WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Old Stillaguamish River Channel Diel Surveys July and September 2004

Abstract

Two diel (24-hour) surveys examining changes in temperature, pH, conductivity, salinity, and dissolved oxygen were conducted in the Old Stillaguamish River Channel on July 28-30 and September 7-9, 2004. The surveys were a collaborative effort between the Washington State Department of Ecology (Ecology) and the Stillaguamish Tribe Natural Resources Department.

The purpose of the surveys was to provide new baseline data that reflect any changes that a new tide gate may have on water quality in the channel. The data may also be used in future water quality investigations of the Old Stillaguamish River Channel.

No comparative analysis of the 2004 data to previously collected data is provided; however, quality assurance results suggest that data collected by the Stillaguamish Tribe are comparable to Ecology data. Temperature, pH, and dissolved oxygen water quality criteria violations occurred in the channel during both surveys. Further monitoring is recommended.

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Introduction

Area Description

The Old Stillaguamish River Channel is a vestigial channel connecting the mainstem of the Stillaguamish River to Port Susan and Skagit Bay (Figure 1). The channel was left as a secondary outlet after the main portion of the Stillaguamish River was diverted to Port Susan via Hatt Slough over 70 years ago. The Old Channel meanders for eight miles until it bifurcates at about river mile (RM) 1.5; South Pass transports about 80% of the flow to and from Port Susan; and West Pass carries the remaining flow to and from Skagit Bay.

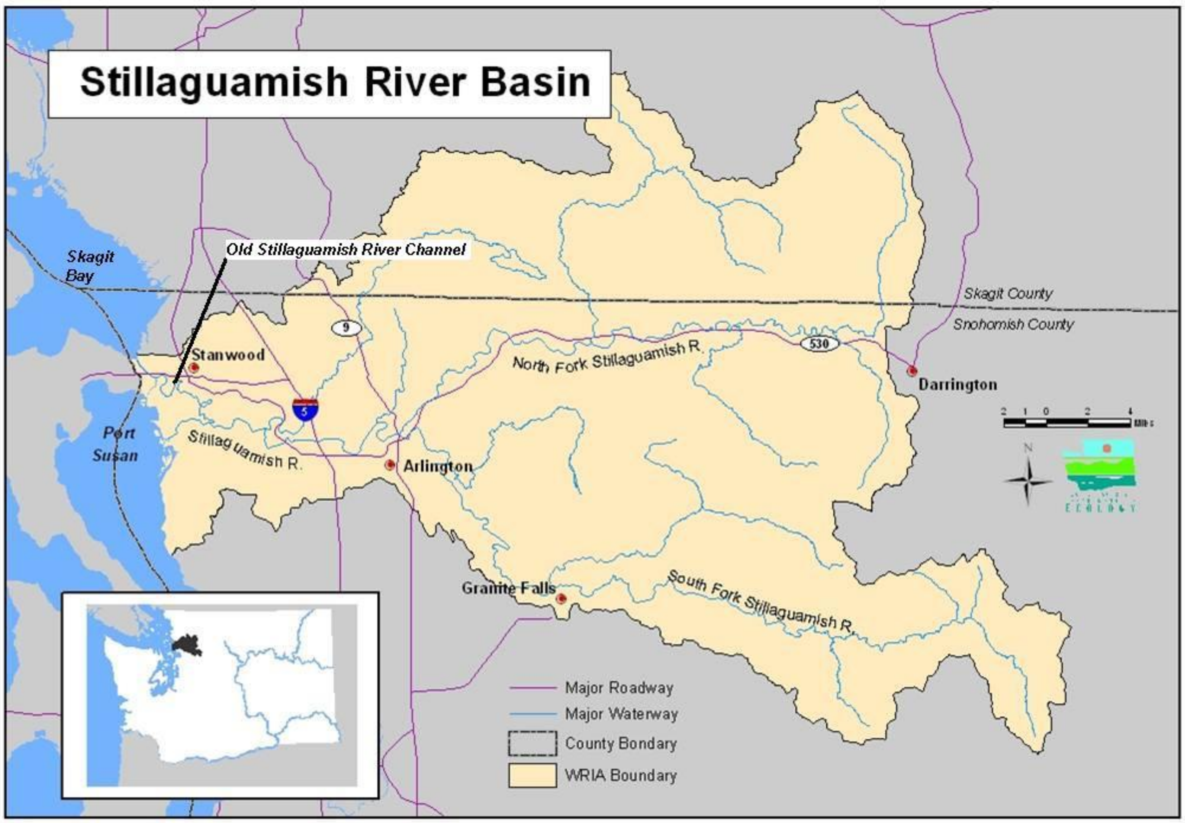

Figure 1. Overview of the Stillaguamish River basin, including the Old Stillaguamish River Channel.

The major sources of freshwater to the channel are the Stillaguamish River, Church Creek/ Jorgenson Slough, Miller Creek, Irvine Slough, Douglas Slough, the Stanwood wastewater treatment plant (WWTP), and multiple drainage ditches. The Stillaguamish River provides the greatest volume to the channel during higher flow and flood conditions. Church Creek/ Jorgenson Slough is the largest of the groundwater-fed local watersheds.

During the wet season, the Old Channel is primarily a freshwater watercourse as streamflows increase from the Stillaguamish River and local tributaries. Fewer flood events in the past several years have resulted in a build-up of sediment and vegetation at the bifurcation point and in other reaches of the channel. This has reduced the amount of Stillaguamish River flow into the channel and has exacerbated the poor flushing during the low-streamflow season. It also has decreased the channel capacity during flood periods.

During the dry season, freshwater inflows from the Stillaguamish River, tributaries, and drainage ditches are limited, and the channel functions much like a tidal slough. The flushing rate of the Old Channel was estimated to be three days during periods of low flow and poor tidal exchange (Glenn, 1996). Marine water, the small volume of freshwater, and WWTP effluent are trapped during a combination of low tidal exchanges. Sills and bars have developed in lower reaches of the channel that further isolate pools during some periods of the tide cycle.

Some high tides nearly inundate the channel with marine water. Summer salinities of 0.5 parts per thousand (ppt) to 2 ppt have been recorded near the head of the Old Channel at Norman Road (Joy, Coffler, and Gridley, 2004). Occasionally, this brackish water is forced out of the Old Channel into the Stillaguamish River (Joy, 2004) because the high tide from West Pass and up through the Old Channel is earlier than the high tide from Port Susan influencing Hatt Slough.

In 2003, the Stillaguamish Flood Control District installed a flow control structure with removable gates at the head of the Old Stillaguamish River Channel. The purpose of the structure is to enhance flushing of the Old Channel with freshwater from the Stillaguamish River. The control structure operates during the summer low-streamflow season and allows Stillaguamish River water to enter the Old Channel, but does not allow water back into the river from the Old Channel. Theoretically, the water volumes built up against the gate would have more head pressure to push more marine or brackish water out of the Old Channel to South Pass and West Pass on the following ebb tide.

The municipal wastewater effluent quality and quantity of the Stanwood WWTP has also been recently modified. In 2004, the City of Stanwood completed design and operational changes to its WWTP from a facultative lagoon system to an activated sludge facility. The lagoons remain as emergency overflow structures, but they can also be used during critical receiving water periods to hold effluent for a couple of months.

