Dosewallips River Habitat Assessment:
Coupling High-Resolution Remote Sensing and Ground Surveys to Prioritize Aquatic Conservation, Olympic Mountains, Washington State

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Executive Summary

Though the Dosewallips River has been identified as a priority watershed for salmon conservation there is little available aquatic habitat data, hindering effective natural resource management decision-making. We initiated the present study to correct this data gap and guide future aquatic habitat protection and restoration efforts in the watershed. The Dosewallips River corridor's inaccessibility and natural hazards render traditional ground-based habitat surveys impractical. Moreover, the patchiness of key habitat features such as large wood (LW) jams, pools, and secondary channels warrants a continuous survey approach so that biological hotspots are not missed and natural longitudinal variability is adequately characterized along the entire river corridor.

Recent advances and integration of remote sensing, GIS, and GPS technologies offer aquatic ecologists new tools to conduct broad-scale river-floodplain habitat assessments. We combined 20 cm-resolution LIDAR and digital orthophotography with ground surveys to map LW, pools, and secondary channels along 22 kilometers of the Dosewallips River. Reaches were classified by geomorphic and land use setting, and select ground surveys of low-gradient tributary and side channels (or 'secondary channels') as well as mainstem river channels were conducted. Field surveys validated that we detected and accurately characterized LW jams, pools, and secondary channels, but missed LW key pieces and could not predict the extent of secondary channel perennial flow based on elevations relative to the mainstem channel.

Our whole-river LW jam, pool, and secondary channel survey results showed striking among-reach differences in the distribution and character of key aquatic habitat features. Large wood jams ranged 0-26.9/km and pools ranged 1.4-23.5/km with most among-reach variation explained by geomorphic setting and historical land use. Median jam frequency measured 4.5 and 6.1 times higher in unconfined-natural as compared to unconfined-modified and confined/moderately confined geomorphic reach types, respectively. Median pool frequencies measured 2.0 and 2.3 times higher in unconfined-natural as compared to unconfined-modified and confined/moderately confined reaches.

Median residual pool depth from confined/moderately confined reaches was nearly twice that from unconfined-modified and unconfined-natural reaches.

Secondary channel intersection frequencies were 2.9 and 3.4 times higher in unconfined-natural as compared to unconfined-modified and confined reaches. Moreover, secondary channel relative elevations from modified alluvial reaches exhibited skewed distributions, revealing mainstem channel incision or aggradation that varied consistently with their land use legacy and geomorphic setting. Less disturbed alluvial reaches had more normal and evenly distributed secondary channel relative elevations.

To provide a broader temporal context for our investigation, we incorporated information from archival records, interviewed long-time landowners, and examined historical photos for select alluvial reaches. Based on this historical information and mainstem river ground surveys that bracketed a 25-year flood event in January 2002, we conclude that though degraded habitat conditions currently prevail along the Dosewallips River, natural recovery of in-channel LW is occurring as mediated by flood disturbance.

We highlight habitat protection and restoration needs, prioritizing reaches for property acquisition/easements, engineered logjam construction, bank armoring removal, and floodplain restoration. The results of this investigation are already aiding habitat protection and restoration efforts in the watershed, and serve as a long-term baseline monitoring tool. With additional refinement these methods represent a low-cost, effective approach to quantifying aquatic habitat conditions in other remote Pacific Northwest large river environments.

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Acknowledgments

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Introduction and Background

The Dosewallips River has been identified in several recent assessments as a priority conservation area for threatened salmon in Hood Canal (USFS 1999, WDFW and PNPTT 2000, May and Peterson 2003, HCCC 2004) and Puget Sound (Frissell et al. 2000). While habitat data exists for many other Hood Canal watersheds, there is little available for the Dosewallips watershed, hindering effective salmon recovery management and restoration planning. Field observations suggest that mainstem river salmon spawning and rearing environments have been simplified, lost, or degraded as a result of historical and ongoing land use practices. Baseline habitat data on the quantity, quality, and distribution of pools and large wood (LW) are needed to track habitat changes over time and to address the appropriateness and location of habitat protection and enhancement measures (USFS 1999, WDFW and PNPTT 2000).

Traditionally, cost and logistical constraints have limited the acquisition of spatially extensive, yet adequately detailed data on which to base effective habitat management decisions. However, recent advances in remote sensing, geographic information system (GIS), and global positioning system (GPS) technologies have facilitated the development and integration of new tools to assist salmon recovery managers (c.f. Lunetta et al. 1997, Neale 1997, Torgerson et al. 1999). Airborne Light Detection and Ranging (LIDAR) and digital photogrammetry technologies offer particular promise in river-floodplain systems due to their high spatial resolution, ability to penetrate obscuring forest canopies, and relative cost-effectiveness (Gilvear et al. 1995, Lane 2000, Lefsky et al. 2002, Marcus 2002, Dowling and Accad 2003, Hagerud et al. 2003). Coupling airborne remote sensing with conventional ground surveys, scientists are expanding the scope and spatial extent of habitat analyses to describe riverine landscape elements at scales relevant to ecosystem management concerns and fish life history processes (Fausch et al. 2002, Poole et al. 2002).

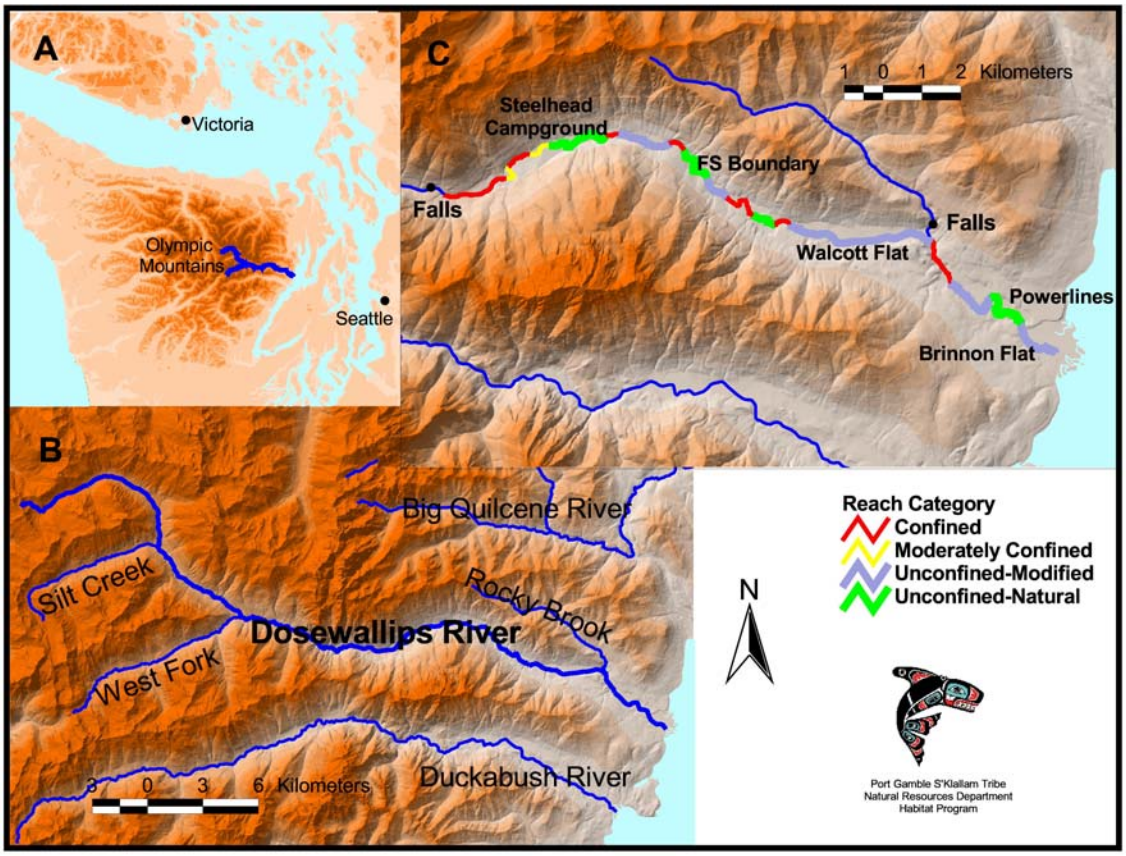
In this study we combined remote sensing and ground surveys of the Dosewallips River and its floodplain to generate baseline aquatic habitat data in order to support effective habitat management decision-making. High-resolution LIDAR-based topographic maps of the river-floodplain system were combined with ground- and digital imagery-based inventories of LW, pools, and secondary channels to describe the river-wide distribution of key salmon habitat elements and their geomorphic context upstream to river kilometer (RK) 22.0. We combined this data with information from historical records, archival aerial photos, and resident interviews to identify critical conservation areas and potential restoration measures.

Study Area

Located in east Jefferson County (Washington State, USA), the Dosewallips River drains a 316 km^2 area of steep terrain on the east side of the Olympic Peninsula (Figure 1). The 48 km-long river descends steeply from 1700 m elevation at its headwaters to a 1.8 km^2 estuarine delta on Hood Canal, the western arm of Puget Sound. The underlying geology is composed of clastic sedimentary rocks at the headwaters and basalt in the middle and lower portions of the watershed, with limited glacial and fluvial deposits in the lower-river floodplain-delta area. During the latest Vashon Stade of the Fraser glaciation (13,000 years before present), an alpine glacier advanced down-valley to within 5 km of the present-day river mouth (Garcia 1996).

Mean annual precipitation and temperature is estimated at 1264 mm and 9.9° C, respectively, with 80% of precipitation falling as rain or snow during the October-April period (Quilcene 2 SW 47°49'N, 122°55'W). Average annual discharge measures 12.6 cubic meters per second (cms, range 1.9-373.7 for the years 1931-1958) at RK 11.4. The Dosewallips River has two annual runoff peaks, one occurring November-February associated with winter rain, the other occurring in May-June associated with spring snowmelt (USFS 1999). The largest recorded peak discharges on the Dosewallips River were 373.7 cms on 26 November 1949 and 308.6 cms on 5 November 1934, with estimated recurrence intervals of 83 and 32 years respectively. Based on highly-correlated stream flow records from the adjacent Duckabush River, other large flood events occurred on 12 December 1995 and 7 January 2002 with estimated recurrence intervals of 67- and 25-years, respectively (Cenderelli et al. 2003).

Figure 1. Location map (A) showing the Dosewallips watershed in Puget Sound, Washington State. Inset map (B) shows the Dosewallips River, its principal tributaries, and adjacent eastern Olympic Mountain rivers; and (C) depicts the study area, highlighting key reaches and anadromous fish migration barriers.



Dominant vegetation is composed of Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) forests, shifting to true fir (*Abies* spp.) and mountain hemlock (*Tsuga mertensiana*) above 1100 m elevation. Along the mainstem river-floodplain, black cottonwood (*Populus trichocarpa*) and red alder (*Alnus rubra*) forests predominate (USFS 1999).

The upper 60% of the Dosewallips watershed is undeveloped and protected within Olympic National Park, while the middle-lower 30% of the basin is in Olympic National Forest (WDFW and PNPTT 2000). An impassable falls limits salmon use to the lower 23 kilometers of river. As with other west Hood Canal watersheds, private ownership is concentrated along lower reaches of the river where land use is dominated by pastureland, residential development, and clearcut logging. Dosewallips State Park occupies land on the south side of the river near the mouth, and the town of Brinnon is located to the north within the floodplain-delta area.

Historically, intensive timber harvest and fires have impacted the river corridor and hillslopes of the middle and lower watershed. Logging in the watershed began in 1859 using ox teams, and progressed to the use of railroads and a splash dam near the turn of the century, which were replaced by trucks after 1920. A splash dam built by the Sims Logging Company at the head of the Dosewallips canyon (RK 6.3) in 1917 was in operation for 9-10 years. When water was released, most logs that had been accumulated behind the dam were flushed all the way to Hood Canal suggesting the erosive power of these releases was likely catastrophic for salmon and their habitat in the lower river. Railroad logging of the watershed was extensive; the longest railroad line was built on the south side of the river from Brinnon upstream to approximately RK 16.4. More recent plans for hydroelectric development of the watershed (1950s-1990s), have been abandoned (USFS 1999). Due to the watershed's healthy ecological condition and relative isolation from growth pressures, the Dosewallips has been identified as a high-value conservation area for threatened salmon, Roosevelt elk, and other priority species (Frissell et al. 2000, May and Peterson 2003, HCCC 2004)

Methods

We coupled ground surveys of select Dosewallips tributary, side channel, and mainstem reaches with remote sensing techniques to provide a whole-river perspective on the distribution and character of large wood (LW), pools, and secondary channels. Habitat features were mapped from high-resolution digital aerial photos and a LIDAR-derived elevation model. For ground surveys of tributary, side channel, and river mainstem environments, we employed modified Washington Timber-Fish-Widlife (TFW) ambient monitoring surveys (Pleus et al. 1999, Schuett-Hames et al. 1999). Table 1 outlines the target features, attributes, and criteria for each of the survey types and Table 2 defines habitat feature categories. For perspective on riverine habitat changes through time, we integrated historical information, examined archival aerial photos, and conducted interviews with long-time residents; these results are summarized in Appendices A and B.

Aerial survey

High-resolution (0.2 m pixel) true-color digital aerial photography and LIDAR were acquired on 28 March 2002 for the lower 22 kilometers of the Dosewallips River and its floodplain-delta. Image sensors were flown from the belly pod of a Bell JetRanger 206B helicopter at an approximate above ground elevation of 650 m in flight lines running parallel to valley length. TerraRemote Sensing Inc. (Victoria, B.C. Canada) collected LIDAR and digital photo imagery utilizing a proprietary system composed of a 1047 nm Lightwave laser and 28.74 mm focal length Kodak DCS 660 digital camera. Aerial photography was collected at midday during leaf-off, with 60% forward overlap to support generation of stereo photo pairs. Stream flow conditions at the time of the image collection flights were low and clear. In the adjacent Duckabush River, which is gaged and has stream flows that are highly correlated with the Dosewallips River (Orsborn and Orsborn 2000), stream flows were measured at 6.82 cms on 28 March 2002, a level that generally corresponds with winter baseflow.

Precise horizontal coordinates for the imagery were obtained using onboard real-time differential GPS, thereby eliminating the need for ground control, which was impractical due to heavy forest cover and steep topographic relief. After the initial 650 m elevation fly-over, a 200 m down-valley over flight of the river was made to collect a longitudinal water surface elevation profile of the main channel thalweg. Though higher elevation laser returns from surface waterbodies are typically error-prone due to signal scatter (Hagerud and Harding 2000), our low elevation helicopter overflight produced a high density of positive returns in the active channel. During laser image post-processing this high-resolution active channel elevation data was merged with the valley-wide data set to produce a single, seamless elevation model.

TerraRemote Sensing Inc. performed image post-processing utilizing dedicated, proprietary software. Virtual deforestation algorithms were used to create a bare-earth terrain model by removing elevations associated with vegetation, houses, and other cultural features. The constructed digital terrain model was then used to rectify aerial photos and support the generation of orthophotographs of the river and its adjacent floodplain. The contractor delivered a bald-earth digital elevation model of the river-floodplain system, raw uncorrected digital photos, and orthophotographs.

Orthophoto mapping and interpretation

We mapped channel features using heads-up digitizing over orthophotos in ArcView GIS 3.2a, supplemented with information from LIDAR-derived elevation data, and uncorrected digital photos manipulated and examined in Adobe PhotoShop 6.0. Feature digitizing in ArcView was conducted at scales of 1:400 to 1:1000 to ensure consistent resolution of all features across the study area. Examination of raw uncorrected digital photos provided additional perspective on fine-scale habitat features that were poorly resolved in corresponding orthophotos. The senior author conducted all photo interpretation work, with the exception of two reaches that were field-surveyed for ground-truthing purposes; these reaches were photo-mapped separately by R. Grotefendt and field data was then used to validate the photo interpretation work.

We used ArcGRID to convert processed LIDAR x-y-z data to an ArcINFO grid format. ArcView GIS Spatial Analyst 1.1 was used to derive a 0.2-m contour interval map from raster elevation data, which was layered over digital orthophotos for interpretation. River-wide valley bottom elevation data and aerial photos were used to first define geomorphic reach boundaries based on natural floodplain extent and degree of human modification (Table 1). Unconfined, alluvial reaches were classed as “modified” if they exhibited extensive human settlement of the adjacent floodplain and/or visible bank armoring that isolated the river from secondary channel networks. To properly categorize reaches we supplemented our LIDAR topographic data with prior geomorphic mapping of the river valley by Garcia (1996) and Klawon (2004).

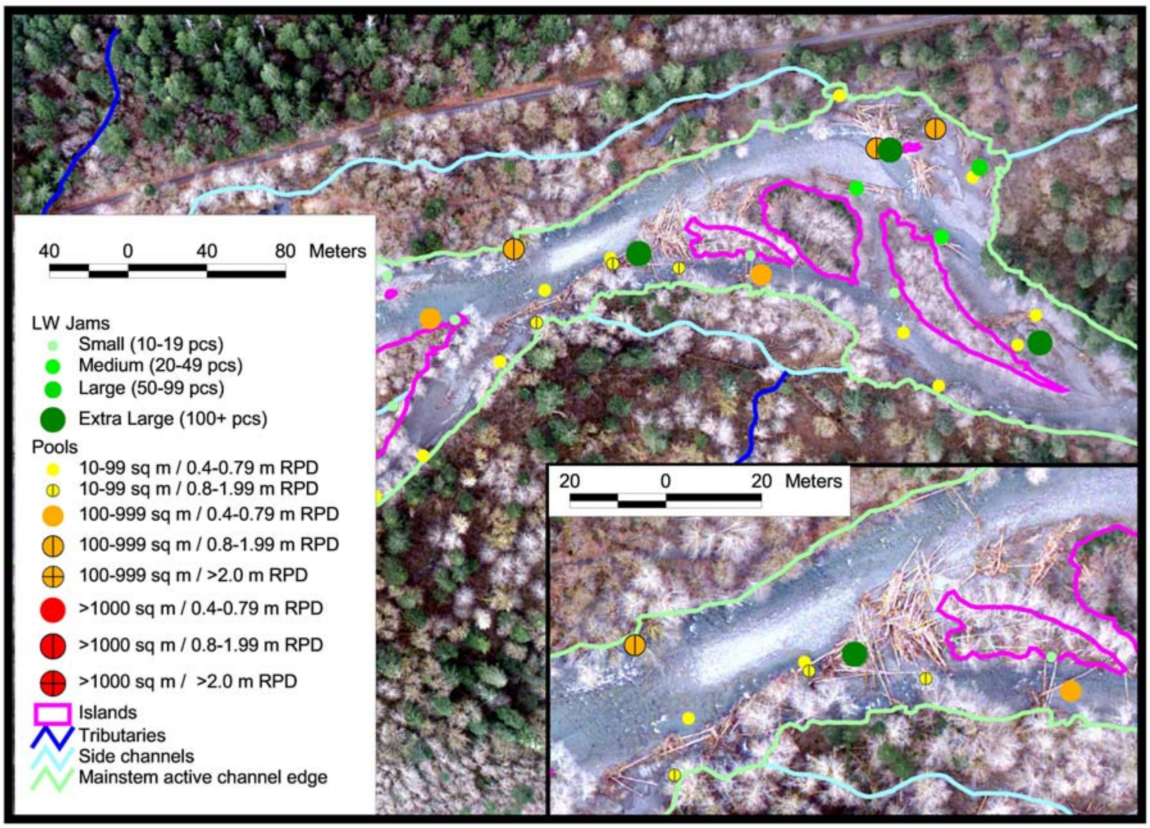
Table 1. Mainstem channel reach confinement categories, definitions, and numbers in the Dosewallips River (after Pleus and Schuett-Hames 1999, table 5). In the analysis and summaries, we combined confined and moderately confined categories.

Valley Confinement Category	Definition	Number
Confined	Floodplain width < 2 active channel widths	7
Moderately Confined	Floodplain width 2-4 active channel widths	2
Unconfined-Modified	Floodplain width > 2 active channel widths; Human modifications of channel-floodplain	6
Unconfined-Natural	Floodplain width > 2 active channel widths; Little/no human modifications of channel-floodplain	4

Channel plan form features were digitized as a series of point, line, and polygon features (Figure 2). Line segments representing single continuous features were later closed and topology corrections made using an ArcView GIS extension, "the Engine" ver 2.0 (GeoKinetic Systems Inc., Vancouver BC). The active channel edge was digitized as a series of lines along the outer left and right banks of all mainstem channels greater than one-third of the reach-average active channel width. The active channel edge was interpreted to be generally coincident with the bankfull channel edge, where gravel bars and wetted channels give way to perennial vegetation and organic soils on the active floodplain surface. Where overhanging vegetation obscured channel edges, the 0.2-m contour interval map was used to make a best approximation of the channel edge location. Islands (digitized as polygons) were defined as those areas with >5 year old vegetation lying within the active channel area. Side channels (those less than one-third of the mainstem reach-average active channel width), tributaries, and the mainstem channel thalweg were digitized as line features. Due to the difficulty of discriminating side channels from independent low-gradient tributary channels that traverse the river floodplain in aerial photos, in our analysis and the following discussion we refer to these features collectively as 'secondary channels', as distinct from the river mainstem channel.

Potential pools within the mainstem active channel were mapped from aerial photos, and classed by size, primary forming factor, and whether obscured by tree cover or not. Potential pools were identified as areas with minimal surface water turbulence visible in aerial photos, and with relatively flat longitudinal profiles in the 0.2 m contour map. Pool positions were mapped as points at their approximate center, and a moveable scaled graphic was used to visually assign pools to size categories. Minimum pool dimensions were: ≥10 m^2 in area, and ≥0.4 m residual pool depth. Since pool depth information could not be remotely sensed, only the minimum area criterion was used to photo-identify potential pools, which were later visited in the field for depth measurements (see below).

Figure 2. High-resolution digital orthophotography used to map large wood, jams, pools, and secondary channels in the Dosewallips River. Photo depicts a portion of the Steelhead Campground reach (RK 17.3) used to ground-truth photo mapping and interpretation.



Large wood jams and key pieces in the mainstem active channel were similarly mapped and photo-interpreted. For potential key pieces (≥9 m^3 in volume), occurring singly or in jams, we used a minimum length and midpoint diameter lookup table to determine if minimum volume criteria were met (Schuett-Hames et al. 1999). The photo-measured log length was assumed equal to its total length (i.e. we did not account for logs lying at an angle vertically). For key pieces, we measured and recorded the photo-measured midpoint diameter, total length, lowest zone, and noted if the piece formed a pool or was partially obscured by tree cover. Suspecting that we would under-count LW jam pieces in the photos, we mapped all jams containing three or more logs measuring ≥2 m in length and ≥10 cm in diameter river-wide. We mapped jams as polygons, counting qualifying pieces, recording total area, measuring maximum height above the adjacent streambed from the contour map, and noting lowest zone, jam type, and whether pool-forming and/or partially obscured by tree cover.

Mainstem river ground surveys

In order to ground-truth our photo-interpretation, we used a global positioning system (GPS) survey of all individual LW pieces, jams, and other channel features in two mainstem reference reaches of the Dosewallips River. Steep topography and heavy vegetation cover obscured satellite reception, necessitating the use of an integrated GPS-laser rangefinder-compass system to calculate horizontal offsets to channel features from unobscured positions. An integrated Trimble Pro-XR GPS/Impulse 200 laser rangefinder/Mapstar digital compass system was used to precisely geo-locate individual LW pieces, LW jam center and perimeter positions, as well as secondary channels, and survey start- and endpoints.

We selected two reaches with abundant LW deposits under varying degrees of aerial visibility, a human-modified 640-m reach at RK 1.1 and a relatively undisturbed 770-m reach at RK 17.3. Initial surveys were conducted from 18 September-1 October 2001 in anticipation of an impending image acquisition flight. Stream flows on the nearby Duckabush River were extremely low during this period, ranging 1.86-2.66 cms. After significant weather delays and an estimated twenty five-year flood event on 7 January 2002 that reset channel conditions and redistributed LW, we resurveyed the two reaches from 10-26 April 2002, within four weeks following the aerial survey overflight – a period which experienced relatively low flow conditions. Duckabush River stream flows during the April field survey were slightly elevated (ranging 9.12-15.40 cms) as compared to conditions at the time of the flight (6.82 cms).

