Stillaguamish Water Quality Trend Report

The State of the Stillaguamish from 1993 - 2013

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Stillaguamish Tribe of Indians

Acknowledgements

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There are numerous people such as Stillaguamish Tribal Members, Natural Resources Department Staff, employees from other organizations that work in the Stillaguamish Watershed, and groups such as the Stillaguamish Clean Water District and the Stillaguamish Watershed Council (formerly the Stillaguamish Implementation Review Committee) that have contributed in one way or another to the Stillaguamish Water Quality Program. All of their efforts to contribute to clean water in the Stillaguamish Watershed is much appreciated. Specifically, much credit needs to go to Pat Stevenson, Environmental Manager for the Stillaguamish Tribe. Pat's lifelong work to improve environmental conditions in the Stillaguamish cannot be understated. Without Pat, there would be no drive to complete this report.

Lastly, Don Klopfer deserves much of the credit for the development of the Stillaguamish Water Quality Program. Don was the Tribe's Water Quality Biologist from 1992 – 2012 when he retired. Don built the Water Quality Program from the ground up and made it into the respected institution that it is.

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Executive Summary

From 1993 – 2013 the Stillaguamish Tribe conducted water quality monitoring in the Stillaguamish Watershed. During this time, the Tribe monitored over 200 sample sites. Sixty-five sites had long enough data sets (n > 50 samples) to determine trends in 4 water quality parameters: temperature, dissolved oxygen, turbidity, and fecal coliform. For this analysis, data within sub-basins were pooled to determine trends at the sub-basin scale. We used a modification of the seasonal Kendall test (Hirsch *et al.* 1982), known as the regional Kendall test (Helsel and Frans 2006), to detect trends from all sites within a sub-basin. No sub-basin showed significant trends in all 4 water quality parameters. Of the 68 separate statistical trend analyses (17 sub-basins x 4 water quality parameters) conducted, 23 indicated improving water quality (6 improving in temperature, 6 improving in dissolved oxygen, and 11 improving in fecal coliform) and 6 indicated worsening water quality (all 6 worsening in turbidity). We also used these tests to detect trends within individual sites. Results from this investigation were used to develop recommendations for water quality monitoring in the Stillaguamish Watershed by the Stillaguamish Tribe.

Introduction

The Stillaguamish Tribe, party to the Point Elliot Treaty (Treaty) of 22 January 1855, was federally recognized in October 1976. The Treaty, signed by Isaac Stevens, Governor of Washington Territory, on behalf of the U.S. Government and Puget Sound Tribes, forced Tribes to reservations but also ensured that they would maintain their fishing rights throughout their "usual and accustomed grounds and stations *(U&A)* in common with all citizens of the Territory". However, not long after signing the Treaty, the Tribes were persistently harassed by the State of Washington for fishing in the areas expressly described in the document. The Federal government intervened on behalf of the Tribes after decades of persecution, filing suit in 1974 against the State of Washington for prohibiting the Tribes from exercising their rights as outlined in the Treaty. The suit, *U.S. v. Washington*, Civil 9213, also known as the Boldt Decision, granted the Stillaguamish Tribe, amongst others, the right take up to 50% of all harvestable (beyond what is required to ensure reproductive success) fish within their respective U&A fishing areas. Along with the right to take 50% of harvestable fish, the Tribe was also given co-management authority of the resource to ensure proper management. The adjudicated U&A for the Stillaguamish Tribe is the entire Stillaguamish Watershed, including portions of both Snohomish and Skagit Counties, Washington.

Because the welfare of the Stillaguamish Tribe is the responsibility of the U.S. Government, it became the responsibility of the Bureau of Indian Affairs (BIA) to manage fish, shellfish, and other natural resources for the benefit of the Tribe. Seeing the benefit of having each Tribe manage its own resources, the BIA entered into a contract with the Stillaguamish Tribe for the purpose of providing management of fish and shellfish resources within the Stillaguamish Watershed. This allowed the Tribe to establish a Natural Resources Department with the mission to manage, protect, and conserve those natural resources that are required to sustain healthy populations of fish, shellfish, and wildlife within the Stillaguamish U&A.

The Stillaguamish Tribe's Natural Resources Department operates a Water Quality Program. From 1993-present, the Tribe has collected water quality data throughout the Stillaguamish Watershed. Over the past 20 years, over 220 different sites have been sampled. Most sites are project specific and do not have long data sets (typically 2-3 years maximum), while others have longer data sets (> 5 years).

The purpose of this report is three-fold:

1. Examine long term data sets to determine trends in water quality.
2. Determine if any trends identified in data sets are statistically significant.
3. Provide recommendations for future monitoring efforts in the Stillaguamish Watershed.

Methods

Water Quality Program

The Stillaguamish Tribe's Water Quality Program was largely developed as a result of the Stillaguamish Watershed Action Plan (SWAP). In 1987 the Washington State Department of Ecology began developing the SWAP as a unified plan for the Stillaguamish basin, specifically addressing the issues regarding pollution and the degradation of natural resources. The SWAP set forth recommendations intended to control, prevent, and reduce various non-point sources of pollution. The Stillaguamish Tribe, along with the Tulalip Tribes and Snohomish County were designated as the co-lead agencies for the coordinated oversight and implementation of the SWAP.

The primary purpose of the Water Quality Program is to gather baseline information consistent with established programs in the Stillaguamish Basin. The approach used was twofold; 1) to collect detailed environmental information from long term established sites and 2) screen other sensitive locations in the Stillaguamish Watershed based on a systematic sampling design. The Stillaguamish Tribe's Water Quality Program added to existing databases in Snohomish County and Washington State Department of Ecology and was used to increase the likelihood of finding areas of noncompliance with state water quality standards. It is intended that the Stillaguamish Water Quality Program allows for the long term tracking of water quality parameters between sites in different land use areas and to identify occurrences of U&A waters not meeting beneficial uses.

The Stillaguamish Tribe operates an EPA approved water quality monitoring program and the Tribe follows a Quality Assured Project Plan (QAPP) to conduct routine sampling. Sampling methods mainly consist of monthly or quarterly grab samples. Throughout the 20 years of sampling as analyzed in this report, the Tribe has monitored water quality at over 200 different locations within the Stillaguamish watershed. Most of these sites were temporary and/or project specific. Whenever possible, the Tribe coordinated with other agencies to compliment efforts in the Stillaguamish. Data from the routine monitoring allows for the long term tracking of water quality to show trends and relationships between major drainages within the Stillaguamish Watershed. Sites were divided out into water quality zones based on their basin/sub-basin

Samples were collected following a systematic design. Typically, samples were collected from Monday – Friday during working hours. Early in the Tribe's Water Quality Program, samples were collected from sites on a monthly basis, however during the 2002 season, the Tribe switched to a quarterly sampling design with samples collected in March, June, September, and December. Whenever possible through other projects or for supplemental sampling purposes, other samples were collected to compliment the quarterly sampling. The idea with the quarterly sampling was to still collect samples that represented "wet months" (October – April) and "dry months" (May – September) despite decreasing the sampling effort. Sampling effort decreased due to funding limitations.

Tribal Laboratory Facility Description

The Stillaguamish Tribal Water Quality Laboratory has evolved through the years. Initially, the laboratory was located in a 120 ft^2 room of the Tribe's Water Treatment Center on the now listed

Reservation in Arlington, Washington. The laboratory now resides in the Tribe's Natural Resources Department in Arlington, Washington. The function of the laboratory is to perform basic water chemistry in accordance with established protocols that meet EPA's requirements. Independent labs performing fecal coliform analyses for the Tribe also meet EPA's requirements for the associated tests.

The Tribe's EPA Lab Registration number is WA01020. The Tribe has participated in EPA Performance and Evaluation Audits until 1999 when the program changed over to private companies. The Tribe has continued to participate in Performance Evaluation Audits every year with private companies (such as Absolute Standards). The Tribe performs audits on the specific parameters that are analyzed in the laboratory. The P.E. Audits are available upon request.

Database Management

Original field and laboratory data sheets are maintained and kept by the water quality supervisor located at the Stillaguamish Tribe's Natural Resources Department in Arlington, Washington. The Water Quality Program follows established Standard Operating Procedures (SOP's) for handling records and information obtained from field work. Waters tested for fecal coliform bacteria are sent to accredited laboratories under Chain of Custody protocols for regular analyses and QA/QC requirements.

Field and laboratory data sheets are reviewed by the water quality supervisor and are maintained in binders. The data is entered into a SQL database through a Microsoft Access® front end. Data in the database is checked and verified against original datasheets every year. Quality assured and checked data are then submitted to EPA's Water Quality Exchange (WQX) database and subsequently STORET (STOrage and RETrieval).

Statistical Analysis

Analysis of our water quality data presented a number of analytical challenges common to many water quality data sets (Hipel and McLeod 1994). Specifically:

- The data are non-normally distributed with extremely high counts commonly occurring
- The data are measured at irregular time intervals
- There are long time periods during which no data are collected
- There may be seasonal patterns in the data, and
- The data may be serially correlated.

All of these combine to make the detection of long-term trends in the data challenging. Bob Conrad, a biometrician with the Northwest Indian Fisheries Commission (NWIFC) greatly helped the Tribe at the start of our water quality analyses by reviewing the data to help select the appropriate statistical tools. Mr. Conrad's initial analyses of our data was three fold:

1. Exploratory data analysis to examine important characteristics of the data and determine the appropriate method for trend analyses,
2. Trend analyses, which are designed to determine if there have been changes (monotonic increases or decreases) in results over time, and whether these changes define a statistically significant trend, and

3. Analyses to examine similarities in results and trends among sites in a zone.

As part of the exploratory data analysis, we investigated the data for normality, seasonality, and serial correlation. Each parameter (fecal coliform, turbidity, dissolved oxygen, and temperature) was investigated separately within water quality sub-basins. Data normality was investigated by using frequency histograms. Data was found to be not normally distributed.

The data tended to exhibit seasonality. Seasonality occurs if one part of a year produces consistently higher or lower values than other parts of the year (Hrynkiw *et* al. 2003). Site temperatures and fecal coliform were generally higher during the drier time periods (May – September). Dissolved Oxygen and turbidity were generally lower during the dry time period. Temperatures and fecal coliforms were generally lower during the wetter time periods (October – April), whereas dissolved oxygen and turbidity were higher. As a result, we grouped the data into two seasons, wet and dry to help capture this seasonality. In addition, grouping the data into 2-seasons addresses another problem we encountered with the data- the relatively high frequency of missing data at most sites.

Due to the sporadic sampling at each site through its period of record, there were many months where no samples were collected. This creates some difficulty when conducting the seasonal Kendall test. Harcum *et al.* (1992) suggests that quarterly averaging data provided additional power to trend tests compared to analyzing monthly data when 40% or more of the monthly data are missing. We expanded this method to our samples and took either the arithmetic mean, geometric mean, or median of samples (as discussed below) in the wet or dry seasons to address this issue.

The last part of the exploratory analysis involved investigating the data for serial correlation. Serial correlation refers to the correlation between observations at the same site that are close in time. Significant serial correlation indicates that data are not independent, which is a necessary assumption for the Mann-Kendall trend analysis. The presence of significant serial correlation in the data requires removing it through de-trending or de-seasonalizing it before running the trends test (Hrynkiw *et al*. 2003). Harcum *et al.* (1992) determined that trend tests can still be accurate in most cases when there are 10 – 15 years of data and serial correlation is < 0.80. We therefore determined serial correlation of the data and determined significance by using the Ljung-Box statistic using both IBM SPSS Statistics 21 (Conrad 2013) and R. Serial correlations were predominately small with roughly 80% of the correlations being between -0.15 and +0.15 for the four parameters analyzed (DO, temperature, turbidity, and fecal coliform). This is well below the 0.80 level identified by Harcum *et al*. (1992) which is the threshold where serial correlation becomes a concern to the non-parametric trend test. Based on generally low level of serial correlations across all sites we concluded that serial correlation was not present to a degree that violated the assumption of independence required for the Mann-Kendall tests and that de-trending of the data was not necessary.

The Mann-Kendall (MK) test (also referred to as Kendall's tau) was used to detect trends at a site (Harcum *et al*. 1992). The seasonal Kendall (SK) test described by Hirsch *et al.* (1982) was used to test for trends using the combined quarterly data from each site. Finally, an adaptation of the SK test – the regional Kendal (RK) test described by Helsel and Frans (2006) – was used to test for trends using the data from all sites in a water quality sub-basin. These tests are designed to detect a monotonic trend or change during a specified period of time. Missing values present no computational or theoretical problems for applying these methods as long as they are no more than 50% of the data (Harcum *et al.* 1992). The methods are non-parametric so do not require normality assumptions and are robust against outliers (Hrynkiw *et al*. 2003).

All three tests compute a statistic called *S*. A positive value of *S* indicates an upward trend (increasing measurement over time) and a negative *S* indicates a downward trend (decreasing measurement over time). These tests are designed to provide a single summary statistic for the entire record (string of data) and do not indicate when there are trends in opposing directions in different periods within the string. Results for the trends are summarized as the *S* value and the significance level (*P*) of the *S* value. Significance levels were categorized as:

1. ***, highly significant, $P \leq 0.01$,
2. **, significant, $0.01 < P \leq 0.05$,
3. *, moderately significant, $0.05 < P \leq 0.10$, and
4. NS, not significant, $P > 0.10$.

Data from each site was analyzed for each season, wet (October –April) and dry (May – September). The data analyzed were constructed slightly different amongst the different parameters. It is typically recommended that the mean or median of the observations be used when there are multiple observations for one year (Hirsch *et al.* 1982 and Hipel and McLeod 1994), however slight variations of this was conducted for each parameter.

Water Quality Sub-basins

In order to investigate water quality trends at the sub-basin scale, we divided the Stillaguamish Watershed into 17 water quality sub-basins, which are essentially delineated major sub-basins in the watershed. All sub-basins had at least one monitoring site, but most had multiple monitoring sites. Data analyses largely discussed in this report are on the sub-basin scale. This was done in order to relate broader land use activities to overall water quality trends within each sub-basin. A map depicting the water quality sub-basins is presented in Figure 1.

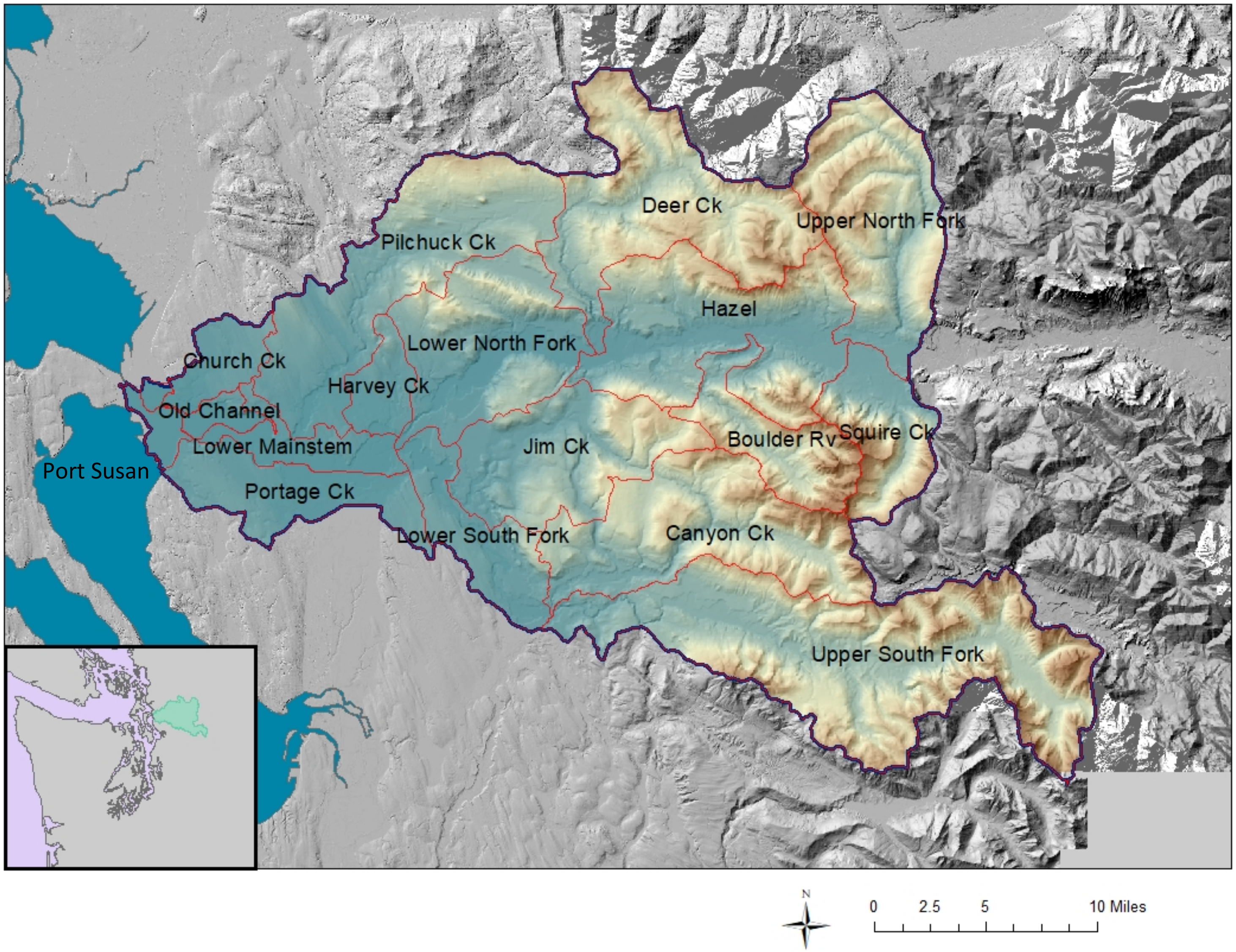


Figure 1. Map of watershed and sub-basins.

Parameters

The Stillaguamish Tribe's Water Quality Program measures surface and marine waters for a number of parameters. We used 4 parameters (temperature, dissolved oxygen, turbidity, and fecal coliform) in this report for two reasons: 1) These 4 parameters are key indicators of stream health for fisheries resources and for human contact. 2) The sample size of those 4 parameters is much higher than any other parameter collected by the Tribe. Measurement quality objectives and treatment requirements for all parameters listed above are presented in Table 1.

Temperature

Water temperature is an important parameter for determining water quality due to direct impacts on aquatic life. Water in streams vary with air temperature with warmer temperatures usually found downstream (Smith 1981). Many factors affect stream temperature and rate of diurnal fluctuation including stream depth, air temperature, riparian vegetation, and groundwater. Salmonids are particularly sensitive to high water temperatures with lethal limits ranging from 23° -26° C depending on the species (Carter 2005). Five salmon species, steelhead and bull trout return annually the Stillaguamish Basin (steelhead, bull trout and Chinook salmon ESA-listed as threatened), with some running up the river in greatest numbers during the height of the summer when ambient air temperatures peak. Sustained high temperatures can act as a physical barrier for salmon, blocking passage to spawning grounds further upstream. In contrast, groundwater can be a potentially moderating effect on temperature. Rainbow trout have also been shown to seek thermal refuge near groundwater seeps that tend to be cooler than surface water in the summer and warmer in the winter (Matthews and Berg 1997).

State water quality criteria for temperature are as follows:

- 7DADMAX of 16° C for Core Summer Habitat
- 7DADMAX of 17.5° C for Aquatic Life

7DADMAX = the seven-day average daily maximum.

Dissolved Oxygen

Dissolved oxygen (DO) is a common parameter in water quality analysis because of its direct effect on aquatic life. Individual species vary in their tolerance of low DO levels. Washington State sets the minimum concentration at two different levels based on use. These are:

- 1-Day Minimum of 9.5 mg/L for Core Salmon Habitat
- 1-Day Minimum of 8.0 mg/L for Aquatic Life

Table 1. Parameter treatment requirements and measurement quality objectives.

Parameter	Analytical Procedure	Sample Volume (mL)	Sample Container	Preservation	Holding Time	Precision	Accuracy	Lower Reporting Limit
Dissolved Oxygen	EPA 360.1	N/A	*In situ*	On-site	No Holding	± 0.2 mg/L	± 0.2 mg/L	± 0.1 mg/L
pH	EPA 150.1	N/A	*In situ*	On-site	No Holding	± 0.2 pH	± 0.2 pH	± 0.2 pH
Temperature	EPA 170.1	N/A	*In situ*	On-site	No Holding	± 0.2 °C	± 0.2 °C	-1 °C
Turbidity	EPA 180.1	100	P, G	Cool, 4° C	48 Hours	< 20% RSD	1 NTU	1 NTU
Fecal Coliform (MF)*	SM 9222 D	100	P, G	Cool, 4° C	6 Hours	< 25% RSD[¥]	2 cfu/100mL	2 cfu/100mL
Fecal Coliform (MPN)**	SM 9221 E	100	P, G	Cool, 4° C	6 hours	< 25% RSD[¥]	2 MPN/100mL	2 MPN/100mL

*samples analyzed by either North Creek Analytical, Test America, or Edge Analytical, ** samples analyzed by either North Creek Analytical, Test America, or Washington Department of Health

P = Poly plastic bottle, G = Glass bottle, RSD = Relative Standard Deviation, [¥]= Log Transformed Data

Temperature is often a controlling factor in DO concentrations. Lower water temperatures increase the solubility of oxygen; however, lower temperatures can also be an indication of groundwater infiltration that tends to be naturally lower in DO (Matthews and Berg 1997). Demand for oxygen in the stream occurs primarily through respiration of aquatic organisms and decomposition of organic material. High levels of autochthonous (created in the stream) and allochthonous (delivered to the stream) organic matter can deplete DO as decomposers respire. Sources of allochthonous wastes may be natural or anthropogenic. Manure runoff from agricultural areas have been a historic source of human-derived oxygen demanding pollutants, as well as any land use that involves excess biological material that can be delivered to the stream.

Turbidity

Turbidity is an optical property of water where suspended and dissolved materials cause light to be scattered rather than transmitted in straight lines (Bash *et al.* 2001). It is often used as a surrogate to estimate suspended sediment concentration (SSC), since turbidity can be correlated to SSC. Turbidity is a widespread water quality parameter throughout monitoring programs from different agencies. Its use is largely attributed to the ease and cost of using a nephelometric turbidity meter in comparison to the direct measurement of suspended solids.

A number of studies have illustrated the effects of turbidity on salmonids. Lloyd (1987) suggested that high levels of suspended solids, and thus likely turbidity, may be fatal to salmonids, while low levels may cause chronic sublethal effects such as loss or reduction of foraging capacity, reduced growth, increased stress, and interference with environmental cues that are necessary for migration. Salmonid populations that are not adapted to higher levels of turbidity may be negatively affected by levels that are generally considered low (18 – 70 NTU) (Gregory 1992). Turbidity can also have negative effects on salmonid habitat through the reduction in spawning habitat, changes to hyporheic upwelling, and damage to redds (Lloyd 1987).

Human activities including logging, road building, urbanization, agriculture, and construction have often resulted in periodic pulses or chronic levels of turbidity in streams (Bash *et al.* 2001). Water quality criteria for turbidity largely revolve around an understanding of background conditions. Determining background levels of turbidity, however, is a difficult endeavor considering that nearly the entire watershed has been influenced by human activities (SIRC 2005). Background conditions need to take several items in consideration such as drainage basin area, underlying soils, precipitation, and seasonality. To determine background turbidity, a stratified sample allowing one to differentiate between different physical and biological processes affecting watersheds is necessary (Bash *et al.* 2001). In Washington State, water quality criteria for turbidity are as follows:

- If background turbidity < 50 NTU, then anything > 5 NTU increase is a violation.
- If background turbidity > 50 NTU, then anything > 10% increase is a violation.

Fecal Coliform

Fecal coliform is an important parameter for measurement in water quality analyses. Fecal coliform are a group of bacteria found in the feces of humans and warm-bloodied animals such as livestock, pets and wildlife. Their presence and concentration in surface water is indicative of the amount of sewage waste and/or manure entering surface waters. There is a direct relationship between the presence of fecal coliform bacteria and the presence of illness-causing pathogens which can be inadvertently ingested through primary contact with fecal coliform contaminated waters or through ingestion of shellfish. High levels of fecal coliform can cause other problems as well. Sewage and manure contain nitrogen and phosphorus which promote algal growth and subsequent die-offs resulting in poor aesthetic properties and depleted oxygen levels. In marine environments, fecal coliform is monitored over shellfish growing areas in order to protect public health from consuming contaminated shellfish. Shellfish concentrate fecal coliform and associated pathogens from the water around them so water quality standards around shellfish growing areas are more stringent than those for primary contact.

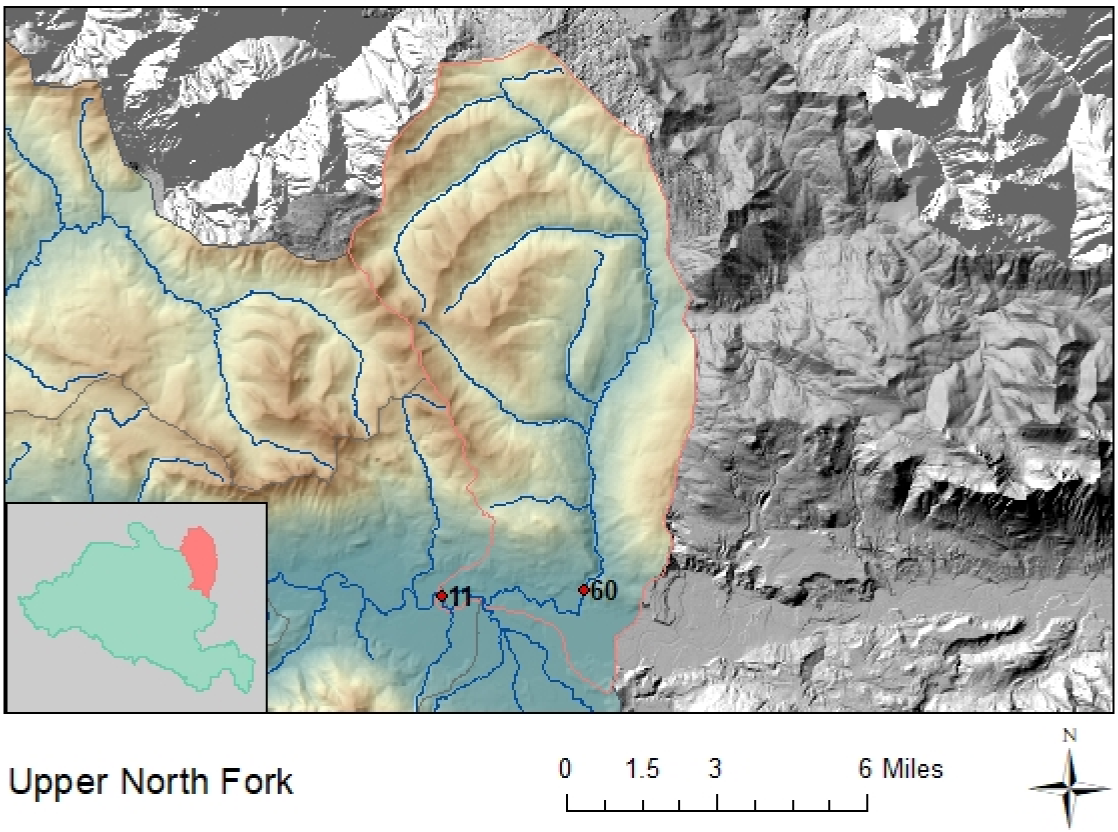
There are two methods used to monitor fecal coliform. For freshwater, membrane filtration is employed and results are reported as colony forming units (cfu)/100mL. For marine waters, multiple tube fermentation methodology is used and results are reported as most probable number (mpn)/100mL. These two methods are not comparable and often will yield different results on the same water sample. Washington State water quality standards for fecal coliform are as follows:

- For Freshwater:
    - Geometric mean = 100 cfu/100 mL
    - ≤10% of samples exceeding 200 cfu/100 mL
- For Marine water:
    - Geometric mean = 43 mpn/100 mL
    - Estimated 90^{th} percentile of 14 mpn/100 mL

Results

North Fork Stillaguamish Sub-Basins

UPPER NF



The Upper North Fork of the Stillaguamish is mostly comprised of land managed by the US Forest Service (78% of acres). Although logging occurred historically in this area currently there is very little activity. Samples were collected from only two locations, SSID #060 (NF Stillaguamish at the Bridge to Nowhere) and #011 (NF Stillaguamish at Whitehorse Bridge).