Previous Studies

Based on data collected during a receiving water survey at the Stanwood WWTP in 1992 (Glenn, 1996) and from monitoring conducted by the Stillaguamish Tribe (Klopfer, 1997), segments of the Old Stillaguamish River Channel were placed on the 1998 Section 303(d) list of the federal Clean Water Act by the Washington State Department of Ecology (Ecology). Reaches were not meeting water quality standards for fecal coliform bacteria, ammonia, lead, copper, and nickel.

Subsequently, research by the Stillaguamish Tribe and Ecology documented more water quality problems in the Old Stillaguamish River Channel (Klopfer, 2000; Glenn, unpublished data). For example, fall and winter sampling in 1999 documented potential criteria violations for some metals (Glenn, unpublished). Klopfer (2000) observed a diel dissolved oxygen range from 5 to 15 mg/L in July and August 2000. The widely variable dissolved oxygen concentrations suggested a potential nutrient or oxygen demand problem in the Old Channel.

In 2000, Ecology began a Total Maximum Daily Load (TMDL) technical study of the Stillaguamish River basin that included the Old Stillaguamish River and its drainage area because of their 303(d) listings (Joy, 2004). The data collected during the 2000 -2001 study found that poor flushing from decreased freshwater inputs created a situation where nutrients and oxygen-demanding loads were trapped and cause excessive aquatic productivity. Large diel swings in pH and dissolved oxygen, as well as elevated water temperatures, occurred; water quality criteria were not met under these conditions (Figure 2).

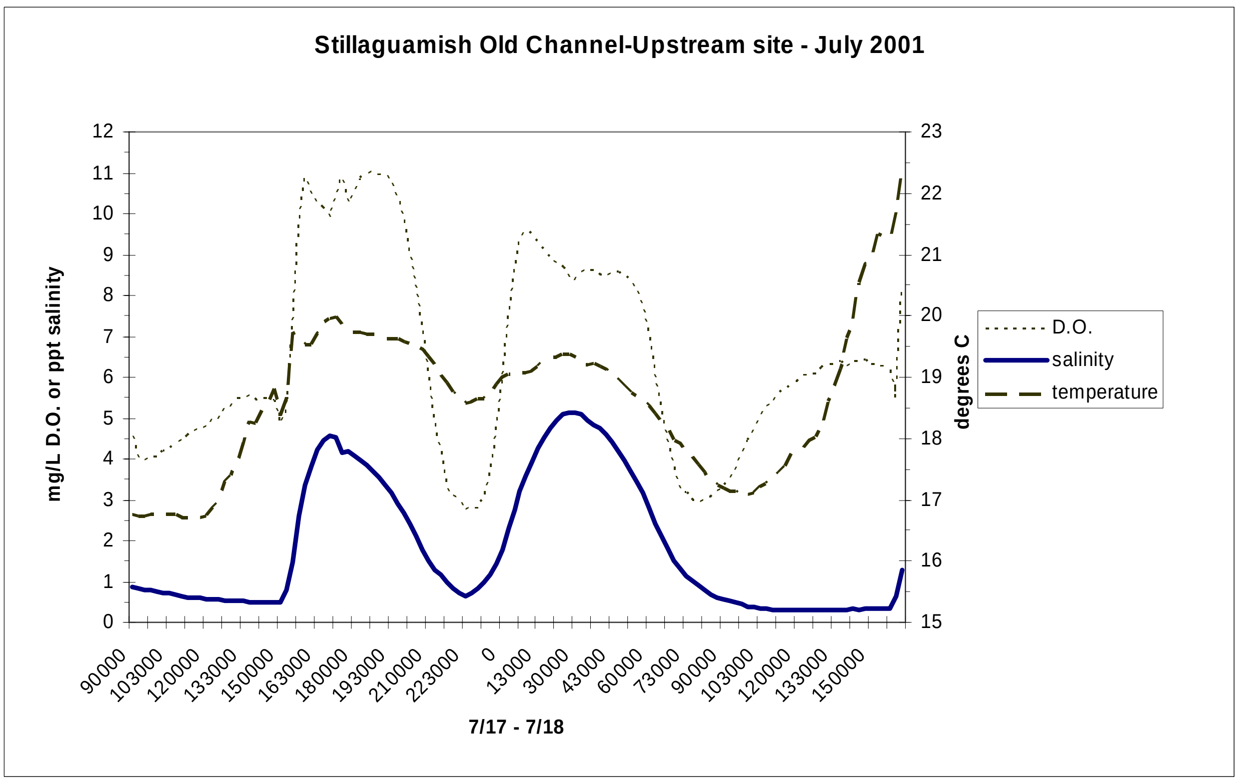

Figure 2. Dissolved oxygen (D.O.), temperature, and salinity data recorded in the Old Stillaguamish River over 31.5 hours in July 2001.

Tributaries to the Old Stillaguamish River Channel also do not meet all water quality standards. Jorgenson Slough was included on the 1998 303(d) list for not meeting fecal coliform bacteria criteria. It was listed again, along with Church Creek, Miller Creek, and Irvine Slough, on the final 2004 303(d) list. Parameters of concern listed on the draft list for tributaries to the Old Stillaguamish River Channel include fecal coliform and dissolved oxygen.

Water Quality Standards

According to Chapter 173-201A of the Washington State Administrative Code (WAC), the Old Stillaguamish River Channel and associated tributaries are designated as Class A (excellent) waterbodies. Classifications are assigned based on general characteristics, characteristic uses, and water quality criteria.

Class A freshwater and marine water are differentiated on the basis of vertically averaged salinity measurements and are subject to different water quality criteria. A waterbody where 95% of the vertically-averaged, daily maximum salinity values are less than or equal to one part per thousand (ppt) is considered freshwater. Changes in salinity that would result in seasonal water quality classification and standards changes are not specifically addressed in Chapter 173-201A.

Table 1 outlines Class A freshwater and marine water quality standards for the parameters included in this study. Table 2 includes proposed criteria changes that are currently awaiting approval from the U.S. Environmental Protection Agency. Under the proposed new criteria, the Old Stillaguamish River Channel is considered a '*salmon and trout spawning noncore rearing and migration area*' of excellent quality for aquatic life. It is possible that this classification may be reassessed prior to implementing the proposed criteria. As a result, the proposed new criteria for all classifications are presented.

The water quality of the Old Channel is of concern because of fish passage to Church Creek, a salmon spawning stream, and because of active shellfish beds in Port Susan and Skagit Bay. It also could be an estuarine rearing area. Excessive temperatures, low dissolved oxygen, and rapid changes in pH can create barriers to fish migration and rearing. Elevated fecal coliform bacteria concentrations and poor dilution and dispersion of bacteria loads can result in shellfish harvesting closures.

Table 1. Class A (excellent) water quality standards (Chapter 173-201A WAC) for the parameters included in the Old Stillaguamish River Channel diel surveys, 2004.

Criteria Category	Statistic	Criterion	Other
Dissolved oxygen			
Freshwater	Minimum	8.0 mg/L	
Marine	Minimum	6.0 mg/L	95% vertically average daily maximum salinity $\geq$1ppt
pH			
Freshwater	Maximum Minimum	8.5 6.5	
Marine	Maximum Minimum	8.5 7.0	95% vertically average daily maximum salinity >1ppt 95% vertically average daily maximum salinity >1ppt
Temperature			
Freshwater		18°C	
Marine		16°C	95% vertically average daily maximum salinity >1ppt

Table 2. Proposed changes to water quality standards (Chapter 173-201A WAC) that may be used in future assessments of the Old Stillaguamish River Channel.

