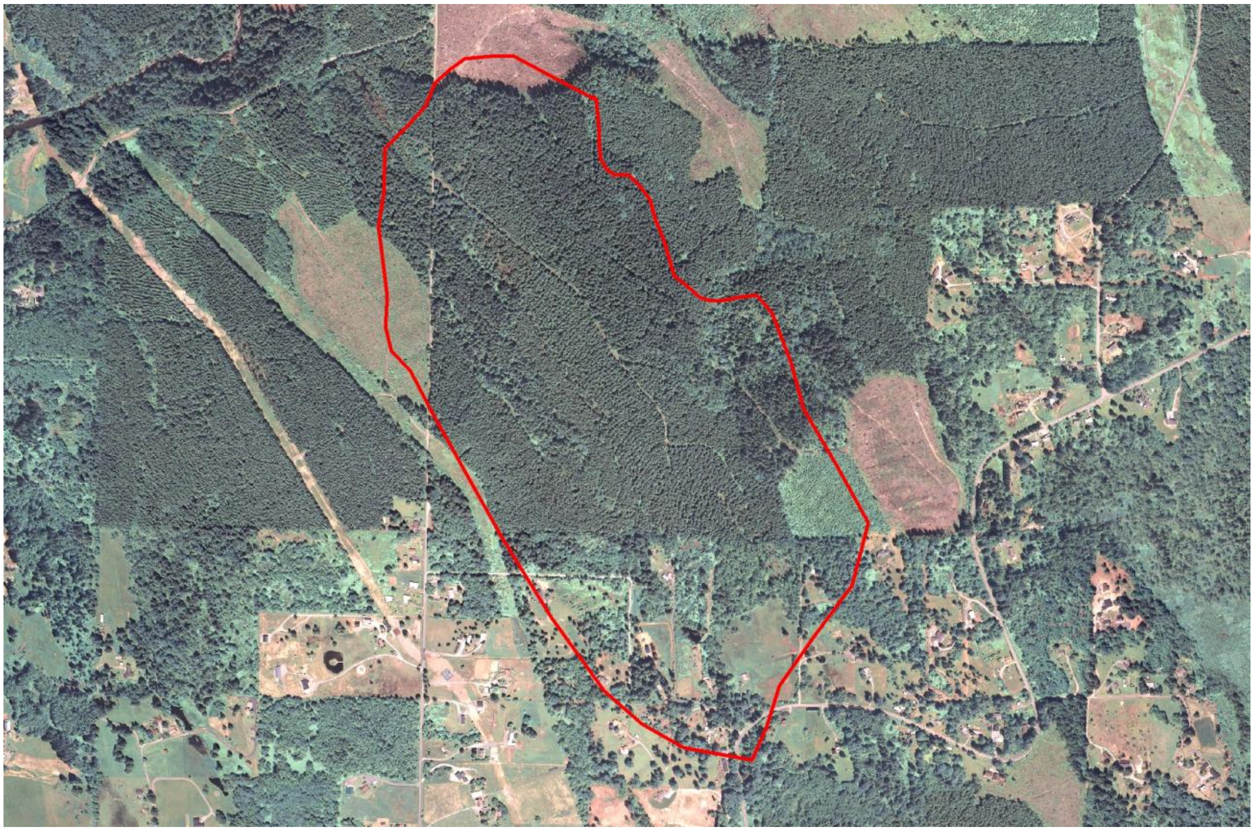
Appendix C.

Snohomish County
Public Works



Intensive Catchment Study Status Report

For Snohomish County Critical Area Monitoring
Surface Water Management

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1. Introduction

While the remote sensing and shoreline condition components of the CAR monitoring plan are designed to rapidly detect changes to the physical conditions of critical areas, the third component of the monitoring plan was initiated to directly assess impacts to ecological functions of riparian corridors. The study will test the effectiveness of the new code by assessing instream metrics in small watersheds (or catchments) that are experiencing new development and compare the results with those from similar catchments that remain relatively undeveloped during the study. By pairing catchments with similar characteristics, except for the level of development under the new regulation, we can achieve a high level of certainty that any differences we detect are due to the effects of development activities.

Because instream physical and biological conditions are known to be spatially and temporally variable, we focus our assessment on metrics that have a high signal to noise ratio and/or have been documented as useful indicators of alteration of the ecological functions of riparian buffers. The chosen metrics are stream temperature, conductivity, pool average maximum depth and frequency, channel cross-sectional dimensions and bank full width and benthic index of biological integrity B-IBI.

Bankfull width and depth

Stream channels change dimensions in response to changes in watershed or riparian conditions (e.g. clearing or paving) that alter stream flow, sediment delivery and transport, and vegetation or woody debris recruitment from riparian areas. The bankfull width – depth ratio, in which 'bankfull' refers to the bankfull discharge and depth refers to the average water depth associated with that discharge, is a sensitive indicator of trends in channel stability and disturbance to channels or watersheds (Rosgen, 1996). An increasing width – depth ratio (channel increases in width and decreases in depth) often results from watershed disturbance, which in turn causes bank erosion and a reduction in the channel's ability to transport sediment (Rosgen, 1996). Streams with high bankfull width – depth ratios also tend to have reduced shading and shallower dry-season flows, which may result in elevated water temperatures.

Bankfull width:depth ratio was chosen as a monitoring indicator because it is sensitive to changes in upstream watershed conditions and can be precisely measured. Bankfull width and depth will be measured in the field using a stadia rod, measuring table and level using field indicators and survey techniques outlined in Rosgen (1996).

