**Snohomish County**
**Public Works**

# Intensive Catchment Study Status Report:

*Functions and Values Assessment of Critical Areas*
*For Snohomish County Critical Area Monitoring*
Surface Water Management

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December 2010

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# Table of Contents

# Table of Figures

## List of Tables

# 1. Introduction

The remote sensing and shoreline condition components of the CAR monitoring plan are designed to measure the actual area of critical areas and to rapidly detect changes to the physical conditions of these areas. This component of the monitoring plan was initiated to directly assess the functions and values of riparian corridors and to detect changes in functions and values over time. This component will also provide an on-the-ground correlational comparison to impacts and change that is identified in the Land Cover Change Detection portion of monitoring. It will test the effectiveness of the SCC 30.62A 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. Assessing catchments along a spectrum of both degree of anthropogenic change, and anticipated speed of change will further point to specific landscape conditions where critical area functioning is most sensitive to development activities as defined by SCC 30.62A.

Since instream physical and biological conditions are known to be spatially and temporally variable, the assessment is focused on metrics that have a high signal to noise ratio or have been documented as useful indicators of alteration of the ecological functions of riparian buffers. The chosen metrics are stream temperature, conductivity, channel cross-sectional dimensions and bank full width, pool average maximum depth and frequency, and benthic index of biological integrity (B-IBI). Secondary water quality measures included turbidity, dissolved oxygen, and pH. Landscape characterization has been employed to compare the measured metrics with changing catchments. Table 1 lists these functional indicators in detail.

**Table 1 Functional indicators measured.**

| Indicator Class | Measurement |
|---|---|
| Chemical | Continuous In-stream Temperature |
| | Continuous Riparian Buffer Temperature |
| | Water Quality: Conductivity |
| | Water Quality: Dissolved Oxygen |
| | Water Quality: pH |
| | Water Quality: Turbidity |
| | Water Quality: Temperature (calibration) |
| Physical | Cross-sectional Dimensions Survey |
| | Bankfull Width |
| | Bankfull Depth |
| Habitat | Pool Frequency |
| | Pool Depth |
| Biological | Benthic Index of Biotic Integrity (B-IBI) |
| Landscape | Land Cover Mapping – 2007, 2009 (seven classes) |
| | Critical Areas and Buffer Coverage |
| | Land Cover Change (between 2007-2009) |

## 1.1. Continuous In-stream Water and Air 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, stream flow, 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). This increase can lead to lethal water temperatures for aquatic species during periods of sustained heat.

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).

## 1.2. Water Quality

### 1.2.1. 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.

### 1.2.2. Dissolved Oxygen

Dissolved oxygen (DO) is a measure of oxygen dissolved in water, and is described as mg of oxygen per liter of water. Dissolved oxygen in the water column is utilized by aquatic organisms for aerobic respiration. Larger rivers and streams with high gradient generally tend to have higher levels of dissolved oxygen. Small streams may initially have moderately high levels of DO. However, they are subject to faster oxygen depletion than larger systems due to overall load. DO concentration is affected by a number of factors including stream velocity, water temperature, altitude, sediment concentration, and stream vegetation. The introduction of pollutants tends to decrease dissolved oxygen by increasing the metabolism of bacteria, which will continue to consume oxygen until it is depleted. The clearing of streamside vegetation also tends to decrease DO by allowing sunlight to warm the water. As water temperature increases, the solubility of oxygen decreases. The decrease of dissolved oxygen can impair both juvenile and adult aquatic organisms, and can become lethal below threshold levels or otherwise inhibit the progression through morphological life stages.

### 1.2.3. Temperature

Steam temperature can vary in different portions of the stream. Surface temperature may be warmer than temperatures found in deep pools due to insolar warming. Contact with the water table or springs may impart a cold water input to the stream, while surface water inputs such as tributaries may add warm water. Collection of stream temperature concurrently with other water quality measures allows for comparison of the water quality sample to continuous in-stream temperature monitoring.

### 1.2.4. pH

pH is a measure of hydrogen ion dissolved in a liquid. As pH deviates from the neutral value of 7, the water chemistry allows for progressively more toxic conditions. An increase in stream acidity, which may result from the introduction of acid-based products, increases the solubility of heavy metals as well as the liberation of toxins such as cyanides and sulfides. The increase in alkalinity, which may result from construction and other types of runoff, increases the toxicity of potentially existing pollutants such as ammonia. Established regulations set minimum healthy stream pH at 6.5 and maximum pH at 8.5.

### 1.2.5. Turbidity

Turbidity is a measure of amount of suspended solids in solution. Turbidity increases are a result of erosion. Natural erosion processes contribute sediment to streams, which is a natural and necessary component for stream ecosystem maintenance. However, increases in turbidity stemming from improper agricultural activities, logging, construction, and stormwater runoff can inhibit normal stream process and aquatic life. Increased sediment load can reduce algal and invertebrate growth, effectively cutting off the base of the aquaic food chain. It can also lead to egg and juvenile entrapment, as well as salmonid feeding and growth.

## 1.3. Cross-sectional Survey

### 1.3.1. 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 to depth ratio, where ‘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 to 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 to depth ratios also tend to have reduced shading and shallower dry-season flows, which may result in elevated water temperatures.

Bankfull width to 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 are measured in the field using a stadia rod, measuring table and level using field indicators and survey techniques outlined in Rosgen (1996).

## 1.4. Stream Habitat

### 1.4.1. 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 large wood, sediment loading, and channel type (Montgomery et al, 1995). Low pool frequency often indicates inadequate large wood 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), pool frequency was selected as a monitoring indicator.

## 1.5. Biological Indicators

### 1.5.1. 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 in a sample from the streambed. 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.

### 1.6. Catchment Landscape Analysis

The combination of natural processes and anthropogenically induced processes make up the majority of the driving force behind ecosystem maintenance or change within each catchment. Other components may include climactic and other landscape level processes. Land cover and land cover change were mapped in each of the catchments. Land cover mapping included both natural areas and human-dominated landscapes, broken into seven classes. These maps were completed as part of the first component of the Critical Areas Monitoring program: the Land Cover Classification and Change Mapping component. Critical areas, such as streams, Fish and Wildlife Conservation Areas (FWHCAs), wetlands, and wetland buffers were mapped using a combination of satellite imagery, feature-based datasets, and other ancillary data. Other natural areas such as upland forest were mapped primarily using satellite imagery. Human-dominated land cover types such as bare earth and impervious surfaces were also mapped primarily using satellite imagery. The time period that has been reviewed, to date, was imagery acquired in 2007 and 2009. Change detection maps were generated using variation between the imagery collected in those two year periods.

## 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 five km$^2$ in size (Figure 1).

Potential treatment catchments were identified using a series of GIS screens. New permit applications, land use, 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 or containing 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. Additional catchments were selected to provide areas with additional levels of variability. This variability is desirable as it will help to define conditions in both ends of the continuum in terms of types and rates of change.

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 program.

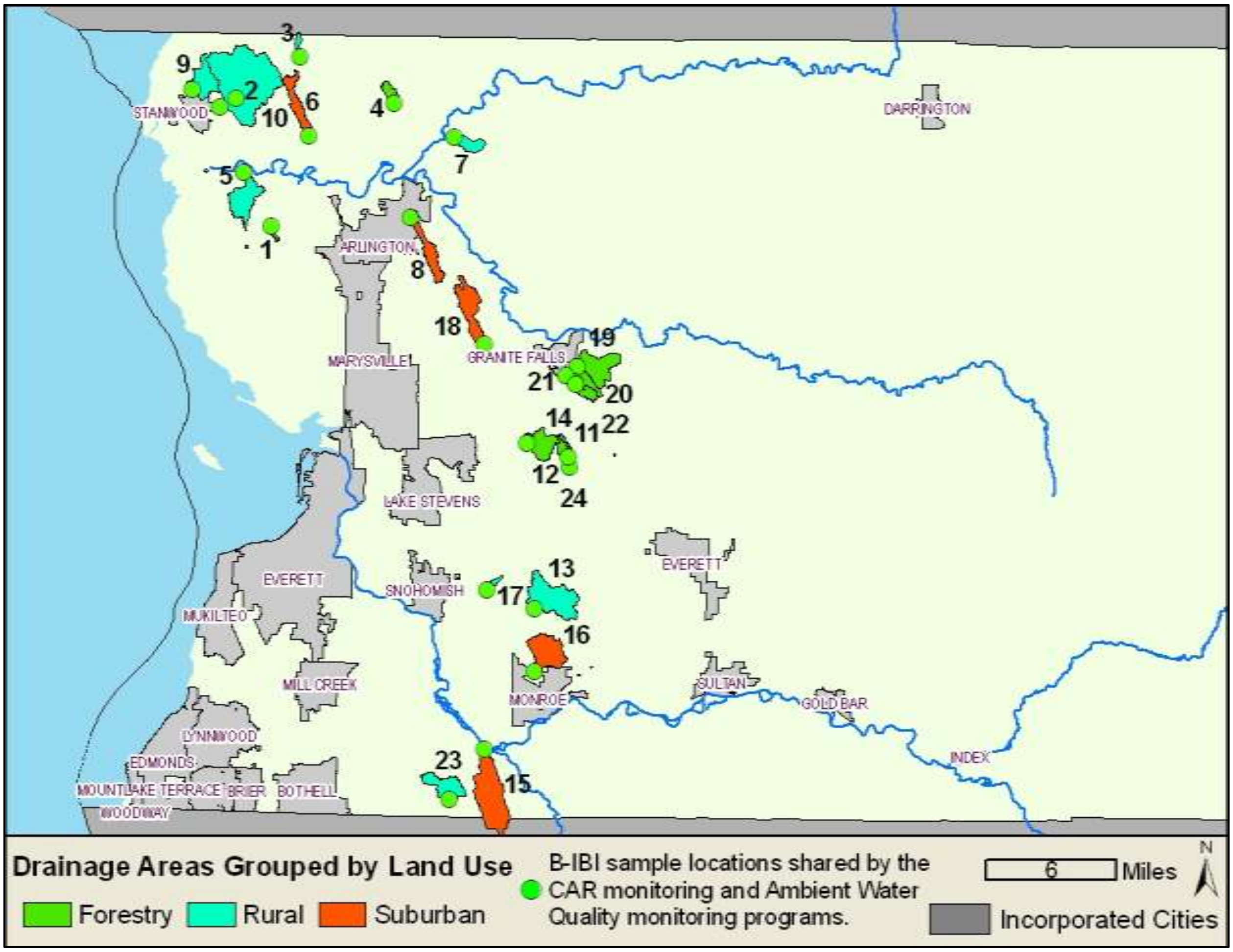

**Figure 1 Location of headwater monitoring sites.**

Seven sites were selected and sampled in unincorporated Snohomish County in 2008. These sites have a letter designation in their ID (Table 2). 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 was a need to reevaluate catchment pairs and, select additional catchments for 2009 sampling that may be paired or evaluated with 2008 catchment results. Site number 24 (7-1B) was only sampled in 2008, as permission for site access was revoked.

**Table 2 Catchment ID, stream name and size.**

| Report ID | Catchment ID | WRIA Basin | Catchment Acreage | Stream Name | Tributary To: |
|---|---|---|---|---|---|
| 1 | 5-149 | 5 | 78 | unnamed | Fish Creek |
| 2 | 5-187 | 5 | 4975 | Church Creek | Jorgenson Slough |
| 3 | 5-2A | 5 | 135 | unnamed | Pilchuck Creek |
| 4 | 5-2B | 5 | 294 | Harvey Creek | Armstrong Creek |
| 5 | 5-300 | 5 | 1227 | Glade Bekken | Stillaguamish River |
| 6 | 5-305 | 5 | 792 | unnamed | Pilchuck Creek |
| 7 | 5-37 | 5 | 425 | unnamed | NF Stillaguamish |
| 8 | 5-3C | 5 | 772 | Portage Creek | Thomsen Slough |
| 9 | 5-42 | 5 | 1013 | Douglas Creek | South Douglas Slough |
| 10 | 5-54 | 5 | 1386 | Church Creek | Jorgenson Slough |
| 11 | 7-1A | 7 | 400 | unnamed | Carpenter Creek |
| 12 | 7-1C | 7 | 103 | unnamed | Carpenter Creek |
| 13 | 7-221 | 7 | 1975 | French Creek | Snohomish River |
| 14 | 7-235 | 7 | 899 | Dubuque Creek | Pilchuck River |
| 15 | 7-279 | 7 | 2462 | Ricci Creek | Snohomish River |
| 16 | 7-282 | 7 | 1331 | Cripple Creek | French Creek |
| 17 | 7-329 | 7 | 69 | Star Creek | Pilchuck River |
| 18 | 7-3A | 7 | 1254 | Little Pilchuck | Pilchuck River |
| 19 | 7-72 | 7 | 1203 | Coon Creek | Pilchuck River |
| 20 | 7-933 | 7 | 1409 | Coon Creek | Pilchuck River |
| 21 | 7-981 | 7 | 403 | Swartz Creek | Pilchuck River |
| 22 | 7-982 | 7 | 278 | Trib to Millard lake | Pilchuck River |
| 23 | 8-156 | 8 | 917 | Bear Creek | Sammamish River |
| 24 | 7-1B | 7 | 342 | unnamed | Carpenter Creek |

Seventeen sites were added and sampled in 2009, bringing the total number of active catchments to 23. These catchments were chosen to represent a mix of ecological community types, a varying likelihood for the degree of development, and the rate of development. Six sites are located on public lands, while the remaining 17 are located on a mix of private timberlands, platted designated open spaces, and private residential property. Catchments range from 69 acres to 4975, with a mean size of about 1000 acres (4.05 $km^2$). Topography within catchments and the elevation catchment pour point is variable; sample locations at the catchments' lowest points range from approximately 60 m to over 180 m above sea level. The geology among catchments was predominantly glacial till, though catchment #3 (5-2A) is entirely sedimentary and catchment #4 (5-2B) has a large intrusive component making up the upper portion of the drainage. 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.

The 23 sample drainages span the development, spatial, land cover, and land use spectrum, and as such, can be grouped for analysis in a number of different ways. Their broad distribution across western Snohomish County allows grouping and analysis by WRIA. Alternatively, they can be grouped and compared based on those areas that remain undeveloped versus those that are developing. They can also be segregated into rural/agricultural, suburban, and forestry groupings. Finally, they can be grouped based on size and type of critical areas present.

## 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 following SWM and Department of Ecology protocols. 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

### 2.3.1. Continuous Temperature Monitoring

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, and were later uploaded to an Access database. 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.

### 2.3.2. Water Quality Monitoring

Water quality measurements were collected using two pieces of equipment. A Hydrolab Minisonde 5a was used to measure water temperature (°C), dissolved oxygen (mg/L), pH, and conductivity (µg/L). A Hach 2100P Turbidimeter was used to measure turbidity (NTU).

**Calibration**
Calibration records for water quality instruments are retained for five years as required by section S9 of the NPDES permit and Washington State archival timelines.

The Hydrolab Minisonde 5a for insitu measurement was set up, maintained and calibrated per the manufacturer's specifications prior to beginning each sampling run. All instruments and sensors were also factory calibrated and maintained on an annual basis. Calibration dates and results were recorded in a log, and the log will be retained for five years as recommended by Washington State archival timelines.
http://www.hachenvironmental.com/pdf/S5_Manual.pdf

Daily calibration checks for pH, Conductivity, and Dissolved Oxygen were conducted on the Hydrolab and Hach instruments. Calibration checks were recorded on a calibration check sheet containing date and sample run fields such that field staff or the project manager could track calibration checks for all sites sampled on the same day.

The turbidimeter was calibrated following manufacturer's recommendations
http://www.hach.com/fmmimghach?/CODE%3A4650088-2008-0416048%7C1
using primary standards on a quarterly basis, while secondary standard checks using Stablcal ™ were conducted daily after each sampling run.

**Sample Collection**
Preparation of the Hydrolab Minisonde 5a and HACH 2001P turdidimeter, and insitu sampling was accomplished by ensuring that the instrument was set up, calibrated, maintained, and stored according to manufactures guidance.

Field collection procedures were performed in accordance with manufactures guidelines for the waterbody type and localized conditions encountered at sample catchments.

### 2.3.3. 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 points at every 0.5 meters, right bank and left bank hubs (top and base of rebar), bankfull indicators, thalweg, and other noteworthy features. 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.

### 2.3.4. Bankfull Width

As the survey team walked the stream recording pool data, they identified and measured bankfull width and bankfull height at five appropriate locations in the reach. For the purposes this survey bankfull width is defined as the width of a stream channel at the point where over-bank flow begins during a flood event. In entrenched channels with disconnected or undeveloped floodplains, bankfull indicators may include the top of deposited bedload (gravel bars), stain lines, the lower limit of perennial vegetation, moss or lichen, a change in slope or particle size on the stream bank and undercut banks (USFS 2006). Bankfull data and station number were recorded in the field computer.

### 2.3.5. Pool Quantity and Characteristics

Pool quantity and characteristics 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. 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. These data were transferred to a geodatabase in the office.

### 2.3.6. 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.

## 2.4. Landscape level analysis

A detailed description of the methodologies employed to accomplish wetland mapping, land cover classification, and change detection can be found in Appendix A. All map products cover western Snohomish County, including all areas within the 23 catchment boundaries. The wetland maps include open water, emergent, scrub/shrub, and forested wetlands, and uplands. The land cover classification map is broken into 8 classes (Table 3) that contains a combination of vegetative land cover and land use. The change detection map displays changes in landcover within the project area between 2007 and 2009.

The area within each catchment was analyzed using each of these three map products. As land use changes, alteration of land cover change will be correlated with the impact on ecological indicators. This analysis has not yet been performed. To date, landscape level analysis has primarily characterized conditions specific to each catchment.

**Table 3 Land cover classes contained within 2007 and 2009 Snohomish County Land Cover Classification Maps.**

| Land Cover Classes | |
|---|---|
| 1. Open Water | 5. Forest |
| 2. Wetlands | 6. Impervious Surface |
| 3. Grass & Pasture | 7. Bare Earth |
| 4. Shrubs & Small Tree | 8. Cloud Cover |

## 2.5. 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 houses all spatial and tabular data for the catchment study has been developed. This database serves as a repository for all data collected and streamlines the procedures for data processing, quality control and summarization.

## 2.6. Sampling Schedule

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 2008 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 was 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, 2 and 10, and 9 and 20 are not discrete drainages; one catchment is contained within the other for each of these pairs. For this and other reasons, these catchments will not be paired to each other. However, they will provide additional information about changes in ecosystem function within reaches of the same stream.

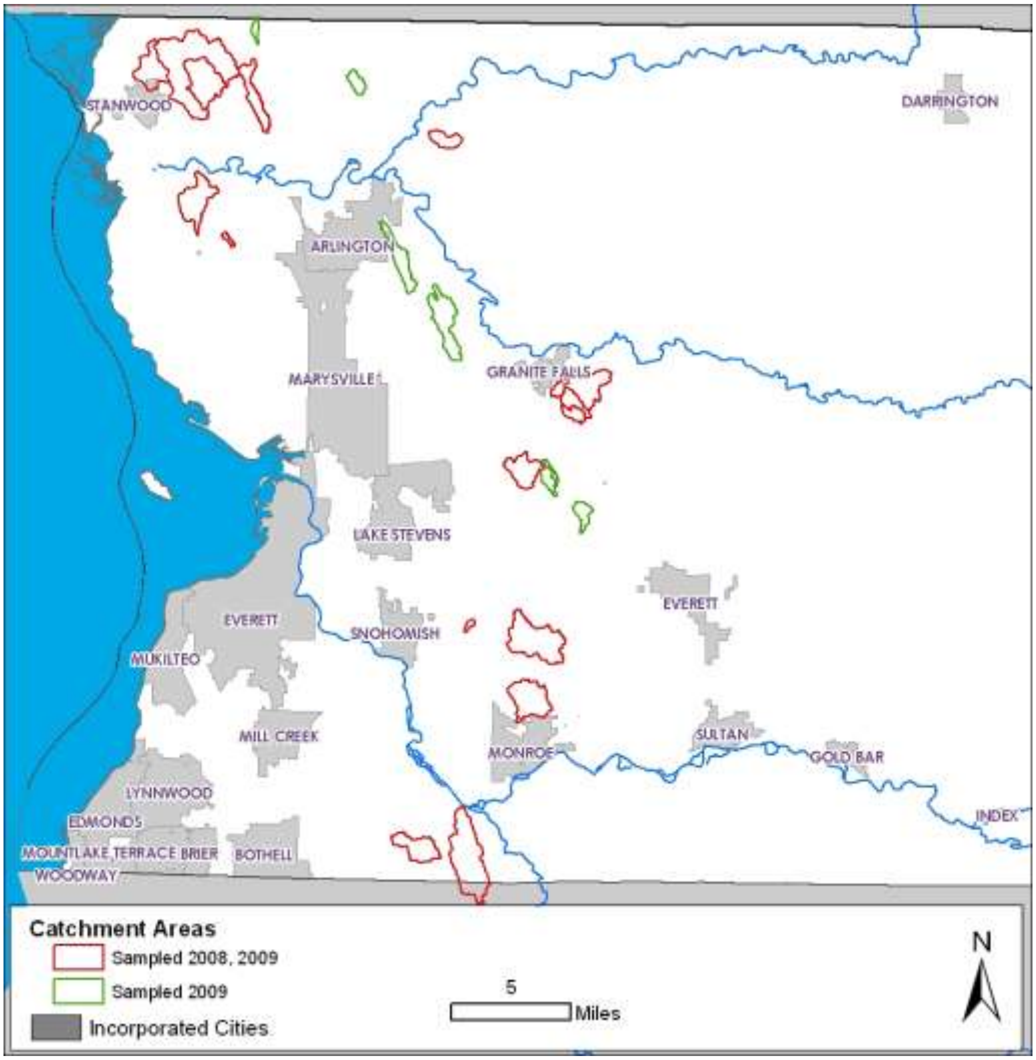

**Figure 2 Location of sampled catchments identified by site ID.**

Table 4 lists the sampling dates for various stream metrics during 2009 and 2010. 2008 is not shown as all continuous temperature loggers were deployed in June, but programmed to turn on July 1, 2008 and turn off at the end of August. No water quality measurements were collected. B-IBI, habitat surveys, and cross-sectional surveys were all collected in the last week of July and first week of August.