Category	Statistic	Criterion	Beneficial use protected
Dissolved Oxygen			
Freshwater	One day minimum not exceeded more than once in 10 years	9.5 mg/L	Char areas, salmon and trout spawning, and core rearing and migration areas
		8.0 mg/L	Salmon and trout spawning areas, and non-core rearing and migration areas
		6.5 mg/L	Salmon and trout rearing and migration only
Marine	One day minimum	7.0 mg/L	Extraordinary quality for aquatic life
		6.0 mg/L	Excellent quality for aquatic life
		5.0 mg/L	Good quality for aquatic life
		4.0 mg/L	Fair quality for aquatic life
Temperature			
Freshwater	7-day average of the daily maximum temperatures	12°C	Char areas
		16°C	Salmon and trout spawning areas, and core rearing and migration areas
		17.5°C	Salmon and trout spawning areas, and non-core rearing and migration areas
		17.5°C	Salmon and trout rearing and migration only
Marine	Highest one day maximum	13°C	Extraordinary quality for aquatic life
		16°C	Excellent quality for aquatic life
		19°C	Good quality for aquatic life
		22°C	Fair quality for aquatic life

Problem Statement

Ecology plans to address pH, dissolved oxygen, nutrient, and other water quality issues in the Old Stillaguamish River Channel and associated tributaries with TMDLs in the near future. Basic data are needed to determine if conditions have substantially changed since 2000 – 2001. Installing the flow control gate in 2003 and upgrading the Stanwood WWTP in 2004 could have potentially affected water quality by influencing dilution, dispersion, and pollutant loading in the Old Channel. The fecal coliform, nutrient, dissolved oxygen, pH, and temperature data collected during the TMDL study in 2000 and 2001 may not adequately reflect the new conditions since these changes have taken place.

The primary objective of the Old Stillaguamish River Channel diel surveys is to provide a new baseline dataset that reflects any changes the new flow control structure and WWTP operations may have on water quality in the channel. The surveys are also useful for the Stillaguamish Tribe researchers in their on-going studies of the Old Channel water quality for the Stillaguamish Flood Control District. The compatibility of Stillaguamish Tribe generated data and Ecology data is also a concern. Compatible data would enhance analytical abilities for both groups.

Monitoring data of dissolved oxygen, pH, salinity, and temperature are needed during low streamflow and poor tidal exchange events so that diel minimums and maximums can be observed. These data will help Ecology determine if additional data are needed for the future TMDL study to calculate the assimilative capacities of nutrients and oxygen-demanding materials in the Old Stillaguamish River Channel. The data will help the Stillaguamish Tribe assess their data as they document changes in water quality from installing the flow control gate.

Methods

Two diel[1] surveys were conducted in the Old Stillaguamish River Channel during 2004. The diel surveys were scheduled in conjunction with diurnal[2] surveys conducted by the Stillaguamish Tribe's Natural Resources Department as described in the Quality Assurance (QA) Project Plan (Coffler, 2004). During each survey data loggers were deployed for 48 hours at three sites to collect temperature, pH, specific conductance, salinity, and dissolved oxygen readings.

Ecology supplied, calibrated, deployed, and picked up the data loggers in addition to performing Winkler titrations of dissolved oxygen samples. The Stillaguamish Tribe supplied and calibrated field meters, collected instantaneous field data measurements, and performed mid-cycle checks of the data loggers. Field methods, protocols, and standard operating procedures employed during the surveys are described in the QA Project Plan (Coffler, 2004).

The first diel survey occurred on July 28-30, 2004. Multiple-probe data loggers were placed at Stations OSRC1, OSRC2, and OSRC3 (Table 3 and Figure 3). Daily mean flow measurements recorded at the Snohomish County flow monitoring station on the Stillaguamish River at Interstate 5 bridge were between 1200 and 1400 cfs (Snohomish County, 2005). The maximum tidal range was seven to eight feet (Appendix B, Figure B4). Stillaguamish Tribe staff took temperature, dissolved oxygen, specific conductivity, and salinity measurements at near-hourly intervals at OSRC1 and OSRC2 from 0630 hours to 2130 hours on July 29.

The second survey was scheduled to occur on August 31-September 2, 2004, but it was rescheduled after a significant amount of rain caused a sudden increase in the Stillaguamish River flows the week prior. Researchers decided that low-flow conditions would not be adequately characterized under the receding storm event conditions.

Table 3. Description and coordinates of monitoring sites included in the Old Stillaguamish River Channel diel surveys, July and September 2004.

Ecology Station ID	Stillaguamish Tribe Station ID	Station Descriptions on the Old Stillaguamish River Channel	Latitude	Longitude
OSRC1	090	At Norman Road bridge	48.2132 N	-122.3268 W
OSRC2	145	Off Florence Road	48.2213 N	-122.3310 W
OSRC3	165	At Marine Drive bridge	48.2257 N	-122.3382 W
OSRC4	066	At private dock off Leque Road	48.2360 N	-122.3650 W

[1] Diel – 24-hour period
[2] Diurnal – daytime only

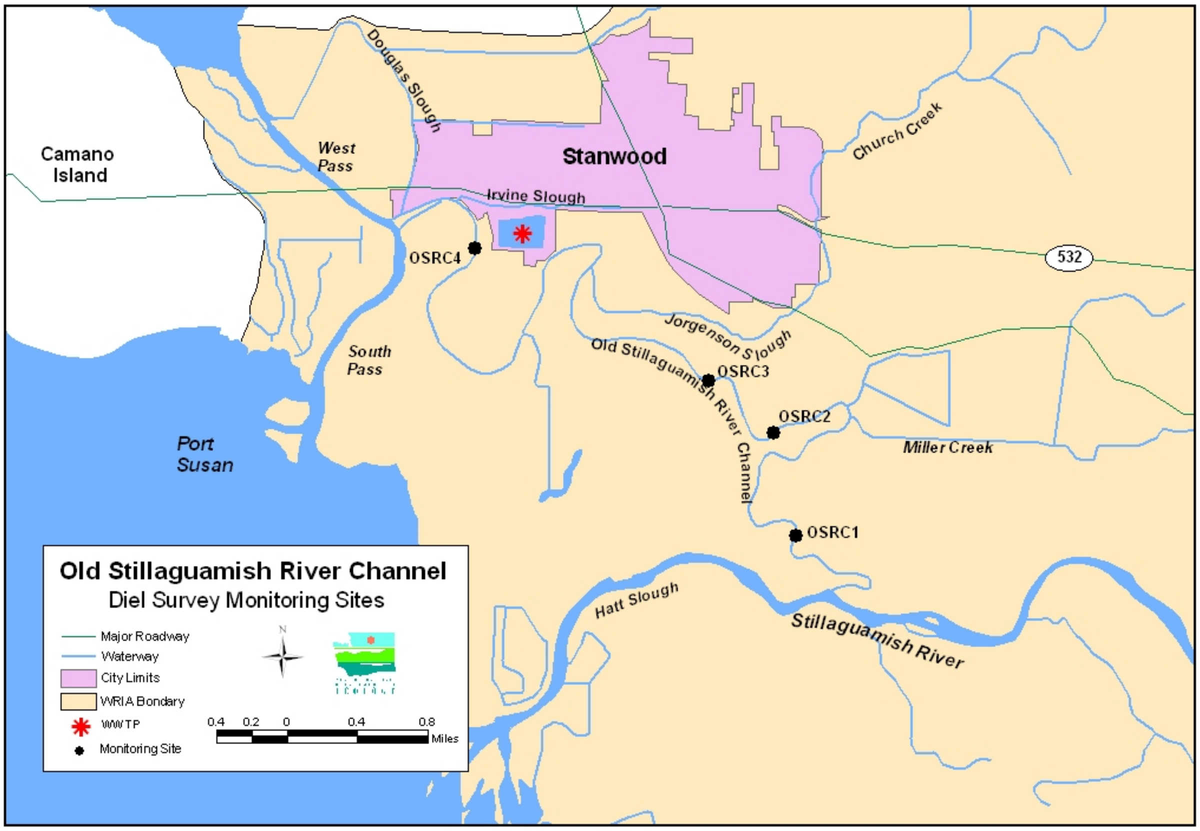

Figure 3. Monitoring sites for the Old Stillaguamish River Channel diel surveys.

