

## **Acknowledgements**

### *Snohomish County Executive*

Robert Drewel

### *Snohomish County Council*

John Koster	Council District 1
Kirke Sievers	Council District 2
Gary Nelson	Council District 3
Dave Gossett	Council District 4
Jeff Sax	Council District 5

### *Department of Public Works*

Peter Hahn, Director

### *Surface Water Management (SWM) Division*

Joan Lee, P.E., Director  
Meg Moorehead, Salmon Recovery Program Manager

### *Project Staff*

Robert Aldrich, Jeff Collins, Andrew Haas, Frank Leonetti, L. Ted Parker, Michael Purser, Michael Rustay, Rob Simmonds, Jennifer Slavick

### *Contributing Staff*

The following people have made significant contributions to this project and the completion of this report: SWM staffers Suzanne Brunzell, Christine Coats, Kathy Hagerty, Deborah Haynes, Dave Ward and the staff of David Evans and Associates (DEA).

Cover photograph of Snohomish County Surface Water Management (SWM) staff Mike Rustay conducting stream habitat survey on the Boulder River, 2000. Photographer Ted Parker.

printed on recycled paper

## **Introduction**

In 2000, Snohomish County Public Works Surface Water Management (SWM) initiated a multi-year habitat inventory of wadable, fish-bearing streams in Snohomish County. This report summarizes preliminary analysis of year 2001 data. Snohomish County staff habitat assessment reports from data collected in 2000 (Snohomish County SWM 2001a) and 2001, which will include analyses of habitat parameters in relation to watershed-scale, land cover data and performance criteria of habitat quality.

Following the development and improvement of a physical habitat survey protocol for wadable streams (Snohomish County SWM 2000 & 2001b), field crews gathered quantitative data on pools, woody debris, streambank stability, and surface fine sediments in spawnable gravels during summer low flow conditions. For efficient expenditure of public resources, the survey is confined to parameters which are (relatively) unambiguous in the field, are closely linked to watershed-scale processes, and are directly related to the life history requirements of salmonids.

The goal of the wadable stream habitat survey is to provide quantitative data to inform local salmon programs. The primary objective is to document current conditions at the subbasin and reach scales for use in monitoring and adaptive management. A secondary objective is to provide quantitative habitat data to support stormwater and habitat restoration (capital improvement) projects.

Field surveys in 2001 were conducted in five subbasins; French Creek, Grandview Area, Lake Stevens, Stillaguamish Canyon and Upper North Fork Skykomish (U.N.F Skykomish), which were selected based on a stratified-random experimental design. In the design, Snohomish County subbasins were grouped based on similar characteristics, and each group was randomly sampled in general accordance with the group's proportional representation among all Snohomish County subbasins. Within these subbasins, field crews surveyed approximately 25 percent of fish-bearing streams in each channel type and re-surveyed 5-10 percent for quality control and to evaluate quality assurance. In future years, SWM will sample the remaining subbasins and resample previously sampled reaches for trend analysis and effectiveness monitoring.

## **Methods**

### **Subbasin Grouping**

Subbasins were grouped for analysis based on three variables: percent impervious surface, mean elevation and erodible geology. Each variable was separated into four continuous categories that were assigned letters A through D (Table 1). The name for each subbasin group was derived from these letters.

**Table 1: Letters assigned to variable categories**

Variables	A (Lowest)	B (Low-Medium)	C (Medium-High)	D (Highest)
Total Impervious Area (%)	0-6	7-12	13-24	>24
Mean Elevation (m)	0-198	198-381	381-686	>686
Erodible Geology (%) (vro, vrl, mw)	0-4.2	4.2-17.5	17.5-30	>30

For example, a subbasin with 6% impervious area, a mean elevation of 396 m and 5.7% erodible geology was placed in the ACB group while a subbasin with a similar mean elevation and contributing area but an impervious area of 20% was placed into group CCB. Once grouped, subbasins throughout the county were randomly selected for survey.

