

2011 North Fork Stillaguamish River Habitat Inventory and Assessment of Change Since 2002



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Notice to Reader

The river habitat monitoring effort described in this report was implemented in 2011, prior to the large 2014 SR530 landslide. Much of the data analysis, interpretation and report writing herein were completed prior to this event. As such the report does not include any references to the 2014 SR530 landslide. The report does mention the 2006 Steelhead Haven landslide (same location as 2014 SR530 landslide) in so far as how the slide altered river habitat conditions investigated as part of this monitoring effort. In addition, the report includes measurement of observed river bank conditions and wood count at the toe of the 2006 Steelhead Haven landslide. None of these observations were made with the express intent of measuring or interpreting the status, stability or disposition of 2006 slide material or the constructed wood crib wall.

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Executive Summary

Snohomish County Surface Water Management (SWM) inventoried habitat on the North Fork (NF) Stillaguamish River in the summer of 2011. SWM assessed 31 miles (≈50 kilometers) of the river, from the mouth of Squire Creek to the junction of the North and South Forks. The goals of the habitat inventory were to:

1. Identify and measure river habitat conditions important for Chinook salmon.
2. Determine where and what habitat has changed between 2002 and 2011.
3. Compare results with the 10-year Habitat Goals in the Stillaguamish Watershed Salmon Recovery Plan (SSRP).

This assessment collected information on four key salmonid habitat features: streambank conditions, side channels, large woody debris, and pools. Data was collected and analyzed by river segments, NF1-7 (Figure 1), established from prior assessments.

Table 1 provides a summary of findings as interpreted by SSRP limiting factors.

Bank Condition

In 2011, the length of stream bank in the project area was 97 kilometers (km) and was largely natural (85.8%). Streambank armoring composed of large riprap or smaller rubble bordered approximately 13 km of streambank. Other non-natural structures composed approximately 0.6 km of streambank.

A comparison between 2002 and 2011 shows that the length of stream bank changed very little but bank conditions deteriorated. Between 2002 and 2011, the quantity of observed riprap increased by over 1,200 meters, a 2% increase. Natural edge habitat decreased by approximately 2%. The decline in natural bank conditions varied between 0.5% in NF4 to 4.7% in NF5. Only one segment, NF6, showed an increase in natural edge habitat (3%). An estimated 84.2 acres (0.34 km²) of streambank area eroded between 2002 and 2011. In NF6, the count of eroded streambank locations and the area eroded as a total percent of the mainstem channel was greatest.

Related SSRP Goals: Removal of 4.1 miles bank armoring in first 10 years of plan; Less than 10% bank armor by segment and 90% natural edge habitat by segment: Three reaches, NF1, NF6 and NF7 met the less than 10% bank armoring goal in 2011. In 2002, NF5 also met this goal but lost 4.7% of its natural streambank by the 2011 assessment, partly due to emergency riprap armoring. An increase in the extent of observed riprap material, even given 390 meters of bank armor removal since 2005, may be due to recent exposure of older bank armoring or due to new placement of riprap material. These were not distinguished in the field.

Side Channels

In 2011, there were 25 side channels in the project area, 2 fewer than in 2002, totaling approximately 13 km. Overall, there was a loss of 10 side channels and formation of 8 new side channels and the total length of side channels increased by 5.2% between 2002 and 2011. All reaches, except NF4, lost side channels. NF5 lost four side channels, NF6 lost two, and NF1-3 and NF7 lost one. NF6 showed a 22% increase in side channel number (from 9 to 11) and a 38.9% increase in side channel length. NF1 lost its only side channel between 2002 and 2011. Side channel loss was primarily due to channel filling and

vegetation growth or capture of the side channel by the mainstem due to natural river migration. In some cases, channel switching occurred which affected the calculation of changing side channel length.

Related Recovery Plan Goals: 30 acres of side channel restored: 22.5 acres of side channel habitat has been restored at project locations since 2005. Based on this assessment of non-project side channels, there was 649 meters of restored side channel. While this does indicate an overall improvement, it does not suggest achievement of the remaining 7.5 acres of restoration needed to meet the SSRP goal.

Large Woody Debris

In the sub-sampled reaches in 2011, there were 27 wood jams with an average size of 252 m². In 2002, there were 42 jams in the same sub-sampled reaches that averaged 365 m². NF1, NF5 and NF6 showed the greatest declines in total jams. Jam frequency declined in all reaches, except for NF3, which increased, and NF7, which did not change. Overall, the count, frequency, spacing and size (including estimated volume) of wood jams declined between 2002 and 2011.

In addition to wood contained in jams, there were 565 individual wood pieces (>2.0 m long, >0.1 m diameter) counted in 2011, only 16 of which had a diameter ≥60cm and were ≥ 15m long. In 2002, there were 346 individual pieces of wood. Although the count of individual wood pieces increased by 63%, this was primarily due to a statistically significant increase in the number of smaller diameter pieces that had an “older” decay status. There were fewer of the largest diameter pieces, >90cm, in 2011. Because of the greater estimated loss of wood from jams, the net change in total wood quantity is estimated to have declined by 24% to 31%.

Approximately 20% of the wood in 2011 was from conifer trees. The decay class composition of “older” wood increased from 13% to 31% over time.

Related Recovery Plan Goals: 80 key pieces per mile and 51 log jams constructed: The 2011 survey found only 2.2 pieces per mile in the project area of the NF Stillaguamish. “Key” pieces of wood, as identified within SSRP goals, are longer than 15 meters and have a diameter greater than 60 cm. Between 2002 and 2011, the estimated number of key pieces decreased from 43 to 38. Although the count of natural jams and estimate of total natural wood has decreased, construction of wood jams has occurred since 2002. However, the rate of constructed wood jams does not offset total jam loss.

Pools

There were 120 pools in 2011 compared to 107 pools in 2002. Total pool area increased by 26% though some of this change may have been due to flow differences between sample years. Pool frequency was 4.4 pools/km. Pool count in the combined area of NF1, NF 2 and NF3 increased by 19 pools while pool count decreased by 6 pools in the combined area of NF 5, NF6 and NF7. Pool count in NF4 was unchanged. 32.5% of the pools were wood-formed, 31.7% riprap-formed, 20.8% bedrock-formed, and 14.2% were free-formed by lateral or converging scour. There was an increase in bedrock, riprap, and wood-formed pools while the number of free-formed pools decreased. Wood-formed pools increased the most due to increases in NF1, NF2 and NF3. The increase in wood-formed pools, and therefore pools overall, appears to be due to the increase in individual wood pieces. Smaller and shallower pools on average in NF2 highlight the result of pools formed from individual pieces. These pools may not persist if individual wood pieces are transported in higher river flow conditions.

Related Recovery Plan Goals: Improved pool function from placement of wood.

Table 1: SSRP limiting factors, monitoring metric, and general changes in conditions between 2002 and 2011.

Limiting factor/ Assessment element	Monitoring metric	2011 inferred change since 2002	Positive ▲, Negative ▼, NC- no change
Bank Conditions	Length of riprap; % armored	More riprap	▼
	% length natural streambanks	Increase in NF6; Decreases in NF1-5 & NF7	▼
Side Channels	Side channel count	Fewer total	▼
	Side Channel length	Higher overall due to large increase in NF5 & NF6; Decreased length elsewhere	▲
Wood	Wood jam count/ frequency	Decreased overall; Increase in NF3	▼
	Wood jam type	Decrease in bar apex & meander jams.	▼
	Jam size	Decreased average jam size (footprint).	▼
	Individual wood piece count	Increased	▲
	Wood piece size, location, decay	Greater proportion of smaller pieces; Fewer key pieces; Downstream shift in piece locations; Older decay status	▼
	Estimated total wood load	Decreased	▼
Pools	Pool count	Increased in NF1-3, particularly NF2.	▲
	Pool count	Pool count decreased in NF5 due to the 2006 Steelhead Haven landslide.	▼
	Pool area (total & % area)	Substantial increase in total pool area in NF1-3 but could be flow related; Minor changes elsewhere	▲
	Pool area (total & % area)	Decrease in total pool area and % pool area in NF5 and NF7; NF6 increased in % area, but decreased in total pool area.	NC
	Wood pools	Increased number and area, most notably in NF1-3 and NF6.	▲
	Riprap pools	Increased by count and total area;	▼

Limiting factor/ Assessment element	Monitoring metric	2011 inferred change since 2002	Positive ▲, Negative ▼, NC- no change
		Accounts for 58% of increase in pool area	
	Pool depth, all	Generally no change in residual pool depths; NF5 had deeper pools; Wood-formed pools in NF2 quadrupled; Pool depth was shallower	NC
	Pool size	Average pool size increased	Unk.

Habitat-related status and trends parameters included in this report should be updated as needed to determine progress toward meeting desired future habitat conditions in the SSRP, preferably at least every 10 years. For future monitoring, specific recommendations are included in Appendix E: Possible Future Steps for Monitoring.

Introduction

The purpose of this habitat inventory was to characterize the status of bank conditions, side channels, woody debris, and habitat units (primarily pools) in the NF Stillaguamish River and compare the 2011 inventory to the 2002 inventory (Haas et al., 2003). Habitat inventory data collected in 2002 established baseline conditions and were used to develop Salmon Recovery Plan targets and habitat restoration strategies (Stillaguamish Implementation Review Committee (SIRC), 2005). The 2011 inventory provides an update of important habitat conditions relevant to the Salmon Recovery Plan 10-year habitat project and future condition goals (Table 2) and is specifically focused on the evaluation of selected metrics (shaded in Table 2) among all habitat goals.

A description of the four key habitat features - bank condition, side channels, large woody debris, and pools – and their importance to salmonids follows.

Table 2: SSRP 10-Year Habitat Goals

Habitat Goal	Units	10-Year Quantity	Desired Future Condition
Riparian	Acres Planted	400	80% of stream shoreline (length) has 200' buffer width
Estuary	Acres Restored	195	80% of historic area is accessible and useable
	Acres Created	120	
Wood	Engineered Log Jams	51	80 pieces/mile of “key” pieces/ improved pool function
Floodplain	Acres Restored, side channels	30	≤10% bank armor by reach / 90% natural edge habitat by reach
	Armoring Removed, miles	4.1	
Sediment	Landslide Treatments	2	< 12% fine sediment (6.35 mm) in spawning areas
	Forest Road Treatment, miles	106	
Acquisition	Acres Acquired	1445	
Hydrology			80% of forest cover is hydrologically mature

Bank Conditions

Streambank conditions are important for salmon recovery as juvenile salmon rely on complex stream edges to provide shade, cover, and slower velocity water. Streambank conditions are integrated across important edge habitats, including banks, bar, and backwater edge types (Beechie, Liermann, Beamer and Henderson, 2005). Bank modifications generally “harden” a bank, limiting sediment inputs, reducing or eliminating natural channel migration, reducing edge habitat complexity and cover and reducing or isolating floodplain habitats from connectivity to the main river channel. The streambank conditions influence the density of fish use and therefore capacity of bank habitat for juvenile salmon rearing (Beamer and Henderson, 1998; Beechie et al., 2005).

Side Channels

Side channels are prone to forming in low gradient unconstrained floodplains (Beechie, Liermann, Pollock, Baker, and Davis, 2006) where they are important habitats for juvenile salmon rearing as they

generally provide slower water velocity, more frequently spaced pools with higher amounts of cover, greater woody debris frequency, and additional edge habitat. Side channels often have lower water temperature compared to mainstem rivers in summer due to shading, tributary inflow, and cold groundwater discharge near floodplain margins (Morley, Garcia, Bennett, and Roni, 2005; Snohomish County, unpublished data). Due to the armoring of streambanks with riprap and the filling in of historical side-channel habitats, side channel numbers and length have suffered the greatest loss of all habitat types. Because of their importance to juvenile salmon rearing and the magnitude of side channel loss, the losses in side channels and connectivity to off-channel ponds may disproportionately affect rearing success relative to impacts affecting other habitat types (Pess et al., 1999).

Large Woody Debris

Woody debris is an essential natural component of river systems (Beechie et al., 2006; Roni, Beechie, Pess and Hanson, 2014). Natural woody debris and constructed wood projects create beneficial habitat for fish (i.e. scour pools) and cover from predators (Roni, Hanson, and Beechie, 2008; Pess, Liermann, McHenry, Peters, and Bennett, 2012). Woody debris influences habitat formation by creating complex flow pathways, sorting and storing gravel, and influencing erosion patterns that create a mosaic of channel, habitat, and vegetation types (Latterell and Naiman, 2007). The quantity of wood in aquatic systems has been dramatically reduced due to anthropogenic (human) land uses changes including timber harvest, channel and bank modifications, and the removal of wood to improve navigation or reduce potential property and infrastructure damage (Gregory, Boyer and Gurnell, 2003).

Pools

Pools are areas of slow moving water that are deeper than the other parts of the channel. They can be cool water refuges and holding areas for adults prior to spawning and are areas where juvenile fish can congregate during high, fast flows. Pools are generally formed by the presence of some resistant channel feature that creates hydraulic scour, like wood, bedrock or lateral bank resistance. Pools may also form due to flow convergence in mid-channel trench pools. High quality pool habitat for juvenile rearing consists of backwater pools in mainstem or side channels, not formed by riprap, with some type of in-water cover (Beechie et al., 2005). Wood-formed pools are relatively deep for their generally smaller size, provide the highest amount of percent cover, and can generally form where large woody debris is stable in the wetted channel. This means that wood-formed pools are most likely created in-between other pool types, thereby forcing an increase in the frequency of pool spacing overall (Montgomery, Buffington, Smith, Schmidt, and Pess, 1995).

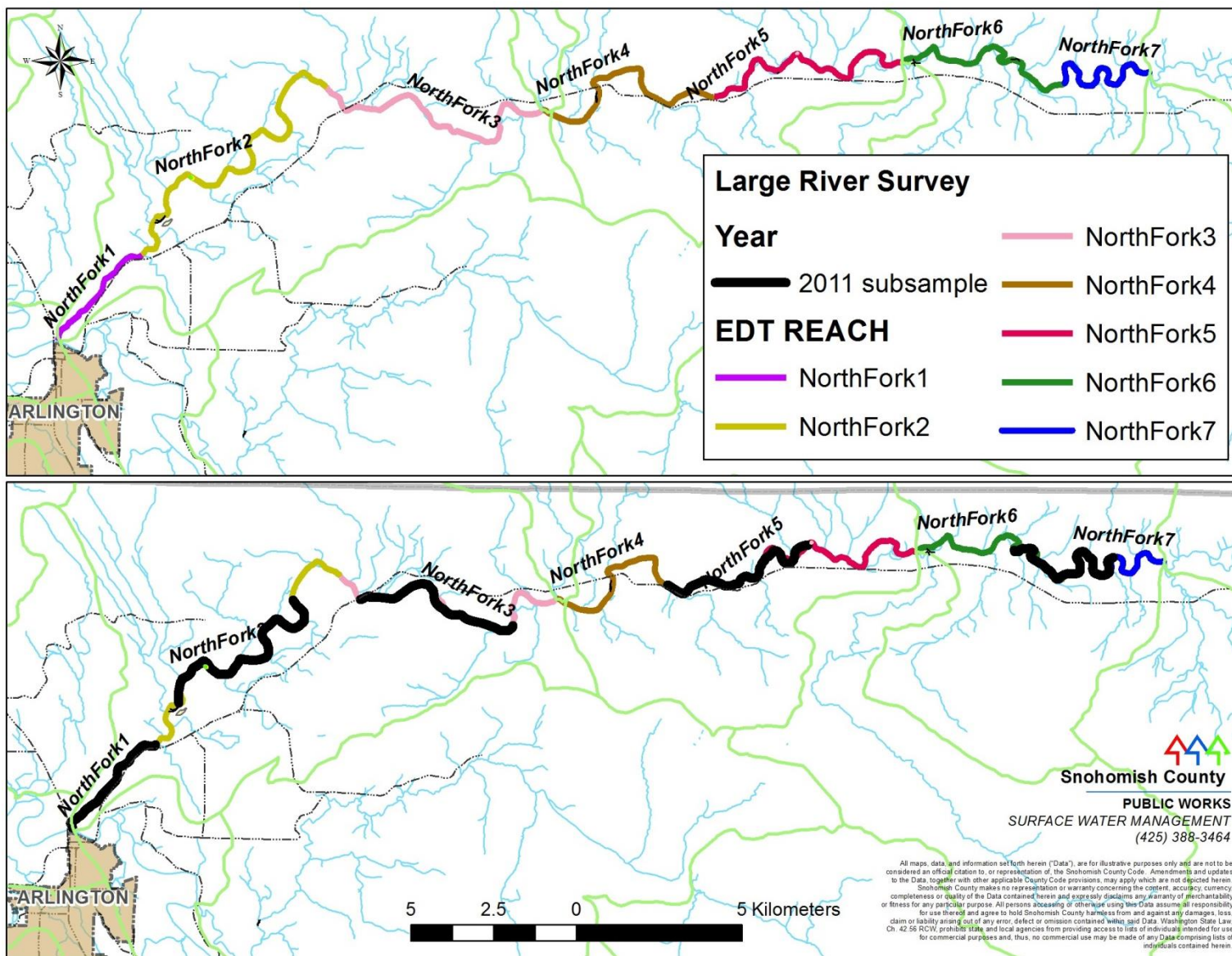


Figure 1: Seven NF Stillaguamish River reaches and survey location boundaries (lower panel).