The September survey was undertaken September 7-9, 2004. During the survey, data loggers were placed at Stations OSRC1, OSRC2, and OSRC4 (Table 3 and Figure 3). Daily mean flow measurements recorded at the Snohomish County flow monitoring station on the Stillaguamish River at the Interstate 5 bridge were between 1400 and 1700 cfs (Snohomish County, 2005). The maximum tidal range was six feet (Appendix B, Figure B8). Stillaguamish Tribe staff took temperature, dissolved oxygen, specific conductivity, and salinity measurements at near-hourly intervals at OSRC1 and OSRC2 from 0730 hours to 1930 hours on September 8.

Data logging instruments were placed in the thalweg of the channel and suspended 0.3 – 0.6m above the bottom of the channel. The instruments at OSRC1 and OSRC3 were suspended between an anchor block and a buoy on a short tether. At OSRC2, a pier was used as an anchor, and the loggers were fastened to a floating dock at OSRC4.

After deployment, logged data were downloaded into Microsoft Excel® spreadsheets for quality assurance and graphical analyses. Logged and field-collected data are available on request in Excel® format.

Data Quality

Ecology personnel calibrated the multi-probe data loggers according to Watershed Assessment Section protocols (Ecology, 1993). The pH, conductivity, and dissolved oxygen probes of the multi-probe data loggers were post-checked against known standards. Stillaguamish Tribe personnel calibrated field meters according to their standard operating procedures (see Coffler, 2004 Appendix).

During the July survey, the data logger placed at OSRC1 malfunctioned at approximately 31 hours into the logging period. The seal protecting the battery compartment failed, allowing water to leak in and rust the battery connections. All meter measurements collected at OSRC1 during the July survey are considered estimates.

The conductivity probe on the data logger placed at OSRC3 during the July survey failed to record measurements greater than 1000 uS/cm. These measurements are recorded as >1000 uS/cm and marked as estimates.

Salinity probes on the data loggers placed at OSRC3 during the July survey, and OSRC1 during the September survey, also failed. No salinity measurements were recorded on either occasion, but conductivity was recorded at OSRC1. Salinity was estimated based on conductivity measurements using the algorithm programmed into the data logger

where

$salinity = c_1C^4 + c_2C^3 + c_3C^2 + c_4C + c_5$ where C = specific conductance in mS/cm, c_1 = 5.9950 x 10^{-8}, c_2 = -2.3120 x 10^{-5}, c_3 = 3.4346 x 10^{-3}, c_4 = 5.3532 x 10^{-1}, and c_5 = -1.5494 x 10^{-2} (Hydrolab, 1999).

Results were checked against salinity measurements obtained at deployment, mid-cycle, and pick-up. The calculated salinity values are marked as estimates.

Data quality results obtained by side-by-side measurements collected are presented in Table 4. Similar parametric data for individual sites are in Appendix A. Data generated by the data loggers and meters used by Stillaguamish Tribe and Ecology, and Winkler titrations of dissolved oxygen, produced some differences. An objective of ≤10% relative standard deviation (% RSD) between analytical methods of simultaneously collected measurements was uniformly applied to all of the parameters. The data quality objective was met by the overall % RSD statistics for all parameters except salinity.

Data collected by the Stillaguamish Tribe and Ecology appear to be very comparable in quality. Besides salinity, only the dissolved oxygen % RSD statistic between the data logger and the Stillaguamish Tribe data at OSRC1 during the July survey also was outside of the 10% goal (Appendix A). The dissolved oxygen measurements from that data logger may have been biased high. Water leaking into the battery compartment may have contributed to the erroneous readings. The dissolved oxygen measurements collected by the Stillaguamish Tribe compared much better to the Winkler titration checks than the data logger measurements did (Appendix B, Figure B1).

Table 4. Overall data quality results from both Old Stillaguamish River Channel diel surveys expressed as average relative standard deviation (% RSD) of simultaneous measurements taken by combinations of different methods.

Analysis	Method Comparison	Precision (% RSD)
Dissolved Oxygen	Ecology DataSonde Logger to Winkler Titration	3.6
	Stillaguamish Tribe Meter to DataSonde	6.0
	Stillaguamish Tribe Meter to Winkler Titration	2.9
pH	Ecology DataSonde logger to Field Meter Check	3.1
	Stillaguamish Tribe Meter to DataSonde	2.3
Salinity	Stillaguamish Tribe Meter to DataSonde (for salinities > 0.1 ppt)	11.8
Specific Conductivity	Ecology DataSonde Logger to Field Meter Check	3.7
	Stillaguamish Tribe Meter to DataSonde	4.3
	Stillaguamish Tribe Meter to Field Meter Check	7.9
Temperature	Ecology DataSonde Logger to Field Meter Check	0.18
	Stillaguamish Tribe Meter to DataSonde	1.7
	Stillaguamish Tribe Meter to Field Meter Check	1.5

Salinity measurements did not meet the 10% RSD goal for several reasons. When salinity values are less than 0.7 parts per thousand (ppt), a difference of 0.1 ppt results in a RSD greater than 10%. A majority of the salinities were less than 1 ppt. Some additional error was a result of the data loggers reporting to hundredths of a ppt, and Stillaguamish Tribe staff reporting to tenths of a ppt. Most of the 15 salinity measurements over 1 ppt agreed to within 10%; however, five in this range (20%) taken at two sites did not for reasons unknown.

Results

Logging data for each deployment are graphically presented in Appendix B. Logger output is available in Excel® format on request. Measurements were recorded every 30 minutes for 48 hours during the July survey, and every 15 minutes for 48 hours during the September survey.

Vertically averaged salinity measurements were not collected in this study. Salinities at the time of minima or maxima parameter values were used to determine whether a site is subject to potential freshwater or marine water-quality criteria violations. Table 5 is a statistical summary of each site for both surveys (minimum, maximum, average values).

Table 5. A summary of diel data collected from four sites in the Old Stillaguamish River Channel during July and September of 2004. Estimated values are followed with a "J".