**Channel Classification and Delineation**

The physical habitat survey uses the Rosgen method of stream classification to divide streams with similar morphologies into named channel types (Rosgen 1996). The Rosgen method uses physical characteristics (i.e. stream channel gradient, sinuosity, entrenchment, and width to depth ratio) to classify stream reaches. Data from a previous survey (Pess, *et al.* 1999), office measurements and knowledge of stream systems throughout the county were used to perform an abbreviated Level 1 Rosgen classification of Washington Department of Natural Resources (DNR) type 1, 2 and 3 streams (fish-bearing) in subbasins surveyed in 2001. The Level 1 survey breaks streams into nine Rosgen channel types (Table 2). An additional channel type (X) classification was added to the 2001 survey in order to recognize the unique physical characteristics observed in straightened and ditched channels.

**Table 2: Level 1 characterization delineative criteria (adapted from Rosgen 1996)**

Stream Type	Entrenchment Ratio (FPW/BFW)	Width to Depth Ratio (BFW/BFD)	Sinuosity $\left(\frac{\text{Stream Length}}{\text{Valley Length}}\right)$	% Gradient $\left(\frac{\text{Valley Gradient} \times 100}{\text{Sinuosity}}\right)$
Aa+	< 1.4	<12	1.0 – 1.1	>10
A	< 1.4	<12	1.0 – 1.2	4 – 10
B	1.4 to 2.2	>12	>1.2	2 – 3.9
C	>2.2	>12	>1.4	< 2
D	N/A	>40	N/A	< 4
DA	>2.2	Variable	Variable	< .5
E	>2.2	<12	>1.5	< 2
F	<1.4	>12	>1.4	< 2
G	<1.4	<12	>1.2	2 – 3.9
X	< 1.4	<12	1.0	< 2

FPW = Flood prone width (channel width @ 2x max BFD), BFW = Bankfull width  
BFD = Bankfull depth

For subbasins in the Stillaguamish River basin, values for channel gradient were derived primarily from Pess, *et al.* (1999). In the Snohomish River basin, gradient was measured using the United States Geological Survey 10-meter resolution Digital Elevation Model (DEM) and a Geographic Information System (GIS). Entrenchment and width to depth ratios were approximated using data from Pess, *et al.* (1999), contour and shaded relief maps, and prior knowledge of stream channels. SWM GIS staff merged the stream classification layer with the County hydrography coverage. This coverage was used to calculate total lengths of each Rosgen channel type in each subbasin. Field observations made during the channel survey were used to verify and adjust Rosgen channel type delineations made in the office.

### **Habitat Parameters**

The habitat survey protocol includes eight parameters: channel gradient, channel length, bankfull width, woody debris (large woody debris (LWD) and small woody debris (SWD)), pools, streambank instability, surface fine sediment in spawning riffles, and secondary and off-channel habitat (Snohomish County SWM 2001b). To meet County objectives, while maintaining consistency with regional approaches to data collection in streams, the protocol adopts and adapts techniques used to measure habitat parameters from other stream surveying methods (USFS 1999, Bauer and Burton 1993, Overton, *et al.* 1997). A description of each parameter and the reported results are provided below:

#### ***Channel Gradient***

Channel gradient is defined as the change in vertical elevation per unit of horizontal distance or rise/run. Gradient was used to determine channel type and reach breaks. Gradient was determined by DEM mapping technology. During the 2000 survey, gradients were also collected in the field to confirm gradient determined via DEM technology. The reported values are the ranges in channel gradient that, in part, define Rosgen channel types (see Table 2).

#### ***Total Stream Length, Surveyed Length, Unit Reach Length, and Dry channels***

Total stream length for each channel type includes all DNR type 1, 2, and 3 streams. Surveyed length values reported represent the cumulative length of all reaches surveyed within a given channel type. Field crews surveyed approximately 25% of the total stream length for each channel type. In some cases, less than 25% of the total stream length for a channel type was surveyed due to inaccessibility or to an insufficient reach length being available to meet the criteria for statistical analysis.

In 2001, a unit reach length of 20-30 bankfull channel widths was adopted as a standard survey reach length (Rosgen 1996). Bankfull width measured at the beginning of each unit reach was used to calculate the unit reach length. If the unit reach surveyed was less than 20 channel widths, the data were combined with the adjacent reach of the same channel type, if possible. Year 2000 survey reaches were not broken into unit reaches.

