PHYSICAL HABITAT SURVEY AND MONITORING PROTOCOL FOR LARGE RIVERS VERSION 1.1

SNOHOMISH COUNTY SURFACE WATER MANAGEMENT
(12/2/02)

Introduction

Background

In 1999, Snohomish County Public Works Surface Water Management (SWM) initiated a multi-year stream habitat inventory of fish bearing streams in Snohomish County. A quantitative, rapid and repeatable survey protocol for wadable streams was developed (SWM, 2000, SWM, 2001a) and implemented in 10 subbasins during the 2000 and 2001 field seasons (SWM, 2001b, 2002). An additional 10 subbasins were surveyed as part of the Drainage Needs Report (DNR) project in 2001. By the end of the 2002 field season, an estimated 120 miles of wadable streams will have been surveyed and characterized in the Stillaguamish, Snohomish, and Cedar-Sammamish watersheds, approximately one-third of Snohomish County subbasins.

To fill aquatic habitat conditions data gaps in Snohomish County, SWM developed this physical habitat survey protocol for larger, nonwadable streams and rivers. Nonwadable streams and rivers provide some of the most critical habitat for Endangered Species Act-listed chinook salmon and native char, and thus data on current conditions in these areas provides an important foundation for salmon conservation plans and actions. Furthermore, physical habitat data from large rivers are valuable for flood modeling and management.

This protocol was implemented on the North Fork, South Fork and lower Stillaguamish River in 2002. Approximately 67 miles of bank conditions and approximately 35 miles of geomorphic characteristics, pools and large woody debris (LWD) were inventoried. External funding has been awarded for inventory of the lower Skykomish and Snohomish Rivers in 2003.

The goals of this survey are to:

- Provide supporting data and analysis for salmon conservation, flood management, and capital project design and permitting;
- Collect data on current conditions as a benchmark for future trend analysis and adaptive management; and
- Identify restoration needs and potential projects based on watershed, reach and site-specific analysis.

The expected products from this survey are:

- an updated Geographic Information System (GIS) layer showing the location and stability of all dikes, levees, berms, revetments, deflectors and other anthropogenic modifications;
- an updated GIS hydrography layer to include better coverage of secondary channel habitat (i.e. side-channels and off-channel habitat); and
- a report summarizing current aquatic habitat conditions in large rivers, examining relationships among parameters and comparing results to habitat performance criteria.

Methods

Approach

The physical habitat survey and monitoring protocol for large rivers consists of two surveys, a Bank Condition survey and a Geomorphic Habitat survey. The bank survey occurs prior to the geomorphic survey. Data are gathered continuously on bank conditions along the right and left banks. Parameters include bank modifications, toe class material and instability. The Bank Condition survey is also used to reconnoiter for the Geomorphic Habitat survey, and thus Global Positioning System (GPS) points are collected at pools and LWD jams. The geomorphic survey is conducted along unit reaches that comprise approximately fifty percent of geomorphic reach length. Data are gathered on the dimensions and characteristics of pools, LWD pieces, and LWD jams.

Reach Delineation and Selection

The delineation of geomorphic stream reaches for this project uses existing reach databases as the foundation. Boundaries are adjusted for consistency with Snohomish County's Endangered Species Act (ESA) subbasins coverage. County staff classify geomorphic reaches based on gradient and entrenchment in accordance with Rosgen Level I stream classification methods (Rosgen, 1996). Reach demarcations that are uncertain are field verified. Geomorphic reach delineation in the Stillaguamish River basin relied heavily on Collins, et al. (2002). Reaches in the Snohomish River basin have not been delineated at this time, but a similar procedure can be followed.

Each geomorphic reach is divided into quarters. Half the reach (upper, middle two quarters, or lower) is randomly selected for the geomorphic unit survey. A length of 20 bankfull channel widths is the minimum survey length (unit reach). A subset (approximately 10%) of surveyed reaches is resurveyed for data quality and assurance.

Field Equipment

Field computer (2)
Measuring tape
Range Finder
Flagging tape
First aid kit safety gear
Hand-held calculator
Two inflatable boats
Trimble GPS units (2)
Stadia rod
Field map and clipboard
Hand-held sonar
Logger's diameter tape
Two-way radios

Field Computers and File Management

The bank condition portion of this survey employs Trimble's Pro XR GPS receiver with a TSC1 data collector to record locations and attributes of modified and unstable riverbanks. Because reaches are surveyed using non-motorized watercraft and some channels exceed 100 m in width, the survey requires the use of two GPS units - one for each bank. Consequently, two GPS bank condition files are associated with each reach. All files are stored with a unique name created by combining letter values assigned to each reach and riverbank surveyed.

During the geomorphic survey, data are entered into a spreadsheet database contained on a Juniper Systems' Allegro Field PC™, a rugged hand-held field computer. Detailed operating instructions for both hardware and software are contained in the Allegro Field PC Owner's manual, available to all surveyors. The following section describes the procedure each survey team should follow to ensure all data are stored in a useful and organized format.