Station No.		Temperature (°C)	pH (s.u.)	Conductivity (umhos/cm)	Salinity (ppt)	D.O. (mg/L)
July						
OSRC1	min	21.6J	7.02J	103J	0.0J	7.9J
	max	24.5J	7.73J	228J	0.1J	10.2J
	average	22.6J	7.39J	139J	0.0J	9.4J
OSRC2	min	21.7	6.91	500	0.3	4.2
	max	27.5	8.03	6112	3.4	10.8
	average	25.0	7.33	2798	1.5	7.6
OSRC3	min	22.2	6.95	605	0.3J	4.7
	max	27.4	7.89	–	–	11.0
	average	25.3	7.32	–	–	8.0
September						
OSRC1	min	15.0	6.29	68	0.0J	5.5
	max	17.9	7.10	174	0.1J	9.6
	average	16.4	6.70	95	0.0J	8.0
OSRC2	min	15.1	5.25	279	0.1	6.1
	max	19.2	7.46	3874	2.1	11.3
	average	17.4	5.73	1377	0.7	8.2
OSRC4	min	16.5	7.35	4480	2.5	6.8
	max	18.9	8.01	30387	18.8	10.4
	average	17.8	7.71	15121	8.9	8.6

°C – degrees centigrade
s.u. – standard units
umhos/cm – micromhos per centimeter
ppt – parts per trillion
mg/L – milligrams per liter

Both temperature and dissolved oxygen freshwater criteria violations were recorded at OSRC1 during the July survey (Table 6). As mentioned earlier, the dissolved oxygen values from the data logger are estimates, but the Stillaguamish Tribe data confirmed the presence of depressed dissolved oxygen concentrations (Appendix B, Figure B1). Stations OSRC2 and OSRC3 exhibited both marine and freshwater characteristics during the July survey. OSRC2 had temperature and dissolved oxygen violations under both conditions (Appendix B, Figure B2). OSRC3 had temperature violations under both conditions, but dissolved oxygen violations occurred under freshwater conditions only (Appendix B, Figure B3).

Table 6. Class A (excellent) water quality critieria violation observed in the Old Stillaguamish River Channel on July 28-30, 2004 and September 7-9, 2004.

Survey	Site	Class A Criteria	Criteria Violations		
			Dissolved Oxygen	pH	Temperature
July	OSRC1	Freshwater	X		X
	OSRC2	Marine/Freshwater	X/X		X/X
	OSRC3	Marine	- /X		X/X
September	OSRC1	Freshwater	X	X	
	OSRC2	Marine/Freshwater	- /X	X/X	X/X*
	OSRC4	Marine			X

* The maximum freshwater temperature was less than 1˚C above the 18˚C criterion.

Dissolved oxygen and pH data collected at OSRC1 during the September survey did not meet Class A freshwater criteria (Table 6; Appendix B, Figure B5). The pH values and temperatures at OSRC2 were also out of compliance with freshwater and marine criteria during the September survey (Table 6; Appendix B, Figure B6). Dissolved oxygen violations of freshwater criteria, but not marine criteria, were documented at OSRC2 during the September survey (Table 6).

Temperature data recorded at OSRC4 indicates the Class A (excellent) marine criteria for temperature were not met during the September survey (Table 6; Appendix B, Figure B7).

Conclusions and Recommendations

The Old Stillaguamish River Channel diel surveys were conducted during 2004 to collect new baseline data for analysis in future water quality studies of the channel. Most quality assurance criteria were met. The Stillaguamish Tribe diurnal data and the Department of Ecology data logger data were complementary.

Comparisons of these 2004 diel survey data to 2000 – 2001 Total Maximum Daily Load (TMDL) and Stillaguamish Tribe data were not included in this assessment.

Water quality criteria violations observed during the 2004 surveys suggest that future TMDL evaluations are necessary. Diel surveys are a necessary tool for evaluating water quality in this complicated waterbody.

Further investigations of water quality, particularly temperature, pH, and dissolved oxygen levels during low-streamflow periods, are recommended. A better understanding of the tidal exchange and streamflow dynamics is also needed. More quality control in measuring salinity will be essential to properly interpret pH, temperature, and dissolved oxygen data.

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Appendix A. Stillaguamish Tribe and Department of Ecology Data Comparisons

Comparisons were made between field data collected by the Ecology Hydrolab DataSonde, the Stillaguamish Tribe Natural Resources meters, and the Ecology dissolved oxygen (DO) Winkler titration method.

Table A1. The percent relative standard deviation (RSD) statistics for measurements made by two methods conducted simultaneously.

Station No.	Method Comparison	Temperature	pH	Conductivity	Salinity	DO
July						
OSRC1	DataSonde to Tribe meter	1.6%	1.1%	2.4%	0.0%	13.1%
	DataSonde to Winkler Titration	–	–	–	–	7.8%
	Tribe meter to Winkler Titration	–	–	–	–	2.7%
OSRC2	DataSonde to Tribe meter	1.5%	2.9%	3.5%	11.0%	3.5%
	DataSonde to Winkler Titration	–	–	–	–	4.9%
	Tribe meter to Winkler Titration	–	–	–	–	2.7%
OSRC3	DataSonde to Tribe meter	0.5%	2.6%	2.0%	–	0.8%
	DataSonde to Winkler Titration	–	–	–	–	0.5%
	Tribe meter to Winkler Titration	–	–	–	–	1.2%
September						
OSRC1	DataSonde to Tribe meter	2.1%	–	5.6%	–	2.5%
	DataSonde to Winkler/Ecology meter	0.1%	1.5%	7.8%	–	1.9%
	Tribe meter to Winkler/Ecology meter	–	–	6.8%	–	3.8%
OSRC2	DataSonde to Tribe meter	1.9%	–	5.2%	13.2%	5.7%
	DataSonde to Winkler/Ecology meter	0.2%	6.4%	2.0%	–	5.9%
	Tribe meter to Winkler/Ecology meter	–	–	4.9%	–	2.5%
OSRC4	DataSonde to Tribe meter	1.2%	–	9.8%	11.4%	5.4%
	DataSonde to Winkler/Ecology meter	0.2%	1.3%	1.3%	–	1.8%
	Tribe meter to Winkler/Ecology meter	–	–	11.9%	–	4.5%

Appendix B. DataSonde Output and Stillaguamish Tribe Data

July 2004 Survey

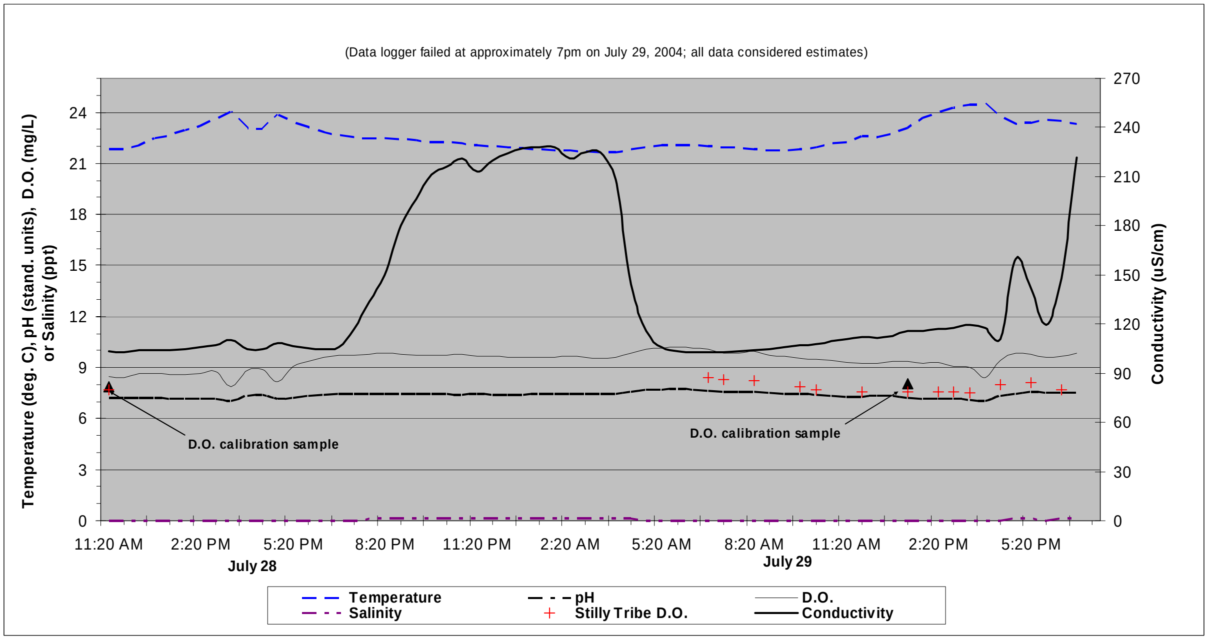

Figure B1. Diel data collected at OSRC1 (Norman Road bridge) on July 28 and 29, 2004.

