2011 Stream Health Assessment for City of Bothell Streams

City of Bothell™

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2011 Stream Health Assessment for City of Bothell Streams

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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, e.g., monitoring, is one means to determine attainment of the goal.

The City of Bothell has adopted ordinances and department goals to protect, maintain, and restore the City's waters through knowledge of past, current, and future trends and conditions. Bothell Municipal Code (BMC) 18.01.010 (18) defines Storm and Surface Water Management Services in part as "…water quality and environmental monitoring…" Ordinance 1968 (2006) adopted in 2005 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

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

Objective

Monitor surface waters along select water quality measures to develop baseline data for future trend identification. Assess data for occurrences of degraded conditions and quantify levels observed. Document channel conditions, bank erosion or armoring, 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 to 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 having easy accessibility and located as far down stream as practical. Streams sampled were selected to provide as broad of coverage as possible of the various land uses present in the city.

Chemical

At each site monthly chemical 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 anomalies, such as dramatic changes to pH levels or sudden encounters of high specific conductivity levels, are observed during routine sampling further sampling will be considered. Elements to be assessed may include measurements of fecal coliform, copper, zinc, lead, and cadmium, hardness, pesticides, and TSS.

Temperature

Stream temperatures will be taken at each site using two methods. One method will be an instantaneous measure collected at the time of general water quality sample. The second will be by using in-stream temperature loggers. The loggers will be placed in-stream and set to record continuous temperature every 15 minutes.

Physical

Hydrology Flows

Visual estimates will be made during general site sampling events. At general sampling events, flows will be estimated and recorded in cubic feet per second (CFS) or, if flows are quite small, in gallons per minute (gpm). Macroinvertebrate sampling events have flows measured by timing a floating object over measured area of homogenous width and depth profile.

During years of Bioassessment Surveys, the following data will be collected:

- Pebble counts
- Channel morphology measurements
- Canopy closure
- Type and amount of in-stream habitat
- Frequency of large wood in-stream
- Riparian/watershed condition assessment
- Biological
    - Macroinvertebrate samples
    - Fish surveys

Quality Assurance/Quality Control (QA/QC)

To ensure accurate and precise data, all meters are calibrated at a minimum of once per month or per manufacture's recommendations. Records shall be kept to compare meters to solutions of known concentrations and any time a meter is calibrated or tested for accuracy.

Field data collection is conducted by a professional aquatic ecologist. At times an assistant may work in a supervised capacity under the aquatic ecologist. Replicate samples will be collected for all chemical samples and macroinvertebrates sampling. Water quality samples sent to outside laboratory will be subject to the laboratory's QA/QC methods.

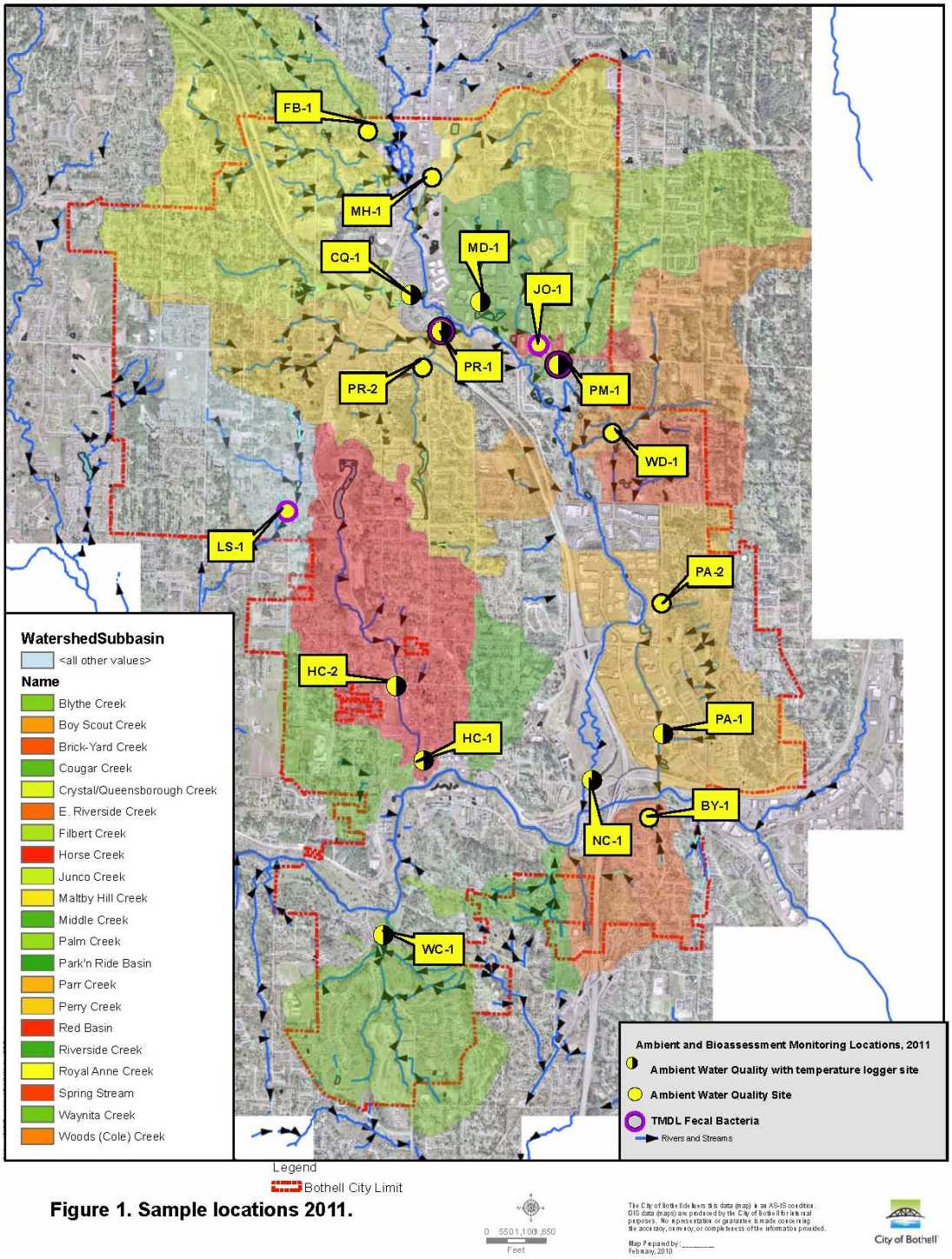

Figure 1. Sample locations 2011.

Results

Sample Station Selection

17 sites were selected for sampling in 2011 (see Figure 1). Not all sites selected in 2011 were sampled in 2010. Three sites were eliminated in 2011 and one new site was added. The sites eliminated were two upstream locations on Perry Creek and the upstream site on Crystal Creek. North Creek near its confluence with the Sammamish River was added to the roster of sample sites. Horse, Parr, and Perry Creeks have retained their two sample locations in all years sampled. The streams selected represent over 80 percent of the watershed area within the city.

Sites were sampled for water quality parameters and fecal coliform bacteria, and some had temperature loggers installed. This report will not assess the results of fecal coliform bacteria sampling. Those results are discussed in a separate annual report (Loch 2012).

Basin Descriptions

Fourteen sub-basins were sampled among the 17 sample sites (see Figure 1). General basin characteristics are summarized for natural features in Table 1 and for built environment in Table 2. The information about natural feature summarizes our current available knowledge. In the future, it is expected that the natural features summary will be expanded to include but not be limited to: canopy coverage, riparian zone, and forested conditions.

The complete ambient monitoring data set for 2011 may be found in Appendix A.