Pool frequency and depth

Pool frequency is a common measure of salmon habitat quality and complexity. Pools provide critical rearing areas for juvenile salmonids and holding areas for adult salmonids when they return to their natal streams to spawn. Pool frequency is primarily a function of LWD, sediment loading, and channel type (Montgomery et al, 1995). Low pool frequency often indicates inadequate LWD loading or excess sedimentation. Because of its importance in providing habitat for salmonids and because it is a metric that can be measured rapidly with precision (Kauffman et al, 1999), it was selected as a monitoring indicator

Water temperature

Water temperature is a controlling factor in the rate of metabolic and reproductive activities for aquatic life that affects physical and chemical water indicators in the stream environment. An increase in temperature can increase metabolic activity, lower dissolved oxygen levels, and provide conditions for the growth of disease-causing organisms and undesirable algae. Weather, streamflow, streamside vegetation, groundwater inputs, and water release from industrial activities influence water temperature. Removal of the forest canopy of streams in the Pacific Northwest has been documented to increase peak water temperatures in the summer by 3 to 8 degrees Celsius (MacDonald et al. 1991).

Performance criteria for water temperature are based on temperature regimes established for adult salmon migration (EPA, 2002). Lab studies of disease risk to migrating adult salmon indicate elevated risk above 14^{o}C and high risk above 17^{o}C (EPA 2003).

Conductivity

Conductivity is a measure of the ability of a substance to conduct an electric current, and for water, is related to the total concentration of dissolved ions. Conductivity in natural waters is measured as the inverse of resistance in umhos/cm. Distilled water has a conductivity of about 1 umhos/cm, and melted snow can have a conductivity of 2 to 42 umhos/cm. The typical range for drinking water in the United States is 30 to 1,500 umhos/cm, and streams in the Pacific Northwest usually fall at the low end of that range (MacDonald et al. 1991).

Conductivity can be used as an indicator of contaminants in streams from urban or agricultural activities. May et al. (1997) found a strong correlation ($r^2=0.83$) between conductivity and the percentage of total impervious area in the Puget Sound lowland region. Conductivity in surface water can be increased by substances such as metals from road runoff, zinc from galvanized fencing and roofing, fertilizers, de-icing salts, and dust reduction compounds. Nutrients such as nitrogen and phosphorus are minor components of conductivity. Land clearing activities can increase conductivity by increasing sediment in water and thus the amount of dissolved ions. Conductivity is regarded as a sensitive indicator of change and an early warning if land development impacts are not being mitigated.

Benthic Index of Biological Integrity (B-IBI)

The Benthic Index of Biological Integrity (B-IBI) is a single index value derived from the relative numbers of different types of stream macroinvertebrates. Karr (1998) developed a B-IBI for Puget Sound streams in which scores range from 50 (indicating pristine conditions) to 10 (indicating highly degraded conditions). The index provides a lumped measure of the effects of physical and chemical conditions in the stream, riparian areas, and the watershed upstream of the sample site.

Booth et al. (2002) presented a graph that plotted percent total impervious surface in Puget Sound watersheds against B-IBI scores; the data were compiled from studies by Kleindl (1995), May (1996), and Morley (2000). The data show a general decline in B-IBI scores with increased imperviousness, but with significant variability.

At this time it is not possible to draw strong conclusions about an individual driving factor in a watershed (such as the percentage of impervious area in riparian buffers) based solely on an individual B-IBI score. Significant changes in B-IBI scores along with changes in other watershed metrics, however, can indicate potential problems associated with land use, and thus the need for a more detailed examination of watershed conditions. For this reason and because B-IBI provides a holistic view of the health of critical areas, B-IBI was selected as an indicator for this monitoring program.

In 2008 we began work on our catchment study by identifying several potential catchments, investigating sampling sites, obtaining right of entry permission from property owners and conducting sampling at seven sites. Summary data from this initial effort are reported below. B-IBI data are not reported as laboratory analysis was not complete at the time of this report. Conductivity measurements were not performed during 2008 survey season because continuous sampling probes were not available to the project.

2. Methods

2.1 Site Selection Process

The catchment selection process was unbiased, but non-random. Catchments were selected based on their anticipated level of future development and other site characteristics. Third and forth order catchments were targeted because they support perennial fish-bearing streams, yet are small enough to respond rapidly to land use changes within the riparian forest and contributing drainage area. Targeted catchments were between one and three km^2 in size.

Potential treatment catchments were identified using a series of GIS screens. New permit applications, landuse, zoning, and property ownership data were evaluated to predict the potential of development in areas of unincorporated Snohomish County. Generally, areas within or near urban growth areas zoned residential development and/or contained many parcels owned by development companies or LLC’s were considered likely candidates for development in the near term. Stream systems within areas with high potential for development were evaluated for total catchment area, potential for perennial flow, and site accessibility.

Once reasonable treatment catchments were delineated, potential control catchments were identified as near the treatment site as possible. Control catchments generally contained a large proportion of publicly owned land or were private land zoned for other than residential use. Like their treatment counterpart, stream systems within these catchments were evaluated for accessibility and perennial flow.

Field crews conducted initial field visits of potential sites to assess sampling suitability. Several complicating factors were found during the initial visits including streams that were too small and would likely go dry and streams with no defined channel due to flow through wetlands or beaver ponds. Site access and landowner permissions were also factors in determining if a site was suitable. Sites deemed unsuitable because of localized conditions were moved upstream or downstream to better locations or in one case was moved to an adjacent catchment. When no alternative location could be found, the sites were dropped from the study.

