

# URBAN STREAMS MONITORING PROGRAM REPORT 2014

City of Bellingham  
Department of Public Works Laboratory  
April 2015





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## Executive Summary for 2014

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The status of Bellingham's urban streams for the period ending in 2014 is mixed. Only Hanna Creek was able to meet all Department of Ecology standards ensuring the highest water quality. In line with historical trends, Chuckanut Creek and Padden Creek at 38th St. displayed good overall water quality, while most of the Padden Creek drainage, two of the Whatcom Tributaries (Lincoln and Fever Creeks) and the mouth of Squalicum Creek displayed the poorest overall water quality.

**Fecal Coliform:** As in years past, fecal coliform levels were most often the limiting factor in determining overall classification of the streams. Fecal coliform levels were also the *only* measured parameter to show any significant change over the past 10 years. Decreasing geometric means (geomean) trends were recorded at 10 of the 19 currently monitored sites, while increasing geomeans were recorded at only two. Because of substandard historical values, it could be said that the fecal coliform parameter has had the best chance for improvement of the measured analytes. It is a testament to the City's stormwater management, stream cleanup, and restoration efforts that so much progress has been made.

That said, there is still room for improvement on the fecal coliform front. The three greatest decreases over the past 10 years were seen on Connelly Creek (-13.3 cfu/100 ml/yr), Cemetery Creek (-11.4 cfu/100 ml/yr), and Squalicum Creek at East Bakerview (-6.9 cfu/100 ml/yr). Yet, in the 25 years of urban stream sampling, none of these sites have ever qualified for the Aquatic Life Use (ALU)/Class A standard (100 CFU/100 ml, w/ no more than 10% of all samples exceeding 200 CFU/100 ml). Elsewhere, Fever and Lincoln Creeks (+ 4.4 and + 9.0 cfu/100 ml/yr, respectively), were the only two sites to show significant increases to fecal coliform geomeans over the past 10 years. This suggests that special attention

may want to be paid to efforts in these sub-watersheds.

**Dissolved Oxygen:** Historically, only Chuckanut Creek has been able to meet the 9.5 mg/l ALU/Class AA designation for dissolved oxygen with any consistency, being assigned the ALU/Class AA designation six out of the last 10 years. In 2014 however, Hanna Creek, Padden Creek at 14th, and the Mouth of Squalicum Creek all joined Chuckanut Creek in this rating. Regardless, analysis of data over the past 10 years shows no statistically significant change to dissolved oxygen levels at any of the urban streams monitoring locations.

**Temperature:** Ambient temperatures in 2014 were warmer than usual. According to the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center, summer temperatures in Washington were "much above normal". Even so, 11 of the 19 samples sites still met the 16°C ALU/Class AA designation. With the exception of Whatcom Creek sites, all of the urban stream monitoring sites have obtained the ALU/Class AA criteria four or more times over the past 10 years (based on conventional sampling). No statistically significant trends were found in temperature data for 2005-2014.

**pH, Conductivity and Turbidity:** The pH of Bellingham's urban streams has been consistent, with all sites staying within the ALU/Class AA/B/C range over the past 10-years. Likewise, conductivity has been stable, showing no appreciable differences over the last decade. Turbidity values were varied, with the 2014 average turbidities below the 5 and 10-year averages on Chuckanut Creek and all of Whatcom Creek and its tributaries, mixed results in the Padden Creek Drainage and all above the 5 and 10-year averages in the Squalicum Drainage. No statistically significant trends in turbidity records were found for the past 10 years.

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## Introduction

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The health of urban waterways has become an increasingly prominent and politically charged topic on a national scale. Legislation to protect our aquatic resources has become more stringent and the trickle down effects can be seen in tighter controls on municipal, industrial and construction stormwater permits, an increasing number of clean-up/restoration projects, and an increase in mandated water quality monitoring efforts. Like many other local jurisdictions, improving water quality is now among the top priorities of the City of Bellingham, as witnessed in its Legacies and Strategic Commitments to its citizens.

At 25 years and counting, the City of Bellingham's Urban Stream Monitoring Program (USMP) is one of the longest standing status and trends programs in the region. Maintaining such a robust data set has allowed the City to not only quantify improvements to water quality due to restoration, stormwater treatment and stewardship efforts, but also to win the support of the Washington State Department of Ecology in conducting innovative Total Maximum Daily Load pilot projects (see Sections 1.1 and 2.0).

The City of Bellingham (City) recognizes that urban activities impact streams and is working to understand and minimize these impacts through a variety of water quality improvement programs. These programs include stream clean-up, restoration, hydrological gauging, stormwater treatment, illicit discharge elimination, water quality monitoring, public education and ordinances that protect critical areas.

This report describes many of the current efforts of the City to improve water quality in its jurisdiction, and updates the on-going water quality monitoring results with data from 2014. Section 1.0 details the listed status of urban streams within the City's boundaries. Section 2.0 describes the work undertaken in 2014 to clean up and restore streams. Section 3.0 details the City's hydrological monitoring. The activities of the City of Bellingham Storm and Surface Water Utility are outlined in Section 4.0. Section 5.0 describes the current Washington State water quality standards as well as the methodology by which our laboratory collects and analyzes water quality data. Sections 6.0 - 9.0 contain updated long term water quality data. Finally, section 10.0 provides summary of the state of Bellingham's urban streams in 2014.



## 1.0 Status and Trends

One of the benefits of maintaining such a long standing water quality data set is that it facilitates tracking the condition of streams, which in turn allows impaired water bodies to be identified, problem areas to be targeted for remediation and the results of restoration efforts to be quantified.

### 1.1 Bellingham's 303(d) Listings

Section 303(d) of the Federal Clean Water Act requires states to develop lists of impaired water bodies. Table 1.1-1. catalogs current 303(d) category 5 (impaired) and 4a (active TMDL) listings for urban streams within Bellingham's boundaries. Maps of current listed stream reaches can be found in Appendix D. As Mill Wheel and Silver Beach Creeks are tributaries to Lake Whatcom, they are monitored as part of Lake Whatcom Total Maximum Daily Load (TMDL) efforts and are not included as part of the Urban Streams Monitoring Program. A TMDL is a structured water quality improvement plan that establishes limits on pollutants that can be discharged to a water body in order for state water quality standards to be met. Information regarding Lake Whatcom can be found at: <http://www.cob.org/services/environment/lake-whatcom/index.aspx>.

The determination of which water bodies included on the 303(d) list will be assigned TMDL plans is made by the Washington State Department of Ecology (Ecology). Of Bellingham's urban streams, Padden, Squalicum, Whatcom Creek and its tributaries are all assigned, or are in the process of being assigned a TMDL for fecal coliform and temperature. Foreseeing this possibility years ago, the City has been actively putting pollution control projects in place on these streams. Such projects include innovative water quality studies, habi-

tat studies, clean-up work and restoration efforts.

The City has been conducting enhanced water quality monitoring of select 303d listed stream reaches in an effort to better understand the water quality dynamics of impaired local waters. For more information on enhanced monitoring, please see section 5.2.2 of this document.

Table 1.1-1. Bellingham's Urban Stream 303(d) Impaired waters (categories 4a & 5) listings by parameter.

Creek	Temp	DO	Fecal	Zinc
Chuckanut		5	5	
Padden	4A	5	5	
Connelly	4A	5	5	
Whatcom	4A	5	5	
Hanna	4A		5	
Cemetery	4A	5	5	
Lincoln	4A	5	5	
Fever	4A	5	5	5
Squalicum	4A	5	5	
Baker		5	5	
Mill Wheel			5	
Silver Beach			5	

### 1.2 Trend Studies

From the onset of the USMP, the data collected by the City of Bellingham has been presented mostly as it relates to state and federal water quality standards. While that information is critical to defining the current status of our waterways, the value of this dataset for showing trends and forecasting future conditions has been somewhat underutilized. In recent years, the evaluation of water quality trends has become a much more prominent tool in deciding where and how to focus clean-up and restoration efforts. As such, status and trends monitoring is now a critical part of State issued NPDES municipal stormwater permit requirements, with sampling getting underway in 2014.

Figure below is an example of how long term status and trends data can be utilized. The figure exhibits the ten year trend in fecal coliform geometric means (geomeans) as they relate to dissolved oxygen changes at the Dupont St. monitoring site on Whatcom Creek (the 30-value moving geomean is the standard used by the National Shellfish Sanitation Program, 2011). While an interesting offset is apparent in the trend of geomeans fluctuating with dissolved oxygen levels, linear modeling shows there is very little probability that the decreasing trend in fecal coliform geomean is dependent on dissolved oxygen change ( $r^2 = 0.01$ ). Further, the slope of the dissolved oxygen trendline over the period is not significantly different than zero ( $p = 0.74$ ,  $\alpha = 0.05$ ), suggesting that factors other than dissolved oxygen regime change (e.g. clean-

up and source control) are likely responsible for decreases. As shown in the 2013 Urban Streams Monitoring Report, this conclusion also holds true for other measured parameters, such as temperature.

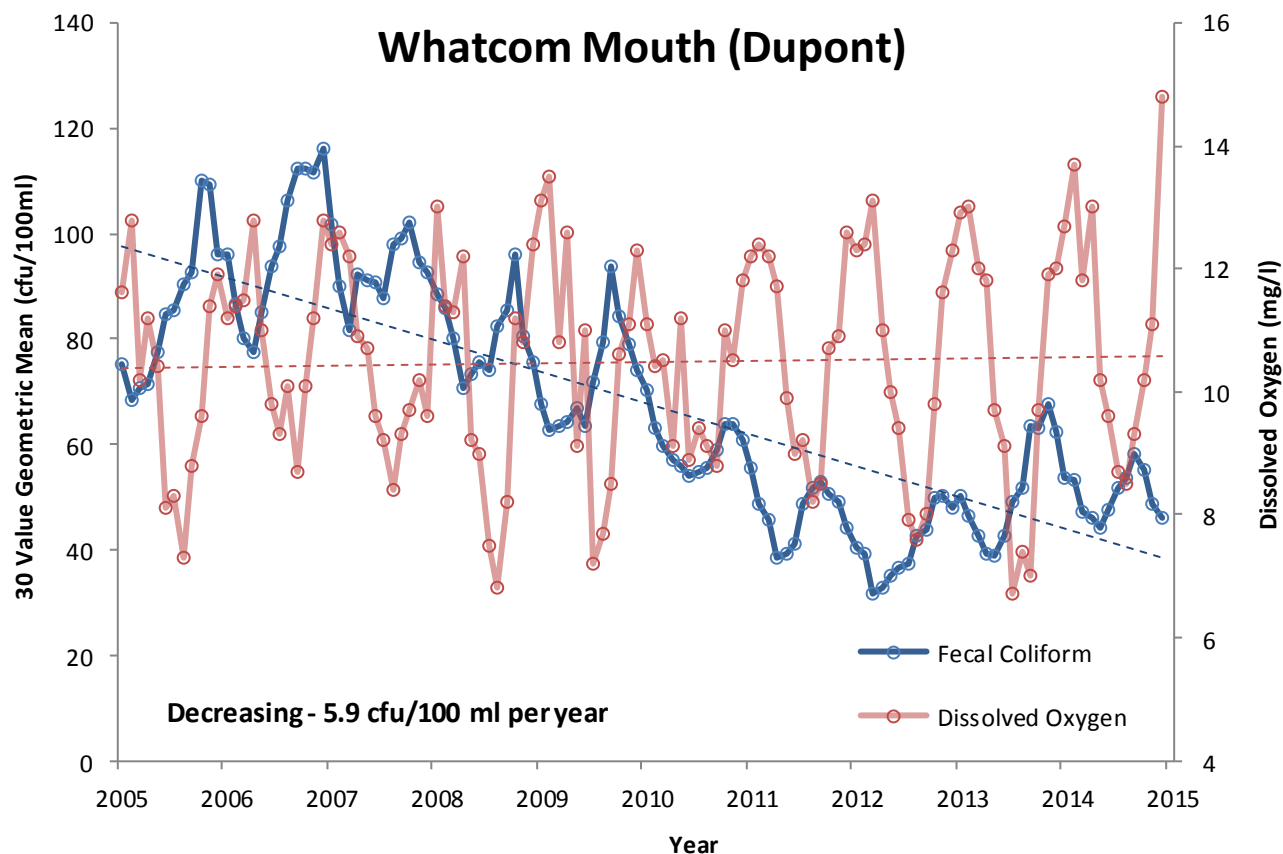


Figure 1.2-1. Ten-year trends in 30-value moving fecal coliform geometric means as they relate to dissolved oxygen (DO) at Whatcom Creek's Dupont site for the period 2005-2014. While fecal coliform values show a decreasing trend of  $-5.9$  cfu/100 ml per year, the slope of the dissolved oxygen DO shows there is very little probability that the decreasing fecal coliform trend is dependent on DO change ( $r^2 = 0.01$ ). The 30-value moving geomean is the standard used by the National Shellfish Sanitation Program (2011).



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## 2.0 Stream Restoration

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The City has spent considerable effort in recent years on stream restoration projects designed to mitigate habitat degradation that has occurred as a consequence of urbanization. In 2014, the City continued development of a Habitat Restoration Master Plan based on aquatic and terrestrial habitat function. The master plan provides guidance on where best to apply preservation, restoration and recovery efforts across the City. There was particular focus put on two large scale urban stream restoration projects in 2014, mostly in the form of planning and community involvement. Work on both projects will be carried out in 2015.

The first is a major re-route of Squalicum Creek designed to address problems with thermal loading in Sunset Pond and Bug Lake. These two water bodies are man-made lakes created during the construction of I-5 for fill material. Because the ponds are both shallow and wide, they absorb large amounts of solar heat, causing peaks in water temperature that are not healthy for salmon.

The Squalicum Creek Re-route project involves re-routing large sections of Squalicum Creek around the two man-made ponds, through a new channel, reactivating remnant channels, and reconnecting the stream with its floodplain. The project also eliminates an existing fish passage blockage under I-5, thus opening up over 22 miles of salmon habitat upstream of I-5. The projects will dramatically decrease water temperatures, and improve dissolved oxygen, biotic integrity, and beneficial habitat in Squalicum Creek. More information can be found on the City's website here: <http://www.cob.org/services/environment/restoration/squalicum-creek-reroute.aspx>

The second major project is the daylighting of a significant reach of Padden Creek between 17th St. and 22nd St. This section of the creek currently flows through a 100+ year old brick tunnel deemed a major blockage to fish passage according to Washington Department of Fish and Wildlife ratings. In 2014, the Washington Department of Transportation began the process by opening a channel and constructing a bridge for the creek to flow under on SR11/ Fairhaven Parkway. In 2015, the City will continue the daylighting process for the rest of the reach, adding habitat, protecting residences and improving the Padden Creek flood plain as they do. More information on the Padden Daylighting Project can be found here at: <http://www.cob.org/government/departments/pw/projects/padden-creek-daylighting.aspx>

Figure 2.0-1 shows the locations of restoration projects on Bellingham's urban streams. Projects have included restoring and replanting riparian buffers, removing artificial channel modifications, stabilizing banks, and improving fish habitat through a variety of specific habitat objectives. Details of past projects can be found in Appendix A. More information on all the City's restoration efforts can be found at: <http://www.cob.org/services/environment/restoration/index.aspx>





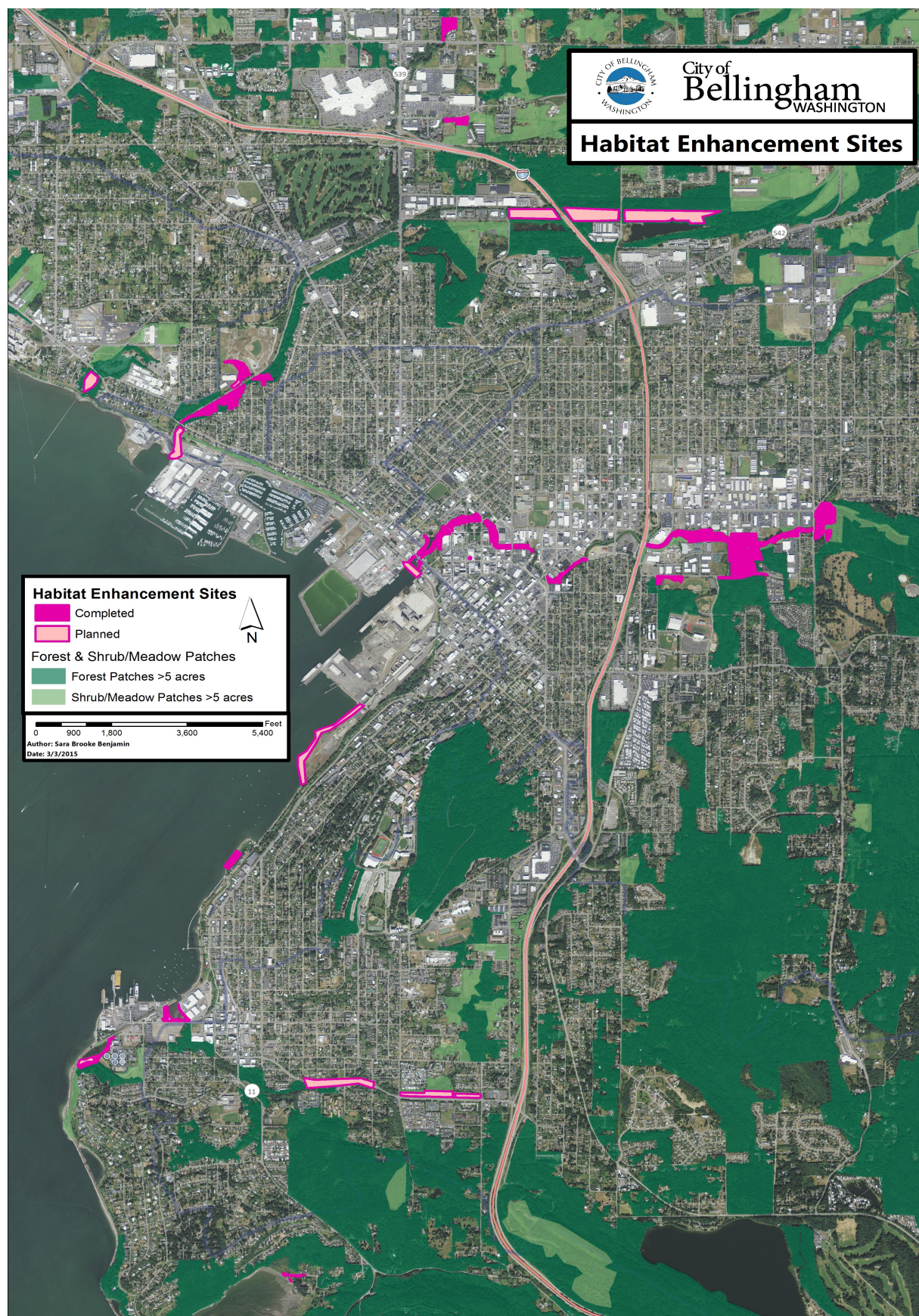


Figure 2.0-1. Locations of completed and planned City of Bellingham habitat restoration/enhancement sites (2015).



### 3.0 Stream Hydrology

Stream hydrology data provide information for developing restoration strategies, determining the adequacy of stormwater infrastructure to control for flooding and assessing land use impacts to stream flows. The City of Bellingham Storm and Surface Water Utility is currently supporting hydrological assessment of specific reaches on Whatcom, Squalicum, Padden, and Chuckanut Creeks.

Decisions based on the analysis of stream discharge affect the operation of in-stream flood control dams (present on Padden, Connelly, Squalicum, and Whatcom Creeks), the type and size of new stormwater structures to be installed, where different types of stream restoration can have the greatest success, assessing available fish habitat, determining the potential for erosion, scouring and water quality impacts to receiving waters. It can also be used by City planners when considering development options within a watershed. Finally, the hydrology of a given stream can often be tied to changes seen in water quality data.

Hydrologic data is analyzed by water year. Water year (WY) is the common time convention used by hydrologists for compiling and reporting streamflow data. The water year for the western United States is from October 1<sup>st</sup> to September 30<sup>th</sup>. The water year splits data during a relatively dry period

during which streamflow does not change significantly from day to day (end of summer, early autumn), rather than in the midst of the wet season during which flows can change rapidly from day to day.

Table 3.0-1 compares mean annual WY discharge (runoff) for the period of record to the average annual WY precipitation recorded near Bellingham's discharge monitoring stations. These figures are calculated by normalizing the total annual mean discharge rates by the area of the respective watershed. As expected, Whatcom Creek had the greatest mean discharge per square mile, even after excluding runoff in the Lake Whatcom Basin. Surprisingly however, Chuckanut Creek had a higher mean discharge than both Padden and Squalicum Creeks. As the Chuckanut Creek Drainage is largely comprised of forested areas in contrast to the more urban (and impervious) landscape surrounding the other creeks, these results were somewhat unexpected. However, when City of Bellingham rainfall data were analyzed it was found that the Chuckanut Basin receives significantly more rain annually than either the Padden and Squalicum basins. This, accompanied by stream bathymetric properties (steep banks) and flood control dam modulation on Padden and Squalicum goes a long way towards explaining this result.

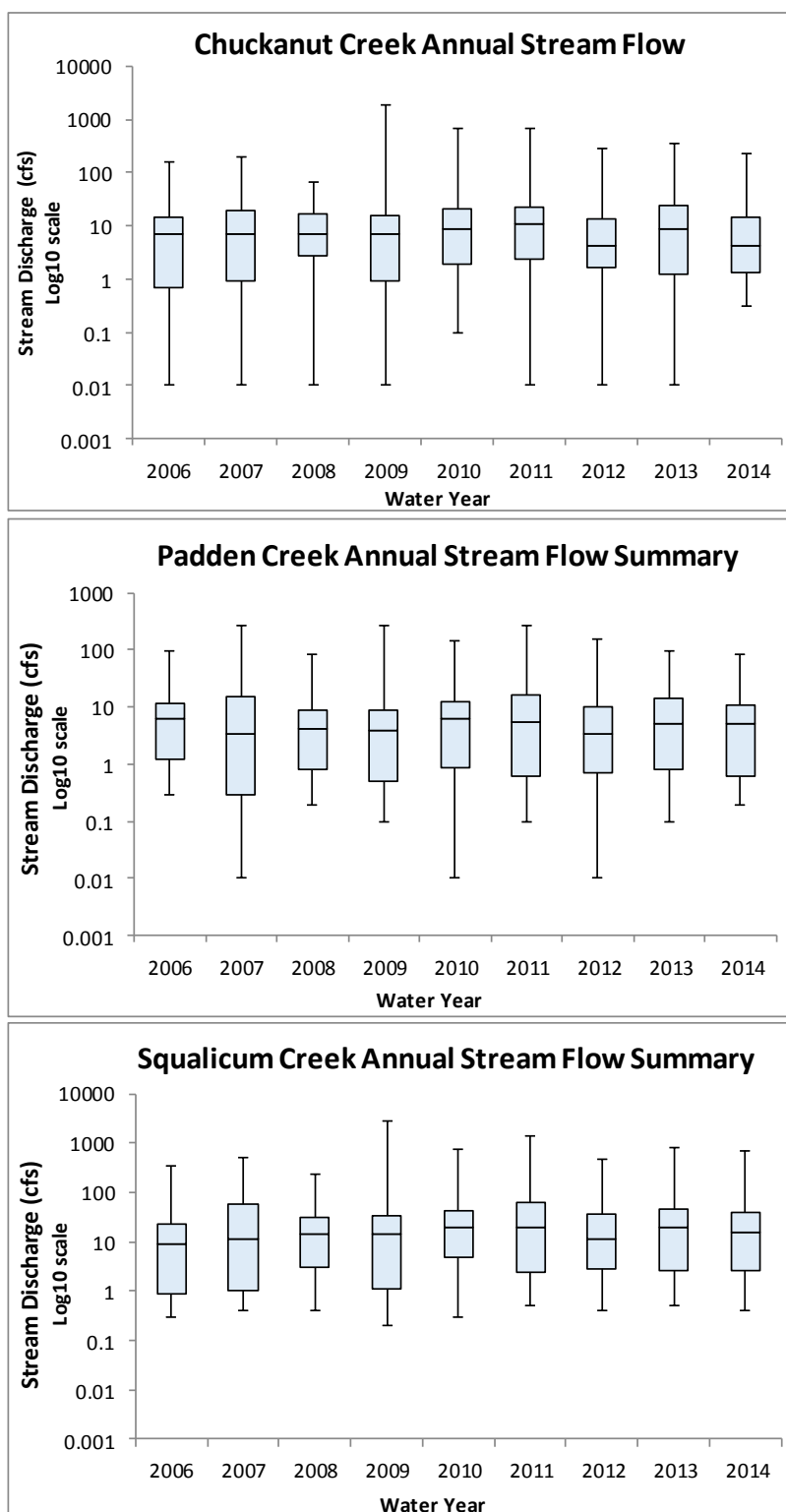
Table 3.0-1. Mean annual WY discharge and average annual precipitation at sites representative of Bellingham's four major stream basins, 2005-2014.

Stream Basin	Chuckanut	Padden	Squalicum	Whatcom
Mean Annual Discharge (cfs/sq. mile)	1.9	1.4	1.3	15.9
10-year Average Annual Rainfall (in.)	61	42	35	41

Combined with historical weather, restoration and Urban Streams Program data, hydrology information can be used to qualify changes to stream water quality, stream morphology, and to better predict and manage for conditions that lead to flooding and scouring. Figures 3.0-1 through 3.0-5 use box and whisker plots to depict the high, low, median, 25th and 75th percentile flow by year at each of Bellingham's gauging stations. This allows for inter-annual variance to be examined, and exceptional events to be highlighted.

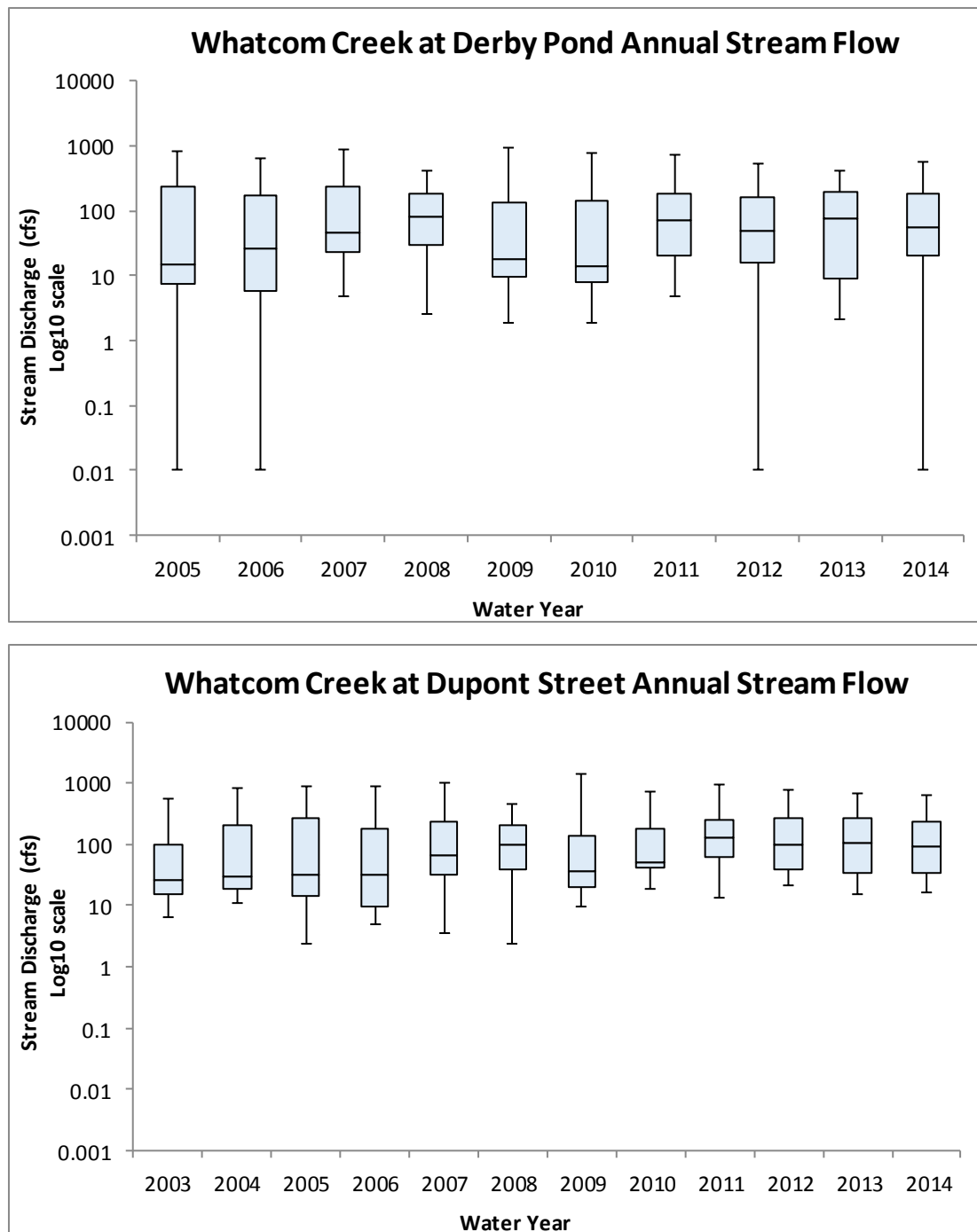
Hydrology data can then be further broken down to examine site specific seasonal patterns and variability. Figures 3.0-6 through 3.0-10 show us the mean, maximum, minimum and  $\pm 1$  standard deviation flow on a monthly basis for the period of record. This can be used for project design purposes to estimate the likely range of values for monthly flows.

Finally, Bellingham's hydrology data can be used to conduct flood frequency analysis (FFA), which uses distribution modeling to predict flood event magnitude and frequency. Table 3.0-2 shows FFA for Chuckanut, Padden and Squalicum Creeks. Flood frequency analysis is not available for Whatcom Creek because of consistent use of control structures to regulate discharge during high flow events. See pg. 74 for more information regarding flow and control structures on Whatcom Creek.

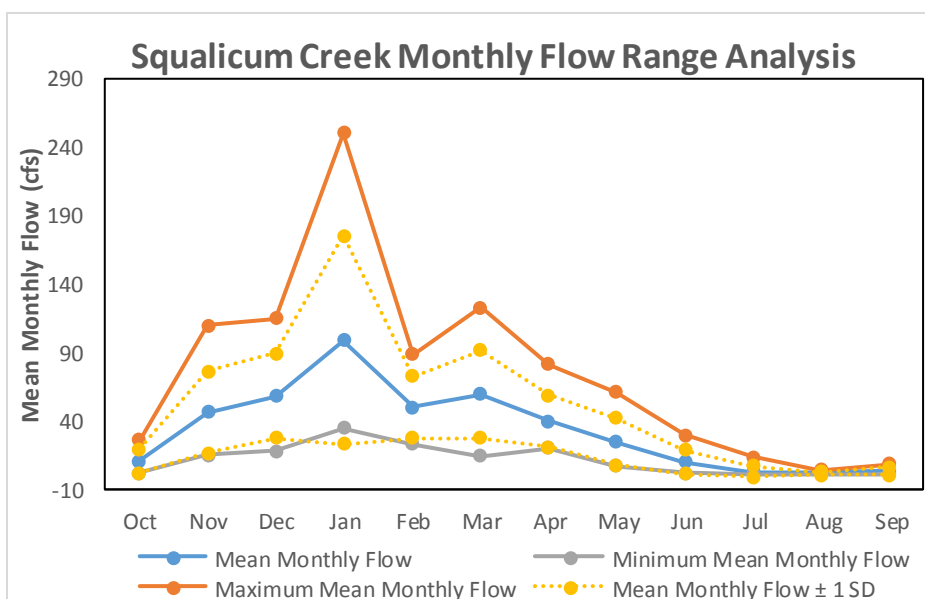
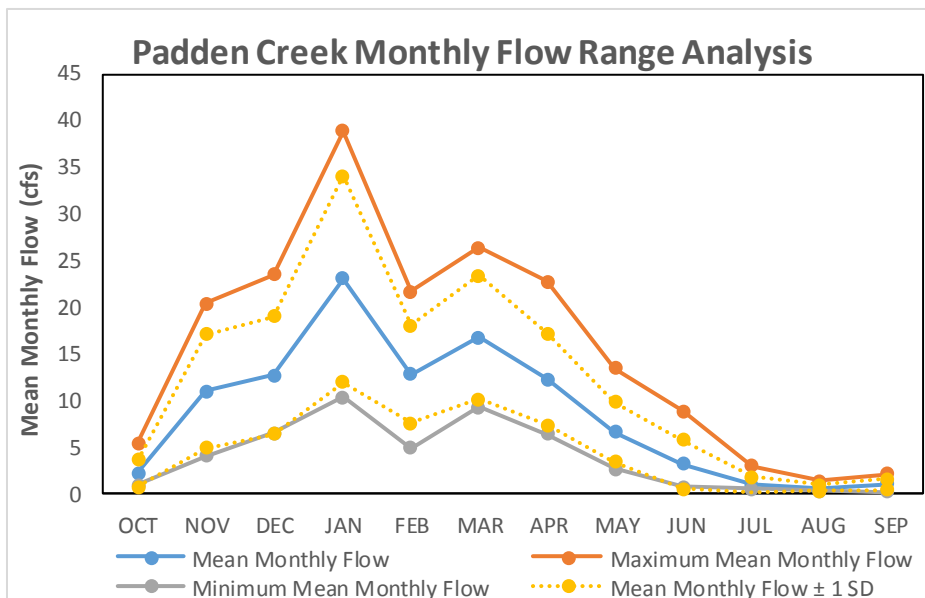
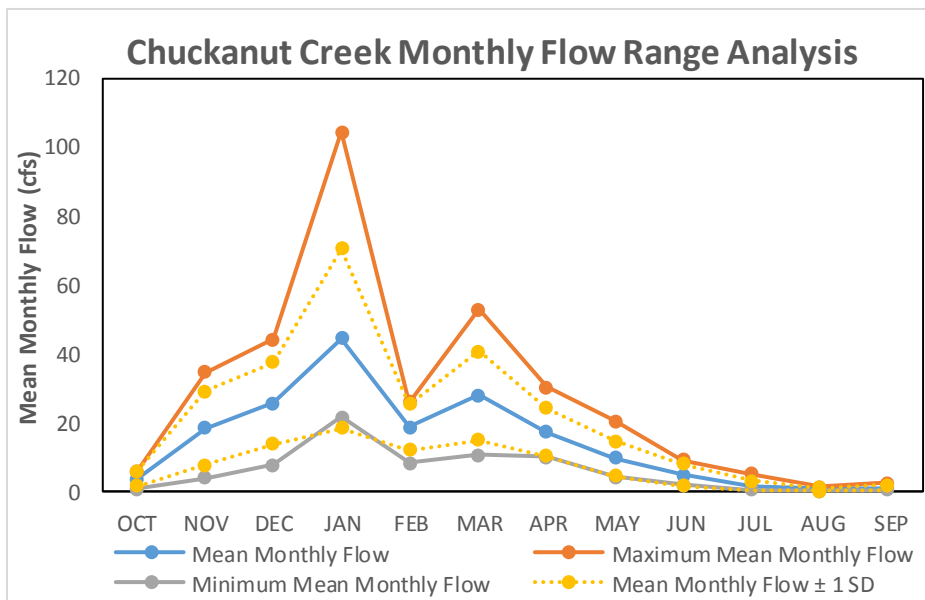


Figures 3.0-1 through 3.0-3. Box and Whiskers plots of water year stream flows for City of Bellingham gauging stations since program inception. Medians are depicted by the horizontal lines through the boxes, while the 25th and 75th percentiles are represented by the bottom and top of the boxes, respectively. Whiskers indicate minimums and maximums. Minimums shown at 0.01 cfs should be considered  $< 0.1$  cfs and are for all intent and purposes equivalent to 0 cfs. Data presented on a logarithmic scale.

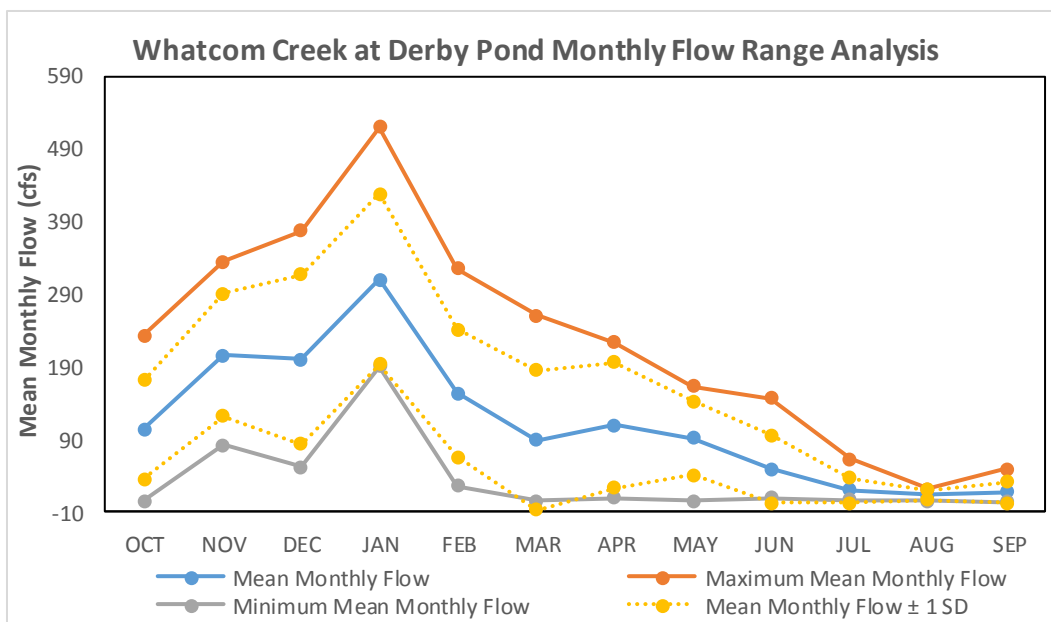




Figures 3.0-4&5. Box and Whiskers plots of water year stream flows for City of Bellingham gauging stations on Whatcom Creek. Medians are depicted by the horizontal lines through the boxes, while the 25th and 75th percentiles are represented by the bottom and top of the boxes, respectively. Whiskers indicate minimums and maximums. Minimums shown at 0.01 cfs should be considered < 0.1 cfs and are for all intent and purposes equivalent to 0 cfs. Data presented on a logarithmic scale.



Figures 3.0-6 through 3.0-8. Mean, maximum, minimum and  $\pm 1$  standard deviation of flow presented on a monthly basis for Chuckanut, Padden and Squalicum Creeks. This data can be used to predict expected flow range. When comparing between stations, please note the difference in scaling.



Figures 3.0-9&10. The mean, maximum, minimum and  $\pm 1$  standard deviation of flow presented on a monthly basis for Whatcom Creek hydrology stations at Derby Pond and Dupont St. When comparing between stations, please note the difference in scaling.

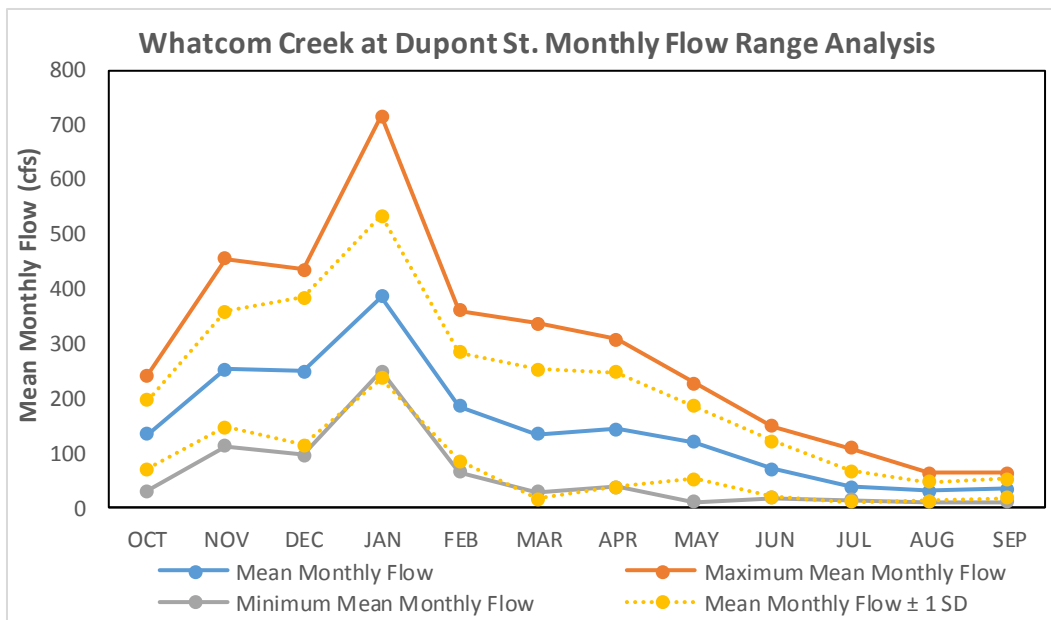


Table 3.0-2. Flood Frequency analysis (FFA) for Chuckanut, Padden and Squalicum Creeks. Table indicates how often (return period) the predicted event magnitude can be expected. <sup>‡</sup>Event magnitude rounded to 2 significant figures.

Selected Return Periods (years)	Predicted Event Magnitude (cfs) <sup>‡</sup>		
	Chuckanut	Padden	Squalicum
2	290	140	620
5	710	230	1,300
10	1,200	300	1,900
20	1,900	370	2,900

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## 4.0 Stormwater Treatment

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Over the years, Bellingham has built and expanded buildings, roadways, sidewalks, landscaping and other portions of an urban landscape. Bellingham also receives on average 36 inches of rainfall per year. Naturally, runoff from the urban landscape has grown with the City.

Through the years, understanding of impacts from urban runoff has also grown. Stormwater has come to be considered the single greatest source of pollutants entering U.S. waterways. A study by the Department of Ecology (2008) found that nearly 75% of pollution entering the Puget Sound is from stormwater outfalls. In Bellingham, a large portion of the City's stormwater system drains to urban streams on its way to Bellingham Bay.

In 1990 the City of Bellingham began a Storm and Surface Water Utility (SSWU) to address the issues of stormwater pollution. Under the auspices of the federal National Pollutant Discharge Elimination System (NPDES) for stormwater, the SSWU is charged with working towards improvement

of water quality in Bellingham's streams, lakes and nearshore waters.

With a population of under 100,000, Bellingham is considered a Phase II municipality for the purposes of NPDES permitting. This permit defines the requirements of the City for stormwater clean-up and management. The SSWU program provides services including: maintenance of our existing stormwater systems, review and enforcement of stormwater pollution codes, administration of stormwater mitigation, educational outreach, and water quality monitoring towards meeting compliance. The City's Storm and Surface Water Utility is constantly evaluating, retrofitting and improving Bellingham's stormwater system towards the goal of protecting the health of local water bodies and by extension, its citizens.

The City of Bellingham stormwater system is comprised of both natural and manufactured conveyance and detention systems. Natural conveyance systems include creeks and lakes that receive and channel runoff from rain and other sources. Manufactured conveyance systems consist of a network of open ditches, catchbasins, closed pipes, manholes, and water quality facilities such as ponds, vaults, storm filters, and bioswales. Bellingham also continues to be a leader among Phase II municipalities in integrating low impact development (LID) into infrastructure (Figure 4.0-1). All of these systems work in concert to control the quantity and improve the quality of runoff before it is discharged into major streams, lakes and Bellingham Bay.

Since the advent of the SSWU many stormwater mitigation facilities have been constructed. They fall in two categories, public facilities constructed to mitigate public or regional issues and private facilities owned and maintained by the private sector.



Figure 4.0-1. The green roof installed on the Bellingham Children's Museum. An example of the City of Bellingham's commitment to LID practices.