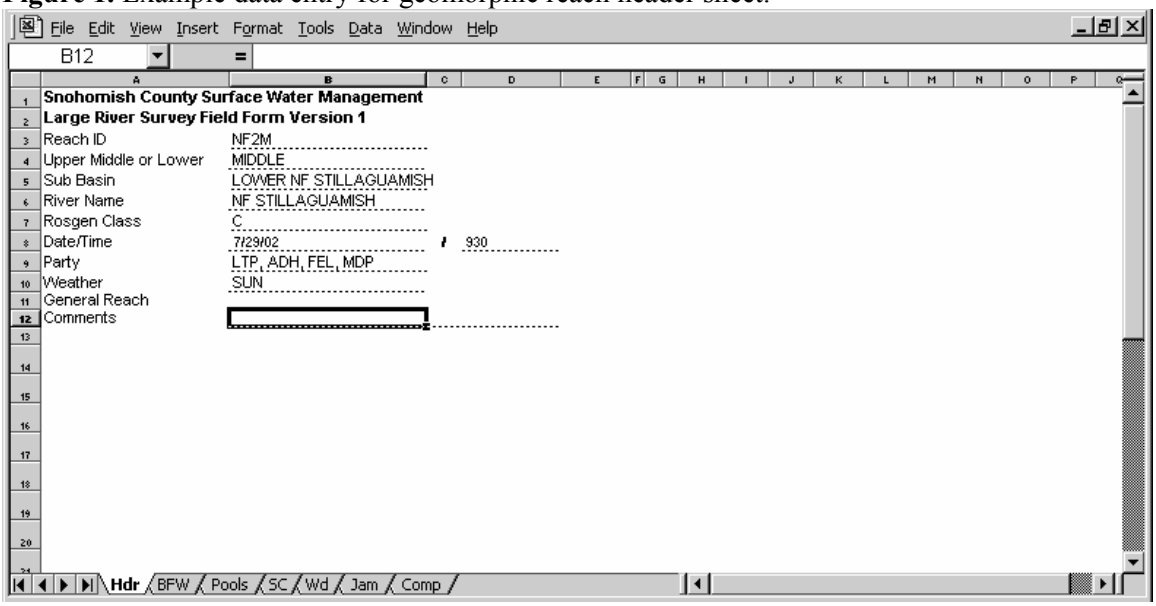
The Field PC is activated by pressing the On/Off button (as long as the batteries remain charged, the field computers will revert to suspended mode when turned "off" or not used for a predetermined amount of time). Once activated, most of the subsequent functions are most easily achieved using the touch screen. If for any reason during the survey the touch screen becomes inoperable, most necessary functions can be accessed using the keypad in much the same way as on a desktop PC.

At the beginning of each unit reach, the shortcut to **BRSFS.pt** (the main database file) is opened (double tap). The file contains seven worksheets: one header sheet containing the information about the reach to be surveyed, five sheets for habitat parameter data entry and a compilation sheet that organizes data from each of the previous sheets into a single spreadsheet (for data management purposes only). Before entering any data, the ***Save As*** command in the ***File*** menu is used to save the file as the designated reach identification number. Make sure the file saves to the C drive, as this is the solid-state hard drive that stores data even in the event power is lost. A backup copy of the blank spreadsheet is located in **C_MyDocs** in case the original is saved over.

Once the file is saved as the reach identification number, the caps lock is engaged and all known reach information is entered into the spaces provided in the header sheet (Figure 1). Habitat information is entered into the habitat parameter sheets which are found by tapping on the tabs at the bottom of the screen. The file is saved periodically to ensure a minimal loss of data in the event of a computer lockup. At no time should data be entered into the compilation sheet (while the sheet is protected, some data entries are still possible). If data is entered inadvertently into the compilation spreadsheet, the ***Undo*** function under the ***Edit*** pull down menu is used to remove entries (deleting the entry may also delete equations built into the sheet). At the end of the reach, all remaining blanks in the header sheet are filled in and a final save performed before closing the file.

Completed reach files are transferred to an office computer after each day of survey and checked for invalid or missing data. Any anomalies are flagged and reported to the data manager.

Figure 1. Example data entry for geomorphic reach header sheet.



Bank Condition Survey

The objectives of the Bank Condition survey are to classify, characterize and map hydromodifications, streambank instability, edge habitat and secondary (including floodplain) habitat features in one integrated survey (see definitions below). The survey involves both aerial orthophoto interpretation and field sampling techniques. Edge and secondary habitat units are delineated through orthophoto interpretation. A secondary objective of the field survey component is to gather GPS locations of pools and LWD jams (see definitions below) in support of the geomorphic unit survey and to better quantify pool and LWD jam frequency along the entire geomorphic reach.

Definitions:

Hydromodifications: human-made alterations to the stream channel, shoreline, and banks, which functionally act to limit channel and floodplain response to watershed processes, such as the delivery and routing of water, sediment, and large woody debris.