2.2 Office Preparation

Prior to field sampling, survey equipment was assembled and prepared. Accuracy of temperature loggers was assessed in an ice bath and at ambient room temperature. Recorded temperatures were compared to an ASTM Certified Thermometer with +0.10C resolution. Loggers that did not perform to specified accuracy were not used in this study. A data dictionary file for the Trimble ProXH GPS unit was developed and tested. Along with the data dictionary, background images for each sample location were created and loaded onto GPS unit.

A list of property owners for the potential sample sites was created from parcel data extraction. Public Works right-of-way specialists contacted property owners by letter and/or telephone seeking permission to access streams on private property. The list was updated with current status of permission, granted or denied. Sample sites were adjusted based on permission status and if they desired, property owners who granted permission were contacted before surveyors entered their property.

2.3 Field Procedures

Temperature

Two Onset Pro V2 temperature loggers were placed at each sample site in early summer. One logger was placed in the stream to continuously measure water temperatures while another was placed near the stream to record air temperatures. Loggers were placed in discrete locations out of direct sunlight. Logger ID, position, site description and launch time notes were recorded on field forms along with sketches of logger placement. Crews also took photographs and recorded GPS locations to aid in the recovery of loggers. Loggers remained in the stream until late summer when they were retrieved and returned to the office for data processing.

Instream Physical and Biological Measurements

The following metrics were collected from sites over a one or two day period per site. Survey teams entered each site and identified the downstream extent of the reach. The downstream point was often dictated by a property boundary, road crossing or tributary junction. A representative bankfull width measurement was recorded and a reach length of 20 to 30 times this width was established. To aid in the identification of reach boundaries and stream features on return visits, reach start and end points and locations of habitat units and other measurements are recorded using a Trimble GeoXH handheld GPS.

B-IBI

In each reach, surveyors identified three uniform representative riffles for B-IBI samples and began sampling them in an upstream direction. The Surber Sampler frame was set firmly on the substrate so that it was sealed against the substrate and the net was extended downstream optimizing the flow through it and into the collector. Using a small scrub brush, all large gravel and larger size particles were thoroughly cleaned, while holding them inside the net. Cobbles were placed outside the frame area after cleaning. Using a weed tool or large screwdriver crews agitated the sediment within the frame to a depth of 10 cm for about 60 seconds, while continuing to hold the frame securely against the substrate and checking the inside perimeter of the frame for larger organisms that may not have been carried into the net. The sampler was lifted and pulled upstream to rinse organisms, detritus and sediment into the collector. A spray bottle and pump sprayer containing stream water was used to rinse any remaining organisms into the collector. Large rocks in the collector were re-cleaned, inspected and removed. Any mussels, crayfish, or fish were noted and returned to the stream.

Crews sampled the remaining two riffles into the same collector creating a composite sample. After the third riffle was sampled, the material in the collector was transferred into a jar, using the spray bottle to gently concentrate the sample material. Samples were preserved in 90% alcohol solution. A sampling label was placed in the jar and a second label added on the outside of the jar. The sampler was rinsed thoroughly before moving on to the next reach. Labeled samples were stored until they were shipped to a certified laboratory for analysis.

Pool Quantity and Characteristics

Surveyors walked the reach with a hipchain identifying pool habitats. At each pool, maximum and tailout depths were measured to determine if the pool met a minimum residual depth (max depth – tailout depth) of 0.1 meters. Data for pools meeting the depth criterion were recorded along with the hipchain station in a handheld GPS field computer.

Bankfull Width

As the survey team walked the stream recording pool data, they identified and measured bankfull width at five appropriate locations in the reach. Bankfull data and station number were recorded in the field computer.

Cross-sectional Dimensions

One representative riffle in each sample reach was identified for cross-sectional survey. To monument the cross-section, surveyors hammered rebar into the ground on the terrace above each bank positioned so a survey tape stretched between the hubs was perpendicular to the channel thalweg. Using an autolevel and survey rod, relative elevation and distance starting from the right bank hub were measured and recorded for each station along the cross-section. Stations included right bank and left bank hubs, changes in slope, bankfull indicators, wetted edges, thalweg, and bars within the channel. Data were recorded in a field notebook with the site ID, time and date and surveyor names. Bankfull depth values are derived from the cross-section elevations.

2.4 Data post processing

Because survey crews use multiple recording methods and data loggers in this study, data from each metric were processed separately but were always stored in files or tables that identify the site ID. Temperature files were transferred from loggers using Onset Hoboware software. The files were exported to comma delimited text files and opened in a Microsoft Excel. Air and water temperature data for each site were combined into one table, formatted, appended to a master table and imported into a geodatabase. Summary values for air and water temperature were calculated in Access and a report table containing values for each site was created. Data for pools and bankfull widths were transferred from Trimble GPS units and exported to .DBF files using Trimble Pathfinder Office software. Tables from each site were checked for completeness and data quality and are merged into single files for each metric category. Data from cross-sectional surveys recorded in field notes were entered into Microsoft Excel spreadsheets and saved.

A relational database that will house all spatial and tabular data for the catchment study is being developed. This database will serve as a repository for all data collected and will streamline the procedures for data processing, quality control and summarization.

3. Results and Discussion

In 2008, field data were collected at seven sites in unincorporated Snohomish County. Because of a short time period between the initial site screening process and the field sampling season for this first year of survey, site suitability and ease of sampling took precedence over catchment characteristics. Sites on public land or with single landowners were selected for survey first while sites with multiple landowners and questionable access were reserved. Due to field-assessed site conditions, access issues and other factors several sample locations identified in the office were relocated by field crews. While the new sites were ideal for field samples, moving the sample locations affected the associated contributing areas and therefore the characteristics of previously paired catchments. The result of this is a need to reevaluate catchment pairs and, when necessary, select additional catchments for 2009 sampling that may be paired or evaluated with 2008 catchment results.