Temperature:

Temperature in the Upper North Fork sub-basin significantly decreased throughout the period of record (1993 – 2008) without regard to season. This trend was also observed during the wet season. There are a few potential reasons for this decreasing trend. For starters, since the Northwest Forest Plan became law in 1994, harvest of trees in US Forest Service (USFS) lands ceased. The USFS owns 88% of the land area in the Upper North Fork Stillaguamish sub-basin. This potentially allows for increased growth and potential shade which could have reduced stream temperatures. Another reason is due to our sampling design. From 1993 - 2000 our sampling regime was more random and covered all months, although not every month was sampled each year. From 2001 – 2013 the Tribe switched to quarterly sampling

(March, June, September, and December) thus eliminating the months of July and August during the dry periods and April, October, and November during the wet periods. Temperatures during these months tend to be the highest in their respective periods (Figure 2). By altering the sampling scheme, it is possible that we biased against these warmer months which would lead to a decreasing trend.

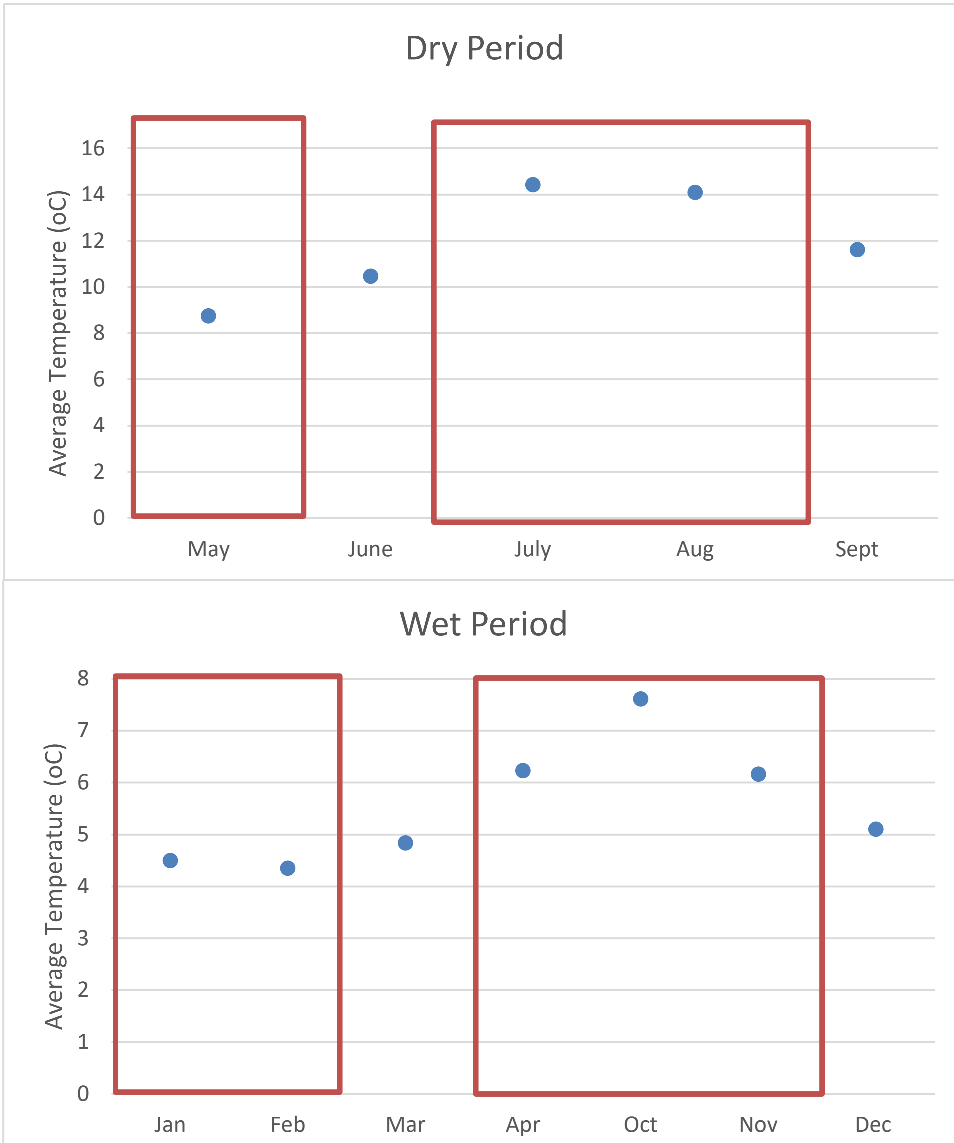


Figure 2. Upper North Fork Stillaguamish average temperatures by month (1993 – 2008). Boxes indicate months when sampling ceased during change to quarterly sampling regime from 2001 – 2008.

Dissolved Oxygen:

Along with the significant decrease in temperature, the Upper North Fork sub-basin displayed a significant increase in dissolved oxygen during its period of record. Dissolved oxygen and temperature and intrinsically tied together as colder water holds more dissolved oxygen. Dissolved oxygen never reached 9.5 mg/l or lower in any of our samples since 1996.

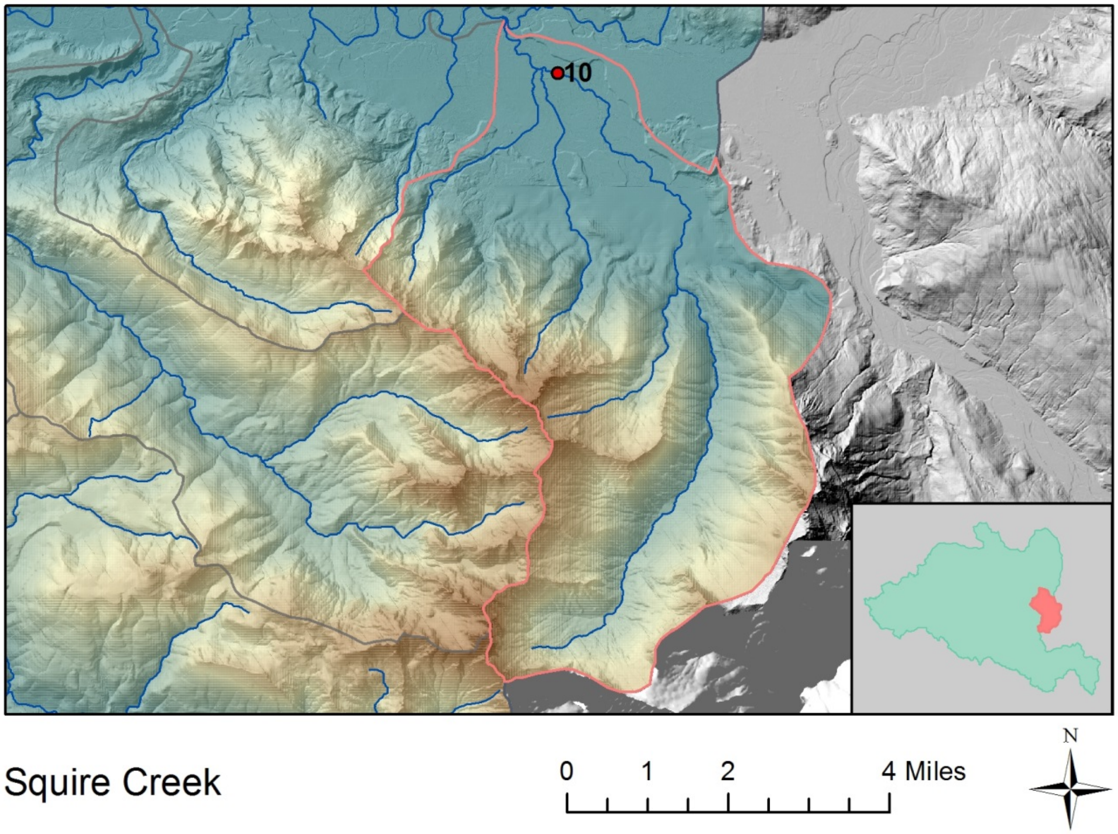
Turbidity:

Turbidity data was collected in the Upper North Fork from 1993 – 2013. There were no significant trends observed in turbidity from the Upper North Fork. Turbidity has been consistently low with monthly median values barely reaching over 3 NTUs. Highest turbidities tend to be during the wet months following rain events. A large portion of the Upper North Fork sub-basin is managed by the USFS (88%), which has been operating under the Northwest Forest Plan and therefore hasn't been harvesting trees in large quantities.

Fecal Coliform:

There were no significant trends observed in fecal coliform from the Upper North Fork. This sub-basin is dominated with commercial and national forests, with some residential neighborhoods at the lower end of the sub-basin. Fecal data collection from this zone ended in 2005 because there were no real concerns in terms of fecal pollution. This is evidenced by the running 10-sample geometric mean never reaching above 12 cfu/100 mL. Only two samples from the entire period of record (1996 – 2005) were higher than 100 cfu/100 mL (210 and 230).

SQUIRE CREEK



The Squire Creek sub-basin only had one sample site, located on Squire Creek at Hwy 530 (SSID #010). The majority of the land (69%) is under USFS management under the Mount Baker-Snoqualmie National Forest as the Boulder River Wilderness Area. Both Three Fingers and Whitehorse Mountains, the two highest peaks in the Stillaguamish Watershed (6,840+ feet) are located at the head of the sub-basin near the town of Darrington, WA. Outside of a county park and a few other state and county properties, the remaining 7% of ownership is private and generally located in the lower sub-basin. Sampling ceased in 2008 so results may not accurately depict current status.

Temperature

There were no significant trends observed in temperature other than a moderately significant decreasing trend in wet season temperatures. This trend, however, appears to be due to the change in sampling that occurred after 2001 to quarterly sampling. After 2001, samples were only collected in December and March and other "wet months" like October were no longer sampled. A review of the data shows that all of the high temperatures (greater than 7^{o} C) during the wet months from 1994 – 2001 were in October or November (months that were no longer sampled after 2001). Only one data point from 2002 – 2008 had temperatures > 7^{o} C. This is a case where the change in sampling regime likely biased the data. Nevertheless, temperatures in Squire Creek, as of 2008, remained low.

Dissolved Oxygen

There was a moderately significant increasing trend observed in DO. This was also the case during the wet season. Dissolved oxygen in the Squire Creek sub-basin has not been an issue in the past as only 1% of samples collected during the period of record has been less than 9.0 mg/L.

Turbidity

There was no trend observed in Squire Creek turbidity throughout its period of record. Ten-sample median turbidities rarely reached levels above 1 NTU (Figure 3). A large rockslide and debris flow took place in February 2002, but its impact on instream turbidities appeared to be minimal as the maximum turbidity ever observed was 92.8 NTU in December 2007. A slight peak in turbidity occurred in March 2002 of 20.5 NTU, but every sample from then to the December 2007 sample was no higher than 10 NTU.

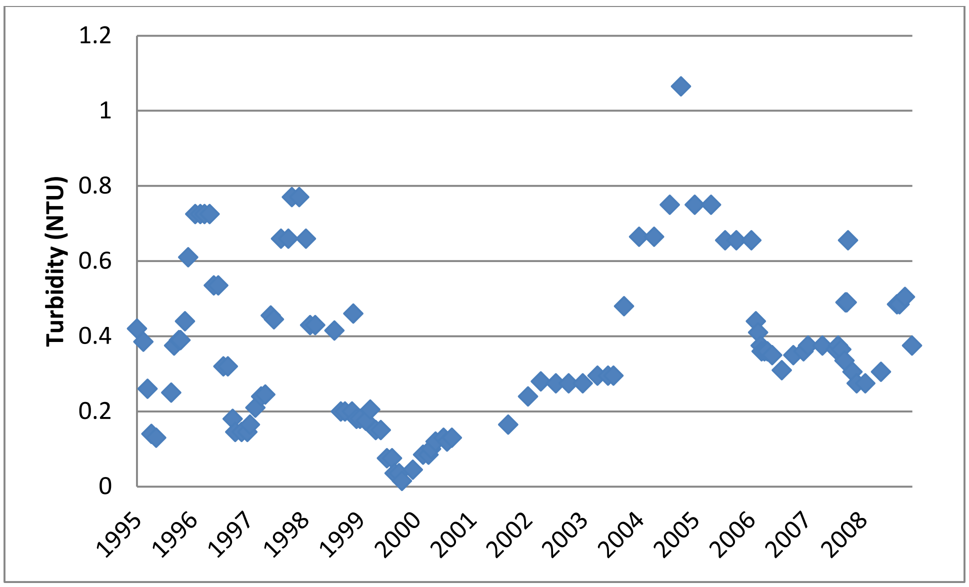
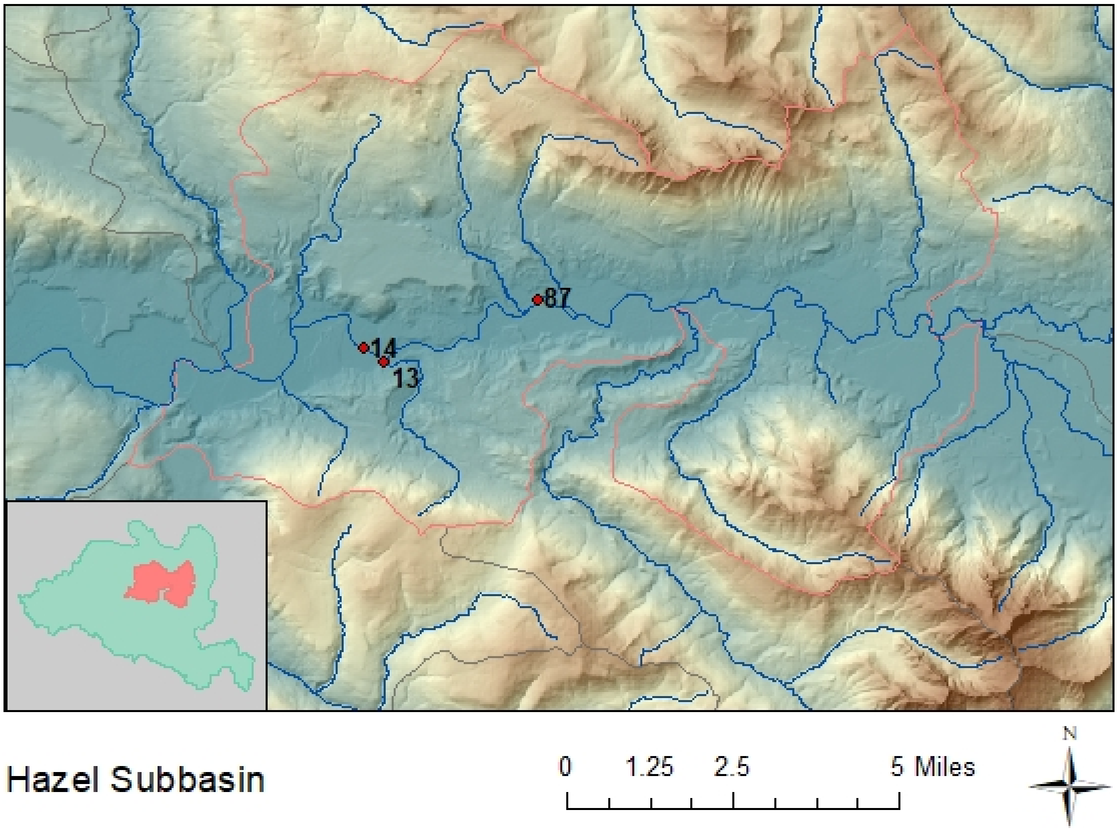


Figure 3. Ten sample median turbidity in Squire Creek sub-basin

Fecal Coliform

Fecal Coliform was only collected form 1996 – 2004. During that time frame there were a two high results of 130 and 280 cfu/100mL in 11/1996 and 9/2000 respectively, however with the large proportion of Wilderness Area in the sub-basin, it is likely that most fecal pollution is from natural origins. Sampling ceased in 2004 due to that very nature and it is not necessary at this point in time to begin sampling again for fecal coliform unless changes in land use occur in the future.

NORTH FORK HAZEL



The North Fork Stillaguamish at Hazel is marked by some of the most productive salmonid habitat in the Stillaguamish Watershed. This area also has one of the biggest chronic landslides in the entire watershed, known as the Steelhead Haven Landslide (SHL; more recently referred to as the Oso Landslide). Prior to March 2014, the SHL failed and damned the North Fork Stillaguamish on several occasions (1968, 2006, etc.). The SHL has a documented history of movement since the 1950's (Miller and Sias 1997). Most of the surrounding area in this sub-basin is dominated with commercial forest land. There are some rural residential holdings along with some agriculture, but those are a minimum in terms of area in this sub-basin. A total of 3 sites were used in this sub-basin, 2 of which were on the North Fork Stillaguamish and 1 on a tributary, Montague Creek. Montague Creek is also home to a number of landslides. Kennard and Pess (1994) found 33 shallow rapid landslides in the Montague drainage basin, 32 of which were associated with forest practices such as clear-cuts and road building. There is a large deep-seated landslide termed "Big Slump" that is currently contributing most of the sediment in Montague Creek

Temperature

There were no significant trends observed in temperature in this sub-basin nor from individual sites. Temperatures in this sub-basin have consistently been relatively low. Figure 4 illustrates this in showing that only approximately 5% of all samples collected in this sub-basin have been equal to or greater than

16° C (Core Summer standard) and only 2% equal to or greater than 17.5° C (Aquatic Life/Salmon Spawn, Rear, Migration standard).

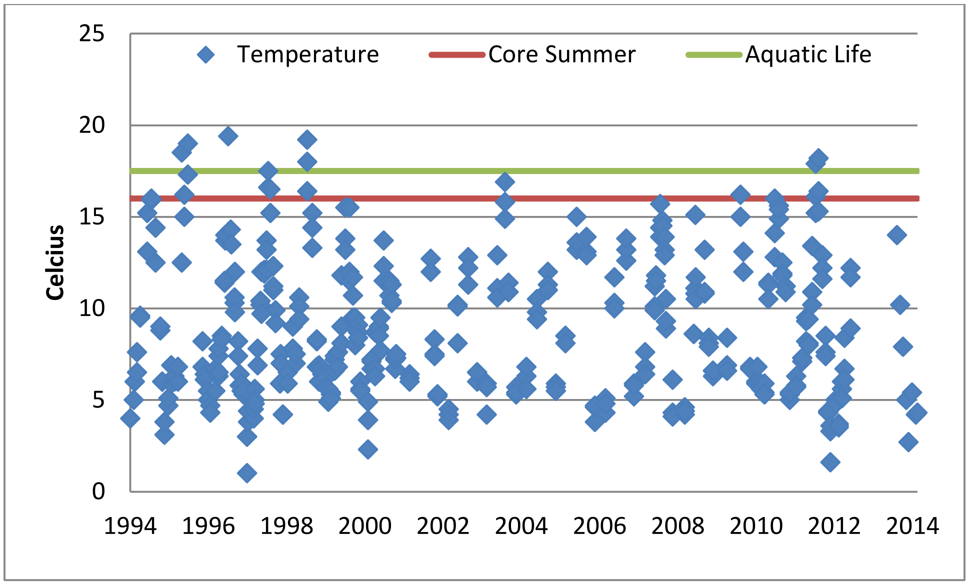


Figure 4. Temperatures (°C) in the Hazel sub-basin compared to core summer and aquatic life water quality standards.

Dissolved Oxygen

There was a moderately significant trend observed in dissolved oxygen within the Hazel sub-basin. The data show that there was a peak of measurements between 9/2011 – 12/2011 where DO from the combined sites was consistently over 13 mg/l. The Mann-Kendall test used for this analysis is susceptible to end of dataset extremes to influence significance (Hirsch *et al*. 1982). There is no real explanation for high DO observed during those months. The Tribe operates an EPA registered lab and follows strict protocols for calibration and use of meters.

Turbidity

The North Fork Hazel sub-basin did not show any significant trends in turbidity despite two of the three individual sites displaying significant increasing trends in turbidity throughout their period of record. The North Fork at C-Post (SSID 087) and Montague Creek (SSID 013) showed highly significant increases in turbidity without regard to season and during the dry season. Montague also showed highly significant increases in turbidity during the wet season. The “Big Slump” landslide in the Montague basin has been active lately, likely explaining the increase in Montague. It is a little more unclear on increases in turbidity observed at C-Post especially during the dry months (Figure 5). This increase would be considered a water quality violation. According to the Washington State Water Quality criteria for turbidity, an increase of 5 NTU’s over background, if background is less than or equal to 50 NTU would constitute a violation of the criteria.

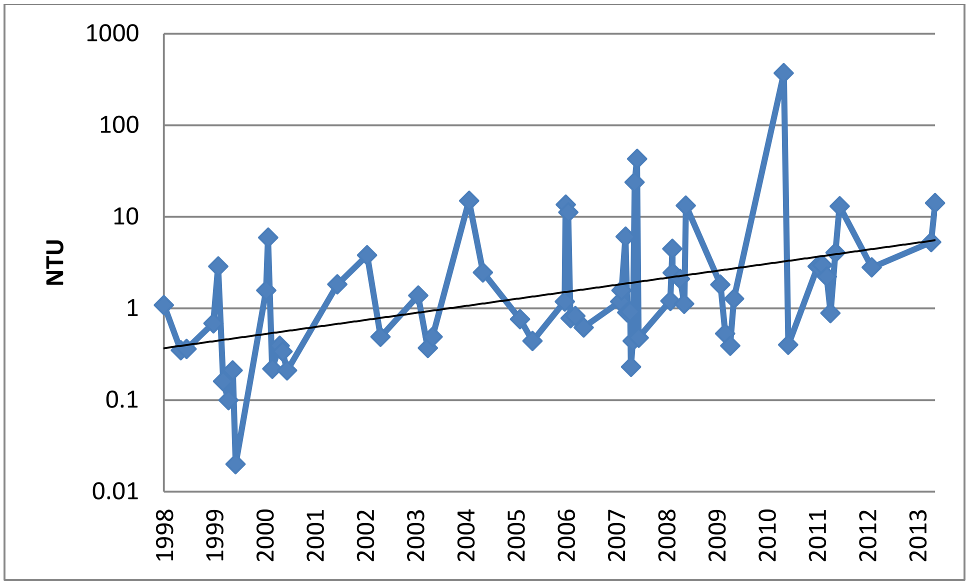
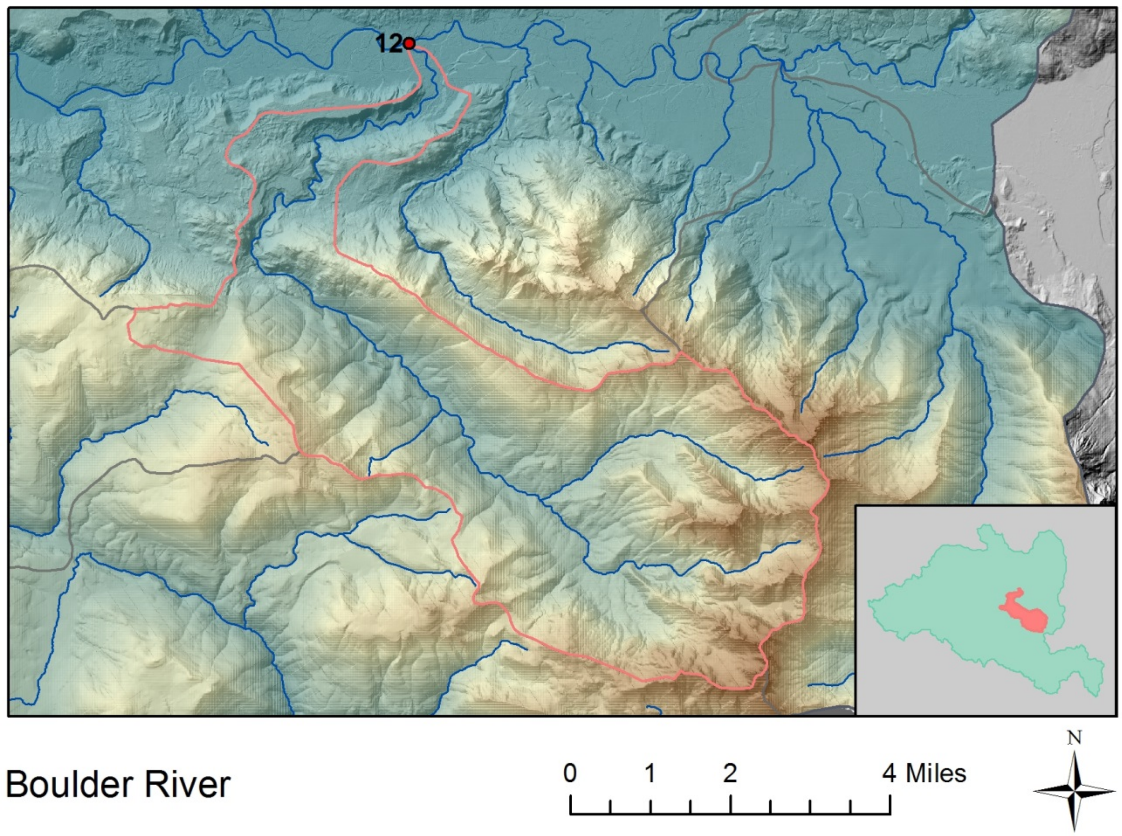


Figure 5. Dry period turbidity measured at the North Fork Stillaguamish at C-Post (SSID 087).

Fecal Coliform

None of the individual sample sites showed any trend in fecal coliform concentration over their period of record. Fourteen samples (n = 135), or 10% of the samples, from this sub-basin had fecal coliform over 200 cfu/100 mL. This is right at the threshold of the "not more than 10% of the samples" criteria. No other agency, state or local, currently monitors the North Fork Stillaguamish in this sub-basin for fecal coliform. WDOE samples at two sites in the North Fork Stillaguamish, one 7.8 miles downstream in our Lower North Fork sub-basin, and the other 12.4 miles upstream, in our Upper North Fork sub-basin.