**Public Facilities:** There is a total of 394 facilities owned and maintained by the Storm and Surface Water Utility. These facilities include 5 regional detention ponds; 128 detention/water quality ponds, vaults or pipes; 84 water quality swales; 104 storm filters; 73 rain gardens and miles of ditches being maintained to provide a water quality function.

**Private Facilities:** There are 788 facilities on private properties providing treatment and/or storage of stormwater, serving an area totaling approximately 2,932 acres. Private stormwater systems include approximately 164 detention facilities, 605 water quality/combined facilities and 19 miscellaneous facilities (oil water separators etc).

As part of a continued commitment to improve the health of Lake Whatcom and meet the goals of the lake's TMDL, a key component to the City's stormwater treatment strategy is implementing controls that reduce the amount of phosphorus entering Lake Whatcom. As of 2014, there were 39 public and 7 private stormwater facilities within the City's jurisdiction of the Lake Whatcom watershed, treating approximately 330 acres.

In 2014, there were 69 single family home stormwater retrofits completed under the Homeowner Incentive Program (HIP) for Lake Whatcom residents. That brings the total properties retrofit under the program to 127. Under the program, participants were eligible for up to \$6,000 reimbursement for retrofits such as rock-filled infiltration trenches, reforestation plantings, riparian and shoreline restoration, removal of impervious



surfaces, permeable paving, and watershed-friendly bioretention (rain gardens). A total of 362 individual Best Management Practices (BMPs) for phosphorus reduction were installed during the grant period (2011-2014). Two elementary schools and one shared gravel alley were also retrofit under HIP, as examples of neighborhood-scale retrofitting.

In 2014, the City also continued to maintain and upgrade stormwater systems to maximize phosphorus capture and removal, while adding additional systems to address untreated areas. Two major retrofit projects were completed in 2014. In one project, runoff from about one mile of Northshore Drive and adjacent properties now enters new media filter drain (MFD) trenches installed within the road shoulders. State-approved Technology Assessment Protocol - Ecology, General Use Level Designation (TAPE-GULD) documents indicate that MFD systems may reduce total and dissolved phosphorus levels more than any other treatment BMP available. In another project, a partnership with the Parks and Recreation Department, runoff from lawn and landscape areas at Bloedel Donovan Park now enters a new MFD trench buried beneath a large beach constructed using phosphorus-treatment-rated sand. These two projects increased phosphorus capture capacity in the watershed by approximately 35 additional pounds per year.

More information regarding the Storm and Surface Water Utility and its programs can be found online at <http://www.cob.org/services/utilities/surface-storm/index.aspx>.



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## 5.0 Water Quality Monitoring

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The Urban Streams Monitoring Program is one of the longest running monitoring programs within the City. Beginning in 1990, the program was developed by the City to obtain baseline water quality data for streams in Bellingham, and to use this data to assess water quality in those streams. The City also uses the data to compare the water quality in Bellingham's urban streams to the water quality standards described in the Washington State Department of Ecology (Ecology) rule - Chapter 173-201A WAC, *Water Quality Standards for Surface Waters of the State of Washington* (1997, 2003, 2006). However, the USMP is not intended to directly interface with the Ecology rules as they pertain to regulatory compliance or determination of impaired status, but to give context to the water quality observed in Bellingham's urban streams.

Ecology uses various water quality criteria to protect existing and designated uses of surface waters in Washington. The WAC was originally promulgated in 1997 and underwent significant revision in 2003. These revisions changed the 1997 class-based system to a designated uses approach. The 2003 rule underwent further revisions after the US Environmental Protection Agency (EPA) failed to approve portions of the rule. Ecology adopted revisions to the 2003 rule on December 21, 2006. Under the 2006 rule, Bellingham's urban streams are designated as Aquatic Life Use (ALU) of Core Summer Salmonid Habitat for temperature, dissolved oxygen, pH, and turbidity. Bellingham's streams are also designated for Primary Contact Recreational Use (RU) according to fecal coliform count. With the exception of the fecal coliform bacteria standard that was approved by the EPA in 2005, these changes apply to all stream monitoring conducted since 2006. For purposes of this report, the class-based designations

are presented in addition to use-based criteria. This allows for ease of comparison of streams from year to year.

### 5.1 Procedures and Quality Control

All analyses are performed by the staff of the City of Bellingham's state accredited laboratory. Protocols used are described in Standard Methods for the Examination of Water and Wastewater, 22nd Edition (APHA, AWWA, WEF, 2012). Protocols for each parameter are listed in Appendix B.

Samples for fecal coliform bacteria are collected one to six inches below the surface of the water in clean, sterile 250-ml polypropylene bottles. Samples are kept on ice for transportation to the laboratory. In the laboratory, samples are handled according to SM 9060 B until analyzed. Analysis for fecal coliform bacteria (SM 9222 D) is completed within six hours of collection (Appendix B).

Quality control for fecal coliform includes a laboratory duplicate (one sample, two measurements) and a field duplicate (two samples collected from the same sampling location) analyzed monthly along with regular stream samples. The laboratory duplicates serve to check the reproducibility of the instruments and the Laboratory Analyst technique. The purpose of the field duplicate is to indicate site heterogeneity or how representative the measurement is for a particular site. Agreement between the duplicates is assessed. If the difference between the duplicate samples is out of the calculated range of acceptable results or data appear questionable, the data are investigated. Results of the investigation are noted. The data can be left unchanged, flagged, or removed as the investigation dictates (Appendix B).

Field measurements for dissolved oxygen (SM 4500-O G), temperature (SM 2550 B), pH (SM 4500-H<sup>+</sup> B), and conductivity (SM 2510 B) are taken using a YSI Pro Plus field monitor. Quality control includes pre and post calibration of the YSI Pro Plus, testing check standards, and two field duplicates (two measurements from the same sampling location). If check standard measurements are out of a specified range, the instrument is recalibrated and retested with the check standards (Appendix B). Assessment of field duplicates follows the same procedure as for fecal coliform bacteria.

ments are out of a specified range, the instrument is recalibrated and retested with the check standards (Appendix B). Assessment of laboratory and field duplicates follows the same procedure as for fecal coliform bacteria.

Turbidity measurements (SM 2130 B) are conducted on a Hach 2100P meter. Quality control includes a laboratory duplicate, a field duplicate, and testing check standards. If check standard measure-





## 5.2 Sampling

### 5.2.1 Conventional Sampling

This year marks 25 years that the City of Bellingham has been monitoring urban streams. Twelve of the current sites have been consistently sampled throughout. Five more sites were added in 2002, one was added in 2006, and another was added to start 2014. In addition, the longstanding site at 22nd St. on Padden Creek was moved in 2014 to 24th St. in order to accommodate in-stream work being done there. The quantity of samples collected per year from each site has varied from four to twelve. Since 2002 all sites have been sampled monthly. Latitude and longitude of each sample site are provided in Table 5.2-1.

Table 5.2-1. Latitude and longitude of urban stream sample sites, NAD84 datum.

Stream Site	Latitude	Longitude
Chuckanut Creek (Mouth)	48° 42' 02"	122° 29' 37"
Padden Creek (38 <sup>th</sup> St.)	48° 42' 20"	122° 28' 02"
Padden Creek (30 <sup>th</sup> St.)	48° 42' 49"	122° 28' 41"
Connelly Creek (Donovan)	48° 43' 01"	122° 28' 47"
Padden Creek (24th St.)	48° 42' 54"	122° 29' 56"
Padden Creek (14th/Gage)	48° 42' 54"	122° 29' 10"
Padden Creek (Mouth)	48° 43' 10"	122° 30' 25"
Whatcom Creek (Control Dam)	48° 45' 27"	122° 25' 20"
Hanna Creek (WTP)	48° 45' 08"	122° 26' 08"
Cemetery Creek (Whatcom Cr)	48° 45' 12"	122° 27' 12"
Lincoln Creek (Fraser)	48° 45' 06"	122° 27' 36"
Fever Creek (Valencia)	48° 45' 35"	122° 26' 47"
Whatcom Creek (Valencia)	48° 45' 14"	122° 26' 42"
Whatcom Creek (I-5)	48° 45' 15"	122° 27' 45"
Whatcom Creek (Dupont)	48° 45' 20"	122° 28' 50"
Squalicum Creek (E. Bakerview)	48° 47' 21"	122° 26' 18"
Squalicum Creek (Meridian)	48° 46' 32"	122° 29' 07"
Baker Creek (Squalicum Pkwy)	48° 46' 29"	122° 29' 29"
Squalicum Creek (Mouth)	48° 45' 47"	122° 30' 22"



Sampling locations are shown on the drainage basin maps supplied in Appendix E of this report. The sampling program includes four sites on Whatcom Creek as well as four of its tributaries - Hanna, Cemetery, Lincoln, and Fever Creeks (Whatcom Drainage Map). There are three sampling sites on Squalicum Creek and a sampling site on its main tributary, Baker Creek (also known as Spring Creek - see section 9.0, Squalicum Drainage Map). Padden Creek is sampled at five locations and on its main tributary, Connelly Creek (Chuckanut and Padden Drainage Map). Chuckanut Creek is sampled only near the mouth (Chuckanut and Padden Drainage Map).

Levels of fecal coliform bacteria, dissolved oxygen, temperature, pH, turbidity, and conductivity are measured at each site. All but conductivity are water quality parameters included in the WAC. Criteria included in the WAC but not sampled by the City include bioassessment, contaminated sediments, phosphorus, toxic substances and total dissolved gases.



The maximum, minimum and average conductivity results for individual stream segments can be found on page 27. The 2014 results for this parameter have not changed significantly from prior years. Conductivity measurements for 2002 and earlier can be found in the *Urban Streams Monitoring Program Report 2002* (City of Bellingham, 2002b).

### 5.2.2 Enhanced Sampling

In 2014 the City of Bellingham continued to conduct enhanced sampling on select 303d listed stream reaches. Enhanced sampling uses continuous monitoring equipment and more frequent grab sampling to rigorously investigate the causes and validity of 303d listings. Data collected via these methods provide a more comprehensive picture of overall water quality in the City's urban streams.

The advantages of enhanced sampling include allowing for better estimation of overall geometric means for fecal coliform, along with the ability to calculate 7-day averages of daily maximums (7DADMAX) and 7-day averages of daily minimums (7DADMIN) from continuous monitoring data. Ecology currently considers the 7DADMAX for temperature and 7DADMIN for dissolved oxygen the best ways to assess water quality for these parameters. They are the preferred method for determining 303d status.

As Bellingham's streams are most often listed for exceedences of fecal coliform, dissolved oxygen and temperature standards, sampling efforts are usually conducted during Ecology's designated "dry" summer season (June 1 - September 30) when these factors are of most concern. Results of enhanced sampling are then included in class/aquatic life use/recreational contact use designation analysis for the streams monitored that year.

In 2014, the mouths of Bellingham's four primary streams were chosen for monitoring using enhanced sampling protocol. A focus was put on fecal coliform levels, as they have been shown to be a good indicator of stream health when other measured parameters show little change historically. As of the last statewide Water Quality Assessment, fecal coliform levels are the most cited parameter for listing of Bellingham's urban streams on the 303d list (100% listed). There has also been an increased interest in the amount of fecal coliform bacteria entering our marine near-shore environment in recent years. Enhanced sampling was conducted at the mouths of Chuckanut, Padden, Squilicum and Whatcom Creeks from June 1st until October 1st. Detailed results of enhanced fecal coliform sampling at these sites can be found in section 5.3.1. Enhanced monitoring results for temperature and dissolved oxygen are not available for 2014. These parameters will return in 2015.



### 5.2.3 Historical Sampling

Historically, Bellingham's urban streams have rarely met all of the water quality standards for overall Class A designation (Table 5.2-2). The overall classification of a stream is based on the parameter which confers the lowest class designation on that water body.

Based on conventional sampling in 2014, Hanna Creek was the only site to Meet all the ALU/Class AA standards. Chuckanut Creek and Padden at 38th met Class A standards, while all Whatcom Creek sites, Squalicum Creek at E. Baker-view and Meridian, and Baker Creek met Class B standards. None of the other urban stream sites were able to meet either

the Class A or Class B standards.

In 2014, Chuckanut Creek, Padden Creek at 38th, Hanna Creek and all the Whatcom Creek sites met Primary Contact Recreational Use standards. Only Hanna Creek met all of the Aquatic Life Use requirements of Core Summer Salmonid Habitat.

The following sections provide conventional sampling data collected during 2014. Historical data for is also provided for comparison of the water quality parameters sampled for each site. Raw data tables used to construct percent exceedence figures are provided in Appendix C.

Table 5.2-2. Overall class designation for all stream segments from 1995 to 2014. ("AA" - surpassed Class A standards; "A" - met Class A standards; "B" - did not meet Class A standards but met Class B standards; "X" - did not meet Class B standards). Designations based on conventional sampling.

Sampling Site	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14
Chuckanut (mouth)	X	X	B	X	X	A	X	B	X	B	X	X	B	B	B	AA	AA	B	B	A
Padden (38th)		B	B	X	AA	A	X	A	B	X	A	A	A	X	A	A	B	A	A	A
Padden (30th)	X	A	B	X	X	A	A	A	X	X	X	B	B	X	B	B	A	B	X	X
Connelly (Donovan)	X	X	B	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Padden (24th)											X	X	X	B	X	B	X	X	X	X
Padden (14th/Gage)																				X
Padden (mouth)	X	X	B	X	X	B	X	X	X	X	X	X	X	B	X	X	X	X	X	X
Whatcom (Control Dam)	X	X	B	X	B	B	B	X	X	X	X	X	B	B	B	B	B	B	B	B
Hanna (WTP)	X							B	X	X	X	X	X	X	B	A	X	X	B	AA
Cemetery (Whatcom Cr)	X	X	B	X	X	X	X	X	X	X	X	X	X	X	X	B	X	X	B	B
Lincoln (Fraser)	X	X	B	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fever (Valencia)	X	X	X	X	X	X	X	X	B	X	X	X	X	X	X	X	X	X	X	X
Whatcom (Valencia)													A	B	B	A	A	A	B	B
Whatcom (I-5)	X	X	B	X	X	B	X	B	B	X	B	B	B	B	B	A	A	A	B	B
Whatcom (Dupont)	X	B	B	X	X	X	X	B	X	X	X	X	B	X	X	A	B	B	B	B
Squalicum (E. Baker-	X	X	X	X	X	B	X	X	X	X	X	X	X	X	X	B	B	X	X	B
Squalicum (Meridian)	X	X	B	B	B	X	B	B	A	X	X	B	A	X	A	A	A	X	X	B
Baker (Squalicum)	X	X	A	B	X	X	X	X	X	X	X	X	X	X	X	B	X	X	X	B
Squalicum (Mouth)	X	X	A	X	X	X	X	X	X	B	X	X	X	A	X	B	X	X	X	X

\*For consistency and ease of comparisons, Ecology class designations used before 2006 are presented in addition to current Ecology designated use standards. They are not meant to directly interface with the Ecology rules as they pertain to determination of impaired status but to give context to the water quality observed in Bellingham's urban streams.

## 5.3 Water Quality Parameters

### 5.3.1 Fecal Coliform Bacteria

The water quality parameter that historically has most often determined the overall classification of Bellingham's urban streams is fecal coliform bacteria. Stream sites sampled for the USMP rarely meet the Primary Contact Recreational Use (Class A) standards for this parameter (Table 5.3.1-1).

In 2014, Hanna Creek, along with Whatcom Creek at the Control Dam, Valencia and I-5 were the only sites to meet the stringent Class AA criteria for fecal coliform bacteria. Chuckanut Creek, Padden Creek at 38th and Whatcom Creek at Dupont met Class A criteria. Cemetery Creek and the E. Bakerview, Meridian and Baker Creek sites in the Squalicum Creek Drainage met Class B standards. The remaining 8 sites did not

meet Class A or B criteria for fecal coliform. Figure 5.3.1-1 shows the minimum, maximum, and geomean values for all stream segments sampled in 2014. Figure 5.3.1-2 provides the percent of samples that exceeded fecal coliform water quality standards.

Fecal coliform bacteria are normal inhabitants of the digestive tracts of warm-blooded animals. The presence of fecal coliforms in water indicates potential contamination from fecal sources. While these bacteria do not usually cause illness directly, fecal coliforms are considered an indicator of pathogens that cause a variety of waterborne illnesses and conditions including eye, ear, and skin conditions, upper respiratory illness, and most commonly, gastrointestinal illness.

Table 5.3.1-1 The fecal coliform bacteria class designation for all stream segments from 1995 to 2014. ("AA" - surpassed Class A standards; "A" - met Class A standards; "B" - did not meet Class A standards but met Class B standards; "X" - did not meet Class B standards). Designations based on conventional sampling.

Sampling Site	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14
Chuckanut (mouth)	A	X	A	X	X	A	X	B	X	B	X	X	B	B	B	AA	AA	B	B	A
Padden (38th)		AA	AA	X	AA	AA	X	AA	B	X	A	AA	AA	X	AA	A	B	A	A	A
Padden (30th)	B	A	A	X	X	AA	A	A	X	X	X	B	B	X	B	B	A	B	X	X
Connelly (Donovan)	B	X	B	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Padden (24th)											X	X	X	B	X	B	X	X	X	X
Padden (14th/Gage)																				X
Padden (mouth)	X	X	B	X	X	B	X	X	X	X	X	X	X	B	X	X	X	X	X	X
Whatcom (Control Dam)	A	B	B	A	A	AA	A	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	B	AA	AA
Hanna (WTP)	X							A	X	X	X	X	X	X	B	A	X	X	B	AA
Cemetery (Whatcom Cr)	X	X	B	X	X	X	X	X	X	X	X	X	X	X	X	B	X	X	X	B
Lincoln (Fraser)	X	X	B	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fever (Valencia)	X	X	X	X	X	X	X	X	B	X	X	X	X	X	X	X	X	X	X	X
Whatcom (Valencia)													AA	AA	A	AA	AA	A	AA	AA
Whatcom (I-5)	X	X	B	A	X	AA	X	AA	AA	X	B	A	AA	AA	B	AA	AA	A	A	AA
Whatcom (Dupont)	X	B	B	X	X	X	X	B	X	X	X	X	B	X	X	AA	B	B	B	B
Squalicum (E. Baker-	B	X	X	X	X	B	X	X	X	X	X	X	X	X	A	B	A	X	X	B
Squalicum (Meridian)	B	X	B	A	B	X	B	A	AA	X	X	B	A	X	A	AA	A	X	X	B
Baker (Squalicum)	X	X	A	A	X	X	X	X	X	X	X	X	X	X	X	B	X	X	X	B
Squalicum (Mouth)	B	X	A	X	X	X	X	X	X	B	X	X	X	A	X	B	X	X	X	X

While the origin of fecal coliform bacteria in streams is assumed to be from fecal sources, the levels of bacteria found in streams arise from a variety of causes. Most bacteria are likely washed into streams via surface runoff (primarily from wildlife and pet waste), but leaking sewer lines are also of concern. This initial flush of bacteria may be diluted as the stream proceeds downstream or may settle into bottom sediments where extended survival and growth are possible, particularly as temperatures increase (Ishii et al., 2006; Davies et al., 1995; Goyal and Adams, 1984). Recreational and wildlife activities as well as agitation from storm events can cause resuspension of sediment-bound bacteria, increasing the bacterial concentration in overlying waters.

Bellingham's urban streams are classified as Primary Contact Recreational waters by the Surface Water Standards 2006 rule (WAC 173-201A-200). Under the 1997 rule Bellingham's streams were designated as Class A waters (WAC 173-201A-030). Table 5.3.1-2 compares the 1997

rule to the 2006 rule. The requirements for Class A and the designated use are equivalent.

The fecal coliform criteria for Class A (Primary Contact Recreational) fresh waters includes a geomean value of 100 or less colony forming units (CFU) per 100 milliliters (ml) water where not more than 10 percent of all samples obtained for calculating the geomean exceed 200 CFU/100 ml (WAC 173-201A-030, WAC 173-201A-200 Table 200 (2)(b)).

The Class B (Secondary Contact Recreational) fresh water fecal coliform criteria includes a geomean of 200 or less CFU/100 ml with the caveat that not more than 10 percent of all samples obtained for calculating the geomean have values exceeding 400 CFU/100 ml (WAC 173-201A-030, WAC 173-201A-200 Table 200 (2)(b)). Tables 5.2-2 and 5.3.1-1 classify streams using a geomean calculated from all samples taken within the year, taking into account the percent of those samples that exceed 200 (or 400) CFU/100 ml.

Table 5.3.1-2. Comparison of the 1997 Ecology rule to the 2006 rule for the fecal coliform bacteria standard for fresh surface waters in Washington.

FECAL COLIFORM BACTERIA		
1997 Rule	Geometric Mean	2006 Rule
Class		Category
Class AA	50 CFU/100 ml, no more than 10% of all samples exceed 100 CFU/100 ml	Extraordinary Primary Contact
Class A	100 CFU/100 ml, no more than 10% of all samples exceed 200 CFU/100 ml	Primary Contact
Class B	200 CFU/100 ml, no more than 10 % of all samples exceed 400 CFU/100 ml	Secondary Contact



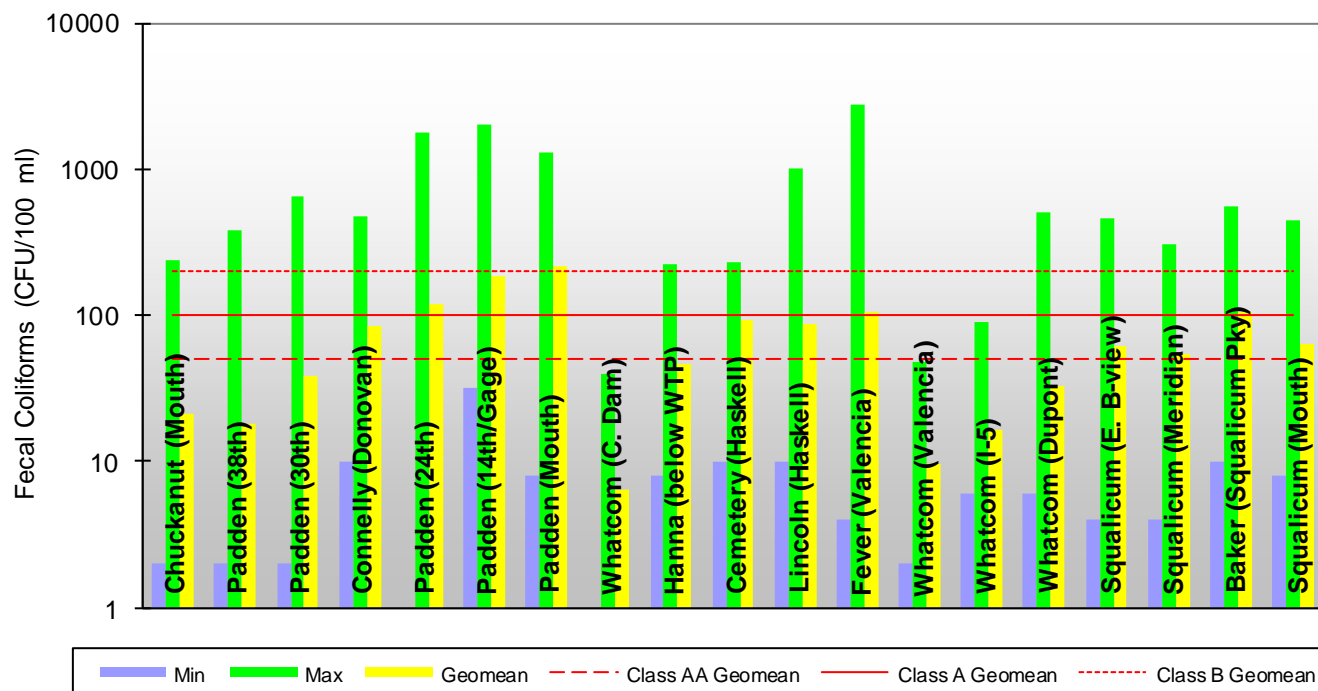


Figure 5.3.1-1. Fecal coliform bacteria minimum, maximum, and geomean values for all stream segments sampled in 2014. Red lines indicate the maximum geomean value allowed by the Class AA, A (Primary Recreational Contact), and B criteria for fecal coliform bacteria. *Note this graph uses a logarithmic scale.*

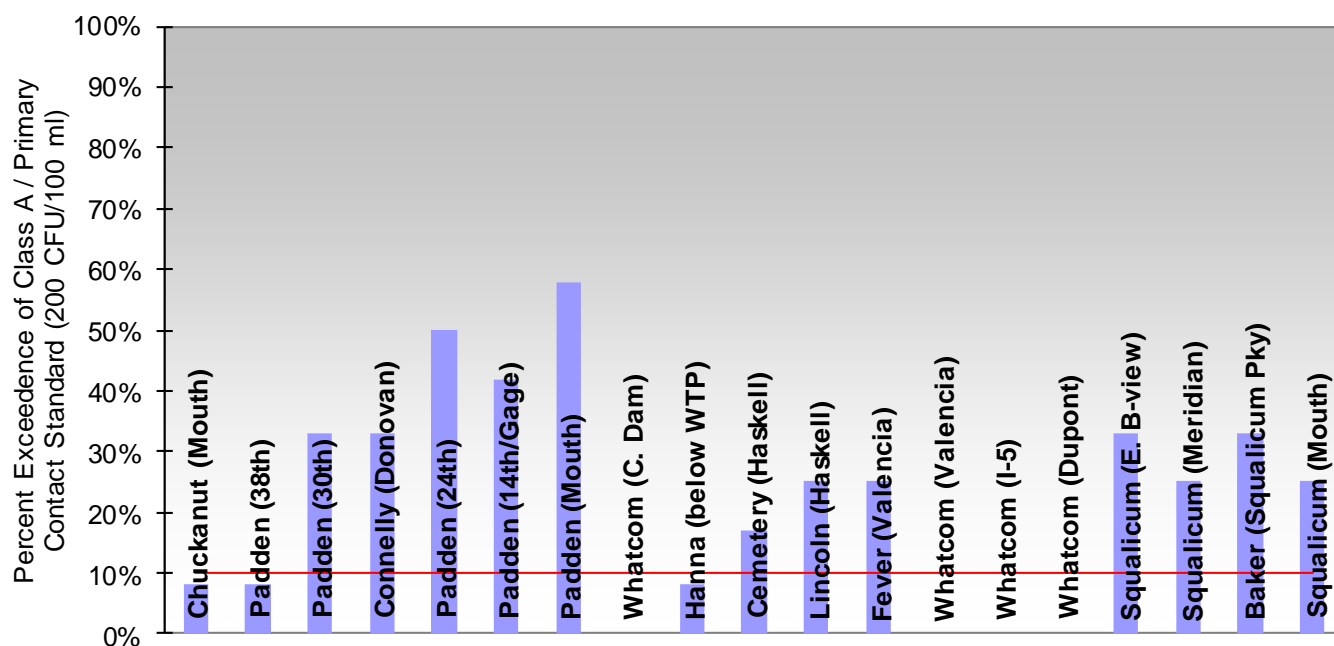


Figure 5.3.1-2. Fecal coliform percent exceedence of the Class A / Primary Recreational Contact standard for all stream segments sampled in 2014. Whatcom Creek had no exceedences for 2014. Based on conventional sampling events.



Table 5.3.1-3. Results of enhanced fecal coliform sampling June 1 - October 1, 2014.

Fecal Coliform (CFU/100 ml)	Chuckanut	Padden	Squalicum	Whatcom
<b>Geomean</b>	<b>162</b>	<b>519</b>	<b>264</b>	<b>112</b>
<b>Samples &gt; 200</b>	6/17	16/17	11/17	4/17
<b>Minimum</b>	43	150	17	20
<b>Maximum</b>	880	3200	2800	500

Substantiating the results of conventional sampling, enhanced fecal coliform sampling during the critical period (June 1 - October 1) of 2014 shows that none of the mouth sites on Bellingham's four largest urban stream drainages were able to meet the Class A/Primary Recreational Use standard of a geomean of 100 CFU/100 ml and no more than 10% of all samples greater than 200 CFU/100 ml.

When evaluating conventional data, these sites are most often disqualified based off of the 10% of all samples rule.

Enhanced sampling provides further clarity into the condition of the four creek mouths in 2014, as the geometric means calculated for the critical period were all above the 100 CFU/100 ml threshold as well (Table 5.3.1-3, Figure 5.3.1-3).

Standing out from the other sites in 2014 is the mouth of Padden Creek, which recorded a critical period geomean of 519 CFU/100 ml and a minimum value of 150 CFU/100 ml. This suggests special attention would be warranted there.

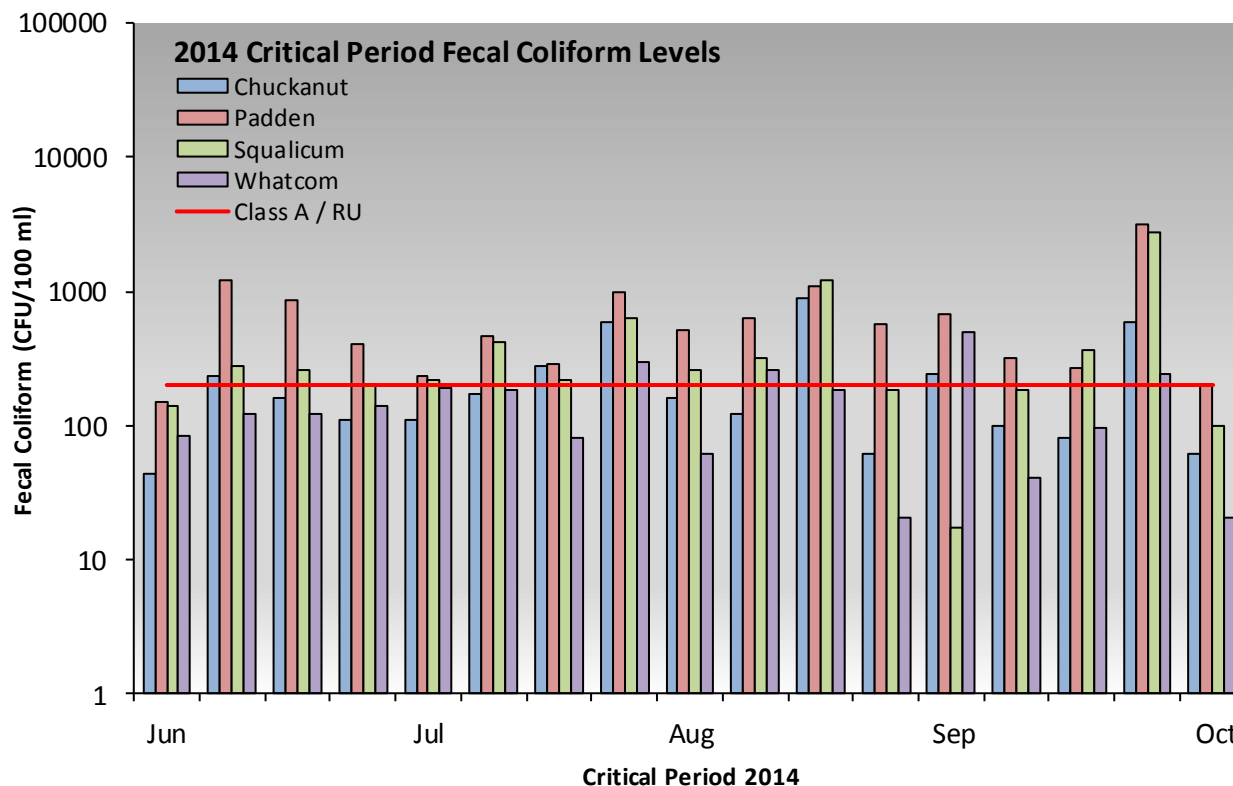


Figure 5.3.1-3. Fecal coliform levels measured at the mouths of Bellingham's four largest creeks during the 2014 critical period (June 1 - October 1). All sites exceeded the Class A/Primary Contact Recreational Use Standard.

### 5.3.2 Dissolved Oxygen

In 2014, Chuckanut Creek, Padden Creek at 14th, Hanna Creek and Squalicum Creek at the Mouth met the stringent Core Summer Salmonid Habitat Aquatic Life Use (ALU) criterion for dissolved oxygen. The Core Summer Salmonid Habitat ALU level for dissolved oxygen equates to a Class AA designation.

All other Padden Creek sites, Connelly Creek, the Valencia, I-5 and Dupont sites on Whatcom Creek, Fever Creek, all other Squalicum Creek sites, and Baker Creek met the Class A criterion for dissolved oxygen in 2014 (Table 5.3.2-1). Whatcom Creek at the Control Dam, Cemetery Creek and Lincoln Creek met Class B standards. Figure 5.3.2-1 provides the minimum, maximum, and average values for dissolved oxygen in all stream segments sampled in 2014. Figure 5.3.2-2 shows the percent of samples that fell below the Class A and ALU criteria.

Aquatic organisms require oxygen to survive. Oxygen in water is gained from the atmosphere and produced during photosynthesis. Running water, because of its churning action, contains higher levels of oxygen than still water. Oxygen is consumed during respiration, decomposition, and various chemical reactions.

Oxygen in water is measured in its dissolved form. The amount of oxygen dissolved in water is related to temperature. Cold water can hold more oxygen than warm water; warm water becomes saturated with oxygen more quickly than cold water. In summer months as the water becomes warmer, it holds less and less dissolved oxygen. If the water becomes too warm, even at 100% saturation, dissolved oxygen levels may become suboptimal for some fish and other aquatic organisms.

In addition to elevated temperature, inputs of pollution can cause lower dis-

Table 5.3.2-1. Dissolved oxygen class designation for all stream segments from 1995 to 2014. ("AA" - surpassed Class A standards; "A" - met Class A standards; "B" - did not meet Class A standards but met Class B standards; "X" - did not meet Class B standards). Designations based on conventional sampling.

Sampling Site	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14
Chuckanut (mouth)	X	B	A	A	A	A	A	A	B	A	A	AA	A	A	AA	AA	AA	AA	A	AA
Padden (38th)		B	A	A	A	A	A	A	A	B	A	A	A	B	A	A	A	A	A	A
Padden (30th)	X	A	A	A	A	A	A	AA	B	B	A	A	A	A	A	A	A	AA	A	A
Connelly (Donovan)	X	B	A	B	A	B	B	A	B	B	A	A	A	A	B	A	B	A	A	A
Padden (24th)											A	AA	A	A	A	A	A	AA	A	A
Padden (14th/Gage)																				AA
Padden (mouth)	X	B	A	A	A	A	A	A	A	B	A	A	A	A	B	A	A	A	A	A
Whatcom (Control Dam)	X	B	A	B	B	A	B	A	B	B	A	A	A	A	B	A	B	A	B	B
Hanna (WTP)	X							B	AA	B	A	A	A	AA	A	A	A	AA	A	AA
Cemetery (Whatcom Cr)	X	B	B	B	A	A	B	B	X	X	X	A	X	X	X	B	X	X	X	B
Lincoln (Fraser)	X	B	B	X	A	A	B	B	B	B	B	A	B	B	B	B	B	B	B	B
Fever (Valencia)	X	B	A	B	A	A	A	A	A	B	B	A	A	A	A	A	A	A	A	A
Whatcom (Valencia)													A	A	A	A	A	AA	A	A
Whatcom (I-5)	X	B	A	A	AA	A	A	A	A	B	A	A	A	A	A	A	A	A	A	A
Whatcom (Dupont)	B	B	A	A	AA	A	B	A	A	X	B	A	A	B	B	A	A	B	B	A
Squalicum (E. Bakerview)	X	X	X	X	B	B	A	X	X	X	X	X	X	B	X	A	B	B	X	A
Squalicum (Meridian)	X	B	B	A	B	A	A	A	A	B	B	A	A	A	A	A	A	A	B	A
Baker (Squalicum)	X	B	A	A	A	AA	A	A	B	B	B	B	A	A	A	A	B	A	B	A
Squalicum (Mouth)	X	B	A	A	A	AA	A	A	B	B	A	A	A	A	A	A	A	A	A	AA

solved oxygen levels. Feces from animals and failing septic systems, grass clippings, leaves and woody debris, and urban and agricultural run-off, all contain organic matter that is decomposed by microorganisms, which use oxygen in the process. The amount of oxygen consumed by these organisms in breaking down organic compounds is known as biochemical oxygen demand (BOD). BOD also measures oxygen consumed by the chemical oxidation of inorganic matter. Variables that can affect the rate of oxygen consumption include temperature, pH, the types and abundance of microorganisms, and the type of organic and inorganic materials present in the water (USEPA, 1997). If BOD is high, less dissolved oxygen is available to fish and macroinvertebrates.

To meet the stringent Core Summer Salmonid Habitat ALU criterion, the revised 2003 WAC states that dissolved oxygen must remain above 9.5 mg/L. This equates

to Class AA by the 1997 rule. Also by the 1997 rule, dissolved oxygen must be 8.0 mg/L or higher to qualify as a Class A stream and 6.5 mg/L or higher to meet Class B standards. WQP Policy 1-11 (Ecology, 2012) states that a water body may be considered impaired when a minimum of 3 and at least 10% of single grab samples, such as those collected for the Urban Streams Monitoring Program, in a given year do not meet the dissolved oxygen water quality criteria.



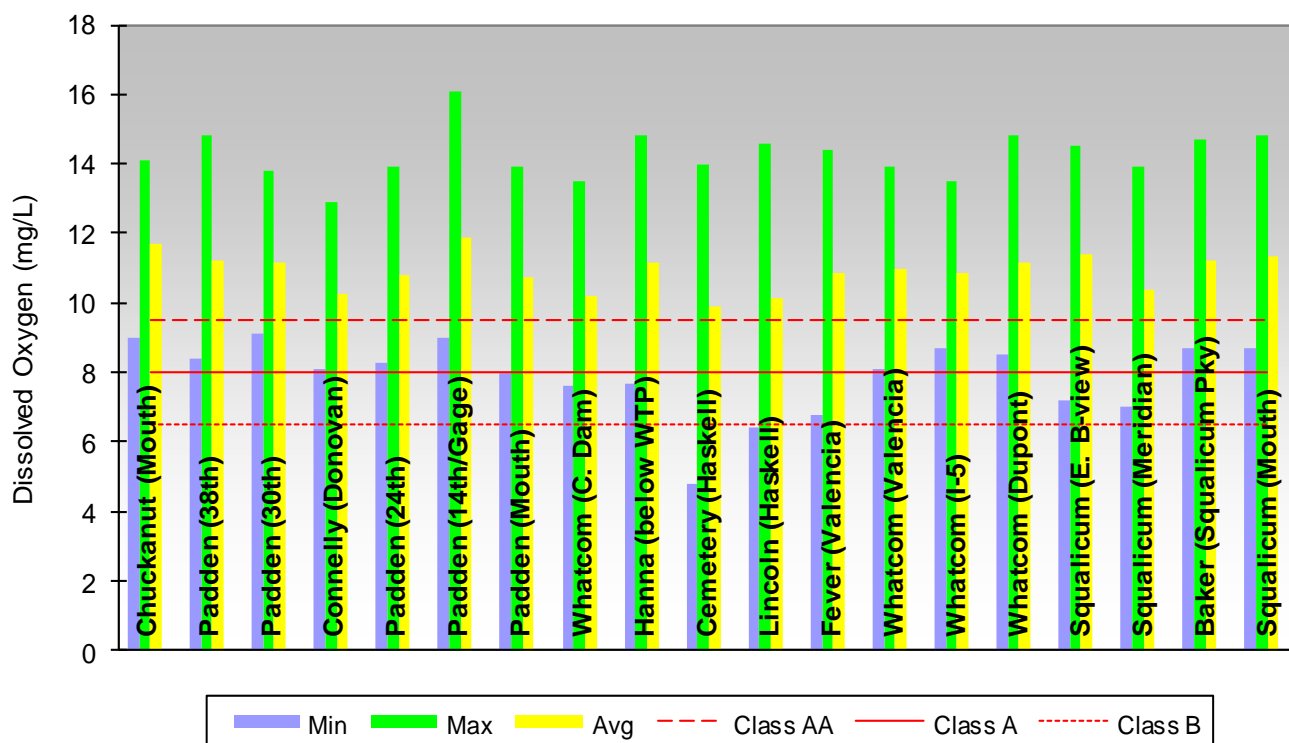


Figure 5.3.2-1. Minimum, maximum, and average dissolved oxygen levels for all stream segments sampled in 2014. Red lines indicate the lowest dissolved oxygen levels allowed for the different surface water classes (AA, A, and B). The Core Summer Salmonid Habitat Aquatic Life Use (ALU) designation is equivalent to Class AA.

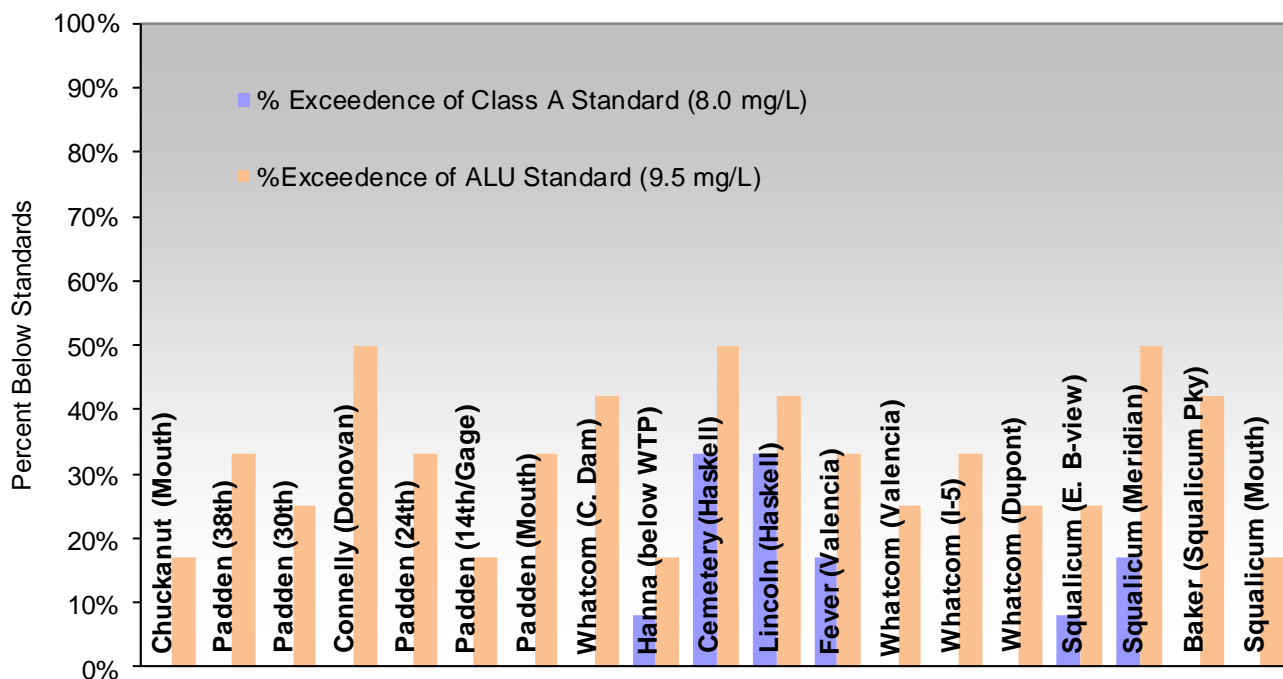


Figure 5.3.2-2. Percent of dissolved oxygen samples below the Class A (8.0 mg/L) and Aquatic Life Use (ALU, 9.5 mg/L) standards for all stream segments sampled in 2014.



### 5.3.3 Temperature

In 2014, eleven urban stream segments met the stringent Core Summer Salmonid Habitat ALU / Class AA standard for temperature, four sites met the Class A standard, while all main stem Whatcom Creek sites were in the Class B category. Figure 5.3.3-1 shows minimum, maximum, and average temperatures found in the stream segments in 2014. Figure 5.3.3-2 provides the percent of samples that exceeded the Class A criterion.