The seven resulting sampled catchments (Figure 1) are located in unincorporated Snohomish County east of the County's major urban growth areas. The catchments varied in size from less than one-half km^2 to greater than five km^2. Topography and elevation varied as well among catchments with sample locations at the catchments' lowest points ranging from approximately 60 m to over 180 m above sea level. The geology among catchments was predominantly glacial till, though catchment 2A is entirely sedimentary and catchment 2B has a large intrusive component making up the upper portion of the drainage. Five out of the seven sampled catchments were zoned entirely rural residential-five acre with the remaining two catchments zoned primarily for forest practices or other natural resource use. Land cover, including built and vegetative cover for the entire catchment and just the riparian corridor, is currently being assessed using products from the remote sensing component of the monitoring program and will be a included in future reports. Generally, catchments have a wide range of cover types from completely forested to rural development/lawn/pasture. They all have riparian corridors that are considered intact though not without signs of human alteration or degradation.

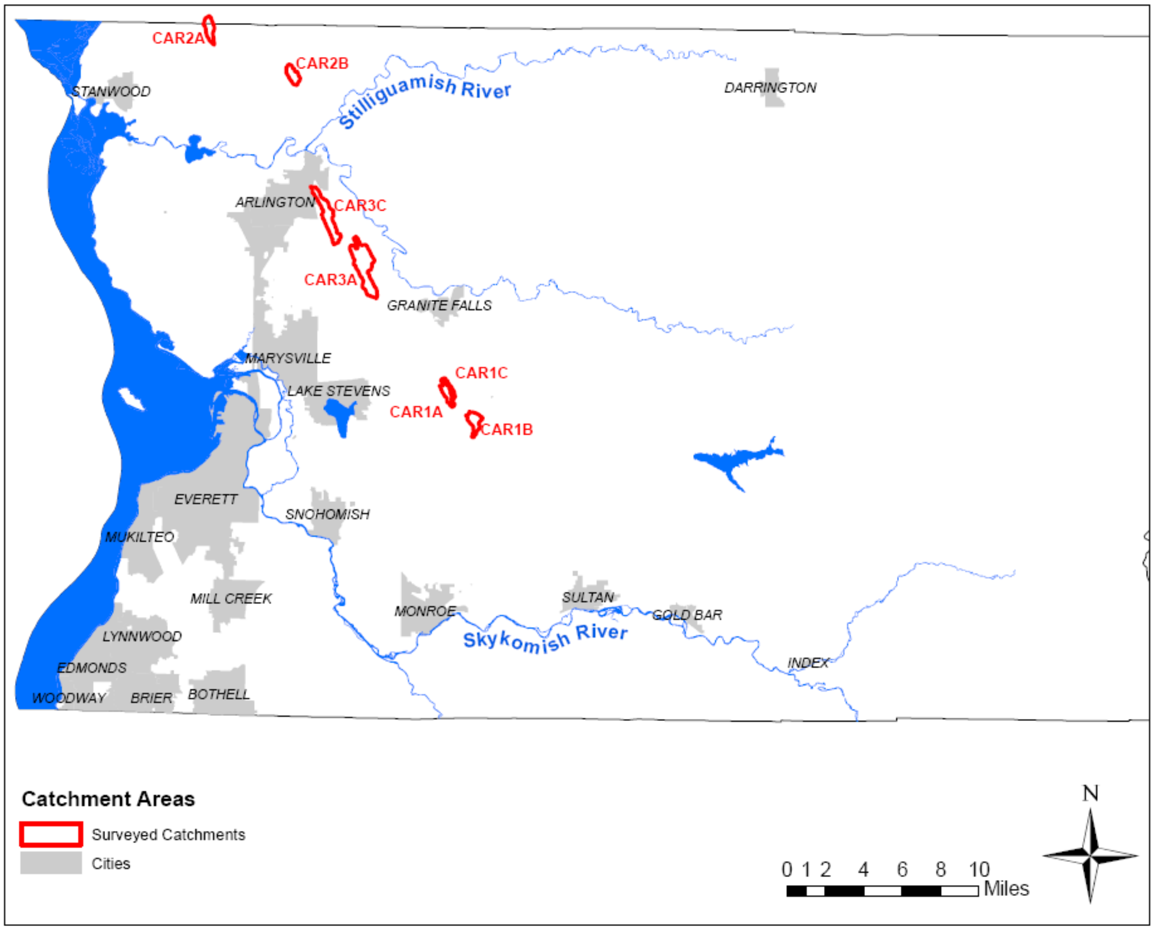

Figure 1. Location of Sampled Catchments Identified by Site ID.

Special mention of individual catchments is required in several instances due to nonstandard occurrences. Representatives for the land owner of sample site 1B contacted the County late in the sample season and rescinded permission for access to the site. Though the summary data collected prior to the notification are included in this report, the site will be replaced in 2009. Catchment 2A is located on the Snohomish/Skagit County line. Approximately 0.34 square kilometers (26%) of the catchment falls within Skagit County. Because this catchment is owned primarily by a private timber company and was selected because it would likely remain undeveloped, the fact that a quarter of the catchment is within another jurisdiction should not influence the study results. Finally, catchments 1A and 1C are not discrete drainages as the runoff from 1C contributes to that of 1A. For this and other reasons, these catchments will not be paired to each other.