BOULDER RIVER



There was only one sampling site in this sub-basin and it was located on Boulder River at Hwy 530 (SSID #012). This sub-basin is largely forested with approximately 95% of the total area covered by forests. It has a significant portion of its area in US Forest Service (USFS) land (75%) and as part of the Mount Baker-Snoqualmie National Forest and as the Boulder River Wilderness. There are some rural residential properties in the lower portion of the sub-basin comprising of around 3% of the total land area. The highest point of the Stillaguamish Watershed, Three Fingers Mountain (6,859 feet), partially drains into Boulder River. Boulder River was sampled from 1994 – 2008, so results discussed do not provide an adequate depiction of current status.

Temperature

There were no significant trends observed in this sub-basin with regard to temperature. Grab sample temperatures in this system never reached above 16° C. The highest temperature we ever recorded in the Boulder sub-basin was 15.7° C in August 1997.

Dissolved Oxygen

There was a significant increasing trend observed in dissolved oxygen. One incident occurred in November 1998 where DO was less than 9.5 mg/L (8.8 mg/L). It is unclear exactly the cause of this low reading. A replicate sample during that same day indicated a comparable result indicating it was a legitimate sample. Nevertheless, DO remains high in this sub-basin and there is no real need at this point to continue to monitor it unless there are changes to land uses.

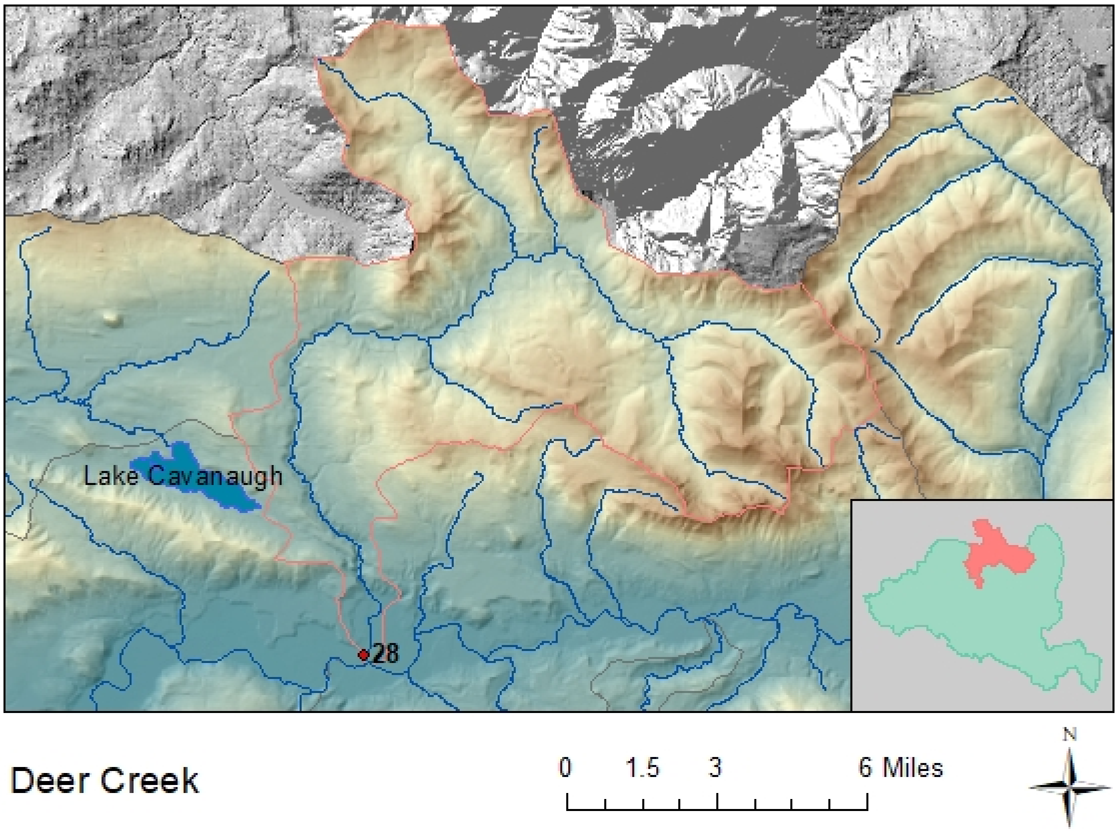
Turbidity

There were no significant trends observed in turbidity in this sub-basin. Boulder River is sometimes highly turbid, depending on the activity of unstable glacial deposits higher in the watershed. Perkins and Collins (1997) noted that of the 517 landslides documented in the North Fork Stillaguamish River drainage, 31 (6%) occurred in the Boulder River sub-basin. Ten-sample median turbidities have ranged from a low of 0.44 NTU to a high of 26.9 NTU. Since this sub-basin is largely contained within the Boulder River Wilderness Area any changes in turbidity are driven by natural processes.

Fecal Coliform

We only collected fecal data from the Boulder River sub-basin from 1996 – 2006. During this time, there were no significant trends observed in fecal coliform. As mentioned above, this sub-basin is mainly under management of the USFS as a Wilderness Area and presence of fecal coliform is most likely from wildlife. Geometric means of fecal data were less than 10 cfu/100 mL and there were no samples with fecal coliform greater than 75 cfu/100 mL throughout the period of record. There is no reason to resume sampling for fecal coliform in this sub-basin as long as it maintains its wild landscape.

DEER CREEK



The Deer Creek sub-basin predominately includes undeveloped forested land; however, it has historically been of greater concern for water quality than similar forest-dominated sub-basins in the Stillaguamish watershed. Legendary steelhead runs popularized by Zane Grey are dramatically lower than they were in the early 1900's (a loss of over 90%). Fine sediments delivered to the channel by the Deforest Creek landslide and forest practices are thought to be the main culprits behind the reduction in quality instream habitat and the loss of this once great run. The Tribe has monitored water quality at 9 different locations in Deer Creek throughout the years, but only one site near the mouth (SSID #028), had enough data to include in this report.

Temperature:

There were no significant trends observed in temperature during the period of record in the Deer Creek sub-basin. Despite this, temperatures tend to remain high during the summer months. Twenty-five percent of all dry season samples were greater than 16^{o} C. Roughly 10% were greater than or equal to 20^{o} C. This is a concern for the already depleted summer steelhead and Coho runs in this sub-basin.

Dissolved Oxygen:

In 1992 the Tulalip Tribes Natural Resources Division identified Deer Creek as an area of concern for dissolved oxygen (Nelson *et al*. 1995). In the 1995 study, measurements more closely resembled lower quality Mainstem sites, rather than upper basin tributaries. Stillaguamish Natural Resources sampled Deer Creek at Highway 530 from 1994 through 2012. Measurements during this period of record show a statistically significant increasing trend in DO regardless of season. There was also an increasing trend in dissolved oxygen during the dry season with no values below the Washington State Aquatic Life/Salmonid Spawn, Rear, Migration standard of 8.0 mg/L. Usually dissolved oxygen and stream temperatures go hand in hand so it is somewhat surprising that there is a significant increase in DO without a corresponding significant decrease in temperature.

Turbidity:

Deer Creek did exhibit an increasing trend in turbidity over its period of record. This was also true during the dry season. Deer Creek is home to the Deforest Creek landslide and many other, smaller, glacially derived landslides which directly deliver to surface waters. The Deforest Creek slide, in particular, is known for contributing to the dramatic reduction of some of the best steelhead waters in the country. Perkins and Collins (1997) estimated that through 1993 a total of over 2-million cubic meters of sediment from landslides was delivered out of the Deer Creek sub-basin. It is largely believed that the Deforest Creek landslide has stabilized in recent years as french drains were installed to divert water from the slide and alder and other trees have begun to colonize the scarp (Pat Stevenson, pers. comm). There are a number of potential explanations for this such as forest practice activities, increases in precipitation, or the scouring of deposited bank and bed sediments from previous landslides.

Forest practices require a FPA (forest practice application) to be filed with the Washington Department of Natural Resources (WDNR). The presence of a FPA does not necessarily mean that a ground disturbing activity has occurred and thus does not necessarily relate to actions that would cause sediment delivery. FPAs are filed for a range of forest practice activities, some of which would be actions that could cause sediment delivery. Nevertheless, in an attempt to help explain this significant increase in turbidity we used the number of FPAs received by the WDNR as a surrogate to estimate ground disturbing activity. We related FPAs received with the annual median turbidity measured in the Deer Creek sub-basin (Figure 6).

There appears to be a tendency for turbidity increases with corresponding increases in the number of FPA's requested to the DNR. The relationship is not strong (r^2= 0.29) so there are other issues involved in the increase. Another potential reason could be from precipitation. Annual precipitation measured in Arlington, WA had a slight increasing trend during the period of record (1993 – 2013) as well (Figure 7). A combination of forest practices, increasing precipitation and bank and bed scour from landslide deposits are likely to be the main reasons for this increase in turbidity observed in the Deer Creek sub-basin.

Fecal Coliform:

The Deer Creek sub-basin did exhibit improvement for its period of record while consistently passing water quality standards for fecal coliform. This sub-basin only had one sample site located near the mouth of the basin. Throughout its period of record, Deer Creek only had three (6%) samples with fecal coliform over 200 cfu/100 mL. This isn't surprising due to the > 85% of undeveloped forest land upstream of the sample sites.

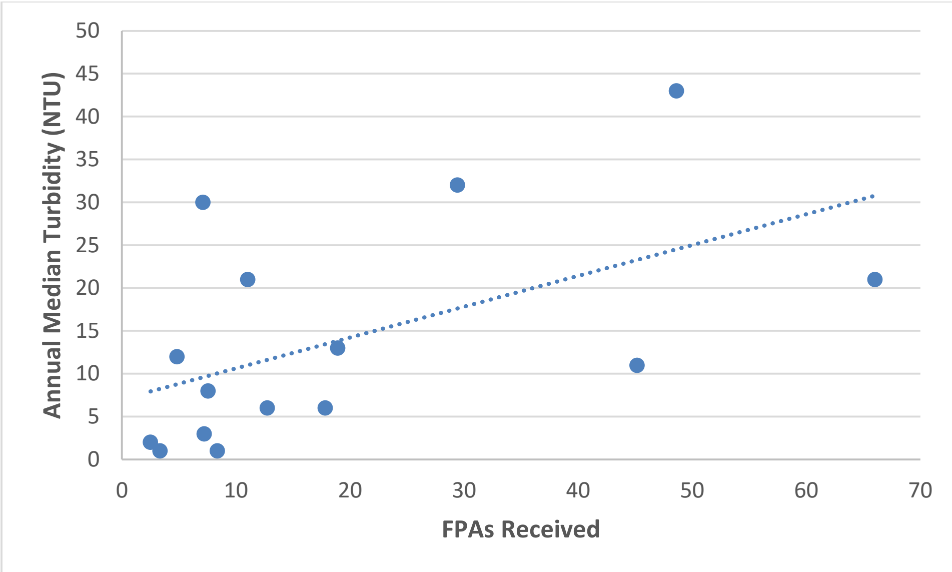


Figure 6. Relationship between the number of FPAs received by the Washington DNR and annual median turbidity in the Deer Creek sub-basin

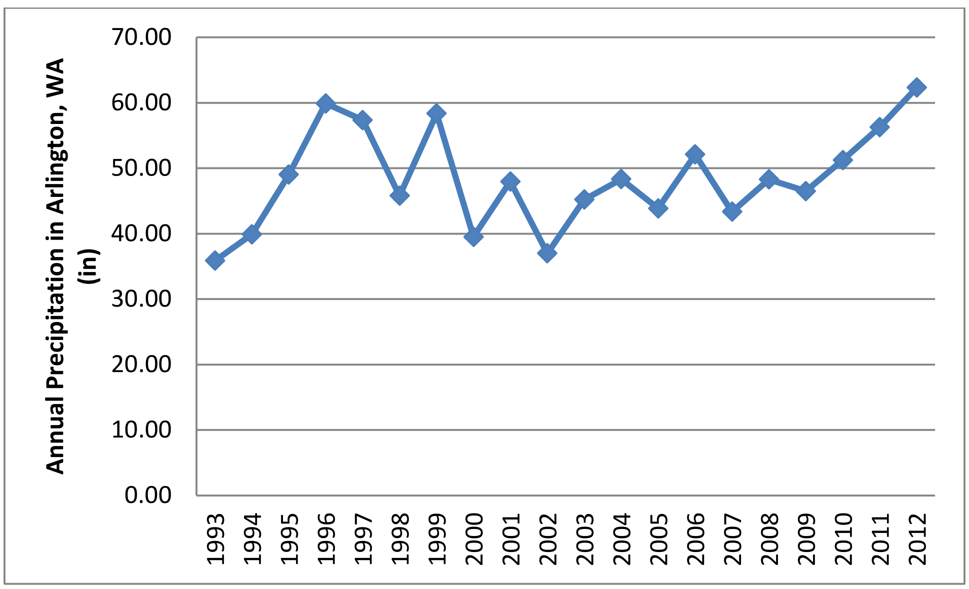
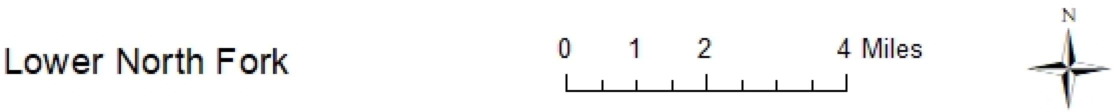


Figure 7. Annual precipitation (inches) measured in Arlington, WA from 1993 – 2012.

LOWER NF



The Lower North Fork Stillaguamish sub-basin has two sites that were sampled with enough consistency to be used in this analysis. These two sites are not spatially or environmentally similar. SSID# 119 is on the North Fork Stillaguamish at its mouth near Haller Park and SSID# 016 is on Johnson Creek, a small forested tributary. Data collected from #119 ended in 2008 so the relevance of results from this site should be taken with this in mind.

Temperature:

There was a significant decreasing trend in temperature in this sub-basin. This is due in large part to the temperatures at Johnson Creek which also showed a significant decrease in temperature over its timeframe. Only 5% of the temperature grab samples from the North Fork at Haller Park have been greater than 16^{o} C, however continuous temperature data collected by the Tribe in 2001 resulted in a 7DADMAX of 21.7^{o} C. Temperatures at Johnson Creek have consistently been below 16^{o} C and therefore meet water quality standards. Haller Park is likely much more representative of the sub-basin as a whole due to its location at the downstream end of the sub-basin. However, it has been nearly 10 years since the site was sampled, making it difficult to determine the current status of temperature in the Lower North Fork.

Dissolved Oxygen:

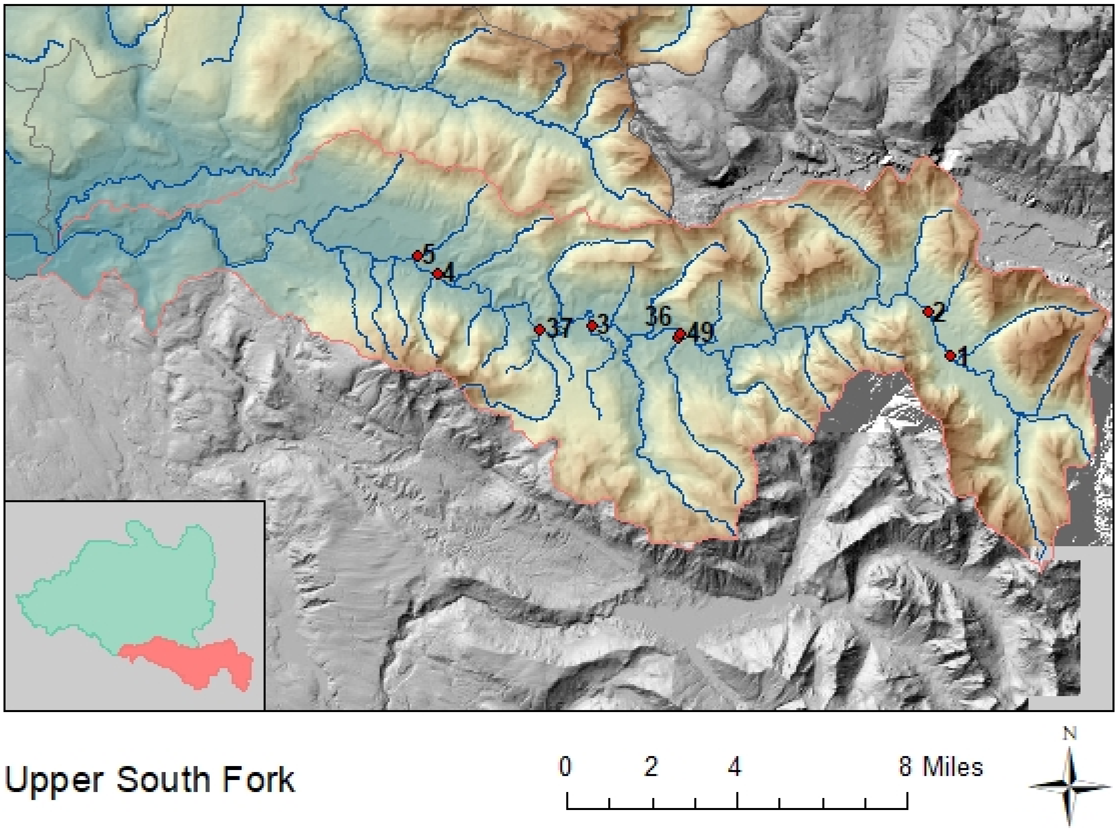
There was a significant increasing trend observed in DO in this sub-basin. Both sites exhibited this increase individually. It is likely that this is attributed to the significant decrease in temperature observed in this sub-basin. Dissolved oxygen in this sub-basin meets water quality criteria. Roughly 97% of all the DO samples in this sub-basin were greater than or equal to 9.5 mg/L, so an increase in DO in this sub-basin continues to provide adequate oxygen concentrations to salmonids and other aquatic resources.

Turbidity:
There were no significant changes in turbidity in this sub-basin throughout its period of record. Neither site exhibited a significant change. With the time lapse in data collected from the Haller Park site it is difficult to make a determination on current status of turbidity in this sub-basin.

Fecal Coliform:
There was a moderately significant decreasing trend observed in this sub-basin for fecal coliform. As mentioned above the last sample collected from SSID# 119, the North Fork at Haller Park, was in 2008 and combined with little overlap in sampling with SSID #016, it is difficult to make sense of any trend observed. Individually, the sites showed no trend one way or another.

South Fork Stillaguamish Sub-basins

UPPER SF



The Upper South Fork consists of roughly 80% USFS land as the Mount Baker-Snoqualmie National Forest with some developed riparian zones, infrequent logging operations, and a section of the South Fork which has been nominated to the National Wild and Scenic River System. There were a total of eight sample sites in this sub-basin, however, some sites did not contain enough data to include in all analyses. Temperature and dissolved oxygen data were analyzed at 3-sample sites: Boardman Creek, Mallardy Creek, and the South Fork at Red Bridge (SSID #003, 036, and 049 respectively). Turbidity data were analyzed at the three sites above, plus the South Fork at Big Four, South Fork at Beaver Creek, Benson Creek, Turlo Creek, and Black Creek (SSID #001, 002, 004, 005, and 037 respectively). Temperature, DO, and turbidity data were collected from 1993 – 2008 in the upper South Fork so results presented here may not accurately portray current status. No site had an adequate number of fecal samples for trend analysis since data related to this parameter was only collected from 1996 – 2002.

Temperature:

Water temperatures are relatively low in the upper South Fork, with average dry season temperatures less than 11^{o}C. These cool temperatures are reflective of the mature forest cover and high elevation terrain that feeds this sub-basin. There have been higher temperatures observed in the upper South Fork but nearly all measurements above 16°C occurred at Boardman Creek. None exceeded 20°C. These higher temperatures in Boardman are puzzling due to the excellent riparian habitat upstream and that it is fed by Boardman Lake, which is at 2,985' and cold. However, this is not a major concern since temperatures rarely exceed 16°C and measurements of Boardman Creek indicate a very significant decreasing trend for temperature. Mallardy Creek also shows a moderately significant decreasing trend. The Red Bridge site on the Upper South Fork has no significant trend, which is not concerning given the cool temperatures common to this reach.

Dissolved Oxygen:

A significant increasing trend was observed only at Boardman Creek for dissolved oxygen. This corresponds with the significant decreasing trend observed in Boardman for temperature. As far as the entire Upper South Fork sub-basin is concerned, DO has consistently met State water quality standards whereas only 4% of all samples have been ≤ 9.5mg/L and only 1 sample has been ≤ 8.0 mg/L.

Turbidity:

There has been a significant increasing trend observed in turbidity in this sub-basin (Figure 8). As mentioned above this sub-basin is largely contained within the Mount Baker-Snoqualmie National Forest which has been under the Northwest Forest Plan since 1994 which called for decreased timber harvest in National Forests. Although forests have been allowed to return to more mature age stands in the Upper South Fork, Purser *et al.* (2009) describes that chronic landslides in Gold Basin, Boardman Creek and Deer Creek continue to deliver fine sediment. Boardman Creek was the only individual site to show a significant increase in turbidity within this sub-basin. Purser *et al.* (2009) suspected that bank conditions and failing USFS roads are the primary culprits, thus increasing fine sediment pollution to the South Fork Stillaguamish. The Tribe is in the middle of a turbidity monitoring program in the Upper South Fork Stillaguamish. This program is monitoring turbidity changes as a result of the Gold Basin Landslide Remediation Project which will implemented in the near future. This data will prove valuable in the coming years to determine the current status of turbidity in the Upper South Fork.

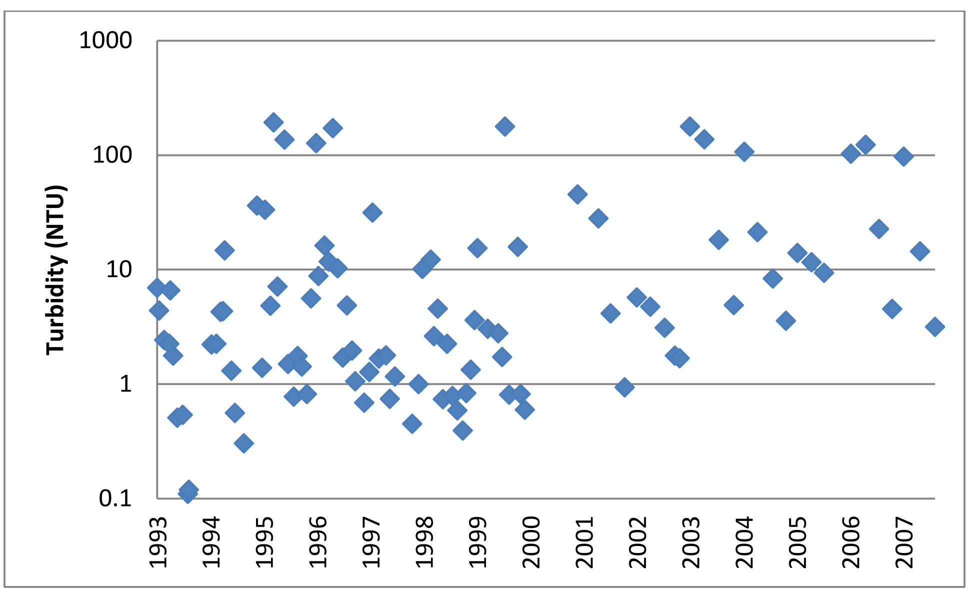
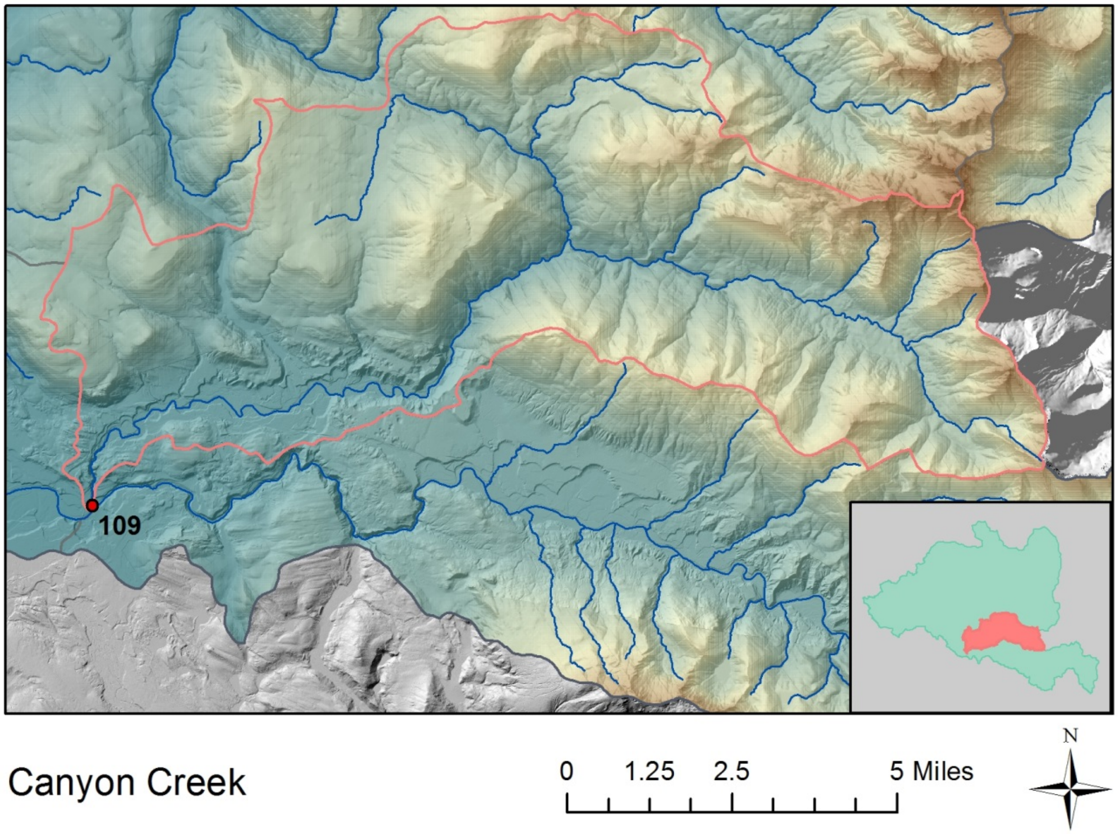


Figure 8. Median turbidity (NTU) from sites sampled in the Upper South Fork Stillaguamish.

CANYON CREEK



Canyon Creek had one sample site monitored from 1999 – 2008 (SSID #109 Canyon Creek at Mouth) so results from this site may not accurately portray current status. This sub-basin drains an area of roughly 58 square miles and approximately 60% of this is contained in the Mount Baker – Snoqualmie National Forest. The rest of the sub-basin is largely owned by commercial timber companies (31%) and private residences. According to Perkins and Collins (1997), 112 (37%) of the 306 documented landslides in the South Fork Stillaguamish River drainage occurred in the Canyon Creek sub-basin. Perkins and Collins (1997) also mention that the Canyon Creek sub-basin was the only major sub-basin that showed an increased rate of landsliding in their analysis.