***Natural Streambank Instability*:** banks are unstable if they show indications of any of the following features at or above bankfull (Bauer and Burton 1993):

Breakdown: obvious blocks of bank broken away and lying adjacent to the bank breakage.

Slumping or False bank: the bank has obviously slipped down, cracks may or may not be obvious, but the slump feature is obvious.
Fracture: a crack is visibly obvious on the bank indicating that the block of bank is about to slump or move into the stream.
Vertical & Eroding: the bank is mostly uncovered as defined below *and* the bank angle is steeper than 80^{o} from the horizontal.

Hydromodified Streambank Instability: a failing hydromodification (riprap bank, levee/dike, armoring of any kind, deflectors, groynes, etc.) is one that shows visible signs of sloughing, erosion, undercutting, slumping, erosion beside or behind the structure at either the upstream or downstream end, exposure of underlying material, tension cracks (long cracks running parallel to the river on top of bank), leaning trees, or armor material (e.g., riprap) that has been relocated by the river such that it no longer prevents migration.

Stable Streambanks: natural streambanks covered with any of the following features are considered stable:

- perennial vegetation ground cover > 50%.
- roots of vegetation cover > 50% of the bank.
- ≥ rocks of cobble size protect 50% of the bank surfaces or larger.
- ≥ 50% of the bank surfaces are protected by logs of ≥10-cm diameter.
- otherwise, banks are considered uncovered.

Edge Habitat*:* edge habitat is characterized as to type based on the following definitions from Hayman, et al. (1996):

Bank edge: vertical, or nearly vertical shore.
Bar edge: shallow, low gradient interface with the shore.
Backwater edge: enclosed, low-velocity areas separated from the main channel.

Secondary Channel Habitat: aquatic floodplain features such as oxbows, side-channel sloughs, side-channels, beaver ponds and tributary streams.

Procedure:

Office Preparation

Map production is the first step in the Bank Condition survey. Maps displaying hydrography (water courses, shorelines or water boundary), reach breaks, river miles, previously known hydromodifications and fish blockages, boat put-in/take-out locations and the 100-year floodplain over recent orthophotos are produced for each reach. These maps act as a template for orthophoto interpretation, a field guide and a backup to GPS data collection. If previous survey points were recorded upstream or downstream of the area scheduled for survey, this data is also included on the field map to provide reference for start and/or end points and to facilitate seamless data collection. Maps (including the orthophoto layer) are reviewed and potential hydromodifications that do not appear in the current database are noted for field verification.

Field Survey

The field survey focuses on characterizing streambank stability and hydromodifications. Edge habitat and secondary channel habitat is not ground-truthed as part of this survey. The position of pools and LWD jams are recorded as point data to facilitate the subsequent geomorphic inventory. Bank instability and hydromodifications are continuously recorded using a Trimble GPS Pathfinder Pro and TSC1 data collector. The Pathfinder's horizontal accuracy is sub-meter on a second-by-second basis. Surveys are conducted from two separate boats, one on each bank. In addition, one crew collects GPS locations for pools, and one crew collects GPS locations for LWD jams. If the channel is bifurcated, then hydromodifications and bank instability are measured along the outer banks only.

Hydromodification data are collected in two point feature classes: continuous bank modifications, which while collected as points will ultimately be converted to lines, and floodplain and instream modifications, such as tide gates and deflectors, which will remain as points. Specific data inputs and a copy of the data dictionary is found in Appendix A.

Bank Modifications:

To simplify data collection, bank modifications are recorded as point features along a continuous riverbank. At a change in any of the descriptive attribute fields listed below, a GPS point is recorded as near the location of change as possible. The attributes given to a point characterize the length of bank between this point and the nearest downstream modification point on the same bank. Survey teams will collect data points at the beginning of attribute changes while surveying in a downstream direction, or at the end of attribute changes if surveying in an upstream direction. Attributes are collected for the bank condition point feature, BNKCNDPT, in the following fields:

> ***RIVER_BANK*** each point is collected as describing the left or right bank (facing downstream).
>
> ***CONDITION*** categorizes the bank as being either "natural" or "modified".
>
> ***STABILITY*** is recorded for both natural and hydromodified banks, describes whether or not the bank is intact or failing based on criteria listed above.
>
> ***CONTINUITY*** clarifies the organization of bank modification points within a file and aids in the subsequent joining of multiple files. The furthest upstream point on each riverbank is labeled *start* and attributed to describe the bank downstream. The most downstream bank modification point recorded for each bank is labeled *end* and should only contain information in the *River Bank* and *Continuity* fields. This point is a terminus for attributes assigned to the bank at the point immediately upstream. All bank modification points recorded between the start and end points are assigned *serial* with one exception. If for any reason a section of bank between the start and end points is not surveyed, the continuity field for

the point at the upstream end of the section is labeled *break*. When survey is resumed the first bank modification point recorded is again assigned *serial* continuity.