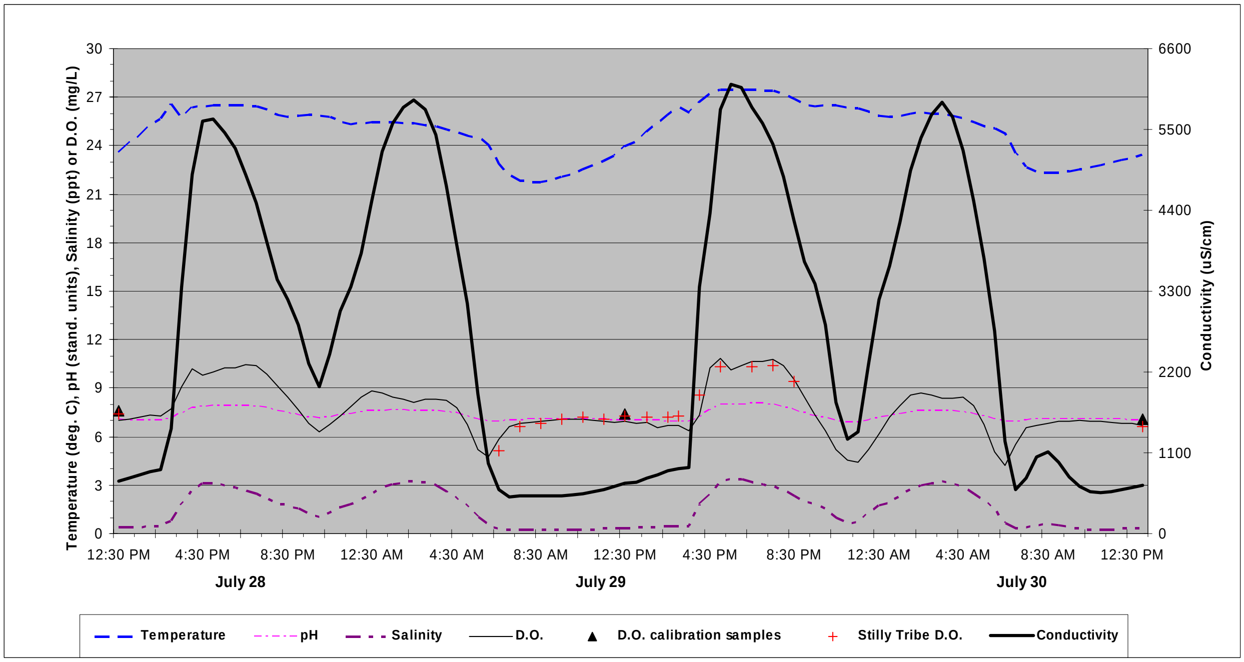

Figure B2. Diel data collected at OSRC2 (off Florence Road) on July 28 to 30, 2004.

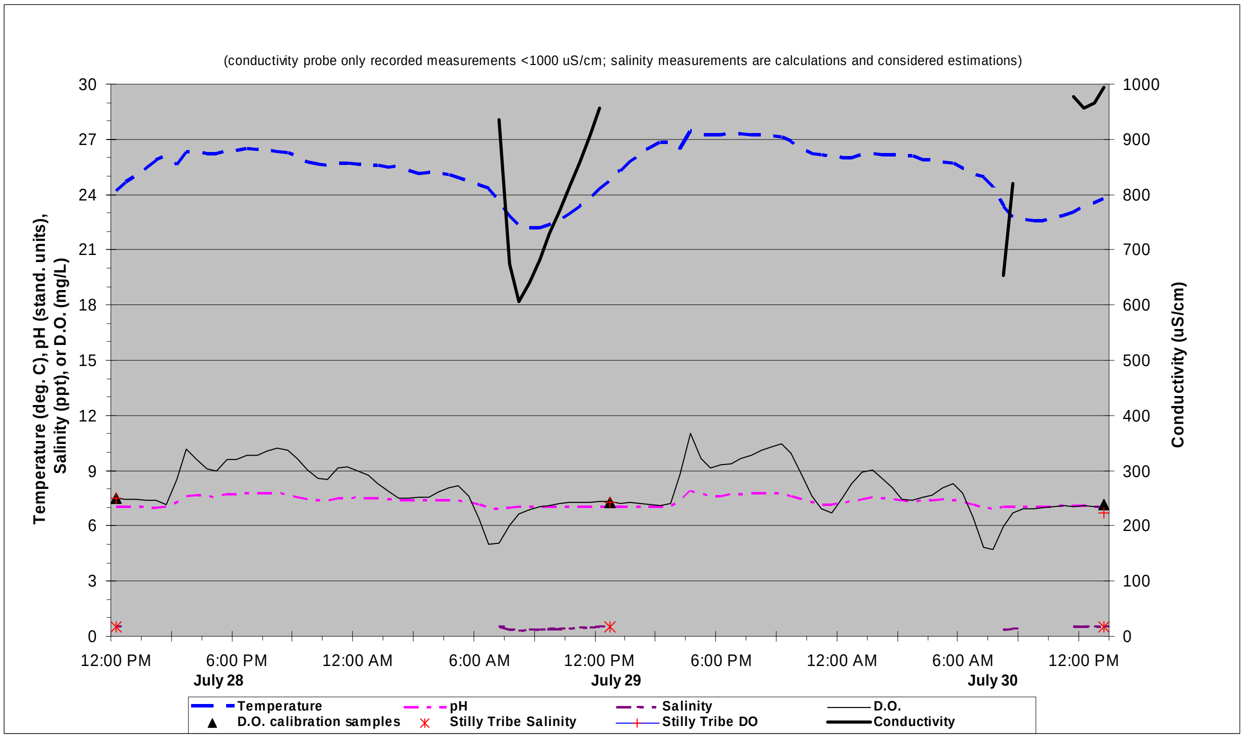

Figure B3. Diel data collected at OSRC3 (Marine Drive) on July 28 to 30, 2004.