Temperature

There was a moderately decreasing trend observed in temperature without regard to season in this sub-basin throughout its period of record. The wet season also showed a significantly decreasing trend in temperature. Temperatures were not terribly high as only 2% of samples were greater than 16^{o} C and none were greater than 17.5^{o} C. However, continuous data collected by the Tribe in 2001 that was used in the State's temperature TMDL study have shown that 7DADMAX reached 20^{o} C which is a violation of State Clean Water criteria.

Dissolved Oxygen

There was no significant trend observed in dissolved oxygen in this sub-basin. Dissolved oxygen levels remain fairly high in Canyon Creek as there were no samples that violated the 9.5 mg/L criterion during the period of record. There is no reason to sample DO in this sub-basin unless it becomes clear that land uses activities have changed.

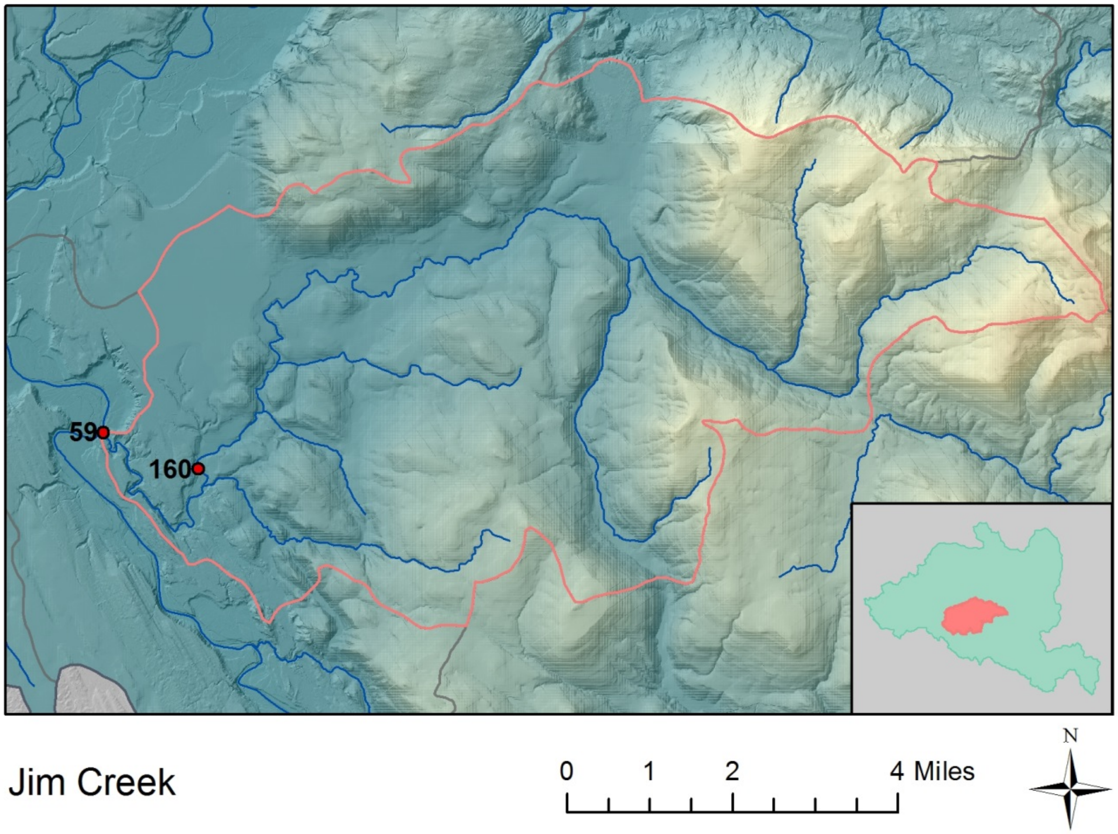
Turbidity

There was no significant trend observed in turbidity in this sub-basin. This is despite the fact that, as described above, Canyon Creek has been documented to contain 37% of the landslides in the South Fork Stillaguamish drainage. Although no trends were observed, we did document on one sampling event over 300 NTU in turbidity in 2001. Only one sample post 2001 was greater than 50 (54 NTU in 2007).

Fecal Coliform

There were no trends observed in fecal coliform in this sub-basin either. Data are sparse and for not a very long time span (1999 – 2006). As mentioned above, most of the sub-basin is forested (90%+) so most fecal pollution entering the system is likely natural in origin.

JIM CREEK



The Jim Creek sub-basin had two sample sites that were monitored from 1998 – 2008, Jim Creek at Jordan Rd (SSID #059) and Jim Creek at Whites Rd (#160). This sub-basin of 49 square miles discharges into the South Fork Stillaguamish. The upper portion of the sub-basin is forested and managed by commercial timber companies and a United States Navy Base. The lower portion of the sub-basin is rural residential and agricultural.

Temperature

There were no significant trends observed in temperature in this sub-basin other than a moderately decreasing trend observed at site #160 site. Temperatures were largely below Core Summer Habitat temperatures with only 6% of the samples greater than 16° C. Current temperature regimes are unknown since sampling ceased in 2008, however, Pelletier and Bilhimer (2004) added sections of Jim Creek to their temperature TMDL study because those sections did not meet state water quality criteria for temperature in 2001.

Dissolved Oxygen

There were no significant trends observed in DO in this sub-basin during its period of record. The Jim Creek sub-basin maintained fairly high DO levels with only 2% of samples below the 9.5 mg/L threshold.

Turbidity

There were no significant trends observed in turbidity in this sub-basin. Perkins and Collins (1997) noted that of the 306 landslides identified in the South Fork Stillaguamish River drainage, 63, or 21%, occurred in the Jim Creek sub-basin. Horner *et al.* (1986) identified Jim Creek as one of the major contributors of suspended sediment to the South Fork through computer models. Nelson *et al.* (1995) demonstrated that suspended sediment in Jim Creek wasn't nearly as high as Horner *et al.* (1986) noted. Our results seem to align with those of Nelson *et al.* (1995).

Fecal Coliform

There was a highly significant reduction in fecal coliform observed in the Jim Creek sub-basin throughout its period of record (1996 – 2006). Jim Creek was added to the State's 303(d) list for fecal coliform in 1998 (Joy 2004) and was found to have some of the highest recorded values in the Nelson *et al.* (1995) study. This was largely attributed to the high rural residential and agricultural land uses in the lower portions of this system. Our data has shown that the two individual sites monitored in this sub-basin have improved during the wet season and also without regard to season. The reduction in fecal coliform can be seen in Figure 9 which shows the falling 10-sample geometric mean throughout the period of record.

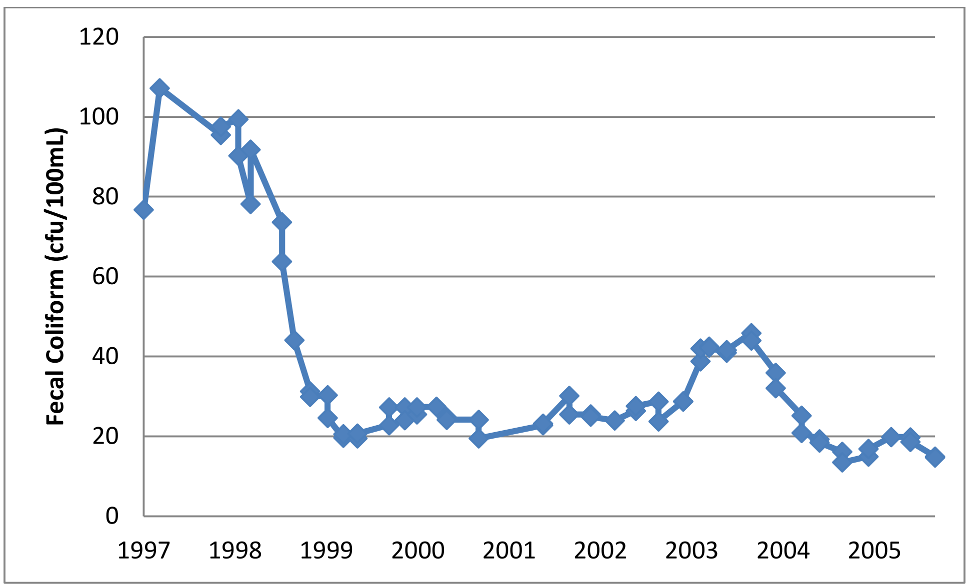
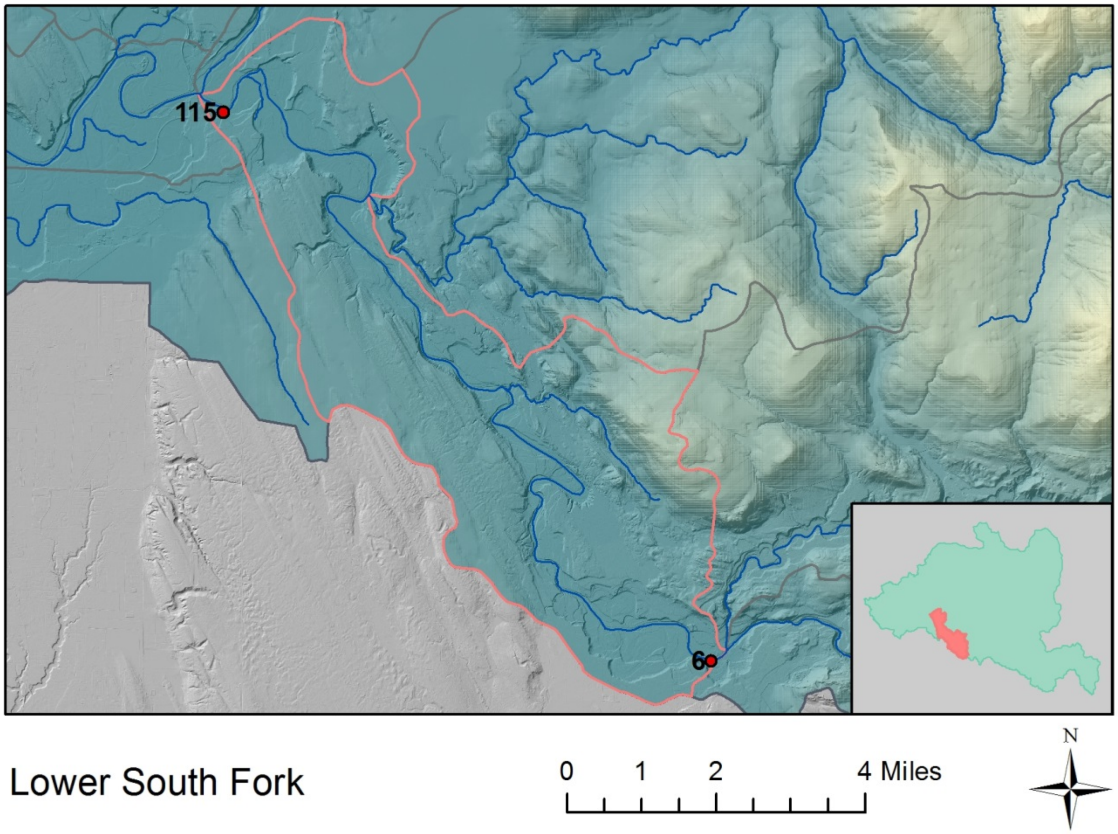


Figure 9. The 10-sample geometric mean of fecal coliform in the Jim Creek sub-basin.

LOWER SF



The Lower South Fork has two sample sites, both located at bridges crossing the South Fork of the Stillaguamish. The sample sites are located adjacent to the cities of Arlington (SSID #115) and Granite Falls (SSID #006) respectively which likely influences water quality. The Lower South Fork is a mixture of land uses like residential, commercial, and forestry. Data were collected from 1993 – 2008 so results presented may not accurately portray current trends.

Temperature:

Both sites indicate a decreasing trend in temperature overall and in the wet season. The upstream site (#006) also had a significant decreasing trend in the dry season. Over the course of the sampling regime temperatures exceeded the Department of Ecology threshold of 16^{o}C about 12% of the time including multiple samples above 20^{o}C.

Dissolved Oxygen:

Dissolved oxygen levels have shown a significant increasing trend in this sub-basin both in the dry season and without regard to season. This is perhaps a by-product of the lower temperatures observed as mentioned above. Dissolved oxygen levels were fairly decent in this sub-basin regardless as only 7% of samples collected were ≤ 9.5 mg/L and no samples since 2003 were ≤ 9.5 mg/L. No samples were ≤ 8.0 mg/L.

Turbidity:

Turbidity significantly increased in this sub-basin throughout the period of record for the wet, dry, and without regard to season (Figure 10). The upper site (#006) also exhibited a significant increase in wet season and without regard to season. This sub-basin has long been plagued by increased sedimentation. Purser *et al.* (2009) ranked fine sediment sources in the South Fork Stillaguamish during a three-year study (2006 – 2008) and found that during that time period a bend in the river, Trangen Meander, was one of the biggest contributors to fine sediments in the South Fork. Trangen Meander is located within the Lower South Fork Stillaguamish sub-basin between the two sample sites. Other sources are from the Upper South Fork Stillaguamish sub-basin such as the Gold Basin landslide, Boardman Creek and other tributaries. These sources have higher percentages of silts and clays that are likely to stay in suspension throughout the South Fork Stillaguamish and as such will appear more in turbidity samples. The increase in precipitation as measured in Arlington (Figure 7) would also explain the increase in turbidity measured in the Lower South Fork. Future plans are underway to implement a sediment reduction project at the Gold Basin landslide and therefore it is recommended to begin monitoring for turbidity in this sub-basin again in order to get a better understanding of the remediation on downstream turbidity.

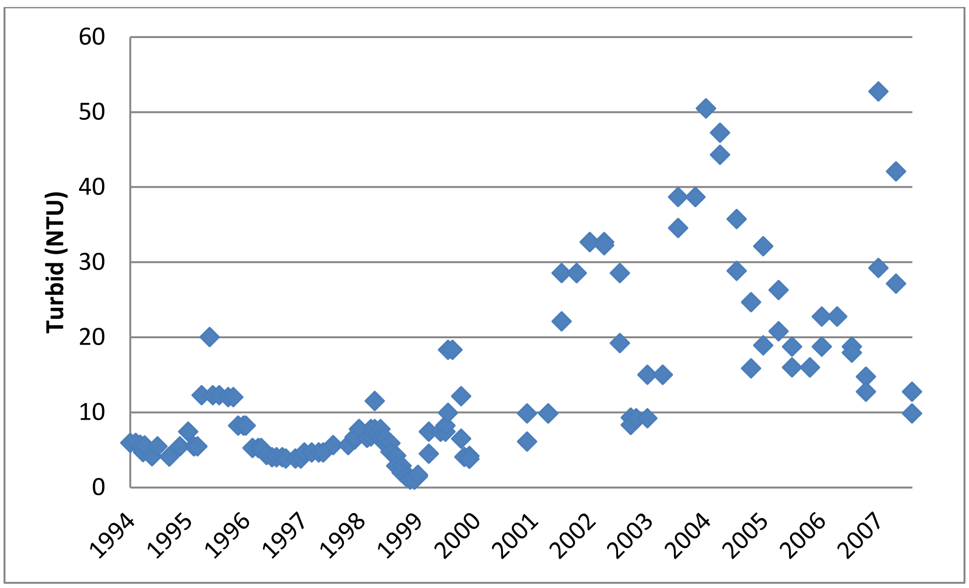


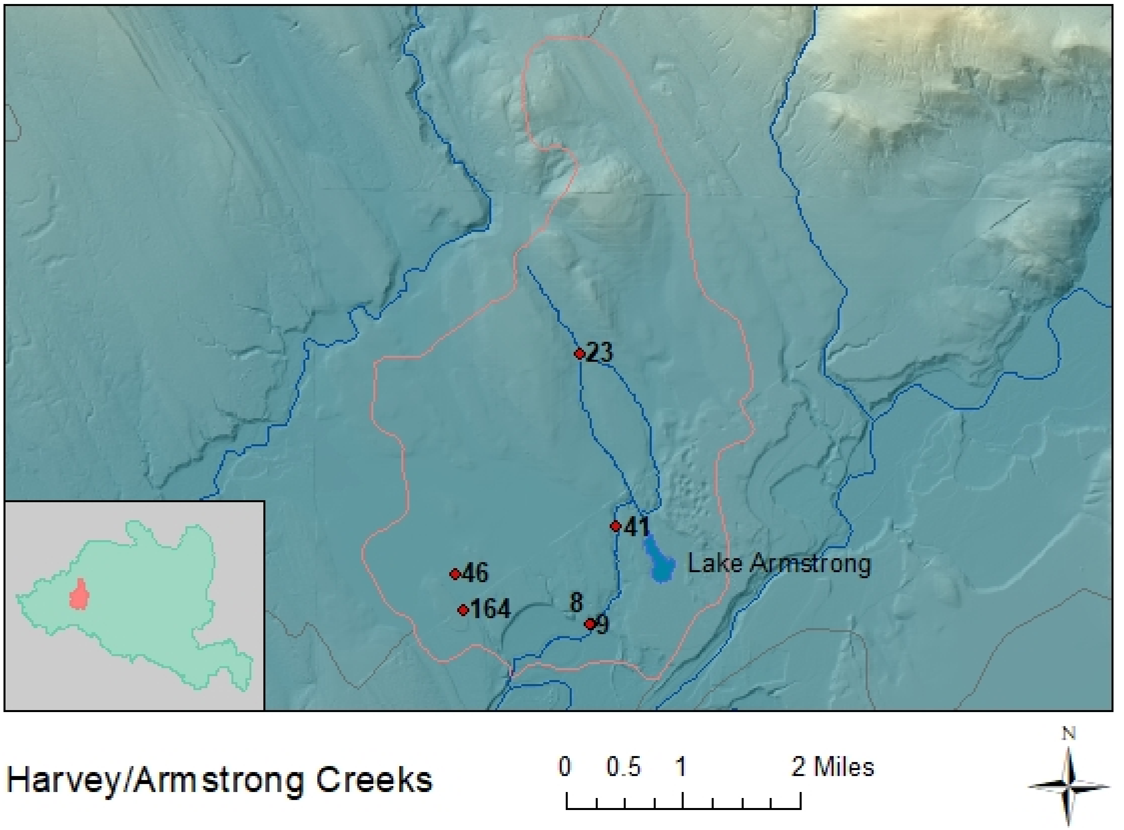
Figure 10. The 10-sample median turbidity (NTU) in the Lower South Fork sub-basin.

Fecal Coliform:

There were no significant trends observed in this sub-basin for fecal coliform. Ten-sample geometric means were never higher than 32 cfu/100mL. The highest percentage of samples greater than 200 cfu/100mL was 7% and occurred during a short period from September 1997 – March 1998.

Mainstem Stillaguamish Sub-basins

HARVEY/ARMSTRONG



The Harvey/Armstrong Creek sub-basin has its headwaters in commercial timberland and then flows through rural residential areas with occasional small farms. After the confluence with Harvey Creek, Armstrong Creek flows into the Mainstem Stillaguamish River just below the City of Arlington. From 1993 to the present there have been a total of six different sampling sites but only one has been sampled in the last eight years (#009). The current sampling location is directly below the outfall of Harvey Creek Hatchery in an area that has recently become an active beaver complex.

Temperature:

There were no significant trends observed in the Harvey/Armstrong sub-basin for temperature during the period of record. Three individual sites showed moderately increasing trends during the dry season, but this data truncated in 2008. The longest running data set from this sub-basin (SSID 009; 1994 - 2014) has not shown any trend in temperature. Temperatures in this sub-basin remain low as only 4% of all temperature data collected were greater than or equal to 16° C.

Dissolved Oxygen

There were no significant trends observed in this sub-basin for dissolved oxygen other than some of the individual sites showed some significant trends either during the wet season, the dry season or without respect to season. The site with the largest dataset, SSID 009 (1994 – 2013), showed a decreasing trend in DO during the dry season, however, DO maintained at fairly high levels with only about 4% of the samples less than or equal to 9.5 mg/L. None of the samples at SSID 009, were less than 8.0 mg/L.

Turbidity

There were highly significant increasing trends in turbidity in the Harvey/Armstrong sub-basin in the wet season and without regard to season. Figure 11 illustrates this increasing trend. Despite the increase, turbidity still remains fairly low as the 10-sample median never reached above 5 NTUs throughout the period of record. Four of the five sites monitored in this sub-basin also showed significant increases without regard to season.

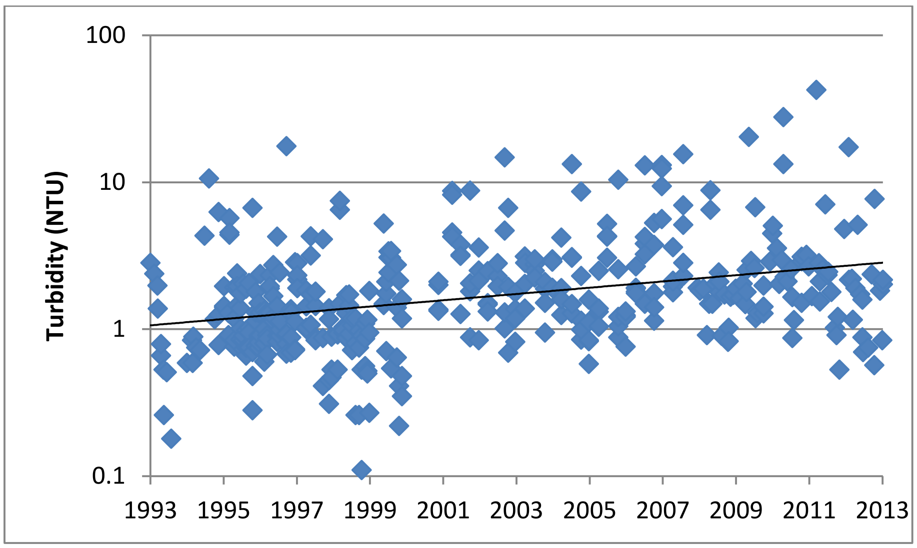


Figure 11. The 10-sample median turbidity (NTU) from the Harvey/Armstrong sub-basin.

Fecal Coliform

Many of these landowners in the Harvey/Armstrong sub-basin have farm animals and are on septic systems. This is evidenced by the fact that Harvey/Armstrong Creek has been on the State's 303d list since 1996 for fecal coliform. The State also determined during their TMDL study in the Stillaguamish Watershed that Harvey/Armstrong did not improve since the 1998 listing of that creek on the 303d list and may have even worsened (Joy 2004). Our data has shown that since 1996, fecal coliform in the Harvey Armstrong sub-basin has improved significantly. Fifty percent of our first 10 samples collected in this sub-basin were greater than 200 cfu/100 mL. This was reduced to 10% from our last 10 samples. Based on our data, 2003 was a peak year in fecal coliform in the Harvey/Armstrong sub-basin with a geometric mean of 168 cfu/100 mL and 47% of samples greater than 200 cfu/100 mL (Figure 12). The sub-basin as a whole consistently met water quality standards since 2010 with geometric means never reaching above20 cfu/100 mL and less than 10% of samples greater than 200 cfu/100 mL.

Of the five sites the Stillaguamish Tribe routinely sampled in the Harvey/Armstrong sub-basin, three displayed significant improvements during their period of record. These three are Harvey Creek at the Hatchery (SSID #009; $p < 0.01$), Harvey Creek at Grandview Rd (#023; $p < 0.10$) and Kackman Creek at

252nd (#046; $p < 0.05$). Of greatest interest is SSID #009 as it is located the furthest downstream. This site, located at the Tribe's hatchery, showed significant improvements during both seasons as well ($p = 0.03$ and 0.02 in wet and dry seasons respectively) further indicating that reductions in fecal coliform were a result of land use changes.

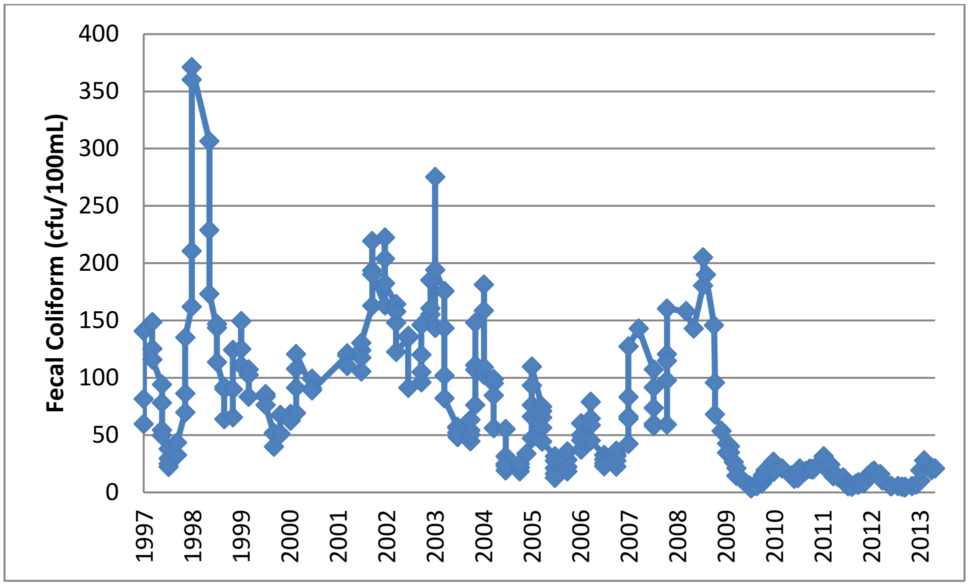
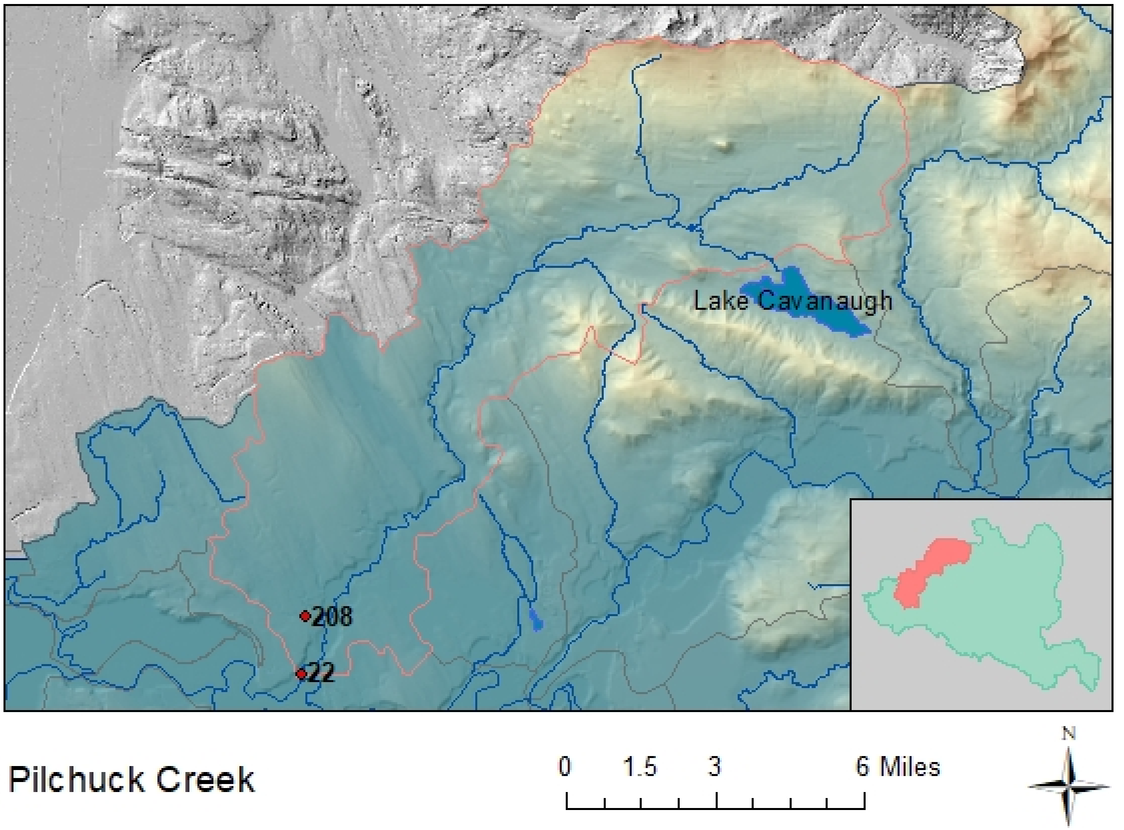


Figure 12. The 10-sample geometric mean of fecal coliform (cfu/100mL) in the Harvey/Armstrong sub-basin.