Temperature

Water temperature loggers were recovered in good condition for all sampled sites. Air loggers were recovered for all sites where they were placed. Site 3C was added to the list of sites late in the field season. The water temperature logger for this site was placed approximately 600 m downstream of the sample reach as part of another Surface Water monitoring effort. An air temperature logger was not placed for Site 3C. The following figures (2 - 8) display minimum, average and maximum daily water temperatures as well as average daily air temperatures from mid July through the end of August.

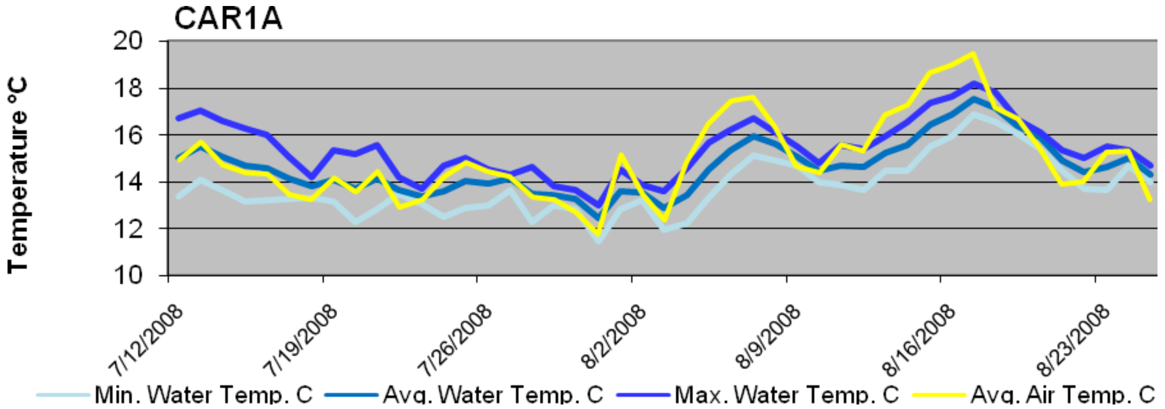

Figure 2. Water and air temperatures from mid July to the end of August site 1A

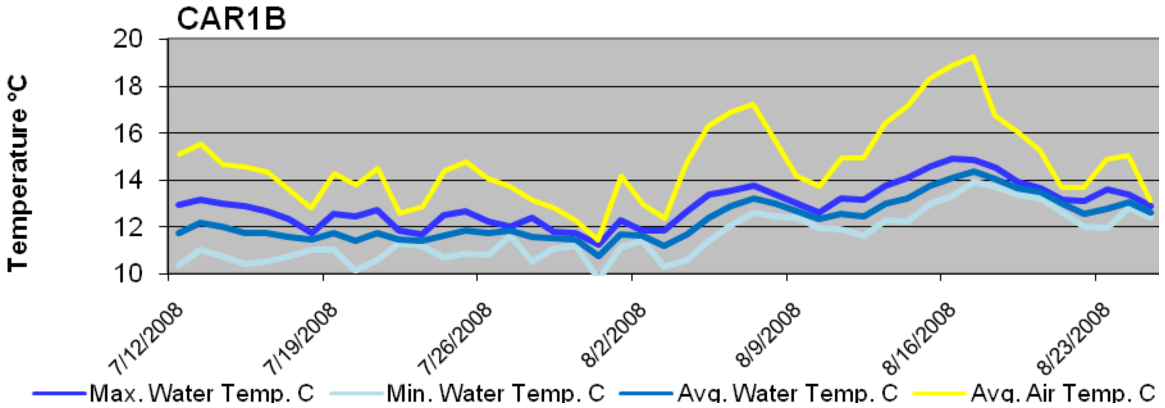

Figure 3. Water and air temperatures from mid July to the end of August site 1B

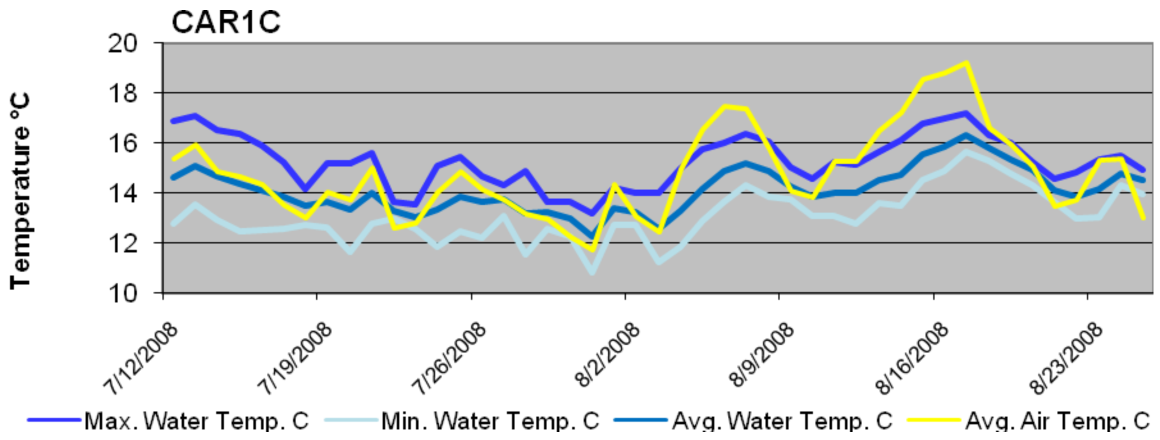

Figure 4. Water and air temperatures from mid July to the end of August site 1C

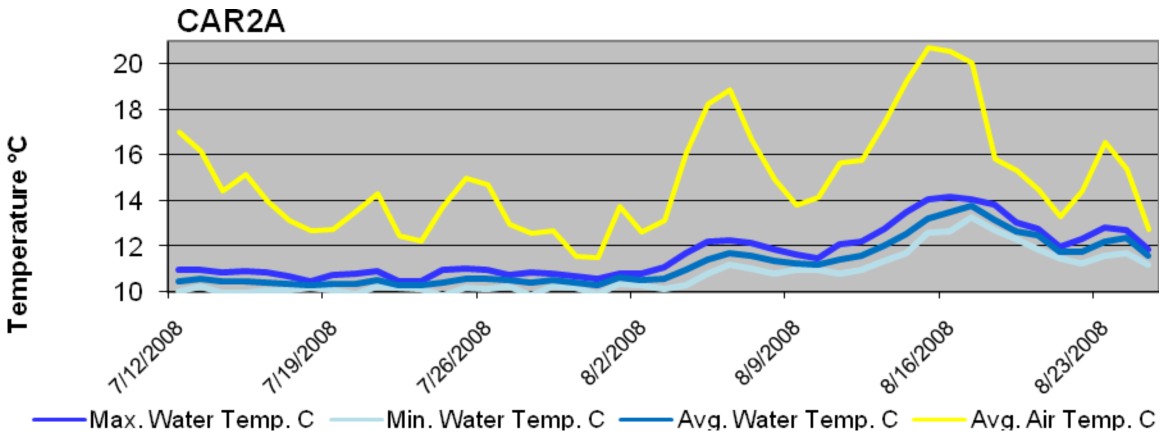

Figure 5. Water and air temperatures from mid July to the end of August site 2A

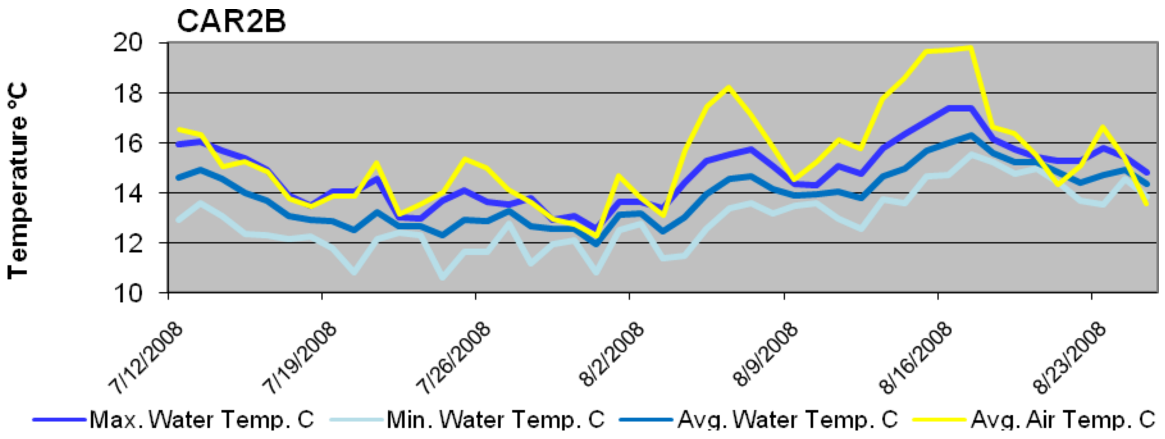

Figure 6. Water and air temperatures from mid July to the end of August site 2B

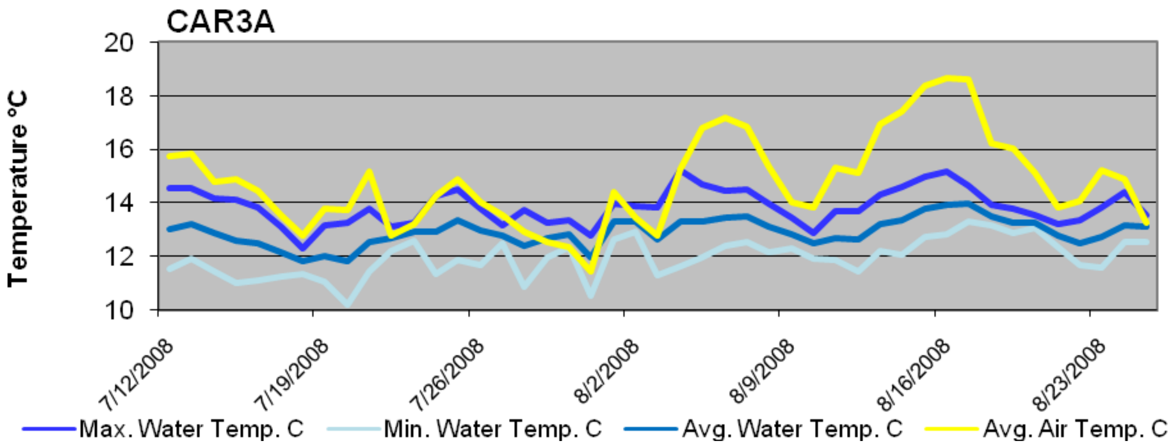

Figure 7. Water and air temperatures from mid July to the end of August site 3A

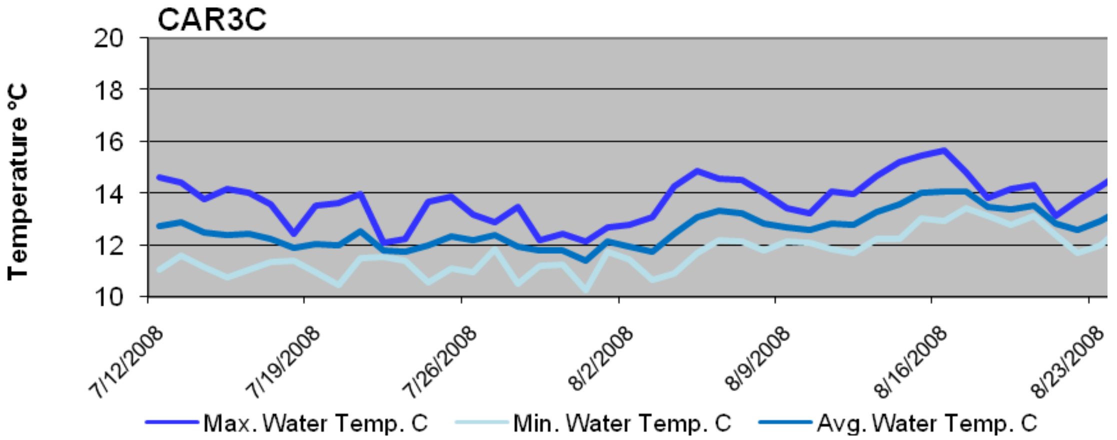

Figure 8. Water temperature from mid July to the end of August site 3C