Fish-bearing (type 1, 2 and 3) channels that were dry at the time of the survey were surveyed for only for bankfull widths, wood and bank instability. Standing water in

channel depressions within dry channels was also recorded when it met the area and depth criteria for pools. Dry channels were not surveyed in 2000.

### ***Bankfull Width***

Bankfull width is the width of a stream channel at the point where over-bank flow begins during a flood event. Bankfull width can be indicated by deposited bedload, stain lines, the lower limits of perennial vegetation and a change in slope or particle size on the stream bank (USFS 1999). Bankfull width was measured at three locations of a unit reach survey; at the first straight riffle with uniform banks; at the unit reach midpoint length; and at the end of the unit reach . Bankfull width threshold criteria were used to determine the minimum size of pools and woody debris to be sampled. Mean bankfull width by Rosgen channel type was reported based on the mean bankfull width calculated for each unit reach surveyed. The bankfull width was measured at the first straight riffle and at locations where significant changes in reach width occurred during the 2000 survey.

### ***Secondary Channel and Off-Channel Habitat***

Secondary channels (e.g. side-channels, side-channel sloughs) are defined as channels separated from the main channel by a stable vegetated island and that contain the smaller portion of total discharge. Field crews measured wet and dry secondary channel area and surveyed pools, LWD, bank instability and surface fine sediment. Off-channel habitats, including marshes, ponds and oxbow lakes that may influence or be influenced by stream flow at different stages, but were not directly part of the present stream surface flow, were noted in comments. Only wet channels were surveyed during the 2000 survey. Mean secondary channel area by Rosgen channel type was reported as a percentage of the estimated total channel area for each unit reach surveyed.

### ***Pools***

A pool is a closed topographic depression within a stream channel, which is characterized by low water velocity, low gradient and fine substrate grain size. Pool dimensions were measured to determine habitat area for holding and rearing. Residual pool depth, wetted area and functional habitat area were measured for each pool meeting the bankfull width, residual depth and surface area criteria used by Pleus, et al. (1999) (Table 3). This decreased the pool criteria threshold size compared to the 2000 survey pool size criteria by Johnston and Slaney (1996).

***Table 3: Minimum pool dimensions (Pleus, et al. 1999)***

Bankfull Width (m)	Area (m <sup>2</sup> )	Residual Pool Depth (m)
0 – 2.	0.5	0.10
2.5 – 4.9	1.0	0.20
5.0 – 9.9	2.0	0.25
10.0 – 14.9	3.0	0.30
15.0 – 19.9	4.0	0.35
>20	5.0	0.40

Data are reported by channel type as mean percent pool surface area, mean pool frequency and mean functional pool area (including standard deviation). Summary values include main channel and secondary channel pools.

**Woody Debris**

Woody debris is defined as downed wood that intercepts bankfull flow and is large enough to influence the formation of habitat (USFS 1999). Woody debris was placed into three categories; large woody debris (LWD - length class 1 or 2), stumps/sticks with rootwads (SSR), and small woody debris (SWD). In order to be counted as LWD, wood must be  $\geq 7.6$  meters (length class 1) or greater than twice the bankfull width of the channel being surveyed (length class 2), whichever is less, and be  $\geq 30$  cm diameter at a distance of 7.6 m from the base or twice bankfull width, which ever is less.

SSR (length class 3) was assigned to woody debris which did not meet the LWD criteria, but had a rootwad with a mean diameter of  $\geq 1$  m and was at least 10 cm in diameter for at least 2 meters in length (Pleus, et al. 1999). SWD (length class 4) was tallied for the unit reach being surveyed and consisted of all wood not meeting the criteria for LWD and SSR classes, but having a diameter of 10 cm for at least 2 m in length. LWD was placed into three categories (single pieces (LWD), stumps (SSR) and jams (LWD and SSR)) and characterized by rootwad presence/absence, wood type (conifer/deciduous/unknown) and decay class (Table 4).

Year 2000 surveys placed LWD into 2 categories;  $\geq 7.6$  m or greater than twice the bankfull width of the stream reach being surveyed, which ever is less (and  $\geq 30$  cm diameter as above). Stumps were the 2<sup>nd</sup> length class, but length and diameter were not classified or measured. SWD was not tallied in year 2000, and decay class followed that shown in Table 4.

