Health Assessment of City of Bothell's Streams: 2010-2013

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City of Bothell™

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Executive Summary

The City conducted surface water quality monitoring to determine the effectiveness of City programs to protect, preserve and enhance surface waters. The health of surface waters, city streams, was measured using the chemical, physical and biological conditions. The city has adopted programs and rules whose intent is to protect and improve the health of streams, wetlands, and rivers, collectively referred to as critical areas.

The monitoring was set up to answer the question "Is what we are doing making a difference to the streams"? The monitoring used a broad set of measures to provide signals along the continuum of stream health. Several lines of evidence were used to obtain status and trends. They included: chemical (Dissolved Oxygen, pH, and conductivity), physical (temperature, habitat, sediment, and large wood), and biological (stream insects, and fish populations).

The monitoring began in 2010 with monthly water quality samples collected at approximately 17 stream stations. In 2010 and 2013, 7 of these sites received bioassessment surveys, which included samples of stream insects and fish communities. The results found all streams in various stages of decline. There was little to no change over the 4-year period of study. While some streams improved others worsened over time. In aggregate there was not a perceptible trend of improvement. Some monitoring indicated potential for future worsening of conditions.

The simple answer to the important question, "Are things improving in our streams?" is "No." While some measures improved between 2010 and 2013, the vast majority stayed the same or declined.

The results presented here indicate that what we are currently doing, e.g. critical area protection measures and surface water management practices, are not effective at improving conditions, restorative, nor protecting all equally from further decline over the period studied. It is possible, but not proven, that these efforts may have kept things from getting worse. However, there were multiple signals that things could get worse if, for example, ambient air temperatures warm, causing further downward pressure on dissolved oxygen levels or the decline in stream insect density cascades into a loss of diversity.

There is a real potential for a needed paradigm shift from what we have been doing to adopting a different approach. It is recommended that this critical finding be used to evaluate each program and regulation to their appropriateness at improving the long term health of streams. It might be that we need to modify our paradigm to a different approach if our goal remains to protect and restore the health of City streams.

Introduction

The City of Bothell's Comprehensive Plan, *Imagine Bothell…*, calls for actions to "protect, preserve, and enhance those features of the natural environment which are most sensitive to human activities." Collection of data and observations (i.e. monitoring) is one means to determine attainment of that goal.

The City of Bothell has adopted ordinances and Department goals to protect, maintain, and restore its waters through knowledge of past, current, and future trends and conditions. The City of Bothell's Municipal code 18.01.010 (18) defines Storm and Surface Water Management Services in part as "…water quality and environmental monitoring…." Ordinance 1968 (2006) effective in 2007 stipulates the expenditure of Surface Water Management fees be used to conduct Storm and Surface Water Management Services.

The monitoring effort will facilitate the City's commitment to wise management of land and water for the benefit of current and future generations. A primary measure of success will be attainment of beneficial uses as designated by city, state, and federal water quality standards.

Goal

Create a means by which the City of Bothell can measure and describe in a quantitative and qualitative manner, whether it has achieved its objective to protect and restore the chemical, physical, and biological integrity of the City's surface waters.

Objectives

Annually monitor surface waters along select water quality measures to develop baseline data for future trend identification. Document stream channel conditions, habitat, water quality, macroinvertebrates, and fish populations. Use information to facilitate City policy and land use rules, prioritize restorative actions, and direct future program monitoring efforts. Use the assessment to measure compliance with the Federal National Pollutant Discharge Elimination System (NPDES) Phase II permit, Endangered Species Act, and Clean Water Act.

Methods

Sample Station Selection

Selection of sites was determined through in-office review of maps and follow-up field surveys. Sites were selected based on their representativeness of the stream and upstream land use patterns. Sites were located as far downstream as was practical.

Chemical

At each site, monthly water quality measures were taken of dissolved oxygen, temperature, turbidity, conductivity, specific conductivity, and salinity. The samples

were collected in the field using portable handheld meters. If deemed appropriate from initial sample results, future water sampling could include samples for laboratory analysis. Elements to be assessed might include measures of fecal coliform, copper, zinc, lead, cadmium, hardness, pesticides, and TSS.

Temperature

Stream temperatures were taken using two methods. One method required an instantaneous measure collected at the time of general water quality sample with YSI 85 meter. The second method involved use of a continuous instream temperature data logger. The data loggers were installed in each stream and were set to record continuous temperature every 15 minutes.

Physical

Hydrology Flows

Visual estimates of flow were made during monthly water quality sampling events. Flows were estimated and recorded in cubic feet per second (cfs) or, if flows were slight, estimates were made in gallons per minute (gpm) and then converted to cfs.

Pebble Counts

A Wolman pebble count was conducted at each stream reach sampled for macroinvertebrates. At each riffle sampled for stream insects, a measuring tape was placed perpendicular to stream flow across the selected riffle. A minimum count and measure of 50 pebbles were collected at each riffle within the ordinary high water mark. The four riffles sampled were cumulatively summed for each reach for a composite of one 200-pebble count. Analysis of data used transformation of the pebble counts to phi values. The phi values are then converted to D_{50} and D_{84} values and expressed as percent cumulative frequency. A D_{50} value of 5 can be interpreted as 50% of the substrate being 5mm or smaller, whereas a D_{84} value of 5 can be read as 84% of the substrate being 5mm or smaller.

Channel Morphology

At each of the four riffles sampled for macroinvertebrates, a cross section was taken of bankfull depth and width. A laser level was placed on top of the bankfull, leveled, and aimed perpendicular to the channel. Depth measures were read off of stadia rod at evenly-spaced intervals to obtain channel profile. Two ratios, bankfull width (BFW) to depth (D) and a wetted width (WW) to BFW, were calculated to assess channel characteristics.

Canopy

Canopy density is a measure of one's view to the sky while standing in the middle of the stream channel. A densitometer was used with the view taken from four orientations, then summed and averaged for a percent closure. It is a measure of how much sky is obstructed by the surrounding canopy. The measures were taken at each riffle sampled

for macroinvertebrates and then averaged for a single measure for the sampled stream reach.

Instream Habitat

A simple instream habitat assessment was conducted as recommended by Scholz and Booth, 1999. Only pools meeting TFW 1993 manual for minimum size and depth criteria were included in this report. Pool measures collected include pool residual width and depth. All other stream habitat (i.e. riffles and glides) were not included in the surveys.

Large Wood

Large wood surveys stratified the count of pieces into four categories: Whether the wood was primarily a root wad or log and whether the wood was located in primarily wetted channel or within the bankfull width. To be counted, the wood needed to be a minimum of 1 meter (~3 feet) in length and greater than 25 cm (10 inches) in diameter.

Watershed Condition

Lengths of roads per square mile or road density were calculated. Total impervious surface was to be determined for each watershed and expressed as a percentage of area. This work was not performed due to map GIS limitations. Other conditions were summarized as acres of lakes, ponds and percentage of wetlands in the basin. Streams were defined as piped or natural channel. A summary of storm water systems, i.e. number of catch basins, and land use zoning was performed by watershed.

Biological

Macroinvertebrate

Streams had a reach delineated that ranged from shortest of 27 wetted channel widths to 40 wetted channel widths in length. Standard methodology for reach is 40 wetted channel lengths. Urban streams often lack a clear uninterrupted reach of 40 wetted channel lengths.

Within the reach, four riffles were selected that were representative of the reach. Each riffle was sampled using a Surber Sampler and all four riffles were composited into one sample for lab assessment. The samples were shipped to a lab to perform a sort and 500-count of macroinvertebrates. Macroinvertebrates were identified to species and genus when possible. The results were scored using Fore 1999 Biotic Index of Biological Integrity (B-IBI) metrics.

Fish

Fish were captured using an electro-fisher gear. A onetime pass-through was conducted within the stream reach. Block nets were installed at the down and upstream ends of the sampled reach. All fish captured were identified to species, counted, and measured for fork length.

QA/QC

To ensure accurate and precise data, all meters are calibrated at a minimum of once per month or per manufacturer's recommendations. Calibration records were kept of water quality meters. Meters were checked for accuracy prior to each monthly sampling event and calibrated according to manufacturer's recommendations.

Field data collection was supervised by a professional aquatic ecologist. A 10 percent replicate sample was collected for macroinvertebrate survey. Samples were sent to an outside laboratory and subjected to the laboratory's QA/QC methods.

Data Analysis

Streams were assessed and described noting how and where impaired conditions occur. This report will summarize data from 2010 through 2013. Since monitoring began in 2010, sites have been added and dropped from the monitoring program. On average, 17 sites have been monitored each year through 2013. If analysis of a particular site found that there was little to no significant added value or uniqueness, the site was dropped and a new one added to take its place.