Methods

Study Area

The NF Stillaguamish River was divided into 7 reaches (Figure 1) in 2002 based on prior delineation for Ecosystem Diagnosis and Treatment (EDT) habitat modeling. For each reach, the upper third, middle third or lower third was randomly selected in 2002 for sampling, though 100% of NF1 was sampled and 100% of all reaches were sampled for bank conditions. The actual reach lengths sampled deviated somewhat based on river access (

Table 3). The same reaches were re-sampled in 2011.

Data Collection and Analysis

Up to four field crew, using two inflatable rafts, collected data according to the methods described below and outlined in Appendix A: 2011 NF Stillaguamish River survey components. Unless stated, 2002 data collection was identical to that described below and based on Snohomish County Public Works Surface Water Management (SWM) (2002).

Channel and reach - Continuous GPS waypoints and wetted widths from individual habitat units were collected to estimate reach length in 2002 and 2011. Additionally, aerial photography was used to estimate some channel lengths not surveyed. A LiDAR-based digital elevation model in GIS was used to calculate estimates of total reach area.

River flow - Average daily flow was obtained from the NF Stillaguamish River gage (USGS Gage 12167000 - <http://waterdata.usgs.gov/nwis/uv?12167000>). Flow conditions on the dates of field surveys were compared graphically to determine if flow conditions might have affected the interpretation of the habitat inventory data. Additionally, annual peak flows between the surveyed years (i.e. 2002-2011 water years) were graphed to determine whether maximum flows between years should be considered as an additional factor influencing observed changes in habitat inventory data.

Side channels – A census of side channel locations for the entire length of the North Fork Stillaguamish was completed in 2002 and 2011. Side channel inlets, outlets, and routes were delineated using air photos, LiDAR, and field data collection. This survey used the most unambiguous descriptors of side channels (gravel-bedded inlet and outlet and length) to avoid selection bias and measurement error associated with side channel width and area, particularly wetted habitat that varies by season and flow. 2001 black and white air photos (approximately 3-ft resolution) and 2002 field data were used to determine the 2002 side channel count. A later review of the first LiDAR mapping in 2005 indicated that three additional side channels were present in 2002. Using GIS, side channel length was measured based on the observed inlet and outlet locations and lowest elevation pathway within side channels.

In 2011, the side channel inventory objectives were to field identify and map the inlet and outlet locations (with GPS) and measure length using LiDAR in GIS. Side channel count, location and length by reach were compared between years. Side channels within the repeat surveyed areas were sampled for streambanks, pools and wood. Side channel count and length relative to mainstem length by reach is reported for all reaches. The simple metrics reported here are intended to be indicators that are linked

to and reflect dynamic floodplain and channel migration processes, not absolute values of side-channel or off-channel habitat connectivity (by stage), quality, area, or rate of change.



Figure 2: Raft-based data collection of habitat unit dimensions and wood inventory NF6, August 31, 2011. All woody debris was absent in 2002. Note the gravel-bedded inlet to a side channel behind the raft.

Streambanks – Only NF6 and NF7 were surveyed in 2011 as NF1–5 were resurveyed in 2008. 2011 air photos and field survey points were used to determine right- and left-bank alignments. The 2011 bank alignment was compared to the 2002 bank alignment and channel erosion locations and area were calculated. The bank condition criteria listed below were used to delineate unique streambank segments, identified by field-collected start and end GPS points:

- Bank type – modified or natural (change in type recorded with GPS position)
- Bank stability – stable or eroding (change in stability recorded with GPS)
- Bank material – natural earth/gravel or artificial riprap/structural (change in bank material recorded with GPS)
- Eroded area – polygon locations of lateral bank erosion were delineated and measured in a GIS by comparing 2003 and 2011 air photos and field survey points from 2002 and 2011. The number and area of eroded streambanks was used as an indicator of channel migration process that may be related to changing habitat conditions.

This data was imported into GIS and used to calculate the streambank length of each unique segment.

Based on repeat quality control surveys implemented in 2006, the identification of bank armoring (presence of riprap and start/stop locations) and the estimation of percent total armoring is very precise and repeatable (Leonetti, Thomas, Gaddis, Rustay and Haas, 2008). Greater uncertainty exists when comparing results of natural unstable streambanks between years because the interpretation of bank instability is dependent upon multiple criteria and bank erosion (active sloughing) is rarely visible during summer surveys. Larger calculated differences between years in certain reaches likely reflect real differences.

Pools - Pools were identified and mapped based on the following:

- Pool type (primary or backwater)
- Forming feature (wood-, riprap/structure-, bedrock-, or free-formed)
- Maximum depth (at least 1.0 m deep, measured to nearest 0.01 m with stadia rod)
- Tailout depth (nearest 0.01 m)
- Residual depth (at least 0.4 m, calculated by subtracting tailout depth from maximum depth)
- Pool surface area (nearest 0.1 m²)
- Dominant fish cover type (visually determined as wood, rock, vegetation, debris, other)
- Fish cover area (visually as none, 0-10%, 10-40%, 40-75%, >75% of surface area).

Results from 2011 were compared to pool values from 2002. The protocols for pool measurement were identical between years, though in 2002, primary and backwater pools were not separately recorded, nor was fish cover type and area. The frequency distribution of pool characteristics between years were evaluated using goodness of fit testing (Statsoft, 2012) based on the null hypotheses that 2011 distributions are the same as 2002 distributions.

Other off-channel habitats within the floodplain may be totally separated from mainstem flow in summer, but are connected and provide access and habitat opportunities in winter and spring, as “ponded” areas (Pess et al., 1999). These locations may not have easily identifiable gravel-bedded channel inlets and outlets (Figure 2) for field-based demarcation. This inventory does not attempt to estimate or summarize the total amount of all possible off-channel rearing area within the floodplain that would also vary considerably depending on flow stage. Furthermore, this report does not provide the needed information to estimate total or relative side-channel changes (gains/losses) by reach over time and at specific locations that would be important for estimating restoration potential.

Large Woody Debris (LWD) – Woody debris, defined as pieces ≥ 2 meters long and ≥ 10 cm in diameter (e.g., Schuett-Hames, Pleus, Ward, Fox and Light, 1999) was classified and inventoried in mainstem and side channels within sub-sampled reaches. Jam identification was based on the Snohomish County protocol for woody debris jams (Rustay, Leonetti, Haas, Purser and Gaddis, 2008), which requires at least 3 pieces of large woody debris ≥ 7.6 meters long (≈ 15 feet) and ≥ 30 cm (≈ 12 inches) in diameter (based on USFS, 1998). The following wood jam data were collected:

- LWD jams were mapped (GPS location) and counted
- Jams were identified by type (Bar Apex, Meander or Bar Top jam (Abbe & Montgomery, 2003))
- Jam channel position was recorded (in-channel-wet, on gravel bar-dry, on vegetated bar, on bank or at base of forested island)
- Jam base area (footprint) was measured along multiple axes to estimate area or was determined by creating a GPS polygon area
- Jam height was measured based on visually estimating the average jam surface elevation and measuring that height on a stadia rod above the lowest identifiable gravel surface elevation
- Jam volume (m³) was calculated based on jam base area and jam height ($l \times w \times h$).

Additionally, in 2002, 21 wood jams were inventoried for LWD piece count and wood characteristics (length, diameter, root wad, wood type, and decay class) in addition to the jam size measurements. In 2011, individual pieces of woody debris in jams were not counted or inventoried for composition and characteristics. Rather, in 2011, the jam inventory data from 2002 and other Snohomish County rivers were used to develop a linear relationship between jam area and volume and piece number (see Appendix C). This relationship was used to estimate the count of woody debris pieces in jams in 2011.

For individual pieces of wood not contained in jams, field crews visually determined diameter and length class. Many pieces were measured, particularly at size class breaks. The following data were collected for individual wood pieces:

- LWD piece diameter class (10-30cm, 30-60cm, 60-90cm, >90 cm)
- LWD length class (2-7.6 m, 7.6-15m, >15m)
- Rootwad (≥ 1 meter circumference) – Yes/No
- Wood type – Deciduous, Conifer, or Unknown
- Wood decay status – Old, Intermediate, New

The frequency distribution of woody debris piece size characteristics between years were evaluated using goodness of fit testing (Statsoft, 2012) based on the null hypotheses that 2011 distributions are the same as 2002 distributions.

Results and Discussion

Channel and Inventory Area

Reach length and bankfull width, surveyed lengths, and calculated wetted survey area for 2011 are included in

Table 3. Some results from 2002 are also included for comparison. The surveyed reach length ranged from 28.5% 100% of the total reach length. The 2011 total survey length was approximately 1.1% less than in 2002, primarily due to mainstem channel reduction in NF5 and NF6. The calculated 2011 total wetted survey area was approximately 10.7% less than 2002. This difference would have been greater except that NF 3 and NF5 were sampled during higher flows (). NF5 had greater surface area in 2011 than 2002, due to the higher flow stage and increased surface area near and upstream from the 2006 Steelhead Haven landslide. The difference between years for NF3 was negligible, but NF3 was sampled at the highest flow level during the summer survey period in 2011 (Figure 1).

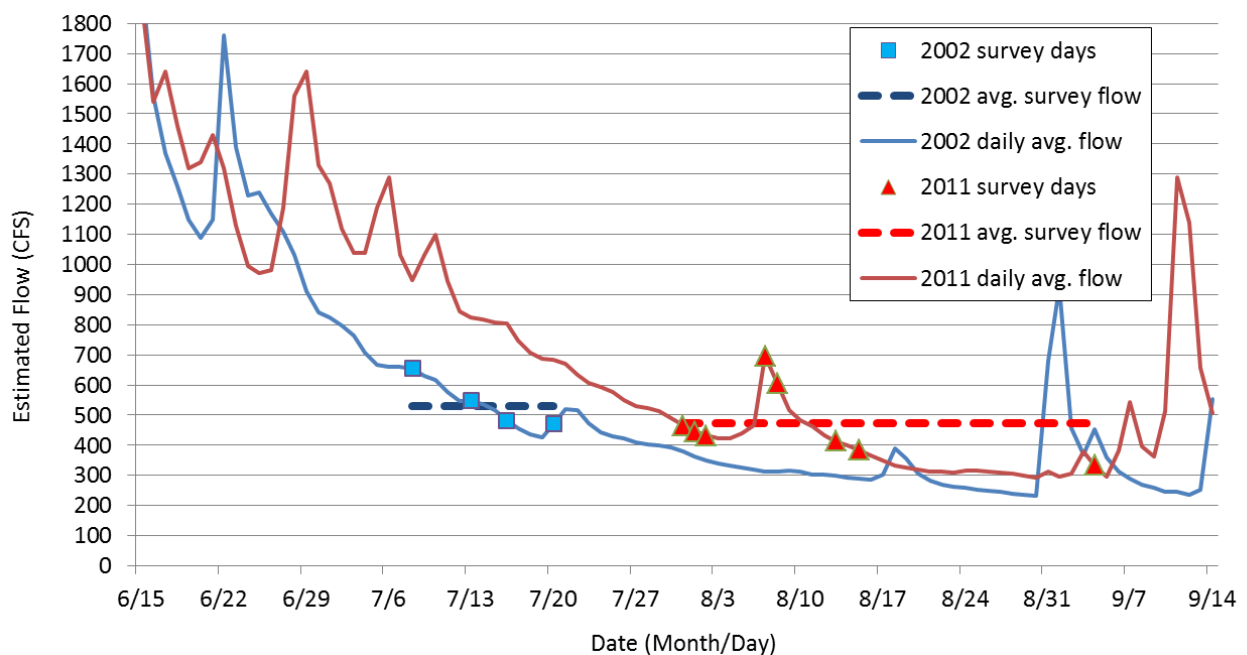


Figure 3: Estimated daily mean flow (cubic feet per second) in 2002 and 2011 from USGS gage 12167000 NF STILLAGUAMISH RIVER NEAR ARLINGTON, WA. Field survey sample days for each year are shown, as is the average flow for sample days in each year (dashed lines).

Table 3: NF Stillaguamish River reach characteristics, survey length and area by year. Bolded values are the larger survey area between years.

Reach	Reach boundary		Reach length, (m)	Bankfull width, avg. (m)	Surveyed length (m)		Wetted survey area(m ²)	
	Up	Down	2011	2011	2002	2011	2002	2011
NF7	Squire Creek	Between Segelsen & Fortson	4,860	40.0	2,602	2,641	64,357	58,914
NF6	Between Segelsen & Fortson	Boulder River	6,720	45.3	2,981	2,630	68,684	57,772
NF5	Boulder River	Rollins Creek	7,890	73.5	3,748	3,552	130,855	150,023
NF4	Rollins Creek	Deer Creek	7,320	60.5	2,087	2,087	75,849	69,654
NF3	Deer Creek	Grant Creek	8,770	82.7	5,412	5,481	225,958	228,213
NF2	Grant Creek	Whitehorse crossing	11,260	80.3	7,107	7,122	258,798	195,218
NF1	Whitehorse crossing	NF/SF confluence	3,882	72.0	3,858	3,882	147,779	117,536
Total			50,702		27,795	27,395	972,280	877,330

Flow

Gage data from the NF Stillaguamish River showed that daily average flow (cubic feet per second) in summer 2011 was higher than 2002 (Figure 3). However, in 2002, field sampling occurred earlier in the summer, which resulted in lower average daily flows during survey days in 2011 compared to 2002.

Annual peak flow was graphed for the NF Stillaguamish River for the period of record. The 2002 and 2011 survey years are highlighted in Figure 4 as red circles. The five highest peak flows on record by water year (October 1-September 30) occurred between the 2002 and 2011 sample years. Higher peak flows can increase bank erosion, alter channel alignment and flow routing, mobilize streambeds, and increase woody debris recruitment and transport.