**Table 4 Sampling Schedule for Catchments in 2009 and 2010**

| Report ID | Catch ID | 2009 | | | | | 2010 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Spring WQ, temp logger deploy | Mid-Season WQ | Habitat Survey, B-IBI | X-Sec | Fall WQ sampling & temp logger retrieval | Spring WQ, temp logger deploy | Mid-Season WQ | Habitat Survey, B-IBI | X-Sec | Fall WQ sampling & temp logger retrieval |
| 1 | 5-149 | 7/23 | 8/25 | 8/25 | 8/25 | 10/23 | 6/4 | 9/1 | 9/1 | 10/20 | 10/20 |
| 2 | 5-187 | 6/26 | 8/20 | 8/20 | 9/3 | 10/23 | 5/19 | 8/3 | 9/24 | 10/6 | 10/6 |
| 3 | 5-2A | 7/9 | dry | 12/11 | 12/11 | 12/11 | 5/19 | 9/1 | 9/1 | 10/7 | 10/7 |
| 4 | 5-2B | 7/9 | 9/10 | 8/24 | 9/10 | 10/16 | 5/20 | 8/3 | 8/3 | 10/7 | 10/7 |
| 5 | 5-300 | 7/23 | 8/25 | 8/20 | 8/25 | 10/23 | 5/4 | 9/8 | 9/24 | 10/20 | 10/20 |
| 6 | 5-305 | 6/26 | 8/25 | 9/8 | 9/8 | 10/16 | 6/4 | 9/3 | 11/3 | 10/6 | 11/3 |
| 7 | 5-37 | 7/9 | 8/20 | 8/20 | 9/2 | 10/2 | 5/20 | 9/3 | 10/6 | 10/6 | 10/6 |
| 8 | 5-3C | 7/18 | 9/17 | 8/19 | 9/17 | 10/2 | 5/20 | 8/26 | 8/26 | 10/7 | 10/7 |
| 9 | 5-42 | 6/26 | 9/8 | 9/17 | 9/8 | 10/23 | 5/20 | 8/3 | 10/20 | 10/20 | 10/20 |
| 10 | 5-54 | 6/26 | 8/27 | 8/20 | 8/27 | 10/16 | 5/19 | 8/3 | 8/3 | 10/20 | 10/20 |
| 11 | 7-1A | 7/10 | 8/19 | 8/19 | 9/4 | 10/2 | 5/18 | 8/10 | 8/10 | 10/22 | 10/22 |
| 12 | 7-1C | 7/10 | 8/27 | 8/27 | 8/27 | 10/2 | 5/18 | 8/5 | 10/26 | 10/26 | 10/26 |
| 13 | 7-221 | 7/2 | 8/18 | 8/18 | 8/18 | 10/2 | 5/17 | 8/4 | 8/4 | 10/27 | 10/29 |
| 14 | 7-235 | 6/19 | 8/19 | 8/19 | 8/19 | 10/16 | 5/18 | 8/13 | 10/29 | na | 10/29 |
| 15 | 7-279 | 7/18 | 9/2 | 9/2 | 9/2 | 10/29 | 5/17 | 8/10 | 8/10 | 11/3 | 11/3 |
| 16 | 7-282 | 6/16 | 9/4 | 9/4 | 9/4 | 10/2 | 5/17 | 8/18 | 7/31 | 10/29 | 10/29 |
| 17 | 7-329 | 7/2 | 8/18 | 8/18 | 8/18 | 10/29 | 5/17 | 8/4 | 8/4 | 11/3 | 11/3 |
| 18 | 7-3A | 7/10 | 9/2 | 8/19 | 9/2 | 10/29 | 6/4 | 8/26 | 8/26 | 10/22 | 10/22 |
| 19 | 7-72 | 6/19 | 9/3 | 9/3 | 9/3 | 10/29 | 5/19 | 8/2 | 8/2 | 10/29 | 10/29 |
| 20 | 7-933 | 6/19 | 8/18 | 8/18 | 8/18 | 10/16 | 5/19 | 8/17 | 8/17 | 10/22 | 10/22 |
| 21 | 7-981 | no | 8/26 | 8/26 | 8/26 | na | 5/19 | 8/2 | 10/27 | 10/27 | 10/27 |
| 22 | 7-982 | 7/23 | 8/26 | 8/26 | 8/26 | 10/16 | 5/19 | 8/2 | 8/2 | 10/27 | 10/27 |
| 23 | 8-156 | 7/31 | 8/21 | 8/21 | 9/2 | 10/29 | 5/17 | 8/18 | 7/31 | 11/3 | 11/3 |

# 3. Results and Discussion

## 3.1. Continuous In-stream Water and Air temperature

Water and air temperature loggers were recovered in good condition for all sampled sites in 2008. In 2009, one air logger was lost when a road crew cut down and removed a tree that the logger was secured to. In 2010, two water loggers were lost due to bank erosion during a large storm, and one air logger was lost due to theft. The following figures (Figure 3 - Figure 8) display minimum, average and maximum daily water temperatures as well as average daily air temperatures from mid July through the end of August in 2008.

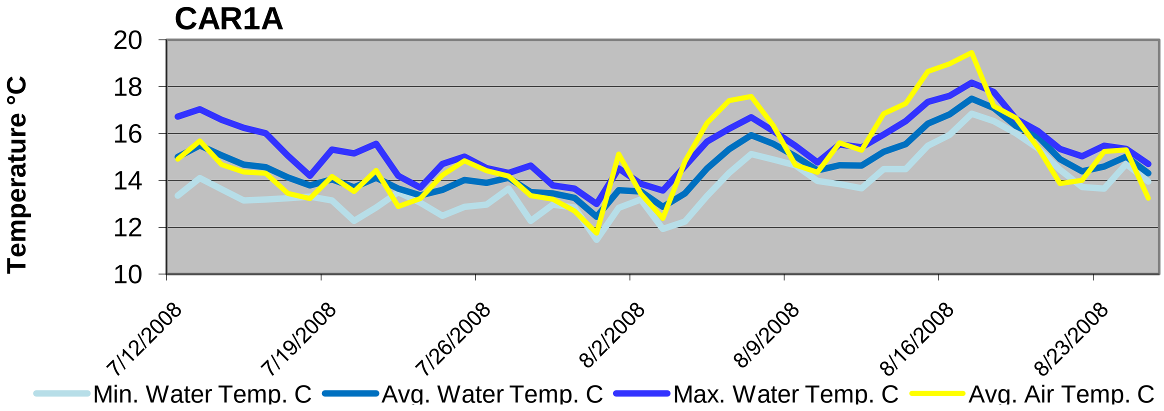

**Figure 3 Water and air temperatures from mid July to the end of August site 1A**

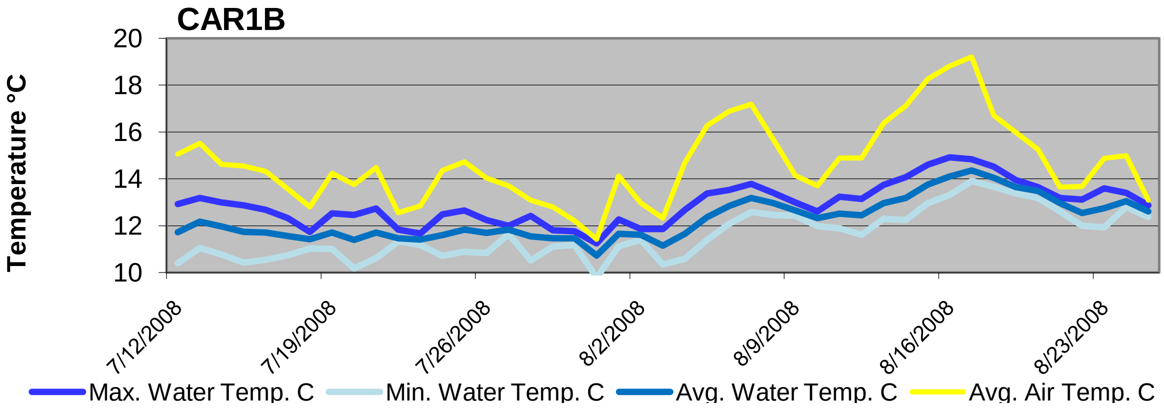

**Figure 4 Water and air temperatures from mid July to the end of August site 1B**

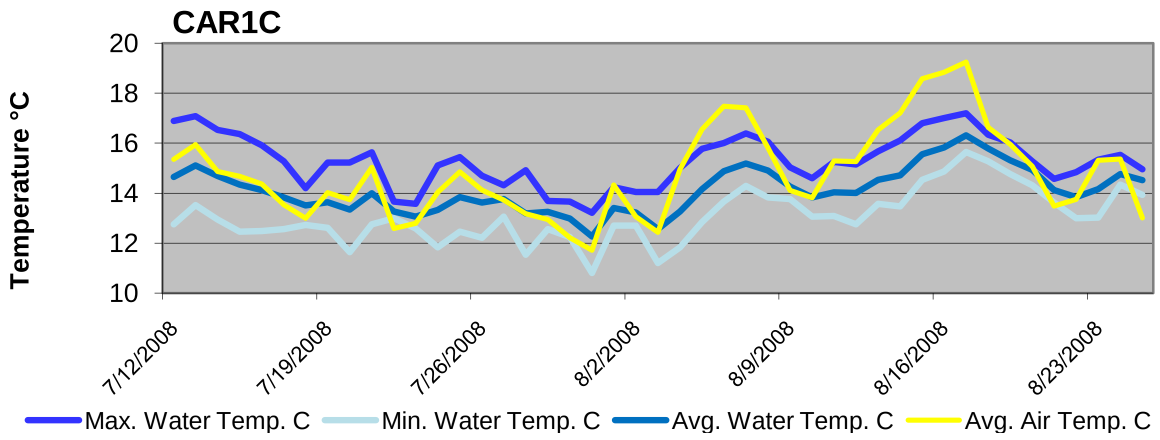

Figure 5 Water and air temperatures from mid July to the end of August site 1C

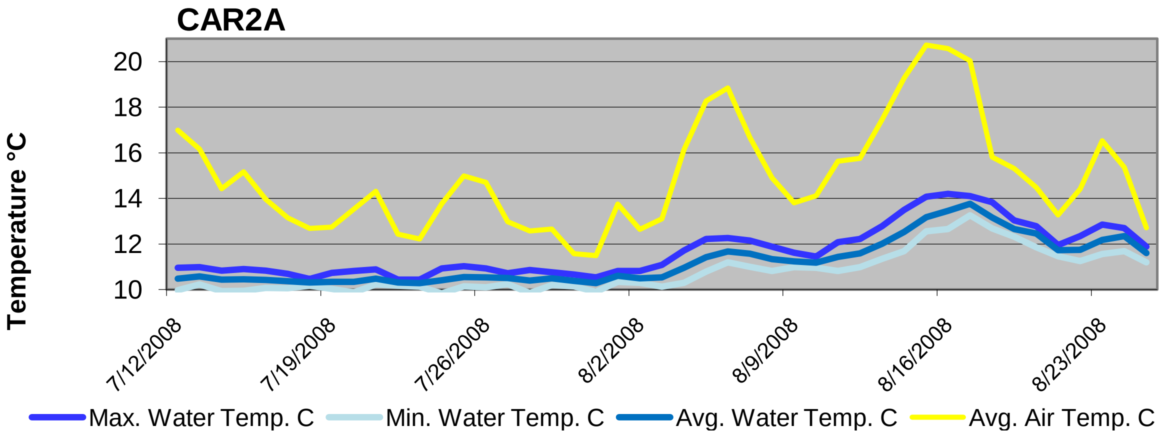

Figure 6 Water and air temperatures from mid July to the end of August site 2A

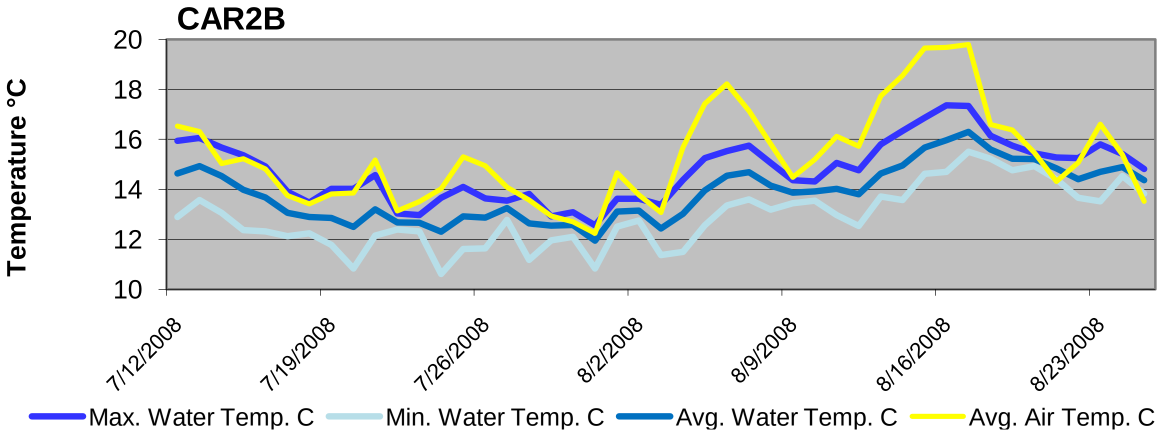

Figure 7 Water and air temperatures from mid July to the end of August site 2B

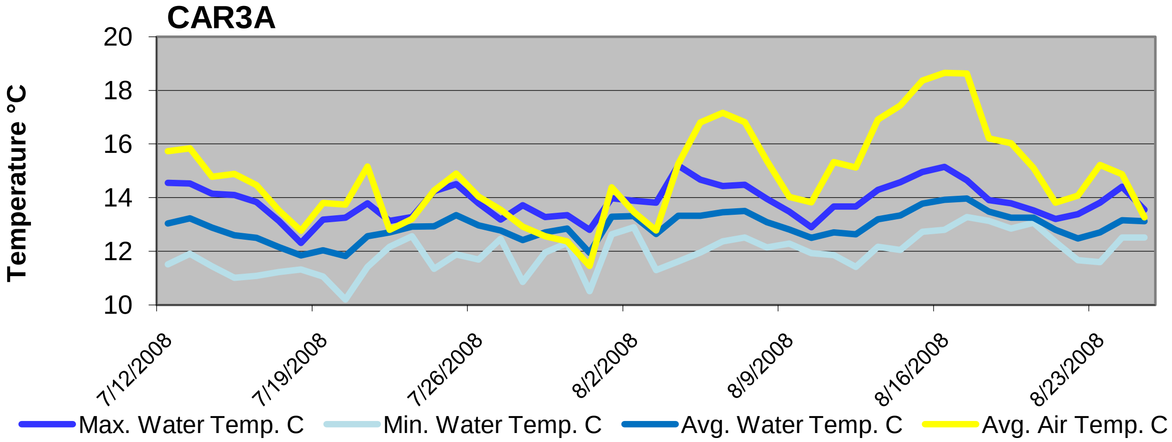

**Figure 8 Water and air temperatures from mid July to the end of August site 3A**

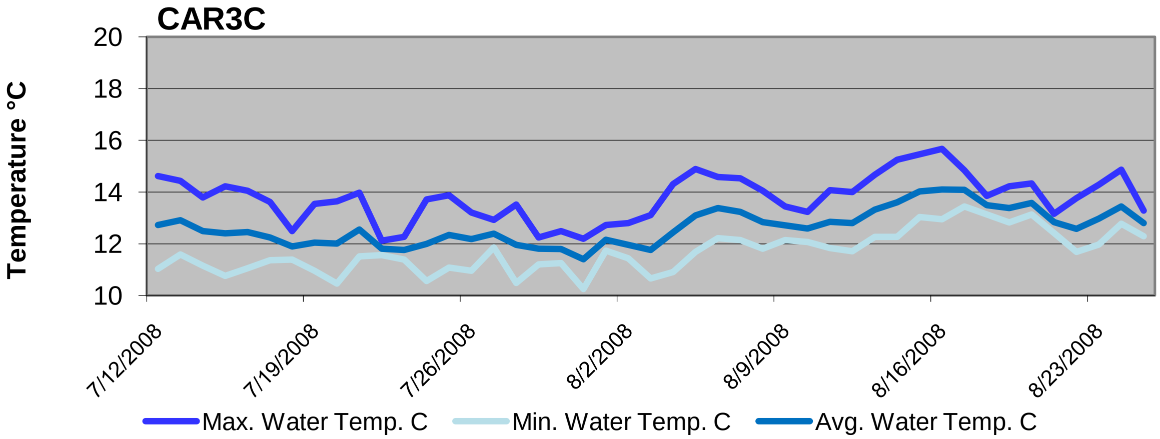

**Figure 9 Water temperature from mid July to the end of August site 3C**

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.

2009 and 2010 continuous temperature data is not presented as it has not yet been processed.

## 3.2. Water Quality

### 3.2.1. Conductivity

Conductivity was measured at all catchments three times per year during 2009 and 2010 (Figure 10). Samples generally remained within the range of about 50 to 200 µg/L. Catchment 9, Dubuque Creek, consistently remained about 150 µg/L higher than the average of all catchments. This may be due to the clearing of approximately 22.8 acres (~2.6% of Catchment 9) of mature forest for a large subdivision which began just before the first conductivity point shown in Figure 10 in 2007. Streams cross the cleared areas at least 4 times and clearing and grading had occurred up to or past the fringe of at least one previously-forested wetland in 2009. The cleared areas have remained bare earth from 2007 through 2009. Less substantial clearing has taken place in other

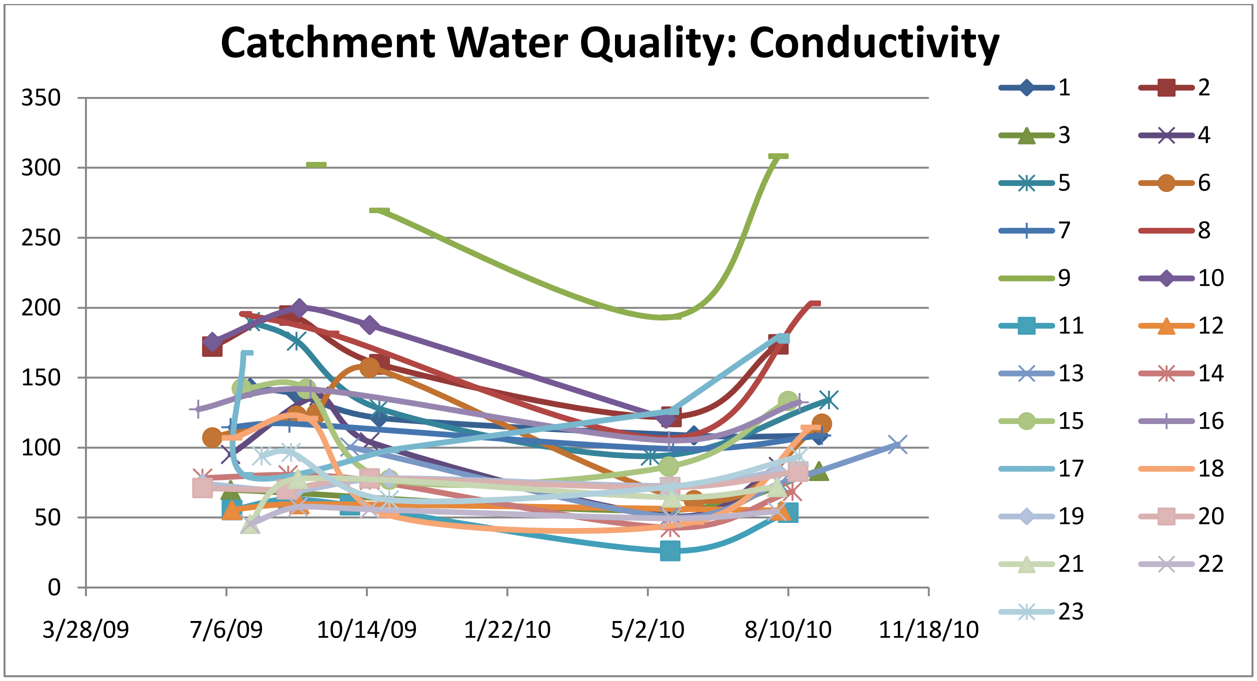

Figure 10 2009-2010 conductivity measures (µg/L) across 23 sample sites.

### 3.2.2. Dissolved Oxygen

Dissolved oxygen (DO) was measured at all catchments three times per year during 2009 and 2010 (Figure 11). DO levels generally remained above the minimum water quality DO criteria of 8 mg/L and concentrated around 10 mg/L. Annual decreases in DO coincided with seasonal high temperatures in July and August each year; within the range of about 50 to 200 µg/L. Catchments 14, 21, and 23 all fell below 8 mg/L in early August each year. Each of these catchments have large wetlands located above the sample reach.

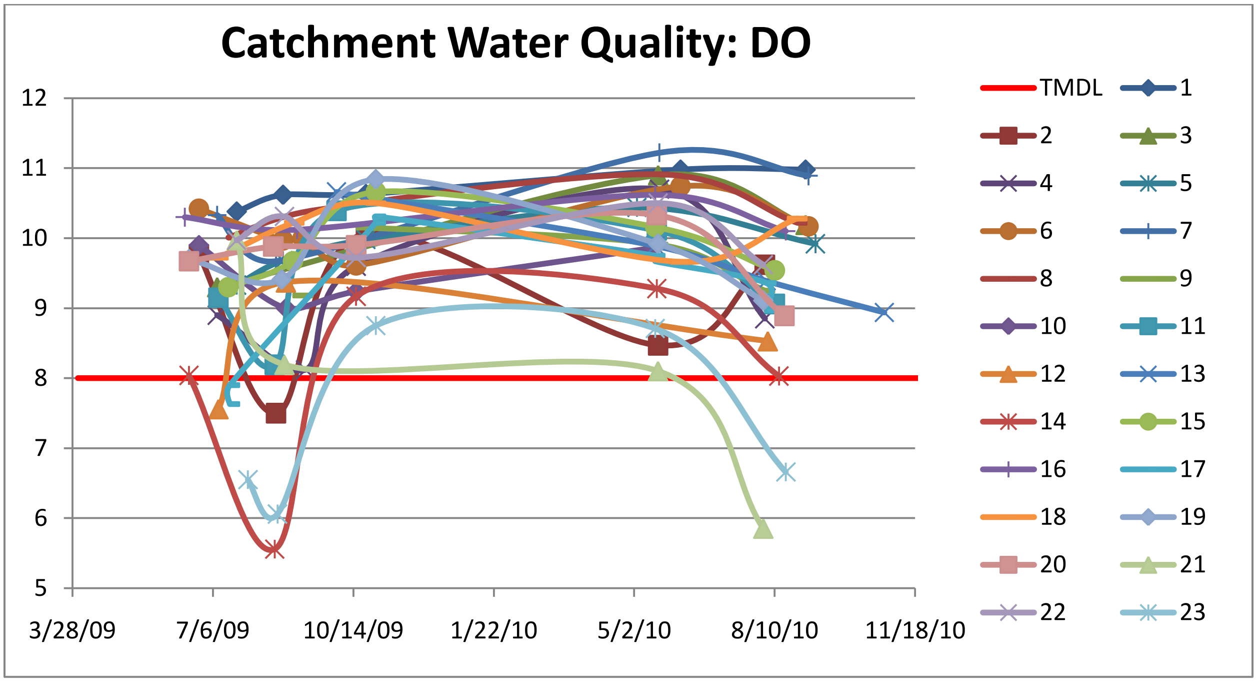

**Figure 11 2009-2010 dissolved oxygen measures (mg/L) across 23 sample sites. Water quality DO standards for the streams in this study are either set at a minimum value of 8 for streams designated as Spawning and Rearing or 9.5 for streams designated as Core Summer Habitat. A value of 8.0 is shown in the figure for reference only.**

### 3.2.3. Temperature

Discreet temperature measurements were collected at all catchments three times per year during 2009 and 2010 (Figure 12). Temperature levels generally remained below the established maximum water quality criteria of 16 °C for streams designated as Core Summer Habitat. The 2009 summer was unusually hot, while the 2010 summer was cooler than normal. Peak summer stream temperatures reflected this ambient variation. Almost half of all catchments exceeded 16°C in 2009, while about a quarter exceeded 16 °C in 2010. In 2009, Catchments 23 and 17 reached summer stream temperatures of 24 and 21°C, respectively. In 2010 catchment 23 had a maximum temperature of 18°C, and catchment 17 did not surpass the set limit of 16°C. However, in 2010 catchment 20 reached almost 20°C. This is noteworthy, since it did not exhibit the same trend in the previous, yet hotter year, and nearly met the temperature criteria about a mile upstream (catchment 19).