Table 1. 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	Artificial Open Ch.	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
Cougar Creek	256	228	0.02	0.3	0		0.26
Park-n-ride Basin	161	161	0	0	0		0
Little Swamp Creek	368	353	0.84	5.7	0.12		1.62
Blythe Creek	21	21	0	0.1	0		0
E. River Side Creek	136	75	0.13	0	0.02		0.47
River Side Creek	123	40	0.02	6.6	0		0.38
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
Boy Scout Creek	106	106	0	0.3	0		0.39
Junco Creek	134	134	0.55	4.3	0.09		0.84
Crystal Creek	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
Royal Anne Creek	468	286	1.29	16.3	0.13		3.15
Filbert Creek	426	31	0.24	18.5	0.02		0.3
Maltby Hill Creek	321	304	2.14	13.7	0.05		1.89
Spring Stream	211	151	1.25	12.3	0.03		1.43
Red Basin	40	23	0.75	0.08	0		0
Totals	**7214**	**5457**	**31.79**	**6**	**2.63**	**0**	**27.26**

[1]Does not include measures for watershed parameters outside of City boundaries.
[2]Does not include all piped stream and natural stream lengths due to inaccurate GIS data layer

Table 2. Summary of built environment by watersheds.

	Total	In City	Built Environment[1]		Storm Water System[1]			
	Basin	Basin	%	Road Length	# Catch	Pipe Ln.	Ditch Ln.	Dominant/Subdominant
Stream	Acres	Acres	Impervious	mi/mi sq.	Basins	Miles[1]	Miles	Landuse (Percentage)
Tributaries to Sammamish river								
Parr Creek	749	719	Not Available	13.1	1488	35.04	5.67	R-AC Op,LI/ R-9,600 (44% & 21%)
Horse Creek	743	714	Not Available	14.1	1162	20.23	1.09	R-8,400/R-9,600 (30% &22%)*
Cougar Creek	256	228	Not Available	17.4	552	10.89	1.39	R-8,400/R-9,600 (60% & 21%)
Park-n-ride Basin	161	161	Not Available	21.6	298	5.8	0.26	R-8,400-9,600/Downtown (77% & 20%)
Little Swamp Creek	368	353	Not Available	11.4	346	6.47	0.76	R-9,600/R7,200& 8,400 (60% & 21%)
Blythe Creek	21	21	Not Available	0	5	0.31	0.02	R-9,600/R-40,000 (84% & 26%)
E. River Side Creek	136	75	Not Available	14	73	1.76	0.78	R-9600/R-2,800,OP,NB (79% & 9%)
River Side Creek	123	40	Not Available	12	36	0.76	0.43	R-9,600/R-40,000 (44% & 43%)
Waynita Creek	563	425	Not Available	10.7	578	14.18	0.42	R-9,600/R-40,000 (96% & 4%)
Brick Yard Creek	160	155	Not Available	21.9	283	7.05	0.9	R-9,600/GC (79% & 12%)
Tributaries to North Creek								
Perry Creek	702	702	Not Available	17.6	1189	22.22	4.72	R-9,600/R-AC, OP,CB (52% & 10%)
Boy Scout Creek	106	106	Not Available	14.2	193	4.03	1.29	R-9,600/R-AC (87% & 11%))
Junco Creek	134	134	Not Available	6.9	164	3.98	0.7	R-9,600/OP,LI (57% & 37%)
Crystal Creek	387	378	Not Available	18.8	497	10.17	2.26	R-7,200/R-8,400 & 9,600 (53% & 30%)
Middle Creek	268	268	Not Available	8.8	526	9.93	3.13	OP,LI/R-9,600 (91% & 8%)
Palm Creek	436	103	Not Available	14.9	91	2.14	0.21	R-9,600/R-40,000 LID (91% & 8%)
Woods Creek	435	80	Not Available	6.2	21	0.29	0.31	LID R-40,00/LID R-9,600 (63% & 21%)
Royal Anne Creek	468	286	Not Available	12.5	215	5.53	2	R-9600, 7,200/OP,LI (75% & 13%)
Filbert Creek	426	31	Not Available	16.8	73	1.82	0.27	R-5,400a/R-9,600 (67% & 33%)
Maltby Hill Creek	321	304	Not Available	11.3	349	7.2	0.81	R-9,600/OP,CB,LI (77% & 11%)
Spring Stream	211	151	Not Available	9.2	205	3.65	0.88	R-5,400a/R-9,600(72% & 17%)
Red Basin	40	23	Not Available	22.3	79	1.86	0.26	OP,LI/R-9,600 (43% & 20%)
Totals	**7214**	**5457**		**14**	**8423**	**175.31**	**28.56**	Color indicates ambient monitoried streams

[1] Includes only area inside city borders. * Contains 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 Commerci

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 fuel storage.

Chemical

Monthly measurements began in March 2010 for most sites. Measurements included dissolved oxygen, specific conductivity, salinity, pH, and NTUs. In November and December 2011, no chemical measures were collected due to a faulty meter.

Dissolved Oxygen (DO)

Dissolved oxygen levels for all but three creeks (Junco, Palm, and Waynita) failed to meet Washington State Department of Ecology's water quality standard of DO ≥ 9.5 mg/l (see Figure 2). In its lower reach, Parr Creek had an annual average below State standards. It had DO lethal levels (a lethal level to salmonids is < 3.3 mg/l [Spence et. al. 1996]) for salmonids in September and October. Middle Creek experienced lethal levels of DO in 2010, but not in 2011. Dissolved oxygen levels were generally slightly higher throughout City streams between 2010 and 2011.

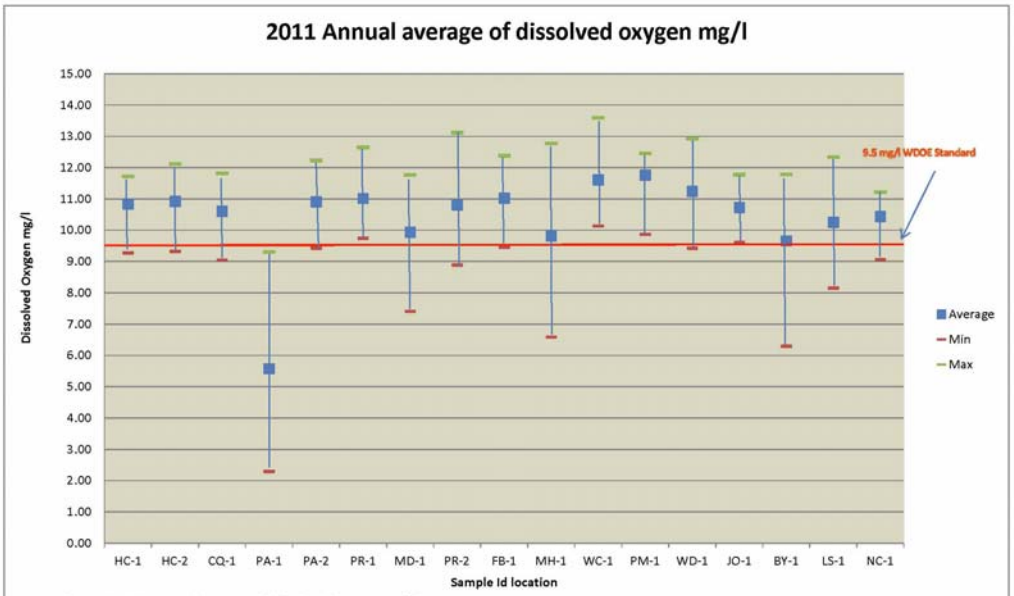

Figure 2. 2011 Annual average of dissolved oxygen mg/l.

Conductivity

Specific conductivity throughout the City is seasonally influenced. Highest readings occurred in the summer; lowest readings typically occurred in late spring. The highest readings for specific conductivity in 2011 occurred on Perry Creek and at Upper Parr Creek, 262 *u*s/cm and 257 *u*s/cm respectively (see Figure 3.). Woods Creek consistently had the lowest annual average in 2010 and 2011 out of all 17 stream locations sampled. There is a large pond just upstream of the Woods Creek sample site that may be influencing levels of conductivity. Ponds and lakes often allow pollutants to settle out of the water column prior to its outlet discharge.