The following measures were used to describe watershed and stream attributes for use in preparing an Esoteric Score (E). The measures were derived from study results of regional and local research, state water quality standards, and relative measures observed for streams in City of Bothell. The esoteric scores are solely for the use of comparing City of Bothell streams to each other and may have no broad regional use in other Puget Sound streams.

Attribute scoring for streams that received Bioassessment Surveys

1) ***Channel Substrate Conditions*** where % of fines < 2mm at > 15% of substrate (Scrivener and Browlee, 1989), score 1 if true; 2 if false.

2) ***Aquatic Habitat Diversity*** target condition ranking (May, 1996), score 5 if good; 3 if fair; 1 if poor.

3) ***Fish Diversity*** (relative measure based on City of Bothell stream survey results)
   - Score 5 = only native species with three or more species.
   - Score 4 = native and non-native species present and number of salmonid age classes is ≥3 and/or 2 or more salmonid species and other native non-salmonids have 2 or more age classes present.
   - Score 3 = native and non-native species present and number of salmonid age classes is ≥ 2.
   - Score 2 = 1 or more non-native species are classified as Tolerant (Zaroban et al. 1999) and/or salmonids present with only one age class present.
   - Score 1 = no fish present or only non-native species.

4) ***B-IBI, Biological Integrity of Macroinvertebrate Community***:
   - Score 5 = B-IBI value of ≥ 43 to ≤ 50, no impairment detected.
   - Score 4 = B-IBI value of ≥ 35 to ≤ 42, slight impairment.
   - Score 3 = B-IBI value of ≥ 28 to ≤ 34, moderate impairment.
   - Score 2 = B-IBI value of ≥ 20 to ≤ 27, severe impairment.
   - Score 1 = B-IBI value of ≥ 10 to ≤ 19, extreme impairment.

5) ***Large Organic Wood*** where large organic wood (LOD) frequency to BFW spacing target condition classified (May, 1996), score 5 if good; 3 if fair; 1 if poor.

6) ***Stream Temperature*** based on WDOE WQ standards:
   - Score 5 = no excursion of WDOE WQ standards.
   - Score 4 = excursion of WDOE WQ standards for 13 C 7DADMax from September 15th through May 15th.
   - Score 3 = excursion of 16 C WDOE WQ standards.
   - Score 2 = excursions of 13 C and 16 C WDOE WQ standards.
   - Score 1 = any occurrence of lethal level temperatures to salmonids (> 23 C 1-day max or 7DADMax > 22 C), or between September 15th through May 15th 1-day max > 17.5 C (lethal to developing fish embryos).

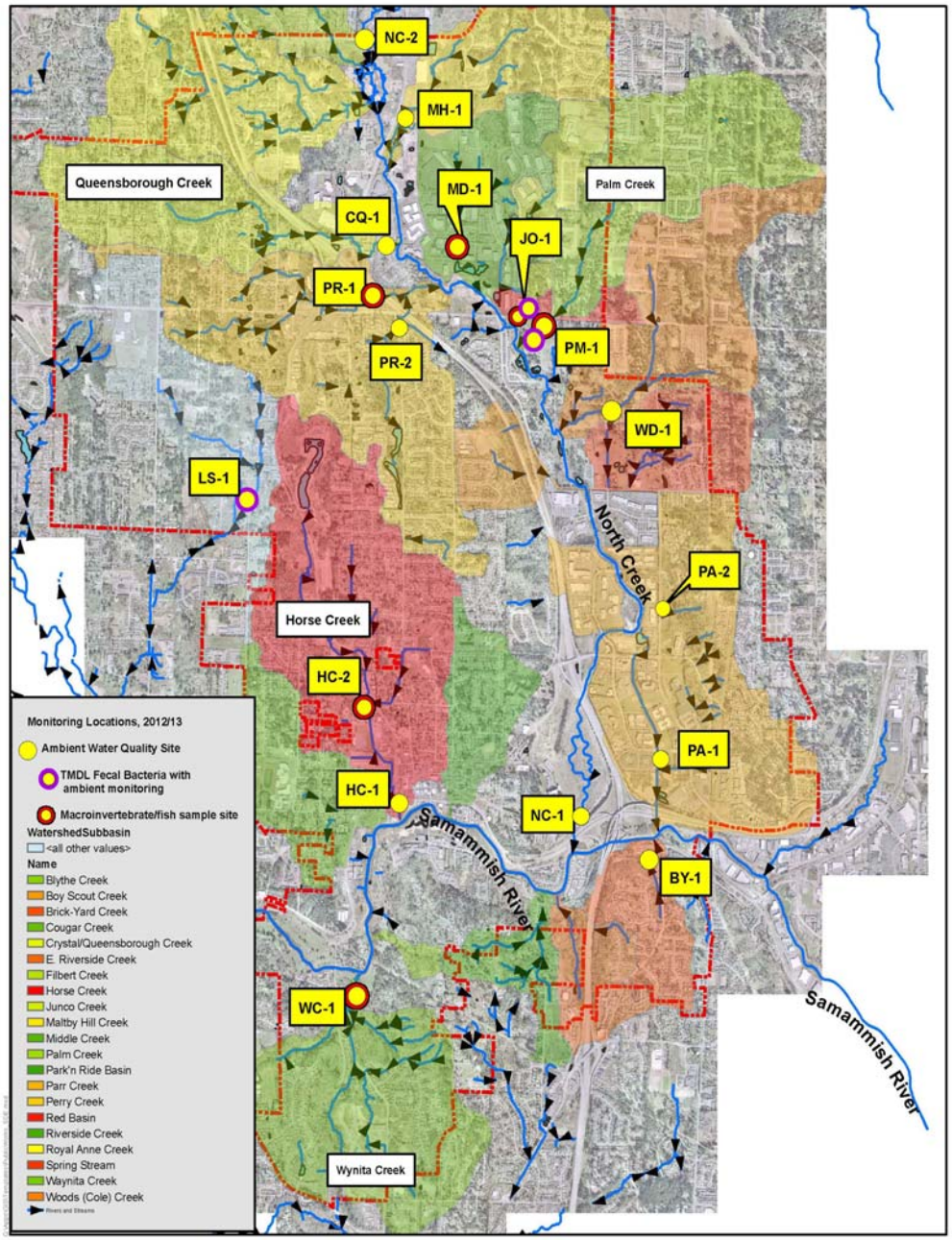
7) ***Dissolved Oxygen***, based on WDOE WQ standards and scientific literature concerning reduced growth and lethal levels to salmonids.
   - Score 5 = no measures below WDOE WQ standards.
   - Score 4 = minimum measure > 8.0 to < 9.5 mg/l.
   - Score 3 = minimum measure > 5.0 to < 8.0 mg/l.
   - Score 2 = minimum measure > 3.3 to < 5.0 mg/l or annual average below state standard of 9.5 mg/l.
   - Score 1 = minimum measure < 3.3 mg/l.

8) ***pH Levels***, if above or below WDOE WQ standards, score 1 if true; 2 if false.

The Esoteric Impairment Score (EIS) was tabulated for each watershed that received a bioassessment survey. The results should be restricted to the relative use of comparing each of the sampled streams in the study to each other. The results can be used to rank streams for future actions based on the individual impaired attributes and/or a water body's overall score. The lowest esoteric score possible is eight, 8; the highest score possible is thirty four, 34.

Table 1. Esoteric Score and its stream health status indicator

Esoteric Score	Stream Health Condition
34 to 28	**Good:** no measurable signs of stress
27 to 21	**Moderate:** some signs of stress, some could be severe.
20 to 14	**Poor:** signs of moderate to severe stress across most measures.
≤ 13	**Severe:** typically all measures show high stress.



Legend
Bothell City Limit

0 480 960 1,440
Feet

The City of Bothell delivers this data (map) in an AS-IS condition. GIS data (maps) are produced by the City of Bothell for internal purposes. No representation or guarantee is made concerning the accuracy, currency, or completeness of the information provided.

Map Prepared by: A. Loch
December 2013

City of Bothell

Figure 1. Water quality sample locations for 2012 and 2013.

Results

Sample Station Selection

A total of 17 sites (Figure 1) were since 2010. Of those seventeen sites fifteen have been monitored since 2010. One new site was added in 2011 and one in 2012. Out of the fifteen sites the same seven sites received bioassessment surveys in 2010 and in 2013. Fecal bacteria samples are collected monthly at three of the seventeen sites. The fecal bacteria sampling is part of the City's Total Maximum Daily Load (TMDL) implementation plan. The fecal bacteria data is reported separately in an annual report to the Washington Department of Ecology.

All seventeen sites were minimally sampled once monthly for dissolved oxygen, conductivity, temperature, pH, salinity, turbidity (NTU), and visual flow estimates. Seven of the sites received a more intensive bioassessment survey in late summer of 2010 and 2013. Data from year round temperature loggers are available from six streams for 2012. The complete 2013 stream temperature loggers data is unavailable until later in 2014. Of the six sites with temperature loggers in 2012 four of those sites have had temperature loggers installed since 2010.