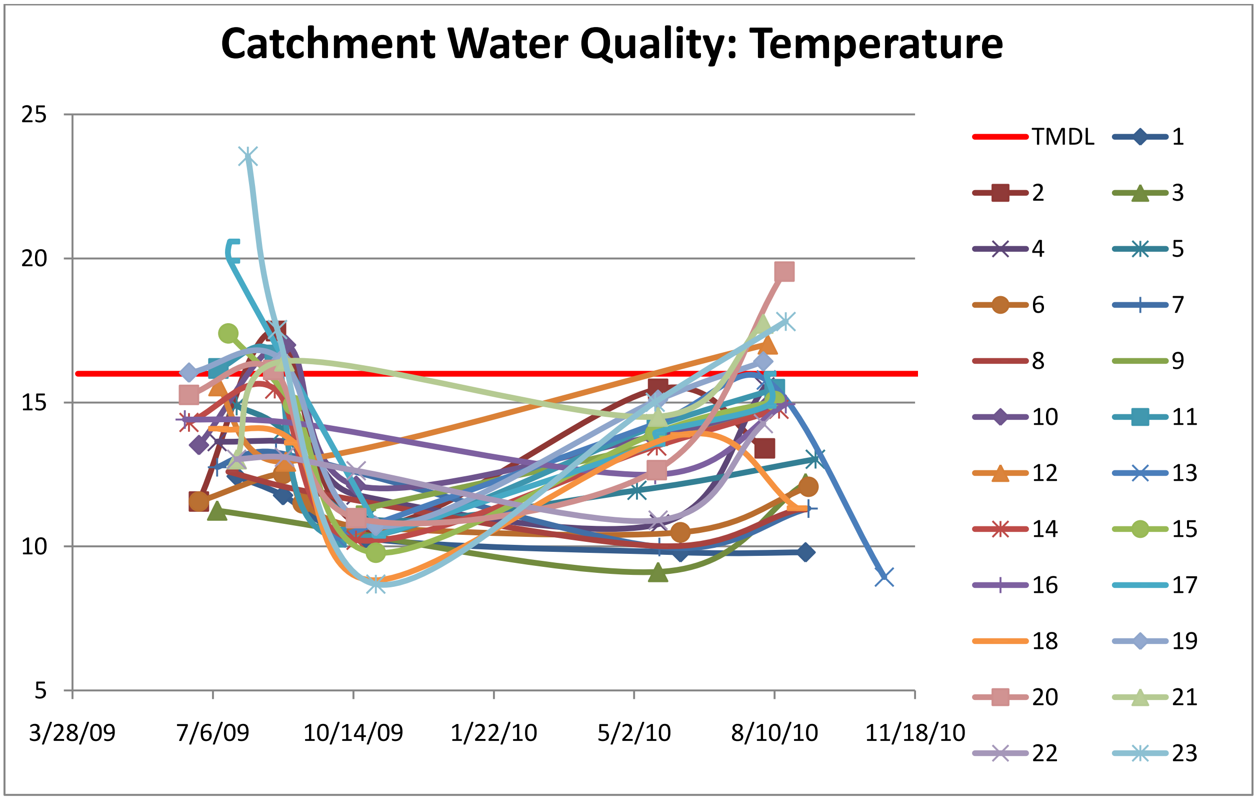

**Figure 12 2009-2010 discrete temperature measurements (°C) collected across 23 sample sites. Water quality temperature standards for the streams in this study are either set at a maximum value of 17.5 °C for streams designated as Spawning and Rearing or 16 °C for streams designated as Core Summer Habitat. A value of 16 °C is shown in the figure for reference only.**

### 3.2.4. pH

Discreet pH measurements were collected at all catchments three times per year during 2009 and 2010 (Figure 13). pH generally remained within the established water quality criteria range of 6.5-8.5 for streams designated as either Spawning and Rearing or Core Summer Habitat.

Stream samples generally remained within the range of about 6.75 to 7.75, averaging about 7.25 in 2009. In 2010 pH tended to be nearly evenly split among catchments, with about half centered just below neutral 7, and half centered around about 7.5. It is unclear whether this bimodal tendency can be attributed to the underlying geology of certain catchments or other drivers.

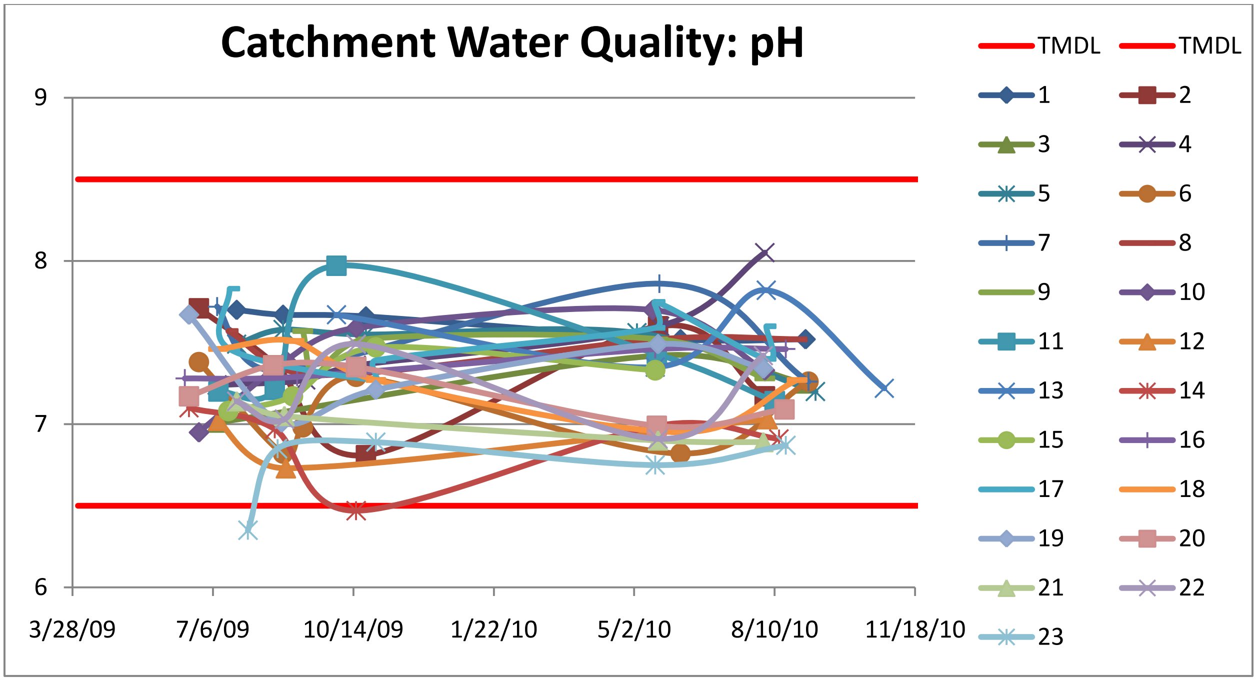

**Figure 13. 2009-2010 pH measurements collected across 23 sample sites. Water quality pH standards for the streams in this study are set at a maximum value of 8.5 and a minimum value of 6.5 for both streams designated as Spawning and Rearing, and streams designated as Core Summer Habitat.**

### 3.2.5. Turbidity

Turbidity measurements were collected at all catchments three times per year during 2009 and 2010 (Figure 14). Turbidity generally remained below about 3 NTU, with some instances of elevated values up to almost 12 NTU. Water quality standards place limits on turbidity as any value that exceeds 5 NTU over stream baseline values. Based on the relatively low and consistent values observed, these appear to be all primarily baseline measurements.

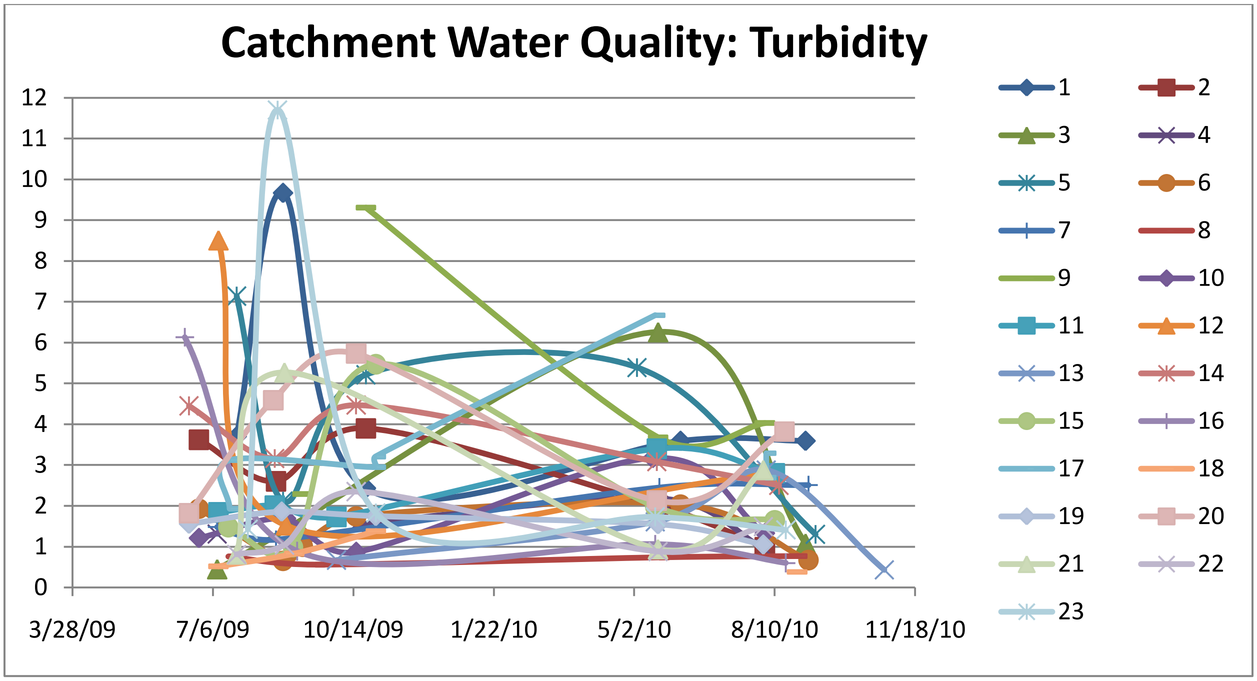

**Figure 14. 2009-2010 turbidity measurements (NTUs) collected across 23 sample sites. Water quality turbidity standards for the streams in this study are set at 5 NTUs over baseline. It was assumed that the majority of the values recorded here are part of the baseline.**

## 3.3. 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 inter-site comparisons across years once sufficient data have been collected to differentiate change from yearly fluctuation. All cross-sections were benchmarked with rebar so surveys can occur at 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. 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.

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.

### 3.3.1. Channel cross-sections

Channel cross-sections were collected at bench-marked points in each sample drainage. While changes to stream channel shape were identified in most sample reaches, further data must be collected before inferences can be made regarding trends in stream channel morphology (e.g., increase in the width-depth ratio resulting from increased sediment). Figure 15 through Figure 34 shows cross-sectional diagrams that have been processed. Normalization of intra-year data proved to be more challenging than was expected. Additionally, in 2010 the methodology was updated to include collection of points at every 0.5 meters. This can cause the 2008/09 and 2010 measurements to appear visually different. Figure 31 is an excellent example of this. Collecting points at every 0.5 meters will help to make data normalization easier in the future.

**Catchment 1**

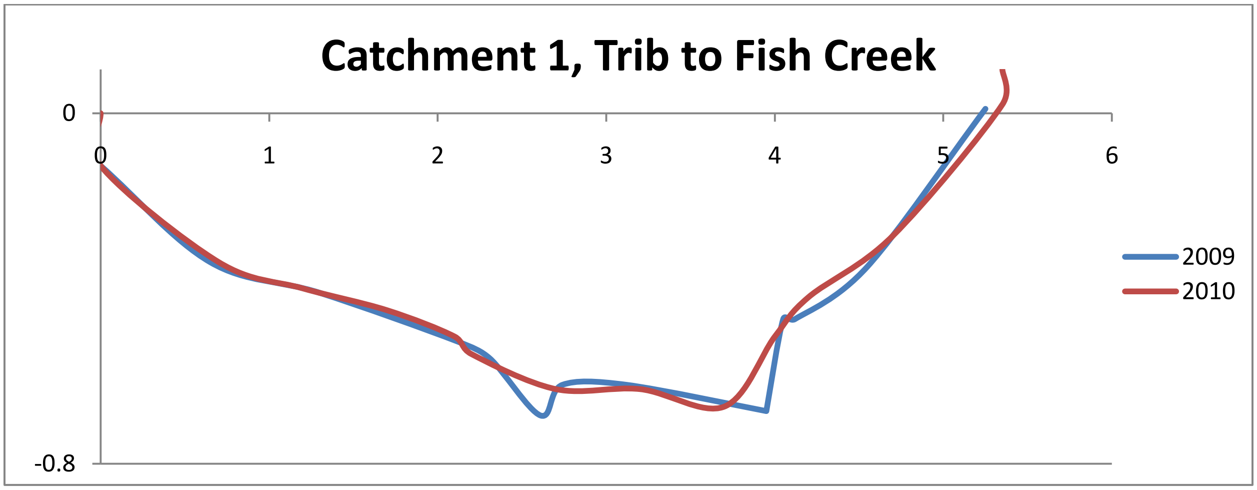

Figure 15 Catchment 1 channel cross section diagram.

**Catchment 2**

Further data is needed to compare cross-sectional data in Catchment 2. Data collected in 2009 and 2010 are incomplete. Further years are needed to show a reliable trend.

## Catchment 3

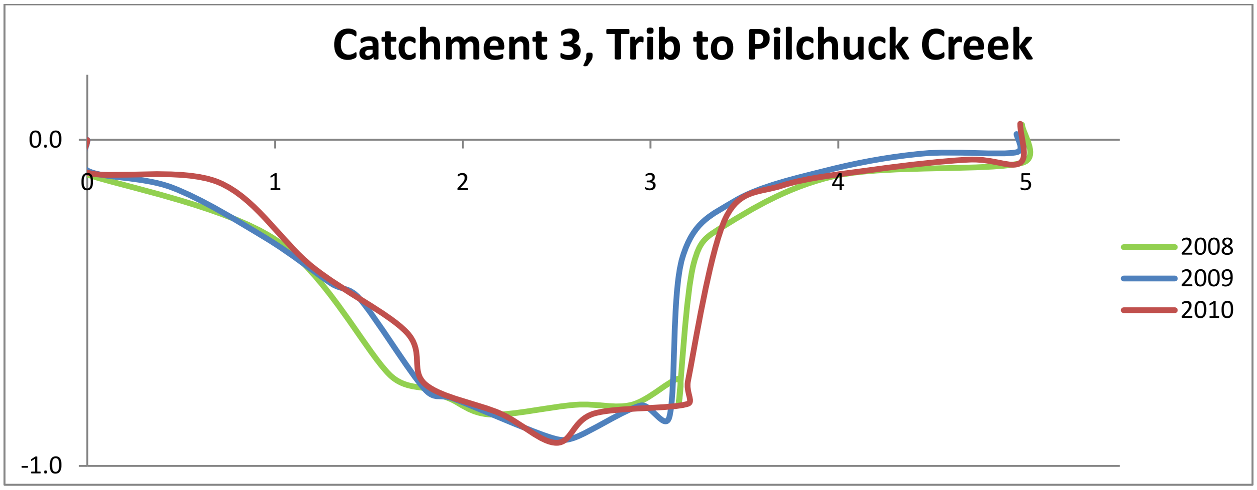

**Figure 16 Catchment 3 channel cross section diagram.**

## Catchment 4

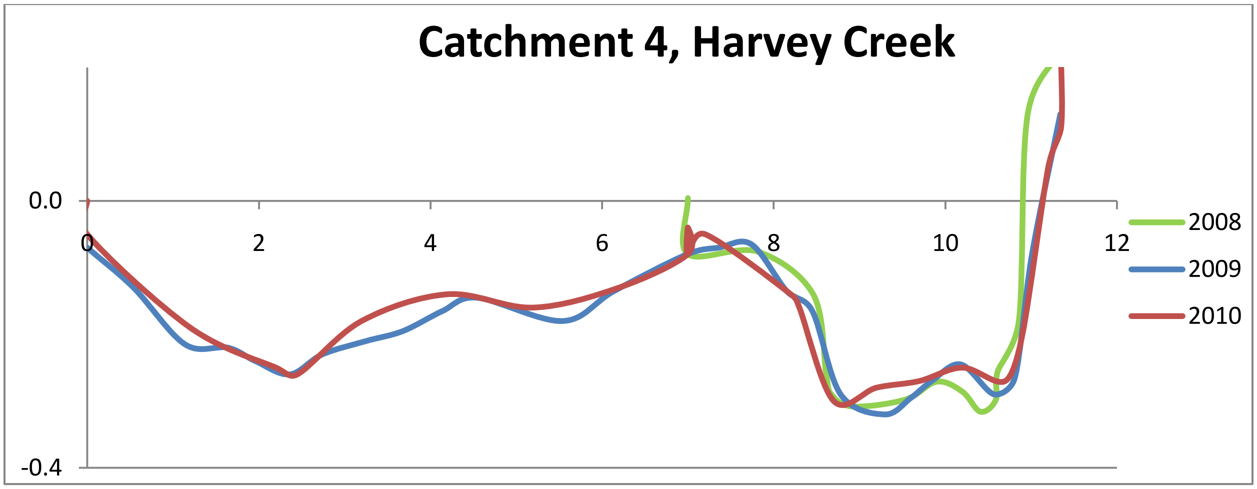

**Figure 17 Catchment 4 channel cross section diagram.**

Heavy flow in Harvey Creek caused the stream to overtop the bank and scour a new secondary channel over the winter of 2008-2009. Cross section measurements were expanded past the new ordinary high water mark.

**Catchment 5**

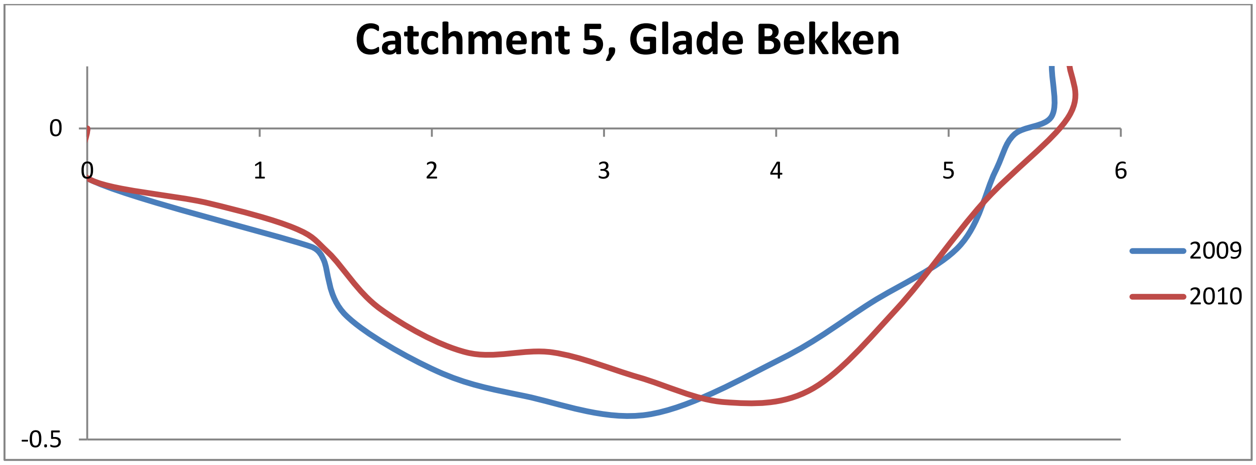

Figure 18 Catchment 5 channel cross section diagram.

**Catchment 6**

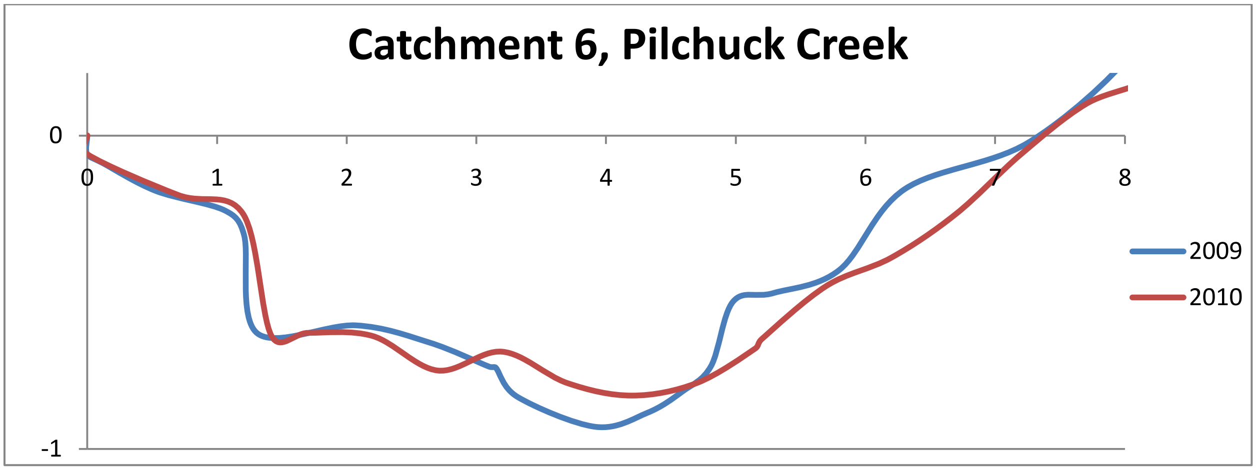

Figure 19 Catchment 6 channel cross section diagram.