**Table 4: Decay class criteria (adapted from Schuett-Hames, et al. 1994 and Collins, et al. 2000)**

2001 Class	2000 Class	Bark	Twigs	Texture	Shape	Wood Color
1	1	Intact	Present	Intact	Round	Original Color
1	2	Intact	Absent	Intact	Round	Original Color
3	3	Trace	Absent	Smooth	Round	Darkening
5	4	Absent	Absent	Abrasion	Round/Oval	Dark
5	5	Absent	Absent	Vesicular	Irregular	Dark

Data are reported as mean LWD frequency, percent conifer (decay classes 1-3) and mean decay class value. Percent conifer and decay class parameters were derived from data pooled from all unit reaches within Rosgen channel types. Mean decay class values are calculated with two significant figures to capture the distribution of decay classes within a reach. This is acknowledged to be more precise than the data collected, but is thought to be reflective of the continuous wood decay process.

### ***Streambank Instability and Hydromodifications***

Streambank instability is indicated by the presence of the following conditions at or directly above the bankfull depth: breakdown; slumping (false bank); fracture; or vertical and eroding bank (Bauer and Burton 1993)(see Snohomish County SWM 2000 for definitions). Any bank that has less than 50% cover [e.g, perennial vegetation, roots, rocks (cobble size or larger), logs] was also considered unstable. Bank hydromodifications were recorded by type and material. Bank instability and hydromodifications were measured with a hipchain along both banks. In year 2000, only the right bank was measured for instability. In addition, hydromodifications were not identified but lengths were recorded as unstable. Data were reported as mean percent unstable banks and hydromodifications by Rosgen channel type.

### ***Surface Fine Sediment***

Surface fine sediment is defined as particles <6.3 mm. Measurements were taken in downstream riffles of the first four measurable pools, in riffles with flow, depth and substrate ( $\leq 128$  mm) in the range of suitable habitat for spawning by salmonids. Sampling transects were placed in 2 m up or downstream from the pool tailout/riffle crest in the most likely spawning location. Percent surface fines were measured at four equally spaced points using a 100-point grid along a transect perpendicular to flow (Rhodes and Purser 1998, Bauer and Burton 1993). Data were reported as mean percent surface fines by channel type, based on mean percent surface fines from unit reaches (regardless of the number of samples obtained in each unit reach). Fine sediments were measured at adult holding pools (residual depth  $\geq 0.5$  m residual) during the 2000 survey.

## **Results**

2001 physical habitat surveying totaled over 28 km of stream length in five subbasins and was distributed over 190 unit reaches and seven Rosgen channel types. Table 5 shows watershed group characteristics and salmonid fish use for each subbasin surveyed in 2001. Tables 6-10 show the summary physical habitat parameters (means and standard deviations) by channel type for each subbasin. Figures 1-5 (interleaved with Tables 6-10) display the DNR hydrography and Rosgen channel types for each subbasin.

## **Preliminary Interpretation**

Table 11 shows various criteria which are being used by habitat managers in the Puget Sound region to evaluate the conditions of physical habitat. Figures 6-11 display the results of the 2001 survey compared to these criteria.

**Table 11. Physical Habitat Evaluative Criteria<sup>1</sup>.**

	WRIA5 <sup>2</sup> (Stillaguamish) = “Suitable”	WRIA 7 <sup>3</sup> (Snohomish) = “Intact”	NMFS Pathways and Indicators <sup>4</sup> = “Properly Functioning”
Pools	Pool habitat is > 50% of the low flow surface area	Not Applicable	Meets pool frequency standards (variable by channel width; 184 pools/mile for small streams to 18 pools per mile for the largest streams) and large woody debris recruitment standards (see above)
LWD	> 2 pieces per channel width	<ul style="list-style-type: none"> <li>▪ 2-4 pieces LWD/channel width for channels greater than 20 m wide</li> <li>▪ &gt; 0.5 pieces LWD/channel width for channels 10-20 m wide</li> <li>▪ &gt; 0.3 pieces LWD/channel width for channels less than 10 m wide.</li> </ul>	>80 pieces/mile, >24” in diameter, >50 feet in length
Bank Stability	Shoreline hardening or unstable banks affect <10% of shorelines	Less than 10% actively eroding bank.	On average, less than 10% of banks are actively eroding
Hydro-modifications	Shoreline hardening or overwater structures affect <10% of shorelines	Shoreline hardening or overwater structures affect <10% of shorelines	Shoreline hardening or overwater structures affect <10% of shorelines
Surface fines	<10% surface fines (<6.35 mm) in spawning areas	<12% surface fines (under 0.85 mm) in spawning areas	<12% fines (<0.85 mm) in gravel, turbidity low