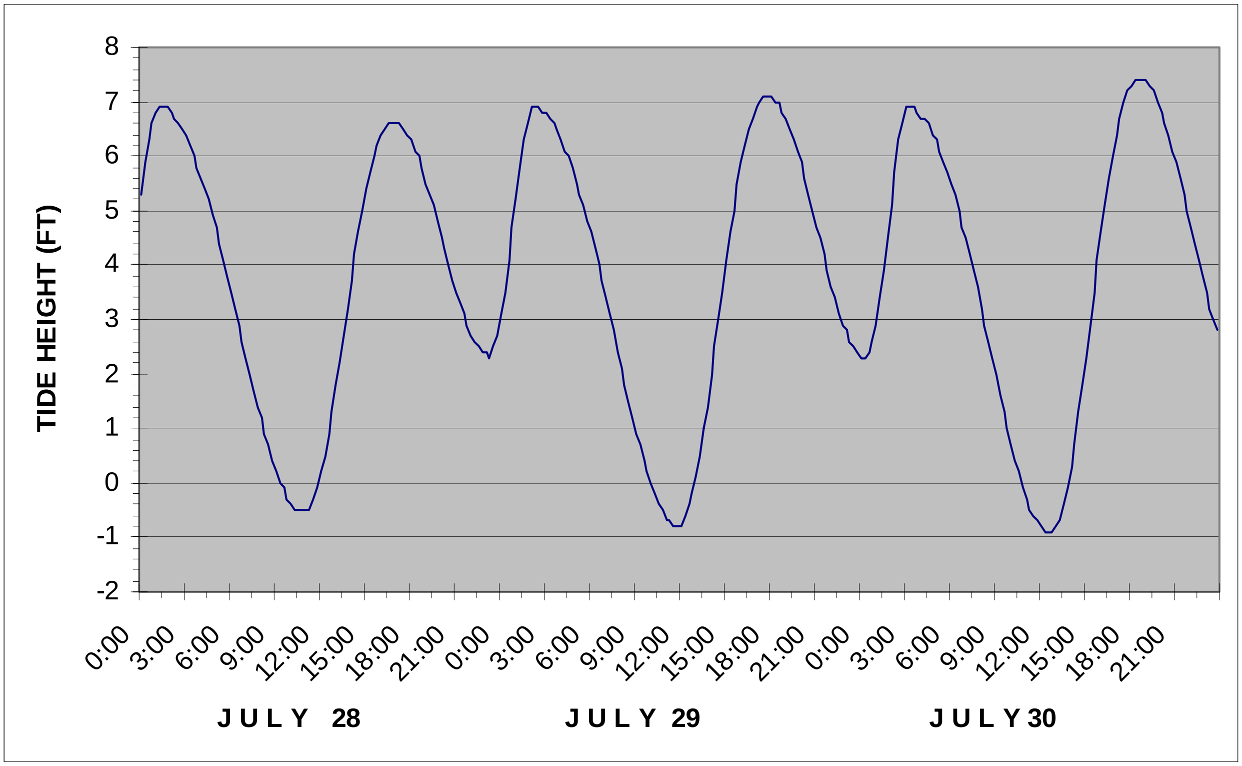

Figure B4. Tide heights for the Stillaguamish River at Stanwood on July 28 to 30, 2004 from NOAA predictions, Station identification number 1131.

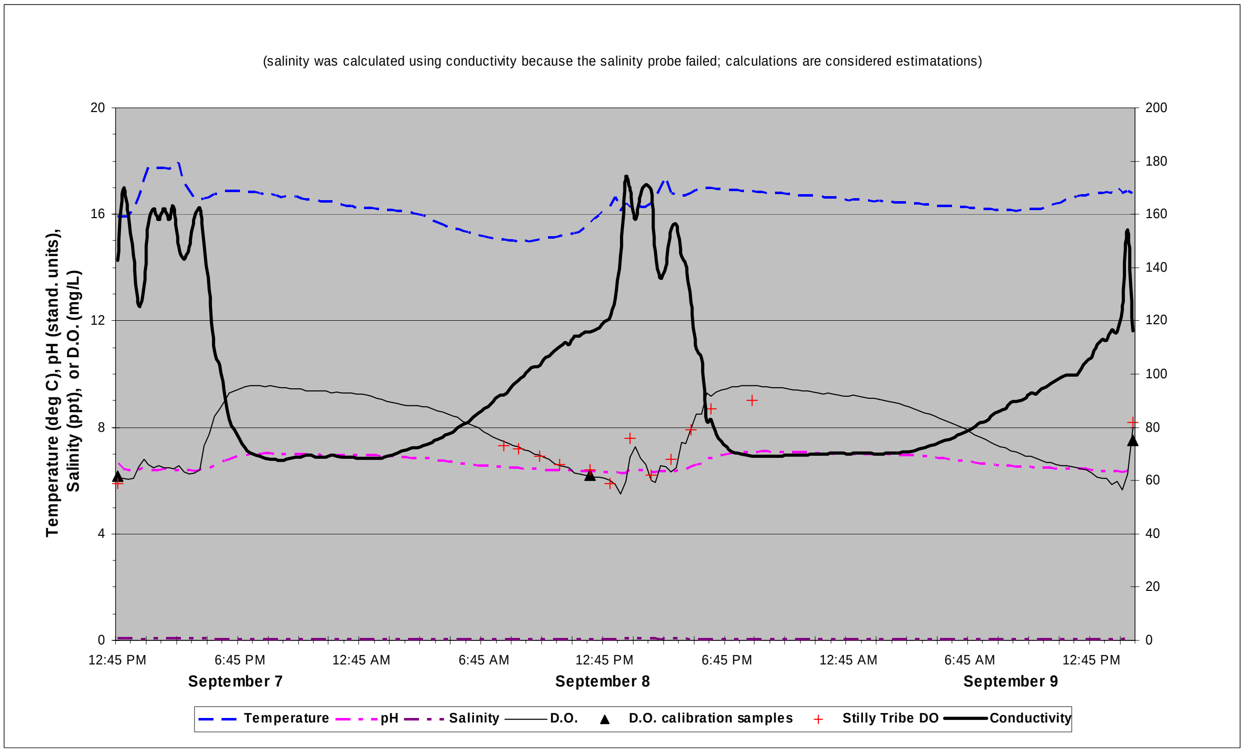

Figure B5. Diel data collected at OSRC1 (Norman Road bridge) on September 7 to 9, 2004.