**Catchment 7**

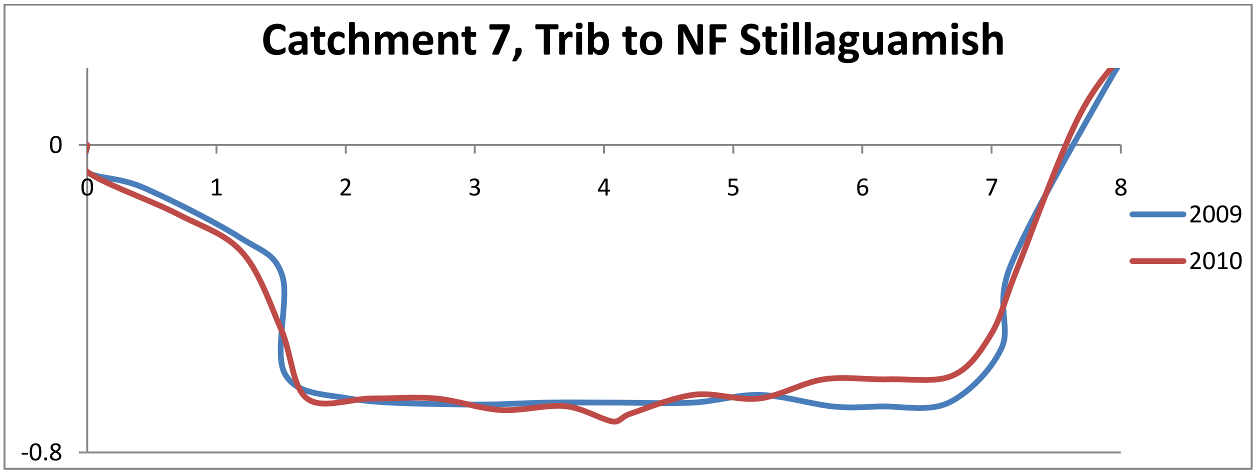

Figure 20 Catchment 7 channel cross section diagram.

## Catchment 8

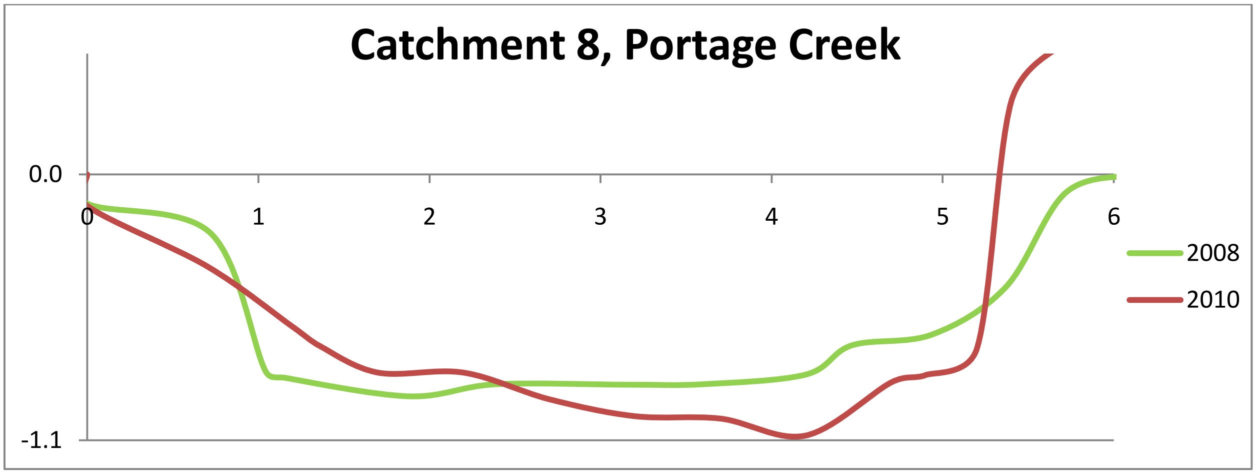

**Figure 21 Catchment 8 channel cross section diagram.**

## Catchment 9

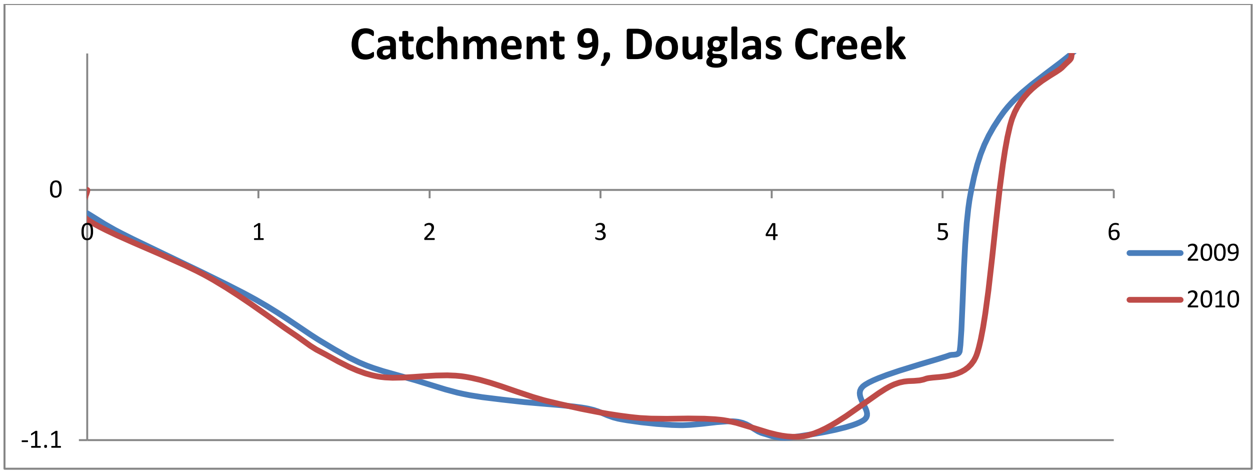

**Figure 22 Catchment 9 channel cross section diagram.**

## Catchment 10

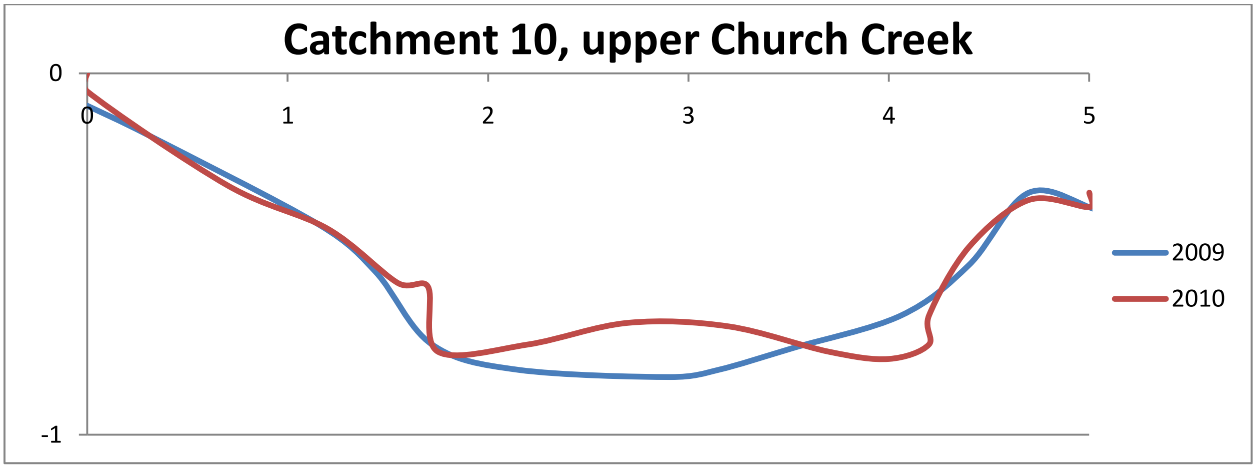

**Figure 23 Catchment 10 channel cross section diagram.**

## Catchment 11

Further data are needed to compare cross-sectional data in Catchment 11. Data collected in 2009 and 2010 are incomplete. Further years are needed to show a reliable trend.

## Catchment 12

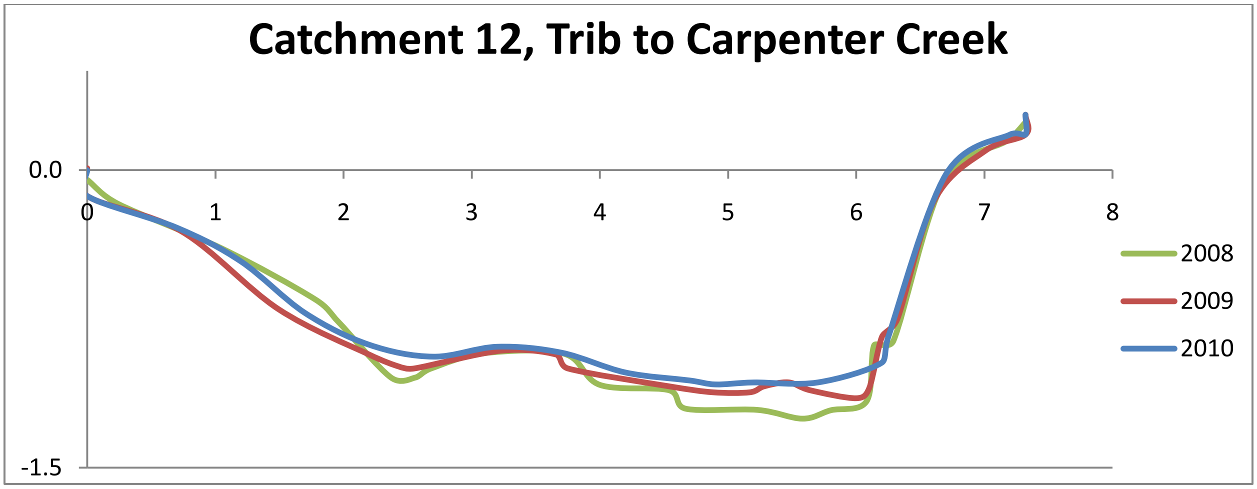

Figure 24 Catchment 12 channel cross section diagram.

## Catchment 13

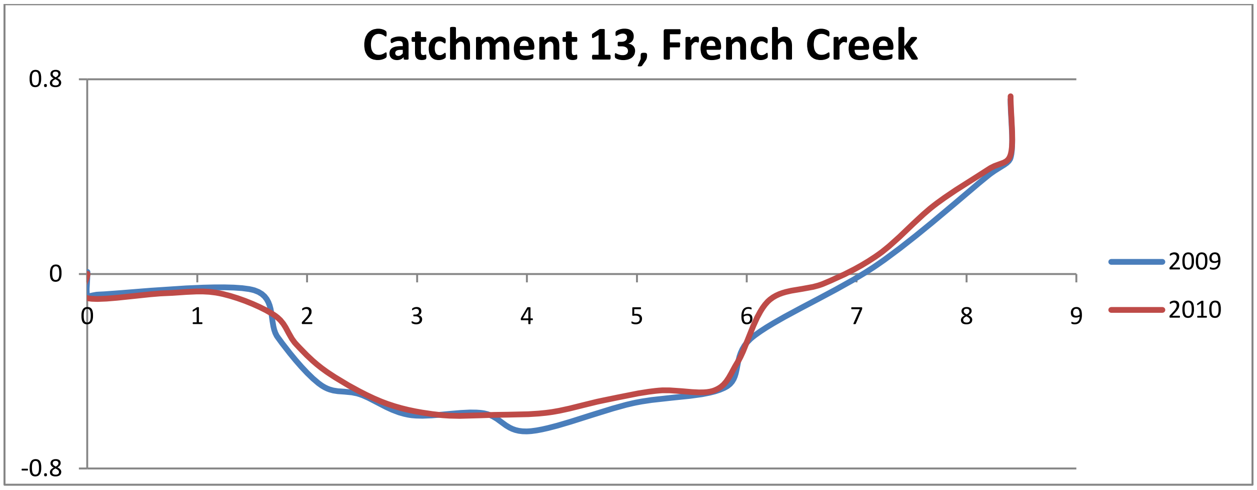

Figure 25 Catchment 13 channel cross section diagram.

**Catchment 14**

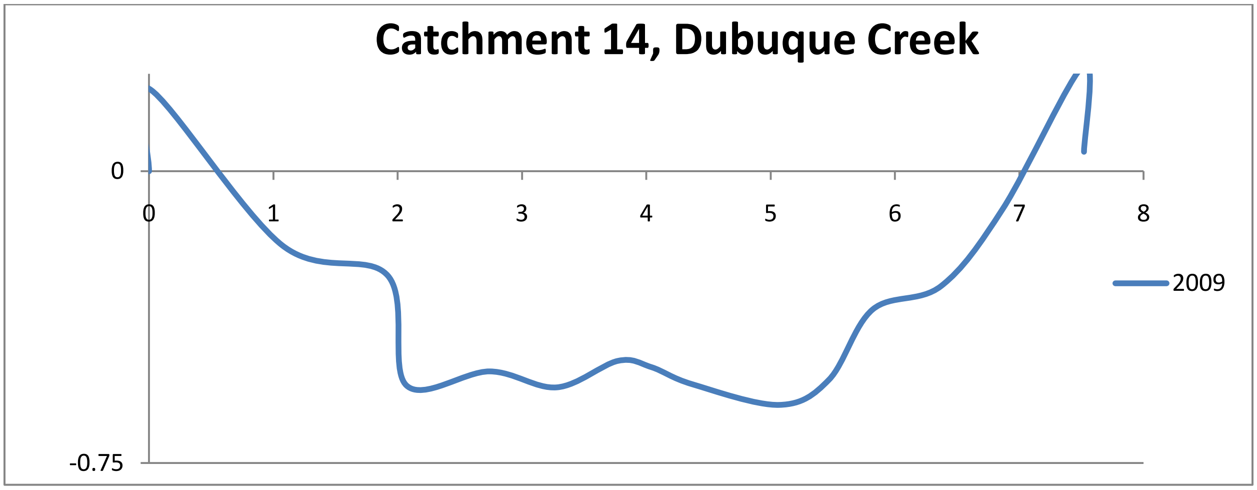

**Figure 26 Catchment 14 channel cross section diagram.**

Cross-sectional data were not collected in Catchment 14 in 2010 due to time restrictions in the field season.

**Catchment 15**

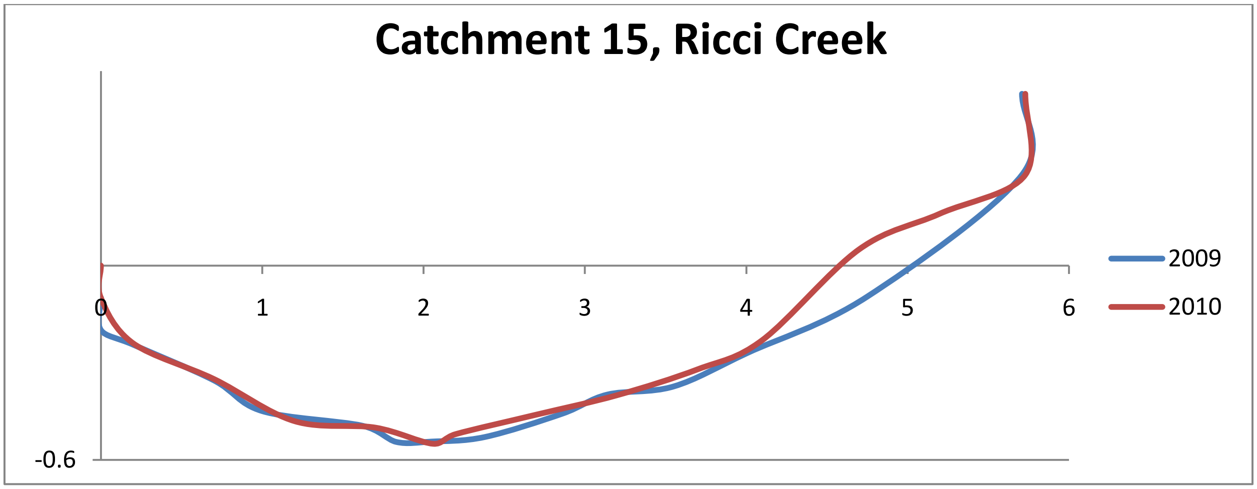

**Figure 27 Catchment 15 channel cross section diagram.**

### Catchment 16

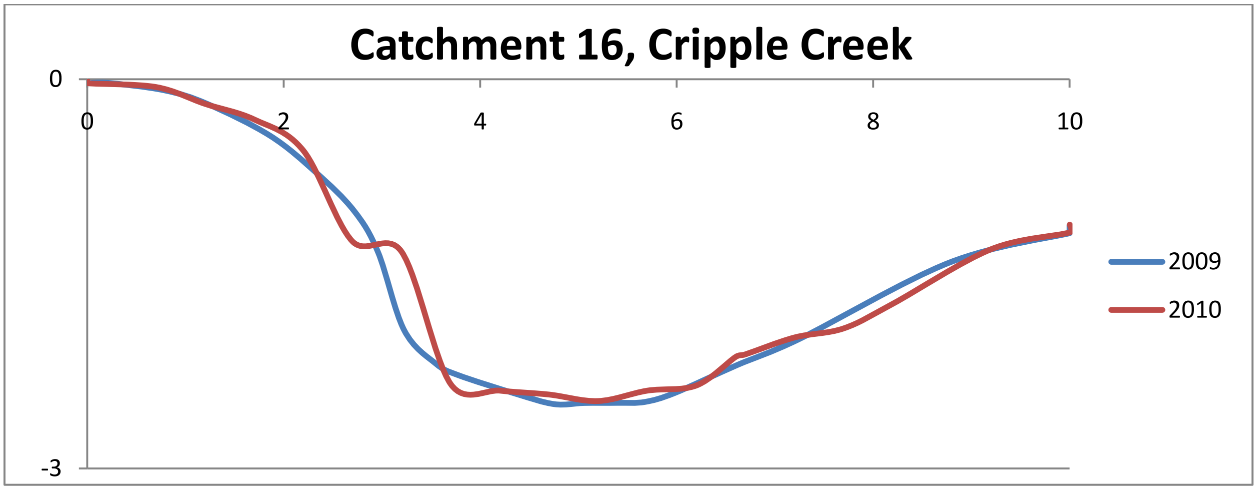

Figure 28 Catchment 16 channel cross section diagram.

### Catchment 17

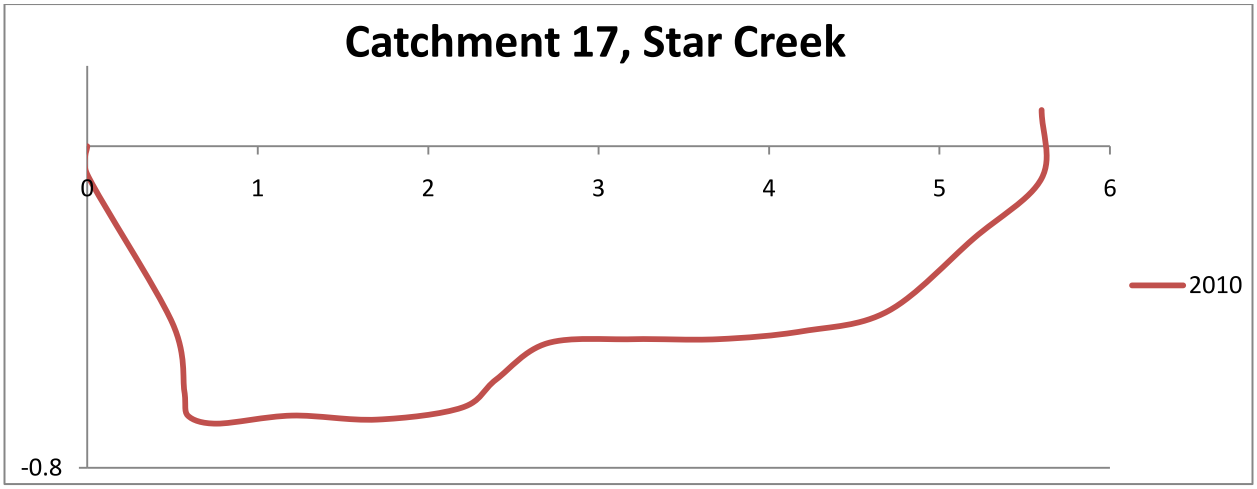

Figure 29 Catchment 17 channel cross section diagram.

Catchment 17 cross-sectional data are not shown due to inconsistencies in the raw data. Further surveys will help with the 2009 data normalization.