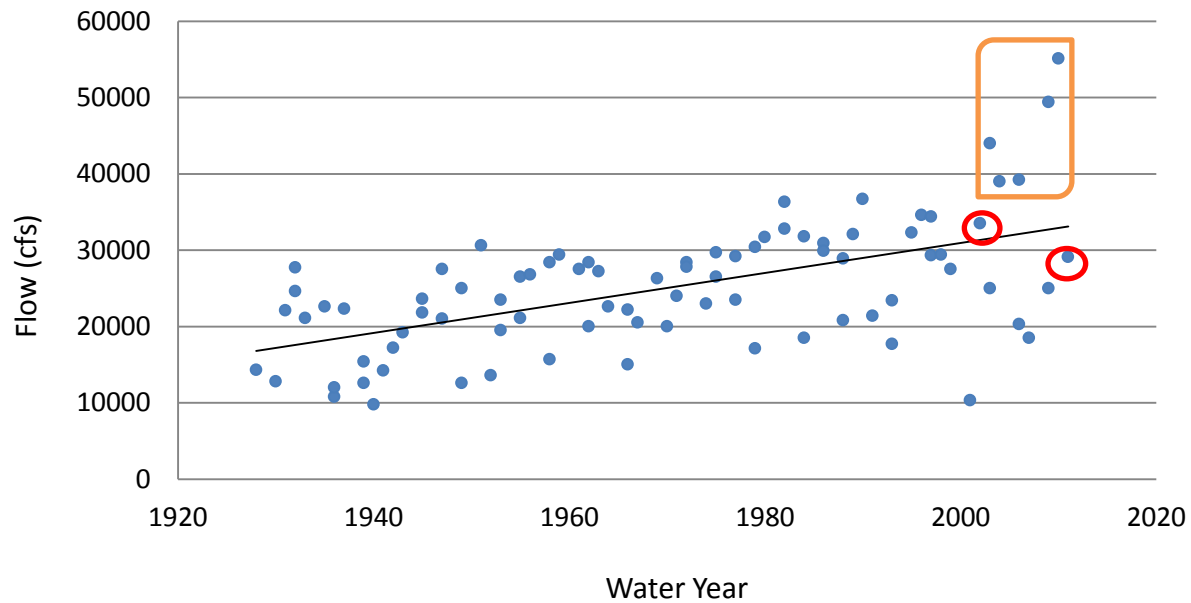


Figure 4: Estimated water year peak annual flow by year for USGS 12167000 NF STILLAGUAMISH RIVER NEAR ARLINGTON, WA. Survey years 2002 and 2011 are shown with red circles. Annual peak flows between sample years are highlighted in orange polygon.

Bank Conditions

2011 aerial photos were used to map the alignment of the mainstem of the NF Stillaguamish River (Appendix B: Map Folio). Figure 5 highlights one location in NF6 where the alignment of the river changed. Total streambank length (combined right and left banks) and the percent total modified versus natural edge conditions are shown in Table 1. Total bank length did not change appreciably. An increase in total bank length within the same river miles would be indicative of increasing river sinuosity or increasing length of floodplain islands that split flow. Compared to 2002, the total length of natural stream bank decreased by more than two kilometers in 2011 (Table 4), even given the higher peak flow events. Most of the decrease occurred in NF5 because of the 2006 Steelhead Haven landslide that filled the previous channel and shortened the length of the river.



Figure 5: Example of 2002 river bank alignment (brown lines) versus 2011 alignment (yellow/ green lines). 2011 river banks are coded as natural/stable (green) and natural/unstable (yellow).

Unlike natural streambanks which are composed of earth or gravel, modified streambanks in the NF Stillaguamish are composed of, in order of occurrence, riprap (and rubble), structural (e.g., bridge footings/piers), and bank-placed anchored wood (Table 4). The proportion of modified streambank increased between years in all reaches except NF6 (Table 4). NF2 and NF3 were the most modified river reaches by percent of total length. The length of riprap increased in all reaches except NF6, where a long rock revetment eroded away. Placed wood also increased in NF6, at the new channel inlet to the side channel restoration at Blue Slough. It is unclear whether the increased riprap in NF2 and NF3 is due to new riprap placement or to channel migration that exposed riprap at historical locations. In NF5, a large increase in bank modification is mostly due to the large wood crib wall constructed after the 2006 Steelhead Haven landslide that was approximately 530 meters in length.

Table 4: River reach and total length in meters of streambank toe material in 2002 and 2011.

Reach	Earth/Natural			Rip Rap			Structural		Wood	
	2002	2011	Diff	2002	2011	Diff	2002	2011	2002	2011
NF7	5,367	5,351	-17	320	428	108	27	22	0	0
NF6	12,249	12,598	349	1,559	1,082	-477	0	0	0	59
NF5	14,920	13,847	-1,073	1,123	1,299	176	0	473*	0	57
NF4	12,966	12,892	-74	1,879	1,957	79	0	0	0	0
NF3	14,215	13,740	-474	3,161	3,585	424	0	47	0	0
NF2	18,569	17,804	-765	3,359	4,247	887	0	0	0	0
NF1	7,235	7,043	-193	417	500	83	0	0	0	0
Total**	85,522	83,275	-2,247	11,818	13,098	1,280	27	542	0	115

*Steelhead Haven wood crib wall. ** Right and left streambank total.

Unstable banks are either natural eroding streambanks or failing bank modifications. Bank instability decreased in NF4 and NF7 while bank instability increased in all other reaches except NF2, which had no change (Table 5). NF6 had the largest overall change with a 6% increase in unstable banks. This was due in part to erosion and loss of a long rock revetment as mentioned above that likely occurred during one or more of the peak flows between sample years. Appendix B: Map Folio shows bank conditions in 2011 in map view.

Table 5: Streambank condition and instability ratings as percent of river reach length in 2002 and 2011. Shaded values do not yet meet the desired future conditions from Table 2. Bolded values reflect changes in status that now meet desired future conditions.

Reach	Length of Bank (km)		Modified			Natural			Unstable Bank		
	2002	2008, 2011	2002	2008, 2011	Change	2002	2008, 2011	Change	2002	2008, 2011	Change
NF7	5.8	5.8	7.1%	7.7%	0.7%	92.9%	92.3%	-0.7%	31%	28%	-3%
NF6	13.8	13.7	11.3%	8.3%	-3.0%	88.7%	91.7%	3.0%	22%	28%	6%
NF5	16.0	15.7	7.0%	11.7%	4.7%	93.0%	88.3%	-4.7%	23%	25%	2%
NF4	14.8	14.8	12.7%	13.2%	0.5%	87.3%	86.8%	-0.5%	15%	14%	-1%
NF3	17.4	17.4	18.2%	20.9%	2.7%	81.8%	79.1%	-2.7%	13%	15%	2%
NF2	21.9	22.1	15.3%	19.3%	3.9%	84.7%	80.7%	-3.9%	12%	12%	0%
NF1	7.7	7.5	5.5%	6.6%	1.2%	94.5%	93.4%	-1.2%	8%	11%	3%
Total	97.4	97.0	12.2%	14.2%	2.0%	87.8%	85.8%	-2.0%			

Differences in streambank location between 2002 and 2011 based on GIS mapping were used to estimate total erosion area. GIS mapping identified 66 locations where lateral channel erosion could be measured (Table 6). In total, approximately 84.2 acres eroded. NF5 AND NF6 had the largest number of erosion locations and the most area eroded (Table 6). A large part of the total eroded area in NF5 and NF6 was due to the new channel alignment and left bank erosion after the 2006 Steelhead Haven landslide. Approximately 60% of the channel erosion occurred upstream of NF4 (Table 6), which totaled only about 39% of the river length (Figure 6). NF5, NF6 and NF7 had higher streambank instability (%) and higher erosion rates whereas NF1, NF2, NF3 and NF4 had lower erosion rates and a higher percentage of modified streambank. Locations of lateral channel erosion are identified in Appendix B: Map Folio. Erosion was not quantified in side channels, but may have affected results (next section).

Table 6: Count and area of lateral erosion by reach in 2011 and cumulative distribution of erosion areas.

Reach	Count of Erosion Locations	Acres Eroded	Average Acres per Area	Standard Deviation of Average	Acres Eroded/ Channel Area (%)	Cumulative Downstream Distribution
NF7	8	4.7	0.6	0.5	9.7	0.1
NF6	17	17.3	1.0	0.6	23.0	0.3
NF5	14	27.1	2.3	3.3	18.9	0.6
NF4	6	3.8	0.6	0.6	3.4	0.6
NF3	9	13.2	1.5	1.4	7.4	0.8
NF2	9	16.1	1.8	2.2	7.2	1.0
NF1	3	2.1	0.7	0.7	3.1	1.0
Total	66	84.2				100%

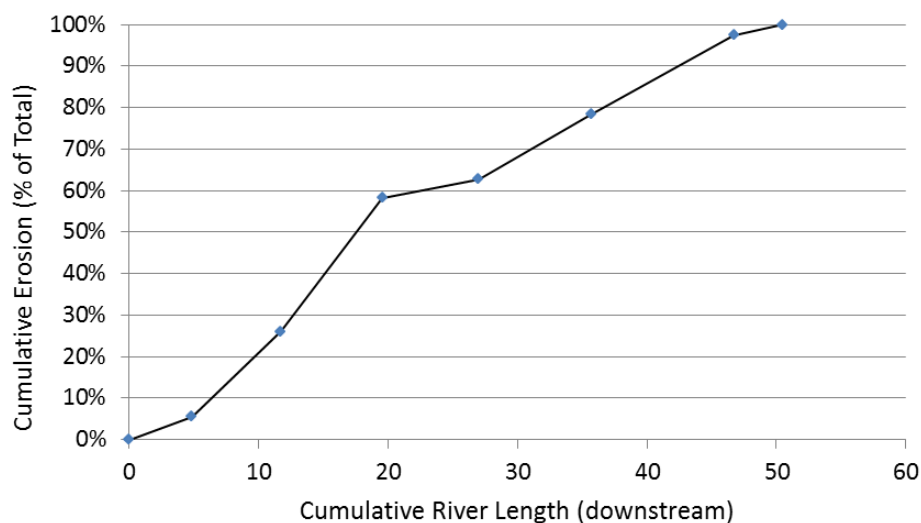


Figure 6: Cumulative total erosion (as % of total) from GIS mapping between 2003 and 2011 in downstream direction by river reach.

Side Channels

In 2002, 27 side channels totaling 12,269 meters were identified in the entire NF Stillaguamish River (not just the sampled reaches) (Table 7). Over half the side channels (15 out of 27) were in located in NF5 and NF6. Among the 27 side channels identified in 2002, 17 remained largely unchanged by 2011. 25 side channels were identified in 2011 in the entire NF Stillaguamish River (not just sampled reaches). While

the total side channel count changed little by river reach between years, in the combined areas of reaches NF5, NF6, and NF7, eight new side channels were identified and seven side channels were lost, reflecting more dynamic channel responses here than elsewhere (Table 7). In NF5 and NF6 combined, side channel length increased by 36% over the 2002 amount. The total estimated side channel length increased slightly in 2011 (Table 7) to 12,918 m. In the combined area of NF1, NF2, NF3, and NF4, there was a decrease in side channel count and a corresponding 23% decrease in total side channel length.

Table 7: Side channel characteristics by reach in 2002 and 2011.

Reach	Reach length (m)	Side channel count		Same side channels in 2011 Count	Gain/Loss Count	Side channel length (m)		SC length/mainstem length (%)	
		2002	2011			2002	2011	2002	2011
NF7	4,860	1	1	0	1/-1	331	244	6.8	5.0
NF6	6,720	9	11	7	4/-2	3,431	4,766	51.1	70.9
NF5	7,890	6	5	2	3/-4	2,480	3,286	31.4	41.6
NF4	7,320	0	0	N/A	N/A	0	0	0.0	0.0
NF3	8,770	5	4	4	0/-1	2,612	2,065	29.8	23.5
NF2	11,260	5	4	4	0/-1	2,815	2,558	25.0	22.7
NF1	3,882	1	0	0	0/-1	600	0	15.5	0.0
Total	50,702	27	25	17	8/-10	12,269	12,918	24.2	25.5

Wood Jams and Individual Woody Debris

Total wood abundance decreased in 2011 relative to 2002, primarily due to a decline of natural log jams, from 42 jams in 2002 to 27 jams in 2011 (Table 8). All three jam types - bar apex, bar top and meander (see Appendix D: Miscellaneous Data Tables) – declined in 2011, particularly bar apex jams. Of note, among the 19 constructed log jams in NF5 and NF6 (as of 2014), only one was located in the sub-sampled reaches. In 2011, 12 out of 27 jams were in contact with the low flow channel, which means they likely provide cover at low flow, scour functions at higher flow, and may resist peak flow events.

Between 2002 and 2011, the average size of wood jams decreased in area and estimated volume by approximately 26% (Table 8). Of the 27 jams identified in 2011, seven were in the same locations as in 2002. Among these seven jams, three jams increased in area by a combined 508 m². However, the other four jams decreased in area by a combined 4,050 m². Of 46 jams originally observed in the surveyed area in 2002, 39 were gone from their original location. This reflects a greater rate of jam loss than new jam formation between the sampled years.

In 2002, wood pieces in 15 of the 42 LWD jams were counted (245 pieces). Based on this effort and subsequent inventories of wood jams in the Skykomish and Sauk rivers (Snohomish County, unpublished data), a linear relationship between jam size and piece count was developed (see Appendix C: Wood jam size and piece count relationship). Based upon this linear relationship and a 90% confidence interval, the remaining 27 jams identified in 2002 had between 656 and 727 pieces. In total, an estimated 898-970 wood pieces were in the 42 LWD jams in 2002. In 2011, based on measuring the area of jams and relationship above, the estimated count of LWD in jams was 347-385 pieces.

Table 8: Wood jam abundance, frequency, average size, and count by jam type in 2002 and 2011.

Reach	Mainstem survey length (m)		Total Jam Count		Jam frequency (jams/km)		Average Jam size (m ²)		Average Jam volume, estimate (m ³)	
	2002	2011	2002	2011	2002	2011	2002	2011	2002	2011
NF7	2602	2641	5	5	1.9	1.9	384	236	849	499
NF6	2981	2630	16	12	5.4	4.4	452	314	669	449
NF5	3748	3552	8	3	2.1	0.8	153	224	251	543
NF4	2087	2087	2	0	1.0	0.0	205	0	222	0
NF3	5412	5481	2	5	0.4	0.9	514	138	1037	225
NF2	7107	7122	2	1	0.3	0.1	696	237	1568	852
NF1	3858	3882	7	1	1.8	0.3	220	N/R	604	N/R
Total / Average	27,795	27,395	42	27	1.5	1.0	365.1	251.9	628.1	441.8

Individual wood pieces increased by 63% from 2002 to 2011, from 346 to 565 pieces (Figure 8). There was a consistent increase in piece count within most reaches and there was an increase in piece count for all but one LWD size class (diameter and length; Figure 9 and Figure 9). However, small diameter pieces (<30 cm) disproportionately increased in frequency relative to larger pieces (Figure 9; Chi-square test of observed vs. expected diameter class frequencies: Chi-Square=28.98, degrees of freedom (df) = 7, p = 0.00014; Statsoft, 2012). This indicates that smaller pieces were a greater proportion of the total in 2011 than in 2002.

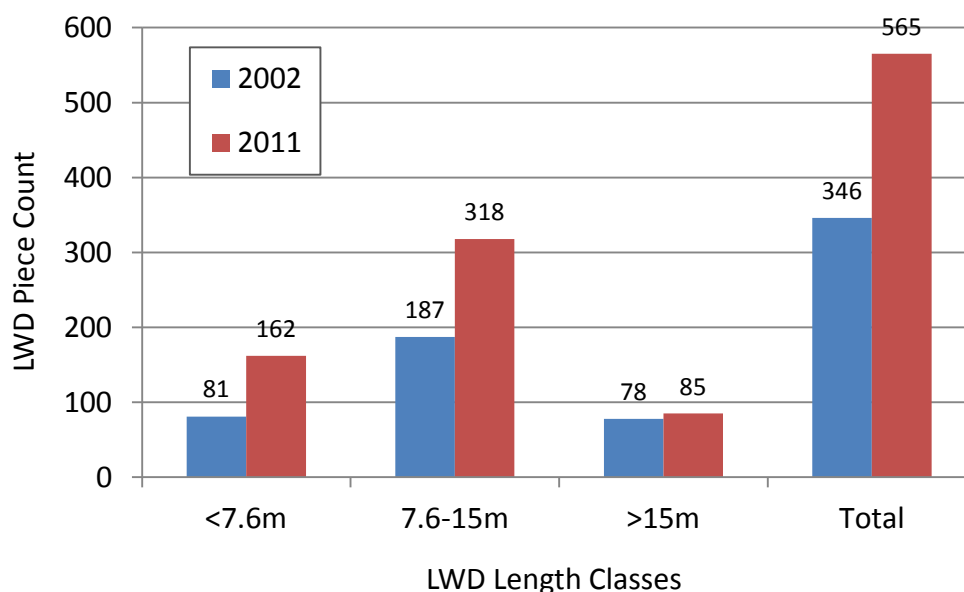


Figure 7: Individual LWD piece count by river reach. Total does not include wood in jams.

