafter referring to stream segments located upstream from HHD.

3. METHODS

3.1 MONITORING OVERVIEW

Establishing baseline conditions and monitoring changes in habitat conditions that result from restoration efforts and changing land and water management practices is fundamental to the recovery and conservation of salmonids. Monitoring is defined as a series of measurements that are repeated over time with the goal of detecting change (MacDonald et al. 1991). Monitoring differs from typical habitat assessments, which generally focus on making a single set of observations to characterize conditions at a given point in time. A critical element of monitoring is to develop specific project objectives and to identify monitoring parameters that are sensitive to the projects or programs to be implemented and that are quantifiable by direct measurement. Monitoring protocols must provide a statistically defensible method for evaluating and minimizing error (Johnson et al. 2001). To be useful in the context of a long term monitoring program, parameters to be tracked must be measurable with a known degree of precision and accuracy (Bauer and Ralph 1999). The specific objective of the reach scale monitoring described in this report was to establish baseline conditions from which future changes in habitat may be identified.

3.2 STRATIFICATION OF SURVEY AREA

Baseline habitat surveys encompassed instream habitats within the upper Green River, between approximately RM 69 (head of existing Howard Hanson Reservoir at 1,147 ft. elevation) to approximately RM 86 (High Trestle Railroad Bridge) during low flow conditions. Additional baseline habitat monitoring was conducted in the following streams or stream segments (Figure 1): Sunday Creek, Smay Creek, North Fork Green River; Gale Creek; Charley Creek; McDonald Creek; Cottonwood Creek; Piling Creek; and Signani Slough. The lower one mile of Champion Creek was also intended to be surveyed, however, due to dry summer weather conditions, this stream was dewatered, and hence not surveyed. Survey reaches were delineated as follows:

Reach 1: Upper Mainstem Green River;

Reach 2: Sunday Creek (RM 3.5, Snow Creek, to mouth)

Reach 3: Smay Creek (RM 1.7, W. Fork, to mouth)

Reach 4: Lower North Fork Green River (1,320 ft – 1,147 ft);

Reach 5: Lower Gale Creek (1,280 ft – 1,147 ft);

Reach 6: Lower Charley Creek (1,240 ft – 1,147 ft);

Reach 7: Lower Piling Creek (1,240 ft – 1147 ft);

Reach 8: Lower Cottonwood Creek (1,240ft – 1,147 ft);

Reach 9: Lower McDonald Creek (1,240 ft – 1,147 ft); and

Reach 10: Signani Slough (mainstem Green River to pond area).

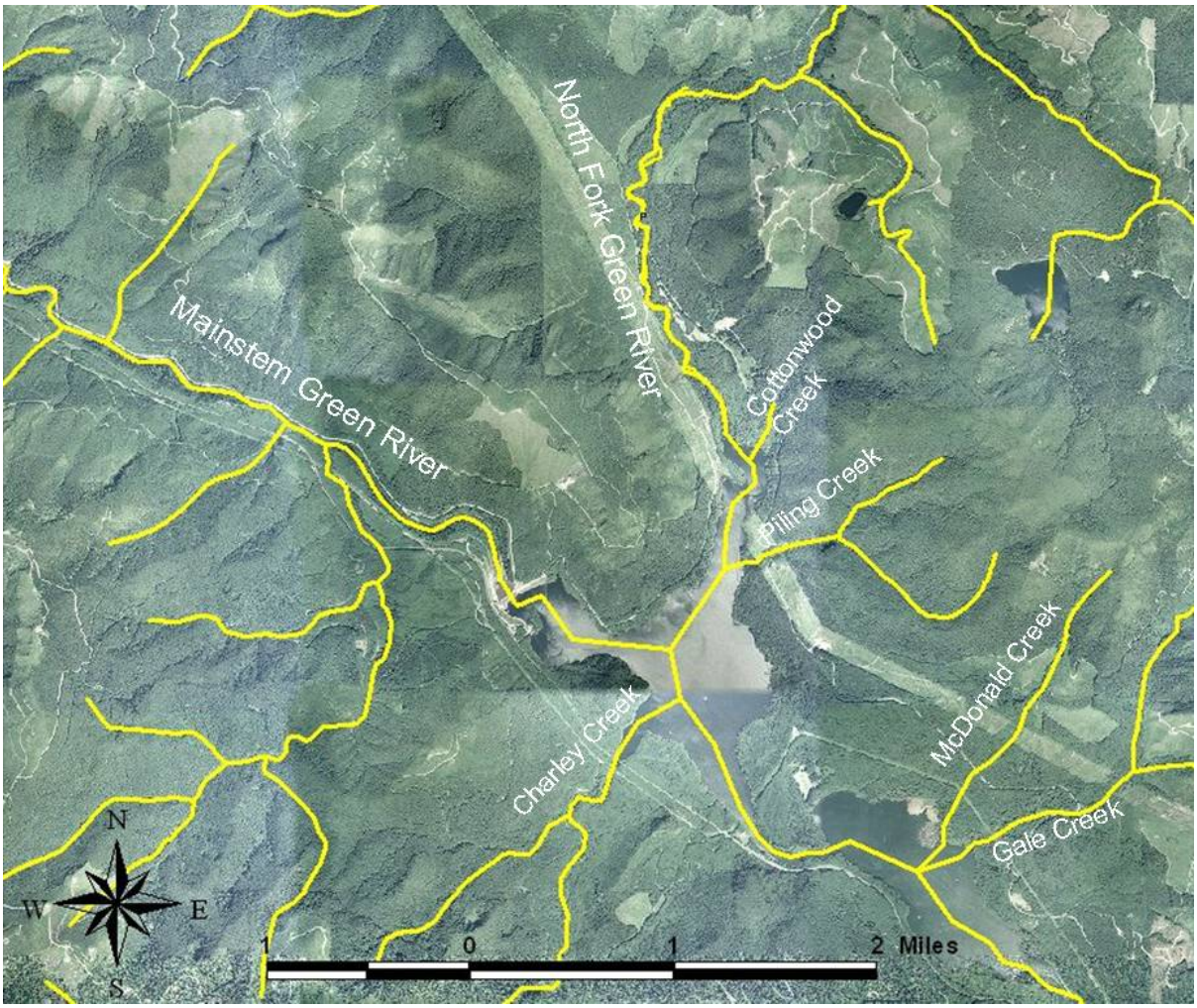

Figure 1. Map of select study tributaries at Howard Hanson Reservoir, King County, Washington, 2006.

3.3 MONITORING PARAMETERS

A set of key parameters was developed at the monitoring workshop (R2 2002) and was utilized as part of the middle Green River reach scale habitat monitoring program and was used during baseline habitat surveys in the upper Green River. Key parameters represent habitat attributes that: 1) are expected to be most responsive to management actions or restoration and mitigation projects and 2) can be accurately quantified with minimal measurement error or observer bias.

Key parameters that were quantitatively measured throughout the survey area during reach scale habitat monitoring included bankfull width (where practical), canopy cover, pool habitat unit location and dimensions, LWD, and riffle particle size distributions. Definitions and procedures used to measure attributes of each of these key parameters are described below.

Bankfull Width

Bankfull width is the distance between the bankfull channel edges, which are defined by the abrupt changes in bank morphology, composition and vegetation (Figure 2). Bankfull channel width was measured to the nearest 2-meters approximately every 300 meters using a laser rangefinder in the tributary surveys. The extreme width of the bankfull channel of the upper mainstem Green necessitated the estimation of bankfull width at most locations, and was unable to be determined in a timely manner at others. The location of bankfull width transects were recorded using GPS and marked on laminated copies of aerial photographs covering the river corridor. All GPS measurements were subject to available satellite reception. Stream canopy coverage was especially heavy in the tributary surveys, inhibiting GPS reception. The location of woody debris jams on the aerial photos when GPS coverage was not available were estimated from measured stream lengths and recognizable landmarks. Photographs were taken looking downstream at each bankfull width transect.

Canopy Cover

Canopy cover refers to the amount of area over the stream channel that is shaded by riparian trees or shrubs. At each bankfull width transect a spherical densiometer was used to assess canopy cover. Canopy cover data was collected in the center of the wetted channel at four locations.

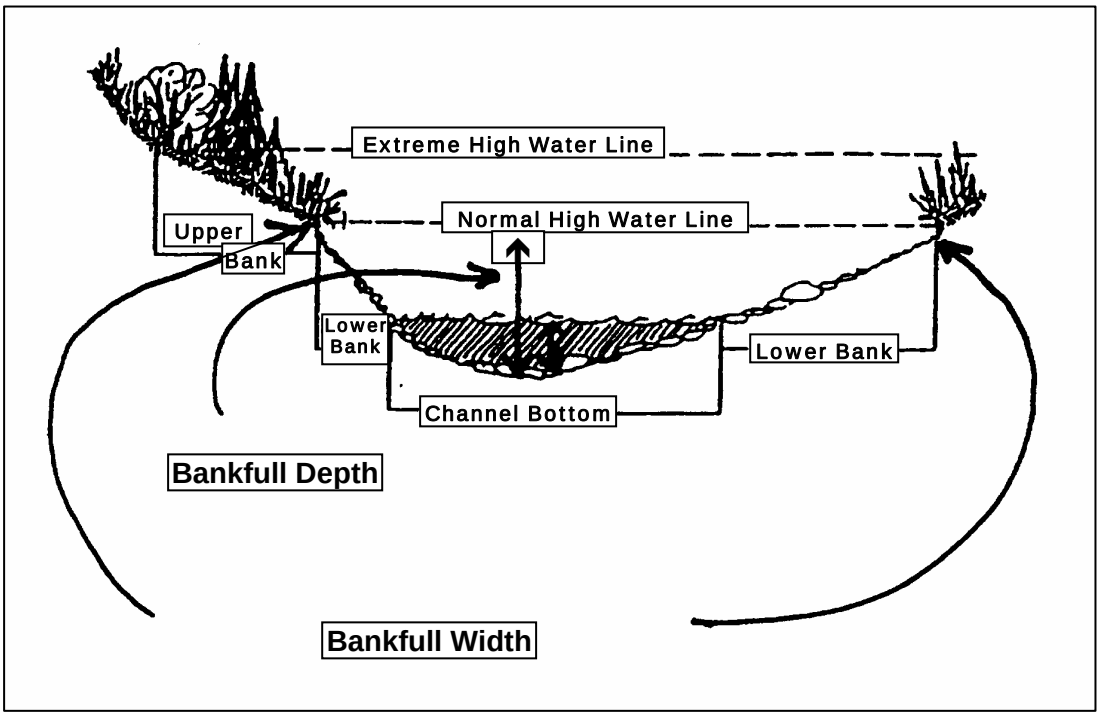

Figure 2. Identification of bankfull width, bankfull depth, and lower bank (adapted from Pfunkuch 1975).

Habitat Units

Habitat units represent short reaches of channel with unique depth, velocity and morphologic characteristics. All habitat units identified during the surveys were delineated on the aerial photo basemaps. However, based on the results of the literature review documenting major difficulties in the repeatability and accuracy of measurements conducted in habitat types other than pools, quantitative measurements were only collected in pool habitat units. Habitat units were classified according to a modified version of the hierarchical system developed by Hawkins et al. (1993). This system recognizes two basic classes of habitat: fast water habitat and slow water habitats. For this survey, those basic habitat classes were further broken down into seven habitat types (Figure 3).

Slow water habitat types consist of pools and backwaters. Pool habitats are areas where water is impounded within a closed topographical depression. Such depressions commonly form where water has scoured out a concavity in the channel bed or where the channel has been dammed. Pool habitats were further stratified as scour or dammed and by their formative characteristics (Figure 3). Backwater habitats are areas of low or no velocity separated from the main flow hydraulically and physically.

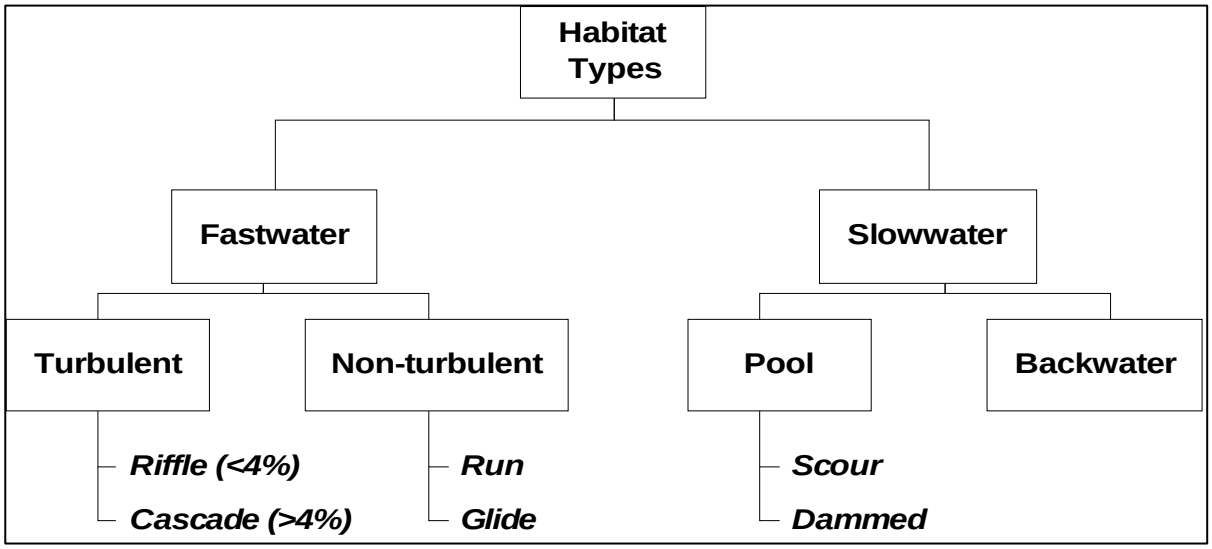

Figure 3. Habitat type classification system for upper Green River Baseline mainstem habitat monitoring (adapted from Hawkins et al. 1993).

Fast water habitat types generally have a velocity that is greater than 0.3 meters per second. Fast water habitat types are further characterized as turbulent or non-turbulent. Fastwater habitats exhibiting surface turbulence include cascades and riffles. Turbulent, fast water habitats with a water surface slope greater than 4 percent are classified as cascades. Turbulent fast water habitats with a water surface slope less than 4 percent are classified as riffles. Fast water habitats that do not exhibit surface turbulence often appear pool-like because of their depth and lack of surface agitation. However, unlike pools, non-turbulent fastwater habitats do not exhibit a well-developed depression. Non-turbulent habitat units that are deep and swift with a well-defined thalweg are classified as runs. Non-turbulent fastwater habitats with low to moderate velocity, a uniform bed, and no defined thalweg were classified as glides.

Side channel units were defined as being larger split channel areas where the dividing habitat included mature vegetation (versus channel braiding with dividing gravel bar habitat). Side channels with flowing water were surveyed where possible, but side channel habitat information was kept separate from the mainstem habitat unit data. Dry or abandoned side channels were noted in the field notes, but not surveyed (with the exception of woody debris, which was surveyed).

Pools

Pool habitat units are bounded by an upstream pool head and a downstream riffle crest (Figure 4). For the mainstem and North Fork surveys to be classified as a pool habitat unit, the concave depressional area was required to occupy at least 25 percent of the wetted channel width and have a residual depth greater than 1.5 feet (0.5 meter).[1] Smaller pool units, pocket pools, were noted on the map and described in field notes, but not measured. For the smaller tributary surveys a minimum pool depth of 1.0 foot (0.33 meter) was used. Quantitative measurements were collected at each pool habitat unit. Each pool habitat unit was located using GPS (where possible). Pool length and width were measured using a laser rangefinder. The length of each pool was measured along the center of the wetted channel. Three to six width measurements per pool perpendicular to the pool centerline were obtained depending on the pool length and complexity. The maximum pool depth was measured using a graduated wading rod. Riffle crest depths were measured to the nearest 0.1 foot utilizing a graduated wading rod.

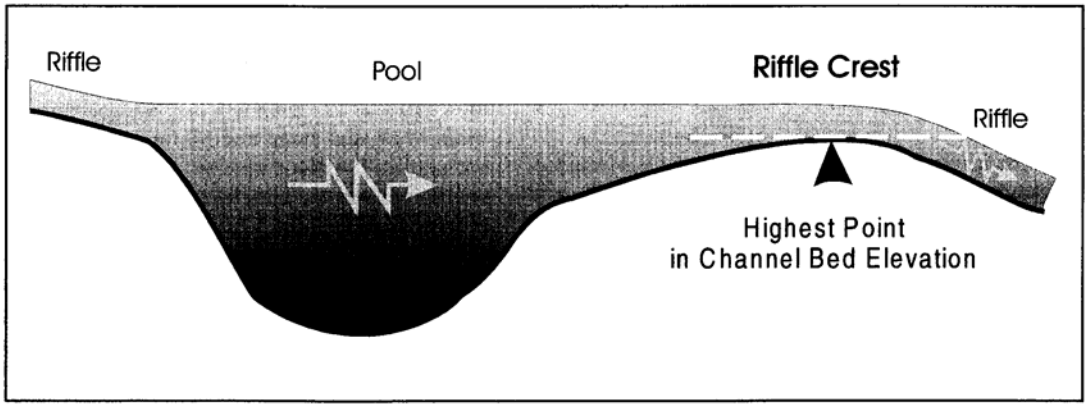

Figure 4. Upstream and downstream boundaries used when defining a pool habitat unit (adapted from Pleus et al. 1999).

The factor responsible for forming each pool was also recorded. Pool forming factors include both natural and man-made features. Natural pool-forming factors include LWD, bedrock, boulders, bedforms or the confluence with a tributary or side channel. Pools formed by bedforms include those formed by bed steps (a bed step is a transverse rib of boulders or cobbles that extends across the entire channel) and those formed by the hydraulics associated with a

[1] The minimum residual depth of 0.5 meter was selected to delineate pools of sufficient size as to be stable for comparison in future surveys.

riffle/pool sequence. Pools were defined as being formed by boulders where single large individual boulders or groups of boulders result in local scour. Man-made pools include those formed by dams, culverts, bridge abutments or constructed and anchored LWD or engineered log jams (ELJs). In addition to the pool forming factor, the pool type was also recorded. Pool types include scour or dammed.

Large Woody Debris

Large woody debris was recorded using a modified version of the Level 1 protocol[2] outlined in the TFW Method Manual for Large Woody Debris Survey (Schuett-Hames et al. 1999). Only wood located wholly or partially within zone 1 (wetted channel) or zone 2 (bankfull channel) was counted (Figure 5). A piece of wood had to be at least 10 cm (4 in) diameter and 3.65 meters (12 ft) long to count as a piece of LWD, and a debris jam had to contain 10 pieces of LWD to count as a debris jam. Debris jams were categorized by size as follows: 10 to 50 pieces, small; 50 to 100 pieces, medium; and greater than 100 pieces, large. The location of LWD jams (> 100 pieces) were recorded using GPS (where possible) and marked on the aerial photograph based on readily recognizable landmarks. Jams were assigned a sequential alphabetical code for reference purposes.

To ease data collection efforts, individual pieces with a diameter smaller than 30.5 cm and a length of less than 9.1 meters shall be counted only when they occur as part of a qualifying debris jam. Individual pieces this size that are not incorporated into a jam are unlikely to remain stable in the channel or influence channel morphology. Single pieces of LWD will be tallied by size classes as follows: diameter 30.5 to 50 cm, medium log; diameter greater than or equal to 50 cm but less than 85 cm, large log; diameter greater than or equal to 85 cm, key piece.[3] The count of wood also noted whether individual pieces of wood that are not part of a debris jam were cut or had an attached rootball or not (Figure 4). To qualify as a rootball, the size of the rootmass must be a minimum of 1.2 meters in diameter.

Riffle Substrate

Riffles represent locations within the channel where bedload is stored between high flow events. They are generally composed of well-sorted material that is representative of the size of

[2] The TFW manual (Schuett-Hames et al. 1999) describes two levels of survey intensity. Level I surveys are appropriate for extensive reach-scale efforts. Intensive Level II surveys are most appropriate for short survey segments and best suited for site-specific monitoring.

[3] Perkins (1999) estimated that the minimum size of a key piece of LWD in the mainstem Green River is 85 cm in diameter and at least 10 meters long.

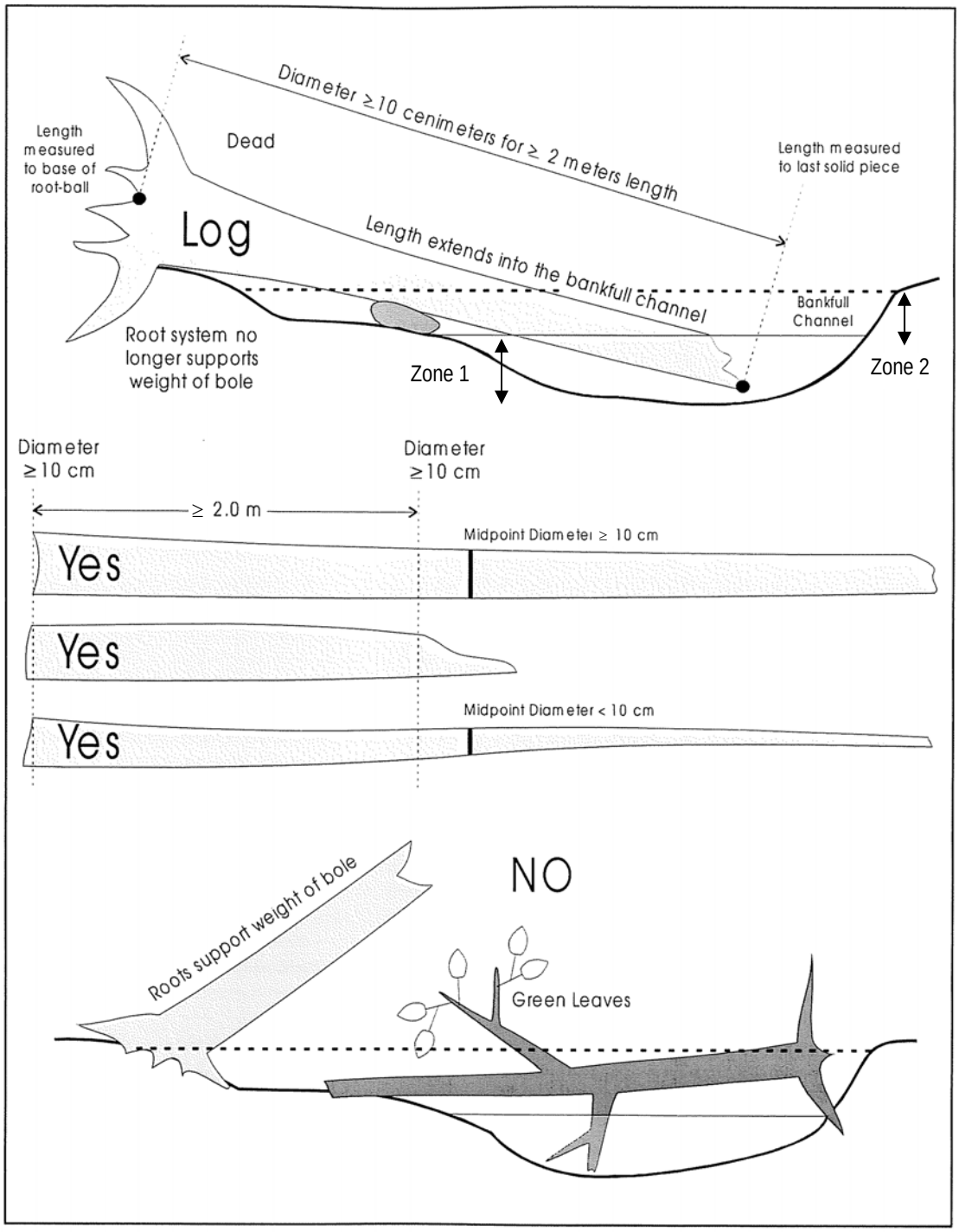

Figure 5. Criteria for identification of individual LWD (adapted from Schuett-Hames et al. 1999).

sediments transported through a given stream reach. As such, they represent good locations to obtain a sample of sediment when the goal is to characterize bedload composition.

Riffle substrate was characterized by conducting five pebble counts per reach in randomly selected riffle habitat units (Wolman 1954). The b-axis of 100 randomly selected particles will be measured for each pebble count. Where the river is wadable, pebble count surveys traversed the entire active channel. If the river was not wadable, pebble counts were extended from the bankfull channel margin to a point where the water depth exceeded approximately 2 feet. The location of sites where pebble counts were conducted was recorded using GPS (where possible) and marked on the aerial photograph based on readily recognized landmarks.

Potential Migration Barriers

Areas where the upstream migration of salmonids may be delayed include shallow riffles or steep cascades. The location of riffles with a maximum depth of less than 6 inches (15 cm) across the entire wetted channel were recorded using GPS (if possible) and/or marked on a photograph. Cascades or bedrock chutes with a maximum depth of less than 6 inches (15 cm), a drop of more than 3.3 feet (1.0 m), or a water surface slope greater than 12 percent were also identified and denoted using GPS and/or on a photograph.

Streambank Armoring

Areas where the streambank was armored with rip rap were recorded with GPS (where possible) and/or marked on a photograph.

3.4 QUALITY ASSURANCE/QUALITY CONTROL

The quality assurance quality control (QA/QC) program is a critical part of a successful monitoring project. For the Upper Green River Baseline Habitat Monitoring Program, QA/QC measures will be implemented at a variety of levels.

Equipment Calibration and Gear

Field equipment used to measure habitat attributes was checked for damage and calibrated at the beginning and end of field work. Laser rangefinders was checked by sighting to a clear, stationary target then measuring the distance to that target with a metric surveyors tape. Wading rods and depth sounders were also cross-referenced metric surveyors tapes.

Equipment number and wading gear used to survey each reach was documented at the start of the survey. These records of the gear and equipment used to conduct surveys are important to ensure the repeatability of future surveys.

Categorical Data Collection

Specific definitions of all categorical data (e.g., habitat types, LWD size classes, bankfull width indicators) were reviewed by all survey team personnel prior to initiating field work. Team members worked closely together throughout the surveys to standardize categorical data calls.

Data Entry Check

All data forms, field books and calculations were reviewed for errors and discrepancies within three weeks following the end of the surveys. Outlying data points were verified, corrected if necessary or eliminated from the analysis population if deemed erroneous. Updated aerial photo coverage was made available in the summer of 2006. All original field data from the 2005 aerial base maps were transferred through GIS to the 2006 coverage. Some habitat features had changed in the interval between 2005 data collection and 2006 aerial photography. All habitat features outlined in the 2006 GIS files have been confirmed. In certain incidents, the 2006 aerial coverage indicates a different habitat type was present than was observed in the 2005 field survey, i.e., stream channels may have been altered during the intervening high flows between 2005 survey and 2006 photography. Furthermore, the 2006 photos were taken at a higher flow condition than that at which the surveys were performed. This was particularly noticeable in the downstream end of Sunday Creek where the “main channel” on the photo was dry at the time of the survey.

All data was entered into MS EXCEL spreadsheets then cross-checked against the original field forms by a second person who had also been involved in the field work. Data analyses were performed with ArcInfo and ArcView GIS tools. A GIS basemap was constructed depicting habitat units, LWD jams and pebble count sites. Individual pieces of LWD were not recorded on the GIS maps. Habitat unit boundaries were visually identified on the photobase maps and may not have the same dimensions as field measurements. Habitat unit lengths utilized in this summary were taken from the GIS data (most accurate estimate, accounts for stream sinuosity); habitat unit widths were taken from field measurements (most accurate estimate, aerial photo taken at a higher flow level than when the survey was performed). The date and initials of the individuals responsible for the original data entry and the data review will be recorded on the original field notes.

4. RESULTS

REACH 1: UPPER MAINSTEM GREEN RIVER

In 2005, the mainstem Green River above Howard Hanson Reservoir was surveyed from the confluence with Sunday Creek downstream to the railroad bridge just before the reservoir inundation zone at an approximate elevation of 1,147 feet. The survey was completed between the 5th of August and the 11th of August 2005. In 2006, the mainstem survey was extended in the upstream and downstream directions. The first section extended from the High Trestle Railroad Bridge downstream approximately 1.1 miles to the confluence of Sunday Creek (the upstream end of the 2005 survey). The second section began at the railroad bridge near the inundation zone (downstream end of 2005 survey) and continued downstream to Howard Hanson Reservoir. The total survey of Reach 1 covered approximately 19.2 miles. Reach 1 was subdivided into five sections as follows:

Section 1: High Trestle Railroad Bridge downstream to Sunday Creek confluence, (1.1 miles);

Section 2: Sunday Creek confluence downstream to McCain Creek, (5.0 miles);

Section 3: McCain Creek confluence downstream to Smay Creek,(4.7 miles);

Section 4: Smay Creek confluence downstream to railroad bridge at inundation, (6.9 miles);

Section 5: Inundation zone down to Howard Hanson Reservoir, (1.5 miles).

Each section was delineated according to similar habitat conditions (i.e., flow levels, channel characteristics) and identifiable landmarks that were present. Each individual habitat unit (riffle, pool, cascade or run) was assigned a unique reference number (ref #). These reference numbers correspond with the GIS information provided with this report. While each number is unique, due to the staggered progression of the survey over two years, these reference numbers are not entirely sequential. Section 1 begins with ref # 300 and continues through 317. Section 2 starts with ref # 1 and continues sequentially downstream through the rest of the river, ending at 227 at Howard Hanson Reservoir. On occasion a reference number may have been entirely omitted when QA/QC procedures were done. Individual woody debris jams were assigned an alphabetical code beginning upstream with Jam A and ending downstream with Jam BW.

Section 1: High Trestle Railroad Bridge to Sunday Creek

Section 1 was the most upstream section surveyed on the mainstem Green River (Figure 6). This section began at the High Trestle Railroad Bridge and continued downstream approximately 1.1 miles to the confluence with Sunday Creek (Figure 7). This section was surveyed on 23 August 2006, during low flow conditions. Inflow at HHD on this date was 136 cfs (USACE 2007). Water temperature at the time of the survey was 13ºC. From the steep headwaters above, the valley floor in this reach becomes increasingly broad and flat (Williams et al. 1975). The habitat in this section is primarily long riffles (75.7% by area) interspersed with shorter pool units (22.2%), and some run habitat (2.2%) (Table 1). Eight individual pools were identified in this section (Appendix A). Average residual pool depth was 2.4 feet, reflecting the low stream flow present during the survey. Woody debris was the dominant pool forming factor accounting for 75 percent of all pools formed. The amount of woody debris per mile was greater in this section than in any of the Green River surveyed downstream, however, the number key pieces per mile was low (0.9) (Table 2). There were seven jams identified (6.3 per mile) in Section 1 (Appendix B). Jams A and F were pool forming factors for pool reference unit #s 302 and 308 respectively.

One wetted side channel was present in this survey; other side channels were dry at the time of the survey. This side channel began at Jam E (Figure 7). The wetted side channel contained less than 5 percent of the streamflow, and was intermittently not flowing along its length. Two pebble counts were performed in Section 1 (Appendix B). The measured sediments were predominantly large gravel, with an average D50 of 81.2 mm.