The WAC 173-201A-030 states that temperatures in Core Summer Salmonid Habitat (2006) / Class AA (1997) streams may not exceed 16°C, Class A streams may not exceed 18°C, and Class B streams may not exceed 21°C. A water body is considered impaired if a minimum of 3 of all samples and greater than 10% of samples taken during the year in question are in exceedence. A temperature measurement in excess of the standard is not a violation, however, if the exceedence is the result of

natural conditions. In this case, temperature increases due to human activities shall not exceed 0.3°C and incremental temperature increases from nonpoint sources shall not exceed 2.8°C (WAC 173-201A-030, WQP 1-11). Finally, certain reaches of Chuckanut, Squalicum and Whatcom Creeks are listed by Ecology as requiring supplemental spawning and incubation protection for salmonids. Those reaches require temperatures below 13°C from Feb. 15 - June 15.

According to WQP 1-11, Aquatic Life Use criterion for temperature is preferably based on a rolling 7 Day Average of Daily Maximums (7DADMAX). It is only in the absence of continuous monitoring data that single grab sample data is considered. In 2014, the sampling frequency for the Urban Streams Monitoring Program did not allow for the calculation of this value for most stream segments. However, the necessary continuous monitoring programs are now being run as part of TMDL and restoration studies. As results become available they will be incorporated into the Urban Streams Monitoring Report.

Table 5.3.3-1. Temperature class designation for all stream segments from 1995 to 2014. ("AA" - surpassed Class A standards; "A" - met Class A standards; "B" - did not meet Class A standards but met Class B standards; "X" - did not meet Class B standards). Designations based on conventional sampling.

Sampling Site	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14
Chuckanut (mouth)	A	A	B	B	AA	AA	AA	AA	AA	AA	AA	AA	A	AA	AA	AA	AA	AA	AA	AA
Padden (38th)		A	B	A	AA	AA	A	AA	A	A	AA	A	A	AA	A	AA	AA	AA	AA	A
Padden (30th)	B	A	B	A	AA	AA	A	AA	B	A	AA	AA	A	AA	A	AA	AA	AA	A	A
Connelly (Donovan)	A	B	B	B	AA	AA	A	A	A	A	AA	AA	A	AA	AA	AA	AA	AA	A	AA
Padden (24th)											AA	AA	A	AA	AA	AA	AA	AA	A	A
Padden (14th/Gage)																				AA
Padden (mouth)	A	A	B	B	AA	AA	A	A	A	A	AA	AA	A	AA	A	AA	AA	AA	A	AA
Whatcom (Control Dam)	B	X	B	X	A	B	B	B	X	X	X	X	B	B	B	B	B	B	B	B
Hanna (WTP)	B							X	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	A	AA
Cemetery (Whatcom Cr)	A	B	A	B	AA	AA	A	A	A	A	AA	AA	A	A	A	A	AA	AA	B	AA
Lincoln (Fraser)	B	B	A	B	AA	AA	A	AA	A	A	AA	AA	AA	AA	AA	AA	AA	AA	A	AA
Fever (Valencia)	A	A	B	B	AA	A	A	A	A	A	A	A	A	AA	A	AA	AA	AA	A	A
Whatcom (Valencia)													B	B	B	A	A	A	B	B
Whatcom (I-5)	B	B	B	X	AA	B	B	B	B	B	B	B	B	B	B	A	A	A	B	B
Whatcom (Dupont)	B	B	B	X	AA	B	B	B	B	B	B	A	B	A	A	A	A	A	B	B
Squalicum (E. Baker-	A	B	B	B	AA	A	A	A	A	A	A	AA	A	AA	AA	AA	AA	AA	A	AA
Squalicum (Meridian)	A	B	B	B	A	AA	A	AA	AA	AA	A	A	AA	AA	AA	A	AA	AA	AA	AA
Baker (Squalicum)	A	A	A	B	AA	AA	AA	AA	A	A	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Squalicum (Mouth)	A	A	A	A	AA	AA	AA	AA	AA	A	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA



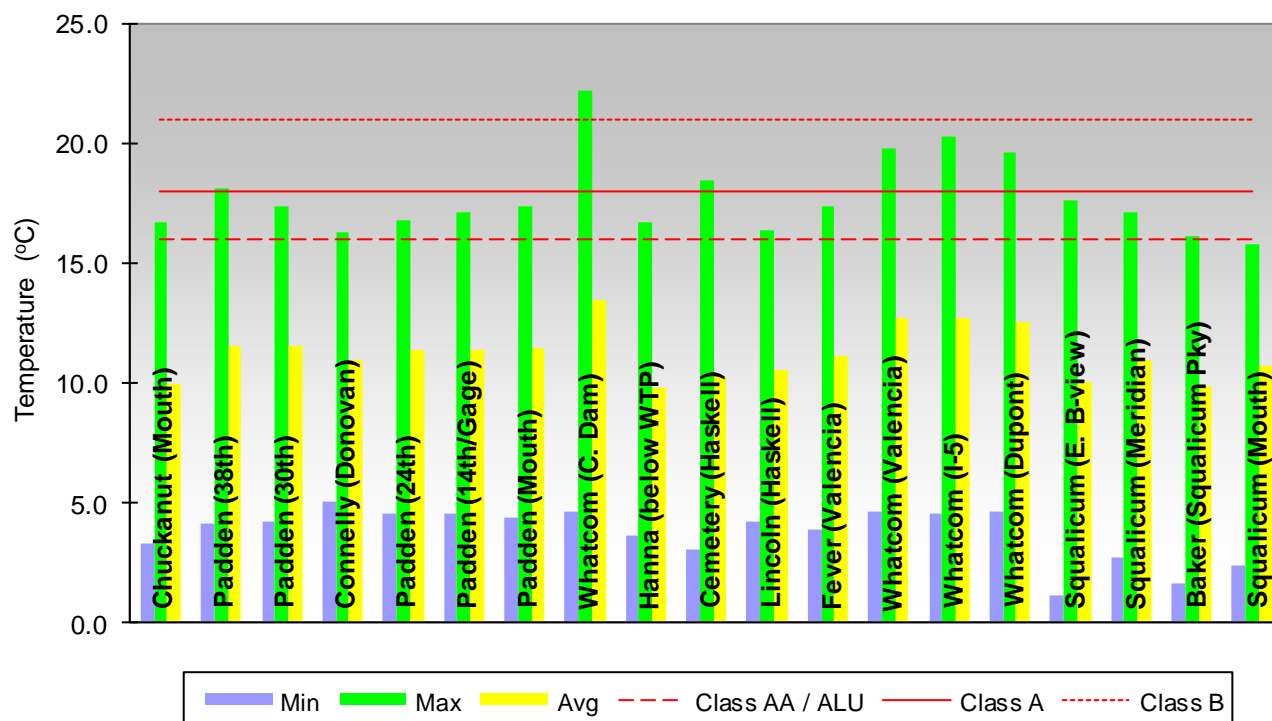


Figure 5.3.3-1. Minimum, maximum, and average temperature values for all stream segments sampled in 2014. Red lines indicate the highest temperature allowed by the different surface water standards (AA/ALU, A, and B).

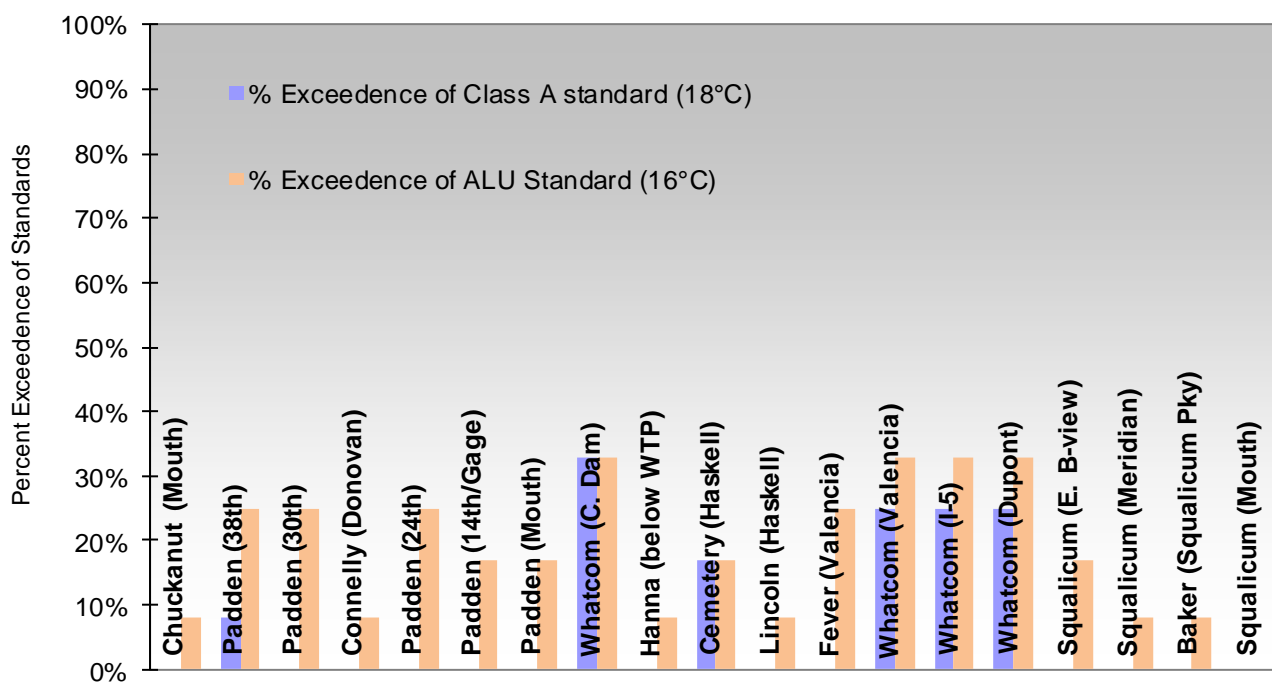


Figure 5.3.3-2. Percent temperature exceedences of Class A (18°C) and Aquatic Life Use (ALU, 16°C) standards for all stream segments sampled in 2014.

### 5.3.4 pH

The stream segments sampled in the Urban Streams Monitoring Program almost always meet Aquatic Life Use (ALU) and Class AA/A/B standards for pH. In 2014 that trend was continued.

The pH of water measures the concentration of hydrogen ions in the water, or the relative acidity or alkalinity of water. The value of pH is calculated using the negative logarithm of the hydrogen ion concentration. Thus, a change of one pH unit represents a 10-fold change in the concentration of hydrogen ions.

The pH of a stream can affect organisms living in the water directly. The chemical conditions in acidified waters are intolerable to some aquatic creatures or have sublethal physiological effects; some animals may actively avoid such waters. There are also indirect effects. The solubility and availability of nutrients can be affected by pH. Heavy metals can be more soluble at lower pH, therefore more bio-

available and consequently more toxic.

A change in pH can indicate the presence of pollution. Organic matter introduced into streams during periods of low flow can cause low pH values. Lime applied to agricultural lands, lawns, and golf courses can be washed into streams during storm events, raising pH. Additionally, photosynthesis, respiration, and decomposition also affect pH levels.

The pH of uncontaminated rainwater in equilibrium with atmospheric carbon dioxide is 5.6. Normally the acids in rainwater are neutralized as the rainwater passes through soil (Allan, 1995). In urbanized areas much of the precipitation falls onto impervious surfaces and flows directly into rivers and streams. There may be further acidification processes at work on these surfaces (Mason, 1989). Even when there are not large areas of impervious surface, the acid neutralizing mechanisms in the soil may not be able to keep pace during heavy continuous rain. During an event of this type, rainwater runs over the surface and

Table 5.3.4-1. The pH class designation for all stream segments from 1995 to 2014. ("AA" - met Class AA/A/B standards; "X" - did not meet Class AA/A/B standards).

Sampling Site	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14
Chuckanut (mouth)	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Padden (38th)		AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Padden (30th)	X	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Connelly (Donovan)	X	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Padden (22nd)											AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Padden (mouth)	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Whatcom (Control Dam)	X	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Hanna (WTP)	AA							AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Cemetery (Whatcom Cr)	X	AA	AA	AA	AA	AA	X	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Lincoln (Fraser)	X	AA	AA	AA	AA	AA	X	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Fever (Valencia)	X	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Whatcom (Valencia)													AA	AA	AA	AA	AA	AA	AA	AA
Whatcom (I-5)	X	AA	AA	AA	AA	AA	X	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Whatcom (Dupont)	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Squalicum (E. Baker-	X	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Squalicum (Meridian)	X	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Baker (Squalicum)	X	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
Squalicum (Mouth)	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA

enters streams with its chemical composition little changed (Mason, 1989).

Class AA/A/B and Core Summer Salmonid Habitat ALU designated surface water pH must be within the range of 6.5 to 8.5 (WAC 173-201A-030). A stream segment is in violation if more than 3 excursions and greater than 10% of the grab samples taken are outside the 6.5 to 8.5 range (Department of Ecology, WQP Policy 1-11, 2012).

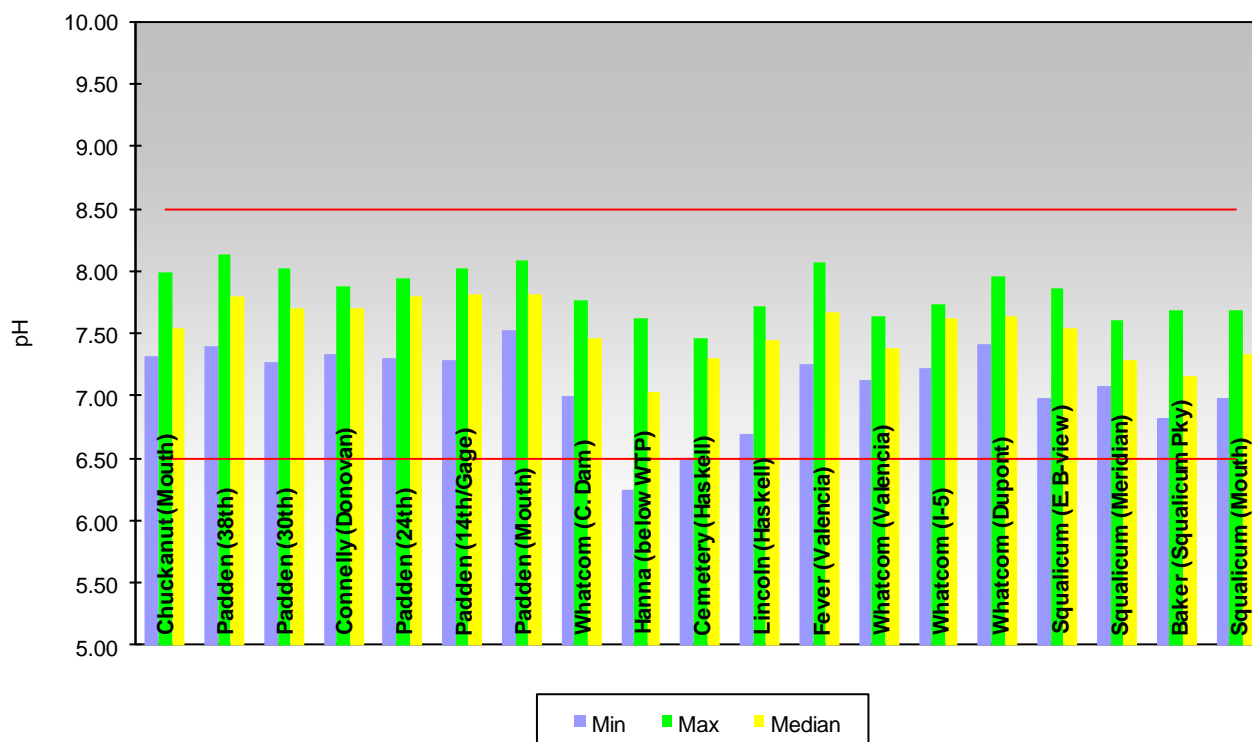


Figure 5.3.4-1. The pH minimum, maximum, and median values for all stream segments sampled in 2014. Red lines indicate the minimum and maximum values allowed by the Class AA/A/B and Aquatic Life Use (ALU) criteria for pH.



### 5.3.5 Turbidity

Turbidity measures the degree to which light traveling through a water column is scattered by the suspended organic (including algae) and inorganic particles in the water. Turbidity is commonly measured in Nephelometric Turbidity Units (NTU) and is used to estimate the amount of total suspended material in the water. Turbidity readings can be affected by season, water color from dissolved solids (Malcomb, 1985) and the shape, size, and surface area of particles (Packman et al., 2002).

The amount of suspended materials found in stream systems can be attributed to many factors. The flow rate of a water body is a primary factor influencing turbidity concentrations. Fast running water can carry more particles and larger sized sediment. A change in flow rate can also affect turbidity. If the speed of the water current increases, particulate matter from the bottom sediments may be re-suspended.

Heavy rains can pick up sand, silt, clay, and organic particles from the land, particularly from disturbed surfaces, and carry them to surface waters. Erosion from rainfall, run-off, and high stream velocities may result in higher concentrations of suspended particles in streams. Watershed development and poor land use practices in combination with natural processes can cause increased erosion, organic matter, and nutrients, all of which cause increases in suspended materials and algae growth. There are large amounts of impervious surfaces and land disturbing activities in urban stream corridors where natural settling areas have been removed. As a consequence, during storm events sediment is carried through storm drains to streams and rivers.

Some suspended matter is natural and beneficial to aquatic systems. Excess-

es, however, can affect the health of aquatic organisms. Studies have found that exposure to turbidities of 25 to 50 NTU for extended periods can reduce feeding and growth in trout and salmon fingerlings and may cause them to emigrate (Sigler et al., 1984; Harvey, 1989). Other studies have found that turbidities between 10 and 60 NTU for only two to four days can disrupt feeding and territorial behavior in juvenile salmon (Berg, 1982; Bjornn and Reiser, 1991).

The Ecology turbidity criterion for Class A surface waters is based on a relative change in NTU above background rather than a single value or range of values. "Turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background is more than 50 NTU" (WAC 173-201A-030).

These criteria are mainly used to measure inputs from point sources such as streamside construction activities (Joy, 2002). In this case, background turbidity is established by sampling upstream from the construction site. Determining background turbidity for stream systems that lack such a point source is problematic and the Ecology policy fails to address this issue. Bellingham streams lack reference sites that could provide a true background turbidity measurement.

Due to difficulty in applying point source criteria to non-point source systems, turbidity is not included in class determination for Bellingham's urban streams. In order to provide more pertinent context to the turbidity values recorded by the Urban Streams Monitoring Program, this report presents turbidity trends for the past 10 years and comparisons between this year's data and the previous 5 and 10 year overall turbidity averages.

For the ten year period ending in 2014, none of the stream sites sampled as part of the Urban Streams Monitoring Program displayed turbidity trends that were significantly different than zero.

In February, October and December of 2014, stream sampling occurred during winter storms that each recorded an inch or more of rainfall. Due to these occurrences, the turbidities of most samples were higher for these months, but not high enough to affect the annual average drastically. However, the power of stormwater to alter urban stream conditions becomes apparent when examining other water quality parameters. For example, fecal coliform levels were ele-

vated compared to surrounding months at nearly all sampling sites during these periods.

The 5-year, 10-year, and 2014 average turbidities are detailed in Table 5.3.5-1. Figure 5.3.5-1 provides minimum, maximum, and average turbidity values for all stream segments sampled in 2014.



Table 5.3.5-1. Yearly, 5-year and 10-year average turbidities.

Stream Segment	2014 Average	5 Year Average	10 Year Average
Chuckanut Cr (Mouth)	2.78	4.47	4.76
Padden Cr (38th)	3.09	2.95	2.81
Padden Cr (30th)	4.46	4.25	3.51
Connelly Cr (Donovan)	3.73	7.09	6.58
Padden Cr (24th)	3.04	5.18	4.63
Padden Cr (14th/Gage)	4.16	4.16	4.16
Padden Cr (Mouth)	3.23	8.38	6.62
Whatcom Cr (C. Dam)	1.49	1.56	1.57
Hanna Cr (below WTP)	3.27	5.34	5.59
Cemetery Cr (Haskell)	4.32	6.82	7.19
Lincoln Cr (Haskell)	4.78	6.76	6.82
Fever Cr (Valencia)	3.56	5.80	5.84
Whatcom Cr (Valencia)	1.85	2.06	2.34
Whatcom Cr (I-5)	2.00	2.75	2.74
Whatcom Cr (Dupont)	2.87	3.20	3.31
Squalicum Cr (E. Bakerview)	6.09	8.46	8.29
Squalicum Cr (Meridian)	7.96	9.98	9.21
Baker Cr (Squalicum Pky)	5.52	7.50	7.03
Squalicum Cr (Mouth)	5.81	8.30	7.98

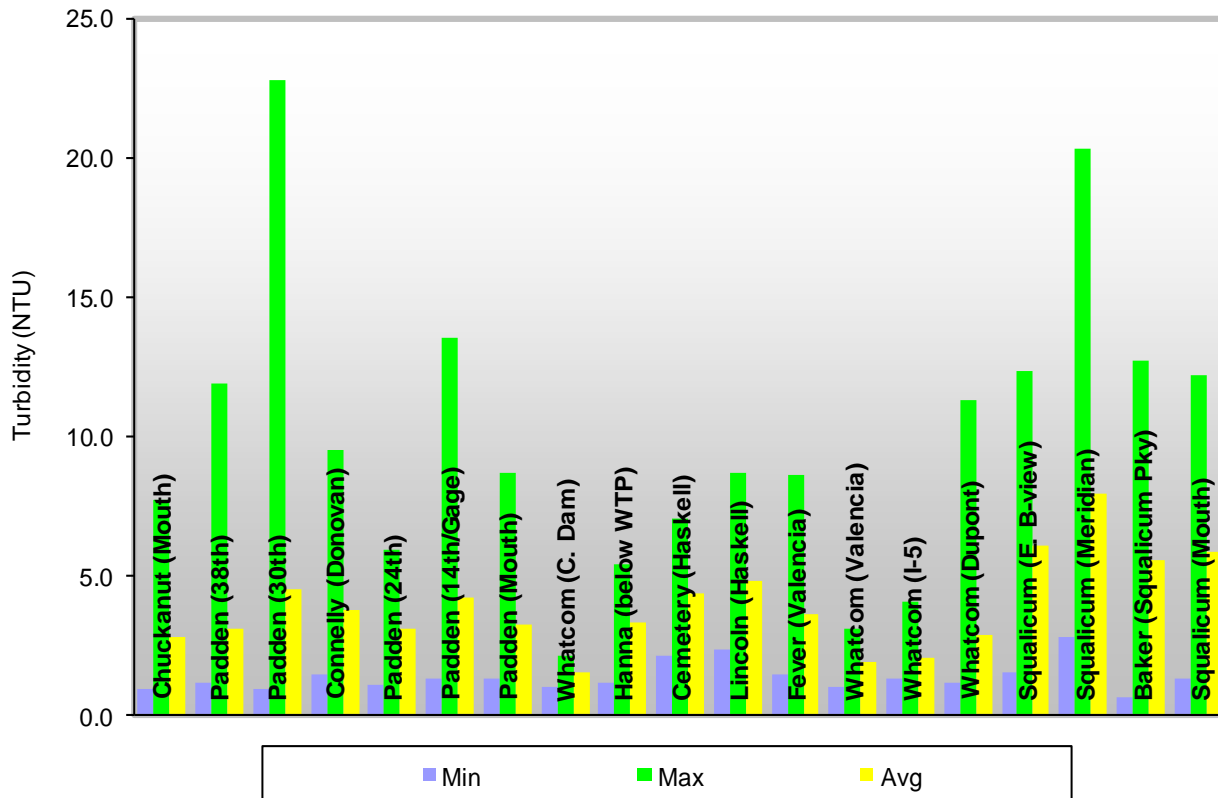


Figure 5.3.5-1. Minimum, maximum, and average turbidity values for all stream segments sampled in 2014.



### 5.3.6 Specific Conductivity

Conductivity measures the ability of water to conduct an electric current and is directly related to the total dissolved ions in the water. Conductivity is reported in microSiemens per centimeter ( $\mu\text{S}/\text{cm}$ ) corrected to  $25^{\circ}\text{C}$ . Conductivity in streams can be extremely variable. This natural variation is due to the characteristics of a watershed: mainly the type of rocks weathered, how much precipitation falls, the composition of the precipitation (largely dependant on distance from the ocean), and the relative contribution of ground water to total flow (Allan, 1995). Groundwater typically contains higher concentrations of ions than surface water because of a longer association with rocks (Allan, 1995). Since stream flow is reliant on a combination of surface water and groundwater, during drier periods the concentration of ions in a stream may increase as stream flow becomes more dependent on groundwater inputs. Evaporation can also contribute to increased conductivity levels by concentrating ions in water.

Conductivity can be useful as a general water quality measurement. Pollution

from point and non-point sources contributes to the amount of dissolved ions in water. Significant changes in conductivity measurements can indicate contamination from these sources.

The USEPA found that rivers in the United States had a range from 50 to 1500  $\mu\text{S}/\text{cm}$  (1997). The USEPA also reported that streams that supported "good mixed fisheries" had a range from 150 to 500  $\mu\text{S}/\text{cm}$ . Conductivity outside this range may not support some aquatic organisms.

The City of Bellingham has monitored conductivity since 1994. Historically, the range has been from 28 to 581  $\mu\text{S}/\text{cm}$ . This excludes measurements of 1001  $\mu\text{S}/\text{cm}$  taken at Squalicum Creek mouth in 1996 and 890  $\mu\text{S}/\text{cm}$  taken at Padden Creek mouth in 2001. These measurements were taken at the mouths of streams and it is suspected that the high values are the result of salt water wedges, an effect of high tide.

In 2014, conductivity in Bellingham's urban streams ranged from 34 to 306  $\mu\text{S}/\text{cm}$  (Figure 5.3.6-1), which is not appreciably different from previous years.

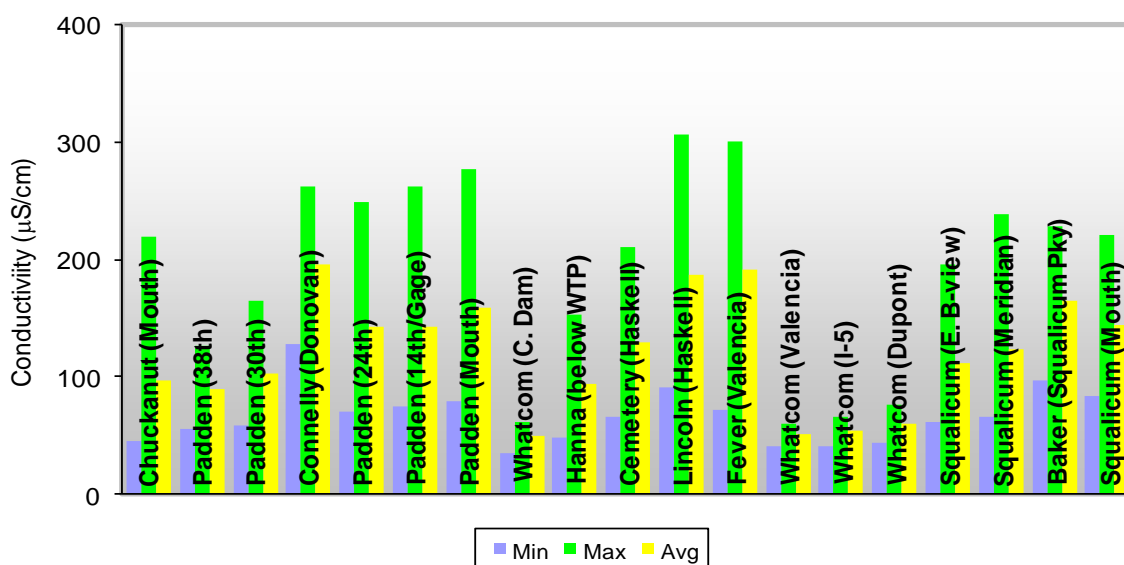


Figure 5.3.6-1. Minimum, maximum, and average conductivity values for all stream segments sampled in 2014. No numeric criterion exists in the WAC for conductivity.

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## 6.0 Chuckanut Creek Drainage Basin

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The drainage area of Chuckanut Creek is approximately 4,834 acres (City of Bellingham, 1995). The creek flows through mostly forested lands and some residential areas. It discharges to an estuary in Chuckanut Bay, adjacent to Bellingham Bay. Most of the creek lies outside Bellingham city limits.

Chuckanut Creek has been included in Bellingham's Urban Stream Monitoring Program since 1990 and is sampled at one site, near the mouth (Figure 6.0-1). Samples are collected approximately 1200 feet from the discharge point into Chuckanut Bay (Chuckanut Drainage Map).

Chuckanut Creek met all Aquatic Life Use (ALU) criteria in 2014 (temperature - 16°C, dissolved oxygen - 9.5 mg/L, and pH 6.5 - 8.5 s.u.), and the Primary Recreational

Contact designated use criteria for fecal coliform (geomean  $\leq 100$  CFU/100 ml; no more than 10% of samples  $> 200$  CFU/100 ml).

These results translate to Class AA criterion for temperature, dissolved oxygen and pH, and the Class A criteria for fecal coliform (geomean  $\leq 100$  CFU/100 ml; no more than 10% of samples  $> 200$  CFU/100 ml), earning Chuckanut an overall Class A rating for 2014.

The average turbidity for 2014 was 2.8 NTU, which is below both the 5 year average of 4.5 NTU and the 10 year average of 4.8 NTU. Conductivity was relatively unchanged from previous years.



Figure 6.0-1 Chuckanut Creek mouth sampling site.

## Fecal Coliform Bacteria

Fecal coliform concentrations for 2014 follow the expected trend of higher values in the warmer months, possibly as bacteria become more concentrated due to lower flows, and/or as higher temperatures encourage extended survival or growth of bacterial populations. The geomean

obtained from conventional sampling at the Chuckanut Creek mouth site was 21 CFU/100 ml. In contrast, critical period enhance sampling had a geomean of 162 CFU/100 ml. Analysis of the 30 value moving geometric mean for all conventional samples taken over the last 10 years show a significant decreasing trend of  $-3.9$  CFU/100 ml/year (Figure 6.0-3).

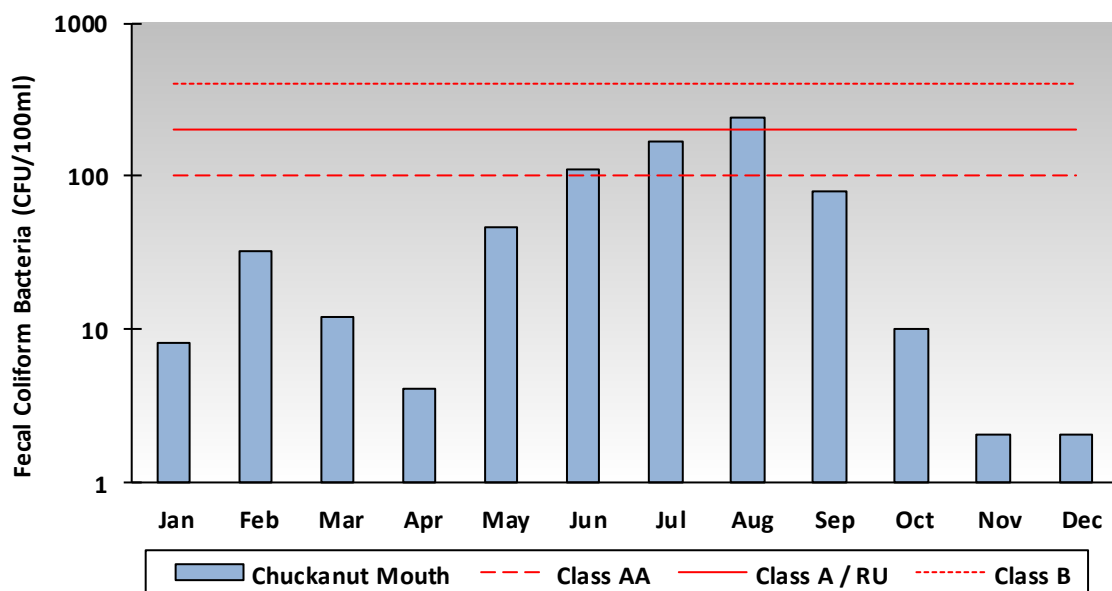


Figure 6.0-2. Fecal coliform bacteria levels for Chuckanut Creek sampling site by month for 2014. Red lines indicate the numeric criteria for the calculated geomean for the different surface water classes (AA, A, and B). The Primary Contact Recreational Use (RU) designation is equivalent to Class A. *Note this graph uses a logarithmic scale.*

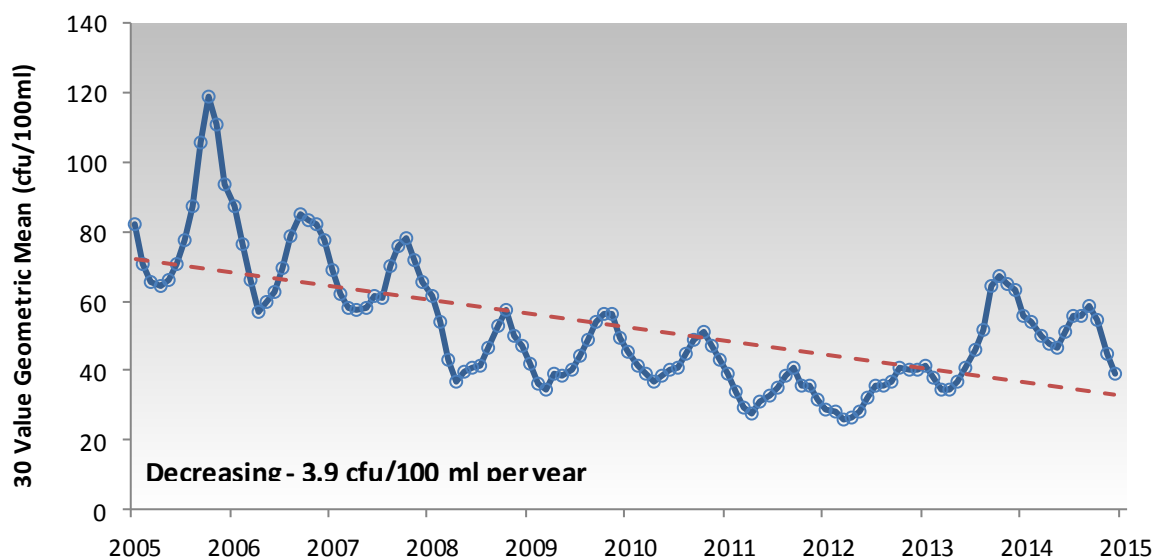


Figure 6.0-3. Thirty value moving geometric mean trend for all samples collected 2005 through 2014. Trend (red) shows significant decreasing trend of  $-3.9$  cfu/100 ml/year ( $p = 5.2 \times 10^{-14}$ ,  $\alpha = 0.05$ ).

## Dissolved Oxygen

Dissolved oxygen levels for 2014 follow a typical seasonal trend of low levels found in the warmer summer months when temperatures are higher (Figure 6.0-4). The low dissolved oxygen level was 9.0 mg/L and the average was

11.7 mg/L. Dissolved oxygen levels in Chuckanut Creek fell below the ALU standard of 9.5 mg/L twice in 2014. While the ten year trend in dissolved oxygen values appears positive, the slope of the trendline is not significantly different than zero (Figure 6.0-5).

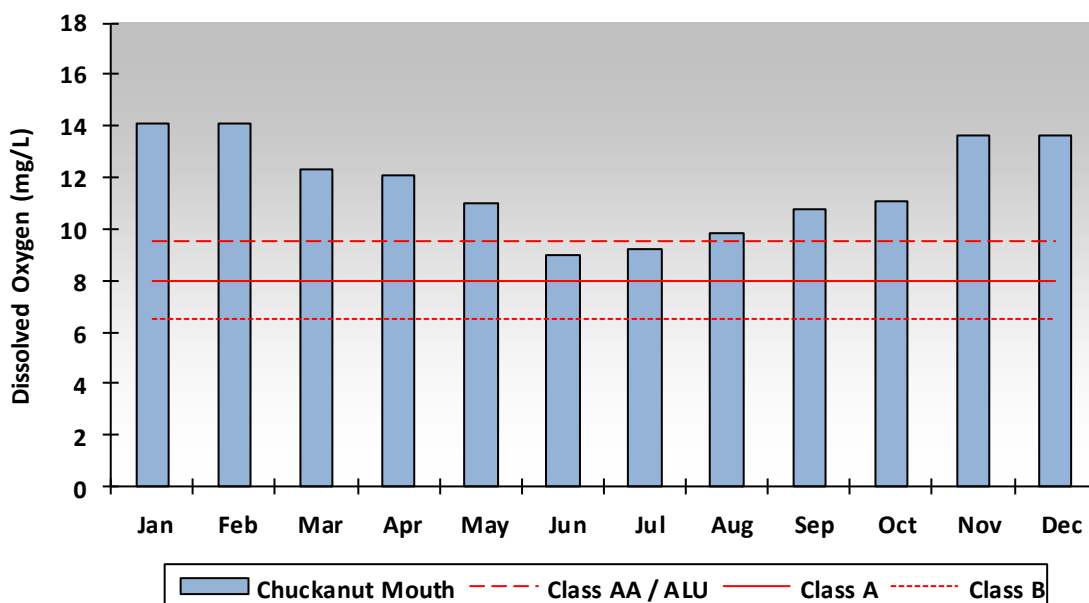


Figure 6.0-4. Monthly 2014 dissolved oxygen levels for Chuckanut Creek. Red lines indicate the lowest dissolved oxygen levels allowed by the different surface water standards (AA, A, and B). Core Summer Salmonid Habitat Aquatic Life Use (ALU) is equivalent to Class AA.

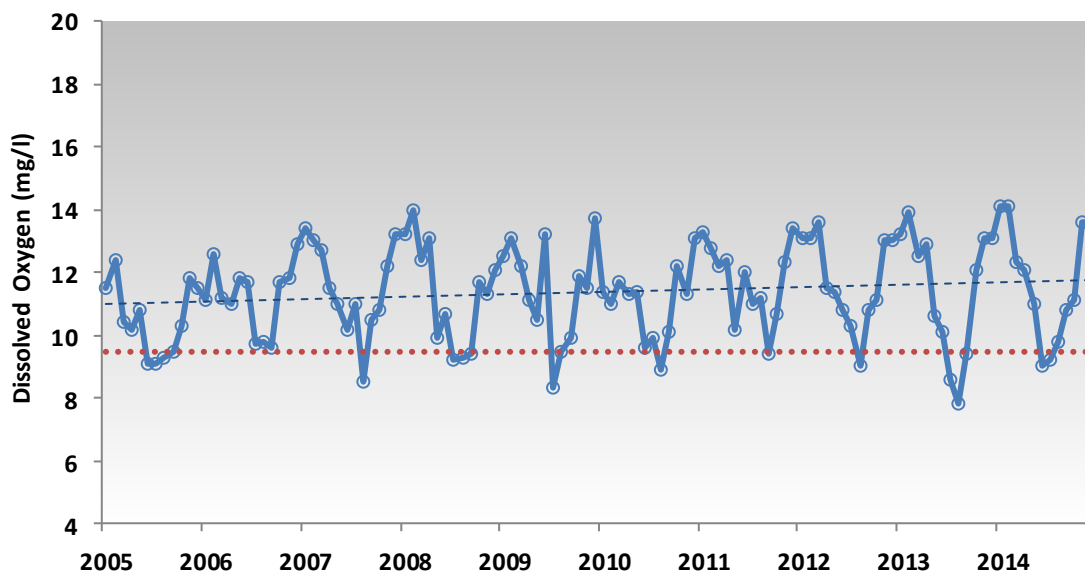


Figure 6.0-5. Ten year dissolved oxygen trend for Chuckanut Creek (2005-2014). Although the trendline (blue) appears positive, the probability that the slope is different than zero is not significant ( $p = 0.11$ ,  $\alpha = 0.05$ ). Red dotted line indicates the Aquatic Life Use criteria of 9.5 mg/L.



## Temperature

The recorded temperature for Chuckanut Creek did not exceed the Class A criteria (18°C) in 2014, and exceeded the Aquatic Life Use (ALU) (16°C) standard only once during the year. The temperature profile followed normal seasonal trends (Figure 6.0-6). The maximum temperature for 2014 was recorded in July at

16.7°C. The average temperature was 10.0°C.

Temperatures in Chuckanut Creek rarely exceed standards. The Core Summer Salmonid Habitat ALU standard has been exceeded only four times in the past 10 years. The slope of the 10 year trendline is not significantly different from zero (Figure 6.0-7).

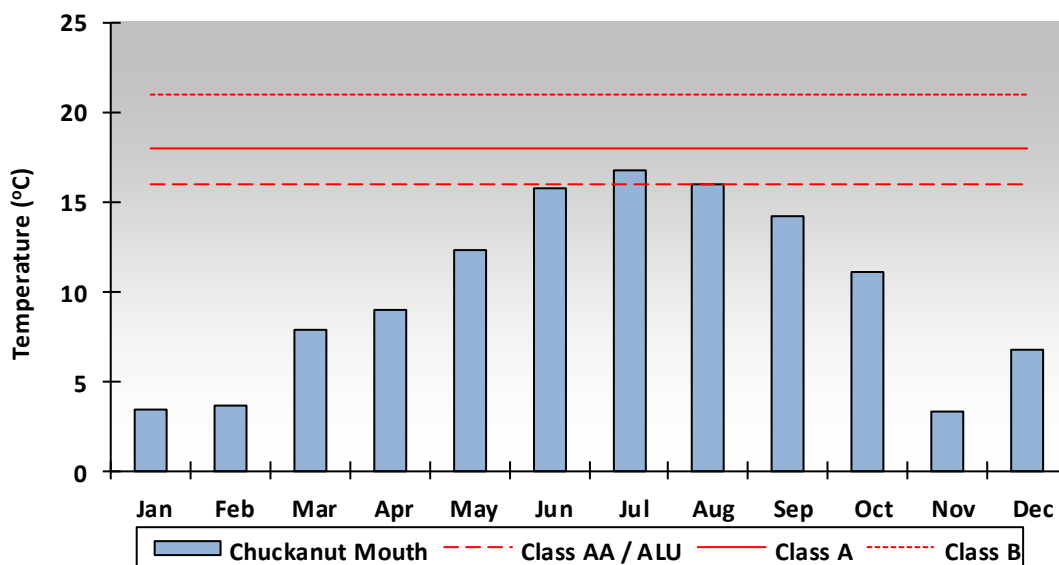


Figure 6.0-6. Monthly temperature measurements for the Chuckanut Creek sampling site in 2014. Red lines indicate the highest temperatures allowed by the different surface water standards (AA, A, and B). The Core Summer Salmonid Habitat ALU is equivalent to Class AA.

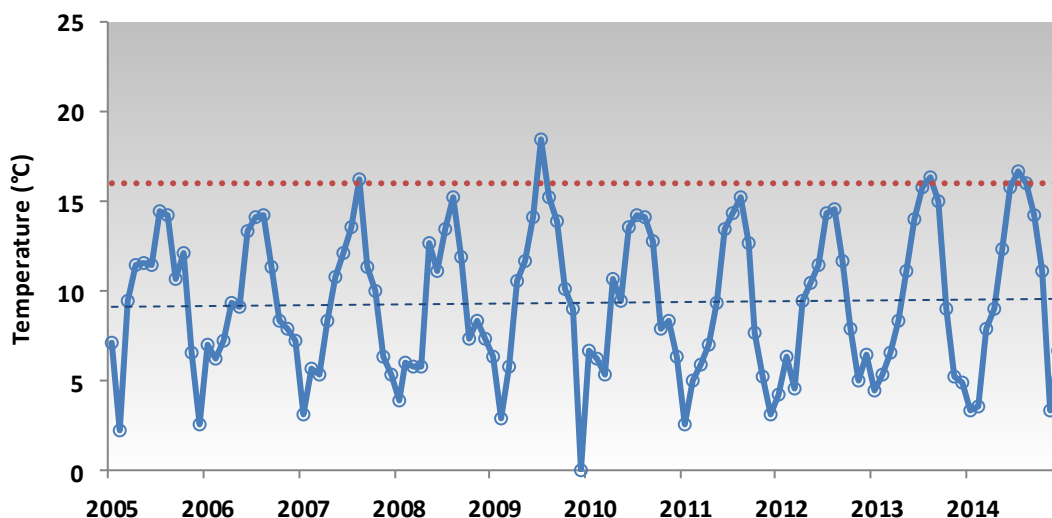


Figure 6.0-7. Ten year temperature trend for Chuckanut Creek (2005-2014). Although the trendline (blue) appears slightly negative, the probability that the slope is different than zero is not significant ( $p = 0.75$ ,  $\alpha = 0.05$ ). Red dotted line indicates the Aquatic Life Use criteria of 16°C.