<sup>1</sup> Evaluative criteria have not been adopted in WRIA 8 (Cedar-Sammamish).

<sup>2</sup> Stillaguamish evaluative criteria were developed and adopted by the Stillaguamish Technical Advisory Group, a locally-based, multi-jurisdictional committee of biologists, habitat specialists, and environmental planners and coordinators. The criteria themselves were derived from values reported by NMFS (1996) or in the original literature (e.g., Bilby and Ward 1989; Bjornn and Reiser 1991).

<sup>3</sup> Snohomish evaluative criteria were developed and adopted by the Snohomish Basin Salmonid Recovery Technical Committee, a locally-based, multi-jurisdictional committee of biologists, habitat specialists, and environmental planners and coordinators. The criteria themselves were derived from values reported by WFPB (1997) and NMFS (1996).

<sup>4</sup> NMFS (1996)

### ***Pools***

Pool habitat is an important component of fish-bearing streams. Pools provide cover and refuge to adult and juvenile salmonids during flow and temperature extremes. The distribution and size of pools will differ based on the size, gradient, bedload and structure of each stream. Generally, small, high-gradient streams are expected to have a higher frequency of smaller pools than larger low-gradient streams. Human activities that alter a system's flow regime, large wood recruitment or sediment input can affect the quantity and quality of pool habitat.

Throughout the five subbasins sampled in 2001, Rosgen C channels had the highest mean percent pool area, more than double the other channel types (Figure 6). Remaining channel types are not significantly different from each other, all falling between 10 and 25 percent pool area. Pool frequencies (Figure 7) differed from percent area numbers. Aa+ channels across subbasins averaged just above 45 pools per kilometer while remaining channels averaged between 10 and 25 pools per kilometer.

Table 11 displays criteria used locally to assess pool abundance. Year 2001 results reveal many of the Rosgen channel types surveyed do not meet thresholds used in WRIA 5 or indicated by NMFS (currently there is no WRIA 7 pool criteria threshold). It is important, when viewing these comparisons, to keep in mind differences in the definitions used to classify a stream feature as a pool. It is reasonable to expect at least slightly lower pool area and frequency numbers in SWM 2001 data due to minimum pool size standards used during survey (see methods section).

Only the average percent pool area in C type channels in Grandview, Lake Stevens and Stillaguamish Canyon subbasins exceed the WRIA 5 criteria of greater than 50 percent of the total low flow area. High pool percentages in Lake Stevens and Stillaguamish Canyon subbasins are likely a result of beaver ponds that occasionally spanned the lengths of entire unit reaches. NMFS criteria for pools are based instead on pool frequency. Criteria differ for streams with different channel widths based on data from surveys of control streams throughout the Northwest and Alaska. While most average channel type values in Upper North Fork Skykomish, Stillaguamish Canyon and Grandview subbasins meet or are just below NMFS thresholds, those in Lake Stevens and French Creek subbasins fall far short. One potential cause of this shortfall is that these same reaches contained the lowest average woody debris frequencies.

### ***Woody Debris***

LWD provides a wide range of benefits for salmonids including pool and side-channel formation, cover and nutrient retention. Past and present human activities have reduced the size and abundance of LWD across the region. Figure 8 shows LWD abundance by Rosgen channel type and subbasin in comparison to the watershed and NMFS criteria.

Only the Upper North Fork Skykomish subbasin met the LWD criteria identified in WRIA 5 and WRIA 7. All other subbasins were significantly below this level. Grandview and Stillaguamish Canyon subbasins had the second highest level of wood

loading per channel width, followed in decreasing order by French Creek and Lake Stevens subbasins. LWD loading in the subbasins surveyed in 2001 is inversely proportional to total impervious surface in the subbasin.

