Clackamas County Water Environment Services

Clackamas County Service District #1

Benthic Macroinvertebrate and Geomorphological Monitoring Report 2014

FINAL REPORT- June 3, 2015

prepared by

WATERWAYS CONSULTING, INC.

COLE ECOLOGICAL, Inc.

TABLE OF CONTENTS

Figures

Tables

Appendices

1.0 INTRODUCTION

1.1 INTRODUCTION

As Portland, Oregon's popularity and population increase, so do the demands on regional and local resource managers to maintain and improve aquatic resource conditions, functions and values. Clackamas County Water Environment Services (hereafter referred to as WES), is one of a number of agencies responsible for wastewater and stormwater management in the region. In an effort to better understand the effects of these management activities on watershed health and the status of aquatic resources in the district, WES periodically assesses aquatic resource and physical habitat conditions as part of their watershed health focus and integrated watershed management approach. The information and data derived from this monitoring are used to help determine the success of water resource management efforts and inform future work.

Macroinvertebrate assessments were initiated by WES in 2002 to evaluate the condition of streams within Clackamas County Service District Number 1 (CCSD #1) and the Surface Water Management Agency of Clackamas County (SWMACC Macroinvertebrate communities, physical habitat, and water chemistry were sampled within these two service areas in the fall of 2002 (Cole 2003), 2007 (Lemke and Cole 2008a; Lemke and Cole 2008b), 2009 (Lemke and Cole 2010a; Lemke and Cole 2010b), 2011 (Lemke et al. 2012a, Lemke et al. 2012b) and most recently in 2014. Starting in 2009, following development of basin plans for the Kellogg-Mt. Scott and Rock Creek Watersheds, WES expanded their efforts to include assessments of stream geomorphology (2009, 2011 and 2014). While some overlap in macroinvertebrate and geomorphic monitoring reaches occurred in 2009, an effort was made in 2011 to co-locate the monitoring reaches to more comprehensively assess aquatic resource conditions in monitored reaches. Assessments conducted at eight of the 23 CCSD #1 monitoring reaches in 2014 included biological (macroinvertebrates), physical habitat, synoptic water quality, and geomorphic parameters. Macroinvertebrate monitoring was conducted in an additional seven reaches, while geomorphic monitoring was conducted in an additional eight reaches. The intent of these efforts is to provide a robust characterization of conditions within CCSD#1 stream reaches.

1.2 SETTING

WES performs stormwater management activities in two districts: Clackamas County Service District #1 (CCSD #1) and the Surface Water Management Agency of Clackamas County (SWMACC), both in northern Clackamas County. Most of the CCSD #1 area occurs within Portland's Urban Growth Boundary (UGB) and includes the Kellogg/Mt Scott Creeks drainage, as well as Rock Creek and a number of smaller creeks and tributary drainages (Figure 1:). The Kellogg/Mt. Scott creeks watershed is the largest drainage predominantly contained within CCSD #1. The watershed drains 40.5 square kilometers in a westerly direction through heavy residential development to the Willamette River. Rock Creek, draining 25.0 square kilometers, is located to the east of Mt. Scott Creek. Only the lower portion of the drainage occurs inside the service district. Rock Creek and three smaller drainages to the west—Carli (1.4 square km drainage), Sieben (5.3 square km drainage), and Cow (3.3 square km drainage) creeks—flow through a mosaic of suburban and rural land use to discharge directly into the Clackamas River, which bisects northern Clackamas County on its course to the Willamette River. The topography within CCSD #1 is primarily gently rolling hills. Land use varies from urban to rural with some small remaining tracts of forested and agricultural (upper half of Rock Creek watershed) lands. The Kellogg-Mt. Scott subbasin is a highly developed urban watershed that is approximately 34% impervious, while the Rock Creek subbasin was estimated to be approximately 13% impervious in 2007. Areas of more topographic relief within CCSD #1 support streams with higher gradients, more heterogeneous habitat (riffle/pool complexes), and larger and more heterogeneous substrate; whereas areas with little or no topographic relief contain low-gradient streams with primarily pool and glide habitat and finer streambed materials.

In most cases, stream channels within the study area have been impacted by current or past land uses and by direct channel modification, each of which have contributed to the alteration of natural hydrology and morphology of these systems. These changes have no doubt affected stream physical habitat and water quality, which in turn have led to varying degrees of degradation of aquatic communities. Given trends in future development of the Portland metropolitan area, it is likely that there will be increased pressure on streams and their watersheds in the CCSD #1 service area from urban and suburban development and a continued trend towards increasing hydromodification.

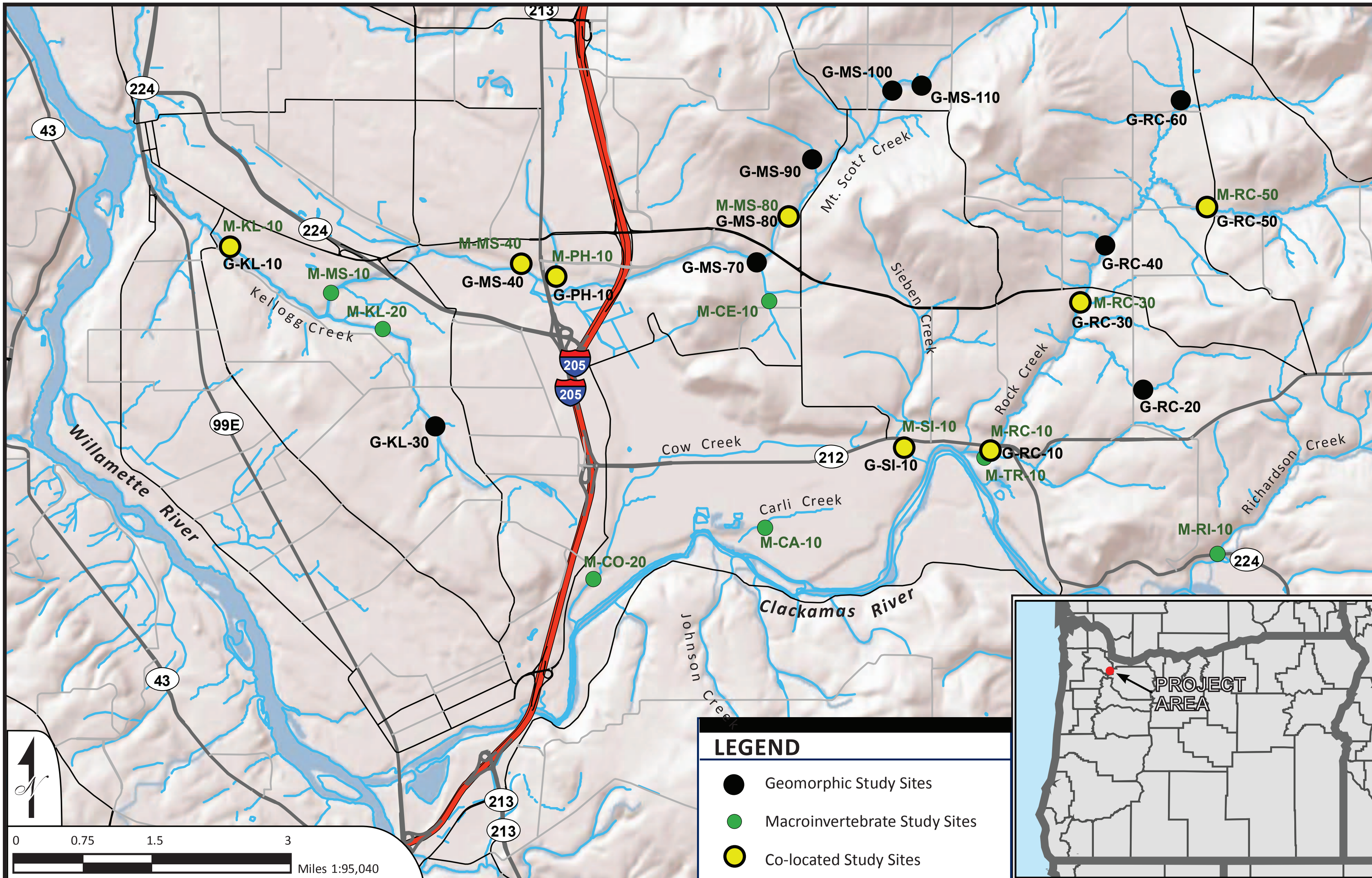


FIGURE 1

Geomorphic and Macroinvertebrate Study Sites for 2014 in Clackamas County's Service District 1 (SD1) near Portland, Oregon.

WES MONITORING

SD1 FINAL REPORT
JUNE 2015

WATERWAYS CONSULTING, INC.
Santa Cruz, CA | watways.com | Portland, OR

1.3 PROJECT NEED / OBJECTIVES

Much of the CCSD#1 District has been or is in the process of being urbanized. In addition, much of the watershed was historically converted from forest to agricultural uses, a gridded pattern of roads have been developed, stream channels have been directly modified, and wetlands have been filled. This process has been shown to modify the timing and magnitude of discharge to stream channels and is referred to as hydromodification. Hydromodification has the potential to affect the morphologic character of stream channels that receive affected storm flows. The effects of hydromodification are often observed throughout the channel network since, functionally, the geometry of a stream channel (e.g. – channel width, channel depth) is directly correlated with discharge.

When the hydrology of a watershed is modified, the observed changes have a profound effect on the character of stream channels, both spatially and temporally. Headwater channels often incise, widen, and experience headward migration. Erosion in these headwater channels results in aggradation and widening of higher order channels downstream. Eventually the headwater channels adjust and the process is typically transferred downstream. Main stem channels often go through cycles of aggradation and downcutting in response to the processes occurring in the lower order channels upstream. Typically, bank erosion is a significant issue in main stem channels as they aggrade, downcut, and widen. Ultimately, these hydrologic and geomorphic changes result in degradation of physical habitat and water quality conditions necessary to support healthy, diverse, native aquatic communities (fish and macroinvertebrates, in particular). Eventually, stream channels adjust to changes in the hydrology of the watershed and reach some degree of equilibrium. The length of time it takes to reach equilibrium varies on a reach by reach basis and is a function of the magnitude of the impact, substrate conditions, riparian corridor conditions and a variety of other factors.

Evaluating the effects of hydromodification on stream channels requires a characterization of channel conditions over time. While a one-time evaluation provides an understanding of the extent to which channel conditions have deviated from a desired state as a result of hydromodification, the rate of change and trajectory of that change will remain unknown. To fully understand the effects of hydromodification on a watershed requires a time series of data throughout the watershed.

In response to the need to understand how watershed conditions are changing over time and a desire to monitor the effectiveness of stormwater management practices and treatments designed to mitigate the impacts of hydromodification, WES retained Waterways Consulting, Inc. and Cole Ecological, Inc. to perform a comprehensive aquatic resource and geomorphic assessment within CCSD#1. This assessment was aimed at characterizing current conditions, and determining changes and trends in relation to past conditions. The results will also be used to compare with future surveys to continue to evaluate the effects of changing land use and stormwater management strategies over time. This report provides a detailed description of the methods, results, and interpretation of this comprehensive aquatic resource assessment conducted in 2014, as well as comparisons with results from previous years. These results are used to identify changes in resource conditions over time and evaluate the need for management actions, particularly in relation to addressing hydromodification, improving the capacity of streams to support diverse, native aquatic communities, and to improving overall watershed health.

2.0 ASSESSMENT METHODOLOGY

The assessment methodology was designed to establish and evaluate discrete sampling areas, or reaches, distributed throughout the CCSD #1 service area, using a sampling approach that was efficient and repeatable to understand trends at both local (reach) and (to a certain degree) watershed scales. The results and interpretation of the data allow for inference of both reach-specific and watershed-scale conditions. The data allow for general examination and detection of broad longitudinal (upstream to downstream) trends resulting from *cumulative net effects* of disturbance versus restoration activities , but are not meant to identify site-specific effects from particular activities. A more robust sampling and experimental design would be necessary to make inferences regarding the effects of specific activities on specific reaches. Moreover, the data from this study cannot be used to make inferences regarding reach-specific conditions, channel instability, or degradation occurring *outside* of the discrete study reaches. A more complete inventory of reaches throughout these drainage networks would be necessary to understand conditions at the reach scale across the length of these networks.

In total, 23 reaches were sampled within the CCSD#1 area in 2014 (Figure 1; Table 1). Macroinvertebrate assessments were conducted in 15 reaches, while geomorphic assessments were conducted in 16 reaches; 8 of these monitoring reaches overlapped.

2.1 SITE SELECTION

A preliminary list of possible survey sites was prepared in 2009 based upon existing WES biological assessment sites and recommendations included in the Watershed Action Plans for Kellogg/Mt Scott and Rock Creeks. To refine the list, WES, Waterways Consulting, and ABR, Inc. team members met to discuss site access, monitoring goals, and the suitability of individual sites to the goal of long term monitoring. Before survey activities began, Waterways conducted field reconnaissance to evaluate access and other potential constraints at the targeted sites. Landowner outreach was performed by WES securing access permission for sites not located on public land. From these efforts a list of 18 targeted survey sites was agreed upon in 2009. One site was removed from the list (Site SD1-G16) because landowner access was not granted, resulting in a total of 17 sites surveyed in 2009.

In 2011, the monitoring sites surveyed in 2009 were revaluated by WES and ABR. In all but one case, the same sites were resurveyed in 2011. For 2011, site SD1-G15 was dropped because it was determined at a subsequent field visit that the original selection of the site as a reference condition for the rest of the SD1 sites was difficult to justify given the impacted condition of lower Richardson Creek. The same sites surveyed in 2014 were surveyed in 2011 with a few exceptions. In 2014, Cedar Creek was not sampled for macroinvertebrates because flows were insufficient. Table 1 provides site information for the 2014 geomorphic and macroinvertebrate survey reaches.

A description of site codes:

To standardize the naming convention at each of the sites a new site nomenclature system was developed following completion of the sampling in 2011. These site codes were utilized in this report and the 2011 report. The first letter (M or G) identifies the sampling location as either a macroinvertebrate site or a geomorphic site. The second group of letters is a two letter code representing the stream name. The numbers at the end of the code represent the proximity to the mouth of the stream relative to the overall length of the channel. As the numbers increase, the site moves farther upstream from the mouth of the stream. Example:

M-KL-10

M: Macroinvertebrate Reach
KL: Kellogg Creek
10: Approximately 10% of the total distance from the mouth to the headwaters.

Table 1. Site information for stream reaches where channel morphology assessment was conducted in Clackamas County Service District #1 (CCSD #1), Oregon.

Reach ID	Previous Site Codes	Stream	Reach Description	Latitude / Longitude	Years Sampled
Kellogg Creek Subbasin					
M-KL-10 G-KL-10	SD1-M18 SD1-G11	Kellogg Creek	Upstream of Kellogg Lake behind Rowe Middle School	-122.627590 / 45.431408	M: 09,11,14 G: 09,11,14
M-KL-20	SD1-M12a	Kellogg Creek	Upstream of Rusk Road	-122.47233 / 45.39766	M: 11,14
G-KL-30	SD1-G12	Kellogg Creek	Along Aldercrest Court	-122.595816 / 45.411825	G: 09,11,14
Mt. Scott Creek Subbasin					
M-MS-10	SD1-M4a	Mt. Scott Creek	Mt. Scott Creek North Clackamas Park	-122.61228 / 45.42657	M: 11,14
M-MS-40 G-MS-40	SD1-M3 SD1-G10	Mt. Scott Creek	Downstream of Route 213 behind N. Clackamas Aquatic Center, Three Creeks Restoration Site	-122.581013 / 45.429195	M: 02,07,09,11,14 G: 09,11,14
G-MS-70	SD1-G5	Mt. Scott Creek	Downstream of SE Sunnyside Rd	-122.545050 / 45.430010	G: 09,11,14
M-MS-80 G-MS-80	SD1-M2 SD1-G6	Mt. Scott Creek	Upstream of 122nd and Sunnyside intersection; downstream of Spring Mountain dam removal project	-122.538525 / 45.435633	M: *02,*07,*09,11,14 G: 09,11,14
G-MS-90	SD1-G13	Mt. Scott Creek	Along public footpath between SE Cedar Way and SE Otty Rd	-122.536271 / 45.441385	G: 09,11,14
G-MS-100	SD1-G7	Mt. Scott Creek	Upstream of King Rd; Happy Valley City Park	-122.523676 / 45.448990	G: 09,11,14
G-MS-110	SD1-G8	Mt. Scott Creek	Downstream of SE 145th Ave.; Happy Valley City Park	-122.518994 / 45.449554	G: 09,11,14
M-PH-10 G-PH-10	SD1-M5a SD1-G9	Phillips Creek	Upstream of SE 84th Ave.	-122.576544 / 45.428978	M: 02*,07*,09*,11,14 G: 09,11,14
M-CE-10	SD1-M15	Cedar Creek	Downstream of Mather Rd.	-122.54313 / 45.42570	M: 02, 07, 09, 11
Rock Creek Subbasin					
M-RC-10 G-RC-10	SD1-M10a SD1-G1	Rock Creek	~120 m upstream of the confluence with Trillium Creek	-122.507913 / 45.409126	M: 02*,07*,09*,11,14 G: 09,11,14
G-RC-20	SD1-G2	Rock Creek	Tributary to lower Rock Creek off of SE 172nd Ave.	-122.484009 / 45.415894	G: 09,11,14
M-RC-30 G-RC-30	SD1-M11a SD1-G3	Rock Creek	Downstream of Sunnyside Rd.	-122.493493 / 45.426235	M: 02*,07*,09*,11,14 G: 09,11,14
G-RC-40	SD1-G4	Rock Creek	Downstream of SE 172nd Ave. South of Troge Rd	-122.490070 / 45.431893	G: 09,11,14
M-RC-50 G-RC-50	SD1-M17 SD1-G17	Rock Creek	Along Troge Rd at Foster Rd.	-122.472508 / 45.435700	M: 09,11,14 G: 09,11,14
G-RC-60	SD1-G18	Rock Creek	Tributary to upper Rock Creek upstream of SE Hemrick Rd.	-122.478122 / 45.447941	G: 09,11,14
M-TR-10	SD1-M7a	Trillium Creek	Near Confluence with Rock Creek	-122.50910 / 45.40830	M: 09,11,14
Tributaries to the Clackamas River					
M-CA-10	SD1-M16	Carli Creek	~300m downstream of SE 120th Ave.	-122.54375 / 45.40056	M: 07,09,11,14
M-CO-20	SD1-M14a	Cow Creek	Downstream of private driveway off of SE Dean Drive	-122.57084 / 45.39488	M: 11,14
M-RI-10	SD1-M12	Richardson Creek	Upstream of Highway 224	-122.47233 / 45.39766	M: 02,07,09,11,14
M-SI-10 G-SI-10	SD1-M8 SD1-G14	Sieben Creek	Downstream of Hwy 212/224	-122.521944 / 45.409770	M: 02,07,09,11,14 G: 09,11,14

* asterisk in the "Years Macros Sampled" column indicates a shifted reach location, but not by more than 200m from 2014 reach
Latitude/Longitude listed corresponds to the site benchmark recorded using a hand held GPS unit.
"M"=Macroinvertebrate, "G"=Geomorphic

2.2 GEOMORPHIC MONITORING

The geomorphic assessment at each of the sites included the following five elements:

1) Longitudinal and cross section profile surveys;
2) Measurement of surficial substrate conditions;
3) Collection of a bulk sample of bed conditions;
4) Measurement of pool characteristics, and an
5) Assessment of bank conditions at various sites throughout the CCSD #1 area.

The following sections provide detailed descriptions of the methods utilized in conducting this assessment.

2.2.1 Geomorphic Site Monumentation and Reoccupation

The primary objective of this geomorphic monitoring effort was and is to characterize baseline conditions and reoccupy the same locations in the future to assess rates of change over time. Consequently, establishing long-term monumentation that was not prone to vandalism but was easy to find and reoccupy was critical.

At each site, a permanent benchmark was established and monumented with a 3/8 x 12 inch rebar stake to establish a reference elevation of the study site for future monitoring efforts. Similarly, rebar stakes were used to monument cross section endpoints. In addition to a rebar stake, GPS points, photos and notes were collected further describing each benchmark and cross section endpoint locations in 2009. Benchmark locations were selected with accessibility and longevity in mind. The use of rebar allowed the ability to place the monument flush with the ground to prevent vandalism and the ability to relocate the monument with a metal detector for reoccupation of the same location. Where foot traffic was light, additional visual aids, such as flagging or wood lathe, were placed at the site to further aid relocation. Upon resurvey in 2014 some monuments had been disturbed or could not be located, in which case new rebar was set at the closest location possible using the available information. Elevation adjustment were made, where necessary, to account for any new monumentation that was established.

2.2.2 Geomorphic Field Data Collection

For the 2014 geomorphic monitoring year, field data was collected between 4 November 2014 and 17 December 2014. The following sections describe the methods and equipment used to perform longitudinal and cross section profile surveys, characterize surficial and bed substrate conditions, pool characteristics and bank conditions.

Longitudinal Profile Survey

A longitudinal profile was measured at each site by surveying the average thalweg profile. Surveys were conducted using an auto-level, 200 or 300 foot tape and a 25 foot rod. In reaches consisting of pool and riffle structure, profile points were measured mainly at riffle crests and tails. In instances where the reach structure consisted of glides or large or very deep pools, thalweg measurements were taken at changes in grade. The length of the thalweg profiles encompassed a minimum of 15-20 times the estimated average bankfull width. Site notes and photos were collected at the longitudinal profile endpoints.

The location of longitudinal profiles were chosen to capture geomorphic information in areas containing depositional features (riffles, bars, etc.), where feasible, or to identify features such as knickpoints[1]. Although the endpoints of the longitudinal profiles were not monumented, every attempt was made to survey the same segment of channel.

Cross Section Survey

Cross Section surveys were conducted using an auto-level, 200 foot tape, stakes and a 25 foot rod. Section endpoints were monumented with 3/8 x 12 inch rebar stakes wherever possible. Notes and photos were also collected at the cross section endpoints. At all but one site, three cross sections were measured. Cross sections included notes depicting major breaks in slope, tops of bank, toes, bankfull estimates, right edge of water, left edge of water and thalweg.

The locations of the cross sections were chosen based upon the form of the channel, observed geomorphic characteristics, line of sight, and accessibility. Sections were established perpendicular to the stream channel, preferably at pool tails or riffle crests when possible. If areas of incision or headcuts were observed, efforts were made to measure cross sections both upstream and downstream of these features.

Pebble Counts

Pebble counts were conducted to characterize surficial substrate conditions on depositional features such as bars. The method employs techniques outlined by Wolman, 1954. Assessments were conducted under low flow conditions and counts were restricted to exposed depositional bars. Depositional features were chosen because they represent grain sizes that are moving as bed load. In some cases, pebble counts of the active bed were not conducted due a lack of exposed depositional features or where the streambed was dominated by bedrock. A bulk sample of alluvial bed material was also collected, where feasible, (discussed below) to characterize surficial and subsurface conditions.

Pebble counts were conducted as follows: Sediment was characterized by measuring the median width of 100 random "pebbles" from each exposed bar. Measurements were made using a standard metric ruler and pebbles were collected randomly from the toe of each footstep while traversing the length of the depositional feature. In an effort to minimize personal bias, each pebble count involved collection of one-half of the data points (50 pebbles each) by the two survey team members. Any particle measuring less than 1 mm was recorded as "sand".

Bulk Sediment Sample Collection

To better quantify the degree to which fine sediment is impacting aquatic habitat, bulk bed samples were collected in pool tail-out locations using the technique outlined in McNeil and Ahnell, 1964. Bulk samples were collected to characterize physical habitat conditions in a location that is important to salmonids (tail of pool). The McNeil sampler collects bed material from both the surface and subsurface and retains the fine fraction, which can be lost using other techniques (e.g. – shovel). Samples collected in the McNeil sampler were transferred to a doubled poly sample bag, labeled, and temporarily stored. Once all samples were collected they were sent to Professional

[1] A knickpoint is a term to describe a location in a channel where there is a sharp change in channel slope resulting in a pronounced discontinuity in bed elevations downstream compared to upstream (i.e. – waterfall).

Service Industries (PSI), Inc. in Portland, OR to be sorted and measured for volumetric size distribution (see Appendix D).

Pools Survey

Pools are an important indicator of the quality of aquatic habitat. Many degraded systems that have high fine sediment loads and lack structural elements are characterized by a lack of profile diversity. Pool characteristics, including the density of pools and their depth, are closely linked to geomorphic conditions and the ability of the system to create and maintain habitat quality. In an urban system, where hydromodification has occurred, a stream channel may lack deep, high quality pools because the channel has scoured to bedrock and there are little to no structural elements present to encourage sediment storage and natural pool-riffle morphology. Similarly, early stages of hydromodification may have produced high rates of erosion in the upper tributaries of a watershed resulting in sedimentation of pools along higher order stream channels where deep pools were historically abundant. By monitoring pools long-term, the underlying geomorphic and sediment transport conditions can be qualitatively evaluated.

To establish a baseline of pool characteristics, maximum pool depth and maximum residual pool depth (maximum depth minus thalweg depth at pool tail) were recorded for each pool in the project reach. A 25-foot stadia rod was used to measure pool depth. This approach provides important information about pool quality, the implications of hydromodification, and sediment transport conditions and is much less intensive than an approach such as the V* rating (Lisle and Hilton, 1992) which requires intensive sampling at multiple pools in each project reach.

Bank Erosion Evaluation

The degree of bank erosion is a good indicator of the overall stability of the channel and can define the trajectory of channel conditions (e.g. – unstable but improving, stable but degrading, etc.). Stream channels that are subjected to hydromodification go through a well-defined evolutionary process that eventually leads to a new state of quasi-equilibrium (Simon, 1989). The extent and rate of bank erosion, combined with knowledge about the degree of incision and state of riparian vegetation, are key components in understanding what stage of development the channel is in and how it might behave in the future.

To establish a baseline and to understand how hydromodification has affected each of the project reaches, areas with active bank erosion were characterized and measured. Areas of active bank erosion were rated based upon a subjective scale of activity from 1 to 5, with 1 being slightly active and 5 being very active. Height and length estimates of bank erosion areas were quantified. Areas of active erosion were recorded independently for right and left banks.

2.2.3 Geomorphic Data Analysis

Data collected in the field was compiled and analyzed and compared with monitoring results collected in previous years. The following section outlines specific methods and calculations used to assemble the data and generate appropriate site metrics. Maps, photos, and results of the physical data collection are summarized, by site, in Appendix A. The field data sheets for each site are included in Appendix C. A report from PSI, Inc. summarizing the bulk sediment sample analysis results for each site is included as Appendix D. In addition, we have provided a digital Appendix that includes all of the results, scanned copies of the data sheets, GIS data and photos of each of the sites for use in future monitoring efforts.

Longitudinal Profile Survey

Information collected for average thalweg profiles is shown in a profile figure for all reaches surveyed. Average bed slope was determined by fitting a linear trendline to all points collected during the survey. Longitudinal profiles from 2009, 2011, and 2014 are compared by lining up their intersection with the upstream cross section at the site, as some small differences can arise from exactly how the tape is arranged throughout a reach from one monitoring year to the next. Longitudinal profile figures for each site are located in Appendix A.

Cross Section Survey

As with the longitudinal profiles, each cross section profile is presented in a figure "looking downstream" with a station of 0 feet being the river left start of the cross section. Bankfull width and depth were determined for each cross section based on indicators noted in the field. In cases where bankfull indicators were of poor quality or nonexistent, bankfull was estimated based on slope breaks within the channel and indicators from other cross sections within that reach. Bankfull depth was estimated as the difference between the measured thalweg elevation and the average of noted bankfull elevations. A bankfull width to depth ratio (W/D) was calculated for each cross section. Results depicting cross section profiles and average bankfull and average W/D ratios for each site are located in Appendix A. Bankfull measurement values presented in Table 7 represent an average of all the cross sections surveyed at that site. The W/D ratio decreases as a channel incises. An entrenchment ratio was also calculated for each cross section. Entrenchment is the ratio of the flood-prone width to the bankfull width, with the flood-prone width measured at two times the bankfull depth. Thus the entrenchment ratio represents a measure of channel incision. Large entrenchment ratios indicate greater floodplain connection. An entrenchment value of 1 indicates that a functional floodplain does not exist on the measured channel.

Bed elevation change was also calculated for each cross section. The average bed elevation was calculated by averaging all the elevation recorded between the channel toes. A positive change indicates that channel bed aggraded, while a negative change indicates that the channel bed was scoured.

Further analysis of changes in the cross-section profiles from 2009 to 2014 was performed with WinXSPRO Channel Cross Section Analyzer software (USDA). GINI coefficient values were calculated to compare the 2009 surveys to 2011, the 2011 surveys to the 2014, and overall changes from 2009 to 2014. The GINI coefficient evaluates the cross sectional shape from the distribution of channel depth measurements and ranges from 0 in a flat, wide channel to 1 in a deep, narrow channel. GINI coefficients are useful in detecting changes in channel form. The GINI coefficient is independent of cross sectional area or stage height from bankfull estimates and provides a repeatable long-term index. An increase in the GINI coefficient from survey years indicates the channel is becoming narrower and deeper in shape, while a decrease indicates the channel is flattening and widening.

In 2014, Waterways also added an analysis for channel capacity. Peak flow data was compared with an analysis of a representative cross section from each site to assess the approximate return event at which the channel overbanked. The hydrology for the SD1 sites was assembled from the WES Watershed Action Plan completed in 2009 by Brown and Caldwell, Swanson Hydrology and Geomorphology, and Ellis Ecological Services for which peak discharges were estimated for large parts of the Rock Creek and Kellogg-Mt. Scott Creek Watersheds. The 5-year event was interpolated from the data included in the report, which was limited to the 2-year, 10-year, and 100-year events.

To assess the capacity of the channel, survey data for a representative cross section from each survey reach was entered into AutoCAD Civil3D Extension, Hydraflow Express. This program calculates a rating table of discharge and normal depth using Manning's Equation. Station and Elevation data along with a Manning's n values and channel slope were entered into the software. Manning's n values were estimated from descriptions in the "Manning's n for Channels" table from Chow (1959) that best matched observed field conditions. The Hydraflow Express Extension outputs a visual of the water depth in the channel for each associated flow rate. The first flow rate at which the banks were overtopped was recorded and compared with the peak flows from the Action Plan. The range of return events between which the overtopping event falls is reported in Appendix A.

Pebble Counts

For each pebble count a particle size distribution was determined and particle diameters for D_{16}, D_{50} and D_{84} were calculated and presented in Appendix A. D_{16}, D_{50} and D_{84} describe a grain size distribution through a percent finer notation. For example, D_{16} describes the grain size at which 16 percent of the sample is finer than the noted value. This is a valuable metric to understand differences in surficial bed conditions between sites or changes over time. A significant difference in the mean particle size from survey years in the pebble counts was tested by a two-sample, two-tailed t-test assuming equal variances (p=0.05).

Bulk Sediment Sample Collection

All bulk sediment samples were collected in the field and evaluated based upon methods outlined in McNeil and Ahnell, 1964. While McNeil and Ahnell evaluated samples in the field, samples collected for this work were evaluated in a laboratory by Professional Service Industries (PSI), Inc. in Portland, OR. Samples were dried to constant mass, washed over a #200 sieve and dried once more. Dried and washed samples were sorted using standard 12" sieves manufactured by Dual Manufacturing Co. in sizes 50.0mm (2"), 37.5mm (1½"), 31.5mm, (1¼"), 25.0mm (1"), 19.0mm (¾"), 12.5mm (½"), 9.5mm (3/8"), 6.30mm (1/4"), 4.75mm (No.4), 2.36mm (No.8), 2.0mm (No.10), 1.18mm (No.16), 0.85mm (No.20), 600µm (No.30), 425µm (No.40), 300µm (No.50),150µm (No.100), and 75µm (No.200). Once sorted, the volume of material retained in each sieve was determined using a 1000ml graduated cylinder and measuring the volume of displaced water to 1ml. Samples too large to fit within a 1000ml graduated cylinder (particles over 2") were measured using an overflow apparatus where overflow water displaced by the sample was collected in and measured with a graduated cylinder. Bulk sample results were evaluated to determine percent of sediment matrix less than 6.30mm and percent of matrix less than 0.85mm.

Pools Survey

Data collected for pools was an overall tally of pools observed at each site and a maximum depth and maximum residual depth for each pool. Maximum residual pool depth is calculated as the maximum pool depth minus the depth of the pool crest and represents a seasonally independent measure of pool depth that is not a function of discharge. Average maximum pool depth and average maximum residual pool depth for each site are presented in Table 7.

Bank Erosion Evaluation

Values of percent erosion were calculated for each study site. Estimates of the percent of banks eroding were calculated independently for each bank. The estimated percent erosion was calculated using an overall survey reach length determined from the longitudinal profile survey and total estimated active erosion length for each bank. Results are presented in Table 8.

2.3 MACROINVERTEBRATE MONITORING

Macroinvertebrate sampling contained the following elements:

1) Instream physical habitat and riparian assessment
    a. Habitat surveys
    b. Cross Section Surveys
    c. Riparian surveys
2) Water Chemistry Sampling
3) Macroinvertebrate community assessment
    a. Field sampling

The following sections provide detailed descriptions of the methods utilized in conducting this assessment.

2.3.1 Macroinvertebrate Field Data Collection

For the 2014 macroinvertebrate monitoring year, macroinvertebrate communities, physical habitat, and water chemistry were sampled at the 15 survey reaches between 16 September and 24 September 2014. First, each survey reach was marked and the reach length was measured. Each sample reach measured 20 times the average wetted width or 75-m, whichever length was greater. Waypoints were acquired for the start and end of each reach using a GPS unit and the reach length was measured.

Instream Physical Habitat and Riparian Assessment

Habitat surveys were performed in the reaches following a modified Rapid Stream Assessment Technique (RSAT) which consisted of data collection from individual channel habitat units, three channel cross sections, and the adjacent riparian zone (Table 2). First, the valley type within each survey reach was broadly classified as U-type, V-type, ponded, or floodplain. A plan view of the reach was sketched as the survey was performed. The physical habitat data were then collected using the following procedures:

Table 2. Environmental parameters measured in the field to characterize stream reaches in the Clackamas County (CCSD #1), Oregon, in the fall of 2014.

Variable	Quantitative or Categorical	Visual Estimate or Measured Variable
Reach length (m)	Q	M
Valley type	C	V
Channel unit gradient (%)	Q	M
Wetted width (m)	Q	M
Bankfull width (m)	Q	M
Bankfull height (m)	Q	M
Floodprone width (m)	Q	M
Floodprone height (m)	Q	M
Mean water depth (cm)	Q	M
Rapids (% of reach length)	Q	M
Riffles (% of reach length)	Q	M
Glides (% of reach length)	Q	M
Pools (% of reach length)	Q	M
Substrate composition	Q	M
Riffle (or Glide) Substrate embeddedness (%)	Q	M
Large wood tally	Q	M
Overhead canopy cover (%)	Q	M
Reach-wide substrate embeddedness (%)	Q	V
Eroding banks (%)	Q	V
Undercut banks (%)	Q	V
Mean riparian buffer width (m)	Q	V
Riparian zone tree cover (%)	Q	V
Non-native riparian vegetation cover (%)	Q	V
Dominant adjacent land use	C	V
Water temperature (°C)	Q	M
Specific conductance (μS/cm)	Q	M
Dissolved oxygen (mg/L)	Q	M

Habitat Units Survey

The number, length, width, maximum water depth, and gradient of pools, glides, riffles, and rapids were recorded in each reach. The following definitions were adapted from the Oregon Department of Fish and Wildlife's (ODFW) Methods for Stream Habitat Surveys (2002) and Armantrout (1998) and used for this study:

Pool: Water surface slope is usually zero. Pools are normally deeper and wider than aquatic habitats immediately upstream and downstream.

Glide: There is a general lack of consensus of the definition of glides (Hawkins et al. 1993). For the purposes of this study, a glide was defined as an area with generally uniform depth and flow with no surface turbulence. Glides have a low-gradient water surface profile of 0–1% slope. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. Glides are generally deeper than riffles with few major flow obstructions

Riffle: Fast, turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates. Riffles generally have a broad, uniform cross section and a low-to-moderate water surface gradient, usually 0.5–2.0% slope and rarely up to 6%.

Rapids: Swift, turbulent flow including chutes and some hydraulic jumps swirling around boulders. Rapids often contain exposed substrate features composed of individual bedrock or boulders, boulder clusters, and partial bars. Rapids are moderately high gradient habitat, usually 2.0–4.0% slope and occasionally 7.0–8.0%. Rapids also include swift, turbulent, "sheeting" flow over smooth bedrock.

The following attributes were then measured or visually estimated in each channel unit. Substrate composition was visually estimated in each unit using substrate size classes adapted from the United States Environmental Protection Agency's (USEPA) Environmental Monitoring & Assessment Protocols (EMAP) protocols for wadeable streams (USEPA 2000). Percent actively eroding banks and percent undercut banks (both banks, combined) were each visually estimated. Water surface slope of each unit was measured with a clinometer. Additionally, all woody debris measuring at least 15 cm in diameter and 2 m in length was tallied for each unit and the configuration, type, location, and size of root wads and pieces of wood were noted. Overhead cover was measured with a spherical densiometer in four directions (upstream, downstream, right, and left) from the center of the stream at evenly spaced intervals along the length of the reach. Habitat features such as beaver activity, culverts, and potential fish passage barriers were noted by habitat unit.