Within three basins, two or more sample locations were established. The three basins had dissimilar land use between their upper (single family residential) and lower reaches (commercial businesses). Locations were selected to detect any significant difference in their stream water quality conditions. The complete ambient monitoring data set for all sample locations may be found in Appendix A.

Basin Descriptions:

Thirteen sub-basins were sampled among the 17 sample sites (Figure 1). Basins' natural characteristics are summarized in Table 2. The largest basin at 749 acres is Parr Creek. It has a unique characteristic in that it flows, via a pipe system, under North Creek and emerges on the other side. The watershed is primarily commercial business, North Creek Business Park (Table 3).

Watershed Condition

Watershed condition was assessed using geographic information system (GIS). The following was performed on a basin by basin query in 2012 (Table 2): road density, total impervious surface, and stream channel conditions (natural vs. piped/ditch).

Table 2. Summary of natural features by watershed.

Stream	Total Basin Acres	In City Basin Acres	Natural Features[1] Lakes/Ponds Acres	% basin Wetlands	Stream miles within City Borders[2] Piped	Ditched	Stream Natural Ch.
Tributaries to Sammamish River							
Parr Creek	749	719	2.37	4	0.22		2.27
Horse Creek	743	714	8.1	3	0.7		1.75
Little Swamp Creek	368	353	0.84	5.7	0.12		1.62
Waynita Creek	563	425	1.16	2.7	0.3		4.09
Brick Yard Creek	160	155	0	0.8	0.15		0.26
Tributaries to North Creek							
Perry Creek	702	702	6.89	8	0.37		3.69
Junco Creek	134	134	0.55	4.3	0.09		0.84
Queensborough Crk	387	378	1.45	1.6	0.17		1.6
Middle Creek	268	268	2.99	6.5	0.06		1.25
Palm Creek	436	103	0	3.9	0.11		0.74
Woods Creek	435	80	1.6	19	0.09		0.88
Maltby Hill Creek	321	304	2.14	13.7	0.05		1.89

[1]Does not include measures for watershed parameters outside of city boundaries.

[2]Full GIS data analysis is incomplete, date here is preliminary.

Table 3. Summary of built environment by watersheds.

Stream	Total Basin Acres	In City Basin Acres	Built Environment[1] % Impervious[2]	Road Length mi/mi sq.	Storm Water System[1] # Catch Basins	Pipe Ln. Miles[1]	Ditch Ln. Miles	Dominant/Subdominant Landuse (Percentage)
Tributaries to Sammamish river								
Parr Creek	749	719	41.52	13.1	1488	35.04	5.67	R-AC Op,LI/ R-9,600 (44% & 21%)
Horse Creek	743	714	35.6	14.1	1162	20.23	1.09	R-8,400/R-9,600 (30% &22%)*
Little Swamp Creek	368	353	26.59	11.4	346	6.47	0.76	R-9,600/R7,200& 8,400 (60% & 21%)
Waynita Creek	563	425	22.67	10.7	578	14.18	0.42	R-9,600/R-40,000 (96% & 4%)
Brick Yard Creek	160	155	40.61	21.9	283	7.05	0.9	R-9,600/GC (79% & 12%)
Tributaries to North Creek								
Perry Creek	702	702	36.64	17.6	1189	22.22	4.72	R-9,600/R-AC, OP,CB (52% & 10%)
Junco Creek	134	134	34.87	6.9	164	3.98	0.7	R-9,600/OP,LI (57% & 37%)
Queensborough Cr.	387	378	38.16	18.8	497	10.17	2.26	R-7,200/R-8,400 & 9,600 (53% & 30%)
Middle Creek	268	268	47.96	8.8	526	9.93	3.13	OP,LI/R-9,600 (91% & 8%)
Palm Creek	436	103	28.11	14.9	91	2.14	0.21	R-9,600/R-40,000 LID (91% & 8%)
Woods Creek	435	80	11.21	6.2	21	0.29	0.31	LID R-40,00/LID R-9,600 (63% & 21%)
Maltby Hill Creek	321	304	26.92	11.3	349	7.2	0.81	R-9,600/OP,CB,LI (77% & 11%)

[1] Includes only area inside city borders. [2] Data from Haley and Jonsson, 2014. * Has downtown core, dense urban at 12%.

Landuse Acronyms: LID: Low Impact Development Standards mandatory

R: Residential OP: Office Park CB: Community Business NB: Neighborhood Business GC: General Commercial

R-AC: Residential Activity Center, density controlled by site and building envelope regulations. May include OP, CB, NB, and/or LI

LI: Light Industrial may contain heavy industry, i.e. back up power supply facilities with large quantities of below and above ground fuel storage.

Chemical

Dissolved Oxygen (DO)

In general over the past four years all streams experienced periods of dissolved oxygen falling below the state standard of 9.5 mg/l. The exception is Palm Creek which only experienced one month reading below state standards in 2012. This one monthly occurrence followed a lengthy 77 day record setting drought period. A yearly summary of number of months with a reading below state standards over number of months sampled is depicted in figure 2. To show the relationship between water temperature and dissolved oxygen the temperature data is provided too. As water warms it loses its capability to hold oxygen. Hence, dissolved oxygen levels are in part a result of ambient air temperature which in turn drives stream temperatures.

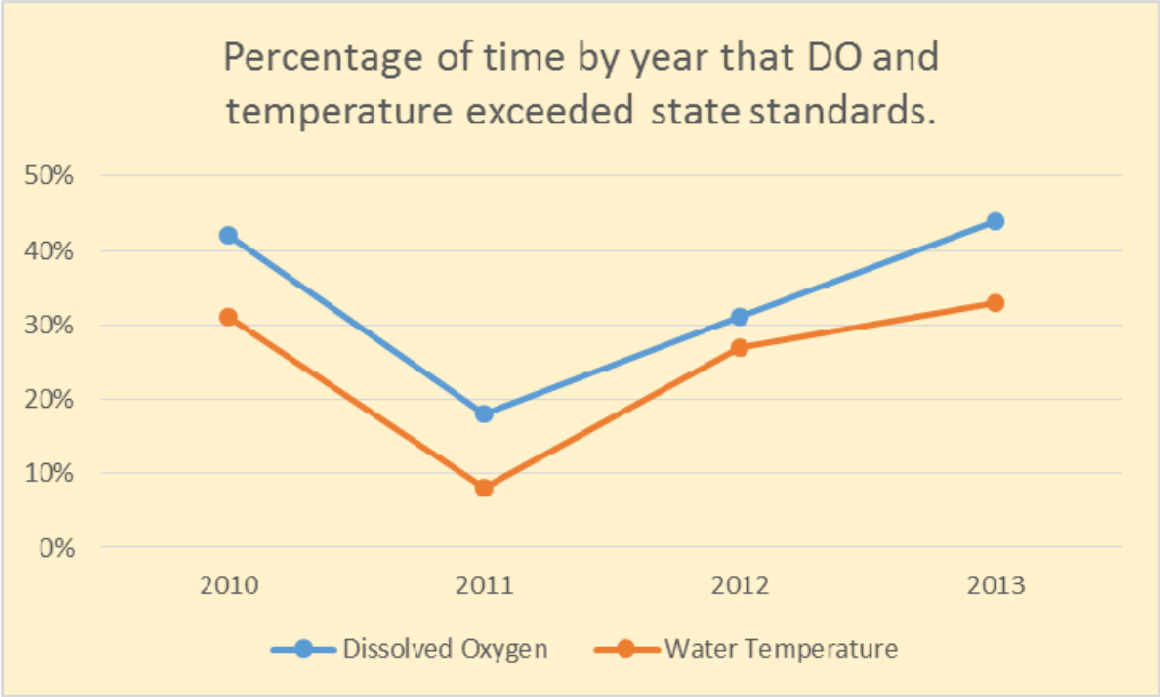


Figure 2. The percentage of months for all monitoring stations where dissolved oxygen levels fell below state standards and percentage of days at all monitoring stations of water temperatures that failed to meet, exceeded, state standards. Water temperature for 2013 is preliminary estimate based in part on monthly ambient monitoring and not from continuous stream temperature loggers.

Parr Creek (PA-1), Middle Creek (MD-1), Maltby Hill Creek (MH-1), and Little Swamp Creek (LS-1) often have annual averages below state standards. Parr Creek has occasionally experienced lethal levels of low DO to salmonids. These levels often begin in late spring to early summer and last into the early part of autumn. At no time have dissolved oxygen levels ever met state water quality standards in Parr Creek at the lower stream station (PA-1). The levels at the upper station tend to meet state standards most times of the year. Middle Creek had one occurrence of lethal levels during August 2010. (Lethal level to salmonids is: < 3.3 mg/l, Spence et. al. 1996.)