Figure 6. Section 1 of the upper Green River mainstem habitat survey, King County, Washington, 2006.

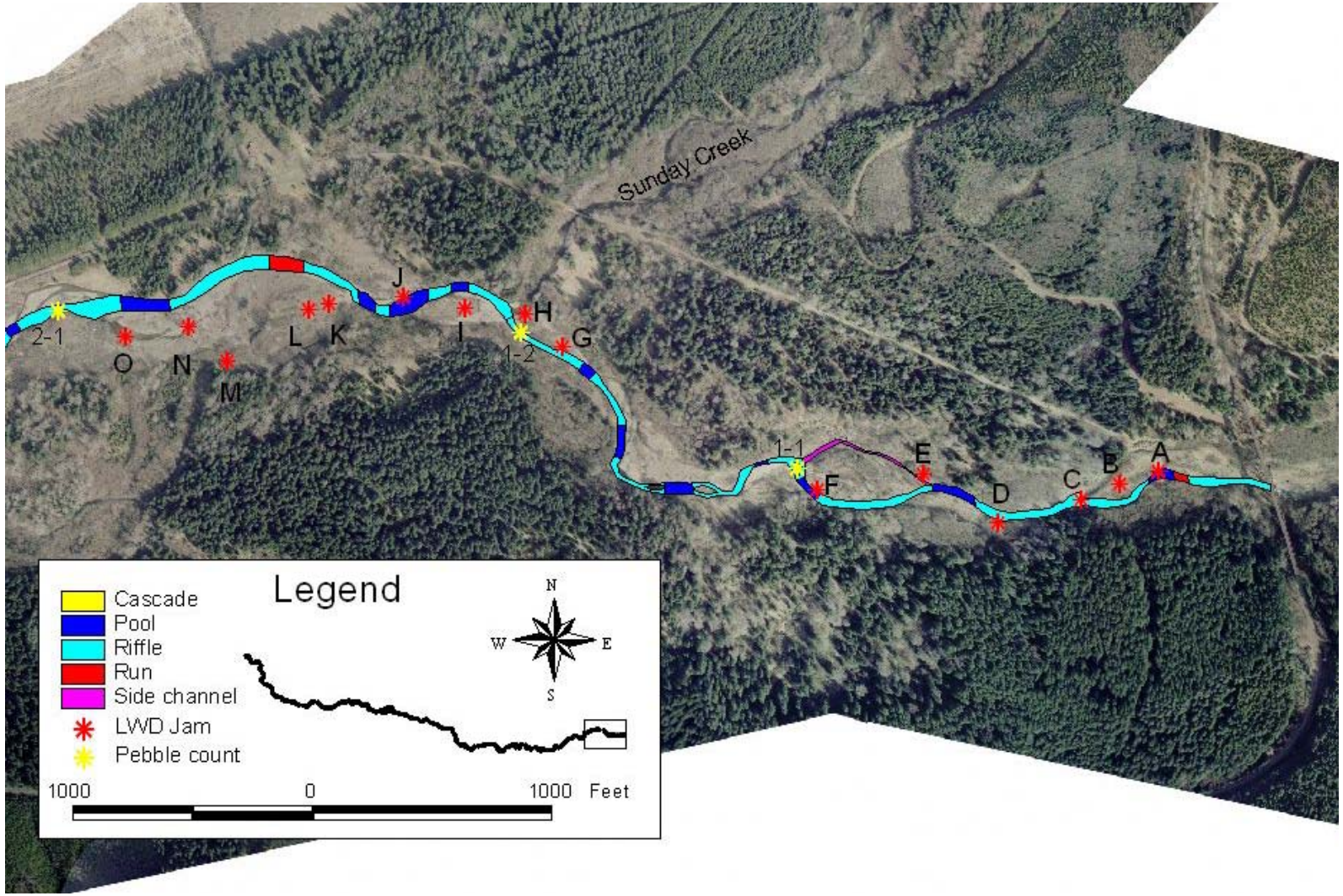

Figure 7. Section 1 and upstream start of Section 2, Upper Green River, King County, Washington, 2005.

Table 1. Summary data for Section 1 of the 2006 Upper Green River habitat survey, King County, Washington.

Section 1	
Length (feet)	5,834.7
Average bankfull width (feet)	1,074
Average wetted width (feet)	26.7
Pool Frequency (channel widths / pool)	27.3
Percent pool by length	19.8%
Percent pool by area	22.2%
Average residual pool depth (feet)	2.4
Dominant pool forming factor	Wood
% Pools formed by LWD	75.0%
Total Woody Debris (not including jams)	87
WD frequency (pieces / channel width)	0.4
WD / mile	78.7
Total # Key pieces zone 1	1
Total # Key pieces zone 2	0
Key frequency (pieces / mile)	0.9
Total # Jams zones 1 and 2	7
Average D 16	30.8
Average D 50	81.2
Average D 84	160.3
Average shade	21.9%

Table 2. Total woody debris in Section 1 of the upper Green River, King County, Washington, 2006.

Section 1	**Zone 1**	**Zone 2**
Log - Medium	5	9
Log - Medium with Rootwad	3	15
Log - Large	3	8
Log - Large with Rootwad	2	5
Key piece	1	0
Key piece with Rootwad	0	0
Rootwad	8	28
Small Jam	3	2
Medium Jam	2	0
Large Jam	0	0
TOTAL Woody Debris	*22*	*65*
TOTAL Jams	*5*	*2*

Section 2: Sunday Creek to McCain Creek

Section 2 began consecutively downstream to Section 1 at the mouth of Sunday Creek. This section was surveyed during summer low flow conditions on 9 and 10 August 2005 (Figure 8). Average inflow discharge at HHD for these dates was 176 cfs (USACE 2007). Sunday Creek is a major tributary to the Green River, substantially increasing stream flow at this point. This section is 5.0 miles in length, ending at the mouth of McCain Creek (RM 79.7) (Figures 8, 9 and 10). Section 1 is an unconfined floodplain channel that meanders through a wide valley with some highly braided areas (Figure 8). The channel primarily alternated between pool and riffle habitat. The dominant habitat type was riffle, comprising 47.7 percent of the habitat area. The next most common habitat type was pool, comprising 43.9 percent by area (Table 3). Run units were also present (8.5 percent). Average wetted width nearly doubled over the upstream Section 1 to 60.6 feet.

One recently abandoned major side channel (dry) was identified starting at the site of Jam R (Figure 9). Only two side channel complexes with flowing water were present in this reach. The first began just upstream of Jam Z, (ref # 52). This side channel was a highly braided reach between the railroad tracks (north side) and the mainstem river (south side) with much beaver activity and ponds. Flow through this side channel complex was estimated at 10-20 percent of the mainstem flow. The second flowing side channel began just upstream Jam AL, and is a small side channel on the south side of the mainstem channel. This channel contained less than 5 percent of the mainstem flow. Any other side channels did not contain flowing water at the time of the survey.

Section 2 had 43 individual pools identified, and the greatest percentage of pool habitat by area or length of the sections surveyed in the Green River (Appendix A). The primary pool forming factor was wood (51.2%) (Table 3). The total woody debris pieces per mile, 66.9, was lower than in Section 1 upstream, but more than twice as high as the downstream sections of the Green River. Section 2 contained many more key sized pieces of woody debris; 14.4 per mile, the greatest of all the sections surveyed (Table 4). Jam AA was a very large jam readily identifiable on the aerial photo (Figure 10). A total of six pebble counts were performed in this section (Appendix B). The mean D50 of all surveys was 66.4mm. This was the smallest average D50 particle size for all sections surveyed.

Figure 8. Section 2 of the upper Green River mainstem habitat survey, King County, Washington, 2006.

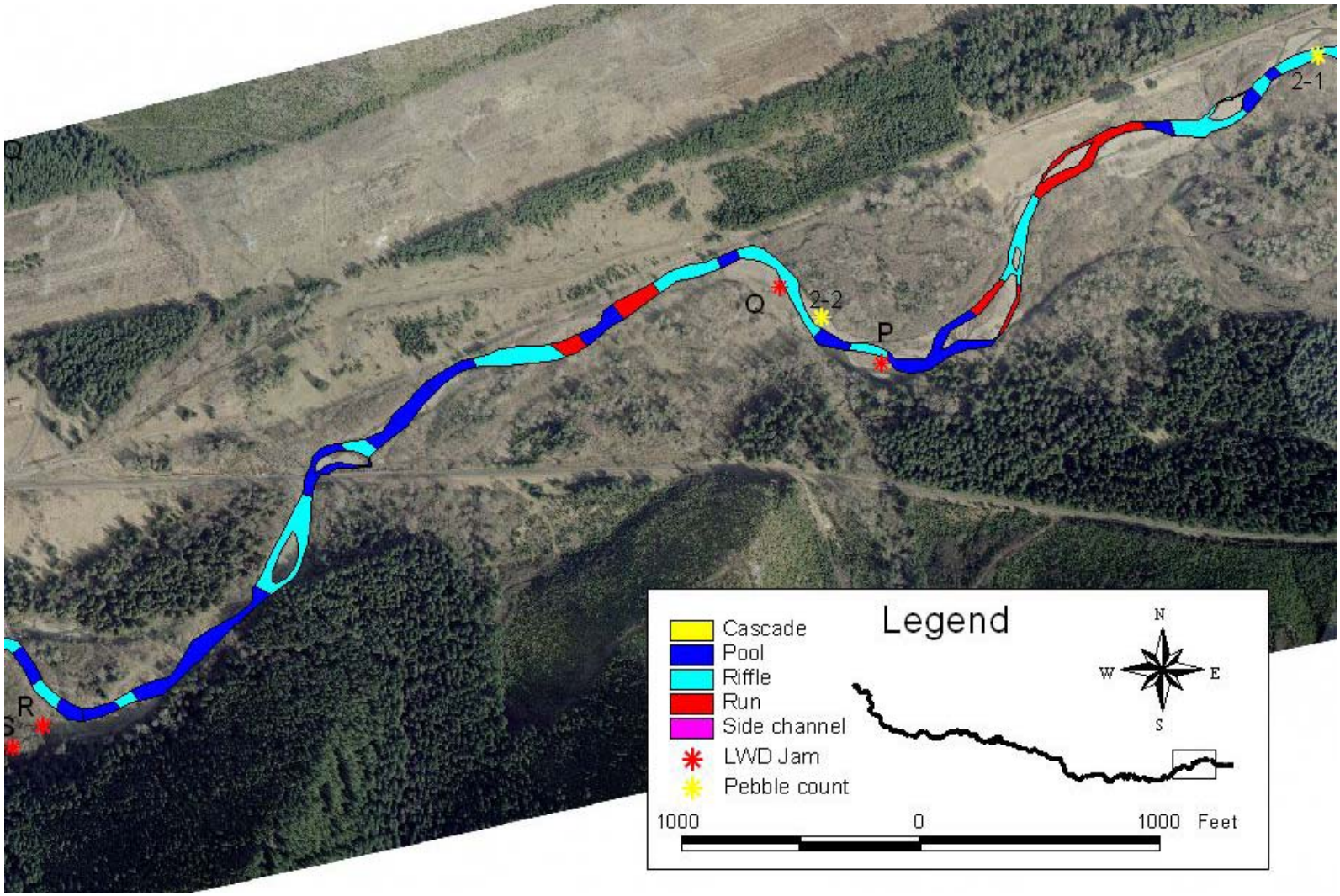

Figure 9. Middle of Section 2, Upper Green River, King County, Washington, 2005.

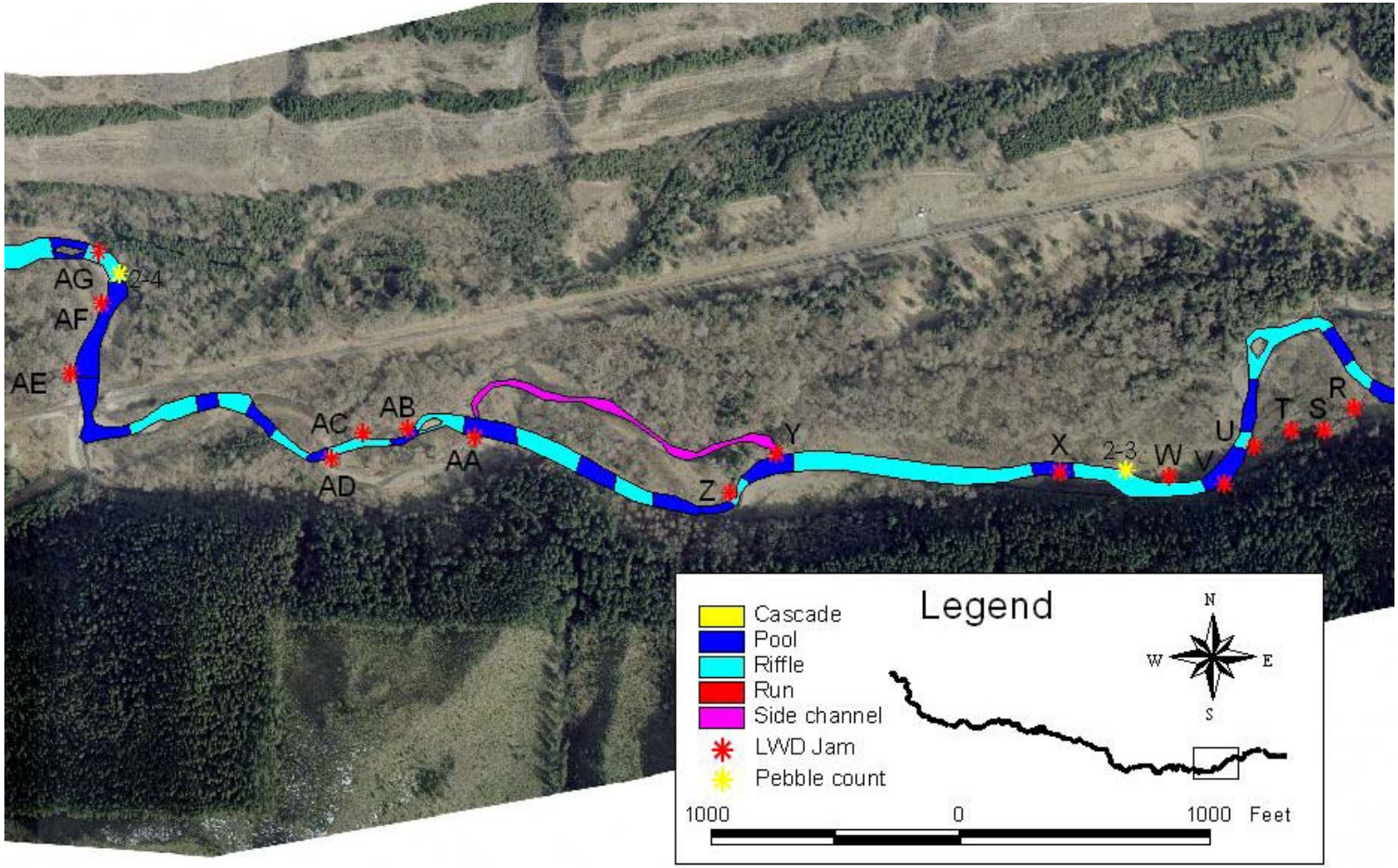

Figure 10. Downstream portion of Section 2, Upper Green River, King County, Washington, 2005.

Table 3. Summary data for Section 2 of the 2005/2006 Upper Green River habitat survey, King County, Washington.

Section 2	
Length (feet)	26,355.0
Average bankfull width (feet)	626.7
Average wetted width (feet)	60.6
Pool Frequency (channel widths / pool)	10.1
Percent pool by length	42.1%
Percent pool by area	43.9%
Average residual pool depth (feet)	3.3
Dominant pool forming factor	Wood
% Pools formed by LWD	51.2%
Total Woody Debris (not including jams)	334
WD frequency (pieces / channel width)	0.8
WD / mile	66.9
Total # Key pieces zone 1	11
Total # Key pieces zone 2	61
Key frequency (pieces / mile)	14.4
Total # Jams zones 1 and 2	32
Average D 16	29.1
Average D 50	66.4
Average D 84	133.9
Average shade	19.0%

Table 4. Total woody debris in Section 2 of the upper Green River, King County, Washington, 2005/2006.

Section 2	**Zone 1**	**Zone 2**
Log - Medium	13	45
Log - Medium with Rootwad	2	37
Log - Large	11	55
Log - Large with Rootwad	9	32
Key piece	2	21
Key piece with Rootwad	9	40
Rootwad	21	40
Small Jam	4	12
Medium Jam	3	8
Large Jam	2	3
TOTAL Woody Debris	*67*	*270*
TOTAL Jams	*9*	*23*

Section 3: McCain Creek to Smay Creek

Section 3 began immediately downstream of Section 2, beginning from the mouth of McCain Creek and extending to the mouth of Smay Creek (RM 75.3). This reach was surveyed on 10 and 11 August 2005 and encompassed 4.7 miles (Figures 13-15; 17). Average inflow discharge at HHD for these dates was 174 cfs (USACE 2007). Initially, Section 3 was increasingly confined with bedrock formations and some cascade units opening up to include slower run units at the downstream end (Figure 11). Overall, riffle units comprised 67.7 percent of the habitat by area. Pool, run and cascade units were 18.0, 12.3, and 1.9 percent respectively (Table 5). Section 3 had the lowest percentage of pool habitat area of the all the sections surveyed in the Green River. The dominant pool forming factor was bedrock (60%). No pools were formed by woody debris in Section 3. Average shade measured 27.5%, the highest for all sections surveyed. This is an indication of the confined non-braided channel present in this section.

No side channels containing flowing water were observed during this survey. Side channels beginning at Jams AE and AF were highly braided with intermittent flow and ponded water. This was a complex area containing many branching channels. Jam AM was located at the head of a side channel that was dry in the upstream half and contained ponded water in the downstream half at the time of the survey. One large forested island is present near Champion Creek at Jam AQ, flow was approximately equal on both sides (north and south) of the island (Figure 14). A smaller forested island was present near jam AS.

The initial bedrock reach (approximately 4,500 feet) contained very different habitat conditions from the other stream sections (Figure 12). This portion of the channel was straight, confined and contained little gravel substrates. Very little woody debris was present in the bedrock reach. An old man-made bridge abutment contains woody debris near the entrance of Rock Creek. This jam consisted of twelve key pieces that were not included in woody debris totals. Six pebble counts were completed in Section 3. The average D50 was 89.3mm (Appendix B).

Figure 11. Section 3 of the upper mainstem Green River habitat survey, King County, Washington, 2005.

Figure 12. Bedrock reach of Section 3, upper mainstem Green River habitat surveys, King County, Washington, 2005.

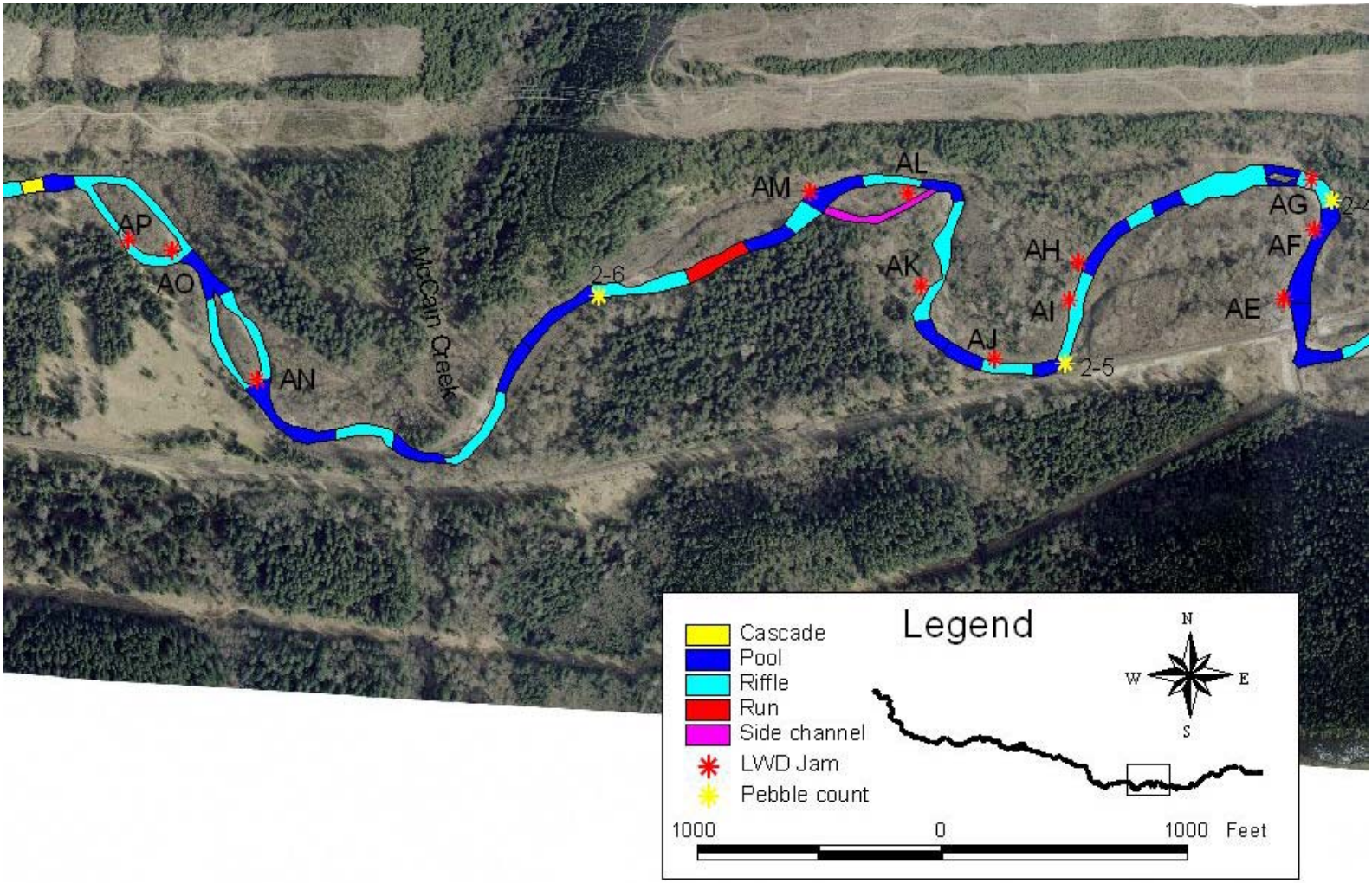

Figure 13. Downstream end of Section 2, start of Section 3, Upper Green River, King County, Washington, 2006.

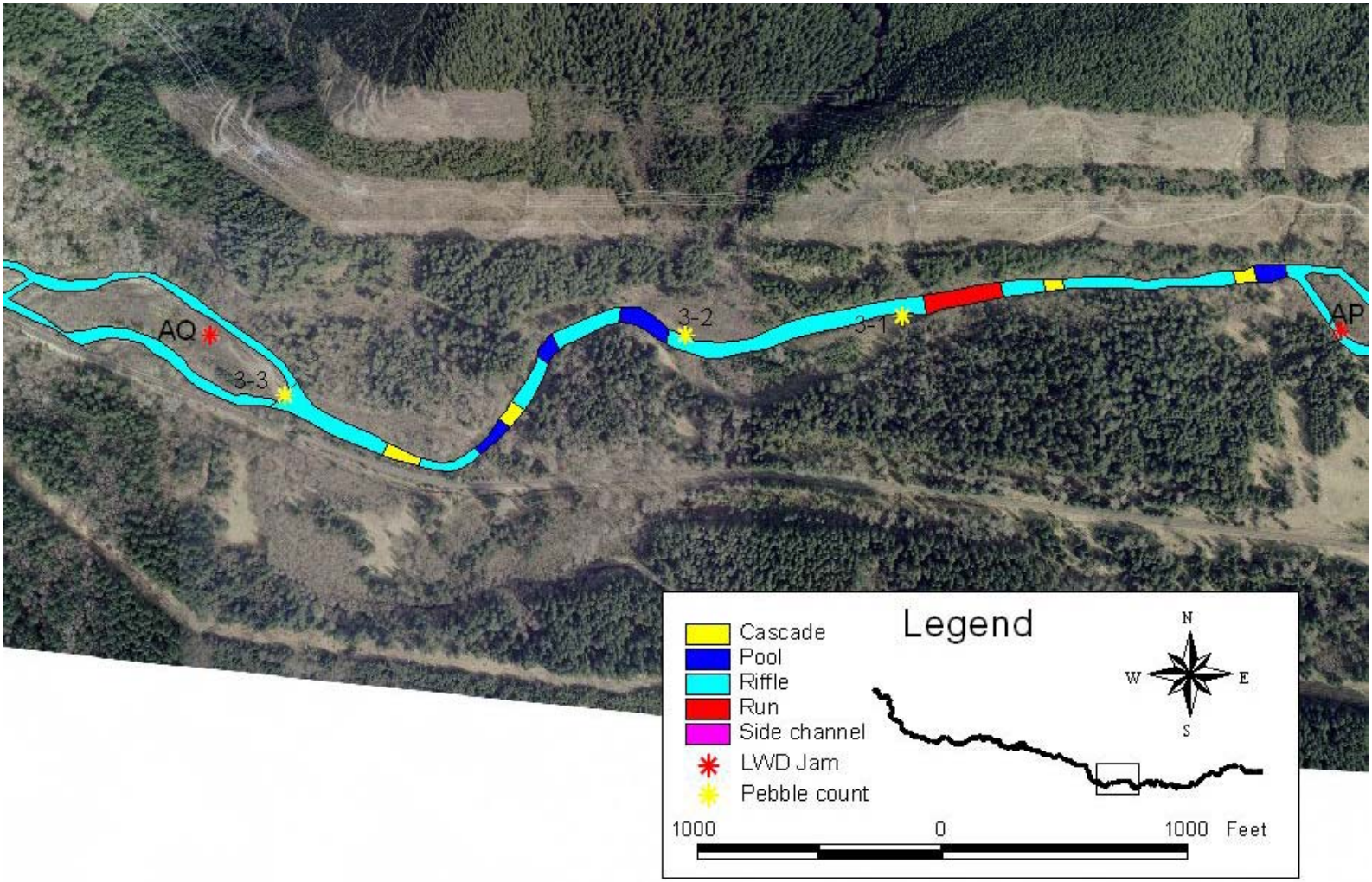

Figure 14. Upstream middle Section 3, Upper Green River, King County, Washington, 2006.

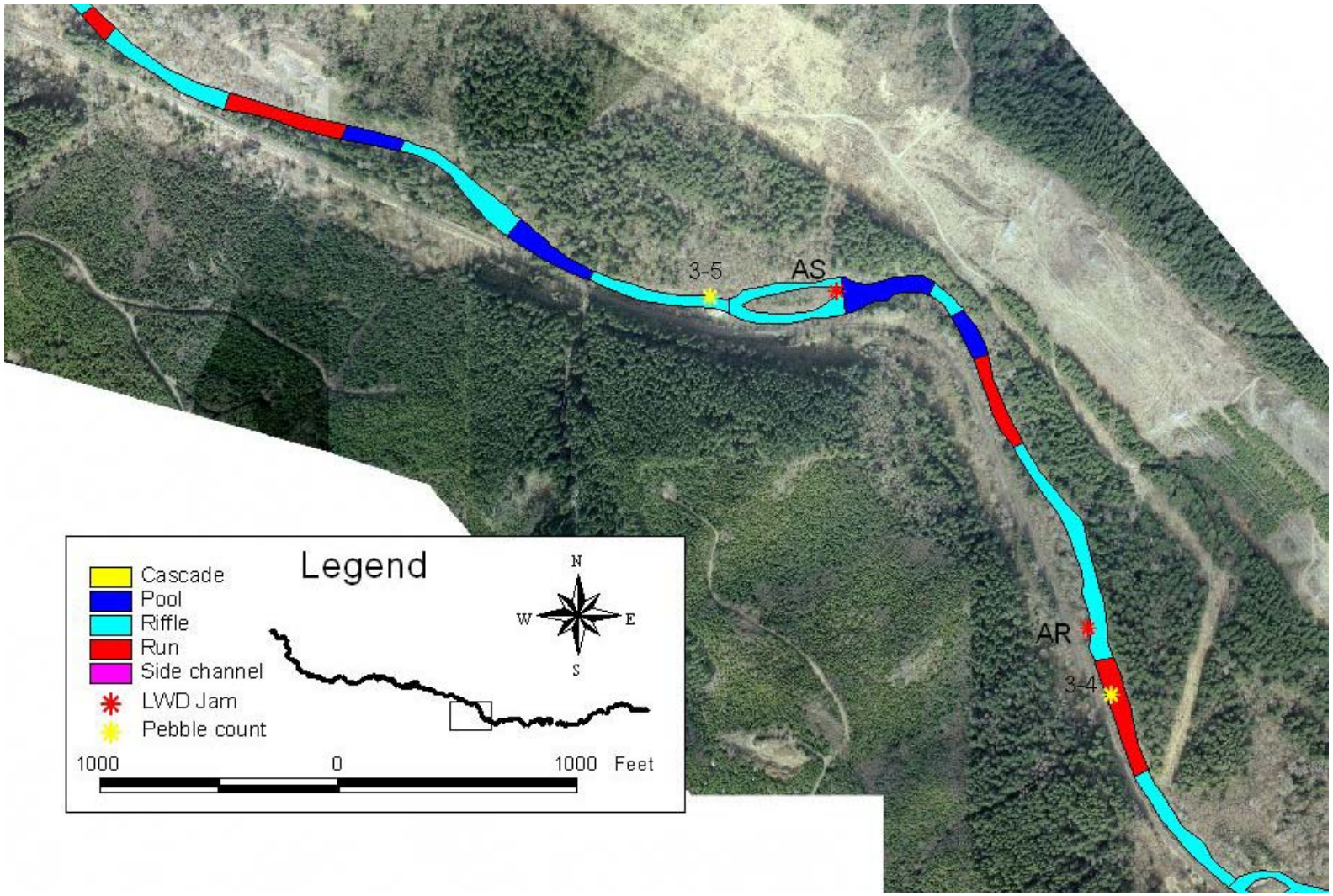

Figure 15. Lower middle Section 3, Upper Green River, King County, Washington, 2006.

Table 5. Summary data for Section 3 of the 2005/2006 Upper Green River habitat survey, King County, Washington.

Section 3	
Length (feet)	24,918.0
Average bankfull width (feet)	Extreme width, not measured
Average wetted width (feet)	75.6
Pool Frequency (channel widths / pool)	22.0
Percent pool by length	19.5%
Percent pool by area	18.0%
Average residual pool depth (feet)	4.4
Dominant pool forming factor	Bedrock
% Pools formed by LWD	0.0%
Total Woody Debris (not including jams)	144
WD frequency (pieces / channel width)	0.4
WD / mile	30.5
Total # Key pieces zone 1	15
Total # Key pieces zone 2	30
Key frequency (pieces / mile)	9.5
Total # Jams zones 1 and 2	8
Average D 16	28.9
Average D 50	89.3
Average D 84	227.6
Average shade	27.5%

Table 6. Total woody debris in Section 3 of the upper Green River, King County, Washington, 2005/2006.