Cross-section Surveys

Channel dimensions were measured at three transects occurring within each sample reach. The three habitat units were selected according to the following guidelines:

1. Three separate riffles were sampled if three or more riffles occurred in the reach.
2. If two riffles occurred in the reach, both riffles and a representative glide or pool (least preferred) were sampled. If riffles were of sufficient length (i.e. 10% of the reach length) then more than one set of cross-section measurements were made in the riffle to ensure that all measurements were taken from this habitat type.
3. If only one riffle occurred within the reach, two additional units that represented channel dimensions and substrate composition were sampled. If the riffle was longer than 20 m, then all three sets of measurements were taken from the riffle.
4. If no riffles occurred in the reach, three units that were representative of the channel dimensions and substrate composition occurring within the reach were sampled.

At each of the three channel cross sections, wetted width (WW), bankfull width (BFW), maximum bankfull height (BFHmax), the bankfull height at 25%, 50%, and 75% across the distance of the bankfull channel, and the flood-prone width (FPW) were measured with a tape measure and survey rod. From these channel-dimension data, width-to-depth and channel-entrenchment ratios were later calculated. Water depths were recorded at 10%, 30%, 50%, 70%, and 90% across the width of the wetted channel. The floodplain accessible height (as measured on the lower of the two banks) and bank angles were visually estimated.

Pebble counts were performed in riffles when they represented an adequate amount of the stream channel area to allow measurement of at least 100 substrate particles along transects. If riffles occupied less than 10% of the total habitat area in the reach (e.g., if macroinvertebrate samples were collected from glides), then pebble counts occurred in glides. Pebble counts were performed using the "heel-to-toe" method, starting at the bankfull edge on one side of the channel and walking heel-to-toe to the other edge (USEPA 2000). With each step, the surveyor looked away and touched the streambed at the tip of their toe. The size class and embeddedness of each piece of streambed substrate was estimated until at least 100 particles were counted.

Riparian Surveys

Adjacent riparian conditions were characterized beyond the left and right banks separately and according to a number of attributes. The dominant plant community type(s) (riparian forest, willow shrub-scrub, upland forest, etc.) occurring in the riparian zone to the edge of human-dominated activity was classified and recorded and the approximate width of each of these community types was visually estimated. The percent vegetative cover of the canopy layer (>5 m high), shrub layer (0.5 to 5 m high), and groundcover layer (<0.5 m high) was estimated, as well as the percent cover of invasive or non-native species as a single estimate across all three vegetative layers. The dominant adjacent land use outside of the vegetated riparian buffer was noted, and then a cross-sectional diagram of the riparian zone was sketched.

Water Chemistry Sampling

Water chemistry was measured during macroinvertebrate sampling from each reach. Water temperature (°C), dissolved oxygen saturation (percent), dissolved oxygen concentration (mg/L), conductivity (µS/cm), and specific conductance (µS/cm) were measured in situ with a YSI Model 556 multi-parameter water chemistry meter. Specific conductance is conductivity normalized to 25°C, thereby allowing more direct comparison of conductivity between water bodies or within a particular waterbody at different times. The YSI meter was calibrated daily for dissolved oxygen.

Macroinvertebrate Community Assessment

Field Sampling

Macroinvertebrates were collected using the Oregon Department of Environmental Quality's (DEQ) Benthic Macroinvertebrate Protocol for Wadeable Rivers and Streams (DEQ 2003). An 8-kick composite sample was collected from riffles in reaches that had sufficient riffle habitat; glides were sampled in reaches that lacked riffle habitat. Instream sampling points were selected to apportion the eight kick samples among as many as four habitat units. Macroinvertebrates were collected with a D-frame kicknet (30 cm wide, 500 µm mesh opening) from a 30 x 30 cm (1 x 1 ft.) area at each sampling point. Larger pieces of substrate, when encountered, were first hand-washed inside the net, and then placed outside of the sampled area. Then the area was thoroughly disturbed by hand (or by foot in deeper water) to a depth of ~10 cm.

The eight samples from the reach were composited and carefully washed through a 500 µm sieve to strain fine sediment and hand remove larger substrate and leaves after inspection for clinging macroinvertebrates. The composite sample was placed into one or more 1-L polyethylene wide-mouth bottles, labeled, and preserved with 80% denatured ethanol for later sorting and identification at the laboratory.

Sample Sorting and Macroinvertebrate Identification

Samples were sorted to remove a 500-organism subsample from each preserved sample following the procedures described in the DEQ Level 3 protocols (Water Quality Interagency Workgroup [WQIW], 1999) and using a Caton gridded tray, as described by Caton (1991). Contents of the sample were first emptied onto the gridded tray and then floated with water to evenly distribute the sample material across the tray. Squares of material from the 30-square gridded tray were transferred to a Petri dish, which was examined under a dissecting microscope at 7–10X magnification to sort aquatic macroinvertebrates from the sample matrix. Macroinvertebrates were removed from each sample until at least 500 organisms were counted, or until the entire sample had been sorted.

Following sample sorting, all macroinvertebrates were identified to the level of taxonomic resolution recommended for Level 3 macroinvertebrate assessments (WQIW 1999). Chironomidae midges collected in glide samples were identified to genus/species. Aquatic insects were keyed using Merritt, Cummins, and Berg (2008), Wiggins (1995), Stewart and Stark (2002), and a number of regional and taxa-specific keys.

Quality Assurance

Following Level 3 protocols (WQIW 1999) duplicate composite samples were collected at two reaches including riffle samples from two Rock Creek reaches, M-RC-30 and M-RC-50. These duplicate samples were compared to the original samples to assess within-reach sample variability attributable to both sampling error and spatial variability within the reach.

2.3.2 Macroinvertebrate Data Analysis

Existing tools for analysis of macroinvertebrate data in western Oregon have been developed from, and therefore are only appropriate for, assessment of assemblages collected from coarse substrates in riffle habitat. However, riffle habitat is infrequent or absent from some stream types such as many of the low-gradient, fine-sediment-dominated streams of the Willamette River valley floor. Therefore, assessing macroinvertebrate communities of valley floor streams requires sampling from other habitats such as sand and silt-dominated glides. Glide and pool habitats are unlikely to support the same biological potential with respect to species richness as do riffle habitats because a number of characteristics known to influence macroinvertebrate community composition such as stream substrate, water velocity, and abundance and types of organic materials naturally differ between valley floor streams and valley foothill/Coast Range streams. Consequently, use of existing bioassessment tools and their attendant condition thresholds is inappropriate for assessing the condition of benthic communities in these valley floor streams. Analysis of glide samples collected from these streams with existing bioassessment tools would result in artificially lower index scores and corresponding impairment classifications. Consequently, analysis of macroinvertebrate taxonomic and count data differed between riffle and glide samples, as detailed below.

Analysis of riffle samples from higher-gradient reaches

Both multimetric analysis and predictive model analysis were used to analyze riffle sample data from higher-gradient reaches. Multimetric analysis employs a set of metrics, each of which describes an attribute of the macroinvertebrate community that has been shown to be associated with one or more types of pollution or habitat degradation. Each community metric is converted to a standardized score; standardized scores of all metrics are then summed to produce a single multimetric score that is an index of overall biological integrity. Reference condition data are required to develop and use this type of assessment tool. Metric sets and standardized metric scoring criteria are developed and calibrated for specific community types, based on both geographic location and stream/habitat type. The DEQ has developed and currently employs a 10-metric set for use with riffle samples from higher-gradient streams in western Oregon (WQIW 1999). Owing to the same difficulties of developing a predictive model for lower-gradient, valley floor streams, no multimetric index has been developed for use with macroinvertebrate communities from this stream type.

The DEQ 10-metric set includes six positive metrics that score higher with improved biological conditions, and four negative metrics that score lower with improved conditions (Table 3). The Modified Hilsenhoff Biotic Index (HBI), originally developed by Hilsenhoff (1982), computes an index to organic enrichment pollution based on the relative abundance of various taxa at a reach. Values of the index range from 1 to 10; higher scores are interpreted as an indication of a macroinvertebrate community more tolerant to fluctuations in water temperature, fine sediment inputs, and organic enrichment. Sensitive taxa are those that are intolerant of warm water temperatures, high sediment loads, and organic enrichment; tolerant taxa are adapted to persist under such adverse conditions. The DEQ taxa attribute coding system was used to assign these classifications to taxa in the data set (DEQ, unpublished information).

Metric values first were calculated for each riffle sample and then were converted to standardized scores using DEQ scoring criteria for riffle samples from western Oregon streams (Table 3). The standardized scores were summed to produce a multimetric score ranging between 10 and 50. Reaches were then assigned a level of impairment based on these total scores (Table 4).

Table 3: Metric set and scoring criteria (WQIW 1999) used to assess condition of macroinvertebrate communities sampled from riffles in stream reaches within Clackamas County (CCSD #1), Oregon, in the fall of 2014.

	Scoring Criteria		
Metric	**5 (good)**	**3 (fair)**	**1 (poor)**
	POSITIVE METRICS		
Taxa richness	>35	19–35	<19
Mayfly richness	>8	4–8	<4
Stonefly richness	>5	3–5	<3
Caddisfly richness	>8	4–8	<4
Number sensitive taxa	>4	2–4	<2
Number sediment sensitive taxa	≥2	1	0
	NEGATIVE METRICS		
Modified HBI[1]	<4.0	4.0–5.0	>5.0
% Tolerant taxa	<15	15–45	>45
% Sediment tolerant taxa	<10	10–25	>25
% Dominant	<20	20–40	>40

[1] Modified HBI = Modified Hilsenhoff Biotic Index

Table 4. Multimetric score ranges for the assignment of macroinvertebrate community condition levels (WQIW 1999).

Level of Impairment	Score Range (scale of 10 - 50)
None	> 39
Slight	30–39
Moderate	20–29
Severe	< 20

PREDATOR (PREDictive Assessment Tool for Oregon) is a predictive model that evaluates macroinvertebrate community conditions based on a comparison of observed (O) to expected (E) taxa (Hawkins et al. 2000, Hubler 2008). The observed taxa are those that occurred at the reach, whereas the expected taxa are those commonly occurring (>50% probability of occurrence) at reference reaches. The expected taxa, therefore, are taxa that are predicted to occur within a reach in the absence of disturbance Biological condition is determined by comparing the O/E score to the distribution of reference reach O/E scores. One major strength of PREDATOR over the multimetric approach is that a single predictive model can be constructed to assess biological conditions over a wide range of environmental gradients such as stream slope, longitude, or elevation, whereas separate multimetric tools would have to be developed to make accurately assess condition. PREDATOR is able to predict taxonomic composition across a range of naturally occurring environmental gradients with discriminant functions models (DFMs). Discriminant functions analysis is used during the model building phase to identify the environmental variables that are statistically related to natural gradients in macroinvertebrate community composition (Hawkins et al. 2000). These "predictor variables" are then used in the resulting model to predict macroinvertebrate community composition in the absence of disturbance. The model assigns a probability of class membership of each test site to the different classes of test sites specified in the model based on the environmental predictor variables that are input into the model. Once predictor variables and taxonomic data have been input into the model, the probability of occurrence of each taxon at a given test site (in the absence of disturbance) is calculated based on the frequency of occurrence of each taxon in each class of site weighted by the probability that the site belongs in each class.

Two PREDATOR models are currently in use in Oregon, including the Marine Western Coastal Forest (MWCF) model that encompasses the Coast Range and Willamette Valley (Hubler 2008). With this information, the model calculates the O/E score for each site. Using the MWCF biological condition thresholds (Hubler 2008), higher-gradient streams with O/E scores ≤0.85 (≤10^{th} percentile of reference site scores) were classified as "most disturbed", 0.86 to 0.91 (>10^{th} to 25^{th} percentile) as "moderately disturbed", and 0.92 to 1.24 (25^{th} to 95^{th} percentile) as "least disturbed." These condition threshold values differ from those used to assign impairment classifications in the 2009 study, based on newer information provided by the DEQ. As such, impairment classifications (not scores) reported in 2007 and 2009 may have changed at some sites, but have been updated in this report.

Analysis of glide samples from lower-gradient reaches

Glide samples were also analyzed using the multimetric analysis and the MWCF Predictive Model. Impairment classifications were not assigned however. Nine metrics, some of which differ from those used for analysis of riffle samples, were used to evaluate glide samples from low-gradient reaches (Table 5). In general, glides and pools (depositional habitats) support a lower diversity of aquatic macroinvertebrates and the organisms occurring in these habitats tend to be more tolerant of disturbance than are organisms occurring in riffles. Metrics that previously have been shown to effectively characterize macroinvertebrate communities in low-gradient streams (Cole 2002) and those that provided a range of values among glide samples were selected for inclusion in the set; metrics that showed little variation among low-gradient reaches, such as sensitive taxa richness, were excluded from the data set.

Table 5. Metric set used to assess condition of macroinvertebrate communities sampled from glides in Clackamas County (CCSD #1), Oregon in the fall of 2014

Metric
Taxa richness
EPT taxa richness
% Dominant (1 taxon)
Modified HBI
% Sediment tolerant taxa
% Tolerant taxa
% Chironomidae
% Mollusca
% Oligochaeta

Correlation Analysis

Relationships between benthic community condition scores (both multimetric scores and O/E scores) and selected environmental variables were examined using nonparametric correlation analysis. Spearman's Rho correlation analysis was used to determine the strength of association between measured environmental attributes and macroinvertebrate community condition. To increase the power of these statistical tests, the reaches where riffles were sampled were pooled across both CCSD #1 and SWMACC to increase the sample size for analysis. Correlation analysis was not conducted for data derived from glide samples due to a low sample size (n=6).

Stressor Identification

Following calculation of multimetric and O/E scores, relationships between multimetric and O/E scores and selected environmental variables were examined among higher-gradient and lower-gradient reaches separately using nonparametric correlation analysis (Spearman's Rho) to determine whether biological integrity is related to other measures of environmental conditions in CCSD#1 streams and to identify potential causative factors of impairment. Correlation analysis focused on variables previously known to correlate with macroinvertebrate community conditions (Lemke et al. 2011).

As in 2011, weighted-average inference models developed by the DEQ (Huff et al. 2006) and elements a comprehensive stressor-identification framework named the Causal Analysis/Diagnosis Decision Information System (CADDIS, USEPA 2010) were used in these analyses to further identify potential causes of measured stress to macroinvertebrate communities. Weighted-average inference models were developed to reveal shifts in assemblage composition that implicate either substrate degradation (i.e. fine sediment pollution) or temperature pollution. These weighted-average inference models for temperature and sediment are to be used as screening tools to detect stress in wadeable Oregon streams. Inferred values at a test site are compared to conditions observed at regional reference sites to determine if there is a difference in assemblage-level preferences for temperature or fine sediment (Huff et al. 2006). The 90th percentile of the distribution of inferred temperature and fine-sediment values from regional reference sites is used to determine whether a particular site is potentially stressed by one or both of these attributes.

In the analysis for this study, temperature stress and fine-sediment stress weighted-average inference models were first run to derive estimates of inferred water temperatures and sediment levels in each study reach. Both temperature and fine-sediment models were applied to riffle data from higher-gradient reaches, while only the temperature model was applied to glide data from lower-gradient reaches. Glide data were not run through the fine-sediment model because fine sediment levels would be expected to differ significantly between the higher- and lower-gradient reach types. For riffle samples from higher-gradient reaches, the DEQ's thresholds of 18.2 °C for temperature and 15% of fine sediment (75th percentile of the distribution of DEQ Willamette Valley reference site scores) were used to determine whether each was functioning as a potential stressor in each sample reach (Huff et al. 2006).

The Causal Analysis/Diagnosis Decision Information System (CADDIS) is an online application designed to help users conduct causal assessments, primarily in stream ecosystems (USEPA 2010). CADDIS provides a logical, step-by-step framework for Stressor Identification based on the U.S. EPA's Stressor Identification Guidance Document, as well as additional information and tools that can be used in these assessments. The core of the CADDIS framework is a five-step process that includes: 1) defining the case (effects to be analyzed and the geographic scope of the effects/analysis), 2) listing candidate causes, 3) evaluating data from the case (the field data from this study), 4) evaluating data from other sources, and 5) identifying probable causes of measured biological stress.

Elements of the CADDIS stressor identification framework were used to further assess the likelihood that the measured community disturbance was related to specific environmental conditions (stressors). This was achieved for higher-gradient reaches by first examining MWCF O/E and multimetric score condition classes to determine which reaches were classified as moderately disturbed or worse. These reaches were identified as priorities for further stressor identification exercises. Temperatures and fine-sediment stressor model results were then evaluated in relation to O/E and multimetric condition classes to determine whether one or both were potentially contributing to or producing the measured biological condition. Results of correlation analyses between macroinvertebrate scores and environmental gradients were used to further identify candidate causes and were used to determine what range of values of each environmental attribute was potentially associated with a particular biological condition.

Using the combined results of the overall community condition classes, stressor scores and classes, and relationships between environmental gradients and biological conditions, each candidate stressor (temperature, fine sediment, and dissolved oxygen for higher-gradient reaches) was assigned a likelihood class for each reach. Importantly, not all elements of the CADDIS framework were included in this process. In particular, not all potential stressors operating at different scales (nutrients, riparian conditions, landscape-level stressors, etc.) were assessed, either because data were lacking (as in the case of nutrients, metals, etc.) or because the stressors examined were assumed to serve as appropriate proximal surrogates for potential stressors such as reduced riparian functioning (temperature) or reduced habitat heterogeneity (fine-sediment levels). Furthermore, because the effects of elevated water temperature, fine sediment, and depleted dissolved oxygen on benthic communities are well documented, outside sources of information were not consulted to lend support to the determinations made using the study data. Finally, we did not score the stressors using the specific scoring system developed by CADDIS; rather, best professional judgment was used to evaluate reach-specific biological and environmental information and likelihood of cause was determined using a weight-of-evidence approach.

3.0 OBSERVATIONS AND RESULTS

3.1 SITE DESCRIPTIONS

The results of the analysis for each individual site are presented in Appendix A. The figures in Appendix A, representing longitudinal profiles and cross sections, are an important visual accompaniment to the following descriptions of the individual sites. The tables, in which multiple variables are presented, also aid in understanding the trends discussed below.

Lower Kellogg Creek: G-KL-10, M-KL-10

The Lower Kellogg Creek site is adjacent to Rowe Middle School. The survey reach begins at a constructed rock weir upstream from the school and extends downstream past a fence at the school property boundary. The 0.6% slope channel is straightened and armored with pockets of rip rap and large boulders along both banks. In the upper extents, the bed appears to have scoured from 2009 to 2011 and subsequently aggraded from 2011 to 2014. The bulk sediment sample reflects this fluctuation as well, with a decrease in smaller sediments 2009 to 2011 and an increase from 2011 to 2014. It is possible that a large event washed sediment out between 2009 and 2011 and that there is a source of fine sediment that is continuing to resupply this site. This can have implications on the macroinvertebrate community, as discussed below. That being said, the bed material consists mostly of very angular rock heavily armored by rip rap and placed boulders. The riparian canopy is patchy and narrow due to the presence of adjacent residential properties where vegetation is managed. This can lead to high water temperatures, negatively impacting habitat. A fallen tree at the lower extents of the reach has caused erosion on the right bank downstream of the school property. Over time the GINI coefficient has decreased suggesting that the stream is widening and will most likely continue to widen and erode unprotected banks that lack riparian vegetation.

Instream physical habitat is dominated by riffles (68.6%) in this reach, followed by glides (31.4%). Substrate in riffles comprises a heterogeneous mixture of coarse substrates ranging from fine gravels to boulders. Substrate embeddedness in riffles was moderately high at 21.6%. Macroinvertebrate communities in this reach have received MM scores ranging between 16 and 22 since sampling was initiated in this reach in 2009. The reach scored a 22, or moderately disturbed, in both 2011 and 2014. MWCF O/E scores have ranged from 0.242 to 0.630 since 2009, all scores occurring in the most disturbed class. EPT richness in this reach is moderately low, as 3 mayfly, 0 stonefly, and 3 caddisfly taxa were sampled in 2014. Nearly half (44%) of the community is represented by taxa classified as generally tolerant to disturbance. Since 2009, both fine sediment stressor scores and temperature stressor scores have consistently implicated these two factors as likely stressors to macroinvertebrate communities in this reach.

This site was accessed via the Rowe Middle School frontage. Call ahead and stop at main office to check in when on site.

Middle Kellogg Creek: M-KL-20

The current middle Kellogg Creek reach has been included in the macroinvertebrate and physical habitat sampling portion of WES monitoring since 2011, when the reach was relocated approximately 600 m upstream from the reach sampled in 2002, 2007, and 2009. Geomorphic monitoring is not conducted at this site. The current reach occurs immediately upstream of Rusk

Road, where it flows through a residential area and is bordered by maintained yards on both banks. This reach exhibits a moderately low gradient of 0.6%, and is dominated by slow-water habitats, accordingly. Pools and glides compose 75% of the reach habitat, while riffles represent 25% of the reach habitat. Substrate in riffles is dominated by coarse gravel and cobble habitat that is moderately embedded at 17.4%. The riparian buffer in this reach is very narrow, averaging only approximately 4 m wide, as a result of maintained lawns occurring through most of this reach.

Macroinvertebrate communities in this reach exhibit very similar conditions to those in lower Kellogg Creek, as MM scores have ranged between 18 and 22. MWCF O/E scores have ranged only between 0.533 and 0.581. EPT richness is moderately low in this reach, as 2 mayfly, 0 stonefly, and 4 caddisfly taxa were sampled in 2014. An HBI score of 5.6 is among the highest measured in 2014, indicative of a macroinvertebrate community that is relatively tolerant to organic enrichment pollution. FSS and TS scores in both 2011 and 2014 have indicated that fine sediment and temperature are likely stressors in this reach.

Upper Kellogg Creek: G-KL-30

Site G-KL-30 is located along Aldercrest Ct. The upstream extent of the survey reach is a bridge at 6650 Aldercrest Ct and extends downstream to the bridge at 6450 Aldercrest Ct. The channel is low gradient and was historically straightened. Most of the survey reach flows in a ditch adjacent to the road. Bed conditions consist mostly of compacted silt and sand with some gravel and cobble. The reach runs through residential area and lacks riparian canopy vegetation, with the exception of some cattail and small riparian trees. Reed canary grass and Himalayan blackberry encroaches on the channel. In 2009, the homeowner at 6450 Aldercrest Ct mentioned that the creek has been aggrading over time and that the risk of flooding to his property and home has increased significantly. The channel bed has scoured since 2009 but the encroaching vegetation is most likely causing the channel capacity to decrease. The channel capacity for 2014 was estimated to be less than the 2-year event.

This site has access along Aldercrest Ct. Check with the homeowner at 6450 Aldercrest Ct for access to the downstream portion of the survey reach.

Mt. Scott Creek at North Clackamas Park: M-MS-10

This reach occurs in lower Mt. Scott Creek in a recently restored reach. Recent restoration activities have included riparian planting and instream large woody debris placement. First sampled in 2011, this reach occurs less than 200 m upstream of a reach sampled in 2002, 2007, and 2009. The existing reach occurs on a wide, low floodplain and exhibits a meandering pattern on a 0.6% reach gradient. While habitat is dominated by slow-water habitats (74.1% pools and glides), riffles occur in sufficient abundance to warrant macroinvertebrate sample collection from this habitat type. Riffle substrate was dominated by coarse gravel and cobbles; embeddedness was relatively low at 6.2%. Owing to recent riparian planting throughout the reach, the buffer width averaged 55 m. Canopy cover averaged 83% through the reach.

Macroinvertebrate communities in this reach have received MM scores of 18 in 2011 and 22 in 2014. MWCF O/E scores have also been low, ranging between 0.339 and 0.436. Nearly half (44.5%) of the community is represented by taxa classified as generally tolerant to disturbance. Since 2011, both fine sediment stressor scores and temperature stressor scores have consistently implicated these two factors as likely stressors to macroinvertebrate communities in this reach, although the 2014 fine sediment stressor score was nearly half the value of the 2011 FSS score.

Mt. Scott Creek Downstream of SE 82nd Ave: G-MS-40, M-MS-40

This site on Mt Scott Creek is located downstream of SE 82nd Ave, within the Three Creeks Natural Area. The survey reach is adjacent to a fenced, poplar remediation area and begins at a riffle approximately 400' upstream from a steel bridge crossing and extends downstream of the bridge. The channel is low gradient and contains long pools separated by small riffles. The channel is relatively straight and incised in most places. The upper two cross sections experienced little change between survey years, but the lower cross section widened and aggraded between 2009 and 2014, which is evidenced in the GINI coefficient increase and a large increase in the width to depth ratio. This channel widening has also caused an increase in bank erosion, especially in the downstream extents of the reach. Currently, the channel can hold between the 2 year and 5 year event. Bed conditions consist of mixed gravels and fines with small exposed depositional features. There was a small but statistically significant increase seen in the mean particle size from the pebble counts from 2009 to 2014, but not from 2011 to 2014. The widening and increase in particle size could indicate that armoring of the bed, associated with more frequent high flows from the urban watershed, is resulting in erosion of the finer grained bank material. The survey reach includes a healthy riparian zone with a diversity of plant species.

Habitat in this reach comprises a relatively even mix of pools, glides, and riffles. Macroinvertebrates were sampled from riffles, which represented approximately 35% of the total reach length. Substrate in riffles was heavily dominated by coarse gravel and secondarily by fine gravels. Embeddedness was moderately high in these substrates, at 19%. Canopy cover was heavy in this reach (95%), and a wide riparian buffer occurs on each side of the creek.

Macroinvertebrate communities have consistently received MM scores between 14 and 20 in the five years of monitoring work since 2002. 2014 represented the first year that the multimetric index scored better than severely disturbed. MWCF O/E scores have scored between 0.291 and 0.581, the highest score received in 2014. Seven EPT taxa were sampled from this reach in 2014, yet nearly half of the organisms in the sample (40.7%) were classified as generally tolerant to disturbance. Since 2002, both fine sediment stressor scores and temperature stressor scores have consistently implicated these two factors as likely stressors to macroinvertebrate communities in this reach, although the 2014 fine sediment stressor score was nearly half the value of the 2011 FSS score.

This reach was accessed via foot trails from the North Clackamas Aquatic Park parking lot.

Mt Scott Creek Downstream of SE Sunnyside Road: G-MS-70

This site is located within Mt Talbert Nature Park downstream of SE Sunnyside Rd. The upstream end of the survey reach is located underneath the pedestrian bridge. This low gradient sinuous channel is slightly incised and contains sections of exposed bedrock as well as good pool/riffle sequences, depositional features, and distinct pool features. A slight overall change in channel morphology or substrate was observed at this reach between survey years. The channel experienced an increase in sediment size on depositional features but also an increase in fines from the bulk sample. This indicates a flashy hydrology that quickly reaches a high peak flow that washes the fines off of depositional features and a rapid receding limb that deposits those fines in the pool features at this site. This section of Mt Scott Creek flows along the margin of Mt Talbert Nature Park and exhibits a mature wooded riparian zone and dense ground cover.

The site was accessed via a hiking/nature trail whose trailhead exists within the Miramont Pointe parking lot south of SE Sunnyside Rd.

Mt. Scott Creek near SE 122nd Ave: G-MS-80, M-MS-80

This site is located on Mt Scott Creek along SE 122nd Ave in the area where restoration work was completed prior to 2009 to remove an earthen dam and restore the stream channel to a more natural condition. The survey reach extends upstream from the pedestrian bridge. This section of Mt Scott Creek is steep, relatively straight and dominated by engineered pool/riffle structures comprised of cobbles and boulders, effectively armoring most of the channel. This reach has experienced little change in the upper and lower extents but appears to have deepened and narrowed at the middle cross section, which is reflected in the 50% rise in the GINI coefficient since 2011. The longitudinal profile appears to indicate that there may be the start of a headcut or an area of scour just upstream of the bridge. Given that the reach is comprised of larger material, headcut migration will likely be slow if it continues to move upstream. There is a healthy riparian area throughout the survey reach.

Habitat in this reach consists of an even distribution of riffle and pool habitat occurring on a channel gradient exceeding 4%. Embeddedness in the riffle was measured at 18.6% in 2014; riffle substrate is dominated by cobbles and secondarily by coarse gravels. Macroinvertebrate community MM scores have ranged between 20 and 24 (moderately disturbed) since 2009, while 2002 and 2007 scores were 16 each year. MWCF O/E scores have ranged between 0.387 and 0.484 since 2002, with no trending evident during this time period. Six EPT taxa were sampled from this reach in 2014, and as with other Mt. Scott reaches, this reach included a large percentage of disturbance tolerant taxa (44.2%). Since 2002, fine sediment scores in all assessment years and temperature stress scores in most years indicate that both fine sediment and temperature are likely stressors in this reach.

The site was accessed via trail/bridge access along SE 122nd Ave.

Tributary to Mt. Scott Creek: G-MS-90

Site G-MS-90 is located on a tributary to Mt Scott Creek and is adjacent to a paved pedestrian path that connects SE Cedar Way and SE Otty Rd. The survey reach is a small, steep (>6% slope) channel that appears to have been constructed as part of the housing developments occurring on either side. Stabilization work was completed on this reach in September 2014, a couple of months prior to the monitoring survey, to address instability observed between 2009 and 2011. Prior to stabilization this reach was experiencing heavy erosion and localized areas of scour and deposition In areas of aggradation, the footpath that runs along the creek was at a lower elevation than the creek bed and flooded frequently. With further aggradation, the flooding would have increased and threatened local infrastructure. The stabilization project installed a series of rock grade control weirs to stabilize the channel, prevent further erosion, and contain it at high flows. Considering the amount of infrastructure surrounding the reach and the flashiness of the system, the channel is now estimated to contain the 100-year event. The project also involved removing non-native species and re-planting the riparian corridor.

The site was accessed via pedestrian footpath from SE Cedar Way.

Mt. Scott Creek near Happy Valley Park: G-MS-100

Site G-MS-100 is located along Mt Scott Creek between King Rd and Happy Valley Park. The survey reach is located downstream from the southern park boundary beginning at a barbed wire fence across the stream channel and extending downstream. In general, the channel has a moderate gradient with a slope of 1.5%, consists of pool/riffle sequences and has incised to bedrock in places. Since the previous survey in 2011, the reach has experienced a slight increase in bed elevation, indicating aggradation throughout the channel; little else has changed. Evidence of headcuts are present in the upstream extents of the reach, but most areas are dominated by bedrock with a very thin veneer of angular rock and some fine sediment. An increase in the width to depth ratio indicates a widening and flattening of the channel which is most likely due to bedrock preventing downward erosion. This trend is not prominent enough to be evident in the GINI coefficient change. No depositional features were observed. Thick riparian vegetation is present along the entire survey reach but is largely dominated by blackberry in the understory. In many cases lateral erosion along bedrock has weakened root structures, increasing deposition, and causing trees to fall over into the channel.

This site was accessed from the southern end of the Happy Valley Park.

Mt. Scott Creek Downstream of SE 145th Avenue: G-MS-110

This site on Mt Scott Creek is located downstream of SE 145th Ave within the Happy Valley Wetland Park (different from, but adjacent to the Happy Valley Park). The survey reach is located downstream of a constructed duck pond. The channel within this reach is small and low gradient consisting of glide habitat with a bed dominated by fines and clay. Bulk sediment analysis shows extremely high percentage of fines with 99% smaller than 6.3mm in both 2009 and 2011. Bulk sediment analysis was not performed at this site in 2014 due to the high degree of fine sediments present. This area was most likely a historic marsh/meadow/wetland in which a single thread channel was created to maximize farming acreage. Increased urbanization has resulted in additional flow to the area, thereby enforcing development of a single thread channel. The channel appears to have moved slightly laterally in the upper extents but experienced little change altogether. The longitudinal profile shows areas of aggradation which may be due to debris jams causing pools that slow water and trap sediments. The increase in the number of pools counted in the survey may also be due to the large number of debris jams at this site. The reach contains a riparian area consisting mostly of woody vegetation and grasses and is likely partially inundated during the rainy season.

This site was accessed from the Happy Valley Park using the boardwalk system but could easily be accessed from other entry points into the Happy Valley Wetland Park area near SE 145th Ave.

Phillips Creek: G-PH-10, M-PH-10

Site G-PH-10 on Philips Creek is located downstream of SE Sunnybrook Blvd along SE 84th Ave. The survey reach begins at the Sunnybrook Blvd culvert and extends downstream, ending at a culvert at SE 84th. This steep channel is heavily influenced by urbanization with confinement by gabion walls in the upstream half, bridge abutments, and culverts at both ends. A large depositional feature is present at the downstream end of the study reach suggesting that the culverts under SE 84th are undersized, resulting in backwatering and deposition of bed load during peak flow events. An increase in elevation from 2011 to 2014 at the lower end of the longitudinal profile further supports this theory. The size of pebbles on depositional features has increased and the amount of fine sediment in the pool tails has decreased since 2011. The channel contains long riffles and the bed is dominated by gravel, sand and small cobbles. The lower section is less confined and has access to some floodplain and a narrow riparian area, which is inundated at approximately the 2 year event.

Habitat in this reach includes 34.4% riffles and 65.6% slow-water (glides and pools) habitat on a 2.6% channel gradient. Riffles in this reach are heavily dominated by coarse gravel and cobbles; these coarse substrates averaged 11.2% embeddedness in riffles. A narrow riparian buffer occurs along this reach, averaging only 9 m wide on each side of the stream, but the trees are sufficient to provide 85% canopy cover. Riparian invasive plant species, including reed canary grass and Himalayan blackberry, was estimated to represent 43% of the riparian vegetative cover.

Macroinvertebrate communities have received MM scores of 16 (2011) and 22 (2014) in the two years this reach has been sampled. MWCF O/E scores have scored exclusively in the "most disturbed" class, ranging from 0.387 to 0.436. EPT richness included 2 mayfly taxa, 1 stonefly taxon, and 3 caddisfly taxa in 2014. One sensitive taxon belonging to the stonefly family Capniidae was sampled from the reach in 2014. The modified HBI score of 5.9 was the highest among all CCSD#1 macroinvertebrate samples collected in 2014, indicating a community that is largely tolerant to organic enrichment pollution. Temperature and fine sediment stressor scores from both 2011 and 2014 have consistently indicated that these two factors are likely stressors to biological communities in this reach.

This site is accessed via the Costco parking lot off SE 84th Ave.

Lower Rock Creek: G-RC-10, M-RC-10

This site is located in the lower section of Rock Creek between Hwy 212/224 and the confluence with the Clackamas River. Below the highway bridge is a small gorge, the lower end of which is where the survey reach was established. Downstream of the mouth of the gorge the stream channel is very dynamic with large depositional features and large accumulations of woody debris. A restoration project was recently constructed from the downstream end of the monitoring reach to the mouth at the Clackamas River. All three cross sections on this reach experienced deposition between 2009 and 2014, with the upstream extent experiencing the most deposition. This may be due to block failures of the vertical bedrock walls through the gorge that have added large boulders and cobbles to the reach, impeding flow and causing aggradation. Pebble count substrate size increased significantly from 2009 to 2011, but experienced little change from 2011 to 2014. Fine sediment from the bulk sample also increased from 2009 to 2011 but experienced little change since then. The gorge channel bed is moderately steep and is dominated by bedrock with well-formed pool and riffle structures as well as gravel bars. The bed is well armored and consists primarily of cobble and small boulders with patches of gravel. Armoring is likely the result of increased runoff from upstream land uses that have washed out the finer material. A significant amount of gravel appears to move through this reach, as evidenced by the pebble count, although very little storage occurs in this reach due to the confined nature of the channel. Bank toes are well protected by bedrock and there was no active bank erosion present in either survey year although some bedrock slabs, composed primarily of siltstone, have failed, resulting in the delivery of a large amount of material and wood to the streambed.

Beginning in 2011, macroinvertebrate sampling and concurrent physical habitat sampling have occurred primarily in the small gorge below the Highway 212/224 Bridge. While this sampling occurred in the recently restored section (prior to restoration) from 2002 and 2009, the reach has been relocated approximately 90 m upstream and no longer includes the restored stream section. Accordingly, the biological monitoring results for this section of Rock Creek across all years from 2002 to 2014 exclude any potential effects of the restoration project.

Habitat in this reach primarily comprises riffles (45.8%) and pools (41.3%). Channel gradient in this reach is approximately 1%. Riffle substrate is dominated by fine and coarse gravels that average 11.6% embeddedness. A mature and relatively wide (75 m average width) riparian buffer occurs on both sides of this reach, providing a measured 90% canopy cover.

Since 2007, macroinvertebrate communities in this reach have consistently received multimetric scores corresponding to only slightly disturbed conditions (range of scores = 30 to 34 across 4 years of sampling). While MWCF O/E scores have not varied widely (0.774 to 0.918), corresponding condition classes have ranged between least and most disturbed. The reach presently supports a diverse EPT community, as 6 mayfly, 6 stonefly, and 3 caddisfly taxa were sampled from the reach in 2014. One stonefly classified as sensitive to disturbance, *Dyspraxia Augusta*, was sampled from the reach in 2014. Only 8.7% of individuals sampled in 2014 were classified as tolerant to disturbance. Temperature stress scores have consistently flirted around the 18.2°C benchmark, resulting in temperature being classified as a potential biological stressor in this reach. However, sediment stressor scores since 2007 are among the lowest measured across the CCSD#1 reaches, resulting in sediment currently being classified in this reach as an unlikely stressor.