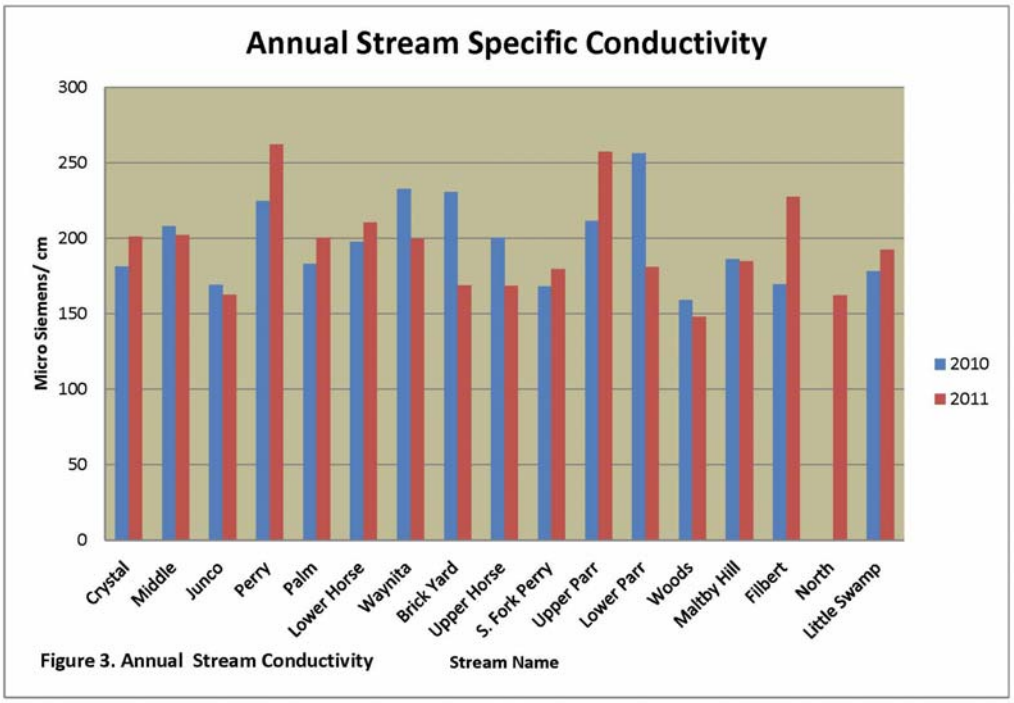

Figure 3. Annual Stream Conductivity

pH

No site had recorded measures below State water quality standards. One site (Woods Creek) had a one-time pH value, 8.64, that was above State standards on September 16, 2011. In 2011, Little Swamp Creek had the lowest annual average pH of 7.48; Waynita Creek had the highest annual pH value at 8.1. In general, average pH for all streams was 0.73 or 7.3-fold change between low and high pH readings. The greatest difference annually within stream occurred in Woods Creek with a 1.22 pH change over the course of 2011. This represents a slightly greater than 10-fold change in value.

NTUs

Turbidity levels typically increased in response to turbid runoff during rain events. In 2010 and 2011, Parr Creek tended to have high turbidity readings throughout the year in part due to dense algae diatom blooms from in-channel and an upstream eutrophic wetland pond. Eutrophic conditions occur when a water body has levels of nutrients that promote heavy plant and algae growth. The plant growth can lead to a decrease in dissolved oxygen. There was one occurrence of turbidity unrelated to rain events on Waynita Creek in April 2011. The left bank tributary immediately upstream of the sample location had a measure of 36 NTUs. The source of the turbidity was unknown.

Temperature

Temperature loggers were deployed at nine sites in the first week of June 2011. Previous loggers had been deployed in early April 2010 and retrieved in late May 2011. The loggers measured stream temperature at 15-minute intervals. One deployed logger (in Perry Creek) had faulty temperature records causing it to not meet QA/QC protocol and its data could not be used. Loggers were retrieved in May 2012. The results presented here cover the period from January 1, 2011 to December 31, 2011 with a gap from May 20 to June 6. Waynita Creek and North Creek data collection began in June 2011. North Creek (NC-1) was added to the ambient monitoring program in June 2011. For all other sites, data was cropped pre-retrieval and post-deployment to the same dates to allow for comparable assessments between streams.

Figure 4 depicts the number of days a site failed to be within Washington State Department of Ecology Water Quality Standards. The State standards vary depending on time of year and fish use designation. For all streams in Bothell, the Aquatic Life Temperature Criteria has been adopted for salmon and trout spawning, not to exceed 13 C from September 15 to May 15, and core summer salmonid habitat, not to exceed 16 C during any time of the year.

All streams except one (Palm Creek) failed to meet WDOE's temperature standards in 2011. The high stream temperatures were typically noted to begin in May and continued till about mid-October. Middle Creek and Parr Creek had the most days above WDOE standards at 58 and 42 days respectively. Overall temperatures in 2011 were slightly cooler than 2010 with the number of exceeding days in 2011 nearly 1/3 less than 2010.