Thermographs were similar among most sites with water temperatures tracking fairly consistently with air temperatures. Because of the small size of the study streams and the low flow conditions there was little lag time between air and water temperature fluctuations. The two sites that stand out as having particularly cool as well as fairly stable temperatures across the sample timeframe were site 1B and to an even greater extent, 2A. These catchments are primarily forested and the stream channels are well shaded by mostly evergreen riparian canopy. Though 1B has several large (most likely beaver-formed) wetlands along the channel that might be expected to increase residence time and therefore water temperature, both streams were quite cool likely due to significant groundwater input which reduced the influence of residence time and air temperature.

B-IBI

Benthic invertebrate samples were successfully collected at each of the seven catchments. Scores will be reported

Cross-sectional Survey and Channel Dimensions

Cross-sectional surveys were performed at each site at a representative riffle. While these data are helpful in comparing one site to another with respect to stream channel size and entrenchment, they will be best used in with-in site comparisons across years. All cross-sections were benchmarked with rebar so surveyors can occur in the same site in future years. Significant down-cutting, aggradation or widening of the channel indicates altered hydrology or sediment input or transport caused by changes within the catchment. Figure 10 displays cross-section data for each site. The chart illustrates cross-sectional dimensions of a representative riffle for each catchment sample site. Relative vertical and horizontal distances are calculated from the channel thalweg. A bankfull depth value is generated for each reach using cross-section elevations for BFW and thalweg stations. The bankfull depths for all reaches (Table 1) were very shallow (less than a quarter-meter) as was expected in these small streams.

Bankfull widths were measured throughout the reach. The first BFW value measured dictated the length of the survey reach (20-30x BFW) and subsequent measurements were made at riffles where indicators were evident. Table 1 lists BFW values by reach.
Ideally reaches were to be 20-30 times the average BFW of the channel and this occurred in six out of the seven sites. Site 3A, at 60 m, was short of the full 20 times the average BFW value of 3.86 meters.

Table 1. Bankfull Width and Depth Values

Site ID	Reach Length	BFW Meas. Per Reach	Min BFW (m)	Max BFW (m)	Avg BFW (m)	StDev BFW (m)	BFD From x-Sec (m)
CAR1A	60	4	2.50	3.25	2.86	0.42	0.20
CAR1B	60	6	1.64	2.68	2.18	0.47	0.22
CAR1C	60	6	1.60	4.58	2.55	1.06	0.09
CAR2A	40	5	1.25	2.12	1.63	0.31	0.11
CAR2B	60	6	1.70	2.30	1.96	0.22	0.05
CAR3A	60	5	3.22	4.40	3.86	0.52	0.16
CAR3C	90	5	3.00	3.93	3.38	0.34	0.09