The site was accessed via unofficial footpaths/trails through CCSD #1 Conservation Easement parcel property that is located just west of the 224/212 bridge over Rock Creek. Trails are steep and can be slick in wet conditions.

Tributary to Lower Rock Creek: G-RC-20

This tributary to Lower Rock Creek is located to the east of SE 172nd Ave. between SE Shishaldin Ct and SE Obrist Ln. The survey reach is located downstream of a culvert and extends through a field in a rural/residential area and downstream from a large residential subdivision. This reach consisted of a very small, steep channel with a slope of 2.4 % (in 2014) with very little riparian vegetation besides grasses and blackberry. The upper cross sections experienced little change from 2009 to 2014. The channel has a uniform profile that is being encroached by vegetation which may be contributing to the slight reduction in bankfull width. No depositional features were observed, suggesting that the channel is dominated by transport processes, which limit opportunities for sediment deposition and storage.

The site is accessed via an unmarked road off SE 172nd Ave.

Rock Creek Downstream of Sunnyside Road: G-RC-30, M-RC-30

This site is located on Rock Creek downstream of SE Sunnyside Rd with the upstream extent of the survey reach starting at a bedrock riffle just downstream of the Sunnyside Rd Bridge. The survey reach is dominated by bedrock and boulders with little to no stored sediment. The moderately steep channel has a slope of 1.5% in 2014. The upper extents experienced scour from 2011 to 2014 while the lower extents experienced slight aggradation. The channel is very straight in this area and lacks structure. No depositional features were present and the bed consisted mainly of bedrock with boulders and small pockets of gravel. Banks are well vegetated and riparian vegetation increases with distance downstream from the bridge. The survey reach is located just downstream of an area where restoration activities had recently taken place, likely in association with bridge construction or maintenance, although it appears as though some of the restoration elements have failed.

Physical habitat in this reach is dominated by pools (59.6%) followed by riffles (32.4%). A heterogeneous mixture of substrates occurs in riffles sampled for macroinvertebrates and includes lightly embedded (5.3) gravels, cobbles, boulders, and bedrock. Canopy cover averaged 93% throughout the reach. Macroinvertebrate communities scored as slightly disturbed (32) with the multimetric index and as least disturbed (0.967) with the MWCF O/E model. Each of these scores was the highest this reach has received since sampling was initiated here in 2002. Furthermore, both MM and O/E scores suggest potentially improving biological conditions in this reach over this time period. For example, MM scores have increased from 22 in 2002 to 34 in 2014 with intermediate scores occurring from 2007 through 2011 Additional data points in future years will allow determination of whether this apparent improvement holds or simply results from year-to-year variation in community conditions. While the data still warrant classifying temperature and fine sediment as likely and potential stressors, accordingly, both sets of scores currently exhibit a general trend of improving condition over time.

The site is accessed via CCSD #1 owned parcel adjacent to the storm and sewer district construction road (Rock Creek Interceptor Project) to the north of the Sunnyside Rd Bridge.

Rock Creek Downstream of 172nd Avenue: G-RC-40

Rock Creek flows through the old Pleasant Valley Golf Course at this site. The survey reach begins just downstream of a small check dam and extends downstream past the golf course boundary. The low gradient channel consists of a pool and riffle morphology created by natural boulder weirs and deposition of coarse sediment. The channel bed consists of bedrock and small gravels armored by large gravel and boulders. The channel experienced scour from 2009 to 2011 but experienced subsequent aggradation between 2011 and 2014. The depositional features and the pool tails coarsened from 2009 to 2011 and subsequently got smaller, on average, between 2011 and 2014. In addition, the fines from the bulk sample increased from 2011 to 2014 into the high sediment intrusion rating. This indicates an added source of sediment upstream of the reach, potentially associated with bank erosion or construction activities at 172nd Avenue.

This channel was previously listed in the recommendations of this report as ‘at risk’ due to a coarsening of depositional features and exposed bedrock. The alluvial layer became finer from 2011 to 2014 and the reach appears to be aggrading, indicating that the reach is stabilizing. That being said, the channel is estimated to hold somewhere between the 5-year and 10-year event. This reach could benefit from increased floodplain connectivity especially given that the site has little adjacent infrastructure. A portion of the creek along the right bank borders a previously mowed area (historic fairway of a golf course) and the margin along that bank consists mostly of grassy vegetation. The remainder of the banks and floodplain contain a more diverse inventory of riparian vegetation as well as areas of thick blackberry.

The site was accessed via golf course boundary near SE 172nd Ave.

Rock Creek at Troge Road Downstream of SE Foster Rd: G-RC-50, M-RC-50

This site on Rock Creek is located downstream of SE Foster Rd and runs along Troge Rd. The survey reach starts at the downstream end of a private driveway culvert and extends to a fence marking the property boundary. This is a moderately steep and incised channel with a slope of 1.5%. The survey reach is transport dominated with no depositional features and the bed consists of armored cobble with a few patches of gravel. Further incision was observed at the upper two cross sections, more heavily in the uppermost, with some deposition occurring in the downstream section, as evidenced by the increase in the GINI coefficient by 10% to 20% in the upper two sections from 2009 to 2011. This trend was less pronounced between 2011 and 2014. The bulk sediment sample data shows an increase in fine sediment since 2011, possibly due to upstream construction activities. No active bank erosion was observed in 2009 and only small amounts in 2011 and 2014. The survey reach currently has a narrow riparian area with a mix of native and non-native vegetation. The landowner is attempting to restore riparian vegetation to the site.

Physical habitat in this reach is dominated by small pools (59.6%) and secondarily by short riffles (25.5%). Riffle substrate consists primarily of coarse gravel and cobbles that were 10.7% embedded by fines in 2014. Owing to the presence of Troge Road on the right bank and a yard on the left bank, the vegetated riparian zone only averages 6 m wide. However, tree and shrub cover are sufficient to provide 93% canopy cover through the reach.

Since sampling was initiated in this reach in 2009, macroinvertebrate communities have exclusively received moderately disturbed MM scores, while MWCF O/E scores have occurred in both the moderately and most disturbed ranges. The reach supports a moderately rich EPT community, as 14 such taxa were sampled from the reach in 2014, including the flat-headed mayfly *Cinygma* sp. An HBI score of 4.4 in 2014 was among the lowest HBI scores measured from CCSD#1 reaches, indicative of a community slightly less tolerant to organic enrichment pollution than those occurring on most other CCSD#1 reaches. However, both TS and FSS scores have consistently indicated that each of these factors is a likely biological stressor in this reach.

The survey reach is easily accessed from the property driveway off of Troge Road.

Upper Rock Creek: G-RC-60

This site on Upper Rock Creek is located upstream of SE Hemrick Rd between SE 172nd Ave and SE Foster Rd. The incised and very straight survey reach is located entirely within a single private property dominated by unmowed grass along the creek banks. The thick growth of reed canary grass extends into and across the entire stream channel and much of the survey reach is backwatered by a private road culvert and debris jam. Bed conditions on this low gradient channel are mostly masked by the heavy growth of grass and no depositional features were easily observed. In the few small areas that were not deep pools or heavy grass, bed conditions were observed to consist of mixed gravels and fines. No active bank erosion was observed in 2009, but in 2011 there was some active erosion on the banks just above the downstream culvert where a small rock weir was present. This erosion was not active during the 2014 survey. The reach appears to have established inset benches due to past incision and widening and subsequent incision. Although the inset benches are inundated at less than the two year flow event, the channel does not have direct connection with the larger floodplain. Thus, the channel also has a relatively high GINI coefficient due to incision issues. This being said, the channel appears to be aggrading, especially at the lower part of this reach.

This reach was further investigated by Waterways in 2013 as part of a stream repair feasibility assessment. This reach was previously listed as 'at risk' in the recommendations section but has been moved to the 'stable-at risk' category due to the landowners efforts to replant the site with native vegetation. The upstream end of this site, at the property boundary, has a headcut that should continue to be monitored in future years. If the knickpoints begins to headcut further upstream, further action should be taken.

The survey reached is easily accessed from both banks at 17951 SE Hemrick Rd.

Trillium Creek: M-TR-10

Trillium Creek is a tributary stream that enters Rock Creek in the restoration reach at G-RC-10 from river left. This small stream occurs in narrow valley confined by steep valley walls. The stream channel is straight, appears incised, and actively eroding. Eroding banks occurred along 85% of the reach length. The reach gradient is currently 2.8%. A general lack of large wood results in dominance of riffle habitat along 72.7% of the reach length. Substrate in these riffles is heavily dominated by coarse gravel and cobbles that average a moderately high 25% embeddedness by fine materials. A wooded riparian buffer averages 48 m wide through the reach, but is narrower on the river left side as a result of recent home construction.

Macroinvertebrate communities in this reach were classified as severely disturbed by the multimetric index and as correspondingly most disturbed by the MWCF O/E model in 2014. Since the inception of macroinvertebrate sampling in this reach, MM scores have declined slightly from 24 (2009), to 20 (2011), to 18 (2014), indicating potentially worsening conditions in this reach. Six EPT taxa and no sensitive taxa were sampled from this reach in 2015. Despite high embeddedness values in this reach, fine sediment stressor scores have not yet implicated fine sediment as a stressor. Temperature stress scores have been marginally on either side of the temperature stress threshold value. Accordingly, both FSS and TS are presently classified as potential stressors in this reach.

Carli Creek: M-CA-10

Carli Creek is a small tributary to the lower Clackamas River. The lower reaches of this creek flow through a heavily commercialized/industrialized area. The survey reach occurs in a small, narrow stream valley bordered on each side by commercial and industrial activity. A narrow riparian forested zone averaging less than 20 m occurs on both sides of the creek. Resulting canopy cover over the stream channel is a favorable 95%. The reach flows relatively straight through this narrow valley, within which a small floodplain also occurs. The channel gradient averages 2.7% through this reach and habitat is relatively evenly dominated by small pools and riffles, occasionally interceded by shallow glides. Substrate in riffle habitats is dominated by coarse gravel and cobbles, which averaged a very low 1.2% embeddedness, suggesting that sediment is either being captured upstream or passing through this section.

Macroinvertebrate communities have scored exclusively as severely disturbed by MM scores and most disturbed by MWCF O/E scores since sampling was initiated here in 2007. Despite similar condition classes across all years, both MM and O/E scores were higher in 2014 than in any other year. Furthermore, 2014 fine sediment stressor scores were less than half than FSS scores in any other year, and the temperature stress score was lower than the 18.2^{o}C threshold for the first time since sampling was initiated in 2007. Only one EPT taxon, the almost ubiquitous mayfly *Baetis tricaudatus*, was sampled from this reach in 2014; but also was the most dominant taxon by a wide margin. These results collectively suggest that some improvement in biological condition has potentially occurred in this reach.

Cow Creek: M-CO-20

Cow Creek is a small tributary to the lower Clackamas River. The lower reaches of this creek flow through agricultural lands and are bordered by residential development to the west beyond a narrow riparian buffer on the river right bank. The channel in this reach is low gradient (0.6%) slightly sinuous, single-threaded, and flows through a narrow floodplain dominated by reed canary grass. Habitat is this reach consists exclusively of glides (71.7%) and pools (28.3%). The occupant of the farmhouse at this location reports that he used to observe steelhead spawning in gravels and cobbles in this reach nearly 50 years ago, an indication, if even anecdotally, of the extent to which lower Cow Creek's character and habitat quality has changed since that time.

The monitoring reach in Cow Creek was re-sited upstream by approximately 600 m to its present location in 2011 following access issues to the reach sampled in 2007 and 2009. For trending purposes, the biological conditions results from both reaches are considered together. The macroinvertebrate community in lower Cow Creek has received MWCF O/E scores ranging from 0.19 in 2007 to 0.44 in 2014. Two EPT taxa were sampled from the Cow Creek reach in 2014, including two *Baetis tricaudatus* specimens and a single *Hydropsyche* specimen. Nearly 80% of the macroinvertebrate community was represented by the generally tolerant Chironomidae family of midges. Improvement of biological conditions in this reach will likely require significant improvements to both hydrologic regime and habitat condition.

Richardson Creek: M-RI-10

Richardson Creek is a tributary to the Clackamas River. The Richardson Creek reach immediately upstream of Highway 224 has been sampled by WES in every monitoring year since 2002. The reach was selected for inclusion in the monitoring program to represent locally least-disturbed stream conditions. While the percent forested area in the drainage basin is not the highest among the CCSD#1 study sites, the Richardson Creek system owes its relatively less disturbed ecological condition to the abundance of intact riparian forest occurring throughout most of its middle and lower reaches.

The reach upstream of Highway 224 is a higher-gradient section of stream (3.4%) and is dominated by riffle habitat (78.7%) interspersed with small pools. Riffle Substrate in this reach is dominated by coarse gravel and cobbles averaging 10.4% embeddedness. A wide riparian buffer zone extends laterally by over 100 m on each bank, offering ample riparian tree cover (>70%) and canopy cover (86%).

Macroinvertebrate communities in this reach have consistently scored in the slightly disturbed range using the multimetric index, as scores have range from 30 in 2002 to 38 in 2009 and 2014. MWCF O/E disturbance classes have been less consistent, ranging from most to least disturbed, but the score range has been relatively narrow (0.774 to 0.919). More EPT taxa were sampled from this reach than any other in 2014 and included 5 mayfly taxa, 9 stonefly taxa, and 6 caddisfly taxa. Three taxa classified as sensitive to disturbance were also sampled from this reach, including the stoneflies Capniidae (immature), *Despaxia augusta*, and *Zapada frigida*. A modified HBI of 3.9 was the lowest measured among the CCSD#1 reaches in 2014. Since 2002, sediment stressor scores have never exceeded the 19% threshold, and temperature stress scores are marginally above and below the temperature stress threshold of 18.2ºC; suggesting that neither temperature nor fine sediment are likely biological stressors in this system at present.

Sieben Creek: G-SI-10/M-MS-10

Sieben Creek flows directly into the Clackamas River and is nestled between the Shadowbrook Mobile Home Park and adjacent neighborhood to the east. Access is directly off of Hwy 212/224. The survey reach is low gradient with a slope of 0.8 %, straight and heavily incised with the channel cut to bedrock in most areas. A thin alluvial layer is present in some areas consisting primarily of gravel and sand. The creek exhibits a muted pool and riffle character and a small number of depositional features persist within the 216-foot survey reach, despite how incised the reach is. Bank erosion is prevalent with considerable toe slumping and undercutting along a bedrock shelf. Between 2011 and 2014, the upper section experienced erosion and scouring while the lower section experienced deposition. In addition, the bulk sediment sample shows that the amount of fine sediments are decreasing, indicating that there is a lack of sediment from upstream. Within the deep, incised channel there is little to no riparian vegetation. The top of bank areas are directly adjacent to Shadowbrook properties with a small "buffer zone" adjacent to housing along the left bank. Most bank vegetation consists of thick blackberry and mature native and non-native trees.

The marginal instream habitat consists of a relatively even distribution of riffles, shallow glides, and small pools. Riffle habitat was dominated by gravel and cobble substrates averaging 11% embeddedness. Owing to the highly disturbed setting within which this reach occurs, the riparian-zone vegetation was dominated by the invasive Himalayan blackberry.

Macroinvertebrate communities in this reach have consistently scored between the upper end of the severely disturbed values range and the lower end of the moderately disturbed values range, most recently having received an MM score of 20 in 2014. These results suggest that the reach has maintained a consistent macroinvertebrate community condition since monitoring was initiated in 2002. In 2014, 5 EPT taxa were sampled from this reach, including immature nymphs of the sensitive stonefly family, Capniidae. Temperature stress results values have been lower than the 18.2ºC threshold in four of five years measured, resulting in temperature currently being classified as an unlikely biological stressor in this reach. Conversely, fine sediment stressor scores have consistently exceeded the FSS score threshold of 19%, but only by a narrow margin, resulting in fine sediment currently being classified as a potential stressor in this reach.

This survey reach is accessed along the east end of the Shadowbrook Mobile Home Park behind a utility shed.

3.2 SUMMARY RESULTS

In the following section the results from the data collected in 2014 are presented and compared to data from previous years. Spatial and temporal trends in the data are assessed at the site level and across the Kellogg, Mt. Scott and Rock Creek watersheds for both geomorphic and macroinvertebrate parameters, where appropriate. As mentioned previously, many of the geomorphic and biological parameters that were measured are reach specific criterion, such as bank erosion, that cannot be extrapolated to elsewhere in the watershed. Those parameters may be representative of larger watershed-scale, cumulative effects, but the analysis of those data are limited to conditions at the project area. Conversely, other parameters, such as temperature, are more longitudinally connected and are more fitting for stream-wide trend assessment. Furthermore, geomorphic monitoring has only occurred since 2009, so there is not enough data to address long term shifts, but these data can aid in an assessment of short term variations. The macroinvertebrate monitoring has been occurring since 2002 and has more insight into the longer term changes.

In addition to the inherent variability from site to site, stochastic events, such as large floods or nearby mass wasting events, have the potential to skew the results at a particular site and suggest a significant deviation from the observed long-term trend. The impact those discrete events have on site conditions may be ephemeral and should be considered in relation to the hydrology that occurred within the intervening years between sample dates. To evaluate the hydrologic context, Waterways reviewed available annual peak flow data for the years surrounding the surveys. High peak flows can have significant effects on geomorphologic conditions and associated biological communities. The peak flow data was compiled from the USGS National Water Information System (NWIS) for gages on Mt. Scott Creek and Rock Creek, which are gages that are most representative of conditions within the CCSD #1 study area. The highest annual peak flow event occurred in January 2009, prior to the start of the geomorphic analysis. The data can be viewed in Figure 2.

Ultimately, the data are meant to evaluate temporal trends in the measured parameters at each site as indicators of watershed health. Identifying point sources of erosion, active headcuts, tributary headcutting, or restoration or enhancement opportunities would require longitudinal surveys utilizing techniques such as rapid geomorphic or biological assessment protocols.

Table 6 summarizes the geomorphic information collected at each site and Table 7 and Table 8 summarize pertinent geomorphic parameters estimated from field data collected in 2014.

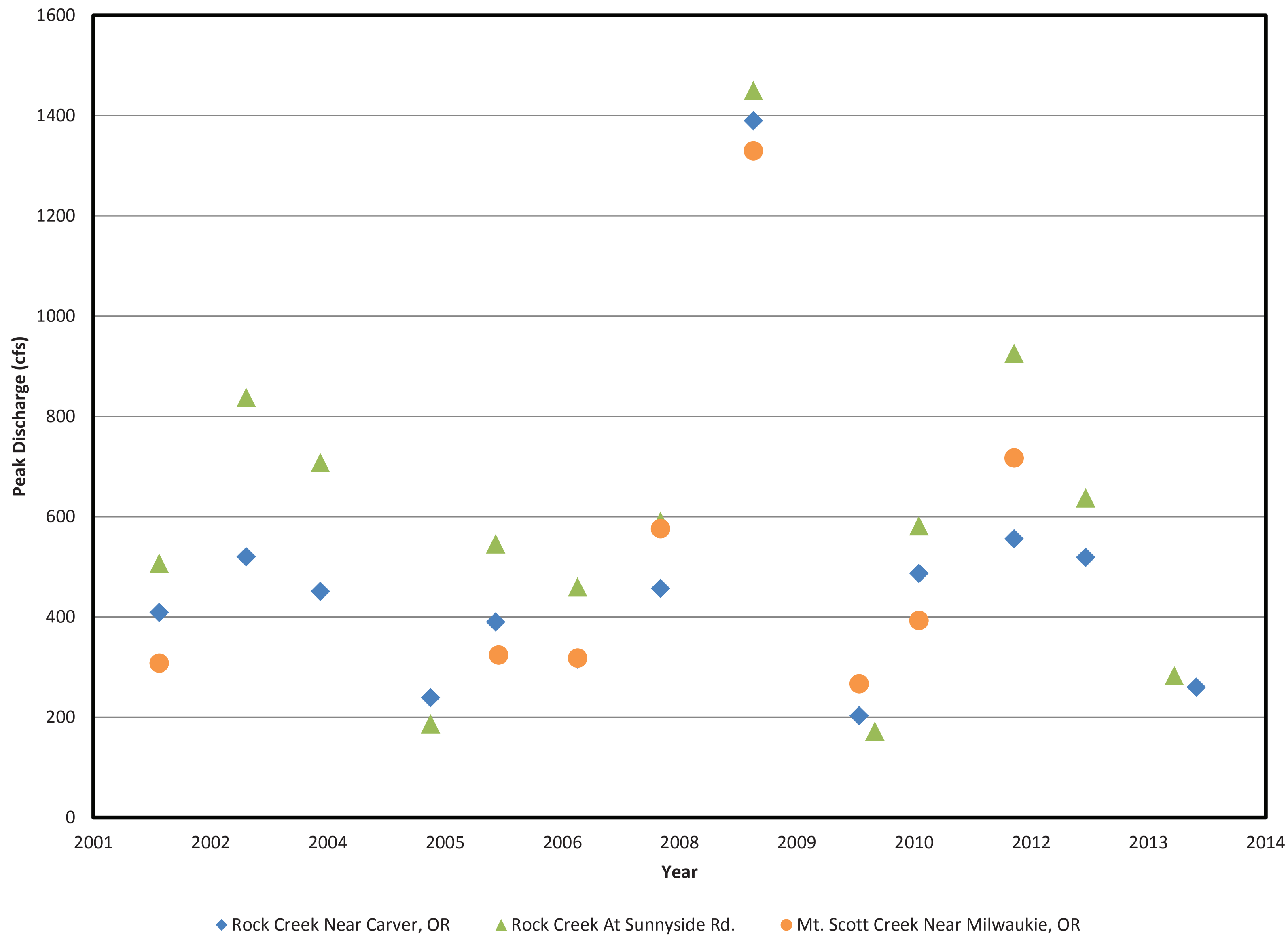


FIGURE **2**

Annual peak flow data from three USGS gages in the CCSD #1 area.

WES MONITORING

SD1 FINAL REPORT

JUNE 2015

WATERWAYS CONSULTING, INC.

Santa Cruz, CA | watways.com | Portland, OR

Table 6. Geomorphic data collected in 2014 for long-term monitoring- Clackamas County Service District (CCSD #1), Oregon.

Site ID	Longitudinal Profile	Cross Sections	Bank Erosion	Pool Depths	Bulk Sample*	Pebble Count**
Kellogg Creek Subbasin						
G-KL-10	X	X	X	X	X	
G-KL-30	X	X	X	X		
Mt. Scott Creek Subbasin						
G-MS-40	X	X	X	X	X	X
G-MS-70	X	X	X	X	X	X
G-MS-80	X	X	X	X	X	X
G-MS-90	X	X	X	X	X	
G-MS-100	X	X	X	X		
G-MS-110	X	X	X	X		
G-PH-10	X	X	X	X	X	X
G-RC-10	X	X	X	X	X	X
Rock Creek Subbasin						
G-RC-20	X	X	X	X		
G-RC-30	X	X	X	X		
G-RC-40	X	X	X	X	X	X
G-RC-50	X	X	X	X	X	
G-RC-60	X	X	X	X		
Tributaries to the Clackamas River						
G-SI-10	X	X	X	X	X	

* Bulk samples were not collected at sites that lacked significant alluvial material or were dominated by bedrock.

** Pebble counts were only taken at sites where exposed depositional features were present.

Table 7. Channel parameters calculated for each study reach in 2014 - Clackamas County Service District #1 (CCSD #1), Oregon.							
Site ID	**Channel Slope (%)**	**Bankfull Width (ft.)**	**Bankfull Depth (ft.)**	**Bankfull W/D Ratio**	**Entrenchment Ratio**	**Avg. Max Pool Depth (ft.)**	**Avg. Max Res. Pool Depth (ft.)**
Kellogg Creek Subbasin							
G-KL-10	0.6	37.7	2.0	19.1	1.57	1.8	1.1
G-KL-30	0.4	8.7	1.35	6.48	1.99	0.8	0.5
Mt. Scott Creek Subbasin							
G-MS-40	0.4	22.6	1.4	15.7	1.18	1.7	1.3
G-MS-70	0.5	23.2	1.7	16.4	1.58	1.7	1.5
G-MS-80	2.9	12.8	2.0	6.5	2.68	1.4	1.1
G-MS-90	6.1	5.2	1.4	3.7	3.00	0.6	0.5
G-MS-100	1.5	18.1	1.0	18.1	1.77	1.6	1.1
G-MS-110	0.8	11.6	1.7	6.8	3.00	1.3	1.0
G-PH-10	1.8	21.6	1.6	20.1	2.00	2.0	1.9
Rock Creek Subbasin							
G-RC-10	1.8	37.5	2.44	15.50	1.16	3.1	2.6
G-RC-20	2.4	5.5	1.16	4.92	3.00	0.6	0.4
G-RC-30	1.5	23.1	1.4	17.60	1.32	1.5	1.1
G-RC-40	1.0	19.0	2.43	7.74	1.99	1.8	1.0
G-RC-50	1.5	11.5	1.3	9.2	1.96	1.3	0.8
G-RC-60	0.7	11.6	2.3	5.2	2.34	2.6	1.0
Tributaries to the Clackamas River							
G-SI-10	0.8	8.8	1.2	7.8	1.23	1.7	1.3

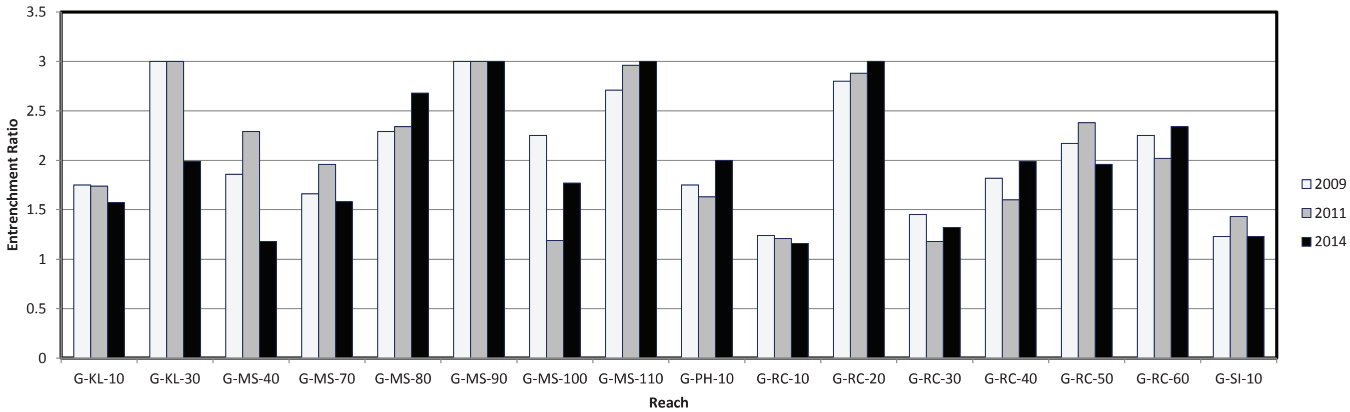
Entrenchment ratio, width to depth ratio, and the GINI coefficient were calculated and plotted on a bar chart for all streams surveyed in 2009, 2011, and 2014 (Figure 3). The sites that saw the most drastic changes in these values occurred across all of the watersheds in the SD1 area. Lower Kellogg Creek (G-KL-30) saw decreases in entrenchment and increases in the GINI coefficient. Mt. Scott downstream of SE 82nd Avenue (G-MS-40) experienced decreases in entrenchment and increases in W/D ratio. Mt. Scott Creek near Happy Valley Park (G-MS-100) and Mt. Scott Creek downstream of 145th Avenue (G-MS-110) have experienced fluctuations in entrenchment ratio over the years but saw drastic increases in W/D ratio in 2014. . Lower Rock Creek (G-RC-10) had the highest GINI coefficient in 2009 but has decreased over the years, indicating that the channel bed is aggrading. Sieben Creek (G-SI-10) continues to maintain a high GINI coefficient due to the incision through this reach.

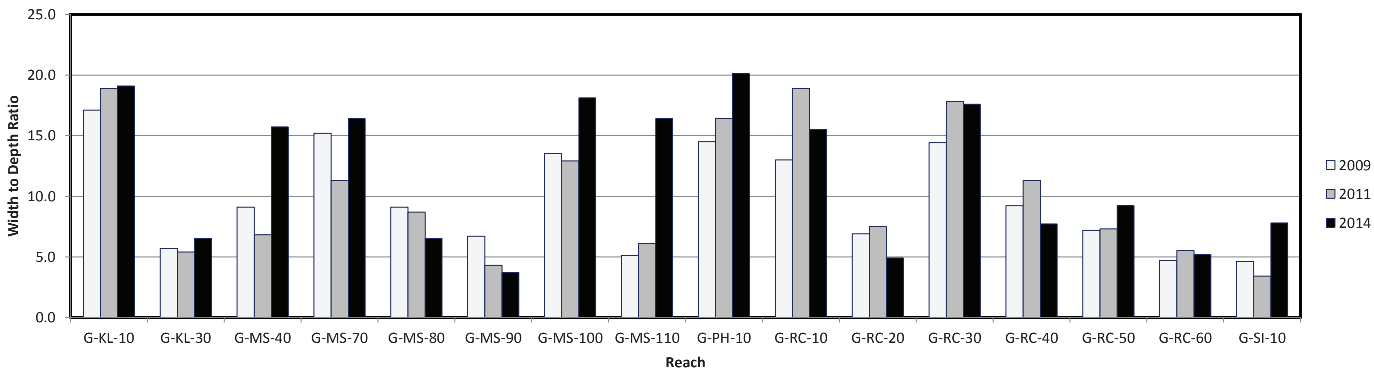
Table 8. Bed substrate and bank conditions in 2014 for each study reach - Clackamas County Service District #1 (CCSD #1), Oregon.

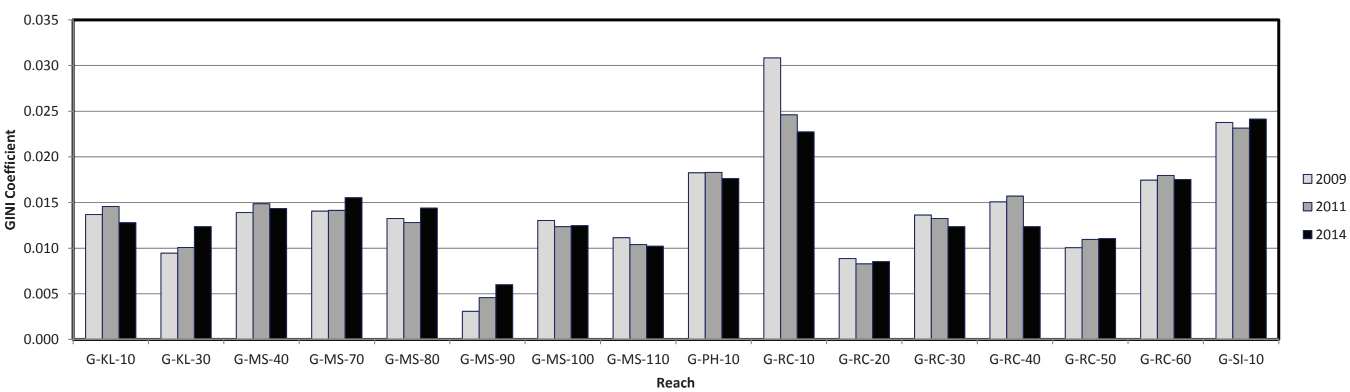
Site Code	% Left Bank Erosion	% Right Bank Erosion	D_{16} (mm)	D_{50} (mm)	D_{84} (mm)	% Bulk Sample < 6.30mm	% Bulk Sample < 0.85mm
Kellogg Creek Subbasin							
G-KL-10	0	11.1	NA	NA	NA	35	24
G-KL-30	0	0	NA	NA	NA	NA	NA
Mt. Scott Creek Subbasin							
G-MS-40	2.5	12.5	22	36	60	NA*	14
G-MS-70	5.1	11.1	25	45	81	37	27
G-MS-80	2.1	0	35	80	111	24	14
G-MS-90	8.7	0	NA	NA	NA	38	31
G-MS-100	1.0	3.0	NA	NA	NA	NA	NA
G-MS-110	0	0	NA	NA	NA	NA	NA
G-PH-10	3.6	0	28	53	80	22	9
Rock Creek Subbasin							
G-RC-10	0	0	29	60	91	19	14
G-RC-20	0	0	NA	NA	NA	NA	NA
G-RC-30	0	5.1	NA	NA	NA	NA	NA
G-RC-40	7.5	0	45	80	135	39	30
G-RC-50	6.8	7.4	NA	NA	NA	55	33
G-RC-60	0	0	NA	NA	NA	NA	NA
Tributaries to the Clackamas River							
G-SI-10	0	49.1	NA	NA	NA	20	8

*Lab forgot to include 6.30 mm sieve for site G-MS-40

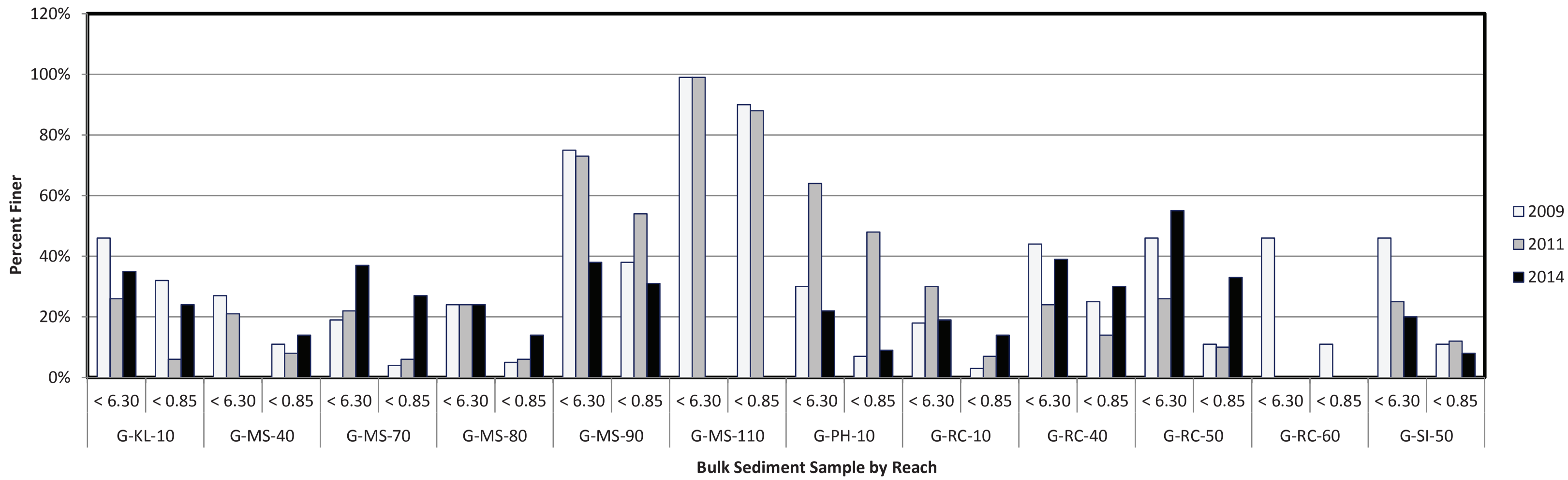
In 2014, a bulk sediment sample was collected at 10 reaches and pebble counts were conducted at 6 reaches. Rock Creek, downstream of 172nd (G-RC-40), exhibited the highest D_{16}, D_{50}, and D_{84} particle sizes in 201 (Figure 4). G-RC-40 also saw an increase in fines from the bulk sediment survey. Mt. Scott downstream of SE Sunnyside Road (G-MS-70) showed an increase in both the fines from the bulk sediment survey and the particle size in the pebble count. Rock Creek downstream of 172nd Avenue (G-RC-40) Rock Creek at Troge Road (G-RC-50) saw a drastic decrease in fines from the bulk sediment survey in 2011 and a subsequent drastic increase in fines in 2014. This variability is seen at many of the sites, with a similar, but opposite effect in the particle size from the pebble count.