## Catchment 18

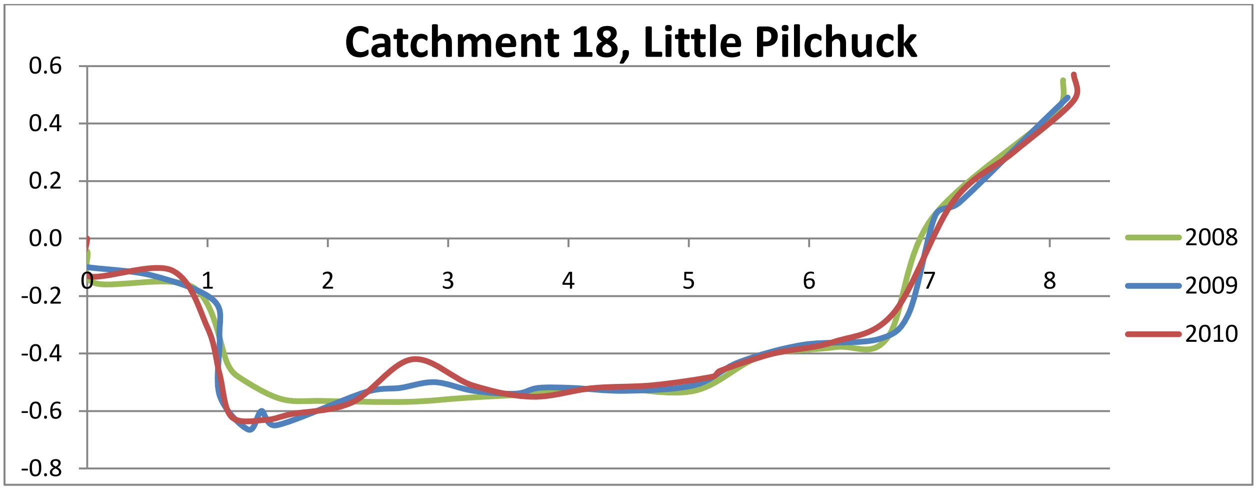

**Figure 30 Catchment 18 channel cross section diagram.**

## Catchment 19

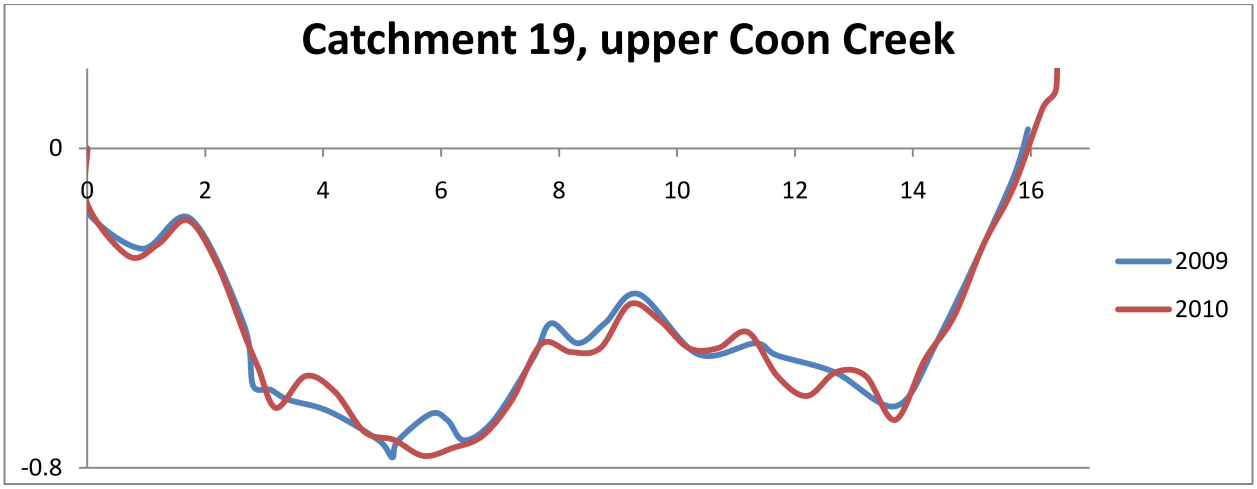

**Figure 31 Catchment 19 channel cross section diagram.**

## Catchment 20

Further data are needed to compare cross-sectional data in Catchment 20. Data collected in 2009 and 2010 are incomplete. Further years are needed to show a reliable trend.

## Catchment 21

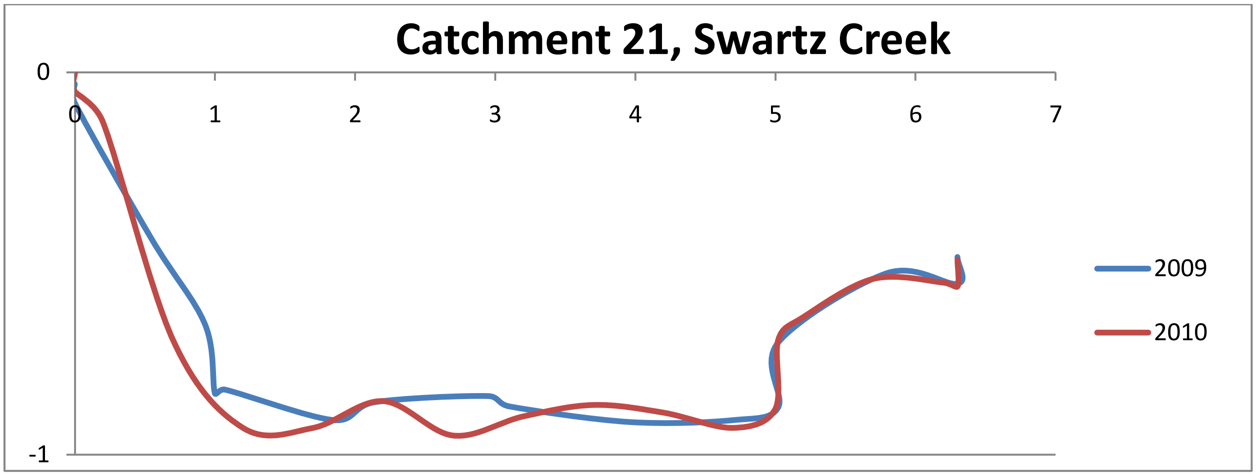

Figure 32 Catchment 21 channel cross section diagram.

## Catchment 22

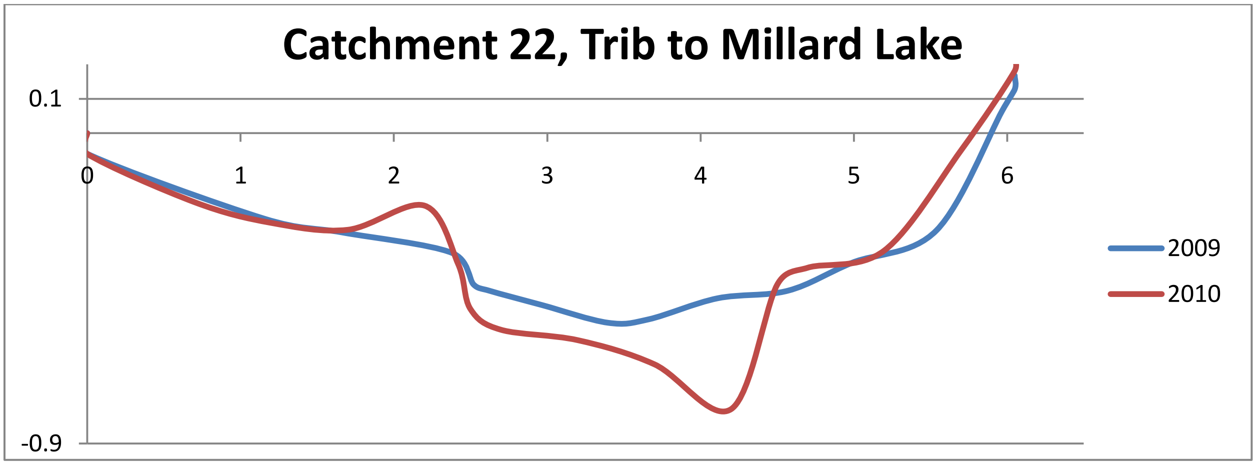

Figure 33 Catchment 22 channel cross section diagram.

## Catchment 23

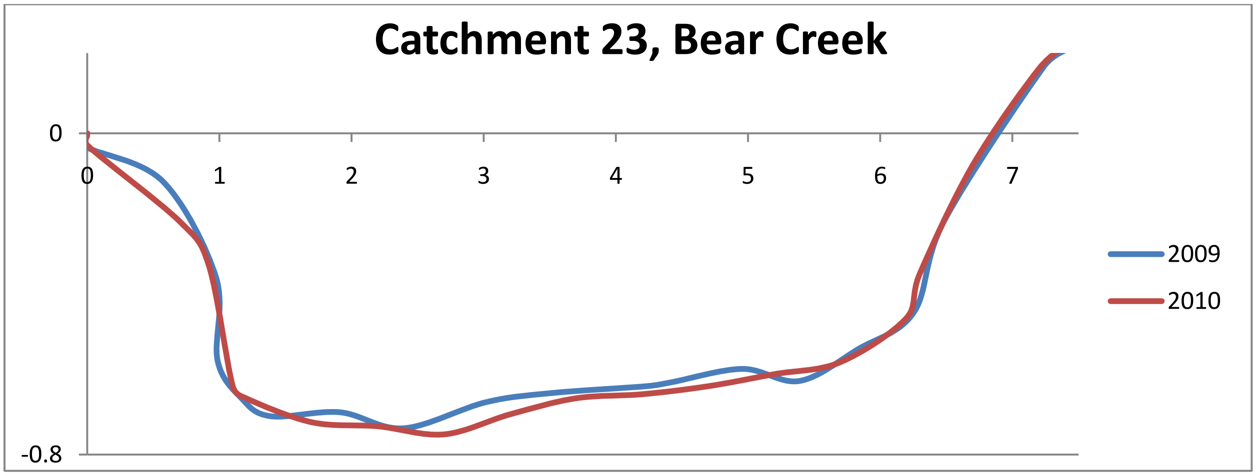

Figure 34 Catchment 23 channel cross section diagram.

### 3.3.2. 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 to depth ratio, where '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 to 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 to depth ratios also tend to have reduced shading and shallower dry-season flows, which may result in elevated water temperatures.

Bankfull width to 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 were measured in the field using a stadia rod, measuring table and level using field indicators and survey techniques outlined in Rosgen (1996).

Bankfull depth measurements were taken from channel cross-section measurements in 2008. In 2009 and 2010, bankfull depth measures were collected concurrently with individual bankfull width measures.

**Table 5 Bankfull width and depth measurements at each catchment.**

| Report ID | Site ID | Year | BFW Meas. Per Reach | Min BFW (m) | Max BFW (m) | Avg BFW (m) | Ave BFD (m) |
|---|---|---|---|---|---|---|---|
| 1 | 5-149 | 2009 | 6 | 1.80 | 2.80 | 2.20 | 0.24 |
| 1 | 5-149 | 2010 | 4 | 1.80 | 2.20 | 1.95 | 0.18 |
| 2 | 5-187 | 2009 | 5 | 2.50 | 4.00 | 3.22 | 0.33 |
| 2 | 5-187 | 2010 | 3 | 4.10 | 4.60 | 4.40 | 0.26 |
| 3 | 5-2A | 2008 | 5 | 1.25 | 2.12 | 1.63 | 0.11 |
| 3 | 5-2A | 2009 | 6 | 1.20 | 3.30 | 2.00 | 0.31 |
| 3 | 5-2A | 2010 | 4 | 1.20 | 2.00 | 1.63 | 0.22 |
| 4 | 5-2B | 2008 | 6 | 1.70 | 2.30 | 1.96 | 0.05 |
| 4 | 5-2B | 2009 | 5 | 2.10 | 2.60 | 2.42 | 0.26 |
| 4 | 5-2B | 2010 | 5 | 2.00 | 2.80 | 2.48 | 0.15 |
| 5 | 5-300 | 2009 | 5 | 2.60 | 3.90 | 3.26 | 0.30 |
| 5 | 5-300 | 2010 | 5 | 2.80 | 3.90 | 3.20 | 0.22 |
| 6 | 5-305 | 2009 | 5 | 2.00 | 3.90 | 2.72 | 0.26 |
| 6 | 5-305 | 2010 | 6 | 0.30 | 4.10 | 2.47 | 0.27 |
| 7 | 5-37 | 2009 | 3 | 3.90 | 5.60 | 5.00 | 0.19 |
| 7 | 5-37 | 2010 | 5 | 3.50 | 5.70 | 4.94 | 0.24 |
| 8 | 5-3C | 2008 | 5 | 3.00 | 3.93 | 3.38 | 0.09 |
| 8 | 5-3C | 2009 | 5 | 2.50 | 5.10 | 3.74 | 0.35 |
| 8 | 5-3C | 2010 | 5 | 2.30 | 3.25 | 2.81 | 0.21 |
| 9 | 5-42 | 2009 | 5 | 2.10 | 3.30 | 2.82 | 0.27 |
| 9 | 5-42 | 2010 | 5 | 1.40 | 5.20 | 3.18 | 0.32 |
| 10 | 5-54 | 2009 | 3 | 3.80 | 5.60 | 4.47 | 0.27 |
| 10 | 5-54 | 2010 | 5 | 2.80 | 3.70 | 3.32 | 0.20 |
| 11 | 7-1A | 2008 | 4 | 2.50 | 3.25 | 2.86 | 0.20 |
| 11 | 7-1A | 2009 | 4 | 3.50 | 5.10 | 4.33 | 0.39 |
| 11 | 7-1A | 2010 | 5 | 3.30 | 4.20 | 3.84 | 0.28 |
| 12 | 7-1C | 2008 | 6 | 1.60 | 4.58 | 2.55 | 0.09 |
| 12 | 7-1C | 2009 | 6 | 1.60 | 4.30 | 2.62 | 0.24 |
| 12 | 7-1C | 2010 | 3 | 1.40 | 1.70 | 1.57 | 0.17 |
| 13 | 7-221 | 2009 | 5 | 3.60 | 4.70 | 3.98 | 0.29 |
| 13 | 7-221 | 2010 | 5 | 3.10 | 4.60 | 3.88 | 0.36 |
| 14 | 7-235 | 2009 | 4 | 3.20 | 4.70 | 3.80 | 0.32 |
| 14 | 7-235 | 2010 | 6 | 2.80 | 5.10 | 3.75 | 0.23 |
| 15 | 7-279 | 2009 | 5 | 3.40 | 4.40 | 3.92 | 0.28 |
| 15 | 7-279 | 2010 | 5 | 3.30 | 4.00 | 3.70 | 0.23 |
| 16 | 7-282 | 2009 | 5 | 1.60 | 4.10 | 2.96 | 0.36 |
| 16 | 7-282 | 2010 | 4 | 2.50 | 3.40 | 2.98 | 0.29 |
| 17 | 7-329 | 2009 | 6 | 1.70 | 2.50 | 2.18 | 0.25 |
| 17 | 7-329 | 2010 | 5 | 1.40 | 2.10 | 1.76 | 0.13 |
| 18 | 7-3A | 2008 | 5 | 3.22 | 4.40 | 3.86 | 0.16 |
| 18 | 7-3A | 2009 | 5 | 3.10 | 8.20 | 4.78 | 0.28 |
| 18 | 7-3A | 2010 | 4 | 2.75 | 3.80 | 3.12 | 0.26 |
| 19 | 7-72 | 2009 | 4 | 4.00 | 7.00 | 5.48 | 0.26 |
| 19 | 7-72 | 2010 | 4 | 3.00 | 7.50 | 5.20 | 0.30 |
| 20 | 7-933 | 2009 | 4 | 4.40 | 5.10 | 4.85 | 0.25 |
| 20 | 7-933 | 2010 | 5 | 2.60 | 5.10 | 4.22 | 0.38 |
| 21 | 7-981 | 2009 | 5 | 3.50 | 5.90 | 4.72 | 0.24 |
| 21 | 7-981 | 2010 | 5 | 3.10 | 7.90 | 5.00 | 0.17 |
| 22 | 7-982 | 2009 | 5 | 2.40 | 4.50 | 3.44 | 0.20 |
| 22 | 7-982 | 2010 | 4 | 1.70 | 3.40 | 2.38 | 0.30 |
| 23 | 8-156 | 2009 | 5 | 2.20 | 5.20 | 4.24 | 0.41 |
| 23 | 8-156 | 2010 | 5 | 1.60 | 5.10 | 3.62 | 0.31 |

## 3.4. Stream Habitat

### 3.4.1. Pool frequency and depth

Physical habitat surveys including pool frequency and depth were conducted at all catchments each year. A detailed analysis of the relationship between change in pools and development pressures as they relate to critical area regulations has not yet been performed. Initial data suggests that intra-annual climactic variation may be difficult to tease out from other drivers; additional collection years are required to do so.

**Table 6 Pool frequency and depth, 2008-2010.**

| Report ID | Site ID | Year | Pool Count | Ave Max Depth | Max Depth Std Dev | Ave Residual Depth | Residual Depth Std Dev | Pools/ KM |
|---|---|---|---|---|---|---|---|---|
| 1 | 5-149 | 2009 | 0 | NA | NA | NA | NA | 0 |
| 1 | 5-149 | 2010 | 3 | 0.13 | 0.02 | 0.11 | 0.01 | 75 |
| 2 | 5-187 | 2009 | 4 | 0.20 | 0.06 | 0.16 | 0.06 | 50 |
| 2 | 5-187 | 2010 | 9 | 0.37 | 0.24 | 0.29 | 0.22 | 150 |
| 3 | 5-2A | 2008 | 3 | 0.17 | 0.02 | 0.14 | 0.02 | 75 |
| 3 | 5-2A | 2009 | 4 | 0.22 | 0.06 | 0.16 | 0.03 | 100 |
| 3 | 5-2A | 2010 | 0 | NA | NA | NA | NA | NA |
| 4 | 5-2B | 2008 | 4 | 0.17 | 0.05 | 0.15 | 0.05 | 67 |
| 4 | 5-2B | 2009 | 9 | 0.12 | 0.01 | 0.10 | 0.00 | 129 |
| 4 | 5-2B | 2010 | 8 | 0.18 | 0.03 | 0.15 | 0.04 | 133 |
| 5 | 5-300 | 2009 | 9 | 0.19 | 0.05 | 0.15 | 0.06 | 113 |
| 5 | 5-300 | 2010 | 9 | 0.23 | 0.09 | 0.16 | 0.08 | 113 |
| 6 | 5-305 | 2009 | 14 | 0.23 | 0.12 | 0.20 | 0.12 | 175 |
| 6 | 5-305 | 2010 | 14 | 0.26 | 0.04 | 0.18 | 0.05 | 175 |
| 7 | 5-37 | 2009 | 10 | 0.28 | 0.08 | 0.19 | 0.07 | 100 |
| 7 | 5-37 | 2010 | 15 | 0.45 | 0.49 | 0.33 | 0.50 | 150 |
| 8 | 5-3C | 2008 | 4 | 0.21 | 0.06 | 0.16 | 0.07 | 44 |
| 8 | 5-3C | 2009 | 6 | 0.21 | 0.10 | 0.15 | 0.09 | 100 |
| 8 | 5-3C | 2010 | 8 | 0.18 | 0.03 | 0.13 | 0.03 | 89 |
| 9 | 5-42 | 2009 | 4 | 0.16 | 0.04 | 0.15 | 0.03 | 67 |
| 9 | 5-42 | 2010 | 12 | 0.21 | 0.12 | 0.18 | 0.12 | 120 |
| 10 | 5-54 | 2009 | 6 | 0.37 | 0.21 | 0.32 | 0.22 | 100 |
| 10 | 5-54 | 2010 | 8 | 0.20 | 0.05 | 0.16 | 0.04 | 133 |
| 11 | 7-1A | 2008 | 7 | 0.15 | 0.02 | 0.13 | 0.02 | 117 |
| 11 | 7-1A | 2009 | 8 | 0.17 | 0.04 | 0.14 | 0.04 | 100 |
| 11 | 7-1A | 2010 | 6 | 0.16 | 0.02 | 0.14 | 0.02 | 75 |
| 12 | 7-1C | 2008 | 1 | 0.15 | NA | 0.13 | NA | 17 |
| 12 | 7-1C | 2009 | 4 | 0.14 | 0.05 | 0.12 | 0.04 | 67 |
| 12 | 7-1C | 2010 | 2 | 0.15 | 0.01 | 0.10 | 0.00 | 50 |
| 13 | 7-221 | 2009 | 10 | 0.26 | 0.07 | 0.17 | 0.06 | 125 |
| 13 | 7-221 | 2010 | 10 | 0.22 | 0.06 | 0.15 | 0.06 | 125 |
| 14 | 7-235 | 2009 | 14 | 0.20 | 0.06 | 0.16 | 0.05 | 200 |
| 14 | 7-235 | 2010 | 14 | 0.43 | 0.48 | 0.26 | 0.25 | 233 |
| 15 | 7-279 | 2009 | 11 | 0.24 | 0.08 | 0.17 | 0.07 | 138 |
| 15 | 7-279 | 2010 | 7 | 0.29 | 0.05 | 0.19 | 0.05 | 88 |
| 16 | 7-282 | 2009 | 2 | 0.19 | 0.00 | 0.15 | 0.01 | 33 |
| 16 | 7-282 | 2010 | 2 | 0.20 | 0.03 | 0.18 | 0.03 | 33 |
| 17 | 7-329 | 2009 | 6 | 0.15 | 0.02 | 0.11 | 0.04 | 120 |
| 17 | 7-329 | 2010 | 5 | 0.17 | 0.05 | 0.15 | 0.05 | 100 |
| 18 | 7-3A | 2008 | 1 | 0.31 | NA | 0.29 | NA | 17 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 18 | 7-3A | 2009 | 6 | 0.22 | 0.08 | 0.17 | 0.07 | 100 |
| 18 | 7-3A | 2010 | 8 | 0.19 | 0.06 | 0.16 | 0.07 | 133 |
| 19 | 7-72 | 2009 | 9 | 0.23 | 0.10 | 0.20 | 0.11 | 90 |
| 19 | 7-72 | 2010 | 15 | 0.21 | 0.09 | 0.18 | 0.09 | 150 |
| 20 | 7-933 | 2009 | 6 | 0.29 | 0.10 | 0.21 | 0.09 | 75 |
| 20 | 7-933 | 2010 | 10 | 0.27 | 0.08 | 0.16 | 0.06 | 111 |
| 21 | 7-981 | 2009 | 18 | 0.28 | 0.09 | 0.21 | 0.09 | 171 |
| 21 | 7-981 | 2010 | 24 | 0.31 | 0.10 | 0.22 | 0.11 | 229 |
| 22 | 7-982 | 2009 | 5 | 0.19 | 0.06 | 0.15 | 0.08 | 63 |
| 22 | 7-982 | 2010 | 7 | 0.23 | 0.08 | 0.18 | 0.07 | 140 |
| 23 | 8-156 | 2009 | 9 | 0.28 | 0.06 | 0.19 | 0.07 | 90 |
| 23 | 8-156 | 2010 | 6 | 0.26 | 0.05 | 0.19 | 0.04 | 60 |

### 3.4.2. Pool quantity and Characteristics

Pools were identified and measured over a distance of approximately 20 to 30 channel widths for the 23 sites. Pools were generally spaced far apart and due to the small size and power of sample streams, were shallow in depth. 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 hydrology.