Section 3	**Zone 1**	**Zone 2**
Log - Medium	2	32
Log - Medium with Rootwad	3	16
Log – Large	1	16
Log – Large with Rootwad	0	2
Key piece	13	21
Key piece with Rootwad	2	9
Rootwad	13	14
Small Jam	1	5
Medium Jam	0	1
Large Jam	0	1
TOTAL Woody Debris	*34*	*110*
TOTAL Jams	*1*	*7*

Section 4: Smay Creek to Railroad Bridge at Start of Inundation Zone

Section 4 extends from Smay Creek 6.9 miles downstream to the start of the inundation zone at the railroad bridge (Figures 17-21). This section was surveyed between 5 and 8 August 2005. Average inflow discharge at HHD for these dates was 184 cfs (USACE 2007). The channel in this section is increasingly wide, with mature riparian bank vegetation (Figure 16). The stream channel is confined in some locations by the railroad tracks and road present on either bank.

Section 4 habitat is primarily riffle (59.8%), alternating with pool (19.5%) and run (19.4%). Pools in this section were predominantly mid-channel scour pools formed by existing bedform. Only 7.7% of pools were formed by woody debris (Table 7).

One major side channel is present in this reach, starting immediately downstream from the engineered log jam site of Maywood (Jam AV). An estimated 30 percent of the streamflow was in the side channel at the time of the survey. Jams AX, AY, AZ, BA, BB and BC were located in this side channel. Jam AV was an engineered log jam artificially placed in the stream channel. In addition to Jam AV, 25 other naturally occurring jams were located in Section 4 (Table 8). Ten pebble counts were measured in this Section. Average D50 measured 85.0 mm (Appendix B).

Figure 16. Section 4 of the upper mainstem Green River habitat survey, King County, Washington, 2005.

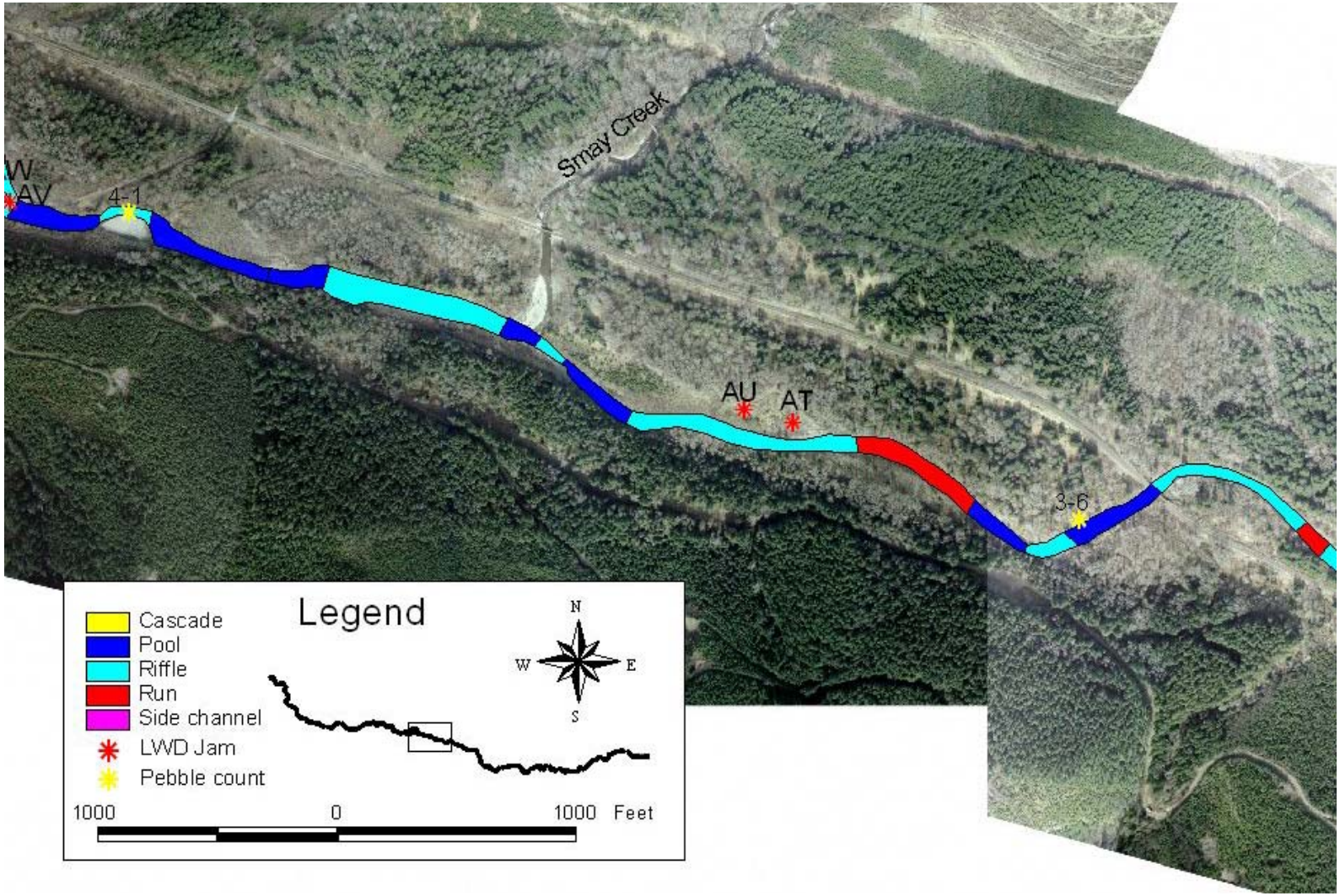

Figure 17. Downstream portion of Section 3, start of Section 4, Upper Green River, King County, Washington, 2006.

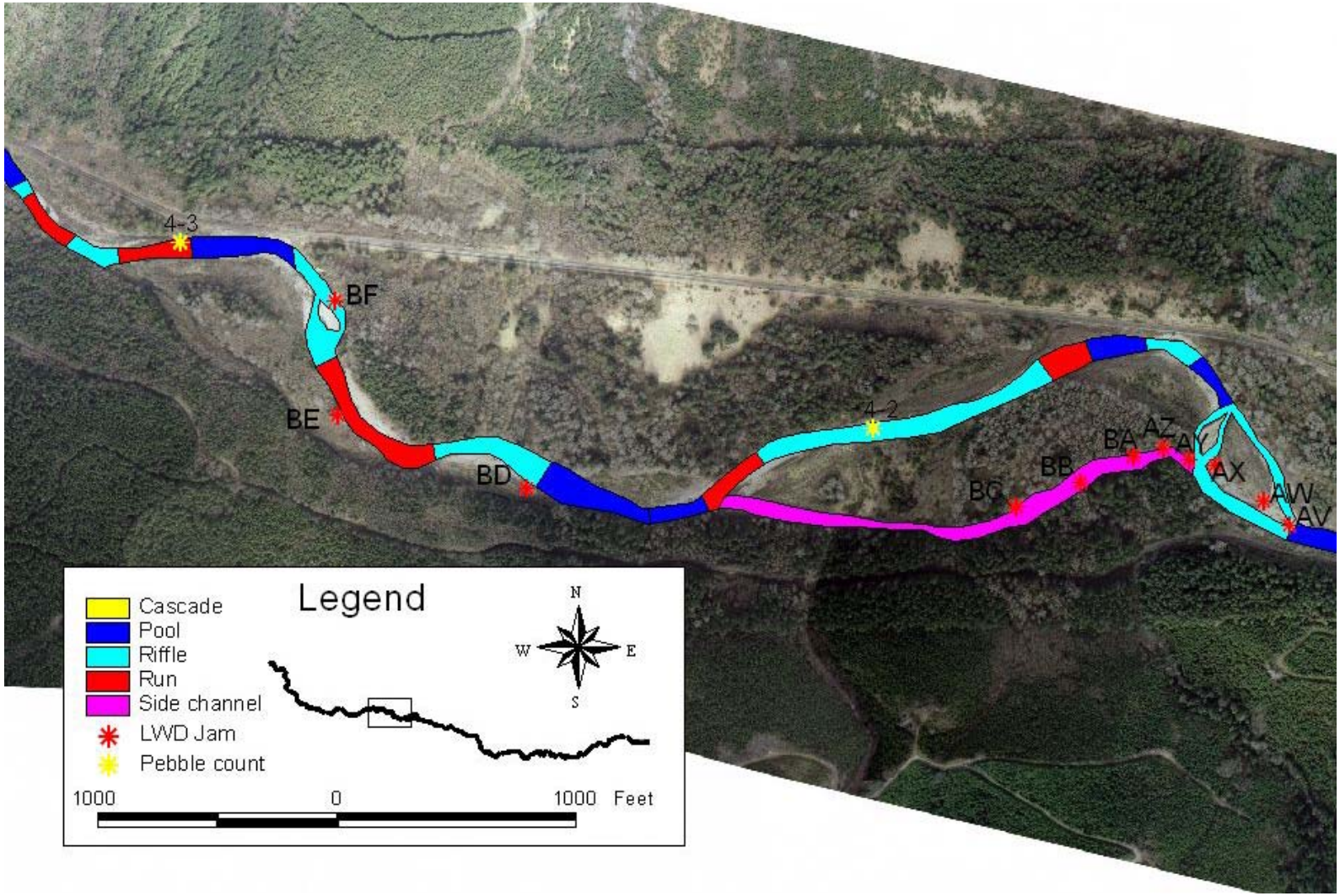

Figure 18. Upstream portion of Section 4, Upper Green River, King County, Washington, 2006.

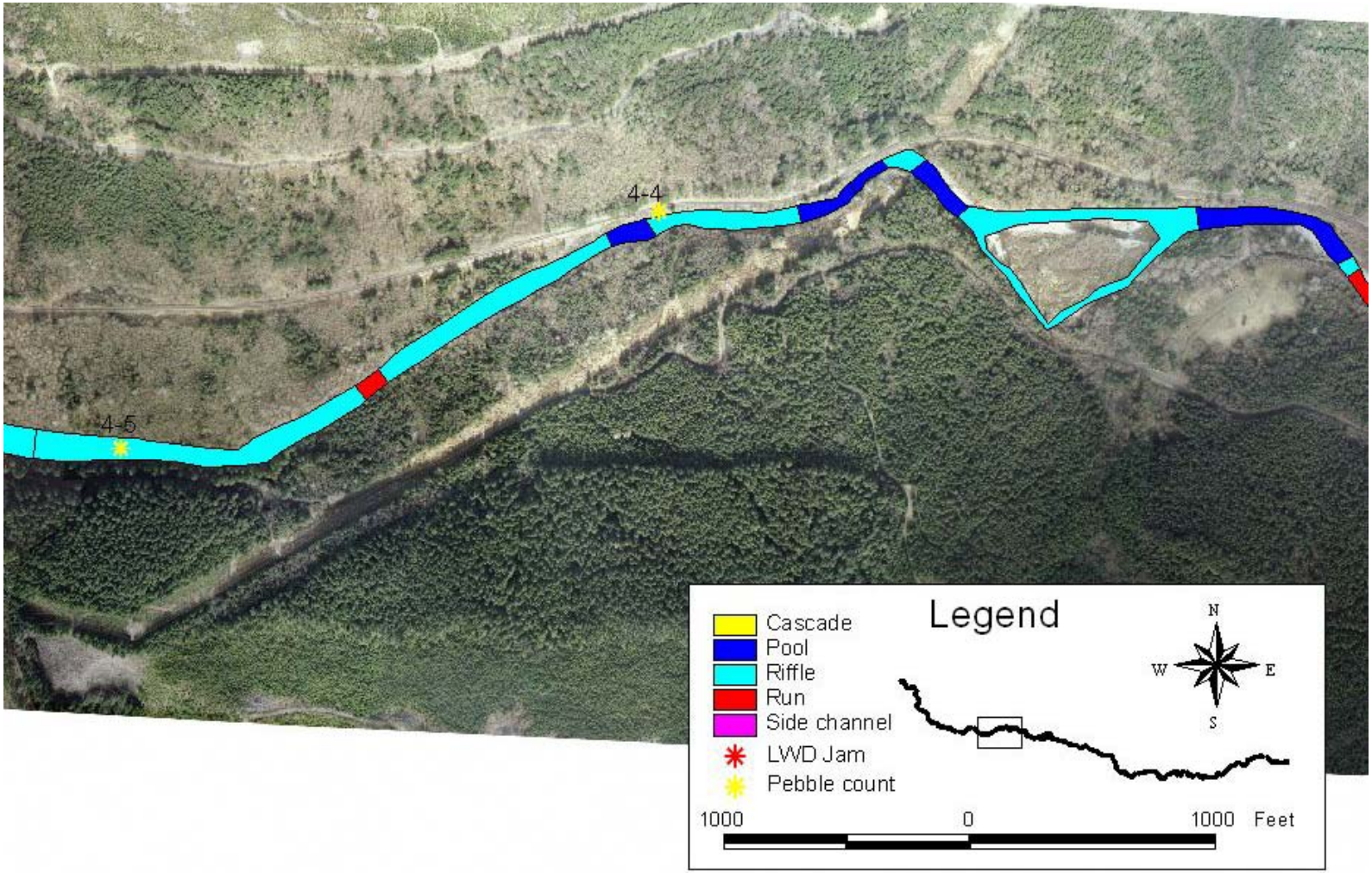

Figure 19. Upper middle of Section 4, Upper Green River, King County, Washington, 2006.

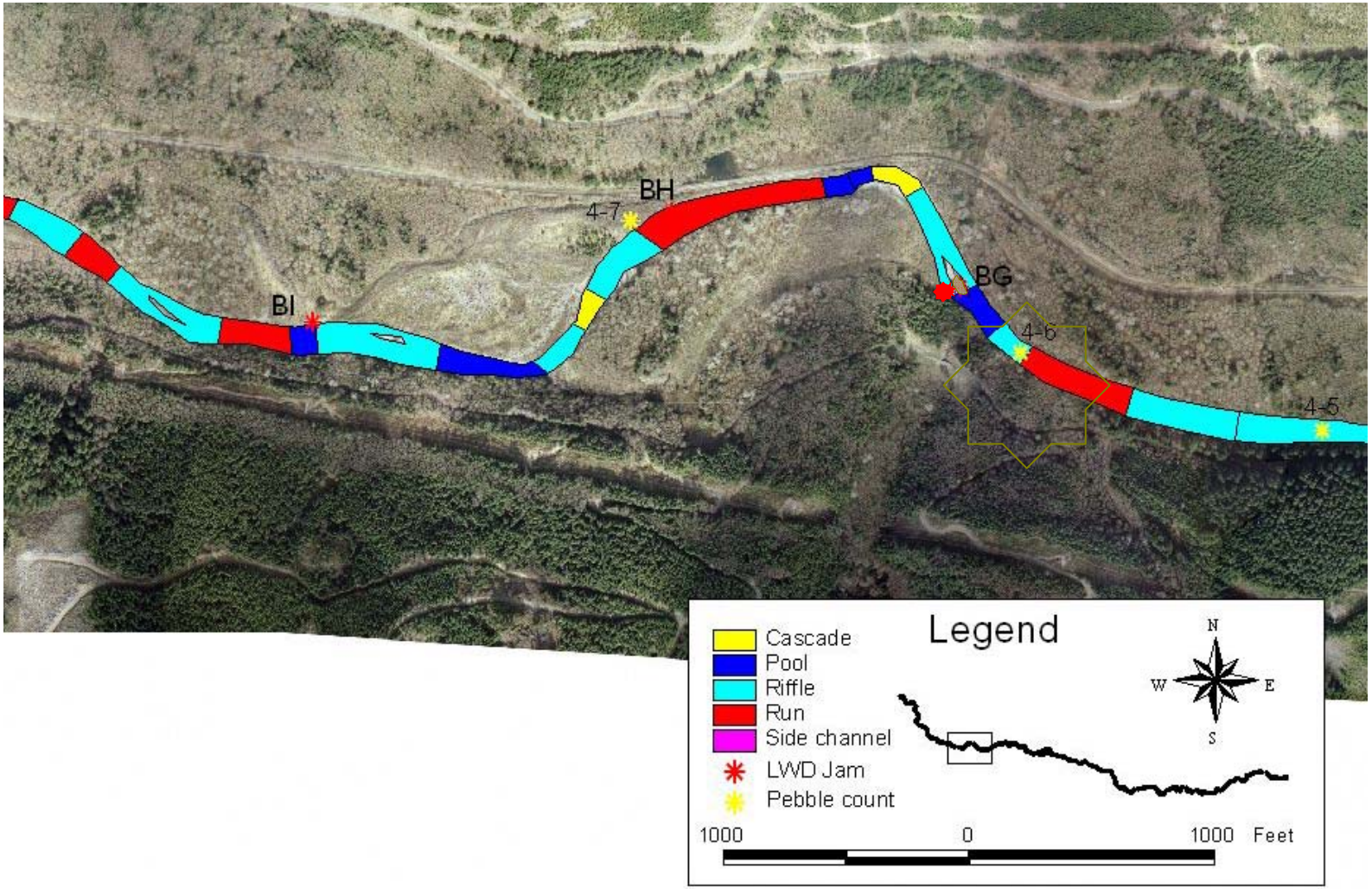

Figure 20. Lower middle of Section 4, Upper Green River, King County, Washington, 2006.

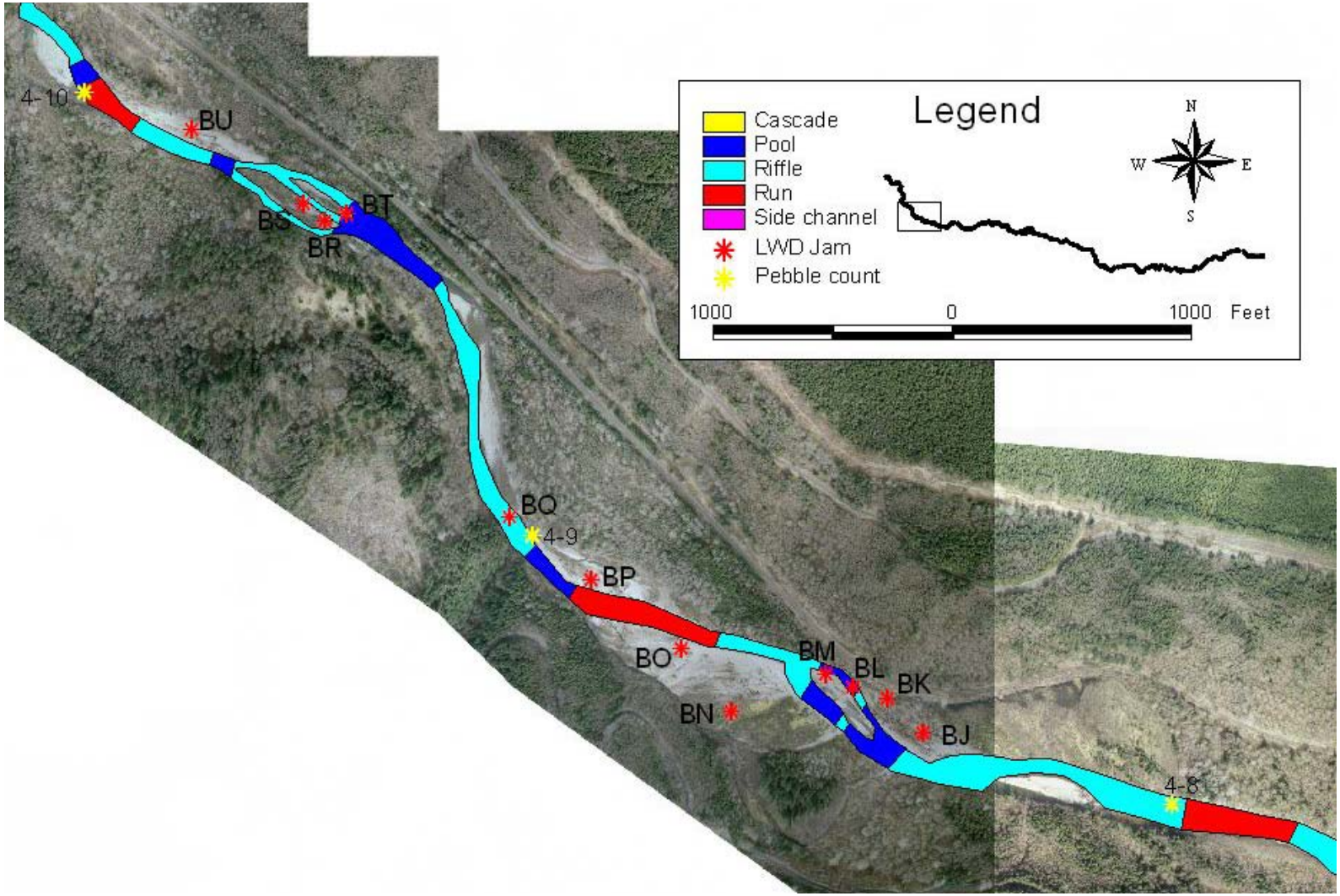

Figure 21. Downstream Section 4, Upper Green River, King County, Washington, 2006.

Table 7. Summary data for Section 4 of the 2006 Upper Green River habitat survey, King County, Washington.

Section 4	
Length (feet)	36,652.8
Average bankfull width (feet)	984
Average wetted width (feet)	89.4
Pool Frequency (channel widths / pool)	15.8
Percent pool by length	25.4%
Percent pool by area	19.5%
Average residual pool depth (feet)	4.8
Dominant pool forming factor	Bedform
% Pools formed by LWD	7.7%
Total Woody Debris (not including jams)	302
WD frequency (pieces / channel width)	0.7
WD / mile	41.3
Total # Key pieces zone 1	12
Total # Key pieces zone 2	63
Key frequency (pieces / mile)	10.5
Total # Jams zones 1 and 2	26
Average D 16	36.8
Average D 50	85.0
Average D 84	171.3
Average shade	15.0%

Table 8. Total woody debris in Section 4 of the upper Green River, King County, Washington, 2006.

Section 4	**Zone 1**	**Zone 2**
Log - Medium	11	63
Log - Medium with Rootwad	3	42
Log - Large	3	31
Log - Large with Rootwad	6	19
Key piece	3	25
Key piece with Rootwad	9	38
Rootwad	2	47
Small Jam	6	18
Medium Jam	1	1
Large Jam	0	0
TOTAL Woody Debris	*37*	*265*
TOTAL Jams	*7*	*19*

* total includes one engineered log jam, artificially placed

Section 5: Inundation Zone to Reservoir

Section 5 is the downstream most survey section (Figure 24). This section began consecutive to the end of Section 4 and extended approximately 1.5 miles downstream to Howard Hanson Reservoir. This section was surveyed on 15 September 2006. Average inflow discharge at HHD for this date was 154 cfs (USACE 2007). This reach is a broad floodplain that is periodically inundated by reservoir operations (Figures 22 and 23). No major tributaries enter the mainstem in this reach. Average wetted width of Section 5 was similar to that of Section 4 (92.4 and 89.4 feet respectively) (Table 9).

Unlike upstream survey sections, the dominant habitat type, as measured by area, in Section 5 was run (45.1%). Other habitat types included: 33.3% riffle and 21.6% pool, no cascades were present in this section. Three pools were identified in Section 5, each with a different formation factor (Appendix A). Only one of the three was formed by woody debris (a tree). Woody debris per mile ratio was lowest of all sections surveyed, measuring 20.7 pieces per mile (Table 9). Two jams were present, one of which was a man-made revetment (Jam BV). Near the reservoir was an area of large logs and rootwads (about 20) that had been previously placed and are now covered by 3 to 4 feet of sediments (Table 10). These logs did not meet the criteria for a jam. No side channels were identified in this section. Two pebble counts were taken in this section, with an average D50 of 87.5mm (Appendix B).

Figure 22. View of a pool near the downstream survey end of Section 5, upper mainstem Green River habitat surveys, King County, Washington, 2006.

Figure 23. View of Section 5 survey end at Howard Hanson Reservoir, upper mainstem Green River habitat surveys, King County, Washington, 2006.

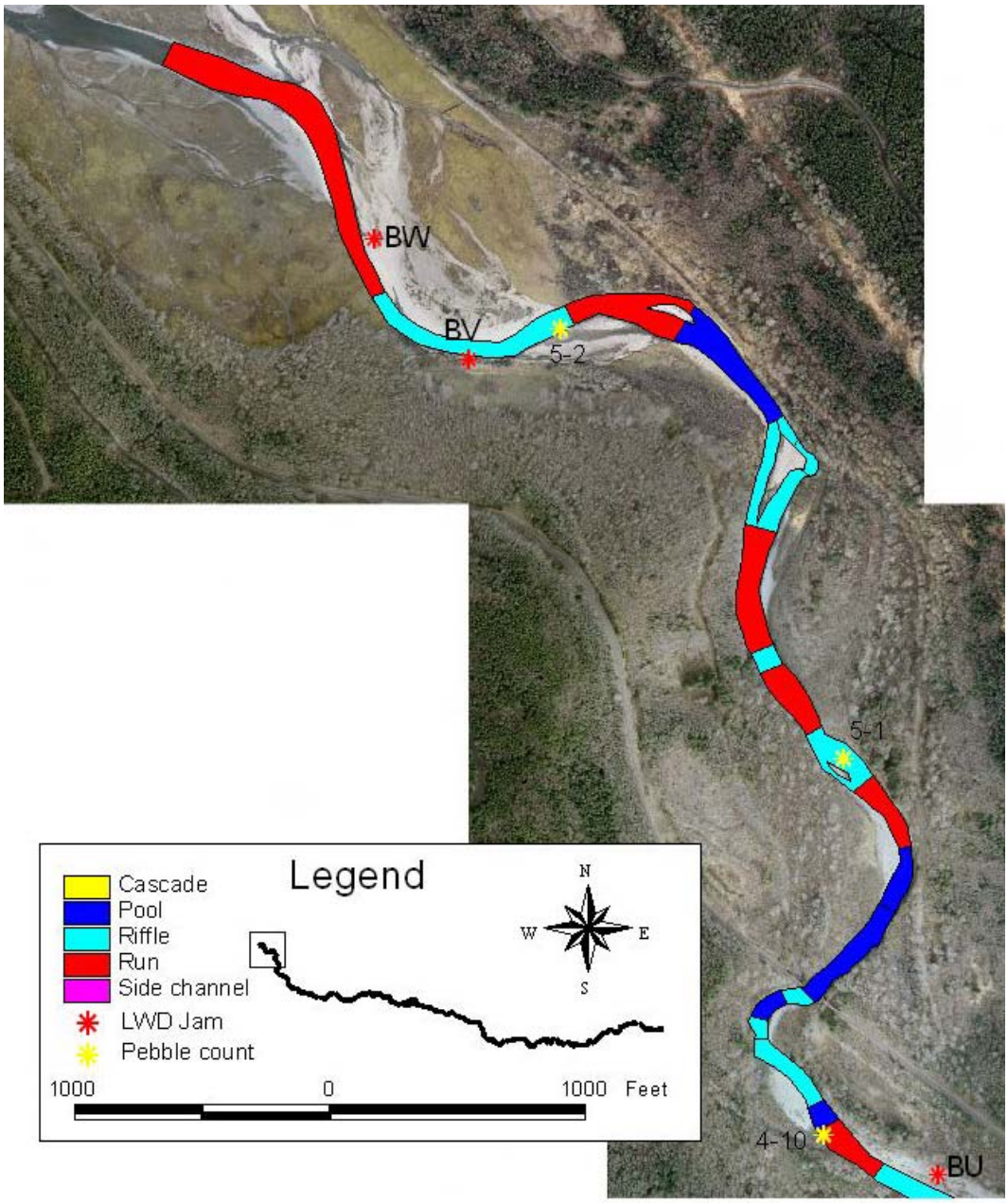

Figure 24. Section 5, Upper Green River, King County, Washington, 2006

Table 9. Summary data for Section 5 of the 2006 Upper Green River habitat survey, King County, Washington.

Section 5	
Length (feet)	7,899.9
Average bankfull width (feet)	Extreme width, not measured
Average wetted width (feet)	92.4
Pool Frequency (channel widths / pool)	28.5
Percent pool by length	20.5%
Percent pool by area	21.6%
Average residual pool depth (feet)	4.1
Dominant pool forming factor	Varied
% Pools formed by LWD	33.3%
Total Woody Debris (not including jams)	31
WD frequency (pieces / channel width)	0.4
WD / mile	20.7
Total # Key pieces zone 1	0
Total # Key pieces zone 2	4
Key frequency (pieces / mile)	2.7
Total # Jams zones 1 and 2	2
Average D 16	35.4
Average D 50	87.5
Average D 84	165.7
Average shade	15.1%

Table 10. Total woody debris in Section 5 of the upper Green River, King County, Washington, 2006.

Section 5	**Zone 1**	**Zone 2**
Log - Medium	1	0
Log - Medium with Rootwad	0	8
Log - Large	0	10
Log - Large with Rootwad	0	8
Key piece	0	4
Key piece with Rootwad	0	0
Rootwad	0	0
Small Jam	0	1
Medium Jam	1	0
Large Jam	0	0
TOTAL Woody Debris	*1*	*30*
TOTAL Jams	*1*	*1*

REACH 2: SUNDAY CREEK

The survey of Sunday Creek was performed on 23 and 24 August 2006. The survey began at the confluence of Snow and Sunday Creeks (RM 3.5), and continued southerly downstream to the Green River (Figure 25). Streamflow at the time of the survey was very low (Figure 26). Water temperature measured 10.5ºC. Sunday Creek exhibits moderate stream gradient conditions and is less mountainous than other tributaries in the area (Williams et al. 1975).

Intermittently, Sunday Creek flows directly under the Bonneville Power Association overhead transmission lines. This section of the creek has minimal mature riparian vegetation. The channel is also confined by the presence of road 54 on the west bank. Near Jam H (ref #48), Sunday Creek is highly braided with several channels becoming subsurface flow.

Approximately one half mile above the Lester Road Bridge the main flow of Sunday Creek has shifted to the channel in the east (near Jam J) leaving the other channel dry. During high flow periods, both channels most likely contain flowing water. Twenty-nine individual pools were observed in Sunday Creek. The dominant pool forming factor was wood, accounting for 34.5% of the pools. Twenty-seven jams were present in Sunday Creek (Figures 26, 27 and 28). Small pockets of spawning-sized gravel were present at approximately half of the pool units. Five pebble counts were completed in Sunday Creek (Appendix B). Measured D50 averaged 88.0 mm.

Figure 25. Sunday Creek, upper mainstem Green River habitat surveys, King County, Washington, 2006.