Entrenchment Ratio (top graph) and Width to Depth Ratio (middle graph) and GINI coefficient (bottom graph) calculated from survey data collected from reaches in Clackamas County (CCSD#1), Oregon in the fall of 2009, 2011, and 2014	WES MONITORING SD1 FINAL REPORT JUNE 2015	WATERWAYS CONSULTING, INC. Santa Cruz, CA · watways.com · Portland, OR	**FIGURE** **3**



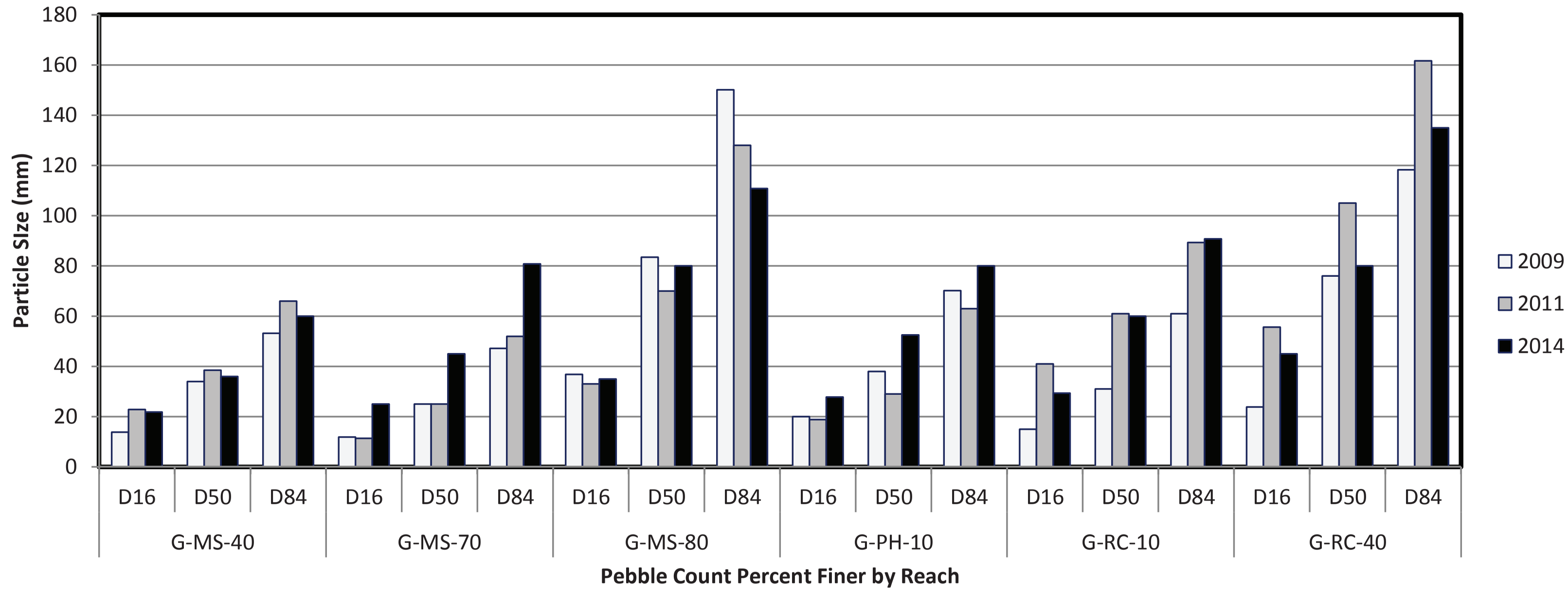


FIGURE 4

Bulk sample results (top graph) and pebble count results (bottom graph) sampled from reaches in Clackamas County (CCSD#1), Oregon in the fall of 2009, 2011, and 2014

WES MONITORING

SD1 FINAL REPORT
JUNE 2015

WATERWAYS CONSULTING, INC.
Santa Cruz, CA | watways.com | Portland, OR

Instream Physical Habitat and Associated Environmental Conditions

In 2014, all 13 reaches in which macroinvertebrates were sampled from riffles were analyzed together as "higher-gradient reaches". The one reach in Cow Creek (M-CO-20) from which only a glide sample was collected was analyzed separately. The 13 reaches from which riffles were sampled had channel slopes ranging from 0.6 to 4.2% (mean: 1.9%) with riffles comprising 25.0 to 78.7% (mean: 42.3%) of the instream habitat (Table 9). The Cow Creek reach (M-CO-10) was classified as a lower-gradient reach with a slope of 0.7% and a high proportion of slow-water habitat units (pools: 28.3.7%; glides: 71.7%). The Mt. Scott Creek reach at N Clackamas Park (M-MS-10) and the Kellogg Creek reach upstream of Rusk Road (M-KL-20) exhibited channel characteristic that are intermediate of higher- and lower-gradient reaches with an average channel slope of 0.6% and riffle habitat, but were included with the higher-gradient reaches for analysis owing to the prevalence of riffle habitat and coarse substrates in both reaches.

Higher-gradient reaches had a high proportion of coarse substrates within riffles (mean: 98.1%; range: 93.3 to 100.0%) and a low proportion of fine substrates (mean: 1.9%; range: 0.0 to 6.7%) when compared to the substrate within lower-gradient Cow Creek reach glides (M-CO-10; coarse substrate: 0.0%; fine substrate: 88.5%). Glide Substrate embeddedness in this reach was high (91.7%) while riffle substrate embeddedness in the higher-gradient reaches was relatively low (mean: 13.0%; range: 1.2 to 25.0%; Table 9).

Table 9. Environmental conditions of a lower reach (Cow Creek; M-CO-10), from which glides were sampled and 13 higher-gradient stream reaches in which riffles were sampled for macroinvertebrates in Clackamas County (SWMACC), Oregon in the fall of 2014.

	Lower-gradient	Higher-Gradient (n= 13)			
Environmental parameter	**M-CO-20**	**Mean**	**SD**	**Min**	**Max**
Channel slope (%)	0.7	1.9	1.2	0.6	4.2
Wetted width (m)	1.8	3.4	2.2	1.5	7.9
Bankfull width (m)	3.0	6.3	2.4	2.9	9.5
Percent pools	28.3	38.8	16.9	0.0	59.6
Percent glides	71.7	18.9	10.0	3.3	35.0
Percent riffles	0.0	42.3	18.9	25.0	78.7
Percent rapid	0.0	0.3	1.1	0.0	4.0
Percent coarse substrate in glides	0.0				
Percent fine substrate in glides	88.5				
Substrate embeddedness in glides	92.7				
Percent coarse substrate in riffles		98.1	2.4	93.3	100.0
Percent fine substrate in riffles		1.9	2.4	0.0	6.7
Substrate embeddedness in riffles		13.0	6.9	1.2	25.0
Eroding banks	0	31	28	2	85
Undercut banks	0	8	8	0	32
Large wood tally (#/m)	0.12	0.07	0.06	0.00	0.22
Overhead cover (%)	58	90	6	77	99
Mean riparian width (m)	18	39	34	4	100
Riparian zone tree cover (%)	0	64	13	45	80
Riparian zone non-native Veg. Cover (%)	100	27	18	5	70
Water temperature (°C)	15.9	16.0	1.0	13.7	17.5
Dissolved oxygen (%)	56.4	85.5	8.8	71.4	98.9
Dissolved oxygen (mg/L)	5.57	8.46	0.99	6.94	10.26

The lower-gradient Cow Creek reach (M-CO-10) had a narrower riparian buffer (18 m) and lower overhead canopy cover (58%) as compared to most of the higher-gradient reaches. Among the higher-gradient reaches, riparian buffer widths ranged from 4 to 100+ m (mean: 39 m), while overhead cover ranged from 77 to 99% (mean: 90%; Table 9).

A number of water chemistry parameters were measured during macroinvertebrate sample collection within each reach. . While water temperatures were consistently lower than 18ºC across all sites, dissolved oxygen concentrations ranged from 5.57 mg/L to 9.26 mg/L (Table 9). Dissolved oxygen concentrations were uniformly higher in the higher-gradient reaches when compared to the lower-gradient Cow Creek reach (M-CO-10; Table 9).

Based on calculations made in 2011, urban land use is lowest in the drainage basin upstream of the Richardson Creek reach (M-RI-10) and highest in the drainage basin upstream of the lower Carli Creek reach (M-CA-10; Table 10). At the subbasin level, urban land use was highest in the Kellogg Creek subbasin (91.7%), followed closely by the tributaries to the Clackamas River (89.6%) and the Mt. Scott Creek subbasin (88.3%). Urban land use in the Rock Creek subbasin was 36.3%. While the data are limited to the drainage basins upstream of the survey reaches within each subbasin, they are representative of the overall land use within each subbasin.

As in all previous sampling years, the highest-quality habitat occurred in the Richardson Creek reach (M-RI-10). This reach is dominated by fast-water habitat (78.7%), a high percentage of coarse substrate (94.0%), and intact riparian buffers with high percentages of tree cover (70%) and overhead canopy cover (86%).

Table 10. Land uses in the drainage basin upstream of monitoring reaches sampled in Clackamas County (CCSD #1), Oregon in the fall of 2014.

			Land Use (Percent)				
Reach ID	**Previous Site Code**	**Stream**	**Urban**	**Forest**	**Agriculture**	**Water**	**Total**
Kellogg Creek Subbasin							
M-KL-10	SD1-M18	Kellogg Creek	88.9	9.1	1.8	0.3	100.0
M-KL-20	SD1-M13a	Kellogg Creek	94.6	5.4	0.0	0.0	100.0
Mt. Scott Creek Subbasin							
M-MS-10	SD1-M4a	Mt. Scott Creek	88.7	8.7	2.3	0.4	100.0
M-MS-40	SD1-M3	Mt. Scott Creek	85.0	12.1	2.6	0.4	100.0
M-MS-80	SD1-M2	Mt. Scott Creek	84.2	11.4	4.3	0.1	100.0
M-PH-10	SD1-M5a	Phillips Creek	93.5	6.1	0.0	0.4	100.0
M-CE-10	SD1-M15	Cedar Creek	89.9	9.9	0.1	0.0	100.0
Rock Creek Subbasin							
M-RC-10	SD1-M10a	Rock Creek	40.2	27.1	32.7	0.1	100.0
M-RC-30	SD1-M11a	Rock Creek	35.5	31.0	33.4	0.1	100.0
M-RC-50	SD1-M17	Rock Creek	29.3	35.8	34.9	0.0	100.0
M-TR-10	SD1-M7a	Trillium Creek	40.3	27.0	32.6	0.1	100.0
Tributaries to the Clackamas River							
M-SI-10	SD1-M8	Sieben Creek	81.0	13.9	5.1	0.0	100.0
M-CA-10	SD1-M16	Carli Creek	98.9	1.1	0.0	0.0	100.0
M-CO-20	SD1-M14a	Cow Creek	89.0	8.5	2.3	0.2	100.0
M-RI-10	SD1-M12	Richardson Creek	42.0	22.0	35.9	0.1	100.0

Macroinvertebrate Community Conditions – Riffle Samples

Riffle samples were collected from 11 higher-gradient stream reaches and two reaches that exhibited intermediate characteristics of both lower- and higher-gradient stream reaches (M-KL-20 and M-MS-10; Table 11). Stream flow conditions were generally at their seasonal averages for weeks prior to and during macroinvertebrate sampling in 2014. No significant storm events occurred in late summer/early fall 2014 that would have potentially affected community composition and rendered results of macroinvertebrate sampling less comparable with past years' sampling.

DEQ multimetric scores of macroinvertebrate communities sampled from riffles ranged from 18 to 38 in 2014, compared to 12 to 32 in 2011, indicating that macroinvertebrate community conditions are severely to slightly impaired within the survey reaches (Table 12). In 2014, the Carli Creek reach (M-CA-10) and Trillium Creek reach (M-TR-10) each received the lowest multimetric score of 18 and a corresponding condition class of severely disturbed (Table 12). While 2011 and 2014 multimetric scores never differed by more than 6 points for any reach, scores were generally higher in 2014 than in 2011 (Table 13). In fact, MM scores increased in 11 of 13 reaches between 2011 and 2014 and decreased in only one reach during the same period (Table 13).

Table 11. Habitats from which macroinvertebrate samples were collected in monitoring reaches sampled in Clackamas County (CCSD #1), Oregon in the fall of 2002, 2007, 2009, 2011, and 2014.

	Year Sampled				
Reach Code	**2002**	**2007**	**2009**	**2011**	**2014**
Kellogg Creek Subbasin					
M-KL-10			Riffle	Riffle	Riffle
M-KL-20				Riffle/Glide	Riffle
Mt. Scott Creek Subbasin					
M-MS-10	Riffle/Glide	Riffle/Glide	Riffle/Glide	Riffle/Glide	Riffle
M-MS-40	Riffle/Glide	Riffle/Glide	Riffle/Glide	Riffle	Riffle
M-MS-80	Riffle	Riffle	Riffle	Riffle	Riffle
M-PH-10				Riffle	Riffle
M-CE-10	Riffle/Glide	Riffle/Glide	Riffle	Riffle	
Rock Creek Subbasin					
M-RC-10	Riffle	Riffle	Riffle	Riffle	Riffle
M-RC-30	Riffle	Riffle	Riffle	Riffle	Riffle
M-RC-50			Riffle	Riffle	Riffle
M-TR-10			Riffle	Riffle	Riffle
Tributaries to the Clackamas River					
M-SI-10	Riffle	Riffle	Riffle	Riffle	Riffle
M-CA-10		Riffle	Riffle	Riffle	Riffle
M-CO-20				Glide	Glide
M-RI-10	Riffle	Riffle	Riffle	Riffle	Riffle

The Richardson Creek reach (M-RI-10) received the highest multimetric scores in 2002 (30 points), 2007 (34 points), 2009 (38 points), 2011 (32 points), and 2014 (38 points; Table 12). The reach has been classified as slightly disturbed in each assessment year. Using the PREDATOR MWCF model, the Richardson Creek reach was classified as "most disturbed" in 2002, 2007 and 2009, "least disturbed" in 2011, and "most disturbed" again in 2014. The remaining 13 reaches received a classification of "most disturbed" by the MWCF model (Table 12). Using both 2011 and 2014 data, MWCF O/E scores most often resulted in a more severe biological condition classification than did MM scores (Figure 5). Among 18 riffle samples collected in 2011 and 2014 and classified by the MWCF model as "most disturbed", only 2 of these received a corresponding "severely disturbed" MM score, 13 received a "moderately disturbed" MM score, and 3 received a "slightly disturbed" MM score (Figure 5). These results highlight the need to carefully and collectively examine the results of these monitoring efforts to ascertain biological conditions, potential causation in observed conditions, and spatial and temporal patterns in those conditions, as later discussed.

Table 12. Western Oregon multimetric scores and PREDATOR MWCF O/E scores calculated from macroinvertebrate samples collected from riffles in 13 stream reaches in Clackamas County (CCSD#1), Oregon, in the fall of 2014.

Reach Code	MM Score	MM Disturbance Class	O/E Score	O/E Disturbance Class
Kellogg Creek Subbasin				
M-KL-10	22	Mod	0.436	Most
M-KL-20	22	Mod	0.581	Most
Mt. Scott Creek Subbasin				
M-MS-10	22	Mod	0.339	Most
M-MS-40	20	Mod/Severe	0.581	Most
M-MS-80	24	Mod	0.484	Most
M-PH-10	22	Mod	0.436	Most
M-CE-10				
Rock Creek Subbasin				
M-RC-10	32	Slight	0.871	Mod
M-RC-30	34	Slight	0.967	Least
M-RC-50	26	Mod	0.774	Most
M-TR-10	18	Severe	0.581	Most
Clackamas River Tributaries				
M-SI-10	20	Mod/Severe	0.484	Most
M-CA-10	18	Severe	0.387	Most
M-RI-10	38	Slight	0.871	Mod

Among the 7 reaches sampled in each assessment year since 2002 (M-MS-10, M-MS-40, M-MS-80, M-RC-10, M-RC-30, M-SI-10, and M-RI-10), multimetric scores suggest variable, yet unchanged or potentially improving biological conditions (Figure 6). MWCF O/E scores generally similarly suggest variable but unchanged and perhaps improving conditions for these 7 reaches (Figure 6). Considering all reaches monitored in each year, both MM scores and MWCF O/E scores suggest potentially improved biological conditions in all streams sampled since 2002 (Figure 7). Importantly, neither the MM scores nor MWCF O/E scores indicate downward trending at any of these reaches over the 12-year monitoring period. Considering the mean values of the 7 reaches sampled each assessment year since 2002, the same subtle, yet positive trend of potentially improving biological conditions is evident with the both the MM and O/E scores (Figure 7).

When multimetric scores of reaches where riffles were sampled were averaged by subbasin, the Mt. Scott Creek (n = 4) and Kellogg Creek (n = 2) subbasins had the lowest multimetric score of 22, while the mean multimetric score for the Rock Creek subbasin was 27.5 (SD: 7.2, n= 4). Tributaries to the Clackamas River, including Sieben and Carli creeks had a mean multimetric score of 19 (1.4= 7, n = 2). For comparison, the Richardson Creek reach (M-RI-10) received a multimetric score of 38 in 2014 (Figure 8).

MWCF O/E scores, when summarized in the same manner, followed a similar pattern (Table 14). The mean O/E score for the Mt. Scott Creek subbasin was 0.46 (SD: 0.10, n= 4), followed by the Kellogg Creek subbasin (mean: 0.51; SD: 0.10, n= 2), and the Rock Creek subbasin (mean: 0.80; SD: 0.17, n= 4; Figure 8). Tributaries to the Clackamas River, including Sieben and Carli creeks had a mean O/E score of 0.44 (SD: 0.07). For comparison, the Richardson Creek reach (M-RI-10) received a multimetric score of 0.87 in 2014.

Table 13. Multimetric scores calculated for riffle samples collected from stream reaches in Clackamas County (CCSD #1), Oregon, in the fall of 2002, 2007, 2009, 2011, and 2014.

	Year Sampled				
Reach Code	**2002**	**2007**	**2009**	**2011**	**2014**
Kellogg Creek Subbasin					
M-KL-10	-	-	16	22	22
M-KL-20	-	-	-	18	22
Mt. Scott Creek Subbasin					
M-MS-10	16	14	16	18	22
M-MS-40	16	18	18	14	20
M-MS-80	16	16	24	20	24
M-PH-10	-	-	-	16	22
M-CE-10	16	10	12	16	-
Rock Creek Subbasin					
M-RC-10	22	32	34	30	32
M-RC-30	22	28	26	28	34
M-RC-50	-	-	26	20	26
M-TR-10	-	-	24	20	18
Tributaries to the Clackamas River					
M-SI-10	24	18	20	22	20
M-CA-10	-	10	12	12	18
M-RI-10	30	34	38	32	38

Table 14. MWCF O/E scores calculated for riffle samples collected from stream reaches in Clackamas County (CCSD #1), Oregon, in the fall of 2002, 2007, 2009, 2011, and 2014.

	Year Sampled				
Reach Code	**2002**	**2007**	**2009**	**2011**	**2014**
Kellogg Creek Subbasin					
M-KL-10			0.242	0.630	0.436
M-KL-20				0.533	0.581
Mt. Scott Creek Subbasin					
M-MS-10	0.291	0.338	0.388	0.436	0.339
M-MS-40	0.291	0.483	0.533	0.484	0.581
M-MS-80	0.387	0.532	0.533	0.580	0.484
M-PH-10				0.387	0.436
M-CE-10	0.387	0.483	0.533	0.387	
Rock Creek Subbasin					
M-RC-10	0.532	0.918	0.775	0.774	0.871
M-RC-30	0.629	0.870	0.678	0.822	0.967
M-RC-50			0.823	0.822	0.774
M-TR-10			0.581	0.629	0.581
Tributaries to the Clackamas River					
M-SI-10	0.194	0.338	0.387	0.436	0.484
M-CA-10		0.097	0.242	0.290	0.387
M-RI-10	0.774	0.773	0.823	0.919	0.871

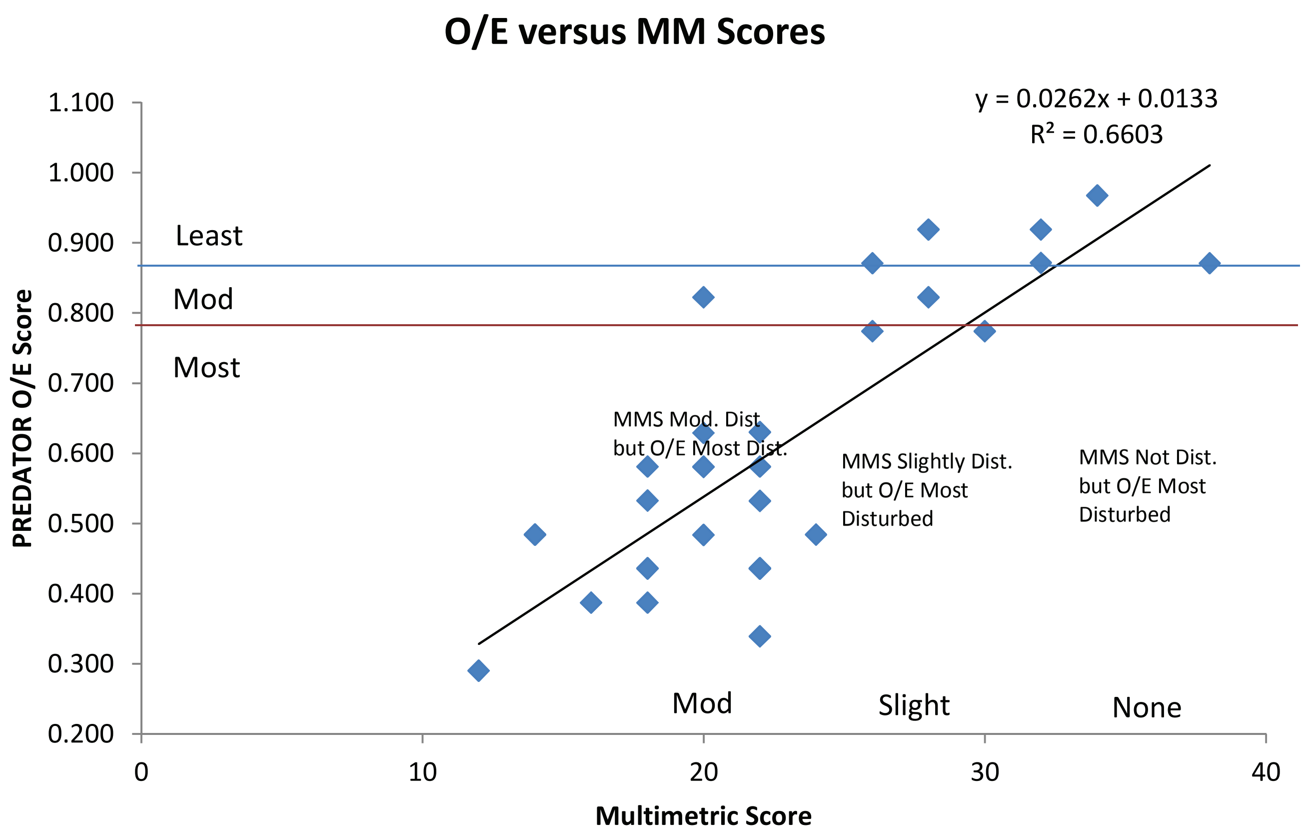


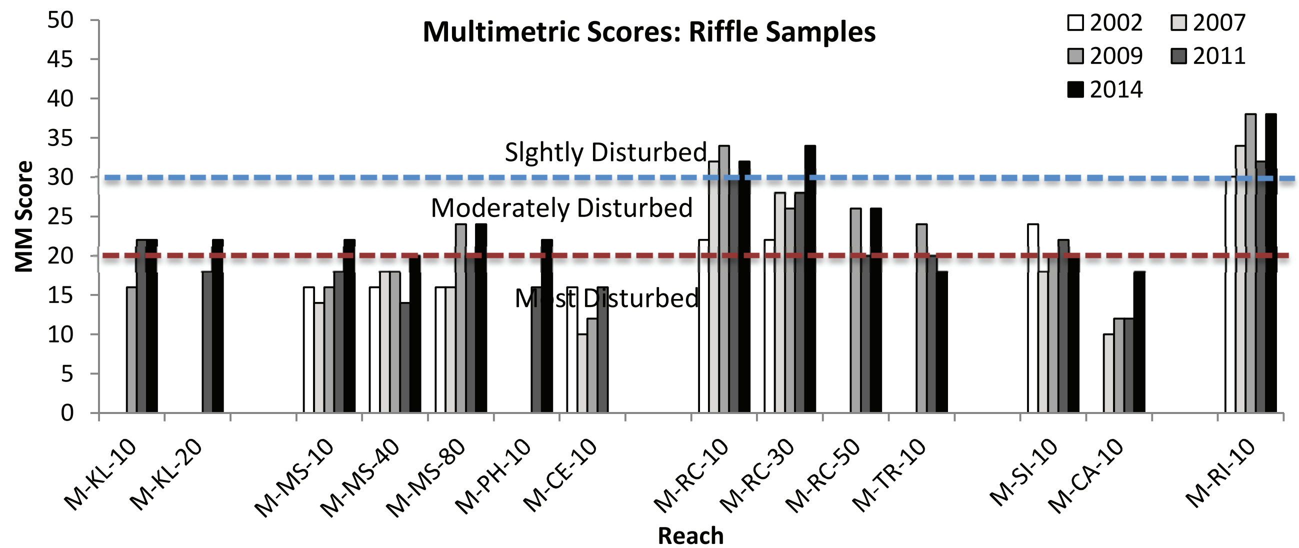
FIGURE 5

Relationships between multimetric scores and PREDATOR O/E model scores of macroinvertebrate communities sampled from riffles in stream reaches in Clackamas County (CCSD#1), Oregon in the fall of 2014.

WES MONITORING

SD1 FINAL REPORT
JUNE 2015

COLE ECOLOGICAL, INC.



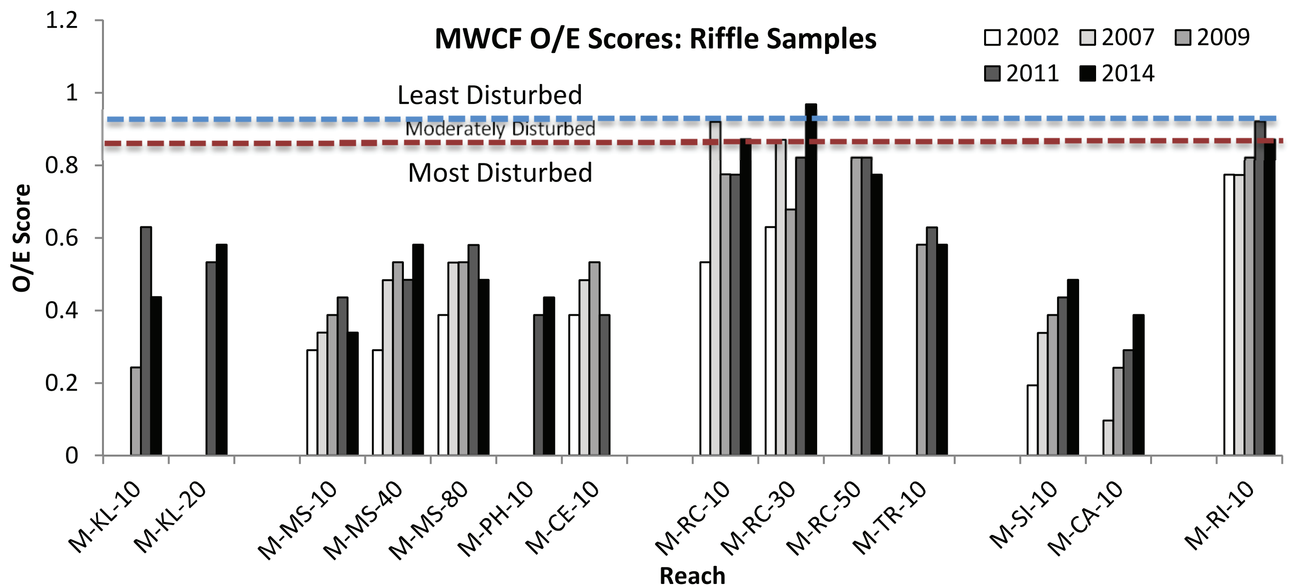


FIGURE 6

Multimetric scores (top panel) and PREDATOR MWCF O/E scores (bottom panel) of macroinvertebrate communities sampled from riffles in Clackamas County (CCSD#1), Oregon in the fall of 2002, 2007, 2009, 2011, and 2014.

WES MONITORING

SD1 FINAL REPORT
JUNE 2015

COLE ECOLOGICAL, Inc.

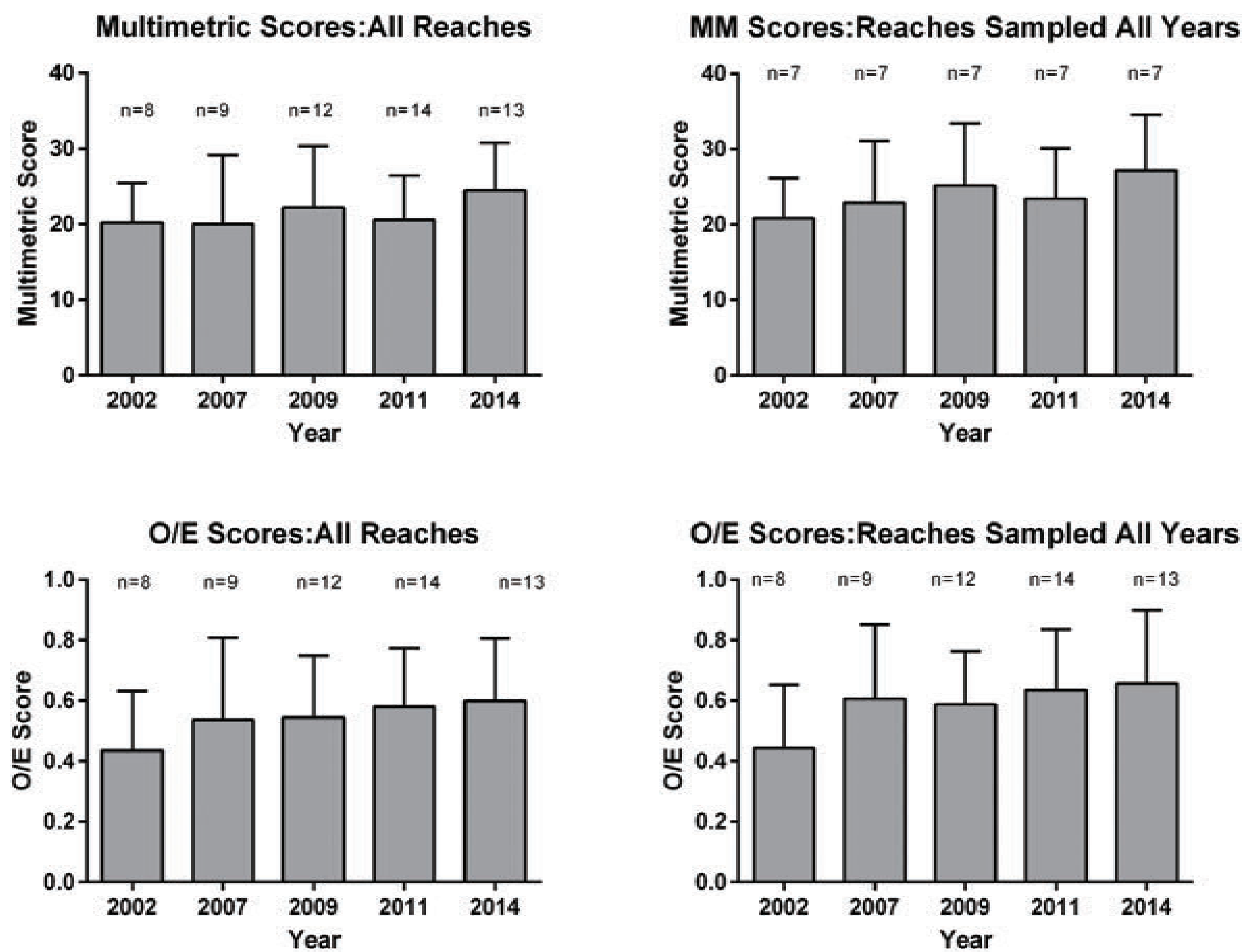
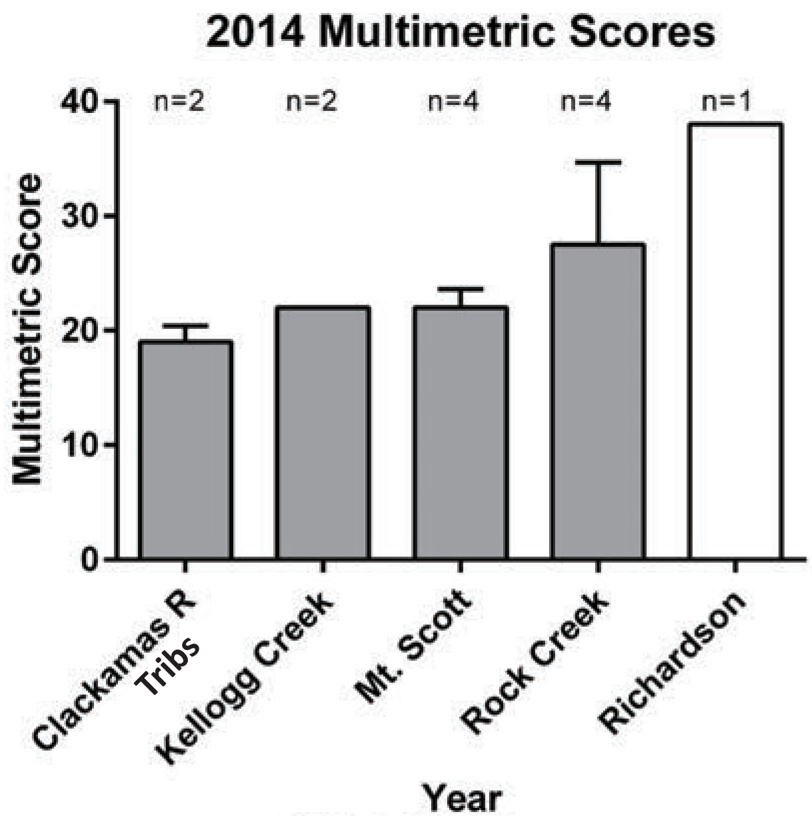
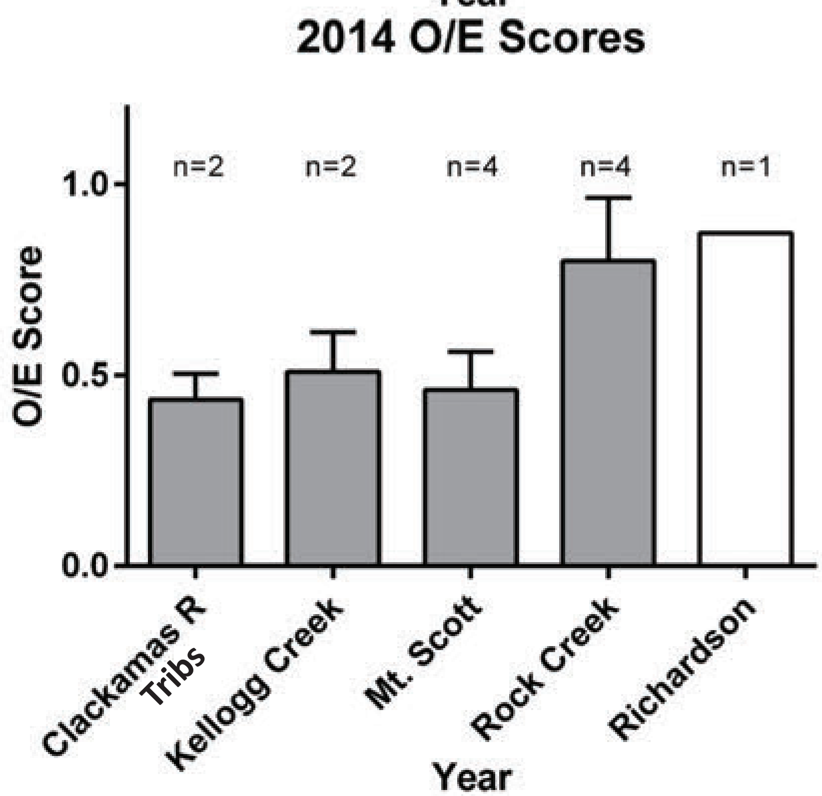


FIGURE 7

Mean multimetric (upper panels) and mean MWCF O/E (bottom panels) scores of macroinvertebrate communities sampled from riffles in Clackamas County (CCSD#1), Oregon in the fall of 2002, 2007, 2009, 2011, and 2014. Left panels include data from all reaches where riffles were sampled, while the right panels include data from a subset of reaches where riffles were sampled in each of the five survey years (n=7).





Mean multimetric scores of riffles sampled from reaches within three Clackamas County (CCSD # 1) subbasins (Kellogg Creek, n= 2; Mt. Scott Creek, n= 4; and Rock Creek, n= 4), Clackamas River tributaries (n= 2), and the Richardson Creek reach. Samples were collected in the fall of 2014.

Individual measures of community condition (using individual metrics) varied among reaches (Table 15). Total taxa richness ranged from 14 taxa in Carli Creek (M-CA-10) to 42 taxa in middle Rock Creek (M-RC-30) and averaged 26.6 taxa across all reaches from which riffles were sampled. Mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) richness again varied among riffle samples. These orders, collectively referred to as "EPT taxa," are generally regarded as sensitive to water pollution and habitat degradation. The Richardson Creek reach (M-RI-10) supported the highest number of EPT taxa in 2002 (17 taxa), 2007 (18 taxa), 2009 (19 taxa), 2011 (18 taxa), and 2014 (20 taxa). The lower (M-RC-10) and middle (M-RC-30) Rock Creek reaches supported the next highest number of EPT taxa, 15 and 18, respectively. The number of taxa represented by each of these orders varied widely among study reaches (Table 15); only one EPT taxon was sampled from Carli Creek (M-CA-10), while only 5 EPT taxa were sampled from the Sieben Creek reach (M-SI-10). At least one sensitive taxon was present in 9 of the 14 reaches where riffles were sampled. The Richardson Creek reach supported the highest number of sensitive taxa, including the stoneflies (Order: Plecoptera) *Despaxia augusta*, *Capniidae*, and *Zapada frigida*. *Zapada frigida* was present only in the Richardson Creek sample, while *Despaxia augusta* was also present in the Rock Creek subbasin (M-RC-10 and M-RC-30), and immature stoneflies belonging to the family Capniidae were also sampled from Mt. Scott Creek (M-MS-80), Phillips Creek (M-PH-10) and Sieben Creek (M-SI-10).