PILCHUCK CREEK



The Pilchuck Creek sub-basin consists mostly of forestland owned by the Department of Natural Resources (DNR) and private timber companies (62% forested). Its head waters originate in forestland and from Lake Cavanaugh. The lower Pilchuck sub-basin shifts to more rural residential land uses. Pilchuck Creek has a documented history of low summer flows (Lombard and Sommers 2004). The causes of which are presumed to be from permit exempt wells, development, and changes to the channel such as loss of wetland connectivity (Lombard and Sommers 2004). Two sample sites were included in this analysis: Secret Creek (SSID #208) a tributary to Pilchuck Creek, and mainstem Pilchuck Creek at Jackson Gulch Road (#022).

Temperature:

In 1998 the State listed Pilchuck Creek on the 303d list because temperatures exceeded 16°C for the seven-day average of maximum daily temperatures (7DADMAX). Our analysis shows that the Pilchuck Creek sub-basin has shown a significantly decreasing trend in temperature between 1993 and 2013. Specifically, the Pilchuck Creek sampling site (SSID #022) showed a significant decreasing trend during its period of record. It is likely that any trend observed in the sub-basin is largely tied to this sampling location, since it is the longest dataset of the two. Despite this observation, high temperatures continue to be a problem, as evidenced by continuous temperature data collected by the Tribe, indicating that 7DADMAX has exceeded 20°C four out of the five-year span between 2009 – 2013 (Brown 2013).

Secret Creek, on the other hand, did not display a significant trend for temperature. It has only been sampled for 5 years, however. Despite rural residential development in the upper basin of Secret Creek, maximum recorded temperature never exceeded 16° C for the period of record, however the 7DADMAX from continuous temperature loggers has exceeded 16° C two of the 4 years data was collected (Brown 2013).

Dissolved Oxygen:

Analysis of data from the Pilchuck Creek sub-basin shows a moderately significant increasing trend in DO. This may be attributed to a significant decreasing trend in temperature that would increase DO solubility. Although there is a moderately increasing trend in DO in this sub-basin, there are still violations to Washington Water Quality standards for dissolved oxygen. Both Pilchuck Creek and Secret Creek have excursions below Core Summer standards of 9.5 mg/L and Aquatic Life standard of 8.0 mg/L (24% and 4 % for Pilchuck Creek and 26% and 10% for Secret Creek respectively). These are usually during the dry summer months when temperatures are highest.

Turbidity:

There was a significant increase in turbidity observed in the Pilchuck sub-basin. Turbidity was fairly stable in this sub-basin from 1995 – 2009 as the 10-sample median maintained around 2 NTU (Figure 13). Following 2009, the 10-sample median ranged from 2 – 12 NTU. We started sampling Secret Creek (SSID# 208) in 2009, however, even without Secret Creek data, the Pilchuck Creek sampling location exhibited a significant increase in turbidity as well. There was no trend observed in Secret Creek. Sampling increased from quarterly to monthly in 2009. It is possible the increase in sampling allowed more opportunity to sample higher turbidities.

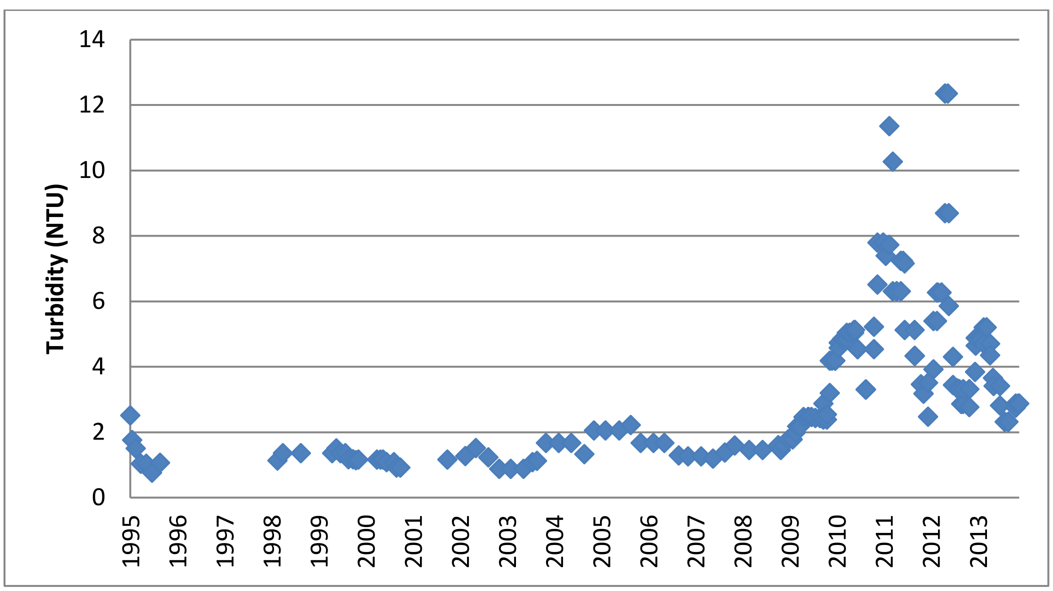
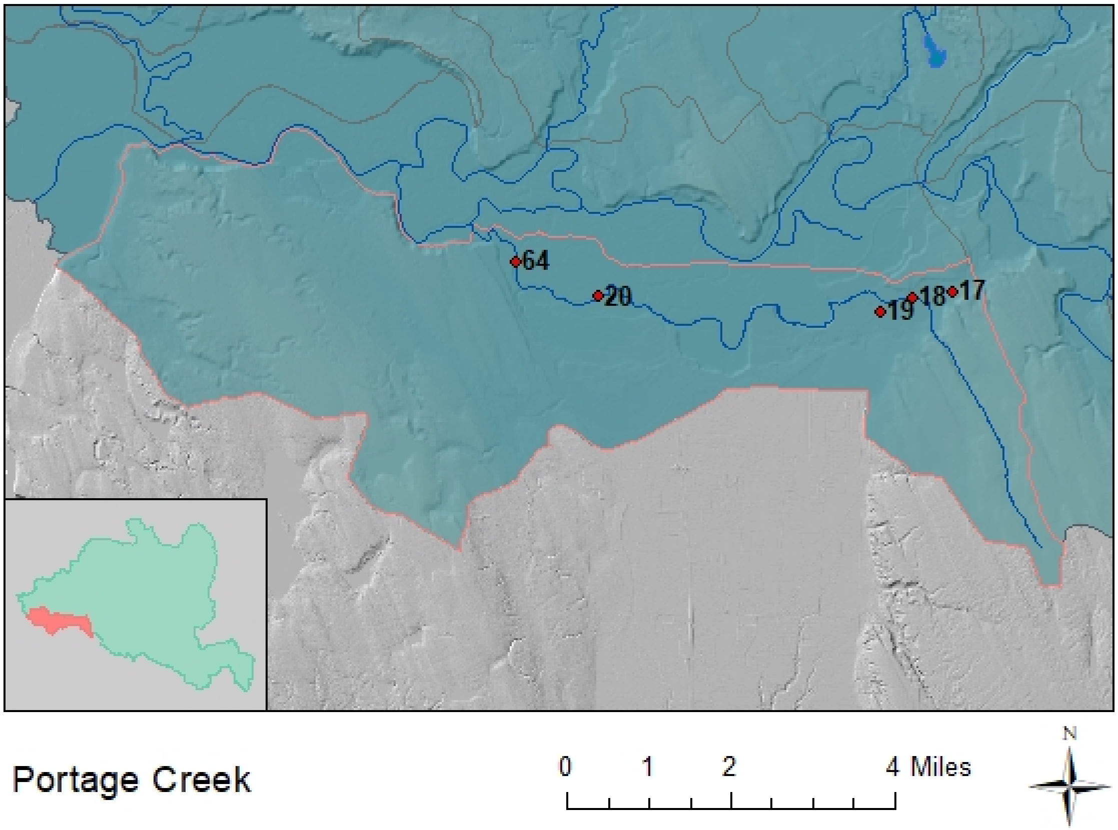


Figure 13. The 10-sample median turbidity in the Pilchuck Creek sub-basin.

Fecal Coliform:

There were no significant trends observed in the Pilchuck sub-basin in fecal coliform. In 2004, Ecology listed Pilchuck Creek on the 303d list for fecal coliform because more than 10% of the samples collected were greater than 200 cfu/100mL (Joy 2004). Our data shows that 11% of samples collected in this sub-basin were greater than 200 cfu/100 mL (geomean of last 30 samples= 20 cfu/100 mL) throughout the period of record. Secret Creek did show a moderately increasing trend in fecal coliform over its period of record (2009 -2014).

PORTAGE CREEK



Portage Creek runs through a partially forested rural residential area before flowing into the City of Arlington. Upon exiting the City of Arlington, the lower portion of the sub-basin is agricultural. It is intersected by Highway 9 and Interstate 5. The Portage Creek sub-basin is the most urbanized sub-basin in the Stillaguamish Watershed. There are five sample sites in this sub-basin: three located at intervals along Portage Creek (SSID #018, Portage at Hwy 9; #020, Portage at 15th, and #064, Portage at 212th), one located on Krueger Creek (SSID #017) and one on Prairie Creek (SSID #019). Krueger and Prairie Creeks are tributaries of Portage Creek. Prairie Creek and Portage at 15th had not been sampled since 2007 and therefore it is difficult to determine existing issues.

Temperature:

There were no significant trends observed in this sub-basin with respect to temperature. Throughout the period of record of temperature data (1993 – 2013) only 3% of samples were higher than 16° C and less than 1% were higher than 17.5° C. We placed Onset© Hobo temperature data loggers in the summers of 2001 and 2002 at the three Portage Creek Mainstem sites (SSIDs 018, 020 and 064). All of these data show that summer temperatures in Portage are fairly constant with fluctuations ranging from 11.5 – 16.5°. This indicates a large groundwater recharge into the system rather than runoff.

Dissolved Oxygen:

Out of the over 440 samples collected in this sub-basin for dissolved oxygen from 1993 – 2013, 39% were less than 9.5 mg/L and 26% less than 8.0 mg/L. This indicates poor oxygen quality in this sub-basin. This was also noted in the State's TMDL study (Joy 2004) and explained as a combination of pollutant sources adding nutrients and lower DO groundwater contributing a larger portion of flow especially during the dry season. Our data supports that DO is lower during the dry season (53% ≤ 9.5 mg/l in dry season vs. 28% ≤ 9.5 mg/l in the wet season). Greater portions of groundwater contributing flow in the summer may also explain why summer temperatures are fairly stable and consistently below 16.5^{o} C as described above.

Turbidity:

There were significant increases observed in this sub-basin in the wet season, dry season, and without regard to season. Two individual sites also depict this trend (Portage at Hwy 9 and Krueger Creek). Portage Creek was listed on the State's 303(d) list in 1996 for turbidity as well (Joy 2004), so there still appears to be much work to do to address this issue in this sub-basin. Turbidity tends to increase with urbanization and Portage Creek has definitely seen an increase in development over the past 20 years. Specifically, the amount of developed area has increased by almost twenty percent from 1987-2011 (CORE GIS 2013). Agricultural practices can also cause increases to turbidity through the removal of functioning riparian zones and by disturbing the soil from conventional tillage or overgrazing. These coupled with increasing precipitation in Arlington (Figure 7) during the period of record are likely causes for this increasing trend in turbidity observed.

Fecal Coliform:

Portage Creek was listed on the State's 303(d) list for fecal coliform in 1996 (Joy 2004). It stayed on the list in 1998 and did not show any improvement in 2001 during the TMDL study (Joy 2004). Our data has shown that this sub-basin has a highly significant improvement in fecal coliform in the dry season and without regard to season throughout its period of record (1996 – 2013). Three of the five individual sites have also demonstrated this decrease in fecal coliform with only Krueger and Prairie Creek showing no trend. The improvements in fecal coliform are demonstrated in the geometric mean of samples collected throughout the years. As seen in Figure 14, the running 10-sample geometric mean has dropped precipitously throughout the period of record so much so that the last samples in 2013 have caused both the geometric mean and the 10% standard to meet State water quality standards.

Prior to 2005 two dairy farms located in the lower portion of Portage Creek were frequently cited for clean water violations. These farms eventually went out of business (2004) and the property they once occupied have been converted to residential properties. The transition away from dairy farms is likely one of the main reasons for this improvement in fecal coliform.

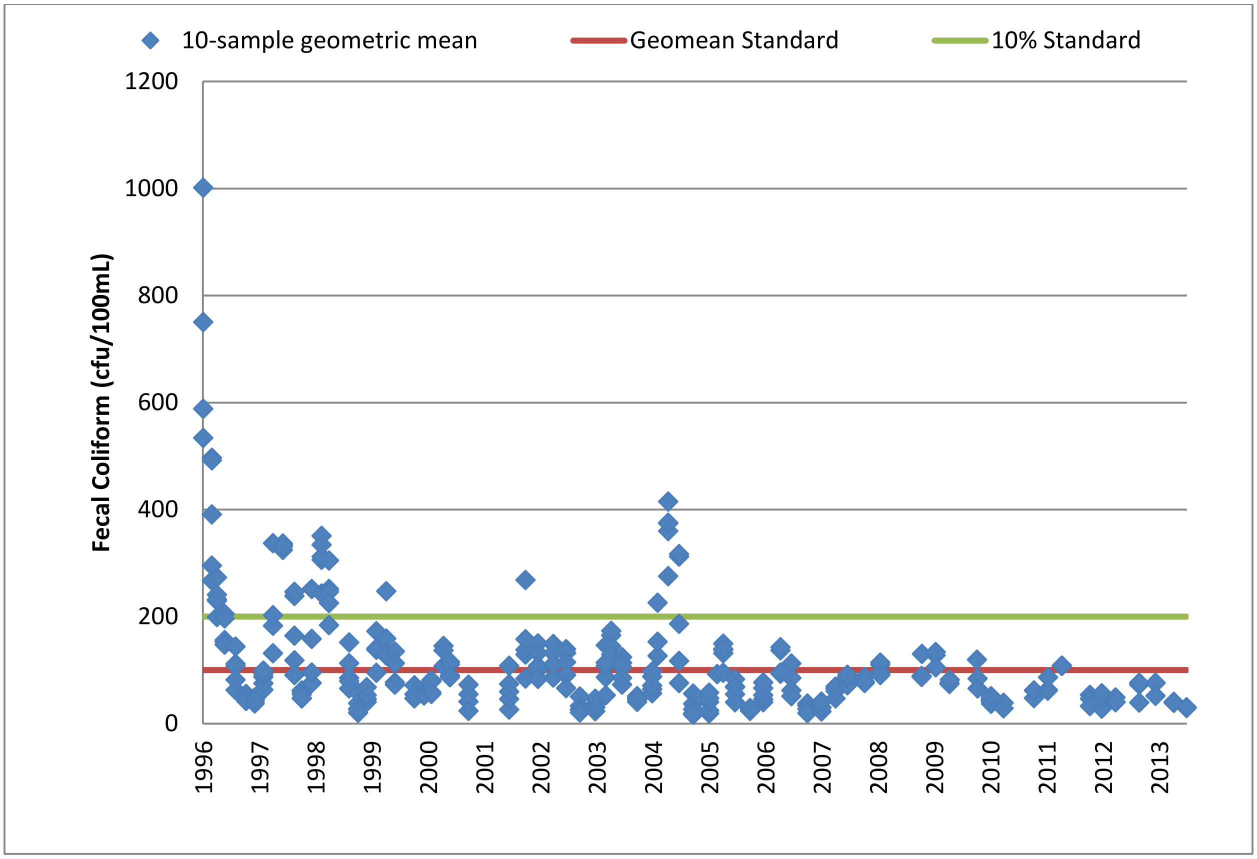
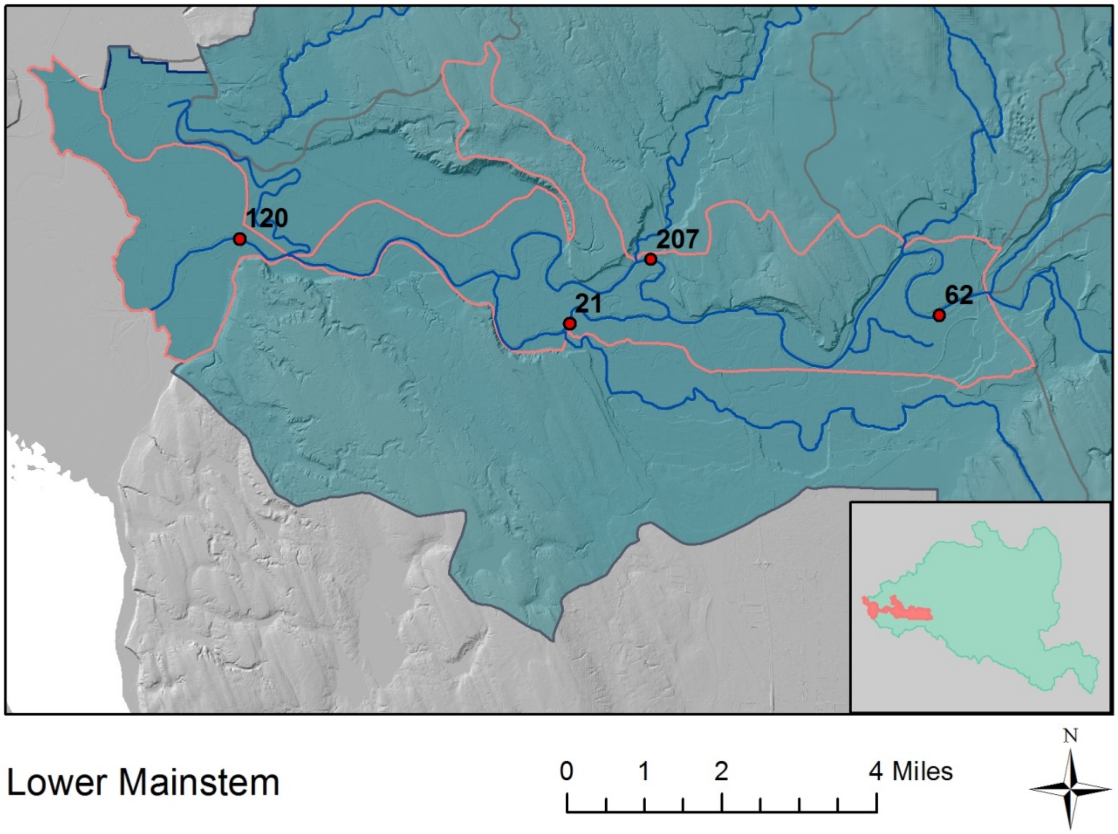


Figure 14. The running 10-sample geometric mean of fecal coliform in the Portage Creek sub-basin compared to Washington State water quality standards.

LOWER MAINSTEM



This sub-basin begins in Arlington, WA where the North and South Fork Stillaguamish meet, forming the Mainstem Stillaguamish, which flows 17.8 miles west through Hatt Slough to Port Susan. This sub-basin is dominated by agricultural land uses with some industrial and residential properties mixed in. The morphology of the Mainstem is unique, splitting into Koch (Cook) Slough and the Mainstem at river mile 10.8, which converge at river mile 6.1, before flowing to the tidally influenced Hatt Slough. There were four sample sites in this sub-basin, one located in each of the four sections defined the by morphology described above. Starting upstream, these sites are the Mainstem at Dike Road (SSID #062), Mainstem upstream of Pilchuck (#207), Mainstem at Silvana (#021), and Hatt Slough at Marine View Drive (#120). Sampling from these sites occurred from 1993 – 2013.

Temperature:

There was a significant decreasing trend observed in the Lower Mainstem temperature throughout the period of record. This improvement is welcomed since there are relatively high temperatures observed in this sub-basin. The Mainstem Stillaguamish is listed on the State's 303(d) list for temperature violations (Pelletier and Bilhimer 2004). Throughout the period of record, 17.5% of all temperature grab samples were > 16^{o} C and 11% were > than 17.5^{o} C. Although our grab sample data show an improvement in temperature throughout the period of record, continuous data collected by the Tribe have shown that 7DADMAX temperatures in the summer are still at critical levels for salmon by reaching 22^{o} C. The Lower Mainstem sub-basin has the least amount of riparian forest cover (16%) of all of the sub-basins in the Stillaguamish Watershed (Purser *et al.* 2003). Riparian forests provide shade and reduce stream temperatures (Pelletier and Bilhimer 2004). A number of riparian plantings have occurred in the Stillaguamish Watershed to promote shade and lower temperatures throughout the previous 20 years.

Dissolved Oxygen:

There were no significant trends observed in dissolved oxygen. The Mainstem Stillaguamish has been on the State's 303(d) list for DO since 1996 (Joy 2004). Based on our data it should continue to be on that list as data as late as August 2013 have shown to be less than 8.0 mg/L. Nutrients from surrounding agriculture and the Arlington Waste Water Treatment Plant (WWTP) (Joy 2004) combined with high summer temperatures are potential reasons for these violations. It is recommended that DO measurements continue in the Mainstem Stillaguamish in order to document changes that will hopefully come to be as riparian plantings continue and grow into maturity.

Turbidity:

There was a moderately increasing dry season turbidity trend observed in this sub-basin. No individual site exhibited any trends in turbidity. The state does not list waters typically based on turbidity concentrations. They will, however, correlate suspended sediment (which is highly correlated with turbidity), with other pollutants such as mercury and arsenic. The State listed the Mainstem in their TMDL report has violating arsenic criteria in 1998 and addressed this in their TMDL study conducted from 2000 - 2002 (Joy 2004). It was shown that higher suspended sediment concentrations contribute to higher arsenic and as such they recommended reductions in suspended sediment to curtail arsenic and mercury. Turbidity measured in the Lower Mainstem Stillaguamish is largely dependent on upstream sediment sources. Localized runoff from agricultural practices, bank erosion and development from within this sub-basin are also potential contributors to suspended sediment and thus turbidity in the Lower Mainstem.

Fecal Coliform:

One of the difficulties we encountered with this sub-basin was that one site, #120 Hatt Slough, has fecal data under two different methods, membrane filtration (mf) and multiple tube fermentation (mpn). These methods are not analogous and results from one do not correspond to equivalent results from another. As a result, for the Mann-Kendall Regional Test (sub-basin approach) only mf data was used to combine with the other three sites in this sub-basin. Site specific Mann-Kendall tests were conducted on #120 with the mpn data since that data set is more robust (62 data points for mf vs 166 for mpn).

The Lower Mainstem has been on the State's 303(d) list for fecal coliform since 1996 and the Mainstem at Hatt Slough was added to the list in 1998 (Joy 2004). Throughout the period of record, the Lower Mainstem sub-basin has significantly improved with regards to fecal coliform (Figure 15). The Tribe began monitoring for fecal coliform in the Lower Mainstem in 1996. Data collected by the Tribe indicates that the Mainstem has met the geometric mean standard, but has occasionally had more than 10% of samples greater than 200 cfu/100 mL. The decreasing trend observed in this sub-basin is largely due to the decreases in fecal coliform observed during the wet season. This would tend to suggest that runoff from various non-point sources has been improving in this sub-basin during the period of record.

Implementation of best management practices from the agricultural community and the City of Arlington would be potential reasons for the improvement. This is evidenced in that the two individual sites that displayed the greatest significant improvement #021 and 062 (Mainstem @ Silvana and Mainstem @ Dike Rd) which are located in the heart of the agricultural community and just outside the City of Arlington, respectively. The City of Arlington completed construction of a 9-acre stormwater wetland in 2011 to treat its largest stormwater drainage system. This wetland will also provide treatment of reclaimed water from the City in the near future. Preliminary data suggested that fecal coliform concentrations were reduced after water was treated from the wetland (Blake, pers comm).