Conductivity

Specific conductivity throughout the City was seasonally influenced. Highest readings occurred in the summer and lowest readings in late spring. The highest readings for specific conductivity occurred on Parr Creek's lower reach and at Waynita Creek. Figure 3 shows the between year variability between sites and years. All sites generally followed the same pattern between years. One exception was Little Swamp Creek and Middle Creek. These two streams showed a steady decline in conductivity since 2010.

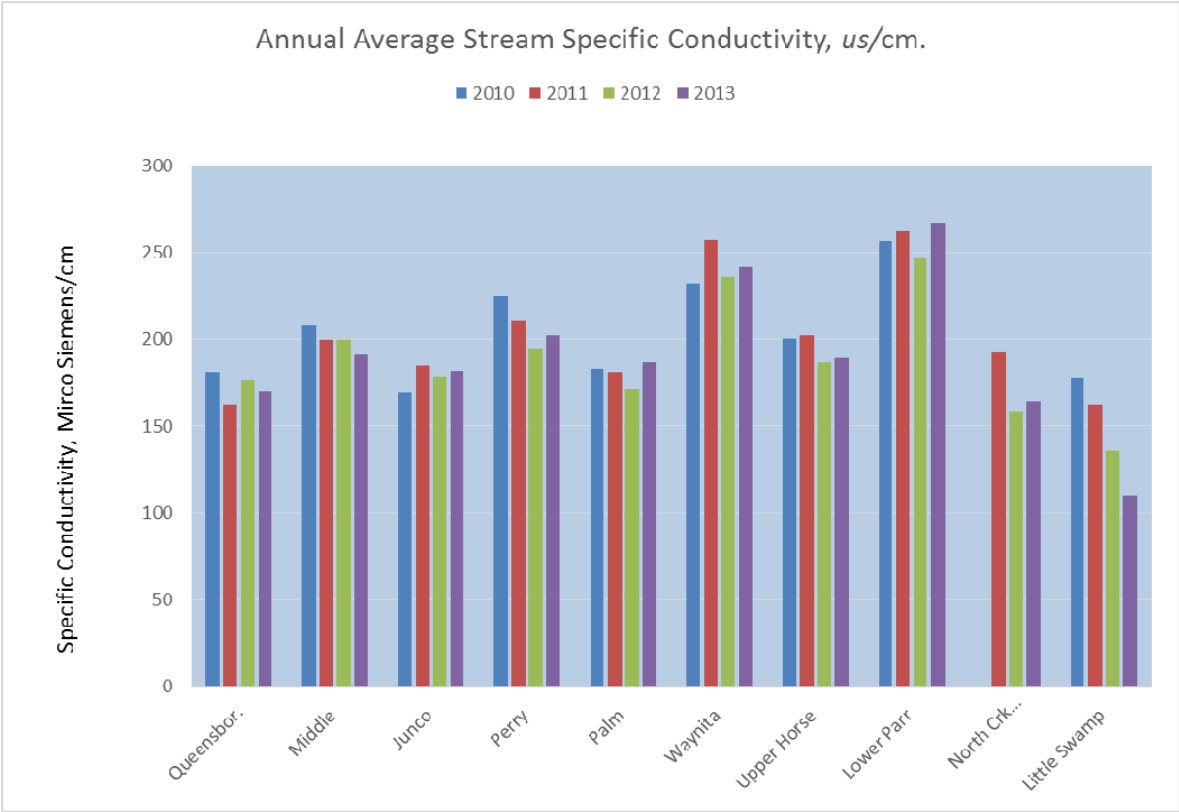


Figure 3. Annual average of stream specific conductivity by stream and year.

pH

Values of pH followed the same seasonal trend as conductivity. No site had annual average pH values below or above state water quality standards. The state water quality standards are 6.5 to 8.5. The overall pattern across the four years is a slight decrease in pH values, figure 4. A decrease in pH indicates stream water chemistry is becoming more acidic. There were infrequent exceedance of state water quality standards at Parr and Queensborough Creek. In 2012 and 2013 pH values fell slightly below state standards of 6.5 in Parr Creek and in 2013 at Queensborough Creek.

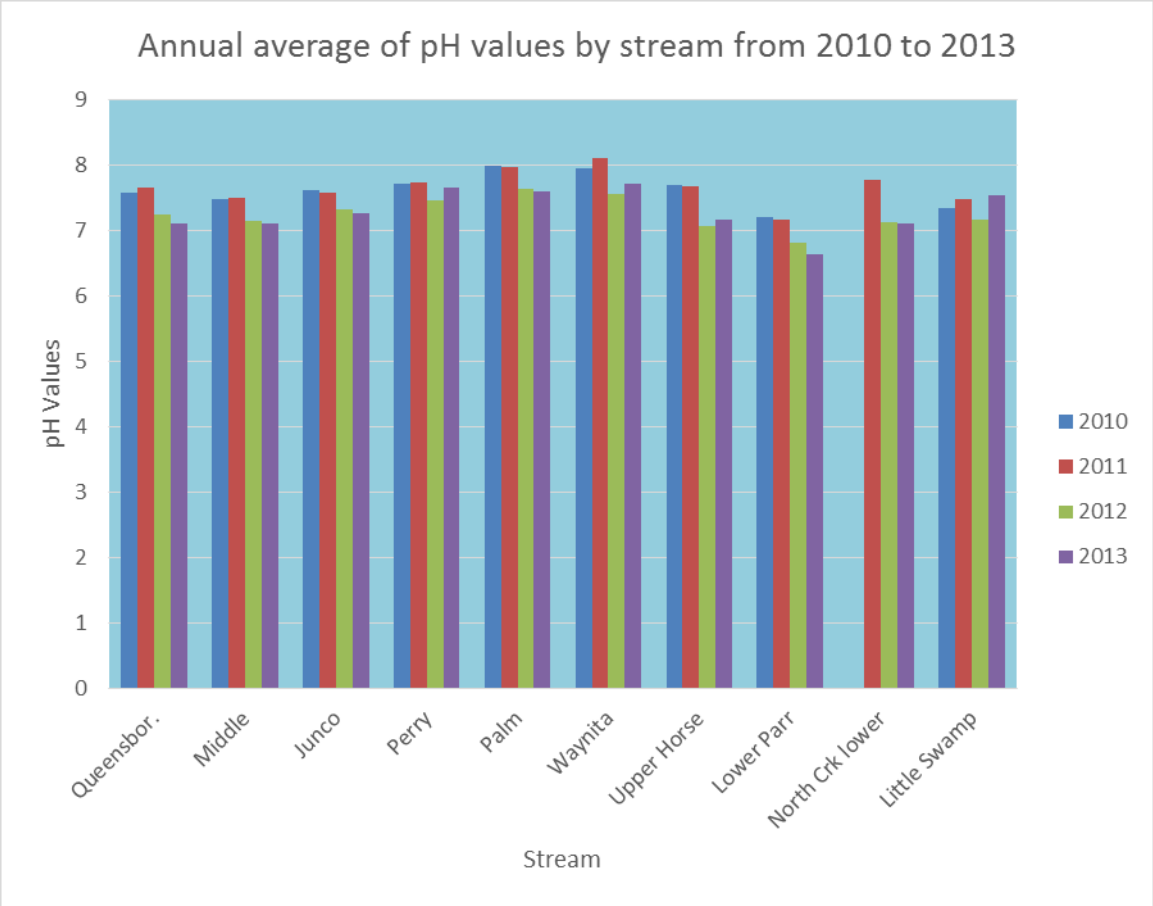


Figure 4. Annual average of stream pH by stream and year.

NTUs (Nephelometric Turbidity Units)

Turbidity levels were typically positively correlated to rain events. Rain events producing runoff increased sediment delivery to streams and is reflected in their turbidity readings. Parr Creek tended to have highest turbidity readings throughout the years due to algae diatom blooms from an upstream wetland pond. Two streams, Horse Creek and Waynita Creek, with active construction or demolition work upstream of the sample locations, at times had elevated levels of turbidity that were unrelated to rain events. The annual average over the past four years was below 10 NTUs for background turbidity levels at all sample locations except for Waynita Creek. Its annual average in 2012 was slightly above 10 NTUs at 11.17 NTUs. This was due to an extreme turbidity event of 86.50 NTUs that occurred from an untraceable source.

Temperature Logger Data 2010 to 2012

Temperature loggers were deployed at various sites over the four years. The loggers measured stream temperature at 15-minute intervals. Several deployed loggers failed to record temperatures. Data was cropped pre-retrieval and post-deployment to allow for same start and finish time for all streams. This allowed direct comparison of logger data between all streams within any given year.