The percentage of tolerant organisms, percentage of sediment-tolerant organisms, and percent dominance by one taxon also varied among reaches, further reflecting the range in macroinvertebrate community conditions in riffles among sampled reaches (Table 15). Fine-sediment stressor model results suggested that macroinvertebrate communities in the Kellogg Creek and Mt. Scott Creek subbasins were likely showing fine-sediment-induced stress across all reaches sampled (Table 16).

Table 15. Macroinvertebrate community metrics calculated for riffle samples collected from stream reaches in Clackamas County (CCSD #1), Oregon, in the fall of 2014 (n= 13).

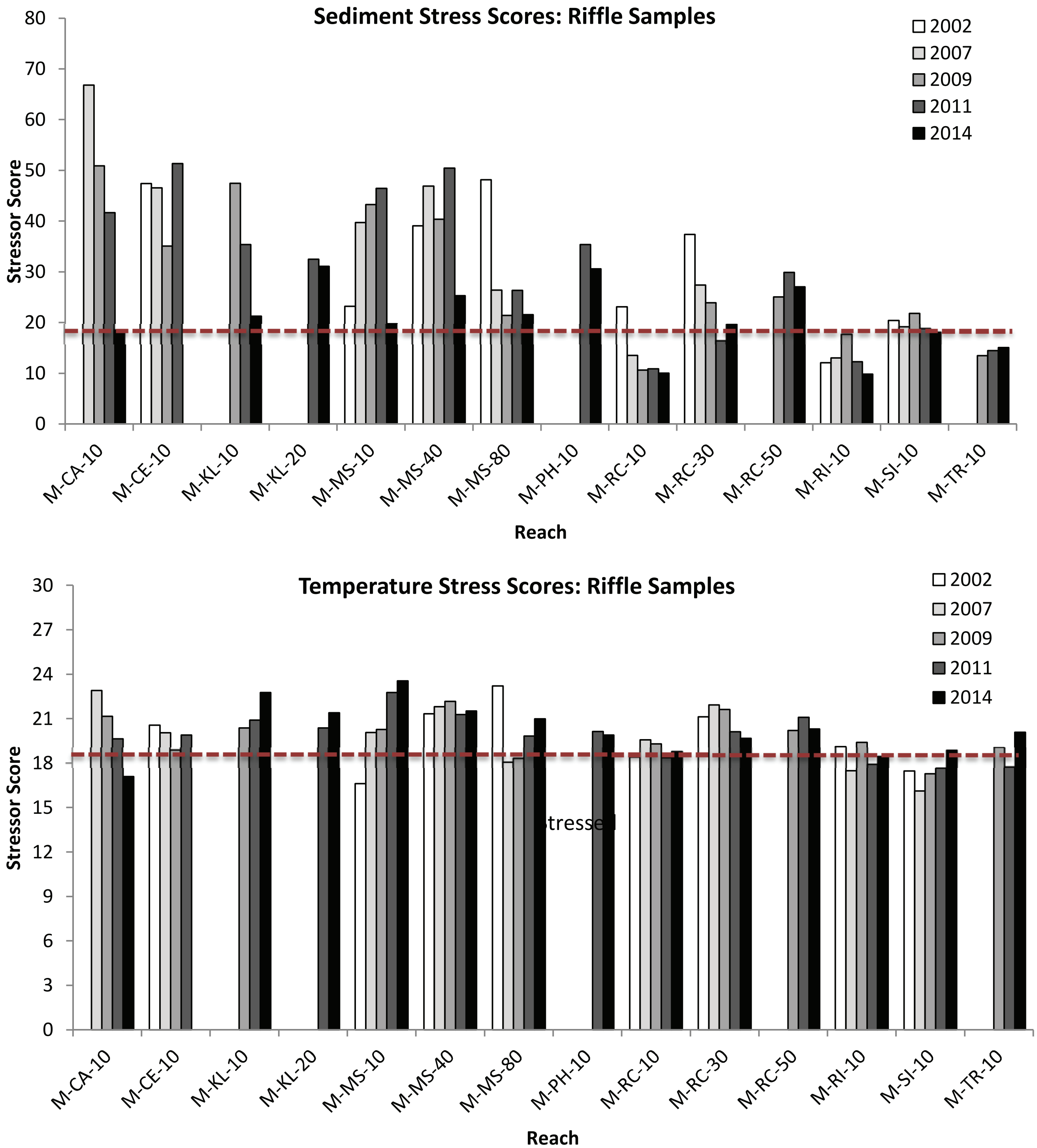
Metric	Mean	SD	Min	Max
Taxa richness	26.6	7.4	14	42
Mayfly richness	3.7	2.4	1	9
Stonefly richness	2.1	2.9	0	9
Caddisfly richness	3.4	1.4	0	6
Number sensitive taxa	0.7	0.9	0	3
Number sediment sensitive taxa	0.2	0.6	0	2
Modified HBI	5.0	0.6	3.9	5.9
Tolerant taxa (%)	24.9	15.9	0.6	44.5
Sediment tolerant taxa (%)	6.6	6.2	0.6	21.3
Dominant (%)	1.8	1.3	1.0	5.0
Total MM Score	24.5	6.3	18	38

Fine-sediment stressor (FSS) model results indicated that macroinvertebrate communities from 10 of the 13 higher-gradient reaches exceeded the DEQ fine sediment stress threshold of 19% for the Willamette Valley (Figure 9). Fine sediment was determined to be a likely stressor in both Kellogg Creek reaches and all 4 of the Mt. Scott Creek reaches sampled in 2014 (Table 16). While Rock Creek exceedances of FSS scores above the 19% threshold were generally considerably lower in 2014 than in past years (Figure 9), historically large exceedances warrant continuing to list all Rock Creek reaches as likely fine sediment stressed (Table 16; Figure 9). Of the reaches sampled for the geomorphic monitoring efforts, the Kellogg Creek reaches had high levels of sediment intrusion. Mt. Scott Creek reaches sampled in 2014 were all rated at moderate to high levels of fine sediment intrusion and many of the reaches saw increases since 2011. Similarly, Rock Creek sites have seen an increase in fine sediments since 2011 but little change since 2009 (Figure 4). The macroinvertebrate study has data from previous years that show that a reduction in fine sediment intrusion is occurring over time, with slight fluctuations between years. The geomorphic data may not go back far enough to reveal this long term trend.

Fine sediment was a likely stressor in only one of the four Rock Creek subbasin reaches, M-RC-50. This reach received an FSS score of 25.5% which was higher than the Willamette Valley threshold of 19% (Huff et al. 2006) and has consistently received FSS scores in the mid to upper 20s since 2009 (Figure 9). Because FSS scores appear to be potentially decreasing in the middle Rock Creek reach (M-RC-30), this reach is presently listed as potentially being stressed by fine sediment (Figure 9, Table 16). Sieben Creek's fine sediment stress scores have consistently scored only marginally higher than the 19% Willamette Valley threshold, warranting a potentially sediment stressed classification for this study (Figure 9). Lower Rock Creek (M-RC-10), Richardson Creek (M-RI-10) and Trillium Creek (M-TR-10) have consistently received FSS scores below the 19% threshold, suggesting no indication of FSS-induced stress in the macroinvertebrate community (Figure 9, Table 16).

Table 16. Summary of stressor identification results for macroinvertebrate communities sampled from 13 higher-gradient and instream reach in Clackamas County (CCSD #1), Oregon, fall 2014. Stressors include elevated levels of fine sediment, elevated water temperature (Temp), and low dissolved oxygen (DO).

Reach ID	Likely Stressors	Potential Stressors	Not Likely Stressors
Kellogg Creek Subbasin			
M-KL-10	Fine sediment, Temp	-	DO
M-KL-20	Fine sediment, Temp	DO	-
Mt. Scott Creek Subbasin			
M-MS-10	Fine sediment, Temp	DO	-
M-MS-40	Fine sediment, Temp	DO	-
M-MS-80	Fine Sediment, Temp	-	DO
M-PH-10	Fine Sediment, Temp	DO	-
Rock Creek Subbasin			
M-RC-10	-	Temp	Fine sediment, DO
M-RC-30	Temp	Fine Sediment	DO
M-RC-50	Fine sediment, Temp	-	DO
M-TR-10	-	-	Fine sediment, Temp, DO
Tributaries to the Clackamas River			
M-SI-10	-	Fine sediment, Temp	DO
M-CA-10	Fine Sediment, Temp	-	DO
M-RI-10	-	-	Fine sediment, Temp, DO



Fine sediment stressor model scores (top panel) and temperature stressor scores (bottom panel) of macroinvertebrate communities sampled from riffles in Clackamas County (CCSD#1), Oregon in the fall of 2002, 2007, 2009, 2011, and 2014. Red lines indicate thresholds above which values indicate a stressed condition.

WES MONITORING

SD1 FINAL REPORT
JUNE 2015

COLE ECOLOGICAL, INC.

FIGURE 9

Temperature stressor model results suggested that macroinvertebrate communities in the Kellogg Creek and Mt. Scott Creek subbasins are likely continuing to show elevated temperature stress (Figure 10, Table 16), as macroinvertebrate assemblages from all 6 of the reaches in the two subbasins received inferred temperature stressor scores higher than the Willamette Valley threshold of 18.2 °C (Huff et al. 2006). Elevated stream temperature is also likely a stressor in two of the four reaches in the Rock Creek subbasin (M-RC-30 and M-RC-50). These reaches are located in the middle and upper portions of Rock Creek. Interestingly, the farthest downstream reach on Rock Creek (M-RC-10) has always received the lowest TS scores among the three Rock Creek reaches. These results suggest a cooler thermal regime in this lower reach than upstream, and could be investigated with continuous temperature monitoring in each of the three monitoring reaches.

Dissolved oxygen field data from 2011 and 2014 suggested that macroinvertebrate communities in the Kellogg Creek and Mt. Scott Creek basins are potentially stressed by low dissolved oxygen concentrations. Low dissolved oxygen was potentially a stressor in one of the two Kellogg Creek reaches (M-KL-20) and four of the five Mt. Scott Creek reaches. Dissolved oxygen in the remaining Mt. Scott Creek reach (M-MS-80) was not likely a stressor based on these limited field data.

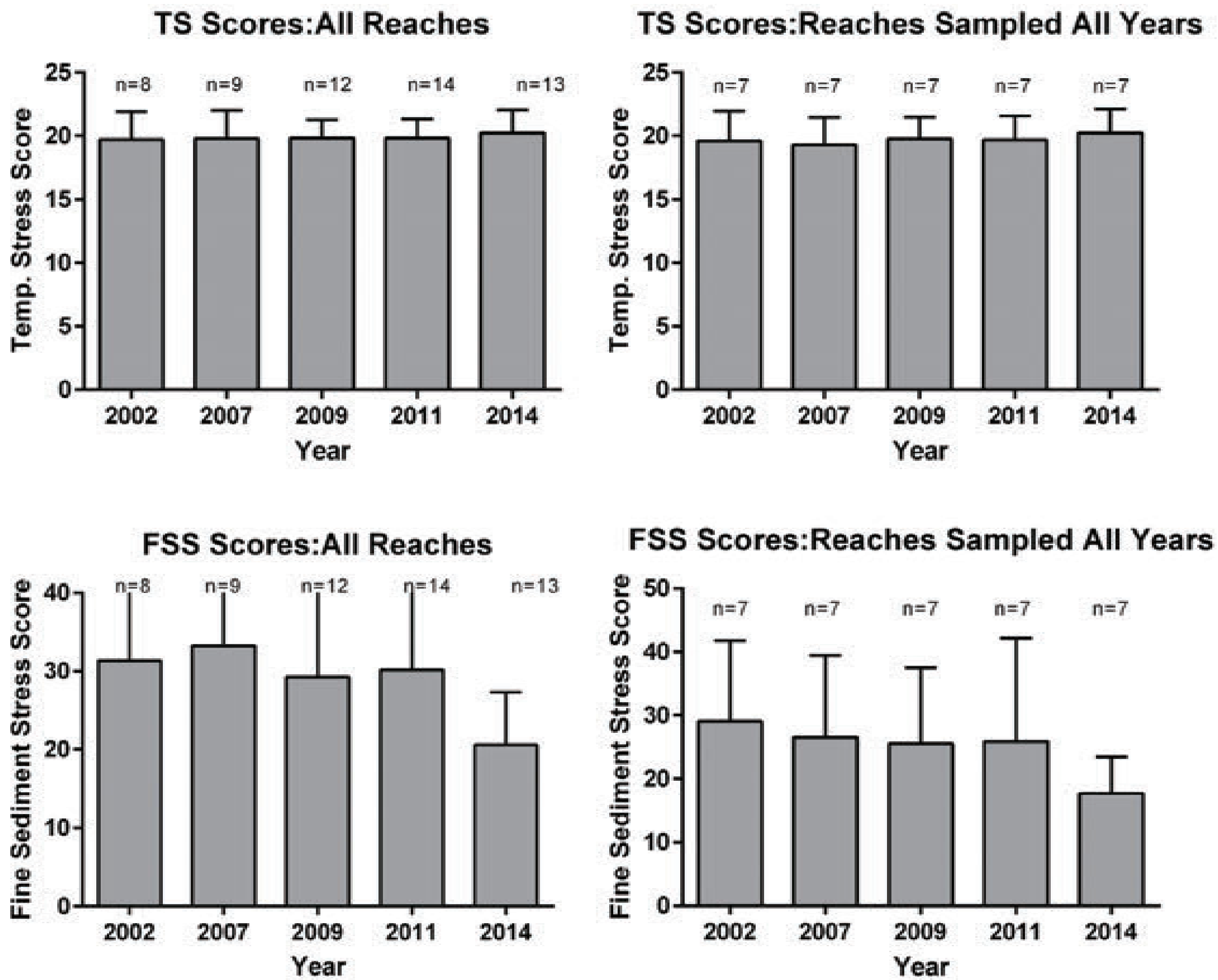


FIGURE 10

Mean temperature stressor scores (upper panels) and mean fine sediment stressor scores (bottom panels) of macroinvertebrate communities sampled from riffles in Clackamas County (CCSD#1), Oregon in the fall of 2002, 2007, 2009, 2011, and 2014. Left panels include data from all reaches where riffles were sampled, while the right panels include data from a subset of reaches where riffles were sampled in each of the five survey years (n=7).

Macroinvertebrate Community Conditions –Glide Samples

A single glide sample was collected from the Cow Creek reach (M-CO-10) in 2014. The Cow Creek reach (M-CO-10) received a MWCF O/E score of 0.435 in 2014 relative to 0.29 in 2011, the first year of sampling Cow Creek in this reach. Macroinvertebrate communities sampled from this reach were characterized as having a low total richness (19 total taxa), few EPT taxa (1 mayfly and 1 caddisfly taxon in 2014), and a high HBI score (HBI = 5.8). While only two EPT taxa – *Baetis tricaudatus* and *Hydropsyche* sp. – were sampled from this reach in 2014, the presence of these two taxa in the subsample is encouraging when compared to the absence of EPT taxa from the subsample in 2011.

Correlation of Community Conditions with Environmental Conditions

Both riffle sample multimetric scores and O/E scores were significantly correlated with land use in upstream drainage area, including percent urban (MM score: Spearman rho = -0.7364, $p < 0.0001$; O/E score: Spearman rho = -0.7806, $p < 0.0001$), percent agriculture (MM score: Spearman rho = 0.6037, $p = 0.0004$; O/E score: Spearman rho = 0.8012, $p < 0.0001$), percent urban and agriculture land uses combined (MM Score: Spearman rho = -0.5948, $p = 0.0022$; O/E score: Spearman rho = -0.6574, $p = 0.0006$), and percent forest (MM Score: Spearman rho = 0.6037, $p = 0.0019$; O/E score: Spearman rho = 0.6641, $p = 0.0005$; Figure 11 and Figure 12).

Among measured physical habitat attributes, wetted width (MM Score: Spearman rho = -0.4202, $p = 0.0289$, O/E Score: Spearman rho = -0.4008, $p = 0.0359$), the percentage of the reach comprised of glide habitat (MM Score: Spearman rho = -0.5173, $p = 0.0082$, O/E Score: Spearman rho = -0.5767, $p = 0.0031$) and the mean riparian buffer width (MM Score: Spearman rho = 0.4479, $p = 0.0209$, O/E Score: Spearman rho = 0.503, $p = 0.0104$) were each significantly correlated with both MM scores and O/E scores (Figure 11 and Figure 12).

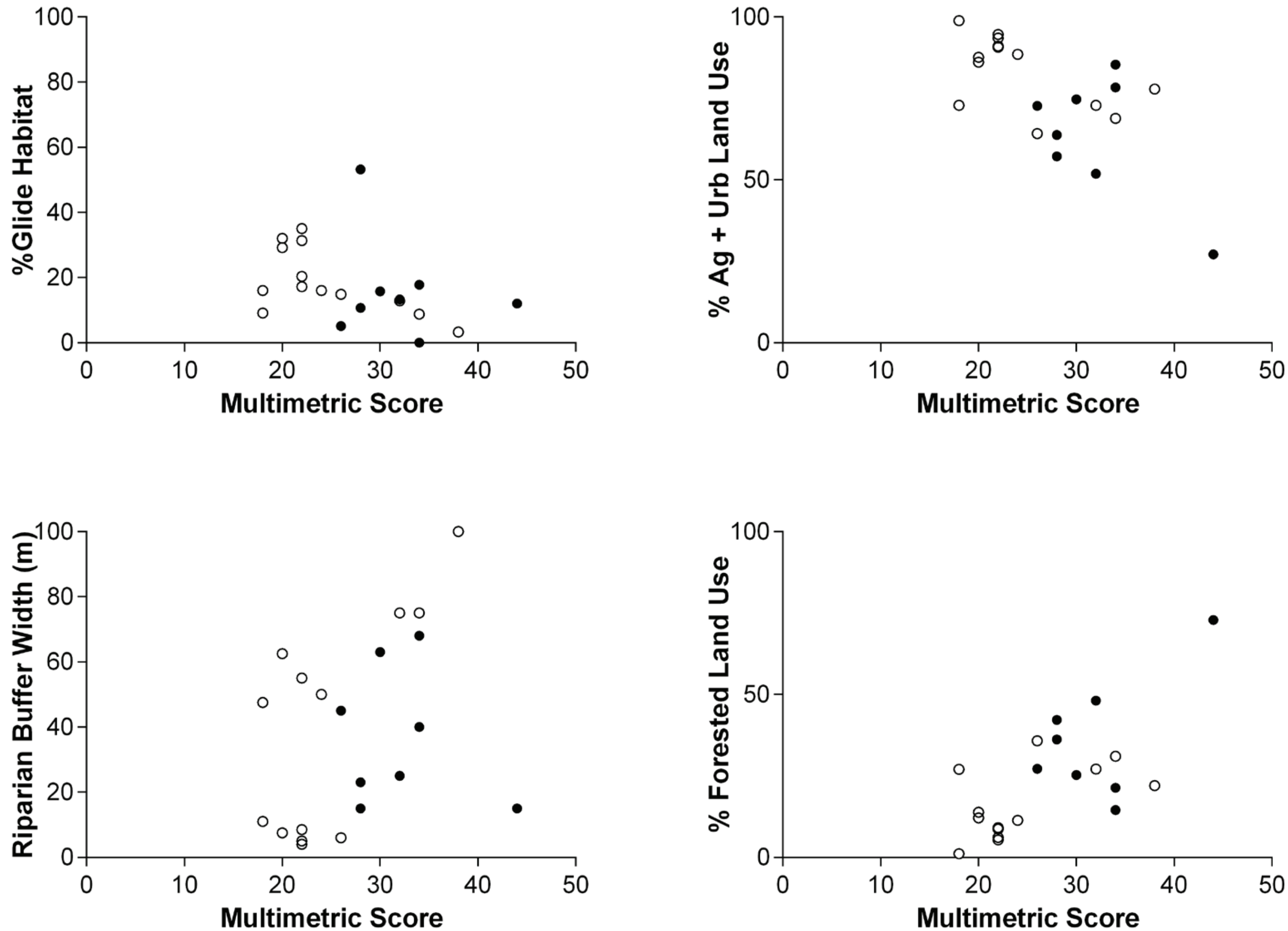


FIGURE 11

Relationships between multimetric scores of macroinvertebrate communities sampled from riffles and select environmental variables in Clackamas County (SWMACC: Solid circles and CCSD # 1: Open circles), Oregon in the fall of 2014.

WES MONITORING

SD1 FINAL REPORT
JUNE 2015

COLE ECOLOGICAL, Inc.

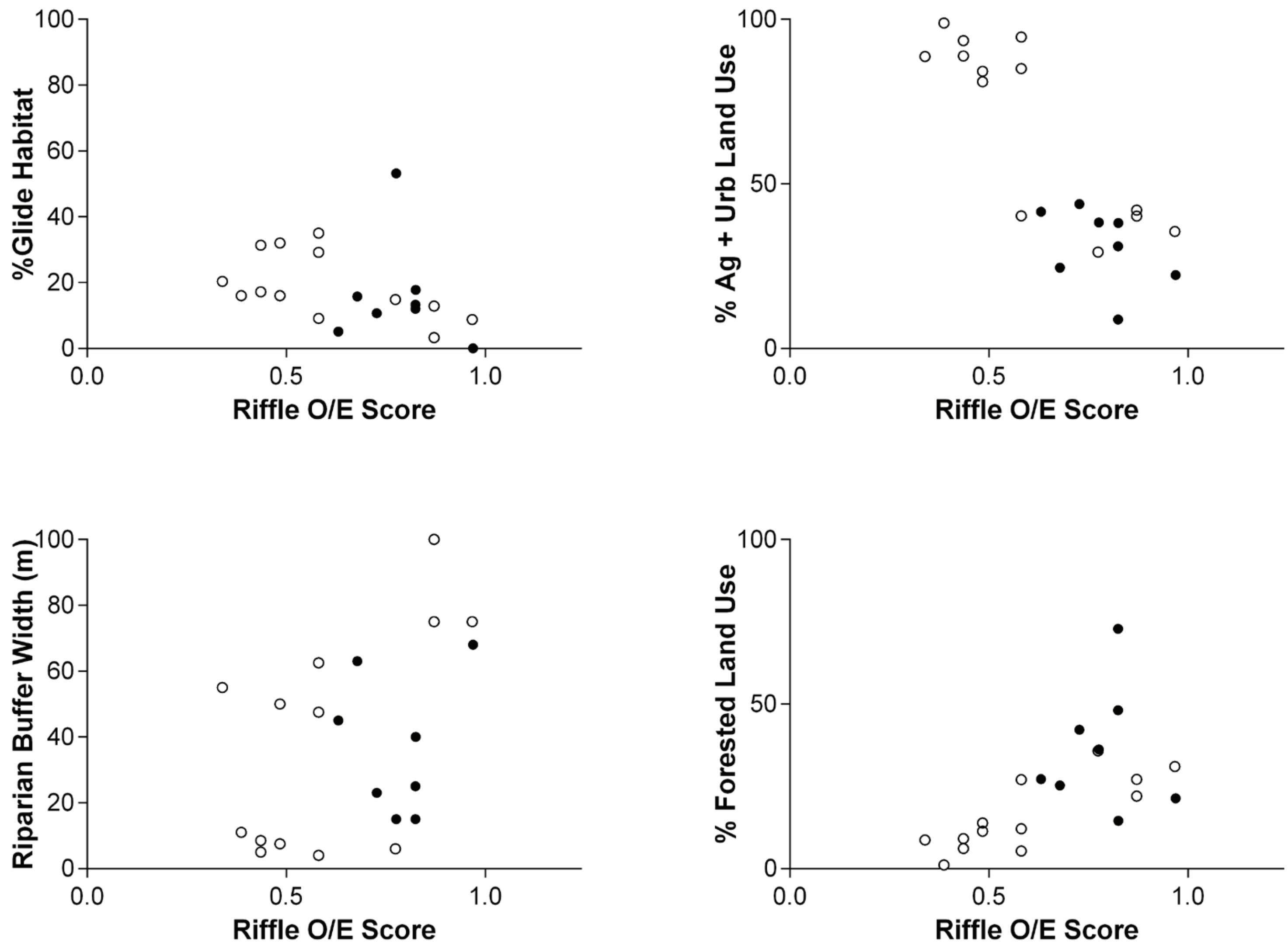


FIGURE 12

Relationships between MWCF O/E scores of macroinvertebrate communities sampled from riffles and select environmental variables in Clackamas County (SWMACC: Solid circles and CCSD # 1: Open circles), Oregon in the fall of 2014.

WES MONITORING

SD1 FINAL REPORT
JUNE 2015

COLE ECOLOGICAL, Inc.

4.0 DISCUSSSION

In general, the results from the geomorphic monitoring must be understood within the context of hydromodification and geomorphic change in the watershed that has been occurring for the past century. These past impacts have already modified most, if not all of the channels within the CCSD #1 service area. A lack of large wood supply, straightening, a modified hydrology, and channel incision are effects that can be observed throughout all sampled watersheds. Consequently, the focus of our analysis is to identify geomorphic trends, what the root causes of those changes might be, and whether or not the trajectory and magnitude of the observed trends presents significant risks to the stability of the reach.

Key indicators of instability would include the presence of a headcut and its rate of migration, which would be identified either through observations in the field or analysis of the longitudinal profile. Rapid channel widening or deepening would also be indicators of overall instability. Similarly rapid channel aggradation could be problematic at the reach scale, through increased water surfaces during high flow events, as well as regional concerns associated with excessive bank erosion or channel incision upstream.

Entrenchment Ratio

A decrease in entrenchment ratio is indicative of a loss of floodplain connection.

An increase in entrenchment ratio indicates an increase in floodplain connection.

Entrenchment ratio, width to depth ratio and the GINI coefficient are all measures of channel incision or widening. The decreases in entrenchment ratio and increases in W/D seen on Mt. Scott downstream of SE 82nd Avenue (G-MS-40) are most likely due to channel widening which is increasing the active channel width and decreasing connection with the floodplain. Mt. Scott Creek near Happy Valley Park (G-MS-100) and Mt. Scott Creek downstream of 145th Avenue (G-MS-110) have experienced fluctuations in entrenchment ratio over the years but saw drastic increases in W/D ratio in 2014. This is most likely due to bank erosion widening the channel and aggradation decreasing the active channel depth, allowing it to maintain connectivity with the floodplain. Yet, this bank erosion has water quality implications discussed below. Lower Rock Creek (G-RC-10) had the highest GINI coefficient in 2009 but has decreased over the years, indicating that the channel bed is aggrading. Sieben Creek (G-SI-10) continues to maintain a high GINI coefficient due to the incision through this reach.

GINI Coefficient

A decrease in the GINI coefficient suggests a flattening and widening of the channel.

An increase in the GINI coefficient means the channel is becoming deeper and narrower.

The GINI coefficient is calculated with the WinXSPRO Channel Cross Section Analyzer software (USDA). The GINI coefficient is the arithmetic average of the differences between all pairs of surveyed elevations, which is calculated by comparing the difference between each pair of surveyed elevations in the cross section with the average of all differences in all surveyed elevations for that cross section. On a flat surface, when all the points are the same elevation, the GINI coefficient is zero. In previous survey years and in 2014, the entire cross section, with all points from the floodplain and active channel, are plugged into WinXSPRO for the GINI coefficient. If the site has a broad floodplain and all these points are included in the WinXSPRO Analysis, the GINI coefficient will be inherently smaller. There would have to be significant changes to the channel *and* floodplain to change the GINI coefficient between monitoring years. In future years, it may make more sense to confine the GINI analysis to the active channel. This approach would allow for improved sensitivity of this monitoring variable to detect trends in channel morphology.

Channel incision and widening can lead to erosion which causes an increase in sediment in the stream. Many reaches throughout the CCSD #1 had high sediment intrusion ratings which has implications for benthic communities. Reaches with the greatest increases in sediment intrusion were Mt. Scott downstream of SE Sunnyside Road (G-MS-70), Rock Creek downstream of 172nd Avenue (G-RC-40), and Rock Creek at Troge Road (G-RC-50). The variation in the bulk sediment sample results across years indicates that fine sediment intrusion is very temporally variable. Future survey years may indicate clearer trends.

Coarsening of depositional features can also result from hydromodification. Rock Creek, downstream of 172nd (G-RC-40), exhibited the coarsest surficial bed material as measured by the pebble count in 2014. Yet, G-RC-40 saw a significant reduction in particle size since 2011. Combined with the fact that the bulk sample showed an increase in fine sediment at this study site in 2014, fining of the pebble count suggests that the trends in the pebble count are mostly likely due to an increase in fine sediment delivery to the site. It will be interesting to see if this trend continues in future survey years and whether or not this is just a temporary impact associated with construction activities in the vicinity of SE 172nd and Troge Road. Mt. Scott Creek, downstream of SE Sunnyside road (G-MS-70) experienced the greatest increase in particle size from 2011 to 2014. It also experienced an increase in fine sediment intrusion, elevating it to the high fine sediment intrusion rating. As discussed in the site description, this is indicative of flashy hydrology but may also be a result of construction activities higher in the watershed. This site should continue to be monitored in the future to see if this trend continues.

These geomorphic instabilities can lead to degraded habitat for macroinvertebrates. As in previous assessments of macroinvertebrate communities of the CCSD #1 service area, macroinvertebrate community conditions varied among stream reaches sampled during 2014. All streams in the survey showed evidence of current or past instabilities and varying degrees of elevated sediment loading, likely resulting from hydromodification. Among the 13 higher-gradient reaches included in this assessment, fine sediment was identified as a "likely stressor" in 8 reaches based on the high inferred fine sediment values produced by the FSS model and as supported by geomorphic and physical habitat data. Stress induced by fine sediment inputs appears to be affecting the macroinvertebrate communities in the Kellogg Creek and Mt. Scott Creek subbasins in particular.

2014 marked the fifth year of macroinvertebrate sampling in the CCSD#1 service area by WES since monitoring was initiated in 2002. Seven stream reaches have been sampled in each assessment year (some reaches have been re-located by short distances but biological results are combined for trending purposes) for macroinvertebrate community conditions in riffles. Collectively, their results suggest that macroinvertebrate community conditions in these streams have largely remained unchanged, if not slightly improved, in some cases. The average multimetric score from these 7 reaches increased from 22.9 in 2002 to 27.1 in 2014, with variation only within these extremes between 2007 and 2011. Potential biological improvements in Mt. Scott Creek at M-MS-80 and in Rock Creek at M-RC-30 during this time period were of particular noteworthiness. The next few monitoring rounds will be of particular interest to see if the data continue to reveal these potential trends at these and other reaches such as lower Mt. Scott Creek (M-MS-10) and Richardson Creek (M-RI-10).

Interestingly, there was general agreement between potential trends in macroinvertebrate community conditions and geomorphic condition ratings in this study. Specifically, most reaches included in the study received an overall geomorphic condition rating of "stable – at risk", and conditions of macroinvertebrate communities in most reaches were deemed to be stable or even slightly improving. Only two reaches included in both the geomorphic and macroinvertebrate studies received geomorphic condition ratings of "At Risk" or "At Risk – Unstable". G-MS-40/MS-40 received the only geomorphic condition rating of "At Risk", and this site has consistently received among the poorest FSS model scores, indicative of a community that is chronically stressed by excessive sediment loading. The Seiben Creek reach G-SI-10/M-SI-10 received the only geomorphic condition rating of "At Risk – Unstable", and also received among the lowest MMI and MWCF O/E scores. Future monitoring should continue to examine overall geomorphic condition ratings in relation to apparent trends macroinvertebrate community conditions to determine whether increasing or decreasing conditions in one corresponds with the other. Of course, other factors such as water quality, water temperature, and streamflow conditions all affect macroinvertebrate community conditions, so the lack of correspondence between these two aspects of the work may indicate that other factors are at play in affecting biological conditions.

As in previous years, disturbance classes derived from multimetric scores did not correspond well with those derived from MWCF O/E scores. In 2014, 10 of 13 higher-gradient reaches received O/E classification of most disturbed. Among those, only two received a corresponding multimetric classification of severely disturbed, while 8 received an MM classification of moderately disturbed. These results generally suggest that the MWCF O/E classification of "most disturbed" corresponds to both the "moderately" and "severely" disturbed classifications of the multimetric index. Richardson Creek received an MM score classification of slightly disturbed, but a moderately disturbed O/E score classification. The apparent disparity in the condition class assignments between the models appears to be partially related to the almost complete absence of some taxa that were predicted to occur at more than half of the reaches under least-disturbed conditions. This across-the-board absence of specific taxa from all or nearly all CCSD#1 samples results in lower O/E scores than corresponding multimetric scores. The O/E scores are more sensitive to the absence of certain taxa because the O/E models are based on the predicted presence of particular taxa, while the multimetric model results are based on broader metrics related to general taxonomic richness and ecological attributes of the taxa that are sampled. In prior studies, O/E scores and multimetric scores have generally shown good correspondence, but when they don't correspond, the O/E scores tend to be lower than the multimetric scores. Because correspondence in conditions classes does not always occur, we suggest continuing to assess macroinvertebrate community conditions using both approaches and focusing primarily on the scores themselves rather than on the resultant condition classes. Longer-term trends in these scores will be most useful for examining and quantifying changes and trends in biological conditions of CCSD #1 streams over time.
Macroinvertebrate community condition in higher-gradient reaches (i.e., from which riffle samples were collected) was once again correlated with land use types and several physical habitat characteristics. Pooling sample data across both service areas (CCSD #1 and SWMACC) provided a larger sample size and a wider range of environmental conditions, allowing for stronger correlations to be made. Although only correlative (i.e. one cannot infer cause and effect), the relationships allow for the identification of environmental stressors that are potentially responsible for producing the observed biological community conditions. Multimetric and O/E scores calculated from riffles samples were highly correlated with percent urban, agriculture, urban/agriculture, and forest land use types. Scores were negatively correlated with percent urban land use and the combination of percent urban and agriculture and uses, while scores were positively correlated with percent agriculture and percent forest land use types. Urban land use is relatively high in the Kellogg Creek (91.7%), and Mt. Scott Creek (88.3%) subbasins when compared to the Rock Creek subbasin (36.3%). %). When multimetric scores of riffle-sampled reaches were averaged, the Mt. Scott Creek and Kellogg Creek subbasins each had the lowest multimetric score of 22, while the Rock Creek

subbasin MM scores averaged 27.5. MWCF O/E scores, when summarized in the same manner, followed a similar pattern with lower mean scores observed in the more urbanized Kellogg Creek and Mt. Scott Creek subbasins (O/E Scores of 0.5 and 0.46 respectively) and a higher mean score observed in the less urbanized Rock Creek subbasin (0.80).

The Carli Creek reach (M-CA-10; CCSD #1), which received the lowest multimetric and MWCF O/E scores among all reaches in both service districts, had the highest percentage of urban land use in the drainage basin upstream of the reach (98.9%). Conversely, the Rock Creek reach (M-RC-30) and Richardson Creek reach (M-RI-10) which received the highest multimetric scores of 34 and 38 respectively, have a relatively low percentage of urban land use in the drainage basin upstream of the reaches (M-RC-30: 35.5% and M-RI-10: 42.0%).

As in previous years of sampling CCSD#1 stream reaches for macroinvertebrates, no freshwater mussels were sampled in 2014. This does not indicate that they are absent from CCSD#1 streams. The methods used in these studies are not intended to detect mussels when they are present. As several Pacific Northwest mussel species are state or federally listed, and as a group, freshwater mussels are generally sensitive to water pollution and habitat alteration, interest in determining their status in northwest Oregon waters is increasing. Protocols specific to detecting their presence and estimating their abundance have been established and would need to be used in order to understand the current status of mussels in CCSD#1 streams.

Urban development results in large impervious surface areas that modify hydrologic patterns and that destabilize streamflows, alter seasonal high and low flows, increase sediment inputs, and modify channel morphology and habitat. Urban stormwater also carries numerous pollutants, some of which can attain toxic concentrations during first-flush storm events. This phenomenon, known as "urban stream syndrome" or "multiple stress syndrome" is well documented among urban streams (Walsh et al. 2005). Mechanisms driving the syndrome are complex and interacting, yet efficient stormwater delivery into highly physically altered (often channelized) receiving waters is largely the source of the various perturbations observed and measured in this and other regional studies of stream condition. These highly m0odified hydrologic patterns destabilize streamflows and alter seasonal high and low flows, pollutant concentrations, temperature and dissolved oxygen extremes, sediment inputs, and channel morphology.

Among pollutants entering streams through stormwater, pesticides are only starting to receive their deserved attention with respect to understanding effects on the ecology of surface waters. Recent work in Clackamas County, Oregon found that several indicators of macroinvertebrate community condition were strongly negatively correlated with streambed sediment concentrations of the pyrethroid insecticide bifenthrin, now widely used in urban areas (Carpenter et al. 2015, in prep). Carpenter et al.'s work suggests that pesticides carried by stormwater may play an important role in the degradation of aquatic communities in some areas, but much more work is necessary on this front. Continued and expanded pesticides monitoring in Clackamas County and elsewhere could assist with further understanding this emerging issue as it relates to stormwater management and consequences to the biology in receiving waters. Four CCSD#1 streams were included in the Carpenter et al. (in prep) study: Carli Creek, Rock Creek, Seiben Creek, and Kellogg Creek. None of these streams were implicated by the Carpenter study as having bifenthrin concentrations in streambed sediments that would potentially be deleterious to macroinvertebrates (Kurt Carpenter, unpublished data).