HMOD_TYPE describes the type of bank modification. Types include *dike/levee, berm, revetment, bulkhead, and grade*. If the type of bank modification is unclear, it is classified as a revetment. Banks whether natural or modified are identified as *stable or unstable* based on whether or not they meet the bank instability definitions (natural and hydromodified).

HMOD_TOE the hydromodification toe class type is determined by visually examining primary bank material below the ordinary high water mark. Toe classes include *Riprap, Rubble, Structural, and Earth*. Bank material greater than 256 mm (10 in) is considered *Riprap*. Bank material less than 256 mm is considered *Rubble* (Beamer & Henderson, 1998). Other classes such as wood, concrete, and gabion are lumped into *Structural* toe class. *Earth* includes soil as well as "natural" toe material. Non-modified banks and banks with setback modifications receive a *N/A* HMOD_TOE value by default.

CONFIDENCE labels each GPS point as being recorded on, near or significantly away from a change in bank condition. *High*, *Moderate*, or *See Photo* confidences are recorded depending on how the surveyor feels the resulting point represents the actual location of the bank condition change. This information is used during post-survey data processing to identify points needing adjustment. *See Photo* confidence values indicate the GPS position is not reliable and points/notes recoded on the aerial photograph should be used to place the point during post processing. When unfavorable satellite positions, topography, vegetation or swift currents prevent point collection using GPS, bank condition, pool and jam points are recorded solely on field maps. These points are integrated with the GPS collected points during post-survey data processing.

Instream and Floodplain Modifications:

Instream modifications are features that are located within or protrude into the channel. They include bridge footings, deflectors, weirs, docks/pilings, and subsurface utility crossings. These modifications are recorded as point features. The positions of pools and LWD jams are recorded as instream points for those portions of reaches not surveyed during the geomorphic survey.

Floodplain modifications are features that interact with or impact secondary channel habitats and are collected as a point feature. Floodplain modifications include culverts, tide/flood gates, pump stations, plugs, and diversion structures that impede or block natural flow and connectivity between secondary habitats such as tributaries, sloughs, lakes, ponds, or side channels and the mainstem.

Attributes for the instream and floodplain modifications feature, INSTFPPT, are collected in the following fields:

RIVER_BANK is collected as describing the left or right bank or center channel (facing downstream).

MOD_TYPE the modification type categorizes the instream modification as occurring either in the stream channel or on the floodplain.

INSTR_TYPE instream type includes bridge footings, deflectors, weirs, docks/pilings, and subsurface utility crossings. Pools and log jams may also be included as instream points. A value of N/A is selected for floodplain points.

FLDPL_TYPE similarly the floodplain type further characterizes floodplain modifications. Floodplain types include: culverts, tide/floodgates, pump stations, Plug dikes, diversion structures and outfalls. A value of N/A is entered for instream points.

FLPL_BLOCK this field describes the floodplain feature blocked by one of the floodplain modifications above. Features include: tributary, side channel, distributary slough, blind tidal slough, pond and unknown. N/A is selected for instream modifications.

CONFIDENCE see above.

Geomorphic Habitat Survey

The primary objective of the Geomorphic Habitat survey is to characterize fish habitat conditions, focusing on pools and LWD in rivers and secondary channel habitats. It is implemented in approximately 50% of each geomorphic reach. Further, approximately 50% of the delineated side channel length is also surveyed. The survey involves both aerial photo interpretation and field sampling.

Definitions:

Bankfull width (BFW) is the width of a stream channel at the point where overbank flow begins during a flood event. In channels with disconnected or undeveloped floodplains, bankfull indicators may include: the top of deposited bedload (gravel bars), stain lines on banks, the lower limit of perennial vegetation, moss on streamside trees or lichen on rocks, a change in slope or particle size on the stream bank, or undercut banks (USFS, 1999).

Wetted width is the width dimension at the low flow channel margin at the time of survey as measured downstream from qualifying pools at the riffle crossover point.

Pools are sections of a stream channel where water is impounded within a closed topographical depression (Abbe and Montgomery, 1996). For a habitat unit to qualify as a pool in this survey it must meet minimum area and depth requirements based on bankfull width dimensions and as indicated by habitat

suitability criteria (e.g. NMFS, 1996). Because all bankfull width dimensions in large rivers are likely to be > 20 m, the minimum area and residual pool depth requirements are 5.0 m^2 and 0.4 m, respectively (after Pleus, et al., 1999). Additionally, pools must be ≥ 1 m at maximum depth.

Woody debris refers to both large and small woody debris, stumps and jams as defined below.

Large woody debris (LWD) is defined as downed wood that intercepts bankfull flow (trunk not branches) in a substantial fashion and is large enough to influence the formation of habitats (USFS, 1999).