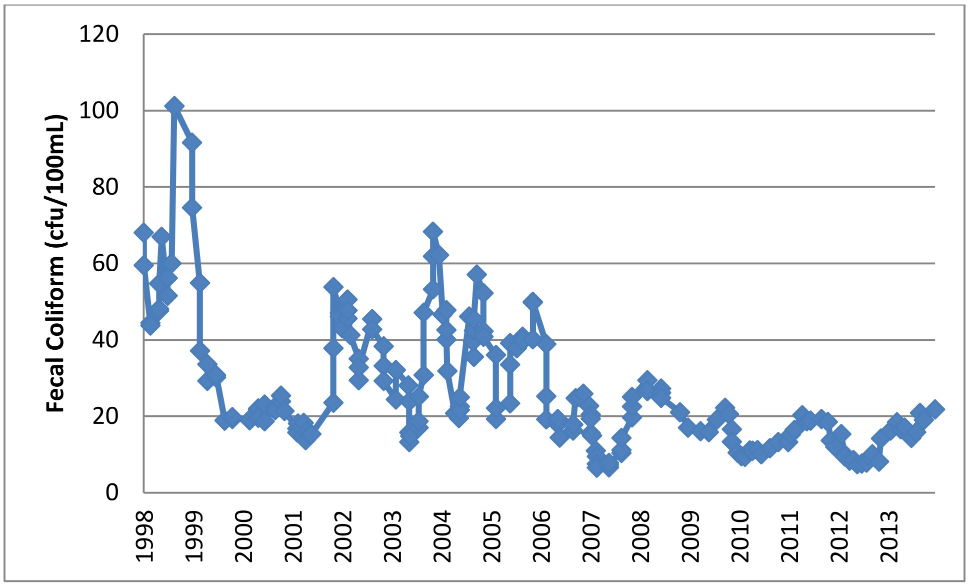
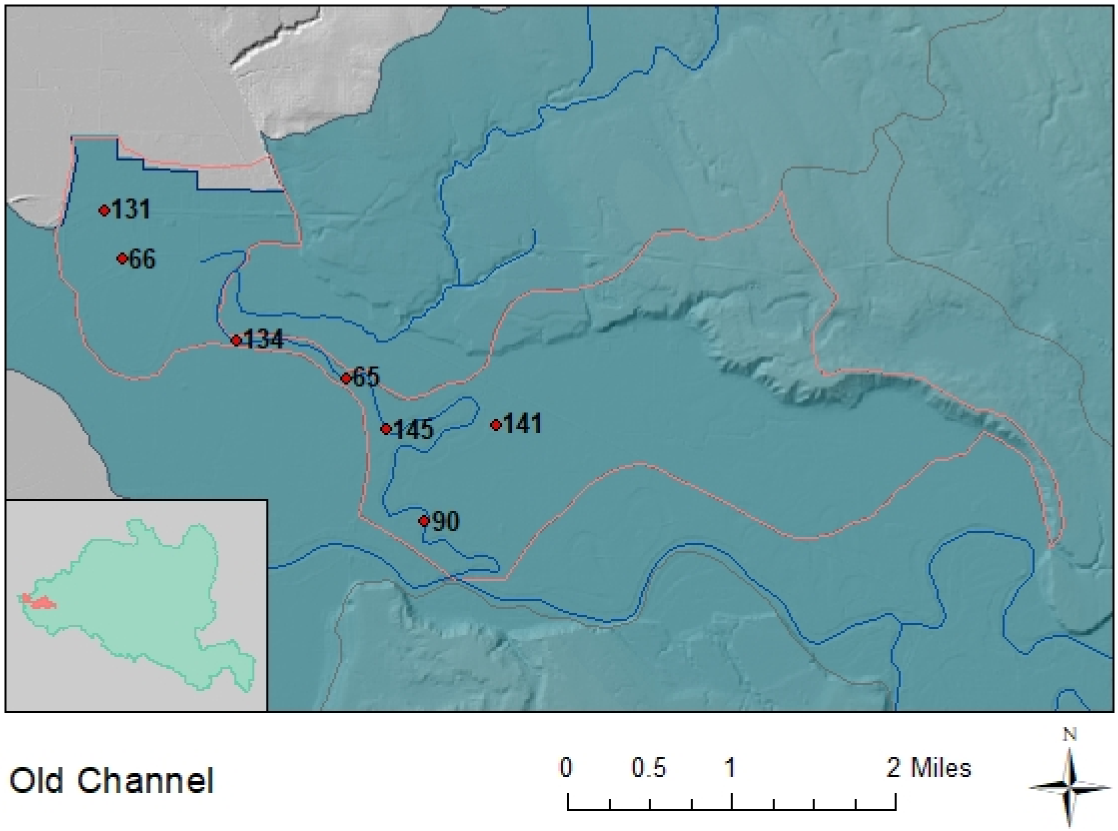


Figure 15. Running 10-sample geometric mean of fecal coliform (cfu/100mL) in the Lower Mainstem Stillaguamish sub-basin.

OLD CHANNEL



The Stillaguamish Old Channel is a distributary to the Mainstem Stillaguamish at river mile 2.75 that flows through the city of Stanwood. The channel has become a secondary outlet after the main flow of the Stillaguamish avulsed to Port Susan via Hatt Slough in the early 1900's. The Old Channel meanders for approximately 8 miles until it bifurcates in Stanwood, with South Pass flowing to Port Susan and West Pass flowing to South Skagit Bay. The Old Channel is a highly altered system that is almost entirely constrained by dikes and armoring placed close to the active channel. The Stanwood wastewater treatment plant releases its effluent directly into the Old Channel where it eventually drains into Port Susan and South Skagit Bay. The main stormwater outfall of Stanwood, Iverson Slough, empties into the Old Channel as well. During the summer low flow months, the Old Channel is mostly disconnected from river flows and acts as a blind tidal channel, but one which drains out via both the top and bottom. For many years, this flow pattern created a "dead zone" of warm, low oxygen water in the middle of the Old Channel that sloshed back and forth without much exchange. In response, a tide gate was installed during the summer months at the bifurcation of the Old Channel and Hatt Slough in 2004. These gates prevent tides from spilling into Hatt Slough, building enough head on the flood tide to flush the Old Channel on the ebb, all the way out West and South Passes. A total of seven sites have been sampled in this sub-basin with enough data to analyze trends in temperature and dissolved oxygen. However, only four sites had enough data for fecal coliform and turbidity analysis. Only two sites, SSID #066 (Old Channel at Leque) and #131 (Douglas Slough) have been sampled through 2013. The other 5 sites ceased in 2008.

Temperature:

No significant trends were present in data collected from the Old Channel, however high maximum temperatures still provide reasons to be concerned in this sub-basin. Temperatures in this sub-basin consistently reach above water quality thresholds of 16° C for Core Summer Habitat and 17.5° C for Aquatic Life. Throughout the period of record, temperatures have been greater than 16° C 31% of the time and greater than 17.5° C 23% of the time. The maximum temperature observed in this sub-basin was located at SSID #066 (27.8° C). This site also had the second highest percentage of excursions above 16° C (36%) and the highest percentage of excursions above 17.5° C. This site is located nearest to marine waters where higher temperatures during the summer are common from tidal exchange. The site closest to the Mainstem, #090 (Old Channel at Norman Road) had cooler temperatures.

Dissolved Oxygen:

Most sites did not exhibit a trend for dissolved oxygen; however, this is still an area of serious concern due to very low DO levels, especially during the dry season. Nearly 30% of samples measured in this sub-basin were below 8.0 mg/L and exceedances occurred across all sample sites. The lowest values (<5.0 mg/L) were almost exclusively measured at tributaries near their intersection with the Old Channel. Both of these sites, Miller Creek (#141) and Douglas Slough (#131), are highly modified drainage ditches with little flow and a close proximity to farmland. Runoff from nearby fields and decaying algae may contribute to lower levels of oxygen in these streams. A lack of riparian vegetation likely also contributes to the observed high temperatures thereby decreasing DO. Only two sites exhibited a significant trend; however, neither site has been sampled in the last eight years. The first of these sites is located at Florence Dock on the Old Stillaguamish Channel (#145) and showed a moderately significant decreasing trend. The second site is located nearby on the Old Channel at Marine View Dr. (#065) and showed a very significant decreasing trend during the dry season. This is concerning since the tide gate installed at the head of the Old Channel was designed to help increase DO in this section. Flow in the Old Channel is very tidally influenced with water moving back and forth much like water sloshing in a bathtub. Both of these trending sites are located near the middle of the Old Channel where little mixing occurs and DO has a greater chance of getting depleted.

Turbidity:

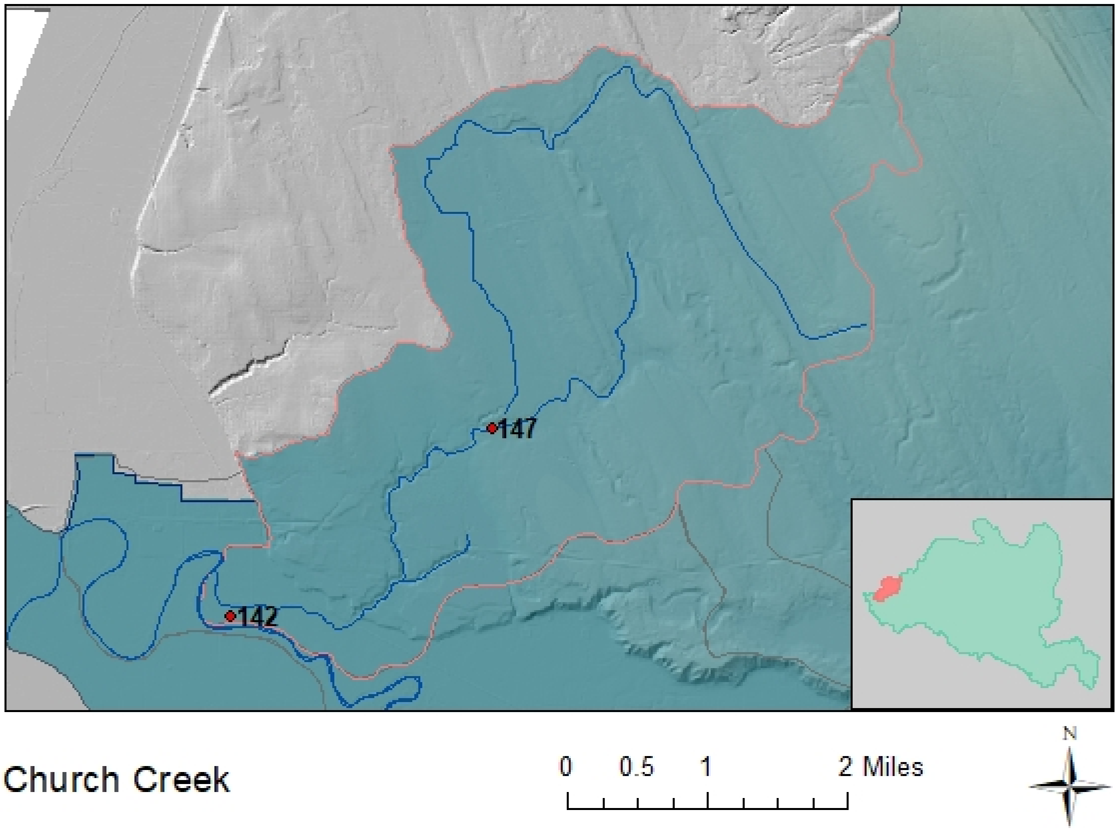
The Old Channel sub-basin did not exhibit any significant trends in turbidity, however, there were significant increases in turbidity observed in two individual sites in the Old Channel sub-basin, SSID's 090 and 065. As a whole, the Old Channel sub-basin has one of the highest annual average turbidities in the Stillaguamish (40.7 NTU). The Old Channel is surrounded by agricultural land and is likely to receive suspended sediments from a combination of agricultural land use practices along with upstream sources. Additionally, the flood tides re-suspend fines from Port Susan, South Skagit Bay and the Old Mainstem itself, greatly increasing the turbidity in the channel over what would be present with river flows alone.

Fecal Coliform:

We used data from four sites in the Old Channel sub-basin to investigate for fecal trends. Based on our analysis, fecal coliform concentrations in the Old Channel sub-basin have decreased highly significantly ($p < 0.01$). The geometric mean of the first 30 sample dates in this sub-basin was 146 cfu/100 mL with

37% of the samples greater than 200 cfu/100 mL. The final 30 sample dates resulted in a geometric mean of 45 cfu/100 mL with 13% of the samples greater than 200 cfu/100 mL. This is roughly a 70% improvement in fecal coliform during the period of record. Improvement is noticed in both standards, but the more stringent 10% standard is still not meeting water quality standards. This improvement is noticed in both the wet and dry seasons as well ($p = 0.01$). Despite the improvement sub-basin wide, only two individual sites showed statistically significant improvements during their period of record, SSID #066 and #131. Site #066 showed improvements in both the wet and dry seasons as well. Douglas Slough (#131) only showed improvements during the wet season, and that improvement was only moderately significant ($p > 0.05$). No improvements were observed in the other two sites located closer towards the Mainstem Stillaguamish. SSID #065 failed both the geometric mean and 10% sample standards at the end of the sampling regime, whereas #090, met the geometric mean standard, but not the 10% sample standard.

CHURCH CREEK



Church Creek is a lower elevation tributary that flows through rural residential areas and the City of Stanwood. There are two sample locations in this sub-basin. The first, collected at Jenson Rd. (SSID #147) is located in a rural residential area with a wide, established riparian zone and a few hobby farms. The second site, at Marine View Dr. (#142), is located downstream in farmland and is low gradient, highly channelized with a tide gate at its confluence with the Old Stillaguamish Channel.

Temperature:

A moderately significant decreasing trend was discovered during the dry season for the period of record. This is interesting because neither site individually showed a significant trend. The upstream site, #147, runs through rural residential homes and hobby farms before flowing through Stanwood. For most of this stretch there is a limited but consistent riparian buffer that provides some stream shade but likely does not substantially lessen stormwater runoff. Downstream Church Creek becomes an open, unshaded agricultural ditch crowded with reed canary grass. Accordingly, the mean temperature at the downstream site is about 3.5°C higher than upstream and reaches a maximum of 25°C. This is well above temperatures where salmonids begin to show ill-effects. In contrast, the upstream site only reaches 17°C. During the wet season the mean, maximum, and minimum temperatures are very similar for both sites. Although a decreasing temperature was observed, temperatures still remain high as almost 42% of all dry season temperatures in the Church Creek sub-basin were higher than 16° C.

Dissolved Oxygen:

There were no significant trends observed in DO in the Church Creek sub-basin throughout the period of record. Almost 40% of all DO measurements collected in the Church Creek sub-basin were below the 9.5 mg/L 1-day minimum for Core Summer Habitat. Of these, 73% were during the dry season which is not surprising considering warmer temperatures during those months. Of the two sites in this sub-basin, the lower site located at Marine View Drive, had 41% of samples below 8.0 mg/L including multiple events during the fall when Coho have historically migrated through that reach. The low DO is likely caused by high average temperatures, lack of aeration from slow-moving current, decomposing reed canary grass, and possibly nutrient loading from the surrounding farmland. Salmon abundance in Church Creek has fallen dramatically in recent years, and while there is not a downward trend, the current levels of DO are cause for concern and continued monitoring.

Turbidity

There was a moderately significant increasing trend observed in the Church Creek sub-basin only during the wet season (Figure 16). No significant trends were observed during the dry season or without regard to season. Partial explanation for this increase could be due to the increase in development in the Church Creek sub-basin during the period of record. From 1987-2011 there was an 8.8% increase in landcover classified as developed in this subbasin (CORE GIS 2013). Increases in development result in more impervious surfaces and more runoff likely increasing turbidity.

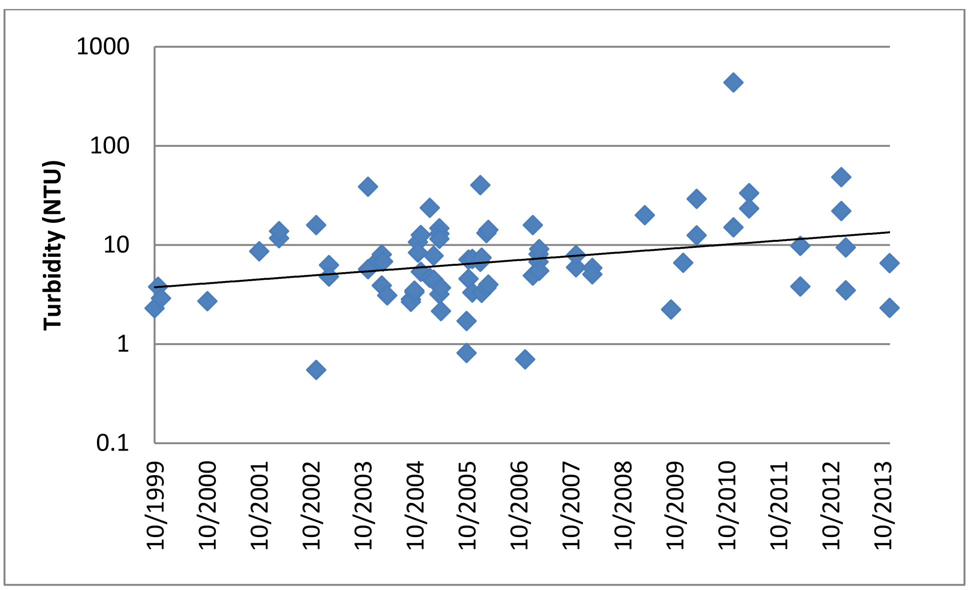
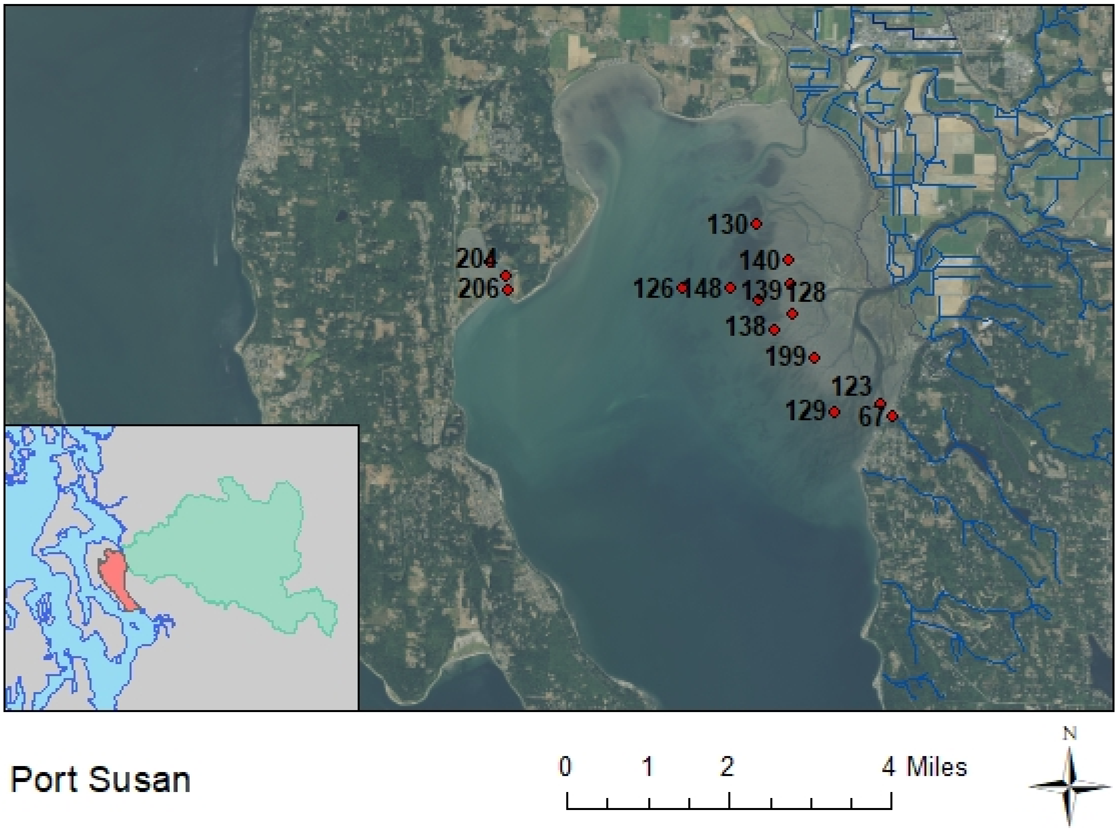


Figure 16. Dry season turbidity (NTU) samples in the Church Creek sub-basin.

Fecal Coliform

The upper portion of the Church Creek sub-basin has some commercial forests, but is largely mixed land uses with fragmented forests, rural residential, medium to low intensity developed land and some hobby farms. Church Creek has been on the 303d list since 1996 for fecal coliform. WDOE's TMDL showed that Church Creek failed both the geometric mean and 10% standards during their 2001-2002 study (Joy 2004). The location WDOE sampled, Church Creek at Park, is located between the two sites sampled by the Tribe. The first 30 samples collected by the Tribe in this sub-basin resulted in a geometric mean of 148 cfu/100mL and 50% of the samples greater than 200 cfu/100mL. Fecal coliform in the Church Creek sub-basin worsened until September 2005 where a geometric mean of 191 cfu/100mL was reached with 57% of the samples collected greater than 200 cfu/100mL. Improvement in this sub-basin is indicated by the samples in the sub-basin meeting the geometric mean standard. The last 30 samples used in this analysis resulted in a geometric mean of 70 cfu/100mL and 23% of the samples greater than 200 cfu/100mL. The main driver for this is due to SSID #142 which showed combined highly significant reductions in fecal coliform as well as moderately significant reductions in both the wet and dry seasons. Despite this improvement, Church Creek at Marine View Drive still had 17% of the previous 30 samples greater than 200 cfu/100mL and would still not meet water quality standards. The upper site sampled in this sub-basin did not exhibit any significant changes in fecal coliform through its period of record. This site meets the geometric mean standard, but 27% of the previous 30 samples were greater than 200 cfu/100mL. Sampling is still current at these locations.

PORT SUSAN



The Stillaguamish Watershed includes 22 miles of marine shoreline the majority of which is located in Port Susan. Estuarine habitat, including eelgrass beds and pocket estuaries, provide important rearing habitat for juvenile Chinook Salmon. However, habitat in Port Susan has been constrained by cut-off sloughs, sediment deposition, invasive species, and hardened banks. Armoring has occurred on approximately 75% of marine shoreline in the Stillaguamish Watershed which limits sediment transport. Additionally, much of the historical nearshore riparian vegetation has been cleared to allow for unobstructed views of Puget Sound (SIRC 2005).

To best reflect the variable conditions within Port Susan a total of fifteen sites are currently sampled. Sampling in Port Susan has occurred from five to fifteen years depending on the site.

Temperature:

Temperature at marine sites was collected within the top one foot of the surface. Long-term measurements of sea surface temperature in Puget Sound are rare, however nearby records from the Strait of Juan de Fuca near Victoria BC dating back to 1921 indicate a warming trend over that period of record (Snover *et al.* 2005). There was no overall trend observed in our 15-year sampling effort in Port Susan for the combined seasons. We did, however, see an increasing temperature trend during the dry season in Port Susan. Two individual sites, SSID's 128 and 129 displayed moderately significant increases in temperature.

Dissolved Oxygen:

DO in marine areas can vary significantly with depth, however only surface water grab samples are included in this analysis. Sufficient levels of DO are required for salmonid health for both returning adults and out-migrating smolts. There was no overall trend for Port Susan, but two locations showed a decreasing trend in DO. Both of these locations are located in Triangle Cove, a protected bay with substantial tidal water exchange with the rest of Port Susan. The site located at the mouth of the bay shows no trend in temperature while the north site in Triangle Cove shows a moderately significant decreasing trend in temperature during the dry season. Since DO is inversely related to temperature one would expect decreasing DO levels to be associated with increasing temperatures but this does not appear to be the case. Other factors may include groundwater inputs which could be determined by analyzing salinity data or increased biological oxygen demand (BOD) from runoff from the surrounding residential areas. All samples collected from Port Susan were above 5.0 mg/L and only 2% of samples fell below the Department of Ecology standard for "Extraordinary Quality" (7.0 mg/L). Regulatory standards for DO are shown below in Table 2.

Table 2. Aquatic Life Criteria for Marine Waters (Washington State Department of Ecology).

Category	**1-day minimum**
Extraordinary Quality	7.0 mg/L
Excellent Quality	6.0 mg/L
Good Quality	5.0 mg/L
Fair Quality	4.0 mg/L

Turbidity

The Port Susan sub-basin did not show any trend in turbidity between 1993 and 2013. There is only one site in this sub-basin where turbidity has been collected; this is from a small stream (Lake Martha Creek) in a rural residential community which has not seen dramatic increases in land development over the period of record.

Fecal Coliform

Port Susan has been on the State's 303d list for fecal coliform since 1996. Joy (2004) concluded that a 61% reduction in fecal coliform in Port Susan would be necessary in order to meet Washington State water quality criteria after conducting the TMDL study in 2000 – 2001. DOE listed sources for fecal coliform as land application of bovine manure, stormwater discharges, discharges from waste water treatment plants, failing septic systems and natural sources from the thousands of water fowl and hundreds of seals that utilize the Port Susan estuary. For the entire period of record, fecal coliform concentrations in Port Susan decreased highly significantly. This decrease was also observed in the wet and dry seasons. Of the 11 sites analyzed for trends in Port Susan, six showed highly significant decreases in fecal coliform throughout their period of record. Three other sites, SSID's #137, 138, and

140, showed significant decreasing trends during wet seasons. The decreasing trend in Port Susan is evidenced in Figure 17, which depicts the geometric mean of all samples collected from all sites sampled each sampling event. According to Figure 17, the geometric mean of all samples in Port Susan has met the geometric mean standard of 43 mpn/100 mL since 11/13/2007. The geometric mean hasn't been above 14 mpn/100 mL (the estimated 90th percentile standard threshold) since 11/19/2009.

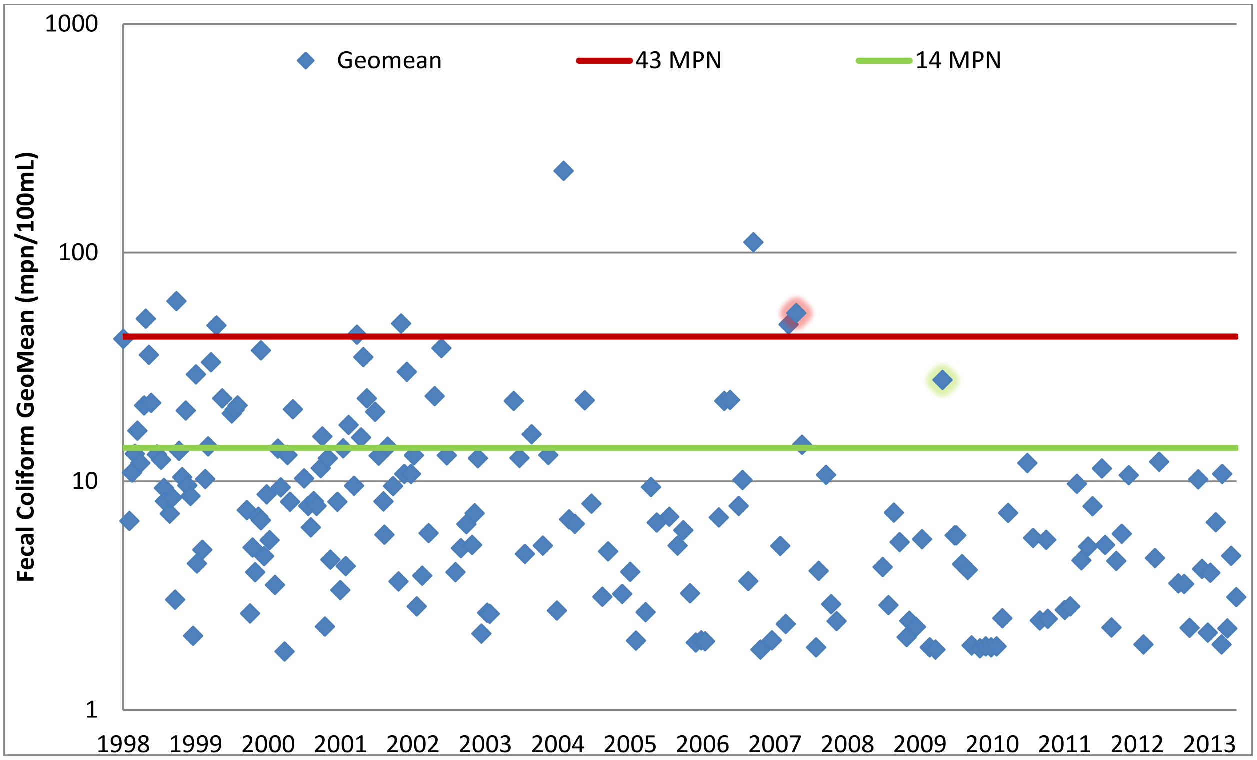


Figure 17. The fecal coliform geometric mean of all samples collected each sampling event. The highlighted red dot indicates the event date 11/13/2007 and the highlighted green dot indicates the event date 11/19/2009 referenced above.