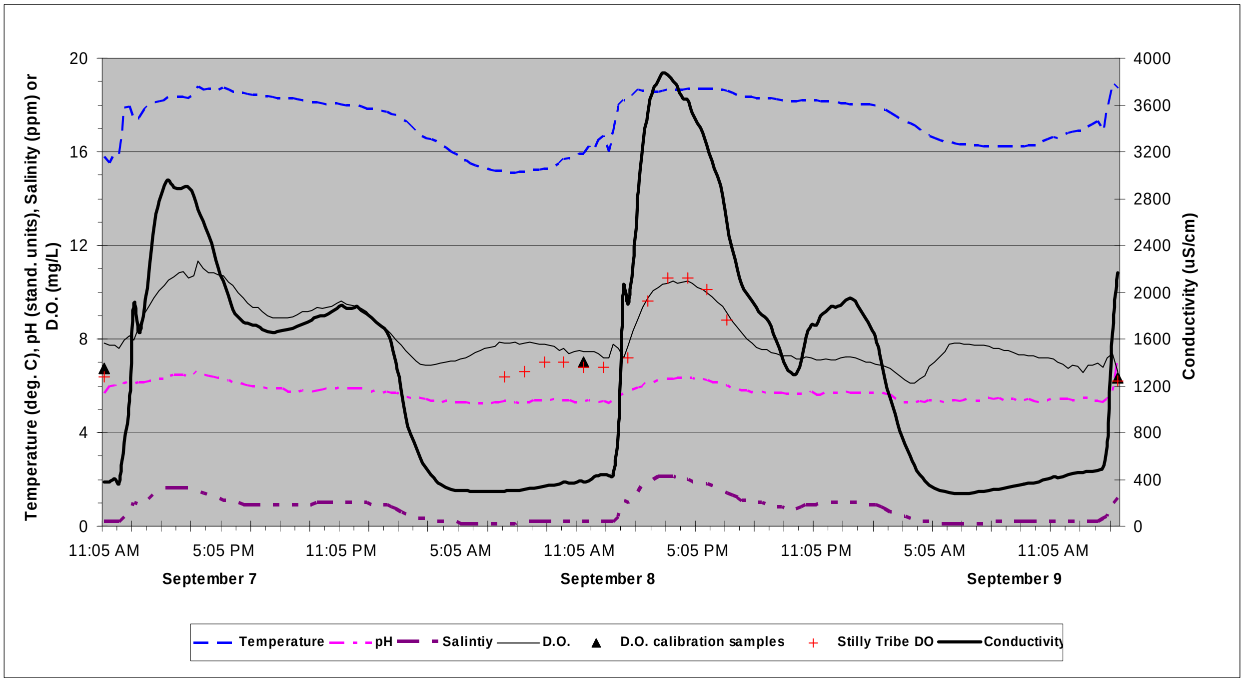

Figure B6. Diel data collected at OSRC2 (off Florence Road) on September 7 to 9, 2004.

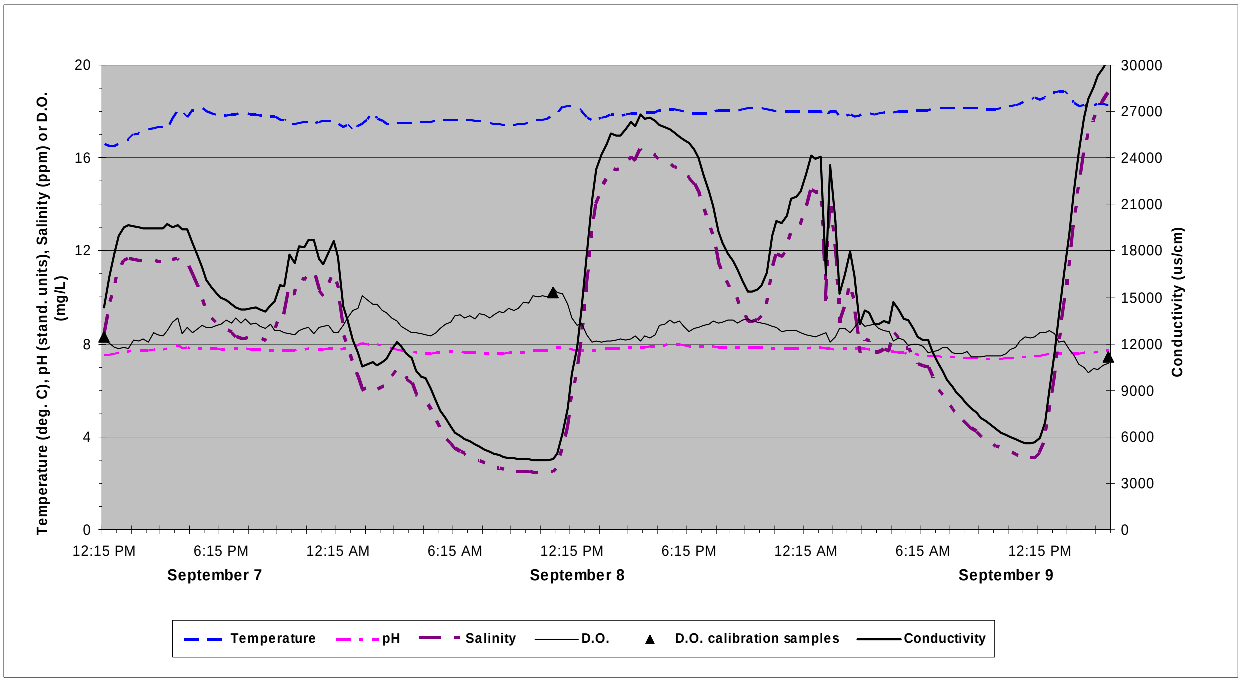

Figure B7. Diel data collected at OSRC4 (off Leque Road) on September 7 to 9, 2004.

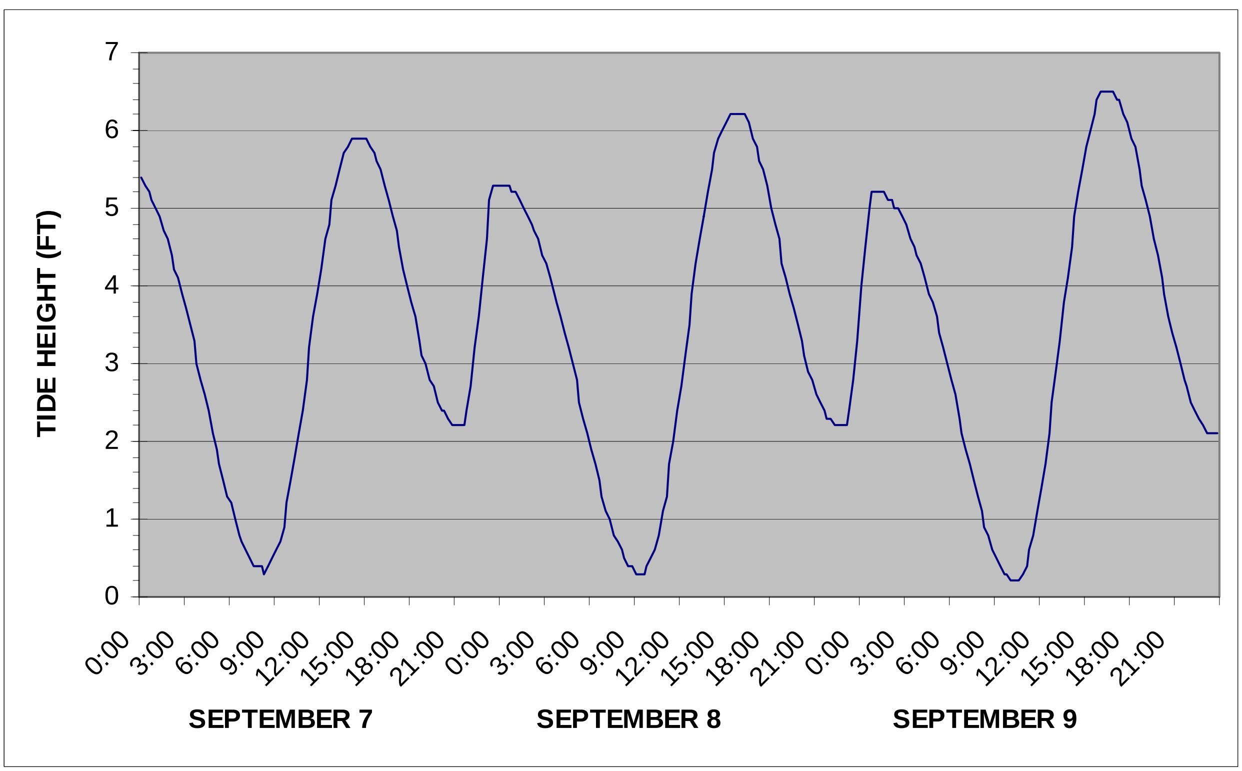

Figure B8. Tide heights for the Stillaguamish River at Stanwood on September 28 to 30, 2004 from NOAA predictions, Station identification number 1131.