While many proximate factors may contribute to the biological disturbances measured in this study, ultimately, causation in most cases could likely be attributed to stormwater. Protection of area streams should focus on minimizing total effective impervious areas and improving stormwater retention and drainage patterns to minimize the hydrologic effects of storm events on stream channel conditions. Certain stormwater mitigation strategies such as artificial wetlands and retention facilities also serve to remove pollutants through physical, chemical, or biological processes. Further development within the CCSD#1 service area will necessitate careful attention to these and other measures intended to preserve and enhance stream conditions and functions. As such measures and other restoration activities are undertaken these data will assist with determining the success of these actions relative to their intended benefits to aquatic life.

5.0 RECOMMENDATIONS AND CONCLUSIONS

The primary objective of this project was to evaluate long-term trends in watershed health at geomorphic and macroinvertebrate monitoring stations throughout Clackamas County's Service District #1. This objective was achieved through continued sampling of macroinvertebrates since 2002 and the establishment of geomorphic monitoring stations in the Kellogg/Mt. Scott, Rock, and Sieben Creek watersheds in 2009 and reoccupation of the sites in 2011 and 2014. Changes in channel geomorphology influence instream physical habitat characteristics such as fine sediment compositions in riffles and pool tails. The geomorphic surveys in this assessment provided insight into the geomorphic processes and conditions that are producing the observed and measured physical habitat characteristics to which the biological assemblages are known to respond. While reach specific recommendations can be made for geomorphic instabilities, such as bank erosion, many of the issues, such as temperature, are watershed-wide. On the contrary, one cannot assume stability across an entire stream or watershed because a studied reach appears stable. Instabilities can be spatially and temporally variable.

In conclusion, the data has been used to qualitatively assign channel condition ratings using key parameters collected at each of the study reaches. Table 17 summarizes standard thresholds for several of the key parameters based on published data. Use of the standard thresholds to define overall channel condition is presented in Table 18.

Throughout the 16 reaches with geomorphic monitoring components, 3 were rated with low floodplain connectivity, 3 were rated 'At Risk' for bank stability, and 5 had high sediment intrusion ratings. Qualitative assessment and best professional judgement led to an overall rating of 'At Risk' or 'At Risk – Unstable' geomorphic rating for three of the sites. The most at risk sites are listed below with recommendations. These bank and channel instabilities identified in the geomorphic assessment result from elevated substrate embeddedness and dominance by small substrate particle sizes, which in turn induce stress on the benthic communities, which was described in the previous discussion section. Recommendations on future monitoring and assessment are summarized below.

Table 17: Channel condition thresholds for key geomorphic and bed substrate parameters.

Parameter	Indicator	Threshold Values	Reference
Floodplain Connectivity	Entrenchment	Low: Entrenchment Ratio < 1.4 Moderate: Entrenchment Ratio from 1.4 to 2.2 High: Entrenchment Ratio > 2.2	Rosgen, 1996
Bed Morphology	Pool Depths	Qualitative based on pool depth, channel size and field observations	
Streambank Conditions	Percent Bank Erosion	Stable: < 5% on both banks Stable - At-Risk: from 5-10% on either bank At-Risk: > 10% on either bank	
Degree of Fine Sediment Intrusion	Bulk Sample Results	Low: 6.3mm < 15%; 0.85mm < 10% Moderate: 6.3mm from 15-30%; 0.85mm from 10-20% High: 6.3mm > 30%; 0.85mm > 20%	Kondolf, 2000

Table 18. Qualitative assessment of 2014 channel conditions for each study reach -Clackamas County Service District #1 (CCSD #1), Oregon.

Site ID	Floodplain Connectivity	Bed Morphology	Stream Bank Conditions	Degree of Fine Sediment Intrusion (6.3mm: 0.85mm)	Overall Channel Condition
Kellogg Creek Subbasin					
G-KL-10	Moderate	Pool-Riffle	At Risk	High	Stable – At Risk
G-KL-30	Moderate	Plane Bed	Stable	NA	Stable – At Risk
Mt. Scott Creek Subbasin					
G-MS-40	Low	Pool-Riffle	Stable – At Risk	Moderate	**At Risk**
G-MS-70	Moderate	Pool-Riffle	At Risk	High	Stable – At Risk
G-MS-80	High	Pool-Riffle	Stable	Moderate	Stable
G-MS-90	High	Plane Bed	Stable – At Risk	High	Stable
G-MS-100	Moderate	Plane Bed	Stable	NA	Stable – At Risk
G-MS-110	High	Plane Bed	Stable	NA	**At Risk**
G-PH-10	Moderate	Pool-Riffle	Stable	Moderate: Low	Stable – At Risk
Rock Creek Subbasin					
G-RC-10	Moderate	Pool-Riffle	Stable	Moderate	Stable – At Risk
G-RC-20	High	Plane Bed	Stable	NA	Stable
G-RC-30	Low	Plane Bed	Stable – At Risk	NA	Stable - At Risk
G-RC-40	Moderate	Pool-Riffle	Stable – At Risk	High	Stable – At Risk
G-RC-50	Moderate	Pool-Riffle	Stable – At Risk	High	Stable – At Risk
G-RC-60	High	Backwatered	Stable	NA	Stable – At Risk
Tributaries to the Clackamas River					
G-SI-10	Low	Plane Bed	At Risk	Moderate: Low	**At Risk-Unstable**

To make this dataset valuable for understanding long-term changes in channel morphology and ecological condition, we recommend the following:

1. That the monitoring effort described in this report is repeated every three years and the geomorphic component following storm events that exceed a 10 year recurrence. Geomorphic data collected in the future should be compared to the baseline data of 2009, 2011, and 2014 to assess the direction and degree of change. Macroinvertebrate data should continue to be compared to regional reference conditions, across all sites included in this study, and over time at each site.
2. The databases developed as part of the Kellogg/Mt. Scott and Rock Creek Watershed Action Plans should be updated to reflect these data. The current database relied solely on fish habitat assessment data that was more general and not necessarily focused on characterizing geomorphic conditions. Updates to the database using these data will only be possible in the reaches where surveys were conducted.
3. Furthermore, as the biological data collected ultimately reveals the overall condition of ecological conditions of Clackamas County streams (as affected by both the physical and chemical environment), macroinvertebrate monitoring should continue at the same interval (every three years) as the geomorphic monitoring. To the extent possible, geomorphic and macroinvertebrate monitoring reaches should continue to be co-located.

This geomorphic monitoring effort provides some insight into channels that are at risk due to hydromodification. This evaluation can aid in attempting to prioritize watershed management and restoration actions, but does not represent a comprehensive assessment or enhancement and restoration opportunities throughout the watershed, nor does it identify site specific areas of channel and bank instability in areas outside the specific monitoring sites.

Based on our evaluation of site conditions and the geomorphic monitoring data, the stream reaches thought to be the most at-risk are as follows (not necessarily in order of priority):

- G-MS-40: This reach runs through the Three Creeks Natural Area. This low gradient reach runs adjacent to a remediation site at the upper extent and near walking paths in the lower extent. From 2011 to 2014, this reach experienced an increase in the width to depth ratio and a decrease in the entrenchment ratio. The banks of the channel are steep and unstable. The channel has experienced a significant amount of bank erosion due to widening in the lower extents. In addition, the particle size in depositional features, from the pebble count, has increased since 2009. This indicates a coarsening of the bed due to hydromodification. Often, when the bed coarsens, an increase in bank erosion is observed due to an increase in the hydraulic resistance of the bed relative to the banks. Since the reach runs through a natural area, there is minimal adjacent infrastructure so there may be an opportunity to restore floodplain connectivity. This could be done by adding large woody to aggrade the channel and by laying back the banks to increase bank stability.

- G-MS-100 and G-MS-110: These reaches are located in upper Mt. Scott Creek in the Happy Valley Area. The G-MS-100 study site is located just downstream of a large headcut. Downstream of the headcut, the channel is incised down to bedrock and lateral erosion has been occurring since 2009. It is likely that the rapid development that has occurred in Happy Valley will result in continued upstream migration of the observed headcut, which could result in several feet of channel incision upstream of G-MS-100, through Happy Valley Park and into Reach G-MS-110. Incision into these reaches would not only degrade channel and aquatic habitat conditions in these two reaches but would also result in delivery of large amounts of fine sediment to downstream reaches. The channel has widened slightly between 2009 and 2014 and some deposition occurred at the downstream cross sections, which is possibly a result of sediment movement from the headcut (Attachment A: Figures A13 and A14). Stabilization measures are currently in the design phase for site G-MS-100 and are scheduled to be implemented in 2015. The work will include addition of large wood to stabilize the existing headcuts and replacement of a culvert with a bridge to increase connectivity, both laterally and longitudinally, with the floodplain.

- G-SI-10: Sieben Creek is a small tributary that flows directly into the Clackamas River and flows between Shadowbrook Mobile Home Park and a neighborhood. The channel is severely incised with steep banks and exposed bedrock in many areas. The banks have high active erosion rates and some of the cross sections have widened since the initiation of the geomorphic monitoring effort. The top of bank contains a narrow vegetative buffer dominated by invasive Himalayan blackberry which is directly adjacent to the mobile home park on the right and to housing on the right bank. Given the proximity to infrastructure, this site should be considered high priority. If the channel continues to widen and erode, it could threaten the adjacent properties.

Long-term monitoring of geomorphic, biological, physical, and chemical conditions in Clackamas County and the lower Tualatin River basin will allow further elucidation of relationships between environmental stressors and biological responses. The stressor models and the CADDIS stressor identification framework should continue to prove useful in identifying causes of measured degradation to biological conditions in Clackamas County streams. This approach could be further strengthened with the inclusion of continuous monitoring data—such as temperature and dissolved oxygen—at or near biological monitoring reaches. Such data would allow more reliable identification of environmental conditions that induce biological stress and therefore development of stronger relationships between environmental and biological condition gradients. To this end, WES hopes to deploy temperature recorders in several reaches each for two years prior to the next sampling event in Rock Creek, Mt. Scott Creek, and Kellogg Creek (Gail Shaloum, WES, personal communication). These locations will overlap with existing biological monitoring locations. Such data will significantly improve the ability to make inferences regarding elevated temperature effects on measured invertebrate community conditions in these area streams.

Detection of longer-term trends in biological conditions in the CCSD #1 service area will benefit from maintaining consistent sample stations across years. Beginning in 2011, a concerted effort was made to cluster monitoring activities within specific reaches, resulting of co-location of 8 geomorphic and biological monitoring reaches in 2014. Monitoring activities currently being conducted within the CCSD#1 service area include the biological (macroinvertebrates) and geomorphic monitoring detailed here, as well as water chemistry and stream flow monitoring. WES administers a Routine and Storm Event-Related Surface/Stormwater Quality and Flow Monitoring Program within the CCSD#1 service area. The Program's services include water quality sample collection and flow measurement; laboratory and field analysis of water samples; and water quality data management and reporting (Swanson 2010). The macroinvertebrate survey reaches within Kellogg Creek (M-KL-20), Mt. Scott Creek (M-MS-10), Phillips Creek (M-PH-10), and Sieben Creek (M-SI-10) are clustered respectively with the WES#14 ,WES#15, WES#11 , and WES#7 monitoring locations. The former three macroinvertebrate reaches were shifted upstream of the previously sampled reaches to align with these monitoring stations. Both routine and storm event monitoring are conducted at these locations with a minimum of 6 routine visits per year and a minimum of 3 storm event-related visits per year. Future macroinvertebrate and geomorphic assessments should incorporate data collected during these visits whenever possible.

6.0 REFERENCES

Armantrout, N. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, MD.

Carpenter, K.D., K.M. Kuivilal, M.L. Hladik, T. Haluska, and M.B. Cole. In prep. Occurrence of bifenthrin, fipronil, and other current-use pesticides in urban streams and stormwater outfalls and their potential effects on stream benthic invertebrates in Clackamas County, Oregon. U.S. Geological Survey, Portland, OR.

Caton L. 1991. Improved subsampling methods for the EPA "Rapid Bioassessment" benthic protocols. Bulletin of the North American Benthological Society 8:317-319.

Cole, M. 2002. Assessment of macroinvertebrate communities in relation to land use, physical habitat, and water quality in the Tualatin River Basin, Oregon. Unpublished report prepared for Clean Water Services, Hillsboro, Oregon 38 pp.

Cole, M.B. 2003. Assessment of macroinvertebrate communities in streams of north Clackamas County, Oregon, 2002. Unpublished report prepared for Water Environment Services of Clackamas County. Oregon City, Oregon. 27 pp.

Cole, M.B. 2004a. Baseline assessment of stream habitat and macroinvertebrate communities in and adjacent to the Damascus Area Urban Growth Boundary Expansion, Oregon. Unpublished report prepared for Metro, Portland, Oregon.

Cole, M.B. 2004b. Assessment of stream macroinvertebrate communities in and adjacent to the City of Wilsonville, Oregon. Unpublished report prepared for the City of Wilsonville, Oregon.

Cole, M.B. and A.P. Harris. 2004. City of Lake Oswego 2004 macroinvertebrate assessment. Unpublished report prepared for the City of Lake Oswego, Oregon.

Cole, M.B., and M.E. Koehler. 2005. Baseline monitoring of restoration projects on Bronson and Fanno Creeks, Washington County, Oregon. Unpublished progress report prepared for Clean Water Services, Washington County, Oregon.

Cole, M.B., J.L. Lemke, and C. Currens. 2006. 2005-2006 Assessment of fish and macroinvertebrate communities of the Tualatin River Basin, Oregon. Unpublished report prepared for Clean Water Services, Hillsboro, Oregon. 68 pp.

Cole, M.B., and J.L. Lemke. 2008. Amazon Creek drainage basin macroinvertebrate study, Oregon, Fall 2008. Unpublished report prepared for the City of Eugene, Public Works-Wastewater Division. Eugene, OR.

Cole, M.B. 2008. Suitability of the MWCF predictive model and condition thresholds for use with macroinvertebrate data from the Prairie Terrace ecoregion of the Willamette River basin, Oregon. Unpublished report prepared for Clean Water Services, Hillsboro, OR.

Cole, M.B., J.L. Lemke, and A.P. Harris. 2011a.Characterization of macroinvertebrate communities in valley-floor stream reaches of the Tualatin River basin, Oregon. Unpublished report prepared for Clean Water Services, Hillsboro, Oregon.

Cole, M.B., J.L. Lemke, and A.P. Harris. 2011b.Comparison of macroinvertebrate communities collected from riffles and glides in Tualatin River basin stream reaches. Unpublished report prepared for Clean Water Services, Hillsboro, Oregon.

Cole, M.B. and J.L. Lemke. 2011. 2010–2011 Assessment of fish and macroinvertebrate communities of the Tualatin River basin, Oregon. Unpublished report for Clean Water Services, Hillsboro, OR.

Cole, M.B. 2014a. 2013 Tualatin River basin macroinvertebrate assessment. Unpublished report for Clean Water Services, Hillsboro, OR.

Cole, M.B. 2014b. Clackamas County NPDES Co-Permittees 2013 Coordinated Macroinvertebrate Assessment. Unpublished report prepared for the cities of Gladstone, Lake Oswego, West Linn, Wilsonville, Oregon City, and Milwuakee, OR.

Cole, M.B. 2015. City of Eugene macroinvertebrate study, Oregon, fall 2014. Unpublished report prepared for the City of Eugene, Oregon.

Department of Environmental Quality (DEQ). 2003. Benthic Macroinvertebrate Protocol for Wadeable Rivers and Streams. Unpublished methods manual. Oregon Department of Environmental Quality, Portland, OR.

Friesen, T. A., and M. P. Zimmerman. 1999. Distribution of fish and crayfish, and measurement of available habitat in urban streams of north Clackamas County. Oregon Department of Fish and Wildlife. Clackamas, Oregon. 68 pp.

Hawkins, C. P., J. L. Kershner, P. A. Bisson, M. D. Bryant, L. M. Decker, S. V. Gregory, D. A. McCullough, C. K. Overton, G. H. Reeves, R. J. Steedman, and M. K. Young. 1993. A hierarchical approach to classifying stream habitat features at the channel unit scale. Fisheries 18 (6): 3-12.

Hawkins, C. P., R. H. Norris, J. L. Hogue, and J. W. Feminella. 2000. Development and evaluation of predictive models for measuring the biological integrity of streams. Ecological Applications 10(5): 1456-1477.

Hilsenhoff, W. L. 1982. Using a biotic index to evaluate water quality in streams. Technical Bulletin No. 132. Department of Natural Resources, Madison, WI.

Hubler, S. 2008. PREDATOR: Development and use of RIVPACS-type macroinvertebrate models to assess the biotic condition of wadeable Oregon streams. Unpublished report prepared by the Oregon Department of Environmental Quality, Watershed Assessment Section. 51 pp.

Huff, D. D., S. L. Hubler, Y. Pan, and D. L. Drake. 2006. Detecting shifts in macroinvertebrate assemblage requirements: Implicating causes of impairment in streams. Oregon Department of Environmental Quality. DEQ06-LAB-0068-TR Version 1.1 37 pp.

Kondolf, Mathias, G. 2000. "Assessing Salmonid Spawning Gravel Quality", Transactions of the American Fisheries Society, 129: pgs. 262-281, 2000.

Lemke, J.L., and M.B. Cole. 2007. City of Lake Oswego 2007 Macroinvertebrate Assessment. Unpublished report prepared for the City of Lake Oswego, OR. 30 pp.

Lemke, J.L. and M.B. Cole 2008. 2007 Assessment of Macroinvertebrate Communities of the Tualatin River Basin, Oregon. Unpublished report prepared for Clean Water Services, Hillsboro, OR.

Lemke, J.L., and M.B. Cole. 2008a. Assessment of Macroinvertebrate Communities in Streams of Clackamas County Service District No. 1, Clackamas County, OR. Unpublished report prepared for Clackamas Water Environment Services, Clackamas, OR.

Lemke, J.L., and M.B. Cole. 2008b. Assessment of Macroinvertebrate Communities in Streams of the SWMACC area of Clackamas County, OR. Unpublished report prepared for Clackamas Water Environment Services, Clackamas, OR.

Lemke, J.L., and M.B. Cole. 2009. City of Lake Oswego 2009 Macroinvertebrate Assessment. Unpublished report prepared for the City of Lake Oswego, OR. 32 pp.

Lemke, J.L. and M.B. Cole. 2010a. Assessment of macroinvertebrate communities in the streams of Surface Water Management Area of Clackamas County, Oregon. Unpublished report for Clackamas Water Environment Services, Clackamas, OR.

Lemke, J.L. and M.B. Cole. 2010b. Assessment of macroinvertebrate communities in Clackamas County Service District No. 1, Clackamas County, Oregon. Unpublished report for Clackamas Water Environment Services, Clackamas, OR.

Lemke, J.L., M.B. Cole, and J. Dvorsky. 2012a. Assessment of macroinvertebrate communities and geomorphic conditions in the Surface Water Management Area of Clackamas County, Oregon. Unpublished report for Clackamas Water Environment Services, Clackamas, OR.

Lemke, J.L., M.B. Cole, and J. Dvorsky. 2012b. Assessment of macroinvertebrate communities and geomorphic condition in the streams of Clackamas County Service District No. 1, Clackamas County, Oregon. Unpublished report for Clackamas Water Environment Services, Clackamas, OR.

Lemke, J.L. and M.B. Cole. 2011. Amazon Basin and Willamette River macroinvertebrate study, Oregon, Fall 2011. Unpublished report prepared for the City of Eugene, Public Works-Wastewater Division. Eugene, OR. Lisle, T.E. and S. Hilton. 1992. The volume of fine sediment in pools: an index of sediment supply in gravel-bed streams. Water Resources Bulletin 28: 371-383.

Lisle, T.E.; Hilton, S. 1992. The volume of fine sediment in pools: an index of sediment supply in gravel-bed streams. Water Resources Bulletin 28: 371-383.

Merritt, R. W., K. W. Cummins, and M.B. Berg (eds.). 2007. An introduction to the aquatic insects of North America. Fourth Edition. Kendall/Hunt Publishing Co., Dubuque, IA. 1158 pp.

McNeil, W.J. and W.H. Ahnell. 1964. Success of pink salmon spawning relative to size of spawning bed materials. U.S. Dept. of the Interior, Fish and Wildlife Service Special Scientific Report – Fisheries No. 469.

Oregon Department of Fish and Wildlife (ODFW). 2002. Methods for Stream Habitat Surveys. Unpublished technical document by the Oregon Department of Fish and Wildlife, Salem, OR.

Rosgen, D. 1996. Applied River Morphology. Wildlands Hydrology. Pagosa Springs, Colorado.

Simon, A. 1989. A model of channel response in disturbed alluvial channels. Earth Surface Processes and Landforms, 14, 11-26.

Stewart, K.W. and B.P. Stark, 2002. Nymphs of North American stonefly genera (Plecoptera), 2nd ed. The Caddis Press, Columbus, OH, 510 pp.

Swanson, A.J. 2010. 2009-2010 Water Quality and Flow Monitoring Report for Clackamas County's, and the City of Happy Valley's Municipal Separate Storm Sewer System Permit (#101348) and the Willamette TMDL Implementation Plan. Clackamas County Water Environment Services, Oregon City, Oregon. October 2010.

United States Department of Agriculture (USDA). , WinXSPRO, A Channel Cross Section Analyzer, User's Manual, Version 3.0. by Thomas Hardy, Panja Palavi, and Dean Matthias. Available from: http://www.stream.fs.fed.us/publications/software.html.\\

U.S. Environmental Protection Agency (USEPA). 2000. Western Pilot Study Field Operations Manual for Wadeable Streams. U.S. Environmental Protection Agency, Regional Ecology Branch, Western Ecology Division, Corvallis, Oregon. May 2000.

U.S. Environmental Protection Agency (Environmental Protection Agency). 2010. Causal Analysis/Diagnosis Decision Information System (CADDIS). Office of Research and Development, Washington, DC. Available online at http://www.epa.gov/caddis. Last updated September 23, 2010.

Walsh, C.J., A.H. Roy, J.W. Feminella, P.D. Cottingham, P.M. Groffman, and R.P Morgan II. 2005. The urban stream syndrome: current knowledge and the search for a cure. J. N. Am. Benhol. Soc. 24(3): 706-723.

Water Quality Interagency Workgroup (WQIW). 1999. Chapter 12: Stream macroinvertebrate protocol, Oregon plan for salmon and watersheds. Water Quality Monitoring Guide Book, Version 1.03. Water Quality Interagency Workgroup for the Oregon Plan.

Wiggins, G.B., 1995. Larvae of the North American caddisfly genera (Trichoptera), 2nd ed. University of Toronto Press, Toronto.

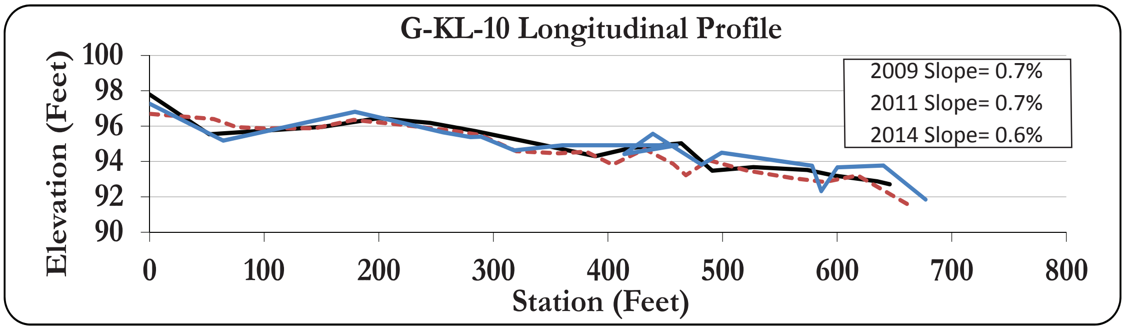
Wolman, M.G. 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union (EOS), v. 35, p. 951-956.

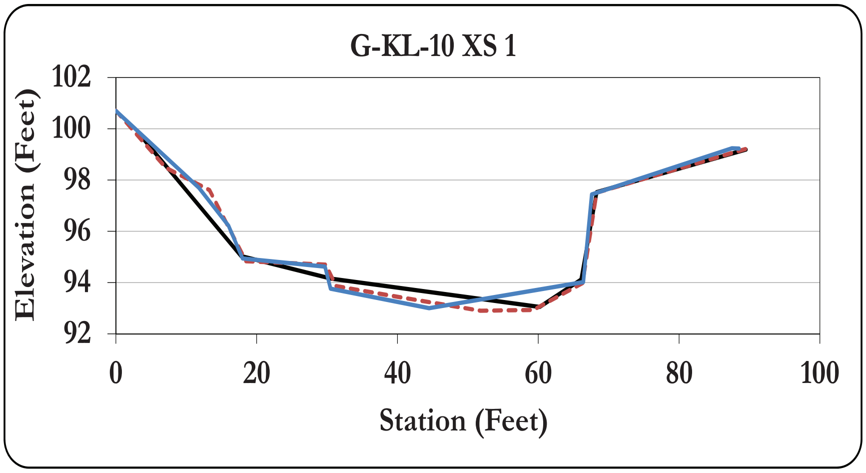
WATERWAYS CONSULTING, INC.

Clackamas County Service District #1
2014 WES Monitoring

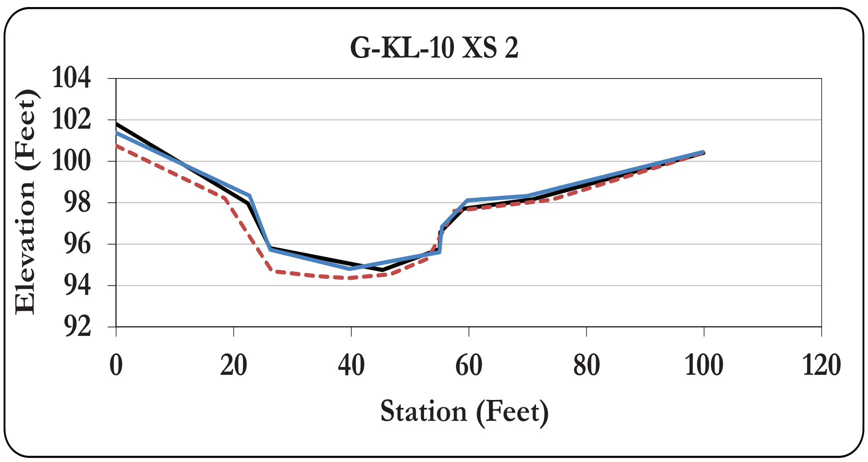
APPENDIX A

Geomorphic Summary Figures

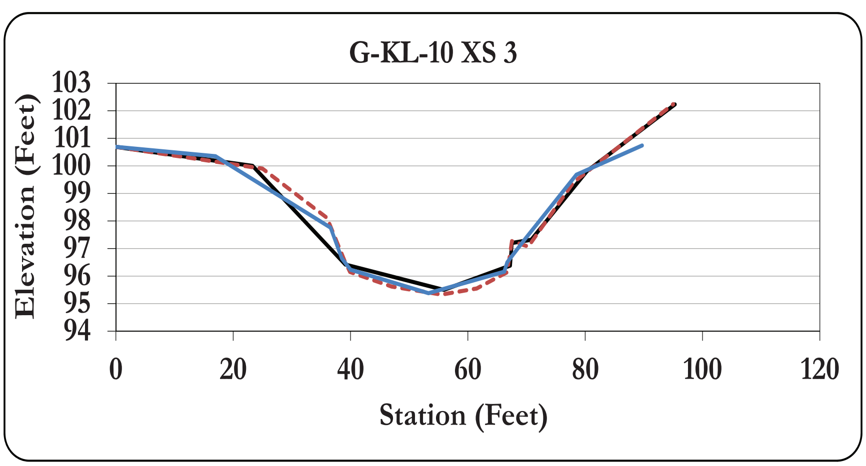




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	0.0	0.016	0.002
		0.018	
2011-2014	-0.2	0.018	-0.003
		0.015	
2009-2014	-0.2	0.016	-0.001
		0.015	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.8	0.015	0.003
		0.018	
2011-2014	+0.7	0.013	-0.001
		0.012	
2009-2014	-0.1	0.015	-0.0002
		0.012	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.1	0.012	0.000
		0.012	
2011-2014	-0.1	0.012	-0.001
		0.011	
2009-2014	0.0	0.012	-0.001
		0.011	

FIGURE A1

Survey data results for site G-KL-10 Lower Kellogg Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.

*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

WATERWAYS CONSULTING, INC.
Santa Cruz, CA | watways.com | Portland, OR

ANALYSIS RESULTS - Lower Kellogg Creek (G-KL-10)

Channel Capacity Flow: Between the **10-year and 100-year** Event (Calculated at XS 2).

Pebble Counts and Bulk Sediment:

Year	Pebble Count			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	N/A			46%	32%
2011	N/A			26%	6%
2014	N/A			35%	24%

*N/A: Sample not taken due to lack of depositional features or conditions in study area.

Pools and Bank Erosion:

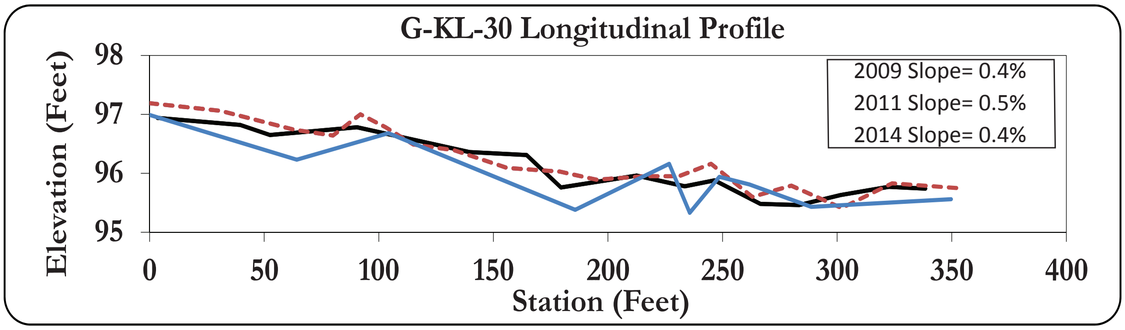
Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	3	2.2 ft	1.1 ft	0%	5.6%
2011	3	1.9 ft	1.2 ft	0%	7.6%
2014	3	1.8 ft	1.1 ft	0%	11.1%

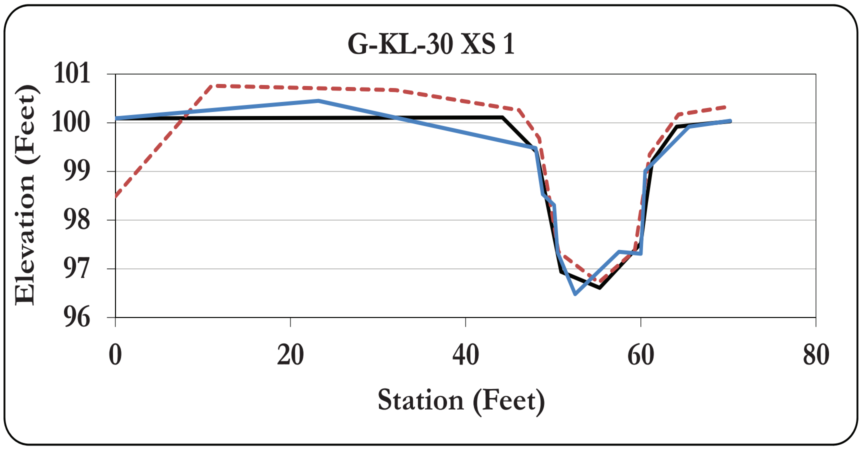
Average Bankfull Width, Depth and Width/Depth Ratio:

Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	39.9	2.3	17.1
2011	41.2	2.54	18.9
2014	37.7	2.0	19.1

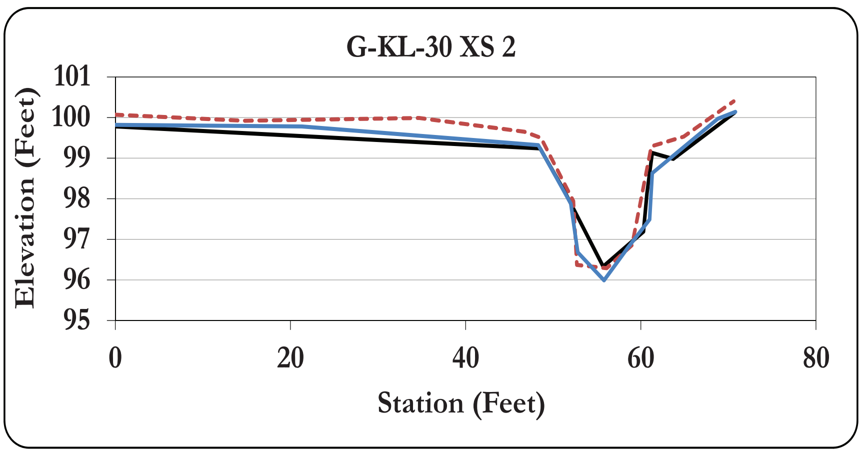
WATERWAYS CONSULTING, INC.
Santa Cruz, CA | watways.com | Portland, OR

FIGURE A2
Results of analysis for site G-KL-10 Lower Kellogg Creek and picture of reach.

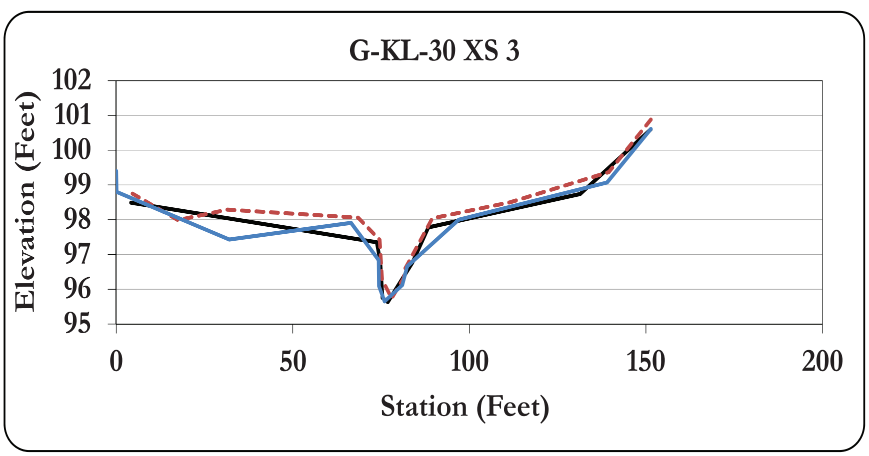




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.4	0.007	0.000
		0.007	
2011-2014	0.0	0.007	0.000
		0.007	
2009-2014	-0.4	0.007	0.000
		0.007	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.6	0.006	0.002
		0.008	
2011-2014	-0.4	0.008	0.000
		0.008	
2009-2014	-1.0	0.006	0.002
		0.008	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	0.0	0.008	0.000
		0.008	
2011-2014	-0.3	0.015	-0.001
		0.014	
2009-2014	-0.3	0.015	-0.001
		0.014	

FIGURE A3
Survey data results for site G-KL-30 Upper Kellogg Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.
*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

ANALYSIS RESULTS - Upper Kellogg Creek (G-KL-30)

Channel Capacity Flow: Less than the **2-year** Event (Calculated at XS 2)

Pebble Counts and Bulk Sediment:

Year	Pebble Count			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	N/A			N/A	
2011	N/A			N/A	
2014	N/A			N/A	

*N/A: Sample not taken due to lack of depositional features or conditions in study area.