Within subbasins, LWD varied by channel type. LWD loading increased with decreasing channel gradient in Upper North Fork Skykomish subbasin, with the highest frequency of LWD loading occurring in C and D channels. In general, the opposite trend was evident in other subbasins, with the highest wood frequency occurring in A and Aa+ channels. The variability in LWD frequency may be attributable to the difference in human activities and the location of human activities within individual subbasins. In the Upper North Fork Skykomish subbasin wood accumulates in C and D channels because of the low gradient and local recruitment through lateral channel migration. Wood in these channels has also formed jams, which in turn trap more wood. In the other subbasins surveyed in 2001, population density and human impacts increase with decreasing channel gradient (C, D, E, F channel types) and in these areas human activities have resulted in the removal of both LWD and recruitment potential.

### ***Streambank Instability***

Stable streambanks are an important feature of habitat conditions which favor salmon survival. Unstable banks increase channel erosion, contribute to the deterioration of channel morphology, increase the amount of fine sediments in spawning gravels, contribute to the infilling of pools, and decrease the stability of LWD in the channel.

The Upper North Fork Skykomish and Stillaguamish Canyon subbasins were the only subbasins that met WRIA 5 and WRIA 7 streambank instability criteria for all channel types (Figure 9). In addition when bank instability for all channel types are combined the percent bank instability stands at 8.2 percent for Upper North Fork Skykomish subbasin and 8.7 percent for Stillaguamish Canyon subbasin. French Creek, Lake Stevens and Grandview subbasins recorded 31.9, 12 and 30.6 percent bank instability respectively.

When comparing bank instability by Rosgen channel types no correlations were observed, however, there may be a correlation between human activities and instability. The human activities in the Grandview subbasin along the Aa+ reaches surveyed were predominately commercial forests which had been recently harvested. Aa+ channels in the Grandview subbasin had instability of 11 percent while in the Upper North Fork Skykomish subbasin, located within the Mt. Baker-Snoqualmie National Forest and subject to a greater degree of aquatic resource protection (FEMAT 1993), instability in Aa+ channels was measured to be 0 percent. Lake Stevens has the highest population density and thus the highest impervious area of the subbasins analyzed for this report. Streambank instability in C channels in that subbasin was the highest at 12 percent. In the second most urban subbasin surveyed in 2001, French Creek, ditched (X) channels had the highest bank instability at 17.8 percent.

### ***Hydromodifications***

Hydromodifications are human-made alterations to the stream channel or shoreline and its banks, which limit channel and floodplain response to watershed processes, such as

the delivery and routing of water, sediment, and large woody debris. Hydromodifications may also promote and propagate adjacent (opposite and downstream) bank instability. The degradation and loss of normative channel conditions and floodplain interaction have been identified as contributing factors to the decline of salmonid populations in the Pacific Northwest. The type and extent of hydromodifications, in part, contributes to this degradation and loss.

Among the five subbasins surveyed in 2001, the hydromodification criterion threshold is exceeded in three subbasins in channel types in different human activity settings (Figure 10). The greatest observed extent of bank hydromodifications are in lower gradient floodplain channel types (C and D) in the Upper North Fork Skykomish and Lake Stevens subbasins. Bank hydromodifications in Upper North Fork Skykomish have resulted from significant public works projects to protect and construct the primary floodplain road, whereas bank hydromodifications in the Lake Stevens subbasin are likely the result of smaller cumulative landowner actions to protect private property from bank erosion and lowland flooding.

The greatest extent of basin-wide hydromodifications was observed in the most populous subbasins, Lake Stevens and French Creek. Although mean values of bank hydromodifications in French Creek do not exceed threshold criteria there is high variability indicating many unit reaches exceeded the threshold criterion and, notably, hydromodifications are present in every channel type surveyed, unlike the less populated subbasins, Upper North Fork Skykomish, Stillaguamish Canyon and Grandview. Furthermore, although the extent of bank hydromodifications in the X channel type in French Creek were observed to be low, it should be emphasized that the ditch channel type has been extensively "hydro" modified over time by actions to channelize and maintain stream geometry and conveyance, in particular.