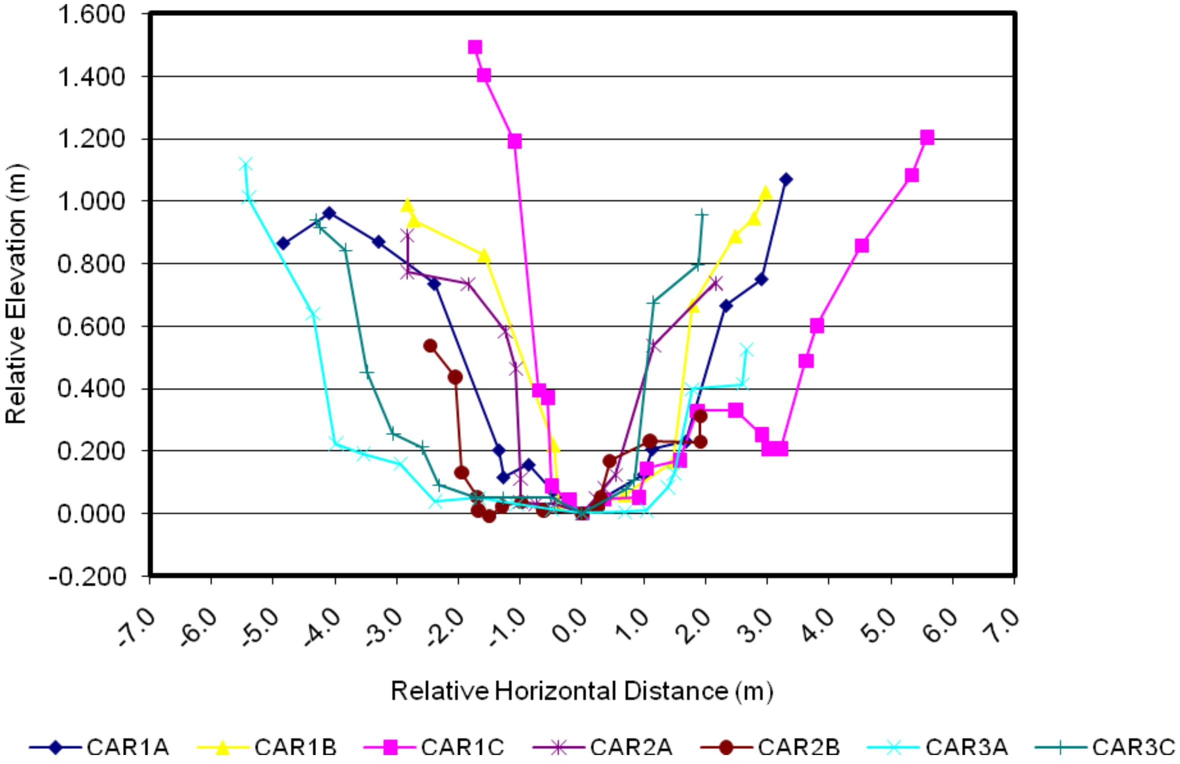

Figure 9. Cross-sectional dimensions of one representative riffle for each sample reach.

Pool quantity and Characteristics

Pools were identified and measured over a distance of approximately 20 to 30 channel widths for the seven sites. Pools were generally spaced far apart and due to the small size and power of sample streams, were shallow in depth. Out of the 29 pools that were recorded, two pools were screened out during data post processing due to residual depths below the 0.1 m threshold. Pool values will be evaluated against those collected in future years to determine if pool numbers and characteristics are changing due to changes in stream complexity and/or hydrology.

Table 2. Pool Quantity and Characteristics by Site

Site ID	Pool Count	Avg Max Depth (m)	StDev Max Depth (m)	Avg Residual Depth (m)	StDev Residual Depth (m)
CAR1A	7	0.15	0.02	0.13	0.02
CAR1B	7	0.25	0.08	0.19	0.08
CAR1C	1	0.15		0.13	
CAR2A	3	0.17	0.02	0.14	0.02
CAR2B	4	0.17	0.05	0.15	0.05
CAR3A	1	0.31		0.29	
CAR3C	4	0.21	0.06	0.16	0.07

4. Conclusions

4.1 Challenges and Limitations

By far the most significant challenge that arose was the identification and selection of catchments appropriate for this study. The initial catchment screen resulted in several catchment pairs, each consisting of catchments considered likely and unlikely to experience development in the near future. This list of potential catchments was quickly reduced in size when initial field reconnaissance revealed some channel sizes or conditions were unsuitable. The list was further truncated after acceptable sites were removed because access was denied by the property owners. This process quickly dismantled proposed catchment pairs leaving us to reevaluate similarities between catchments we sampled and devise better alternatives for selecting sample sites.

The strategy of targeting small catchments for this study gives us the best possibility detecting impacts to riparian functions but it also introduces challenges. These small streams have narrow and shallow riffles that complicate benthic invertebrate sampling. At some sites, surface flow was just deep enough to pass over the Surber sampling frame and into the collection net. In these conditions, we took great care to ensure material stirred from within the sample frame was carried into the net. Large gravels and rocks from within the frame were cleaned inside the net as an extra precaution. Shallow pool depths also pose a problem as pools near the residual depth threshold may be classified differently based on very small changes in flow conditions. The smallest of streams sampled in 2008, though flowing during the entire sample period, are likely to go dry during summers with little precipitation. Sites that are consistently dry during future sampling attempts may have to be moved or dropped from the study.

Finally, the diversity of local conditions we encountered among sample reaches was notable and may further complicate pairing of catchments. While GIS screens and analyses reveal similarities in catchments as a whole, localized recent and historic landuse as well as instream impacts may affect the degree and rate of change to physical and biological conditions more than overall catchment characteristics. This issue requires further analysis and discussion.

4.2 Recommendations and Next Steps

Assessment and modification of the catchment identification and selection process is a key first step as we continue our sampling effort. Because of challenges described above, we will consider alternatives to direct pairing of catchments as a precursor to sampling. One possible option is to put less emphasis on prescreening catchments based on catchment wide characteristics. By relaxing constraints on the catchment selection process we will likely be more successful at finding sites suitable for sampling. Sites may then be post-evaluated for pairing based on catchment and instream characteristics and potential for future development. Alternatively, sampled catchment may remain unpaired and may instead be classified into groups based on the type and/or extent of development occurring within their boundaries over time. These and other alternatives will be explored and the monitoring plan will be modified as necessary.

Once sites were identified, 2008 field sampling went well. The parameters we selected were efficiently collected over a relatively short period of time. There are issues that need to be addressed as monitoring moves forward. In 2008 we did not collect specific conductivity data as planned because in situ, continuous conductivity loggers were not available for purchase. Availability of these loggers will be investigated for sampling in 2009 but alternatives to these devices will also be considered. In the near term, additional field metrics will be considered based on the added benefit weighed against costs in time, budget and ease of sampling. If additional field metrics are deemed reasonable, we will amend the sampling protocol to include additional methods.

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