Figure 5 depicts the percentage of days among all monitored sites that exceeded Washington State Department of Ecology (WDOE) water quality standards, 7DADMax. The 7DADMax is a running average of maximum daily temperature over a 7-day period. For all streams in Bothell, the aquatic life temperature criteria is salmon and trout spawning not to exceed 7DADMax of 13 C from September 15th to May 15th, and core summer salmonid habitat not to exceed 7DADMax of 16 C any time of year.

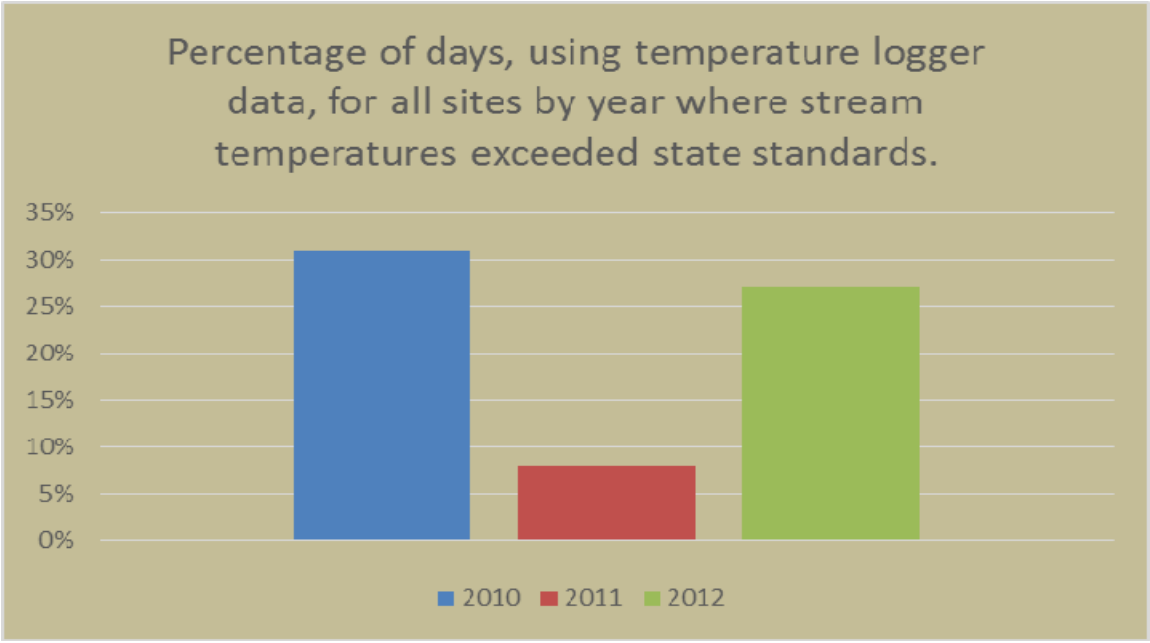


Figure 5. Data from in stream temperature loggers expressed in percentage of days each year for all sites combined that exceeded state water quality standards.

All streams tended to exceed WDOE standards in May, August, and September except for Palm Creek (PM-1) which *never* exceeded WDOE standards throughout its recording period 2010 through 2011 nor at any time during monthly ambient monitoring from 2010 through 2013. Streams routinely met temperature standards for November and December.

An anomaly was observed on May 4, 2010 (Figure 6). On this date all streams experienced a sudden drop in temperatures. Two streams, Queensborough (CQ-1) and Filbert Creek (FB-1) experienced a rapid drop in stream temperature of 5.1 and 5.0 C within 30 minutes. National Oceanic Atmospheric Administration weather records for the day recorded clouds and rain. KOMO TV News station's archives describe a windstorm and convergence zone on May 3, 2010 which was "followed up by impressive hail storms on Tuesday" (May 4, 2010). There are several web cams (Figure 7) that depict accumulation of hail in the area of these two streams' watersheds. Temperature declines in November were slower in developing as they were in response to a weeklong drop in air temperature and light accumulations of snow during this period.

This event highlights how stream's temperature can be affected by localized conditions. Similar changes in temperature can be seen during late summer rain events when warmer summer impervious surface temperatures produce warmer runoff into streams.

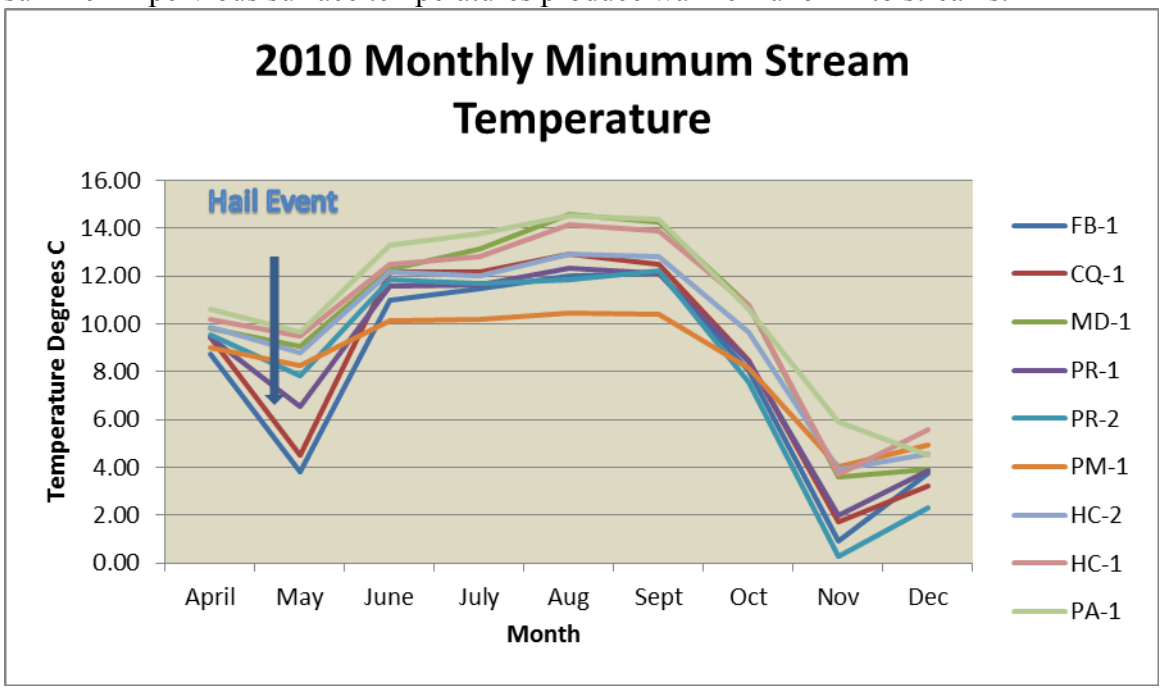


Figure 6. 2010 Monthly average minimum stream temperature.

Figure 7. Washington State Department of Transportation web cam image of I-405 in the vicinity of northwest Bothell, 4:59 PM on May 4th, 2010.

Physical

Hydrology Flows

Instantaneous flow estimates were made visually during routine monthly sample events. Most streams tended to exhibit a nonsymmetrical behavior of having peak flows disproportionately higher than the annual average flow observed during low flow periods. This style of flow data has limited value for assessing streams beyond noting approximate flow volumes on any given sampling day. Figure 8 provides a typical example of annual flow data for relative comparison between streams.