The high variability in bank hydromodifications observed in the populous subbasins may be predictive of the extent of future hydromodifications. That is with increasing population growth, the mean subbasin value may increase and the variability decrease, leading to greater areas of modified streambank. Conversely, the high variability in bank hydromodifications in Upper North Fork Skykomish subbasin are likely reflective of fewer infrastructure projects. The extent and variability would be most likely to change if the floodplain road network were expanded or if significant flood events changed the location of chronic erosion hazard sites in proximity to the primary road or adjacent private property.

### ***Fine Sediments***

The quality of spawning habitat and specifically the amount of fine sediments which may intrude into salmon redds (here measured by percent areal surface fine sediments) is an important component of fish-bearing streams. Human activities that alter a system's flow regime (increasing surface, bank and bed erosion), that increase the amount of bare soil or unpaved road surface, that reduce the potential for deposition of fines on the floodplain, or that contribute to destabilization of potential landslide source areas will increase the amount of surface fines available for deposition and intrusion into redds.

The fine sediment data collected is an *indicator* of potential egg entombment or suffocation rather than a *measure* since the data are collected during the summer low-flow period and not at a time when salmonid eggs are in the redds. Salmon are active spawners that clean their redds prior to egg deposition and fertilization. Surface fines indicate an amount of sediment which exists in the system and is available to intrude into redds after eggs are laid.

Table 11 lists the WRIA 5, WRIA 7 and NMFS criteria used to assess the condition of habitat as affected by percent of surface fine sediments. Fine sediment levels in C, D, and X channel types and throughout physical habitat surveyed in the Grandview, Lake Stevens and Stillaguamish Canyon subbasins exceed the WRIA 5 criterion (Figure 11). Aa+, A, and B channels in Upper North Fork Skykomish subbasin, and B channels in the French Creek subbasin clearly meet the WRIA 5 criteria.

NMFS evaluative criteria, used in WRIA 7, evaluates the percent of surface fines which are less than 0.85 mm in diameter. To collect such data, field samples must be collected, transported, processed and analyzed. Snohomish County currently does not collect data by this method. It is likely, however, that Aa+, A, and B channels in the Upper North Fork Skykomish subbasin, and B channels in the French Creek subbasin, which were found to have mean surface fines (<6.3 mm) of less than 12% will meet the WRIA 7 criterion. In addition, C channels in Upper North Fork Skykomish subbasin and A channels in the French Creek subbasin are also likely to meet the WRIA 7/NMFS criterion.

## References

- Bauer, S.B., and T.A. Burton. 1993. Monitoring protocols to evaluate water quality effects of grazing management on western rangeland streams. U.S. Environmental Protection Agency Region 10, Seattle, WA.
- Bilby, R.E and J.W. Ward. 1989. Changes in characteristics and function of woody debris with increasing size of streams in western Washington. *Transactions of the American Fisheries Society* 118:368-378.
- Bilby, B., G. Pess, B. Feist, and T. Beechie. 1999. Freshwater habitat and salmon recovery: relating land use actions to fish population response. Unpublished report from NMFS, NOAA, Seattle, WA.
- Bjornn, T.C., and D.W. Rieser. 1991. Habitat requirements of salmonids in streams. *American Fisheries Society Special Publication* 19:83-138.
- Collins, B. D., D.R. Montgomery, and A. D. Haas. 2002. Historic changes in the distribution and functions of large woody debris in Puget Lowland rivers. *Canadian Journal of Fisheries and Aquatic Science* 59:66-76.
- FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: An ecological, economic, and social assessment. Washington, D.C.: U.S. Government Printing Office, no. 1993-793-071.
- Johnston, N.T. and P.A. Slaney. 1996. Fish habitat assessment procedures. British Columbia Ministry of Environment, Lands and Parks and British Columbia Ministry of Forests, Watershed Restoration Program, Tech. Circ. No. 8.
- Lunetta, R.S., B.L. Cosentino, D.R. Montgomery, E.M. Beamer, and T.J. Beechie. 1997. GIS-based evaluation of salmon habitat in the Pacific Northwest. *Photogrammetric Engineering & Remote Sensing* 63:1219-1229.
- Montgomery, D.R., and J.M. Buffington, 1993. Channel classification, prediction of channel response, and assessment of channel condition. Olympia, Washington State Department of Natural Resources Report TFW-SH10-93-002.
- National Marine Fisheries Service. 1996. Coastal salmon conservation: working guidance for comprehensive salmon restoration initiatives on the Pacific Coast. USDC-NOAA, NMFS, Portland, OR. Report dated September 15, 1996.
- Overton, C.K., S.P. Wollrab, B.C. Roberts and M.A. Radko. 1997. R1/R4 (Northern/Intermountain Regional) fish and fish habitat standard inventory procedures handbook. Gen. Tech. Rep. INT-GTR-346. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Pentec Environmental, Inc. and NW GIS. 1999. Snohomish river basin conditions and issues report. Final Report. Prepared for the Snohomish Work Group, by Pentec Environmental, Inc. and NW GIS. Project No. 293-001, Everett.