## Turbidity

Turbidity in Chuckanut Creek rarely reaches or exceeds levels considered deleterious to salmon and trout (Berg, 1982; Sigler et al., 1984; Harvey, 1989; Bjornn and Reiser, 1991). This trend continued in 2014. The maximum turbidity measured was 7.7 NTU recorded in February. The minimum

turbidity measured was 0.9 NTU in September.. Higher turbidities are expected during the winter months as more precipitation occurs at this time of year. The average turbidity for Chuckanut Creek in 2014 was 2.8 NTU, which is less than both the 5 year and 10 year averages. The ten year trendline slope is not significantly different than zero (Figure 6.0-8).

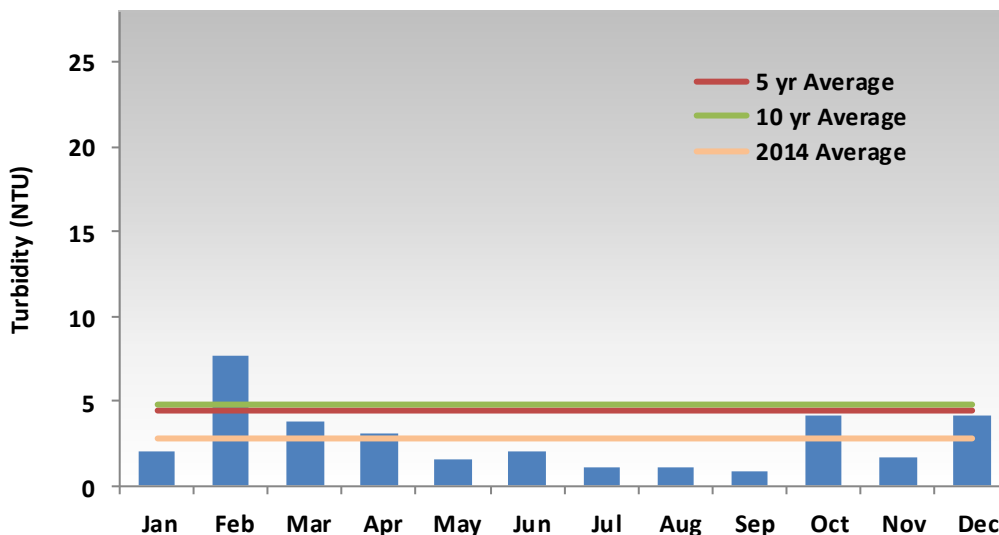


Figure 6.0-8. Monthly turbidity values and yearly averages for the Chuckanut Creek sampling site in 2014. Presented with yearly, 5-year and 10-year averages. Spikes in January, September and November are storm related.

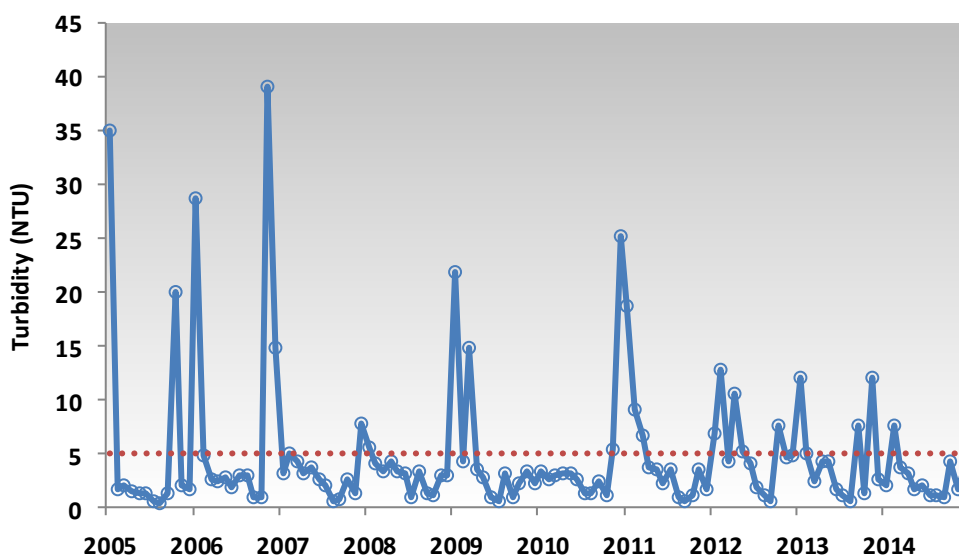


Figure 6.0-9. Ten year turbidity trend for Chuckanut Creek Mouth illustrate the effects of storm events on average turbidity. Red dotted line depicts the ten year average of 4.8 NTU.

## Hydrology

The Chuckanut Creek gauging station has been in service since 2005. It is located approximately 300 feet downstream of the footbridge in Arroyo Park. Chuckanut Creek typically has higher volume of discharge than Padden Creek, but less than Squalicum Creek. Exceptions to this typical trend occur occasionally when rain events cause the peak flow of Padden Creek to spike higher than that of Chuckanut.

397 cfs on November 28th and an median discharge of 7.0 cfs. First quartile flow was 1.3 cfs (i.e. 25% of the flow data was below this value) and Third quartile flow was 17 cfs (i.e. 25% of flow was above this value).

In 2014, Chuckanut Creek had a minimum discharge (flow) of < 0.01 cubic feet per second (cfs) on multiple days in August and September, a maximum discharge of

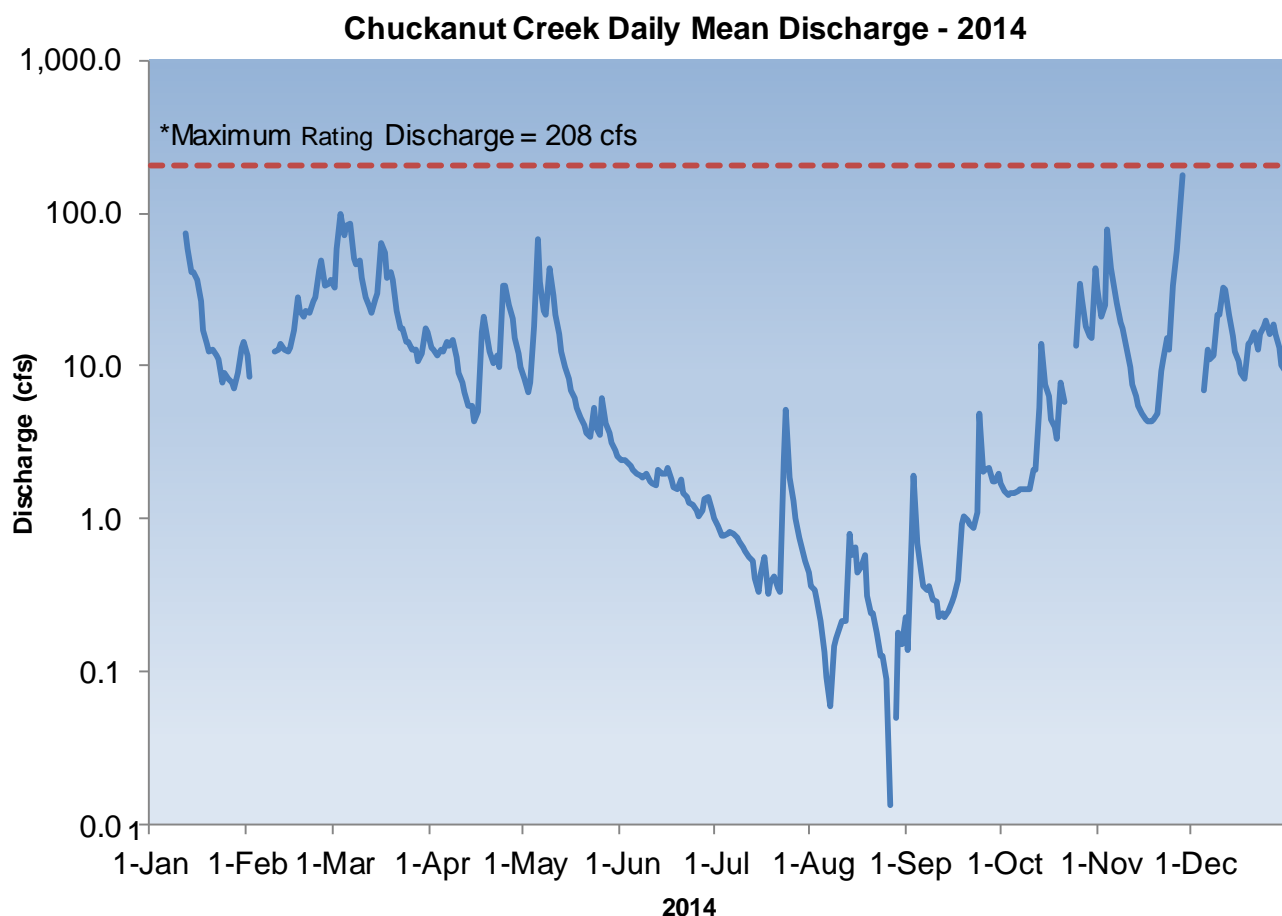


Figure 6.0-10. Daily mean discharge on Chuckanut Creek during 2014. Discharge values above the maximum rating discharge of 208 cfs are of poor quality and should be interpreted cautiously. Breaks in record are due to equipment malfunction. This hydrograph uses a logarithmic scale.

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## 7.0 Padden Creek Drainage Basin

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Padden Creek flows from its headwaters, Lake Padden, to an estuary adjacent to Bellingham Bay. The Padden Creek drainage area is approximately 3840 acres (Ecology, 1997) and the creek receives inputs from Western Washington University as well as residential areas and a commercial area located at the base of Sehome Hill. The largest tributary to Padden Creek is Connelly Creek.

Padden Creek flows through mainly residential areas and parks. A small industrial area is located near the mouth. Much of the riparian zone is wooded. The course of Padden Creek is restricted by the placement of culverts at various points along the waterway, including a 5-block culvert between 17th and 22nd Streets that is currently being removed.

Padden Creek is sampled at five locations: 38th St., 30th St. (Figure 7.0-4), 24th St. (Figure 7.0-15), near the end of 14th St. (Figure 7.0-11) and near the mouth (Figure 7.0-5), approximately 1500 feet upstream from its discharge point. Connelly Creek, the main tributary to Padden Creek, is sampled at Donovan Ave. (Figure 7.0-8).

Based on conventional sampling in 2014, none of the sites in the Padden Creek drainage were able to meet all of the Aquatic Life Use (ALU) and Recreational Use (RU) standards. However, Padden Creek at 38th street did meet overall Class A water quality standards. The sites at 30th Street, 24th Street, 14th Street, the Mouth and Connelly Creek were not able to meet overall Class A or Class B standards.

Monitoring indicates that Connelly Creek, the 14th St/Gage site, and the Mouth of Padden Creek all met the stringent  $\leq 16.0^{\circ}\text{C}$  ALU/Class AA standard for temperature in 2014. The 14th St. site was the only site to



meet the  $\geq 9.5$  mg/L ALU/Class AA standard for Dissolved Oxygen. All the other sites in the drainage met the  $\leq 18.0^{\circ}\text{C}$  and  $\geq 8.0$  mg/L Class A standards respectively.

The limiting factor for most of the Padden Creek drainage sites was fecal coliform values. Only the 38th Street site was able to meet any of the class based standards, receiving a class A fecal coliform rating for 2014 (geomean  $\leq 100$  CFU/100 ml; no more than 10% of samples  $> 200$  CFU/100 ml).

In 2014, the average turbidities for the 24th Street, Padden Mouth and Connelly Creek sites were below both the 5-year and 10-year averages, while the 38th and 30th Street sites were above. The highest average turbidity for 2014 was found at 30th St. (4.5 NTU), while Padden Creek at 24th St. had the lowest average turbidity at 3.0 NTU (Table 7.0-4).



As in years past, all sites on Padden Creek and Connelly Creek met the Aquatic Life Use (ALU) standards for pH (6.5 - 8.5 s.u.). Conductivity was also consistent with previous years.

### Chronic Low Flow Conditions

Low flow conditions of 0.4 cfs or below have been recorded in Padden Creek in every year since the gauge station was installed in 2005. Historically, low flows have been documented in Padden Creek since the 1960's when the City stopped using Lake Padden as a water supply. In 2002 the Washington Department of Fish and Wildlife (WDFW) approved a request from the Nooksack Salmon Enhancement Association (NSEA) to install a siphon pulling water from Lake Padden in order to keep the creek at levels adequate to support fish populations down-



Figure 7.0-1. Dry control gate spillway at Lake Padden in September of 2011.

stream. However, the siphon was removed in 2005 after the City asked that Ecology be consulted regarding the effects of siphoning on Lake Padden shoreline habitat. Pipe flanges were subsequently installed in the Lake Padden control gate (Figure 7.0-1) in case siphoning is requested by state officials in the future. Information regarding Lake Padden water quality can be found here: <http://www.wvu.edu/iws/> and here: <http://www.p4lp.org/>.

### Fecal Coliform Bacteria

The fecal coliform levels found during sampling of Padden and Connelly Creeks followed the expected trend of higher levels in the summer months. With the exception of the Padden Mouth site, the geomeans for 2014 were lower than in 2013 (Table 7.0-1). The number of samples that exceeded 200 CFU/100 ml is presented in Figures 7.0-2a&b.

With the exception of the 38th Street site, all of the monitoring locations in the Padden Creek Drainage had significant descending 10-year trends in fecal coliform geomeans (Figures 7.0-3 a-e.)

Table 7.0-1. Fecal coliform geomean values and 10-year trends for monitoring sites on Padden and Connelly Creeks in 2014.

Sampling Site	Geomean (CFU/100 ml)	Trend (CFU/100 ml/yr)
38 <sup>th</sup> Street	18	0
30 <sup>th</sup> Street	38	-1.1
Connelly	83	-13.3
24th Street	118	0
14th/Gage	187	na
Mouth	213	-0.4

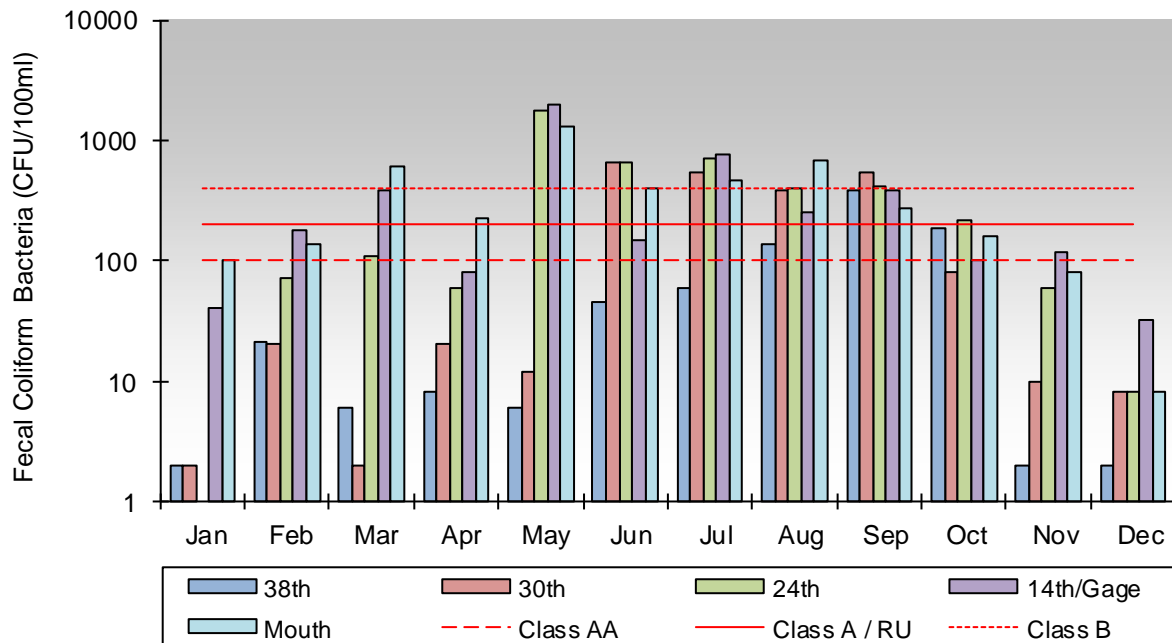


Figure 7.0-2a. Monthly 2014 fecal coliform levels for Padden Creek sampling sites. Red lines indicate the numeric criteria for the calculated geomean for the different surface water classes (AA, A, and B). The Primary Contact Recreational Use (RU) designation is equivalent to Class A. *Note this graph uses a logarithmic scale.*

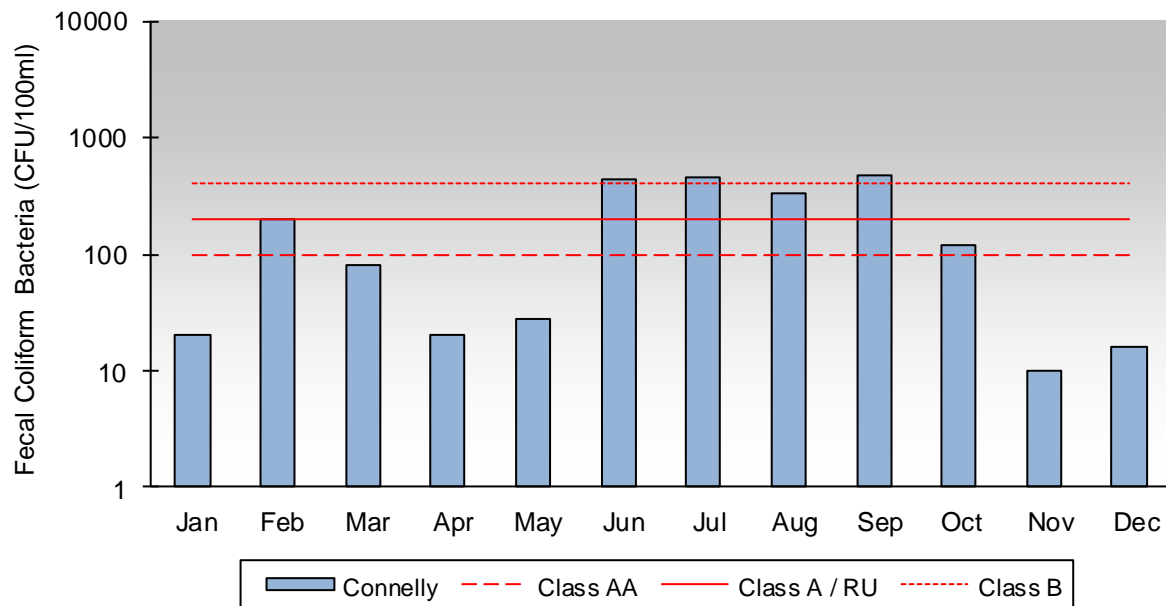
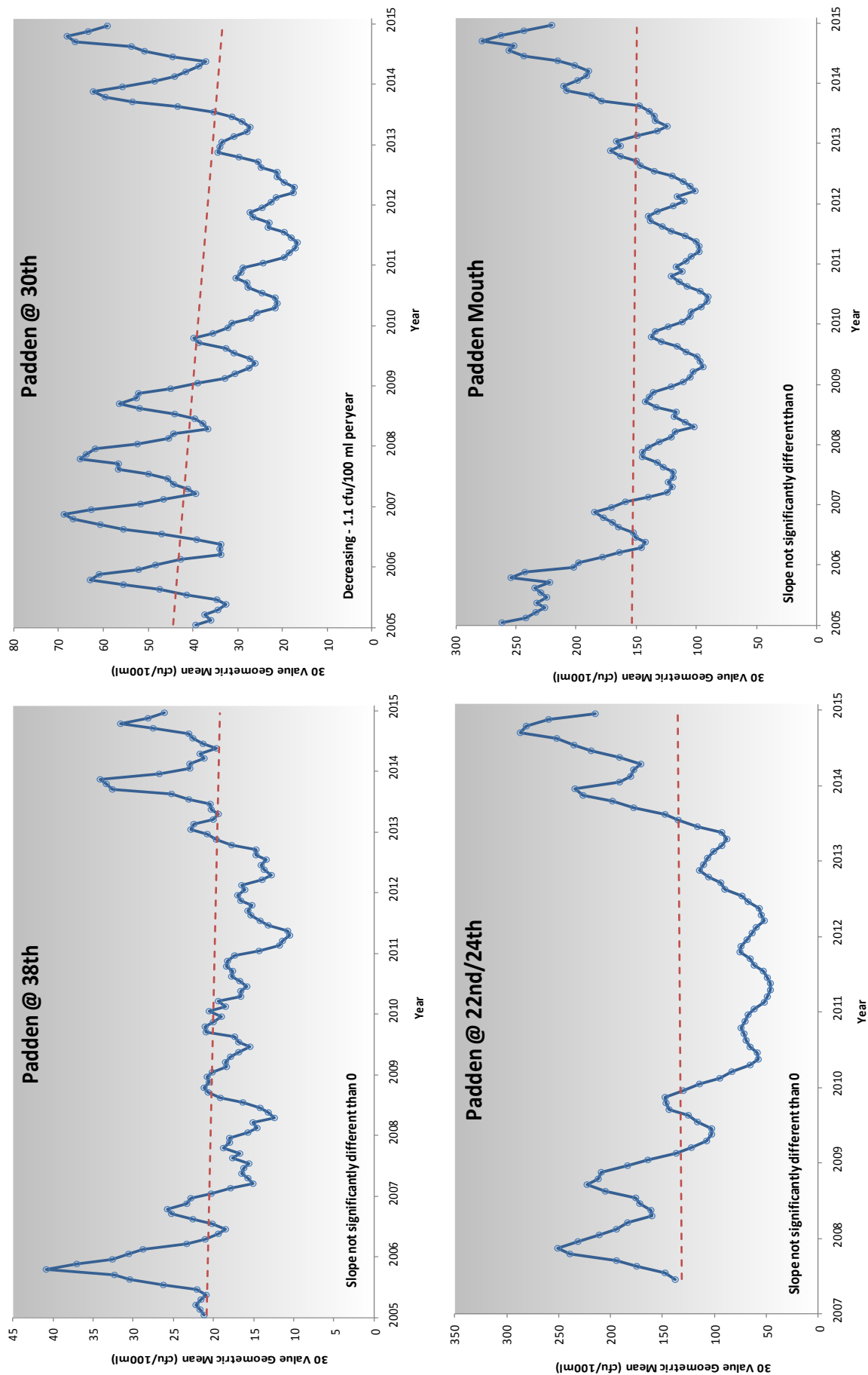
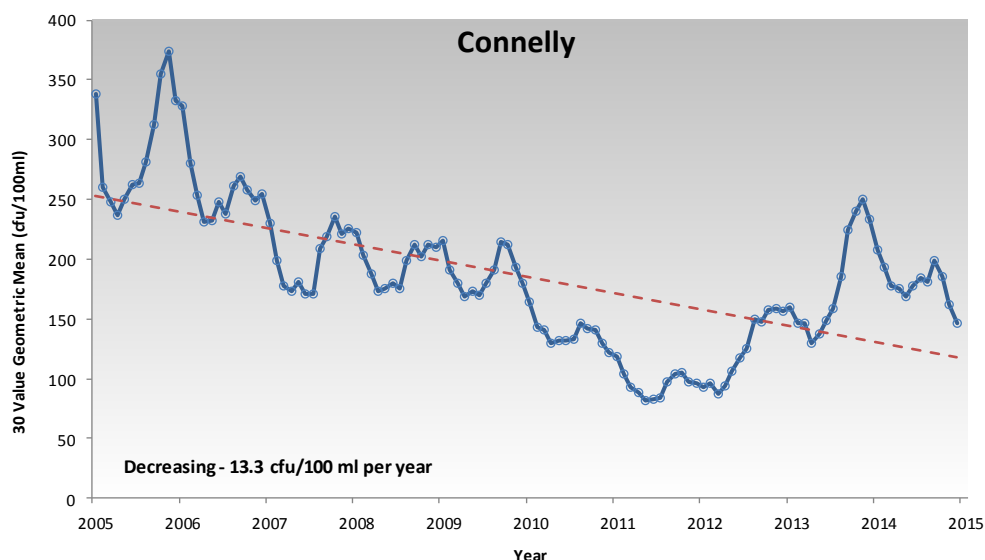


Figure 7.0-2b. Monthly 2014 fecal coliform levels for Connelly Creek sampling site. Red lines indicate the numeric criteria for the calculated geomean for the different surface water classes (AA, A, and B). The Primary Contact Recreational Use (RU) designation is equivalent to Class A.. *Note this graph uses a logarithmic scale.*



Figures 7.0-3 a-d. Thirty value moving geometric mean trends for all fecal coliform samples collected 2005 through 2014. With the exception of the 30th Street site, none of the monitoring locations on Padden Creek had 10-year trends in fecal coliform geomans that were significantly different than 0 (38th:  $p = 0.36$ ; 30th:  $p = 0.01$ ; 22nd/24th:  $p = 0.87$ ; Mouth:  $p = 0.79$ ,  $\alpha = 0.05$ ). Trendline in red.



Figures 7.0-3e. Thirty value moving geometric mean trend for all samples collected at the Connelly Creek site 2005 through 2014. Linear model analysis of the trendline shows significant descending trend of  $-13.3 \text{ cfu/100ml/yr}$  ( $p = 9.83 \times 10^{-15}$ ,  $\alpha=0.05$ ). Trendline in red.

## Dissolved Oxygen

In 2014, all sites in the Padden Creek Drainage remained above the 8.0 mg/L Class A standard, and the 14th St. site met the Core Summer Salmonid Habitat Aquatic Life Use (ALU) criteria of 9.5 mg/L for dissolved oxygen. The Core Summer Salmonid Habitat ALU is equivalent to the Class AA standard. Dissolved oxygen in these two creeks follows an expected trend with lower levels in the warmer summer months (Figures 7.0-6a&b). Average dissolved oxygen values are provided in Table 7.0-2.

While most of the ten year dissolved oxygen trendlines appear positive, recorded values have fallen below the 9.5 mg/L ALU standard at least once every year for every site, and none of the slopes are significantly different than zero (Figure 7.0-7a-e.).

Table 7.0-2. Average dissolved oxygen values for Padden and Connelly Creeks in 2014.

Sampling Site	38 <sup>th</sup> Street	30 <sup>th</sup> Street	Connelly	24 <sup>th</sup> Street	14 <sup>th</sup> Street	Mouth
Average DO (mg/L)	11.2	11.2	10.3	10.8	11.7	10.8



Figure 7.0-4. Padden Creek 30<sup>th</sup> St. sampling site.



Figure 7.0-5. Padden Creek mouth sampling site.



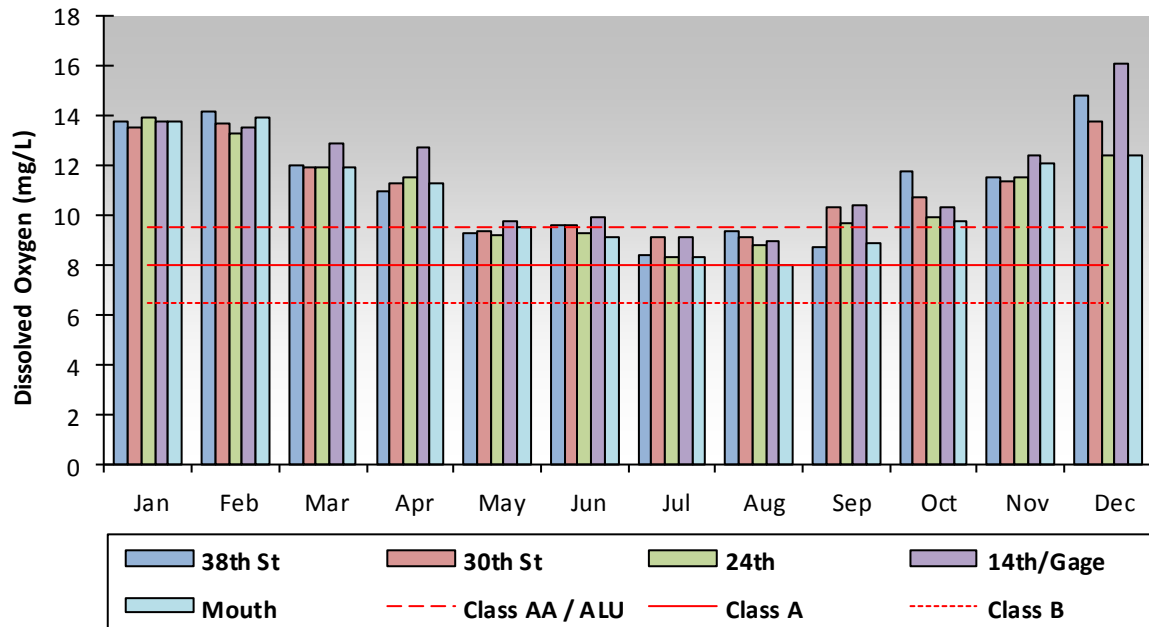


Figure 7.0-6a. Dissolved oxygen for Padden Creek sampling sites by month in 2014. Red lines indicate the lowest dissolved oxygen levels allowed by the different surface water classes (Class AA, A, and B). Core Summer Salmonid Habitat Aquatic Life Use (ALU) is equivalent to Class AA.

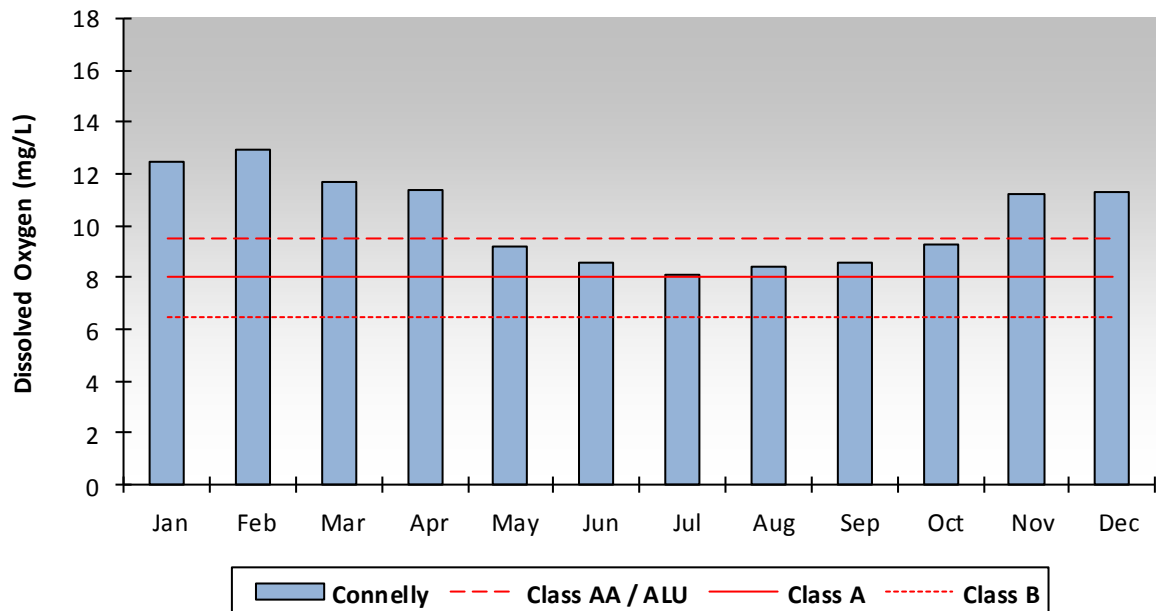
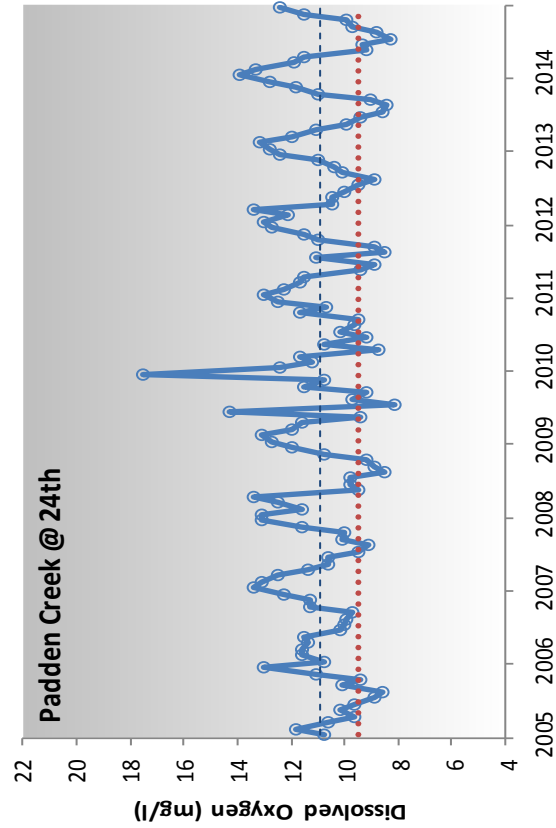
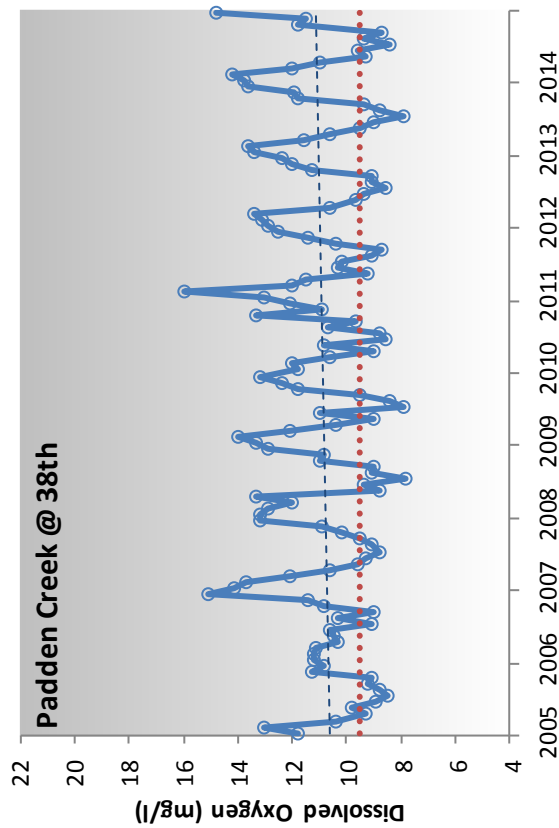
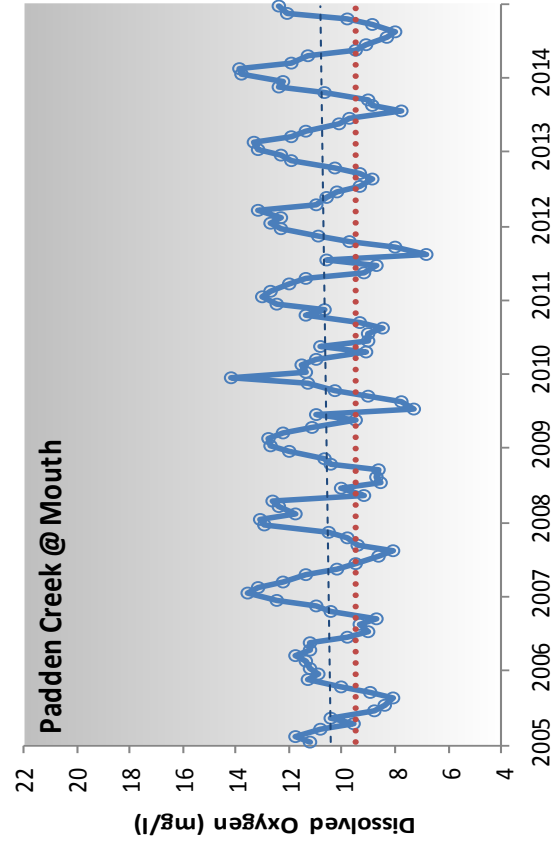
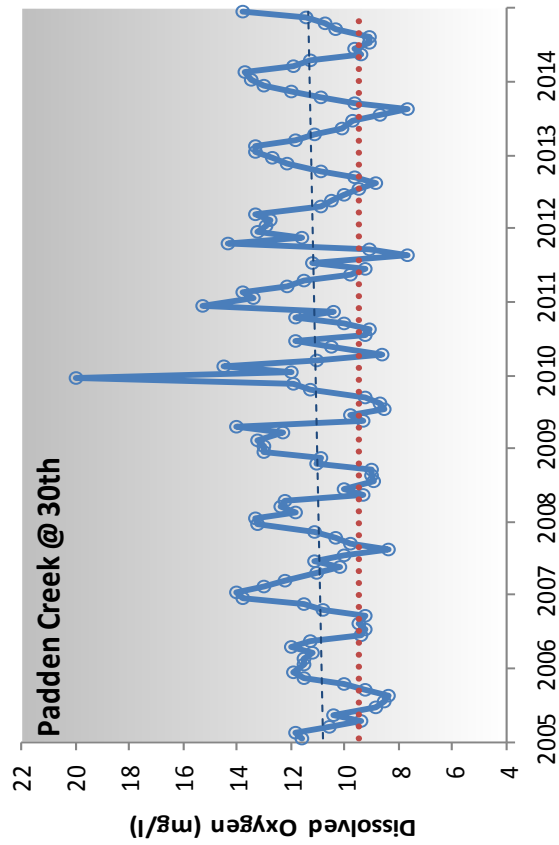


Figure 7.0-6b. Dissolved oxygen for the Connelly Creek sampling site by month in 2014. Red lines indicate the lowest dissolved oxygen levels allowed by the different surface water classes (Class AA, A, and B). Core Summer Salmonid Habitat Aquatic Life Use (ALU) is equivalent to Class AA.



Figures 7.0-7a-d. Ten year dissolved oxygen trend for Padden Creek sites (2005-2014). Although the trendlines (blue) appear positive, the probability that the slopes are different than zero is not significant (38th:  $p = 0.33$ ; 30th:  $p = 0.40$ ; 24th:  $p = 0.98$ ; Mouth:  $p = 0.53$ ,  $\alpha = 0.05$ ). Red dotted line indicates the Aquatic Life Use criteria of 9.5 mg/L.

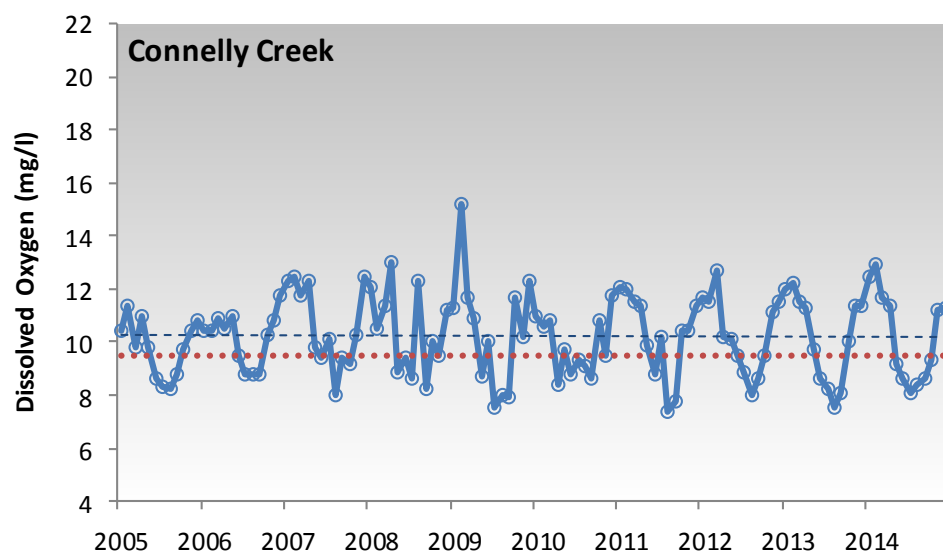


Figure 7.0-7e. Ten year dissolved oxygen trend (blue) for Connelly Creek sites (2005-2014). The probability that the slope is different than zero is not significant ( $p = 0.90$ ,  $\alpha = 0.5$ ).



Figure 7.0-8. Connelly Creek sampling site.

## Temperature

Connelly Creek, Padden Creek at 14th Street and Padden at the Mouth were able to meet the 16°C Core Summer Salmonid Habitat Aquatic Life Use (ALU)/Class AA criterion in 2014. All other sites in the drainage met the 18°C Class A standard. Temperatures in Padden and Connelly Creeks do not exceed standards often. The 18°C Class A standard has not been exceeded in greater than 10% of all samples taken in any year since 1999. The temperature profiles for all segments in 2014 show the expected seasonal trend with higher temperatures in the summer months (Figures 7.0-9a&b). Average temperatures are provided in Table 7.0-3.

Although some of the ten year trend-lines appear slightly negative, none of the slopes are significantly different than zero (Figure 7.0-10a-e.).

Table 7.0-3. Average temperatures for sampling sites on Padden and Connelly Creek, 2014.

Sampling Site	38 <sup>th</sup> Street	30 <sup>th</sup> Street	Connelly	24 <sup>th</sup> Street	14 <sup>th</sup> Street	Mouth
Average Temperature (°C)	11.5	11.5	11.0	11.4	11.4	11.5

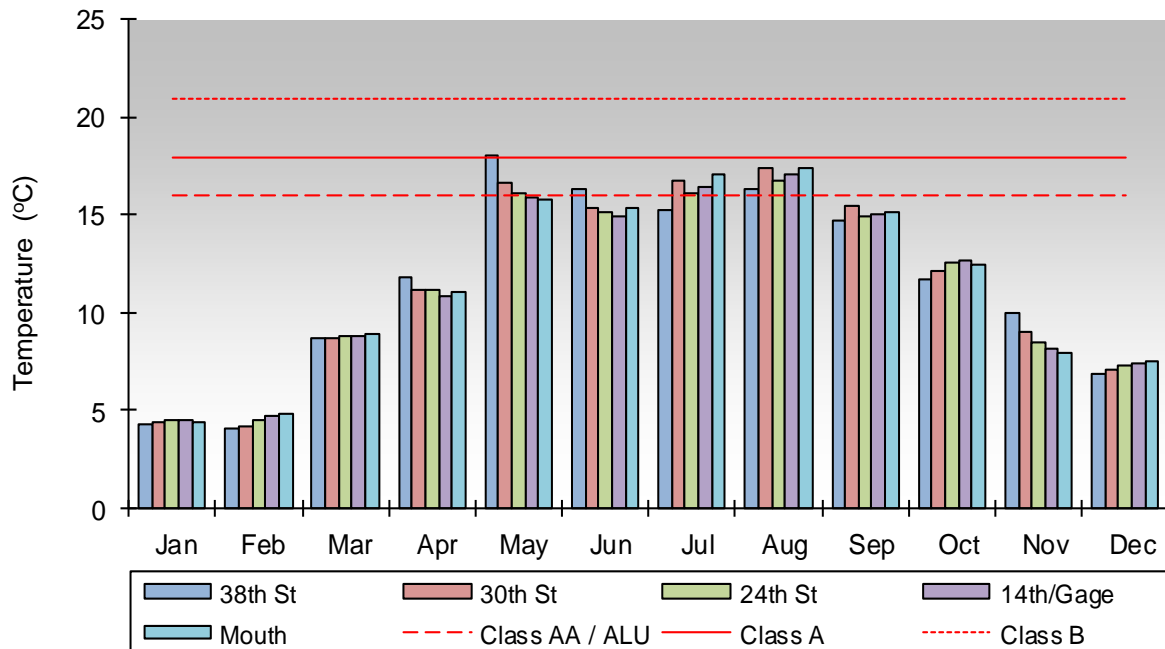


Figure 7.0-9a. Monthly temperature measurements for Padden Creek sampling sites in 2014. Red lines indicate the highest temperatures allowed by the different surface water standards (AA, A, and B).