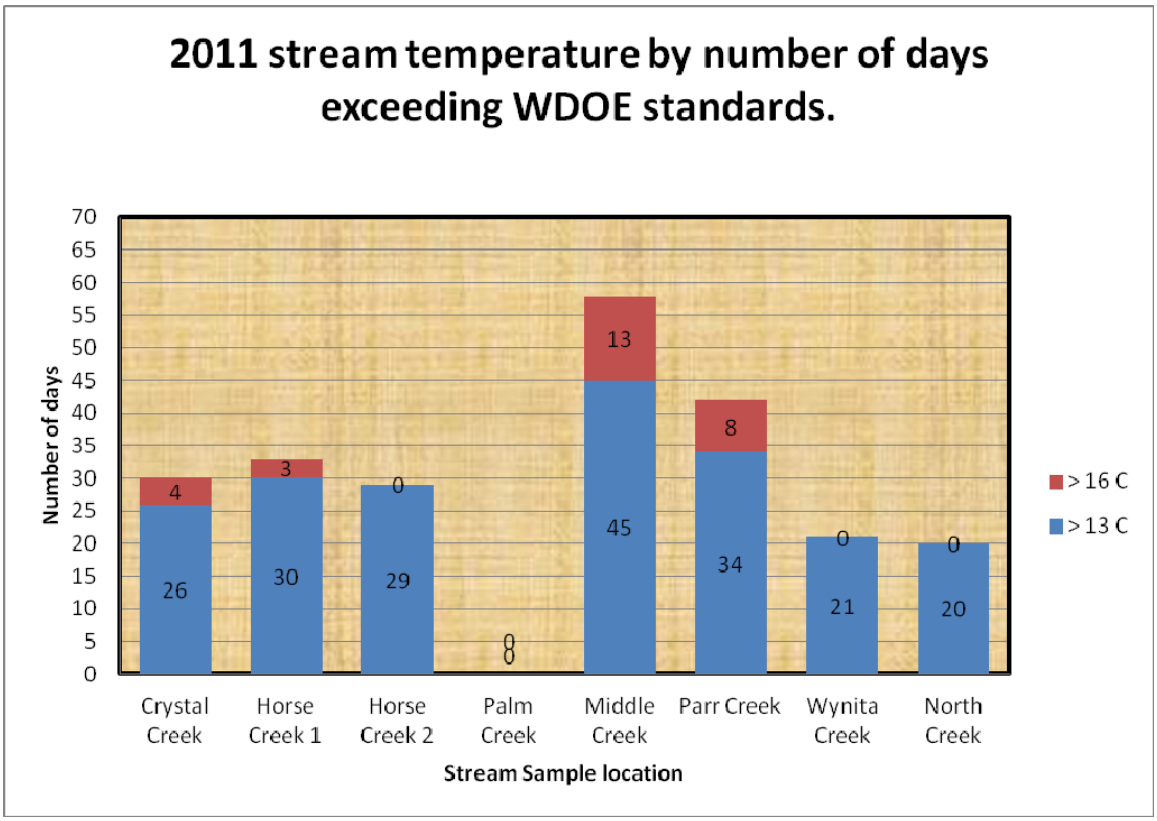

Figure 4: 2011 Stream Temperatures by Number of Days Exceeding WDOE Standards

Physical

Hydrology Flows

Instantaneous flow estimates were made visually during routine sample events (see Figure 6). Stream flows ranged on average from 0.27 cfs (122 gallons per minute) at Matlby Hill Creek to North Creek's 17.2 cfs (7,740 gallons per minute). The next largest stream is Horse Creek at 2.99 cfs (1,346 gallons per minute). It was observed that almost all the streams exhibited a high degree of flashiness. Flashiness is when a stream quickly increases in its flow volume in response to a rain event and as soon as the rain stops the flows begin to recede quickly. This indicates inadequate flow controls serving impervious surfaces such as roads and parking lots. The rapid runoff can lead to a decrease in infiltration rates to ground water thus reducing summer low flow volumes. At other times the increase in peak high flow frequency and magnitude causes stream channel instability, erosion of banks (widening of stream width), down cutting of stream channel (if no bedrock or hardpan is present), and loss of connectivity to its flood plain. The alter stream flows can have a direct affect on macroinvertebrates and fish populations. Their populations become less diverse, robust, healthy, and/or extirpated.

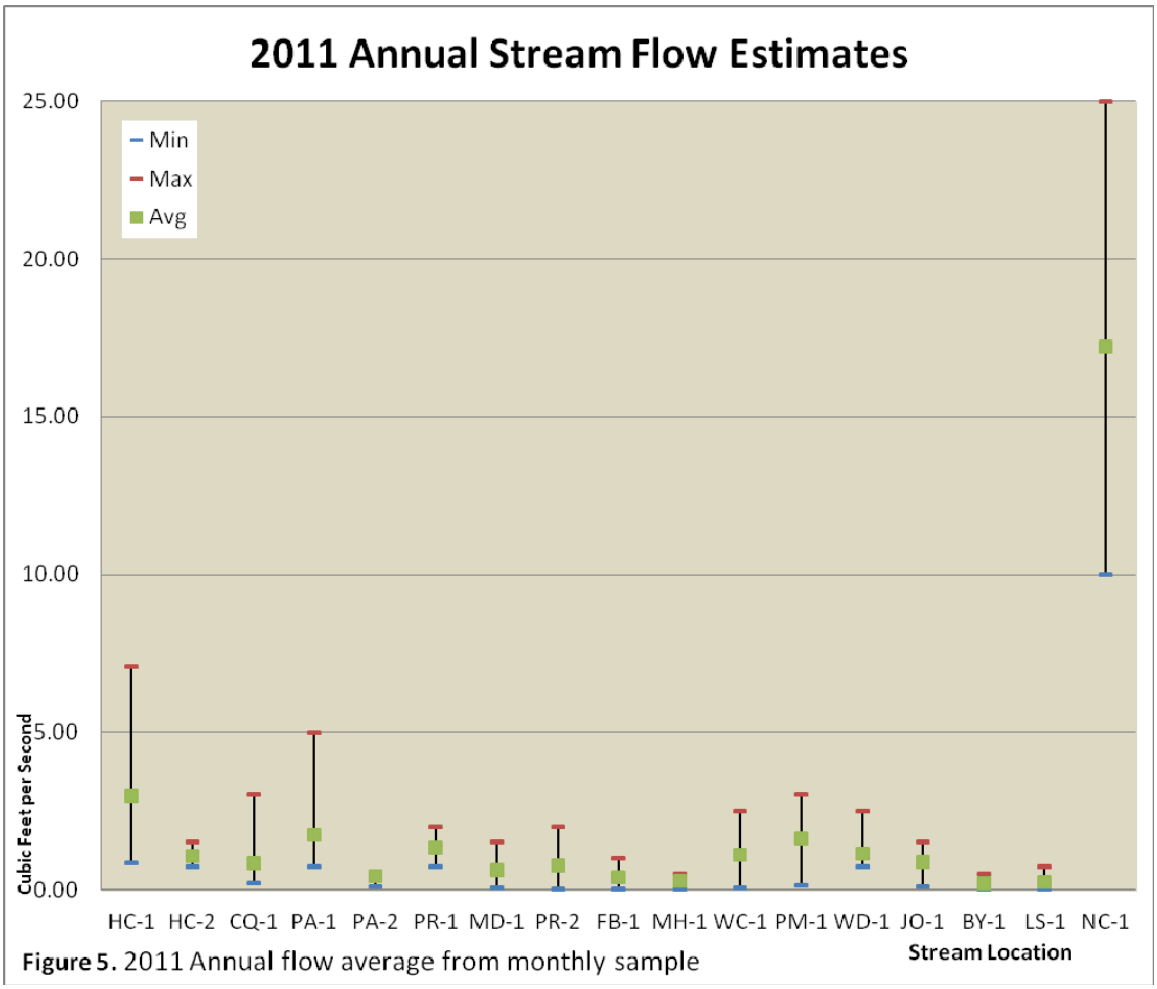

Figure 5. 2011 Annual flow average from monthly sample

Summary

Results from 2011 ambient monitoring found all streams to have clear signs of degraded conditions. Low dissolved oxygen levels and high stream temperatures indicate eutrophication (excessive nutrients) and loss of stream canopy cover. Conductivity measures point to elevated levels of dissolved metals typical of urban environments. In the few instances where 2010 results were compared to 2011, there was a slight improvement in 2011 over the 2010 conditions. These improvements were most likely related to prevailing summer weather patterns being cooler and slightly wetter.

Conditions of natural features and built environment can shed light on causes for measured in-stream degradation. For example, stream length in a pipe has negative consequences for a stream's overall health. It reduces biological activity, creates fish migration blocks, and generally reduces a stream's ability to interact with its surrounding environment. Streams with relatively high road density combined with extensive network of storm water pipes, can cause adverse impacts to water quality and biological conditions. All basins in Bothell had

road densities greater than 5.3 mi/mi^2. May et al., 1996 found that when road densities reach greater than 5.3 mi/mi^2, there is a negative impact on stream health.

Urban streams often have multiple stressors affecting their health, i.e. increase of impervious surfaces, loss of riparian forested corridor, chemical induced changes, and increase in peak flows. The stressors affect each stream differently based on individual characteristics of the watershed and stream channel. Not all stressors affect all streams similarly.

To improve stream health management actions need to be tailored to the individual stream's circumstances. For example, the zoning codes for type and coverage of land use in a basin permit the levels of imperviousness. Commercial and light industrial allow high levels of impervious surfaces, greater than 90% imperviousness, and extensive storm water drainage systems of pipes and catch basins. Hence, in these areas management actions should focus on reducing and disconnecting impervious surfaces from the streams. Whereas, in streams with relatively less imperviousness but may be experiencing loss of in tack riparian corridors or loss of flood plain connectivity the needed actions should focus on restoration of riparian corridors and set back of levees.

The overall impact of urbanization on streams is not limited to the streams themselves but extends out to economically valuable resources, such as property values, fisheries and tourism. City of Bothell actively promotes tourism and the linkage can be made that healthy streams and rivers support a healthy tourism industry. Quality of life for citizens and businesses can be affected by the quality of the natural environment. Efforts to protect and restore the natural features benefit all.

Future

The City is currently carrying out actions to address the challenge of degraded stream conditions. Some of these actions have been ongoing for years, such as the Shoreline Management Plan and Critical Areas Ordinance, and storm water design controls. In 2007 the City was mandated, under National Pollution Discharge Elimination System (NPDES) permit issued by Washington State Department of Ecology, to begin implementation of measures and programs to address storm water impacts on streams. The results here provide a means to measure over time whether the implementation of new storm water measures and programs are effective towards meeting the goal of protecting and restoring the chemical, physical, and biological integrity of the City's surface waters.