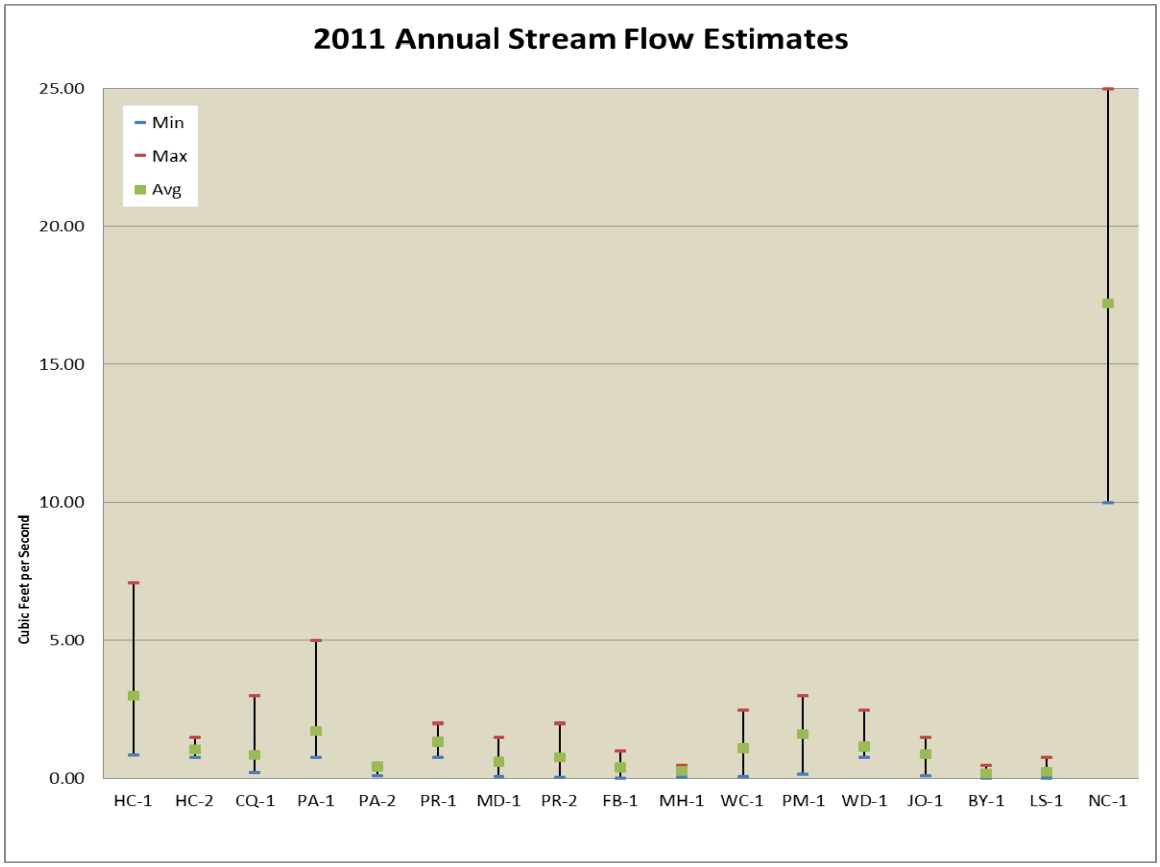


Figure 8. Monthly flow observations for 2011 showing low and high flows by stream site sampled.

Pebble Counts

Sediment pebble counts were conducted at all seven bioassessment sites in 2010 and 2013. Each site was assessed for D50, D84, and percent fines less than 2 mm values, Table 4 and figure 9.

Table 4. Sediment values expressed as D50, D84 and percent fines less than 2 mm for years 2010 and 2013.

Bioassessment	D50		D84		% of Fines < 2 mm	
Site	2010	2013	2010	2013	2010	2013
Horse Cr.	8	11	32	32	35	26
Waynita Cr.	16	22	45	45	23	7
Perry Cr.	8	8	32	32	20	23
Junco Cr.	32	22	64	45	15	9
Q.borough Cr.	2	2	11	11	40	52
Middle Cr.	8	2	22	16	41	39
Palm Cr.	8	16	22	45	39	20

The changes between years saw Horse, Waynita, and Palm Creek having larger size class present expressed as a D50 value (Figure 9). The other sites all saw a decrease in D50 value. Palm Creek had a blocked upstream in channel trash rack that had accumulated large quantities of fines and gravels. The trash rack was cleaned in September 2013, after the pebble count in August, and caused a significant release of fines and small gravels. Hence, the drop in amount of fine sediment observed during the pebble count for Palm Creek was probably related to the upstream trash rack's ability to store sediment. The drop in fine sediment for the other three sites remains unexplained.

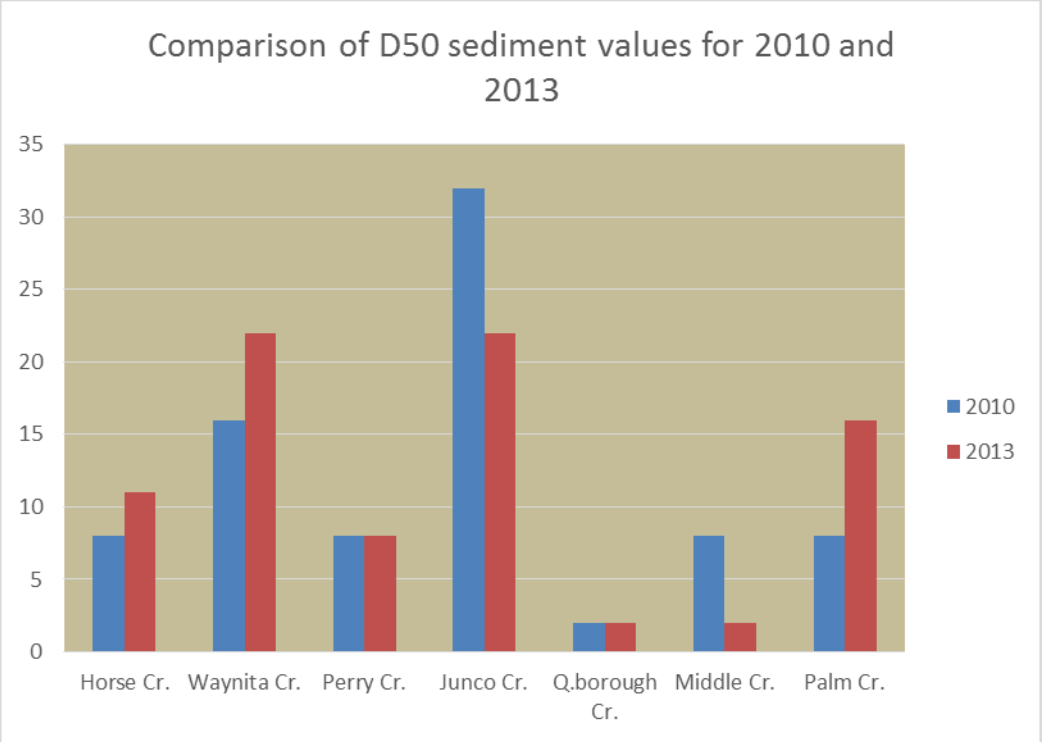


Figure 9. Between year comparison of D50 sediment value for bioassessment surveys in 2010 and 2013.

Middle Creek and Queensborough Creek had the highest percentage of fines < 2mm at 41% and 40% respectively in 2010. In 2013 Queensborough Creek's had the highest % fines 52% while Middle Creek remained virtually unchanged at 39% fines. The presence of fine sediment < 2mm at greater than 15% tends to have negative effects on aquatic biota.

Channel Morphology

Two ratios, bankfull width (BFW) to depth (D), and a wetted width (WW) to BFW, were calculated to assess channel characteristics. Channels with BFW/D ratios of < 12 are highly entrenched, Rosgen 1994. All streams were strongly entrenched with only Junco Creek being relatively less so. In 2013 most streams were unchanged except for Horse Creek and Perry Creek. Horse Creek became more entrenched and Perry Creek less so. Entrenchment typically indicates downcutting of the stream channel, thus orphaning it from its flood plain. Wetted width (WW) to BFW expresses how the stream occupies the channel at low flow. Is it narrowly confined or is it spread out across the bankfull width channel? A WW/BFW of > 40% indicates widths approaching the entire bankfull channel. All the streams exhibited widths that tended to occupy large portions of their bankfull widths (Table 5).

Table 5. Channel morphology measures from bioassessment surveys, 2010 and 2013.

Stream	2010 BFW/ Depth	2013 BFW/ Depth	2010 WW/ BFW	2013 WW/ BFW
Horse Cr.	5.45	3.9	0.60	0.39
Waynita Cr.	5.71	5.88	0.48	0.33
Perry Cr.	3.74	8.75	0.78	0.58
Junco Cr.	11.98	11.25	0.53	0.54
Queensborough Cr.	5.34	5.31	0.45	0.39
Middle Cr.	4.44	5.21	0.7	0.46
Palm Creek	6.59	7.76	0.67	0.53

Canopy Closure, Instream Habitat, and Large Wood

Canopy closure readings, pool area, and large wood counts were taken as part of the bioassessment surveys. Stream canopy closure readings were similar between years except at Waynita, Middle, and Palm Creek which saw an increase between 2010 and 2013 (Table 6). All other sites remained relatively unchanged. There was an increase in pool area for several streams (Horse, Waynita, Junco, and Palm Creek) indicating improved conditions. A review of flows between years found flows were nearly identical between survey years. The increase in % pool area is not well understood given that the streams appeared similar, no anomalies noted, between years. The remaining streams remained essentially unchanged.

The bankfull width spacing between pools is a ratio to normalize streams of different sizes. Nearly all streams saw an improvement in 2013 over the conditions found in 2010. This indicates more pools being created. However the wood surveys, primarily creator of

in stream pools, remained flat and unchanged. It has been shown in previous studies that surveyor variability can skew habitat surveys. The surveyor can introduce his or her own surveyor bias. Declaring a pool to exist requires surveyor judgment. The same surveyor, the author, did all the surveys in both years. However, it cannot be ruled out that the changes observed may be due to surveyor variability and not a true measure of change in the streams. It should be noted that the changes observed did not materially affect the outcome of a stream's condition ranking.