As with diameter, LWD count among length classes increased overall (Figure 10) between 2002 and 2011, with pieces less than 15 meters increasing the most. However, the composition of length class frequency was not significantly different from 2002 (observed vs. expected frequencies: Chi-Square = 9.166, df = 5, p = 0.103).

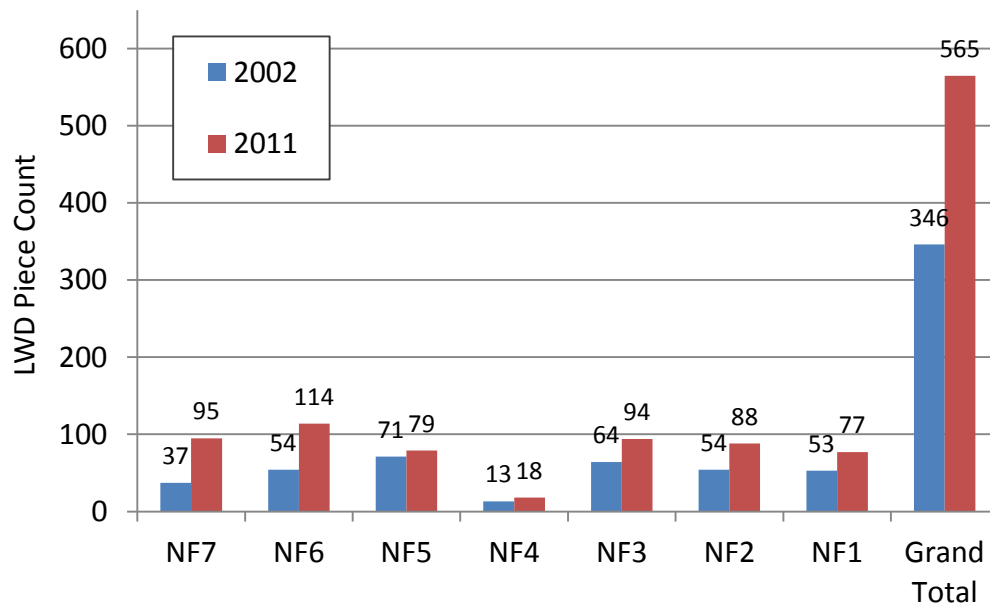


Figure 8: Individual LWD piece count by reach. Total does not include wood in jams.

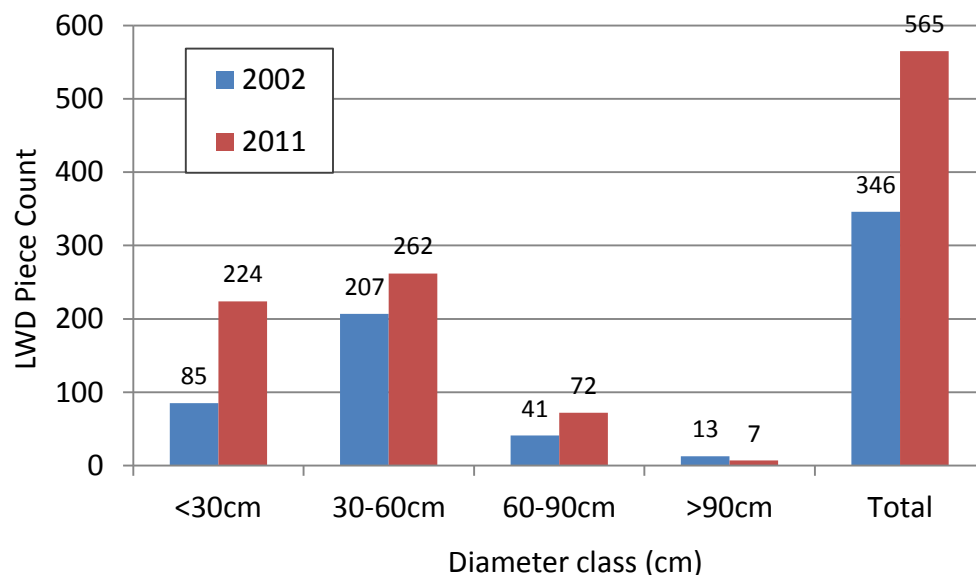


Figure 9: LWD piece count by diameter class. Total does not include wood in jams.

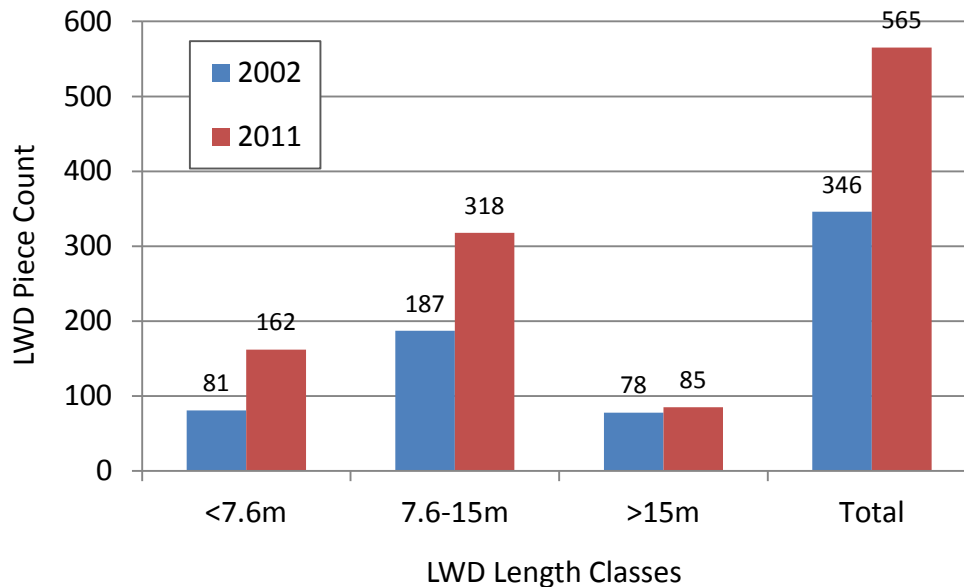


Figure 10: LWD piece count by length class. Total does not include wood in jams.

Key pieces of LWD, a metric used in the SSRP to describe desired future conditions, are those with a length of >15m (≈50ft) and a diameter of >60cm (≈24 inches). Although the total count of all individual wood pieces increased by >63% between 2002 and 2011, the count of these largest pieces actually decreased from 20 to 16 pieces in the survey area (Table 9). The sum of other large pieces (>30cm/>7.6 m) increased by only 10% (Table 9). Including the count of 16 large pieces and an estimate of 22 large key pieces in jams, the total estimate of large key pieces in the NF Stillaguamish River survey area in 2011 is 38 pieces or 2.2 pieces per mile surveyed. This estimate is less than in 2002 and less than the desired future condition of 80 pieces per mile (Table 1).

Table 9: Individual piece count of large LWD size classes in 2002 and 2011 by National Marine Fisheries Service (NMFS) definition (1996).

Reach	≥30 cm diam./ ≥7.6 m length		≥60 cm diam./ ≥15 m length (NMFS)	
	2002	2011	2002	2011
NF7	24	30	1	4
NF6	44	52	11	4
NF5	38	32	3	1
NF4	2	7	0	0
NF3	28	47	3	4
NF2	34	35	2	2
NF1	43	32	0	1
Sub-total	213	235	20	16
Key Pieces in Jams			23*	22**
Total Key Pieces Estimate			43	38
Key pieces/mile surveyed				2.2

*The estimate in 2002 is based on a count of 6 key pieces in 18 sampled jams and an estimate of 17 pieces in 24 unsampled jams, which on average were individually 80% larger (m²) than sampled jams.

**The estimate of 22 key pieces among all estimated wood in jams is based on the fraction of key pieces among 2011 single pieces and the assumption that the 2002 observation of no difference in piece size diameter between jams and single pieces in the NF Stillaguamish River is still valid (Haas et al., 2003).

After the 2006 Steelhead Haven landslide, an LWD crib-wall was constructed on site. Although 136 LWD pieces were counted here, these were not included in the final count of individual pieces discussed below, as they were identified by the Stillaguamish Tribe as a constructed log jam in the NF Stillaguamish (and accounted separately). Elsewhere, eight other individual pieces, apparently placed as part of older bank stabilization treatments, were included in the final count of the individual pieces.

The combined estimate of LWD in jams and individual pieces in all reaches surveyed in 2002 was **1,244-1,316 pieces** (346 individual pieces and 898 to 970 in jams).

The combined estimate of LWD in jams and individual pieces in all reaches surveyed in 2011 was **912 - 950 pieces** (565 individual pieces and 347 to 385 in jams).

The total abundance of LWD in surveyed reaches in 2011 appears to be less than in 2002 by approximately 28%, primarily due to fewer and smaller LWD jams. Even if the 136 LWD pieces tallied at the Steelhead Haven wood crib wall are added to the total estimate in 2011, the maximum combined total (1,086 pieces) is still less than the minimum estimate of total LWD in 2002 by 158 pieces.

In 2011, woody debris had an older decay status (conifer and deciduous type trees combined) in most reaches (Table 10) compared to 2002. In reaches NF3, NF5, and NF3 there was an increase in the proportion of new wood in 2011 compared to 2002; however, these same reaches had a greater fraction of old wood as well. It is possible that woody debris in 2011 was rated “older” due to changes in field personnel and undetermined bias relative to 2002. Although the lead field staff was the same in 2002 and 2011, and training occurred with respect to protocol, this uncertainty remains.

Lastly, the composition of LWD as conifer trees did not change appreciably. However, the subtle increase in conifer composition in downstream reaches (NF1, NF3, NF4, and NF5) suggests there was downstream transport of older conifer pieces. In both years, 86% of individual pieces had rootwads.

Table 10: LWD wood characteristics (% of composition) by reach in 2002 and 2011 (bolded values). Total does not include wood in jams. Percent conifer wood type excludes “old” decay class.

Reach	Diameter class (%)								Decay class (%)						Wood type (%)	
	<30 cm		30 - 60 cm		60 - 90 cm		>90 cm		New		Inter-mediate		Old		Conifer	
Year	'02	'11	'02	'11	'02	'11	'02	'11	'02	'11	'02	'11	'02	'11	'02	'11
NF7	30	49	57	34	11	16	3	1	41	32	54	27	5	41	21	5
NF6	11	34	59	49	22	16	7	1	37	44	43	22	20	34	35	17
NF5	25	43	54	44	17	11	4	1	39	44	44	20	17	35	19	21
NF4	77	33	23	56	0	11	0	0	62	28	38	39	0	33	8	36
NF3	34	36	48	46	11	16	6	2	56	61	38	29	6	11	25	34
NF2	31	50	61	43	7	7	0	0	61	47	37	33	2	20	11	6
NF1	2	26	92	62	4	9	2	3	30	19	42	26	28	55	16	23
Total	25	40	60	46	12	13	4	1	45	42	42	27	13	31	20	20

Pools

Total pool count increased from 107 pools in 2002 to 120 pools in 2011, declining by 6 pools in the combined reaches of NF5, NF6, and NF7 and increasing by 19 pools in the combined area of NF1, NF2, and NF3 (Table 11). Total pool area increased in 6 of 7 reaches and 26.5 % overall (Table 11). In 2011, backwater pools were specifically identified and spatially located. Backwater pools (within the mainstem reaches) were most common in NF3 and NF6, and by area were most abundant in NF6 (Table 11). It is not known whether backwater pools were more numerous in 2011 compared to 2002. In NF5, total pool count and total length of pools decreased the most in part due to the 2006 Steelhead Haven landslide that filled approximately 667 linear meters of the river. However, as a result of pool formation against the constructed right bank wood crib wall, average pool wetted area, maximum depth, residual depth and total pool area increased more than in any other reach (

Table 12). Elsewhere, mean maximum depth, mean residual pool depth, and mean wetted pool area generally increased in comparison to 2002 (

Table 12). As a result, the percent pool area among all habitat types increased by 9.8% in the surveyed area.

The residual pool depth is a flow-independent measure of pool depth, representing the vertical difference between the pool bottom and the downstream pool tailout (or riffle crest). The residual pool depths between years were compared using a Mann-Whitney-U rank test (Statsoft, 2012), which does not require assumptions of normal population distribution to be met. There was no significant difference between 2002 and 2011 for residual pool depths (U=5710; p=0.15; at alpha level 0.05 for all tests), although pools generally were deeper in 2011 (

Table 12).

Table 11: Pool characteristics for reaches in 2002 and 2011. Shaded values represent the larger of the results. The effects of pool width on pool area were not evaluated.

Reach	Pool count ('11 Primary/Backwater)		Sum pool lengths (m)		Pool Area, Total (m ²)		Pool Area, % of survey area		% Back water pools, by pool area	Pool frequency /km	
	'02	'11	'02	'11	'02	'11	'02	'11		'02	'11
7	20	17/ 1	1460	1189	29,153	22,391	42.0	40.3	0.6	7.7	6.8
6	20	16/ 7	946	1298	25,135	25,635	36.6	44.3	11.5	6.7	8.7
5	21	12/ 2	1237	838	25,954	28,040	17.8	19.0	0.7	5.6	3.9
4	4	4/ 0	255	336	5,628	6,731	7.4	9.7	0.0	1.9	1.9
3	16	12/ 7	2229	2124	48,947	67,238	21.9	30.0	7.2	3.0	3.6
2	19	30/ 1	2875	3799	70,719	98,808	27.1	50.6	1.2	2.7	4.4
1	7	10/ 1	1241	1704	32,355	52,036	21.5	44.3	0.2	2.1	2.8
Total	107	101/ 19	10,243	11,289	237,891	300,878	24.5	34.3	3.2	3.8	4.4

Table 12: Pool summary characteristics (mean and standard deviation) by reach in 2002 and 2011. Shaded values represent the larger results.

Reach	Mean max depth (m)		Std. dev. max depth (m)		Mean residual depth (m)		Std. dev. residual depth (m)		Mean wetted area (m ²)		Std. dev. wetted area (m ²)	
	2002	2011	2002	2011	2002	2011	2002	2011	2002	2011	2002	2011
NF7	1.6	1.8	0.6	0.7	1.2	1.3	0.6	0.7	1,458	1,244	1,299	1,029
NF6	1.7	1.8	0.6	0.5	1.2	1.2	0.5	0.5	1,257	1,115	1,328	1,247
NF5	1.6	2.0	0.4	0.9	1.0	1.5	0.4	0.8	1,236	2,003	1,140	2,944
NF4	1.8	1.8	0.7	0.8	1.1	1.3	0.7	0.7	1,407	1,683	1,064	1,865
NF3	1.9	1.9	0.6	0.7	1.3	1.3	0.6	0.6	3,059	3,388	2,394	3,914
NF2	2.4	2.2	0.6	1.0	1.7	1.6	0.7	0.9	3,722	3,187	1,969	2,934
NF1	2.3	2.5	0.7	0.8	1.5	1.8	0.8	0.8	4,622	4,731	1,183	4,569

The frequency distribution of pool maximum depth, tailout depth, and residual pool depth between years were plotted (Figure 12 and Figure 13) and a Chi-square test (Statsoft 2012) was used to evaluate the difference between the expected and observed pool depths. The expected frequency distribution in 2011 was the same as the observed frequency distribution in 2002 and no difference between years was expected. In 2011, the frequency distribution of maximum depths and residual pool depths were not significantly different from 2002 (Figure 12 and Figure 13). However, the frequency distribution of pool tailout depths was significantly deeper (Figure 14). The significant shift in pool tailout depths (Figure 14) was primarily at 0.6 meters, where the frequency doubled. The results suggest the deeper maximum and tailout water depths may have been due to higher flow stage on a couple of sample dates in 2011 or more incised (v-shaped) thalweg.