Employing a user-built data dictionary in TSC-1 GPS dataloggers, we recorded the size, stability, wood type, lowest channel zone, and pool-forming function of all individual LW pieces. For LW jams, we recorded piece counts by log size class, lowest zone, and pool-forming function. We also measured the total length and mid-point diameter of all pieces defined as a "key" (≥9 m^3, based on Schuett-Hames et al. 1999). Single pieces of LW lying in small aggregations (2-9 pieces) were field mapped as separate, individual LW pieces.

Ground surveys of mainstem river pools were conducted following completion of the orthophoto mapping in order to verify pool locations, attributes, and to collect depth measurements. Due to timing constraints, pool ground-truthing did not occur until 20-21 May 2003 following a series of high flow events that altered pool distribution and character. Thus we could not independently evaluate the accuracy of photo-mapped pool data due to the confounding influence of river channel dynamics. We used field mapping information to supplement and update the photo-based data, but did not formally compare the two data sets. Stream flows on the nearby Duckabush River on 20-21 May 2003 were comparable to conditions at the time of the image-acquisition flight, ranging 6.7-7.0 cms.

With mapped potential pool locations identified on laminated aerial photos, we navigated the river in an inflatable kayak making depth measurements and edits to pool location and attribute information. We limited our pool ground survey to reaches downstream of hazardous rapids at RK 19.0, known locally as "The Maze". For all photo-identified and new-found potential pools ≥10 m^2, we measured maximum and tail crest depth using a stadia rod or handheld digital sonar device. Residual pool depth (RPD) was calculated as maximum depth – tail crest depth, and pools that did not meet our minimum depth criterion (RPD >0.4 m) were subsequently excluded from the data set. Pool location and attribute information was later updated in ArcView GIS.

Table 2. Dosewallips River habitat assessment survey types, feature attributes, and criteria. See Table 3 for feature attribute definitions and category descriptions. Pool and secondary channel attributes were first determined from aerial photos, and then updated based on field surveys.

	Survey Type:		
	Orthophoto- and LIDAR-based Mapping	Ground Surveys: Mainstem River: LW, Pools, & Secondary Channel Locations	Ground Surveys: Select Secondary Channels: LW & Pools
Features:			
Large Wood			
jams	3 or more pieces	10 or more pieces	10 or more pieces
key pieces, individual or in jams	>9 cu m	>9 cu m	varied by BFW class
individual non-key pieces	[not mapped]	>2 m long and >10 cm dia	>2 m long and >10 cm dia
attributes			
X Y location[1]	X	X	X
piece size class		X	X
jam piece count[2]	X	X	X
jam area (sq m, from GIS)	X		
jam type	X		
jam height (m, tenths; from LIDAR)	X		
key piece length and midpoint diameter	X	X	X
pool-forming	X	X	X
low est channel zone	X	X	X
w ood type		X	
stability class		X	
obscured (yes/no)	X	X	
Pools	>10 m^2 in area; relatively flat channel locations in long profile	>10 m^2 in area; >0.4 m residual pool depth	varied by BFW class (see Table 3)
attributes			
X Y location[1]	X	x[3]	X
size class	X	x[3]	X
max depth (m, tenths)		X	X
tailcrest depth (m, tenths)		X	X
pool-forming factor	X	x[3]	X
obscured (yes/no)	X	x[3]	
Secondary Channels			
tributary channels	all tributary channels visible in photos and/or LIDAR		
side channels	all side channels visible in photos and/or LIDAR < one-third the reach-average mainstem active channel w idth		
attributes			
X Y location[1]	X	x[3]	
elevation relative to mainstem channel	X		x[4]

1 For tributary and side channel ground surveys, the location of LW pieces, jams, and pools w ere recorded as distances along the survey length vs. an X Y location for the orthophoto- and GPS-based inventories.

2 In LW jam ground surveys, piece counts w ere recorded by size class, w hereas in the orthophoto-based inventory piece size distributions w ere not recorded.

3 Mainstem river pool ground survey w as used to correct and update photo-based habitat attributes; similarly, side channel ground surveys w ere compared to LIDAR-derived relative elevation data.

4 We attempted to use the proportion of perennial vs. intermittent flow in side channels as a surrogate measure to validate LIDAR-derived side channel elevation data.

Table 3. Dosewallips habitat assessment feature attributes, values, and definitions for field- and photo-surveys. Adopted and/or modified from Pleus et al. 1999, Schuett-Hames et al. 1999, and Abbe and Montgomery 1996.

Large Wood			
	piece size class	lowest channel zone	
	rootwad: >20 cm dia	1 in wetted channel	
	small log: 10-20 cm dia & >2 m in length	2 in bankfull channel	
	medium log: 20-50 cm dia >2 m in length	3 above bankfull channel	
	large log: >50 cm dia >2 m in length	4 on floodplain	
	pool-forming	wood type	
	yes: forms a pool >10 m^2	conifer	
	associated scour: forms a pool <10 m^2	deciduous	
	no	unknown	
	stability class		
	root: one or more roots projecting from rootball of piece		
	buried: complete burial of one end or lateral burial of >50% of dia along a portion of length		
	pinned: lodged by other qualifying pieces, standing trees, boulders, or bedrock		
	cabled/anchored: cabled to stream bank or bed		
	in natural jam: part of a natural jam with 10 or more qualifying pieces		
	unstable: none of the above		
	jam type (from Abbe and Montgomery 1996)		
	bar top jam: random accumulations of loosely organized debris on top of a bar with little influence on channel		
	bar apex jam: more stable LW accumulations anchored by 'large pieces' with root wads & showing vertical stacking, located at the upstream end of a gravel bar or island and influencing channel morphology		
	bank jam: stable LW accumulation located at and often armoring concave surface of meander, on stream bank w/ vertical stacking		
		min key piece volume	
	jam size class (for mainstem river survey)	bankful width (m)	volume (cu m)
	small: 10-19 pieces	0 to <5	1
	medium: 20-49 pieces	5 to <10	2.5
	large: 50-99 pieces	10 to <15	6
	extra large: 100+ pieces	15+	9
Pools			
	size class (for mainstem river survey)	min pool area (for secondary channel surveys)	
	small: 10-99 m^2, >0.4 m residual pool depth (RPD)	bankful width (m)	area (sq m)
	medium: 100-999 m^2, >0.4 m residual pool depth (RPD)	<2.5	0.5
	large: 1000+ m^2, >0.4 m residual pool depth (RPD)	2.5-5.0	1.0
		5.0-10.0	2.0
	pool-forming factor	10.0-15.0	3.0
	wood piece: 1-9 qualifying LW pieces, counted individually	15.0-20.0	4.0
	wood jam: >/= 10 grouped qualifying LW pieces	20.0+	5.0
	rock/boulder: one or more rocks >26 cm dia		
	scour-resistant bank: bedrock or human-modified bank		
	meander/free-formed: formed at meander bends or where two channels join		
	unknown		

Secondary channel ground surveys

Ground surveys of select tributary and side channels were conducted during August-September 2001 employing modified TFW ambient monitoring protocols for LW and pools (Pleus et al. 1999, Schuett-Hames et al. 1999). Tributary and side channel surveys began at the confluence with the main river and proceeded upstream to the first anadromous barrier or significant gradient break in tributaries, or to the point of channel initiation in side channels. The location of LW, pools, and wet-dry channel transitions were identified along the survey route using a hipchain to provide data on the distribution of habitat features. Two or more bankfull width (BFW) measurements were used to scale LW key piece and minimum pool size thresholds for individual surveys.

We conducted a TFW ambient monitoring level 1 LW survey, recording the following information on LW pieces and jams (≥10 pieces): distance from survey start (in m), size class, lowest channel zone, pool-forming (Y/N), and total piece count (for jams). In addition, we measured the total length (in m) and midpoint diameter (in cm) for all key pieces exceeding minimum volume criteria (Schuett-Hames et al. 1999). For pools qualifying minimum dimension criteria (Pleus et al. 1999) we recorded: distance from survey start to the pool tail crest, maximum and tail crest depths, length, wetted widths (2 or more), and primary forming factor. We photographed characteristic channel conditions at measured distances upstream from survey start points, and in tributary channels recorded periodic gradient measurements made with an Abney level.

Data processing and analysis

Orthophoto mapping and ground survey data were integrated and summarized in ArcView GIS and Microsoft Excel. For the river mainstem orthophoto mapping, point features were derived from mapped reach boundaries, LW jam polygon and "key piece" line features, as well as tributary and side channel confluence and divergence locations. The river mainstem thalweg line coverage was routed in ArcINFO and used to create event tables addressing channel features along the river. Water surface elevations were sampled at 25 m intervals along the routed thalweg from which reach average slopes and a whole-river longitudinal slope profile were derived. From the line coverage defining the mainstem active channel edge we created a polygon of the active channel area for each geomorphic reach, and used an automated ArcView AVENUE script to sample active channel widths at 100 m intervals for the whole river.

Photo- and field-mapped habitat features were spatially referenced to one another in GIS.

We combined the photo- and field-mapping jam data from the two reference reaches to identify a jam size threshold for photo-mapping LW jams throughout the rest of the river corridor. Multiple linear regression was used to model field counts of LW pieces in jams as a function of photo-measured piece count, jam area, type, maximum height, and whether obscured by tree cover. Dummy variables were used to code categorical data on jam type and whether obscured by tree cover. This model of LW jam field counts was used to estimate true jam piece counts river-wide. We then used modeled piece counts to determine if a LW aggregation qualified as a jam (≥10 pieces).

Secondary channels and their point of intersection with a larger channel are documented biological hotspots for fish and other aquatic organisms (Osborne and Wiley 1991, Schlosser 1995). One useful habitat metric is the frequency of these features along a mainstem river corridor, which is often correlated with LW jam frequency and inversely correlated with stream gradient. Since current levels of in-channel LW are generally lower than the pre-EuroAmerican settlement period, the quantity of remnant or isolated secondary channel environments is a potentially useful indicator of high-value alluvial reaches that have been historically modified but which may have restoration potential. Using GIS we calculated the frequency of secondary channel intersections by reach. To provide historical context on channel conditions in select river mainstem reaches, channel plan form changes were examined in archival aerial photos dating from 1939-1994 and combined with information gleaned from old land survey, as well as government and local history records. The reach-specific details of this historical investigation are summarized in Appendix A.

To examine potential hydrologic connectivity between the river mainstem and secondary channels, we calculated relative elevations between the mainstem and adjacent secondary channels, and compared this with information on the extent of perennial flow in field-surveyed tributary and side channels. We developed an automated ArcView AVENUE script to create channel-floodplain elevation cross-sections at 100-m intervals along and oriented perpendicular to the river valley. Using ArcGIS (ver 8.3), vertices were created at 10-m intervals along each cross-section line, and each vertex in a cross-section line assigned the base mainstem channel river elevation at their intersection. From these line vertices, we created a triangular irregular network (TIN) with each vertex as a triangle corner representing the local mainstem channel elevation at that cross-section. Next, the TIN was converted to a regular interval raster GRID so that it could be manipulated algebraically and subtracted from the original LIDAR elevations. The resulting GRID thus depicted the elevation of the floodplain land surface above the local river surface elevation. Finally, we intersected the mapped tributary and side channel line segments with our floodplain relative elevation GRID to derive a secondary channel line coverage segmented by elevations relative to the river mainstem.

Results

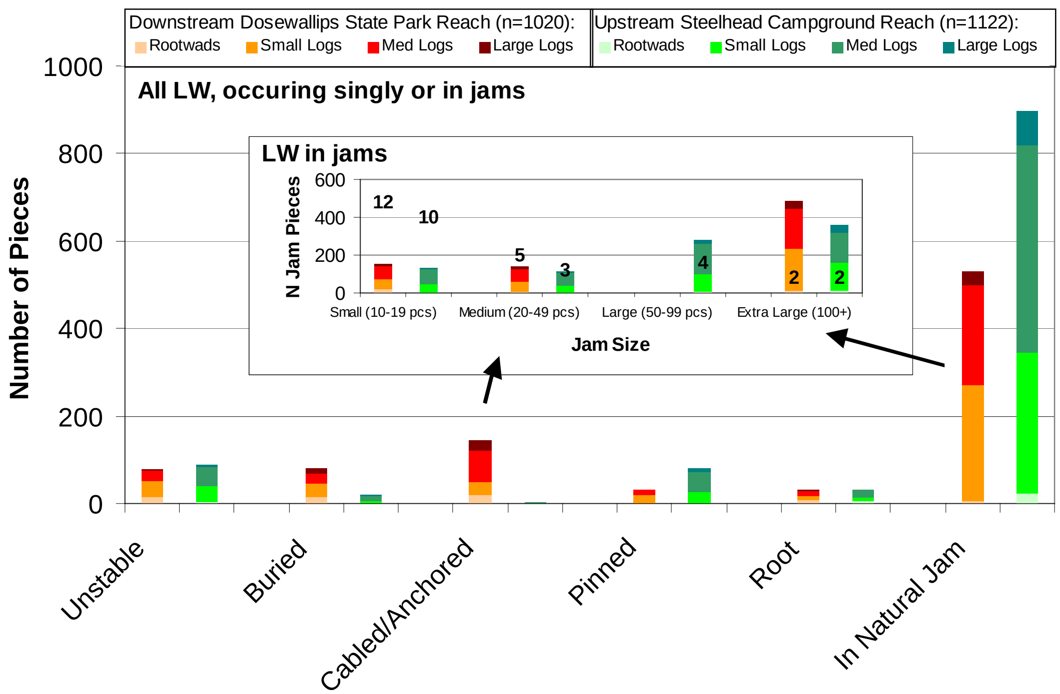
Mainstem river LW ground surveys

On 18 September-1 October 2001, we field inventoried 1344 LW pieces occurring as single pieces or in jams from two mainstem reference reaches of the Dosewallips River, one measuring 640 m long at Dosewallips State Park (RK 1.1) and the other measuring 770 m at Steelhead Campground (RK 17.3; hereafter referred to as the lower and upper reference reaches, respectively). During April 2002, we field inventoried 2143 LW pieces in the two reaches. During the April 2002 survey, hazardous river crossing situations prevented us from inventorying two apparently small jams from the downstream reach and one apparently medium-sized jam from the upstream reach.

The condition and characteristics of LW in the two reaches observed during April 2002 is important for understanding overall aquatic habitat conditions of the Dosewallips River. In the lower and upper reference reaches, 76% and 80% of large wood pieces occurred in jams of ≥10 pieces, respectively (Figure 3, and Appendix Table A1). Including clusters of 3-9 pinned pieces raised the proportion of pieces in jams in the lower and upper reference reaches to 79% and 80%, respectively. Discounting artificial jams cabled or anchored to stream banks in the downstream reach lowered the proportion of pieces in jams to 67%. In the lower reach 13 of 21 jams (62%) and in the upstream reach 16 of 20 jams (80%) formed pools or were associated with significant bed-scour. In the lower reach, most jams (63%) were small (10-19 pieces), and only 11% were composed of ≥50 pieces. In the upper reach, 53% were small (10-19 pieces), 16% were medium (20-49 pieces), and 32% were ≥50 pieces. Six LW key pieces (≥9 m^3) were mapped in the downstream reach, and seven were identified in the upstream reach.

Of the 1021 lower reach LW pieces inventoried, 49% were small logs (10-19 cm diameter) or rootwads, 42% were medium logs (20-49 cm), and 8% were large logs (50+ cm). In the upper reach, 38% of the 1122 mapped LW pieces were small logs (10-19 cm diameter) or rootwads, 53% were medium logs (20-49 cm), and just 8% were large logs (50+ cm). Eight percent of LW pieces from the lower reach were unstable, 14% were cabled/anchored to a bank, 64% were in natural jams of ≥10 pieces, and the balance (14%) included buried, pinned, or root-stabilized pieces. In the upper reach, 8% of LW pieces were unstable, 0.3% were cabled/anchored to a bank, 80% were in natural jams of ≥10 pieces, and the balance (11%) included buried, pinned, or root-stabilized pieces. Of those single LW pieces that could be assigned to a wood type, most were deciduous in both the lower (79%) and upper (64%) reaches.

Figure 3. Large wood characteristics for two field-surveyed reference reaches on the Dosewallips River. The outer graph depicts the distribution of all LW pieces – occurring singly or in jams – by stability factor. The inner graph depicts the distribution of LW pieces – in jams only – by jam size category; numbers above bars indicate the number of jams inventoried by size category. The inner graph includes pieces in natural jams as well as jams cabled/anchored to streambanks.



In general, the characteristics of LW and its channel influences were similar in the two reaches though some informative differences were observed. Most LW pieces occurred in jams of 10 or more pieces, and most jams were associated with pools or significant bed scour. However, 32% of all jams were classed as large or extra large in the upstream reach vs. just 11% in the downstream reach. In the lower river, nearly half of the jams (48%) were cabled/anchored to a bank with most remaining jams representing small bar top jams (after Abbe and Montgomery 1996) with little influence on channel morphology. In the upper reach most jams were bar apex- or bank-type jams, found at the head of islands/large bars or at the outside of meander bends, and appeared to significantly increase channel complexity. Key pieces were scarce in both reaches and generally occurred in jams; most were cottonwood logs. In both reaches 92% of all pieces were <50 cm in diameter, reflecting the small size of most in-channel wood.

A comparison of LW quantities and characteristics in the two reaches from the September-October 2001 and April 2002 surveys shows striking flood-induced habitat changes. Overall, the April 2002 survey revealed a 60% increase in LW loading as a result of the estimated twenty five-year flood event in January 2002. In the downstream reach, LW quantities nearly doubled (93% increase by number, including LW occurring in jams or as single pieces). This large increase was largely attributable to higher densities of small- and medium-sized pieces, many pinned, buried, or newly-recruited to jams. As new LW entered the reach, forming or recruiting to existing jams, the percentage of LW pieces in jams increased from 56% to 76%. The number of jams (≥10 pieces) more than doubled from 9 to 21, while the number of observed key pieces increased from one to six in the reach. Associated with the increased density of LW, more jams were classed as pool-forming or scour-associated in April 2002 (62%) as compared to fall 2001 (55%). In the upstream reach, we observed a smaller (38%) increase in LW quantities with little change in the proportion of LW by size category, stability factor, or in jams. The number of jams increased from 16 to 20, as several new small-medium sized jams were formed. The most dramatic change observed in the upstream reach was an increase in key pieces from zero to seven.

Secondary channel ground surveys

From 13 July-1 October 2001, we surveyed seven side channels and six tributaries in the Dosewallips River valley totaling 2164 m and 2779 m, respectively (Appendix Table A2). In side channels, we inventoried 46 pools and 409 LW pieces, occurring singly or in jams. In tributary channels, we inventoried 109 pools and 572 LW pieces.

Most surveyed tributary and side channel environments were short and small, harboring a fraction of overall available aquatic habitat in the watershed. However, high densities of juvenile coho salmon and cutthroat trout were readily observed in all accessible portions of surveyed secondary channels, underscoring the significance of these environments for salmonid rearing. For surveyed tributaries, median channel length and BFW measured 323 m and 4.5 m, respectively. For surveyed side channels, median channel length and BFW measured 311 m and 3.9 m, respectively.

In side channels, median pool frequency measured 45.9/km (range 15.6-74.6/km), as compared to 49.6/km (range 40.3-98.9/km) in tributaries. Median pool spacing – channel widths/pool, a measure of pool abundance scaled by channel size – was generally higher in side channels: median pool spacing was calculated at 0.56 cw/pool (range 0.22-17.50) in side channels vs. 0.28 (range 0.16-0.52) in tributaries. In side channels, most pools were wood- (40%) or free-formed (43%), whereas in tributaries pool-forming factors were more evenly distributed among wood- (21%), boulder- (36%), scour-resistant bank- (19%), and free-formed (17%) categories.

Large wood frequency was similar in side channels and tributaries, measuring 186.5 pieces/km (range 107.1-285.2) in side channels vs. 208.7 pieces/km (range 97.8-370.5) in tributaries. However, in side channels, 22% of all LW pieces were found in small (10-19 piece) jams, with median jam frequency measuring 2.2/km (range 0-13.0). In tributaries, median jam frequency was lower at 0.4 jams/km (range 0-7.2), with a larger percentage of LW pieces (31%) in jams. Key piece frequency ranged widely among the surveyed side channels and tributaries. Median key piece frequency measured 6.4/km (range 0-46.2) in side channels, as compared to 10.2/km (0-31.3) in tributaries.

Ground-truthing photo-based habitat maps

Remote mapping of potential pools from high-resolution digital photography and a contour elevation map of the active channel proved highly effective for initial characterization of pool distribution. However, field surveys were still necessary to collect pool depth data and confirm initial photo-interpretations. Of 246 photo-identified potential pools, we field-confirmed 127 that met our minimum area and depth criteria in the lower 19 km of the river. From our ground survey, we identified an additional 63 "new-found" pools.

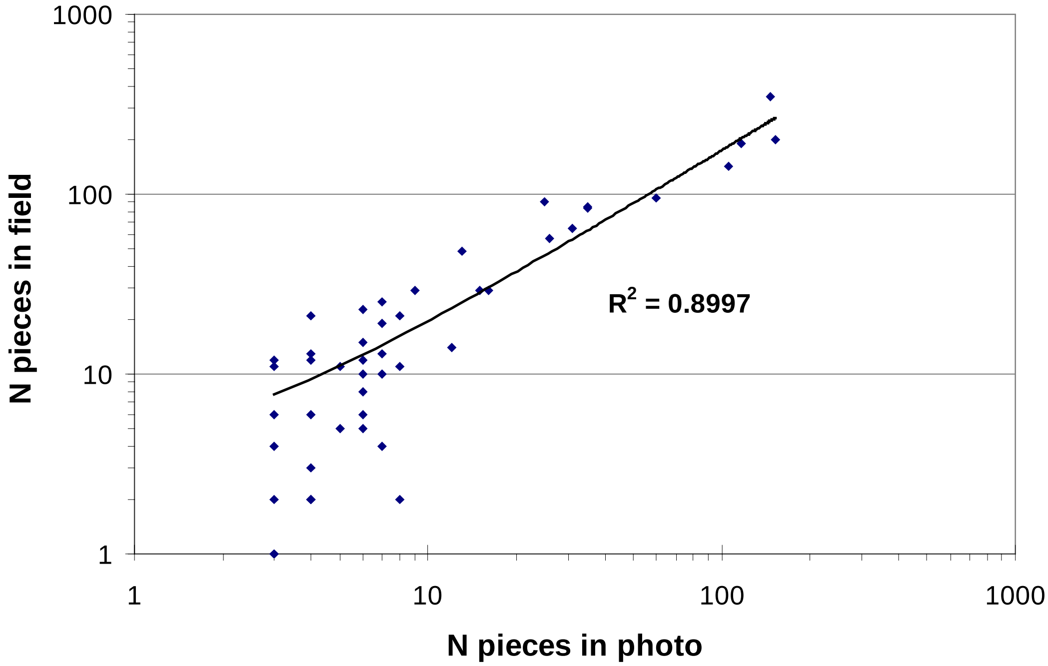
Many of the original photo-mapped pools were later field-identified as "glides", too shallow and turbulent to qualify as pools. A smaller number (<10%), generally located in unconfined reaches, had apparently been eliminated through flood-induced scour and fill in the 13 months between the photo-acquisition flight and ground survey. Most new-found pools (90%) were classed as small with a median RPD = 0.61 m, as compared to 1.01 m for photo-mapped pools. Due to flood-caused channel change, we could not determine if new-found pools were newly-created or if they had simply been missed in the original photo-mapping.

Mapping LW jams of ≥3 pieces from orthophotos, we successfully detected 37 of 41 (90.2%) field-mapped jams in the two reference reaches with field counts of ≥10 pieces. Stream-bank tree cover heavily obscured three of the four missed jams, and the remaining jam was topped with small debris that obscured qualifying log pieces; all four jams were small, composed of 10-16 pieces each. Six of the field-mapped jams were lumped together with other adjacent qualifying jams in the photo-based mapping effort but jam boundaries were approximately correct. Since we targeted the most wood-rich sections of the two reference reaches, and ground survey start- and end-points did not conform with our geomorphic reach boundaries we did not compare overall LW jam frequency estimates from the photo- and ground-based surveys.

Using the lower minimum jam piece count threshold of ≥3 pieces, we photo-mapped 21 additional "potential jams" in the two reaches. Based on the field data, 14 of these "false-positives" represented small aggregations of 2-9 pieces, five represented single pieces with accumulations of small non-qualifying debris, and 2 represented loose, non-touching aggregations of 10-19 pieces that did not qualify as jams in the field. An initial review revealed that photo-interpreted jam boundaries frequently included close-lying individual LW pieces that were not integral to jams as mapped in the field. Therefore, we included all field-mapped single LW pieces within 3 m of jam perimeters in our total field-mapped LW jam piece counts to support direct comparisons with photo-based counts.