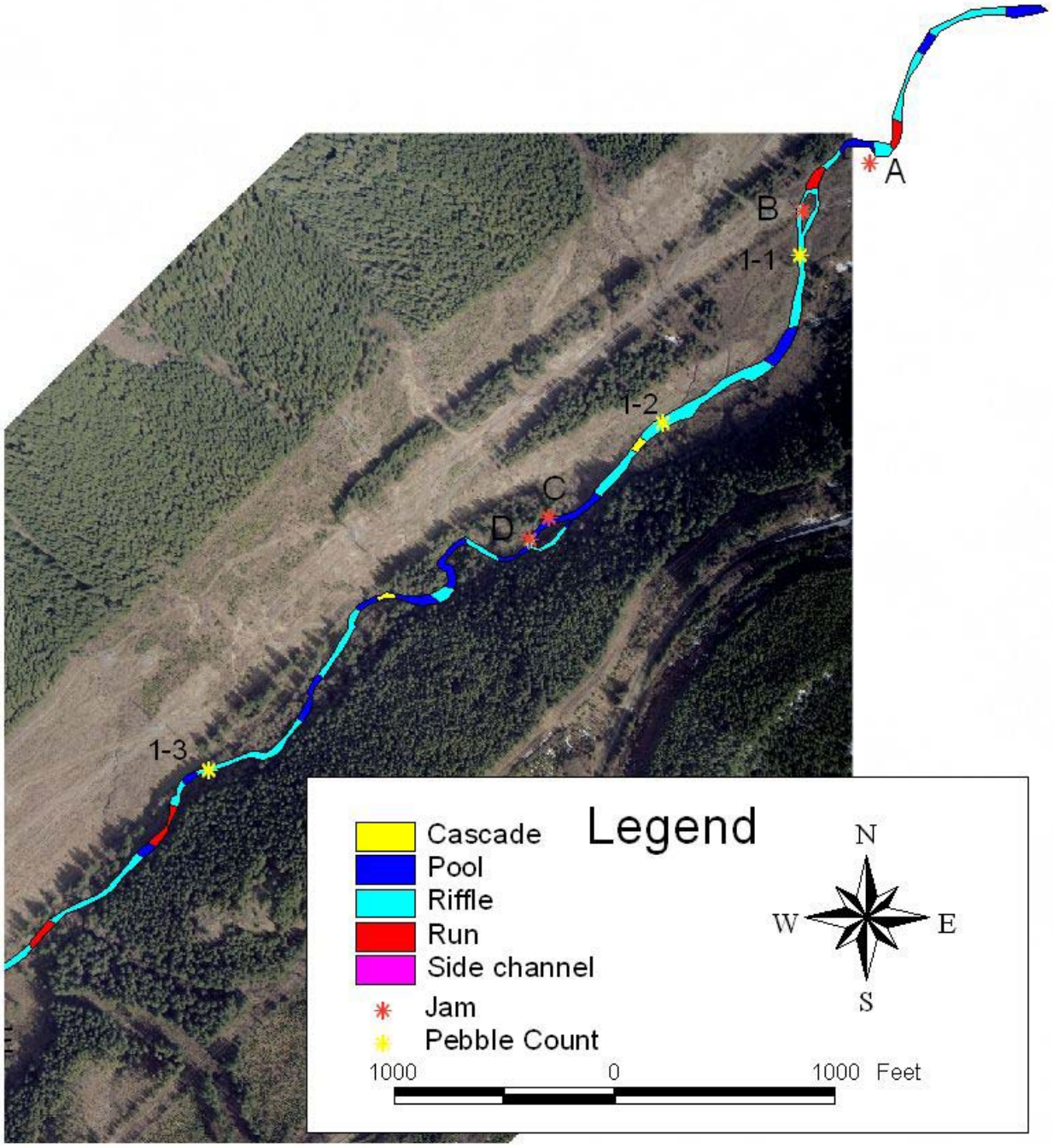

Figure 26. Upper Sunday Creek, upper mainstem Green River habitat surveys, King County, Washington, 2006.

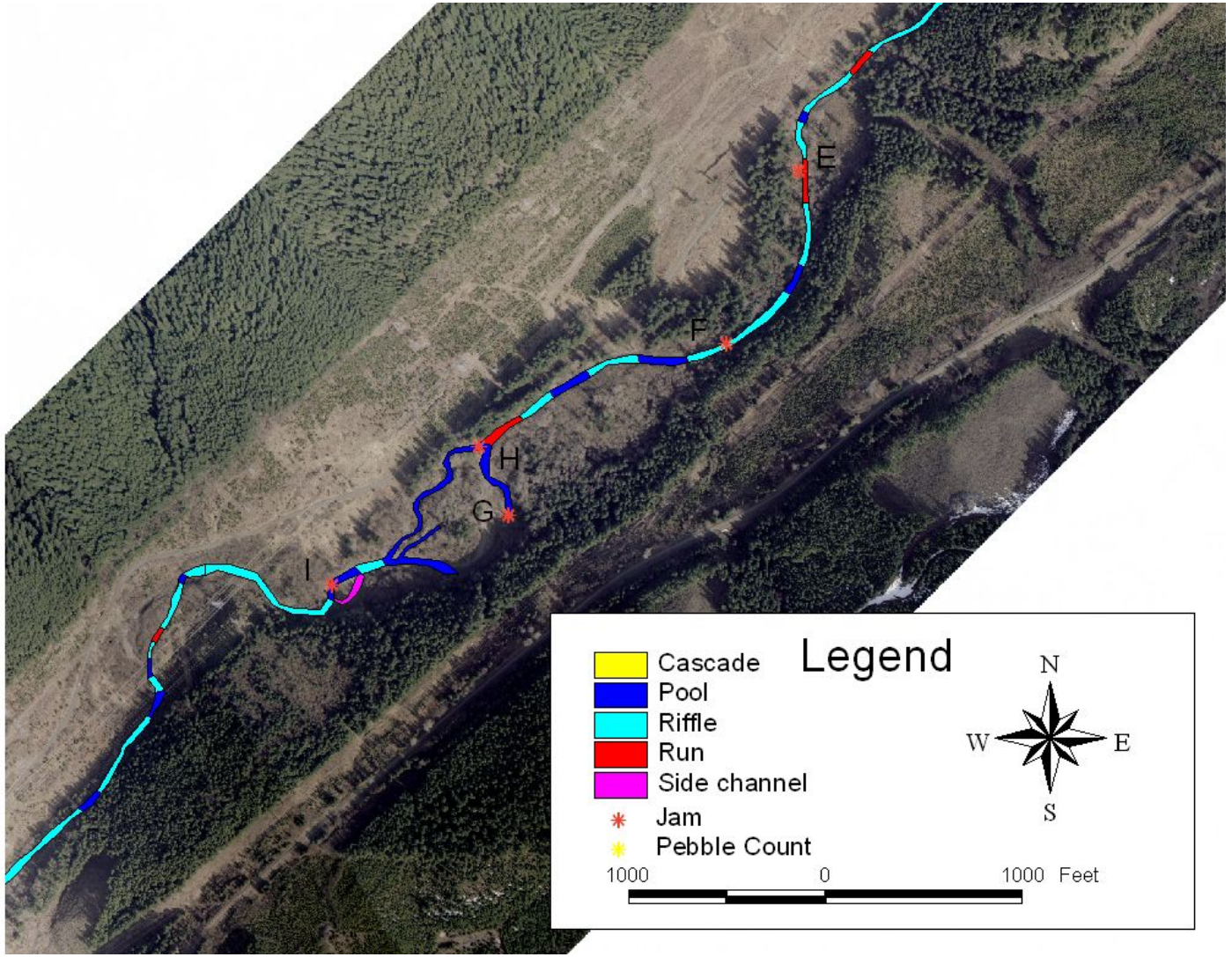

Figure 27. Middle Sunday Creek, upper mainstem Green River habitat surveys, King County, Washington, 2006.

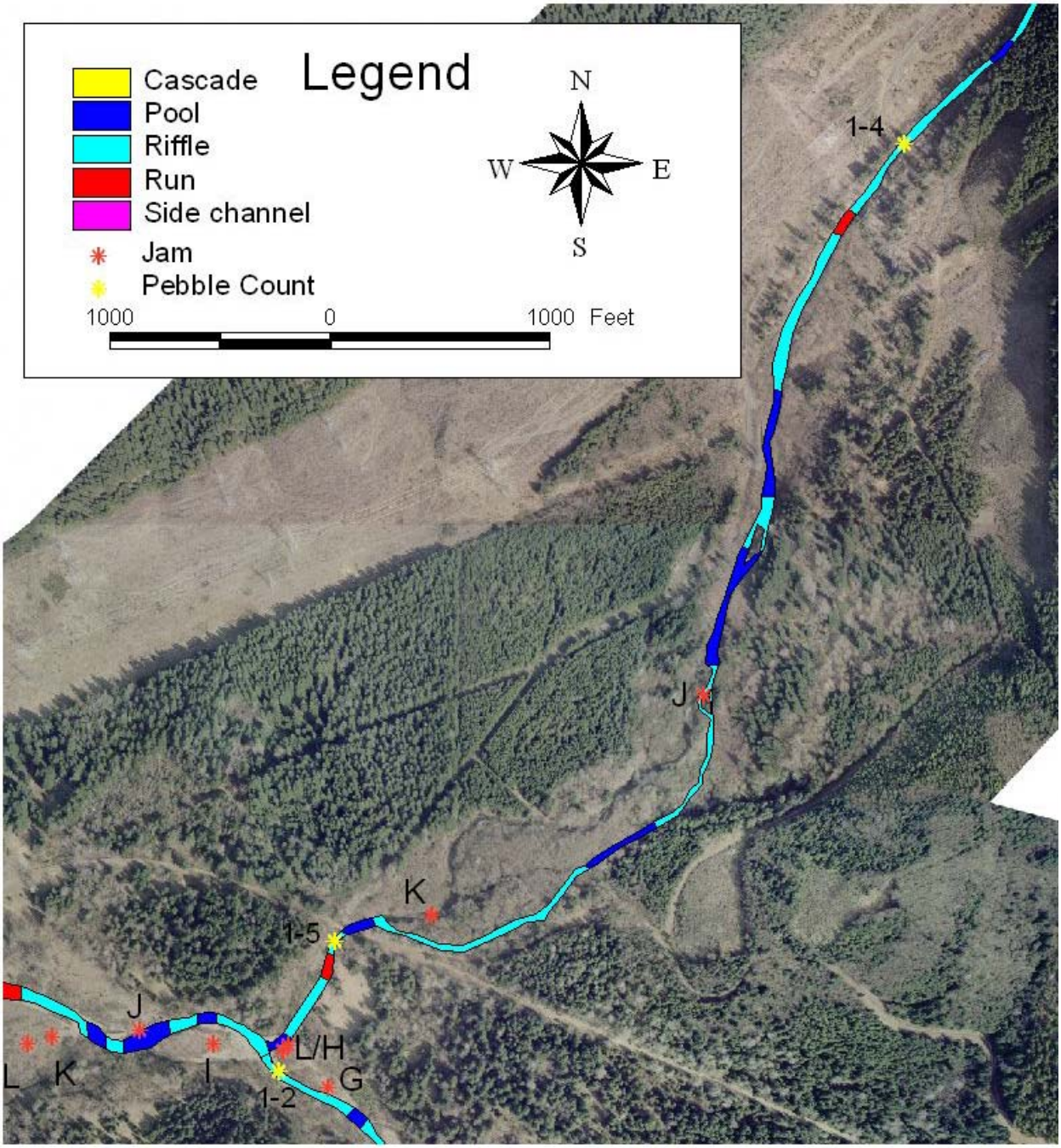

Figure 28. Lower Sunday Creek, upper mainstem Green River habitat surveys, King County, Washington, 2006.

Table 11. Summary data for 2006 Sunday Creek habitat survey, King County, Washington.

Sunday Creek	
Length (feet)	20,103
Average bankfull width (feet)	309.6
Average wetted width (feet)	33.6
Pool Frequency (channel widths / pool)	20.6
Percent pool by length	29.8%
Percent pool by area	39.1%
Average residual pool depth (feet)	2.7
Dominant pool forming factor	Wood
% Pools formed by LWD	34.5%
Total Woody Debris (not including jams)	240
WD frequency (pieces / channel width)	0.4
WD / mile	63.2
Total # Key pieces	9
Key frequency (pieces / mile)	2.4
Total # Jams	27
Average D 16	32.4
Average D 50	88
Average D 84	179.1
Average shade	57.3%

Table 12. Total woody debris in Sunday Creek, upper Green River, King County, Washington, 2005/2006.

Section 5	**Zone 1**	**Zone 2**
Log - Medium	23	46
Log - Medium with Rootwad	15	30
Log - Large	4	8
Log - Large with Rootwad	3	6
Key piece	1	2
Key piece with Rootwad	2	4
Rootwad	32	64
Small Jam	7	14
Medium Jam	1	2
Large Jam	1	2
TOTAL Woody Debris	*80*	*160*
TOTAL Jams	*9*	*18*

REACH 3: SMAY CREEK

The survey of Smay Creek began at the confluence of the West Fork and mainstem Smay Creek (RM 1.7). The survey was performed during summer low flow conditions on 22 and 23 August 2006. Water temperature at the time of the survey was 11ºC.

From the confluence of the West Fork downstream to the powerline crossing, Smay Creek has a broad floodplain with many side channels and braided channel areas (Figure 29). The stream in this section is very dynamic, however it is somewhat confined on the west bank by the road.

The powerline crossings influence Smay Creek for approximately one third of a mile just above the Lester Road Bridge. The powerlines and associated vegetation management activities are limiting mature riparian vegetation and canopy cover in this area. Below the Lester Road Bridge, Smay Creek has a broad open channel. Overall, very little spawning sized gravel substrates are available in Smay Creek.

Nineteen pools were identified in Smay Creek, nearly 85% of which were formed by woody debris (Figures 30 and 31). Total woody debris counts in Smay Creek were quite high, the density (pieces per mile) in Smay measured 138.1 versus 63.2 in Sunday Creek (Table 13). However, only 5.7 key pieces were present per mile in Smay. Six pebble counts were completed in Smay Creek (Table 14 and Appendix B).

Figure 29. Smay Creek near survey start, upper mainstem Green River habitat surveys, King County, Washington, 2006.

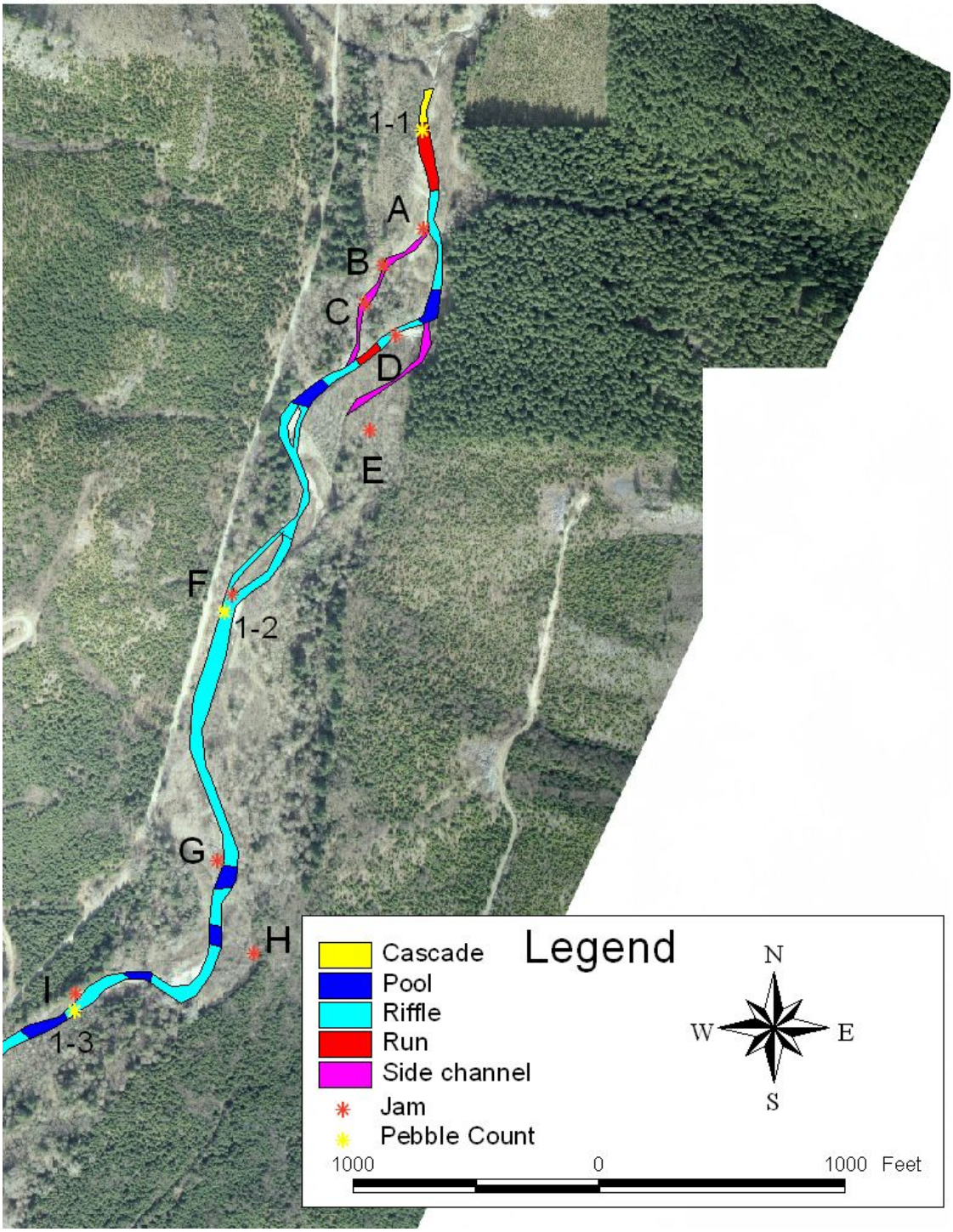

Figure 30. Upstream half of Smay Creek, upper mainstem Green River habitat surveys, King County, Washington, 2006.

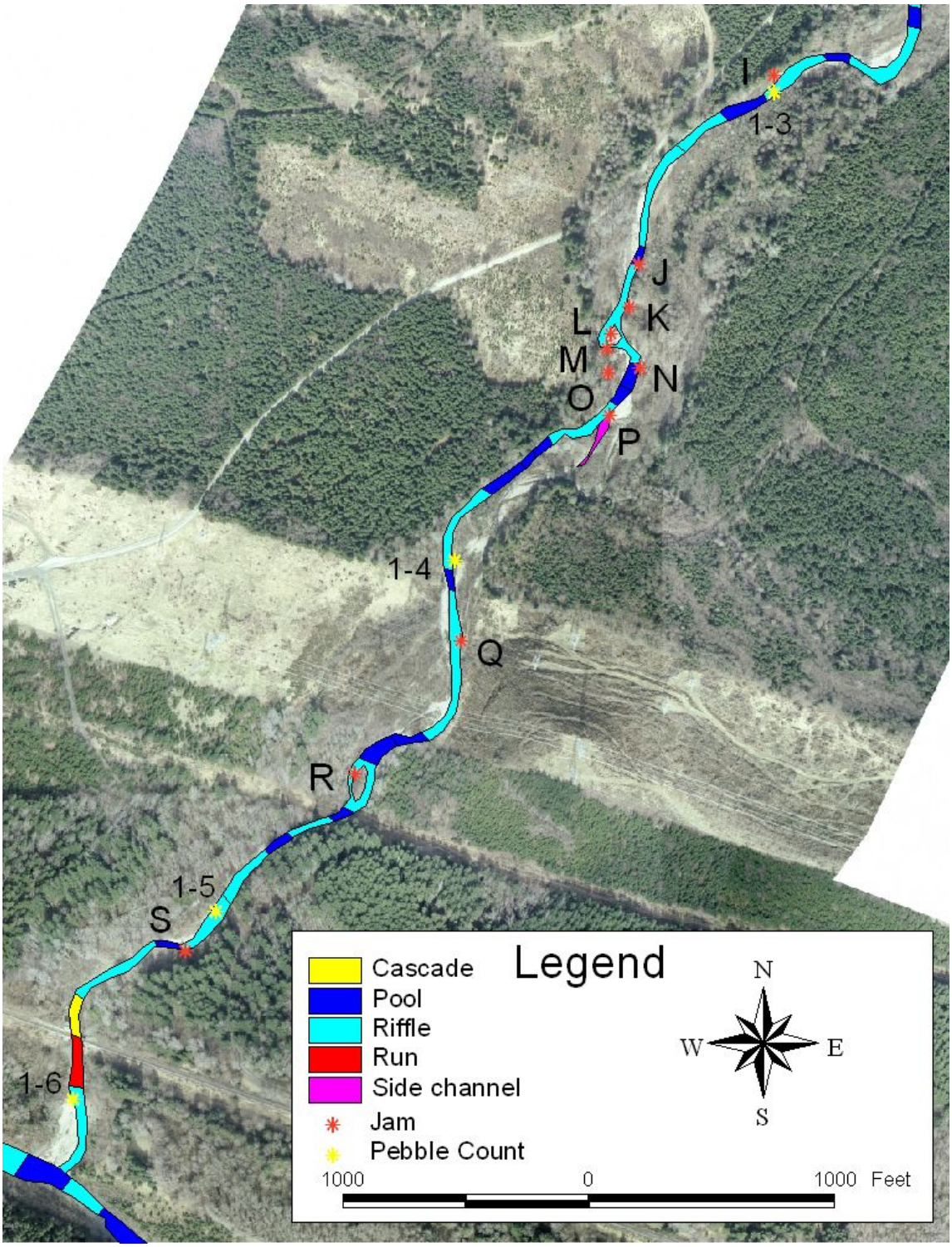

Figure 31. Downstream half Smay Creek, upper mainstem Green River habitat surveys, King County, Washington, 2006.

Table 13. Summary data for 2006 Smay Creek habitat survey, King County, Washington.

Smay Creek	
Length (feet)	10,860
Average bankfull width (feet)	580
Average wetted width (feet)	29.7
Pool Frequency (channel widths / pool)	19.2
Percent pool by length	18.5%
Percent pool by area	15.9%
Average residual pool depth (feet)	2.5
Dominant pool forming factor	Wood
% Pools formed by LWD	84.2%
Total Woody Debris (not including jams)	290
WD frequency (pieces / channel width)	0.79
WD / mile	138.1
Total # Key pieces	12
Key frequency (pieces / mile)	5.7
Total # Jams	45
Average D 16	41.8
Average D 50	92.1
Average D 84	167.6
Average shade	34.8%

Table 14. Total woody debris in Smay Creek, upper Green River, King County, Washington, 2005/2006.

Section 5	**Zone 1**	**Zone 2**
Log - Medium	18	36
Log - Medium with Rootwad	22	44
Log - Large	11	22
Log - Large with Rootwad	7	13
Key piece	1	2
Key piece with Rootwad	3	6
Rootwad	35	70
Small Jam	14	28
Medium Jam	0	0
Large Jam	1	2
TOTAL Woody Debris	*97*	*193*
TOTAL Jams	*15*	*30*

REACH 4: NORTH FORK GREEN RIVER

The North Fork Green River is one of the major tributaries to Howard Hanson Reservoir, entering on the northern shore (Figure 32). The survey of the North Fork Green River by R2 Resource Consultants began on 26 July 2005 and extended through 27 July 2005. The upstream survey end, elevation 1,320 feet, was estimated using topographical maps to be approximately 2.2 miles upstream from the reservoir inundation zone at the time of the survey (Figure 33). The North Fork Green River was surveyed from the approximate elevation of 1,320 downstream 2.2 miles to the reservoir inundation zone (1,147 feet). Summary habitat statistics are presented in Table 15. The channel alternates between pool, riffle and cascade bedforms. The mean bankfull width was 134 feet, while the mean wetted width measured 27.9 feet. Riffle was the dominant habitat type accounting for 59.6% of the total habitat by length.

Figure 32. North Fork Green River, upper Green habitat survey, King County, Washington, 2005.

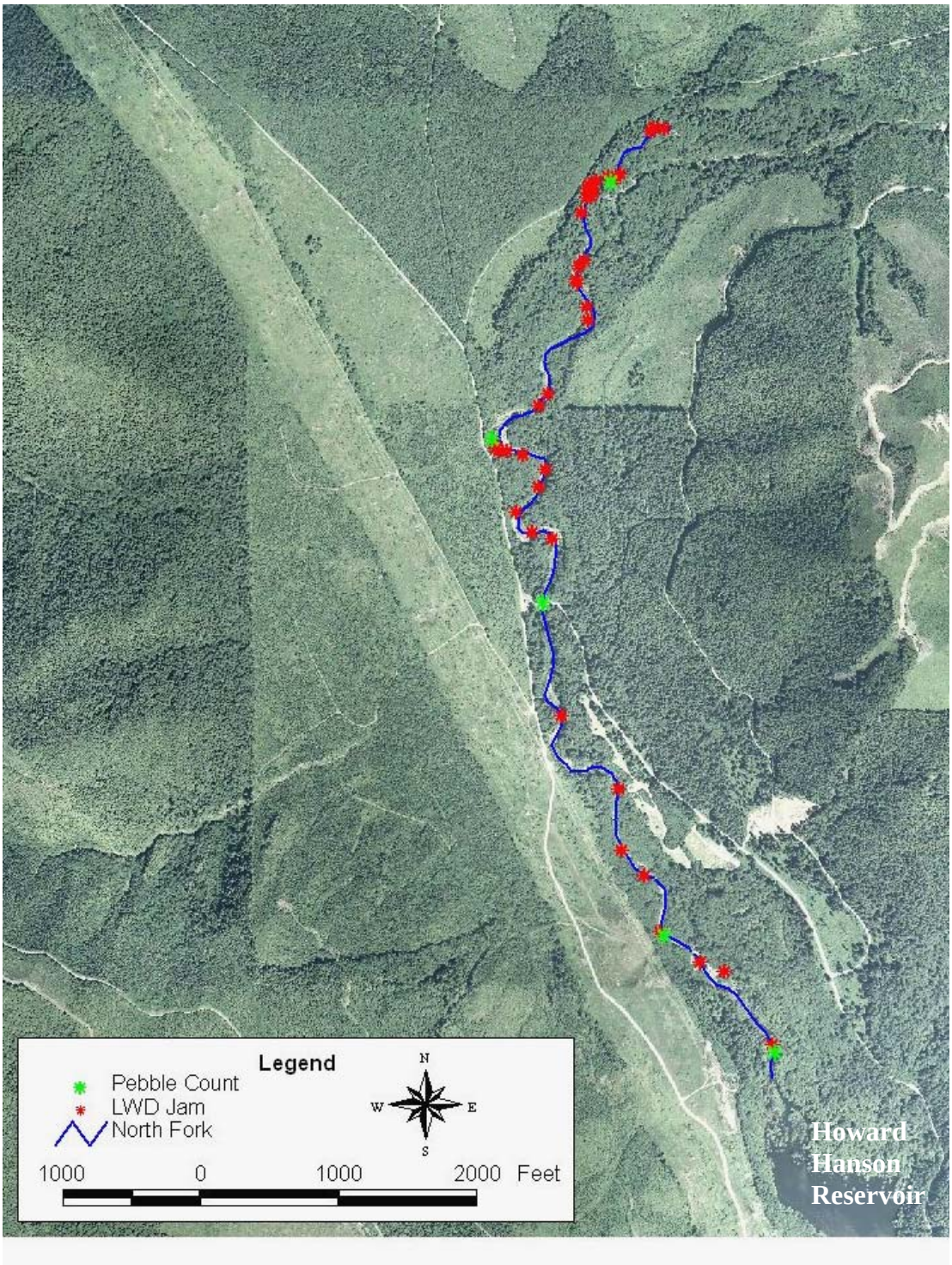

Figure 33. Approximate locations of pebble counts and large woody debris jams in the North Fork Green River, King County, Washington, 2005.

Thirty-two pools were identified in the survey section of the North Fork Green River. This is 21.4% of the total habitat by length. The majority of pools (59.4%) in the North Fork Green River were formed by woody debris.

Forty log jams and 212 individual pieces of woody debris, including 47 key-sized pieces, were identified within the bankfull channel of the North Fork Green River (Table 16). The majority of the debris jams were located above the bridge, the approximate mid-point of the stream survey. GPS coverage was especially limited in the North Fork Green River due to high levels of canopy coverage.

Five pebble counts were completed in the North Fork Green River (Appendix B). The mean D_{50} particle size measured 85.4 mm, and the D_{50} ranged from 40.0 to 115.8 mm. These results are consistent with the general cobble/large gravel substrates found in the riffles in the North Fork Green River.

Table 15. Summary data for 2005 North Fork Green River habitat survey, King County, Washington.

North Fork Green River	
Length (feet)	11,414
Average bankfull width (feet)	134
Average wetted width (feet)	27.9
Pool Frequency (channel widths / pool)	12.8
Percent pool by length	21.4%
Percent pool by area	20.0%
Average residual pool depth (feet)	2.5
Dominant pool forming factor	Log/Wood
% Pools formed by LWD	61.3%
Total Woody Debris (not including jams)	212
WD frequency (pieces / channel width)	0.5
WD / mile	98.1
Total # Key pieces	47
Key frequency (pieces / mile)	21.7
Total # Jams	40
Average D 16	25.0 mm
Average D 50	85.4 mm
Average D 84	173.6 mm
Average shade	51.7%

Table 16. Total woody debris in the North Fork Green River, upper Green River habitat surveys, King County, Washington, 2005.

	Zones 1 and 2
Log - Medium	56
Log - Medium with Rootwad	36
Log - Large	27
Log - Large with Rootwad	26
Key piece	19
Key piece with Rootwad	28
Rootwad	20
Small Jam	34
Medium Jam	5
Large Jam	1
TOTAL Woody Debris	*212*
TOTAL Jams	*40*

REACH 5: GALE CREEK

Gale Creek is located on the northeastern corner of Howard Hanson Reservoir. Gale Creek was surveyed from an approximate elevation of 1,280 feet downstream to the reservoir inundation zone (Figures 34 and 35). The starting elevation was estimated from topographic maps to be midway under the high power transmission lines above the road crossing. This survey encompassed 4,920 feet of stream or 0.93 miles. Habitat data for Gale Creek is summarized in Table 17. The average bankfull width measured 117.2 feet, and the wetted width averaged 18.2 feet. The stream channel alternated between riffle and pool bedforms with a few cascade sections.