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APPENDIX A

2011 Stream Ambient Monitoring Data

Parr Creek

Date	Site Code	Time	DO mg/L	Temp. C	Conduct. *u* s/cm	Specific Condut. *u* s/cm	Salanity ppt	pH	Turbidity NTUs	Flow cfs
1/21/2011	PA-1	11:10 AM	9.31	7.3	76.8	116.3	0.1		9.64	5
2/22/2011	PA-1	1:40 PM	6.36	7.4	191.6	288.3	0.1	7.54	9.98	1.5
3/23/2011	PA-1	11:44 AM	6.12	9.2	214.5	307.6	0.1	6.88	7.84	2
4/20/2011	PA-1	1:46 PM	8.37	11.6	219.6	295.6	0.1	N/C	6.87	0.75
5/19/2011	PA-1	1:45 PM	4.89	14.7	218.2	272	0.1	6.89	7.11	2.5
6/15/2011	PA-1	10:53 AM	6.06	13.5	175.4	224.5	0.1	7.55	7.12	1.5
7/11/2011	PA-1	3:48 PM	5.66	17.1	249.9	294.2	0.1	7.1	8.17	1
8/8/2011	PA-1	12:51 PM	4.2	16.2	238.4	286.8	0.1	7.17	4.54	1
9/16/2011	PA-1	2:02 PM	2.3	15	236.4	292.2	0.1	7.27	6.99	1
10/13/2011	PA-1	1:08 PM	2.47	12.6	186.4	244.5	0.1	6.94	4.54	1
Nov-11		Meter malfunction no sampling								
Dec-11		Meter malfunction no sampling								
		Avg	5.57	12.46	200.72	262.20	0.10	7.17	7.28	1.73
		Std	2.25	3.52	49.72	57.26	0.00	0.27	1.80	1.27
		Min	2.3	7.3	76.8	116.3	0.1	6.88	4.54	0.75
		Max	9.31	17.1	249.9	307.6	0.1	7.55	9.98	5
		Count	10	10	10	10	10	8	10	10

Parr Creek

1/21/2011	PA-2	11:00 AM	10.9	7.6	95.3	142.8	0.1		12.1	1.5cfs
2/22/2011	PA-2	1:54 PM	11.7	7	139.8	213	0.1	7.67	0.74	.5 cfs
3/23/2011	PA-2	1:27 PM	10.2	10.4	151.5	210.1	0.1	7.61	1.64	.75 cfs
4/20/2011	PA-2	1:51 PM	11.5	10.8	154.4	212.3	0.1	n/c	0.92	.5 cfs
5/19/2011	PA-2	2:00 PM	10.4	12.7	162	211.7	0.1	7.41	2.5	.75 cfs
6/15/2011	PA-2	11:04 AM	11	11.5	160.6	216.7	0.1	7.98	4.53	0.5
7/11/2011	PA-2	3:40 PM	12.2	13.2	175.8	227	0.1	7.42	1.8	0.09
8/8/2011	PA-2	12:41 PM	10.6	13.4	175.3	225.6	0.1	7.59	4.4	0.5
9/16/2011	PA-2	1:51 PM	9.43	13	174.7	226.8	0.1	7.96	1.18	0.5
10/13/2011	PA-2	12:25 PM	11.2	11	85.3	116.3	0.1	7.7	1.7	0.5
Nov-11		Meter malfunction no sampling								
Dec-11		Meter malfunction no sampling								
		Avg	10.91	11.06	147.47	200.23	0.10	7.67	3.15	0.42
		Std	0.81	2.25	32.34	38.32	0.00	0.21	3.41	0.18
		Min	9.43	7	85.3	116.3	0.1	7.41	0.74	0.09
		Max	12.2	13.4	175.8	227	0.1	7.98	12.1	0.5
		Count	10	10	10	10	10	8	10	5

Horse Creek

Date	Site Code	Time	DO mg/L	Temp. C	Conduct. *u* s/cm	Specific Condut. *u* s/cm	Salanity ppt	pH	Turbidity NTUs	Flow cfs
1/20/2011	HC-1	10:23 AM	11.4	7.3	124	187.7	0.1		3.78	1.25
2/22/2011	HC-1	9:40 AM	11.7	6.7	119.6	184.1	0.1	8	2.59	1.5
3/22/2011	HC-1	2:07 PM	10.7	9.3	118.8	170.4	0.1	7.82	7.08	1.5
4/20/2011	HC-1	4:05 PM	10.3	10.4	137.1	190.3	0.1	n/c	5.82	1.5
5/20/2011	HC-1	2:00 PM	11.4	12.9	152.3	198.2	0.1	7.68	1.86	2
6/15/2011	HC-1	9:48	10.5	12.8	140.2	182.7	0.1	8.14	4.55	2
7/18/2011	HC-1	12:57 PM	10.9	14.6	175.6	219	0.1	7.42	2.18	1
8/8/2011	HC-1	2:33 PM	10.1	15.3	177.8	218.9	0.1	7.67	1.46	1
9/16/2011	HC-1	10:18 AM	9.28	14.6	188.5	235.3	0.1	7.78	1.33	0.75
10/13/2011	HC-1	2:33 PM	11.3	12.8	150.4	195.9	0.1	7.65	1.38	1
11/16/2011	HC-1	10:50 AM	11.7	8.5	156.3	228.3	0.1	7.64	0.86	1
Dec-11	HC-1	Meter malfunction no sampling								
		Avg	10.83	11.38	149.15	200.98	0.10	7.76	2.99	1.32
		Std	0.75	3.08	24.05	21.09	0.00	0.21	2.05	0.42
		Min	9.28	6.7	118.8	170.4	0.1	7.42	0.86	0.75
		Max	11.7	15.3	188.5	235.3	0.1	8.14	7.08	2
		Count	11	11	11	11	11	9	11	11

Horse Creek

1/20/2011	HC-2	10:35 AM	11.3	6.9	118	180.5	0.1		0.38	1.25
2/22/2011	HC-2	10:52 AM	12.1	6.4	117.7	182.7	0.1	7.71	2.46	1.2
3/22/2011	HC-2	2:30 PM	11	9.4	123	175.3	0.1	7.76	8.65	1.2
4/20/2011	HC-2	3:45 PM	10.1	10.7	137.1	188.9	0.1	n/c	1.18	1
5/20/2011	HC-2	2:16 PM	11.3	13.3	150.3	193.9	0.1	7.71	3.14	1.5
6/15/2011	HC-2	10:02 AM	10.8	12.3	145.9	192.7	0.1	8.07	3.63	1.5
7/18/2011	HC-2	1:37 PM	11.2	14.6	172.4	215	0.1	7.46	2.81	0.75
8/8/2011	HC-2	2:45 PM	10.5	14.9	183.7	228	0.1	7.6	1.23	0.75
9/16/2011	HC-2	11:06 AM	9.33	13.5	169.1	216.9	0.1	7.89	0.36	0.75
10/13/2011	HC-2	2:36 PM	10.7	12.2	169.3	224.3	0.1	7.57	1.88	1
11/16/2011	HC-2	11:07 AM	11.8	7.4	149.9	226.1	0.1	7.25	3	0.75
Dec-11		Meter malfunction no sampling								
		Avg	10.92	11.05	148.76	202.21	0.10	7.67	2.61	1.06
		Std	0.78	3.10	23.10	20.04	0.00	0.24	2.29	0.29
		Min	9.33	6.4	117.7	175.3	0.1	7.25	0.36	0.75
		Max	12.1	14.9	183.7	228	0.1	8.07	8.65	1.5
		Count	11	11	11	11	11	9	11	11