> ***Jams*** are defined as 3 or more touching pieces of LWD (defined above) together producing a single structure significantly intercepting bankfull flow. Report Y or N if piece is part of a jam. Using orthophotos, we have classified jams as fitting three general types (after Abbe and Montgomery, 1996): bar top jams, bar apex jams and meander jams.
>
> ***Bar Top Jams (BTJs)*** are random accumulations of loosely organized debris on top of a bar with little vertical stacking. BTJs have little influence on channel morphology.
>
> ***Bar Apex Jams (BAJs)*** are typically more stable LWD accumulations anchored by large pieces (60-90 cm minimum diameter dependent on bankfull depth) with root wads showing vertical stacking of orthogonal and oblique members located at the upstream end of a gravel bar or forested island. BAJs influence channel morphology and riparian forest development.
>
> ***Meander Jams (MJs)*** are stable jams located at and often armoring concave surface of meander or outer stream bank with key members and vertical stacking. MJs can influence channel morphology by altering river radius of curvature.

Secondary Channel Habitat is composed of side-channel (within the bankfull width) and off-channel (outside the bankfull width) habitat. Side channels are defined as channels that are separated from the main channel by a stable island and contain the smaller portion of the total bankfull flow. A stable island in a forested stream is defined by USFS (1999) as supporting woody vegetation (excluding willow), which is estimated to be at least 5 years old (and covers at least 50% of the island surface). Off-channel habitat includes marshes, ponds and oxbow lakes that are outside the bankfull channel and are not field surveyed.

Procedure:

Office Preparation

Fifty percent of each geomorphic reach (upper half, middle half, or lower half) is randomly selected for detailed survey. Exceptions can occur where the lower half of one reach and the upper half of the next reach are selected for logistical reasons rather than randomly.

A set of reach maps is produced for each survey reach. These maps include orthophotos, reach breaks, boat put in and take out locations, and data gathered during the bank condition survey, including bank characteristics and the location of pools and LWD jams. Areas where additional ground-truthing is necessary to verify the accuracy of the bank condition survey data are flagged with a question mark to be resolved during the field survey.

Field Survey

Because each reach surveyed varies in complexity, the division of labor between surveyors within and between watercraft is variable. Generally, surveyors in one craft are responsible for enumerating and characterizing single pieces of LWD on one bank as well as identifying and measuring pools. Surveyors in the second craft collect LWD data on the opposite bank and are responsible for measuring and sampling jams. However, side channels, long pools and large jams require that there be flexibility in the division of labor between craft.

Bankfull Width

Bankfull width is measured at the crest of the first riffle to verify BFW estimates made using orthophotos in ArcView®. A GPS point is collected at the location of the measurement. Data is entered in field computer in the appropriate worksheet.

Pools

Pools within each surveyed reach are identified based on the reach name abbreviation and pool number (Fig. 2). This pool number is cross-referenced with GPS data previously collected during the bank conditions survey. A minimum residual depth (maximum pool depth minus tailout depth) of 0.4 meter and a minimum of 1 meter maximum depth are required to qualify as a pool. The pool GPS position is entered and labeled.

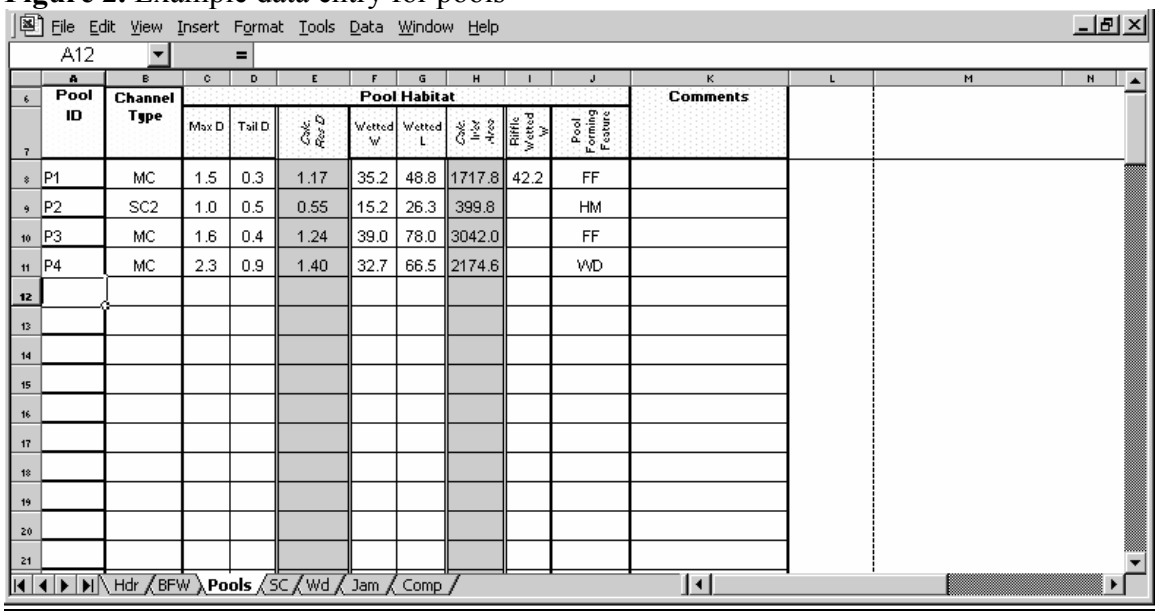
For each pool, average pool width is measured using a laser rangefinder and maximum and tailout depths are measured with a handheld digital sonar gun or stadia rod. Pool lengths are measured in the field with a laser rangefinder or identified on field maps and measured using ArcView® with aerial orthophotos. It is important to note that, in contrast with SWM's protocol for wadable streams, only total pool area is measured, not "functional area." This deviation from the wadable stream survey protocol is based on the assumption that the functional area is equal to the total area at the scale of large rivers.