Analyzing piece counts with linear regression for the fifty qualifying and potential jams from the upper and lower mainstem river reference reaches, we found LW jam piece photo- and field-counts were highly correlated (R^2=0.8997, Figure 4).

Figure 4. Correlation of LW jam piece photo and field counts in two reference reaches of the Dosewallips River.



A linear regression model predicting LW jam piece field count based on input variables for photo piece count, jam area, type, height, and whether partially obscured by tree cover yielded the following model:

LW pieces_field = LW pieces_photo*2.1775 (0.23173 SE) + Area*-0.0431 (0.01753 SE)

The model indicated that photo-based counts of LW in jams missed approximately half of all qualifying pieces, and that more pieces were missed from larger area jams. We then used this model to estimate actual LW jam piece counts for the whole river, multiplying the original photo-based jam area and piece counts measures by the above equation to estimate a corrected jam size.

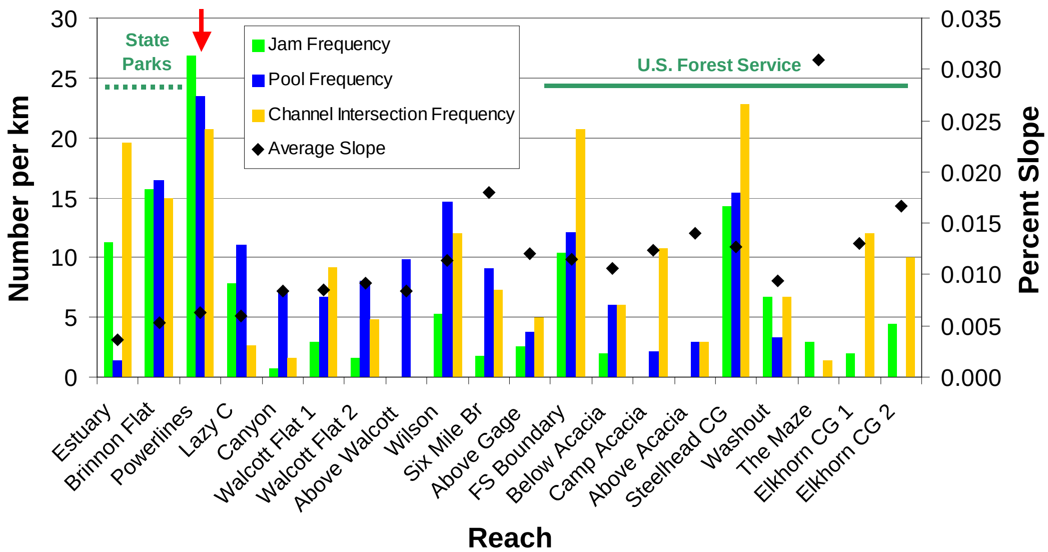
We also examined the correspondence between LW key piece field- and photo-mapping. Ground surveys in the two reference reaches revealed relatively few LW key pieces (n=13, April 2002), which were frequently obscured in jams by smaller LW debris. In addition, we found our 0.2 m-resolution digital photography ill-suited to precise key piece dimension measurements necessary for determining if a piece met the minimum volume threshold. As a result there was a low correspondence between the field- and photo-mapped LW key piece results.

All secondary channels surveyed in the two reference reaches were readily visible in the orthophotos and the 0.2 m contour elevation map. However, we found low correspondence between the proportion of perennial vs. intermittent flow in field-surveyed side channels, and the distribution of LIDAR-derived side channel relative elevations (Figure 9). That is, reaches with side channels with lower relative elevations did not have more extensive perennial flow, indicating that other factors such as sub-surface hyporheic flow paths are likely important. With additional resources, direct measurements of relative elevations between the river mainstem and adjacent side channels may have yielded better results than our indirect approach of measuring the proportion of perennial vs. intermittent flow.

Whole-river jam, pool, and secondary channel distribution

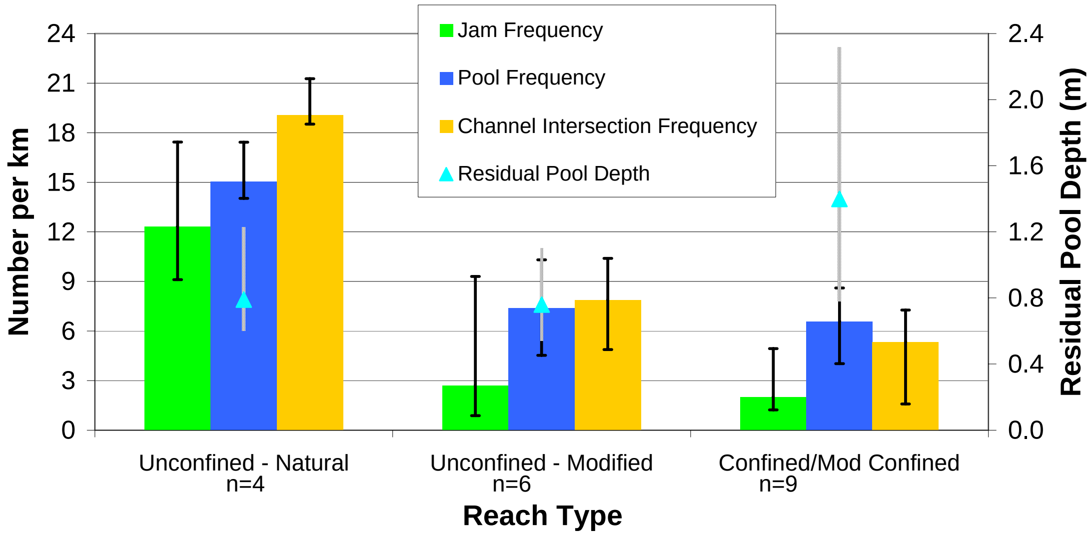
The abundance and frequency of large wood jams, pools, and secondary channel environments showed a striking non-uniform river-wide distribution (Figure 5 and Appendix Table A3). Reaches with the highest habitat metrics were found in relatively undisturbed, low-gradient unconfined reaches with downstream geologic gradient controls such as bedrock outcrops or alluvial fan deposits (Figure 6). Intervening unconfined-modified, and confined/moderately confined reaches had progressively lower LW jam, pool, and secondary channel intersection frequencies, but confined reaches exhibited the highest median residual pool depths.

Figure 5. Frequency of large wood jams, pools, and secondary channel intersections in reaches of the Dosewallips River mainstem. Dark green horizontal bars show reaches in full or partial public ownership. A red arrow highlights the habitat-rich Powerlines reach, presently under private ownership.



Median jam frequency measured 12.3, 2.7, and 2.0/km in unconfined-natural, unconfined-modified, and confined/moderately confined geomorphic reach types, respectively. Pool frequencies measured 15.0, 7.4, and 6.6/km in unconfined-natural, unconfined-modified, and confined/moderately confined geomorphic reach types. Median secondary channel intersection frequency in unconfined-natural reaches measured 20.7/km as compared to 7.1 and 6.1/km in unconfined-modified and confined/moderately confined reach types, respectively. Median residual pool depths ranged 0.79, 0.76, and 1.40 m in unconfined-natural, unconfined-modified, and confined/moderately confined reach types, respectively.

Figure 6. Median residual pool depth, and frequency of LW jams, pools, and secondary channel intersections by geomorphic reach type, Dosewallips River. Error bars are the 25th and 75th percentiles.



Pool and LW jam characteristics also varied by reach and reach type. Bank-type jams were the most common on the Dosewallips River, with bar-apex and bar-top jams becoming more prominent in downstream alluvial reaches (Figure 7). Alluvial (natural unconfined) reaches showed a greater diversity and more even distribution of jam sizes and channel zonation. Similarly, pool-forming factors varied in a predictable fashion (Figure 8). Most pools (58%) in natural unconfined reaches were wood-formed, whereas rock- or scour-resistant bank-formed pools predominated in human-modified and confined reaches (54% and 87%, respectively). Higher pool abundances in unconfined reaches were due largely to increased numbers of small (10-99 m^2) pools; the abundance of medium (100-999 m^2) and large (1000+ m^2) pools showed a more even distribution among reaches and reach types.

Figure 7. LW jam size and type distributions by reach, Dosewallips River.

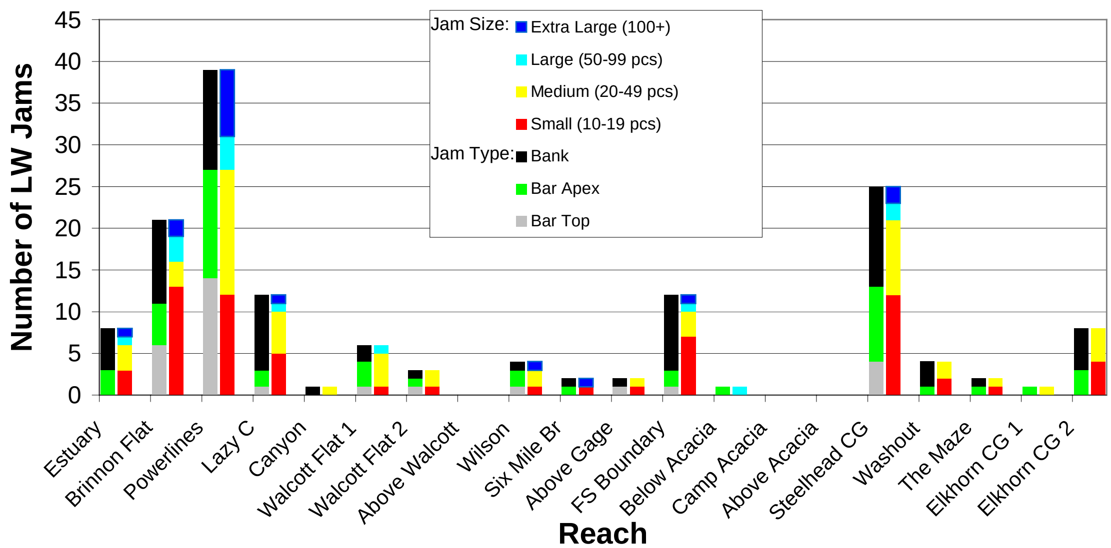
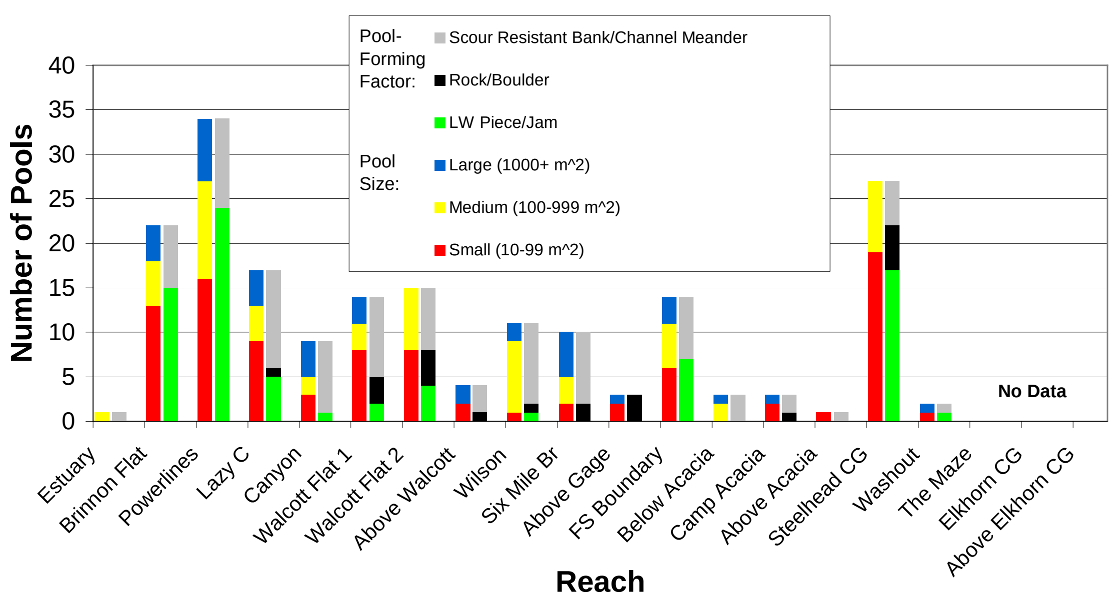


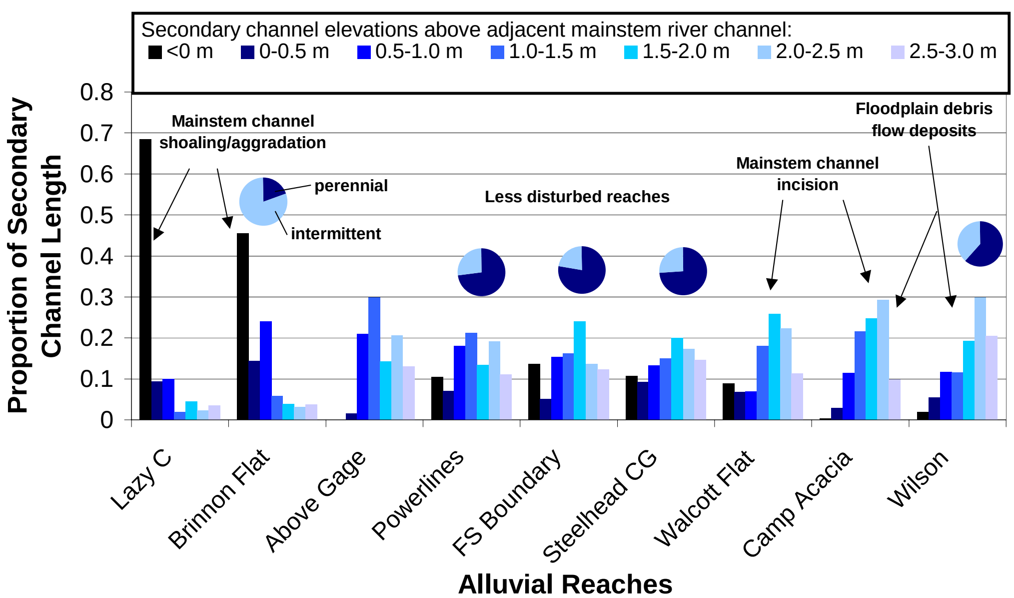
Figure 8. Pool size and forming-factor distributions by reach, Dosewallips River.



River-wide, select reaches harbored disproportionately high frequencies of key habitat features such as jams, pools, and secondary channel intersections (Figure 5), highlighting priority conservation areas. The Powerlines, Steelhead Campground, and Brinnon Flat reaches had the highest overall habitat diversity scores. Among these, the relatively undisturbed Powerlines reach – with the highest habitat diversity scores in the entire river corridor – was notable for the fact that it is wholly in private ownership.

Evaluating the distribution of secondary channel elevations from alluvial reaches in the Dosewallips River revealed distinct patterns related to land use legacies and geomorphic setting. Three reaches with floodplain development and river bank armoring (Lazy C, Brinnon Flat, and Above Gage) exhibited mainstem channel shoaling (aggradation), resulting in lower secondary channel relative elevations. Channelized reaches (Walcott Flat, Camp Acacia) and/or ones with debris flow deposits on the floodplain (Wilson, Camp Acacia) had remnant secondary channels with higher elevations relative to the river mainstem. Less disturbed alluvial reaches (Powerlines, Steelhead CG, and FS Boundary) had more normal and more even distributions of secondary channel relative elevations in the range of 0.5-2.0 m above the mainstem channel.

Figure 9. Distribution of secondary channel elevations relative to the adjacent mainstem river channel in unconfined, alluvial reaches of the Dosewallips River. Pie charts indicate proportion of ground-surveyed secondary channels in perennial vs. intermittent condition. Reaches are arrayed by their modal distribution of relative side channel elevations from lowest (left) to highest (right).



An alternative interpretation for among-reach differences in relative side channel elevations might highlight Garcia's (1996) work, which demonstrated differential rates of uplift and subsidence for discrete along-valley structural blocks. However, this hypothesis – which predicts higher relative elevations from reaches higher in the watershed with greater uplift – is not consistent with the observed order of the distributions (Figure 9).

Discussion

Reach-specific findings and restoration recommendations are discussed in Appendix A (Dosewallips River Reach Narratives) together with information on historical changes and geomorphology for particular reaches. Below we discuss whole-river patterns of habitat feature distribution and characteristics.

Remote mapping of large river habitat features

In this study, we successfully mapped large wood jams, pools, and secondary channel environments in a large river (mean BFW = 47.1 m) employing high-resolution airborne digital photography and LIDAR remote sensing. Field surveys validated that we detected and accurately characterized most LW jams, pools, and secondary channels, but indicated that we were not successful at detecting in-river LW key pieces or predicting the extent of side channel perennial flow based on their elevation relative to the mainstem river. In-channel habitat features were effectively mapped by combining 0.2 m-pixel digital photography and LIDAR elevation data.

Our results illustrate a high degree of among-reach variation in the distribution and abundance of key salmon habitat features on the Dosewallips River. Median jam frequency in unconfined-natural reaches measured 4.5-6.1 times higher than unconfined-modified and confined/moderately confined geomorphic reach types. Median pool frequencies measured 2.0-2.3 times higher in unconfined-natural reaches as compared to other reach types, while median residual pool depth from confined/moderately confined reaches was nearly twice that from unconfined reaches. A more traditional, ground-based habitat inventory in several "representative" reaches would have revealed little of this spatial variability, provided less geomorphic context, and risked entirely missing rare or unique environments (such as the habitat-rich Powerlines reach).

Resource constraints prevented us from directly validating our remotely-sensed secondary channel elevation data. However, observed relative elevation distributions from different reaches (Figure 9) varied in a predictable fashion consistent with our field and historical knowledge of the river corridor. Reaches with floodplain development and river-bank armoring exhibited mainstem channel shoaling (aggradation) resulting in lower relative elevation differences between mainstem and adjacent secondary channels. In reaches with historical logjam removal, channelization, and debris flow deposits on the floodplain the mainstem channel was incised and greater relative elevation differences between the mainstem and adjacent secondary channels were measured. In these more disturbed reaches, the distribution of secondary channel relative elevations was skewed. Less disturbed alluvial reaches had more normal and evenly distributed secondary channel relative elevations. With proper validation, this approach could be used to remotely measure channel incision, and guide efforts to restore and reconnect mainstem river channels with their floodplain and side channel networks.

This effort marks one of the first successful efforts to remotely map channel-floodplain salmon habitat in a Pacific Northwest large-river environment. With additional refinement, these methods offer promise as a low-cost, effective approach to quantify aquatic habitat conditions in other remote watersheds. To be successful, ecologists implementing such an approach will need to consider measures to validate their remote sensing techniques, and effectively match these techniques to ecologically meaningful parameters.

Conservation and management from a whole-river perspective

A whole-river perspective on the distribution of key habitat features suggests that certain reaches, though limited in extent, may have disproportionate importance as salmon spawning and rearing areas. Our assessment proved effective at pinpointing these key conservation areas. In the Dosewallips River, three alluvial valley segments totaling 4.5 km (Powerlines, Steelhead CG, Brinnon Flat; 24% of surveyed channel length) harbor 61% of all logjams and 44% of all pools mapped in the lower 19 km of the river. Available Washington Department of Fish and Wildlife salmon spawning survey data indicate that these reaches serve as critical salmon population strongholds in the watershed (T. Johnson, WDFW, personal communication).

Current Pacific Northwest river habitat management guidelines focus on management targets for large wood and pools that either ignore or cover a limited range of stream geomorphic settings (Fox et al. 2003). For example, the Washington Forest Practices Board only identifies LW targets for stream channels <20 m wide, and pool frequency targets for channels <15 m wide (WFPB 1997). Similarly, NOAA-Fisheries' "properly functioning conditions" directive only identifies pool frequency targets for channels <30.4 m wide and provides a single LW frequency target for all channel types regardless of stream size or geomorphic context (NOAA-Fisheries 1996).

An alternative approach to simplified management targets is to identify and study reaches with less human disturbance as a reference or guide for restoration or enhancement of more perturbed reaches *in similar geomorphic settings* (Fox et al. 2003). The latter approach is particularly warranted where human-disturbed and less disturbed reaches are closely juxtaposed, as in the Dosewallips watershed. However, even more refined numerical management targets can miss or mischaracterize important habitat elements. For example, using modeled LW jam piece counts and field-measured proportions of LW pieces in jams (76-80%), we estimated total LW quantities in Dosewallips River alluvial reaches for comparison with refined LW targets measured by Fox et al. 2003 from western Washington large river reference reaches (30-100 m BFW). Comparing LW piece quantities, one Dosewallips River alluvial reach rated "good" (Powerlines), two reaches rated "fair" (Brinnon Flat and Steelhead CG), with the balance rating "poor." Nonetheless, ground surveys from the "fair"-rated Brinnon Flat and Steelhead CG reaches showed important differences between the two reaches. Steelhead CG reach had three times more jams with >50 pieces and a high proportion of total LW in natural jams (87%), of which 80% significantly influenced pool formation and channel development. In the Brinnon Flat reach most jams were cabled/anchored to stream banks or were small bar top-type jams, with fewer (62%) influencing pool formation and channel development.

A whole-river perspective on the distribution of LW jams, pools, and secondary channel environments informs habitat management decision-making, and provides a basic data foundation for tracking river changes through time. Beyond prioritizing reaches for habitat restoration and protection, the imagery and data collected as part of this study will support long-term monitoring of the Dosewallips River-floodplain system. Future aerial surveys will support detailed analyses of channel plan form changes and shifts in LW jam distribution and abundance by reach.

Fortuitously, this monitoring effort coincided with a 25-year flood event enabling us to track changes in the quantity and distribution of large wood in two key reaches of the mainstem river. This information, combined with historical evidence, suggests that natural recovery of river habitat is already occurring in the Dosewallips River, as mediated by flood disturbances. This suggests that with proper land stewardship, protection of riparian environments, and patience, prospects for salmon habitat recovery in the watershed are good.

Habitat protection and restoration priorities

Based on available habitat data, priority conservation areas in the Dosewallips River valley include the Powerlines, Brinnon Flat, Steelhead Campground, and FS Boundary reaches. Of these, the latter two are already protected in Olympic National Forest while the first is partially protected within Dosewallips State Park. Riparian-floodplain properties under private ownership in the Powerlines and Brinnon Flat reaches should be acquired to safeguard the relatively high-value conservation status of these areas.

Certain reaches of the Dosewallips River offer particular promise as sites for active habitat restoration. Our habitat data and historical research revealed select alluvial reaches transformed by human manipulation from meandering, wood-rich river-floodplain systems into channelized reaches with armored banks, degraded riparian forest, and low in-channel habitat diversity. These include Walcott Flat, Camp Acacia, Brinnon Flat, and Estuary reaches. With relatively sparse human settlement, Walcott Flat and Camp Acacia represent areas where property buyouts or conservation easements could be coupled with restoration of mainstem channel-floodplain connectivity using engineered log jams. In the densely settled Brinnon Flat and Estuary reaches where private residents are concerned with minimizing flood hazards, smaller scale restoration measures will be required. However, due to the significance of the lower river-estuary environment to at-risk fish stocks, a targeted restoration and public education effort in this area is strongly needed.

As an important conservation area in Hood Canal, information from this habitat assessment is already being used to direct and support salmon recovery and restoration activities. In the lower river-estuary a non-profit conservation group, Washington Trout, is leading an effort to remove an estuarine dike, restore river-estuary connectivity, and improve tidal exchange in a blind tidal slough through culvert replacement. Meanwhile, Jefferson County, Washington State Parks, and the Port Gamble S'Klallam Tribe are collaborating to acquire and permanently protect privately-owned, undeveloped riparian-floodplain properties in the Powerlines reach.

Conclusion

Recent calls for continuous, landscape-level conservation assessments of riverine-floodplain systems (Fausch et al. 2002) have been matched with expanded opportunities for such investigations at scales relevant to fish life history processes and real-world conservation concerns. With the rapid growth and integration of GIS, GPS, and remote sensing technologies, the challenge for habitat conservation managers is no longer the technical feasibility of such multi-scale monitoring/assessment studies. Instead, the challenge lies in choosing and utilizing technologies appropriately, implementing proper ground-truthing, and relating spatially-explicit data back to aquatic biota in a manner that informs conservation management and decision-making.