**Table 7 Headwater stream drainage habitat summary values.**

| Drainage ID | Pool frequency 2009 (pools/m) | Pool frequency 2010 (pools/m) | Average residual depth of pools in 2009 (m) | Average residual depth of pools in 2010 (m) | B-IBI score | Bankfull width depth ratio |
|---|---|---|---|---|---|---|
| 1 | 0.03 | 0.08 | 0.1 | 0.11 | 34 | 10.7 |
| 2 | 0.05 | 0.11 | 0.16 | 0.29 | 30 | 16.9 |
| 3 | 0.10 | 0.03 | 0.16 | 0 | na | 7.4 |
| 4 | 0.23 | 0.20 | 0.1 | 0.15 | 32 | 16.3 |
| 5 | 0.11 | 0.11 | 0.15 | 0.16 | 26 | 14.4 |
| 6 | 0.18 | 0.18 | 0.2 | 0.18 | 34 | 9.3 |
| 7 | 0.10 | 0.15 | 0.19 | 0.33 | 44 | 20.8 |
| 8 | 0.10 | 0.13 | 0.15 | 0.13 | 32 | 13.5 |
| 9 | 0.07 | 0.20 | 0.15 | 0.18 | 20 | 9.9 |
| 10 | 0.10 | 0.13 | 0.32 | 0.16 | 30 | 16.6 |
| 11 | 0.10 | 0.08 | 0.14 | 0.14 | 34 | 13.7 |
| 12 | 0.07 | 0.03 | 0.12 | 0.1 | 26 | 9.4 |
| 13 | 0.13 | 0.13 | 0.17 | 0.15 | 42 | 10.9 |
| 14 | 0.18 | 0.18 | 0.16 | 0.26 | 30 | 16.4 |
| 15 | 0.14 | 0.09 | 0.17 | 0.19 | 32 | 16.2 |
| 16 | 0.03 | 0.03 | 0.15 | 0.18 | 38 | 10.2 |
| 17 | 0.15 | 0.13 | 0.11 | 0.15 | 36 | 13.5 |
| 18 | 0.10 | 0.13 | 0.17 | 0.16 | 32 | 12.0 |
| 19 | 0.09 | 0.15 | 0.2 | 0.18 | 40 | 17.3 |
| 20 | 0.08 | 0.13 | 0.21 | 0.16 | 32 | 11.0 |
| 21 | 0.18 | 0.24 | 0.21 | 0.22 | 34 | 29.8 |
| 22 | 0.13 | 0.18 | 0.15 | 0.18 | 36 | 8.0 |
| 23 | 0.09 | 0.06 | 0.19 | 0.19 | 26 | 11.8 |

## 3.5. B-IBI

Benthic invertebrate samples were successfully collected at each of the 7 catchments in 2008, 22 catchments in 2009, and 23 catchments in 2010. Catchment #3 (5-2A) was not collected in 2009 due to lack of sufficient stream flows during the sample period. 2010 scores were not yet available at the time that this report was completed.

**Table 8. B-IBI score and catchment land cover characteristics.**

| Drainage ID | Primary land use within sample drainage | Predicted development trajectory | WRIA | % Impervious cover within drainage | % forest cover within drainage | Drainage area size (acres) | B-IBI Score (2008) | B-IBI Score (2009) |
|---|---|---|---|---|---|---|---|---|
| 1 | forestry | stable | 5 | 2% | 86% | 78 | 36 | 34 |
| 4 | forestry | stable | 5 | 0% | 79% | 294 | 40 | 32 |
| 11 | forestry | stable | 7 | 0% | 88% | 400 | Na[1] | 34 |
| 12 | forestry | stable | 7 | 0% | 83% | 103 | Na[1] | 26 |
| 19 | forestry | stable | 7 | 3% | 67% | 1,203 | Na[1] | 40 |
| 21 | forestry | stable | 7 | 4% | 64% | 403 | Na[1] | 34 |
| 14 | forestry | developing | 7 | 1% | 67% | 899 | Na[1] | 30 |
| 20 | forestry | developing | 7 | 3% | 65% | 1,409 | Na[1] | 32 |
| 22 | forestry | developing | 7 | 4% | 66% | 278 | Na[1] | 36 |
| 2 | rural | stable | 5 | 5% | 45% | 4,975 | 38 | 30 |
| 3 | rural | stable | 5 | 0% | 75% | 135 | 34 | na |
| 7 | rural | stable | 5 | 3% | 50% | 425 | 26 | 44 |
| 17 | rural | stable | 7 | 6% | 20% | 69 | Na[1] | 36 |
| 5 | rural | developing | 5 | 3% | 51% | 1,227 | 34 | 26 |
| 9 | rural | developing | 5 | 9% | 24% | 1,013 | Na[1] | 20 |
| 10 | rural | developing | 5 | 5% | 44% | 1,386 | Na[1] | 30 |
| 13 | rural | developing | 7 | 4% | 54% | 1,975 | Na[1] | 42 |
| 23 | rural | developing | 8 | 6% | 67% | 917 | Na[1] | 26 |
| 6 | suburban | stable | 5 | 2% | 70% | 792 | 32 | 34 |
| 15 | suburban | stable | 7 | 5% | 45% | 2,462 | Na[1] | 32 |
| 16 | suburban | stable | 7 | 8% | 42% | 1,331 | Na[1] | 38 |
| 8 | suburban | developing | 5 | 4% | 54% | 772 | Na[1] | 32 |
| 18 | suburban | developing | 7 | 5% | 48% | 1,254 | Na[1] | 32 |

[1] BIBI was not collected in these locations in 2008

## 3.6. Catchment Landscape Analysis

Catchment boundary polygons were overlaid on the 2007 and 2009 land cover maps (Figure 35) to characterize land cover makeup in each catchment. In addition to catchment-wide characterization, the overlay analysis reported land cover makeup within critical areas and their buffers. Three separate buffer widths were characterized for analysis purposes: 50 ft, 100 ft, and 150 ft. Figure 36 through Figure 58 report the prevalence of the predominant land cover types including natural vegetation (grass, shrub, forest, and wetland), and anthropogenically driven classes (bare earth, impervious). Certain classes such as forest types have been lumped together as they share many of the same ecological attributes and offer greater statistical power.

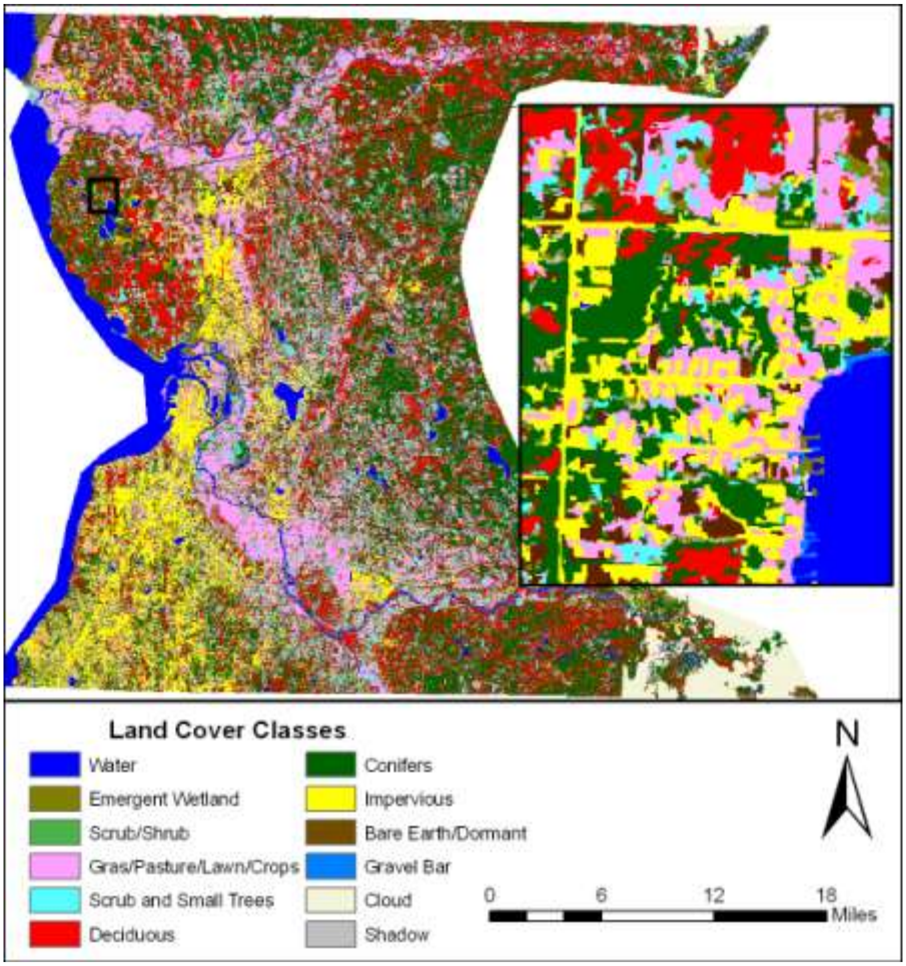

**Figure 35 Example land cover map showing the 2007 map.**

## Catchment 1

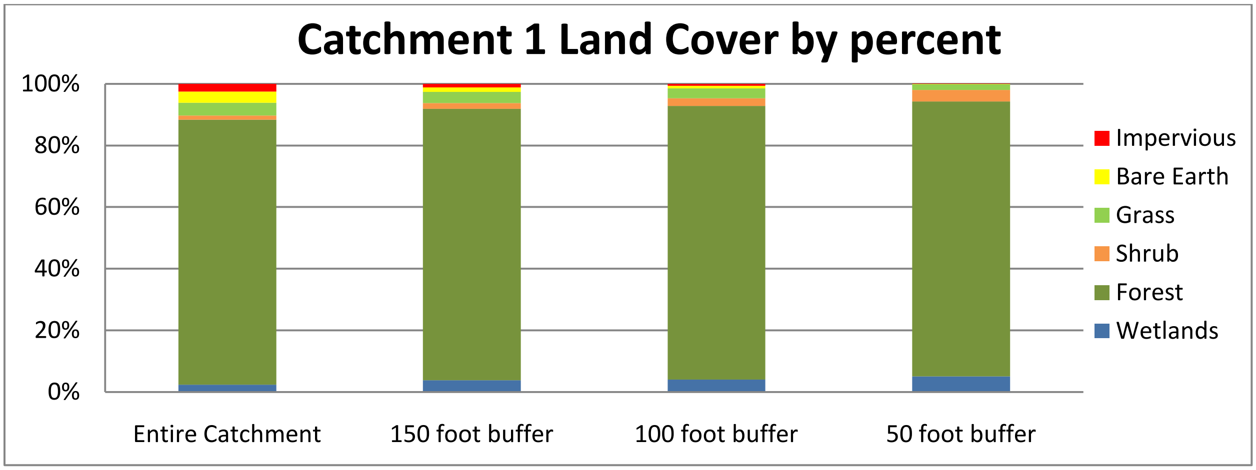

Figure 36 Land cover characterization within headwater stream Catchment 1.

## Catchment 2

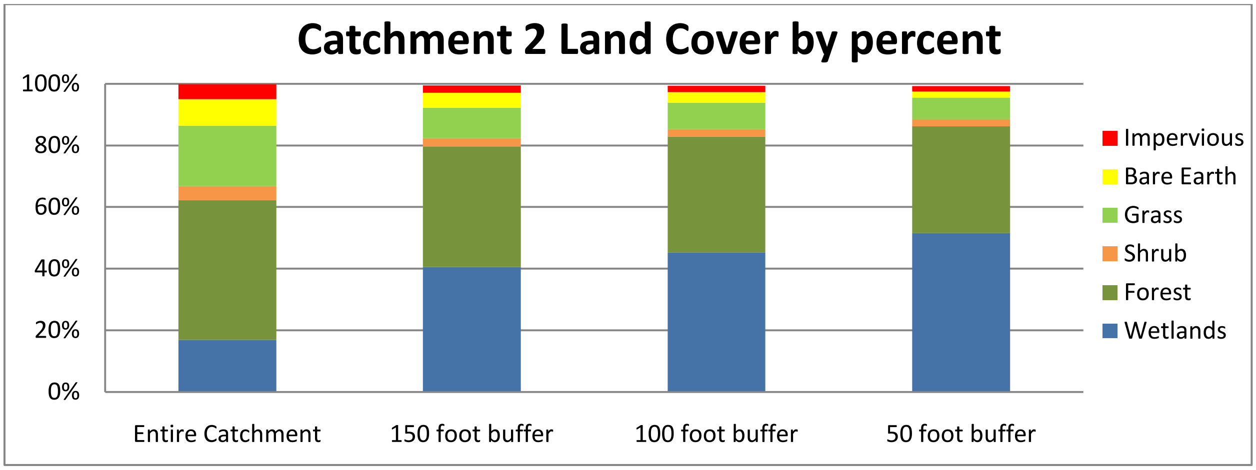

Figure 37 Land cover characterization within headwater stream Catchment 2.

## Catchment 3

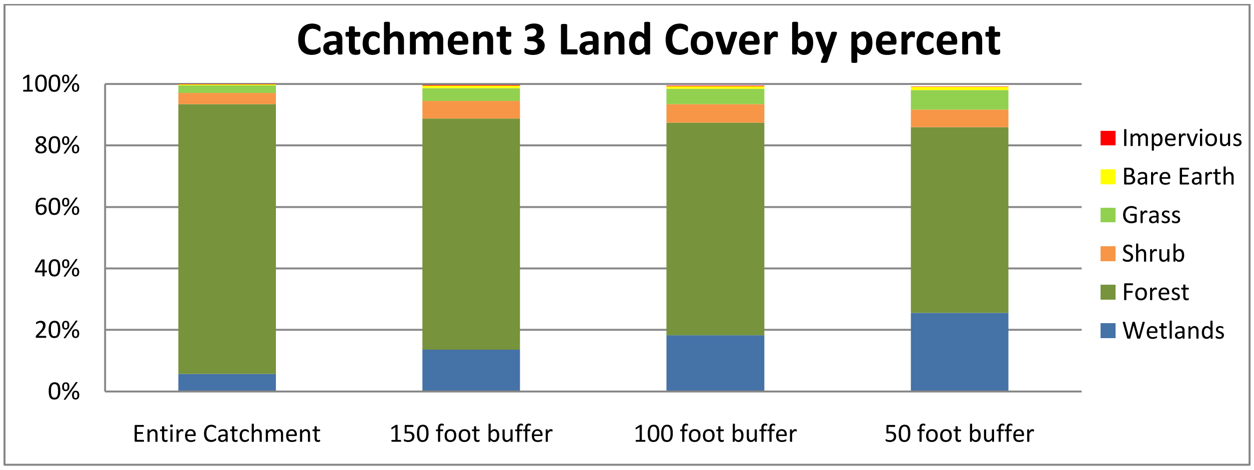

Figure 38 Land cover characterization within headwater stream Catchment 3.