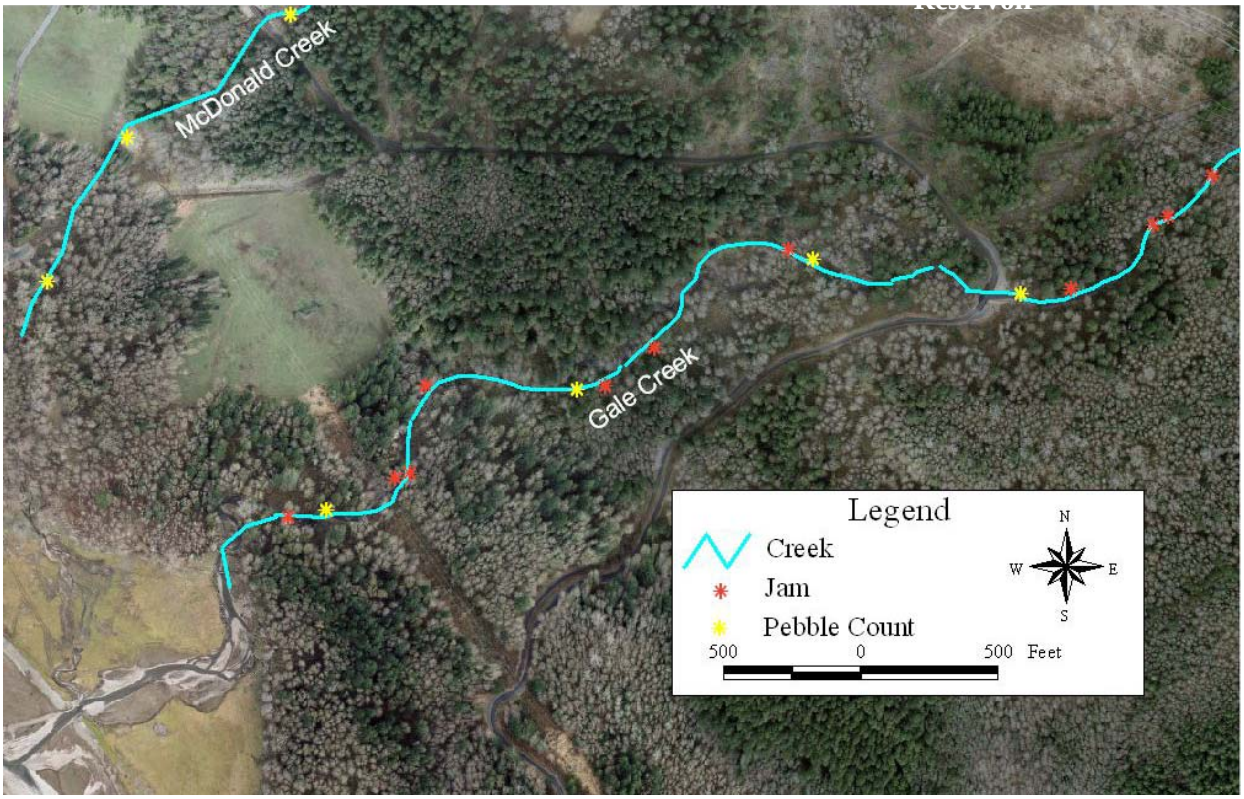

Figure 34. Gale Creek, upper mainstem Green River habitat surveys, King County, Washington, 2006.

Figure 35. Gale Creek, upper Green River habitat survey, King County, Washington, 2005.

A total of thirty-five pools were identified in Gale Creek. The dominant pool forming factor was wood (37.1%). Other pool forming factors included bedform (37.1%) and boulder (14.3%). Pool habitat accounted for 38.8% of the stream by length, the second highest percentage pool habitat of all the streams surveyed. Gale Creek measured only 7.7 channel widths per pool, the lowest of the surveyed tributaries. The high amount of pool habitat can be attributed in part to the large amount of woody debris present in Gale Creek.

In general, woody debris was evenly distributed throughout the survey reach. A total of 121 individual pieces of woody debris and rootwads were identified. Ten small and one medium woody debris jams were present (Table 18).

Four pebble counts were taken in Gale Creek (Appendix B). The mean D_{50} particle size of all pebble counts were calculated to be 56.9 mm with a range of 29.4 to 76.0 mm. Gale Creek substrate was primarily large gravel.

Table 17. Summary data for 2005 Gale Creek habitat survey, King County, Washington.

Gale Creek	
Length (feet)	4,920
Average bankfull width (feet)	117.2
Average wetted width (feet)	18.2
Pool Frequency (channel widths / pool)	7.7
Percent pool by length	38.8%
Percent pool by area	35.6%
Average residual pool depth (feet)	2.5
Dominant pool forming factor	Log/Wood
% Pools formed by LWD	37.1%
Total Woody Debris (not including jams)	121
WD frequency (pieces / channel width)	0.5
WD / mile	129.9
Total # Key pieces	37
Key frequency (pieces / mile)	12.0
Total # Jams	11
Average D 16	19.5 mm
Average D 50	56.9 mm
Average D 84	136.5 mm
Average shade	74.3%

Table 18. Total woody debris in Gale Creek, upper Green River habitat surveys, King County, Washington, 2005.

	Zones 1 and 2
Log - Medium	33
Log - Medium with Rootwad	9
Log – Large	7
Log – Large with Rootwad	17
Key piece	20
Key piece with Rootwad	17
Rootwad	18
Small Jam	10
Medium Jam	1
Large Jam	0
TOTAL Woody Debris	*121*
TOTAL Jams	*11*

REACH 6: CHARLEY CREEK

Charley Creek, located on the southwest side of Howard Hanson Reservoir, is one of the larger tributary streams flowing into the reservoir. The survey of Charley Creek took place on 1 August 2005. Charley Creek was surveyed from downstream of the bridge crossing on Road 3703 (approximately 1,243 ft elevation) to the reservoir inundation zone at 1,147 foot elevation (Figure 36). The survey reach measured 2,345 feet (0.44 miles) in length. Habitat summary data are presented in Table 19. The channel alternated between pool, riffle and cascade bedforms. The dominant habitat type was riffle, comprising nearly 50 percent of the reach by length. Cascade is the next most common type (30.9%) followed by pool (19.8%). Charley Creek exhibited a 4.1% gradient over the survey reach. Stream discharge as measured just above the Road 3703 bridge was 16.4 cubic feet per second (cfs). The only possible passage impediment noted was the small falls present at the conjunction of Charley Creek with the reservoir (Figure 37).

A total of nine pools were identified in Charley Creek, the majority being scour pools (66.7%). These pools comprised approximately 14.5 percent of the total wetted stream channel. The dominant pool forming factor was bedrock followed by boulder. Only one pool was formed by woody debris.

Twenty-nine individual pieces of large or medium woody debris and rootwads including six key-sized pieces were identified. Three small jams were also identified (Table 20). The majority of the large woody debris, including all the jams, occurred within two consecutive units, a riffle and cascade. GPS coverage was unavailable throughout the majority of the channel due to dense canopy coverage. Overall, canopy coverage averaged 76.5 percent.

The substrate noted by observers in Charley Creek was coarse, primarily cobble with some gravel and boulder. The mean D_{50} particle size of both pebble counts was 120.0 mm with a range of 87.7 to 152.3 mm, both within the cobble size range (Appendix B).

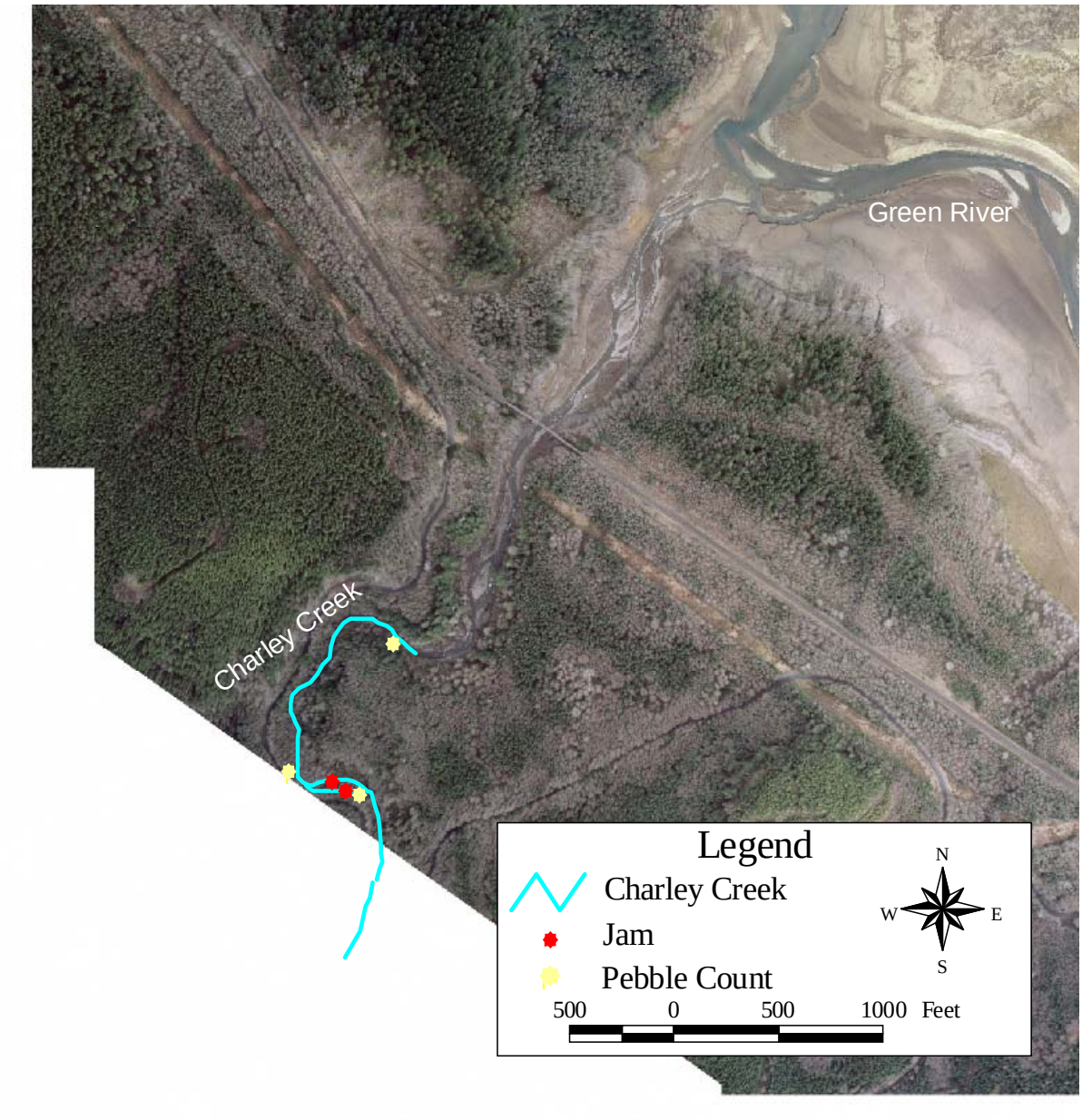

Figure 36. Charley Creek, upper mainstem Green River habitat surveys, King County, Washington, 2006.

Table 19. Summary data for 2005 Charley Creek habitat survey, King County, Washington.

Charley Creek	
Length (feet)	2,345
Average bankfull width (feet)	145
Average wetted width (feet)	29.2
Pool Frequency (channel widths / pool)	8.9
Percent pool by length	19.8%
Percent pool by area	14.5%
Average residual pool depth (feet)	3.6
Dominant pool forming factor	Boulder
% Pools formed by LWD	11.1%
Total Woody Debris (not including jams)	29
WD frequency (pieces / channel width)	0.4
WD / mile	65.9
Total # Key pieces	6
Key frequency (pieces / mile)	13.6
Total # Jams	3
Average D 16	39.9
Average D 50	120
Average D 84	277
Average shade	76.5%

Table 20. Total woody debris in Charley Creek, upper Green River habitat surveys, King County, Washington, 2005.

	Zones 1 and 2
Log - Medium	7
Log - Medium with Rootwad	6
Log - Large	7
Log - Large with Rootwad	1
Key piece	1
Key piece with Rootwad	5
Rootwad	2
Small Jam	3
Medium Jam	0
Large Jam	0
TOTAL Woody Debris	*29*
TOTAL Jams	*3*

Figure 37. Charley Creek looking upstream at reservoir inundation.

REACH 7: PILING CREEK

Piling Creek, a small tributary to Howard Hanson Reservoir, was surveyed on the 27 July, 2005. Piling Creek was surveyed from an approximate elevation of 1,240 feet downstream through the culvert under the 5530 road to the reservoir inundation zone at an approximate elevation of 1,147 feet (Figure 38). The survey encompassed 1,141 feet of stream, with an average gradient of 8.2 percent. GPS coverage was not available in Piling Creek due to thick overstory vegetation. Average canopy coverage was measured at 87.0 percent.

Summary data for Piling Creek is presented in Table 21. The dominant habitat form was percent cascade, measuring 41.9 percent by length. Riffle was second at 24.3 percent. Pool percentage was relatively low compared to the other streams surveyed measuring13.7 percent pool by length. The lower 300 feet of Piling Creek contained a steeper gradient, and contained a cascade step-pool complex.

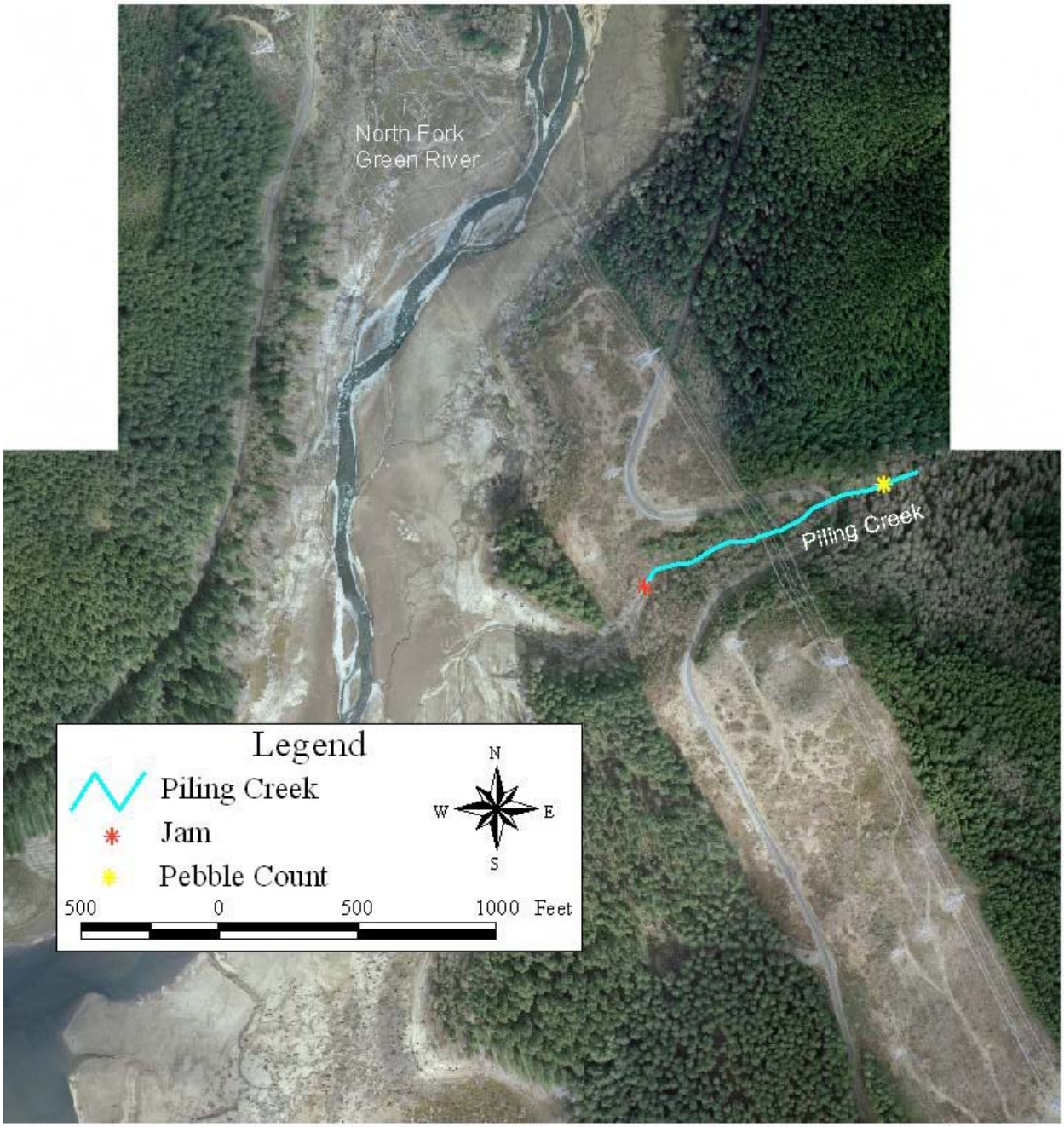

Figure 38. Piling Creek, upper mainstem Green River habitat surveys, King County, Washington, 2006.

In general, flows in Piling Creek at the time of the survey were probably too low to support adult salmon. The only specific possible passage obstruction noted was the culvert under Road 5530 (Figure 39).

Eight pools were delineated during habitat surveys on Piling Creek. These eight pools account for 18.7 percent of the wetted area of the survey reach. Woody debris formed 37.5% (n=3) of the pools.

A total of 32 individual pieces of woody debris and rootwads, including 7 key sized pieces, were identified in Piling Creek (Table 22). Only one jam was identified during the survey. This jam was located at the downstream end of the survey reach, and was the starting point of the survey. In comparison to the other tributary survey streams Piling Creek had a low amount of woody debris jams, but a high count of individual pieces.

One pebble count was completed on Piling Creek, near the downstream survey end (Appendix B). The riffle D_{50} measured 74.5 mm, large gravel or small cobble. The substrates within the creek were relatively uniform throughout the survey reach.

Figure 39. Photo looking upstream at the culvert on Piling Creek under Road 5530, upper Green River habitat surveys, King County, Washington, 2005.

Table 21. Summary data for 2005 Piling Creek habitat survey, King County, Washington.

Piling Creek	
Length (feet)	1,141
Average bankfull width (feet)	68
Average wetted width (feet)	8.7
Pool Frequency (channel widths / pool)	16.4
Percent pool by length	13.7%
Percent pool by area	18.7%
Average residual pool depth (feet)	1.6
Dominant pool forming factor	Bedform
% Pools formed by LWD	37.5%
Total Woody Debris (not including jams)	32
WD frequency (pieces / channel width)	0.2
WD / mile	145.5
Total # Key pieces	7
Key frequency (pieces / mile)	32.4
Total # Jams	1
Average D 16	38.6
Average D 50	74.5
Average D 84	132.4
Average shade	87.0%

Table 22. Total woody debris in Piling Creek, upper Green River habitat surveys, King County, Washington, 2005.

	Zones 1 and 2
Log - Medium	18
Log - Medium with Rootwad	1
Log - Large	3
Log - Large with Rootwad	0
Key piece	6
Key piece with Rootwad	1
Rootwad	3
Small Jam	1
Medium Jam	0
Large Jam	0
TOTAL Woody Debris	*32*
TOTAL Jams	*1*

REACH 8: COTTONWOOD CREEK

Cottonwood Creek is a small tributary to Howard Hanson Reservoir (Figure 41). It enters the reservoir on the northern side near the North Fork Green River. The lower 500 feet of the stream was surveyed on 26 July 2005. This is the reach from the culvert under the 5530 road downstream to the reservoir inundation zone (approximate elevation of 1,147 feet) (Figure 40). There is no flowing water in Cottonwood Creek immediately above the culvert (Figure 42). However, small isolated pools of stagnant water were present. The surveyed reach below the culvert has very low flow and is nearly dewatered in sections. Habitat data for Cottonwood Creek are summarized in Table 23.

Four pools were identified in Cottonwood Creek. Pools accounted for 11.4% of the habitat units by length. Riffle units accounted for 88.6% of the habitat. The dominant pool forming factor was wood. Of all the tributaries surveyed, Cottonwood Creek had the greatest number of channel widths per pool, measuring 27.4.

Sixteen individual pieces of woody debris and rootwads, and two small woody debris jams were enumerated in Cottonwood Creek (Table 24).

A single pebble count was taken in Cottonwood Creek (Appendix A). The D_{50} riffle particle size was 37.3 mm, or medium gravel. The substrates were very uniform throughout the survey reach, with plentiful gravel.

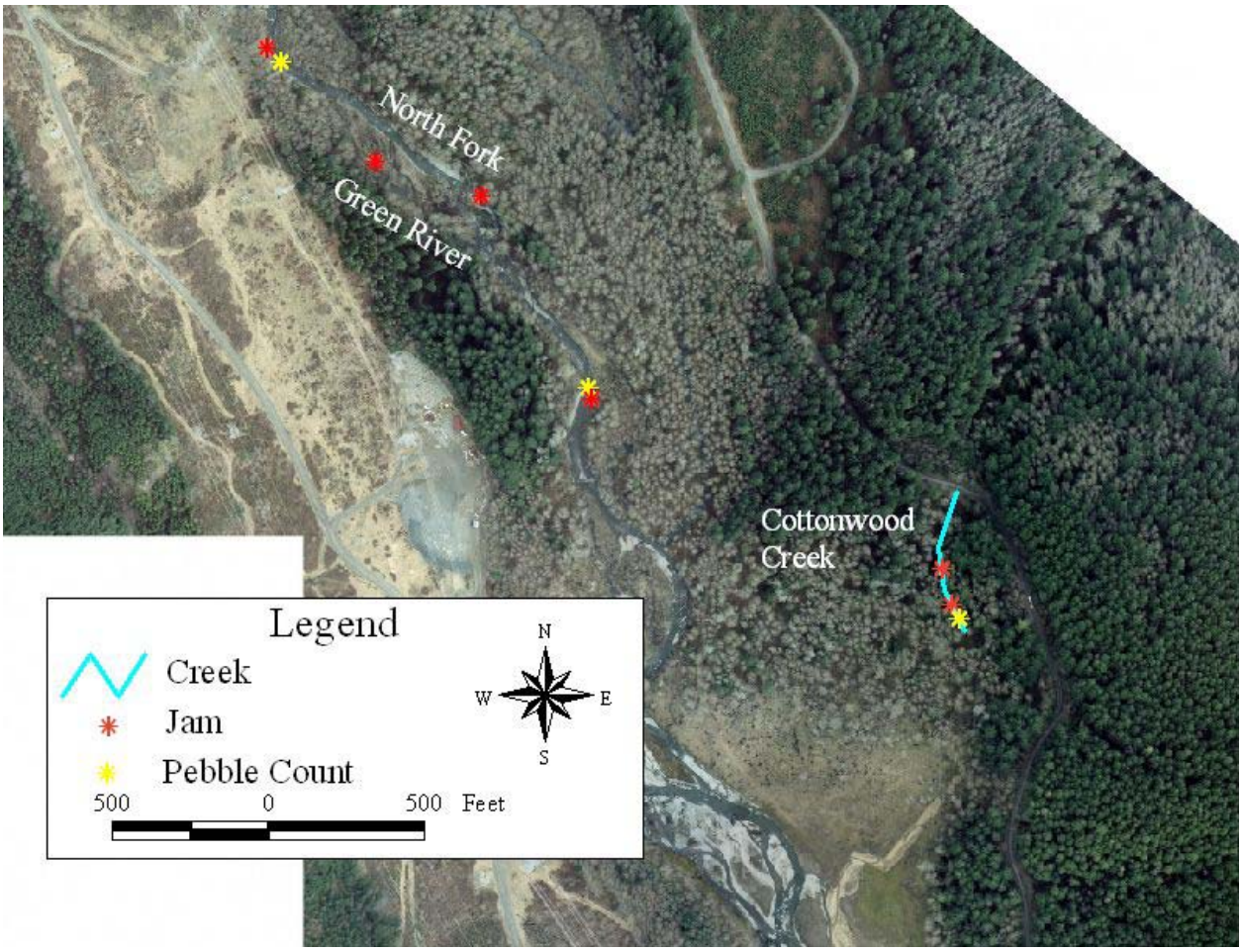

Figure 40. Cottonwood Creek, upper mainstem Green River habitat surveys, King County, Washington, 2006.

Figure 41. Cottonwood Creek near downstream survey end, upper Green River habitat surveys, King County, Washington, 2005.

Figure 42. Culvert under 5530 road on Cottonwood Creek, dry at time of photo, upper Green River habitat surveys, King County, Washington, 2005.

Table 23. Summary data for 2005 Cottonwood Creek habitat survey, King County, Washington.

Cottonwood Creek	
Length (feet)	482
Average bankfull width (feet)	45
Average wetted width (feet)	4.4
Pool Frequency (channel widths / pool)	27.4
Percent pool by length	11.4%
Percent pool by area	15.3%
Average residual pool depth (feet)	1.0
Dominant pool forming factor	Log
% Pools formed by LWD	50.0%
Total Woody Debris (not including jams)	16
WD frequency (pieces / channel width)	0.2
WD / mile	11.1
Total # Key pieces	0
Key frequency (pieces / mile)	0
Total # Jams	2
Average D 16	12
Average D 50	37.3
Average D 84	79.3
Average shade	93.5%

Table 24. Total woody debris in Cottonwood Creek, upper Green River habitat surveys, King County, Washington, 2005.

	Zones 1 and 2
Log - Medium	5
Log - Medium with Rootwad	1
Log - Large	8
Log - Large with Rootwad	2
Key piece	0
Key piece with Rootwad	0
Rootwad	0
Small Jam	2
Medium Jam	0
Large Jam	0
TOTAL Woody Debris	*16*
TOTAL Jams	*2*

REACH 9: MCDONALD CREEK

McDonald Creek flows southerly into Howard Hanson Reservoir just west of Gale Creek on the northeastern corner of the reservoir (Figure 43). The McDonald Creek survey encompassed 3,110 feet (0.59 miles). The survey began at an approximate elevation of 1,240 feet and went downstream through the culvert under Road 5530 to the reservoir inundation zone near elevation 1,147 feet (Figure 44). The overall gradient for this reach of McDonald Creek was 3.0 percent. The stream had heavy canopy cover, 95.5 percent, and thick riparian brush in spots. These conditions inhibited the use of GPS equipment. Streamflow in McDonald Creek was estimated to be less than 2 to 3 cfs. The summary data for McDonald Creek are presented in Table 25.

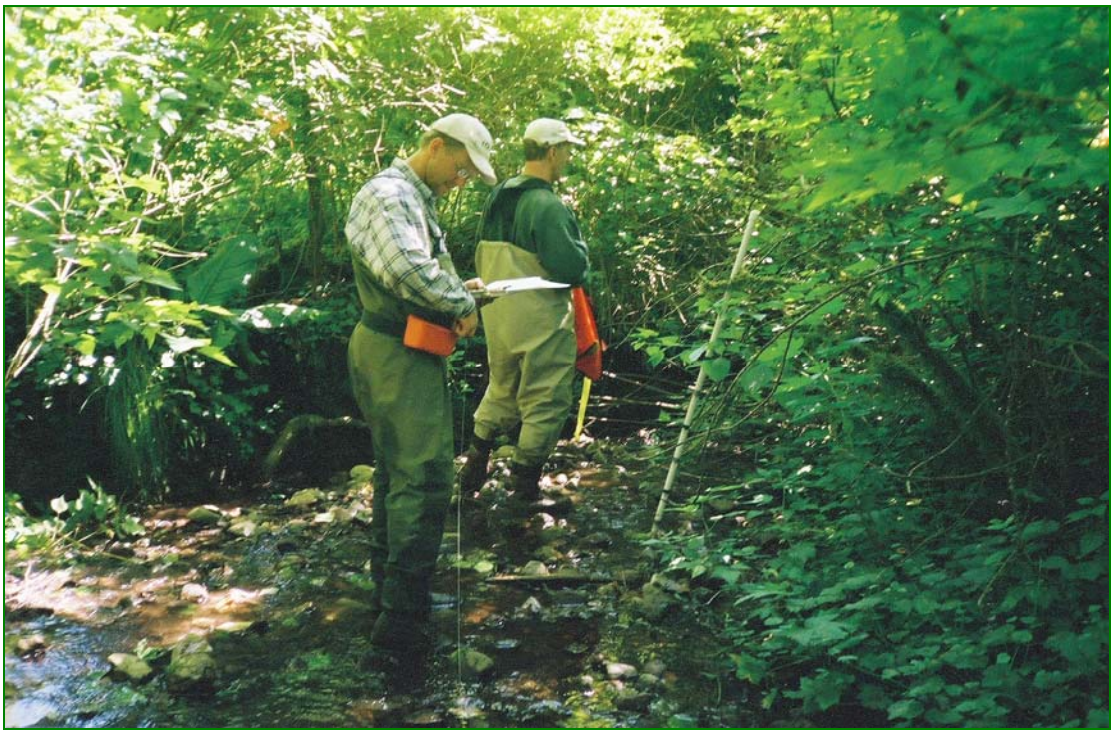

Figure 43. McDonald Creek, upper Green River habitat surveys, King County, Washington, 2005.

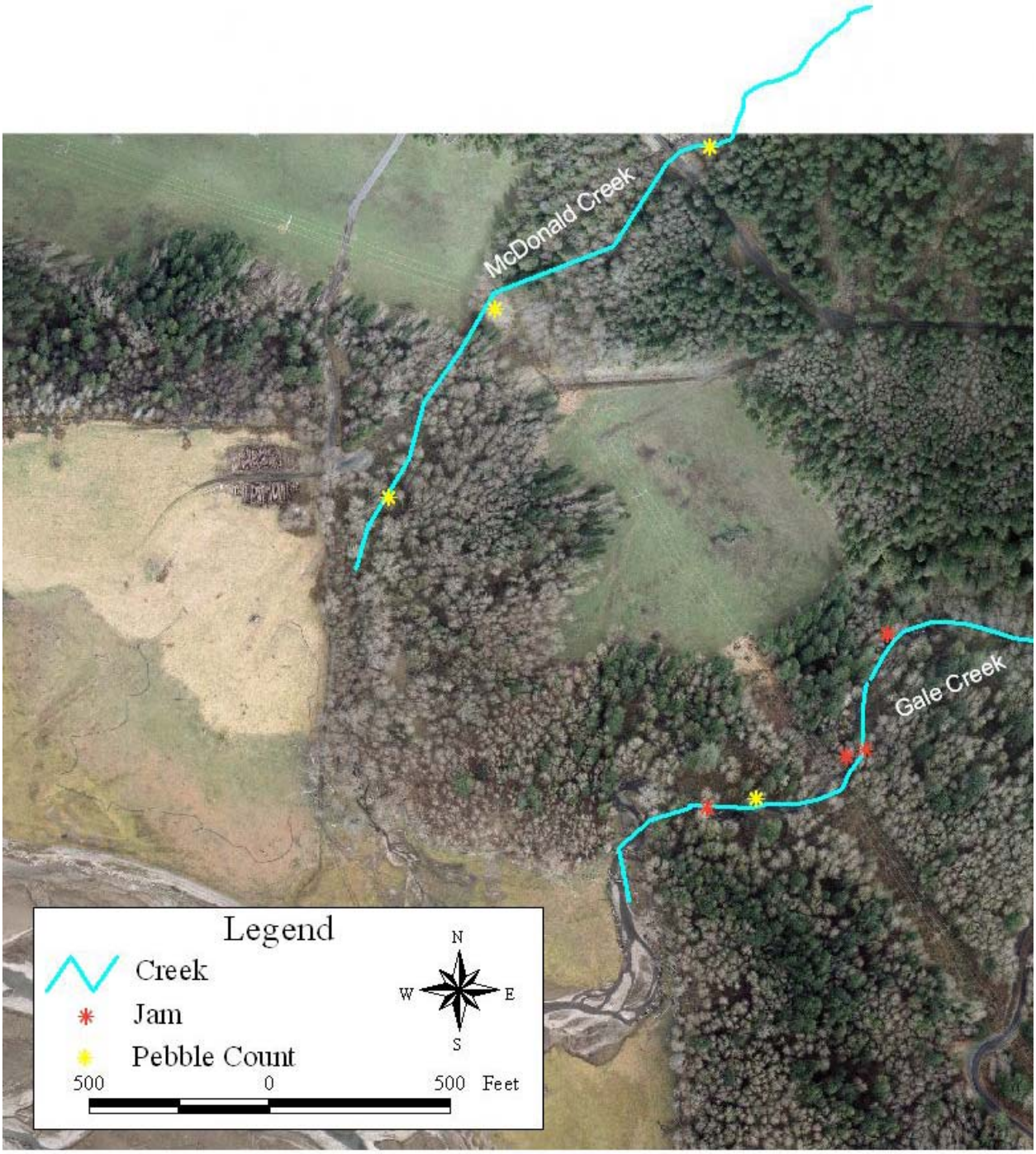

Figure 44. McDonald Creek, upper mainstem Green River habitat surveys, King County, Washington, 2006.