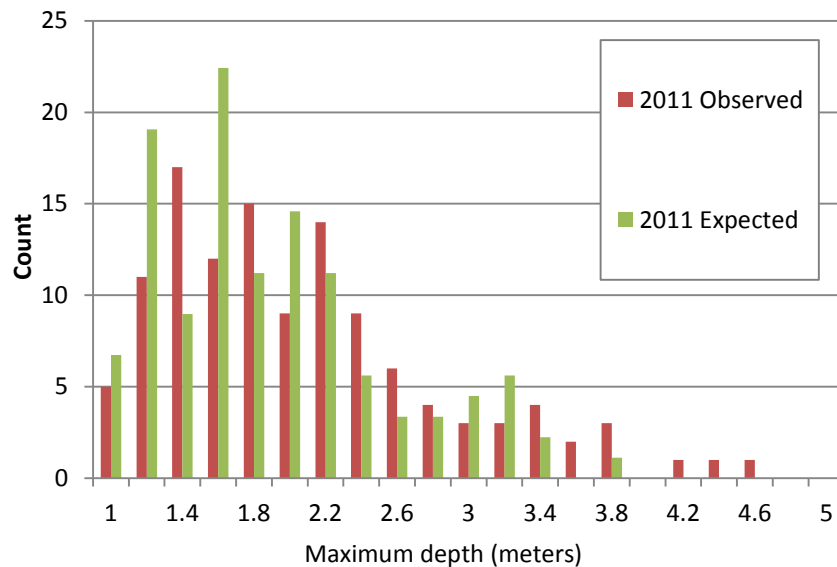


Figure 11: 2011 observed and expected count for pool maximum depth (Chi-Square=30.5 df=20 p= 0.06).

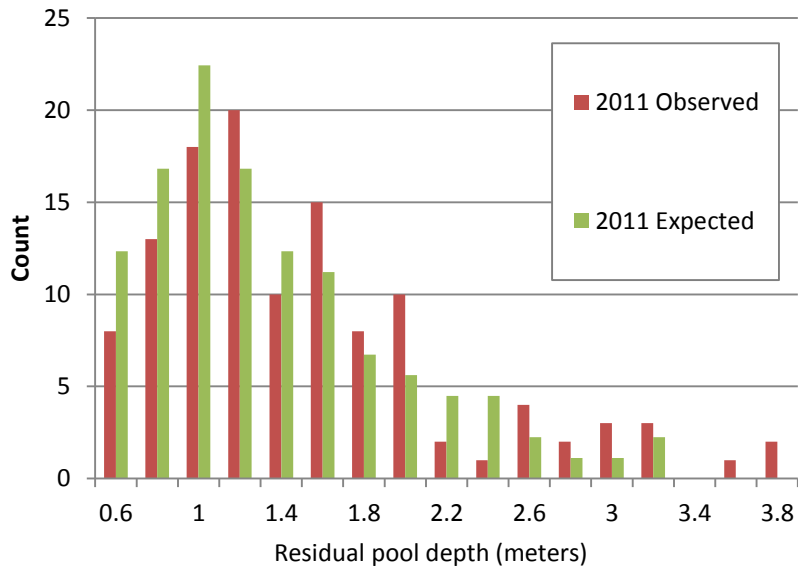


Figure 12: 2011 observed and expected count for residual pool depth (Chi-Square=18.8 df=16 p= 0.28).

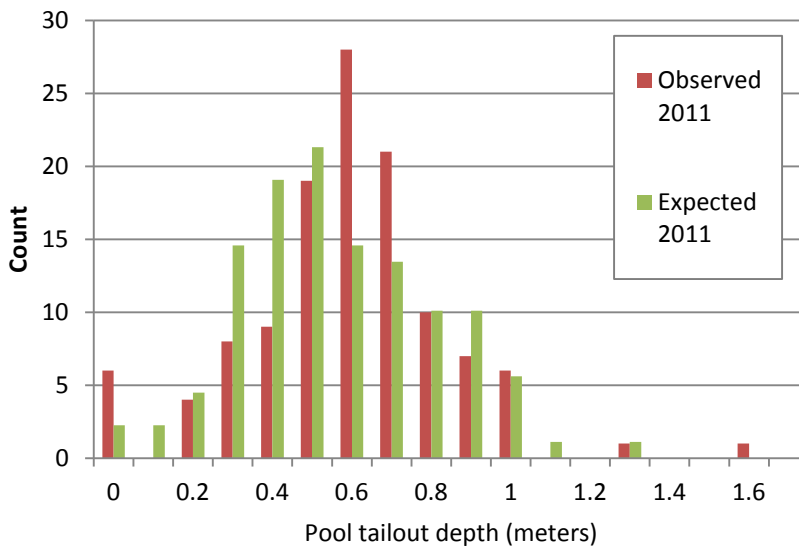


Figure 13: 2011 observed and expected count for pool tailout depth (Chi-Square=35.8 df=17 p= 0.005).

Pools were grouped into one of four categories based on forming factor: wood-formed, free-formed, bedrock-formed, or riprap-formed. Between 2002 and 2011, the count of wood-formed pools increased the most, particularly in combined area of NF1, NF2, and NF3, which increased from 4 to 16 wood-formed pools (

Table 13). Wood-formed pools increased from one-quarter to approximately one-third of all pools in 2011 and were more represented among backwater pools (50%) than primary pools (30%). Bedrock and riprap-formed pools also increased in total count (

Table 13). Free-formed pools were the only pool-forming type to decline in number.

Table 13: Pool count by pool forming features by reach in 2002 and 2011.

Reach	Bed rock		Free form		Rip rap		Wood		Totals	
	2002	2011	2002	2011	2002	2011	2002	2011	2002	2011
NF7	6	7	4	3	3	1	7	7	20	18
NF6	0	0	6	7	5	4	9	12	20	23
NF5	4	2	6	1	3	6	7	4	21	14*
NF4	2	2	1	0	1	2	0	0	4	4
NF3	2	6	5	3	7	5	2	5	16	19
NF2	3	5	1	1	13	16	2	9	19	31
NF1	4	3	2	2	1	4		2	7	11
Totals	21	25	25	17	33	38	27	39	107	120
% Total by year count	19.8	20.8	23.6	14.2	31.1	31.7	25.5	32.5		

*Total includes one pool with no pool forming factor listed

Total pool area increased for all pool types, especially wood-formed pools, which increased by 165% compared to 2002 (Table 14). The area of pools formed by wood made up 7% of all pool area in 2002 and 14% of all pool area by 2011, even though they were the smallest among all pool types in both years. This increase was due to both the increase in the number of wood-formed pools and the larger average size of wood-formed pools in 2011 (Table 15).

Riprap formed pools increased in individual average size by 16% and in total area by 33% (Table 15) in 2011 compared to 2002. As a result, riprap pools accounted for approximately 58% of the increase in total pool area between years. Compared to riprap-formed pools and wood-formed pools, bedrock- and free-formed pools did not change appreciably in total area, though bedrock-formed pools decreased in average size (Table 15) and free-formed pools decreased in overall count. As a share of total pool area in the NF Stillaguamish River, bedrock pools decreased by 21%, largely due to the relative increase in riprap- and wood-formed pools.

Residual pool depth increased on average between years (Table 16), but, as reported above, this did not represent a significant increase in the frequency distribution of residual depths. However, pool depths decreased on average for free-formed pools relative to bedrock-, riprap- and wood-formed pools. Among reaches, pool depth was less in Reach 2, on average, which reflects the increase in the relatively smaller wood-formed pools that were shallower on average in this reach.

Table 14: Total pool area in 2002 and 2011 by pool forming factor and difference between years by reach.

Reach	BEDROCK (m ²)		FREE FORM (m ²)		RIP RAP (m ²)		WOOD (m ²)		Grand Total	
	2002	2011	2002	2011	2002	2011	2002	2011	2002	2011
NF7	15,016	12,432	8,624	4,194	3,374	1,243	2,139	4,522	29,153	22,391
NF6	0	0	11,252	8,025	10,482	9,212	3,401	8,398	25,135	25,635
NF5	1,995	438	11,001	958	8,770	17,625	3,670	8,612	25,436	27,633
NF4	1,478	252	1,268	0	2,882	6,479	0	0	5,628	6,731
NF3	10,029	9,295	9,340	22,447	23,730	24,702	5,849	11,319	48,947	67,238
NF2	10,913	20,668	3,998	2,910	54,836	67,086	971	8,143	70,719	98,808
NF1	19,883	16,675	6,891	13,974	5,581	19,990	0	1,397	32,355	52,036
Total (m ²)	59,314	59,760	52,375	52,509	109,654	146,335	16,030	42,392	237,373	300,878
Difference in 2011		445		134		36,681		26,362		63,505
Increase/decrease, %		0.8		0.3		33.5		164.5		26.8

Table 15: Average pool size by pool forming factor in 2002 and 2011 and the difference (+/-) in mean pool area between years.

Reach	BEDROCK (m ²)		FREE FORM (m ²)		RIP RAP (m ²)		WOOD (m ²)		Grand Mean	
	2002	2011	2002	2011	2002	2011	2002	2011	2002	2011
NF7	2,503	1,776	2,156	1,398	1,125	1,243	306	646	1,458	1,244
NF6	0	0	1,875	1,146	2,096	2,303	378	700	1,257	1,115
NF5	499	219	1,833	958	2,923	2,937	524	2,153	1,272	2,126
NF4	739	126	1,268	0	2,882	3,240	0	0	1,407	1,683
NF3	5,015	1,549	1,868	7,482	3,390	4,940	2,924	1,886	3,059	3,388
NF2	3,638	4,134	3,998	2,910	4,218	4,193	486	905	3,722	3,187
NF1	4,971	5,558	3,446	6,987	5,581	4,997	0	699	4,622	4,731
Total (m ²)	2,824	2,390	2,095	3,089	3,323	3,851	594	1,060	2,239	2,508
Difference in 2011		-434		994		528		466		269
Increase/decrease, %		-15.4		47.4		15.9		78.5		12.0

Table 16: Average pool residual depth by pool forming factor in 2002 and 2011 and absolute difference in mean pool depth between years. Shading reflects the greater pool depth between years by reach for each pool type.

	BEDROCK (m)		FREE FORM (m)		RIP RAP (m)		WOOD (m)		Grand Mean (m)	
Reach	2002	2011	2002	2011	2002	2011	2002	2011	2002	2011
NF7	1.41	1.75	1.00	0.66	0.93	0.70	1.29	1.18	1.21	1.29
NF6	NA	NA	0.95	0.89	1.90	1.66	1.07	1.30	1.24	1.24
NF5	0.76	1.34	1.05	0.60	1.37	1.52	1.06	1.90	1.04	1.54
NF4	0.85	0.90	0.60	NA	2.15	1.73	NA	NA	1.11	1.31
NF3	1.65	1.22	1.40	1.47	1.26	1.55	0.95	1.25	1.31	1.35
NF2	1.62	1.34	0.70	0.83	1.90	2.16	1.05	0.86	1.70	1.61
NF1	1.78	2.18	0.55	1.10	2.30	2.03	NA	1.20	1.50	1.75
Total (m)	1.35	1.49	1.02	0.96	1.65	1.85	1.11	1.23	1.30	1.44
Difference in 2011		0.14		-0.06		0.20		0.11		0.14
Increase/decrease, %		10.1		-5.9		12.4		10.3		10.5

Conclusions

Comparison with 2002 Inventory

Table 17 (same as Table 1) summarizes changes in habitat conditions between 2002 and 2011 and provides an interpretation of the positive or negative change in habitat suitability for Chinook salmon. Further discussion of findings for each habitat feature follows.

Table 17: SSRP limiting factors, monitoring metric, and general changes in conditions between 2002 and 2011.

Limiting factor/ Assessment element	Monitoring metric	2011 inferred change since 2002	Positive ▲, Negative ▼, NC- no change
Bank Conditions	Length of riprap; % armored	More riprap	▼
	% length natural streambanks	Increase in NF6; Decreases in NF1-5 & NF7	▼
Side Channels	Side channel count	Fewer total	▼
	Side Channel length	Higher overall due to large increase in NF5 & NF6; Decreased length elsewhere	▲
Wood	Wood jam count/ frequency	Decreased overall; Increase in NF3	▼
	Wood jam type	Decrease in bar apex & meander jams.	▼
	Jam size	Decreased average jam size (footprint).	▼
	Individual wood piece count	Increased	▲
	Wood piece size, location, decay	Greater proportion of smaller pieces; Fewer key pieces; Downstream shift in piece locations; Older decay status	▼
	Estimated total wood load	Decreased	▼
Pools	Pool count	Increased in NF1-3, particularly NF2.	▲
	Pool count	Pool count decreased in NF5 due to the 2006 Steelhead Haven landslide.	▼
	Pool area (total & % area)	Substantial increase in total pool area in NF1-3 but could be flow related;	▲

Limiting factor/ Assessment element	Monitoring metric	2011 inferred change since 2002	Positive ▲, Negative ▼, NC- no change
		Minor changes elsewhere	
	Pool area (total & % area)	Decrease in total pool area and % pool area in NF5 and NF7; NF 6 increased in % area, but decreased in total pool area.	NC
	Wood pools	Increased number and area, most notably in NF1-3 and NF6.	▲
	Riprap pools	Increased by count and total area; Accounts for 58% of increase in pool area	▼
	Pool depth, all	Generally no change in residual pool depths; NF5 had deeper pools; Wood-formed pools in NF2 quadrupled; Pool depth was shallower	NC
	Pool size	Average pool size increased	Unk.

Bank Conditions

The desired future condition for streambanks in the SSRP are ≤ 10% bank armoring by reach and 90% natural edge habitat by reach. In 2002, reaches NF1, NF5, and NF7 met the goals while in 2011, reaches NF1, NF6, and NF7 meet the goals. In 2011, NF5 had 11.7% modified and 88.3% natural bank, due to the increase in bank armor placed on the left bank after the 2006 Steelhead Haven landslide.

Overall, bank conditions show negative trends between 2002 and 2011 as the length of bank armor along the mainstem channel increased while the percent of natural edge length decreased. The amount of natural streambank decreased in reaches NF1, NF2, NF3, NF4, NF5 and NF7 which is inconsistent with SSRP targets and habitat suitability. The amount of natural streambank increased in NF6 and this river reach also had the greatest number and area of lateral bank erosion locations. This channel migration process may have contributed to NF6 meeting SSRP targets.

The streambank data collected for this report can be used to evaluate the feasibility and placement of future projects to increase the amount of natural streambank to meet SSRP targets and restore reach-scale geomorphic channel responses.

Side Channels

While the total count of side channels decreased from 2002 to 2011, the total estimated side channel length increased slightly. Nevertheless, a localized increase in side channel number and length in the combined area of NF5, NF6 and NF7 suggests more side channel habitat is available to juvenile salmon annually during spring, summer and winter for different species and life history stages. Moreover, the total change in gain and loss of side channels appears to reflect more active channel migration, channel switching, river avulsion, and lateral erosion processes in NF5 and NF6 compared to NF1, NF2 and NF3.

In NF1, NF2 and NF3, three side channel connections have been lost due to sedimentation and vegetation exclusion, eight are the same from 2002 and no new side channels have formed. Increasing the number of side channels in these reaches would likely benefit the greatest number of juvenile salmon over the longest time, including summer when adjacent mainstem river temperatures often exceed thermal suitability (Snohomish County 2013, in progress).

While the results for this survey cannot be evaluated in relation to the SSRP 10-year habitat goal of 30 acres of side channels restored, this data can be used to evaluate the feasibility and priority areas for restoration projects aimed at increasing side-channel availability.

Wood Jams and Pieces

The number of natural LWD jams has decreased in the NF Stillaguamish River, as has the average size of jams. Even the same seven jams present in 2002 and 2011 showed a net loss in total wood jam area, presumably reflecting the decay, breakup and transport of wood from jams. Newly formed jams (between 2002 and 2011) were smaller too. Although the count of individual LWD pieces increased overall, particularly in the combined area of NF1, NF2 and NF3, single pieces in 2011 were statistically smaller in diameter and older in decay status than in 2002. The number of the largest key pieces also decreased slightly between years. These results suggest that jams containing a large number of pieces have disintegrated in number and size from decay processes leading to the individual piece count becoming more abundant in downstream reaches. At the same time, the increase in individual pieces (some newly recruited) does not offset the estimated loss of total pieces from LWD jams.