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Appendix A: Dosewallips River Reach Narratives

This appendix contains details on individual river reaches, surveyed tributary and side channels, as well as historical information for select river reaches, all of which is used to highlight habitat protection and restoration opportunities in the watershed. This information is organized spatially by valley segment from the river mouth upstream to Elkhorn Campground at RK 22.0, including side channels and tributaries.

Information Sources for River History and Geomorphology

To supplement data from our ground and remote sensing surveys of the Dosewallips River, we reviewed available historical materials and geomorphology studies to provide additional context on recent changes to contemporary river-floodplain environments. The results of several parallel studies are incorporated by reference in the following discussion. Klawon (2004) characterized the channel migration zone and provided a historical perspective on channel change in the Dosewallips River valley using archival aerial photos and maps. Aerial photograph data sources and orthorectification procedures are contained in Klawon (2004). For reaches upstream of RK 10.0 not included in the Klawon (2004) study, we examined uncorrected USFS stereo-photographs for the period 1939-1998 (Olympic National Forest Headquarters, Olympia, WA).

Garcia (1996) examined the geomorphic evolution of the Dosewallips River watershed, documenting the advance of an alpine glacier to within 5 km of the present-day river mouth during the latest Vashon Stade glaciation. He determined that abrupt transitions between contrasting alluvial and deeply incised (>20 m) bedrock reaches were the result of differential uplift and subsidence rates of adjacent, discrete structural blocks along the length of the river valley. Through geomorphic mapping, Garcia (1996) demonstrated the role of valley-wall Holocene slump-terraces in the formation of alluvial reaches in geomorphic domains where the stream is not incised in bedrock.

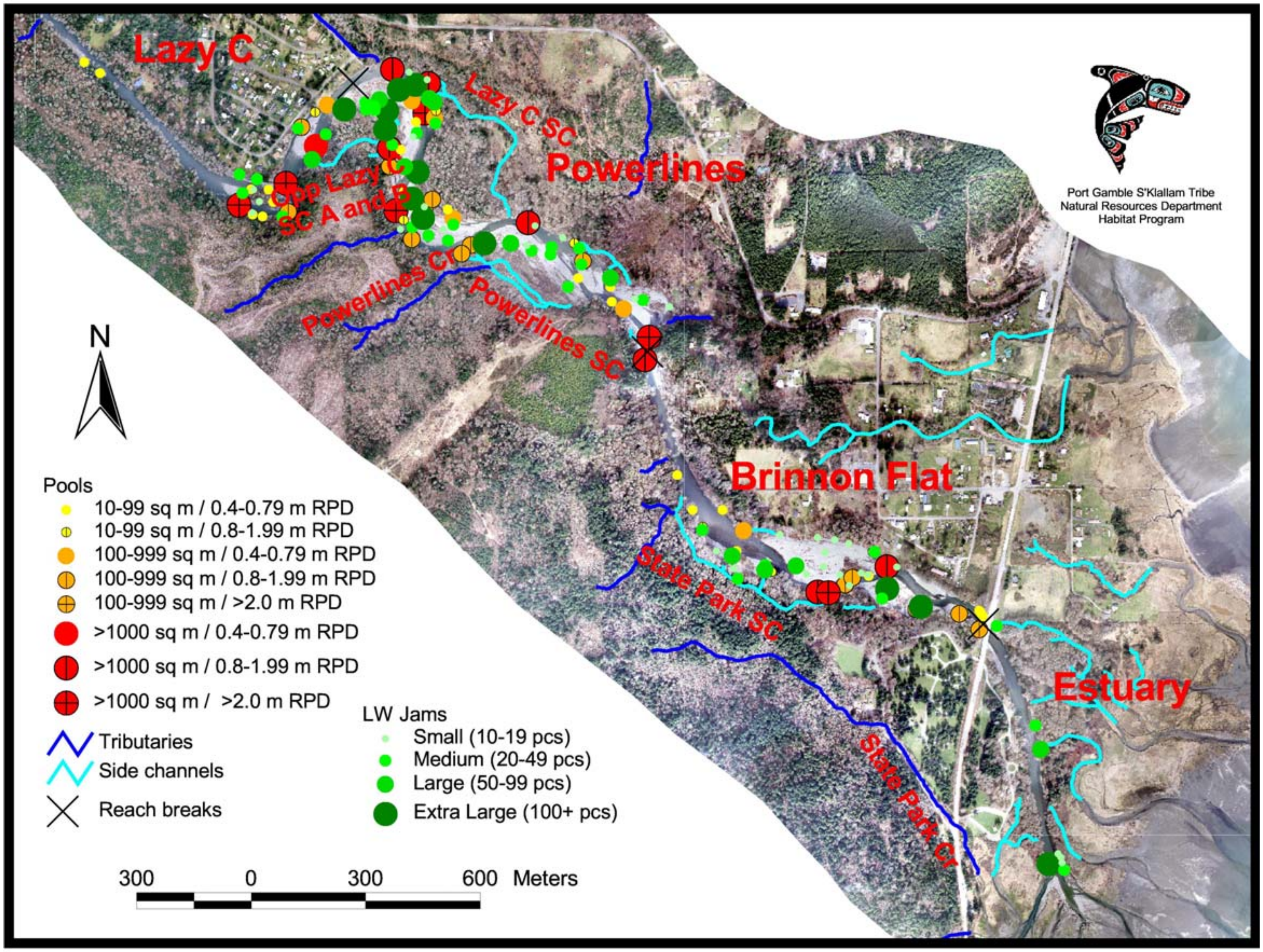
For additional perspective, we integrated information from a local history of the Brinnon area (Bailey and Bailey 1997), archival records from Washington State departments of

Fisheries and Game on file in the State Archives, original General Land Office survey notes as well as interviews with long-time residents (see Appendix B).

Estuary and Brinnon Flat

Extending from the river mouth upstream to a Crescent basalt outcrop at RK 2.0, the Estuary and Brinnon Flat reaches encompass the highly-modified lower river-estuary interface of the Dosewallips River (Figure A1). These reaches have been repeatedly manipulated over the historical period to reduce flood hazard and facilitate human settlement, yet still remain a stronghold for threatened fish stocks such as chinook and summer chum salmon (T. Johnson, WDFW, personal communication). The Estuary reach encompasses the mainstem river and all adjacent distributary and blind tidal channels downstream of the Highway 101 crossing, as well as tidal portions of Walcott Slough that extend west of Highway 101 on the north side of Brinnon. The Brinnon Flat reach extends upstream from the Highway 101 crossing to the Crescent basalt outcrop at RK 2.0, including several tributary and side channels, as well as the non-tidal drainage network of Walcott Slough.

Figure A 1. Estuary to Powerlines reaches, Dosewallips River. Note the density of LW jams and pools in the Powerlines reach, as compared to the adjacent human-modified Lazy C and Brinnon reaches.



The 1889-90 Wickersham expedition of the Olympic Mountains noted that the Dosewallips River at that time had two mouths, and that the river forked “a mile or two from salt water” (Wickersham 1891). This observation is partially corroborated by a 1883 U.S. Coast and Geodetic Survey navigation chart of Hood Canal (T-1558a) showing two and possibly three distinct river entrances, the most upstream of which diverged from the mainstem channel approximately 1100 m upstream from the present river mouth. Perhaps not coincidentally, initial bridges over the river were constructed at this most upstream point of distributary channel divergence, approximately 300 m upstream of the present-day Highway 101 bridge crossing.

Based on archival records and channel changes apparent in historical air photos, the State Park reach has been continuously modified to facilitate human settlement of the Brinnon community for over one hundred years. Initial bridges constructed over the river in this reach were ephemeral. Bridges were constructed or re-constructed in 1888, 1889, 1890, 1894, 1897, 1902, and 1910. In 1923, the Olympic Highway Bridge was constructed, which stood until it was replaced by WSDOT in 2000. Bridge washouts were mentioned frequently and figured prominently in early settlers’ accounts, highlighting the significance of this transportation link to the community (Bailey and Bailey 1997). Logjam removal began at the earliest stages of settlement and was closely associated with the need to prevent bank erosion, minimize the risk of bridge washouts, and contain the river in a single channel. In 1893, County Commissioner E.P. Brinnon moved to have a logjam removed that was threatening one of the early bridges (Bailey and Bailey 1997).

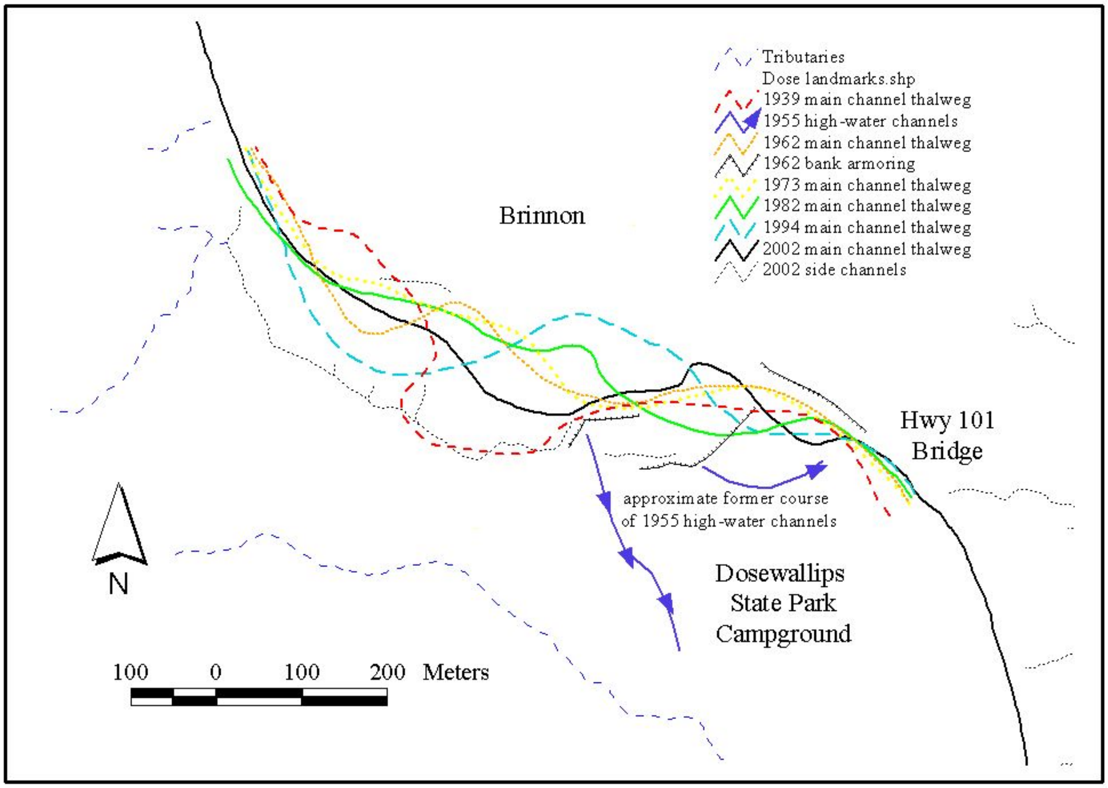
Responding to landowner concerns about bank erosion and property loss in 1955, a state biologist investigating channel conditions in the lower river mapped “high-water overflow channels” on the right-bank farm property that subsequently became Dosewallips State Park. A map of the reach sketched by the investigating biologist clearly identifies the course of the two right-bank overflow channels, one leaving the river approximately 400 m upstream of the bridge and flowing SE towards State Park Creek (Figure A2). The other channel is depicted leaving the river mainstem approximately 170 m upstream of the bridge and then rejoining the mainstem immediately upstream of the bridge. Based on field investigation and examination of LIDAR topographic data, there is no remaining evidence of these channels today, their course having apparently been erased by surface grading when the area was farmed.

In 1955 Washington Dept. of Fisheries granted permission to this landowner to construct a right-bank dike to prevent further erosion and constrict the river to the main channel. Soon thereafter, in 1957, Washington State Dept. of Highways constructed a 175 m dike immediately downstream on the left bank above the Highway 101 crossing. This dike was apparently constructed in response to the right-bank landowner's earlier efforts to train the river away from his property, exacerbating erosion hazard problems at the Highway 101 crossing. This dike was later re-constructed by Jefferson County in 1995. Then in 1959, 1961, and 1964, under Washington State Parks management, right-bank riprap placement, mainstem channel redirection, and logjam removal were used to control continuing bank erosion problems. In addition, the State Parks Department completed dredging of the river channel downstream of the Highway 101 crossing.

Two long-time river resident interviewees (Bob Crowell and Bill Nelson) recounted witnessing flood waters during the 1950s on the Brinnon Flat between the Half-way House restaurant and the Highway 101 bridge (north of the river). The WPA wood removal crews mentioned by Bill Nelson were likely active in this river section. In their interview, Vern and Ida Bailey recounted an early settler – Mrs. Olson – who was able to cross the river in this reach on an old logjam. None of the interviewees indicated the riverbed elevation had changed dramatically in these reaches over their lifetimes.

Channel thalweg shifts mapped from historical air photos indicate that channel conditions in this reach have been extremely dynamic over time, likely related to the long history of bank armoring, bridge (re)construction, wood removal, loss of secondary channels, and legacy impacts from upstream splash-damming (Figure A2). Channel constriction resulting from bridge crossings has also likely played a large role in shaping the channel throughout this reach.

Figure A 2. State Park reach, historical channel patterns and bank armoring.



Most LW jams field surveyed in the Brinnon Flat reach were small-medium in size with little or no influence on channel hydraulics; nearly half (48%) of all jams were cabled or anchored to stream banks. During field surveys, we documented fresh evidence of wood cutting and removal from this reach on gravel bars accessible from both the south (Dosewallips State Park) and north banks (various Brinnon residences). Owing to the low abundance of LW, both the Estuary and Brinnon Flat reaches harbored relatively few, widely spaced pools with low complexity.

Though there is evidence of strong subsurface hydraulic continuity between the lower river and estuarine distributary channels (Aspect Consulting 2004), surface water flow from the river into these channels occurs infrequently and the relative isolation of the mainstem river channel from these channels is likely, in part, related to the history of channel dredging in the lower river. We mapped just one pool in the 710-m long reach of river downstream of Highway 101, and most LW jams were deposits at the river mouth.

Perennial and seasonal distributary channels are heavily used by coho and chum salmon fry (M. Wait, Washington Trout, personal communication).

As part of our tributary and side channel ground surveys, we surveyed a 596 m-long right-bank side channel and 1145 m of a tributary that drains directly to the estuary within this lower river valley segment. The downstream portion of this side channel (named State Park side channel) was occupied by the mainstem river in 1939. Several mainstem river overflow channels and a steep, unsurveyed tributary feed this side channel along its length resulting in a distinct pattern of downstream widening. The lower 50 m of this side channel is armored with riprap on its right bank and is backwatered by the mainstem river during low flow conditions. The remaining channel length has good riparian forest cover and good quantities of in-channel LW, but only experiences seasonal flow.

The adjacent tributary (named State Park creek) flows seasonally along its lower 500 m; flow is minimal but perennial above the main Park access road. This creek contains very low quantities of small LW, and few, widely-spaced shallow pools. Not surprisingly, few fish fry were observed during the summer 2001 field survey. However, the lower channel area is important spawning habitat for fall chum salmon. Historically, the downstream portion of this creek, near the Highway 101 crossing, may have conveyed overbank flows from the Dosewallips River mainstem channel.

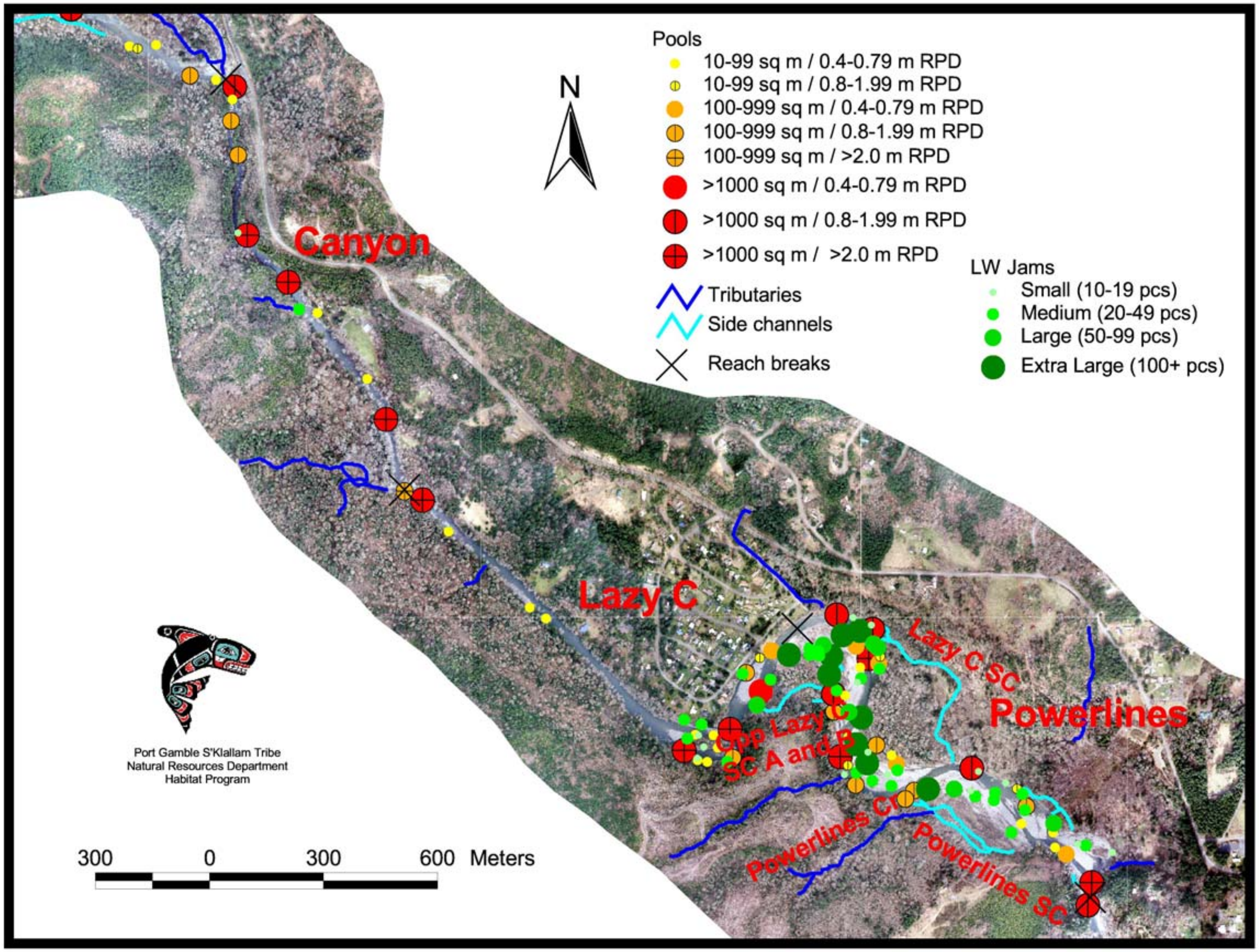
The highly-modified Brinnon Flat reach remains an area of ongoing river management challenges. Constriction of the river channel has contributed to continuing bank erosion problems at Dosewallips State Park and the Highway 101 crossing. Efforts to remove or setback dikes, and to reconnect the river with former distributary channels would likely ameliorate these deleterious historical legacies by increasing channel roughness and flow diversity paths.

The tidal portion of this reach, downstream of the Highway 101 crossing represents an area with strong restoration potential. Through construction of engineered logjams and right-bank riprap removal, habitat diversity and cover for imperiled salmon could be improved.

Powerlines to Rocky Brook Creek

The Powerlines, Lazy C, and Canyon reaches extend from a Crescent basalt outcrop at RK 2.0 upstream to the top of the Dosewallips Canyon at the mouth of Rocky Brook Creek (RK 6.3, Figure A3). This valley segment encompasses two alluvial reaches, one relatively undisturbed (Powerlines, 1450 m long) and one highly modified (Lazy C, 1530 m long), as well as the bedrock-constrained Dosewallips Canyon (1260 m long), and five side channels and seven tributaries (not including Rocky Brook Creek). Historically, these reaches were highly impacted by splash dam operation at the upstream end of the canyon as well as agricultural and later residential development on the floodplain at the Lazy C community.

Figure A 3. Powerlines to Canyon reaches, Dosewallips River. Note the density of LW jams and pools in the Powerlines reach, as compared to the adjacent human-modified Lazy C reach.



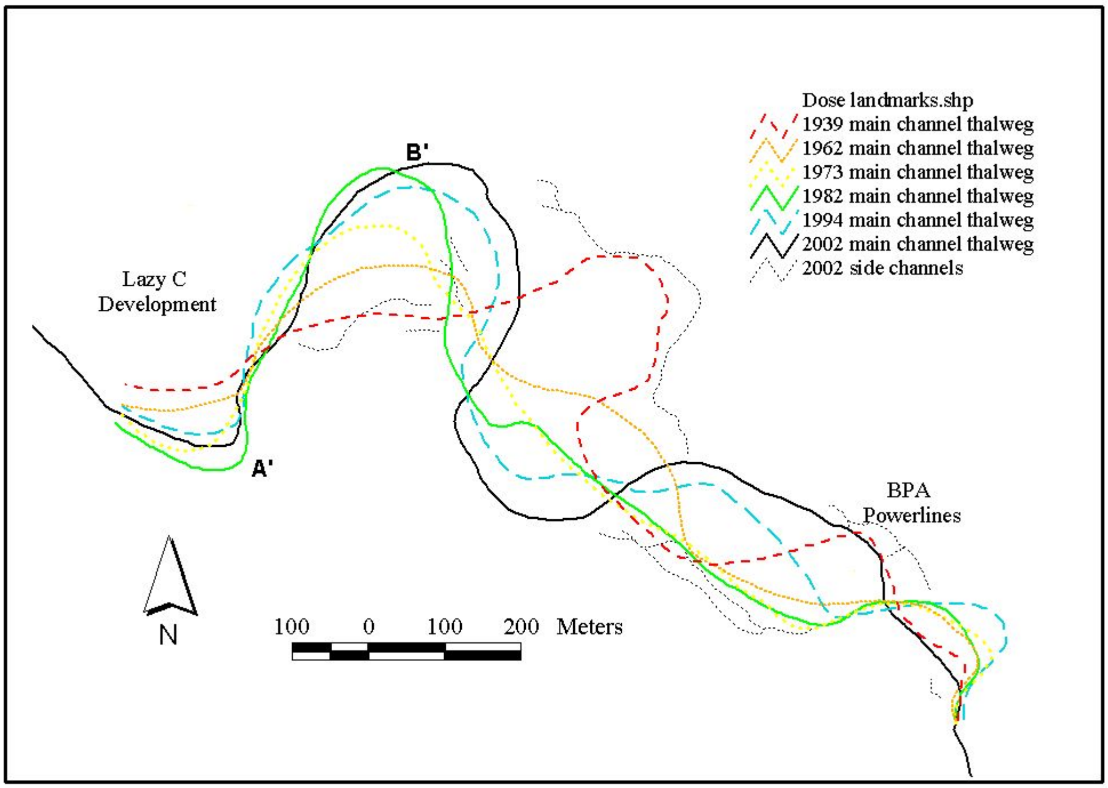
Though historical channel-floodplain modifications to the Powerlines and Lazy C reaches have been less well documented in written records, human impacts to these reaches are clearly visible in the available historical photo record. Klawon (2004) documented geomorphic evidence of secondary channels traversing the floodplain immediately upstream of the Lazy C development from early aerial photos. The historical channel incision noted by Klawon (2004) in the upstream section of Lazy C reach may represent a legacy impact resulting from splash dam operation during 1917-1926.

Early settler accounts mention a "slough backwater" from the river fed by a creek descending the north valley sidewall by the Lazy C development entry road (Bailey and Bailey 1997). Though this slough no longer exists, a floodplain depression is clearly visible in 1939 aerial photos and a 1958 water right application map also depicts a pond to which river water was diverted to serve as a swimming pool for a recreational lodge in operation at the time. When the lodge business was sold and the land subdivided as the Lazy C development, this ground was apparently re-graded and the creek tributary ditched against the north valley wall, erasing any present-day remnant topographic evidence of floodplain secondary channels.