### Catchment 4

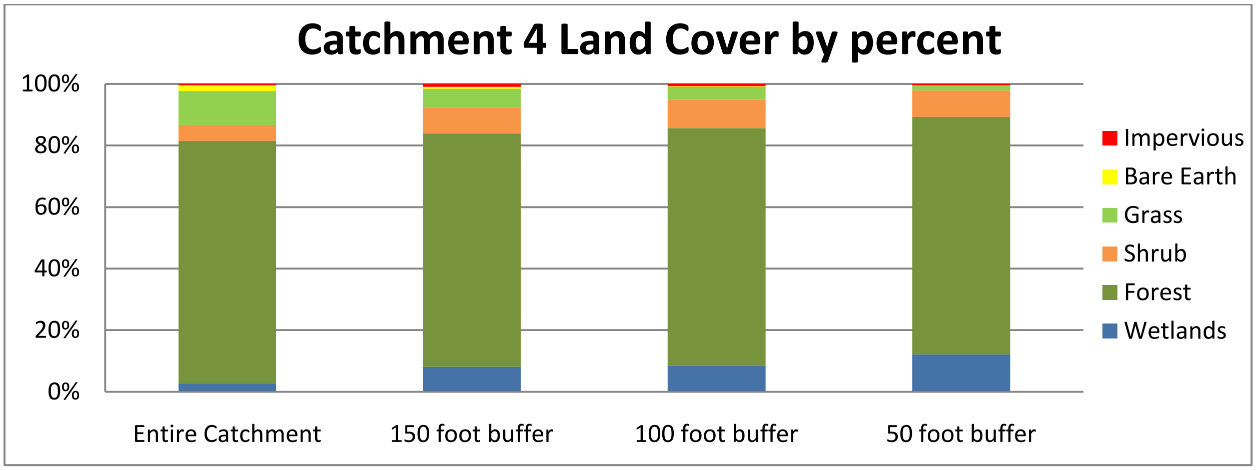

**Figure 39 Land cover characterization within headwater stream Catchment 4.**

### Catchment 5

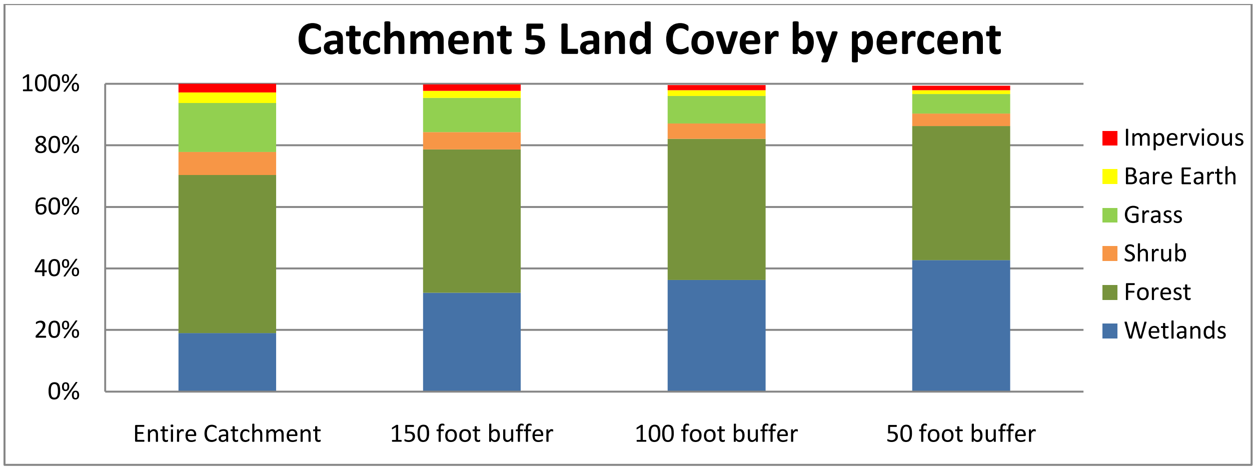

**Figure 40 Land cover characterization within headwater stream Catchment 5.**

### Catchment 6

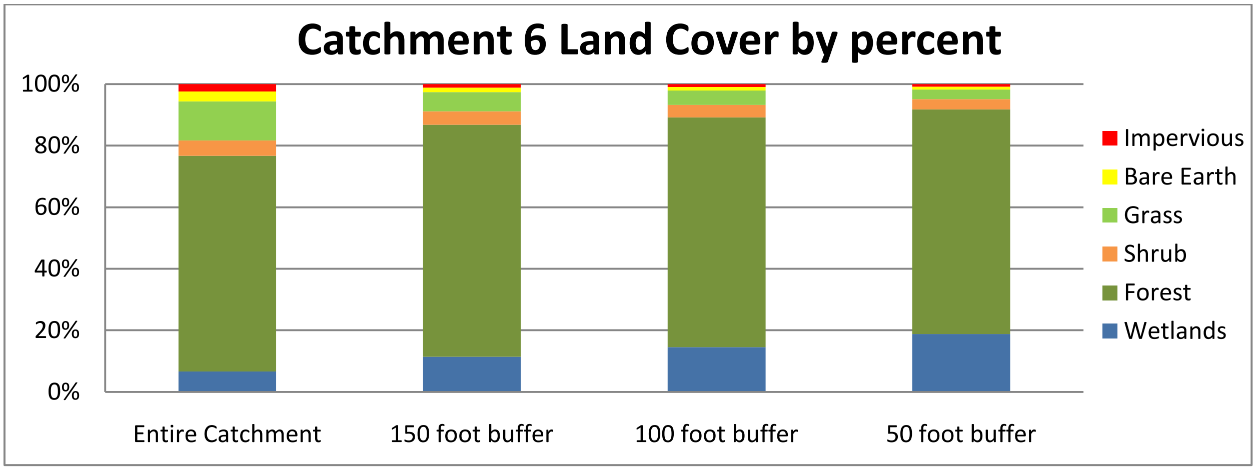

**Figure 41 Land cover characterization within headwater stream Catchment 6.**

## Catchment 7

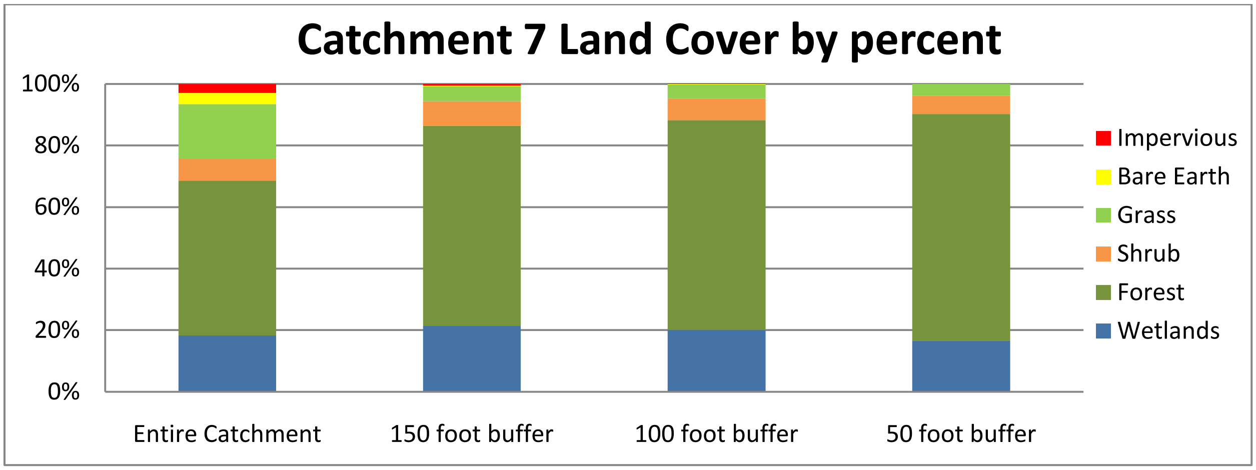

**Figure 42 Land cover characterization within headwater stream Catchment 7.**

## Catchment 8

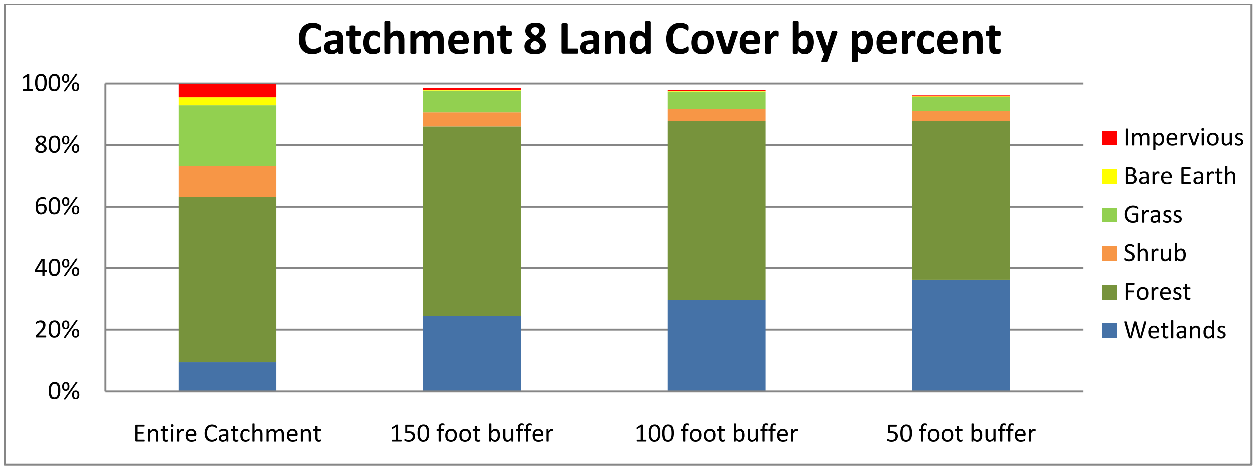

**Figure 43 Land cover characterization within headwater stream Catchment 8.**

## Catchment 9

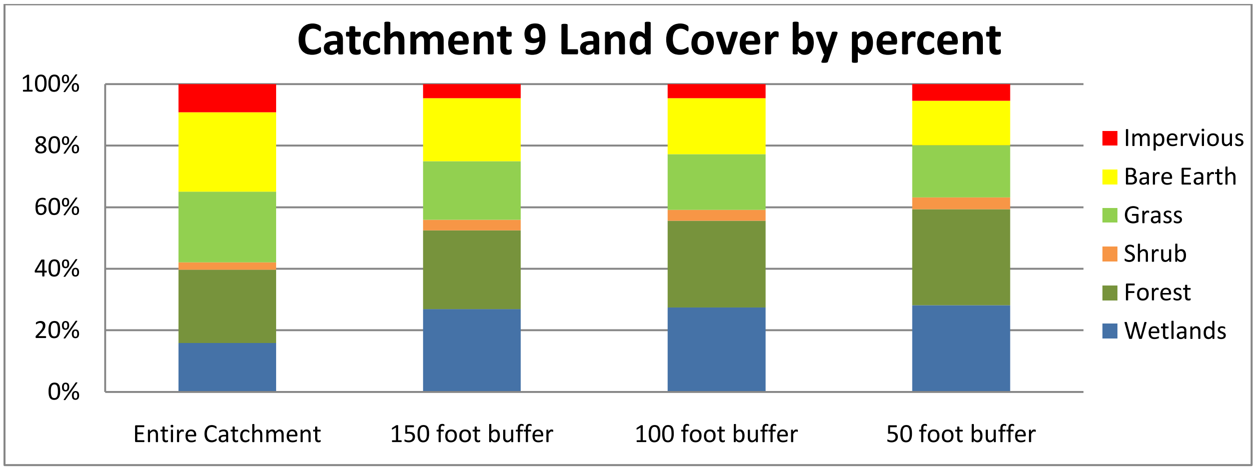

**Figure 44 Land cover characterization within headwater stream Catchment 9.**

## Catchment 10

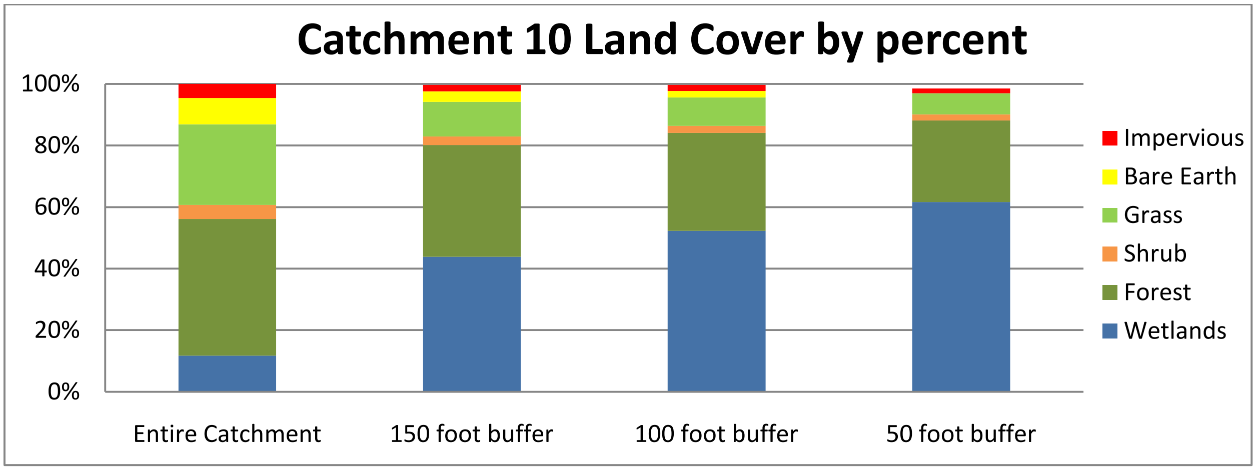

**Figure 45 Land cover characterization within headwater stream Catchment 10.**

## Catchment 11

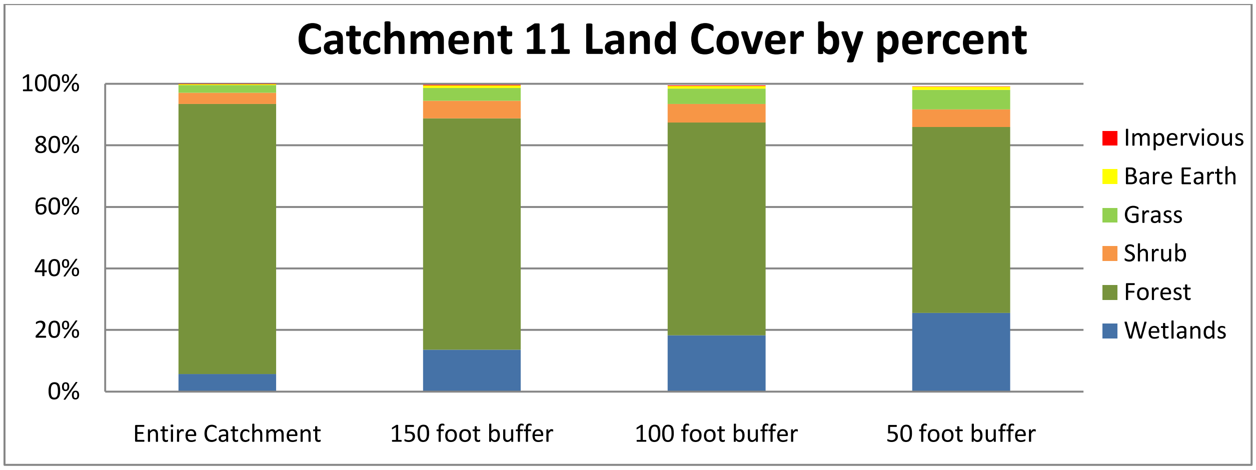

**Figure 46 Land cover characterization within headwater stream Catchment 11.**

## Catchment 12

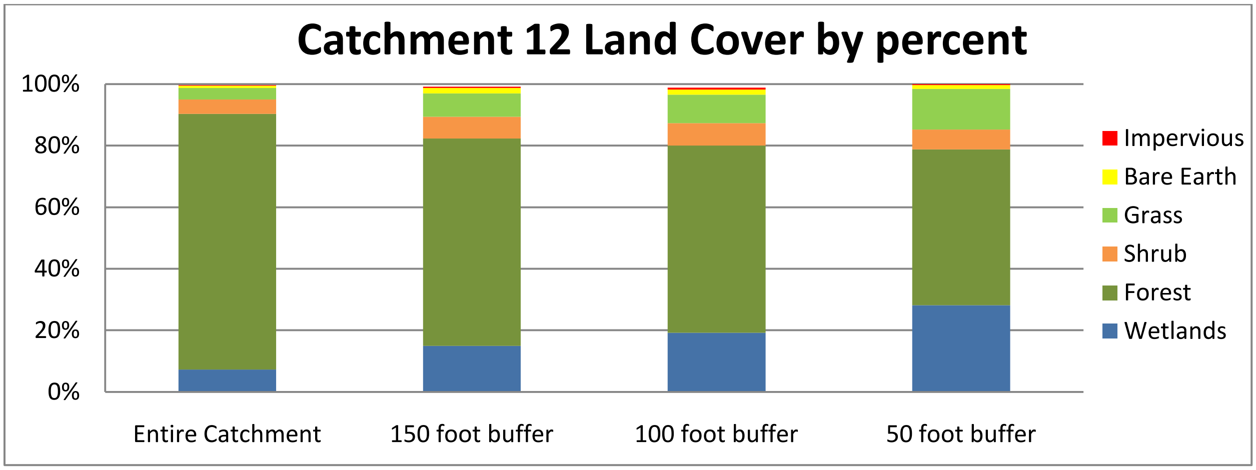

**Figure 47 Land cover characterization within headwater stream Catchment 12.**

## Catchment 13

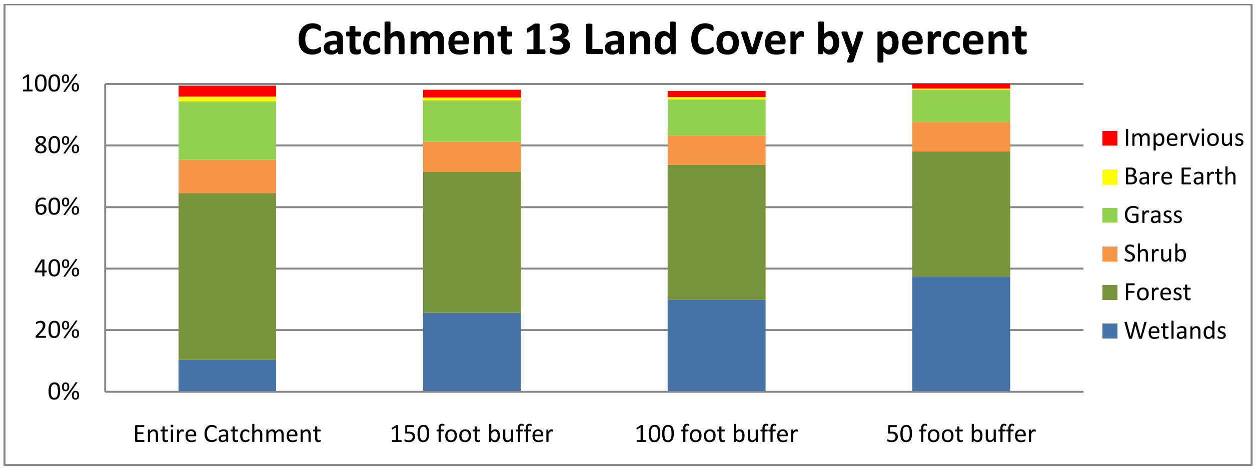

**Figure 48 Land cover characterization within headwater stream Catchment 13.**

## Catchment 14

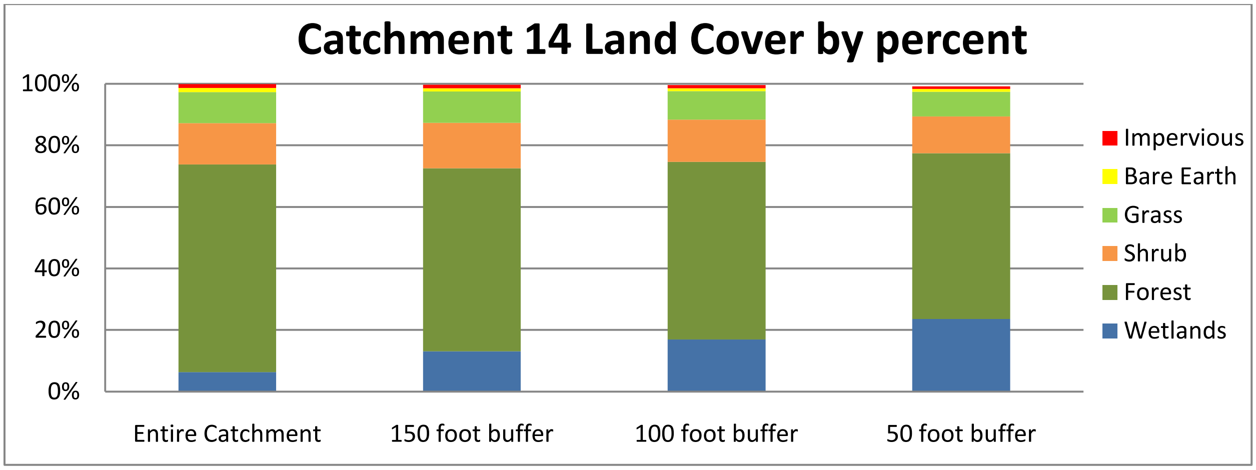

**Figure 49 Land cover characterization within headwater stream Catchment 14.**

## Catchment 15

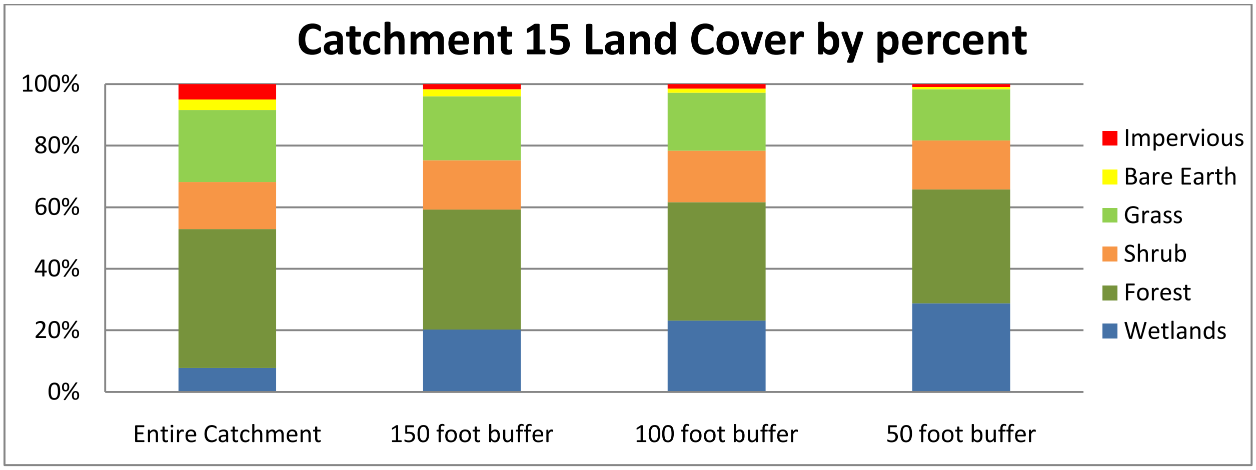

**Figure 50 Land cover characterization within headwater stream Catchment 15.**

## Catchment 16

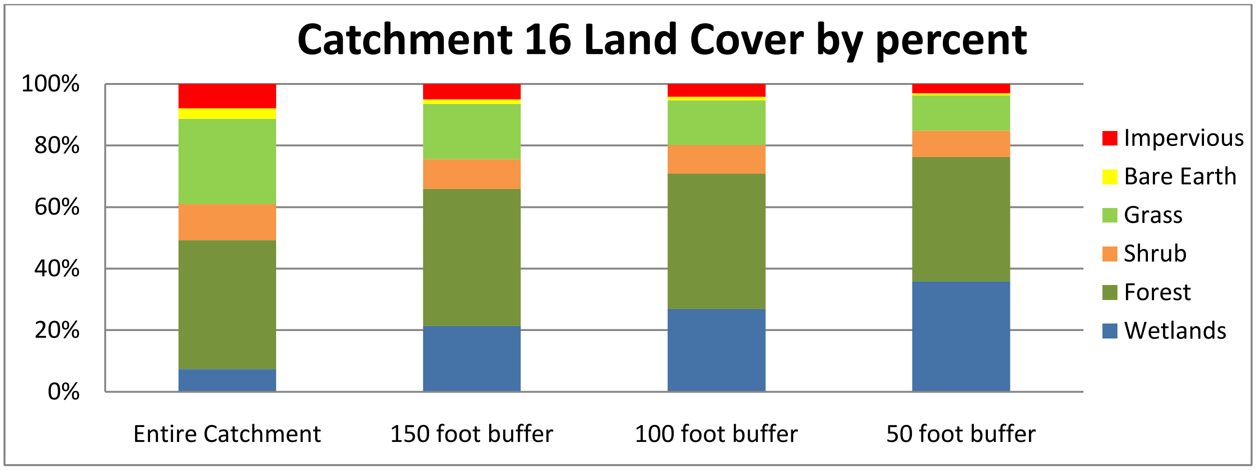

**Figure 51 Land cover characterization within headwater stream Catchment 16.**

## Catchment 17

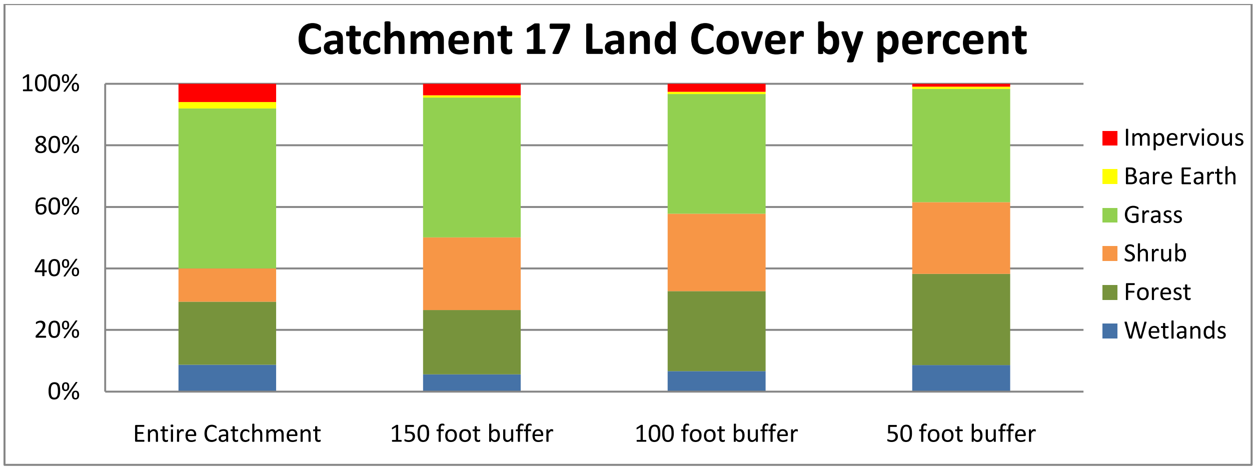

**Figure 52 Land cover characterization within headwater stream Catchment 17.**

## Catchment 18

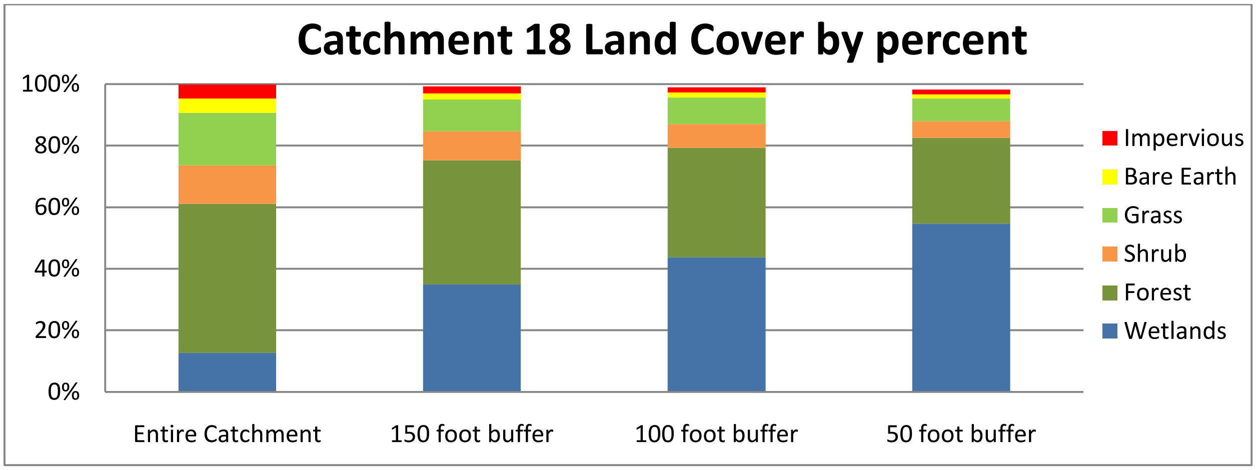

**Figure 53 Land cover characterization within headwater stream Catchment 18.**

### Catchment 19

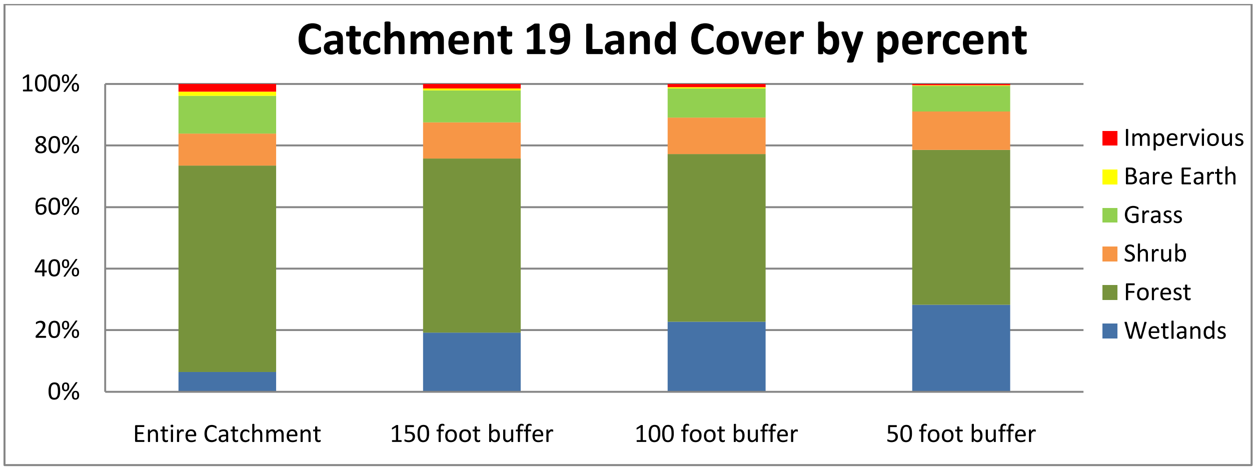

**Figure 54 Land cover characterization within headwater stream Catchment 19.**

### Catchment 20

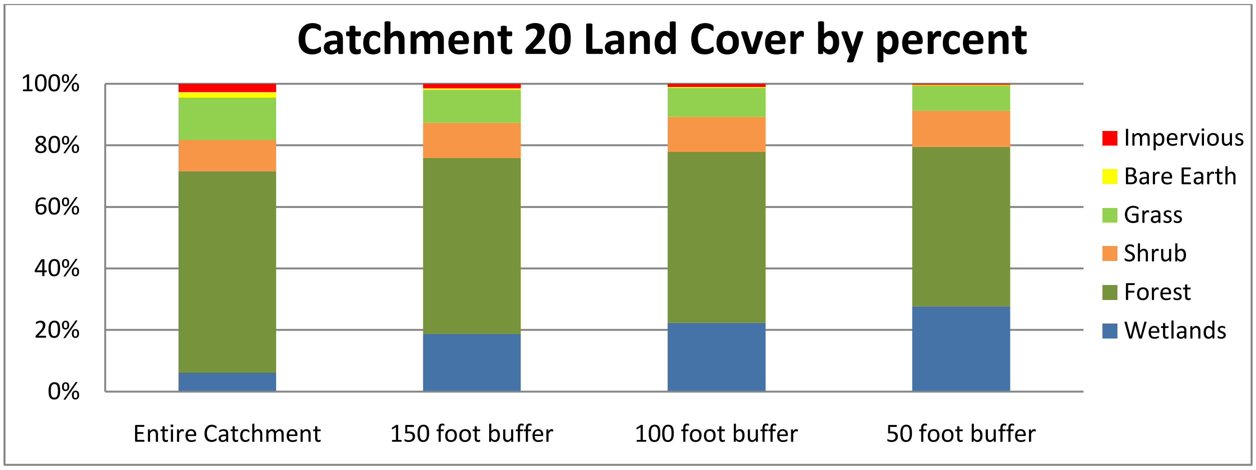

**Figure 55 Land cover characterization within headwater stream Catchment 20.**

### Catchment 21

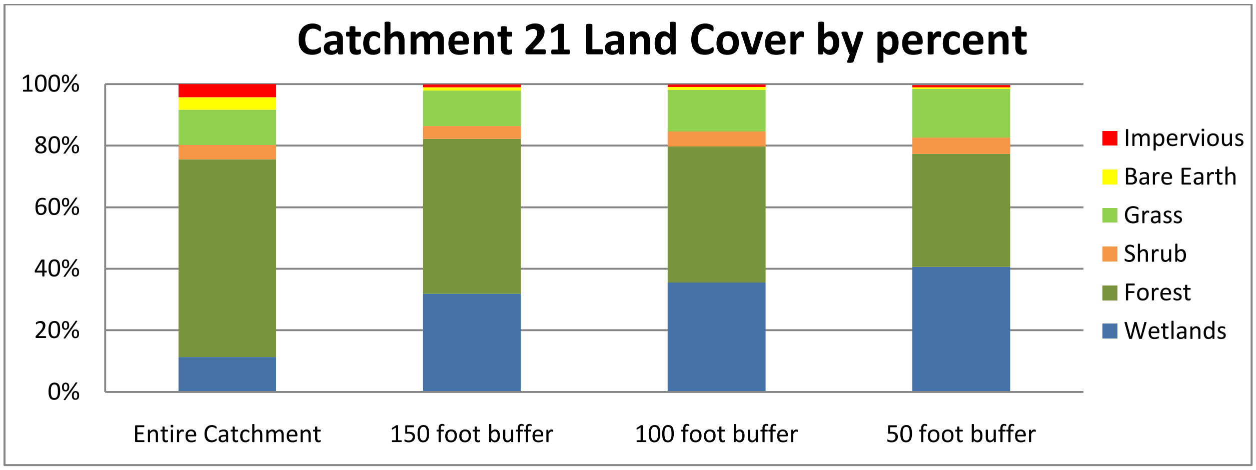

**Figure 56 Land cover characterization within headwater stream Catchment 21.**

## Catchment 22

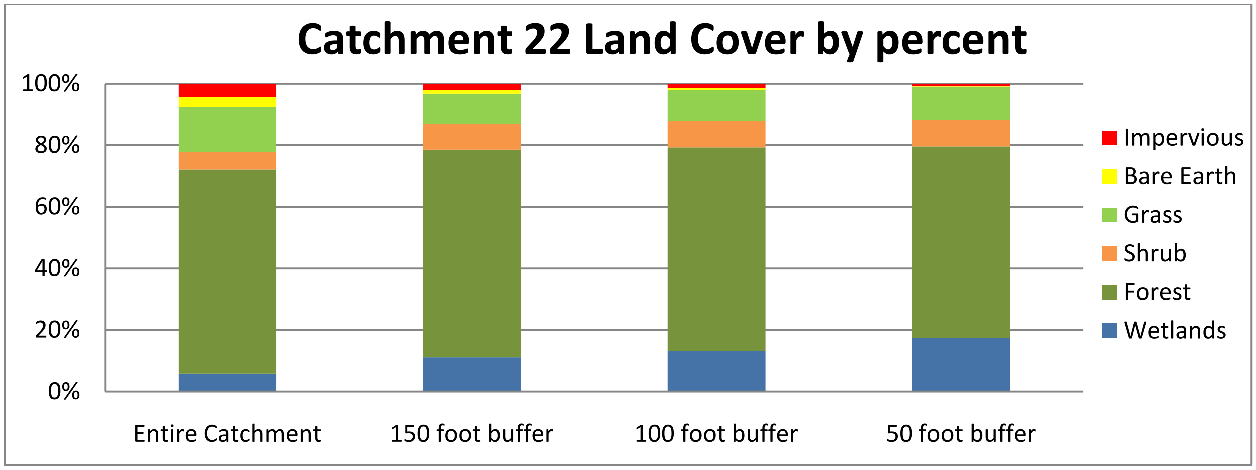

**Figure 57 Land cover characterization within headwater stream Catchment 22.**

## Catchment 23

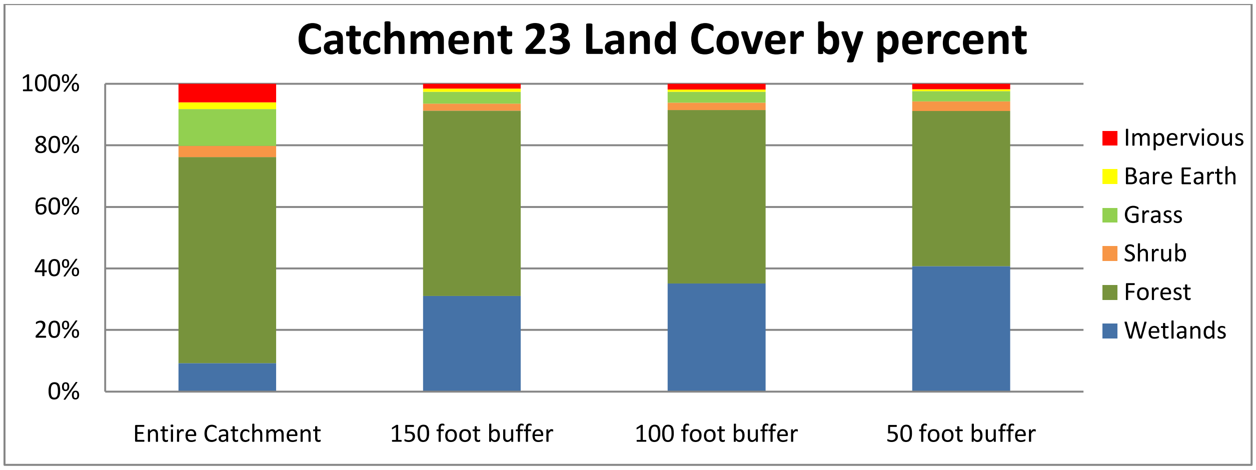

**Figure 58 Land cover characterization within headwater stream Catchment 23.**

# 4. Conclusions

## 4.1. Challenges and Limitations

The most significant challenge that arose among all catchments was the variation observed due to climactic fluctuations between years. 2008 was a fairly normal year, while 2009 was a very hot year and flows were very low during the late summer. 2010 was a very wet and cloudy year. A number of early summer storms greatly affected flow and visibly changed streambed morphology in some streams. It is clear that three years of data will not be sufficient to differentiate climactic flux from development-induced disturbance. Over half of all catchment sample sites are located on private property. Land owners appear to be very supportive of the catchment project in general. However, as property changes ownership, it is likely that permission for entry at some catchments will be lost. The breadth of catchment types in terms of area, development potential, and land cover should help to alleviate loss of statistical power, should catchment numbers decline.

The strategy of targeting small catchments for this study gives us the best possibility of detecting impacts to riparian ecosystem 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. Variation of debris transport and deposition between years can further complicate this issue. These small streams did vary yearly, especially in late summer. Although all streams did flow the entire year, there were some instances of subsurface flow in reaches of streams that were underlain by sand and gravel.

Finally, the diversity of local conditions 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 land use as well as instream impacts may affect the degree and rate of change to physical and biological conditions more than overall catchment characteristics. Multi-dimensional statistical analysis should help to alleviate this issue once sufficient data has been collected. Nevertheless, this issue requires further analysis and discussion.

## 4.2. Recommendations and Next Steps

Assessment and modification of the catchment pairing is a key next step as development pressures begin to escalate once again. To address the 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. Sites may then be post-evaluated for pairing based on catchment and instream characteristics and potential for future development. Alternatively, sampled catchments 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, 2009, and 2010 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. Conductivity, along with other water quality measures, was collected three times each year in 2009, and 2010. Availability of continuous conductivity loggers will be investigated for sampling in the future, should the program be reinitiated. 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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# Appendix

## Water Quality

| Report ID | Catchment ID | Collection Date | Temp (oC) | pH | DO (mg/L) | Conductivity (ug/L) | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|
| 1 | 5-149 | 07/23/09 | 12.44 | 7.7 | 10.38 | 142.7 | 3.7 |
| 1 | 5-149 | 08/25/09 | 11.78 | 7.67 | 10.62 | 138.2 | 9.67 |
| 1 | 5-149 | 10/23/09 | 10.29 | 7.66 | 10.63 | 121.3 | 2.43 |
| 1 | 5-149 | 06/04/10 | 9.8 | 7.52 | 10.98 | 108.7 | 3.59 |
| 1 | 5-149 | 09/01/10 | 9.8 | 7.52 | 10.98 | 108.7 | 3.59 |
| 2 | 5-187 | 06/26/09 | 11.56 | 7.71 | 9.77 | 172.3 | 3.62 |
| 2 | 5-187 | 08/20/09 | 17.48 | 7.36 | 7.5 | 194.4 | 2.6 |
| 2 | 5-187 | 10/23/09 | 10.71 | 6.81 | 10.06 | 159.5 | 3.9 |