Little Swamp Creek

Date	Site Code	Time	DO mg/L	Temp. C	Conduct. *u* s/cm	Specific Condut. *u* s/cm	Salanity ppt	pH	Turbidity NTUs	Flow cfs
1/20/2011	LS-1	11:05 AM	11.6	5.7	89	140.9	0.1		4.01	0.5
2/22/2011	LS-1	11:05 AM	12.3	6.8	105	160.7	0.1	7.69	1.05	0.75
3/22/2011	LS-1	3:34 PM	10.6	9.1	96.1	138.6	0.1	7.83	4.71	0.5
4/20/2011	LS-1	3:32 PM	10.1	10.4	103.1	143.2	0.1	n/c	2.16	0.07
5/19/2011	LS-1	3:38 PM	9.44	14	118.3	150.1	0.1	7.03	3.37	0.5
6/15/2011	LS-1	1:51 PM	10.6	14.1	131.6	166.1	0.1	7.8	3.89	0.06
7/18/2011	LS-1	1:47 PM	10.4	16.3	164.2	196.5	0.1	7.52	2.81	0.02
8/8/2011	LS-1	11:05 AM	8.95	15.8	171.2	207.4	0.1	7.3	3.41	0.01
9/16/2011	LS-1	11:30 AM	8.15	17.1	99.8	117.7	0.1	7.74	3.74	0.2
10/13/2011	LS-1	9:25 AM	9.84	11.9	135.9	181.5	0.1	7.3	5.49	0.03
11/14/2011	LS-1	10:18	10.7	8	123.6	183	0.1	7.12	3.17	0.04
Dec-11		Meter malfunction no sampling								
		Avg	10.25	11.75	121.62	162.34	0.10	7.48	3.44	0.24
		Std	1.17	4.00	27.20	27.46	0.00	0.30	1.19	0.27
		Min	8.15	5.7	89	117.7	0.1	7.03	1.05	0.01
		Max	12.3	17.1	171.2	207.4	0.1	7.83	5.49	0.75
		Count	11	11	11	11	11	9	11	11

Waynita Creek

1/20/2011	WC-1	10:09 AM	12.4	6.1	148.2	232.2	0.1		9.41	1.5
2/22/2011	WC-1	9:26 AM	13.6	4.9	132.1	214.8	0.1	8.08	4.09	1
3/22/2011	WC-1	1:42 AM	11.7	8.4	156	228.8	0.1	8.17	6.59	1.2
4/20/2011	WC-1	3:55 PM	11.2	9.8	169.8	240	0.1	n/c	6.26	1.25
5/20/2011	WC-1	11:35 AM	11.1	11.7	186.1	249.8	0.1	8.01	5.22	1.5
6/15/2011	WC-1	9:33 AM	11.1	12.3	162.7	214.7	0.1	8.16	9.38	1.5
7/18/2011	WC-1	12:39 PM	10.8	14.8	216.7	269.5	0.1	8.04	2.9	0.75
8/8/2011	WC-1	2:22 PM	10.8	15.7	250.9	303.5	0.1	8.25	3.88	0.07
9/16/2011	WC-1	9:50 AM	10.1	13.1	260.9	341.2	0.2	8.32	2.58	0.25
10/13/2011	WC-1	2:06 PM	12.1	11.4	190.9	257.4	0.1	7.96	2.11	2.5
11/16/2011	WC-1	10:39 AM	12.8	5.2	172.6	277.2	0.1	8.03	1	0.5
Dec-11		Meter malfunction no sampling								
		Avg	11.61	10.31	186.08	257.19	0.11	8.11	4.86	1.09
		Std	1.02	3.76	41.24	38.91	0.03	0.12	2.82	0.69
		Min	10.1	4.9	132.1	214.7	0.1	7.96	1	0.07
		Max	13.6	15.7	260.9	341.2	0.2	8.32	9.41	2.5
		Count	11	11	11	11	11	9	11	11

Brick Yard Creek

Date	Site Code	Time	DO mg/L	Temp. C	Conduct. *u* s/cm	Specific Condut. *u* s/cm	Salanity ppt	pH	Turbidity NTUs	Flow cfs
1/20/2011	BY-1	10:48 AM	11.2	7.3	143.6	260.7	0.1		4.01	0.5
2/22/2011	BY-1	9:08 AM	11.8	6.8	130.3	200	0.1	8.15	3.68	0.25
3/22/2011	BY-1	2:41 PM	10.8	8.7	143.8	208.9	0.1	7.65	18.9	0.5
4/20/2011	BY-1	4:18 PM	9.95	9.5	175.3	249.5	0.1	n/c	10.86	0.03
5/19/2011	BY-1	3:06 PM	10.1	12	105.9	141.5	0.1	7.39	4.06	0.5
6/15/2011	BY-1	10:17 AM	10.3	13.2	127.6	165.3	0.1	8.18	5.41	0.06
7/11/2011	BY-1	1:45 PM	10.1	15.2	220.3	270.5	0.1	7.08	5.77	0.02
8/8/2011	BY-1	2:06 PM	6.29	15.8	230.8	280.6	0.1	7.25	3.03	0.02
9/16/2011	BY-1	2:15 PM	7.71	14.8	196.9	244.1	0.1	7.55	1.76	0.03
10/13/2011	BY-1	1:47 PM	8.4	12.4	192.7	253.8	0.1	7.36	3.39	0.01
Nov-11		Meter malfunction no sampling								
Dec-11		Meter malfunction no sampling								
		Avg	9.66	11.57	166.72	227.49	0.10	7.58	6.09	0.19
		Std	1.69	3.31	42.49	46.65	0.00	0.40	5.13	0.22
		Min	6.29	6.8	105.9	141.5	0.1	7.08	1.76	0.01
		Max	11.8	15.8	230.8	280.6	0.1	8.18	18.9	0.5
		Count	10	10	10	10	10	8	10	10

Perry Creek

1/21/2011	PR-1	10:35 AM	11.4	7.1	81.3	125.2	0.1		8.96	2
2/22/2011	PR-1	11:33 AM	12.7	6	136.8	214.5	0.1	7.76	1.97	1
3/22/2011	PR-1	3:09 PM	11.1	10.3	147.3	205.5	0.1	7.77	2.39	1.5
4/20/2011	PR-1	3:00 PM	11.2	10.7	158.1	217.5	0.1	n/c	1.34	1.5
5/19/2011	PR-1	4:00 PM	9.99	14	158.7	201.4	0.1	7.53	2.12	2
6/15/2011	PR-1	2:38 PM	11.4	13	171.2	222.4	0.1	7.87	2.35	1.25
7/11/2011	PR-1	3:15 PM	11.7	14.7	192.5	239.6	0.1	7.55	1.76	0.75
8/8/2011	PR-1	11:32 AM	9.9	14.5	186.3	232.8	0.1	7.81	2.75	1
9/15/2011	PR-1	3:52 PM	9.74	14.5	186.5	233.3	0.1	7.95	2.04	1.2
10/25/2011	PR-1	1:52 PM	10.9	11.2	148	200.9	0.1	7.77	2.12	1.25
11/14/2011	PR-1	10:30 AM	11.2	8.6	151.7	221.3	0.1	7.57	0.86	1.2
Dec-11		Meter malfunction no sampling								
		Avg	11.01	11.33	156.22	210.40	0.10	7.73	2.61	1.33
		Std	0.86	3.11	30.87	31.09	0.00	0.15	2.17	0.39
		Min	9.74	6	81.3	125.2	0.1	7.53	0.86	0.75
		Max	12.7	14.7	192.5	239.6	0.1	7.95	8.96	2
		Count	11	11	11	11	11	9	11	11