For larger key pieces of LWD (>15m (≈50ft) and >60cm (≈24 inches)), 80 pieces per mile represents the properly functioning condition for key piece abundance (NMFS, 1996) cited in the SSRP. If NOAA's criterion for key pieces were applied in the survey area, the NF Stillaguamish would be expected to have > 1,360 key pieces. Alternatively, Fox and Bolton (2007) data's on reference conditions in unmanaged forests showed the median and 75th percentile values for key pieces were 1.3 and 4 pieces, respectively, per 100 meters channel length in channels 10-100 meters wide (Fox and Bolton, 2007). Based on this reference, the NF Stillaguamish River survey area would be expected to have 357-1100 key pieces (based on LWD volume with rootwads). The estimated quantity in 2011 is 38 pieces or approximately 10% of the reference median value.

Counts included only naturally-formed wood jams in the sub-sampled reaches as part of this survey. Since 1998, 19 log jams have been constructed in the NF Stillaguamish (as of 2014). If total jam loss has only occurred within sub-sampled reaches (and not in the un-sampled 47% of the NF Stillaguamish), it could be concluded that the artificial construction of jams has kept pace with natural jam loss. As it appears wood jam abundance in the NF Stillaguamish River has declined or remained the same in every reach, except NF3, it is also likely that jam abundance has decreased in the unsampled portions of reaches. Though not known conclusively, this would suggest jam loss has been greater than jam construction.

Because NF1, NF2 and NF3 show a higher woody debris deficit (and loss of wood jams) than exists in many other reaches, the potential for wood jam construction in these reaches should be investigated.

Pools

Pool count and frequency, average pool size, total pool area and percent pool habitat in the NF Stillaguamish River was greater in 2011 than in 2002 in the sampled area. Notably, pool count decreased in NF5 and NF7 and increased in NF1, NF3 and NF3. Pools formed by scour at large woody debris

increased the most among all pool-form types, particularly in combined area of NF1, NF2 and NF3. In NF2, where pool count, frequency, and total pool area increased the most, mean maximum depth, mean residual depth, and mean wetted pool area decreased, consistent with a shift toward smaller wood-formed pools. This shift is consistent with the observed downstream increase in individual pieces of woody debris.

For bedrock pools, the count increased, but the total area was nearly unchanged, suggesting that there was divergence (splitting) of multiple pools along the same bedrock features. For riprap pools, it is not clear whether old riprapped revetments became exposed or more new riprap contributed to the increase in riprap-formed pools. It is possible that riprap-formed pools increased due to the divergence of multiple pools along continuous riprap features, but unlike bedrock-formed pools, riprap-formed pools increased in surface area by 33%. This increase suggests new large riprap pools formed as opposed to larger pools diverging into more individually smaller pools. The reduction in the count of riprap-formed pools for several reaches could have occurred if the channel migrated away from riprap features, if the depth criteria were not fully met, or if separate riprap-formed pools coalesced. Overall, the increase in count and area of riprap-formed pools is inconsistent with habitat suitability for Chinook salmon, particularly juvenile salmon.

In 2011, pools were identified as primary or backwater types, consistent with Beechie et al. (2005). In 2002, backwater pools were neither deliberately identified nor deliberately excluded. In 2002, there were two pools out of 107 pools with tailout depths of 0.0 (unambiguously an isolated backwater pool). In 2011, 6 pools out of 121 had tailout depths of 0.0. These pools were more abundant in the 2011 survey, either because they were deliberately identified in 2011 or because there actually were more backwater pools in 2011 than in 2002. The observed differences cannot be conclusively interpreted. NF6 contained the most backwater pool area where the extent of riprapped banks declined, local erosion area was highest, side channels increased and switched locations, and wood was most abundant.

Flow cannot be held constant, nor can field work be planned for identical flow conditions among years. Measuring residual pool depth is one way to control for fluctuating discharge. An analysis of pool maximum depths between years shows the frequency distribution of pool depths is skewed to deeper maximum depths in 2011, but the difference was not significant. The water depth at pool tailout locations was skewed deeper in 2011 as well. As a result, the residual pool depths were not significantly different. These results suggest the differences in water depths between years for maximum depth and tailout depth may have contributed to a number of pools meeting the 1.0 meter depth requirement. For pool tailout locations that control the water surface elevation in pools, that difference was approximately 14 cm higher, on average, in 2011 than 2002. As an example, a pool with a maximum depth of 0.9 m and tailout depth of 10 cm in one year would not be counted. In a different year, when the flow stage was approximately 14 cm higher, the maximum depth would be 1.04 m and have a tailout depth of 24 cm, and be counted as a pool based on exceeding the minimum maximum depth criterion.

Based on results reported here, only the following conclusions for pools are supportable:

- There are more pools formed by woody debris in 2011 than in 2002 in the combined area of NF1, NF2 and NF3 and more total pool area formed by woody debris
- There is more total pool area in the combined area of NF1, NF2 and NF3; and probably less in the combined area of NF5, NF6 and NF7.
- There are more pools formed by riprap in 2011 than in 2002.
- There is less pool area as a percentage of total wetted area from bedrock or free-formed pools.
- Pools, collectively, are no more deep or shallow than in 2002.

Due to the sources of uncertainty described above, the simple conclusion that pool count has increased (as in a trend) over time is tenuous. Separating the stage-related differences in fluctuating pool characteristics from real differences in status and trends is challenging and may require more frequent sampling and/or other exploration of pool habitat by variable flow. In addition, the decrease in wood jams does not appear to be intimately related to the status of pools overall under current conditions, especially in NF1, NF2 and NF3. This is partly because a large fraction of wood jams in the NF Stillaguamish form at higher bar top elevations and are less likely to have a functional role in forming pools. Some woody debris not affiliated with wood jams does form small, relatively shallower pools but these may not persist over time.

A substantial increase in the quantity of wood as jams or individual pieces is desired based on SSRP targets, which if realized, will allow for more certain interpretation of changes in pools relative to wood quantity, wood size, persistence and placement or storage locations. The construction of log jams in NF5 and NF6 provides just such an example. Elsewhere, the current increase in pool formation may not last if the quantity of individual pieces or small aggregations of woody debris are not continuously supplied.

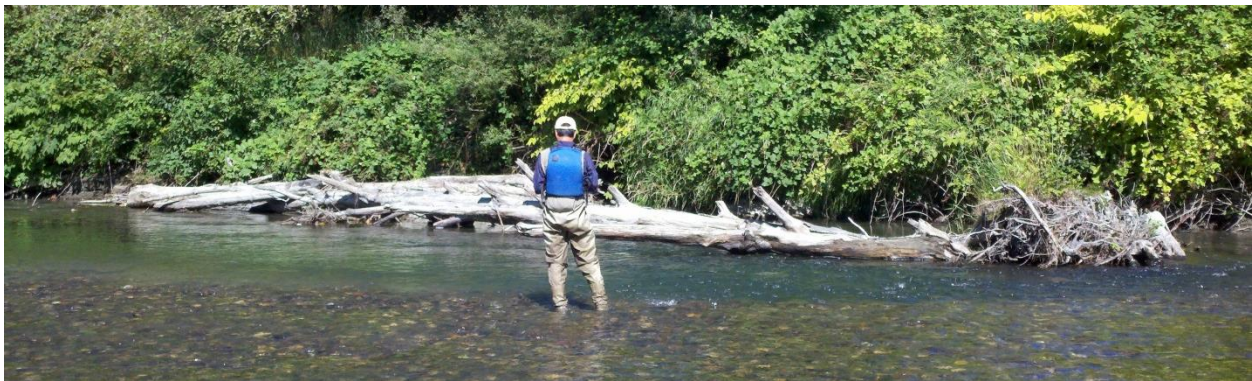


Figure 14: Example of individual woody debris piece forming pool habitat in NF2.

These monitoring results inform our knowledge of the status and trends in habitat parameters important to salmon recovery. Without periodic monitoring information, progress toward plan goals and achievement of future conditions, particularly as North Fork Stillaguamish River projects are implemented, will not be known. Thus, we recommend updating information about habitat status and trends every 10 years, most specifically, in terms of how habitat formation relates to river channel changes affected by management actions. Specific monitoring recommendations are included in Appendix E.

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Appendix A: 2011 NF Stillaguamish River survey components

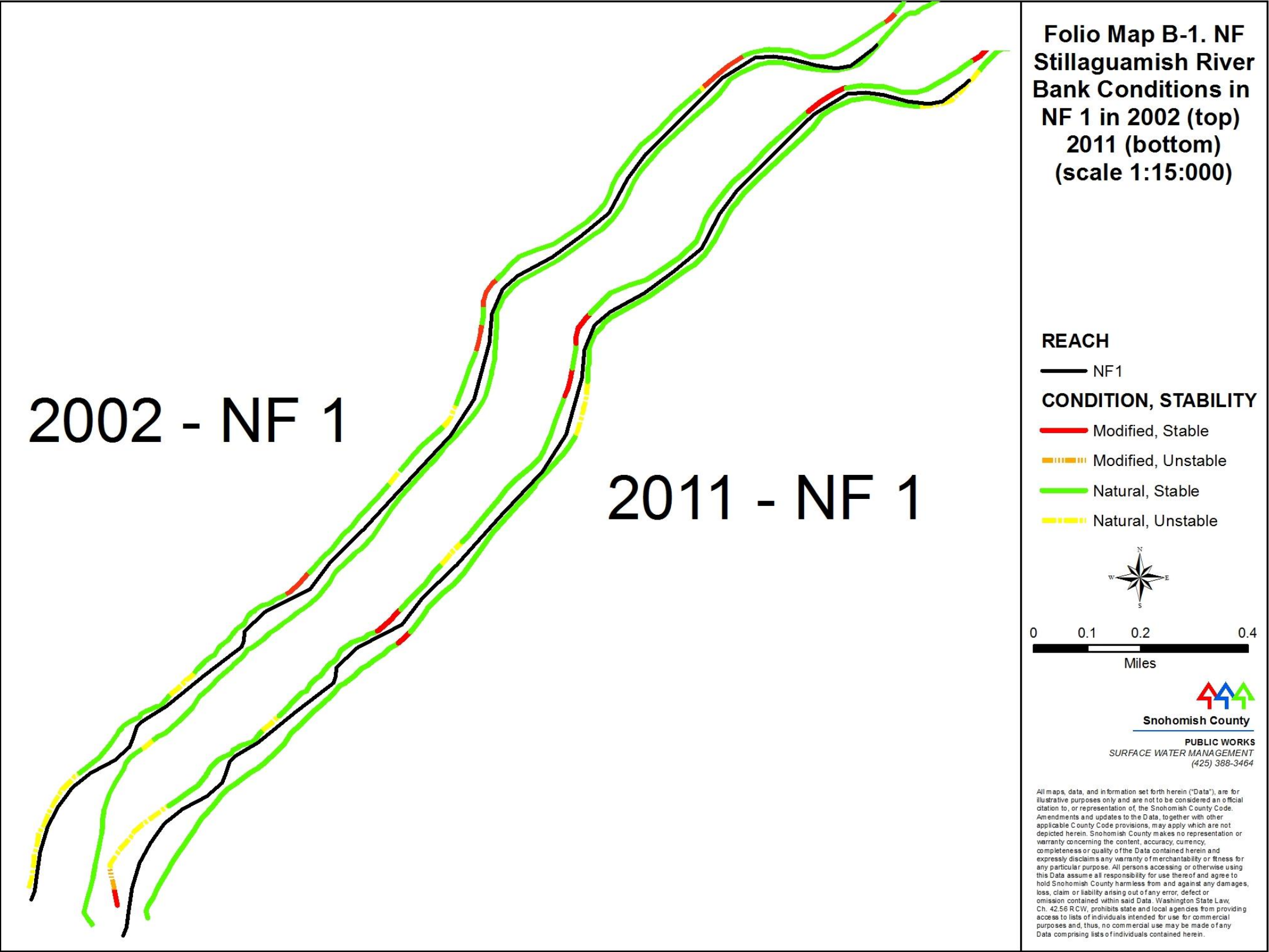
Snohomish County river survey methods are also located at the following URLs:
<http://www.snohomishcountywa.gov/ArchiveCenter/ViewFile/Item/2124>;
<http://www.snohomishcountywa.gov/ArchiveCenter/ViewFile/Item/2125>

Target/ Parameter	Management/ Monitoring Questions	Summary Indicators	Evaluation of Status or Change
Bank Conditions	Are bank conditions favorably changing relative to Salmon Recovery Plan targets (such as reduction in bank armoring, as in Table 1)? Is there an increase in natural streambank length? What is total length of bank modifications (and % of total length), by river reach? What is the length of eroding/ failing modifications and eroding natural banks (and % of total length), by river reach?	Bank lengths of Modified/Stable, Modified/Unstable, Natural/Stable, Natural/Unstable conditions and percentages within each river reach. Total length and percentage of bank material type among reaches (riprap, rubble, structural, and natural classes).	A decrease in bank armoring indicates armor is being removed or channel alignment is moving away from hard structures. An increase in measured length of natural streambanks, including backwater perimeter indicates improvement in quantity of natural edge habitat. An increase in bank armoring indicates bank armor is being added or river is migrating toward previously placed armor that is limiting natural river channel adjustment.
Side-channels	What is the change in side channel habitat relative to Salmon Recovery Implementation targets (is side channel restoration acreage attaining target)? What is the total number and estimated length of side channels, and have these totals changed? What are the physical habitat conditions present in re-surveyed side channels for habitat units and woody debris?	Number of side channel connections and length of side channels within the NF Stillaguamish by individual reaches. The total length of side channels as a proportion of total reach length (as a representation of “off-channel” habitat area and availability	A decrease in the number of side channels with inlet and outlet flow to the mainstem suggests less active river process and reduction in availability of connected habitats. A decrease in the length of side channels suggests a reduction in the side channel habitat type. An increase in connections and length suggests active river process and increased availability of side channel habitat type relative to reach length.
Wood Jams	Are wood jams favorably changing with respect to Salmon Recovery Plan targets (Natural and constructed log jams exceed baseline by 51 jams)? Are natural wood jams increasing? Are jams stable and is jam size increasing? Are Bar apex and Meander jams increasing in total count?	Jam count, jam type, and jam frequency (or spacing) Jam size (piece count, area, and estimated volume), and jams interacting with low flow channel.	Favorable change in wood jams exceeds baseline total by the number of jams constructed to date; Unfavorable change is interpreted to be a decline in natural wood jam count, size of jams, and reduction of bar apex and or meander jams.
Wood Pieces, also Large Woody Debris (LWD)	Is wood debris piece size changing? Is there a change in spatial distribution of wood pieces in the NF compared to 2002? Is there a change in total estimated wood load in the river?	Wood piece diameter, length, and rootwad presence for pieces in jams and individual pieces. For all wood (in jams or individual pieces), total wood frequency, total large wood frequency (>60cm, >15m)	Favorable change in wood characteristics reflects more new wood, more conifer species, larger piece size, greater wood load in all reaches, and increasing number of large key pieces (natural or constructed). Unfavorable change is more old decaying wood, smaller piece sizes, reduced piece count total, fewer key pieces
Pools	Is the number of pools increasing (pool frequency increasing)? Is the number of wood formed pools increasing? Is the number of backwater pools increasing? Is the total area and percentage area of pool habitat increasing? Is the mean size of pools or mean depth of pools changing?	In total, among reaches and by pool forming factor, summarize pool count, pool frequency (by km), percent pool area, average residual pool depth, and average pool size.	Favorable changes in pool metrics reflect greater pool count, more backwater pools, more wood-formed pools, larger average (and total) pool area, greater pool area as percent of all habitat units, deeper pools, and pools with higher cover amounts (from wood, undercut banks, low hanging vegetation). Favorable changes would also reflect a reduction in pools formed by riprap. If this occurs, average pool size may decrease as wood-formed pools are notably smaller than other types (Haas et al. 2003)