| 2 | 5-187 | 05/19/10 | 15.47 | 7.6 | 8.47 | 122 | 2 |
| 2 | 5-187 | 08/03/10 | 13.41 | 7.17 | 9.62 | 173.8 | 0.99 |
| 3 | 5-2A | 07/09/09 | 11.25 | 7.01 | 9.3 | 69.9 | 0.45 |
| 3 | 5-2A | 05/19/10 | 9.12 | 7.42 | 10.9 | 55.3 | 6.26 |
| 3 | 5-2A | 09/01/10 | 12.2 | 7.25 | 10.19 | 83.5 | 1.08 |
| 4 | 5-2B | 07/09/09 | 13.64 | 7.24 | 8.9 | 95.1 | 1.31 |
| 4 | 5-2B | 09/10/09 | 13.5 | 7.27 | 8.12 | 136.8 | |
| 4 | 5-2B | 10/16/09 | 11.79 | 7.36 | 9.6 | 104 | 1.54 |
| 4 | 5-2B | 05/20/10 | 10.78 | 7.6 | 10.7 | 51 | 2.18 |
| 4 | 5-2B | 08/03/10 | 15.54 | 8.05 | 8.85 | 86.4 | 0.94 |
| 5 | 5-300 | 07/23/09 | 14.88 | 7.49 | 9.33 | 190 | 7.14 |
| 5 | 5-300 | 08/25/09 | 14.04 | 7.58 | 9.68 | 176.1 | 2.12 |
| 5 | 5-300 | 10/23/09 | 10.97 | 7.55 | 9.98 | 127.9 | 5.21 |
| 5 | 5-300 | 05/04/10 | 11.95 | 7.56 | 10.44 | 94 | 5.39 |
| 5 | 5-300 | 09/08/10 | 13.03 | 7.2 | 9.92 | 134 | 1.3 |
| 6 | 5-305 | 06/26/09 | 11.56 | 7.38 | 10.42 | 107.2 | 1.929 |
| 6 | 5-305 | 08/25/09 | 12.52 | 6.82 | 9.97 | 122.9 | 0.65 |
| 6 | 5-305 | 09/08/09 | 11.5 | 6.98 | 10 | 124.2 | 1 |
| 6 | 5-305 | 10/16/09 | 10.7 | 7.29 | 9.61 | 157.2 | 1.74 |
| 6 | 5-305 | 06/04/10 | 10.49 | 6.82 | 10.74 | 62.5 | 2.03 |
| 6 | 5-305 | 09/03/10 | 12.07 | 7.26 | 10.17 | 117 | 0.67 |
| 7 | 5-37 | 07/09/09 | 12.75 | 7.72 | 10.33 | 114.5 | 1.48 |
| 7 | 5-37 | 08/20/09 | 13.26 | 7.33 | 9.67 | 117.3 | 1.17 |
| 7 | 5-37 | 05/20/10 | 9.98 | 7.86 | 11.22 | 99 | 2.45 |
| 7 | 5-37 | 09/03/10 | 11.32 | 7.26 | 10.89 | 108.7 | 2.51 |
| 8 | 5-3C | 07/17/09 | 12.6 | 7.57 | 10.01 | 195.6 | 0.76 |
| 8 | 5-3C | 09/17/09 | 11.86 | 7.3 | 10.4 | 181.6 | 0.56 |
| 8 | 5-3C | 05/20/10 | 10.01 | 7.52 | 10.91 | 106.7 | 0.74 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | 5-3C | 08/26/10 | 11.28 | 7.52 | 10.22 | 203.1 | 0.77 |
| 9 | 5-42 | 09/08/09 | 13.71 | 7.28 | 9.18 | 302.1 | 2.29 |
| 9 | 5-42 | 09/17/09 | | | | | |
| 9 | 5-42 | 10/23/09 | 11.33 | 7.28 | 10.15 | 269.5 | 9.31 |
| 9 | 5-42 | 05/19/10 | 13.58 | 7.65 | 9.91 | 193.4 | 3.68 |
| 9 | 5-42 | 08/03/10 | 14.8 | 7.44 | 9.25 | 308.3 | 4.03 |
| 10 | 5-54 | 06/26/09 | 13.52 | 6.95 | 9.9 | 175.4 | 1.21 |
| 10 | 5-54 | 08/27/09 | 16.99 | 7.39 | 9 | 199.6 | 1.69 |
| 10 | 5-54 | 10/16/09 | 12.11 | 7.59 | 9.24 | 187.5 | 0.87 |
| 10 | 5-54 | 05/15/10 | 13.81 | 7.7 | 9.86 | 120.5 | 3.17 |
| 10 | 5-54 | 08/03/10 | 14.82 | 7.33 | 8.95 | 175.4 | 1.33 |
| 11 | 7-1A | 07/10/09 | 16.18 | 7.2 | 9.15 | 55.5 | 1.84 |
| 11 | 7-1A | 08/19/09 | 16.65 | 7.21 | 8.19 | 63.4 | 2.01 |
| 11 | 7-1A | 10/02/09 | 10.32 | 7.97 | 10.39 | 58.9 | 1.73 |
| 11 | 7-1A | 05/18/10 | 14.19 | 7.43 | 10.11 | 26.2 | 3.4 |
| 11 | 7-1A | 08/10/10 | 15.46 | 7.14 | 9.06 | 53.5 | 2.8 |
| 12 | 7-1C | 07/10/09 | 15.57 | 7.02 | 7.56 | 55.6 | 8.51 |
| 12 | 7-1C | 08/27/09 | 12.95 | 6.73 | 9.37 | 59.7 | 1.52 |
| 12 | 7-1C | 08/05/10 | 17.02 | 7.03 | 8.53 | 55.2 | 2.78 |
| 13 | 7-221 | 10/02/09 | 10.3 | 7.67 | 10.66 | 100.4 | 0.67 |
| 13 | 7-221 | 05/17/10 | 14.26 | 7.35 | 9.89 | 50.7 | 1.61 |
| 13 | 7-221 | 08/04/10 | 15.78 | 7.82 | 9.39 | 74.2 | 2.88 |
| 13 | 7-221 | 10/27/10 | 8.94 | 7.22 | 8.94 | 102.3 | 0.43 |
| 14 | 7-235 | 06/19/09 | 14.31 | 7.1 | 8.04 | 78.2 | 4.45 |
| 14 | 7-235 | 08/19/09 | 15.47 | 6.97 | 5.56 | 80.5 | 3.16 |
| 14 | 7-235 | 10/16/09 | 10.22 | 6.47 | 9.17 | 76.6 | 4.47 |
| 14 | 7-235 | 05/18/10 | 13.49 | 6.99 | 9.28 | 42.9 | 3.08 |
| 14 | 7-235 | 08/13/10 | 14.76 | 6.91 | 8.03 | 68.7 | 2.5 |
| 15 | 7-279 | 07/17/09 | 17.4 | 7.53 | 9.3 | 142.3 | 1.48 |
| 15 | 7-279 | 09/01/09 | 14.92 | 7.08 | 9.67 | 142 | 0.99 |
| 15 | 7-279 | 10/30/09 | 9.78 | 7.17 | 10.66 | 77.1 | 5.47 |
| 15 | 7-279 | 05/17/10 | 13.93 | 7.47 | 10.16 | 86.4 | 1.98 |
| 15 | 7-279 | 08/10/10 | 15.05 | 7.33 | 9.54 | 133.3 | 1.65 |
| 16 | 7-282 | 06/16/09 | 14.41 | 7.28 | 10.3 | 127.5 | 6.13 |
| 16 | 7-282 | 09/04/09 | 14.27 | 7.29 | 10.12 | 141.7 | 0.89 |
| 16 | 7-282 | 05/17/10 | 12.49 | 7.46 | 10.62 | 105.2 | 1.06 |
| 16 | 7-282 | 08/18/10 | 14.94 | 7.46 | 10.1 | 132.5 | 0.6 |
| 17 | 7-329 | 07/18/09 | 20.59 | 7.83 | 7.63 | 167.8 | 1.93 |
| 17 | 7-329 | 07/18/09 | 19.92 | 7.46 | 7.9 | 80.6 | 3.12 |
| 17 | 7-329 | 10/30/09 | 10.74 | 7.27 | 10.22 | 98.1 | 2.95 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 17 | 7-329 | 10/30/09 | 10.37 | 7.39 | 10.31 | 98.2 | 3.21 |
| 17 | 7-329 | 05/17/10 | 13.56 | 7.59 | 9.75 | 125.8 | 6.67 |
| 17 | 7-329 | 05/17/10 | 13.95 | 7.75 | 9.67 | 125.2 | |
| 17 | 7-329 | 08/04/10 | 14.88 | 7.4 | 9.36 | 179.7 | 2.69 |
| 17 | 7-329 | 08/04/10 | 16 | 7.6 | 8.97 | 176.4 | 3.29 |
| 18 | 7-3A | 07/10/09 | 14.09 | 7.46 | 9.72 | 107 | 0.52 |
| 18 | 7-3A | 09/02/09 | 13.6 | 7.51 | 10.22 | 120.8 | 0.83 |
| 18 | 7-3A | 10/30/09 | 8.83 | 7.27 | 10.5 | 51.6 | 1.38 |
| 18 | 7-3A | 06/04/10 | 13.88 | 6.95 | 9.66 | 46.9 | |
| 18 | 7-3A | 08/26/10 | 11.33 | 7.27 | 10.28 | 114.5 | 0.38 |
| 19 | 7-72 | 06/19/09 | 16.03 | 7.67 | 9.7 | 74.3 | 1.56 |
| 19 | 7-72 | 08/24/09 | 16.49 | 7.01 | 9.41 | 69.3 | 1.86 |
| 19 | 7-72 | 10/30/09 | 10.71 | 7.21 | 10.84 | 78.1 | 1.75 |
| 19 | 7-72 | 05/19/10 | 15.09 | 7.49 | 9.92 | 72.8 | 1.55 |
| 19 | 7-72 | 08/02/10 | 16.42 | 7.34 | 9.11 | 82.9 | 1.05 |
| 20 | 7-933 | 06/19/09 | 15.26 | 7.17 | 9.67 | 71.1 | 1.82 |
| 20 | 7-933 | 08/18/09 | 16.13 | 7.36 | 9.88 | 70.3 | 4.59 |
| 20 | 7-933 | 10/16/09 | 10.98 | 7.35 | 9.9 | 78 | 5.73 |
| 20 | 7-933 | 05/18/10 | 12.65 | 6.99 | 10.33 | 71.7 | 2.13 |
| 20 | 7-933 | 08/17/10 | 19.54 | 7.09 | 8.89 | 82.9 | 3.82 |
| 21 | 7-981 | 07/23/09 | 13.03 | 7.14 | 9.97 | 45.6 | 0.81 |
| 21 | 7-981 | 08/26/09 | 16.43 | 7.05 | 8.19 | 77.8 | 5.27 |
| 21 | 7-981 | 05/19/10 | 14.51 | 6.9 | 8.1 | 64.5 | 0.94 |
| 21 | 7-981 | 08/02/10 | 17.74 | 6.89 | 5.85 | 72 | 2.88 |
| 22 | 7-982 | 07/23/09 | 13.03 | 7.14 | 9.97 | 45.6 | 0.81 |
| 22 | 7-982 | 08/26/09 | 13.1 | 7.03 | 10.31 | 57.6 | 1.04 |
| 22 | 7-982 | 10/16/09 | 12.63 | 7.49 | 9.72 | 56 | 2.35 |
| 22 | 7-982 | 05/19/10 | 10.91 | 6.91 | 10.5 | 49.5 | 0.88 |
| 22 | 7-982 | 08/02/10 | 14.26 | 7.42 | 9.62 | 54.5 | 1.49 |
| 23 | 8-156 | 07/31/09 | 23.55 | 6.35 | 6.55 | 94.1 | 1.43 |
| 23 | 8-156 | 08/21/09 | 17.53 | 6.85 | 6.06 | 96.6 | 11.7 |
| 23 | 8-156 | 10/30/09 | 8.69 | 6.89 | 8.75 | 62.6 | 1.83 |
| 23 | 8-156 | 05/17/10 | 15.01 | 6.75 | 8.71 | 71.9 | 1.73 |
| 23 | 8-156 | 08/18/10 | 17.81 | 6.87 | 6.66 | 93.7 | 1.41 |