Long-time resident interviews corroborated this information. Arlene Crowell mentioned "lake"-like conditions during the wintertime at Lazy C, and all the interviewees reported floodplain filling and active channelization at Lazy C. The WPA wood removal crews mentioned by Bill Nelson were likely active in this river section. Four of the six interviewees believed this reach of river had changed more than any other reach on the river. Only Vern and Ida Bailey suggested their river section (Walcott Flat) had changed more.

Mainstem river thalweg shifts in this reach clearly illustrate the role that progressive channel migration and avulsion play in the creation of secondary channel environments on the Dosewallips River. By 1973, a left-bank road had been constructed downstream from the Lazy C development and at least six homes or trailers were present. In 1982 much of this road had been washed out and by 1994, downstream home sites had been abandoned and native forest was re-establishing on the floodplain. Several of the side channels surveyed in 2001 occupy the former course of the 1939 mainstem channel (Figure A4). The progressive extension of a meander at A' to a right-bank basalt outcrop has deflected river flow northwards toward the Lazy C development and has contributed to the progressive extension and translation of the large channel meander at B' (near the upstream boundary of the Powerlines reach).

Figure A 4. Powerlines reach, historical channel patterns.



Though splash damming, floodplain development, and bank armoring have contributed to extensive habitat loss and degradation at Lazy C, the adjacent Powerlines reach has suffered from only limited illegal riparian logging and LW removal from the active channel. As a result the channel remains fully connected to its floodplain, LW and pools are abundant, the riparian forest is relatively intact and diverse, and there is an abundance of secondary channel environments, which serve as important refugia for fish and other aquatic biota.

The available survey data indicate habitat conditions in the Powerlines reach are relatively good, as compared to other areas of the river. LW jam and pool frequency in the Powerlines reach were the highest measured in any mainstem river reach. The reach harbored an abundance of large, deep pools – 70% of which were LW-formed. In addition, this reach includes over 503 m of perennial side channel and over 270 m of accessible tributary habitat used by salmon for spawning and rearing. Two surveyed side channels in this reach – the 311 m-long Powerlines and 460 m-long Lazy C side channels – appeared to be heavily modified by wood removal and, in the latter case, by channelization and riparian forest removal. Two smaller side channels (Opposite Lazy C A and B) appeared relatively unmodified.

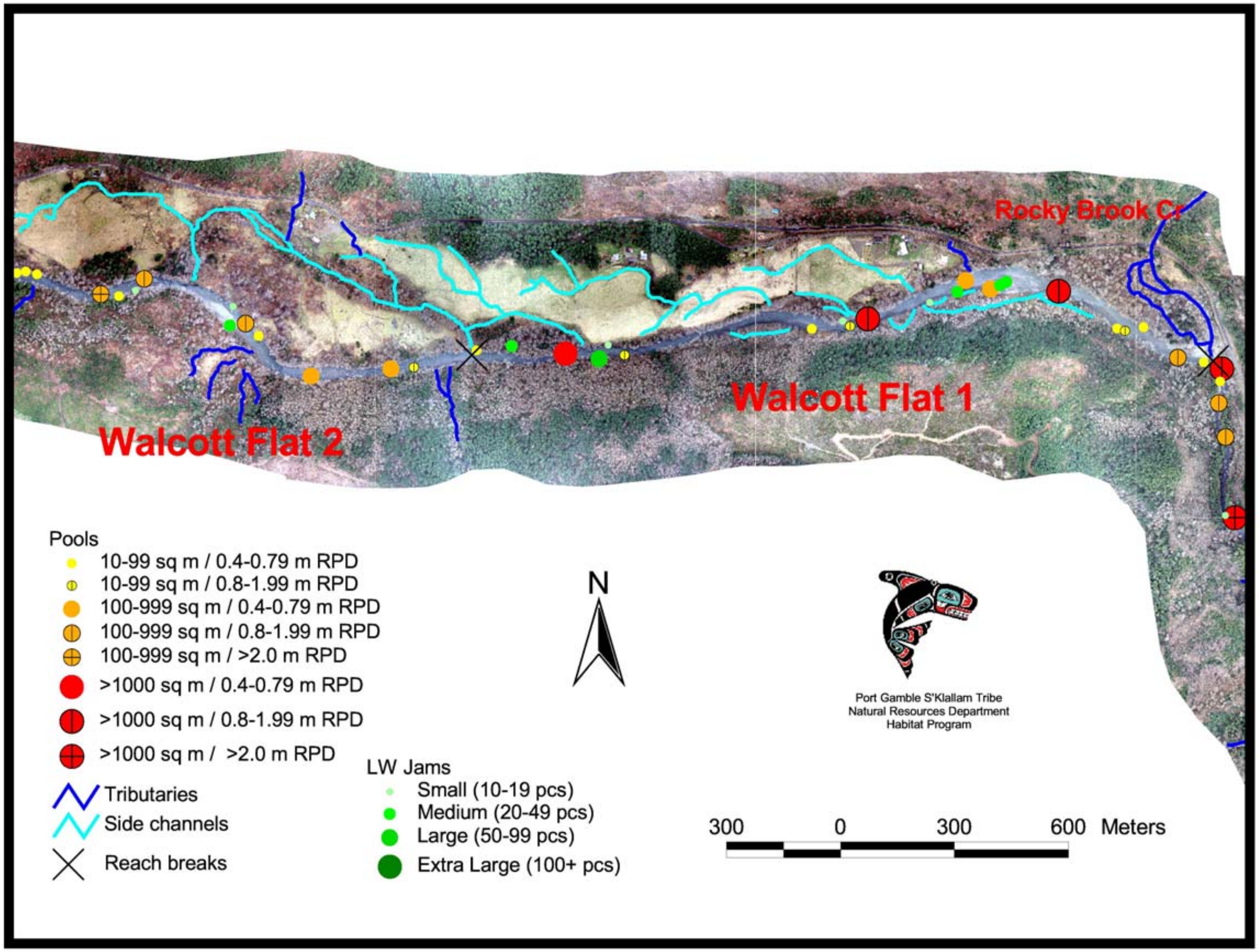
In contrast, the human-modified Lazy C and higher-gradient, bedrock-confined Canyon reaches harbored fewer pools and LW jams. Most pools in these two reaches – 53% and 89%, respectively – had a higher proportion of deep (>2.0 m) pools formed against scour resistant banks.

Though most of this reach is in private ownership, its relative isolation has limited development pressures to date. To fully protect its ecological integrity, opportunities for property buy-outs and/or conservation easements should be investigated. Given the proximity of this reach to Dosewallips State Park, opportunities for collaboration with Washington State Parks, who could serve as long-term stewards of this area, should be pursued. It is notable that this area is also critical to the Dosewallips Roosevelt elk herd and Tribal subsistence hunters.

Rocky Brook Creek to Six Mile Bridge

The valley segment between Rocky Brook and the USFS Six Mile Bridge crossing encompasses a 3940 m-long highly-modified alluvial section (Walcott Flat 1 and 2) separated from a 640-m long relatively undisturbed upstream alluvial reach (Wilson) by a 490-m long reach constrained by tributary alluvial fan deposits (Above Walcott Flat, Figures A5 and A6).

Figure A 5. Walcott Flat reaches, Dosewallips River. Note the low density of pools and small LW jams in this reach, as well as the abundance of remnant side channels, many of which are isolated from the mainstem channel due to channel incision and bank armoring.

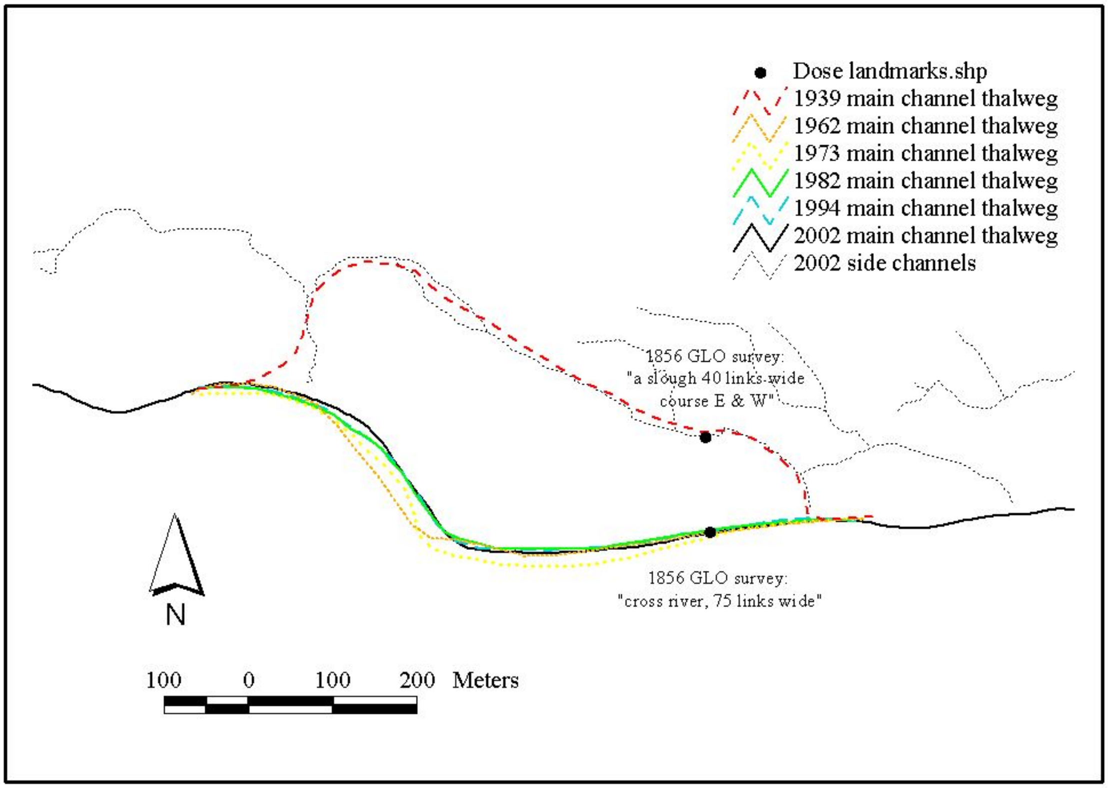


Walcott Flat was the focus of a large-scale channel manipulation effort lasting over ten years. Early land survey records and air photos suggest that historically this reach was a dynamic, unconfined alluvial reach with abundant floodplain rearing environments. GLO survey channel width data indicate that in 1871 a left-bank secondary channel (referred to as a "slough" in the GLO survey notes) conveyed approximately one-third of the river flow through this reach (mainstem channel = 75 links wide vs. secondary channel = 40 links wide, Figure A6, GLO survey notes for the line between sections 29 and 30 Township 26N Range 2W). By 1939 the main channel had shifted to occupy the course of this secondary channel, a channel configuration that lasted until at least 1951. The 1939 air photo also depicts a broad riparian forest corridor that obscures the course of the former and present-day mainstem river channel.

In response to property damage from the 1949 flood, area residents and the Jefferson County flood board obtained permission from WDF to divert the river into its former course as a flood control measure in 1950. Later in 1956 and 1961, area landowners placed left-bank riprap, removed logjams, and graded the channel at key locations along 1900 m of the mainstem channel throughout this reach, with the intent of permanently containing the river against the south valley wall (WDF records, USFS 1999). In their interview, Vern and Ida Bailey recounted removing a large logjam that altered the mainstem river course. Most notably, the Baileys also mention historical and ongoing mainstem channel incision in this reach.

The five subsequent photo series show the progressive loss of riparian forest cover, with the mainstem river channel fixed in its present location, against the south valley wall and a 1065 m-long remnant secondary channel to the north. Field observations of this remnant secondary channel indicate that though salmon have limited access to the downstream portions of this channel, degraded channel conditions prevail along much of its length owing to loss of native riparian cover and lack of flushing flows from the mainstem river channel. Along much of the channel, the accumulation of finer substrates has led to the development of palustrine wetland plant communities.

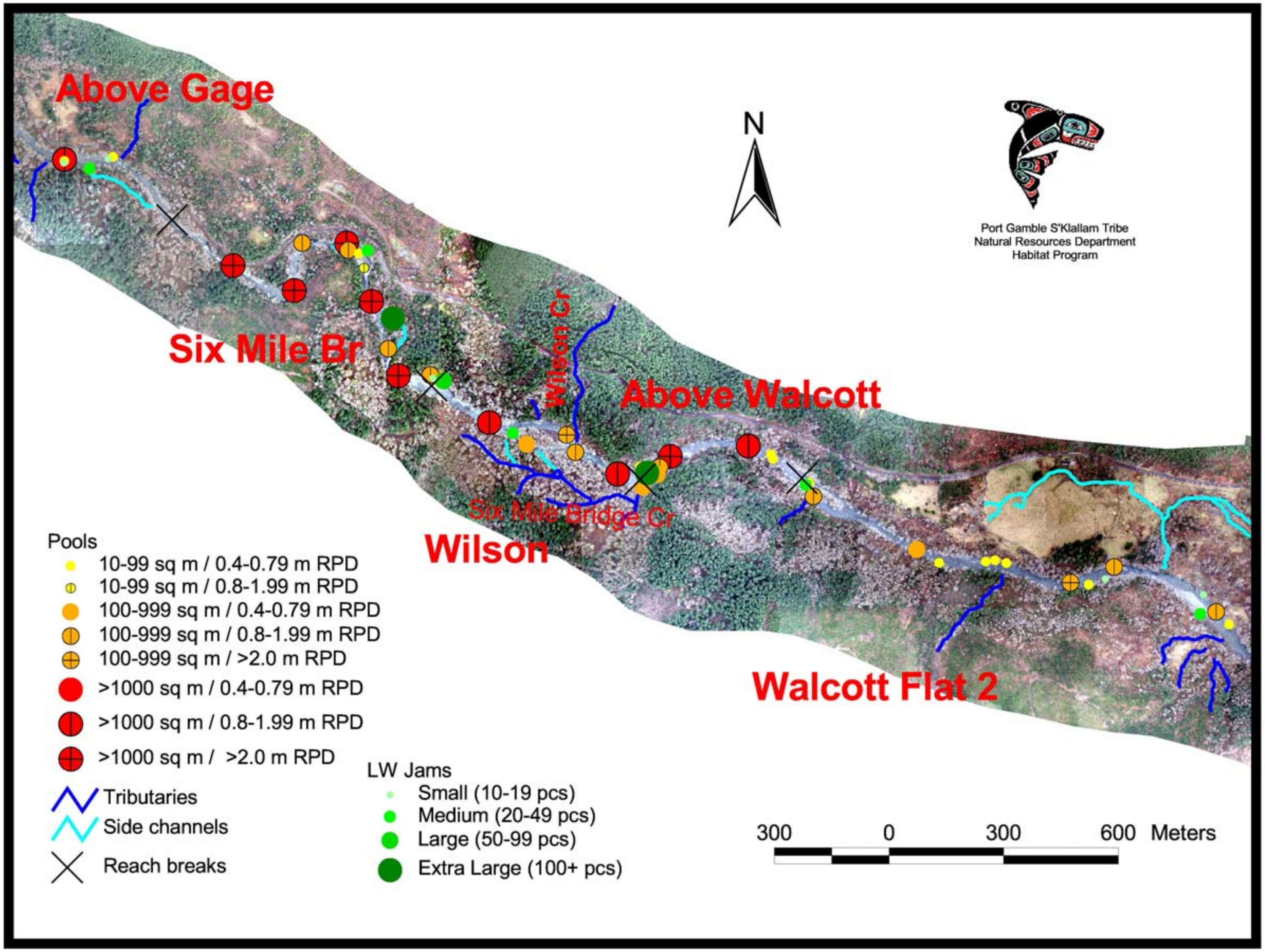
Figure A 6. Upper Walcott Flat reach, historical channel patterns.



Habitat data for Lower and Upper Walcott Flat highlight degraded habitat conditions in these two reaches: a relative lack of LW jams; few, widely-spaced pools – 45% of which were formed by bank scour; and a high proportion of secondary channels classed as 'remnant' or 'isolated' from the mainstem river environment. No side channels were ground surveyed in these reaches, though we did survey two tributaries (Rocky Brook and Six Mile Bridge creeks). The lower 670 m of Rocky Brook (below Dosewallips River Road) contained relatively high LW quantities, over half of which was contained in three jams. The lower 350 m of Rocky Brook flows across an alluvial fan with evidence of recent channel shifting and human modifications. Relatively high residual pool depths recorded in this survey were due principally to several LW jam- and boulder-formed pools.

The available evidence suggests that until 1950, Walcott Flat retained many of the same dynamic alluvial river-floodplain features observed in other areas of the Dosewallips River. Currently, channel incision and bank armoring limit the interaction of the river with its floodplain and there has been extensive, ongoing loss of riparian forest cover. As at the State Park reach, landowners in and adjacent to this reach have continuing bank erosion problems. Due to sparse human settlement and large landownership blocks, there are excellent restoration opportunities in the Walcott Flat reach. Vern and Ida Bailey who own most of this reach maintain a limited conservation easement on their property with the Jefferson Land Trust that could be expanded to include measures to safeguard and restore the integrity and connectivity of the riverine-floodplain-riparian forest system.

Figure A 7. Walcott Flat to Above Gage reaches, Dosewallips River.

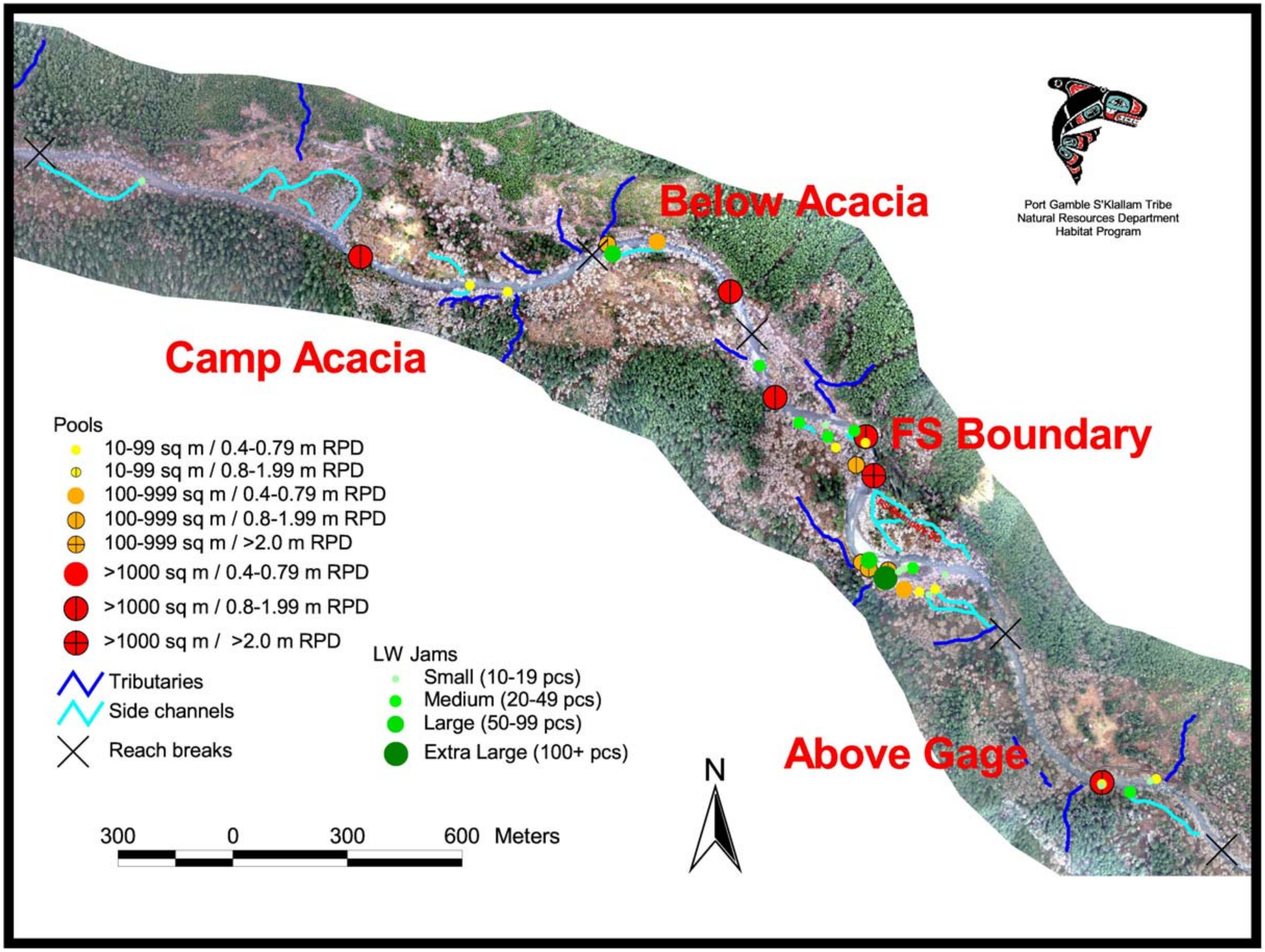


Immediately downstream of Six Mile Bridge lies a 750-m long undisturbed alluvial reach (Wilson) notable for its relative abundance of secondary channel habitat. Opposite the left-bank, inaccessible Wilson Creek, a small tributary enters the river from the south and flows into a remnant secondary channel before draining into the main river at RK 10.7. This so-called 6 Mile Bridge Creek has moderate LW quantities and perennial flow along its lower course, which is apparently fed by hyporheic flow from the main river. Most of this reach lies in USFS ownership and may have potential as a site for engineered LW jams to reconnect remnant secondary channels with the main river.

Six Mile Bridge to Elkhorn Campground

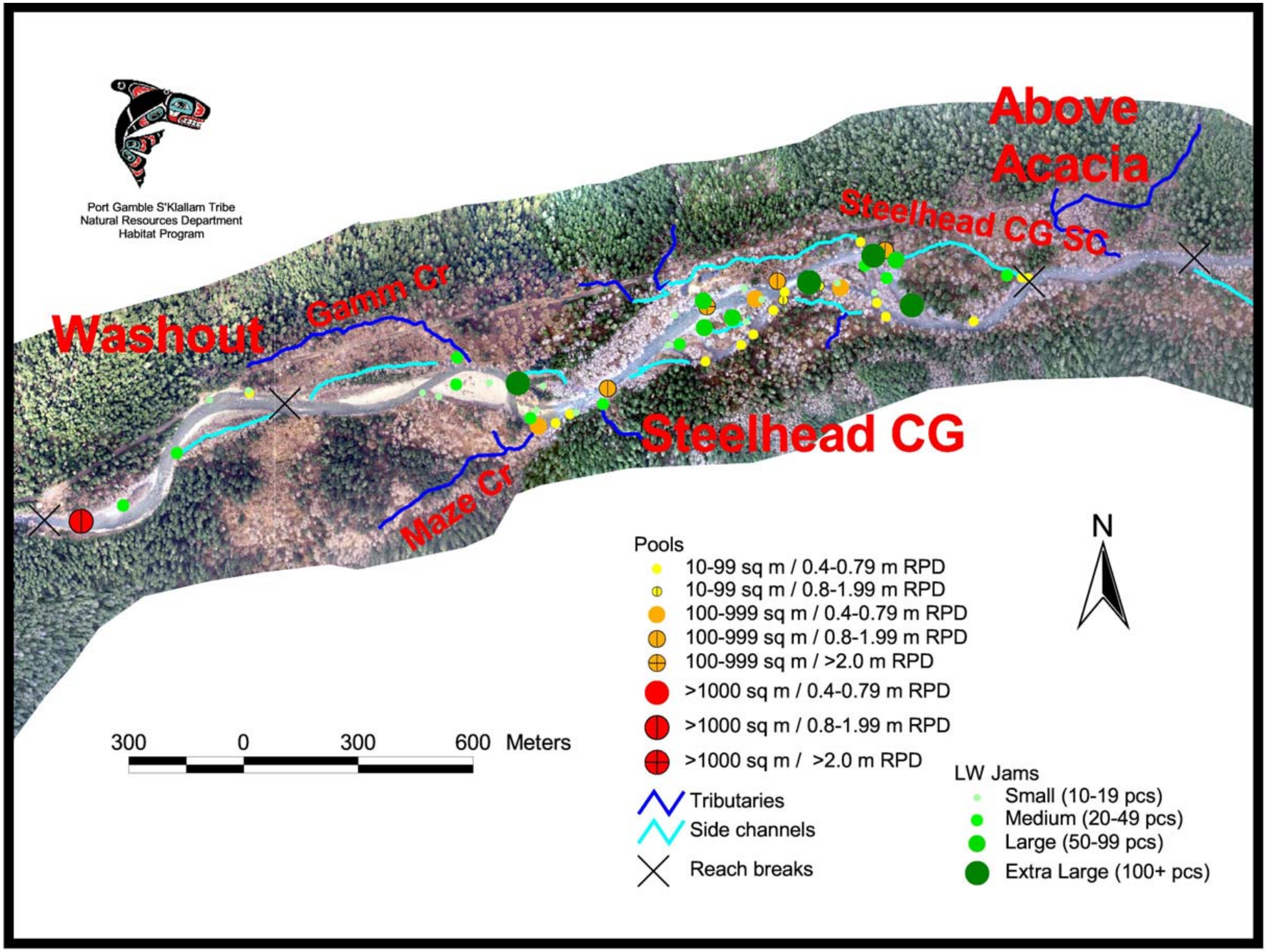
The valley segment lying between Six Mile Bridge (RK 11.5) and Elkhorn Campground (RK 22.0) encompasses two modified alluvial reaches (the 790 m-long Above Gage and 1390 m-long Camp Acacia), and three less-disturbed alluvial reaches (the 1150 m-long FS Boundary, 1750-m long Steelhead CG, and 500 m-long Elkhorn CG) bounded by series of tributary alluvial fan deposits, hillslope slump terrace deposits, and bedrock outcrops (Garcia 1996, Figures A8, A9, A11). As compared to downstream areas, alluvial reaches in this river segment are less extensive, higher gradient, and have fewer restoration opportunities.