Table 6. Results for canopy closure percent, percent in stream pool area, and large wood frequency.

Stream	2010 Canopy Closure %	2013 Canopy Closure %	2010 % Pool Area	2013 % Pool Area	2010 Bankfull Width spacing between pools	2013 Bankfull Width spacing between pools	2010 spacing between wood pcs.	2013 spacing between wood pcs.
Horse Cr.	35%	42%	10%	22%	8.00	5.00	0	0
Waynita Cr.	70%	96%	21%	38%	16	8.9	0	0
Perry Cr.	91%	90%	22%	19%	6	5	0	0.1
Junco Cr.	97%	96%	0%	23%	0	11.1	0.05	0.18
Q.borough Cr.	79%	90%	n/a	0%	n/a	0	0	0.09
Middle Cr.	30%	46%	13%	14%	21	13.4	0	0
Palm Creek	64%	88%	3%	7%	26	15.7	0.05	0.06

May 1996 developed target conditions for instream habitat for Puget Sound Lowland (PSL) streams. Conditions of instream habitat were classified as: good, fair, and poor. Later, we assigned a numerical value to the conditions where 5 = good, 3 = fair, and 1 = poor for use in the Esoteric Ranking of streams overall conditions.

All streams scored, using May 1996 target conditions, a Poor for BFW spacing between pools and BFW spacing between large wood pieces (Table 7). Contributing to Poor pool habitat was the lack of wood in all the streams. The lack of in stream obstructions can impede formation of pools.

Table 7. 2010 and 2013 aquatic habitat diversity ranking based on May 1996 target conditions for in-stream habitat.

Stream	% Pool Area	Pools/ BFW	Wood #pcs/ BFW
Junco Creek	Poor	Poor	Poor
Crystal Creek	Poor	Poor	Poor
Palm Creek	Poor	Poor	Poor
Perry Creek	Poor	Poor	Poor
Middle Creek	Poor	Poor	Poor
Waynita Creek	Poor/Fair	Poor	Poor
Horse Creek	Poor	Poor	Poor

Large wood counts found most streams devoid of large wood. In stream wood, fallen trees with and without branches, promote complex habitat and storage of sediment and flow energy dissipaters. Junco Creek's wood was installed and pinned in place as part of a stream restoration project. All streams were ranked as poor using May 1996 targeted conditions for PSL streams (Table 7).

Biological

Macroinvertebrate Metrics

Macroinvertebrate samples were collected in August and September 2010 and in middle of August in 2013. One replicate sample was collected for quality assurance each year. The replicate's value was within 11% in 2010 and no difference in 2013. The B-IBI metrics counts for all metrics show for both years, stream biota health was severe or at extreme impairment level (Figure 10).

Figure 10. B-IBI scores for 2010 and 2013, bioassessment surveys.

In general, changes observed from 2010 and 2013 saw an increase in percent dominance of the top three most numerous taxa, a drop in total density, vigor, and a loss of long lived taxa (Table 8). Those streams that saw improvements tended to improve for the same reasons. Their predator diversity and long lived taxa improved in 2013. Predator stream insects are at the top of the food web. Low diversity in predators indicates low diversity of available habitat and prey items. Indications suggest that all streams continue to be influenced by low diversity of habitat and prey.

The density of biota in the streams is not a scored metric. However, it does provide a signal that conditions in stream are deteriorating such that the density of insects is in decline. The cause of the decline is not well understood. Comparison of flows at the time of the samples was nearly unchanged between years. Hence, this signal could be

interpreted as an early indicator that conditions are not improving and might be teetering towards further decline.

Table 8. Macroinvertebrate metric values and B-IBI scores for 2010 and 2013.

	Horse Creek		Waynita Creek		Perry Creek		Junco Creek		Q.Borough Cr.		Middle Creek		Palm Creek	
Year	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013
METRIC VALUES														
Taxa richness	20	19	28	29	29	30	27	33	29	25	29	24	26	32
E richness	2	1	3	2	2	2	2	3	2	1	1	1	2	1
P richness	1	1	4	5	3	4	3	1	3	2	0	0	4	7
T richness	2	0	1	5	4	4	4	6	1	1	2	1	5	5
Intolerant taxa richness	0	0	0	1	0	0	2	1	0	0	1	0	0	2
Clinger richness	5	4	11	13	13	11	9	11	10	7	6	5	11	15
LL richness	1	3	4	3	4	2	2	2	4	3	1	1	1	4
% tolerant	1.05%	2.85%	2.07%	5.66%	6.13%	0.99%	14.00%	7.98%	2.77%	0.83%	14.20%	15.11%	3.31%	0.00%
% predator	2.46%	3.66%	6.56%	12.26%	4.28%	4.11%	3.00%	3.90%	10.55%	13.72%	17.16%	2.70%	9.36%	14.52%
% dominance (3)	89.28%	84.55%	56.82%	63.58%	50.56%	62.01%	55.60%	57.98%	61.94%	52.18%	48.92%	71.22%	53.02%	57.26%
B-IBI Score	**16**	**16**	**24**	**28**	**22**	**22**	**18**	**22**	**22**	**22**	**22**	**18**	**24**	**28**

Clinger taxa have physical adaptations that allow them to hold onto smooth substrates in fast water (Fore, 1999). They are particularly sensitive to high levels of fine sediment that fill the spaces between gravel and cobble. Most streams had moderate levels of clinger taxa present with the minority of streams having low clinger taxa present. Streams that had less fine sediment observed in 2013 typically experienced an increase in clinger richness.

Long-living taxa require more than one year to complete their life cycles. They are exposed to all the human activities that influence the stream throughout one or more years. They are good indicators of low flow conditions and catastrophic events that can reduce or eliminate all stream insects within a short period of time. Examples of catastrophic events could include a chemical spill or discharge, low dissolved oxygen levels, periodic dewatering, and temperature extremes. All streams signaled a likelihood of previous catastrophic events

In 2010 and 2013 blackfly larvae, *Simulium,* tended to dominant most streams and often represented the largest percentage of taxa present. Blackfly larvae abundance typically indicates heavy nutrient enrichment. They are collector filter feeders using sticky hair-like fans. They represent more generalist species, as opposed to those which require special foods or particular types of physical habitat. Most streams had no wood-consuming macroinvertebrates. This correlates with the findings of most streams being devoid of in stream wood.

Fish

Electro-fishing surveys occurred in early October and August of 2010 and in early September 2013. Fishing effort, measured as time, in 2010 was 25% greater than in 2013. A total of six species (one non-native and five native) were encountered in 2010. In 2013 that number rose to ten species of which four were non-native and six were native. The increase of non-native species often indicates declining native species habitat. Middle and Horse Creeks were the two streams that had non-native species. Middle Creek had five of the six non-native species. The sample site is immediately upstream of a large shallow open water wetland that receives direct untreated and treated

storm water runoff. The presence of the non-native species Weather Loach (Figure 11) was unusual in that they occurred in relative abundance, accounting for 17% of fish captured in 2013. An encouraging observation was of two juvenile coho salmon at Waynita Creek in 2013. Waynita Creek is the only location were salmon other than cutthroat trout were observed in 2010 or 2013.

Figure 11. View of Weather Loach in upper portion of the photograph.

For general comparison purposes, Table 9 summarizes the fish diversity integrity score for each stream by year. Most streams fish diversity score remained unchanged except for Queensborough Creek which saw a decline due a reduction in salmonid age classes.

Table 9. 2010 and 2013 fish assessment and diversity scores.

	# of Native Species		**# of Non-Native Species**		**# of Salmonid Age Classes**		**# of R. Sculpin Age Classes**		**Diversity Score**	
Year	**2010**	**2013**	**2010**	**2013**	**2010**	**2013**	**2010**	**2013**	**2010**	**2013**
Stream										
Horse Cr.	0	0	0	1	0	0	0	0	**1**	**1**
Waynita Cr.	1	3	0	0	2	2	0	1	**3**	**3**
Perry Cr.	2	2	0	0	2	3	0	0	**3**	**3**
Junco Cr.	1	2	0	0	3	3	0	1	**3**	**3**
Q.Borough Cr.	2	2	0	0	3	1	1	0	**3**	**2**
Middle Cr.	1	1	1	3	0	0	0	0	**2**	**2**
Palm Cr.	2	2	0	0	2	3	1	2	**3**	**3**

Stream Health

Overall stream health was derived from eight aquatic attribute metrics. It is a relative means to determine health along measurable and repeatable surveys across time. These attributes represent the chemical, physical and biological components typically associated with stream health. Table 10 provides summary between years for general trends. In 2013 five sites showed improvement with the biggest gain coming from improved stream temperatures. If stream temperatures are not included, the scores would show that zero streams improved with two in decline and the other five unchanged. Stream temperatures are influenced by ambient air temperatures. The ambient air temperature is a factor of regional cooling or warming.