Prior to WDOH certified samples in 2002, the Tribe sampled mainly during ebb tides in Port Susan from 1998 - 2002. This was in order to capture the "worst case scenario" of fecal coliform in the Bay as ebb tides would, in theory, carry flushed out fecal coliform from runoff and other land-based sources. Once DOH began to certify the samples the tidal schedule switched to more flood tides. This was largely because scheduling was done by the availability of the DOH laboratory and Tribal staff had to accommodate sampling to meet time constraints and tidal levels. As a result, sampling during ebb tides reduced to < 20%. It is possible that the reduction in ebb tide sampling helped create more favorable results in terms of fecal pollution, but it is unlikely that the sole reason behind the measured improvement is due to this schedule change. This is evidenced in that the highest peaks in fecal coliform measured occurred after DOH certified samples. In addition, since Port Susan is the receiving waters of the entire Stillaguamish Watershed, it bears to reason that the reductions in fecal coliform observed basin wide would result in reductions in Port Susan as well.

Conclusions/Recommendations

From 1993 – 2013 the Stillaguamish Tribe monitored water quality throughout the Stillaguamish Watershed. The monitoring was designed to characterize waters through long term ambient monitoring but also included targeted sampling efforts focused on specific projects or areas of concern identified in reports or complaints. It is encouraging to see improvements in a number of water quality parameters throughout the Stillaguamish Watershed. The Stillaguamish Implementation Review Committee (SIRC), now recognized as the Stillaguamish Watershed Council (SWC), and the parties involved in the formation of this group have worked hard to address and fix water quality problems in the Stillaguamish Watershed since the drafting of the Stillaguamish Action Plan in 1990. This report shows that much progress has been made, but there is still much more to do as a number of individual sites still do not meet water quality criteria.

From this trend analysis report, we reach the following conclusions and recommendations:

CONCLUSIONS

1. The sampling regime changed in 2002 from quasi-monthly to quarterly. The intent of this switch was to reduce sampling costs, while still sampling during a range of seasons. This resulted in problems in some datasets such as temperature sampling no longer occurring during the warmest 2-months of the year (July and August).
2. No sub-basin nor individual site monitored displayed an increasing trend in fecal coliform throughout the period of record. This is significant because thirteen 303(d) listings for rivers and streams in the Stillaguamish Watershed in 1998 were for fecal coliform pollution. This improvement in fecal coliform pollution in the Stillaguamish Watershed propelled the 2011 reclassification of the shellfish growing area in Port Susan, which was declassified in the 1980's mainly due to high fecal contamination.
3. No sub-basin nor individual site monitored displayed a decreasing trend in turbidity throughout the period of record. Among the 6 sub-basins that displayed significant increases in turbidity, Deer Creek, Harvey/Armstrong Creek, Pilchuck Creek, Portage Creek, Lower South Fork and the Upper South Fork, the driver of the trend wasn't immediately apparent. It is likely that there was a combination of things attributed to the increase in turbidity measured at these locations. First, three of these sub-basins (Deer, Harvey, and Upper South Fork) had increasing trends in the number of forest practice applications (FPAs) from 1997 – 2013. FPAs can be used as a measure of land disturbances in commercial forests which could help explain this. Second, there was a slight increasing trend in annual precipitation measured in Arlington during this time period. More disturbed earth plus increases in precipitation could make sediments more mobile thus increasing sediment suspension in runoff. Third, in sub-basins like Portage Creek, increases in precipitation plus development are likely to cause increases in runoff and therefore increased turbidity
4. Improvements in temperature and dissolved oxygen appear to be related. Of the 6 sub-basins that decreased in temperature during their period of record, 4 had corresponding increases in

dissolved oxygen. This would make sense since water with lower temperatures support higher dissolved oxygen solubility. One thing to consider, however is the change in sampling design as mentioned in #1 above could have biased these results.

5. The only individual sites to exhibit increasing trends in temperature were two marine sites in Port Susan and two sites in Harvey Creek sub-basin. Of these, only one, SSID 046 Kackman Creek at Kackman Road, exhibited a respective decrease in dissolved oxygen.
6. Twenty of the 48 individual sites monitored for fecal coliform displayed significant decreasing trends during the period of record. Only one, Secret Creek, moderately increased from 2009 – 2013. Secret Creek violates the 2nd standard with 20% of the previous 10 samples ≥ 200cfu/100mL.
7. Of the 48 individual sites monitored for fecal coliform, 11 still violate water quality criteria. The 11 that violate and the standards they violate are listed below (Red indicates failure of standard, Green indicates passing standard).

SSID	Site Name	Sub-basin	Geometric Mean	% > 200cfu /100mL
208	Secret Creek @Alpaca	Pilchuck	30	20
023	Harvey Creek @ Grandview	Harvey/Armstrong	15	20
041	Harvey Creek @ Rhody Farm	Harvey/Armstrong	35	20
164	Kackman Creek @ 55th	Harvey/Armstrong	74	20
064	Portage Creek @ 212th	Portage	58	20
020	Portage Creek @ 15th	Portage	33	20
018	Portage Creek @ Hwy 9	Portage	87	20
017	Krueger Creek @ Burn Rd.	Portage	24	20
147	Church Creek @ Jensen Rd.	Church	72	40
090	Old Stillaguamish @ Norman Rd.	Old Channel	60	30
065	Old Stillaguamish @ Marine View Dr.	Old Channel	107	20

Geomean = 100cfu/100mL; 10 % ≤ 200cfu/100mL

8. Of the 50 individual freshwater sites monitored for dissolved oxygen, 23 still had at least one sample through the final 10 samples lower than the core summer habitat dissolved oxygen standard of 9.5 mg/L. Nine of the individual sites had at least one sample through the final 10 samples lower than the aquatic life standard of 8.0 mg/L. Those 9 are listed below:

SSID	Site Name	Sub-basin	% < 9.5 mg/L	% < 8.0 mg/L
207	Mainstem above Pilchuck	Lower Mainstem	20%	10%
018	Portage Creek @ Hwy 9	Portage	40%	10%
020	Portage Creek @ 15th	Portage	100%	100%
064	Portage Creek @ 212th	Portage	80%	80%
208	Secret Creek @ Alpaca	Pilchuck	50%	30%
022	Pilchuck Creek @ Jackson Gulch	Pilchuck	30%	20%
046	Kackman Creek @Kackman Rd.	Harvey/Armstrong	90%	70%
023	Harvey Creek @ Grandview	Harvey/Armstrong	30%	10%
142	Church Creek @ Marine Veiw Dr.	Church	40%	30%

The final 10 samples were used because with the quarterly sampling that occurred for most of the sites, 10 samples spanned over more than one year.

9. Groundwater seeps into surface water are potential reasons for the low DO observed in Portage Creek at 15th, Portage Creek at 212th and Kackman Creek at Kackman Rd.
10. Grab samples for temperature do not provide a reasonable estimate of water quality conditions. Continuous temperature loggers were not used with much frequency from a majority of sites which made it difficult to determine if water quality standards were being met.
11. Samples from several sub-basins ceased in 2008 making it difficult to determine current status of water quality status.

RECOMMENDATIONS

1. **The Tribe's water quality program should be restructured to sample a select number of sites more frequently rather than a large number of locations quarterly.** The quarterly sampling conducted by the Tribe for most sites from 2002 – 2013 made it difficult to determine how water quality parameters such as the 4 identified in this report changed throughout the seasons and years. As mentioned above, it is possible that the switch to quarterly sampling may have biased our temperature data by ceasing sampling during some of the warmer months. This may have biased the dissolved oxygen data as well since the two are related.
2. **It is recommended that sites that still violated water quality standards be considered for more frequent monitoring.** Several sites, as of 2013, still violated water quality criteria. Some of these sites have not been monitored since 2013 so it would prove beneficial to re-visit those

sites again and sample for a period of time to determine if water quality criteria are still not being met.

3. **Establishment of real-time or continuous water quality data loggers would enhance water quality datasets.** It is recommended that continuous data loggers be placed in locations that make sense. One such location would be Pilchuck Creek. The Department of Ecology operates a stream gage on Pilchuck Creek at Hwy 99, just upstream of the Tribe's water quality site. It is possible that the Tribe can install a water quality meter at the Ecology site and utilize their satellite uplink to also transmit water quality data. A combination of flow with other data such as temperature, dissolved oxygen and turbidity would be valuable to further understand water quality conditions at that site.
4. **Coordination with other stake holders to better monitor the Stillaguamish Watershed.** Sample coordination with other agencies would help bolster monitoring and water quality data collection in the Watershed and could help identify pollution sources. The Department of Ecology has 5-long term sites in the Stillaguamish on the Mainstem and the Forks. Snohomish County has historically monitored at several locations in the Stillaguamish, but their current efforts appear to be project specific. Other organizations like the Snohomish Conservation District have also monitored in the Stillaguamish. By communicating and coordinating with other organizations we can use resources wisely and have a more robust dataset.
5. **Site specific recommendations**
    a. *Squire Creek:* It is recommended that we begin measuring temperature from Squire Creek with continuous temperature data loggers.
    b. *NF @ Hazel:* With the last sample occurring 10 years ago it is recommended that the Tribe consider monitoring again within this sub-basin, perhaps at the North Fork Stillaguamish at Whitman Road (SSID #014) location once again. Fecal coliform sample collection at Whitman Road would complement the WDOE water quality data nicely and help in the understanding of fecal pollution throughout the three sub-basins of the North Fork Stillaguamish.
    c. *Boulder River:* It is recommended that a continuous temperature data logger be placed in this system to determine current temperature regimes.
    d. *Deer Creek:*
        i. It is not necessary to sample this location in the future for fecal coliform due to the remoteness and undeveloped nature of the landscape. Sampling could commence if it becomes evident from downstream sites that fecal coliform issues are prevalent or if large scale land use changes occur that could cause fecal coliform pollution.
        ii. It would prove beneficial to install continuous temperature dataloggers and monitor turbidity in this sub-basin.
    e. Lower North Fork Stillaguamish:
        i. Since it has been > 10 years from the last continuous temperature data collection from the North Fork @ Haller Park (SSID 119) we recommend resuming sampling to provide updated temperature data for the entire North Fork Stillaguamish.

ii. It is recommended that samples are collected again on the North Fork at Haller Park to determine turbidity coming out of the North Fork Stillaguamish.
iii. Due to the time lapse in fecal data collection (ceased in 2008) it is recommended that in order to determine current status of fecal pollution out of the North Fork Stillaguamish sampling should commence at site #119.

f. *Upper South Fork Stillaguamish:* While none of three sites (Boardman Creek, Mallardy Creek and SF Stillaguamish @ Red Bridge) have been sampled since 2008, there hasn't been significant land use changes in the sub-basin to potentially increase temperatures. A substantial USFS harvest along the Upper South Fork is planned in the next five years. Depending on the magnitude and structure of the harvest it may be informative to begin monitoring temperatures again at that time.

g. *Canyon Creek:* It is recommended that we place continuous temperature data loggers in this system to determine current status of temperature since the last recorded temperature grab sample occurred in 2008 and the last continuous temperature data occurred in 2001.

h. *Jim Creek:* It is recommended that continuous temperature data loggers be placed in Jim Creek to understand current conditions of this sub-basin.

i. Lower South Fork Stillaguamish:

i. Since neither site (#006 and #115) has been sampled since 2008 it could be valuable to reexamine dry season water temperatures in these locations, especially given recent warm summer air temperatures.
ii. It would be worthwhile to continue sampling at least one of the two sites (#006 or #115) again in the Lower South Fork to determine current status of dissolved oxygen levels throughout the year.
iii. It is recommended to sample again in this sub-basin, perhaps at the lowest site (#115), for a number of years to re-evaluate the status of fecal coliform pollution in the Lower South Fork Sub-basin since sampling ceased in 2008.
iv. It is recommended to sample for turbidity again in this sub-basin to monitor changes from the proposed Gold Basin landslide remediation project to occur in the near future.

j. *Harvey/Armstrong Creek:* Maintain monthly measurements at the lower site, SSID #009 and consider monitoring on Kackman Creek as well.

k. *Pilchuck Creek:* Maintain monthly measurements at both locations, Pilchuck Creek at Jackson Gulch and Secret Creek.

l. *Portage Creek:* Begin sampling for fecal coliform again at SSID #018 (Portage Creek at Hwy 9) and at SSID #064 (Portage Creek at 212^{th}) to determine fecal coliform status of this system.

m. *Lower Mainstem:* It is recommended that we maintain collection of continuous temperature data in the Lower Mainstem to document changes as restored riparian vegetation grows into maturity.

n. *Old Channel:*
    i. It is recommended that fecal samples be collected again at least at Leque Dock (SSID #066) and potentially at Norman Rd (SSID #090). Another possible location could be in the middle at Marine View Drive (SSID #065) or at Florence (SSID #145)
    ii. It is recommended that continuous temperature dataloggers be placed at 3 sites in the Old Channel, similar to sites listed above, to determine current status.
    iii. It is recommended that DO grab samples also be collected at the above 3 sites.
o. *Church Creek:* It will be important to maintain the two sample sites (SSID# 142 and 147) as this sub-basin continues to exhibit population growth. It is recommended that we coordinate accordingly with partners on sampling in this sub-basin.

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Appendix A

RMK Results

Temperature

			Combined Seasons				Wet Season				Dry Season			
Sub-basin	SSIDs	Years	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend
Port Susan	199, 206, 203, 204, 067, 123, 129, 130, 126, 128, 138, 140, 137, 148, 139	2002-2013	50	0.21	NS	No Trend	-19	0.53	NS	No Trend	69	0.01	***	Increasing
Deer	028	1998-2012	-53	0.15	NS	No Trend	-17	0.54	NS	No Trend	-36	0.15	NS	No Trend
Upper NF	011, 060	1993-2014	-92	0.01	***	Decreasing	-71	0.01	***	Decreasing	-21	0.32	NS	No Trend
Church	142, 147	1999-2013	-46	0.12	NS	No Trend	-1	1.00	NS	No Trend	-45	0.03	**	Decreasing
NF Hazel	014, 013, 087	1994-2014	-67	0.14	NS	No Trend	-44	0.19	NS	No Trend	-23	0.48	NS	No Trend
Harvey	164, 009, 023, 046, 008, 041	1993-2013	-40	0.39	NS	No Trend	-39	0.28	NS	No Trend	-1	1.00	NS	No Trend
Old Channel	066, 131	1997-2013	-50	0.15	NS	No Trend	-14	0.59	NS	No Trend	-36	0.15	NS	No Trend
Pilchuck	022, 208	1996-2013	-85	0.03	**	Decreasing	-45	0.12	NS	No Trend	-40	0.11	NS	No Trend
Lower NF	016, 119	1993-2013	-137	0.00	***	Decreasing	-69	0.06	*	Decreasing	-68	0.03	**	Decreasing
Boulder	012	1994-2013	-50	0.12	NS	No Trend	-52	0.04	**	Decreasing	2	0.96	NS	No Trend
Squire	010	1994-2008	-45	0.11	NS	No Trend	-34	0.10	*	Decreasing	-11	0.58	NS	No Trend
Jim	059, 160	1996-2008	-23	0.34	NS	No Trend	-25	0.14	NS	No Trend	2	0.95	NS	No Trend
Portage	017, 018, 019, 020, 064, 200	1993-2013	-2	0.91	NS	No Trend	-3	0.71	NS	No Trend	1	1.00	NS	No Trend
Canyon	109	1999-2008	-25	0.10	*	Decreasing	-23	0.05	**	Decreasing	-2	0.92	NS	No Trend
Lower SF	006, 115	1993-2008	-81	0.01	***	Decreasing	-46	0.04	**	Decreasing	-35	0.09	*	Decreasing
Upper SF	003, 036, 049	1993-2013	-36	0.29	NS	No Trend	-7	0.82	NS	No Trend	-29	0.17	NS	No Trend
Mainstem	021, 062, 120, 207	1993-2013	-90	0.04	**	Decreasing	-64	0.04	**	Decreasing	-26	0.42	NS	No Trend

Dissolved Oxygen

			Combined Seasons				Wet Season				Dry Season			
Sub-basin	SSIDs	Years	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend
Port Susan	199, 206, 203, 204, 067, 123, 129, 130, 126, 128, 138, 140, 137, 148, 139	2002-2013	22	0.50	NS	No Trend	4	0.89	NS	No Trend	18	0.44	NS	No Trend
Deer	028	1998-2012	32	0.43	NS	No Trend	-1	1.00	NS	No Trend	33	0.23	NS	No Trend
Upper NF	060, 011	1996-2008	90	0.01	***	Increasing	69	0.01	***	Increasing	21	0.32	NS	No Trend
Church	142, 147	1999-2013	12	0.69	NS	No Trend	29	0.17	NS	No Trend	-17	0.38	NS	No Trend
NF Hazel	014, 013, 087	1993-2013	55	0.17	NS	No Trend	9	0.78	NS	No Trend	46	0.09	*	Increasing
Harvey	164, 009, 023, 046, 008, 041	1993-2013	6	0.91	NS	No Trend	31	0.40	NS	No Trend	-25	0.40	NS	No Trend
Old Channel	134, 145, 141, 131, 066, 090, 065	1997-2013	-46	0.14	NS	No Trend	-47	0.06	*	Decreasing	1	1.00	NS	No Trend
Pilchuck	022, 208	1993-2013	62	0.10	*	Increasing	47	0.11	NS	No Trend	15	0.56	NS	No Trend
Lower NF	016, 119	1993-2013	91	0.06	*	Increasing	73	0.04	**	Increasing	18	0.58	NS	No Trend
Boulder	012	1994-2008	65	0.02	**	Increasing	37	0.07	*	Increasing	28	0.14	NS	No Trend
Squire	010	1994-2008	49	0.08	*	Increasing	35	0.09	*	Increasing	14	0.48	NS	No Trend
Jim	059, 160	1996-2008	22	0.22	NS	No Trend	7	0.59	NS	No Trend	15	0.28	NS	No Trend
Portage	017, 018, 019, 020, 064, 200	1993-2013	30	0.52	NS	No Trend	42	0.22	NS	No Trend	-12	0.72	NS	No Trend
Canyon	109	1999-2008	1	1.00	NS	No Trend	4	0.75	NS	No Trend	-3	0.83	NS	No Trend
Lower SF	006, 115	1993-2008	69	0.02	**	Increasing	33	0.11	NS	No Trend	36	0.08	*	Increasing
Upper SF	003, 036, 049	1993-2013	42	0.17	NS	No Trend	9	0.72	NS	No Trend	33	0.11	NS	No Trend
Mainstem	021, 062, 120, 207	1993-2013	58	0.14	NS	No Trend	29	0.33	NS	No Trend	29	0.29	NS	No Trend

Turbidity

			Combined Seasons				Wet Season				Dry Season			
Sub-basin	SSID's	Years	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend
Port Susan	067	2004-2013	-6	0.75	NS	No Trend	7	0.59	NS	No Trend	-13	0.28	NS	No Trend
Deer	028	1994-2012	65	0.09	*	Increasing	17	0.58	NS	No Trend	48	0.05	**	Increasing
Upper NF	011, 060	1993-2013	20	0.57	NS	No Trend	-11	0.70	NS	No Trend	31	0.14	NS	No Trend
Church	142,147	1999-2013	18	0.53	NS	No Trend	43	0.04	**	Increasing	-25	0.19	NS	No Trend
NF Hazel	087, 013, 014	1994-2013	7	0.89	NS	No Trend	-36	0.26	NS	No Trend	43	0.14	NS	No Trend
Harvey	009, 023, 046, 041, 164	1993-2013	111	0.01	***	Increasing	84	0.01	***	Increasing	27	0.36	NS	No Trend
Old Channel	131, 066, 090, 065	1997-2013	3	0.95	NS	No Trend	4	0.90	NS	No Trend	-1	1.00	NS	No Trend
Pilchuck	022	1993-2013	83	0.03	**	Increasing	35	0.23	NS	No Trend	48	0.05	**	Increasing
Lower NF	016, 119	1993-2013	69	0.12	NS	No Trend	20	0.57	NS	No Trend	49	0.09	*	Increasing
Boulder	012	1994-2013	45	0.13	NS	No Trend	16	0.50	NS	No Trend	29	0.13	NS	No Trend
Squire	010	1994-2009	46	0.12	NS	No Trend	16	0.50	NS	No Trend	30	0.11	NS	No Trend
Jim	059, 160	1998-2008	24	0.18	NS	No Trend	7	0.64	NS	No Trend	17	0.15	NS	No Trend
Portage	020, 019, 018, 017, 064	1993-2013	147	0.00	***	Increasing	80	0.02	**	Increasing	67	0.02	**	Increasing
Canyon	109	1999-2008	15	0.34	NS	No Trend	5	0.72	NS	No Trend	10	0.35	NS	No Trend
Lower SF	006, 115	1993-2013	95	0.00	***	Increasing	62	0.01	***	Increasing	33	0.08	*	Increasing
Upper SF	001, 002, 003, 004, 005, 036, 037, 049	1993-2013	102	0.00	***	Increasing	35	0.20	NS	No Trend	67	0.00	***	Increasing
Mainstem	120, 021, 062, 207	1993-2013	51	0.18	NS	No Trend	9	0.78	NS	No Trend	42	0.09	*	Increasing

Fecal Coliform

			Combined Seasons				Wet Season				Dry Season			
Sub-basin	SSID's	Years	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend
Port Susan	067, 123, 126, 128, 129, 130, 137, 138, 139, 140, 148	1998-2013	-110	0.00	***	Decreasing	-56	0.01	***	Decreasing	-54	0.02	**	Decreasing
Deer	028	1994-2012	-29	0.08	*	Decreasing	-17	0.21	NS	No Trend	-12	0.25	NS	No Trend
Upper NF	011, 060	1993-2013	-14	0.30	NS	No Trend	-12	0.25	NS	No Trend	-2	0.90	NS	No Trend
Church	142,147	1999-2013	-72	0.01	***	Decreasing	-31	0.14	NS	No Trend	-41	0.03	**	Decreasing
NF Hazel	087, 013, 014	1994-2013	-29	0.08	*	Decreasing	-21	0.12	NS	No Trend	-8	0.47	NS	No Trend
Harvey	009, 023, 046, 041, 164	1993-2013	-135	0.00	***	Decreasing	-73	0.01	***	Decreasing	-62	0.01	***	Decreasing
Old Channel	131, 066, 090, 065	1997-2013	-140	0.00	***	Decreasing	-71	0.01	***	Decreasing	-69	0.01	***	Decreasing
Pilchuck	022, 208	1993-2013	-1	1.00	NS	No Trend	2	0.97	NS	No Trend	-3	0.92	NS	No Trend
Lower NF	016, 119	1993-2013	-54	0.09	*	Decreasing	-34	0.21	NS	No Trend	-20	0.25	NS	No Trend
Boulder	012	1994-2013	-1	1.00	NS	No Trend	-11	0.44	NS	No Trend	10	0.27	NS	No Trend
Squire	010	1994-2009	-19	0.10	*	Decreasing	-16	0.12	NS	No Trend	-3	0.71	NS	No Trend
Jim	059, 160	1998-2008	-45	0.00	***	Decreasing	-29	0.01	***	Decreasing	-16	0.12	NS	No Trend
Portage	020, 019, 018, 017, 064	1993-2013	-109	0.00	***	Decreasing	-35	0.20	NS	No Trend	-74	0.00	***	Decreasing
Canyon	109	1999-2008	5	0.68	NS	No Trend	2	0.90	NS	No Trend	3	0.71	NS	No Trend
Lower SF	006, 115	1993-2013	-14	0.55	NS	No Trend	0	1.00	NS	No Trend	-14	0.37	NS	No Trend
Upper SF	001, 002, 003, 004, 005, 036, 037, 049	1993-2002	Not Enough Data				Not Enough Data				Not Enough Data			
Mainstem	120, 021, 062, 207	1993-2013	-110	0.01	***	Decreasing	-91	0.00	***	Decreasing	-19	0.50	NS	No Trend

Appendix B

SMK Results

Temperature

			Combined Seasons				Wet Season				Dry Season			
Sub-basin	SSID	Years	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend
Port Susan	067	1996-2013	-41	0.28	NS	No Trend	-19	0.50	NS	No Trend	-22	0.43	NS	No Trend
Port Susan	123	1998-2013	32	0.35	NS	No Trend	4	0.90	NS	No Trend	28	0.22	NS	No Trend
Port Susan	126	1998-2013	8	0.83	NS	No Trend	-14	0.59	NS	No Trend	22	0.34	NS	No Trend
Port Susan	128	1998-2013	55	0.09	*	Increasing	20	0.43	NS	No Trend	35	0.09	*	Increasing
Port Susan	129	1998-2013	55	0.10	*	Increasing	22	0.39	NS	No Trend	33	0.15	NS	No Trend
Port Susan	130	1998-2013	26	0.45	NS	No Trend	-10	0.71	NS	No Trend	36	0.12	NS	No Trend
Port Susan	137	2002-2013	0	1.00	NS	No Trend	16	0.36	NS	No Trend	-16	0.30	NS	No Trend
Port Susan	138	2002-2013	-11	0.65	NS	No Trend	8	0.67	NS	No Trend	-19	0.22	NS	No Trend
Port Susan	139	2002-2013	-4	0.89	NS	No Trend	4	0.85	NS	No Trend	-8	0.63	NS	No Trend
Port Susan	140	2002-2013	4	0.89	NS	No Trend	12	0.50	NS	No Trend	-8	0.63	NS	No Trend
Port Susan	148	2002-2013	8	0.75	NS	No Trend	8	0.67	NS	No Trend	0	1.00	NS	No Trend
Port Susan	199	2008-2013	-11	0.14	NS	No Trend	-7	0.26	NS	No Trend	-4	0.46	NS	No Trend
Port Susan	203	2008-2013	-13	0.07	*	Decreasing	-2	0.81	NS	No Trend	-11	0.06	*	Decreasing
Port Susan	204	2008-2013	-5	0.55	NS	No Trend	-4	0.46	NS	No Trend	-1	1.00	NS	No Trend
Port Susan	206	2009-2013	-10	0.12	NS	No Trend	-4	0.46	NS	No Trend	-6	0.22	NS	No Trend
Deer	028	1998-2012	-53	0.15	NS	No Trend	-17	0.54	NS	No Trend	-36	0.15	NS	No Trend
Upper NF	060	1996-2008	-29	0.15	NS	No Trend	-32	0.03	**	Decreasing	3	0.88	NS	No Trend
Upper NF	011	1993-2013	-94	0.01	***	Decreasing	-73	0.01	***	Decreasing	-21	0.32	NS	No Trend
Church	142	1999-2013	-35	0.23	NS	No Trend	-4	0.88	NS	No Trend	-31	0.14	NS	No Trend
Church	147	2001-2013	5	0.84	NS	No Trend	18	0.24	NS	No Trend	-13	0.35	NS	No Trend
NF Hazel	013	1994-2012	26	0.50	NS	No Trend	10	0.75	NS	No Trend	16	0.54	NS	No Trend
NF Hazel	014	1994-2012	-49	0.23	NS	No Trend	-22	0.46	NS	No Trend	-27	0.36	NS	No Trend
NF Hazel	087	1997-2013	-12	0.76	NS	No Trend	-26	0.34	NS	No Trend	14	0.59	NS	No Trend