Due to the small size of McDonald Creek, data were collected for all pool units with a maximum depth greater than 0.8 feet, rather than 1.0 feet as was stated in the original protocol. Twenty-five pools were identified meeting this adjusted criteria. Average maximum pool depth measured 1.3 feet. The dominant pool forming factor was bedform.

Seventy-six individual pieces of woody debris and rootwads were identified in McDonald Creek, including 19 key sized pieces (Table 26). No woody debris jams were present in the survey reach.

Three pebble counts were completed on McDonald Creek (Appendix A). The D_{50} particle size ranged from a high of 50.3 mm to a low of 25.0 mm, with a mean of 39.5 mm or large gravel sized particles. These measurements are representative of the substrate throughout the survey reach, larger gravel and small cobble.

Table 25. Summary data for 2005 McDonald Creek habitat survey, King County, Washington.

McDonald Creek	
Length (feet)	3,110
Average bankfull width (feet)	77
Average wetted width (feet)	5.9
Pool Frequency (channel widths / pool)	21.1
Percent pool by length	15.0%
Percent pool by area	20.0%
Average residual pool depth (feet)	1.1
Dominant pool forming factor	Bedform
% Pools formed by LWD	36.0%
Total Woody Debris (not including jams)	76
WD frequency (pieces / channel width)	0.1
WD / mile	128.8
Total # Key pieces	19
Key frequency (pieces / mile)	32.2
Total # Jams	0
Average D 16	14.8
Average D 50	39.5
Average D 84	79.2
Average shade	95.5%

Table 26. Total woody debris in McDonald Creek, upper Green River habitat surveys, King County, Washington, 2005.

	Zones 1 and 2
Log - Medium	30
Log - Medium with Rootwad	2
Log - Large	16
Log - Large with Rootwad	4
Key piece	16
Key piece with Rootwad	3
Rootwad	5
Small Jam	0
Medium Jam	0
Large Jam	0
TOTAL Woody Debris	*76*
TOTAL Jams	*0*

REACH 10: SIGNANI SLOUGH

Signani Slough was surveyed from its origin at a large beaver pond downstream 1,330 feet (0.25 miles) to its confluence with the Green River below the Tacoma Headworks (RM 61.0). Historically Signani Slough was a side channel to the Green River. It was cut off early in the 20th century around the time of the construction of the Burlington Northern Santa Fe Railroad and Tacoma's Headworks Diversion Dam. Signani Slough has been reconnected to the mainstem Green River as part of the AWSP. The original design of a 36 inch culvert was replaced with a 16ft. box culvert as part of the AWSP. Signani Slough was surveyed by R2 Resource Consultants on 4 August 2005. This stream channel is heavily influenced by beaver activity. The upper stream channel, above the culvert under the Tacoma Headworks road, is a series of beaver check dams and pools. The lower section, below the culvert, has been modified by recent channel restoration work. Habitat summary data for Signani Slough are presented in Table 27.

Eleven pools were identified in Signani Slough during the survey effort. Nine (81.8%) of these pools were formed by beaver dams, or woody debris. The other pools were formed by bedform features. Pool units comprised approximately 83.5 percent of the total habitat by area. This was by far the highest percentage of pool habitat for the streams surveyed.

Twenty individual pieces of woody debris and rootwads were identified in Signani Slough (Table 28). No collections of woody debris contained pieces of sufficient size to qualify as a debris jam. However, at least seven beaver dams were present in succession in Signani Slough.

The pebble count was taken in Signani Slough in the only wadable riffle location that natural gravel was present (Figure 45). The substrate D_{50} from this count measured 42.8 mm. The substrates below the culvert contain excellent salmonid spawning gravel. Pink salmon were observed spawning in this area later in the fall.

Table 27. Summary data for 2005 Signani Slough habitat survey, King County, Washington.

Signani Slough	
Length (feet)	1,330
Average bankfull width (feet)	40
Average wetted width (feet)	14.2
Pool Frequency (channel widths / pool)	8.5
Percent pool by length	51.5%
Percent pool by area	83.5%
Average residual pool depth (feet)	2.3
Dominant pool forming factor	Dam
% Pools formed by LWD	81.8%
Total Woody Debris (not including jams)	20
WD frequency (pieces / channel width)	0.2
WD / mile	79.4
Total # Key pieces	0
Key frequency (pieces / mile)	0
Total # Jams	0
Average D 16	17.1
Average D 50	42.8
Average D 84	71.9
Average shade	91.9%

Table 28. Total woody debris in Signani Slough, upper Green River habitat surveys, King County, Washington, 2005.

	Zones 1 and 2
Log - Medium	13
Log - Medium with Rootwad	0
Log - Large	2
Log - Large with Rootwad	0
Key piece	0
Key piece with Rootwad	0
Rootwad	5
Small Jam	0
Medium Jam	0
Large Jam	0
TOTAL Woody Debris	*20*
TOTAL Jams	*0*

Figure 45. Pebble count location in Signani Slough, upper Green River habitat surveys, King County, Washington, 2005.

5. SUMMARY AND CONCLUSIONS

The upper Green River, from the High Trestle Railroad Bridge above Sunday Creek to Howard Hanson Reservoir, (approximately 19 miles) exhibits varied physical habitat conditions. However, throughout this section of the river the largely undeveloped nature of the drainage basin has allowed for excellent natural salmonid habitat conditions to be retained. The river has considerable potential for use by spawning and rearing Chinook, coho and sockeye salmon and steelhead trout (for further information specific to the life history and ecology of Green River salmonids refer to R2 2006.)

Pools in particular provide essential habitat for salmonid populations. Large woody debris and associated pool habitat provide juvenile fish cover from predators and refuge during storm events (Bustard and Narver 1975; Lister and Genoe 1979). The abundance of juvenile coho in particular appears to be more strongly influenced by the amount and quality of available pool habitat than other variables (Murphy et al. 1986). Pool areas are also utilized by adult salmon and trout for holding and resting during upstream spawning migrations and shelter during summer low flow periods (Bjornn and Reiser 1991; Heggenes et al. 1991).

There is a high degree of variation in the quantification of natural physical habitat features (i.e., pools) in streams west of the Cascades (Peterson et al. 1992). This variation is due in part to the definition of a pool; however, this variation does also illustrate the importance of local geomorphic features, stream size, and riparian influence on stream habitat characteristics. For the purposes of this report the habitat data collected above HHD and the data collected below the dam by R2 Resource Consultants in 2001 will be compared (R2 Resource Consultants 2002). These two surveys utilized similar survey protocol and definition of pool habitat, with the exception of a shallower residual pool depth for the lower streamflow conditions above the dam (0.5m versus 1.0 m used below). Streamflow at the time of survey was much lower above HHD than in the river below. Flow below the dam ranged from 110-350 cfs, while flow above the dam was estimated to be less than 50 cfs during the surveys.

On average for the entire reaches surveyed (Sunday Creek to the reservoir and RM 64.5 to RM 32) pool percentage measured by length and area were slightly higher for the upper reach than the below the dam (Tables 29 and 30). Fewer channel widths per pool were present on average for the lower river (15 versus 21 respectively). This indicates shorter, more frequent pool units were present in the lower river than the upper. The pool units in the upper river were generally greater in area than in the lower river. Woody debris is a much greater contributing factor in

pool formation in the upper river than the lower river (Tables 29 and 31). An increase in woody debris has been found to be positively correlated to an increase in pool frequency and area (Nelson 1998; Rosenfeld; Montgomery et al. 1995 and Huato 2003).

Table 29. Percent pool by length and area for two habitat surveys, Green River, Washington.

Pool % by length	**1**	**2**	**3**	**4**	**5**	**6**	**Average**
R2 2002 Lower river	20	26	25	7	24	23	20.8
R2 2007 Upper River	20	42	20	25	21	n/a	25.5
Pool % by area							
R2 2002 Lower river	16	20	21	4	19	14	15.6
R2 2007 Upper River	22	44	18	18	20	n/a	25.0
Channel widths per pool							
R2 2002 Lower river	13	11	9	34	11	12	15
R2 2007 Upper River	27	10	22	16	29	n/a	21
% Pool formed by woody debris							
R2 2002 Lower river	0	0	0	0	30	24	
R2 2007 Upper River	75	51	0	7	33	n/a	33

Note: The sections are not the same for the two reaches surveyed; section numbers are used for reference only.

The two tributaries surveyed that flow directly into the mainstem Green River, Smay and Sunday Creeks, both provide high quality streamflow to the river. Smay Creek in particular had a large amount of woody debris forming the majority of the pools present in the stream (Table 32). Sunday Creek contained nearly 40% pool by area, the highest percentage of the upper streams surveyed, the majority again formed by woody debris. Both streams added significantly to the streamflow present at the time of survey (Sunday 6.0 cfs and Smay 9.3 cfs).

The lower survey tributaries, those that drain into Howard Hanson Reservoir, are undeveloped drainages that also provide high quality streamflow (Table 31). All of the tributaries surveyed provided some degree of salmonid habitat. In particular, Charley and Gale Creeks contain possible spawning and rearing habitat. Juvenile coho prefer to rear in side channel habitat with complex woody debris structure, such as is provided by the pools in Signani Slough (Grette and Salo 1986). The North Fork Green River also exhibited excellent salmonid habitat, at the flow level this survey was conducted. During the summer low flow conditions present during the surveys (August 2005), Piling, Cottonwood and McDonald Creeks contained very little

streamflow. However, the inundation zones of these streams still provide habitat to salmonids present in Howard Hanson Reservoir at all flow levels.

Reach scale monitoring conducted over many years, provides a way to quantify and assess changes to habitat over time. The results of this study provide a baseline for monitoring reach scale changes in habitat in the upper Green River watershed. In particular, the number and frequency of pools and pieces of woody debris provide a baseline of information that can be used for comparison with future habitat surveys. For consistency, it is recommended that future surveys be repeated using the same protocol outlined in this report.

Table 30. Summary stream statistics for habitat surveys in the mainstem upper Green River, King County, Washington, 2005/2006.

Green River	All	Section 1	Section 2	Section 3	Section 4	Section 5
Length (feet)	101,660	5,835	26,355	24,918	3,6652	7,899
Average bankfull width (feet)	895	1074	627	n/a	984	n/a
Average wetted width (feet)	69.0	26.7	60.6	75.6	89.4	92.4
Pool Frequency (channel widths / pool)	20.7	27.3	10.1	22.0	15.8	28.5
Percent pool by length	25.5%	19.8%	42.1%	19.6%	25.4%	20.5%
Percent pool by area	25.0%	22.2%	43.9%	18.0%	19.5%	21.6%
Average residual pool depth (feet)	3.8	2.4	3.3	4.4	4.8	4.1
Dominant pool forming factor	Wood	Wood	Wood	Bedrock	Bedform	Varied
% Pools formed by LWD	33.3%	75.0%	51.2%	0.0%	7.7%	33.3%
Total Woody Debris (not including jams)	901	87	337	144	302	31
WD frequency (pieces / channel width)	0.5	0.4	0.8	0.4	0.7	0.4
WD / mile	46.8	78.7	66.9	30.5	41.3	20.7
Total # Key pieces zone 1	39	1	11	15	12	0
Total # Key pieces zone 2	158	0	61	30	63	4
Key frequency (pieces / mile)	10.1	0.9	14.4	9.5	10.5	2.7
Total # Jams zones 1 and 2	75	7	32	8	26	2
Average D 16	32.2	30.8	29.1	28.9	36.8	35.4
Average D 50	85.8	81.2	66.4	89.3	85.0	87.5
Average D 84	171.7	160.3	133.9	227.6	171.3	165.7
Average shade	19.7%	21.9%	19.0%	27.5%	15.0%	15.1%

Table 31. Total woody debris from zones 1 and 2 in all survey tributaries and the mainstem upper Green River, King County, Washington, 2005/2006.

Zones 1 and 2	Mainstem Green River	Sunday Creek	Smay Creek	North Fk. Green River	Gale Creek	Charley Creek	Piling Creek	Cottonwood Creek	McDonald Creek	Signani Slough
Log - Medium	181	69	54	56	33	7	18	5	30	13
Log - Medium with Rootwad	129	45	66	36	9	6	1	1	2	0
Log - Large	138	12	33	27	7	7	3	8	16	2
Log - Large with Rootwad	83	9	20	26	17	1	0	2	4	0
Key piece	90	3	3	19	20	1	6	0	16	0
Key piece with Rootwad	107	6	9	28	17	5	1	0	3	0
Rootwad	173	96	105	20	18	2	3	0	5	5
Small Jam	52	21	42	34	10	3	1	2	0	0
Medium Jam	17	3	0	5	1	0	0	0	0	0
Large Jam	6	3	3	1	0	0	0	0	0	0
TOTAL Woody Debris	*901*	*240*	*290*	*212*	*121*	*29*	*32*	*16*	*76*	*20*
TOTAL Jams	*75*	*27*	*45*	*40*	*11*	*3*	*1*	*2*	*0*	*0*
Woody Debris per mile	*46.8*	*63.0*	*138.1*	*98.1*	*129.8*	*65.3*	*148.1*	*175.8*	*129.0*	*79.4*
Jams per mile	*3.9*	*7.1*	*21.4*	*18.5*	*11.8*	*6.8*	*4.6*	*22.0*	*0.0*	*0.0*

Table 32. Summary stream statistics for all surveyed tributaries and the mainstem upper Green River, King County, Washington, 2005/2006.

	Mainstem	Sunday	Smay	N. Fork	Gale	Charley	Piling	Cottonwood	McDonald	Signani
Length (feet)	101,660	20,103	10,860	11,414	4,920	2,345	1,141	482	3,110	1330
Average bankfull width (feet)	895	310	580	134	117	145	68	45	77	40
Average wetted width (feet)	69.0	33.6	29.7	27.9	18.2	29.2	8.7	4.4	5.9	14.2
Pool Frequency (channel widths / pool)	20.7	20.6	19.2	12.8	7.7	8.9	16.4	27.4	21.1	8.5
Percent pool by length	25.5%	29.8%	18.5%	21.4%	38.8%	19.8%	13.7%	11.4%	15.0%	51.5%
Percent pool by area	25.0%	39.1%	15.9%	20.0%	35.6%	14.5%	18.7%	15.3%	20.0%	83.5%
Average residual pool depth (feet)	3.8	2.7	2.5	2.5	2.5	3.6	1.6	1.0	1.1	2.3
Dominant pool forming factor	Wood	Wood	Wood	Log/Wood	Log/Wood	Boulder	Bedform	Log/Wood	Bedform	Dam
% Pools formed by LWD	33.3%	34.5%	84.2%	61.3%	37.1%	11.1%	37.5%	50.0%	36.0%	81.8%
Total Woody Debris (not including jams)	901	240	290	212	121	29	32	16	76	20
WD frequency (pieces / channel width)	0.5	0.4	0.8	0.5	0.5	0.4	0.2	0.2	0.1	0.2
WD / mile	46.8	63.2	138.1	98.1	129.9	65.9	145.5	11.1	128.8	79.4
Total # Key pieces	39	9	12	47	37	6	7	0	19	0
Key frequency (pieces / mile)	10.1	2.4	5.7	21.7	12.0	13.6	32.4	0	32.2	0
Total # Jams	75	27	45	40	11	3	1	2	0	0
Average D 16	30.2	32.4	41.8	25.0	19.5	39.9	38.6	12	14.8	17.1
Average D 50	85.8	88	92.1	85.4	56.9	120.0	74.5	37.3	39.5	42.8
Average D 84	171.7	179.1	167.6	173.6	136.5	277	132.4	79.3	79.2	71.9
Average shade	19.7%	57.3%	34.8%	51.7%	74.3%	76.5%	87.0%	93.5%	95.5%	91.9%

6. LITERATURE CITED

Bauer, S.B., and S.C. Ralph. 1999. Aquatic habitat indicators and their application to water quality objectives within the Clean Water Act. EPA-910-R-99-014. U.S. Environmental Protection Agency, Region 10, Seattle, Washington. 99 p.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 *in* W.R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19. Bethesda, Maryland.

Bustard, D.R. and D.W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal Fisheries Research Board of Canada 32:667-680.

Cramer, S.P., J. Norris, P.R. Mundy, G. Grette, K.P. O'Neal, J.S. Hogle, C. Steward, and P. Bahls. 1999. Status of Chinook salmon and their habitat in Puget Sound. Consultant Report prepared for the Coalition of Puget Sound Businesses. S.P. Cramer and Associates, Inc. Gresham, Oregon.

Grette, G.B. and E.O. Salo. 1986. The status of anadromous fishes of the Green/Duwamish River system. Submitted to the U.S. Army Corps of Engineers, Seattle District. Seattle, Washington. 213 p.

Hawkins, C.P., J.L. Kershner, P.A. Bisson, M.D. Bryant, L.M. Decker, S.V. Gregory, D.A. McCullough, C.K. Overton, G.H. Reeves, and R.J. Steedman. 1993. A hierarchical approach to classifying stream habitat features. Fisheries 18(6):3-12.

Heggenes, J., T.G. Northcote, and A. Peter. 1991. Seasonal habitat selection and preferences by cutthroat trout (*Oncorhynchus clarki*) in a small, coastal stream. Canadian Journal of Fisheries and Aquatic Sciences 48:757-762.

Johnson, D.H., J.A. Silver, N. Pittman, E. Greda, R. W. Plotnikoff, S. Hinton, B. C. Mason, K.K. Jones, P. Rogers, T.A. O'Neil, and C. Barrett. 2001. Monitoring salmon habitat in the Pacific Northwest - directory and synthesis of protocols for management/research and volunteers in Washington, Oregon, Montana, Idaho and British Columbia. Washington Department of Fish and Wildlife, Olympia, Washington. 134 pp.

Johnson, O.W., M.H. Ruckelshaus, W.S. Grant, F.W. Waknitz, A.M. Garret, G.J. Bryant, K. Neely and J.J Hard. 1999. Status review of coastal cutthroat trout from Washington, Oregon, and California. U.S. Department of Commerce, NOAA. Technical Memorandum. NMFS-NWFSC-37. 292 p.

Lister, D.B. and H.S. Genoe. 1979. Stream habitat utilization by cohabiting underyearlings of Chinook (*Oncorhynchus tshawytscha*) and coho (*Oncorhynchus kisutch*) salmon in the Big Qualicum River, British Columbia. Journal of the Fisheries Research Board of Canada 27:1215-1224.

MacDonald, L.H., A. W. Smart, and R.C. Wissmar. 1991. Monitoring guidelines to evaluate the effects of forestry activities on streams in the Pacific Northwest and Alaska. EPA 910-9-91-001. U.S. Environmental Protection Agency, Region 10, Seattle, Washington. 166 p.

Montgomery, D., R.J.M. Buffington, R.D. Smith, K.M. Schmidt, and G. Pess. 1995. Pool spacing in forest channels. Water Resources Research 31(4):1097-1105.

Murphy, M.L., J. Heifetz, S.W. Johnson, K.V. Koski and J.G. Thedinga. 1986. Effects of clear-cut logging with and without buffer strips on juvenile salmonids in Alaskan streams. Canadian Journal of Fisheries and Aquatic Sciences 43:1521-1533.

Nehlsen, W., J.E. Williams, and J.A. Lichatowich. 1991. Pacific salmon at their crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16:4-21.

Perkins, S.J. 1999. Geomorphic feasibility report for large woody debris placement in the middle Green River, Washington. Prepared for Jones & Stokes Associates, Inc. and U.S. Army Corps of Engineers, Seattle District. Perkins Geosciences, Seattle, Washington. 29 p.

Peterson, N.P., A. Hendry and T.P. Quinn. 1992. Assessment of cumulative effects on salmonid habitat: some suggested parameters and target conditions TFW-F3-92-001. Prepared for the Washington Dept. of Natural Resources and the Coordinated Monitoring, Evaluation and Research Committee Timber Fish and Wildlife Agreement. University of Washington, Center for Streamside Studies. Seattle, Washington.

Pfankuch, D. J. 1975. Stream reach inventory and channel stability evaluation. A watershed management tool. U.S. Forest Service, Lolo National Forest, Missoula, Montana. 25+ p.

Pleus, A., D. Schuett-Hames, and L. Bullchild. 1999. TFW Monitoring Program method manual for the habitat unit survey. Prepared for the Washington State Department of Natural Resources under the Timber, Fish and Wildlife Agreement. TFW-AM9-99-003. DNR #105. June. 41 p.

R2 Resource Consultants, Inc. (R2). 2000. Juvenile salmonid use of lateral stream habitats middle Green River, Washington. 1999 Final Data Report.

R2 Resource Consultants, Inc. (R2) 2002. Green River baseline habitat monitoring, 2001 data report. Prepared for the U.S. Army Corps of Engineers.

R2 Resource Consultants (R2). 2006. Juvenile salmonid use of lateral habitat in middle Green River, Washington. Data report. Prepared for the U.S. Army Corps of Engineers, Seattle District.

Schuett-Hames, D., A. Pleus, J. Ward, M. Fox, and J. Light. 1999. TFW Monitoring Program method manual for the large woody debris survey. Prepared for the Washington State Department of Natural Resources under the Timber, Fish and Wildlife Agreement. TFW-AM9-99-004. DNR #106. March. 33 p.

U.S. Army Corps of Engineers (USACE). 2005. Green River Fish Habitat Mitigation and Restoration Design Documentation Report.

Washington Department of Fish and Wildlife (WDFW) and Western Washington Treaty Indian Tribes. 1994. SASSI: 1992 Washington State salmon and steelhead stock inventory. Appendix One: Puget Soundstocks, South Puget Sound volume. Olympia, Washington.

Washington Forest Practices Board (WFPB). 1997. Standard Methodology for Conducting Watershed Analysis Version 4.0. Washington Department of Natural Resources, Olympia Washington.

Weitkamp, L.A., T.C. Wainwright, G.J. Bryant, G.B. Milner, D.J. Teel, R.G. Kope, and R.S. Waples. 1995. Status review of coho salmon from Washington, Oregon, and California. U.S. Department of Commerce, National Oceanic and Atmosphere Administration Technical Memorandum NMFS-NWFSC-24. 258 p.

Williams, R.W., R.M. Laramie, and J.J. Ames. 1975. A Catalog of Washington Streams and Salmon Utilization. Volume 1 Puget Sound Region.

Wolman, M.G. 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union 35:951-956.

APPENDIX A

Mainstem Green River
Pool and Debris Jam Data

Table A-1. Pool units present in the mainstem Green River survey, 2005/2006.

Section	Ref #	Length ft.	Width ft.	Area sq ft	Max depth ft	Control depth ft	Residual depth ft	Pool type	Pool Forming Factor
1	302	87.4	21.0	1836.2	2.7	0.5	2.2	mcs	Jam A
1	303	64.2	27.0	1733.3	2.2	0.6	1.6	lcs	wood
1	305	243.9	45.0	10975.3	2.5	0.4	2.1	lcs	bedform
1	308	134.0	45.0	6030.4	3.0	0.4	2.6	mcs	Jam F
1	310	70.3	45.0	3164.8	2.7	0.6	2.1	mcs	bedform
1	312	151.2	27.0	4083.3	3.3	0.4	2.9	mcs	wood
1	314	173.9	21.0	3652.1	3.5	0.5	3.0	mcs	wood
1	316	78.3	24.0	1878.9	3.0	0.5	2.5	mcs	rootwad
AVERAGE		***125.4***	***31.9***	***4169.3***	***2.9***	***0.5***	***2.4***		
2	2	91.6	36.0	3299.0	2.5	0.4	2.1	ls	bedform
2	4	225.6	45.0	10150.3	5.0	0.4	4.6	mcs	bedform
2	6	107.9	60.0	6475.3	5.0	0.5	4.5	plunge	wood
2	10	263.7	66.0	17403.2	5.5	1	4.5	plunge	wood
2	12	68.8	42.0	2888.5	4.0	0.4	3.6	ls	wood
2	14	117.4	30.0	3522.6	3.7	0.5	3.2	plunge	rootwad
2	16	152.0	30.0	4560.1	3.5	0.8	2.7	plunge	bedform
2	21	671.2	30.0	20136.1	2.8	0.4	2.4	ls	bedform
2	23	196.5	54.0	10611.8	7.5	0.5	7	trib	bedform
2	25	115.7	48.0	5554.6	3.0	0.6	2.4	ls	creek
2	28	250.3	78.0	19519.6	3.0	0.8	2.2	ls	bedform
2	31	281.2	48.0	13495.5	3.2	0.3	2.9	ls	wood
2	32	442.2	60.0	26529.5	3.2	0.4	2.8	ls	bedform
2	34	367.6	90.0	33081.4	7.0	0.5	6.5	ls	bridge
2	36	911.7	48.0	43759.3	5.0	0.5	4.5	mcs	bedform
2	39	190.8	42.0	8015.2	4.0	0.4	3.6	ls	rootwad
2	40	147.0	42.0	6173.3	5.0	0.4	4.6	mcs	wood
2	42	201.5	30.0	6045.2	3.0	0.5	2.5	mcs	wood

Table A-1. Pool units present in the mainstem Green River survey, 2005/2006.

Section	Ref #	Length ft.	Width ft.	Area sq ft	Max depth ft	Control depth ft	Residual depth ft	Pool type	Pool Forming Factor
2	44	269.1	105.0	28250.7	4.0	0.5	3.5	mcs	wood
2	46	270.6	96.0	25975.6	6.0	0.6	5.4	mcs	wood
2	50	213.3	48.0	10237.6	3.0	0.5	2.5	mcs	wood
2	52	266.7	66.0	17602.9	2.0	0.4	1.6	ls	Jam Y
2	54	169.7	90.0	15272.0	4.0	0.5	3.5	mcs	wood
2	55	251.5	66.0	16596.6	3.0	0.8	2.2	mcs	boulder
2	57	208.1	90.0	18728.4	2.5	0.4	2.1	mcs	bedform
2	59	272.5	120.0	32703.8	3.0	0.5	2.5	mcs	Jam AA
2	61	156.6	48.0	7517.3	3.5	0.4	3.1	mcs	Jam AB
2	63	109.0	66.0	7195.2	3.0	0.5	2.5	mcs	bedform
2	65	183.5	72.0	13209.1	2.0	0.4	1.6	mcs	bedform
2	67	108.1	60.0	6485.0	2.0	0.5	1.5	mcs	wood
2	69	488.7	72.0	35186.2	6.0	0.5	5.5	bridge	bridge
2	70	539.5	66.0	35603.9	3.0	0.6	2.4	ls	wood
2	72	186.1	66.0	12281.7	8.0	0.5	7.5	mcs	wood
2	74	169.4	54.0	9148.1	4.2	0.6	3.6	ls	rootwad
2	76	345.0	90.0	31052.4	3.2	0.5	2.7	ls	bf/trees
2	78	159.5	36.0	5741.8	3.0	0.5	2.5	mcs	railroad
2	80	212.3	48.0	10188.1	2.8	0.4	2.4	ls	wood
2	81	188.9	60.0	11335.5	3.2	0.5	2.7	ls	wood
2	83	248.5	60.0	14912.8	5.2	0.8	4.4	ls	bedrock
2	85	299.5	54.0	16171.4	4.5	0.5	4	ls	wood
2	87	249.6	60.0	14978.3	3.0	0.7	2.3	mcs	bedform
2	90	449.9	60.0	26992.6	3.5	0.5	3	mcs	bedform
2	91	282.0	60.0	16917.0	3.2	0.8	2.4	mcs	bedform
AVERAGE		**258.1**	**60.3**	**15848.9**	**3.9**	**0.5**	**3.3**		

Table A-1. Pool units present in the mainstem Green River survey, 2005/2006.

Section	Ref #	Length ft.	Width ft.	Area sq ft	Max depth ft	Control depth ft	Residual depth ft	Pool type	Pool Forming Factor
3	93	298.3	66.0	19686.2	8.0	0.8	7.2	scour	creek
3	95	273.2	69.0	18847.8	3.0	0.4	2.6	ls	bridge
3	96	292.8	60.0	17569.8	6.0	0.7	5.3	ls	bridge
3	98	280.2	60.0	16809.3	7.0	0.6	6.4	ls	bedrock
3	100	162.8	90.0	14651.0	4.0	0.3	3.7	plunge	bedrock
3	107	286.2	66.0	18886.2	2.8	0.8	2	ls	bedform
3	109	115.5	72.0	8313.1	3.8	0.5	3.3	plunge	bedrock
3	112	200.4	66.0	13228.1	4.0	0.8	3.2	plunge	bedrock
3	121	270.4	78.0	21093.1	4.5	0.6	3.9	mcs	bedrock
3	123	497.0	90.0	44726.5	6.0	0.5	5.5	mcs	bedrock
3	126	494.0	48.0	23712.0	4.5	0.8	3.7	plunge	bedrock
3	128	319.6	48.0	15340.0	4.5	0.8	3.7	scour	railroad
3	133	541.9	102.0	55271.9	5.0	0.6	4.4	scour	railroad
3	135	371.6	66.0	24525.2	7.0	1	6	plunge	bedrock
3	138	466.7	78.0	36402.1	6.0	0.8	5.2	plunge	bedrock
AVERAGE		**324.7**	**70.6**	**23270.8**	**5.1**	**0.7**	**4.4**		
4	140	201.1	90.0	18099.9	9.0	0.8	8.2	scour	creek
4	142	317.6	66.0	20963.8	5.0	1	4	mcs	boulder
4	143	728.3	90.0	65551.4	6.0	1	5	mcs	bedrock
4	145	481.7	96.0	46245.6	8.0	1	7	mcs	boulder
4	149	302.3	75.0	22672.5	5.0	0.8	4.2	mcs	bedform
4	151	313.4	84.0	26327.2	7.0	1	6	mcs	bedform
4	156	306.0	54.0	16523.2	5.0	2	3	plunge	bedrock
4	157	619.0	78.0	48278.7	13.0	1	12	plunge	bedrock
4	161	571.1	48.0	27411.1	8.0	1	7	mcs	bedform
4	166	873.8	54.0	47182.8	5.0	1	4	mcs	railroad
4	168	337.1	48.0	16181.6	5.0	0.8	4.2	lcs	bedform

Table A-1. Pool units present in the mainstem Green River survey, 2005/2006.