For each pool, the primary pool-forming feature is recorded as hydromodification (e.g., riprap or structural), wood (LWD with or without a rootwad or jam), free formed, or

bedrock. Data is entered for each pool in the appropriate field computer spreadsheet (Figure 2).

In cases where a pool is followed downstream by a glide, the tailout of the pool is delineated at the beginning of the glide rather than at the downstream riffle crest. A glide, as defined for this survey, has slow-moving water of uniform depth and in Snohomish County's large rivers is typically 1 m in depth (+/- 0.5 m) at low flow.

Figure 2. Example data entry for pools



Woody Debris

Data is gathered on single pieces of LWD and on LWD jams according to the following protocol for each parameter and entered (Figure 3).

Single pieces

Abundance - all pieces which are greater than 7.6 m in length and 30 cm in diameter at 7.6 meters from the base are recorded.

Length class - log length is measured or visually estimated and recorded in the field computer in three length classes: 7.6-15 m; >15 m; and <7.6 m with a rootwad only. The first five pieces each day are measured and every 10th piece thereafter is also measured to stay calibrated.

Diameter class - log diameter is measured or visually estimated and recorded in four diameter classes; 30-60 cm, 60-90 cm, >90 cm, and <30 cm with a rootwad only. The first five pieces each day are measured and every 10th piece thereafter is also measured to stay calibrated. Log diameter is measured at 7.6 meters from the base of the log.

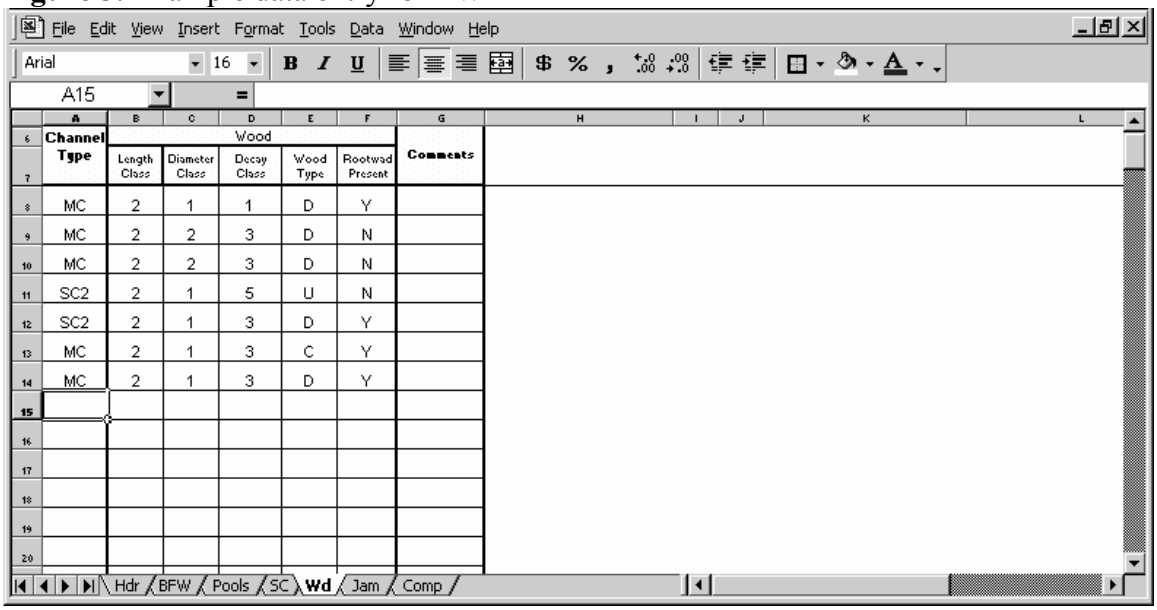
Rootwad presence/absence - for a rootwad to be counted on a piece of woody debris, the mean rootwad diameter must be ≥ one meter. Y or N is reported for rootwad presence.

Decay class - each piece is characterized based on the condition of the wood from natural decay. Table 1 from Schuett-Hames, et al. (1994) lists the criteria for decay class. The five classes of Schuett-Hames, et al. have been simplified into three: "recent" (1), "intermediate" (3) and "old" (5) (Collins, et al., 2002). Pieces within decay class 5 will automatically be classified as wood type unknown.