Harvey	008	1993-2008	25	0.33	NS	No Trend	-4	0.88	NS	No Trend	29	0.05	**	Increasing
Harvey	009	1994-2013	-14	0.77	NS	No Trend	-53	0.12	NS	No Trend	39	0.18	NS	No Trend
Harvey	023	1993-2008	-53	0.23	NS	No Trend	-27	0.43	NS	No Trend	-26	0.38	NS	No Trend
Harvey	041	1995-2008	11	0.34	NS	No Trend	-2	0.90	NS	No Trend	13	0.07	*	Increasing
Harvey	046	1996-2008	20	0.39	NS	No Trend	-12	0.50	NS	No Trend	32	0.03	**	Increasing
Harvey	164	2000-2008	11	0.39	NS	No Trend	4	0.75	NS	No Trend	7	0.37	NS	No Trend
Old Channel	065	1996-2007	-4	0.86	NS	No Trend	-21	0.12	NS	No Trend	17	0.15	NS	No Trend
Old Channel	066	1996-2013	-12	0.77	NS	No Trend	9	0.76	NS	No Trend	-21	0.45	NS	No Trend
Old Channel	090	1997-2008	-32	0.07	*	Decreasing	-29	0.03	**	Decreasing	-3	0.86	NS	No Trend
Old Channel	131	1999-2013	-26	0.38	NS	No Trend	-1	1.00	NS	No Trend	-25	0.23	NS	No Trend
Old Channel	134	2004-2008	-8	0.16	NS	No Trend	-8	0.09	*	Decreasing	0	1.00	NS	No Trend
Old Channel	141	1999-2008	-3	0.86	NS	No Trend	-11	0.21	NS	No Trend	8	0.39	NS	No Trend
Old Channel	145	2001-2008	-13	0.25	NS	No Trend	-8	0.39	NS	No Trend	-5	0.55	NS	No Trend
Pilchuck	022	1993-2013	-102	0.01	***	Decreasing	-70	0.03	**	Decreasing	-32	0.20	NS	No Trend
Pilchuck	208	2009-2013	3	0.74	NS	No Trend	1	1.00	NS	No Trend	2	0.73	NS	No Trend
Lower NF	016	1993-2013	-111	0.01	***	Decreasing	-59	0.08	*	Decreasing	-52	0.04	**	Decreasing
Lower NF	119	1999-2008	-15	0.30	NS	No Trend	-15	0.14	NS	No Trend	0	1.00	NS	No Trend
Boulder	012	1994-2013	-50	0.12	NS	No Trend	-52	0.04	**	Decreasing	2	0.96	NS	No Trend
Squire	010	1994-2008	-45	0.11	NS	No Trend	-34	0.10	*	Decreasing	-11	0.58	NS	No Trend
Jim	059	1996-2008	-18	0.46	NS	No Trend	-21	0.22	NS	No Trend	3	0.90	NS	No Trend
Jim	160	1998-2008	-34	0.07	*	Decreasing	-20	0.14	NS	No Trend	-14	0.31	NS	No Trend
Portage	017	1993-2013	-47	0.28	NS	No Trend	21	0.55	NS	No Trend	-68	0.01	**	Decreasing
Portage	018	1993-2013	-31	0.51	NS	No Trend	15	0.67	NS	No Trend	-46	0.14	NS	No Trend
Portage	019	1993-2008	22	0.46	NS	No Trend	9	0.72	NS	No Trend	13	0.51	NS	No Trend
Portage	020	1993-2007	8	0.79	NS	No Trend	4	0.88	NS	No Trend	4	0.85	NS	No Trend
Portage	064	1996-2013	-55	0.12	NS	No Trend	-29	0.21	NS	No Trend	-26	0.34	NS	No Trend
Canyon	109	1999-2008	-25	0.10	*	Decreasing	-23	0.05	**	Decreasing	-2	0.92	NS	No Trend
Lower SF	006	1993-2008	-101	0.00	***	Decreasing	-64	0.00	***	Decreasing	-37	0.05	**	Decreasing
Lower SF	115	1998-2008	-40	0.03	**	Decreasing	-25	0.06	*	Decreasing	-15	0.28	NS	No Trend
Upper SF	001	1993-2004	-2	0.92	NS	No Trend	-3	0.80	NS	No Trend	1	1.00	NS	No Trend

Upper SF	002	1993-2004	-8	0.47	NS	No Trend	-3	0.80	NS	No Trend	-5	0.45	NS	No Trend
Upper SF	003	1993-2008	-79	0.01	***	Decreasing	-42	0.06	*	Decreasing	-37	0.05	**	Decreasing
Upper SF	004	1993-2002	-21	0.15	NS	No Trend	-3	0.86	NS	No Trend	-18	0.04	**	Decreasing
Upper SF	005	1993-2002	-11	0.47	NS	No Trend	-9	0.47	NS	No Trend	-2	0.90	NS	No Trend
Upper SF	036	1995-2008	-52	0.03	**	Decreasing	-44	0.02	**	Decreasing	-8	0.63	NS	No Trend
Upper SF	037	1995-2002	-23	0.02	**	Decreasing	-12	0.17	NS	No Trend	-11	0.06	*	Decreasing
Upper SF	049	1996-2013	-1	1.00	NS	No Trend	-13	0.59	NS	No Trend	12	0.50	NS	No Trend
Mainstem	021	1998-2013	-62	0.01	***	Decreasing	-42	0.02	**	Decreasing	-20	0.19	NS	No Trend
Mainstem	062	1996-2008	-29	0.17	NS	No Trend	-27	0.07	*	Decreasing	-2	0.95	NS	No Trend
Mainstem	207	2008-2013	-5	0.61	NS	No Trend	-3	0.76	NS	No Trend	-2	0.81	NS	No Trend
Mainstem	120	1998-2013	6	0.88	NS	No Trend	-12	0.65	NS	No Trend	18	0.44	NS	No Trend

Dissolved Oxygen

			Combined Seasons				Wet Season				Dry Season			
Sub-basin	SITE	Years	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend
Port Susan	067	2002-2013	21	0.28	NS	No Trend	24	0.11	NS	No Trend	-3	0.86	NS	No Trend
Port Susan	123	1998-2013	26	0.43	NS	No Trend	16	0.50	NS	No Trend	10	0.68	NS	No Trend
Port Susan	126	1998-2013	-14	0.68	NS	No Trend	4	0.89	NS	No Trend	-18	0.44	NS	No Trend
Port Susan	128	1998-2013	10	0.76	NS	No Trend	3	0.93	NS	No Trend	7	0.77	NS	No Trend
Port Susan	129	1998-2013	21	0.52	NS	No Trend	8	0.75	NS	No Trend	8	0.75	NS	No Trend
Port Susan	130	1998-2013	34	0.29	NS	No Trend	10	0.68	NS	No Trend	24	0.30	NS	No Trend
Port Susan	137	2002-2013	4	0.88	NS	No Trend	6	0.73	NS	No Trend	-2	0.95	NS	No Trend
Port Susan	138	2002-2013	-9	0.70	NS	No Trend	-7	0.68	NS	No Trend	-2	0.95	NS	No Trend
Port Susan	139	2002-2013	0	1.00	NS	No Trend	-2	0.95	NS	No Trend	2	0.95	NS	No Trend
Port Susan	140	2002-2013	-4	0.88	NS	No Trend	-4	0.84	NS	No Trend	0	1.00	NS	No Trend
Port Susan	148	2002-2013	-22	0.31	NS	No Trend	-4	0.84	NS	No Trend	-18	0.24	NS	No Trend
Port Susan	199	2008-2013	45	1.00	NS	No Trend	1	1.00	NS	No Trend	0	1.00	NS	No Trend
Port Susan	203	2008-2013	-15	0.04	**	Decreasing	-8	0.09	*	Decreasing	-7	0.26	NS	No Trend
Port Susan	204	2008-2013	-11	0.14	NS	No Trend	-6	0.22	NS	No Trend	-5	0.45	NS	No Trend
Port Susan	206	2008-2013	-10	0.12	NS	No Trend	-8	0.09	*	Decreasing	-2	0.81	NS	No Trend
Deer	028	1994-2012	32	0.43	NS	No Trend	-1	1.00	NS	No Trend	33	0.23	NS	No Trend
Upper NF	060	1998-2008	33	0.06	*	Increasing	26	0.05	**	Increasing	7	0.59	NS	No Trend
Upper NF	011	1993-2013	101	0.00	***	Increasing	78	0.00	***	Increasing	23	0.28	NS	No Trend
Church	142	1999-2013	-32	0.25	NS	No Trend	-15	0.49	NS	No Trend	-17	0.38	NS	No Trend
Church	147	2002-2013	-8	0.70	NS	No Trend	3	0.88	NS	No Trend	-11	0.43	NS	No Trend
NF Hazel	013	1994-2012	52	0.17	NS	No Trend	22	0.46	NS	No Trend	30	0.23	NS	No Trend
NF Hazel	014	1994-2012	44	0.27	NS	No Trend	1	1.00	NS	No Trend	43	0.11	NS	No Trend
NF Hazel	087	1998-2013	44	0.11	NS	No Trend	14	0.52	NS	No Trend	30	0.11	NS	No Trend
Harvey	008	1993-2008	-7	0.81	NS	No Trend	4	0.88	NS	No Trend	-11	0.49	NS	No Trend
Harvey	009	1994-2013	-17	0.70	NS	No Trend	36	0.26	NS	No Trend	-53	0.07	*	Decreasing
Harvey	023	1993-2008	19	0.68	NS	No Trend	17	0.63	NS	No Trend	2	0.97	NS	No Trend

Harvey	041	1995-2008	-8	0.50	NS	No Trend	-1	1.00	NS	No Trend	-7	0.37	NS	No Trend
Harvey	046	1996-2008	-68	0.00	***	Decreasing	-20	0.25	NS	No Trend	-48	0.00	***	Decreasing
Harvey	164	2000-2008	18	0.14	NS	No Trend	17	0.09	*	Increasing	1	1.00	NS	No Trend
Old Channel	065	1996-2007	-9	0.47	NS	No Trend	92	0.60	NS	No Trend	-15	0.01	***	Decreasing
Old Channel	066	1996-2013	-41	0.16	NS	No Trend	-34	0.14	NS	No Trend	-7	0.74	NS	No Trend
Old Channel	090	1997-2008	-17	0.32	NS	No Trend	-3	0.88	NS	No Trend	-14	0.18	NS	No Trend
Old Channel	131	1999-2013	20	0.41	NS	No Trend	16	0.36	NS	No Trend	4	0.85	NS	No Trend
Old Channel	134	2004-2008	3	0.69	NS	No Trend	3	0.61	NS	No Trend	0	1.00	NS	No Trend
Old Channel	141	1999-2008	6	0.66	NS	No Trend	8	0.39	NS	No Trend	-2	0.90	NS	No Trend
Old Channel	145	2001-2008	-19	0.09	*	Decreasing	-8	0.39	NS	No Trend	-11	0.13	NS	No Trend
Pilchuck	022	1993-2013	66	0.10	*	Increasing	41	0.19	NS	No Trend	25	0.32	NS	No Trend
Pilchuck	208	2009-2013	-9	0.19	NS	No Trend	-5	0.45	NS	No Trend	-4	0.31	NS	No Trend
Lower NF	016	1993-2013	74	0.07	*	Increasing	49	0.15	NS	No Trend	25	0.32	NS	No Trend
Lower NF	119	1999-2008	29	0.04	**	Increasing	29	0.00	***	Increasing	0	1.00	NS	No Trend
Boulder	012	1994-2013	71	0.03	**	Increasing	56	0.02	**	Increasing	15	0.49	NS	No Trend
Squire	010	1994-2008	49	0.08	*	Increasing	35	0.09	*	Increasing	14	0.48	NS	No Trend
Jim	059	1996-2008	14	0.45	NS	No Trend	-3	0.86	NS	No Trend	17	0.21	NS	No Trend
Jim	160	1998-2008	10	0.57	NS	No Trend	8	0.53	NS	No Trend	2	0.93	NS	No Trend
Portage	017	1993-2013	-23	0.60	NS	No Trend	10	0.79	NS	No Trend	-33	0.23	NS	No Trend
Portage	018	1993-2013	41	0.38	NS	No Trend	45	0.18	NS	No Trend	-4	0.92	NS	No Trend
Portage	019	1993-2008	-6	0.86	NS	No Trend	14	0.56	NS	No Trend	-20	0.30	NS	No Trend
Portage	020	1993-2007	-19	0.49	NS	No Trend	-17	0.43	NS	No Trend	-2	0.95	NS	No Trend
Portage	064	1996-2013	9	0.69	NS	No Trend	-5	0.72	NS	No Trend	14	0.43	NS	No Trend
Canyon	109	1999-2008	1	1.00	NS	No Trend	4	0.75	NS	No Trend	-3	0.83	NS	No Trend
Lower SF	006	1993-2008	92	0.00	***	Increasing	47	0.02	**	Increasing	45	0.02	**	Increasing
Lower SF	115	1998-2008	22	0.18	NS	No Trend	15	0.21	NS	No Trend	125	0.59	NS	No Trend
Upper SF	001	1993-2004	2	0.91	NS	No Trend	1	1.00	NS	No Trend	1	1.00	NS	No Trend
Upper SF	002	1993-2004	15	0.09	*	Increasing	8	0.27	NS	No Trend	7	0.24	NS	No Trend
Upper SF	003	1993-2008	74	0.01	***	Increasing	31	0.14	NS	No Trend	43	0.02	**	Increasing
Upper SF	004	1993-2002	-14	0.30	NS	No Trend	-16	0.12	NS	No Trend	2	0.90	NS	No Trend

Upper SF	005	1993-2002	4	0.81	NS	No Trend	6	0.60	NS	No Trend	-2	0.90	NS	No Trend
Upper SF	036	1995-2008	43	0.06	*	Increasing	27	0.11	NS	No Trend	16	0.30	NS	No Trend
Upper SF	037	1995-2002	12	0.20	NS	No Trend	1	1.00	NS	No Trend	11	0.06	*	Increasing
Upper SF	049	1996-2013	-10	0.64	NS	No Trend	1	1.00	NS	No Trend	-11	0.44	NS	No Trend
Mainstem	207	2008-2014	-1	1.00	NS	No Trend	-5	0.55	NS	No Trend	4	0.46	NS	No Trend
Mainstem	021	1993-2008	10	0.70	NS	No Trend	13	0.51	NS	No Trend	-3	0.89	NS	No Trend
Mainstem	062	1998-2008	21	0.21	NS	No Trend	31	0.02	**	Increasing	-10	0.35	NS	No Trend
Mainstem	120	1998-2013	45	0.16	NS	No Trend	20	0.39	NS	No Trend	25	0.28	NS	No Trend

Turbidity

			Combined Seasons				Wet Season				Dry Season			
Sub-basin	SSID	Years	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend
Port Susan	067	2004-2013	-6	0.75	NS	No Trend	7	0.59	NS	No Trend	-13	0.28	NS	No Trend
Deer	028	1994-2012	65	0.09	*	Increasing	17	0.58	NS	No Trend	48	0.05	**	Increasing
Upper NF	011	1993-2013	25	0.47	NS	No Trend	-6	0.85	NS	No Trend	31	0.14	NS	No Trend
Upper NF	060	1998-2009	33	0.08	*	Increasing	18	0.24	NS	No Trend	15	0.21	NS	No Trend
Church	142	1999-2013	36	0.20	NS	No Trend	33	0.11	NS	No Trend	3	0.91	NS	No Trend
Church	147	2002-2013	-8	0.70	NS	No Trend	-11	0.44	NS	No Trend	3	0.88	NS	No Trend
NF Hazel	087	1998-2013	87	0.00	***	Increasing	32	0.16	NS	No Trend	55	0.01	***	Increasing
NF Hazel	013	1994-2012	165	0.00	***	Increasing	87	0.00	***	Increasing	78	0.00	***	Increasing
NF Hazel	014	1994-2012	10	0.82	NS	No Trend	-25	0.40	NS	No Trend	35	0.20	NS	No Trend
Harvey	009	1994-2013	157	0.00	***	Increasing	88	0.00	***	Increasing	69	0.01	***	Increasing
Harvey	023	1993-2013	139	0.00	***	Increasing	98	0.00	***	Increasing	41	0.16	NS	No Trend
Harvey	046	1996-2008	24	0.29	NS	No Trend	4	0.85	NS	No Trend	20	0.19	NS	No Trend
Harvey	041	1995-2008	27	0.01	***	Increasing	12	0.17	NS	No Trend	15	0.04	**	Increasing
Harvey	164	2000-2008	24	0.04	**	Increasing	11	0.13	NS	No Trend	11	0.13	NS	No Trend
Old Channel	131	2002-2013	-18	0.41	NS	No Trend	0	1.00	NS	No Trend	-18	0.24	NS	No Trend
Old Channel	066	1998-2013	-17	0.58	NS	No Trend	-18	0.44	NS	No Trend	1	1.00	NS	No Trend
Old Channel	090	1997-2008	27	0.10	*	Increasing	5	0.76	NS	No Trend	22	0.03	**	Increasing
Old Channel	065	1999-2007	35	0.00	***	Increasing	20	0.05	**	Increasing	15	0.04	**	Increasing
Pilchuck	022	1993-2013	83	0.03	**	Increasing	35	0.23	NS	No Trend	48	0.05	**	Increasing
Lower NF	016	1993-2013	33	0.39	NS	No Trend	1	1.00	NS	No Trend	32	0.20	NS	No Trend
Lower NF	119	1999-2009	19	0.26	NS	No Trend	11	0.44	NS	No Trend	8	0.47	NS	No Trend
Boulder	012	1994-2013	45	0.13	NS	No Trend	16	0.50	NS	No Trend	29	0.13	NS	No Trend
Squire	010	1994-2009	46	0.12	NS	No Trend	16	0.50	NS	No Trend	30	0.11	NS	No Trend
Jim	059	1998-2008	21	0.24	NS	No Trend	3	0.88	NS	No Trend	18	0.13	NS	No Trend
Jim	160	1998-2008	17	0.32	NS	No Trend	5	0.76	NS	No Trend	12	0.25	NS	No Trend
Portage	020	1993-2007	-38	0.14	NS	No Trend	-24	0.25	NS	No Trend	-14	0.37	NS	No Trend

Portage	019	1993-2008	7	0.83	NS	No Trend	-2	0.96	NS	No Trend	9	0.66	NS	No Trend
Portage	018	1993-2013	148	0.00	***	Increasing	87	0.01	***	No Trend	61	0.04	**	No Trend
Portage	017	1993-2013	67	0.09	*	Increasing	33	0.30	NS	No Trend	34	0.17	NS	No Trend
Portage	064	2000-2013	17	0.38	NS	No Trend	3	0.86	NS	No Trend	14	0.37	NS	No Trend
Canyon	109	1999-2008	15	0.34	NS	No Trend	5	0.72	NS	No Trend	10	0.35	NS	No Trend
Lower SF	006	1993-2013	97	0.00	***	Increasing	72	0.00	***	Increasing	25	0.19	NS	No Trend
Lower SF	115	1998-2008	7	0.71	NS	No Trend	3	0.88	NS	No Trend	4	0.75	NS	No Trend
Upper SF	001	1993-2004	3	0.85	NS	No Trend	-4	0.71	NS	No Trend	7	0.37	NS	No Trend
Upper SF	002	1993-2002	-1	1.00	NS	No Trend	-4	0.71	NS	No Trend	3	0.71	NS	No Trend
Upper SF	003	1993-2008	89	0.00	***	Increasing	50	0.03	**	Increasing	39	0.04	**	Increasing
Upper SF	004	1993-2002	7	0.66	NS	No Trend	3	0.86	NS	No Trend	4	0.71	NS	No Trend
Upper SF	005	1993-2002	19	0.19	NS	No Trend	3	0.86	NS	No Trend	16	0.06	*	Increasing
Upper SF	036	1995-2008	31	0.20	NS	No Trend	15	0.44	NS	No Trend	16	0.30	NS	No Trend
Upper SF	037	1995-2002	4	0.76	NS	No Trend	0	1.00	NS	No Trend	4	0.57	NS	No Trend
Upper SF	049	1998-2013	31	0.13	NS	No Trend	8	0.67	NS	No Trend	23	0.05	**	Increasing
Mainstem	120	2000-2008	-13	0.30	NS	No Trend	-2	0.92	NS	No Trend	-11	0.13	NS	No Trend
Mainstem	021	1993-2008	37	0.12	NS	No Trend	15	0.44	NS	No Trend	22	0.15	NS	No Trend
Mainstem	062	1998-2008	25	0.13	NS	No Trend	17	0.21	NS	No Trend	8	0.47	NS	No Trend
Mainstem	207	2008-2013	-3	0.77	NS	No Trend	-1	1.00	NS	No Trend	-2	0.81	NS	No Trend

Fecal Coliform

			Combined Seasons				Wet Season				Dry Season			
Sub-basin	SSID	Years	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend	Score (S)	p-value	Signif.	Trend
Port Susan	067	1996-2013	-52	0.17	NS	No Trend	-23	0.41	NS	No Trend	-29	0.29	NS	No Trend
Port Susan	123	1998-2013	-100	0.00	***	Decreasing	-54	0.02	**	Decreasing	-46	0.04	**	Decreasing
Port Susan	126	1998-2013	-78	0.01	***	Decreasing	-26	0.26	NS	No Trend	-52	0.02	**	Decreasing
Port Susan	128	1998-2013	-117	0.00	***	Decreasing	-86	0.00	***	Decreasing	-31	0.14	NS	No Trend
Port Susan	129	1998-2013	-126	0.00	***	Decreasing	-70	0.00	***	Decreasing	-56	0.01	***	Decreasing
Port Susan	130	1998-2013	-63	0.05	**	Decreasing	-34	0.14	NS	No Trend	-29	0.21	NS	No Trend
Port Susan	137	2002-2013	-23	0.29	NS	No Trend	-30	0.05	**	Decreasing	7	0.68	NS	No Trend
Port Susan	138	2002-2013	-11	0.63	NS	No Trend	-34	0.02	**	Decreasing	-14	0.13	NS	No Trend
Port Susan	139	2002-2013	-58	0.01	***	Decreasing	-44	0.00	***	Decreasing	-14	0.37	NS	No Trend
Port Susan	140	2002-2013	-26	0.23	NS	No Trend	-30	0.05	**	Decreasing	4	0.84	NS	No Trend
Port Susan	148	2002-2013	-13	0.56	NS	No Trend	-24	0.12	NS	No Trend	11	0.49	NS	No Trend
Mainstem	021	1998-2008	-36	0.04	**	Decreasing	-19	0.16	NS	No Trend	-17	0.15	NS	No Trend
Mainstem	062	1996-2008	-42	0.06	*	Decreasing	-44	0.01	***	Decreasing	2	0.95	NS	No Trend
Mainstem	120	1998-2013	-52	0.10	*	Decreasing	-28	0.22	NS	No Trend	-24	0.30	NS	No Trend
Mainstem	207	2008-2014	-3	0.80	NS	No Trend	3	0.76	NS	No Trend	-6	0.22	NS	No Trend
Deer	028	1996-2006	-29	0.08	*	Decreasing	-17	0.21	NS	No Trend	-12	0.25	NS	No Trend
Chruch	142	1999-2013	-72	0.01	***	Decreasing	-37	0.08	*	Decreasing	-35	0.06	*	Decreasing
Chruch	147	2000-2013	-30	0.16	NS	No Trend	-18	0.24	NS	No Trend	-12	0.45	NS	No Trend
Upper NF	011	1996-2004	-13	0.30	NS	No Trend	-10	0.35	NS	No Trend	-3	0.76	NS	No Trend
NF Hazel	014	1996-2006	-15	0.38	NS	No Trend	-11	0.44	NS	No Trend	-4	0.75	NS	No Trend
NF Hazel	013	1996-2006	-21	0.21	NS	No Trend	-11	0.44	NS	No Trend	-10	0.35	NS	No Trend
NF Hazel	087	1996-2006	-21	0.15	NS	No Trend	-17	0.15	NS	No Trend	-4	0.71	NS	No Trend
Harvey	009	1996-2014	-123	0.00	***	Decreasing	-65	0.03	**	Decreasing	-58	0.02	**	Decreasing
Harvey	023	1996-2014	-69	0.06	*	Decreasing	-27	0.33	NS	No Trend	-42	0.09	*	Decreasing
Harvey	046	1998-2008	-31	0.04	**	Decreasing	-25	0.03	**	Decreasing	-6	0.60	NS	No Trend
Harvey	041	1996-2008	-4	0.75	NS	No Trend	-3	0.76	NS	No Trend	-1	1.00	NS	No Trend

Harvey	164	2000-2008	-5	0.73	NS	No Trend	-8	0.47	NS	No Trend	3	0.76	NS	No Trend
Old Channel	131	1999-2013	-44	0.13	NS	No Trend	-37	0.08	*	Decreasing	-7	0.77	NS	No Trend
Old Channel	066	1996-2013	-124	0.00	***	Decreasing	-59	0.03	**	Decreasing	-65	0.02	**	Decreasing
Old Channel	090	1997-2008	3	0.91	NS	No Trend	0	1.00	NS	No Trend	3	0.86	NS	No Trend
Old Channel	065	1996-2007	-21	0.18	NS	No Trend	-17	0.15	NS	No Trend	-4	0.75	NS	No Trend
Pilchuck	208	2009-2014	11	0.10	*	Increasing	9	0.13	NS	No Trend	2	0.73	NS	No Trend
Pilchuck	022	1998-2014	-35	0.28	NS	No Trend	-20	0.43	NS	No Trend	-15	0.49	NS	No Trend
Lower NF	016	1997-2014	-5	0.74	NS	No Trend	3	0.86	NS	No Trend	-8	0.09	*	Decreasing
Lower NF	119	1999-2008	12	0.38	NS	No Trend	92	0.60	NS	No Trend	18	0.04	**	Increasing
Boulder	012	1996-2006	-1	1.00	NS	No Trend	-11	0.44	NS	No Trend	10	0.27	NS	No Trend
Squire	010	1996-2004	-19	0.10	*	Decreasing	-16	0.12	NS	No Trend	-3	0.71	NS	No Trend
Jim	160	1998-2006	-9	0.45	NS	No Trend	-6	0.54	NS	No Trend	-3	0.76	NS	No Trend
Jim	059	1996-2006	-39	0.01	***	Decreasing	-27	0.02	**	Decreasing	-12	0.25	NS	No Trend
Portage	020	1996-2007	-53	0.01	***	Decreasing	-34	0.02	**	Decreasing	-19	0.11	NS	No Trend
Portage	019	1996-2008	-28	0.22	NS	No Trend	-8	0.67	NS	No Trend	-20	0.19	NS	No Trend
Portage	018	1996-2013	-121	0.00	***	Decreasing	-59	0.03	**	Decreasing	-62	0.01	***	Decreasing
Portage	017	1996-2013	-54	0.11	NS	No Trend	-29	0.29	NS	No Trend	-25	0.24	NS	No Trend
Portage	064	1996-2013	-70	0.04	**	Decreasing	-24	0.34	NS	No Trend	-46	0.06	*	Decreasing
Canyon	109	1999-2006	5	0.68	NS	No Trend	2	0.90	NS	No Trend	3	0.71	NS	No Trend
Lower SF	006	1996-2006	-3	0.90	NS	No Trend	-5	0.76	NS	No Trend	2	0.92	NS	No Trend
Lower SF	115	1998-2008	-18	0.32	NS	No Trend	-17	0.21	NS	No Trend	-1	1.00	NS	No Trend