Perry Creek

Date	Site Code	Time	DO mg/L	Temp. C	Conduct. *u* s/cm	Specific Condut. *u* s/cm	Salanity ppt	pH	Turbidity NTUs	Flow cfs
1/21/2011	PR-2	10:42 AM	11.7	6.9	74.2	113.5	0.1		12.4	2
2/22/2011	PR-2	11:41 AM	13.1	5.2	98.7	158.7	0.1	7.92	0.71	0.75
3/22/2011	PR-2	3:00 PM	11	9.2	97.6	139.8	0.1	7.92	1.96	1
4/20/2011	PR-2	3:10 PM	10.6	10.4	111.1	154	0.1	n/c	5.77	0.6
5/19/2011	PR-2	4:10 PM	10.1	14	126.7	159.8	0.1	7.72	1.74	1.5
6/15/2011	PR-2	2:48 PM	11.2	14	133.1	168.3	0.1	7.97	2.03	1
7/11/2011	PR-2	2:10 PM	10.6	16.1	158.6	190.9	0.1	7.39	1.4	0.04
8/8/2011	PR-2	11:41 AM	9.85	15.3	155.3	190.8	0.1	7.53	0.45	0.25
9/15/2011	PR-2	4:01 PM	8.89	15.1	165.6	204.7	0.1	7.78	0.31	0.04
10/25/2011	PR-2	1:43 PM	10.7	10.2	136	189.7	0.1	7.5	1.33	0.5
11/14/2011	PR-2	10:39 AM	11.3	7.3	122.5	185.5	0.1	7.13	2.99	0.75
Dec-11		Meter malfunction no sampling								
		Avg	10.81	11.25	125.40	168.70	0.10	7.65	2.83	0.77
		Std	1.09	3.83	28.47	26.98	0.00	0.28	3.52	0.60
		Min	8.89	5.2	74.2	113.5	0.1	7.13	0.31	0.04
		Max	13.1	16.1	165.6	204.7	0.1	7.97	12.4	2
		Count	11	11	11	11	11	9	11	11

Junco Creek

1/21/2011	JO-1	10:12 PM	10.9	7.6	102.5	153.8	0.1	n/c	4.4	1
2/22/2011	JO-1	2:20 PM	11.8	6.7	119.7	183.8	0.1	7.94	0.42	1
3/23/2011	JO-1	1:57 PM	10.2	10.6	130	179.5	0.1	7.69	1.48	1
4/20/2011	JO-1	2:24 PM	11.2	10.7	131.5	181.2	0.1	n/c	0.5	1.5
5/20/2011	JO-1	3:07 PM	10.8	13.8	144.9	184.4	0.1	7.65	2.04	1
6/15/2011	JO-1	11:34 AM	10.9	11.9	138.8	185.1	0.1	7.89	3.76	1
7/11/2011	JO-1	11:46 AM	11.1	13.7	154.2	196.5	0.1	6.92	2.8	0.75
8/8/2011	JO-1	12:05 PM	9.81	13.9	151.9	193.3	0.1	7.55	2.01	0.75
9/15/2011	JO-1	3:01 PM	9.62	13.4	152.3	195.9	0.1	7.96	1.19	0.75
10/13/2011	JO-1	11:38 AM	10.8	10.8	135.5	186.1	0.1	7.4	0.32	0.1
11/14/2011	JO-1	10:55 AM	10.9	8.3	132.4	194.2	0.1	7.18	0.42	1
Dec-11		Meter malfunction no sampling								
		Avg	10.73	11.04	135.79	184.89	0.10	7.58	1.76	0.90
		Std	0.62	2.60	15.47	11.94	0.00	0.36	1.41	0.34
		Min	9.62	6.7	102.5	153.8	0.1	6.92	0.32	0.1
		Max	11.8	13.9	154.2	196.5	0.1	7.96	4.4	1.5
		Count	11	11	11	11	11	9	11	11

Crystal Creek

Date	Site Code	Time	DO mg/L	Temp. C	Conduct. *u* s/cm	Specific Condut. *u* s/cm	Salanity ppt	pH	Turbidity NTUs	Flow cfs
1/21/2011	CQ-1	9:52 AM	11.4	7	70	106.4	0	N/C	10.57	3
2/22/2011	CQ-1	2:40 PM	11.8	6.3	112.3	174.9	0.1	7.72	1.77	1
3/23/2011	CQ-1	2:25 PM	10.3	10.2	84	117.7	0.1	7.56	1.39	0.5
4/20/2011	CQ-1	2:49 PM	10.4	10.7	78.8	108.3	0.1	n/c	1.25	1
5/20/2011	CQ-1	3:25 PM	10.7	15.1	84	103.7	0.1	7.78	1.3	1
6/15/2011	CQ-1	12:02 PM	11	12.7	148.7	194.2	0.1	7.88	2.37	0.75
7/11/2011	CQ-1	2:34 PM	10.8	15.7	170.9	208.1	0.1	7.29	1.65	0.25
8/8/2011	CQ-1	3:00 PM	9.68	16	174.4	210.9	0.1	7.62	2.07	0.5
9/15/2011	CQ-1	3:18 PM	9.05	15.4	163.6	200.8	0.1	7.92	1.2	0.25
10/13/2011	CQ-1	10:40 AM	11	11	147.5	201.5	0.1	7.53	1.44	0.2
Nov-11		Meter malfunction no sampling								
Dec-11		Meter malfunction no sampling								
		Avg	10.61	12.01	123.42	162.65	0.09	7.66	2.50	0.85
		Std	0.81	3.57	41.85	47.28	0.03	0.21	2.86	0.82
		Min	9.05	6.3	70	103.7	0	7.29	1.2	0.2
		Max	11.8	16	174.4	210.9	0.1	7.92	10.57	3
		Count	10	10	10	10	10	8	10	10

Middle Creek

1/21/2011	MD-1	10:05 AM	10.8	7.5	59.5	89.4	0	n/c	6.2	1.5
2/22/2011	MD-1	2:30 PM	11.8	7	124.2	189.3	0.1	7.65	0.6	0.75
3/22/2011	MD-1	2:14 PM	9.89	12	168.6	224.8	0.1	7.6	1.47	0.75
4/20/2011	MD-1	2:30 PM	10.3	11.8	156.6	209.3	0.1	n/c	2.52	1
5/20/2011	MD-1	3:14 PM	10.9	15.5	179.5	219.1	0.1	7.68	3.31	1
6/15/2011	MD-1	11:41 AM	10.2	13.6	143.7	183.8	0.1	7.69	2.1	0.25
7/11/2011	MD-1	2:26 PM	10.1	16.7	189.6	225.7	0.1	7.3	3.31	0.07
8/8/2011	MD-1	3:10 PM	8.59	16.9	185.4	219.1	0.1	7.33	1.21	0.25
9/15/2011	MD-1	2:50 PM	7.41	16.2	184	221.1	0.1	7.6	0.62	0.25
10/13/2011	MD-1	11:25 AM	9.44	13.3	167.6	215.5	0.1	7.18	0.38	0.3
Nov-11		Meter malfunction no sampling								
Dec-11		Meter malfunction no sampling								
		Avg	9.94	13.05	155.87	199.71	0.09	7.50	2.17	0.61
		Std	1.23	3.57	39.58	41.35	0.03	0.20	1.78	0.46
		Min	7.41	7	59.5	89.4	0	7.18	0.38	0.07
		Max	11.8	16.9	189.6	225.7	0.1	7.69	6.2	1.5
		Count	10	10	10	10	10	8	10	10