Table 1: Decay Class Criteria

Decay Class (Collins, *et al.,* 2002)	Decay Class (Schuett-Hames *et al.* 1994)	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

Figure 3. Example data entry for LWD



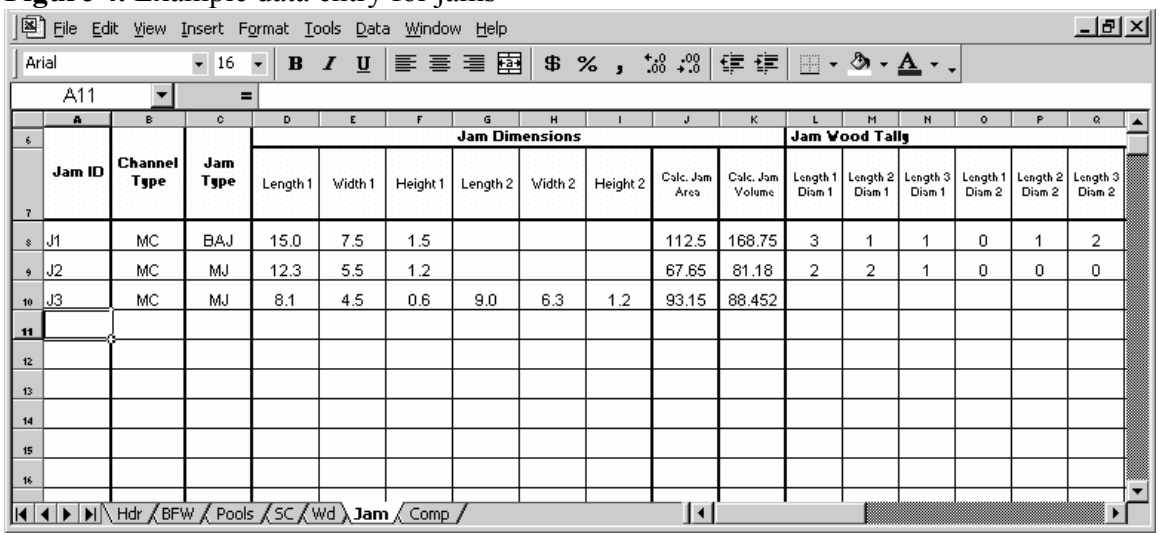
Jams (Fig. 4)

Jam location - The location recorded, using GPS, of all jams wholly or partially (at least 3 pieces) contained within the bankfull width, including side channels, during the Bank Condition Survey.

Jam type - The jam type is recorded based on the three general classes.

Jam dimensions - The volume of each jam is estimated as a rectangle by measuring and recording an average jam height, length and width. For irregularly shaped jams, the area is estimated as two rectangles. Measuring the area as one rectangle is the preferred alternative, and should be adequate in most cases.
LWD dimensions within jams - Approximately one-third of the jams are identified and marked on aerial photos prior to field survey, then sampled for piece data during the Geomorphic Unit survey. If new jams are encountered during the geomorphic surveys that were not enumerated during the bank condition surveys, every third jam is sampled. Within these jams, all LWD pieces are tallied based on length/diameter classes, wood type, rootwad presence/absence, and decay class.

Figure 4. Example data entry for jams



	Jam ID	Channel Type	Jam Type	Jam Dimensions								Jam Wood Tally					
				Length 1	Width 1	Height 1	Length 2	Width 2	Height 2	Calc. Jam Area	Calc. Jam Volume	Length 1 Diam 1	Length 2 Diam 1	Length 3 Diam 1	Length 1 Diam 2	Length 2 Diam 2	Length 3 Diam 2
8	J1	MC	BAJ	15.0	7.5	1.5				112.5	168.75	3	1	1	0	1	2
9	J2	MC	MJ	12.3	5.5	1.2				67.65	81.18	2	2	1	0	0	0
10	J3	MC	MJ	8.1	4.5	0.6	9.0	6.3	1.2	93.15	88.452						

Secondary Channel Habitats

Prior to the bank condition survey or geomorphic survey, aerial photos are interpreted to determine whether or not a potential secondary channel feature is separated from the main channel by a stable island. If a stable island does not separate the feature from the main channel, it should be combined with the main channel measurements. If the feature is located outside the bankfull channel, it should be marked on field maps and described in the comments based on the definition provided above.

For all secondary channels identified, a GPS position is obtained at the first point encountered where the channel connects to the main channel. A determination is made as to whether the secondary channel is dry but within the bankfull channel, connected at one end (channel type SC1), or connected at both ends (channel type SC2) at the time of the survey, and the corresponding code is recorded in the database. The secondary channel is surveyed using the same protocol as for mainstem channels, collecting data on pools, LWD, jams, and bank conditions (outer streambank only), if not previously collected. The wetted and total widths are measured and recorded (length can be measured off of photos in the office) and significant off-channel habitat features, which are outside the bankfull flow, should be noted in the comments but not measured.

Post-Survey Data Processing and Quality Assurance/Control

GPS data collected during the Bank Condition survey is downloaded from the Trimble data collector into Pathfinder Office®, which creates shapefiles for ArcView®, identified by reach location and type (bank condition points, pool and jam location points). Pools and LWD jam positions collected as point data during the Bank Condition survey are incorporated into geomorphic survey shapefiles to integrate with data collected during the geomorphic survey.