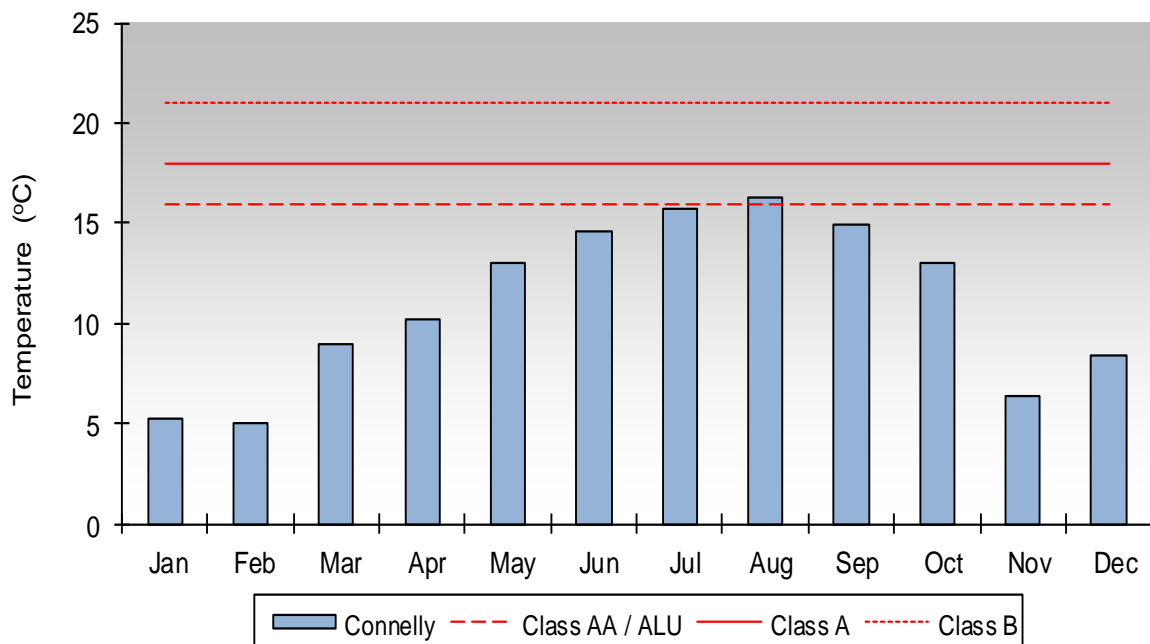
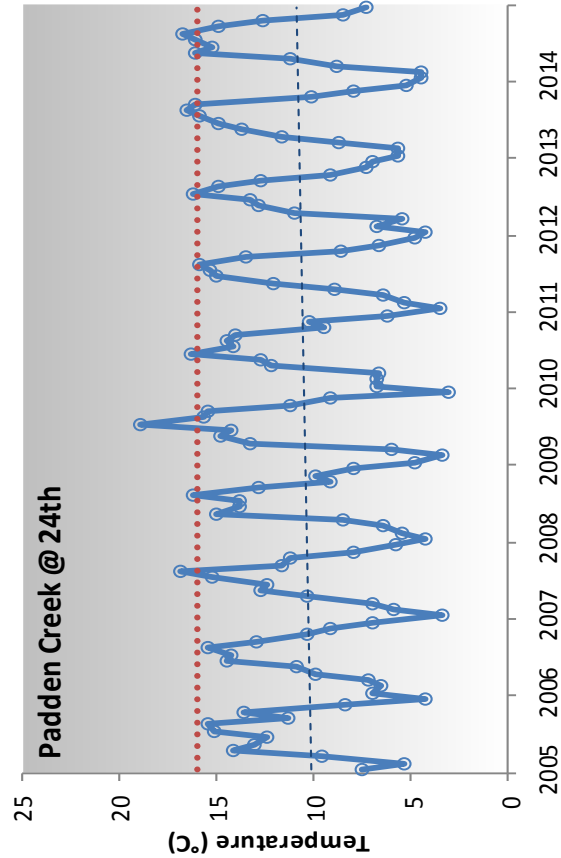
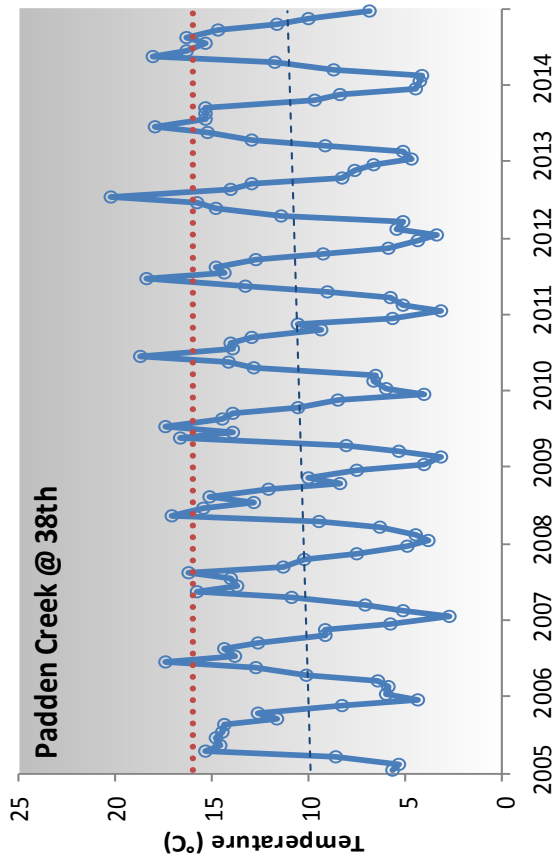
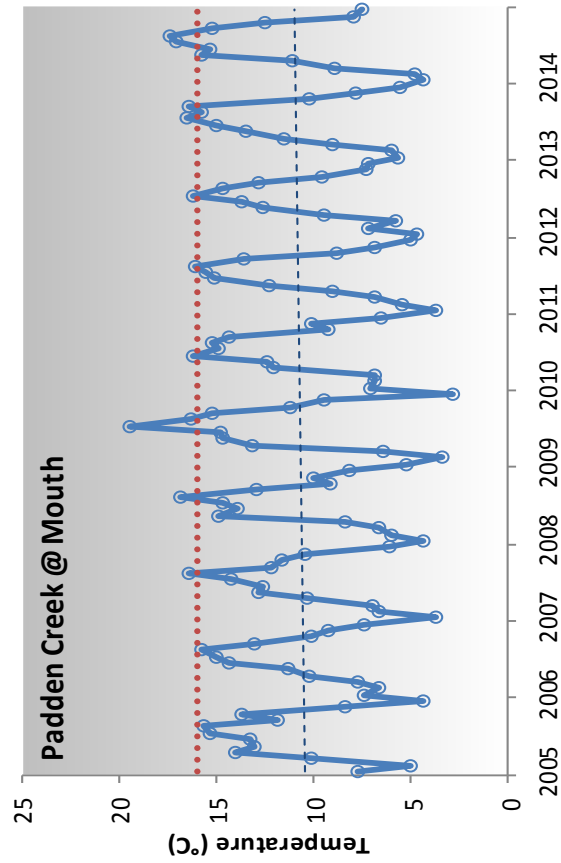
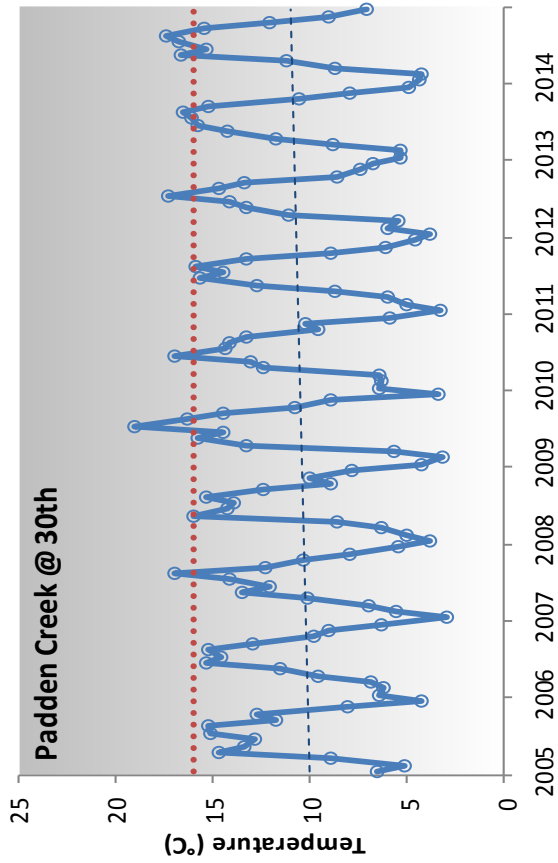


Figure 7.0-9b. Monthly temperature measurements for the Connelly Creek sampling site in 2014. Red lines indicate the highest temperatures allowed by the different surface water standards (AA, A, and B). Core Summer Salmonid Habitat Aquatic Life Use (ALU) is equivalent to Class AA.





Figures 7.0-10a-d. Ten year temperature trends for Padden Creek sites (2005-2014). Although some trendlines (blue) appear slightly negative, the probability that the slopes are different than zero is not significant for all sites (38th:  $p = 0.43$ ; 30th:  $p = 0.44$ ; 24th:  $p = 0.57$ ; Mouth:  $p = 0.67$ ,  $\alpha = 0.05$ ). Red dotted line indicates the Aquatic Life Use criteria of 16°C.

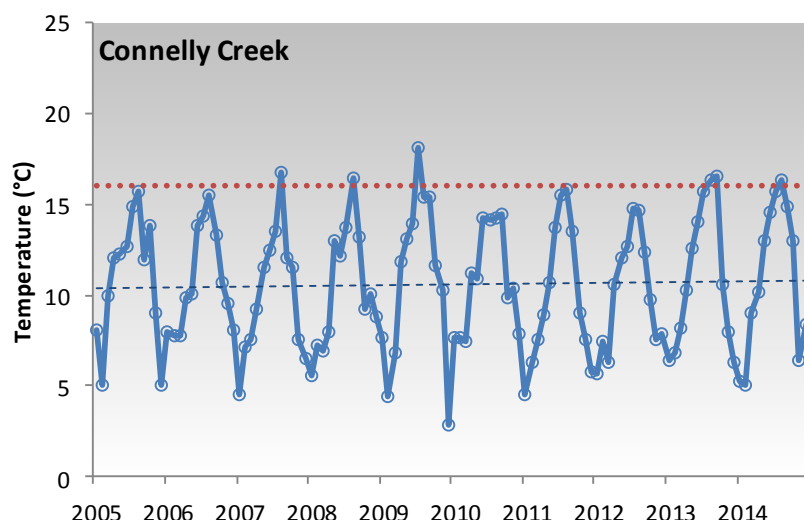


Figure 7.0-10e. Ten year temperature trend for Connelly Creek (2005-2014). Although trendline (blue) appears slightly negative, the probability that the slope is different than zero is not significant ( $p = 0.71$ ,  $\alpha = 0.05$ ).

## pH

The pH at all sites monitored on Padden and Connelly Creeks generally falls within the range prescribed by Ecology for Aquatic Life Use (ALU) and all classes of freshwater bodies (6.5 to 8.5). In 2014, pH for all sites fell within the prescribed range. Graphs are not included in this section because pH is so rarely exceeded.

## Turbidity

Turbidity in Padden and Connelly Creeks is generally below 10 NTU, with occasional spikes. This trend continued in 2014, with the average turbidities for the 24th Street, Padden Mouth and Connelly Creek sites below both the 5-year and 10-year averages. However, both the 38th and 30th Street sites were above the 5-year and 10-year aver-

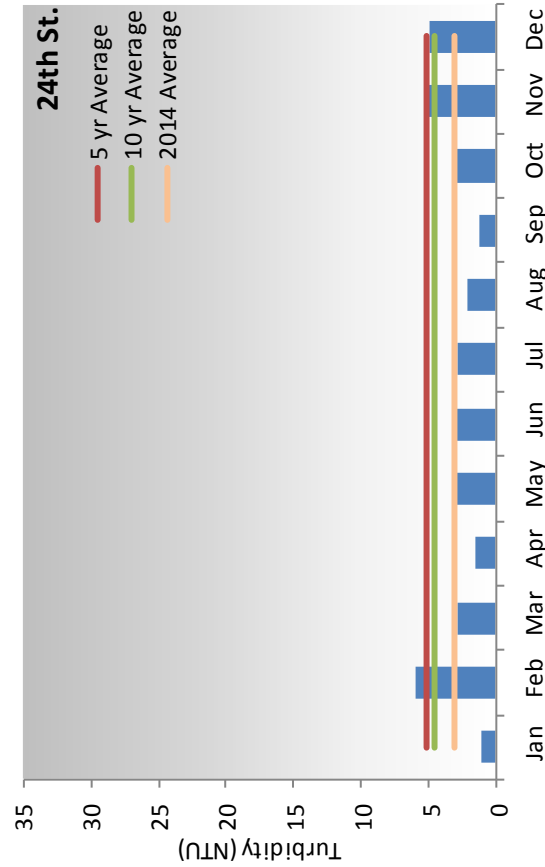
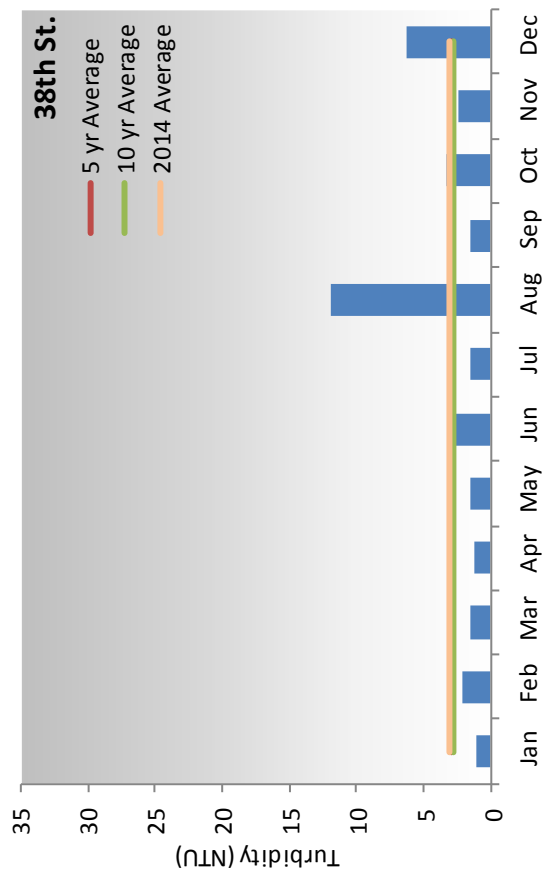
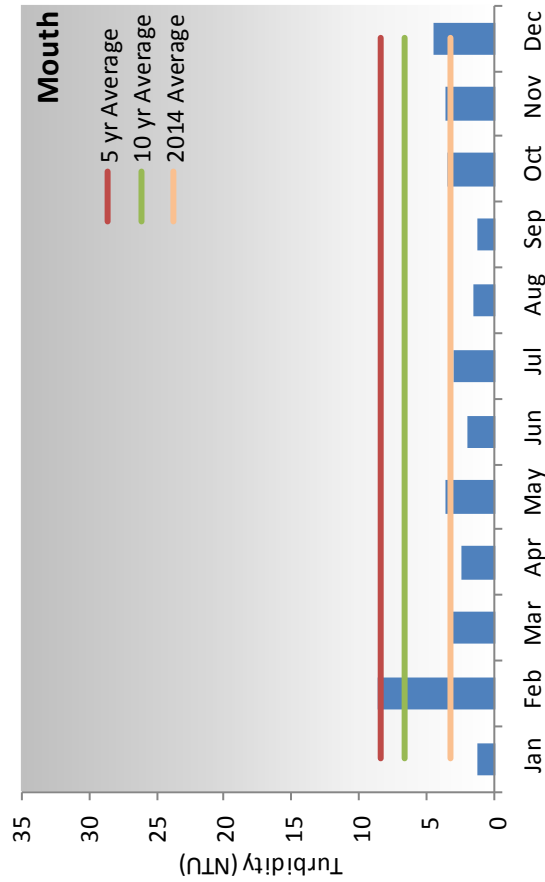
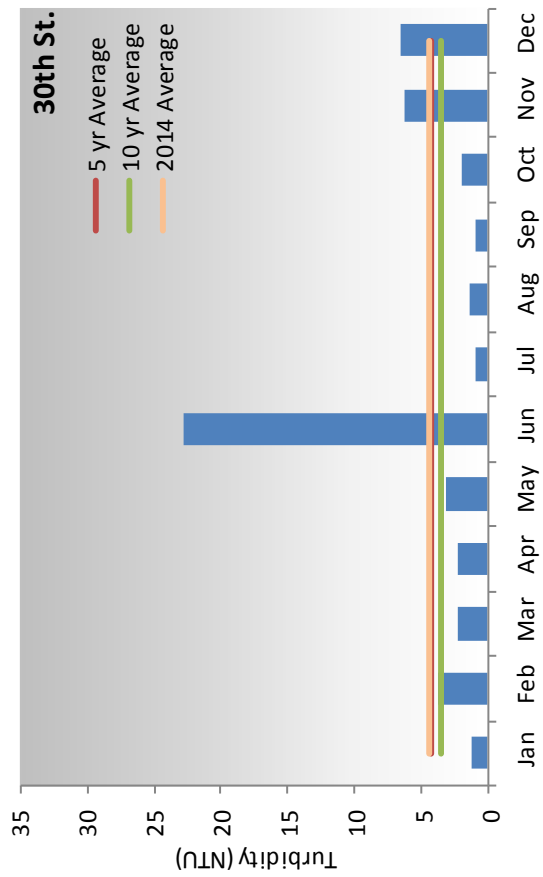
ages. Average, maximum and minimum turbidity values for 2014 are listed in Table 7.0-4. Average turbidity values for Padden Creek in 2014 are displayed alongside their respective 5-year and 10-year averages in figures 7.0-12a-d, while 10-year trendlines are displayed in figures 7.0-13a-d. Connelly Creek average turbidity and trendlines are displayed in figures 7.0-14&15. None of the trendlines were found to be significantly different than zero in 2014.



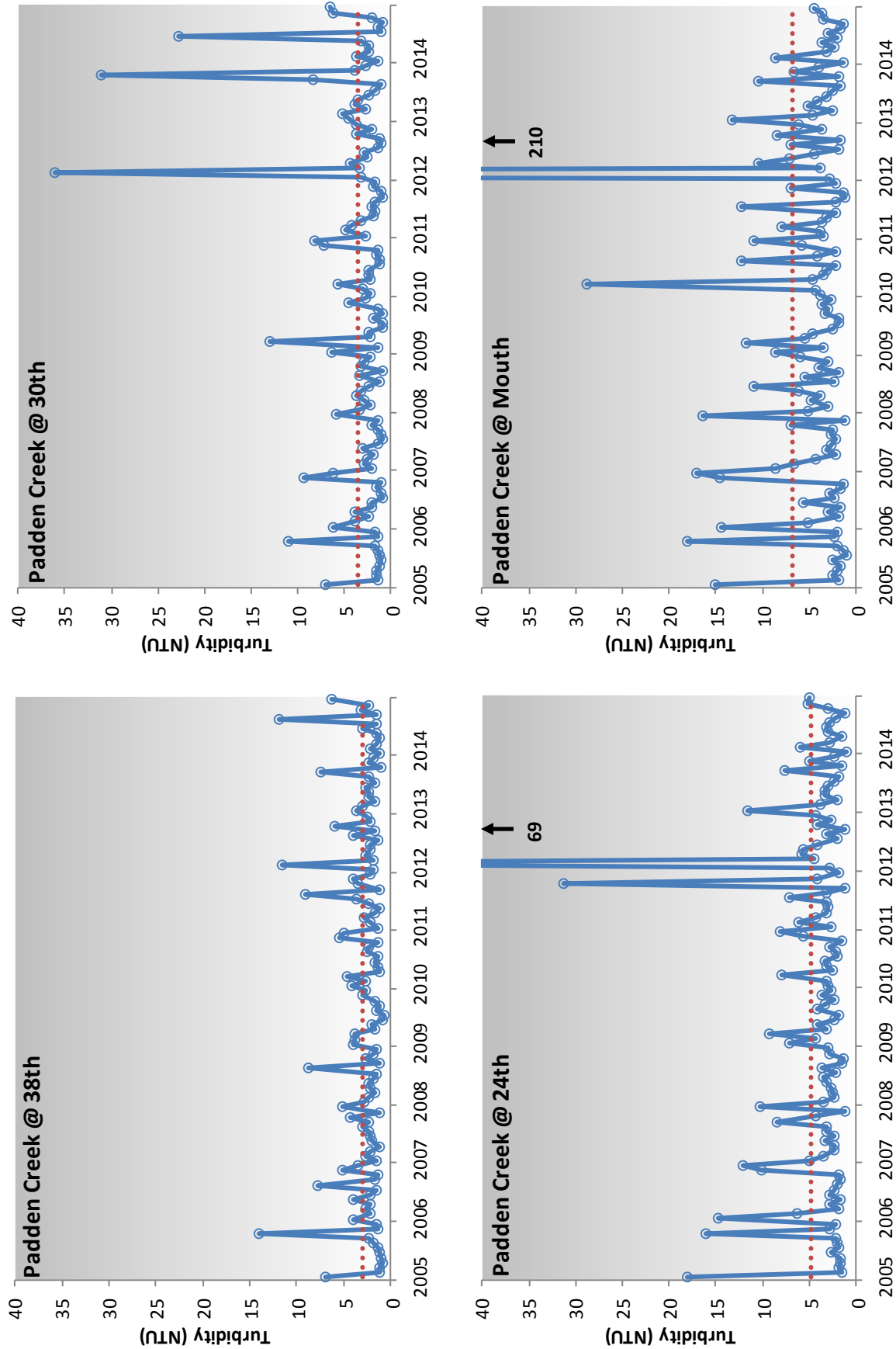
Figure 7.0-11. Sampling location for 14th St./Gage site on Padden Creek. Added in 2014.

Table 7.0-4. The average, maximum and minimum turbidity for sampling sites on Padden and Connelly Creek in 2014.

Sampling Site	38 <sup>th</sup> Street	30 <sup>th</sup> Street	Connelly	24 <sup>th</sup> Street	14 <sup>th</sup> Street	Mouth
<b>2014 Average (NTU)</b>	3.1	4.5	3.7	3.0	4.2	3.2
<b>2014 Maximum (NTU)</b>	11.9	22.8	9.5	5.9	13.5	8.7
<b>2014 Minimum (NTU)</b>	1.1	0.9	1.4	1.1	1.3	1.3



Figures 7.0-12a-d. Monthly turbidity values for Padden Creek sampling sites during 2014. Presented with yearly, 5-year and 10-year averages.



Figures 7.0-13a-d. Ten year turbidity trends for Padden Creek sites illustrate the effects of storm events on average turbidity. Red dotted lines depict the ten year averages. Trendlines (not shown) are not significantly different than zero (38th:  $p = 0.64$ ; 30th:  $p = 0.58$ ; 24th:  $p = 0.79$ ; Mouth:  $p = 0.58$ ,  $\alpha = 0.05$ ).



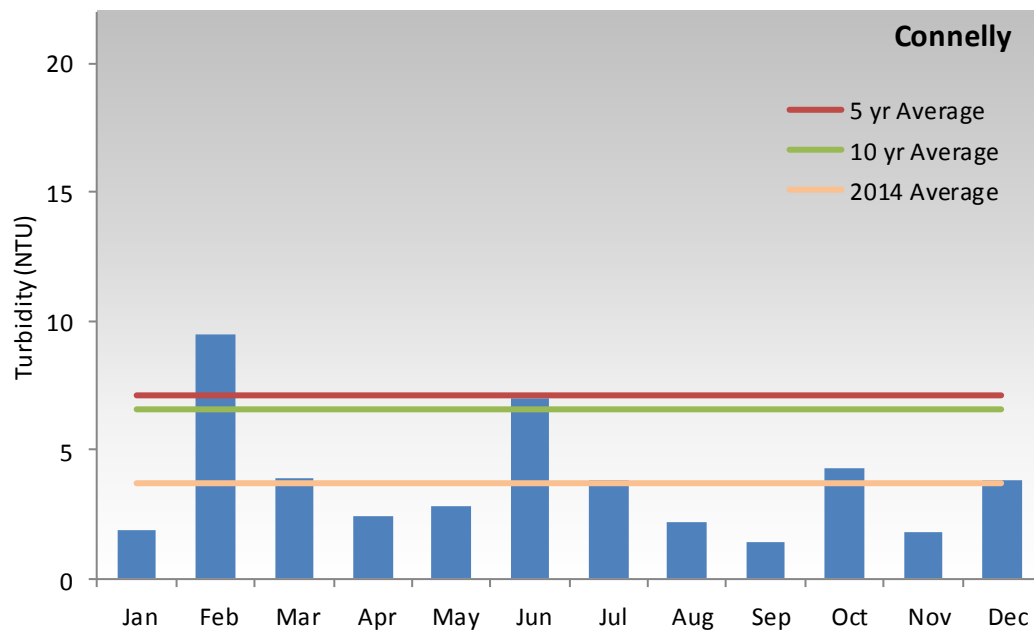


Figure 7.0-14. Monthly turbidity values for Connelly Creek sampling site during 2014. Presented with yearly, 5-year and 10-year averages.

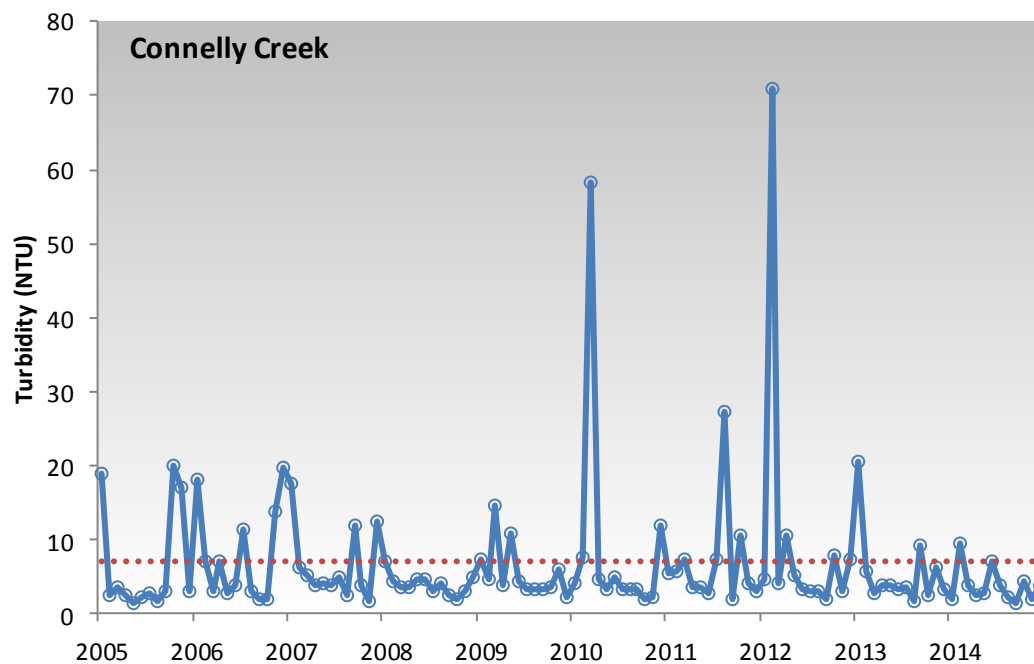


Figure 7.0-15. Ten year turbidity trend for Connelly Creek illustrates the effects of storm events on average turbidity. Red dotted lines depict the ten year averages. Trendlines (not shown) are not significantly different than zero ( $p = 0.70$ ,  $\alpha = 0.05$ ).

## Hydrology

The Padden Creek gauging station has been in service since 2005. It is located in Fairhaven Park approximately 50 feet downstream of the footbridge below the playground. Overall, Padden Creek has lowest discharge volume of all of Bellingham's gauged sites, yet it is also prone to very sudden and steep increases in flow at the start of rain events.

Padden Creek is well known for its low flows during the summer months (Figures 7.0-2 and 7.0-16). Only the contributions of Connelly Creek keep it's downstream reaches flowing. Without adequate flow, it is nearly impossible to meet all of Ecology's water quality criteria.

In 2014, Padden Creek at the gauge had a minimum discharge (flow) of 0.20 cu-



Figure 7.0-15. Low flows at the 22nd St. site on Padden Creek. Most of the visible flow is from Connelly Creek.

bic feet per second (cfs) September 1st, a maximum discharge of 141 cfs on November 28th and an median discharge of 5.8 cfs. First quartile flow was 0.6 cfs (i.e. 25% of the flow data was below this value) and Third quartile flow was 13.3 cfs (i.e. 25% of flow was above this value).

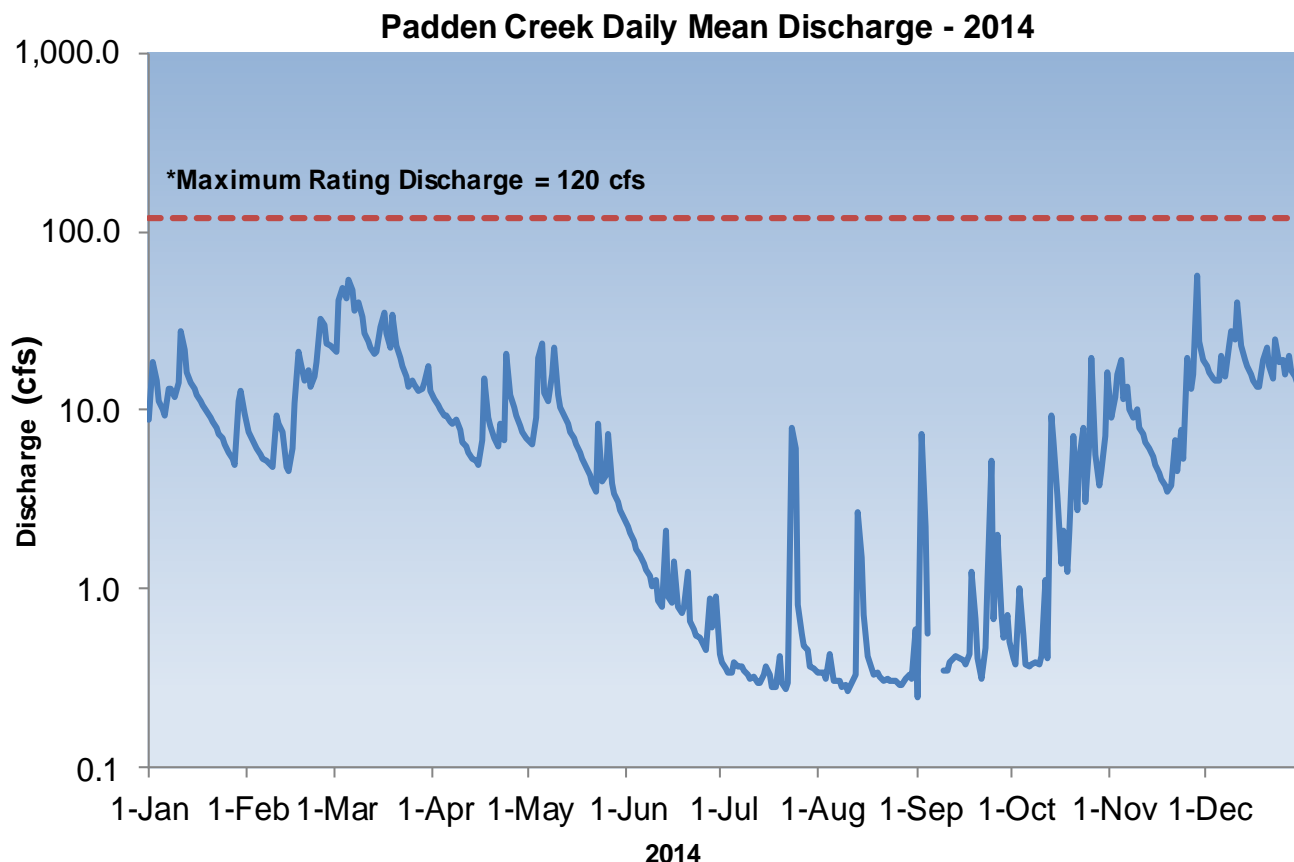
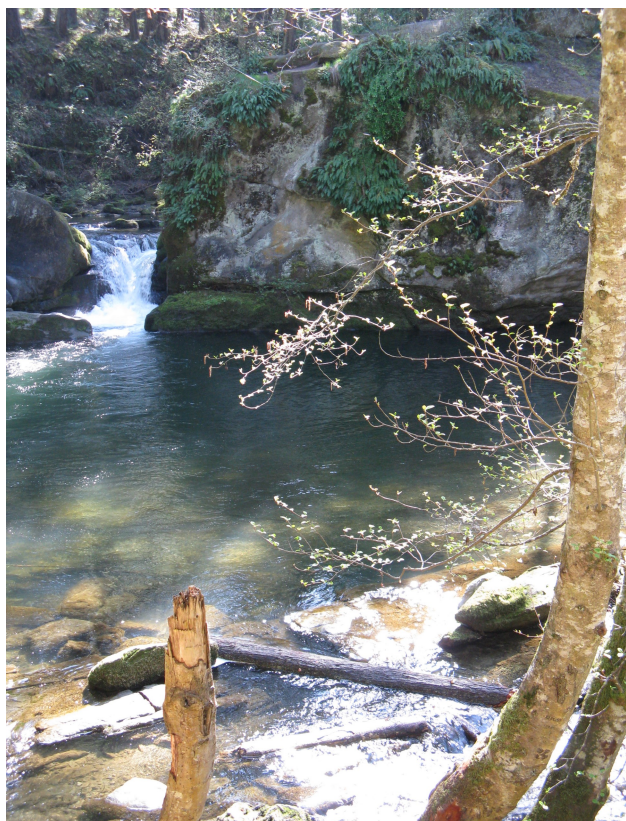


Figure 7.0-16. Daily mean discharge on Padden Creek during 2014. Discharge values above the maximum rating discharge of 120 cfs are of poor quality and should be interpreted cautiously. Data deleted during May due to the sensor being exposed to air during low flows. Data gap during Oct. - Nov. due to equipment malfunction. This hydrograph uses a logarithmic scale.

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## 8.0 Whatcom Creek Drainage Basin

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The origin of Whatcom Creek is the natural outlet of Lake Whatcom at the northwest end of the lake. More information regarding Lake Whatcom water quality can be found at: <http://www.cob.org/services/environment/lake-whatcom/index.aspx>. From the lake outlet, Whatcom Creek flows approximately four miles through residential, commercial, industrial, and wooded areas to the mouth at Bellingham Bay near downtown Bellingham and has a drainage basin of approximately 5,790 acres (City of Bellingham, 1982).

In the upper reaches, the creek cuts through the Chuckanut Sandstone formation, a geological belt of sandstone dating back fifty million years. Erosion of the sandstone has created a deep gorge and waterfalls along the upper reaches. This segment of the creek is in wooded and residential areas. It is shaded and the flow tends to be more rapid.

The creek flattens after leaving the Whatcom Falls Park area and enters a mainly industrial and commercial area. The flow in the lower reaches of the creek is slower than in the upper reaches. A great deal of impervious surface area surrounds this reach of the creek. Much of the creek in this flat area lacks shade, though restoration efforts by the City of Bellingham/Washington Conservation Corps crews in recent years have made enormous strides in revegetating this region with trees and other native plants.

The Whatcom Creek drainage basin contains several creeks that contribute to the flow in Whatcom Creek. Hanna Creek flows into Whatcom Creek in Whatcom Falls Park and is one of the main low flow contributors to Whatcom Creek. Hanna Creek has a drainage area of approximately 480 acres (City of Bellingham, 1995) and flows through residential and wooded areas.

Fever Creek drains into Whatcom Creek near Interstate 5. This small urban creek flows through residential and industrial areas and is characterized by constructed conveyance for much of its run. It has a drainage basin of approximately 580 acres (City of Bellingham, 1995).

Lincoln Creek also discharges to Whatcom Creek near Interstate 5 and flows through constructed channels for much of its course. Lincoln Creek flows through commercial, industrial and residential areas and drains approximately 804 acres (City of Bellingham, 1995).

Cemetery Creek flows through mostly residential and wooded areas and joins Whatcom Creek near Racine Street. It has a drainage area of approximately 1,670 acres (City of Bellingham, 1995).



Whatcom Creek is sampled at four locations: below the Control Dam at the south end of Scudders Pond (Figure 8.0-1), at Valencia St. (Figure 8.0-2), adjacent to Interstate 5 (Figure 8.0-6), and at Dupont St. (Figure 8.0-7). Four Whatcom Creek tributaries are sampled. Hanna Creek (Figure 8.0-10) is sampled below the City of Bellingham Water Treatment Plant approximately 1000 feet upstream from the confluence with Whatcom Creek. Cemetery Creek (Figure 8.0-11) is sampled near the Haskell Business Center, just upstream from the confluence with Whatcom Creek. Lincoln Creek (Figure 8.0-14) is sampled at a location adjacent to the Frank Geri soft-ball fields and approximately 1200 feet upstream from the confluence with Whatcom Creek. Fever Creek (Figure 8.0-15) is sampled at Valencia Street approximately 3500 feet upstream from the confluence with Whatcom Creek (see the Whatcom Drainage Map for sampling locations).

Whatcom Creek and its' tributaries rarely meet all of the designated use criteria. In fact, The City of Bellingham conducted a Total Maximum Daily Load (TMDL) study in 2002/2003 on Whatcom Creek due to an Ecology listing as a 303(d) impaired waterway for temperature and fecal coliform bacteria (Shannahan et al.). Fecal coliform data in the 2004 report of the study detailed the loading of fecal coliforms to the creek system. The City and Department of Ecology are now working cooperatively under a TMDL plan to reduce fecal coliform bacteria in Whatcom Creek (Hood, 2006).

In 2014, every site on Whatcom Creek met the Primary Contact Recreational Use Standard for fecal coliform (geomean  $\leq 100$  CFU/100 ml; no more than 10% of samples  $> 200$  CFU/100 ml). Of the tributaries however, only Hanna Creek was able to meet the Recreational Use Standard. Hanna, Cemetery and Lincoln Creeks did meet the Aquatic Life Use (ALU) tem-



Figure 8.0-1. Whatcom Creek sampling site at the Control Dam.

perature criterion of  $16^{\circ}\text{C}$ , and Hanna Creek met the dissolved oxygen ALU criterion of  $\geq 9.5$  mg/L. All sites remained within the designated pH ALU range of 6.5-8.5.

Using the overall class based system, Hanna Creek was placed in the stringent AA class, while all four Whatcom Creek sites and Cemetery Creek met the criteria for overall Class B designation. Neither Lincoln nor Fever Creeks were able to meet the Class A or B designations due to high fecal coliform levels.

For temperature, Hanna, Cemetery and Lincoln Creeks met the Class AA standard ( $\leq 16^{\circ}\text{C}$ ) in 2014, while Fever Creek met the Class A ( $\leq 18^{\circ}\text{C}$ ) standard and all Whatcom Creek sites met the Class B standard ( $\leq 21^{\circ}\text{C}$ ).

For dissolved oxygen, Hanna Creek met the Class AA (9.5 mg/L), while the Valencia, I-5 and Dupont sites on Whatcom Creek and Fever Creek met the Class A standard (8.0 mg/L). Cemetery Creek, Lincoln Creek and the Control Dam site met the Class B standard (6.5 mg/L).





Figure 8.0-2. Whatcom Creek sampling site at Valencia St.

The Control Dam, Valencia Street and I-5 sites on Whatcom Creek along with Hanna Creek all met the more stringent Class AA standard for fecal coliform bacteria (geomean  $\leq 50$  CFU/100 ml; no more than 10% of samples  $> 100$  CFU/100 ml) in 2014. The Dupont site met the Class A standard (geomean  $\leq 100$  CFU/100 ml; no more than 10% of samples  $> 200$  CFU/100 ml), while Cemetery Creek met the Class B standard (geomean  $\leq 200$  CFU/100 ml; no more than 10% of samples  $> 400$  CFU/100 ml). Lincoln and Fever Creeks were unable to meet Class A or Class B standards.

All stream segments sampled met the Class AA/A/B standard for pH (6.5 to 8.5).

The highest average turbidity on Whatcom Creek was found at the Dupont site (2.9 NTU), while the Control Dam site had the lowest average turbidity (1.5 NTU). Of the tributaries, Lincoln Creek had the highest average turbidity (4.8 NTU) and

Hanna Creek had the lowest (3.3 NTU). Average turbidity values for 2014 are listed along side respective 5 and 10 year averages in Table 8.0-4. Conductivity was consistent with previous years.

### Fecal Coliform Bacteria

Fecal coliform levels in Whatcom Creek and its tributaries were all less than those found in 2013. Geomean values for all sampling locations are provided in Table 8.0-1. Bacterial concentrations were varied throughout the year, but did show a trend of higher values in the summer months (Figures 8.0-4a&b).

While all the Whatcom Creek monitoring sites had significant descending 10-year trends in fecal coliform geomeans in 2014, trends in Whatcom tributaries were mixed. Cemetery Creek was negative, Lincoln and Fever Creeks were positive, and Hanna Creek was not significantly different than zero. Geomeans and trends can be found in Table 8.0-1 & Figures 8.0-5a–h.

Table 8.0-1. Fecal coliform geomean values and trends for sampling sites on Whatcom Creek and its tributaries, 2014.