Palm Creek

Date	Site Code	Time	DO mg/L	Temp. C	Conduct. *u* s/cm	Specific Condut. *u* s/cm	Salanity ppt	pH	Turbidity NTUs	Flow cfs
1/21/2011	PM-1	10:18 PM	11.7	7.6	77.5	116.1	0.1		8.23	3
2/22/2011	PM-1	2:13 PM	12.3	7.5	115.8	174.2	0.1	8.04	1.28	1.75
3/23/2011	PM-1	1:49 PM	11.2	10.1	126	175.9	0.1	7.92	0.47	1.5
4/20/2011	PM-1	2:17 PM	11.2	10.3	132.7	184.4	0.1	n/c	1.63	1.5
5/20/2011	PM-1	2:45 PM	12	12.8	140.8	183.8	0.1	8.12	1.18	2
6/15/2011	PM-1	11:27 AM	12.1	10.8	138.2	189.4	0.1	8.21	0.81	2
7/11/2011	PM-1	12:02 PM	12.5	11.7	145.2	187.8	0.1	7.5	2.76	1.2
8/8/2011	PM-1	12:16 PM	12	12	146.1	194.4	0.1	8.02	2.39	1.5
9/16/2011	PM-1	1:35 PM	9.87	12	148.1	197.1	0.1	8.12	0.22	1.5
10/13/2011	PM-1	11:49 AM	12.2	10.4	139.1	193	0.1	7.8	0.6	0.15
11/14/2011	PM-1	11:05 AM	12.3	8.8	134.3	194.4	0.1	7.87	0.5	1.75
Dec-12		Meter malfunction no sampling								
		Avg	11.76	10.36	131.25	180.95	0.10	7.96	1.82	1.62
		Std	0.75	1.78	20.17	22.77	0.00	0.22	2.27	0.68
		Min	9.87	7.5	77.5	116.1	0.1	7.5	0.22	0.15
		Max	12.5	12.8	148.1	197.1	0.1	8.21	8.23	3
		Count	11	11	11	11	11	9	11	11

Woods Creek

1/21/2011	WD-1	10:25 AM	11.8	7	67.4	102.8	0		9.19	2.5
2/22/2011	WD-1	2:05 PM	12.9	5	96.2	151.1	0.1	7.97	2.14	1
3/23/2011	WD-1	1:39 PM	11.2	10.2	106.3	148.6	0.1	7.73	2.52	1.25
4/20/2011	WD-1	2:17 PM	11.4	11.1	115.4	157	0.1	n/c	1.36	0.75
5/20/2011	WD-1	2:50 PM	10.6	16.2	66.8	79.9	0	7.95	2.18	1
6/15/2011	WD-1	11:18 AM	11.4	12.3	120.9	159.7	0.1	8.19	3.03	1.25
7/11/2011	WD-1	3:30 PM	11.2	17.3	145.9	171	0.1	7.42	1.8	1
8/8/2011	WD-1	12:30 PM	10.6	15	133.9	165.5	0.1	7.96	6.65	1
9/16/2011	WD-1	1:41 PM	9.43	14.8	141.3	175.7	0.1	8.64	0.37	1
10/13/2011	WD-1	12:10 PM	11.8	11.5	124.9	168.4	0.1	7.51	6.57	0.75
Nov-11		Meter malfunction no sampling								
Dec-11		Meter malfunction no sampling								
		Avg	11.24	12.04	111.90	147.97	0.08	7.92	3.58	1.15
		Std	0.92	3.96	28.01	31.49	0.04	0.39	2.86	0.50
		Min	9.43	5	66.8	79.9	0	7.42	0.37	0.75
		Max	12.9	17.3	145.9	175.7	0.1	8.64	9.19	2.5
		Count	10	10	10	10	10	8	10	10

Filbert Creek

Date	Site Code	Time	DO mg/L	Temp. C	Conduct. *u* s/cm	Specific Condut. *u* s/cm	Salanity ppt	pH	Turbidity NTUs	Flow cfs
1/20/2011	FB-1	11:35 AM	12.4	5.4	92.3	147.6	0.1		0.12	1
2/22/2011	FB-1	3:24 PM	11.6	5.6	119.9	190.4	0.1	7.75	Clr	0.75
3/23/2011	FB-1	3:00 PM	11.1	9.1	97.7	140.4	0.1	7.73	0.56	0.75
4/15/2011	FB-1	3:22 PM	11.7	9.3	87.6	125.3	0.1	N/C	1.72	1
5/20/2011	FB-1	3:42 PM	11.1	13.4	113.2	145.6	0.1	7.78	1.42	0.25
6/15/2011	FB-1	2:20 PM	11.4	12.6	124	162.4	0.1	7.99	0.88	0.06
7/18/2011	FB-1	2:00 PM	10.8	15.6	151.8	185.8	0.1	7.2	0.27	0.03
8/8/2011	FB-1	3:30 PM	9.66	16.2	163.6	197	0.1	7.81	1.77	0.01
9/15/2011	FB-1	3:31 PM	9.46	15.1	154.9	191.5	0.1	8.12	0.22	0.01
10/13/2011	FB-1	10:11 AM	11	10.7	144.8	199.1	0.1	7.75	0.21	0.01
Nov-11		Meter malfunction no sampling								
Dec-11		Meter malfunction no sampling								
		Avg	11.02	11.30	124.98	168.51	0.10	7.77	0.80	0.39
		Std	0.89	3.94	27.64	27.31	0.00	0.27	0.68	0.43
		Min	9.46	5.4	87.6	125.3	0.1	7.2	0.12	0.01
		Max	12.4	16.2	163.6	199.1	0.1	8.12	1.77	1
		Count	10	10	10	10	10	8	9	10

Maltby Hill Creek

1/20/2011	MH-1	11:52 AM	10.9	4.2	99	164.4	0.1		5.86	0.25
2/22/2011	MH-1	3:10 PM	12.8	4.7	97	159.7	0.1	7.74	Err	0.5
3/23/2011	MH-1	2:33 PM	11.3	9.2	113.7	162.8	0.1	7.56	1.39	0.5
4/15/2011	MH-1	3:34 PM	11.6	9.9	100.8	141.7	0.1	N/C	1.95	0.5
5/20/2011	MH-1	3:30 PM	9.07	16	147.5	178.3	0.1	7.46	0.98	0.25
6/15/2011	MH-1	11:50 AM	9.95	12.5	135.4	177.9	0.1	7.63	1.37	0.25
7/11/2011	MH-1	2:42 PM	9.3	16.2	172.6	207.7	0.1	7.49	1.58	0.09
8/8/2011	MH-1	3:20 PM	7.24	16.3	179.4	215	0.1	7.43	0.84	0.11
9/15/2011	MH-1	2:40 PM	6.59	15.2	156.7	192.8	0.1	7.75	1.8	0.02
10/13/2011	MH-1	10:30 AM	9.37	10	139.8	195.8	0.1	7.12	2.48	20 gpm
Nov-11		Meter malfunction no sampling								
Dec-11		Meter malfunction no sampling								
		Avg	9.82	11.42	134.19	179.61	0.10	7.52	2.03	0.27
		Std	1.93	4.59	30.54	23.17	0.00	0.20	1.52	0.19
		Min	6.59	4.2	97	141.7	0.1	7.12	0.84	0.02
		Max	12.8	16.3	179.4	215	0.1	7.75	5.86	0.5
		Count	10	10	10	10	10	8	9	9

North Creek

Date	Site Code	Time	DO mg/L	Temp. C	Conduct. *u* s/cm	Specific Condut. *u* s/cm	Salanity ppt	pH	Turbidity NTUs	Flow cfs
6/15/2011	NC-1	10:33 AM	10.7	12.6	131	171.5	0.1	8.05	4.77	20
7/18/2011	NC-1	1:14 PM	10.9	15.5	159.6	194.8	0.1	7.57	2.61	16
8/8/2011	NC-1	3:50 PM	10.3	16.2	169.9	204.3	0.1	7.83	3.18	15
9/16/2011	NC-1	10:46 AM	9.06	13.7	163.3	208.3	0.1	7.82	2.56	10
10/13/2011	NC-1	1:30 PM	11.2	11	134.4	183.2	0.1	7.57	2.09	25
Nov-11		Meter malfunction no sampling								
Dec-11		Meter malfunction no sampling								
		Avg	10.44	13.80	151.64	192.42	0.10	7.77	3.04	17.20
		Std	0.84	2.12	17.72	15.18	0.00	0.20	1.04	5.63
		Min	9.06	11	131	171.5	0.1	7.57	2.09	10
		Max	11.2	16.2	169.9	208.3	0.1	8.05	4.77	25
		Count	5	5	5	5	5	5	5	5