Pess, G.R., B.D. Collins, M. Pollock, T.J. Beechie, A. Haas, and S. Grigsby. 1999. Historic and current factors that limit coho salmon (*Oncorhynchus kisutch*) production in the Stillaguamish River Basin Washington State: implication for salmonid habitat protection and restoration. Prepared for Snohomish County Department of Public Works and the Stillaguamish Tribe.

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

Purser, M.D., and R. Simmonds. 2001. The Snohomish County land cover project. February 2001 Status Report. Snohomish County, Public Works, Surface Water Management.

Rhodes, J.J., and M.D. Purser. 1998. Overwinter sedimentation of clean gravels in simulated redds in the upper Grande Ronde River and nearby streams in northeastern Oregon, USA: Implications for the survival of threatened spring chinook salmon. Pages 403-412 in M.K. Brewin and D.M.A. Monita, tech. coords. Forest-fish conference: land management practices affecting aquatic ecosystems. Proc. Forest-Fish Conf., May 1-4, 1996, Calgary, Alberta. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta. Inf. Rep. NOR-X-356.

Rosgen, D. L. 1996. Applied river morphology. Wildland Hydrology Books, Pagosa Springs, CO.

Schuett-Hames, D., A. Pleas, L. Bullchild, S. Hall. [eds.] 1994. Ambient monitoring program manual. Timber-Fish-Wildlife, TFW-AM9-94-001. Northwest Indian Fisheries Commission, Olympia, WA.

Snohomish County SWM. 2000. Physical habitat survey and monitoring protocol for wadable streams. Snohomish County, Public Works, Surface Water Management, Version 5.0.

Snohomish County SWM. 2001a. Wadable stream habitat survey preliminary results for the year 2000. Snohomish County, Public Works, Surface Water Management, March 2001.

Snohomish County SWM. 2001b. Physical habitat survey and monitoring protocol for wadable streams. Snohomish County, Public Works, Surface Water Management, Version 6.0 (06/01).

Snohomish Salmonid Recovery Technical Committee (SRTC). 2000. Snohomish basin interim habitat recovery goals and performance criteria. Working paper developed under direction from the Snohomish Basin Forum.

Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R. P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR.

Stillaguamish Technical Advisory Group (STAG). 2000. Technical assessment and recommendations for chinook salmon recovery in the Stillaguamish Watershed.

StreamNet Database (Version 98.3). Gladstone (OR) : StreamNet, April 1998. [Leonetti, Frank] 28 December 2000] RL:<<http://www.streamnet.org/accesstable.html>>.

USDA-Forest Service. 1999. Stream inventory handbook: Level I & II. USDA, Region 6, Version 9.9.

Washington Department of Fisheries (WDF), Washington Department of Wildlife, and Western Washington Treaty Indian Tribes. 1993. 1992 Washington State salmon and steelhead stock inventory (SASSI).

Whittier, T.R., R.M. Hughes, and D.P. Larsen. 1988. Correspondence between ecoregions and spatial patterns in stream ecosystems in Oregon. Canadian Journal of Fisheries and Aquatic Science 45:1246-1278.

Williams, R.W., R.M. Laramie, and J.J. Ames. 1975. A catalog of Washington State streams and salmon utilization, Volume 1: Puget Sound region. Washington Department of Fisheries.