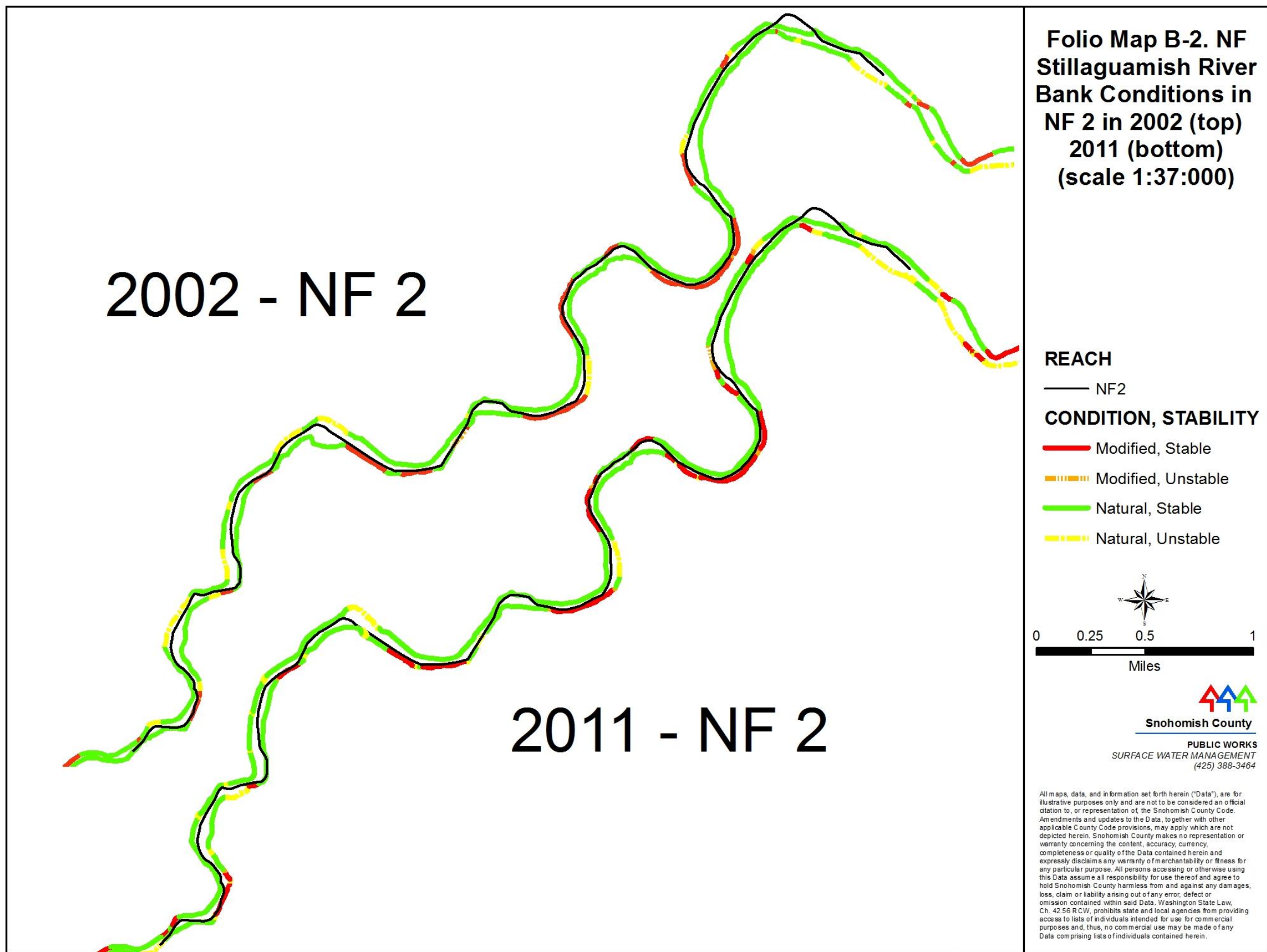
<u>Survey Component</u>	<u>Indicator or parameter of Interest</u>	<u>Target area</u>	<u>Method</u>	<u>Summary metrics</u>
Bank Conditions				
	Bank modification (Yes/No)	Full river survey of water body boundary in EDT reaches 5-7. NF 1-4 were re-surveyed in 2008.	GPS point locations of all bank condition changes during full river survey; points are routed to updated waterbody boundary* to generate length estimates	Total and Percent modification by modification type, bank stability, bank material by reach or whole river. Map deliverable of all feature locations relative to other features of interest.
	Bank type (Levee/revetment, grade, berm, none)	Same	Same	Same
	Bank stability (Stable/unstable)	Same	Same	Same
	Bank material (earth, riprap, rubble, structure)	Same	Same	Same
Habitat				
Geomorphic habitat types	Classified as pools, riffles, glides in mainstem and side channels with added info for the 6 EDT habitat types (backwater pools, primary pools, pool tailout, glides, large cobble/boulder riffles, small cobble/gravel riffles). 2 EDT habitat types (beaver ponds & off-channel habitat factor are not directly measured.	Subsample survey of habitat types in mainstem and side channels among NF 1-7.	All units are identified with GPS point location at downstream extent of each unit. Each unit is measured for wetted width and either measured for length or length is derived from GPS point locations in GIS. See pools below.	Total and percent composition of habitat units by mainstem and side channels as well as central tendency metrics by habitat unit type. Includes additional info for summarizing composition of riffles by type – gravel, small cobble, large cobble, boulder summarized by reach for EDT level 2 inputs.
Large Woody Debris (LWD) – Individual pieces	Targets individual pieces based on diameter, length, and rootwad criteria. Minimum piece size is 2m length and 10 cm diameter, as in 2002. There are 3 length categories and 4 diameter categories. Each piece is determined to have (or not) a rootwad (≥1m diameter).	Sub-sampled within survey reaches. Individual LWD pieces from each reach, including mainstem and side channels.	For individual pieces in sub-sampled area, each piece is classed based on length, diameter, and rootwad. Decay status and conifer/deciduous type are not collected in 2011. No GPS information is needed for individual pieces within subsampled reaches.	LWD frequency, size, loading rate summarized as mean values by reach and whole river between mainstem and side channels and among EDT reaches 1-7
Large Woody Debris (LWD) – Jams	Targets pieces in woody debris jams based on diameter, length, and rootwad criteria	Sub-sampled survey for LWD jams in mainstem and side channels among reaches 1-7.	All jams are identified (GPS) and classified based on type (Bar Top, Bar Apex, Meander, and channel spanning in side channels). All jams are measured for jam length, width, and height with laser rangefinder and a determination is made whether the jam is in contact with low flow wetted channel. A subsample of jams (25%) are inventoried for piece count and pieces sizes.	LWD jam frequency, size, type, loading rate summarized as mean values by reach and whole river between mainstem and side channels
Pool, detailed	Documents type (primary or backwater), area, frequency, pool forming factor and characteristics of pools as rearing, refuge and holding habitat in mainstem and side channel areas	Full river survey for identification of all pools	Pools are classified based on four pool forming factors and are measured (length and width are field measured or GPS positions are taken for later measurement). Pool depth is determined from ODEM echo sounder coupled to GPS. Pools in side channels are field measured and depth determined with stadia rod. The amount of dominant and subdominant cover (by type in categories of cover amount) in or over pools is determined	Total, percent and central tendency summary values for Pool area, depth, frequency, by type, location, and primacy among reaches and whole river

*Water body boundary – the map location equivalent to top of bank that also incorporates unvegetated bars, vegetated bars, active side channels and their banks to bankfull height. The waterbody boundary does not always include inactive side channels, off-channel features (e.g., ponds, oxbows, swales) or developing forested floodplain contained between older floodplain terraces.

Appendix B: Map Folio



X:\ESA\Habitat\Assessment_Inventory\Big River Survey\2011\Maps\Folio spwfe 9/30/2014



X:\ESA\Habitat\Assessment_Inventory\Big River Survey\2011\Maps\Folio spw\fel 9/30/2014

2002 - NF 3

2011 - NF 3

**Folio Map B-3. NF
Stillaguamish River
Bank Conditions in
NF 3 in 2002 (top)
2011 (bottom)
(scale 1:24:500)**

REACH

— NF3

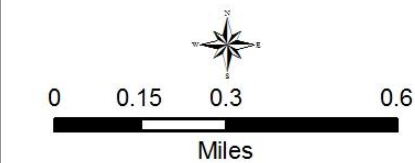
CONDITION, STABILITY

— Modified, Stable

— Modified, Unstable

— Natural, Stable

— Natural, Unstable



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2002 - NF 4/ NF 5

2011 - NF 4/ NF 5

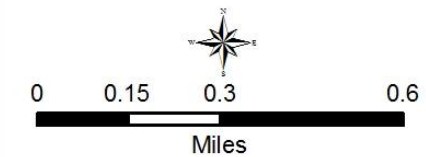
**Folio Map B-4. NF
Stillaguamish River
Bank Conditions in
NF 4-5 in 2002 (top)
2011 (bottom)
(scale 1:22,800)**

REACH

- NF4
- NF5

CONDITION, STABILITY

- Modified, Stable
- Modified, Unstable
- Natural, Stable
- Natural, Unstable

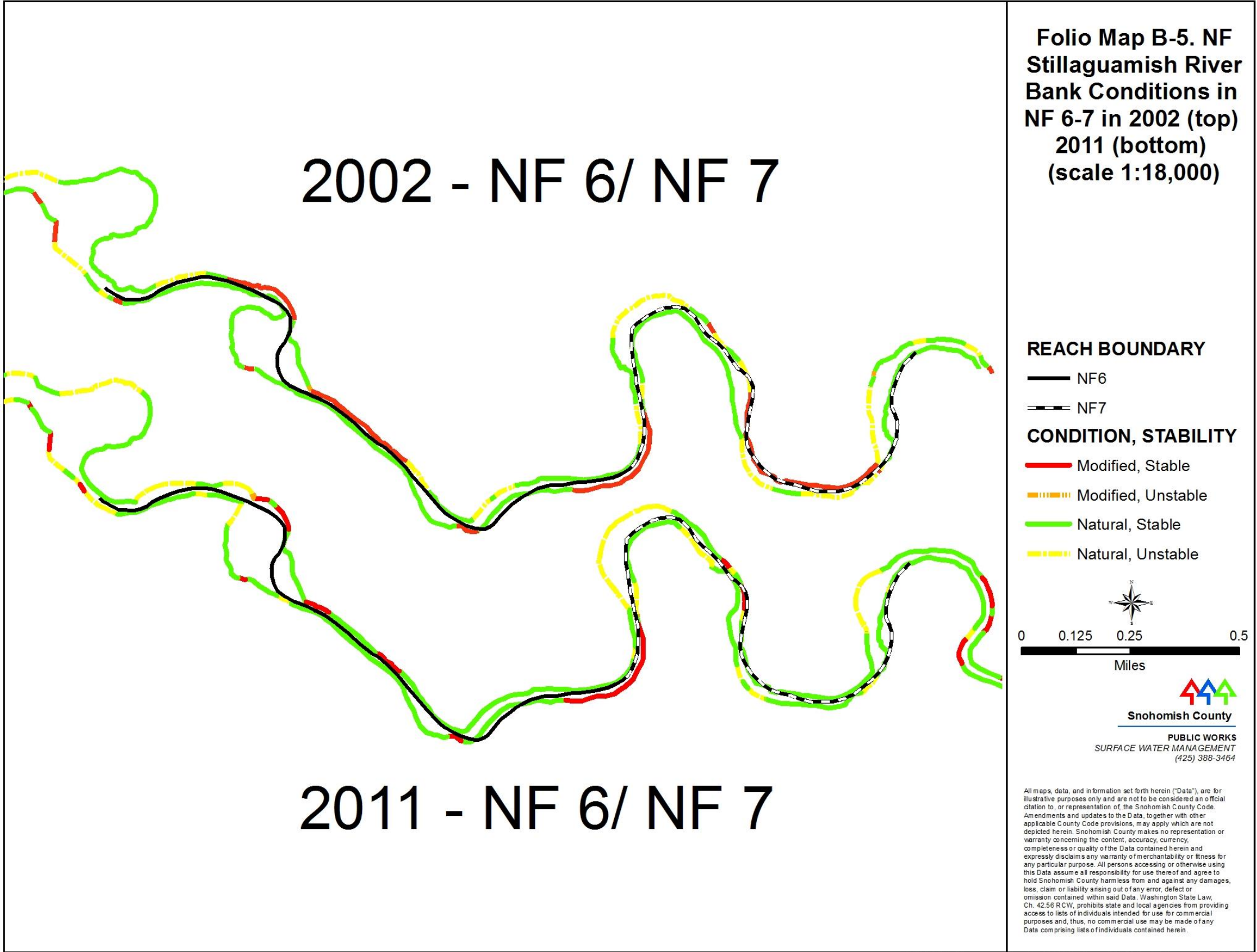


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Appendix C: Wood jam size and piece count relationship

To estimate the total wood abundance for surveyed areas, we used counts of all individual LWD pieces (not part of jams) and estimates of total wood abundance in jams. 267 wood jams of varying size (5-14,000 m³) were inventoried for piece count in the Stillaguamish (2002), Skykomish (2003/2004), and Sauk (2005) rivers based on the minimum piece size criteria of ≥2 m length and ≥10 cm diameter (Schuett-Hames et al. 1999). The wood count per jam was used to estimate the relationship between wood count and jam area and volume. Jam area, then volume, were measured based the shape of the jam footprint (usually rectangular or triangular) - the average length, average width, and estimated average height above the lowest exposed elevation of the jam. These measurements were assumed to be biased toward generating larger estimates of jam size relative to the possible underestimate of total piece count per jam, which moreover was probably biased against accurate piece count in large jams compared to jams with few pieces. Because several jams were very large, they leveraged the relationship such that the vast majority of jams (<2000 m³) were not very well represented. Therefore, jams greater than 2000 m³ were excluded.

In the NF Stillaguamish River, jams observed in 2011 were less than 1100 m² and 1800 m³. This part of the overall data distribution was used to further refine the relationship between jam size and the estimate of piece count. The resulting relationship between piece count and jam area is shown in the following figure. Wood count, irrespective of piece size, accounted for 71% of the variability in jam area. This linear model was used to populate the estimate of woody debris in jams that were measured for jam dimensions only in 2011.

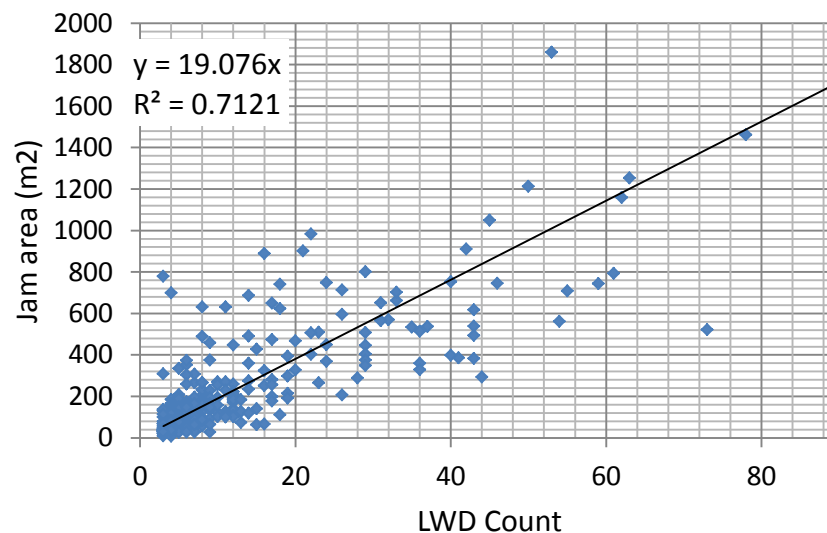


Figure. Relationship between piece count and jam area (footprint) for surveyed wood jams less than 2000 m² in Stillaguamish, Sauk, and Skykomish rivers (2002-2005).

In order to provide a range for the total piece count estimate in 2011, the positive and negative 90% confidence interval of the regression coefficient was used to establish a range of piece count for each jam and for all jams combined. These values are included in the following table. The estimate of wood debris contained in jams in 2011 ranges from 347-385 pieces.

Table. 2011 NF Stillaguamish wood jams from surveyed areas in NF1 – NF7 and estimated wood piece count per jam.