Sampling Site	Geomean (CFU/100 ml)	Trend (CFU/100 ml/yr)
Control Dam	6	- 0.8
Valencia	10	- 0.7
I-5	17	- 2.3
Dupont	33	- 5.9
Hanna	47	0
Cemetery	92	- 11.4
Lincoln	87	+ 9.0
Fever	104	+ 4.4

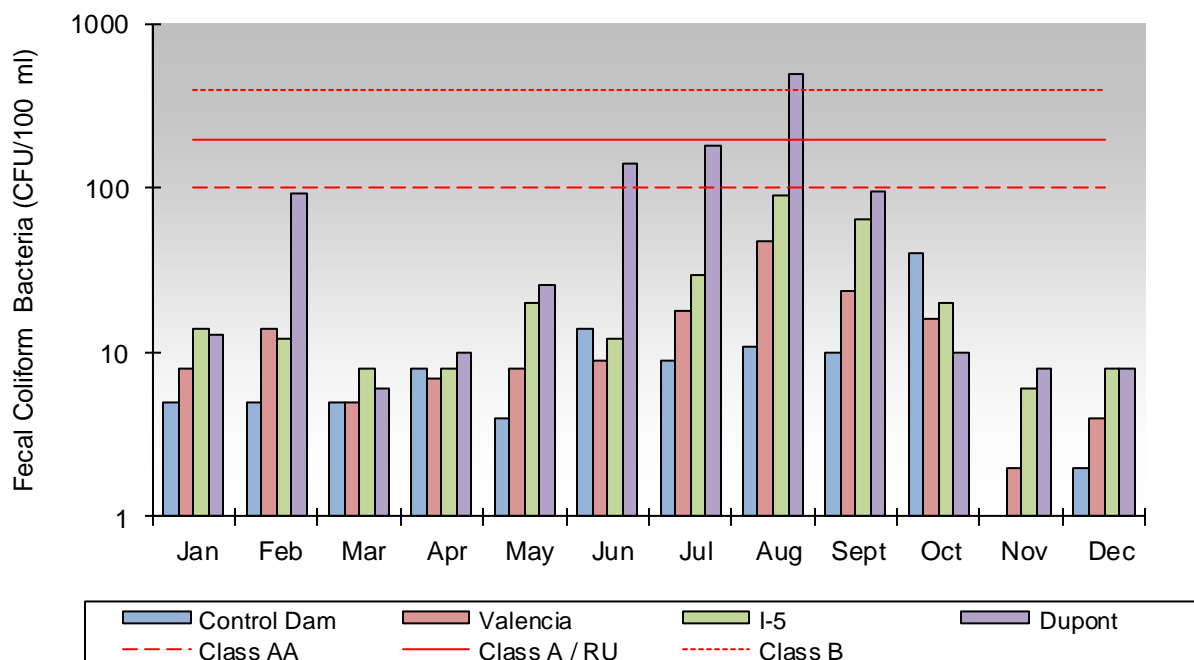


Figure 8.0-6a. Monthly 2014 fecal coliform levels for sampling sites on Whatcom Creek. Red lines indicate the numeric criteria for the calculated geomean for the different surface water classes (AA, A, and B). The Primary Contact Recreational Use (RU) designation is equivalent to Class A. *Note this graph uses a logarithmic scale.*

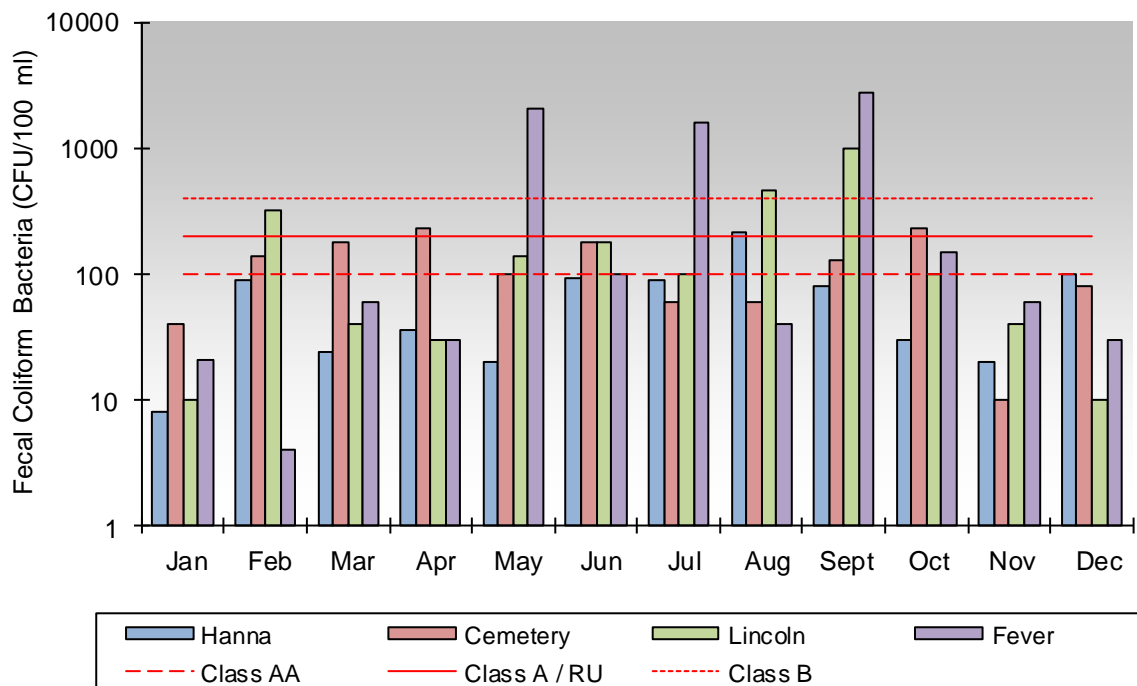
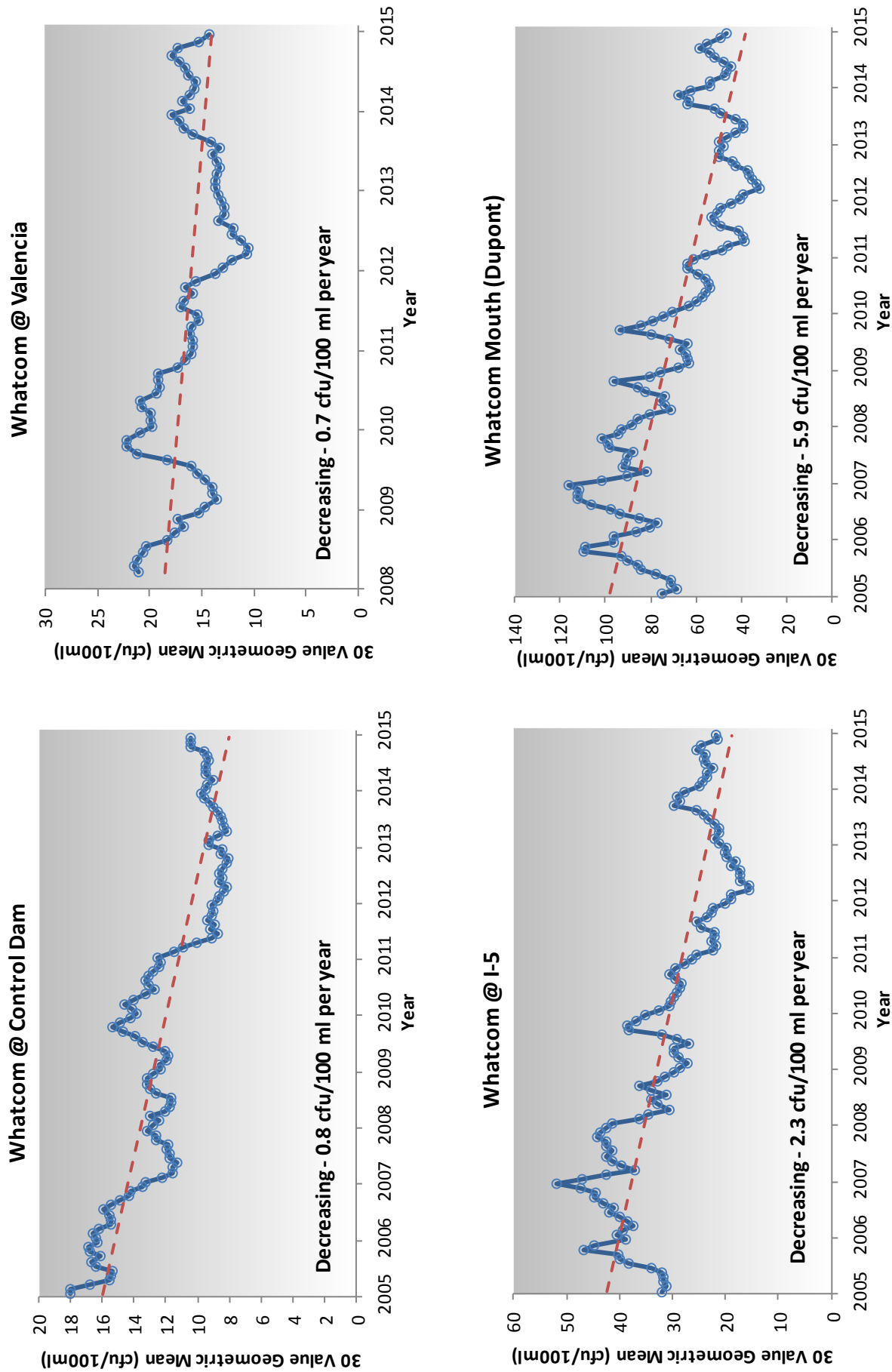
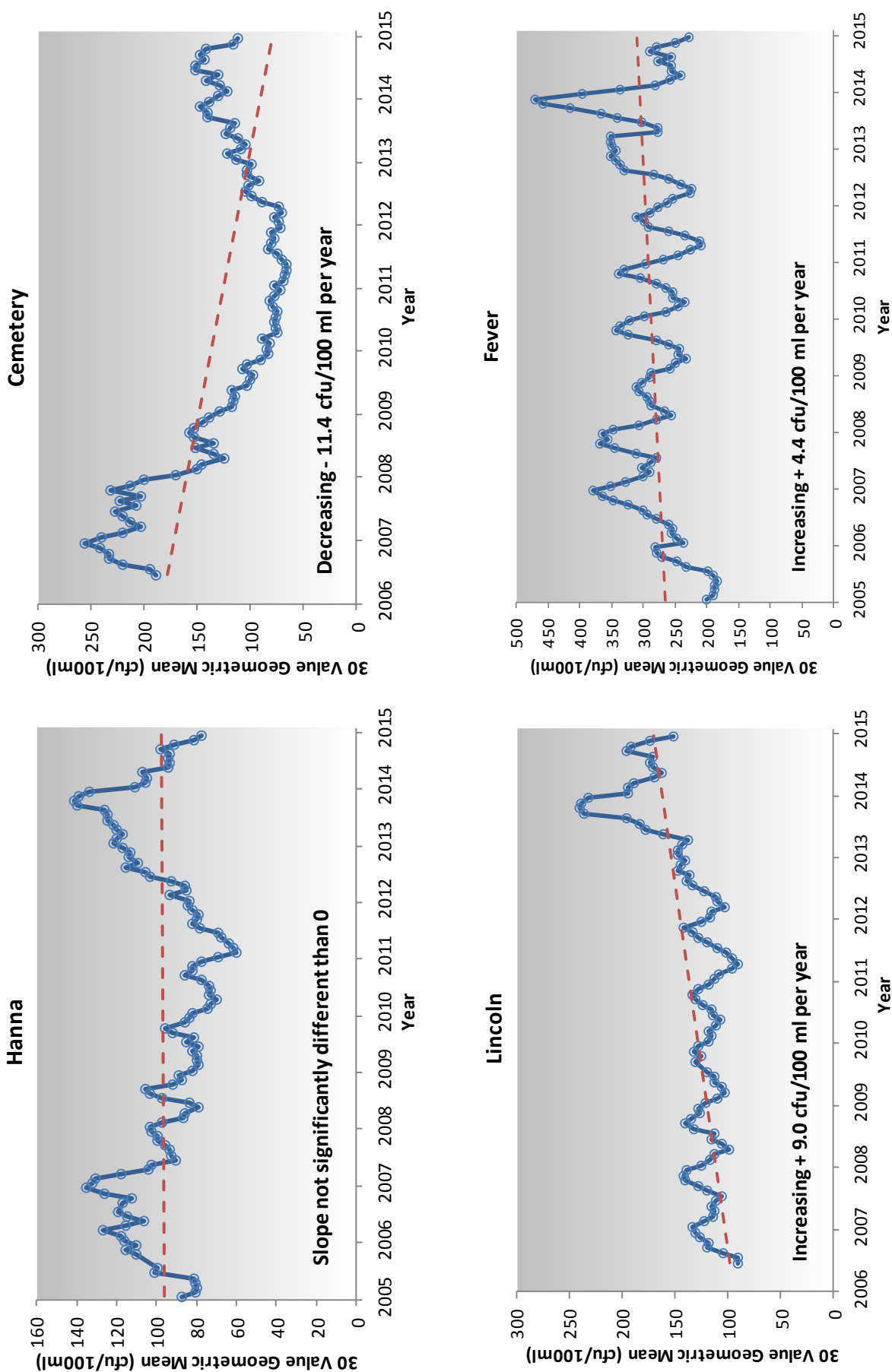


Figure 8.0-6b. Monthly 2014 fecal coliform levels for sampling sites on Whatcom Creek tributaries. Red lines indicate the numeric criteria for the calculated geomean for the different surface water classes (AA, A, and B). The Primary Contact Recreational Use (RU) designation is equivalent to Class A. *Note this graph uses a logarithmic scale.*





Figures 8.0-5 e-h. Thirty value moving geometric mean fecal coliform trends for Whatcom Creek Tributary samples collected 2005 through 2014. Cemetery Creek displayed a significant negative trend ( $6.61 \times 10^{-10}$ ,  $\alpha = 0.05$ ), Lincoln and Fever Creeks were significantly positive ( $p = 2.32 \times 10^{-12}$  and  $0.01$ ,  $\alpha = 0.05$ ), and the slope of the Hanna Creek trendline was not significantly different than zero ( $p = 0.87$ ,  $\alpha = 0.05$ ). Trendlines in red.



## Dissolved Oxygen

During 2014, only Hanna Creek in the Whatcom Creek drainage met the 9.5 mg/L Core Summer Salmonid Aquatic Life Use (ALU) standard for dissolved oxygen. The dissolved oxygen ALU designation equates to the Class AA standard. The Valencia, I-5 and Dupont sites on Whatcom Creek, along with Fever Creek, qualified for the Class A dissolved oxygen standards ( $\geq 8.0$  mg/L). Lincoln, Cemetery and Whatcom Creek at the Control Dam met the Class B standards ( $\geq 6.5$  mg/L; Figures 8.0-8a&b).

The number of times dissolved oxygen levels in Whatcom Creek and its tributaries fell below standards in 2014 was similar to previous years (Figures 8.0-9a-h). Dissolved oxygen followed the expected trend of lower values in the warmer summer months as water temperatures rose. Average dissolved oxygen values are provided in Table 8.0-2.

There were no ten year dissolved oxygen trendlines in the Whatcom Creek Drainage that were significantly different than zero for the period of 2005-2014 (Figures 8.0-9a-h).

Table 8.0-2. Average dissolved oxygen values for Whatcom Creek and its tributaries in 2014.

Sampling Site	C. Dam	Valencia	I-5	Dupont	Hanna	Cemetery	Lincoln	Fever
Average DO (mg/L)	10.2	11.0	10.8	11.1	11.1	9.9	10.1	10.9



Figure 8.0-6. Whatcom Creek sampling site at I-5.



Figure 8.0-7. Whatcom Creek sampling site at Dupont

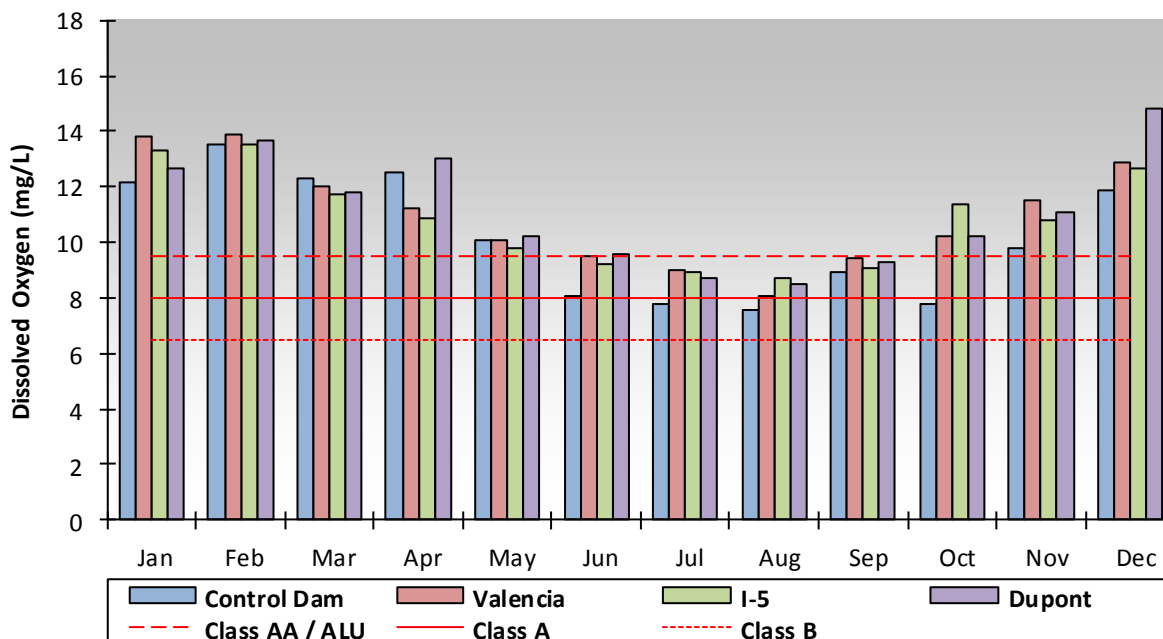


Figure 8.0-8a. Monthly 2014 dissolved oxygen levels for Whatcom Creek sampling sites. Red lines indicate the lowest dissolved oxygen levels allowed by the different surface water classes (AA, A, and B). Core Summer Salmonid Habitat Aquatic Life Use (ALU) is equivalent to Class AA.

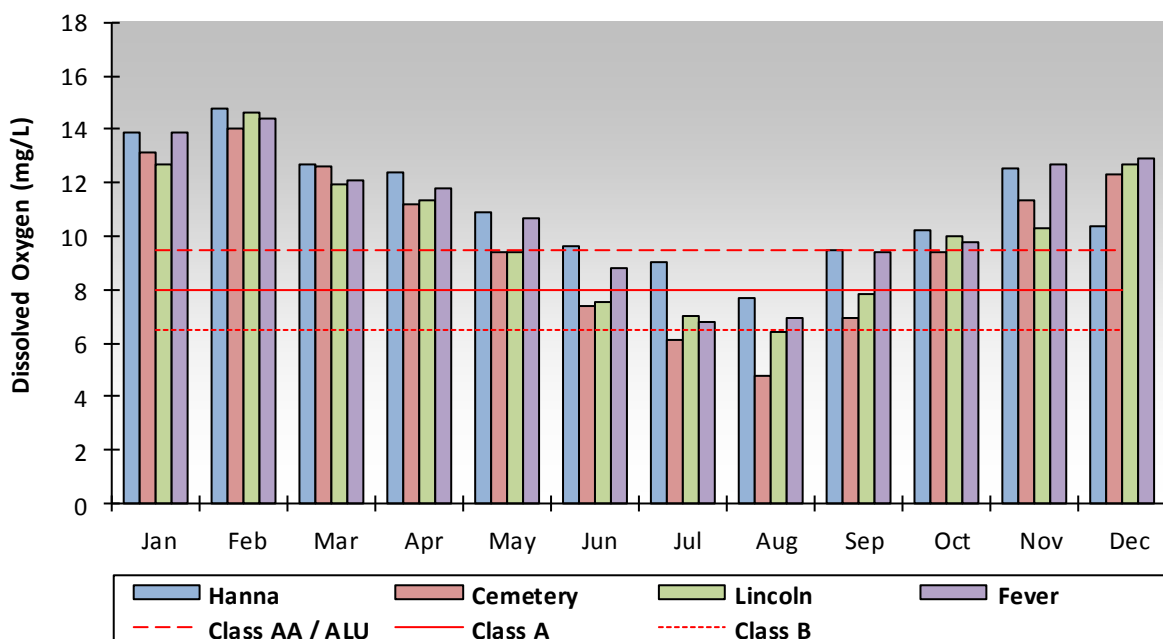


Figure 8.0-8b. Monthly 2014 dissolved oxygen levels for Whatcom Creek tributaries sampling sites. Red lines indicate the lowest dissolved oxygen levels allowed by the different surface water classes (AA, A, and B). Core Summer Salmonid Habitat Aquatic Life Use (ALU) is equivalent to Class AA.

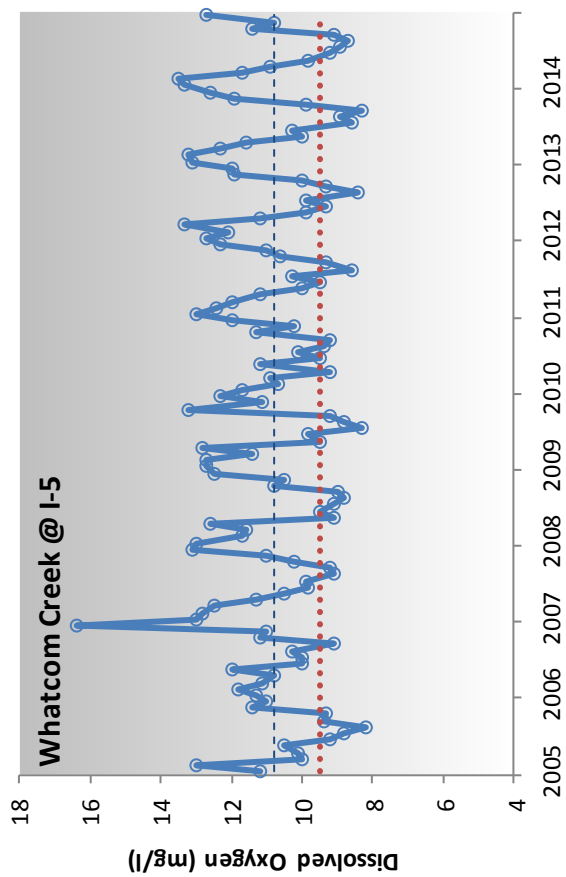
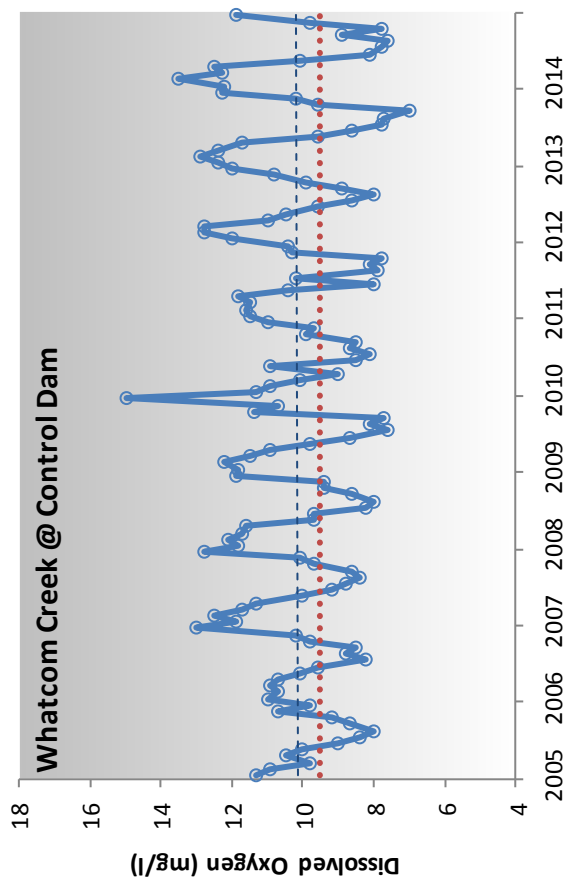
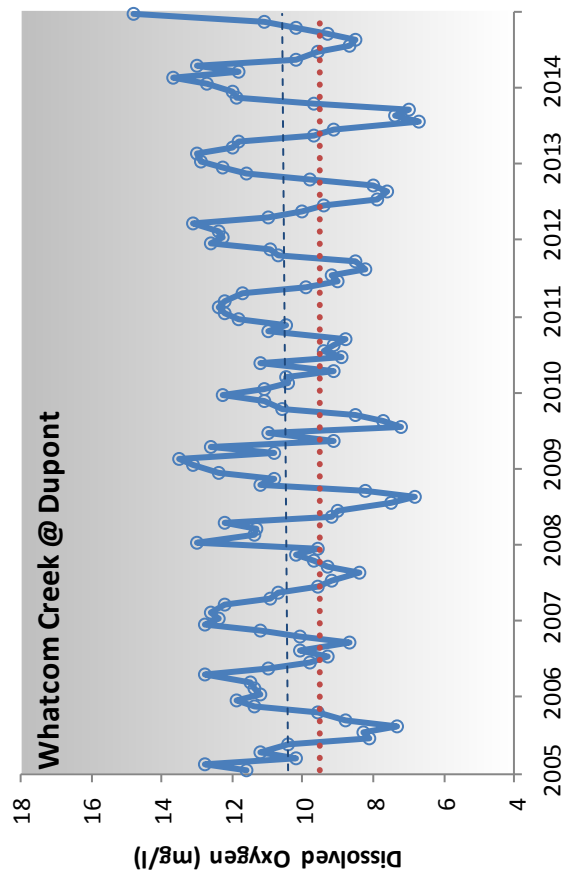
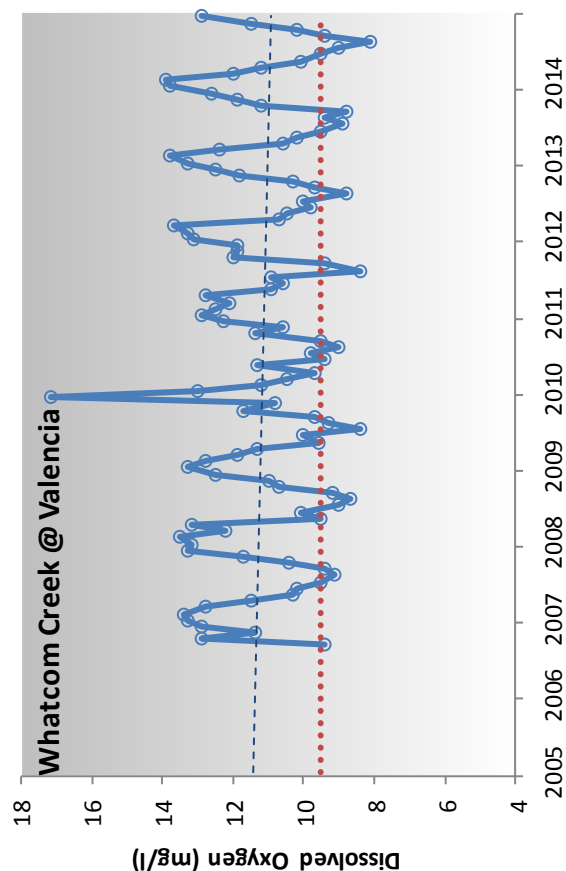


Figure 8.0-9 a-d. Ten year dissolved oxygen trendlines (blue) for Whatcom Creek sites in 2014. None of the trendlines were significantly different from zero (Control Dam:  $p = 0.89$ ; Valencia:  $p = 0.44$ ; I-5:  $p = 0.97$ ; Dupont:  $p = 0.75$ ,  $\alpha = 0.05$ ). Red dotted line depicts the 9.5 mg/l Aquatic Life Use standard.

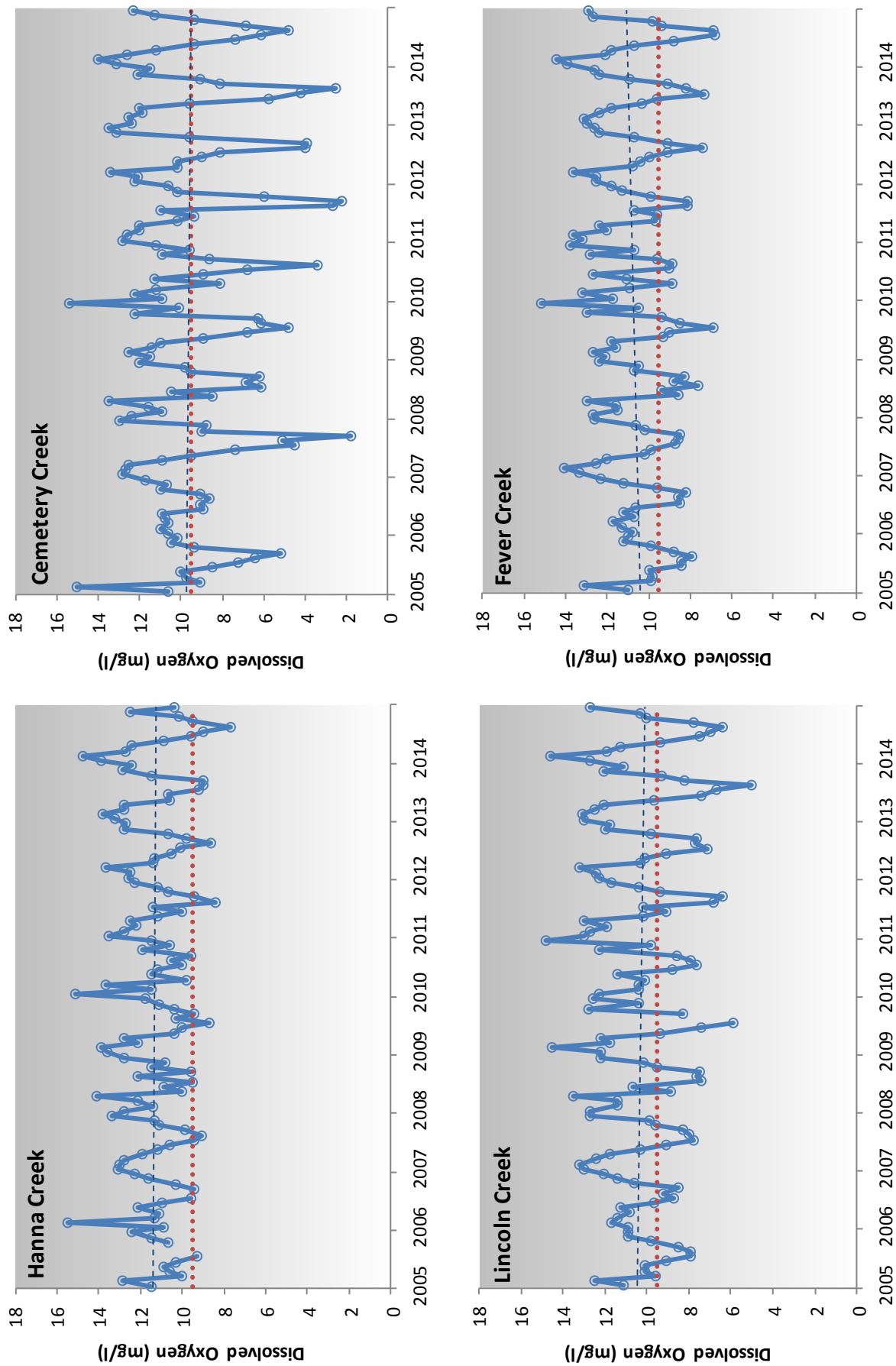


Figure 8.0-9 e-h. Ten year dissolved oxygen trendlines (blue) for Whatcom Creek Tributary sites in 2014. None of the trendlines were significantly different from zero (Hanna:  $p = 0.78$ ; Cemetery:  $p = 0.81$ ; Lincoln:  $p = 0.60$ ; Fever:  $p = 0.29$ ,  $\alpha = 0.05$ ). Red dotted line depicts the 9.5 mg/l Aquatic Life Use standard.





Figure 8.0-10. Hanna Creek sampling site.

Creeks all met the  $<16^{\circ}\text{C}$  ALU criterion, while Fever Creek met the  $< 18^{\circ}\text{C}$  Class A criterion.

The expected seasonal trend with higher temperatures in the warmer summer months is apparent for both Whatcom Creek and its tributaries (Figures 8.0-12a&b). Average temperatures for 2014 are provided in Table 8.0-3. None of the Whatcom Creek Drainage sites displayed ten year trendlines that were significantly different than zero in 2014 (Figures 8.0-13a-h).

## Temperature

Whatcom Creek chronically experiences temperature in excess of the  $16^{\circ}\text{C}$  Core Summer Salmonid Habitat Aquatic Life Use (ALU) designation during the warmer summer months. This phenomenon is not surprising as the source water for Whatcom Creek, basin one of Lake Whatcom, has had recorded temperatures higher than  $20^{\circ}\text{C}$  in the upper epilimnion during summer months.

During 2014, all four Whatcom Creek monitoring sites were only able to meet the  $<21^{\circ}\text{C}$  Class B standard, and also failed to maintain temperatures under  $13^{\circ}\text{C}$  as required for supplemental spawning and incubation protection during May and June. Temperatures above  $16^{\circ}\text{C}$  are not as common in the Whatcom Creek tributaries. In 2014, Hanna, Cemetery and Lincoln



Figure 8.0-11. Cemetery Creek sampling site.

Table 8.0-3. Average temperatures for sampling sites on Whatcom Creek and tributaries, 2014.

Sampling Site	C. Dam	Valencia	I-5	Dupont	Hanna	Cemetery	Lincoln	Fever
Average Temperature ( $^{\circ}\text{C}$ )	13.5	12.7	12.7	12.6	9.8	10.3	10.5	11.1

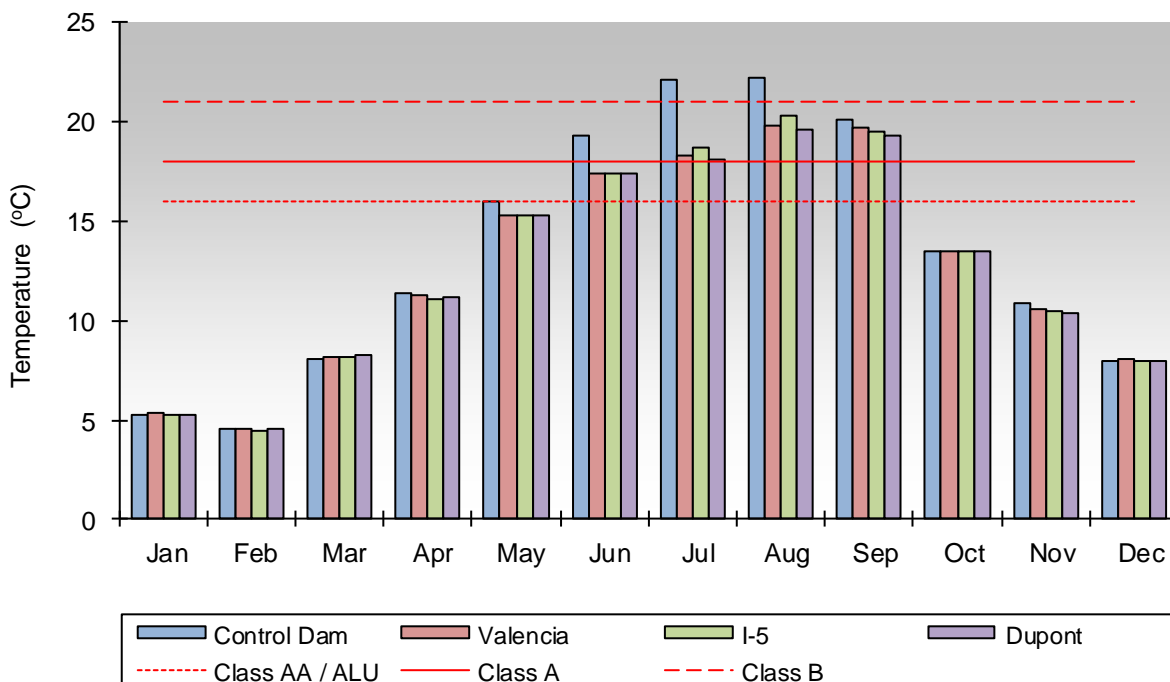


Figure 8.0-12a. Monthly temperature measurements for Whatcom Creek sampling sites in 2014. Red lines indicate the highest temperatures allowed by the different surface water standards (Class AA, A, and B). Core Summer Salmonid Habitat Aquatic Life Use (ALU) is equivalent to Class AA.

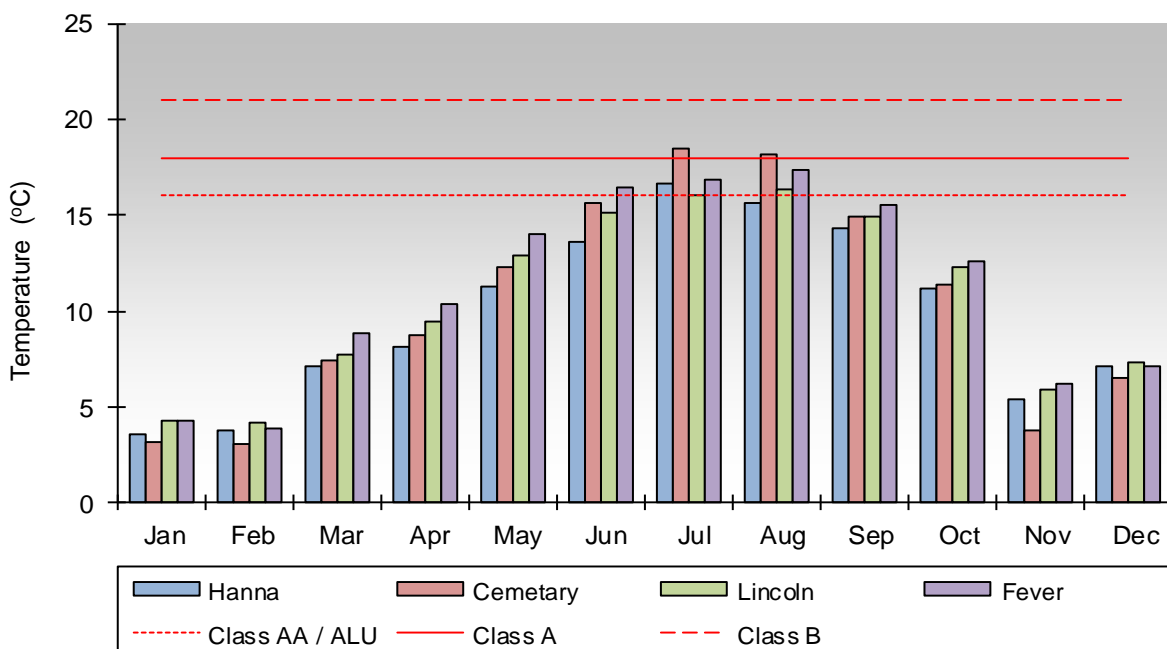


Figure 8.0-12b. Monthly temperature measurements for Whatcom Creek tributaries sampling sites in 2014. Red lines indicate the highest temperatures allowed by the different surface water standards (Class AA, A, and B). Core Summer Salmonid Habitat Aquatic Life Use (ALU) is equivalent to Class AA.

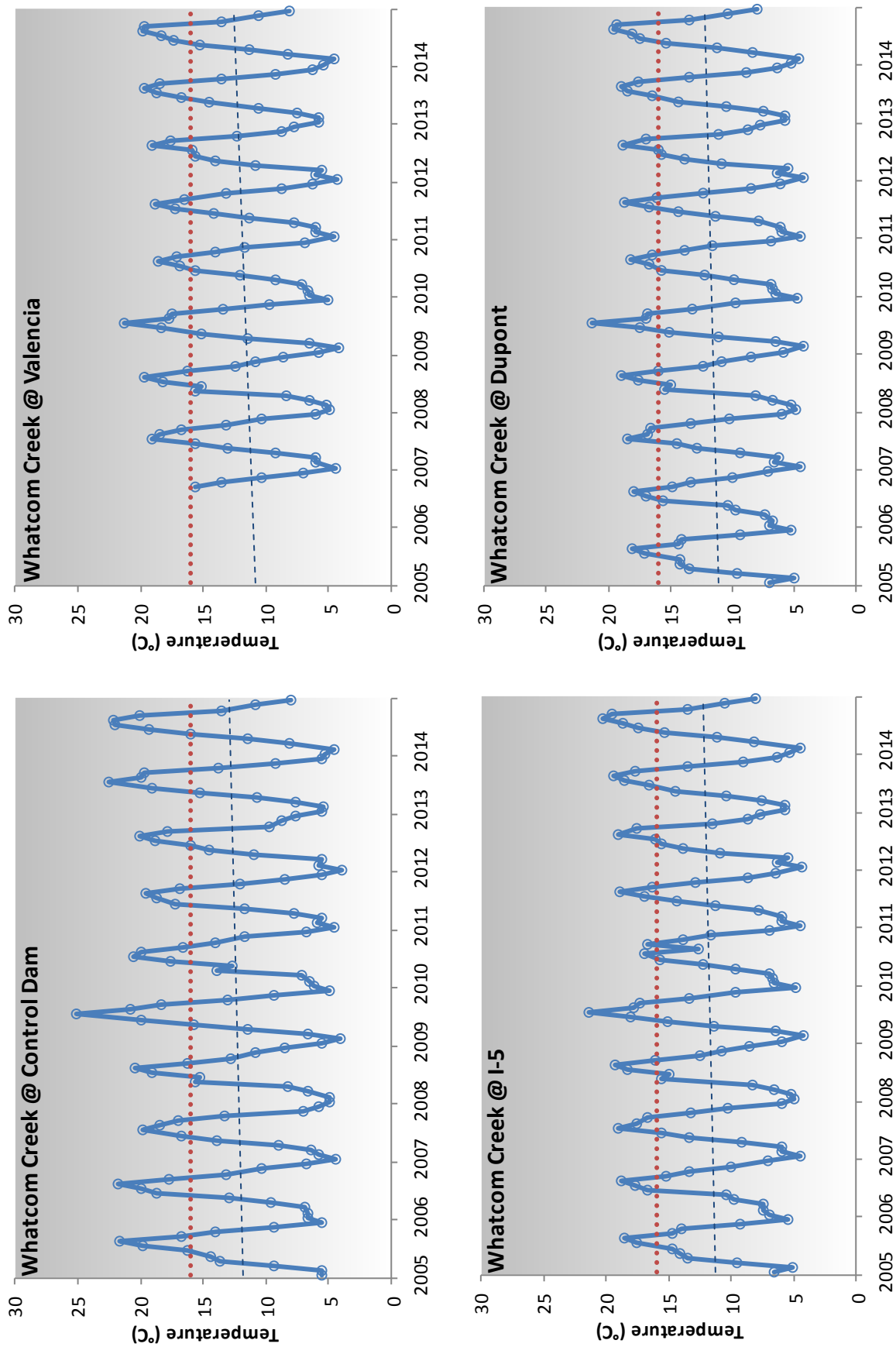


Figure 8.0-13 a-e. Ten year temperature trends at Whatcom Creek sites, 2005-2014. Trendlines (blue) were not significantly different than zero (Control Dam:  $p = 0.56$ ; Valencia:  $p = 0.42$ ; I-5:  $p = 0.54$ ; Dupont:  $p = 0.47$ ,  $\alpha = 0.05$ ). Red dotted line depict the 16°C Aquatic Life Use standard.

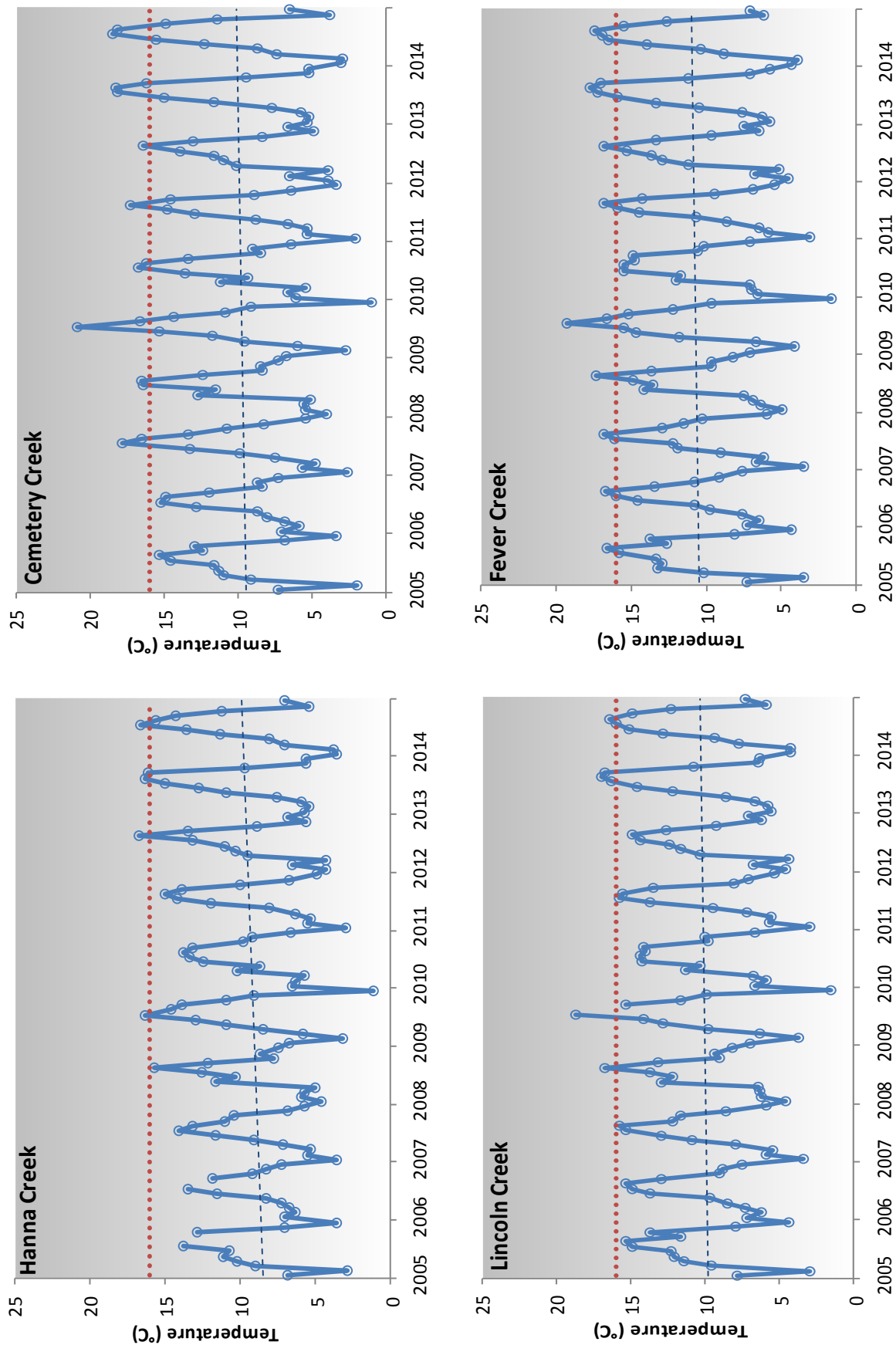


Figure 8.0-13 f-h. Ten year temperature trends at Whatcom Creek Tributaries, 2005-2014. Trendlines (blue) were not significantly different than zero (Hanna:  $p = 0.24$ ; Cemetery:  $p = 0.67$ ; Lincoln:  $p = 0.42$ ; Fever:  $p = 0.70$ ,  $\alpha = 0.05$ ). Red dotted line depict the 16°C Aquatic Life Use standard.