Figure A 8. Above Gage to Camp Acacia reaches, Dosewallips River.



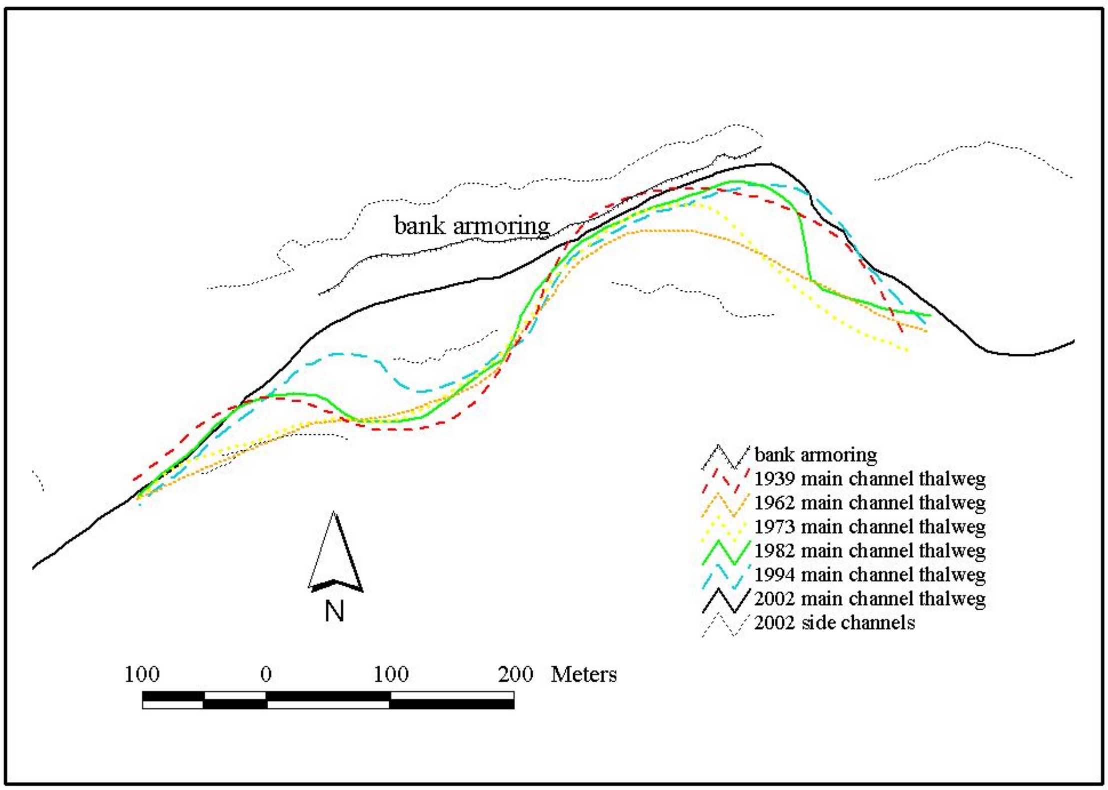
Within the Above Gage reach, the Dosewallips Road isolates the river from a small, developed floodplain area, but upstream from this reach the road route largely traverses adjacent hillslopes. In the FS Boundary reach, recent large floods have contributed to the growth and re-configuration of several large logjams. The largest of these, located at RK 13.6, have created a complex of backwater pools, secondary channels, and LW-formed pools. Upstream lies the human-modified Camp Acacia reach with low abundances of LW and pools. Historical 1939 air photos of the Camp Acacia reach reveal a series of meander scrolls that appear to have been isolated from the river to facilitate residential development.

Figure A 9. Above Acacia to Washout reaches, Dosewallips River. Note the abundance of LW jams and pools in the Steelhead Campground reach.



A large, active alluvial fan deposit at RK 16.5 forms the upstream 1750 m-long Steelhead Campground alluvial reach. The Steelhead Campground reach, on Olympic National Forest lands at RM 10.0 represents one of the most healthy, dynamic river-floodplain systems in the Dosewallips watershed. There is little evidence of anthropogenic channel manipulations, with the exception of a 400-m section of left-bank armoring installed by the USFS to protect the former campground (Figure A10). Due in part to less human manipulation and higher overall reach gradient, mainstem thalweg channel shifting has been less pronounced as compared to downstream reaches over the period of record.

Figure A 10. Steelhead Campground reach, historical channel patterns and bank armoring.

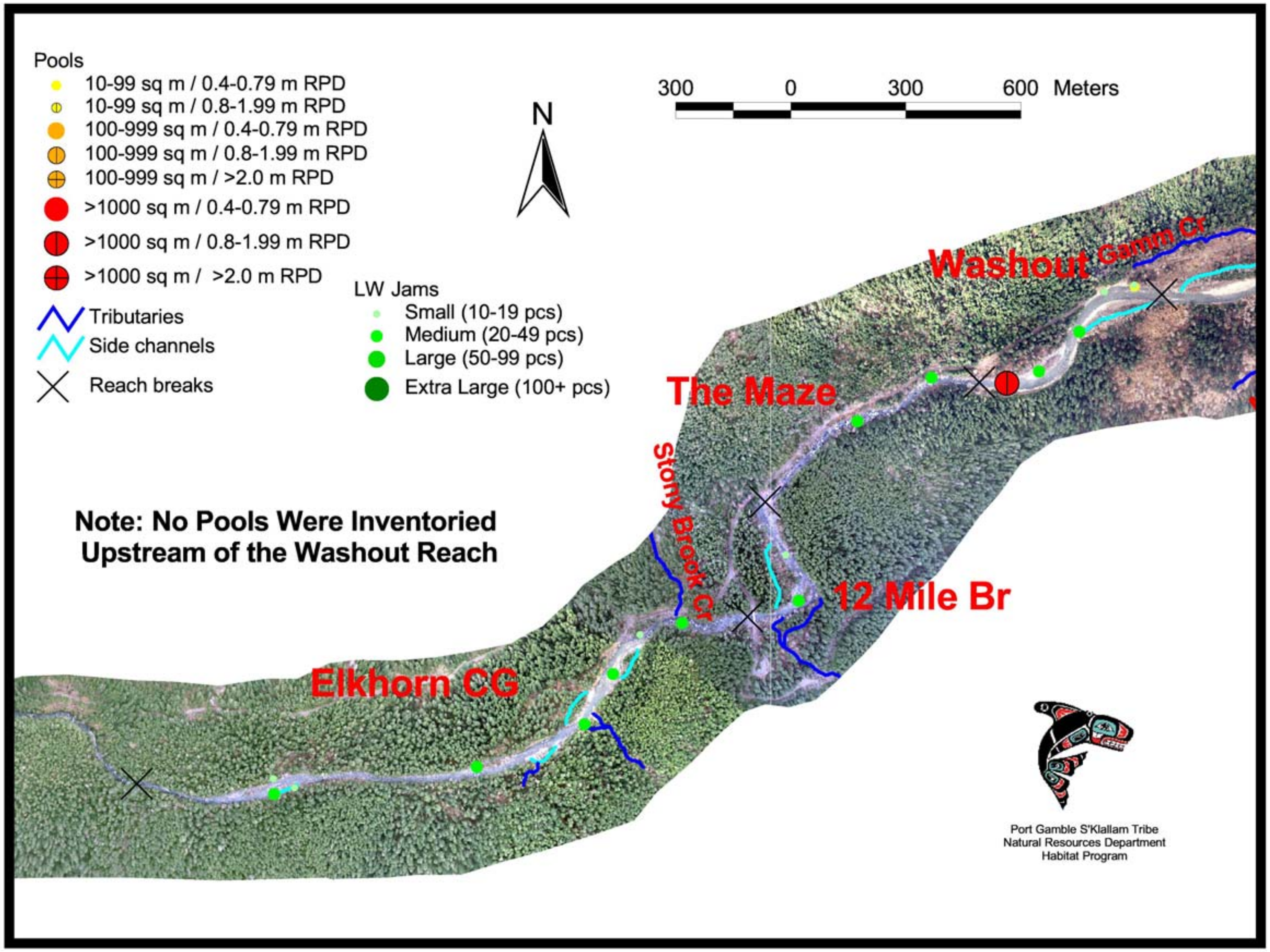


As part of the USFS effort to armor the campground riverbank, off-channel salmon rearing ponds were excavated behind a campground access road and a north valley sidewall tributary diverted into the upstream pond (M. McHenry, USFS, personal communication). These ponds, which have been isolated from mainstem river flood flows have been slowly silting in, though are still heavily utilized by juvenile coho salmon. Removal of the left-bank armoring and access road to restore scouring river flows to floodplain rearing pools represents one of the few important restoration opportunities in this otherwise relatively healthy reach.

In this upstream valley segment, we conducted ground surveys of two side channels (FS Boundary and Steelhead CG side channels), as well as two tributaries (Outhouse and Maze creeks). Though relatively small, these surveyed tributary and side channels had moderate quantities of LW and pool habitats and heavy use by coho salmon fry.

Higher stream gradients and narrow floodplain areas in reaches upstream of Steelhead Campground limit the development of critical salmon habitat features. However, reaches like the Washout represent important LW and sediment sources for downstream alluvial reaches, and warrant thorough protection under USFS land management rules.

Figure A 11. Washout to Elkhorn Campground reaches, Dosewallips River. Higher stream gradients and greater hillslope constraint limit LW jam and pool formation in these upriver reaches.



Available habitat data highlights the relative value of the FS Boundary and Steelhead CG reaches in this upriver valley segment. Both these reaches harbor an abundance of LW jams, pools, and numerous dynamic, interconnected secondary channel environments. These upriver reaches are significant refugia for fish stocks due to their isolation from more intensively managed private lands downstream. Though restoration opportunities are relatively limited in this valley segment, opportunities may exist at Camp Acacia to utilize engineered logjams to re-activate historical river meanders. However, seasonal residential properties would likely need to first be acquired and demolished. In addition, removal of the floodplain road and associated bank armoring at Steelhead CG should be more closely examined.

Summary

Available historical air photos, archival records, and long-time resident interviews for the Dosewallips River document extensive channel manipulations with most activity concentrated in select downstream alluvial reaches during the 1950-1965 period. Historical air photos illustrate contrasting patterns of channel change among different reaches, related in part to the pattern and history of human modifications. Though likely incomplete, these records give some indication of the types and magnitude of channel manipulations on the river to date.

Most alluvial reaches of the Dosewallips River have experienced at least some active channel modification up to the present day. Of the low-gradient response reaches evaluated, the State Park, Lazy C, and Walcott Flat reaches have experienced the most intensive human modification while the Powerlines, FS Boundary, and Steelhead CG reaches retain much of their natural character and habitat-forming processes.

In several reaches (Estuary, Brinnon Flat, Lazy C, Walcott Flat, and apparently Camp Acacia) river channelization has been a significant factor in the simplification and loss of aquatic habitat. In at least one reach, Walcott Flat, residents relate historical and ongoing channel incision, likely resulting from active channelization and logjam removal. Logjam removal – practiced since the early settlement period – has been used in most river reaches to train the river and prevent flood damage to stream banks. The spatial juxtaposing of these reaches in areas adjacent to reaches with relatively abundant LW and interconnected mainstem channel-floodplain systems suggests active management was a dominant factor in their observed changes.

However, in addition to human channel manipulation, natural river channel incision in response to the geologic uplift of the Olympic massif may be partly responsible for observed abandonment of secondary channel environments. Garcia estimated rates of natural river channel incision at the Main Fork/West Fork Dosewallips River confluence (RK 28.1) of 19.4 m over the last 13,000 years for an incision rate of 1.49 mm/yr. Though likely limited in magnitude over the historical period, it is important to consider this geologic context when planning long-term habitat restoration measures in the mainstem river designed to re-connect the river with its floodplain.

Historical analysis of channel-floodplain changes provides important temporal context for our snapshot of current habitat conditions in the Dosewallips River corridor. The integration of historical, ground survey, and remote sensing data provides a robust foundation on which to gage conservation priorities in the Dosewallips River.

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Table A 1. Dosewallips River mainstem large wood ground survey data, April 2002.

RK 1.1 Dosewallips State Park Reference Reach												
By Piece Size												
	Single Pieces		**In Jams**		**Total**			**Reach Length (m)**				
Rootwads	38		45		83	8%		640				
Small Logs	97		325		422	41%						
Med Logs	84		347		431	42%						
Large Logs	23		62		85	8%		**Jams (10 or more pieces)**				
	242		779		1021			#	#/km			
								21	32.8			
By Stability Factor				**Pool Forming?**								
Unstable	77	8%		Yes	8	38%						
Buried	81	8%		No	8	38%		**% of LW in Jams**				
Cabled/Anchore	144	14%		Scour	5	24%		76%				
Pinned	32	3%						79%	counting pinned single pieces			
Root	32	3%		**Key Pieces (>9 m^3)**				67%	counting pinned single pieces			
In Natural Jam	654	64%		#	#/km	% in jams				and natural jams only		
	1020			6	9.4	67%						
By Wood Type				**Jam Size Distribution**								
Conifer	35	21%		Unknown			2					
Deciduous	131	79%		Small (10-19 pcs)			12	63%	excluding unknown jams			
Unknown	76			Medium (20-49 pcs)			5	26%				
	242			Large (50-99 pcs)			0	0%				
				Extra-large (100+)			2	11%				
RK 17.3 Steelhead Campground Reference Reach												
By Piece Size												
	Single Pieces		**In Jams**		**Total**			**Reach Length (m)**				
Rootwads	10		24		34	3%		770				
Small Logs	77		321		398	35%						
Med Logs	122		473		595	53%						
Large Logs	18		77		95	8%		**Jams (10 or more pieces)**				
	227		895		1122			#	#/km			
								20	26.0			
By Stability Factor				**Pool Forming?**								
Unstable	89	8%		Yes	8	40%						
Buried	21	2%		No	4	20%		**% of LW in Jams**				
Cabled/Anchore	3	0.3%		Scour	8	40%		80%				
Pinned	81	7%						87%	counting pinned single pieces			
Root	33	3%		**Key Pieces (>9 m^3)**								
In Natural Jam	895	80%		#	#/km	% in jams						
	1122			7	9.1	100%						
By Wood Type				**Jam Size Distribution**								
Conifer	67	36%		Unknown			1					
Deciduous	118	64%		Small (10-19 pcs)			10	53%	excluding unknown jam			
Unknown	42			Medium (20-49 pcs)			3	16%				
	227			Large (50-99 pcs)			4	21%				
				Extra-large (100+)			2	11%				

Table A 2. Dosewallips River tributary and side channel ground survey data, August-September 2001.

Secondary Channel Name	Survey Length (m)	Perennial Flow Length (m)	Mean BFW (m)	Pools: Total Pools	Median Pool Area (m^2)	Median Resid Pool Depth (m)	Pool Freq (#/km)	Pool Spacing (BFW/pool)	Pool Forming Factors: LW Piece	LW Jam	Boulder	Scour Resistant Bank	Channel Meander	Other/ Unknown	Large Wood: Total LW	LW as Pieces	LW in Jams	Total Jams	LW % in Jams	LW Freq (#/km)	Total Key Pieces	LW Key Piece Freq (#/km)
State Park SC	596	128	35.0	2	160.0	1.04	15.6	17.50		1		1			170	114	56	4	33%	285.2	3	5.0
Powerlines SC	311	108	3.7	5	8.5	0.29	46.3	0.73	2			1	2		58	58	0	0	0%	186.5	2	6.4
Lazy C SC	460	427	6.9	7	26.6	0.34	16.4	0.99	3	1		2	1		51	40	11	1	22%	110.9	0	0.0
Opp. Lazy C SC A	115	107	3.9	7	9.4	0.21	65.4	0.56	1			1	5		16	16	0	0	0%	139.1	1	8.7
Opp. Lazy C SC B	77	67	1.1	5	3.5	0.12	74.6	0.22	4			1			21	11	10	1	48%	272.7	0	0.0
FS Boundary SC	325	196	3.5	9	52.3	0.52	45.9	0.39	4	1		1	2	1	63	48	15	1	24%	193.8	15	46.2
Steelhead CG SC	280	272	5.6	11	26.4	0.32	40.4	0.51	1				10		30	30	0	0	0%	107.1	3	10.7
State Park Cr	1145	453	4.6	20	6.1	0.24	44.2	0.23	6			8		6	112	102	10	1	9%	97.8	14	12.2
Powerlines Cr	277	273	4.4	11	14.3	0.27	40.3	0.40	3	1	4	3			87	49	38	2	44%	314.1	5	18.1
Rocky Brook Cr	672	667	12.6	45	32.2	0.44	67.5	0.28	1	4	28	7	4	1	249	117	132	3	53%	370.5	1	1.5
6 Mile Bridge Cr	221	178	4.7	9	27.9	0.37	50.6	0.52	4		4		1		60	60	0	0	0%	271.5	0	0.0
Outhouse Cr	96	91	2.4	9	41.5	0.21	98.9	0.27				1	7	1	14	14	0	0	0%	145.8	3	31.3
Maze Cr	368	308	2.4	15	8.5	0.20	48.7	0.16	3		3	2	6	1	50	50	0	0	0%	135.9	3	8.2

	N		Median	Median		Median	Median	Median	Median												Median		Median
Side Channels	7	2164	311	3.9	46	23.5	0.33	45.9	0.56	15	3	0	7	20	1	409	317	92	7	22%	186.5	24	6.4
Tributaries	6	2779	323	4.5	109	18.2	0.35	49.6	0.28	17	5	39	21	18	9	572	392	180	6	31%	208.7	26	10.2

Pool Forming Factor by percent:

	LW Piece	LW Jam	Boulder	Scour Resistant Bank	Channel Meander	Other/ Unknown
Side Channels	33%	7%	0%	15%	43%	2%
Tributaries	16%	5%	36%	19%	17%	8%

LW Size Distribution:	Rootwad	Sm Log	Med Log	Lrg Log
Side Channels	6	157	212	34
Tributaries	15	147	378	32

LW Channel Zone Distribution:	Zones 1 & 2	Zone 3
Side Channels	249	68
Tributaries	304	88

Tributary and side channel summaries are totals or percentages, except where reported otherwise.

Table A 3. Dosewallips River mainstem large wood jam, pool, and secondary channel inventory mapped from April 2002 orthophotography and LIDAR.

Reach Number	Distance From River Mouth (km)	Reach Name	Reach Type	Length (m)	Mean BFW (1 SD)	Mean Slope	Large Wood Jams: Total Jams	Jam Frequency (#/km)	Jam Type: Bar Top	Jam Type: Bar Apex	Jam Type: Bank	Jam Size: Small (10-19 pcs)	Jam Size: Medium (20-49 pcs)	Jam Size: Large (50-99 pcs)	Jam Size: Extra Large (100+)	Jams - % Pool Forming
1	0.0	Estuary	Est	713	47.6 (3.4)	0.004	8	11.2	0	3	5	3	3	1	1	38%
2	0.7	Brinnon Flat	U-Mod	1338	92.3 (44.2)	0.005	21	15.7	6	5	10	13	3	3	2	33%
3	2.1	Powerlines	U-Nat	1450	120.6 (38.0)	0.006	39	26.9	14	13	12	12	15	4	8	44%
4	3.5	Lazy C	U-Mod	1535	53.9 (23.6)	0.006	12	7.8	1	2	9	5	5	1	1	67%
5	5.0	Canyon	C	1265	27.2 (8.3)	0.008	1	0.8	0	0	1	0	1	0	0	
6	6.3	Walcott Flat 1	U-Mod	2074	41.9 (12.3)	0.008	6	2.9	1	3	2	1	4	1	0	
7	8.4	Walcott Flat 2	U-Mod	1870	38.6 (7.2)	0.009	3	1.6	1	1	1	1	2	0	0	33%
8	10.2	Above Walcott	C	405	31.8 (6.3)	0.008	0	0.0	0	0	0	0	0	0	0	
9	10.7	Wilson	U-Nat	750	43.9 (19.5)	0.011	4	5.3	1	2	1	1	2	0	1	75%
10	11.4	Six Mile Br	C	1100	28.6 (13.8)	0.018	2	1.8	0	1	1	1	0	0	1	
11	12.5	Above Gage	U-Mod	794	33.4 (6.2)	0.012	2	2.5	1	0	1	1	1	0	0	
12	13.3	FS Boundary	U-Nat	1156	44.4 (19.8)	0.011	12	10.4	1	2	9	7	3	1	1	25%
13	14.5	Below Acacia	C	495	26.3 (7.2)	0.011	1	2.0	0	1	0	0	0	1	0	
14	14.9	Camp Acacia	U-Mod	1388	30.4 (6.2)	0.012	0	0.0	0	0	0	0	0	0	0	
15	16.3	Above Acacia	C	339	30.8 (2.2)	0.014	0	0.0	0	0	0	0	0	0	0	
16	16.7	Steelhead CG	U-Nat	1751	55.6 (16.3)	0.013	25	14.3	4	9	12	12	9	2	2	44%
17	18.4	Washout	MC	597	37.1 (10.0)	0.009	4	6.7	0	1	3	2	2	0	0	25%
18	19.0	The Maze	C	682	29.0 (14.2)	0.031	2	2.9	0	1	1	1	1	0	0	100%
19	19.7	Elkhorn CG 1	MC	498	34.6 (13.5)	0.013	1	2.0	0	1	0	0	1	0	0	100%
20	20.2	Elkhorn CG 2	C	1798	26.6 (8.4)	0.017	8	4.4	0	3	5	4	4	0	0	
								Median								
	By Reach Type:															
	Unconfined - Natural (n=4)			5107		0.010	80	12.3	25%	33%	43%	40%	36%	9%	15%	43%
	Unconfined - Modified (n=6)			9000		0.009	44	2.7	23%	25%	52%	48%	34%	11%	7%	36%
	Confined/Mod Confined (n=9)			7181		0.014	19	2.0	0%	42%	58%	42%	47%	5%	5%	21%

Reach Number	Reach Name	Pools: Total Pools	Pools Spacing (BFW/pool)	Pool Frequency (#/km)	Median Residual Pool Depth (m)	Pool Size: Small (10-99 m^2)	Pool Size: Med (100-999 m^2)	Pool Size: Large (1000+ m^2)	Pool Forming Factor: LW Piece	Pool Forming Factor: LW Jam	Pool Forming Factor: Boulder	Pool Forming Factor: Scour Resistant Bank	Pool Forming Factor: Channel Meander	% LW-formed
1	Estuary	1	47.1	1.4	0.98	0	1	0	0	0	0	1	0	
2	Brinnon Flat	22	2.1	16.4	0.79	13	5	4	6	9	0	5	2	68%
3	Powerlines	34	1.4	23.5	0.92	16	11	7	5	19	0	6	4	71%
4	Lazy C	17	2.8	11.1	0.79	9	4	4	4	1	1	9	2	29%
5	Canyon	9	5.2	7.1	1.46	3	2	4	1	0	0	8	0	11%
6	Walcott Flat 1	14	3.4	6.8	0.76	8	3	3	1	1	3	8	1	14%
7	Walcott Flat 2	15	3.1	8.0	0.70	8	7	0	3	1	4	5	2	27%
8	Above Walcott	4	11.8	9.9	1.04	2	0	2	0	0	1	3	0	
9	Wilson	11	4.3	14.7	0.85	1	8	2	0	1	1	6	3	9%
10	Six Mile Br	10	4.7	9.1	2.27	2	3	5	0	0	2	8	0	
11	Above Gage	3	15.7	3.8	0.79	2	0	1	0	0	3	0	0	
12	FS Boundary	14	3.4	12.1	0.80	6	5	3	1	6	0	4	3	50%
13	Below Acacia	3	15.7	6.1	1.28	0	2	1	0	0	0	1	2	
14	Camp Acacia	3	15.7	2.2	0.58	2	0	1	0	0	1	1	1	
15	Above Acacia	1	47.1	2.9	0.61	1	0	0	0	0	0	1	0	
16	Steelhead CG	27	1.7	15.4	0.67	19	8	0	2	15	5	0	5	63%
17	Washout	2	23.6	3.4	0.92	1	0	1	1	0	0	0	1	50%
18	The Maze													
19	Elkhorn CG 1				NOT SURVEYED									
20	Elkhorn CG 2													
			Median	Median	Median									
	By Reach Type:													
	Unconfined - Natural (n=4)	86	2.6	15.0	0.79	49%	37%	14%	9%	48%	7%	19%	17%	57%
	Unconfined - Modified (n=6)	74	3.3	7.4	0.76	57%	26%	18%	19%	16%	16%	38%	11%	35%
	Confined/Mod Confined (n=9)	29	13.7	6.6	1.40	31%	24%	45%	7%	0%	10%	72%	10%	7%

Reach Number	Reach Name	Secondary Channels: Total Channel Intersections	Channel Intersection Frequency (#/km)	Ratio of Secondary to Mainstem Channel Length	Tributary Length (1)	Side Channel Length (1)
1	Estuary	14	19.6	0.0	0	0
2	Brinnon Flat	20	14.9	1.5	1015	1036
3	Powerlines	30	20.7	1.6	363	1966
4	Lazy C	4	2.6	0.3	114	306
5	Canyon	2	1.6	0.1	158	0
6	Walcott Flat 1	19	9.2	1.9	632	3397
7	Walcott Flat 2	9	4.8	2.4	1930	2647
8	Above Walcott	0	0.0	0.0	0	0
9	Wilson	9	12.0	2.9	1908	293
10	Six Mile Br	8	7.3	0.2	0	193
11	Above Gage	4	5.0	0.6	280	232
12	FS Boundary	24	20.8	2.3	1133	1506
13	Below Acacia	3	6.1	0.2	0	122
14	Camp Acacia	15	10.8	1.4	908	1028
15	Above Acacia	1	2.9	0.0	0	0
16	Steelhead CG	40	22.8	1.9	1031	2242
17	Washout	4	6.7	0.5	0	302
18	The Maze	1	1.5	0.0	0	0
19	Elkhorn CG 1	6	12.0	1.6	534	261
20	Elkhorn CG 2	18	10.0	0.5	362	495
			Median			
	By Reach Type:					
	Unconfined - Natural (n=4)	103	20.7	2.0	4437	6007
	Unconfined - Modified (n=6)	71	7.1	1.5	4879	8646
	Confined/Mod Confined (n=9)	43	6.1	0.3	1054	1372

Reach type summaries are totals or percentages, except where reported otherwise.