Section	Ref #	Length ft.	Width ft.	Area sq ft	Max depth ft	Control depth ft	Residual depth ft	Pool type	Pool Forming Factor
4	170	210.9	48.0	10121.6	6.0	0.8	5.2	mcs	bedform
4	171	320.5	54.0	17305.5	12.0	1	11	plunge	bedrock
4	173	228.2	78.0	17802.6	6.0	1	5	mcs	bedform
4	180	257.5	45.0	11589.3	3.5	1	2.5	ls	Wood
4	183	118.9	45.0	5348.3	3.8	0.8	3	mcs	bedform
4	184	149.9	90.0	13487.8	4.5	1.5	3	mcs	bedform
4	189	544.0	45.0	24479.3	6	1.5	4.5	mcs	bedrock
4	191	140.4	60.0	8426.9	3.5	1.5	2	mcs	bedform
4	198	340.9	60.0	20451.4	3	1	2	mcs	bedform
4	200	582.5	66.0	38442.0	3	1.4	1.6	mcs	jam
4	203	319.8	90.0	28784.6	4	1.5	2.5	ls	bedform
4	205	640.4	135.0	86460.6	6	0.5	5.5	mcs	bedform
4	207	128.0	57.0	7294.8	6	1.5	4.5	mcs	bedrock
4	210	124.5	90.0	11209.3	4	1	3	mcs	bedform
4	212	164.8	90.0	14835.8	6	1	5	mcs	bedform
AVERAGE		**358.6**	**70.6**	**25826.1**	**5.9**	**1.1**	**4.8**		
5	214	606.9	90.0	54622.2	5.0	0.4	*4.6*	lcs	bridge
5	215	319.3	96.0	30652.9	4.5	0.5	*4.0*	lcs	wood
5	224	690.6	90.0	62151.5	5.8	2	*3.8*	lcs	bedrock
AVERAGE		**453.4**	**85.5**	**40106.6**	**5.3**	**0.9**	**4.5**		

Table A-2. Debris jams tallied during the mainstem Green River survey, 2005/2006.

Section	Ref. #	Jam	Zone	Size	Unit
1	302	A	1	medium	pool
1	304	B	2	small	riffle
1	304	C	1	small	riffle
1	304	D	1	small	riffle
1	307	E	2	small	side channel
1	308	F	1	medium	pool
1	317	G	1	small	riffle
2	1	H	2	small	riffle
2	2	I	2	small	pool
2	4	J	2	small	pool
2	7	K	2	small	riffle
2	8	L	2	medium	run
2	9	M	2	small	riffle
2	9	N	2	large	riffle
2	10	O	2	small	pool
2	22	P	2	small	riffle
2	24	Q	2	medium	riffle
2	37	R	2	medium	riffle
2	37	S	2	medium	riffle
2	37	T	2	small	riffle
2	45	U	2	medium	riffle
2	46	V	1	medium	pool
2	47	W	2	small	riffle
2	50	X	1	small	pool
2	52	Y	1	small	pool
2	54	Z	1	medium	pool
2	59	AA	1	large	pool
2	61	AB	2	medium	pool
2	62	AC	1	small	riffle
2	62	AD	2	medium	riffle

Table A-2. Debris jams tallied during the mainstem Green River survey, 2005/2006.

Section	Ref. #	Jam	Zone	Size	Unit
2	70	AE	1	large	pool
2	70	AF	2	large	pool
2	71	AG	1	small	riffle
2	76	AH	1	medium	pool
2	77	AI	2	small	riffle
2	79	AJ	2	small	riffle
2	82	AK	2	medium	riffle
2	84	AL	2	small	riffle
2	85	AM	2	large	pool
3	97	AN	2	small	riffle
3	99	AO	2	small	riffle
3	99	AP	1	small	riffle
3	116	AQ	2	medium	riffle
3	119	AR	2	small	riffle
3	124	AS	2	large	riffle
3	137	AT	2	small	riffle
3	137	AU	2	small	riffle
4	148	AV	1	small	riffle
4	148	AW	2	small	riffle
4	148	AX	1	small	riffle
4	402	AY	1	small	side channel
4	402	AZ	1	small	side channel
4	402	BA	1	small	side channel
4	402	BB	1	medium	side channel
4	402	BC	2	small	side channel
4	158	BD	2	small	riffle
4	159	BE	2	small	run
4	160	BF	2	small	riffle
4	180	BG	2	small	pool
4	185	BH	1	small	run

Table A-2. Debris jams tallied during the mainstem Green River survey, 2005/2006.

Section	Ref. #	Jam	Zone	Size	Unit
4	191	BI	2	small	pool
4	198	BJ	2	small	pool
4	198	BK	2	small	pool
4	200	BL	2	small	pool
4	200	BM	2	small	pool
4	201	BN	2	small	riffle
4	202	BO	2	small	run
4	202	BP	2	medium	run
4	204	BQ	2	small	riffle
4	206	BR	2	small	riffle
4	206	BS	2	small	riffle
4	206	BT	2	small	riffle
4	208	BU	2	small	riffle
5	226	BV	1	medium	riffle
5	227	BW	2	small	run

APPENDIX B

Pebble Count Charts

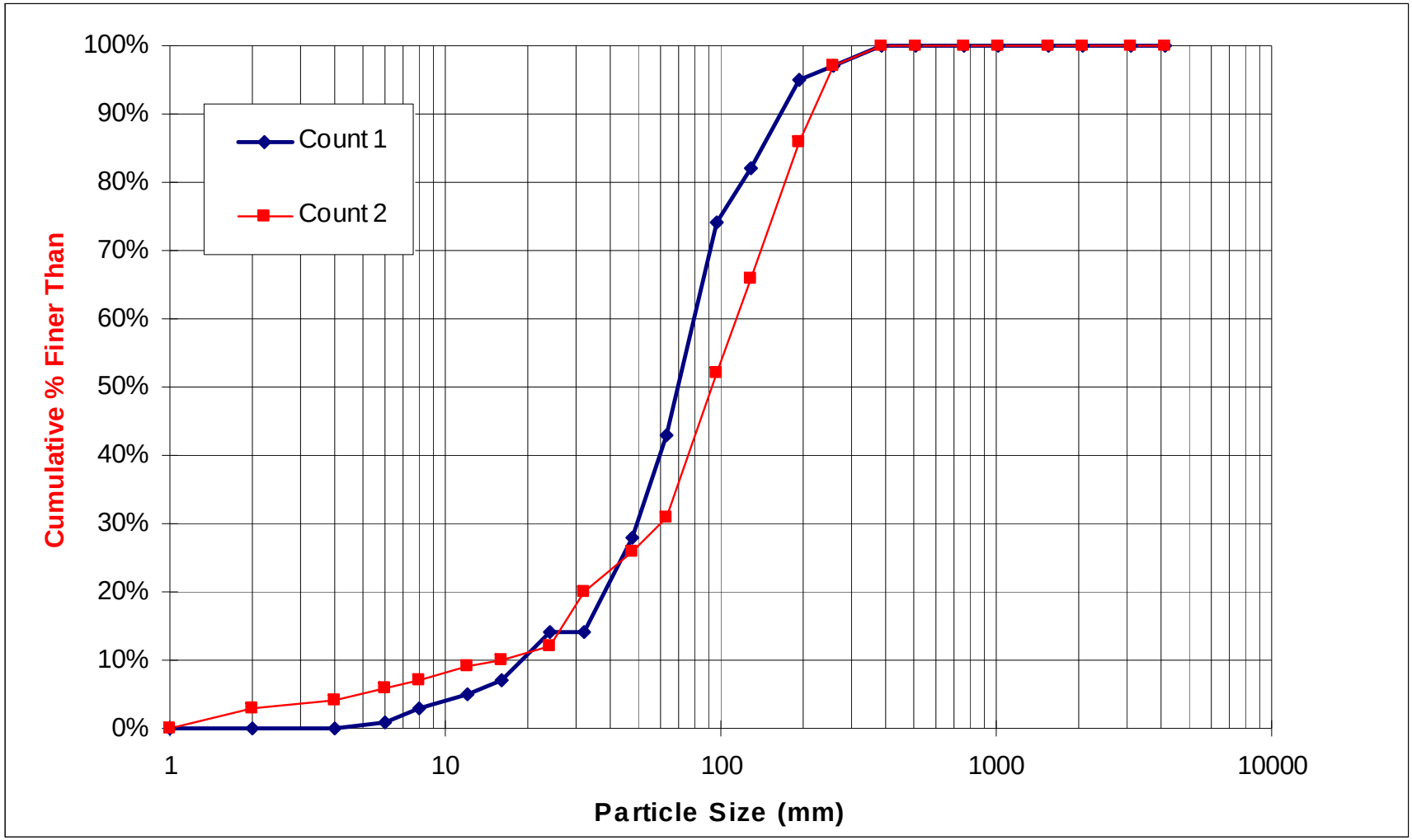

Figure B-1. Pebble Count data for Reach 1, Section 1, King County, Washington, 2005/2006.

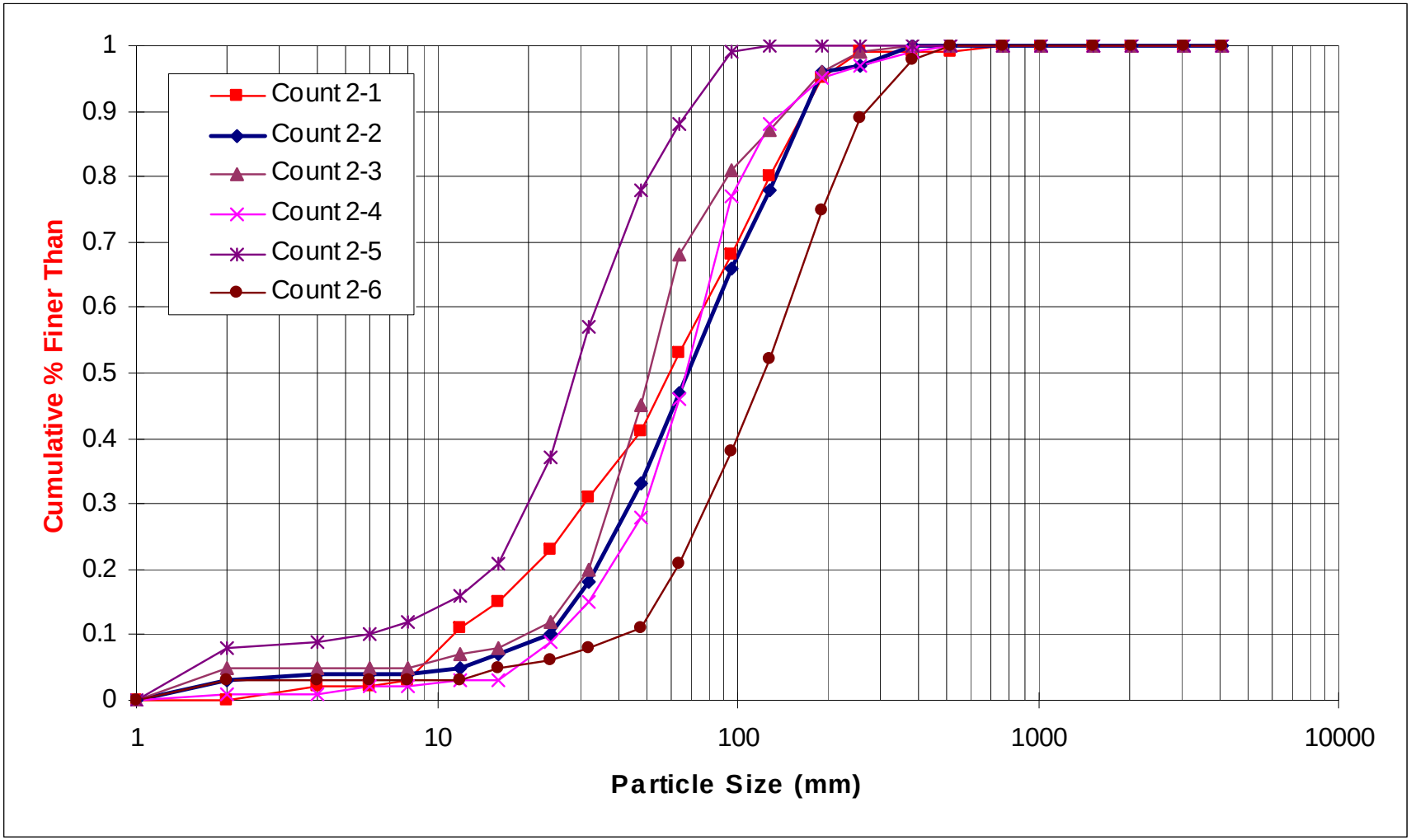

Figure B-2. Pebble Count data for Reach 1, Section 2, King County, Washington, 2005/2006.

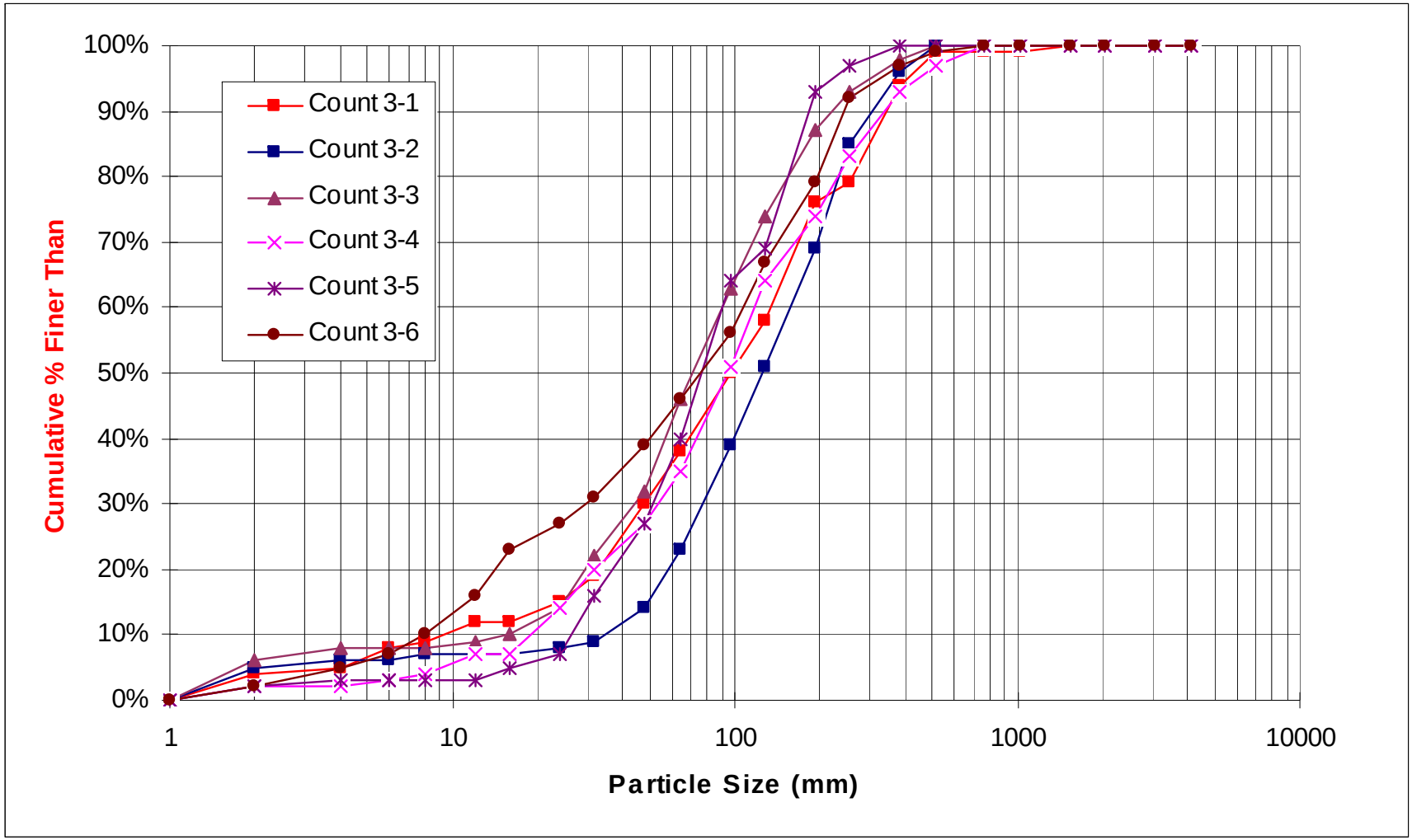

Figure B-3. Pebble Count data for Reach 1, Section 3, King County, Washington, 2005/2006.

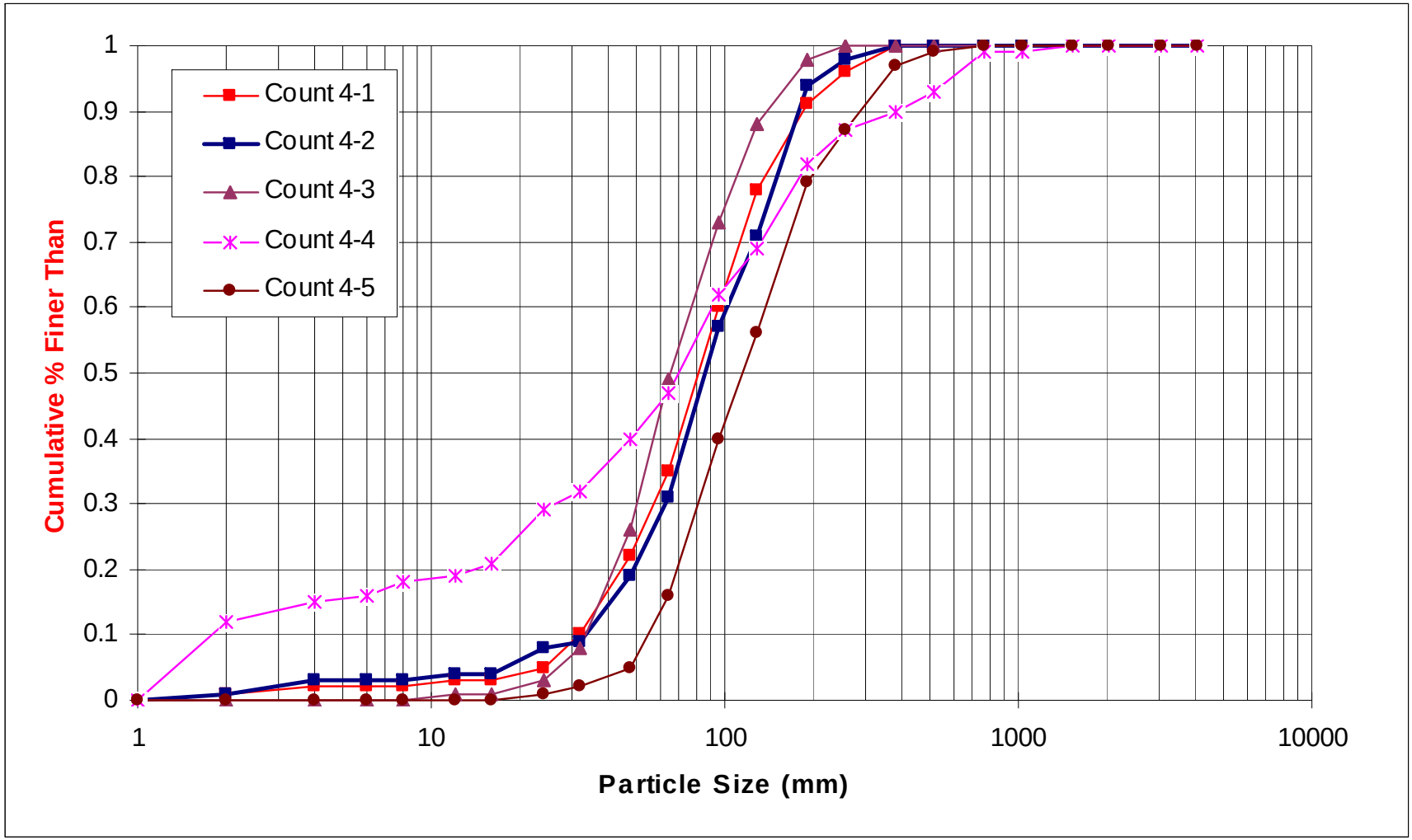

Figure B-4. Pebble Count data for Reach 1, Section 4 upstream, King County, Washington, 2005/2006.

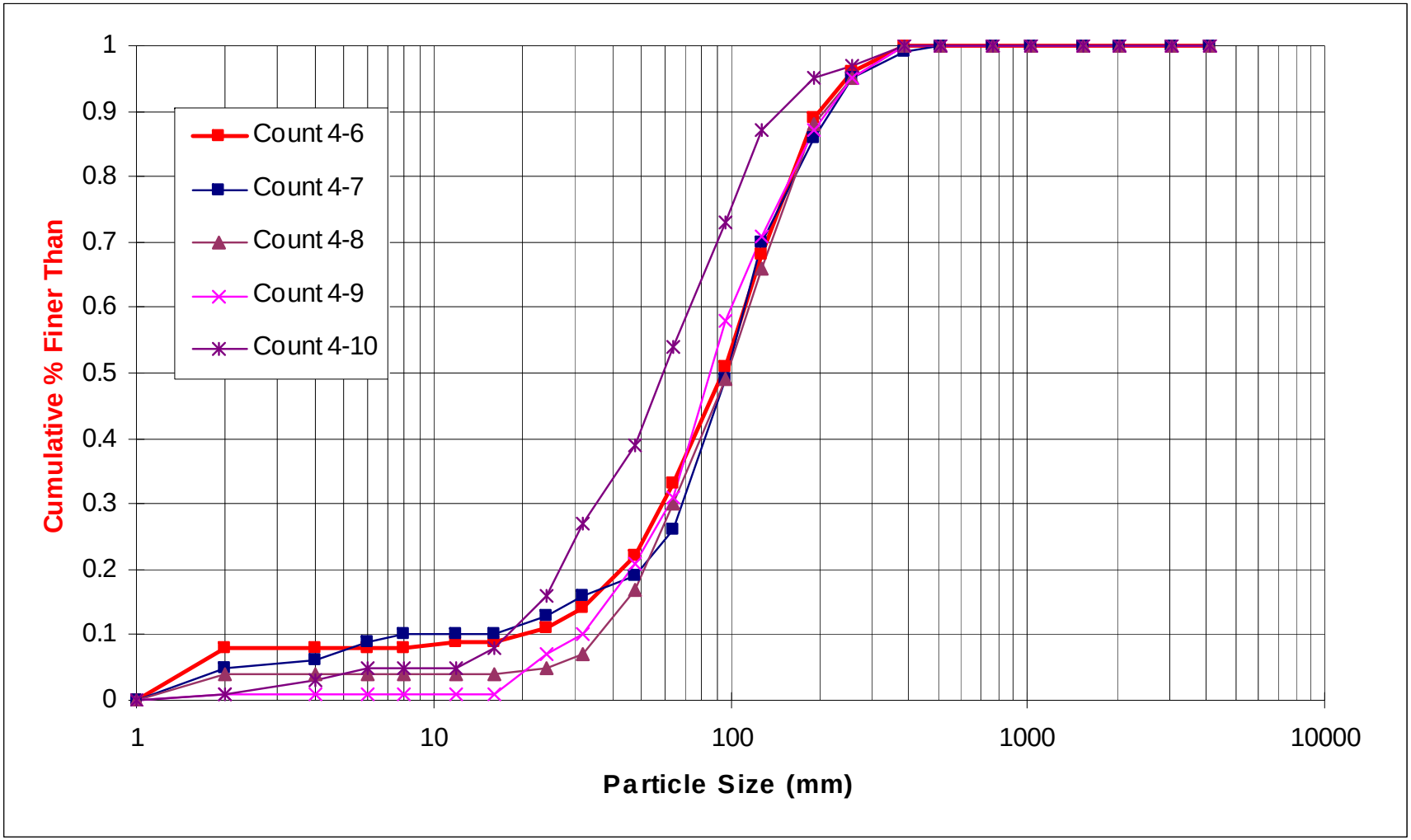

Figure B-5. Pebble Count data for Reach 1, Section 4 downstream, King County, Washington, 2005/2006.

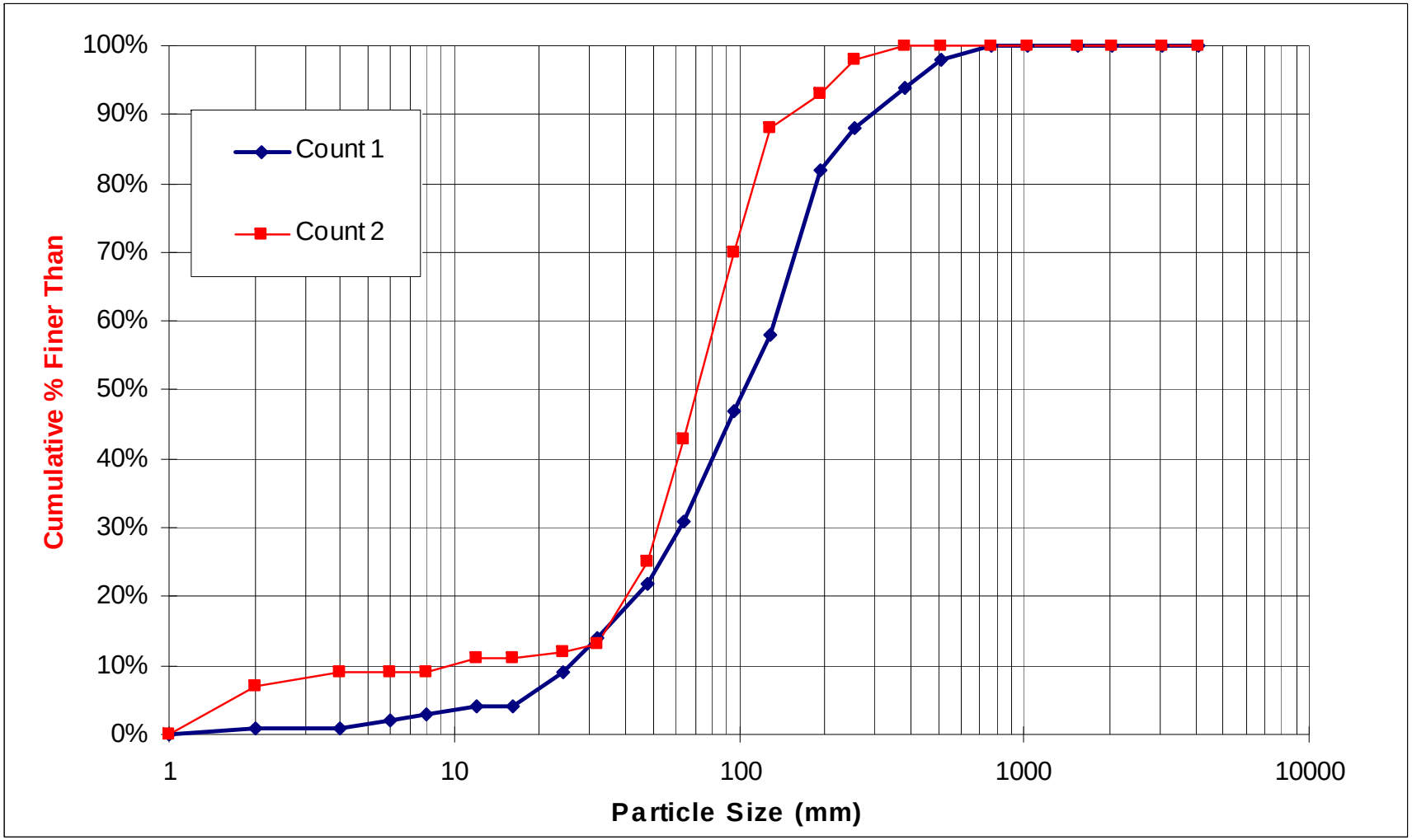

Figure B-6. Pebble Count data for Reach 1, Section 5, King County, Washington, 2005/2006.

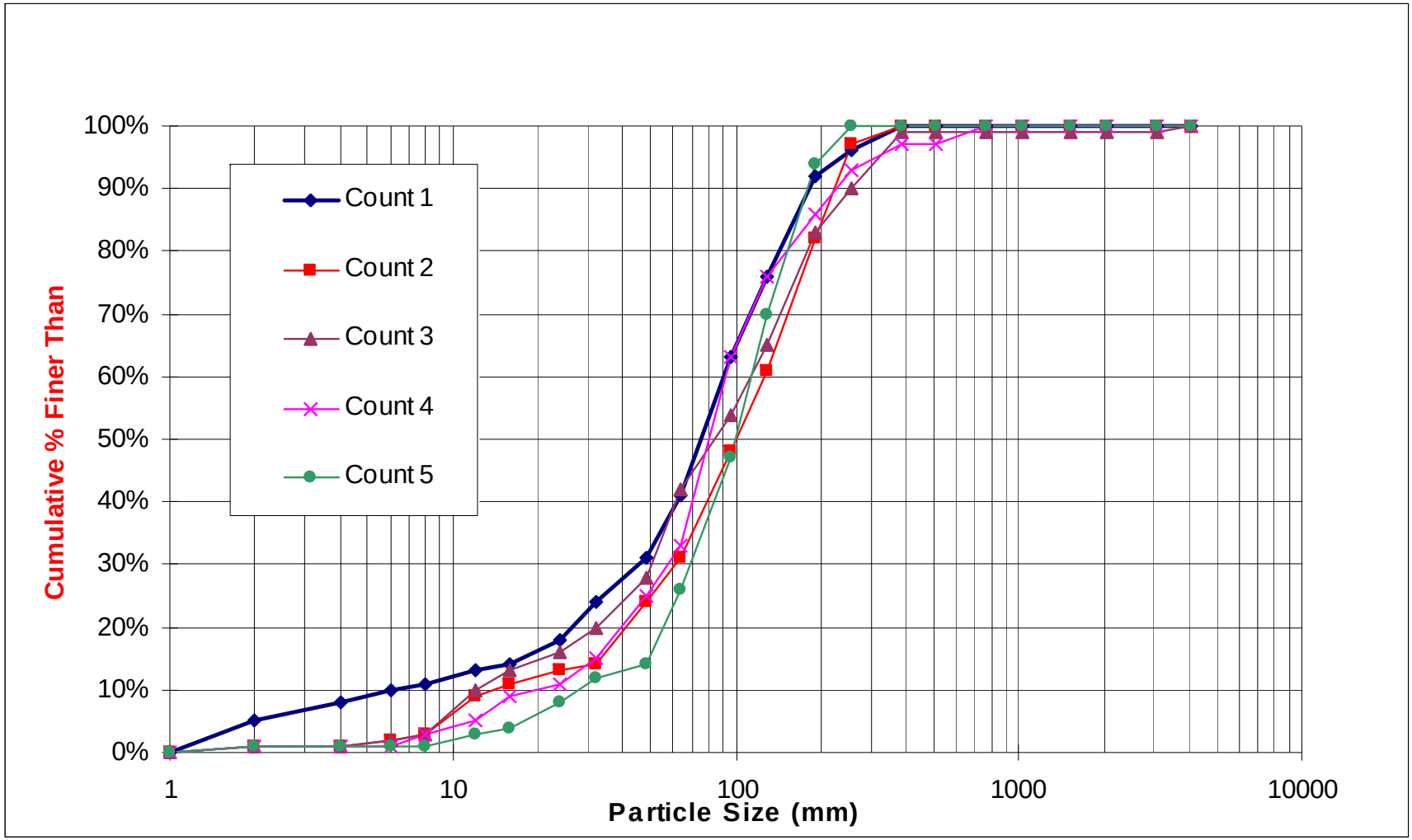

Figure B-7. Pebble Count data for Reach 2, Sunday Creek, King County, Washington, 2005/2006.