## pH

The pH at all sites monitored on Whatcom Creek and its tributaries generally fall within the range prescribed by Ecology for all classes of freshwater bodies, 6.5 to 8.5. During 2014 all Whatcom Creek and tributary sites were once again within this standard. Graphs are not included in this section because pH is so rarely exceeded.

Ten year turbidity trends are displayed in figures 8.0-17a-h. None of the Whatcom Creek Drainage monitoring sites turbidity trendlines were significantly different than zero in 2014.

## Turbidity

Turbidity in Whatcom Creek is usually lower than its tributaries. This trend continued in 2014. The average turbidities and their respective 5 and 10 year averages are provided in figures 8.0-16a-h. Maximum, minimum and average turbidity for all sampling sites in 2014 are provided in Table 8.0-4.

Table 8.0-4. The average, maximum and minimum turbidity for sampling sites on Whatcom Creek and its tributaries in 2014.

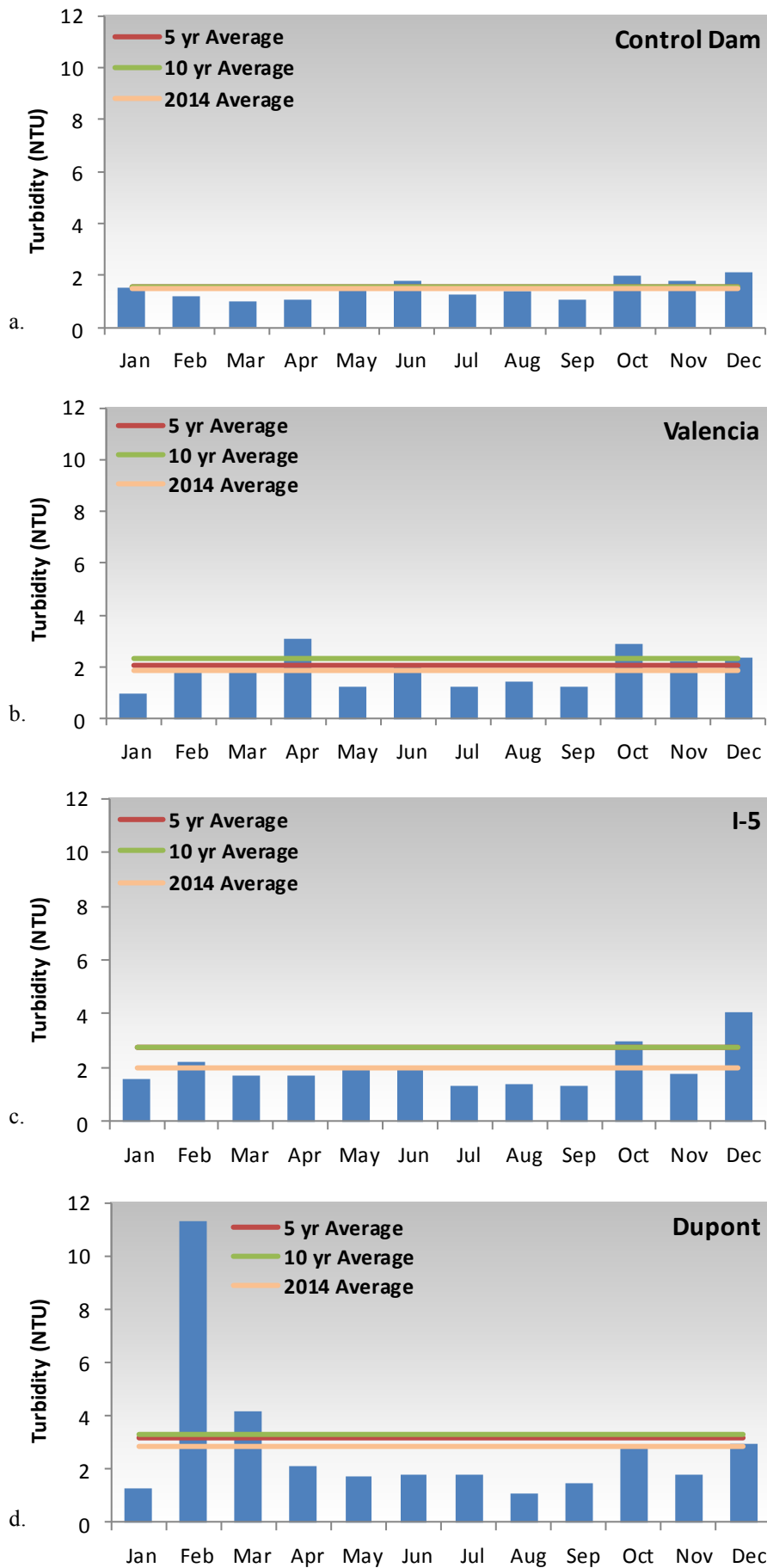
Sampling Site	C. Dam	Valencia	I-5	Dupont	Hanna	Cemetery	Lincoln	Fever
<b>2014 Average (NTU)</b>	1.5	1.9	2.0	2.9	3.3	4.3	4.8	3.6
<b>2014 Maximum (NTU)</b>	2.1	3.1	4.1	11.3	5.4	7.0	8.7	8.6
<b>2014 Minimum (NTU)</b>	1.0	1.0	1.3	1.1	1.1	2.1	2.3	1.4



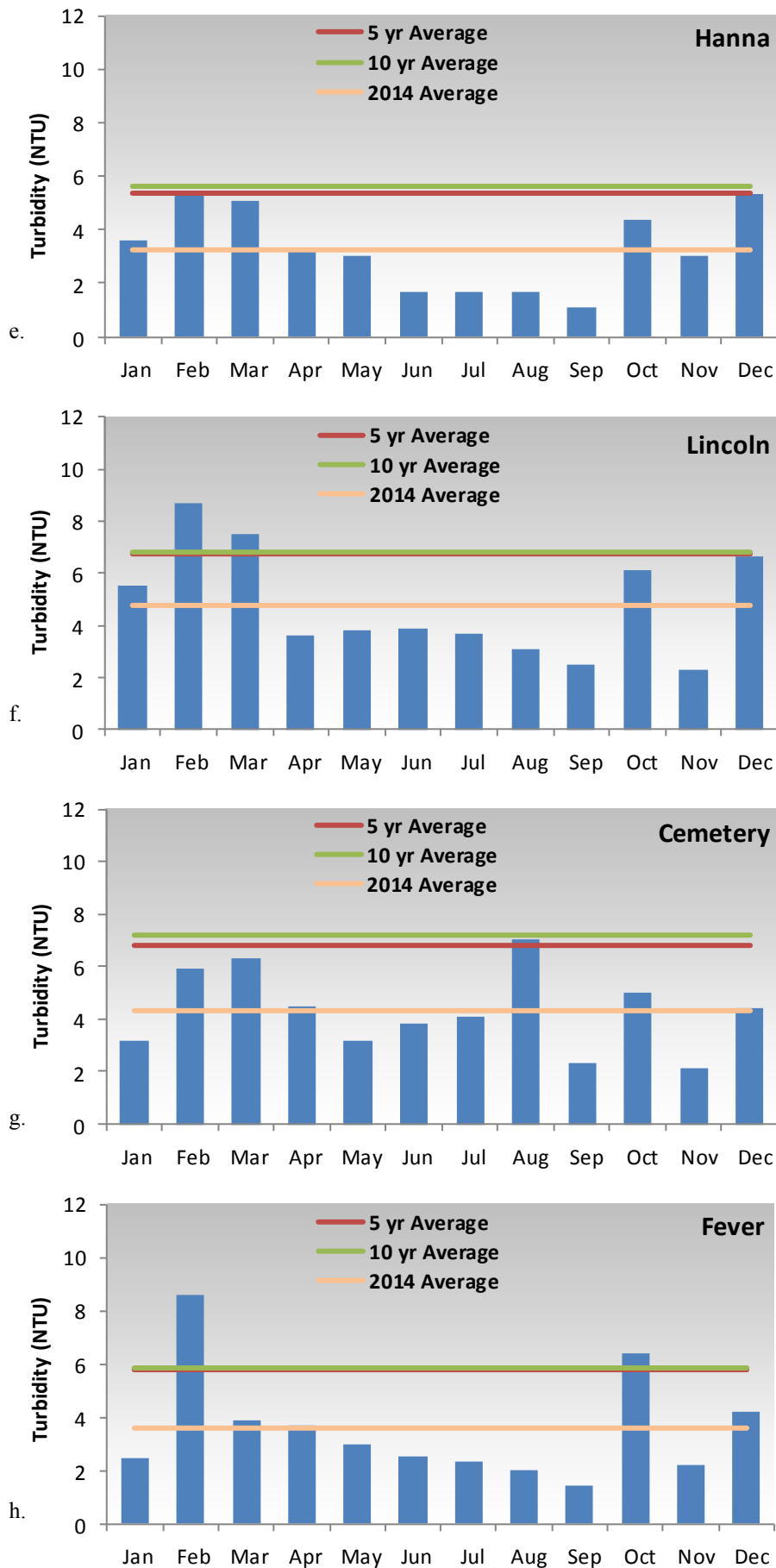
Figure 8.0-14. Lincoln Creek sampling site.



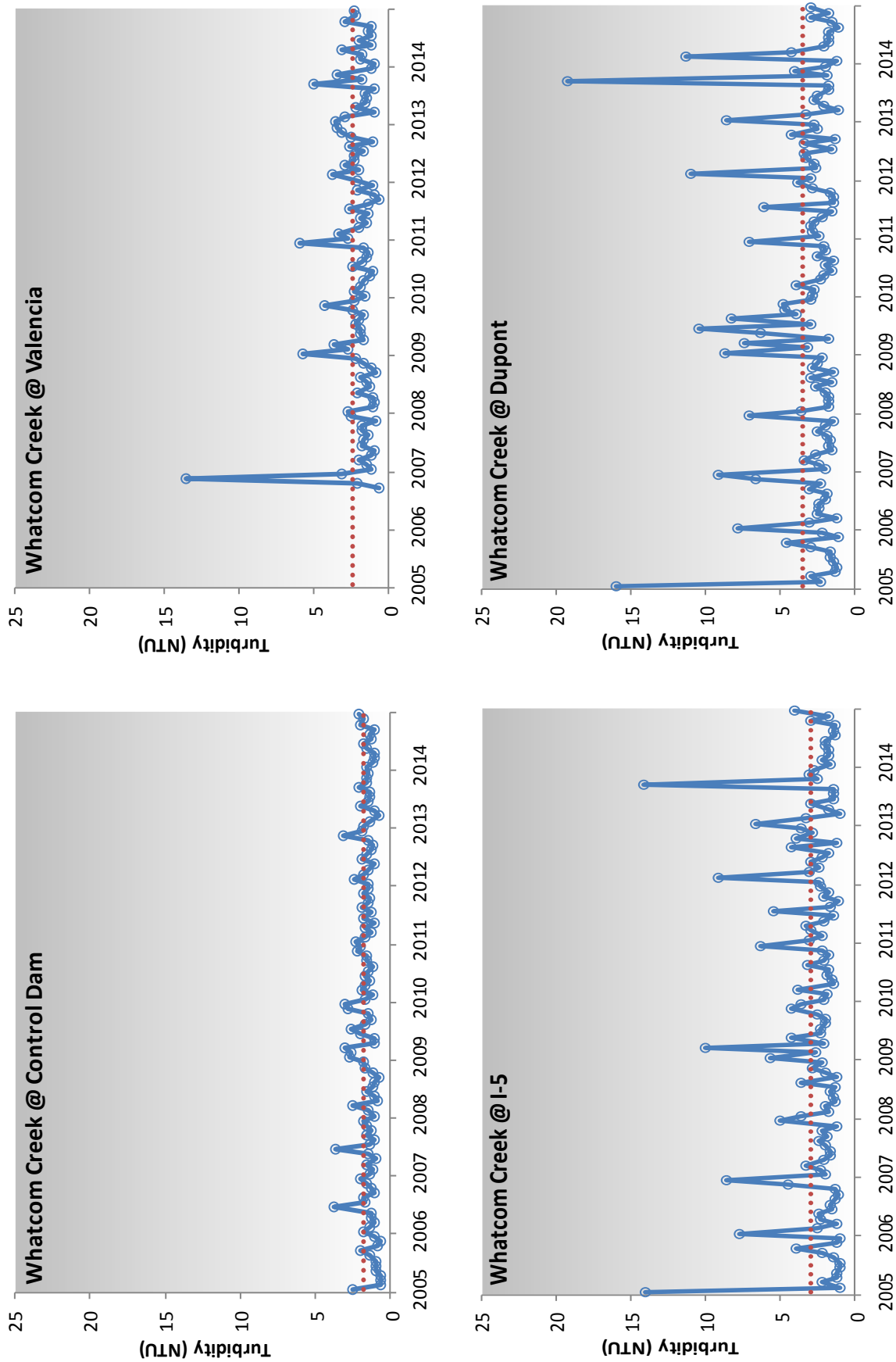
Figure 8.0-15. Fever Creek sampling site.



Figures 8.0-16a-d. Monthly turbidity values for Whatcom Creek Sampling sites in 2014. Presented with yearly, 5-year and 10-year averages.

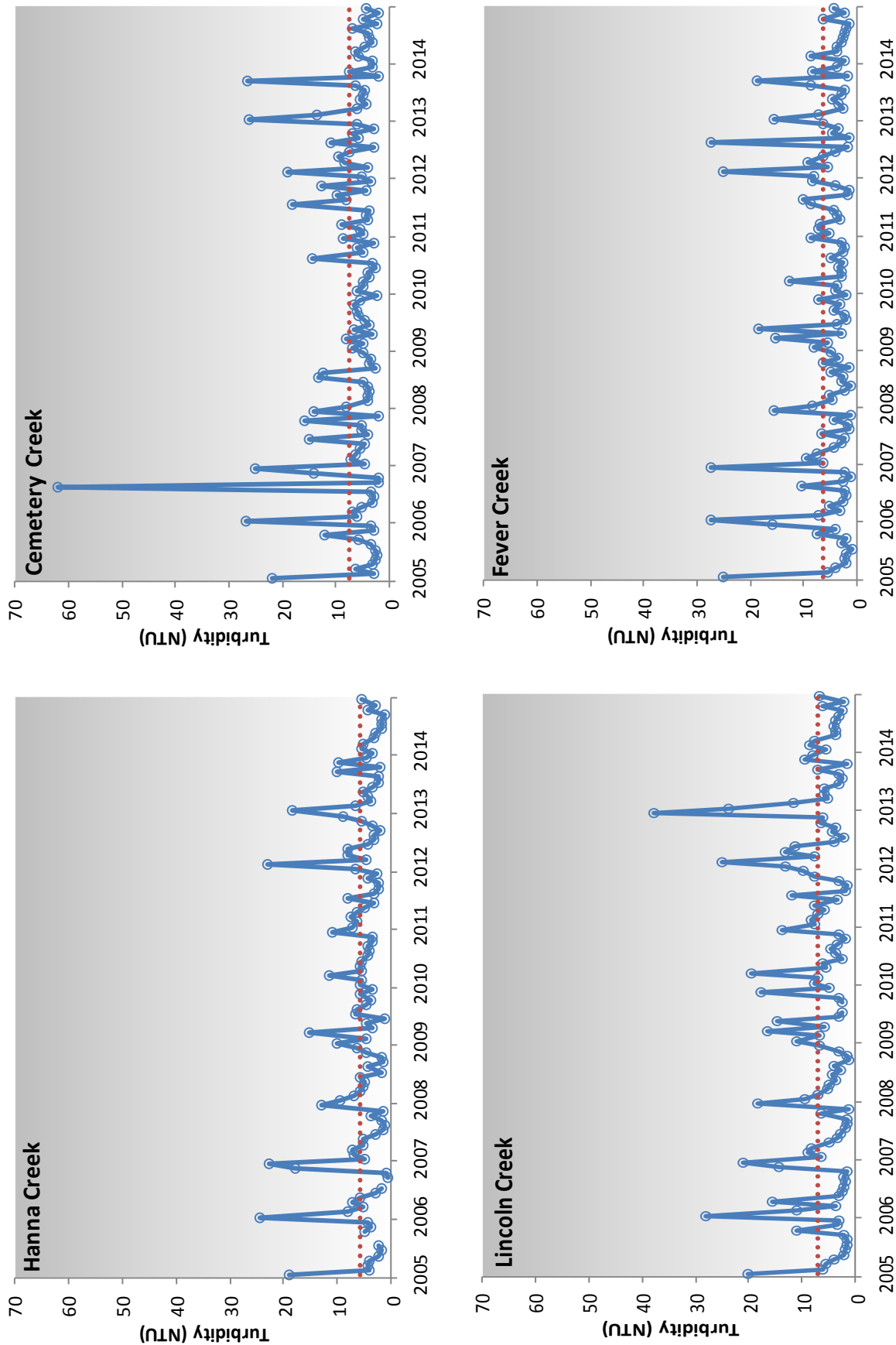


Figures 8.0-16f-h. Monthly turbidity values for Whatcom Creek tributaries in 2014. Presented with yearly, 5-year and 10-year averages.



Figures 8.0-17a-d. Ten year turbidity trends for Whatcom Creek sites illustrate the effects of storm events on average turbidity. Red dotted lines depict the ten year averages. Trendlines (not shown) are not significantly different than zero (Control Dam:  $p = 0.20$ ; Valencia:  $p = 0.65$ ; I-5:  $p = 0.83$ ; Dupont:  $p = 0.89$ ,  $\alpha = 0.05$ ).





Figures 8.0-17e-h. Ten year turbidity trends for Whatcom Creek Tributary sites illustrate the effects of storm events on average turbidity. Red dotted lines depict the ten year averages. Trendlines (not shown) are not significantly different than zero (Hanna:  $p = 0.19$ ; Cemetery:  $p = 0.32$ ; Lincoln:  $p = 0.75$ ; Fever:  $p = 0.57$ ,  $\alpha = 0.05$ ).

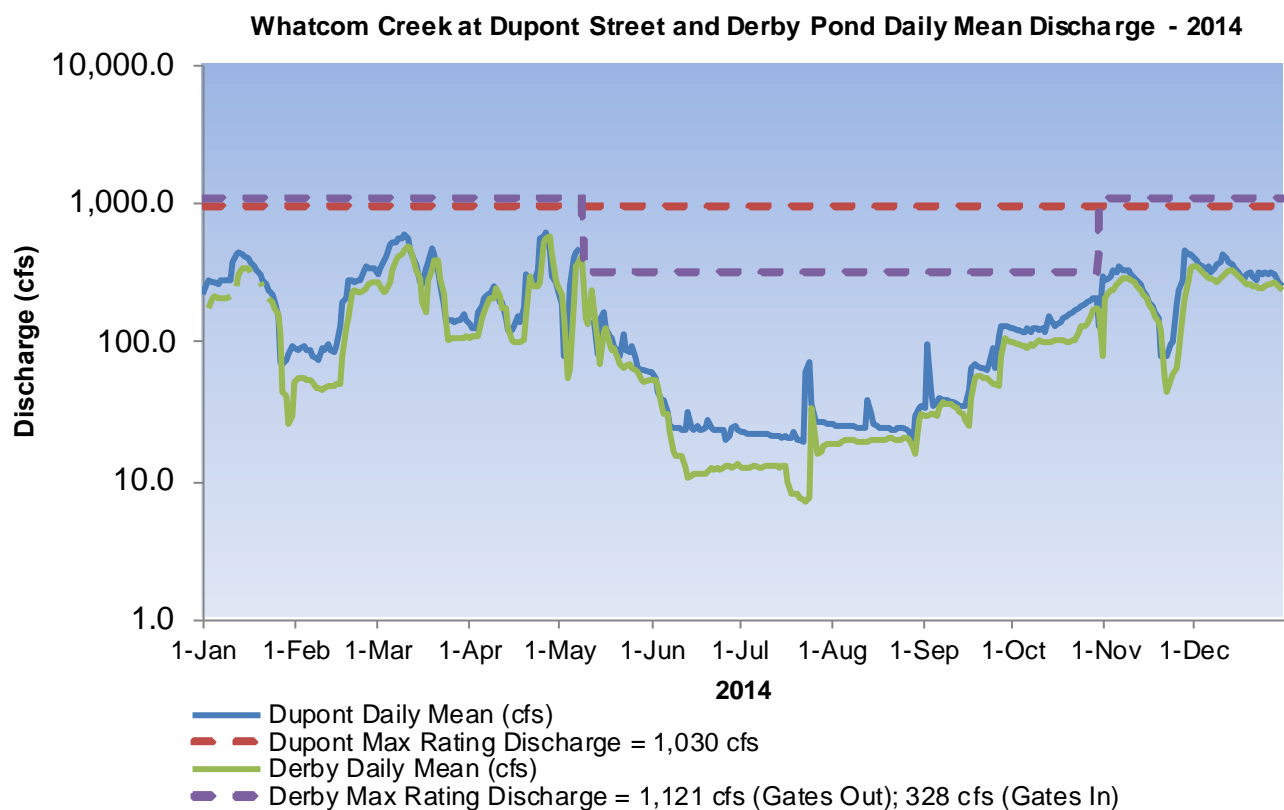
## Hydrology

As the largest urban stream flowing through Bellingham, two gauging stations were established on Whatcom Creek in 2001. One is located in Whatcom Falls Park on the bank of Derby (Fish) Pond and the other above Dupont Street near the mouth. Differences between the hydrographs of the two sites can be explained by a combination of factors: Operation of the control dam and fish hatchery check gates is seen in Derby Pond data as observable drops or climbs, while it is moderated by the influence of tributaries at the Dupont site; and operational changes at the City of Bellingham Screenhouse can also affect flow downstream. Different bathymetric properties (gradual vs. steep banks) at the two sites affects signal moderation when flows change; and the large surface area, sunlight, and slow, pond-like conditions at Derby Pond promote much more evaporation than that of the channelized stream at Dupont Street.

The Control Dam is operated as part of the City's Lake Whatcom level manage-

ment strategy, which is determined by five primary factors: maximum surface elevation as required by law to protect lakeside properties, water availability for storage and treatment, drinking water demand by the citizens of Bellingham, flood control, and salmon habitat in Whatcom Creek. Changes in discharge due to Control Dam operation can be seen approximately 1/2 hour from time of operation at Derby Pond, and 3 to 4 hours later at Dupont St. depending on the amount of discharge. More information regarding Control Dam operation can be found here: <http://www.cob.org/services/environment/lake-whatcom/lw-level.aspx>

In 2014, Whatcom Creek at Derby Pond had a minimum discharge (flow) of 4.8 cubic feet per second (cfs) on May 13th, a maximum discharge of 584 cfs on April 26th, and an median discharge of 99 cfs. Whatcom Creek at Dupont St. on the other hand had a minimum discharge (flow) of 17 cfs on June 26th, a maximum discharge of 653 cfs on April 27th and an average discharge of 122 cfs.



## 9.0 Squalicum Creek Drainage Basin

Squalicum Creek runs almost 10 miles from Squalicum and Toad Lakes to Bellingham Bay and has a drainage area of approximately 15,800 acres (City of Bellingham, 1992). It flows through light industrial and agricultural land before entering Bellingham city limits and passing through industrial, commercial, and residential areas. Channel modification including large culverts and constructed conveyance are present on Squalicum Creek.

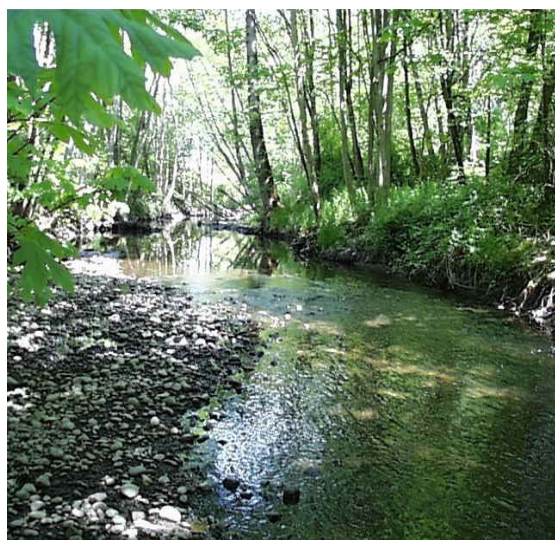


Figure 9.0-1. Squalicum Creek mouth sampling site.

The major contributor to Squalicum Creek is Baker Creek (called Spring Creek in some City documents, but listed as Baker Creek by the state), which has a drainage area of approximately 3,150 acres (City of Bellingham, 1995). Baker Creek flows through agricultural, wooded, industrial, commercial, and residential areas.

Compared to other urban streams, the Squalicum Creek basin has a large proportion of flow that originates from outside city limits. As such, water quality conditions from outside of City of Bellingham jurisdiction can have significant influence on the findings at urban stream monitoring sites.

Squalicum Creek is sampled at three locations: at E. Bakerview Rd. where the creek enters city limits (Figure 9.0-3), in Cornwall Park near Meridian St. (Figure 9.0-11), and the mouth (Figure 9.0-1), approximately 1200 feet upstream from its discharge point into Bellingham Bay (Squalicum Creek Drainage Map). Baker Creek (Figure 9.0-10), Squalicum Creek's major tributary, is sampled just upstream from its confluence with Squalicum Creek at Squalicum Pkwy. (Squalicum Creek Drainage Map).

Every site in the Squalicum Creek drainage met the Core Summer Salmonid Habitat Aquatic Life Use (ALU) criteria for temperature ( $\leq 16^{\circ}\text{C}$ ) in 2014. However, only the Mouth site met the  $\geq 9.5$  mg/L dissolved oxygen ALU measure, and no sites met the Primary Contact Recreational Use standards for fecal coliform (geomean  $\leq 100$  CFU/100 ml; no more than 10% of samples  $> 200$  CFU/100 ml). The Recreational Use standards are equivalent to a Class A rating.

In 2014, the E. Bakerview, Meridian and Baker Creek sites met overall Class B standards, while the Squalicum Mouth site was not able to meet either the Class A or Class B standards. All of the Squalicum drainage sites did meet the Class AA ( $\leq 16^{\circ}\text{C}$ ) temperature criterion. In addition, Squalicum Creek at the Mouth met the Class AA standard for dissolved oxygen (9.5 mg/L), while the other three sites met the Class A standard ( $\geq 8.0$  mg/L). However, for fecal coliform, the E. Bakerview, Meridian and Baker Creek sites could only meet the Class B (geomean  $\leq 200$  CFU/100 ml; no more than 10% of samples  $> 400$  CFU/100 ml) standards, and the Mouth site was not able to meet either the Class A or Class B standard for fecal coliform.



Figure 9.0-3. Squalicum Creek sampling site at E. Bakerview Rd.

The average turbidities for Squalicum and Baker Creek sites in 2014 were all lower than averages in 2013. The highest average turbidity on Squalicum Creek was 8.0 NTU at the Meridian site. The lowest average turbidity was 5.5 NTU at the Baker Creek. Average turbidity values for 2014 are listed along side respective 5 and 10 year averages in Table 9.0-5. Conductivity and pH were consistent with previous years.

Table 9.0-1. Conventional sampling and ten-year trend fecal coliform geomean values for monitoring sites on Squalicum and Baker Creek in 2014.

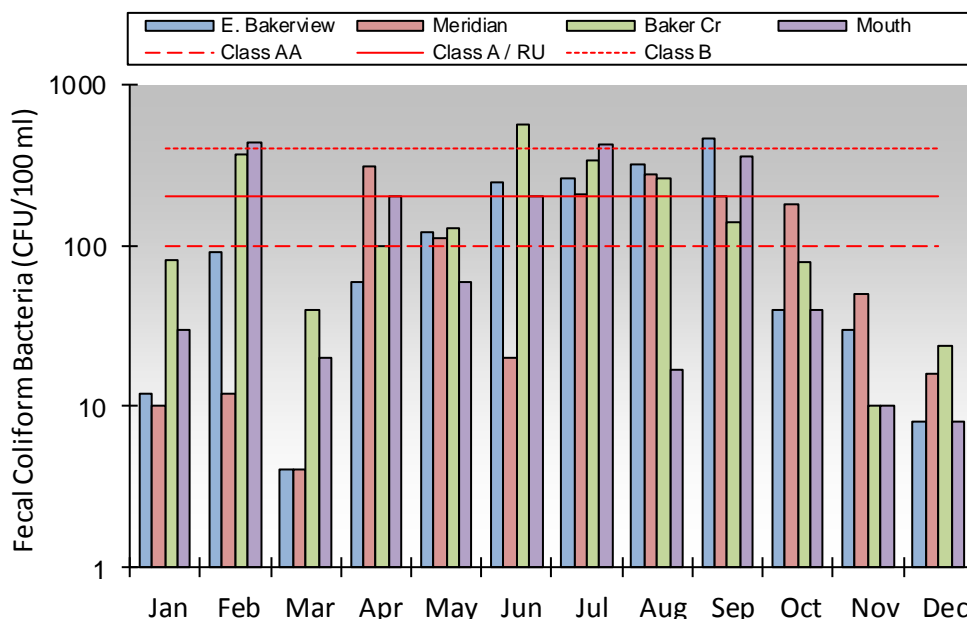
Sampling Site	E. Bakerview	Meridian	Baker Creek	Mouth
Geomean (CFU/100ml)	61	54	106	65
Trend (CFU/100ml/yr)	-6.9	-1.1	0	0

## Fecal Coliform Bacteria

Fecal coliform levels recorded in 2014 were less than values found in previous years (Figures 9.0-4). Despite this, none of the sites in the Squalicum Creek drainage were able to meet the Class A standard (geomean  $\leq 100$  CFU/100 ml; no more than 10% of samples  $> 200$  CFU/100 ml). The E. Bakerview, Meridian and Baker Creek sites did however meet the Class B standard (geomean  $\leq 200$  CFU/100 ml; no more than 10% of samples  $> 400$  CFU/100 ml). The Squalicum Creek Mouth site was unable to meet either the Class A or Class B standard.

As with the majority of our urban creek sites, two sites on Squalicum Creek exhibited negative 10-year trends in fecal coliform geomeans for the period ending in 2014. However, the Squalicum Mouth site and Baker Creek trendlines were not significantly different than zero (Figures 9.0-6a-d).

Figure 9.0-4. Monthly 2014 fecal coliform levels for sampling sites on Squalicum and Baker Creeks. Red lines indicate the numeric criteria for the calculated geomean for the different surface water classes (AA, A, and B). The Primary Contact Recreational Use (RU) designation is equivalent to Class A. *Note this graph uses a log-arithmetic scale.*





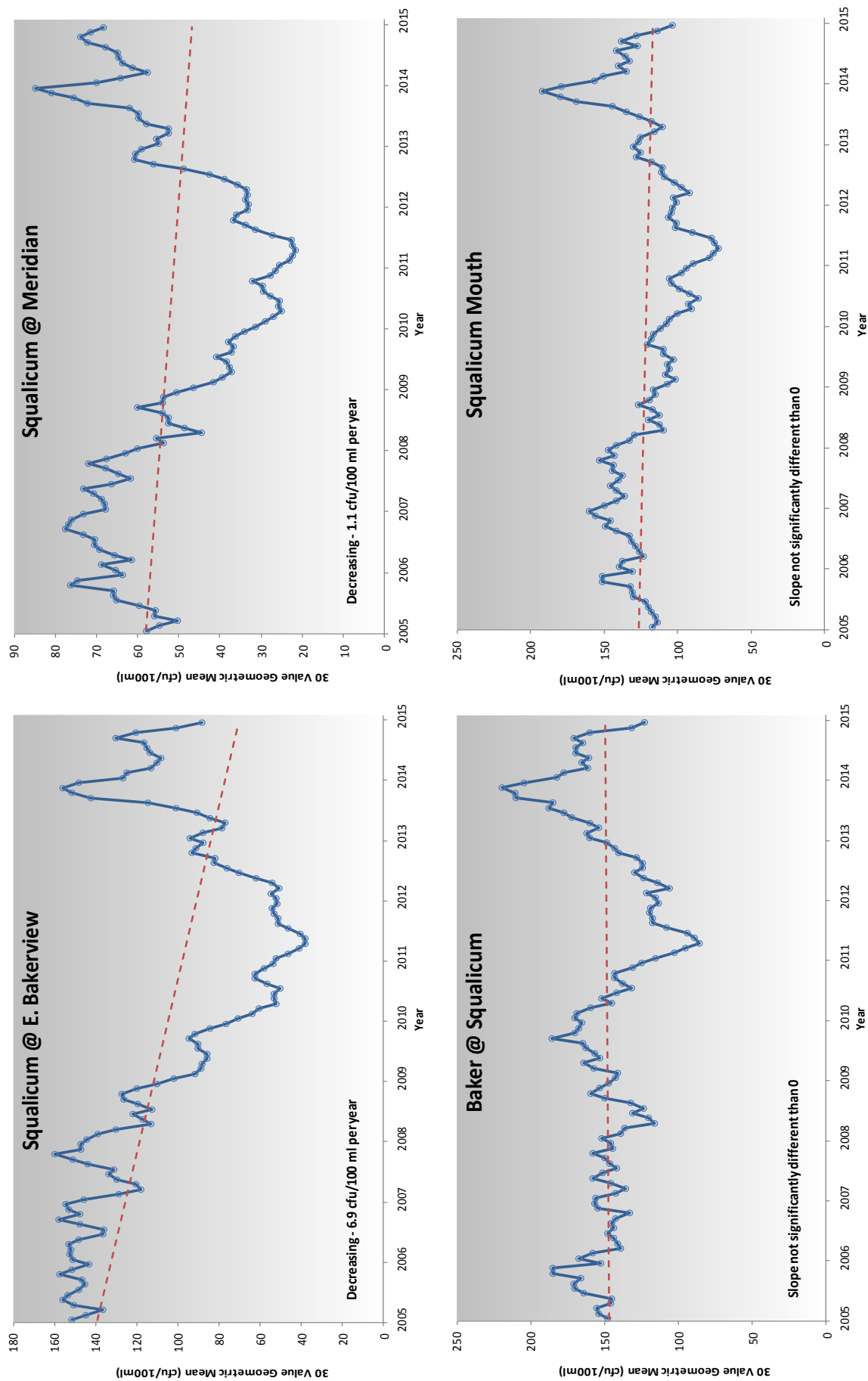


Figure 9.0-6a-d. Thirty value moving geometric mean fecal coliform trends for Squalicum Creek Drainage samples collected 2005 through 2014. Baker Creek and the Squalicum Mouth site did not have a significant descending 10 year trendlines (red) for the period ending 2014 (E.Bakerview:  $p = 2.95 \times 10^{-10}$ ; Meridian:  $p = 0.04$ ; Baker Creek:  $p = 0.72$ ; Mouth:  $p = 0.17$ ,  $\alpha = 0.05$ ). Noticeable uptick during 2013 is likely the influence of sampling during several large, first flush rain events that occurred during the period.

## Dissolved Oxygen

Of the sites in the Squalicum Creek drainage, only the Squalicum Creek Mouth site met the Core Summer Salmonid Habitat Aquatic Life Use (ALU) standard in 2014. At  $\geq 9.5$  mg/L, the ALU is equivalent to Class AA. The other three sites in the Squalicum Creek drainage all met the Class A standard for dissolved oxygen ( $\geq 8.0$  mg/L), which is a significant improvement from last year.

In the past, the E. Bakerview sampling site has frequently experienced low dissolved oxygen levels during the summer months, most likely due to low flows and warmer temperatures (Figures 9.0-8a and 9.0-10). Based on stream discharge levels (Figure 9.0-14), it can be extrapolated that low flows are significant factor in low dissolved oxygen levels throughout the

## Squalicum Creek drainage.

Dissolved oxygen in all creek segments sampled in 2014 followed an expected trend of lower values in the warmer summer months (Figure 9.0-7). Average dissolved oxygen values are shown in Table 9.0-2. There were no ten year dissolved oxygen trendlines in the Squalicum Creek Drainage that were significantly different than zero for the period of 2005-2014 (Figures 9.0-8a-d).

Table 9.0-2. Average dissolved oxygen values for Squalicum and Baker Creek in 2014. Based on conventional sampling.

Sampling Site	E. Bakerview	Meridian	Baker Creek	Mouth
Average DO (mg/L)	11.4	10.4	11.2	11.4

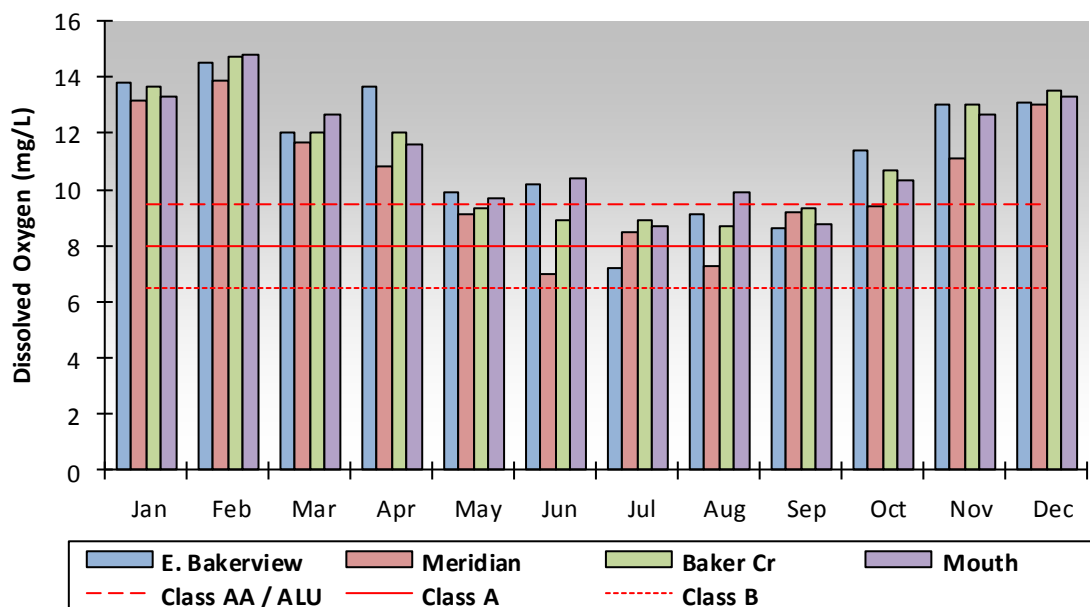
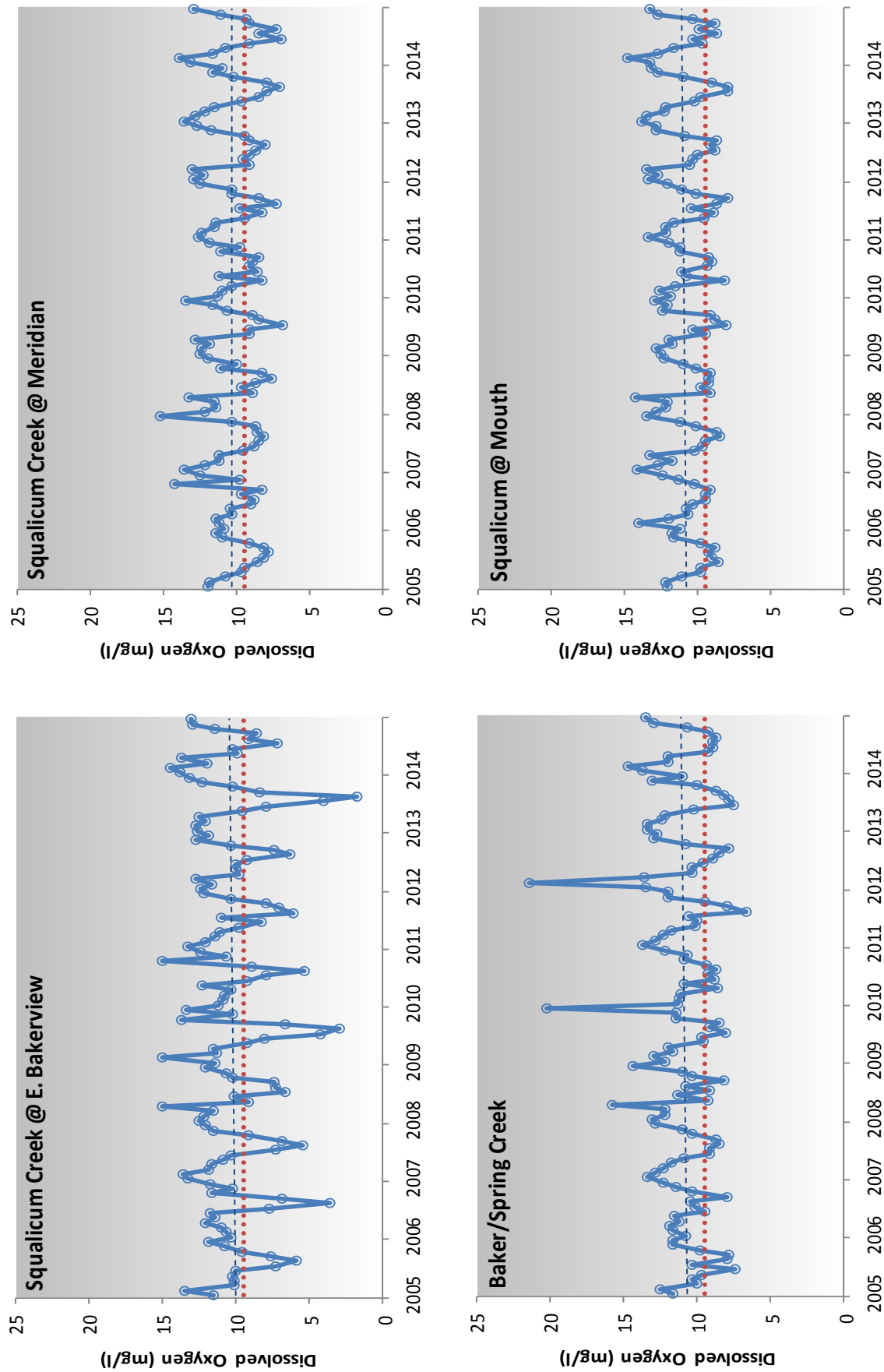


Figure 9.0-7. Monthly 2014 dissolved oxygen levels for Squalicum and Baker Creek sampling sites. Red lines the lowest dissolved oxygen levels allowed by the different surface water classes (AA, A, and B). Core Summer Salmonid Habitat Aquatic Life Use (ALU) is equivalent to Class AA. Based on conventional sampling.