(1) Orthophoto-mapped tributary and side channels include perennial, seasonal, and isolated reaches, which could not be separated from one another based on photo-interpretation.

Tributary length totals exclude high-gradient reaches that are not accessible to anadromous salmon (based on an examination of LIDAR, not ground surveys.

Appendix B: Dosewallips River Resident Interviews

In May 2005, Ted Labbe conducted interviews with long-time residents of the Dosewallips River valley on their personal memories of the river, its fish stocks, and how conditions have changed. Individuals interviewed were: Vern and Ida Bailey, Arlene Crowell, Dick Coone, Bob Crowell, and Bill Nelson. Interviewees were generally asked the same set of questions, though certain questions were tailored to match the particular knowledge of individuals on specific sections of the river, on fishing memories, etc. The interviews were recorded, transcribed, and then drafts provided to interviewees to confirm the collected information. Information from the five interviews below was used to corroborate or add to the findings outlined in Appendix A and the main report.

Interview questions:

1. Please date and describe your earliest recollection of conditions along the Dosewallips River?
2. What kinds of fish do you remember seeing in the river? What kinds were the most numerous? Were there ever many chinook salmon in the Dosewallips River?
3. What do you remember about logjams and side channels in the river? Were they more or less abundant than today?
4. What reaches on the river have changed the most? Please explain.
5. Has the river cut into, filled in, or roughly stayed the same in the reaches you are most familiar with?
6. What were the big flood years? How did the recent flood in January 2002 compare to 1949?
7. What about the 1995 flood on the Duckabush River – was there a corresponding flood on the Dosewallips River that year and how big was it on the Dosewallips as compared to 1949 and 2002?
8. What about fire in the watershed? Do you remember any big fire years and where they burned?
9. What about landslides and road washouts? When and where?
10. Please describe any changes to your or others' lands resulting from past floods, fires, landslides, or road washouts.
11. Are you happy with the way the river is today? What are the biggest problems, if any?

Key findings:

Most interviewees concentrated their answers on the specific reaches they knew best. However, from the pattern of responses to certain questions we can reconstruct general river-wide patterns of change to the Dosewallips River.

Two interviewees who were former fishermen on the Dosewallips River (Bob Crowell and Bill Nelson) remembered catching Dolly Varden (likely bull char, *Salvelinus confluentus*) until the 1940s, after which they apparently disappeared. Both Bob and Bill remembered fishing for chinook salmon (*Oncorhynchus tshawytsch*) during summers on the river, indicating that this population may have had a different run timing than at present. All respondents indicated that fish populations were far more abundant than at present.

Most interviewees indicated that floods or flooding were their earliest, most notable memories of the river. Three of the oldest residents (Bill Nelson, and Vern and Ida Bailey) remembered more abundant wood jams in the river as compared to the present-day. The other respondents were more ambiguous in their answers on this subject, suggesting they did not have strong memories about wood in the river. It is notable that the other interviewees all date their earliest memories from after 1940, presumably post-dating the period when the U.S. Works Progress Administration (WPA) was active removing logjams on the river (according to Bill Nelson).

May 5, 2005 interview with Vern and Ida Bailey:

Vern and Ida Bailey (VB and IB) have lived in the Dosewallips River valley for over eighty years. Ida Bailey was born in 1921 and raised in the Dosewallips River valley, about one-half mile down the river from where she and her husband live today. Ida's grandparents came to settle in the valley in 1906. Vern arrived in the valley in 1939. The Baileys are the official Brinnon community historians and authors of the book Brinnon: A Scrapbook of History. Vern and Ida live on a portion of the original Lucky homestead and own the original Walcott homestead [Walcott Flat 2 reach, RK 9.3]. The interview began with Ida recounting going up the Dosewallips River Road as a kid, and expressing her concern about the difficulty getting the road rebuilt after the washout in 2002.

TL: What are your earliest memories of the river?

IB: I remember when I was eight years old the big king salmon coming up here. There were great big ones as big as this table. Of course you never see them anymore. My dad was a fisherman and he would catch them. And he caught lots of steelhead. And now we hardly ever get a steelhead. I'm sure the steelhead were wild steelhead in those days. I don't know what year the State started planting them.

VB: Steelhead used to be more abundant. The State used to plant steelhead from the hatchery in early spring every year during later years. That happened up until the 1970's when the Tribes got half of the fish and they stopped planting them.

TL: Do you remember a lot of pink and chum salmon in the river? What were the most abundant kind of salmon?

IB: The humpies. There were lots of them. The bear would get them.

TL: Do you think the pinks are less abundant today?

Both: Yes.

TL: What do you remember about wood in the river? Was there more or less than there is today?

IB: There was a lot more than there is today. There used to be big logjams.

VB: Back in the old days there was old-growth that would wash out and form logjams. There were a lot of logjams.

IB: When Mrs. Olson came here to homestead she walked across the river on a logjam [Brinnon Flat, RK 1.5].

TL: So that was in your lifetime. You remember seeing more wood in the river back then.

Both: Oh yeah.

IB: We used to trout fish a lot as kids and we would get on those logjams and fish off of them.

TL: What about this stretch of river? What has changed?

IB: We moved the river. It was right out here just behind our barn, and it was flooding and cutting across our land.

TL: What year was that?

VB: November 1949 was the big flood.

IB: We went to the flood control board for help and they put up half the money and we put up the other half. We moved it back into its original channel over by the hillside.

VB: The river had been in its original channel [near the south edge of the valley wall] but had been changed by a big logjam that had huge old-growth trees, which formed a dam across the river. And the river had to find a new channel so it came around here and cut channels back across to the old river channel in several places. It kept eating its way down and washing away on that big field down there – that was when we changed it. It was that one big logjam that changed the river and then it just took the lowest ground.

IB: We just pulled that whole logjam out and then it was easy for it to go back to its original course.

VB: We did the work in the following year on Labor Day [1950]. That was when we had our permit for it.

TL: What happened downriver from here on the Baisch property?

VB: We put 'shear logs' to keep the river out of the field. We tied big logs off against the bank so that as the river comes up, the logs would rise up and keep debris out of the fields.

TL: What sections of the river have changed the most, as you remember it?

VB: Well, the section that has changed the most is where we changed it. Other than that, the channel has deepened but it is pretty much in its old course.

TL: So by deepened, you mean the river has cut down into its bed?

VB: Yes.

TL: And even more since you reset it over to that original channel?

Both: Yes. It is down-cutting all the time.

VB: It is cutting down even now. Out here a bar is forming on the other side of the river and forcing the river this way. The winter before we put in some more shear logs but we didn't have good cable and they didn't stay, so we probably lost an acre of ground. The river is continually coming this way.

IB: It's always going to change.

TL: I am curious about the big flood years. How big was the 1949 flood as compared to the 2002 flood?

Both: Oh it was a lot worse – worse for us. The flood of 1949 came through this old channel [by the Bailey barn] and it was more restricted than the flood of 2002. Though the flood in 2002 was bigger elsewhere, and may have caused more damage up and down the river. When you think about that mess up at the road washout and down here by Rocky Brook. The 2002 flood was probably bigger and caused more damage [for others, though for us the 1949 was worse].

VB: The channel here was more restricted down here in 1949. There was an island out here, and that island kind of jammed the river and forced it out on the other side. As it washed out, it filled the channel with a lot of material. But now the river is more channelized so the water can move through more easily.

IB: Although my mother used to talk about watching the river wash a barn away, so I wouldn't know if that was the worst flood we've ever had.

VB: That would have been in 1915 or 1916. And that was right here! Back at that time the river was running here [in the channel next to the barn], before any homesteaders came up here. That jam [that caused the river to shift] was pretty ancient. At the time, we figured it was probably one hundred years old.

TL: During the 1949 flood was there a lot of material and debris out over the field?

VB: Well, it was all timbered over there at that time with alder, maple, and cottonwood. It did not get over onto our place, but it did get over onto our folks' place, where the Becks live today. The water was all over that field but not as much debris was there as there was down at the Smith place, where the Baischs live today. That was where the most debris was.

IB: Since it was on my dad's place, I remember it really well because he worked and worked cleaning it up. My dad owned the land where the Baisch's now live until his death in 1970.

TL: Was the work down below with the shear logs done prior to the channel being re-routed up here?

VB: No, that was done at the same time. Our permit was for the whole stretch of the river from the Baischs all the way up here to the top of our property.

TL: Do you know anything about a flood in 1995? There was a large flood on the Duckabush in 1995, and I have been wondering if there was anything on the Dosewallips then.

[At this point, Vern Bailey retrieved his personal diary in which he records rainfall and weather, as well as his daily log and observations.]

VB: We had quite a lot of rain in December, but it looks like – based on the temperature – it would have been snow higher up. There is nothing mentioned of any size in 1995 in here. With a high tide, the Pierce place floods pretty regularly down on the Duckabush – it may have been down there, associated with a high tide.

TL: Do you remember any big fires or landslides during your time on the river?

IB: When I was five years old, in 1926, both sides of the river burned out. I can remember my folks took us down into the field and spread a blanket and told us to stay put on the blanket because they were fighting to save the buildings.

VB: The fire burned to the top of the ridge [pointing to the south] but it kind of skipped on this side [to the north]. It burned just some of it.

TL: Do you remember if there were any landslides that resulted from that fire?

VB: No, we have never seen any landslides on this river that resulted from logging or fires. The only slide we know of is just this side of Steelhead Camp, where the road goes over a hill. There have been slides there that are always caused by a big downpour. One time during the summer there was one there caused by a big cloud burst storm and some campers up there just barely got out.

[Later in the interview VB returned to the subject of slides] There was a slide on the Miller property [Camp Acacia reach, RK 15.6] where a slide came down. They put in a garden patch and cleared an alder and vine maple flat. They had a beautiful crop of oats, and then the slide came down and covered it and their picket fence. That place is just upstream from the Masons' property [known today as Camp Acacia]. That was probably around the turn of the century – around 1907.

TL: Are you generally happy with the river today, or are there problems with it still that you would like to see resolved?

VB: We just need to get some work done on the river where it is cutting and washing. That is the only thing, with the exception of getting the road washout restored.

TL: Do you remember the Lazy C dude ranch?

IB: I can remember back to when it was a farm, after it was homesteaded. Then the Clarks bought it and turned it into a dude ranch that was called the Lazy C. Then they sold it.

VB: The Clarks couldn't keep the payments up so they decided to subdivide to keep from losing it. That is the reason it is subdivided. It should never have been subdivided. That is the reason we fixed our place so that it can't be subdivided.

TL: Looking back at the old air photos, it looks like there might have been an old channel across the floodplain at Lazy C. Did it ever flood across there? Did they re-grade all that?

VB: No, they didn't re-grade it but the river has built up and washed out gravel bars. Micky Thomas told us about his parents buying that place and putting in a big crop. He told us about the river flooding and depositing gravel on the field.

May 6, 2005 interview with Arlene Crowell:

Arlene Crowell (AC) has lived in the Dosewallips River valley since the **1940s?**. Arlene's property lies midway up the Powerline reach at RK 2.8 and includes a portion of the Lazy C side channel. Arlene's deceased husband, Jim Crowell, is the brother of Bob Crowell who was also interviewed. The interview began with an overview of the project with TL explaining his interest in changes to the river over time, for its influence on fish and their habitat.

AC: I used to see where they were spawning. We have lost a lot of that because of logging and filling in the floodplain down here at Lazy C. See that river is not the way it was. He had it all the way to my property line. Part of that has washed onto my property down there. That was all filled. They changed the course of the river by fill and riprap. And it has kind of taken it back with its three branches.

The only thing I really remember about this river is the swinging bridge up at Buck Mountain, up above the Baileys [at/near Six Mile Bridge, location uncertain]. My husband was logging up there. In the late 1960s, the Nordeans (who owned and operated the dude ranch at Lazy C) and the Browns sold out to John D. Swift.

John D. Swift was the one who developed Lazy C. I have never seen so many dump trucks taking gravel down there. It was one solid lot that they dug out. Down below they filled and leveled from the County road – Appaloosa Drive – all the way down. There was a bank about 3-3.5 feet high down to the river we would have to ride down across it with our horses.

We used to ride our horses down there every day. We would ride down there every other day and watch [the development]. He had a guy Jerry on a great huge Cat pushing, pushing… And I would say to him: "What are you doing?" And he would say: "I am pushing tons of fill here." It took him six or seven months to get that all filled in almost to my place. Then the County approved all those roads to be County roads down in that subdivision. I think they had everything but four or five lots sold pretty quickly. The people loved it. Jim, my husband, and Bob, used to say to them: "That's all going to be flooded!" And they would say: "Oh yeah! Why don't you just mind your own business! You're just jealous!" A lot of them later said he was right.

After a big flood in the 1970's I was afraid to ride my horses down there. See it doesn't flood every year… I can't remember the name of the old fellow with the trailer that is right adjacent to my property. All that has to be removed so that it does not wash down to the [State] Park and go into a logjam. That is what happened when they cleared and created lots just upriver from the Lazy C. All the logging slash in the river washed down in a flood and jammed up down here below us. I told my husband I was afraid our land would be washed away from it. And he took his power saw down in his old army truck and cleared the logjam off the part that was on our property.

You have seen that wash [the Lazy C side channel] that is dry right now down below on our property. But of course in the wintertime, it roars! A lot of that stuff got in there. And we got a lot of really nice logs out of it for firewood.

TL: So was he clearing wood out of that particular channel? Was that channel straightened?

AC: Just at the end of it on our property – we cleared it out. John D. Swift had that cleaned out and straightened out with an excavator. It was beautiful. When it comes onto our place it gets kind of 'catawhompus' because they did not get to come in there and do that. I thought that was the prettiest looking thing that I have seen – how they trenched it all out like an irrigation ditch. But Jim was upset. And Bob. Much of the rock they put in there looked really pretty but ended up washing down onto our place.

And every year it does it [flood], and then every year there is more. And like Bob said, that is what killed it. That is why we don't have salmon coming up here spawning anymore. They poisoned it.

TL:	What are your earliest memories of the river?

AC:	How it flooded every year, almost. It used to go right up to Nordean's – the Riverine Lodge [original name of the Lazy C dude ranch]. And so of course they weren't open in the winter. It was like a small lake down there. When Clark bought it from Nordean or Brown – whichever – Clark built a couple of more barns that were washed out after the fourth year.

TL:	When was that?

AC:	That was in the early 1960's. I might be a few years off, though. My son used to play with their adopted grandson. He used to call me mama number two. Our families were close but Jim did not get along with them. There were some property boundary disputes over the years. I was just a neighbor thing – it had been surveyed when Bill Clark bought the land. They don't do things like that anymore. We have a lot more laws protecting our land then they did back then.

The County would never let that Lazy C development do what they did [now]. If they did, the State wouldn't [allow it], because you are not allowed to fill or change the course of a river. But they did [back then]. There wasn't anything [to stop that] then that I know. They ruined the river in my estimation.

TL:	Was that the most dramatic change you have seen on the river that you can remember?

AC:	That was the worst thing that they did on the river – that development. The river would still be in its real channel [were it not for that development]. And we would still have dog fish coming up.

TL:	Chum salmon used to come all the way up to Lazy C?

AC:	Oh, beyond that. Up past the Nelson's place, to the old Hovey place [Canyon reach, RK 5.3]. She was the school cook down here. We used to be able to smell rotten dogs from here at the house. It would stink! The wind comes down the valley and would whip the smell up to our house. There must have been thousands of them. I said, why can't someone come in here and pick them up or let the dog food company have them? We had bear, and hundreds of bald eagle were down there eating, and ravens and crows. They stayed there for months rotting. My dogs used to go down there and roll. And Jim would make me get up in the middle of the night and bathe them!

TL:	Do you remember chinook salmon in the river?

AC:	I cannot tell one species from another. Which one are called "pinks." The guys used to go down there and get the bigger ones – long before the Indians started netting them – and get some to smoke. But I am not sure which kind of salmon it was. The only kind I could identify was steelhead. Bob would come down and fish for them on the Coone property back when the Brits owned it. There was a hole down there, and then another one up on the Nelson property just above Lazy C, and then one up at the cement bridge [Six Mile Bridge] where he used to fish. Bob would Catch the steelhead and bring them in. I canned them and would give my mom half, and Jim and I would keep half.

TL:	Would you say that fish were more abundant then or now?

AC:	Oh gosh, there are hardly any fish now. I have not seen a dog salmon except when my grandson ran over several hundred fish in the river in his monster truck. Phil Henry said he ran over those fish. There were some lying on the bank but none in that side channel on my place. They used to come in there, though. There were hundreds of them. Anyway, I was so angry with him. They arrested him. You cannot run over fish in the river! There wasn't even enough to run over! I could hear the truck running through the river…

TL:	Do you remember there being more or less wood in the river, as compared to today?

AC: There for about ten years there was a lot of wood, and one time they even had Cat in there and down at the Lazy C down where the County Road has been blocked off [at the downstream end of Lazy C reach, RK 3.5]. You can see how the river channels this way but the main part of the river is over on the south side of the valley. The reason it is channeled this way is because there was a logjam over there. And you can see some of the fill on that bar that they dumped in there. And the river is now washing its track on this side, and we actually have three branches to that river right now. But that was where a logjam was hanging up, and it was big – it looked like giant beavers had done it.

TL: So it went across the whole channel?

AC: Oh, it was just intermingled, but it had the roots from stumps and logs. Somebody went down there with a Cat, hooked on a lot of it and drug it out. There might be still some of it that was drug out along that one branch, but I don't know. That was in the late 1970's but I am not sure about the exact year. That was one of them, and then they had one down by the State Park and I think part of that one is still there. It is on the upper side of the bridge. And then they had one on the lower side of the bridge, and somehow I think they cleaned it out but I have never gone down there to see it. So maybe they did not clean it out. I thought that they should have cleaned it out at the Park.

TL: So in this stretch and down by the Park you remember more wood in the river than today?

AC: Oh yeah, no-no. There has been no logging up here to get the stumps and the logs and the dirt and everything else [in recent years]. When they log they tear up, clear, and push it towards the channel and let it wash away. And there has been none of that [recently] that I am aware of.

TL: Those bigger jams that you mentioned, do you remember them moving around or were they pretty stable?

AC: The one on our creek or that little slough going out, it did not move at all. Once it was jammed, it was jammed. It is at the end of our fence [on the downstream end of the side channel that traverses the Crowell property]. The water backed up so far that there is a big slough on the other side of our fence. That hole was formed because of that jam. Then we had one that was not quite as big on that slough up above, right where you cross it – it was on our property. And it was a pretty deep thing, and there were fish in it. Jim said to me: "Hey grab that fishing pole and let's go get some of those trout!" And I said: "What do you mean there is trout, it isn't fishing season." And he said: "What do you mean? Who is going to know? Besides, they [the fish] are land-locked and going to be dead!" He never did, though. He was just teasing.

TL: Well, yeah, sometimes those fish can hold on until the river comes back up. But other times the raccoons will get them.

AC: Well, that water stays year round [in the pool] and it is a mosquito bed, a mosquito breeding ground. Maybe the fish were eating the mosquito larvae. I don't know. But, you know, above our property where it [the river] tore the fence down, that was due to the flood and all the logs lying there. They did not float off. That year and the following year we had water everywhere down there. That was just recently in the last seven or eight years, the same year Jim died. See, otherwise, Jim would have had that fence back up if he had not passed away when he did. Just before that he would go down in the army truck, clearing and cutting it up for firewood.

Donnie told me it flooded after his dad passed away, and he said the old man would have a fit. He said: "Your fence and wood are laying in every which direction down there." But I told him that I am not able to go down there and put the fence back up. The elk took part of this fence down again the other night and I have to go fix it.

TL: You mentioned big changes in the river at Lazy C. Are there other changes in the river course that you remember, either up the river or down below?

AC: The only other part that I know that has really changed is up near Elkhorn where the road has washed out. We used to be able to ride our horses up to the Park, but I am not willing to take my chances now. We used to be able to ride our horses down to Swift's property, cross the river, then follow the [BPA powerline] right-of-way on up to Jupiter Ridge. Then, we would follow the road down to Six Mile Bridge, cross the river and come down the County road to our place. I know my big gelding could still cross the river but I don't know about the rest of the route.

TL: Do you notice if the river down below here has cut down into its bed or filled in?

AC: Well, just in spots. I think it has just washed out a little in places and deposited in others. I don't think it goes clear down to the bay. Although in the wintertime that bay is just mud brown from the [road] washout up here. I imagine on that bank across the river [opposite Lazy C, RK 3.9], that it is washing away and cutting down, but I don't know.

TL: What were the big flood years? You mentioned the flood in the late 1990's. Were there others you remember?

AC: The bigger floods were around 1952 and 1953 – it flooded all the time then. We used to have a regular flood until… Everyone said 'dredge the river' but they never did it except in spots along Lazy C – where they scooped it out with a Cat. We get a good flood every three to four years. If we get a good snow, we get a good flood. We had one about three years that washed into the Lazy C and ruined one woman's electric washer on her back porch.

TL: Do you remember landslides or fire that affected the river.