Point locations and attributes are checked by the person who collected the field data using aerial photos, comments, and other information to ensure that all necessary values have been entered and that data and coding are consistent with other information. Bank condition points are adjusted to a routed streambank or shoreline theme in GIS and otherwise made consistent with digital orthophotography. Continuous line data are generated from primary data points, each segment representing a particular combination of bank condition attributes. This allows individual or combined attributes to be analyzed as to their length or proportion of total length. Individual segments also represent sample points for statistical analysis of individual or combined attributes to answer specific questions.

Geomorphic habitat data on pools, LWD, jams, and cross-sectional measurements are checked for missing or invalid values. Data are compared with shapefiles of location information collected during Bank Condition survey. Point locations and attributes are checked by the person who collected the field data using aerial photos, comments, and other information to ensure that all necessary values have been entered and that data and coding are consistent with other information. Areas of pools and active channels are calculated and proportions are calculated. Pools are counted and frequencies are calculated at different scales. Class information on LWD is counted and combined at various scales to answer specific questions.

For the purposes of quality control, it is recommended that the survey be repeated, using different staff, in at least 10% of the reaches surveyed. This should generally be accomplished close in time (and thus in flow conditions) to the original survey. Data from the quality control survey should be checked against the original survey data immediately to determine whether the different teams are properly implementing the protocol.

Literature Cited

Abbe, T.B, and D.R. Montgomery. 1996. Large woody debris jams, channel hydraulics and habitat formation in large rivers. Regulated Rivers: Research & Management, Vol. 12, 201-221.

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.

Beamer, E.M., and R.A. Henderson. 1998. Juvenile salmonid use of natural and hydromodified stream bank habitat in the mainstem Skagit River, Northwest Washington. Skagit System Cooperative. La Conner, WA. 51 p.

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.

Hayman, R.A., E.M. Beamer, and R.E. McClure, 1996. FY 1995 Skagit River Chinook – Restoration Research Progress Report No. 1. Skagit System Cooperative , LaConner, WA. 113 p.

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.

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.

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

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

Snohomish County SWM. 2002. Wadable stream habitat survey preliminary results for the year 2001. Snohomish County, Public Works, Surface Water Management, March 2001.

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

Appendix A

Data dictionary for bank condition survey

```
"Bank Condition V1", Dictionary, "MRUSTAY"
"BNKCNDPT", point, "Channel Edge Modifications"
   "NAME", text, 16, "Reach/record identifier"
   "RIVER_BANK", menu, required
      "Right"
      "Left"
   "CONDITION", menu
      "Natural"
      "Modified"
   "STABILITY", menu
      "Stable"
      "Unstable"
   "CONTINUITY", menu, required
      "Start"
      "Serial", default
      "Break"
      "End"
   "HMOD_TYPE", menu, "Enter N/A for Natural, Set Back"
      "Dike/Levee"
      "Berm"
      "Revetment"
      "Bulkhead"
      "Grade"
      "N/A", default
   "HMOD_TOE", menu, "Describe bank material at bankfull toe"
      "Rip Rap (GT 256 mm) "
      "Rubble (LT 256 mm)"
      "Structural"
      "Earth/Natural", default
   "CONFIDENCE", menu, "Location confidence"
      "High", default
      "Moderate"
      "See Photo"
   "COMMENT", text, 30, "Description, Misc."
   "COMMENT_2", text, 30
   "COMMENT_3", text, 30

"INSTFPPT", point, "Instream and Floodplain points"
   "NAME", text, 16, "Reach/record identifier"
   "RIVER_BANK", menu, required, "Location of Feature Bank or Mid-
channel"
      "Right"
      "Left"
      "Mid-Channel"
   "MOD_TYPE", menu, required, "Mod effects are in or out of channel"
      "Instream"
      "Floodplain"
   "INSTR_TYPE", menu, required, "Type of In Stream Modification"
      "Pool"
      "LWD Jam"
```

```
   "Bridge Footing"
   "Dock/Marina"
   "Deflector"
   "Log Raft"
   "Pilings"
   "Utility Cross Under"
   "Weir"
   "Other"
   "N/A", default
"FLDPL_TYPE", menu, "Type of Tributary Modification"
   "Culvert"
   "Tide/Flood Gate"
   "Pump Station"
   "Plug Levee/Dike"
   "Diversion Structure"
   "Outfall"
   "N/A", default
"FLPL_BLOCK", menu
   "Unknown"
   "Tributary"
   "Side channel"
   "Distributary Slough"
   "Blind Tidal Slough"
   "Pond"
   "N/A", default
"CONFIDENCE", menu, "Used for post processing of points"
   "High", default
   "Moderate"
   "See Photo"
"COMMENT", text, 30
"COMMENT_2", text, 30
"COMMENT_3", text, 30
```