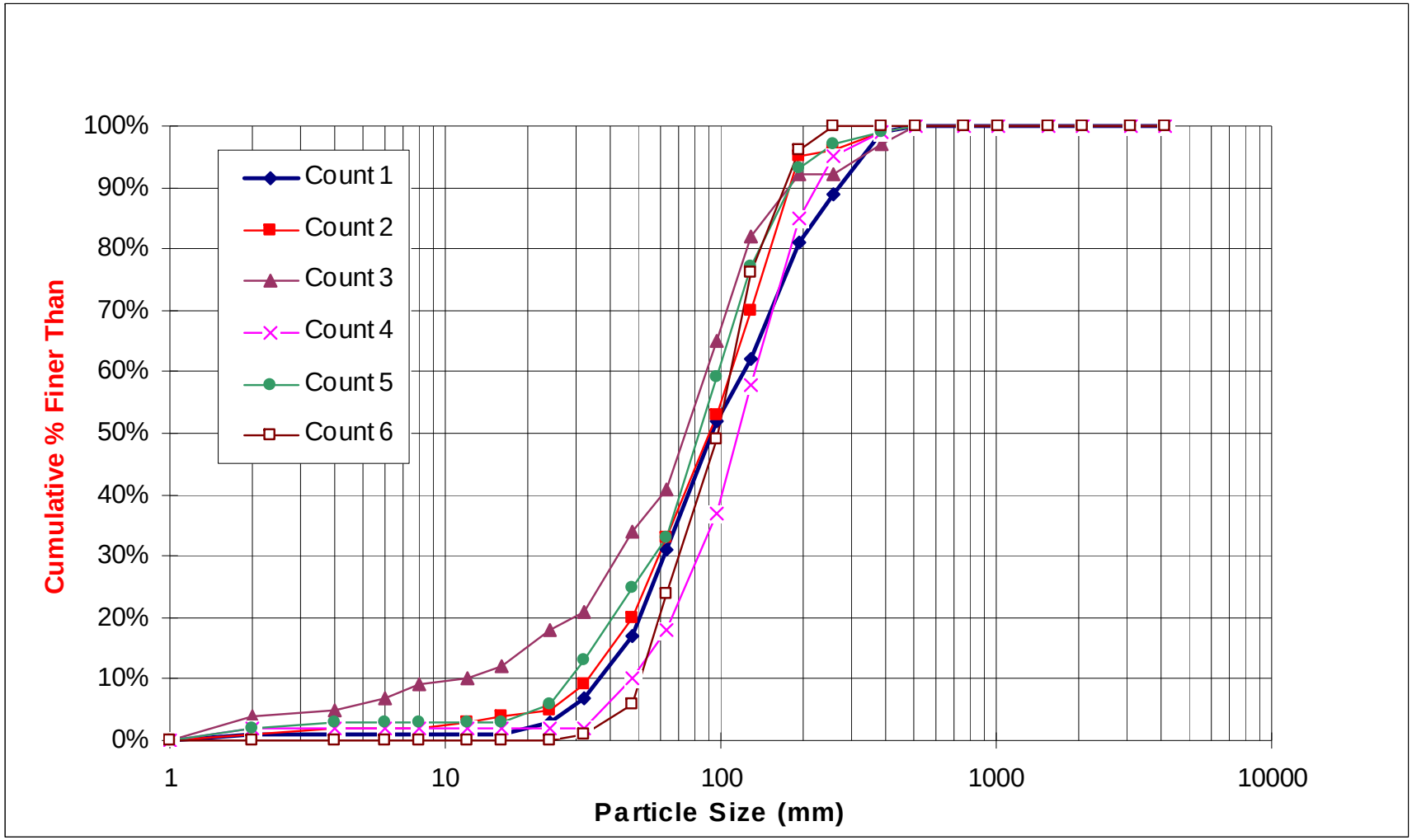

Figure B-8. Pebble Count data for Reach 3, Smay Creek, King County, Washington, 2005/2006.

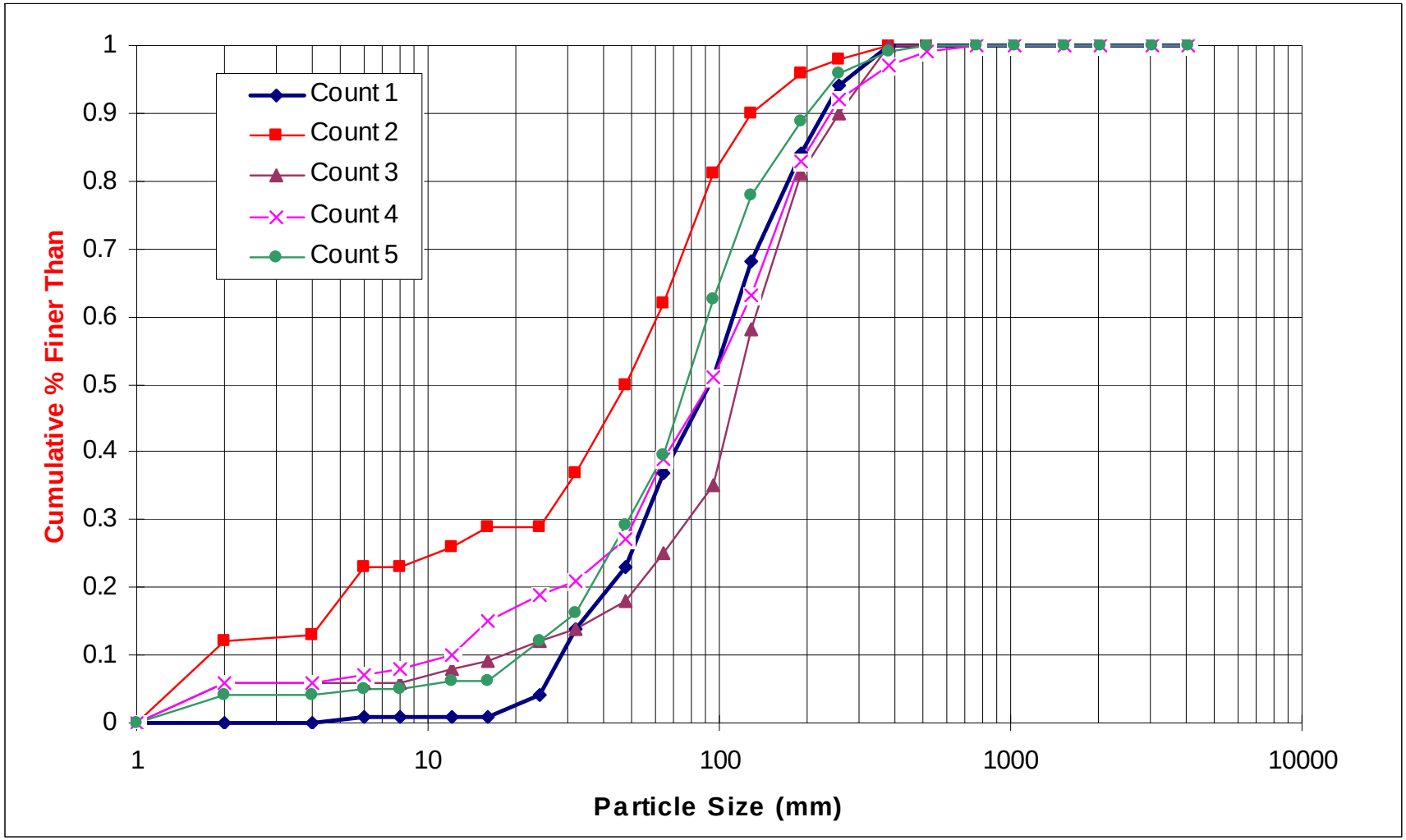

Figure B-9. Pebble Count data for North Fork Green River, King County, Washington, 2005.

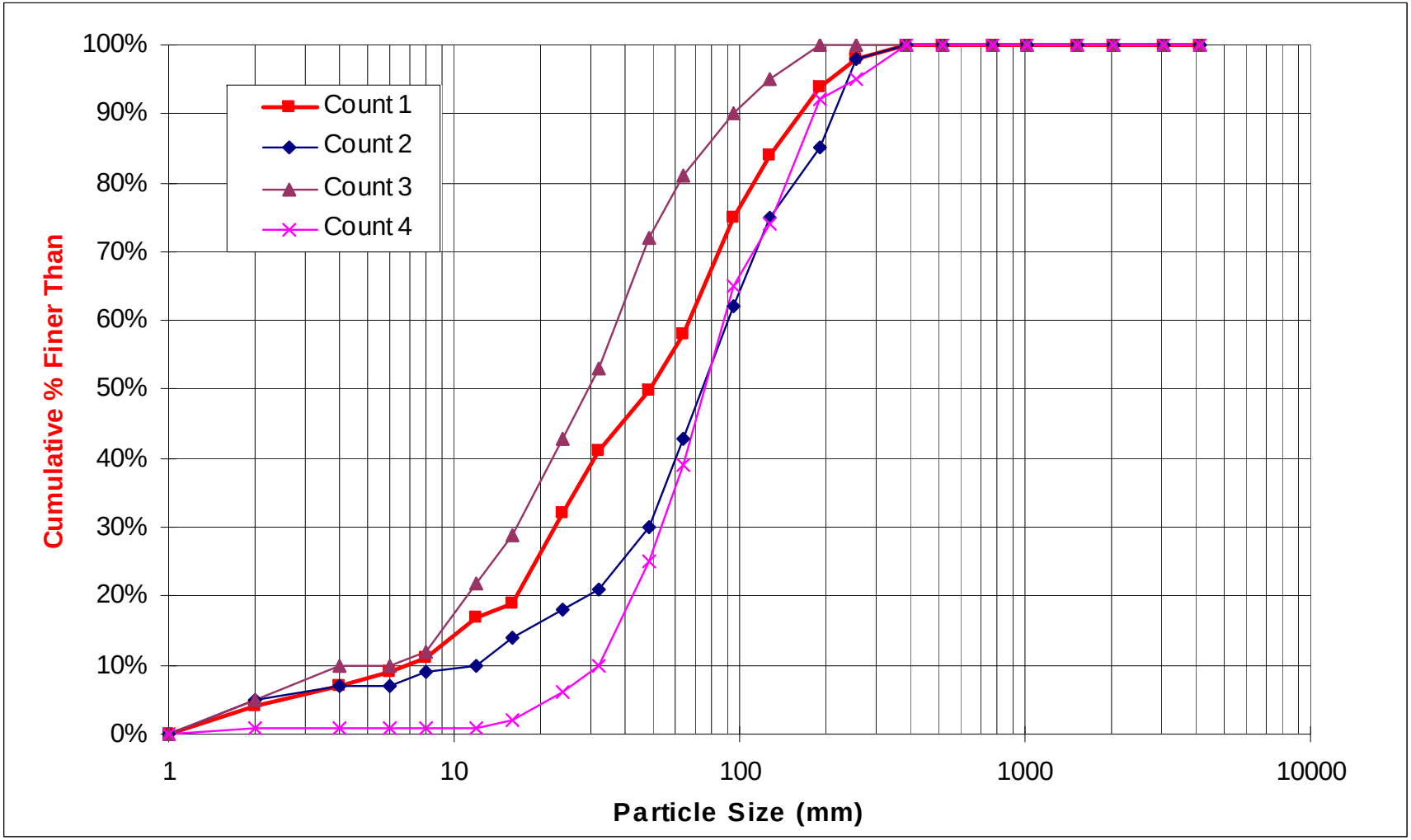

Figure B-10. Pebble Count data for Gale Creek, King County, Washington, 2005.

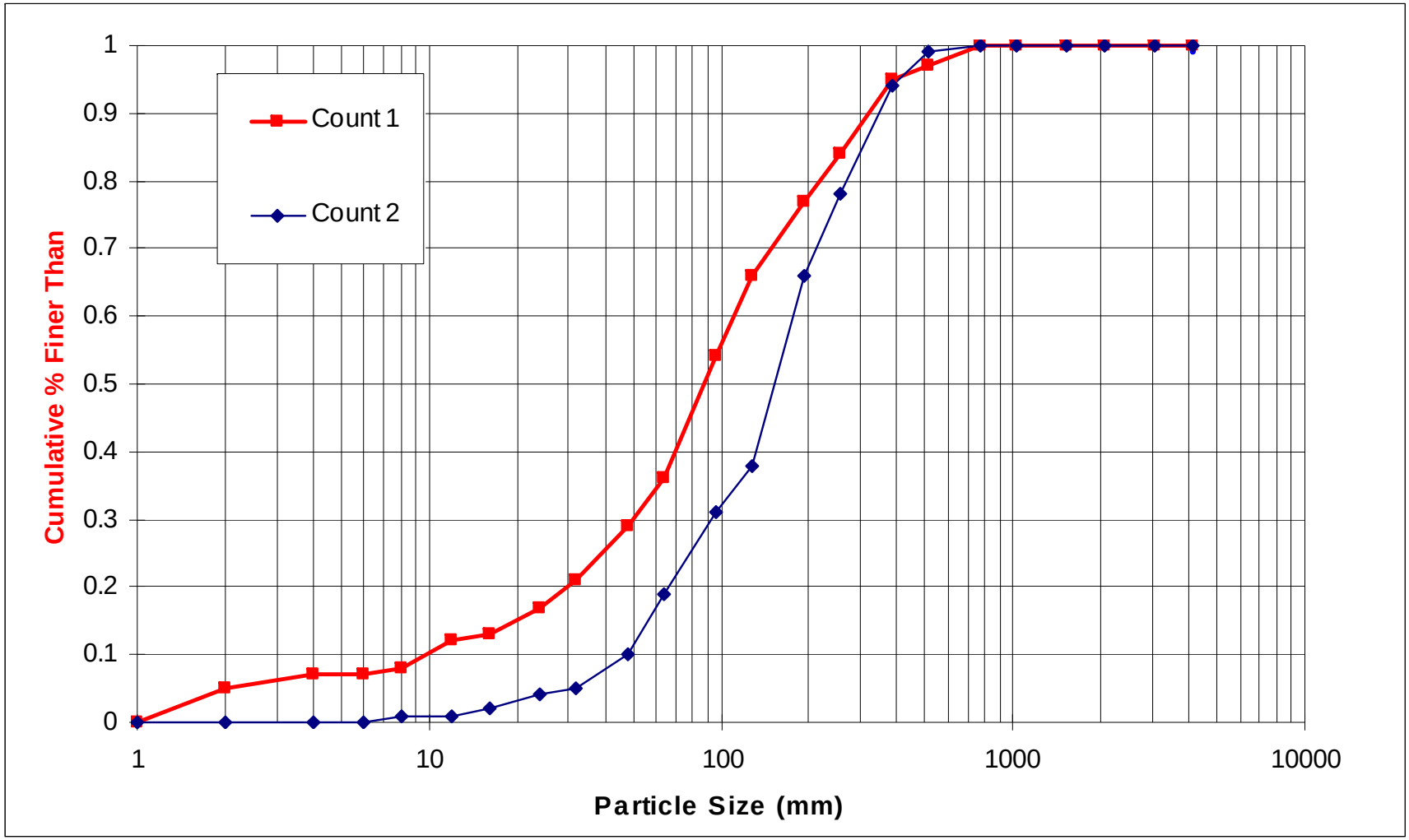

Figure B-11. Pebble Count data for Charley Creek, King County, Washington, 2005.

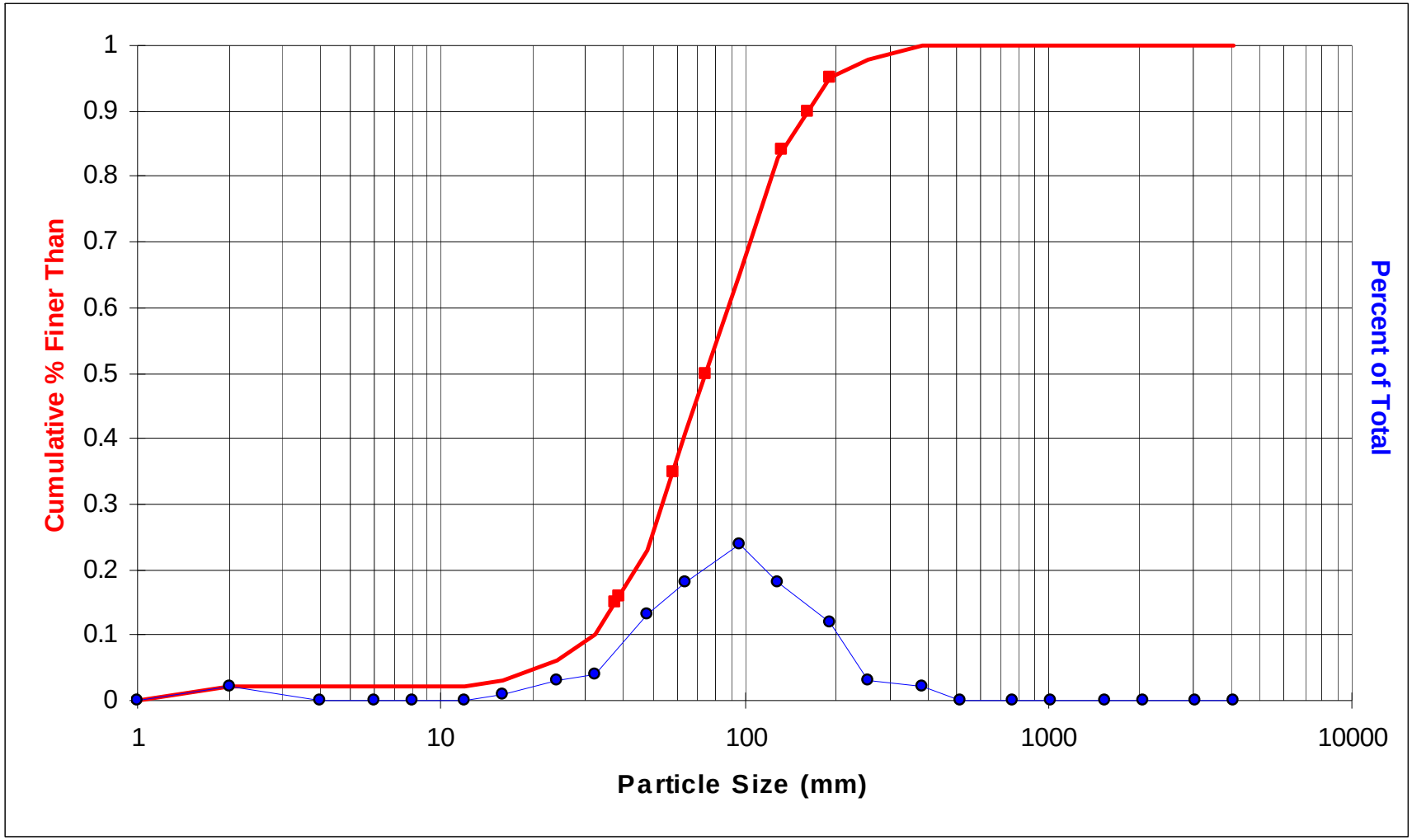

Figure B-12. Pebble Count data for Piling Creek data, King County, Washington, 2005.

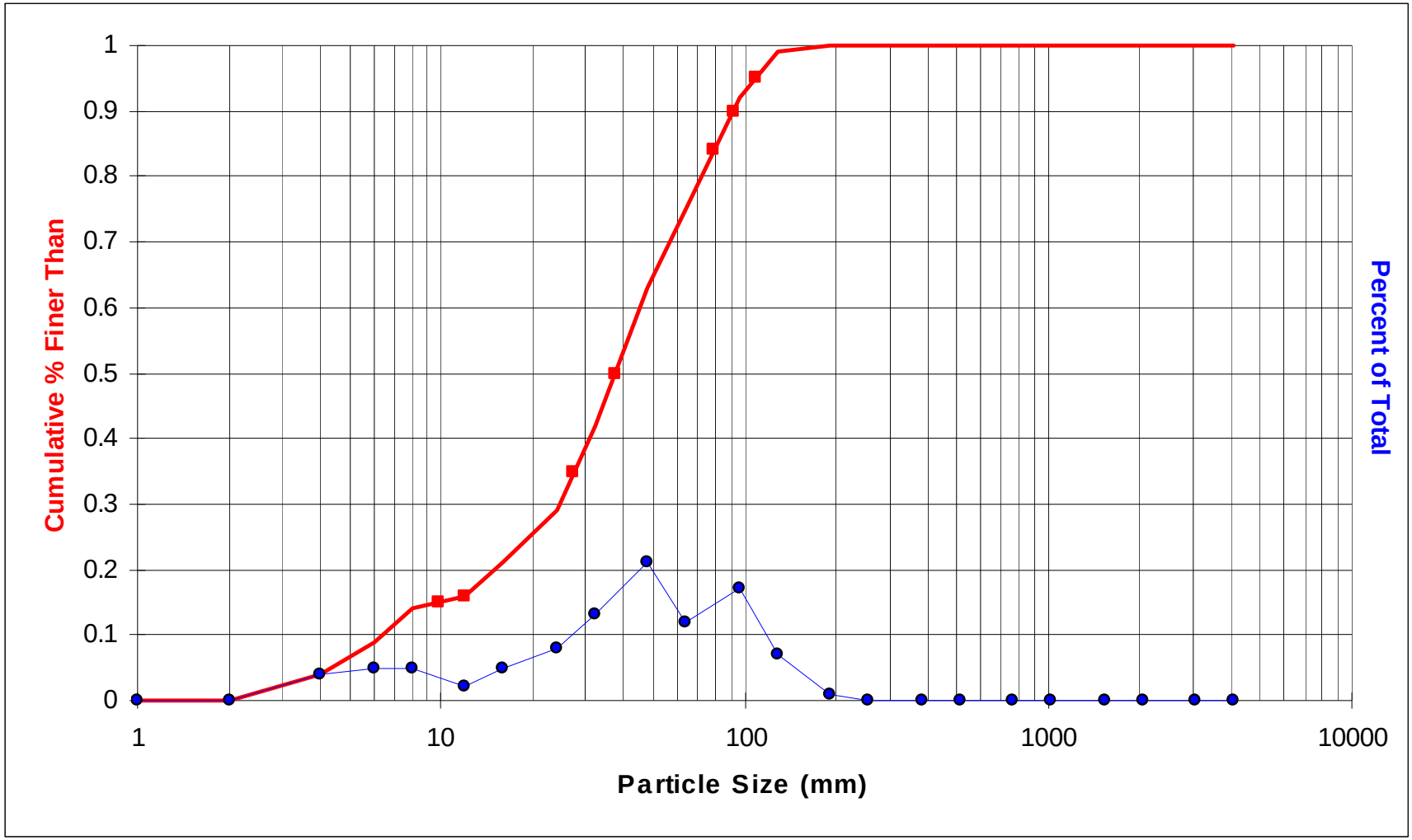

Figure B-13. Pebble Count data for Cottonwood Creek, King County, Washington, 2005.

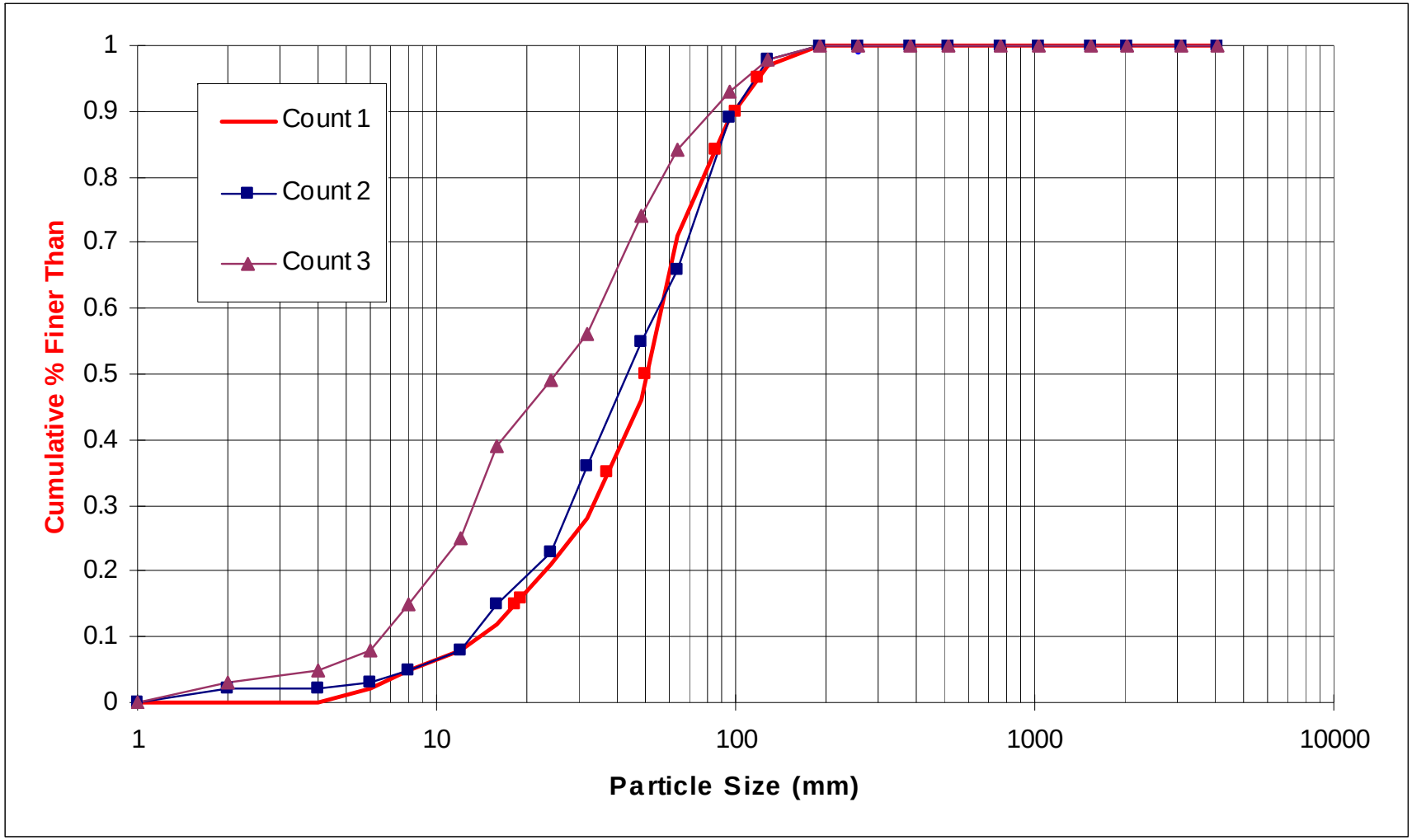

Figure B-14. Pebble Count data for McDonald Creek, King County, Washington, 2005.

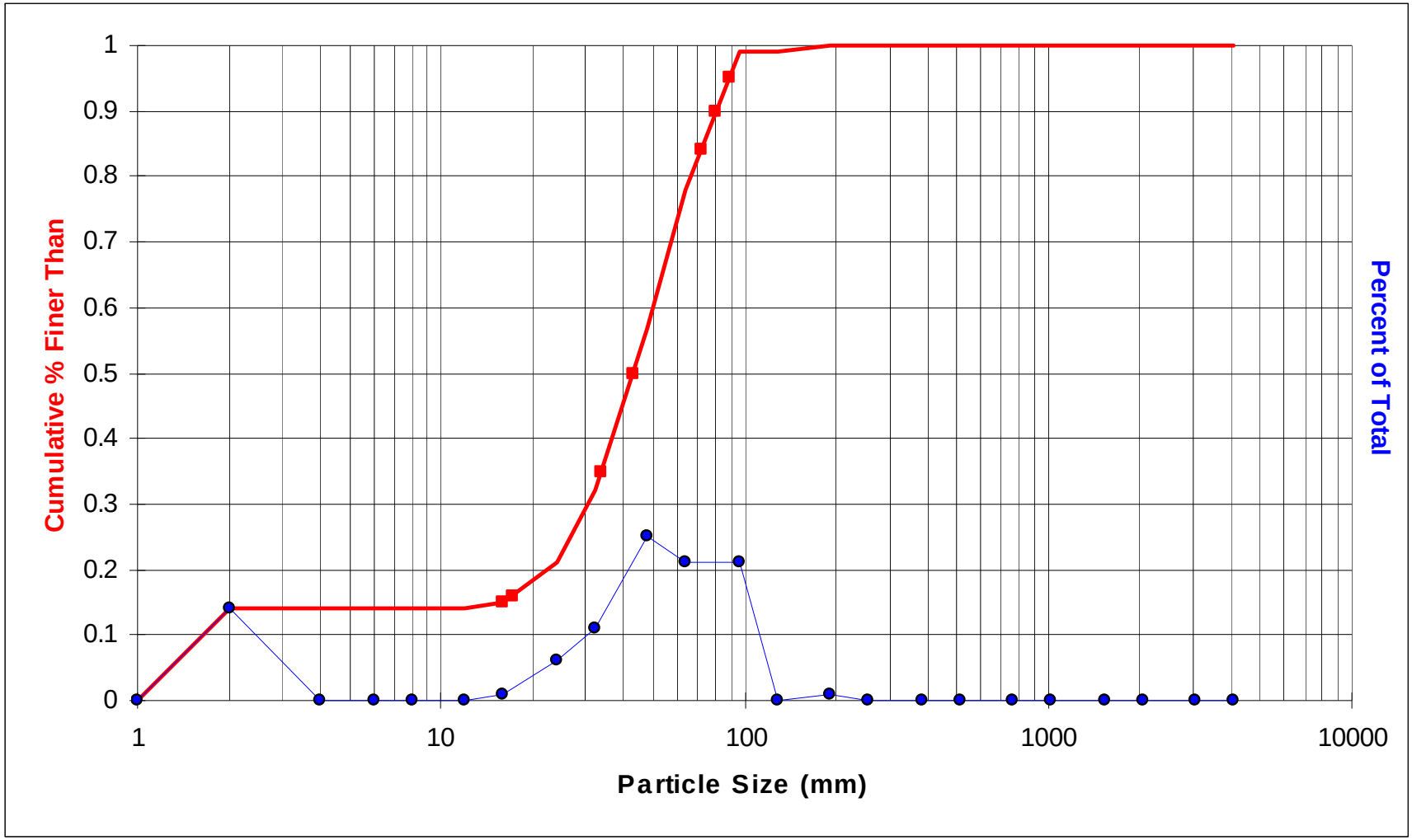

Figure B-15. Pebble Count data for Signani Slough, King County, Washington, 2005.