Figures 9.0-8a-d. Ten year dissolved oxygen trendlines (blue) for Squalicum Creek sites in 2014. None of the trendlines were significantly different from zero (E. Bakerview:  $p = 0.54$ ; Meridian:  $p = 0.99$ ; Mouth:  $p = 0.52$ ; Baker Creek:  $p = 0.05$ ). Red dotted lines depict the 9.5 mg/l Aquatic Life Use standard.

## Temperature

Results of sampling indicate the stringent 16°C Core Summer Salmonid Habitat Aquatic Life Use (ALU) designation was met for all Squalicum Creek Drainage sites in 2014 (Figure 9.0-9). The 16°C ALU is equivalent to a Class AA rating.

Average temperatures for 2014 are provided in Table 9.0-3. None of the Squalicum Creek Drainage sites displayed ten year trendlines that were significantly different than zero in 2014 (Figures 9.0-12a-d).

Table 9.0-3. Average temperatures for sampling sites on Squalicum and Baker Creeks, 2014. Based on conventional sampling.

Sampling Site	E. Bakerview	Meridian	Baker Creek	Mouth
Average Temperature (°C)	10.1	10.9	9.9	10.7

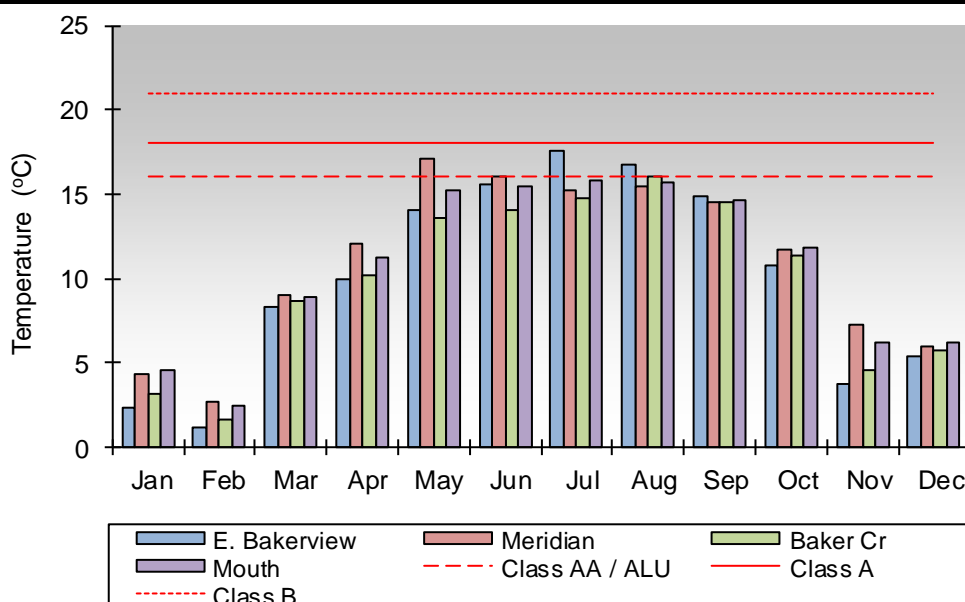


Figure 9.0-9. Monthly temperature measurements for Squalicum and Baker Creek sampling sites in 2014. Red lines indicate the highest temperatures allowed by the different surface water standards (AA, A, and B). Core Summer Salmonid Habitat Aquatic Life Use (ALU) is equivalent to Class AA. Based on conventional sampling.



Figure 9.0-10. Baker Creek sampling site.



Figure 9.0-11. Squalicum Creek sampling site at Meridian St.



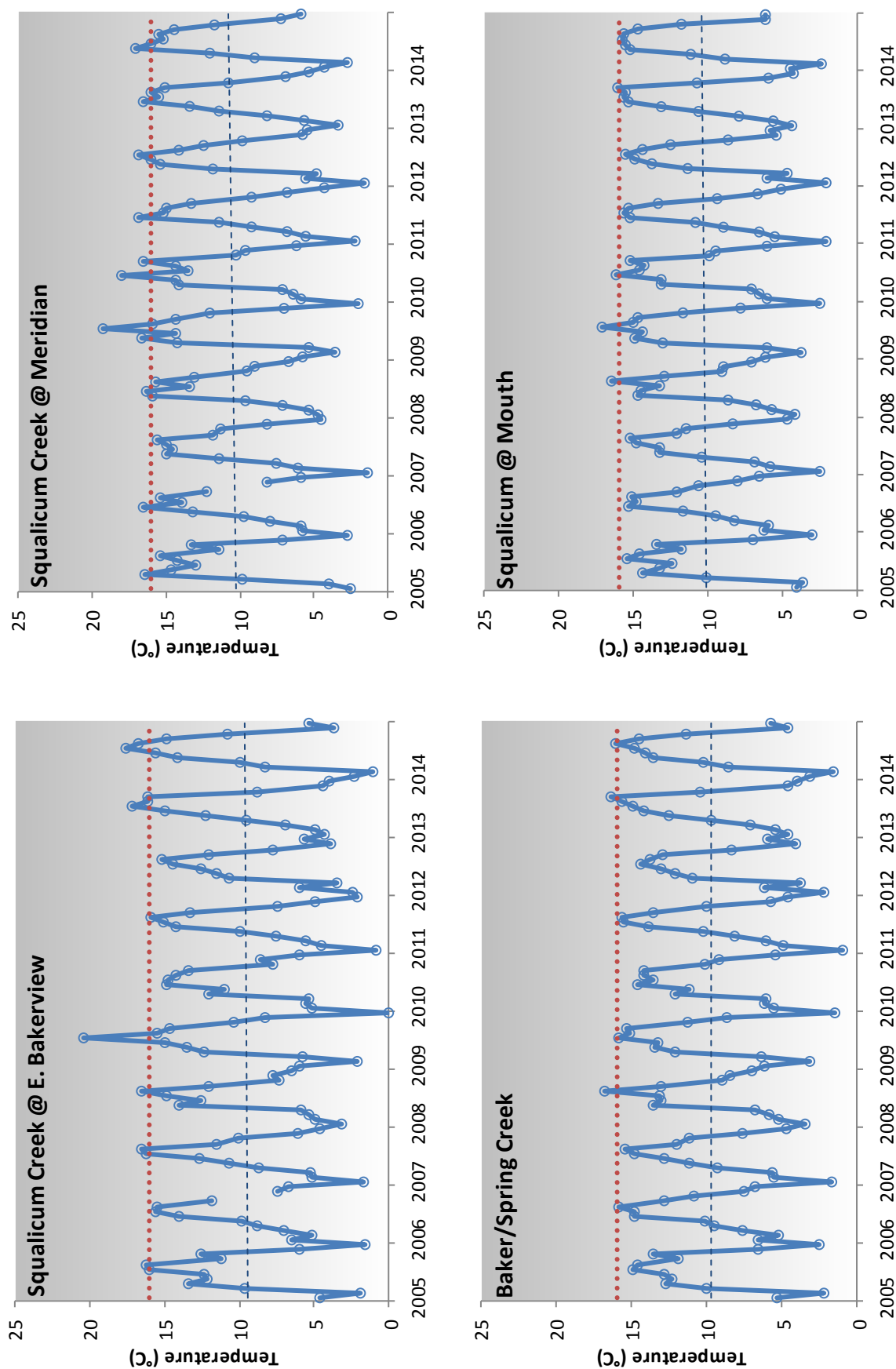


Figure 9.0-12a-d. Ten year temperature trends at Squalicum Creek Drainage sites, 2005-2014. Trendlines (blue) were not significantly different than zero (E. Bakerview:  $p = 0.87$ ; Meridian:  $p = 0.74$ ; Baker:  $p = 0.80$ ; Mouth:  $p = 0.79$ ,  $\alpha = 0.05$ ). Red dotted lines depict the 16°C Aquatic Life Use standard.

## pH

The pH at sites monitored on Squalicum and Baker Creeks generally fall within the range prescribed by Ecology for all classes of freshwater bodies, 6.5 to 8.5. During 2014 all Squalicum and Baker Creek sites were once again within this standard. Graphs are not included in this section because pH is so rarely exceeded.

## Turbidity

The average turbidities of the sampling sites on Squalicum and Baker Creeks in 2014 were lower than 2013 and similar to those of previous years. The average turbidities for all four sites were above their respective 5-year and 10-year averages (Figures 9.0-13 a-d).

In 2014 the turbidity levels in Squalicum and Baker Creeks show the typical trend of lower values in the drier months and higher values during the wet season (Figures 9.0-13 a-d). High values in February correlate with rainfall. Average, maximum and minimum turbidity values for 2014 is provided in Table 9.0-4.

Table 9.0-4. The average, maximum and minimum turbidity values for Squalicum and Baker Creek sampling sites in 2014 .

Sampling Site	E. Bakerview	Meridian	Baker	Mouth
2014 Average (NTU)	6.1	8.0	5.5	5.8
2014 Maximum (NTU)	12.3	20.3	12.7	12.2
2014 Minimum (NTU)	1.5	2.8	0.6	1.3



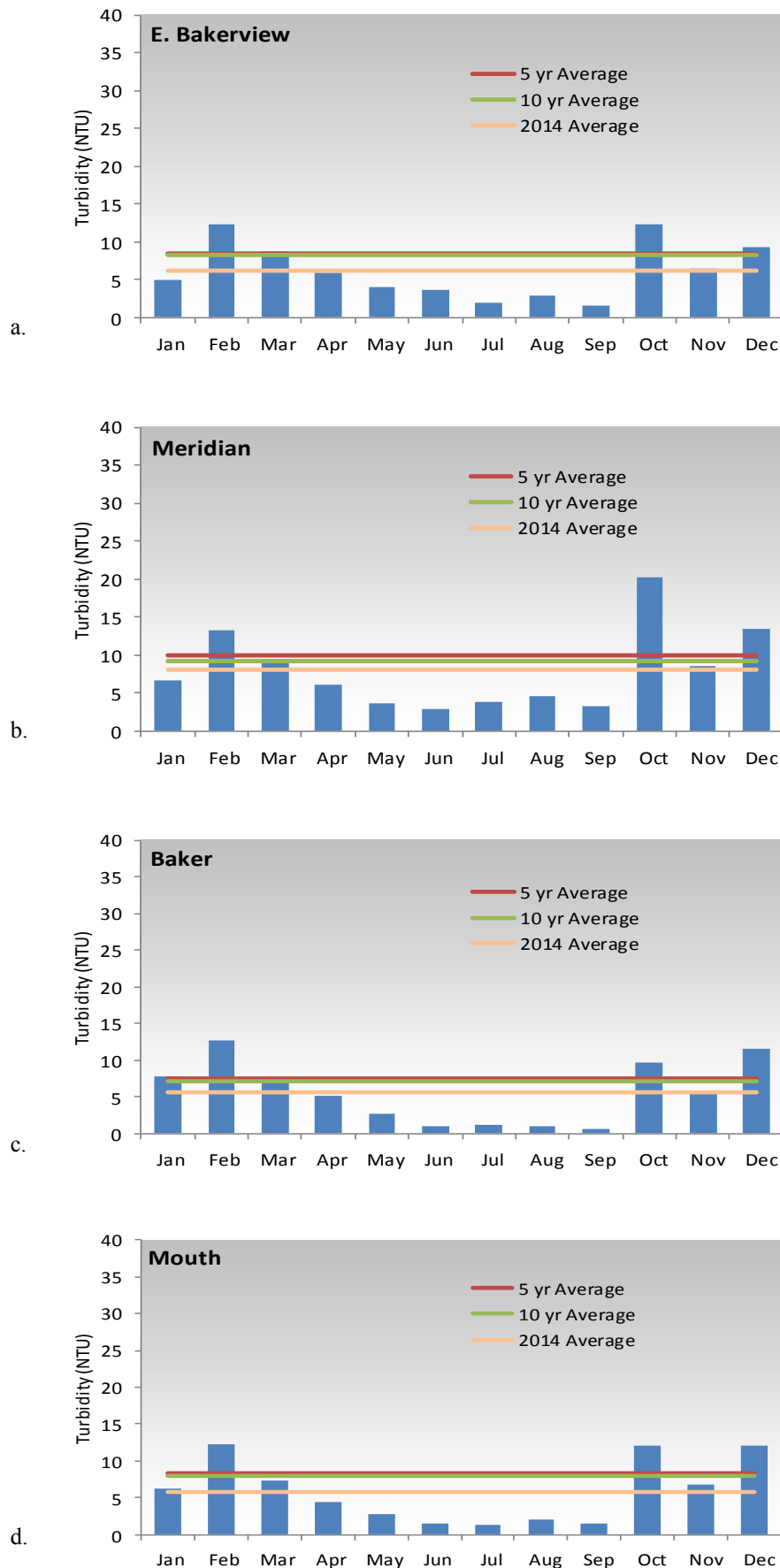


Figure 9.0-13a-d. Monthly turbidity values for Squilicum and Baker Creeks in 2014. Presented with yearly, 5-year and 10-year averages.

## Hydrology

The Squalicum Creek gauging station has been in service since 2005. It is located approximately 100 feet upstream West Street off of Squalicum Parkway.

Squalicum Creek typically has a higher volume of discharge than Padden or Chuckanut Creeks and at times has been observed to be as high as those of Whatcom Creek. However, the duration of high flows in Squalicum Creek is noticeably less than that of Whatcom Creek, as is the average discharge.

In 2014, Squalicum Creek had a minimum discharge (flow) of 0.4 cubic feet per second (cfs) on July 10th, a maximum discharge of 694 cfs on March 3rd and a median discharge of 19 cfs. First quartile flow was 1.9 cfs (i.e. 25% of the flow data was below this value) and third quartile flow was 50 cfs (i.e. 25% of flow was above this value).

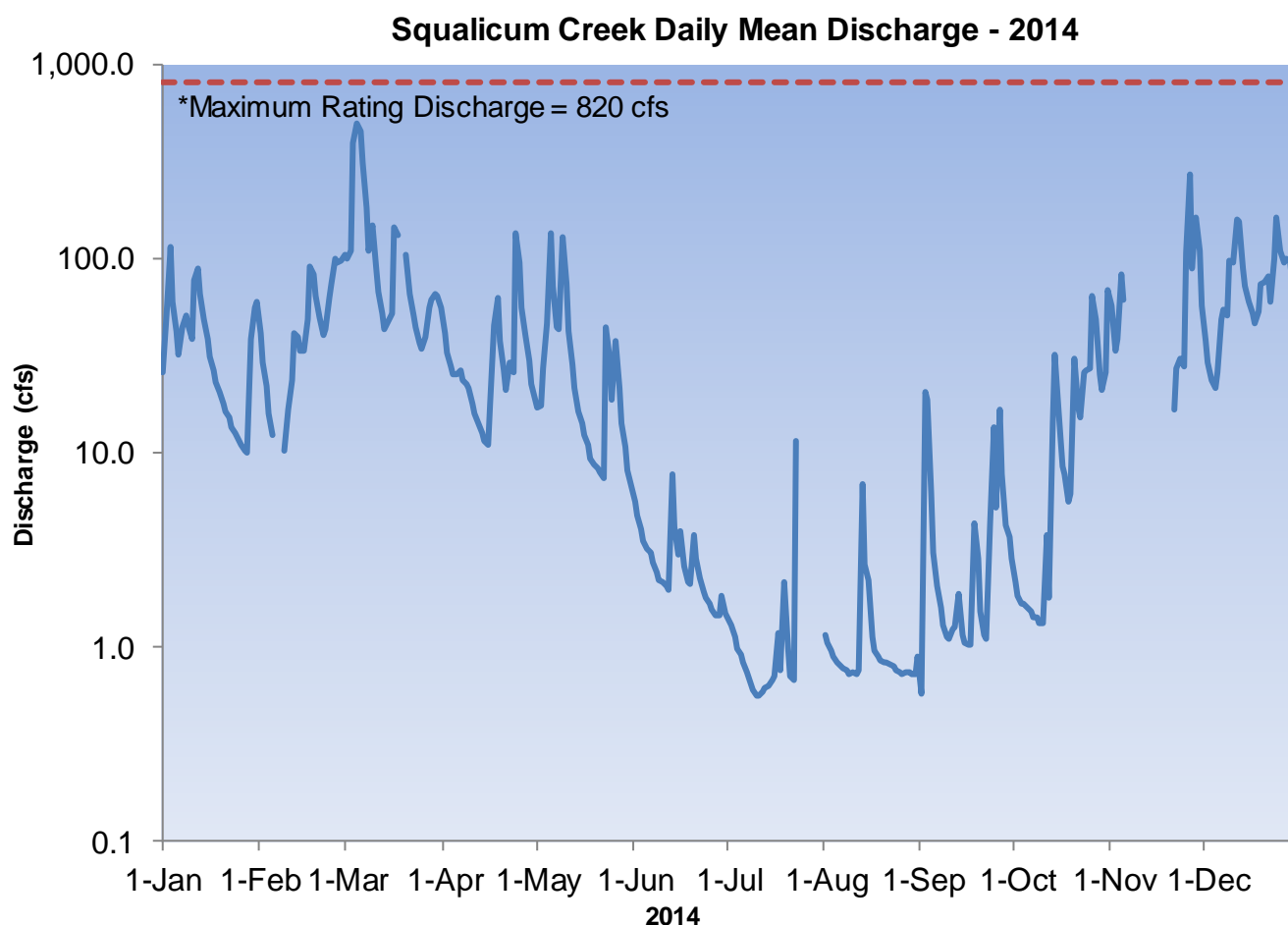


Figure 9.0-14. Daily mean discharge on Squalicum Creek during 2014. Discharge values above the maximum rating discharge of 820 cfs are of poor quality and should be interpreted cautiously. This hydrograph uses a logarithmic scale.



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## Appendix A.

Detail on selected stream restoration projects within the City of Bellingham. LWD = Large Woody Debris

Creek	Location	Project	Year
Padden	24th St.	Installation of fish friendly culvert	1996
Padden	24th St. to 30th St.	Riparian planting and restoration	2003 on
Padden	24th St. to 30th St.	Placement of LWD Recontour banks Reconnect to historic flood plain Add spawning gravel Create overflow channel	2008/ 2009
Padden	Fairhaven Park	Riparian planting and restoration Move trail away from stream bank	2005/ 2006
Padden	Fairhaven Park	Placement of LWD Recontour banks Reconnect to historic flood plain Add spawning gravel	2008/ 2009
Padden	12th St.	Culvert Improvements: Replace baffles Structures to prevent fish from becoming trapped during high flows	2004
Connelly	Donovan Ave.	Installation of fish passable culvert	2004
Whatcom	Marine Heritage Park	Riparian planting and restoration	1995
Whatcom	Whatcom Falls Park to Mouth	Riparian planting and restoration (some small sections not yet planted)	2000 on
Whatcom	North of Cemetery Creek, East of Racine St.	Salmon Park: Placement of LWD Create backwater swales and a side channel: velocity refuge for fish Breached a constructed berm to reconnect to historic flood plain, creating more natural stream flow	2006
Whatcom	City owned property north of Haskell Business Park	Red Tail Reach: Similar projects to Salmon Park	2007/ 2008
Whatcom	Young St. & Commercial	Culvert Improvements: Replace baffles Work on upstream end to improve fish movement	2004
Cemetery	City owned property east of Haskell Business Park, north of Fraser St.	New creek channel created to mimic an undisturbed stream system Placement of LWD Recontour banks Create three large ponds—velocity refuge and overwintering habitat for juvenile fish	2006
Cemetery	Upstream of confluence with Whatcom Creek	Create Backwater swale—velocity refuge for fish Reconnect to historic flood plain	2006

Creek	Location	Project	Year
Lincoln	Maple St.	Installation of fish friendly culvert	1991
Lincoln	Moore St.	Installation of fish friendly culvert	1998
Squalicum	Meridian St.	Installation of fish friendly culvert	1996/1997
Squalicum	Meridian St. to Mouth	Riparian planting and restoration	2005 on
Squalicum	West St. to Mouth	Lower Squalicum Bank Protection Project: Log jams Log crib wall Root wads Create overflow channel	2005
Squalicum	Squalicum Pkwy.	Retrofit all Culverts: Fish friendly Install baffles Create upstream/downstream pools - fish resting areas	2005
Squalicum	Birchwood Ave. & Squalicum Pkwy	Retrofit culvert to force water from subsurface flow during low flow periods into pipe	2004
Baker	Birchwood Ave.	Installation of fish friendly culvert	1996
Baker	Telegraph Rd.	Riparian planting and restoration Create backwater swale—velocity refuge Recontour banks Reconnect to historic flood plain	2006
Baker	Telegraph Rd.	Installation of fish friendly culvert	2004
Willow Spring (Squalicum)	Squalicum Park	Daylight Placement of LWD Riparian planting and restoration Recontour banks	2010



## Appendix B

## Quality Control Protocol

Test	Fecal Coliform	Dissolved Oxygen	Temperature	pH	Turbidity	Conductivity
<b>Holding Time</b>	Within 6 hrs	<i>In situ</i> analysis	<i>In situ</i> analysis	<i>In situ</i> analysis	Usually done within 8 hr. Up to 24 hr.	<i>In situ</i> analysis
<b>Method</b>	SM 9222 D.	SM 4500-O G.	SM 2550 B.	SM 4500-H <sup>+</sup> B.	SM 2130 B.	SM 2510 B.
<b>Instrumentation</b>		YSI Pro Plus	YSI Pro Plus	YSI Pro Plus	Hach 2100P Turbidimeter	YSI Pro Plus
<b>Calibration</b>		Barometric pressure calibration in air.	Factory -set. Annually calibrated against an NIST-traceable thermometer.	Buffers: pH 4.00, 7.00 and 10.00.	Calibrate with primary standards—1, 10, 100, 1000 NTU standards.	Conductivity standard obtained from an external source. Cell coefficient should be 0.475 +/- 1%, if not, investigate.
<b>Check Standard or Calibration Check</b>		Calibration check—test one sample by YSI (STM 4500-O G.) and one by Winkler Method (STM 4500-O C). Both samples from same sample site.		Check standard obtained from an external source. Test before and after run.	Calibration check – primary or secondary standard in the range of interest.	In-house conductivity standard, prepared quarterly. Test before and after run.
<b>QC Objectives</b>	Verification of 10% of samples and adjustment of counts based on verification results. Investigate if natural log of lab or field duplicates are different by more than $\pm 2 \delta$ of calculated control limits.	Investigate if calibration check is different by 0.5 mg/L or more or if field duplicates are different by more than $\pm 2 \delta$ of calculated control limits.	Add or subtract correction factor as necessary. Investigate if field duplicates are different more than $\pm 2 \delta$ of calculated control limits.	Investigate if check standard is different by 0.2 pH units or more or if field duplicates are different by more than $\pm 2 \delta$ of calculated control limits.	Investigate if lab or field duplicates are different by more than $\pm 2 \delta$ of calculated control limits.	Investigate if check standard are different by more than 10% or if field duplicates are different by more than $\pm 2 \delta$ of calculated control limits.

## Appendix C. Exceedence Frequency Tables

Table C-1. Frequency of Class A surface water standard exceedences for fecal coliform bacteria over past 10 years. Class A surface water standards state that no more than 10% of samples used to calculate the geometric mean may exceed 200 cfu/100 ml. Shaded cells indicate the number of exceedences, unshaded cells indicate the number of samples per year.

SAMPLING SITE	2005		2006		2007		2008		2009		2010		2011		2012		2013		2014		Ttl Viol	Ttl Samp	Percent Exceedence
Chuckanut (mouth)	3	12	2	12	2	12	2	12	3	12	1	12	1	12	2	12	2	12	1	12	19	120	16%
	1	12	0	12	0	12	2	12	1	12	1	12	2	12	1	12	1	12	1	12	10	120	8%
	4	12	3	12	3	12	2	12	2	12	2	12	1	12	2	12	3	12	4	12	26	120	22%
Connelly (Donovan)	6	12	7	12	6	12	5	12	4	12	2	12	4	12	7	12	6	12	4	12	51	120	43%
Padden (24th)	7	12	6	12	7	12	3	12	4	12	2	12	2	12	7	12	7	12	6	12	51	120	43%
Padden (14th)																			5	12	5	12	42%
Padden (mouth)	5	12	7	12	5	12	2	12	6	12	5	12	5	12	7	12	7	12	7	12	56	120	47%
Whatcom (Control Dam)	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	120	0%
Hanna (Below WTP)	2	10	4	11	2	12	3	12	2	12	1	12	4	12	6	12	2	12	1	12	27	117	23%
Cemetery (Whatcom)	7	12	7	12	4	12	3	12	3	12	2	12	4	12	6	12	4	12	2	12	42	120	35%
Lincoln (Fraser)	3	12	5	12	2	12	3	12	6	12	2	12	4	12	7	12	5	12	3	12	40	120	33%
Fever (Valencia)	5	12	10	12	6	12	6	12	7	12	7	12	5	12	9	12	9	12	3	12	67	120	56%
Whatcom (Valencia)			0	4	0	12	0	12	1	12	0	12	0	12	1	12	1	12	0	12	3	100	3%
Whatcom (I-5)	2	12	1	12	0	12	1	12	2	12	0	12	1	12	1	12	1	12	0	12	9	120	8%
Whatcom (Dupont)	4	12	3	12	2	12	2	12	5	12	1	12	2	12	2	12	3	12	0	12	24	120	20%
Squalicum (E Bakerview)	4	12	6	12	3	12	3	12	1	12	2	12	1	12	6	12	5	12	4	12	35	120	29%
Squalicum (Meridian)	3	12	2	12	1	12	2	12	1	12	1	12	1	12	2	12	2	12	3	12	18	120	15%
Baker (Squalicum)	4	12	3	12	6	12	7	12	5	12	2	12	4	12	6	12	5	12	4	12	46	120	38%
Squalicum (mouth)	4	12	6	12	4	12	1	12	5	12	2	12	5	12	5	12	6	12	3	12	41	120	34%

Table C-2. Frequency of Class A surface water standard exceedences for dissolved oxygen for past 10 years. Class A surface waters must maintain dissolved oxygen levels of 8.0 mg/L or greater. Shaded cells indicate the number of exceedences, unshaded cells indicate the number of samples per year.

SAMPLING SITE	2005		2006		2007		2008		2009		2010		2011		2012		2013		2014		Ttl Viol	Ttl Samp	Percent Exceedence
Chuckanut (mouth)	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	1	12	0	12	1	120	1%
Padden (38th)	0	12	0	12	0	12	1	12	1	12	0	12	0	12	0	12	1	12	0	12	3	120	3%
Padden (30th)	0	12	0	12	0	12	0	12	0	12	0	12	1	12	0	12	1	12	0	12	2	120	2%
Connelly (Donovan)	0	12	0	12	0	12	0	12	1	12	0	12	2	12	0	12	1	12	0	12	4	120	3%
Padden (24th)	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	120	0%
Padden (14th)																			0	12	0	12	0%
Padden (mouth)	0	12	0	12	0	12	0	12	2	12	0	12	1	12	0	12	1	12	0	12	4	120	3%
Whatcom (Control Dam)	0	12	0	12	0	12	0	12	2	12	0	12	2	12	0	12	3	12	0	12	7	120	6%
Hanna (Below WTP)	0	10	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	1	12	1	117	1%
Cemetery (Whatcom)	3	12	0	12	4	12	3	12	4	12	2	12	3	12	2	12	3	12	4	12	28	120	23%
Lincoln (Fraser)	2	12	0	12	1	12	3	12	2	12	2	12	2	12	3	12	3	12	4	12	22	120	18%
Fever (Valencia)	1	12	0	12	0	12	1	12	1	12	0	12	0	12	1	12	1	12	2	12	7	120	6%
Whatcom (Valencia)			0	4	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	100	0%
Whatcom (I-5)	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	120	0%
Whatcom (Dupont)	1	12	0	12	0	12	2	12	2	12	0	12	0	12	2	12	3	12	0	12	10	120	8%
Squalicum (E Bakerview)	3	12	3	12	3	12	3	12	3	12	1	12	3	12	2	12	3	12	1	12	25	120	21%
Squalicum (Meridian)	1	12	0	12	0	12	1	12	1	12	0	12	1	12	0	12	2	12	2	12	8	120	7%
Baker (Squalicum)	2	12	1	12	0	12	0	12	0	12	0	12	2	12	1	12	2	12	0	12	8	120	7%
Squalicum (mouth)	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	1	12	0	12	1	120	1%

Table C-3. Frequency of Class A surface water standard exceedences for temperature. Class A surface waters must maintain temperature  $\leq 18^{\circ}\text{C}$ . Shaded cells indicate the number of exceedences, unshaded cells indicate the number of samples per year.

SAMPLING SITE	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Ttl Viol	Ttl Samp	Percent Exceedence
Chuckanut (mouth)	0	12	0	12	0	12	0	12	0	12	0	120	1%
Padden (38th)	0	12	0	12	0	12	1	12	0	12	1	120	3%
Padden (30th)	0	12	0	12	0	12	0	12	0	12	0	120	1%
Connelly (Donovan)	0	12	0	12	0	12	0	12	0	12	0	120	1%
Padden (24th)	0	12	0	12	0	12	0	12	0	12	0	120	1%
Padden (14th)										0	12	0	0%
Padden (mouth)	0	12	0	12	0	12	0	12	0	12	0	120	1%
Whatcom (Control Dam)	2	12	3	12	2	12	2	12	4	12	4	120	23%
Hanna (Below WTP)	0	10	0	11	0	12	0	12	0	12	0	117	0%
Cemetery (Whatcom)	0	12	0	12	0	12	0	12	0	12	2	120	4%
Lincoln (Fraser)	0	12	0	12	0	12	0	12	0	12	0	120	1%
Fever (Valencia)	0	12	0	12	0	12	0	12	3	12	0	120	3%
Whatcom (Valencia)		0	4	2	12	2	12	1	12	2	3	100	14%
Whatcom (I-5)	1	12	1	12	2	12	0	12	2	12	3	120	12%
Whatcom (Dupont)	1	12	0	12	1	12	1	12	2	12	3	120	10%
Squalicum (E Bakerview)	0	12	0	12	0	12	0	12	0	12	0	120	1%
Squalicum (Meridian)	0	12	0	12	0	12	0	12	0	12	0	120	1%
Baker (Squalicum)	0	12	0	12	0	12	0	12	0	12	0	120	0%
Squalicum (mouth)	0	12	0	12	0	12	0	12	0	12	0	120	0%



Table C-4. Frequency of Class A surface water standard exceedences for pH over past 10 years. Class A surface waters must maintain pH levels between 6.5 and 8.5. Shaded cells indicate the number of exceedences, unshaded cells indicate the number of samples per year.

SAMPLING SITE	2005		2006		2007		2008		2009		2010		2011		2012		2013		2014	Ttl Viol	Ttl Samp	Percent Exceedence
Chuckanut (mouth)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Padden (38th)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Padden (30th)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Connolly (Donovan)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Padden (22nd)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Padden (14th)																			0	12	0	0%
Padden (mouth)	0	11	1	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	1	1%
Whatcom (Control Dam)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Hanna (Below WTP)	0	9	1	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	116	1	1%
Cemetery (Whatcom)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Lincoln (Fraser)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Fever (Valencia)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Whatcom (Valencia)			0	4	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	100	0	0%
Whatcom (I-5)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Whatcom (Dupont)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Squalicum (E Bakerview)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Squalicum (Meridian)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Baker (Squalicum)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%
Squalicum (mouth)	0	11	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	12	0	119	0	0%

## Appendix D. 303d Listing Maps

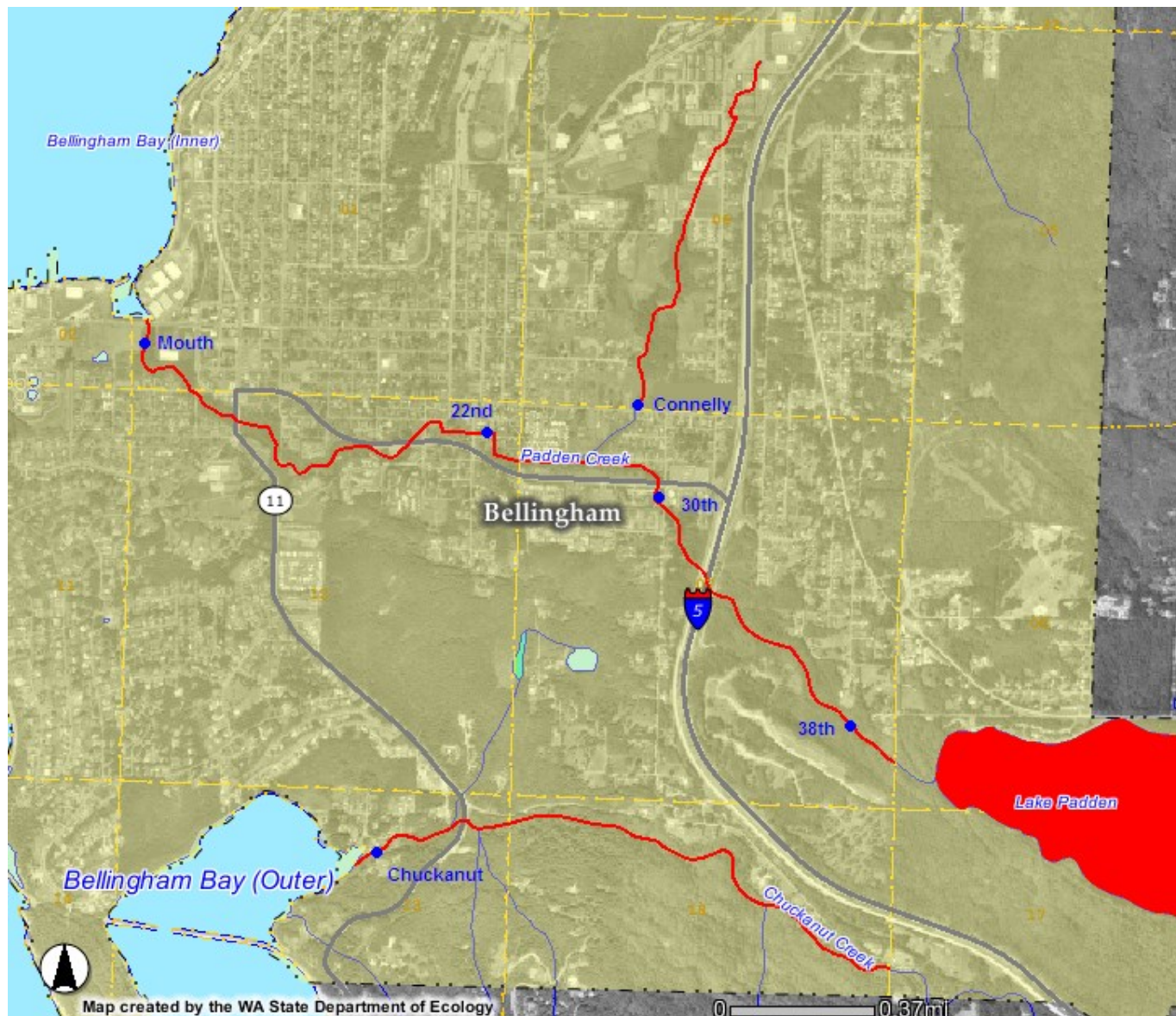


Figure D-1. Map of 303d listed stream segments on Chuckanut and Padden Creek Drainages. Listed segments in red. City of Bellingham sample sites labeled in blue. Yellow shading indicates City limits. All segments are listed for fecal coliform. In addition, the segments containing the Padden Mouth site, the 30th and 38th St. sites, Connelly Creek and the Chuckanut Mouth site are listed for dissolved oxygen. Finally, the Connelly Creek and Padden 30th/38th segments are listed for temperature exceedences.



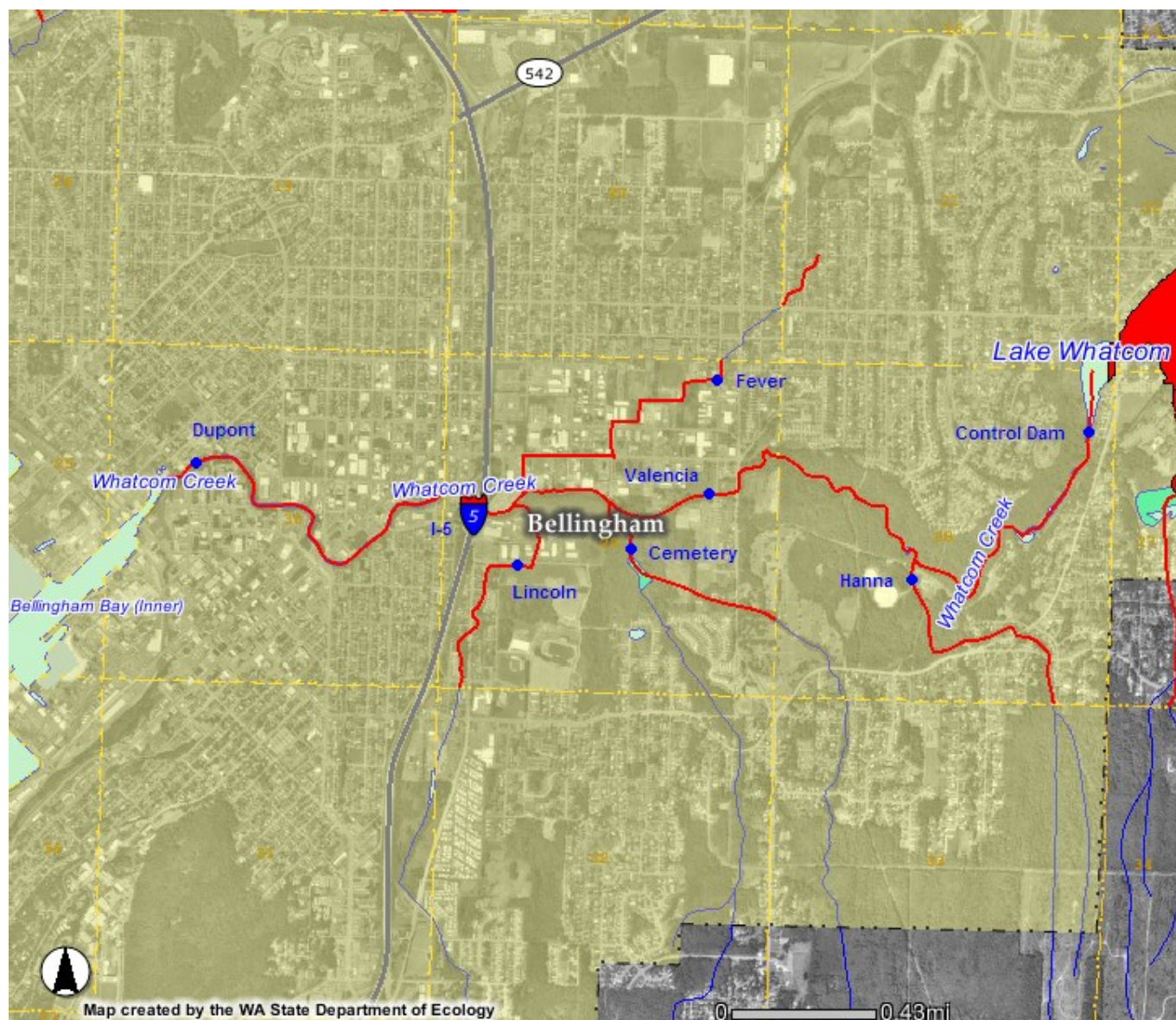


Figure D-2. Map of 303d listings in the Whatcom Creek Drainage. Listed segments in red. City of Bellingham sample sites labeled in blue. Yellow shading indicates City limits. All Segments on Whatcom Creek, as well as Cemetery, Lincoln and Fever Creeks are listed for fecal coliform, temperature and dissolved oxygen. Hanna Creek is listed for fecal coliform and temperature. Fever Creek is also listed for zinc.



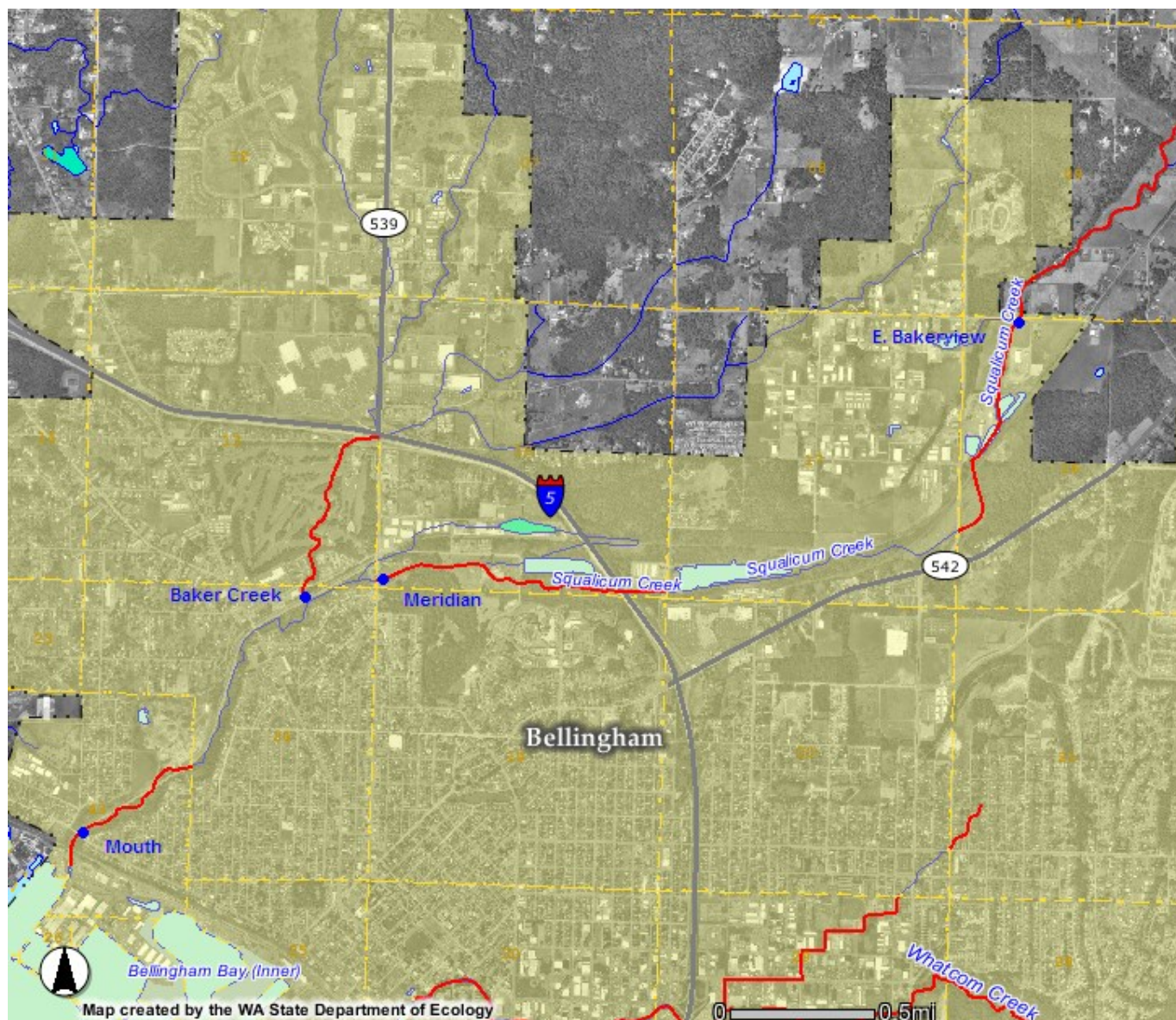


Figure D-3. Map of 303d listings in the Squalicum Creek Drainage. Listed segments in red. City of Bellingham sample sites labeled in blue. Yellow shading indicates City limits. All of the listed segments are listed for excess fecal coliform bacteria. The segment containing the Meridian sampling site and the segment outside the City limits are also listed for temperature and dissolved oxygen. The segment below the E. Bakerview is listed for dissolved oxygen and fecal coliform.



## Appendix E. Drainage Maps