Jam_ID	Jam Type	WET	Zone	Jam length (m)	Jam width (m)	Jam height (m)	Calc. Area (m2)	Calc. Volume (m3)	Reach	Piece count	Lower 90% CI	Upper 90 % CI
	BAJ	N	Active Bar	21	3	0.6	63	37.8	NF7	3	3	3
JamA2	BAJ	N	Vegetated Bar	23	2.5	1.3	57.5	74.75	NF7	3	3	3
JamA4	MJ	Y	Main Channel	24	5	2	120	240	NF7	6	6	7
JamA3	BAJ	Y	Main Channel	33.6	19	2.7	638.4	1723.7	NF7	33	32	35
JamA1	MJ	Y	Main Channel	40.6	7.4	1.4	300.4	420.6	NF7	16	15	17
JamA8	MJ	N	Forested Island	8.5	1.3	0.9	11.1	9.9	NF6	3	3	3
JamA7	MJ	N	Main Channel	16.6	7	1.5	116.2	174.3	NF6	6	6	6
JamA1	MJ	Y	Main Channel	23	3	1.5	69	103.5	NF6	4	3	4
JamA3	MJ	N	Side Channel	25	20	0.8	500	400	NF6	26	25	28
JamA9	BTJ	N	Forested Island	27	3	1.3	81	105.3	NF6	4	4	4
JamA2	MJ	Y	Side Channel	32.9	10.7	1.9	352	668.9	NF6	18	18	19
JamA5	BAJ	N	Vegetated Bar	34.6	5.8	1.34	200.7	268.9	NF6	11	10	11
JamA1	MJ	Y	Side Channel	34.7	4.1	1.3	142.3	184.9	NF6	7	7	8
JamA10	BTJ	N	Forested Island	34.8	10.9	1.5	379.3	568.9	NF6	20	19	21
JamA4	MJ	Y	Main Channel	40	15	2.1	600	1260	NF6	31	30	33
JamA6	MJ	N	Main Channel	46	6.4	1.4	294.4	412.2	NF6	15	15	16
JamA2	MJ	Y	Active Bar	46.5	22	1.2	1023	1227.6	NF6	54	51	57
JamA1	MJ	N	Main Channel	13.5	19.6	2.5	264.6	661.5	NF5	14	13	15
JamA2	MJ	Y	Main Channel	22	6.5	2.5	143	357.5	NF5	7	7	8
JamA1	MJ	Y	Active Bar	53	5	2.3	265	609.5	NF5	14	13	15

Jam_ID	Jam Type	WET	Zone	Jam length (m)	Jam width (m)	Jam height (m)	Calc. Area (m2)	Calc. Volume (m3)	Reach	Piece count	Lower 90% CI	Upper 90 % CI
JamA5	MJ	Y	Main Channel	8	17	1.9	136	258.4	NF3	7	7	8
JamA2	MJ	N	Vegetated Bar	20.64	3.3	2.2	68.112	149.8464	NF3	4	3	4
JamA4	MJ	Y	Main Channel	21.5	5	1.5	107.5	161.25	NF3	6	5	6
JamA10	BTJ	N	Main Channel	26	4.65	0.96	120.9	116.064	NF3	6	6	7
JamA4	BTJ	N	Main Channel	32.8	7.9	1.7	259.12	440.504	NF3	14	13	14
JamA1	BAJ	N	Main Channel	36.4	6.5	3.6	236.6	851.76	NF2	12	12	13
	MJ	N	Active Bar	25	15	NR	375*	NR	NF1	20	19	21
TOTAL										365	347	385

* Jam area of one jam in NF 1 was estimated based on 2011 air photo.

Appendix D: Miscellaneous Data Tables

Table D-1. Reach descriptions. No compelling difference in survey area was calculated in NF 3. Otherwise the larger wetted survey area is shaded.

Reach	Reach boundary		Reach length, (m)	Bankfull width, avg. (m)	CW Units per reach (length/BFW)	Surveyed length (m)		Wetted survey area (m ²)	
	Up	Down	2011	2011		2002	2011	2002*	2011**
NF7	Squire Creek	Between Segelsen & Fortson	4,860	40.0	121	2,602	2641	64,357	58,914
NF6	Between Segelsen & Fortson	Boulder River	6,720	45.3	148	2,981	2630	68,684	57,772
NF5	Boulder River	Rollins Creek	7,890	73.5	107	3,748	3552	130,855	150,023
NF4	Rollins Creek	Deer Creek	7,320	60.5	121	2,087	2087	75,849	69,654
NF3	Deer Creek	Grant Creek	8,770	82.7	106	5,412	5481	225,958	228,213
NF2	Grant Creek	Whitehorse crossing	11,260	80.3	140	7,107	7122	258,798	195,218
NF1	Whitehorse crossing	NF/SF confluence	3,882	72.0	54	3,858	3882	147,779	117,536
Total			50,702		797 CW units	27,795	27,395	972,280	877,330

*Survey area is based on sum of all measured habitat unit areas, not survey length x average wet width.

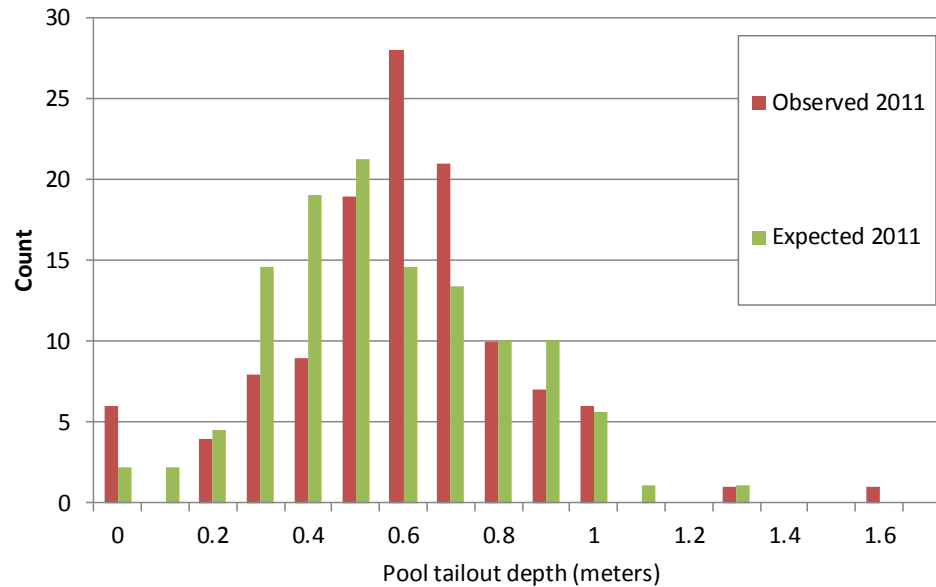
Table D-2. NF Stillaguamish wood jam abundance, frequency, mean size, and count by jam type in 2002 and 2011. See Table for variance estimates of jam area and volume by reach.

Reach	Mainstem survey length (m)		Total Jam Count		Jam frequency (jams/km)		Average Jam size (m ²)		Average Jam volume, estimate (m ³)		Jam Type, 2002 Count			Jam Type, 2011 Count		
<i>Year</i>	<i>2002</i>	<i>2011</i>	<i>2002</i>	<i>2011</i>	<i>2002</i>	<i>2011</i>	<i>2002</i>	<i>2011</i>	<i>2002</i>	<i>2011</i>	<i>BAJ</i>	<i>BTJ</i>	<i>MJ</i>	<i>BA_J</i>	<i>BTJ</i>	<i>MJ</i>
NF7	2602	2641	5	5	1.9	1.9	384	236	849	499	2		3	3		2
NF6	2981	2630	16	12	5.4	4.4	452	314	669	449	5	2	9	1	2	9
NF5	3748	3552	8	3	2.1	0.8	153	224	251	543	2	2	4			3
NF4	2087	2087	2	0	1.0	0.0	205	0	222	0		2				
NF3	5412	5481	2	5	0.4	0.9	1408	138	2864	225			2		2	3
NF2	7107	7122	2	1	0.3	0.1	696	237	1568	852	1		1	1		
NF1	3858	3882	7	1	1.8	0.3	220	N/R	604	N/R	1		6			1
Total / Average	27,795	27,395	42	27	1.5	1.0	365.1	251.9	628.1	441.8	11	6	25	5	4	18

Table D-3. More detailed tables and statistical tests for pools

Reach	Bankfull width, avg. m	Primary pool width, avg. (m)		Sum of Primary Pool Lengths (m)		Pool Count		Pool Area, Total (m ²)		Pool Area, %		Pool Frequency / km	
		'02	'11	'02	'11	'02	'11	'02	'11	'02	'11	'02	'11
7	40.0	17.2	17.3	1460	1169	20	18	29,153	22,391	42.0	40.3	7.7	6.8
6	45.3	17.9	17.2	946	1074	20	23	25,135	25,635	36.6	44.3	6.7	8.7
5	73.5	18.6	28	1237	803	21	14	25,954	28,040	17.8	19.0	5.6	3.9
4	60.5	22.6	16.5	255	336	4	4	5,628	6,731	7.4	9.7	1.9	1.9
3	82.7	21.1	30.9	2229	1797	16	19	48,947	67,238	21.9	30.0	3.0	3.6
2	80.3	23.8	23.1	2875	3706	19	31	70,719	98,808	27.1	50.6	2.7	4.4
1	72.0	26.9	26.7	1241	1675	7	11	32,355	52,036	21.5	44.3	2.1	2.8
Total				10,243	10,560	107	120	237,891	300,878	24.5	34.3	3.8	4.4

Observed vs. Expected Frequencies (2001poolstailmaxdepths)
Chi-Square = 35.81342 df = 17 p = .004858



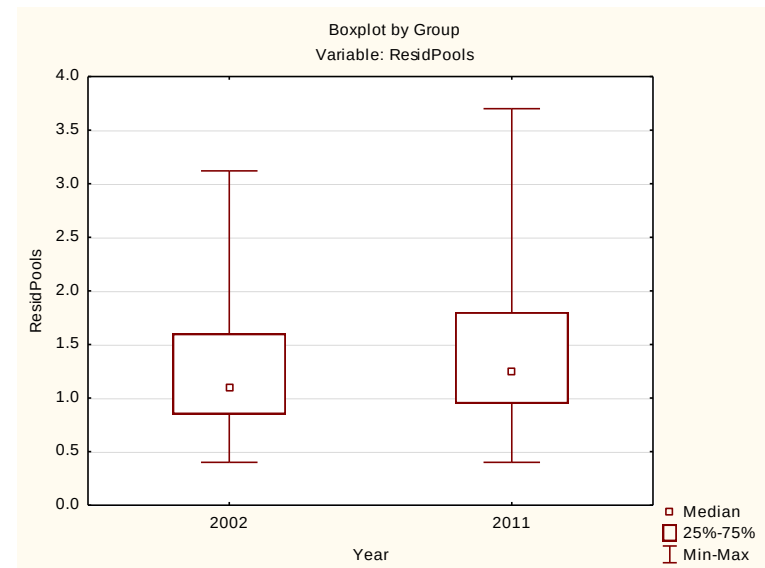
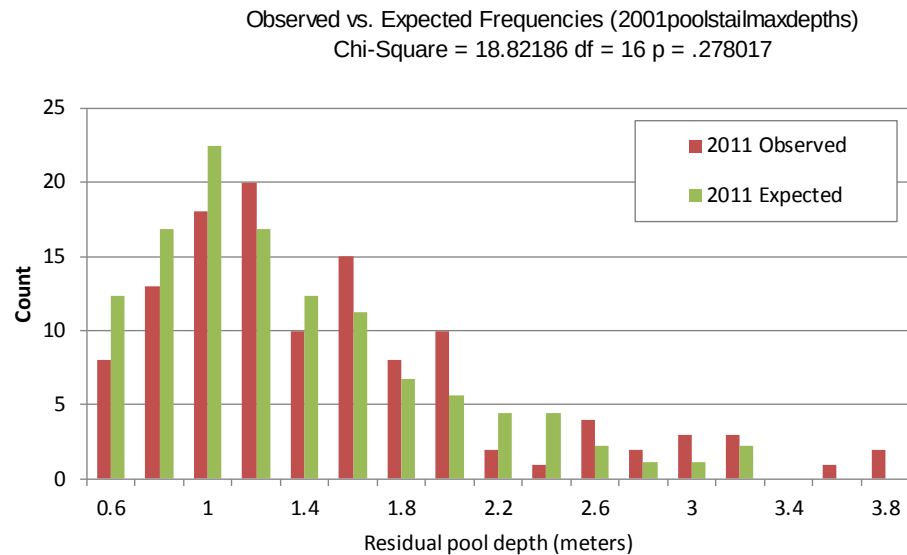
Parametric statistics: Comparison of means
F-Test Two-Sample for Variances

<i>Tailout D</i>	2002	2011
Mean	0.556822	0.58375
Variance	0.062865	0.066183
Observations	107	120
df	106	119
F	0.949866	
P(F<=f) one-tail	0.394381	
F Critical one-tail	0.73079	

t-Test: Two-Sample Assuming Equal Variances

<i>Tailout D</i>	2002	2011
Mean	0.556822	0.58375
Variance	0.062865	0.066183
Observations	107	120
Pooled Variance	0.06462	
Hypothesized Mean Difference	0	
df	225	
t Stat	-0.79668	
P(T<=t) one-tail	0.213239	
t Critical one-tail	1.651654	
P(T<=t) two-tail	0.426478	
t Critical two-tail	1.970563	

Mann-Whitney U Test (w/ continuity correction) (Spreadsheet22)									
By variable Year									
Marked tests are significant at p < .05000									
variable	Rank Sum Group 1	Rank Sum Group 2	U	Z	p-value	Z adjusted	p-value	Valid N Group 1	Valid N Group 2
Tail	11610.50	14267.50	5832.500	-1.18844	0.234659	-1.19449	0.232289	107	120



Log-transformed residual depths (normally distributed) - comparison of means

T-tests; Grouping: Year (Spreadsheet7)											
Group 1: 2002											
Group 2: 2011											
Variable	Mean 2002	Mean 2011	t-value	df	p	Valid N 2002	Valid N 2011	Std.Dev. 2002	Std.Dev. 2011	F-ratio Variances	p Variances
Log2011resid	0.347380	0.370358	-1.49818	225	0.135487	107	120	0.108242	0.121327	1.256404	0.230832

Non-Parametric test of residual pool depths by rank between years

Mann-Whitney U Test (w/ continuity correction) (Spreadsheet7)									
By variable Year									
Marked tests are significant at p < .05000									
variable	Rank Sum Group 1	Rank Sum Group 2	U	Z	p-value	Z adjusted	p-value	Valid N Group 1	Valid N Group 2
ResidPools	11488.50	14389.50	5710.500	-1.43545	0.151161	-1.43647	0.150870	107	120

Appendix E: Possible Future Steps for Monitoring

1. The status and trends in the habitat parameters included in this report could be updated every 10 years, in order to provide information useful for periodic 5-10 year updates of the SSRP, Critical Areas regulation, Shoreline Master program metrics (e.g.; Snohomish County Planning and Development Services, 2006), and County Comprehensive Plan.
2. In addition to updating streambank conditions relevant to SSRP plan targets, plan progress, desired future conditions and project development, bank edge type and area should be classified according to Beechie et al. (2005), to support estimation of channel rearing capacity for salmonids. As bank conditions change by modification, by edge type, by cover and by length/area, estimates of rearing capacity can be computed and updated to better link changes in the geomorphic status of the North Fork Stillaguamish to changes in channel responses and habitat formation to estimate benefits for fish.
3. Add a floodplain component that considers flood inundation extent, floodplain land cover, floodplain infrastructure and habitat isolation, in order to estimate river and floodplain restoration potential and likely river and habitat responses by reach for delineated floodplain units. A delineated channel migration zone (CMZ) that serves multiple management and regulatory purposes would be beneficial. Side channel length and area are included in this component.
4. Use the periodic documentation of changes in woody debris status and trends to inform decision making about wood implementation targets, which could increase or decrease over time depending on the progress and success of wood project implementation and recovery of natural contributions of woody debris.
5. Link the geomorphic river status over time such as channel migration, erosion, gravel bar accumulation (or limits to these processes) to bank conditions, edge habitat quantity and quality, wood recruitment and storage, and changes in the spacing, type, and distribution of habitats for fish.
6. Develop reach scale and subbasin scale monitoring that will allow for comparisons to past data collection (2002, 2011) to future monitoring. Organize census-based monitoring spatially and by channel response metrics to test for reach-scale restoration responses at locations of significant Salmon Plan implementation (e.g., wood complexes in NF5 and NF6).