AC: Not since I have lived here. Nothing big that has resulted in a full-scale operation. The only landslide I know about is the one opposite the Lazy C club house, where the trees are coming down. That 'mudbank' or slide is the only one I have ever seen down by the river [opposite Lazy C, RK 3.9].

TL: You started out talking about how the Lazy C development spoiled the river. How do you feel generally about how the river is today?

AC: They [the Lazy C developers] ruined the river. I am just tickled pink that the John D. Swift property home remnants are going [referring to the plan to remove old home debris by Jefferson County]. There was too much trash and debris down there, like it's a garbage dump. And then in the wintertime it flushed down onto our place. I think it [the river] should be completely left to take its own course and become salmon habitat again – clean salmon habitat! People should not be able to dump their refuge, or whatever they are putting down in there because it does all sift down. All the private sewers down here on this piece next to mine – the piece that the State or the County purchased: where was all of that draining into except the river? I think that is wrong. I mean I don't think we could ever afford a public sewer system but…

Bob [Crowell] can tell you more about the salmon and all that because he used to fish for them. He can tell you the drop, and probably even the years. All I know is that the dog salmon aren't back.

TL: Were those the dog salmon that came in during the summer or the fall?

AC: This was September, October, and November. Because I remember the snow on them, and those dead stinky fish lying under the snow. They would lie there for months. The bear ate them like that. No one hunted the bear because everyone said they tasted like fish!

May 10, 2005 interview with Dick Coone:

Dick Coone (DC) has lived year-round in the Dosewallips River valley since 1983, but before that spent summers on the river back to the 1940s. Dick's maternal uncle, Joseph Dor, originally lived on their property beginning in 1928, and he later sold the property to Dick's mother who passed the property onto Dick and his wife Uerla. The Coone property straddles a large Crescent basalt outcrop that serves as the boundary between the Brinnon Flat and Powerlines reaches, at RK 2.1. The interview began with TL describing the goals and objectives of the Tribe's Dosewallips River habitat assessment.

TL: What are your earliest memories of the river?

DC: The river changes a lot, often. When I first moved here in the winter of 1983-4, we had a lot of snow and rain and we had floods that completely changed the course of the river. The Lazy C phase 3 development and hillside was lost during that winter and the residents were not able to get in there anymore.

My earliest memories of the river are from 1928. My uncle [Joseph Door] worked for the Post Office in Seattle and he had a bad heart, and they told him he did not have much time to live. So he came over here and he found this spot. We lived in Bremerton at that time and would come across to Brinnon on the ferry from Seabeck. I can remember walking up here, and the whole area had been burned over and the trees were all about my size. I remember walking out to the point on my property and being in awe. Wow! I remember thinking: look at that mountain, look at that river, and look at everything down through there. We used to come up and see my uncle every now and then. He was a real jokester and we called his cabin the "Lil' Abner Cabin" – he raised his family in it.

TL: So you were coming over here seasonally then?

DC: Yeah, I loved the area and would come over whenever I got a chance. The war came and I was not able to come over then. But after the war I came over to see him a few times. There was no electricity until 1947. My uncle had a ram pump to get the water up the hill to two fifty gallon drums [from the springs down the valley].

I went up to the land records in Port Townsend. He would buy ten acres for ten dollars, then turn around and sell it for eighty dollars. That is how my mother bought twenty acres across the river – that was 1942. I was not around at that time – I was away at the war. When my uncle got sick in the middle 1950's, he sold the land to my mother for $3000 after she mortgaged her house in Seattle.

At our place there are steep cliffs down to the river that narrows the river. There has always been a big pool at this narrows [at the downstream end of the Powerlines reach, RK 2.1]. In 1983-4, it flooded all the way over the top and a bunch of logs 10' high came down and dammed up the river at the narrows. This stopped the river from eating away at the hillside…I can show you down there.

TL: What kind of fish do you remember seeing in the river?

DC: I can remember real well. Right where the river narrows down, they would go in there and get so heavy you could walk across the river on them. They would hold in the pool there and then go on up. There were all kinds of salmon, lots of them. Until 1983, 1984, 1985, and 1986 when the Indians decided to net the river. They had nets from the Powerlines all the way down and you could go down there and see hundreds of fish laying on the beach where they took the eggs out and threw the carcasses up on the beach. We tried to get the Fish and Wildlife to do something about it but there was nothing they could do.

The winter of 1983-4 was the big flood that washed out part of the Lazy C and downstream areas that have been corrected. The Park area was flooded then too. Just downstream from the Lazy C is where the river changed a lot.

TL: Do you remember chinook salmon?

DC: Well at that time I couldn't tell. I know there were silvers. There were big fish. Now they are coming back, though. Nothing like they were, though. The elk were the same way: I remember 125 elk sitting in my yard down here in 1983. I don't know why but the Indians came in and killed all but seventeen of the herd. I went over to the Indian reservation, and they really did a good job and stopped them from killing them for nearly twenty years. Now they are back up to quite a few.

Piggy and the Springers, who live down the river did a lot of the logging. They had a sawmill then.

TL: You mentioned the logjam that came down. What do you remember about logjams and side channels on the river, generally? Were they more or less abundant, as compared to now?

DC: Well of course here the river narrows down, so it comes down and backs up and then washes out. I called Fish and Wildlife when the river was all up with logs and nothing could get through. They claimed some other group would take care of it, and that group would not take care of it. It was stacked up with a waterfall going over it that was five or six feet or more than that in the middle of the river. Finally it busted loose, but it dammed up the entire river in 1984 or 1985.

Then in 1985 and 1986 after the flood, they brought in some people to fix the damage at Lazy C and put in riprap to keep the water away. They spent $250,000 to study the problem, spent all of it on that and then never had any money to do anything!

In the last ten years, there has been more clear cutting but it is coming back pretty well. I remember lots of logjams. There have been about three or four years with big bunches of logs.

TL: What sections of the river have changed the most since you first arrived.

DC: The reason the river has changed is because a lot of rock has been placed to keep the river in its channel. That has helped a lot. The river has changed from one bank to the other at least four times.

TL: Talking to the Baileys, they report witnessing the river cutting down into its bed over their lifetime. Has the river cut down into its bed or deposited sediment in your reach over the years? Or has it stayed about the same?

DC: No, it is pretty flat down here – there have not been any significant changes like that. Between here and Lazy C it is pretty flat, but there has been a lot of bank erosion in this area. It has changed most around the [BPA] powerlines – over the last four years about fifty feet of bank has been eroded by the river on the north side. You can see old channels across the floodplain where the river used to run – just below us – maybe two hundred or one thousand years ago.

TL: How did the 1983/1984 flood compare to the 2002 flood that washed out the road? What about other big floods?

DC: The 1983-84 flood was a lot bigger. There were no other big floods like that one that I remember. There are high flow years but the water does not come up onto the floodplain very often.

TL: Do you remember a big flood in 1995 – there was a flood on the Duckabush in that year.

DC: Yes, but it still was not that bad. The Lazy C got a little water going through it but it was not bad. But it did change the channels between us and Lazy C [Powerlines reach].

TL: What do you remember about fires and landslides and how they influenced the river?

DC: No, there have not been any. I had a couple [of landslides] along my little road [down to the floodplain] that closed it and prevented us from getting down to the river but nothing significant. The Kelly's were the real old-timers around here that built the roads and logged the area. One of them used to go up and clean out the river around the Lazy C to keep the channels in the right direction. Then they made them keep the bulldozers out of the river. He had a big D8 and he would keep the flow of the river straightened out.

TL: When did that happen?

DC: That was before I came up to live here year-round. That was probably in the 1950's. He did that over a number of years. You could probably get Piggy to tell you about it.

TL: What is your vision for this property?

DC: About the same. I can show you a little bit – we can walk down there.

TL: Are you happy with the way the river is today?

DC: The only trouble was the years where it came up really bad when the logjams clogged up the river. Then it broke loose after a big rain after being there four or six months.

After describing the results of the project, its findings on the river-wide distribution of salmon habitat, and the significance of the Powerlines reach (which includes part of the Coone property), Dick added:

"I say between my cliff down there and the Lazy C is where most of the salmon are. Its flat and it don't move so fast. The river changes and it is still changing today. I figure sometime in the next one thousand years, it will be over here by the hillside."

May 10, 2005 interview with Bob Crowell:

Bob Crowell (BC) has lived in the Dosewallips River valley since the early 1940's when there were only thirteen families in the valley. He has lived in the valley continuously, except for brief stints in the military during World War II, temporary logging jobs in Alaska, and one or two years in Minnesota. Bob spent years fishing the river, and nearby areas of Hood Canal, observing changes on the river. He lives just up Dosewallips Road from Arlene Crowell, before the road descends down to Lazy C. The interview began with TL giving some background on the Dosewallips River habitat assessment, showing BC maps of the river.

BC: This must be Lazy C. Years ago, before we moved here, they logged the valley off and dumped the logs in the river. They had a splash damn below Rocky Brook in the canyon [Canyon reach, RK 6.2]. They would close it up, back the water up, and shoot the logs down to the bay.

TL: Do you remember seeing that splash dam?

BC: No, but you could see parts of it when I was first here. It had been done years before that. You could see it there when I first moved here, now it's pretty much gone. In the early 1900's they logged this area by railroad. Now there's not a railroad until you get to Shelton or Port Townsend. But there used to be a railroad that ran right through our place here, and it forked right out there by my barn. And one [spur] went around on up the hill and swung back around Turner Mountain. That was done even before we moved here. It was old and abandoned and there was no railroad when we arrived.

TL: What's your earliest memory of the river?

BC: I remember from 1943 and then on I used to go fishing all the time. And that river was full of salmon all year round. It had steelhead all winter, and in the spring it had king salmon. And then by August there was a run of chum or dog salmon. Every other year there were humpies. And every fourth year there'd be nothing, then a run of salmon, then nothing, then humpies. Every fourth year on that cycle, there were millions of them. It didn't matter where you went, from the highway to ten or twelve miles up, there were hundreds of them, just everywhere.

How they wiped them out I don't know, but they did. I think the way they did it was with fertilizer that was put on the land after they logged it during the late 1950s or early 1960s – applied with a helicopter. They would not stop for the creeks and whatnot. I'm sure that's what wiped out the king salmon.

From the time I was fourteen or fifteen years old, I would catch 5-11 king salmon every summer. And I didn't have good fishing gear – it was old-fashioned stuff. You lost more than you ever actually caught! The biggest one I ever caught was 34 pounds on this river. But there were bigger ones in here than that! I knew one fellow from Quilcene, who is dead now, who caught a 72 pound king salmon in the 1930s or early 1940s, so there were some big kings in there, mixed in.

TL: So you are saying the kings would run in the late spring, and you would fish for them during the summer?

BC: Right. They would start running at the end of May, right about now, and they were in there until about the fourth of July, and then they would start getting old and they wouldn't be that good. I remember taking the trail down to the river and sitting to watch a certain riffle. I could sit and watch that riffle and within fifteen minutes, if the kings were in the river, you would see one go up the riffle. We would use little spoons or spinners. In the 1960s, they went down hill and more or less disappeared. And I think that's what happened to the humpies, too.

See, by August the kings were pretty much no good anymore, and the humpies would start in. And then a run of summer dog salmon would start up the river. At the end of August and early September, the silvers would start up and they were in there until October. I never caught a summer run steelhead in this river with all the fishing I did. And I don't think I am bragging when I say I know I caught more steelhead out of this river than anyone else alive.

TL: But there was always winter steelhead to be caught?

BC: Oh, all winter long. Every time it would rain it was good for two or three nights…I would fish down the river. In the 1940s I used to catch a few Dolly Varden trout. They were maybe 3-5 pounds. But I was with a guy who caught one that was 18 pounds just above the highway bridge! They were bright and shiny – they had just come out of the saltwater. That was in November through early December. Then it just quit completely, I haven't seen one of them for years and years. And to prove my point, I had the clipping from the Seattle Times. They had a picture of it that was in the Seattle sporting goods store, Ben Paris. That was in the early to middle 1940s. Darrel Harris was the one who caught the fish – he used to live down where the State Park is today.

Any time it rained from November on, this river had fish in it. The Duckabush River had a run of steelhead in it that was thicker than the Dosewallips. But I generally fished this river because I didn't have a car. They used to have a hatchery on the Duckabush River, which they had going when we first moved here. They used to plant five to ten thousand fish in these rivers each summer.

TL: There was a fishing camp on the Duckabush right? Did they ever come up and fish the Dosewallips River?

BC: No, I couldn't tell you. I met people fishing, but I couldn't tell you about that. Seal Rock used to have cabins they would rent to fishermen. Then there was the Riverine Lodge [original name of the Lazy C dude ranch]. And Rainbow Lodge down by the Hamma Hamma had all those cabins.

Down in Pleasant Harbor, before it was full of boats and houses, there were a lot of herring and you could catch a lot of blackmouth all winter long. The herring would come in for two or three months, and they were so thick you could get a bucket full in a half hour. The blackmouth were twice as good as steelhead – I kind of stopped fishing for steelhead for a number of years they were so good.

The bay here was full of salmon up until the early 70's. Now, I don't know when Judge Boldt made his decision but it was around that time. The State of Washington kept it tied up in court for years and years until he made his decision. I might be a year off or so but it was right before that, that Hood Canal was opened to commercial fishing. Before that, Hood Canal was a sanctuary where no commercial fishing was allowed. When they opened it the commercial fishing was intense! You could see a hundred nets from the shore. They hurt them salmon so bad - the nets. Then the Indian fishery started right after that and they did the same thing. Then, also, the seal bounty was lifted in the 1960s and 1970s. You could hear all the seal down in the bay from up here!

More recently fish farming has become a problem. That is when the salmon really dried up. And I would say 'politics' is the reason no salmon are in the river. There is no pollution or dams in this river – there is no reason there should not be salmon in the river. Now, they are spending millions of dollars on the creeks near Port Townsend and Chimacum for dog salmon! But nothing is being done on this river!

Another thing that hurt this river is at the foot of this hill, where there is a good-sized little creek [Lazy C reach, RK 3.5]. That creek used to run right along the foot of the hill for a quarter-of-a-mile and then cut over to the river. It was full of silvers and dogs each winter. When they developed Lazy C, they took that creek and ran it straight out to the river, and the whole deal dried up and the salmon died off. They disappeared.

TL: I understood from talking to Arlene that they put a lot of fill down there and graded the whole floodplain.

BC: Well, yeah. But since we have lived here the river had a straight shot down from Nelson's old place [Canyon reach, RK 5.3] to the Lazy C. The Riverine Lodge was vacant when we moved here. Then

Nordean bought it, and then he sold it to Clark who had it developed. The river had flowed out into that field [at Lazy C, RK 3.8] because you could see the big bank, cut banks, and you could tell where the river had been. But the river was never there while we have been here. The river hit the big rock opposite Lazy C, and it turned it back this way. It has eroded its banks quite a bit. Now, it is running almost at the foot of the hill here now.

They had to have [re-graded that field] because I drive down there now and you can't see any of those things. When I as 16-19 I was fishing that river all the time. I would walk up by Rocky Brook or walk back by the big rock [at the downstream end of the Powerlines reach, RK 2.1], and I could always get steelhead there. It used to be good, if you knew what you were doing.

TL: From your experiences fishing up and down the river, what do you remember about wood jams in the river? Are there more wood jams now? Fewer wood jams? Or about the same as there once were?

BC: I would say there were a lot of little jams all the time. But there were never any big ones, though I did see one, oh, about four winters ago, up past Kidwell's place [Above Gage reach, RK 12.8]. It finally broke loose – up in that place it is probably about the same. Part of that, though, is the river in the last twenty years has not gotten as high as it used to.

The Brinnon store used to be up on the hill there [south of the river], and then it burned down and was moved down to the Brinnon Flat. The year or so after it was built, a large flood almost flooded out the store. The water was five feet from his store and pumps. Many of those houses down there are in trouble if it ever gets that way again.

Before they built that new bridge [over Highway 101 and added approaches] they built the overflow deals [to pass flood waters]. When three conditions occur in combination [it floods]: a lot of snow, pouring down rain, and thirteen foot tides. When that happens, those folks on the lower Duckabush are going to be in trouble. I have seen the Duckabush River flow through Whittaker's old field. That was the highest I've seen it and it was the same way down there in Brinnon. At the old Northrup's place by the Brinnon Booster Club. The Dosewallips River would come right out through Brinnon, right where the Schneider home was [near the fire station] and the Brits place, right near where the gas pumps are.

TL: Was that the 1949 flood?

BC: It could have been, but it may have been in the 1950s. It would pour down rain night and day then. When they get those three conditions happening, there are going to be a whole lot of long faces and awful damage done. The State should never have allowed a house to be built within three or four or five hundred feet of a river, stream, or a lake, or the bay. They would never have the pollution they do now if they had done that. There is no reason in the world to allow people to build their houses 10-20 feet from the edge of the river.

TL: What sections of river do you think have changed the most dramatically?

BC: I think right here at Lazy C and just below. Most other places have stayed fairly well… There are a few places that have jumped over here and there.

TL: Have you noticed any part of the river, including Lazy C, where the bed has built up over time, or has cut down? Have you noticed any changes in the elevation of the riverbed? Not localized changes but along a whole stretch.

BC: Yes, quite a few places have done that. You know where that old gage was [Six Mile Bridge reach, RK 12.4]? That used to be a pretty deep pool all through there. When the road washed out, it filled with gravel and then washed out again. Now, it has pretty much filled in to what it used to be years ago.

TL: This recent flood in January 2002, was that the biggest flood you remember?

BC:	Oh no, I wouldn't even call it the second, third, or fourth biggest. It was big, but I don't think it came anywhere near the older floods or like I witnessed in that one year.

TL:	Do you remember fires or land slides that affected the river?

BC:	Yes, but that was before we moved here. The whole hillside burned over but that was way before my time. I don't remember any fires in my time that got close to the river.

TL:	What do you think about the river today? Do you think the river is better or worse than it was before?

BC:	I remember fishing steelhead at Six Mile Bridge. I caught more steelhead out of that hole than any other hole on the river. Now there's a house there and I can't go fishing there now. After fishing there for thirty or forty years, that is a hard pill to take. And that is happening everywhere along the river. Every one has no trespassing signs. In a way I can understand because residents have problems with trespassers, but it's a pity the State does not have a provision that allows for fishing access.

In the summer you could go down this river at high tide and sit on an old bridge and catch twenty trout, and you would catch trout just as fast as you could drop your hook down there. And the humpies would come in, and you couldn't see the bottom of the river. It would just be black in there [with all the fish]. They would mill around and move in and out [with the tide] and each time a big slug of them would go up the river.

TL:	Did the tidal area extend farther up the river then?

BC:	I don't think so. They had dikes out there to keep it from coming in. It's about the same. But I have not been down there in thirty years. I quit going down there when everyone started developing their lots down there. I caught one awful lot of king salmon and steelhead out of that hole opposite Lazy C there.

The interview concluded with BC talking about changes to the Hood Canal shellfish fisheries and his problems with their management.

May 10, 2005 interview with Bill Nelson:

Bill Nelson (BN) has lived and worked in the area as a logger since 1923. At one time, his family owned 243 acres between Lazy C and Rocky Brook [Canyon reach, RK 5.3]. He has lived in the area his whole life and is the second oldest living long-time resident (second only to Ida Bailey). Bill grew up at Lazy C before it was developed, and then lived in a house upriver of the Lazy C. The interview began with TL explaining the objectives of the Dosewallips River habitat assessment, explaining his specific interest in long-term changes to logjams, pools, and side channels in the river.

BN: There were a lot of logjams in the river at one time. But WPA cleaned logjams out of the river in the 1930's. I don't know how far up the river they went and I don't know how many crews they had but I would suppose they had about a dozen men working on it then. They worked up and down the road and over here at the schoolyard [Brinnon Flat, RK 2.0 – on the west side of Brinnon].

I was a kid in the 1930's. I remember floods every once in a while. Down by the Lazy C, I remember logs being flushed down the river when they would open the splash dam. They had great big cottonwoods down along the bank at Lazy C. Eventually they rotted out or they took them out and the river ate it all out. The cottonwoods were cut and anchored to the bank, so that the river would stay put and the logs flushing down the river would not go out onto the floodplain.

A young girl fell into the river at Rocky Brook and drowned in the pool behind the splash dam. The dam was no longer in operation then, but it was still [partially] backed up there. They blew the remains of the dam then so that the body could be found. That was in the early 1930's and the dam was no longer in operation though it had been used in the 1920's. My brother used to open the dam, and they would open it at midnight. I don't know why.

TL: Do you remember witnessing the splash dam being opened?

BN: No, I was too young. My brother was seventeen years older than me.

TL: Would the logs be carried all the way down to Brinnon?

BN: Oh yeah, but they had to go around and corral up the logs on the banks too.

TL: Do you think logjams and side channels are more numerous now, or less abundant, or about the same?

BN: I don't know about if there is anything in there now. But there used to be quite a few in there. It seems like there were more then, but I don't know. Back before the WPA cut them out.

TL: What about salmon? Did you ever fish the river? What did you fish for?

BN: Oh yeah, there used to be lots of fish. We would fish for everything. There were lots of trout in the river when I was a kid: rainbow and Dolly Varden and cutthroat. Lots of Dolly Varden, and then they quit. I don't fish anymore. There are no fish in the river anymore. There used to be so many…there is no comparison.

TL: When did the Dolly Varden quit?

BN: The last time I remember anyone catching any was in the 1940's when Darrel Harris caught one. There had not been any in there for a while when that happened. But there used to be lots of them.

TL: What about chinook salmon? When would they come into the river?

BN: They would come in about the first of June and we would fish on them during the summer. I have not seen one in the river for years. But of course I am not around the river much anymore, but I used to be.

TL: What about pink salmon (humpies)? Were they always the most numerous fish in the river?

BN: I don't know. There were always lots of humpies. Lots of silvers. Lots of dogs. Quite a few summer dogs and a lot of winter dogs. Lots of king salmon. I mostly fished around our place there, just above Lazy C – about two miles up. I lived on the Lazy C for quite a while and moved off of it in 1935. I lived there before it was a dude ranch, back when it was a logging camp. [Bill retrieves an old photo of the house and Lazy C area looking down from the adjacent hill, before the area was intensively developed].

[I ask about the course of a channel that traverses the field in the photo]

The stream that comes down to Lazy C [on the north side of the river] used to go out into the field and then turned and went down [the valley]. It used to go out farther into the field, but then it got moved over closer to the bank. They channelized it against the bank. I was little at the time, but moved off of Lazy C when I was twelve and moved back up onto our place, just upstream.

TL: What areas of the river that you know have changed the most from what they originally looked like?

BN: The area just below Lazy C has probably changed the most.

TL: Do you remember seeing the river run or flood over at Lazy C?

BN: No. It might have run there at one time but I don't remember that in my time.

TL: Do you think the river has cut down into its bed, or has it raised up, or is it about the same?

BN: Seems like to me it has stayed the same in this reach.

TL: What were the big flood years that you remember?

BN: I don't remember what years. Every couple of years it would flood.

TL: Do you think the big flood in 1949 was bigger than the 2002 flood that washed out the road upstream?

BN: I remember here at Brinnon, the highway used to go down across the flat. There are two little bridges [culverts] the highway crosses on the north side of the river now. I have seen the blacktop from the old road turned right away into that field. The river would wash the road away. Then they put those two bridges [culverts] in there and raised the highway. And now the river doesn't even run down in there! I remember seeing the water run down in there!

[After further clarification, Bill indicated he was referring to the area lying between the Highway 101 bridge over the river and the Halfway House restaurant on the Brinnon Flat, at RK 0.8].

TL: Do you remember fire or landslides in the valley?

BN: I remember a little slide up the river, just this side of the 12 Mile Bridge. That's all I remember.

TL: Was the area burned over when you were young?

BN: No, there was a lot of timber on the hillsides, then. The lower part of the valley was logged over. The railroad extended up the valley on the south side of the river as far as the Kidwell Place [FS Boundary reach, RK 14.0].

TL: What do you think about the way the river is today compared to what it was in the 1930's through the 1950's? Do you think it is in better or worse shape?

BN: I think it is in pretty good shape, except for washouts in peoples' fields like at Lazy C and on the Bailey's place. …they wouldn't let them bulldoze the river [on the old Swift property – below Lazy C; Powerlines reach, RK 3.0]. The river was still over on the bank over there, with logs and stuff. If they had just opened a little channel over there when the fish weren't in, the river would have dug itself back over there and a whole lot of land wouldn't have ended up down in the bay! It used to be right over on the bank on the other side of the river.