The sites did not change their relative ranking between years. Middle Creek is the most degraded with Horse Creek being the next most degraded stream. Palm Creek has the best in stream health followed by Waynita and Junco Creeks in that order.

Table 10. Summary of 2010 and 2013 select attributes for Esoteric (E) score. (2010/2013 values)

Watershed	Channel Substrate	Aquatic Habitat Diversity	Fish Diversity	Macro Invert. Integrity	Large Organic Wood	Stream Temp.*	Dissolved Oxygen	pH	Score Impaired Level
									E
Horse Cr.	1/1	1/1	1/1	1/1	1/1	1/2	4/4	2/2	**12/13**
Waynita Cr.	1/2	1/2	3/3	2/3	1/1	2/2	4/4	2/2	**16/19**
Perry Cr.	1/1	1/1	3/3	2/2	1/1	1/2	4/4	2/2	**15/16**
Junco Cr.	1/2	1/1	3/3	2/2	1/1	1/5	4/4	2/2	**15/20**
Q. Borough Cr.	1/1	1/1	3/2	2/2	1/1	1/2	3/4	2/1	**14/14**
Middle Cr.	1/1	1/1	2/2	2/1	1/1	1/1	1/2	2/2	**11/11**
Palm Cr.	1/1	1/1	3/3	2/3	1/1	5/5	5/5	2/2	**20/21**

* Temperatures are for 2012 monitoring year as 2013 data was unavailable from in streaam temperature loggers.

Summary

Results for ambient water quality monitoring and bioassessment surveys found degraded conditions throughout the City. Best available science has frequently found such levels of degradation to be related to common and pervasive urban development. Urban development is often characterized as having: a dense road network, high levels of impervious surfaces, loss of riparian corridor (treed streamsides), an increase in peak storm flows, inadequate storm runoff controls, reduced wetland acreage, modified stream channel networks, and degraded water quality. It may also include an increase in heavy metals concentrations, nutrients, pesticides and herbicides, and a loss of instream and terrestrial habitat, as well as a decrease (and in some cases extirpation) of native species.

Table 11. Stream health status conditions from Esoteric Scores, 2010 and 2013

Watershed	2010/2013
Horse Creek	**Severe/Severe**
Waynita Creek	**Poor/Poor**
Perry Creek	**Poor/Poor**
Junco Creek	**Poor/Poor**
Q.Borough Cr.	**Poor/Poor**
Middle Creek	**Severe/Severe**
Palm Creek	**Poor/Moderate**

Conclusion

The simple answer to the important question, "Are things improving in our streams?" is "No." While some measures improved between 2010 and 2013, the vast majority stayed the same or declined. There was improvement in a few streams related to reduction of fines in the stream substrate. The improvements may be temporary given the streams seeing the improvement have either recently experienced an increase in fine sediment discharge or their upstream basins are being developed with recorded periodic releases of fine sediment to the downstream waters. Comparing the results from macro invertebrate sampling and fish surveys indicate conditions on the edge of further degradation. These two surveys measure directly the biota and its relationship to in stream health.

The results presented here indicate that what we are currently doing, e.g. critical area protection measures and surface water management practices, are not effective at improving conditions, restorative, nor protecting all equally from further decline over the period studied. It is possible, but not proven, that these efforts may have kept things from getting worse. However, there were multiple signals that things are and could get worse if, for example, ambient air temperatures warm, causing further downward pressure on dissolved oxygen or the decline in stream insect density cascades into a loss of diversity. The increase in non-native fish species, though primarily localized to just one stream, indicates another source of degradation that could spread to other watersheds. The results presented here require serious consideration. It might be that we need to modify our paradigm to a different approach if our goal remains to protect and restore the health of City streams.

Future

To address the impairments noted in this study, the following are recommended actions:

- ✓ Reduce peak flows, discharge of fine sediment, and polluted storm water to streams.
- ✓ Promote Low Impact Development techniques for new development, re-development, and where feasible conduct retrofits of existing underperforming storm water systems.
- ✓ Identify means to retrofit direct discharge of storm water that has been inadequately treated for pollutants and flow volumes.
- ✓ Encourage landowners to enhance and increase riparian zones along streams and wetlands, while *eliminating* future encroachment.
- ✓ Develop and prioritize a watershed-based restoration schedule to address instream deficiencies.
- ✓ Allow for and protect stream channel migration zones within floodplains.
- ✓ Educate landowners on improved vegetation management techniques that reduce applications of fertilizers, herbicides, and pesticides.
- ✓ Develop City plans to reduce road-generated pollutants from reaching streams.
- ✓ Increase forested canopy throughout the City that promotes hydrologic maturity runoff conditions.
- ✓ The City's National Pollution Discharge Elimination System Phase II permit should be closely structured around the identified sources of degradation identified in this report.

Monitoring is recommended to continue for future trend and effectiveness analysis. It is recommended to reduce the number of sites from seventeen to eleven for 2014. Of these seven will continue to be the seven bioassessment sites. The remaining four sites will be North Creek on UW Bothell Campus, Horse Creek at Bothell Landing Park, Parr Creek in the North Creek Business Park, and Little Swamp Creek. The reduction of sites is to improve sampling efficiencies and reduce redundancy.

The results here provide a means to measure over time the city's critical areas protections and surface water programs effectiveness towards meeting the goal to protect and restore the chemical, physical, and biological integrity of the City's surface waters.

Literature Cited

Bullchild, Lyman, Scott Hall, Allen Pleus, and Dave Schuett-Hames eds. Timber Fish and Wildlife. TFW Ambient Monitoring Program Manual. TFW-AM9-93-001. Northwest Indian Fisheries Commission, Washington Department of Natural Resources. 1993.

City of Bothell. Bothell Municipal Code: Title 14, Environment. Bothell, WA: September 2006.

City of Bothell. Imagine Bothell…Comprehensive Plan. Bothell, WA: 1997-2005.

Fore, L.S. Measuring the Biological Integrity of Puget Sound Lowland Streams: Description and Calculation of the Benthic Index of Biological Integrity (B-IBI). Seattle, WA: University of Washington, 1999.

Haley, Duke, J. and William G. Jonsson, 2014. Percentage of impervious surfaces in twenty-two watershed basins City of Bothell. University of Washington Bothell.

KOMO TV 4 News Station. "Archives." November 2010. <http://www.wunderground.com/history/airport/KSEA/2010/11/4/MonthlyHistory.html?req_city=NA&req_state=NA&req_statename=NA>.

KOMO TV 4 News Station. "Archives." 4 May 2010. <http://www.komonews.com/news/local/92822409.html>.

Loch, Andy. Evaluating Effects of Land Use Management of Physical and Biotic Conditions of Small Streams in Puget Sound Ecoregion. Progress Report No. 07. Tulalip Tribes Natural Resources Division. Marysville, WA: 2000.

May, C.W. "Assessment of cumulative effects of urbanization on small streams in the Puget Sound Lowland ecoregion: implications for salmonid resource management." Ph.D. Diss. University of Washington, Department of Civil Engineering, Seattle, WA: 1996. 383.

Rosgen, David L. "A Classification of Natural Rivers." Catena: An Interdisciplinary Journal of Soil Science, Hydrology, Geomorphology, Focusing on Geoecology and Landscape Evolution 22.3 (1994): 169-99.

Plotnikoff, R. W., and S. I. Ehinger. Using Invertebrates to Assess the Quality of Washington Streams and to Describe Biological Expectations. Publication No. 97-332. Washington State Department of Ecology, Ambient Monitoring Section. Olympia, WA: 1997.

Scholz, Jenna G., and Derek B. Booth. Monitoring Urban Streams: Strategies and Protocols for Humid-Region Lowland Systems. University of Washington, Center for Urban Water Resources Management. Seattle, WA: 1999.

Spence, Brian C., Gregg A. Lomnicky, Robert M. Hughs, and Richard P. Novitzki. An Ecosystem Approach to Salmonid Conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp. Corvallis, OR: 1996 (Available from the National Marine Fisheries Service, Portland, OR.)

Whiteway, Sarah L., Pascale M. Biron, André Zimmermann, Oscar Venter, and James W.A. Grant. "Do in-stream restoration structures enhance salmonid abundance? A meta-analysis." Can. J. Fish. Aquat. Sci. 67 (2010): 831-41.

Zaroban, Donald W., Mulvey, Michael P., Maret, Terry R., and Hughes, Robert M. 1999. Classification of Species Attributes for Pacific Northwest Freshwater Fishes. Northwest Science, Vol 73. No. 2. 1999, pgs 81 to 93