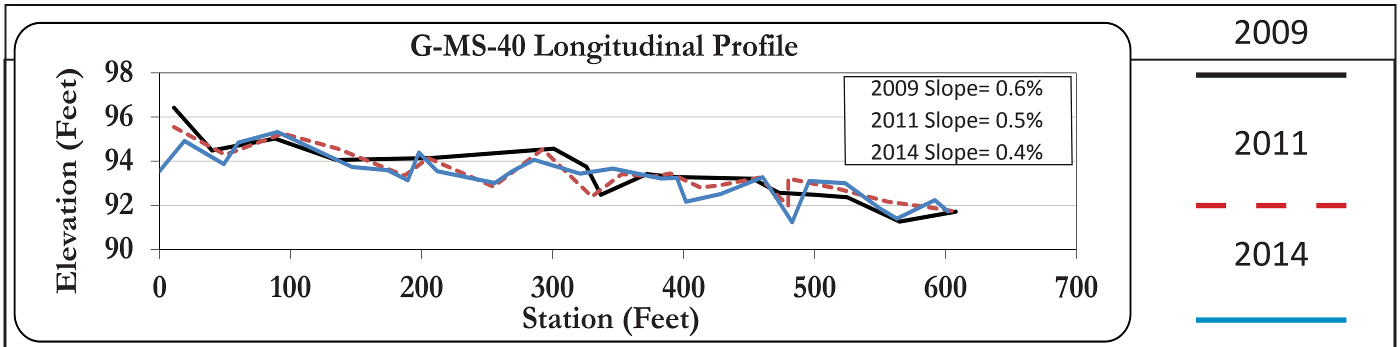
Pools and Bank Erosion:

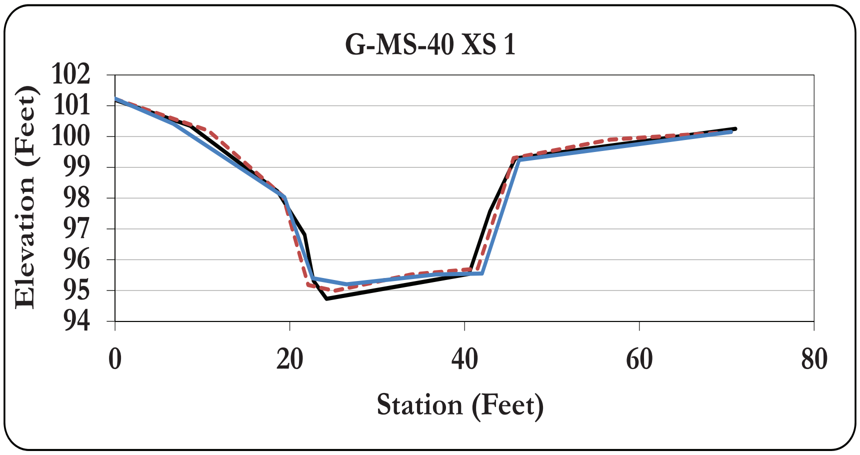
Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	0	-	-	0%	0%
2011	0	1.0 ft	0.3 ft	0%	0%
2014	0	0.8 ft	0.5 ft	0%	0%

Average Bankfull Width, Depth and Width/Depth Ratio:

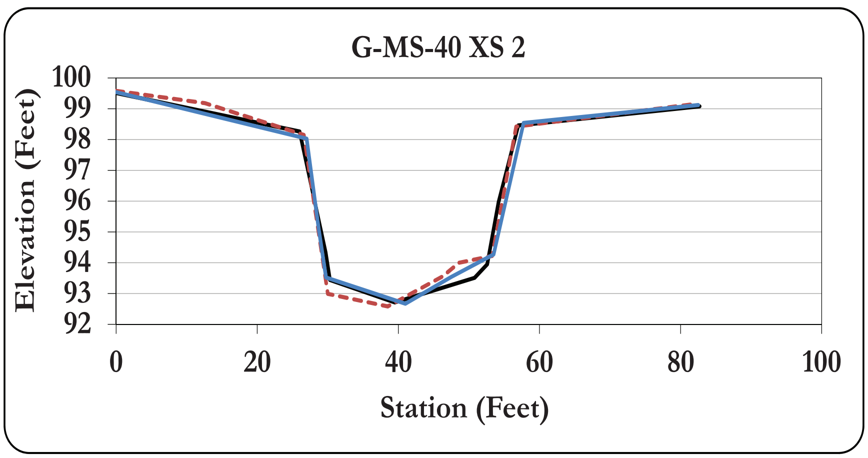
Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	12.3	2.2	5.7
2011	10.6	2.0	5.4
2014	8.7	1.4	6.5

FIGURE A4
Results of analysis for site G-KL-30 Upper Kellogg Creek and picture of reach.

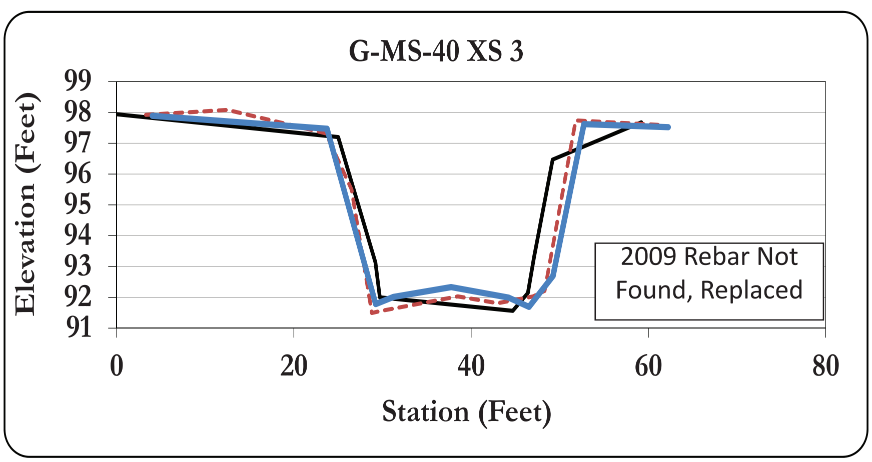




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.1	0.013	0.000
		0.013	
2011-2014	+0.1	0.013	0.000
		0.013	
2009-2014	+0.2	0.013	0.000
		0.013	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.3	0.015	0.001
		0.016	
2011-2014	+0.3	0.016	-0.001
		0.015	
2009-2014	+0.6	0.015	0.000
		0.015	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.0	0.014	0.001
		0.016	
2011-2014	+0.2	0.016	-0.001
		0.015	
2009-2014	+0.2	0.014	0.001
		0.015	

FIGURE A5

Survey data results for site G-MS-40 Mt. Scott Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.

*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

WATERWAYS CONSULTING, INC.

Santa Cruz, CA | watways.com | Portland, OR

ANALYSIS RESULTS - Mt. Scott Creek (G-MS-40)

Channel Capacity Flow: Between the **2-year and 5-year** Event (Calculated at XS 2)

Pebble Counts and Bulk Sediment:

Year	Pebble Count			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	14 mm	34 mm	53 mm	27%	11%
2011	23 mm	39 mm	66 mm	21%	8%
2014	22 mm	36 mm	60 mm	-	14%

Pebble Count: Significant Difference in Mean (from t-test, p=0.05)
YES: between 2009 and 2011, 2009 and 2014. ***NO***: between 2011 and 2014

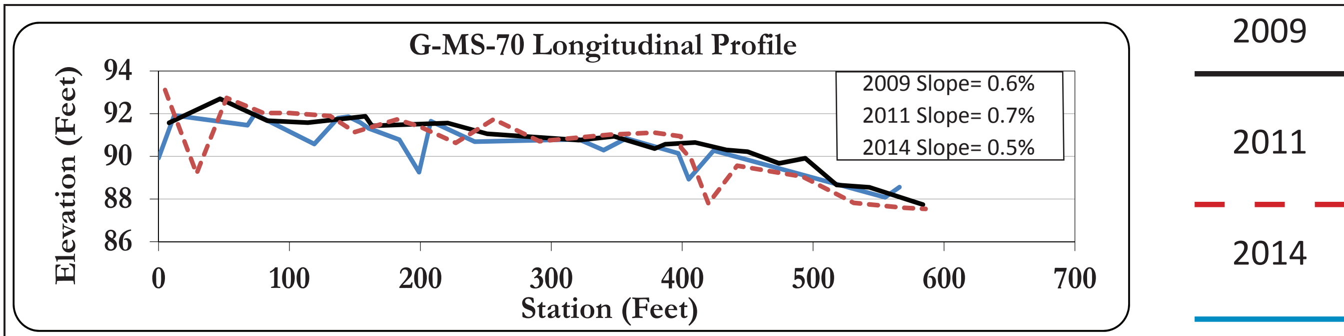
Pools and Bank Erosion:

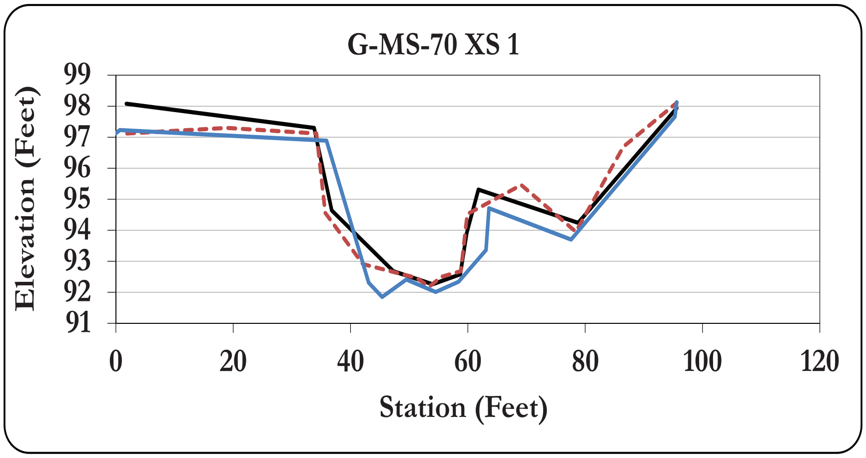
Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	5	1.7 ft	1.2 ft	1.7%	1.7%
2011	5	1.6 ft	1.3 ft	3.3%	16.9%
2014	7	1.7 ft	1.3 ft	2.5%	12.5%

Average Bankfull Width, Depth and Width/Depth Ratio:

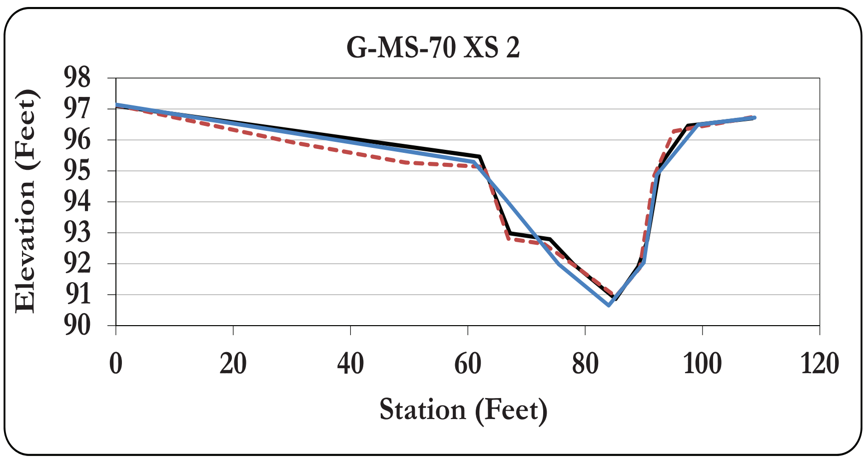
Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	21.2	2.3	9.1
2011	24.2	3.6	6.8
2014	22.6	1.4	15.7

FIGURE A6
Results of analysis for site G-MS-40 Mt. Scott Creek and picture of reach.

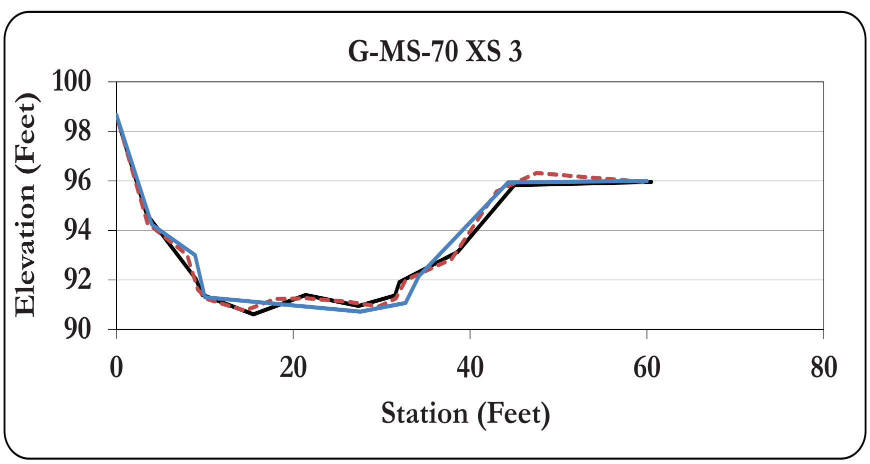




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	0.0	0.016	0.001
		0.017	
2011-2014	-0.1	0.017	0.001
		0.018	
2009-2014	-0.1	0.016	0.002
		0.018	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	0.0	0.013	-0.001
		0.012	
2011-2014	0.0	0.012	0.001
		0.013	
2009-2014	0.0	0.013	0.000
		0.013	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	0.0	0.014	-0.001
		0.013	
2011-2014	-0.1	0.013	0.002
		0.015	
2009-2014	-0.1	0.014	0.001
		0.015	

FIGURE A7
Survey data results for site G-MS-70 Mt. Scott Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.
*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

ANALYSIS RESULTS - Mt. Scott Creek (G-MS-70)

Channel Capacity Flow: Between the **5-year and 10-year** Event (Calculated at XS 2)

Pebble Counts and Bulk Sediment:

Year	Pebble Count			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	12 mm	25 mm	47 mm	19%	4%
2011	11 mm	25 mm	52 mm	22%	6%
2014	25 mm	45 mm	81 mm	37%	27%

Pebble Count: Significant Difference in Mean (from t-test, p=0.05)
YES: between 2009 to 2014, 2011 to 2014 ***NO***: between 2009 and 2011

Pools and Bank Erosion:

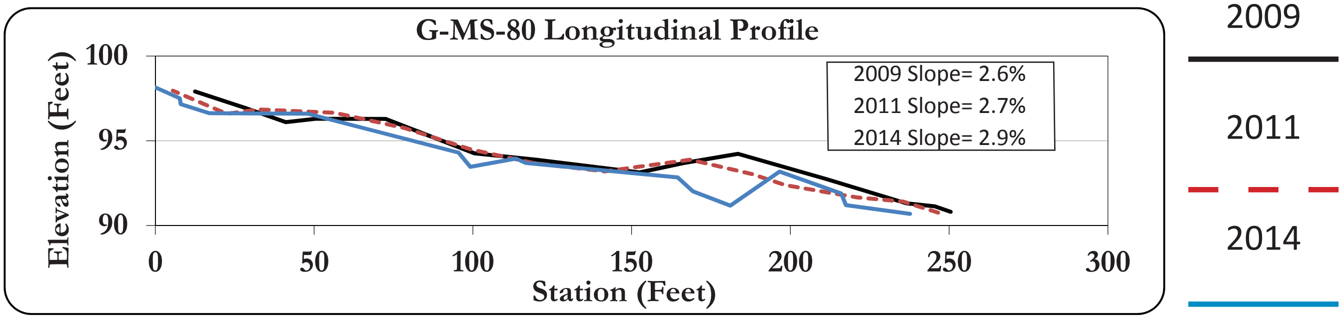
Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	7	1.9 ft	1.4 ft	1%	20%
2011	5	2.0 ft	1.8 ft	11.1%	8.5%
2014	6	1.7 ft	1.5 ft	5.1%	11.1%

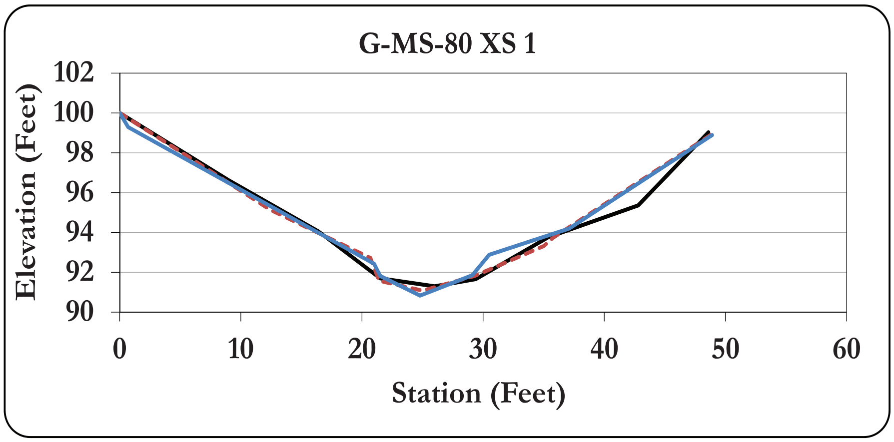
Average Bankfull Width, Depth and Width/Depth Ratio:

Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	23.1	1.7	15.2
2011	26.3	2.4	11.3
2014	23.2	1.7	16.4

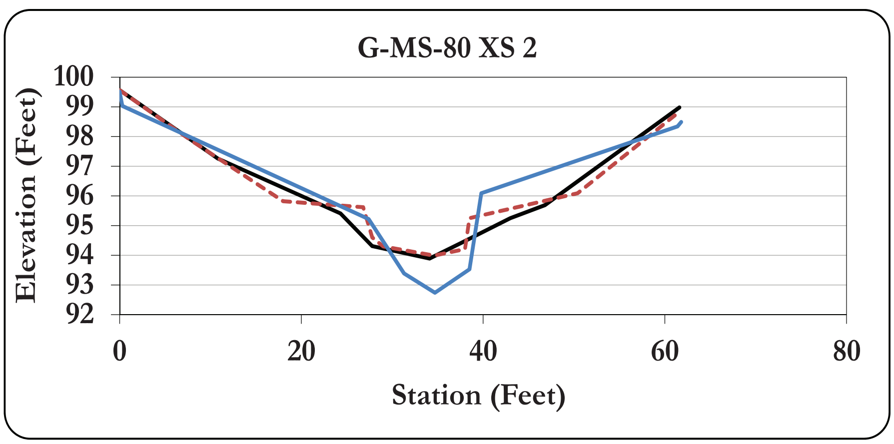
WATERWAYS CONSULTING, INC.
Santa Cruz, CA | watways.com | Portland, OR

FIGURE A8
Results of analysis for site G-MS-70 Mt. Scott Creek and picture of reach.

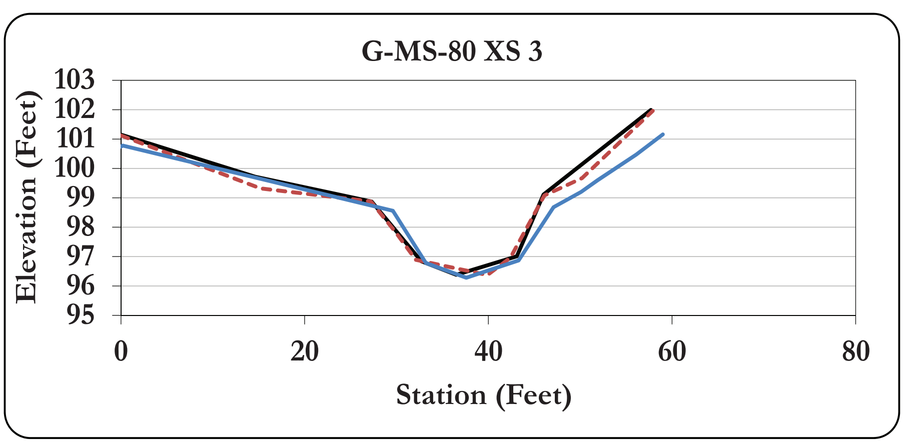




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.1	0.018	0.000
		0.018	
2011-2014	+0.0	0.018	0.001
		0.019	
2009-2014	-0.1	0.018	0.001
		0.019	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.1	0.011	-0.001
		0.010	
2011-2014	-1.1	0.010	0.005
		0.015	
2009-2014	-1.0	0.011	0.004
		0.015	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	0	0.011	-0.001
		0.010	
2011-2014	-0.1	0.010	-0.001
		0.009	
2009-2014	-0.1	0.011	-0.002
		0.009	

FIGURE A9
Survey data results for site G-MS-80 Mt. Scott Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.
*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

ANALYSIS RESULTS - Mt. Scott Creek (G-MS-80)

Channel Capacity Flow: Between the **2-year and 5-year** Event (Calculated at XS 2)

Pebble Counts and Bulk Sediment:

Year	Pebble Count			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	< 0.85 mm
2009	37 mm	84 mm	150 mm	24%	5%
2011	33 mm	70 mm	128 mm	24%	6%
2014	35 mm	80 mm	111 mm	24%	14%

Pebble Count: ***NO*** Significant Difference in Mean (from t-test, p=0.05) for any years

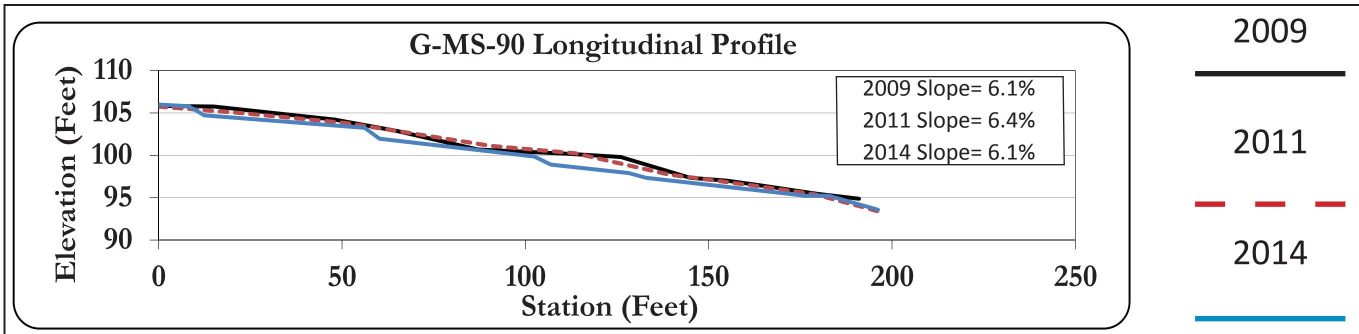
Pools and Bank Erosion:

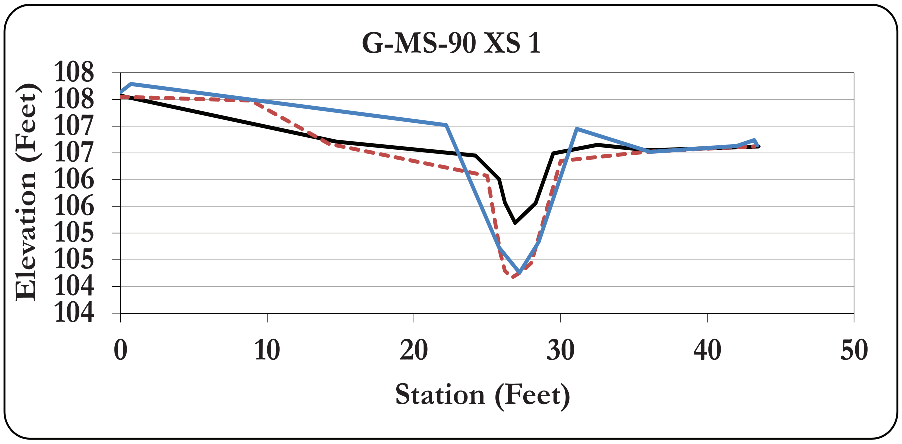
Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	2	1.7 ft	1.5 ft	10.5%	0%
2011	3	1.1 ft	0.7 ft	0%	0%
2014	5	1.4 ft	1.1 ft	2.1%	0%

Average Bankfull Width, Depth and Width/Depth Ratio:

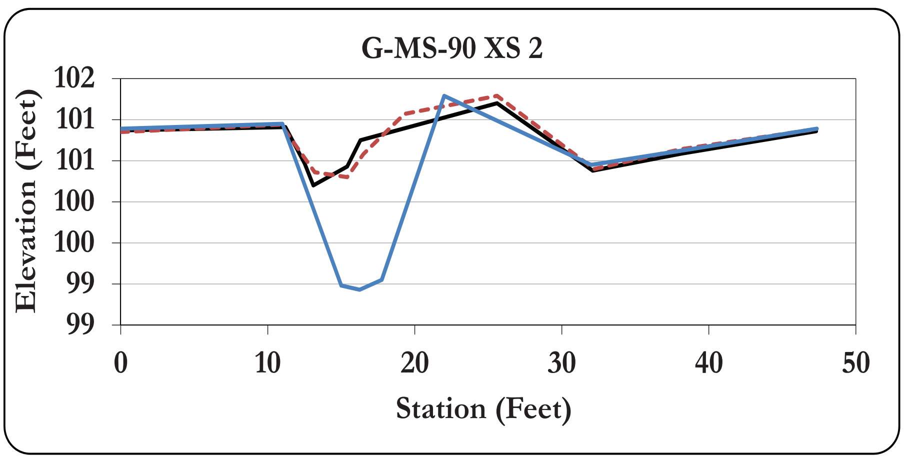
Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	18.8	2.2	9.1
2011	14.1	1.6	8.7
2014	12.8	2.0	6.5

FIGURE A10
Results of analysis for site G-MS-80

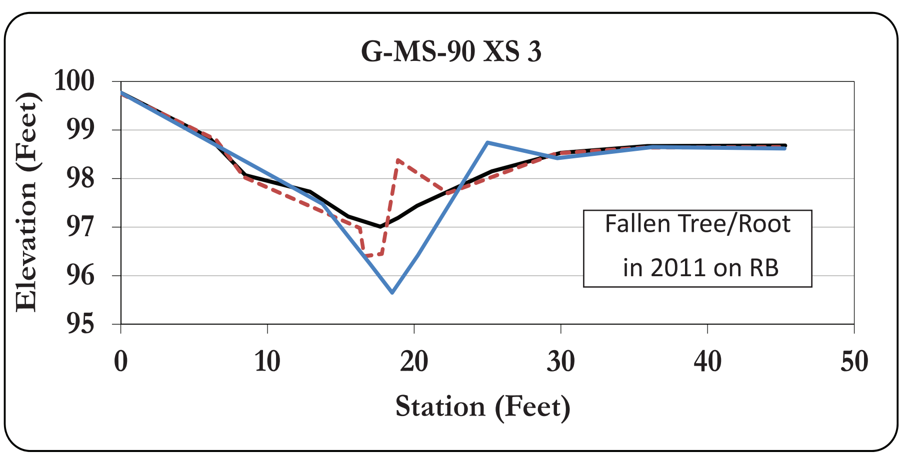




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-1.0	0.003 0.006	0.003
2011-2014	+0.2	0.006 0.006	0.000
2009-2014	-0.8	0.003 0.006	0.003



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.1	0.002 0.002	0.000
2011-2014	-1.3	0.002 0.005	0.003
2009-2014	-1.4	0.002 0.005	0.003



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.7	0.005 0.006	0.001
2011-2014	-0.3	0.006 0.007	0.001
2009-2014	-1.0	0.005 0.007	0.002

FIGURE A11

Survey data results for site G-MS-90 Tributary to Mt. Scott Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.

*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

ANALYSIS RESULTS - Tributary to Mt. Scott Creek (G-MS-90)

Channel Capacity Flow: Greater than the **100-year** Event (Calculated at XS 2)

Pebble Counts:

Year	Pebble Count*			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	N/A			75%	38%
2011	N/A			73%	54%
2014	N/A			38%	31%

*N/A: Sample not taken due to lack of depositional features or conditions in study area.

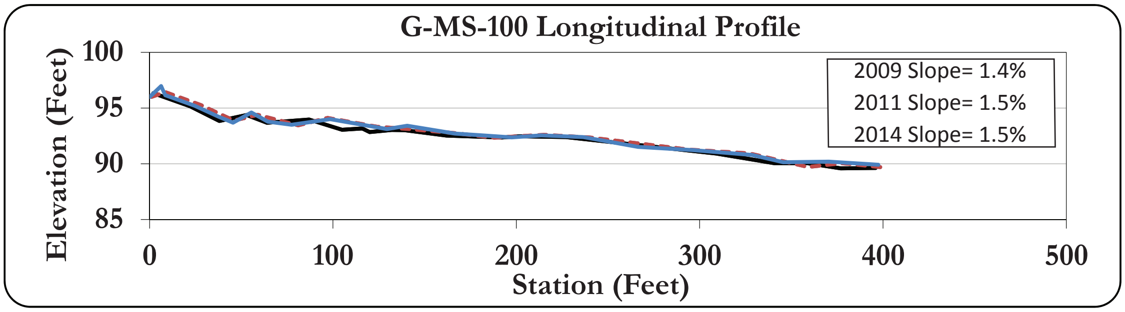
Pools and Bank Erosion:

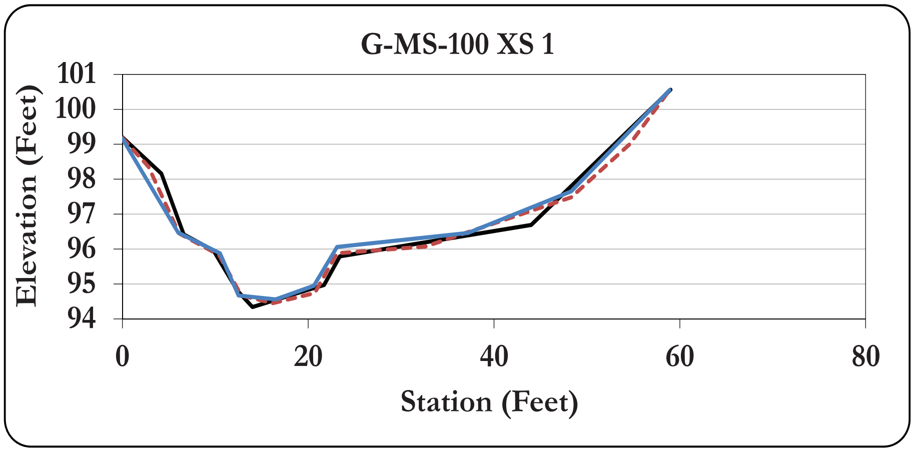
Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	0	-	-	10%	7.9%
2011	2	0.5 ft	0.4 ft	12.5%	16%
2014	1	0.6 ft	0.5 ft	8.7%	0%

Average Bankfull Width, Depth and Width/Depth Ratio:

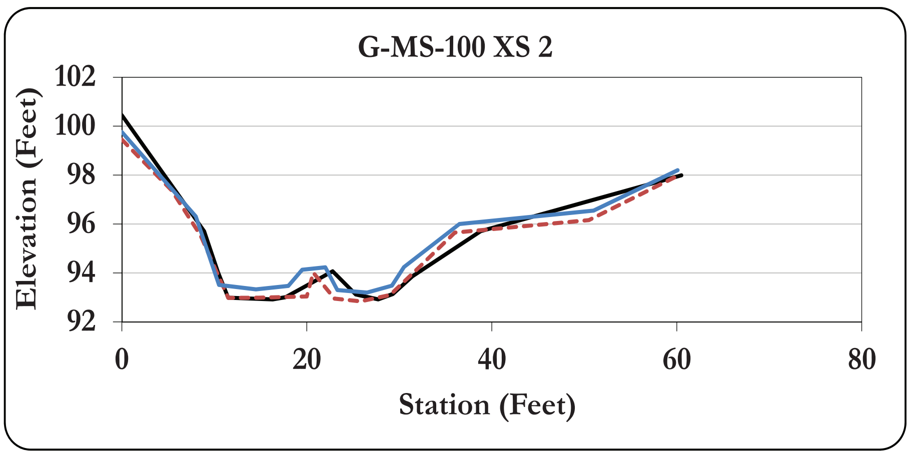
Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	5.9	0.9	6.7
2011	4.4	1.0	4.3
2014	5.2	1.4	3.7

FIGURE A12
Results of analysis for site G-MS-90 Tributary to Mt. Scott Creek and picture of reach.

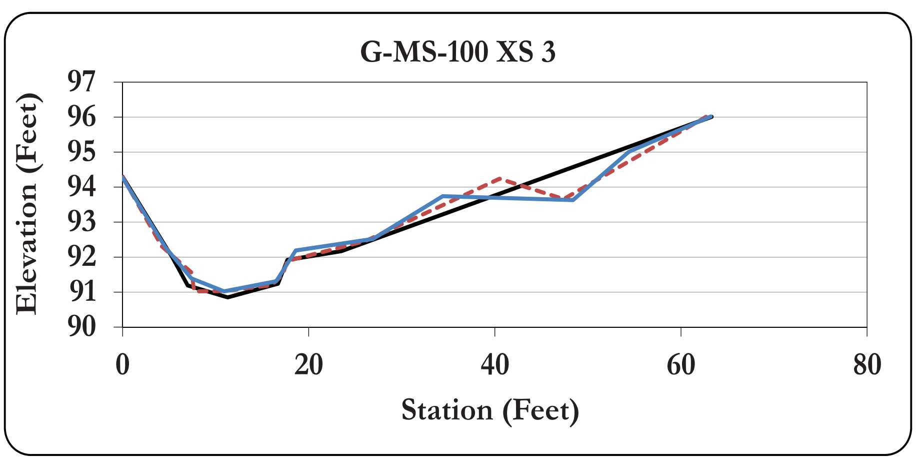




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.6	0.011	0.000
		0.011	
2011-2014	-0.5	0.011	-0.001
		0.010	
2009-2014	+0.1	0.011	-0.001
		0.010	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	0.0	0.019	-0.002
		0.017	
2011-2014	+0.4	0.017	0.001
		0.018	
2009-2014	+0.4	0.019	-0.001
		0.018	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.1	0.009	0.000
		0.009	
2011-2014	+0.1	0.009	0.000
		0.009	
2009-2014	+0.2	0.009	0.000
		0.009	

FIGURE A13

Survey data results for site G-MS-100 Mt. Scott Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.

*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

ANALYSIS RESULTS - Mt. Scott Creek (G-MS-100)

Channel Capacity Flow: Between the **10-year and 100-year** Event (Calculated at XS 1)

Pebble Counts and Bulk Sediment:

Year	Pebble Count*			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	N/A			N/A	
2011	N/A			N/A	
2014	N/A			N/A	

*N/A: Sample not taken due to lack of depositional features or conditions in study area.

Pools and Bank Erosion:

Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	5	0.8 ft	0.5 ft	0%	5%
2011	4	0.9 ft	0.7 ft	2.5%	0%
2014	4	1.6 ft	1.1 ft	1%	3%

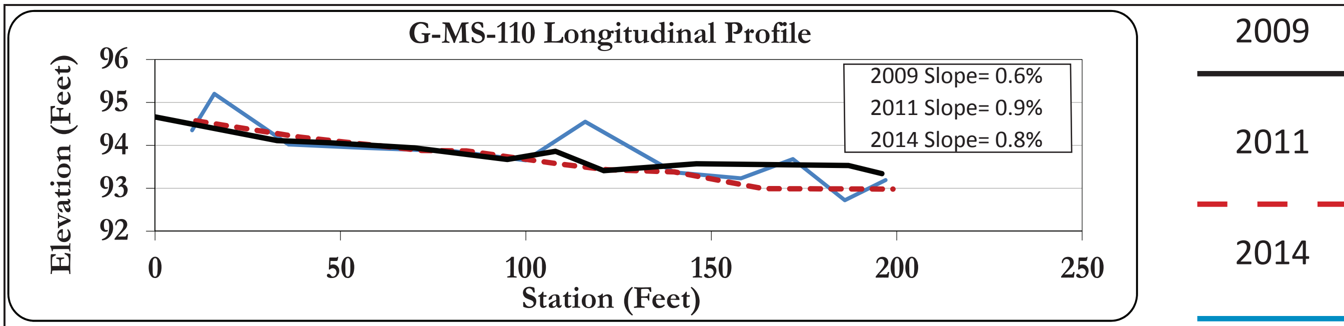
Average Bankfull Width, Depth and Width/Depth Ratio:

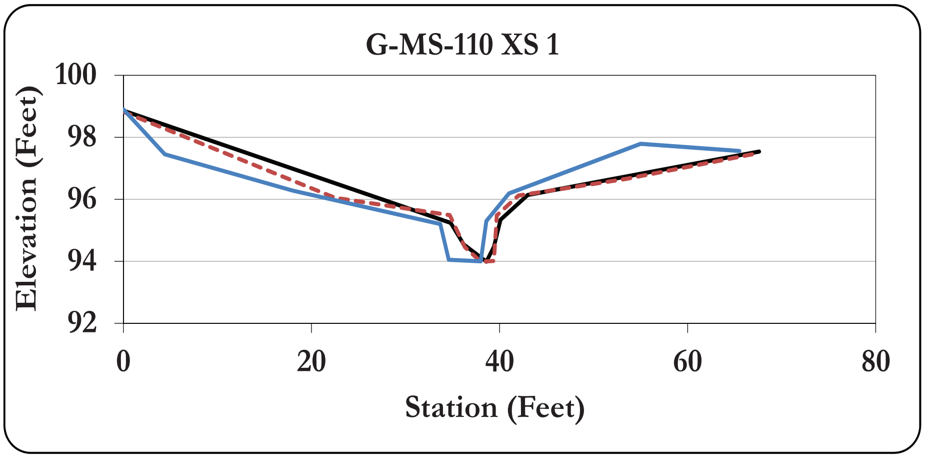
Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	15.7	1.2	13.5
2011	16.1	1.3	12.9
2014	18.1	1.0	18.1

WATERWAYS CONSULTING, INC.

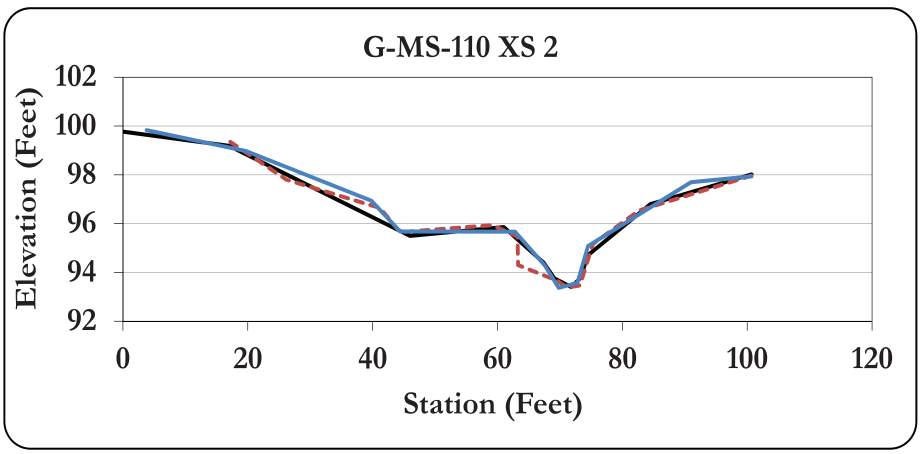
Santa Cruz, CA | watways.com | Portland, OR

FIGURE A14
Results of analysis for site G-MS-100 Mt. Scott Creek and picture of reach.





Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.2	0.009	-0.001
		0.008	
2011-2014	-0.1	0.008	0.001
		0.009	
2009-2014	-0.3	0.009	0.000
		0.009	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.1	0.013	-0.001
		0.012	
2011-2014	+0.2	0.012	-0.001
		0.011	
2009-2014	+0.1	0.013	-0.002
		0.011	

There is no third cross section at this site due to small channel size with little variability

FIGURE A15

Survey data results for site G-MS-110 Mt. Scott Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.

*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

ANALYSIS RESULTS - Mt. Scott Creek (G-MS-110)

Channel Capacity Flow: Between the **5-year and 10-year** Event (Calculated at XS 2)

Pebble Counts and Bulk Sediment:

Year	Pebble Count*			Bulk Sediment*	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	N/A			99%	90%
2011	N/A			99%	88%
2014	N/A			N/A	

*N/A: Sample not taken due to lack of depositional features or conditions in study area.

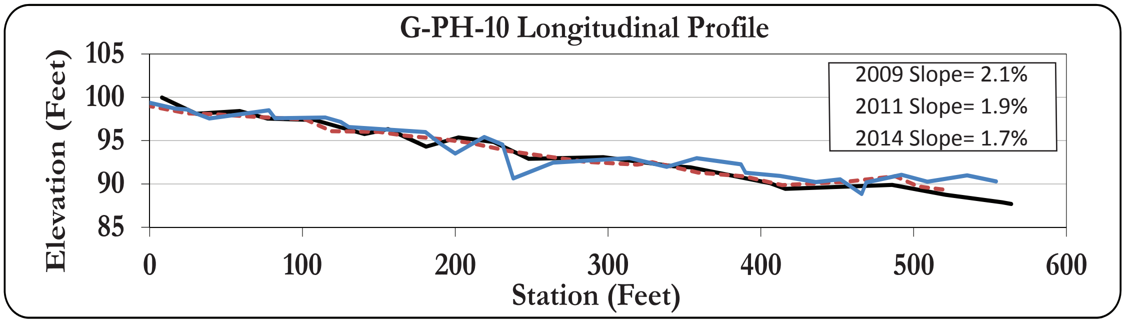
Pools:

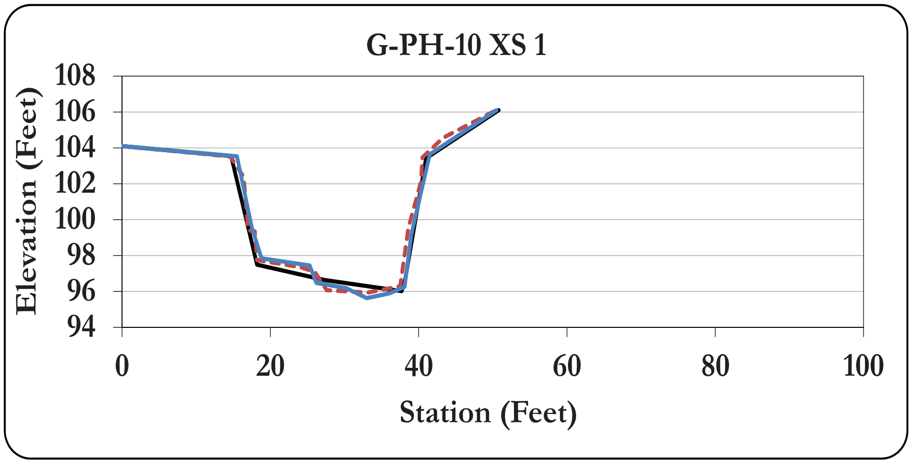
Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	1	0.7 ft	0.4 ft	0%	0%
2011	1	1.5 ft	1.3 ft	0%	0%
2014	4	1.3 ft	1 ft	0%	0%

Average Bankfull Width, Depth and Width/Depth Ratio:

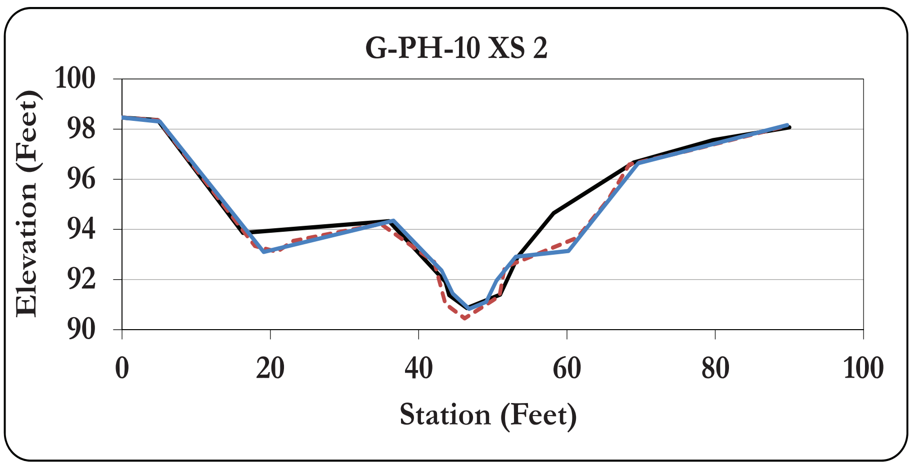
Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	6.2	1.2	5.1
2011	8.5	1.4	6.1
2014	11.6	1.7	16.4

FIGURE A16
Results of analysis for site G-MS-110 Mt. Scott Creek and picture of reach.

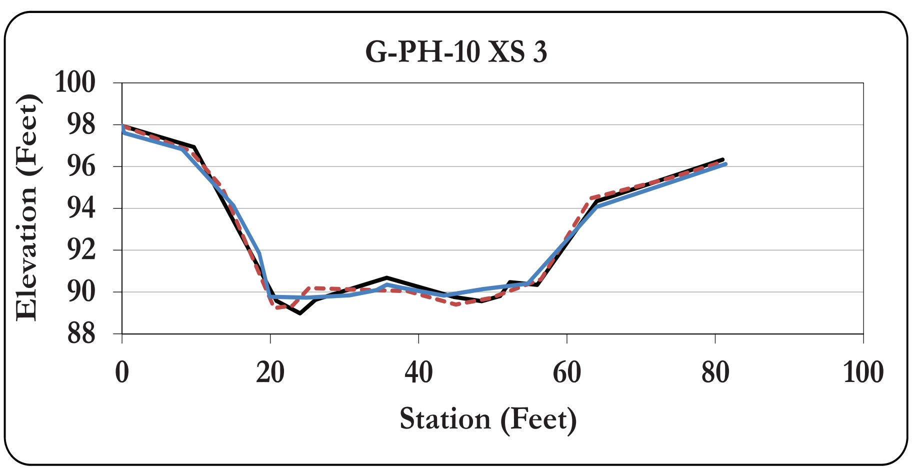




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.7	0.021	-0.002
		0.019	
2011-2014	+0.9	0.019	0.000
		0.019	
2009-2014	+0.2	0.021	-0.002
		0.019	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.3	0.017	-0.001
		0.016	
2011-2014	+0.4	0.016	0.000
		0.016	
2009-2014	+0.1	0.017	-0.001
		0.016	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+1.2	0.017	0.002
		0.019	
2011-2014	+0.3	0.019	-0.002
		0.017	
2009-2014	+1.5	0.017	0.000
		0.017	

FIGURE A17
Survey data results for site G-PH-10 Phillips Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.
*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

WATERWAYS CONSULTING, INC.
Santa Cruz, CA | watways.com | Portland, OR

ANALYSIS RESULTS - Phillips Creek (G-PH-10)

<u>Channel Capacity Flow:</u> (For the Inset Channel): Less than the **2-year** Event (Calculated at XS 2)

<u>Pebble Counts and Bulk Sediment:</u>

Year	Pebble Count			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	20 mm	38 mm	70 mm	30%	7%
2011	19 mm	29 mm	63 mm	64%	48%
2014	28 mm	53 mm	80 mm	22%	9%

Pebble Count: Significant Difference in Mean (from t-test, p=0.05)

YES: between 2009 and 2014, 2011 and 2014. ***NO***: between 2009 and 2011

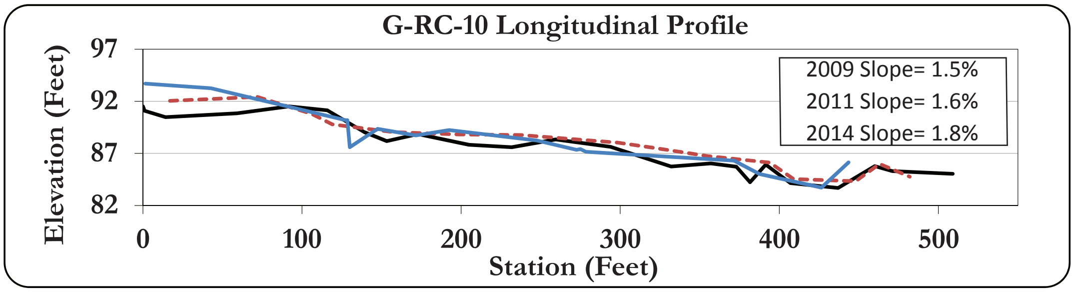
<u>Pools and Bank Erosion:</u>

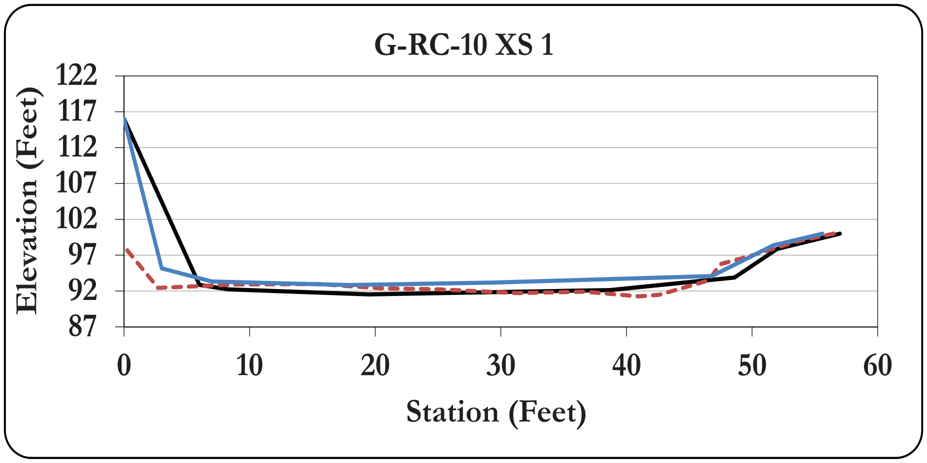
Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	5	1.8 ft	1.5 ft	7.2%	7.2%
2011	5	2.1 ft	1.6 ft	3.9%	0%
2014	6	2 ft	1.9 ft	3.6%	0%

<u>Average Bankfull Width, Depth and Width/Depth Ratio:</u>

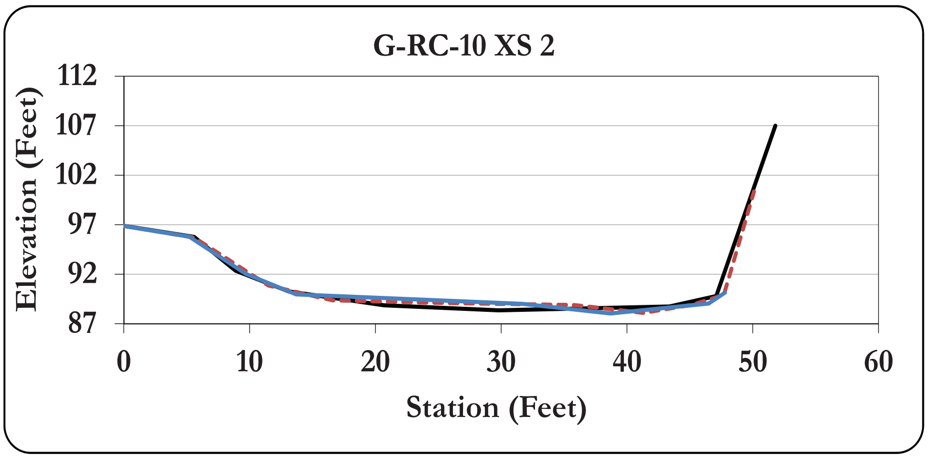
Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	23.1	1.7	14.5
2011	24.4	1.7	16.4
2014	21.6	1.6	20.1

FIGURE A18
Results of analysis for site G-PH-10 Phillips Creek and picture of reach.

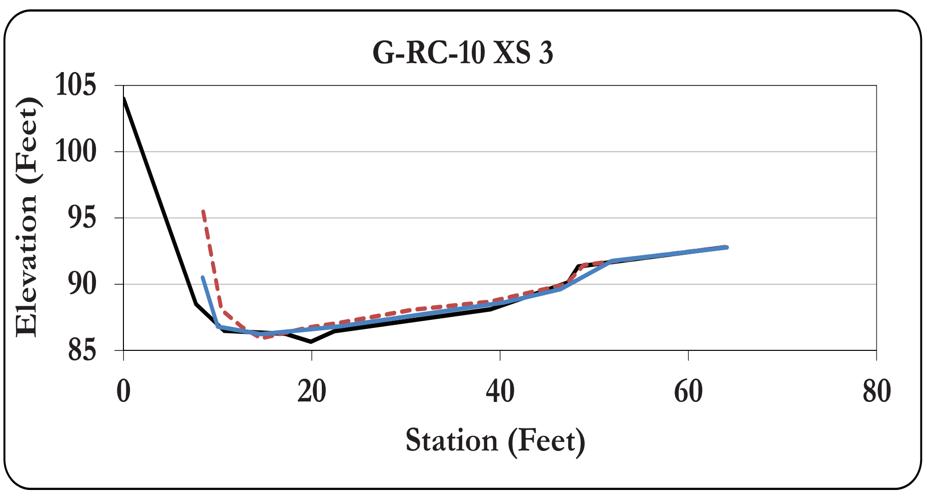




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.3	0.035	-0.006
		0.029	
2011-2014	+1.1	0.029	0.002
		0.031	
2009-2014	+1.4	0.035	-0.004
		0.031	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.7	0.031	-0.009
		0.022	
2011-2014	-0.1	0.022	-0.004
		0.018	
2009-2014	+0.6	0.031	-0.013
		0.018	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+1.5	0.027	-0.005
		0.022	
2011-2014	-0.6	0.022	-0.002
		0.020	
2009-2014	+0.9	0.027	-0.007
		0.020	

FIGURE A19

Survey data results for site G-RC-10 Lower Rock Creek taken in 2009 , 2011, and 2014. Cross section profiles are shown as looking downstream.

*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

WATERWAYS CONSULTING, INC.
Santa Cruz, CA | watways.com | Portland, OR

ANALYSIS RESULTS - Lower Rock Creek (G-RC-10)

Channel Capacity Flow: Greater than the **100-year** Event (Calculated at XS 2)

Pebble Counts and Bulk Sediment:

Year	Pebble Count			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	15 mm	31 mm	61 mm	18%	3%
2011	41 mm	61 mm	89 mm	30%	7%
2014	29 mm	60 mm	91 mm	19%	14%

Pebble Count: Significant Difference in Mean (from t-test, p=0.05)

YES: between 2009 and 2014, 2009 and 2011 ***NO***: between 2011 and 2014

Pools and Bank Erosion:

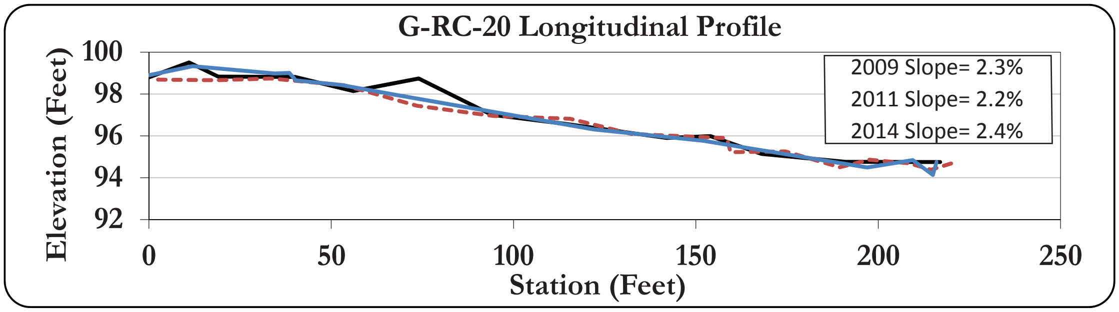
Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	6	1.7 ft	1.4 ft	0%	0%
2011	2	2.0 ft	1.6 ft	0%	0%
2014	1	3.1 ft	2.6 ft	0%	0%

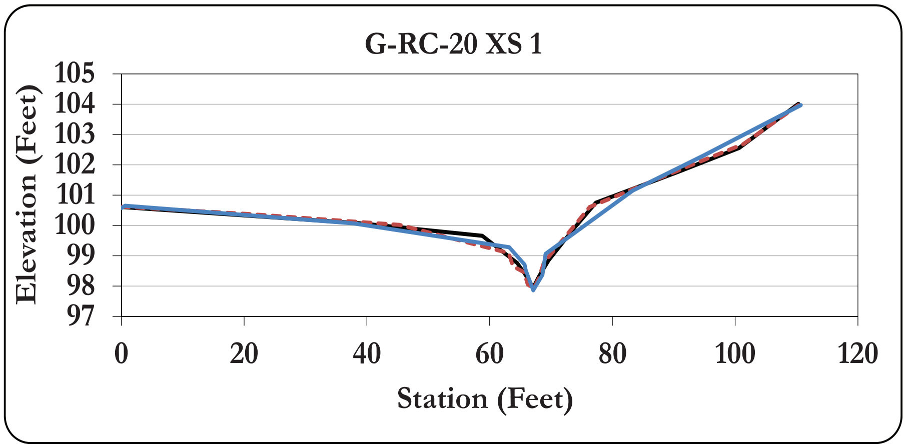
Average Bankfull Width, Depth and Width/Depth Ratio:

Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	37.7	3.0	13.0
2011	36.6	2.6	18.9
2014	37.5	2.4	15.5

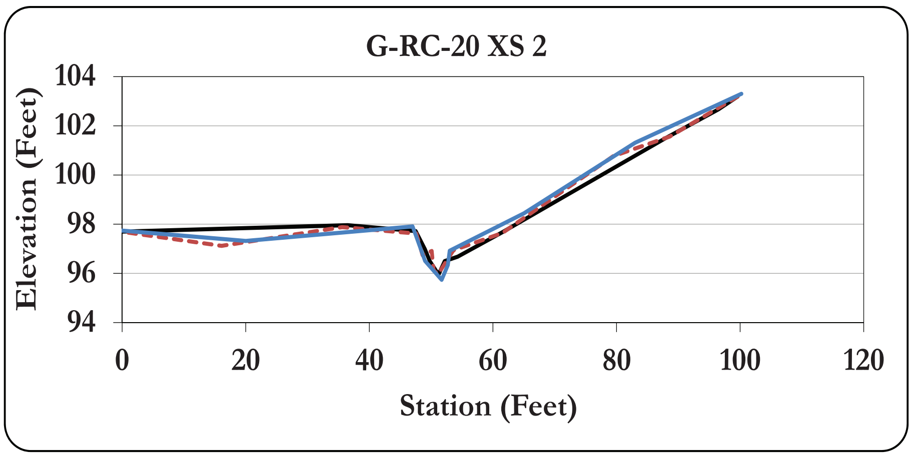
WATERWAYS CONSULTING, INC.
Santa Cruz, CA | watways.com | Portland, OR

FIGURE A20
Results of analysis for site G-RC-10 Lower Rock Creek and picture of reach.

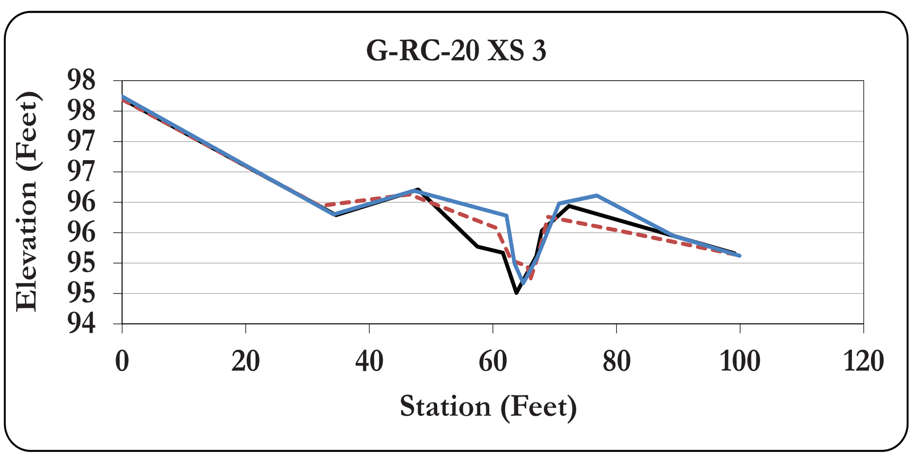




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	0.0	0.010	0.000
		0.010	
2011-2014	0.0	0.010	-0.001
		0.009	
2009-2014	0.0	0.010	-0.0001
		0.009	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.4	0.013	-0.002
		0.011	
2011-2014	-0.5	0.011	0.001
		0.012	
2009-2014	-0.1	0.013	-0.001
		0.012	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	0.0	0.004	0.000
		0.004	
2011-2014	0.0	0.004	0.000
		0.004	
2009-2014	0.0	0.004	0.000
		0.004	

FIGURE A21
Survey data results for site G-RC-20 Tributary to Lower Rock Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.
*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

ANALYSIS RESULTS - Tributary to Lower Rock Creek (G-RC-20)

Channel Capacity Flow: Greater than the **100-year** Event (Calculated at XS 2)

Pebble Counts and Bulk Sediment:

Year	Pebble Count			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	N/A			N/A	
2011	N/A			N/A	
2014	N/A			N/A	

*N/A: Sample not taken due to lack of depositional features or conditions in study area.

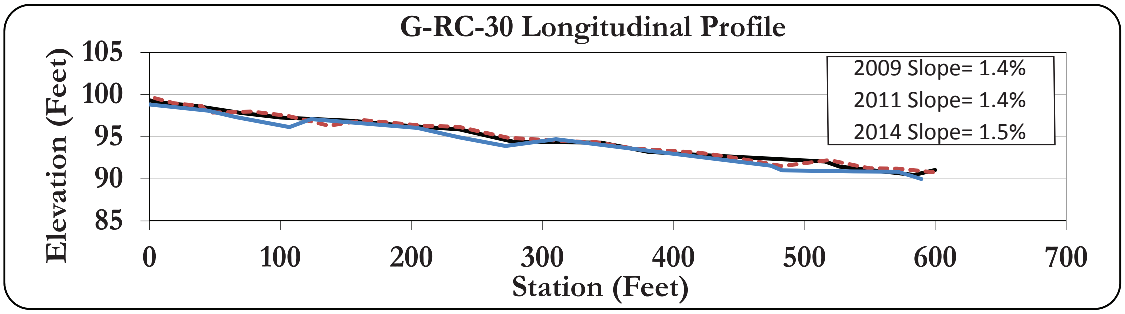
Pools and Bank Erosion:

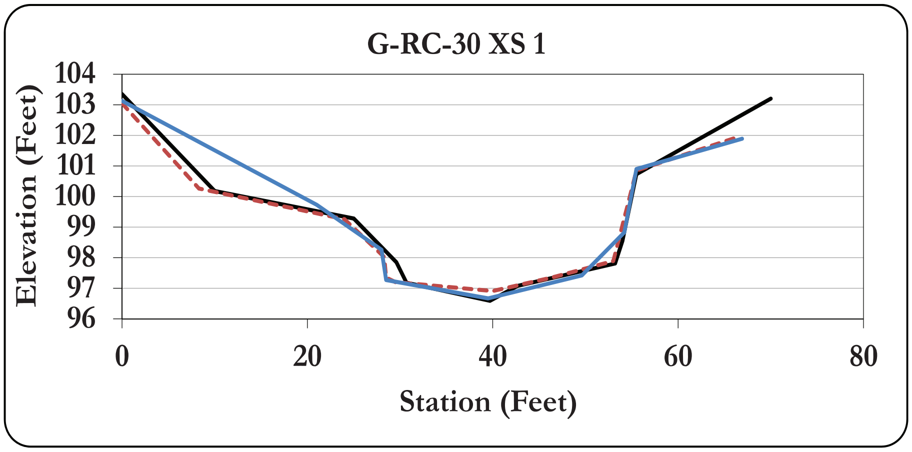
Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	3	0.9 ft	0.6 ft	0%	0%
2011	0	-	-	0%	0%
2014	3	0.6 ft	0.4 ft	0%	0%

Average Bankfull Width, Depth and Width/Depth Ratio:

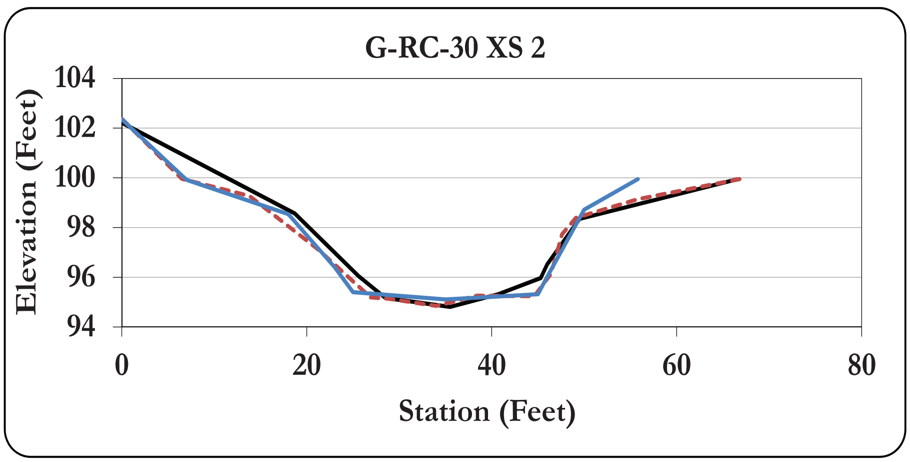
Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	6.6	0.9	6.9
2011	7.7	1.1	7.5
2014	5.5	1.2	4.9

FIGURE A22
Results of analysis for site G-RC-22 Tributary to Lower Rock Creek and picture of reach.

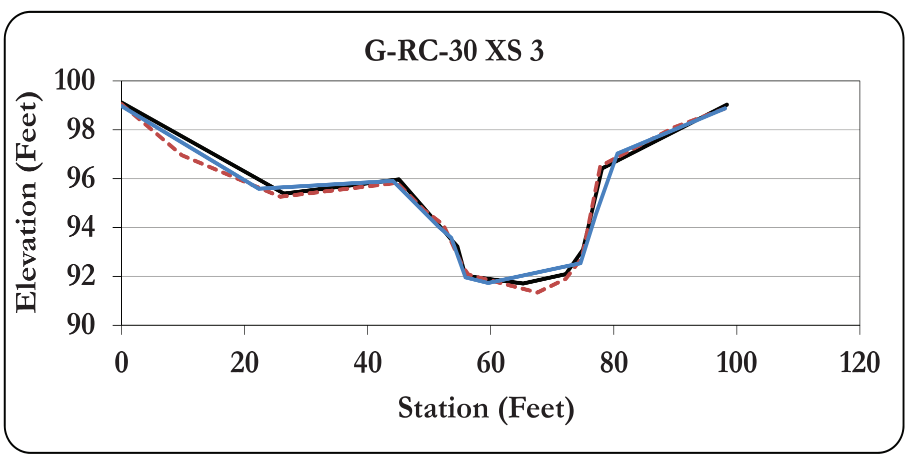




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.4	0.013	-0.001
		0.011	
2011-2014	-0.2	0.011	0.001
		0.012	
2009-2014	+0.2	0.013	-0.001
		0.012	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	0.0	0.013	0.000
		0.013	
2011-2014	+0.2	0.013	0.000
		0.013	
2009-2014	+0.2	0.013	0.000
		0.013	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.1	0.016	0.000
		0.016	
2011-2014	+0.3	0.016	-0.001
		0.015	
2009-2014	+0.2	0.016	-0.001
		0.015	

FIGURE A23

Survey data results for site G-RC-30 Rock Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.

*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

ANALYSIS RESULTS - Rock Creek (G-RC-30)

Channel Capacity Flow: Greater than the **100-year** Event (Calculated at XS 2)

Pebble Counts and Bulk Sediment:

Year	Pebble Count			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	N/A			N/A	
2011	N/A			N/A	
2014	N/A			N/A	

*N/A: Sample not taken due to lack of depositional features or conditions in study area.

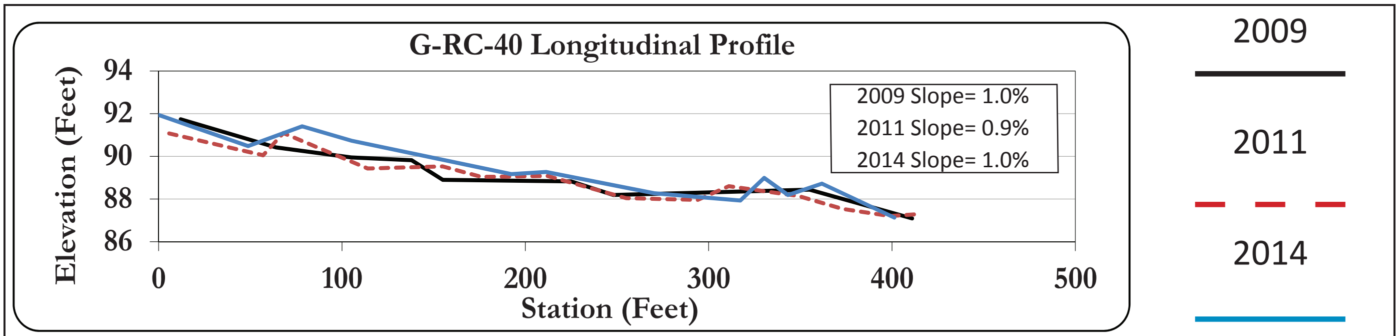
Pools and Bank Erosion:

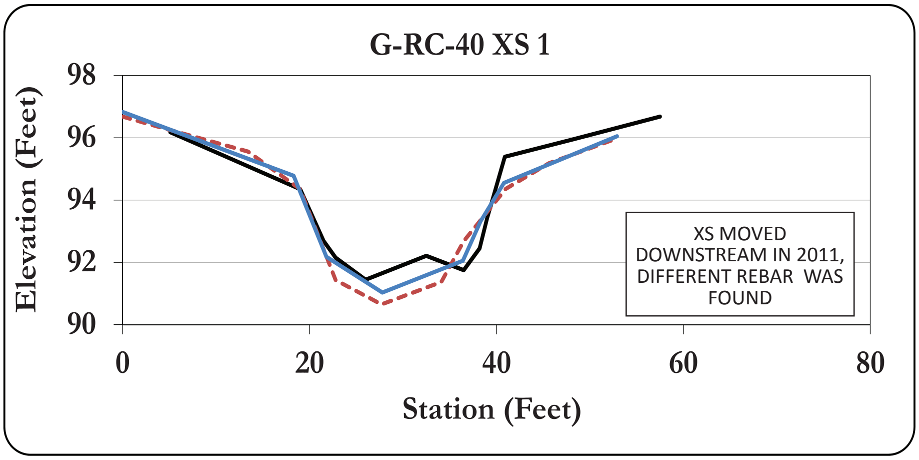
Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	4	1.4 ft	0.9 ft	0%	0%
2011	3	1.2 ft	0.9 ft	0%	6%
2014	2	1.5 ft	1.1 ft	0%	5.1%

Average Bankfull Width, Depth and Width/Depth Ratio:

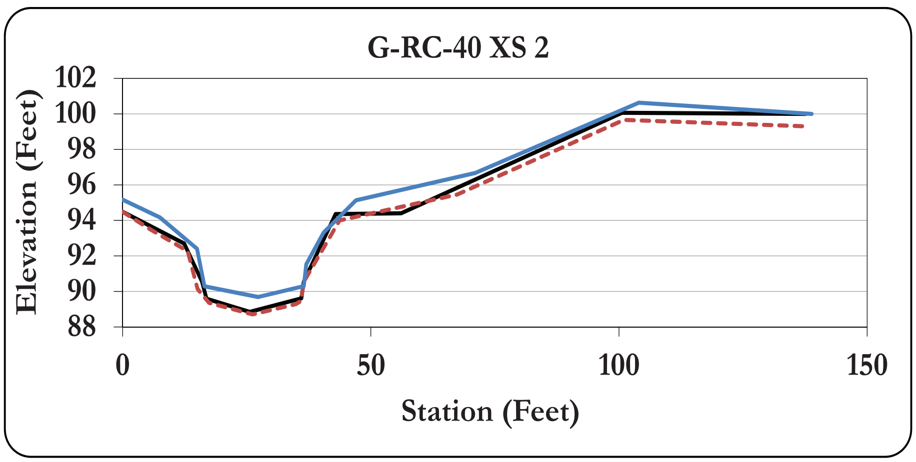
Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	21.7	1.5	14.4
2011	23.1	1.4	17.8
2014	23.1	1.4	17.6

FIGURE A24
Results of analysis for site G-RC-30 Rock Creek and picture of reach.

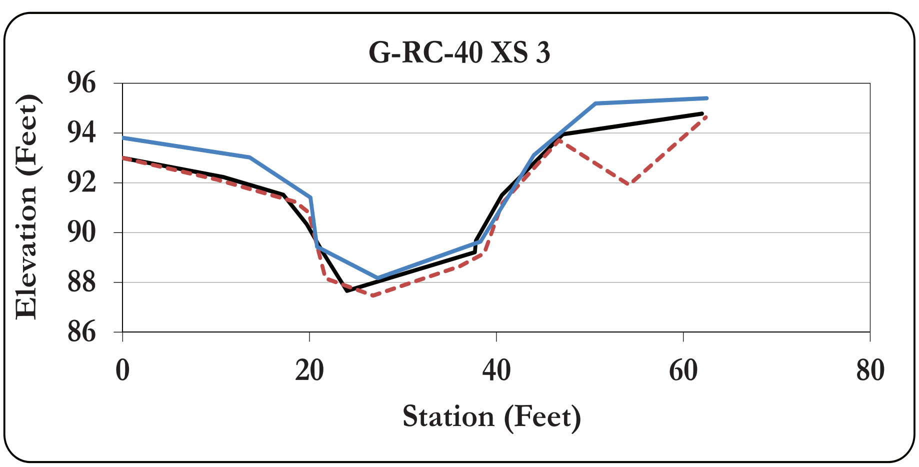




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.8	0.011	0.001
		0.012	
2011-2014	+0.6	0.012	-0.001
		0.011	
2009-2014	-0.2	0.011	0.000
		0.011	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.2	0.021	0.000
		0.021	
2011-2014	+0.9	0.021	0.000
		0.021	
2009-2014	+0.7	0.021	0.000
		0.021	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.3	0.013	0.001
		0.014	
2011-2014	+0.7	0.014	0.001
		0.015	
2009-2014	+0.4	0.013	0.002
		0.015	

FIGURE A25

Survey data results for site G-RC-40 Rock Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.

*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

WATERWAYS CONSULTING, INC.

Santa Cruz, CA | watways.com | Portland, OR

ANALYSIS RESULTS - Rock Creek (G-RC-40)

Channel Capacity Flow: Between the **5-year and 10-year** Events (Calculated at XS 2)

Pebble Counts and Bulk Sediment:

Year	Pebble Count			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	24 mm	76 mm	118 mm	44%	25%
2011	56 mm	105 mm	162 mm	24%	14%
2014	45 mm	80 mm	135 mm	39%	30%

Pebble Count: Significant Difference in Mean (from t-test, p=0.05)

YES: between 2009 and 2011, 2011 and 2014. ***NO:*** between 2009 and 2014.

Pools and Bank Erosion:

Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	3	1.5 ft	0.7 ft	2.5%	1%
2011	4	1.2 ft	0.9 ft	7.3%	7.3%
2014	2	1.8 ft	1 ft	7.5%	0%

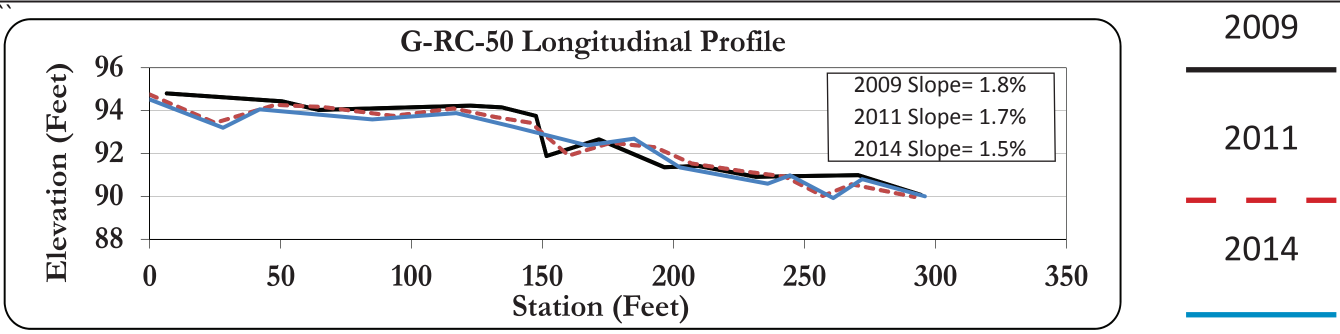
Average Bankfull Width, Depth and Width/Depth Ratio:

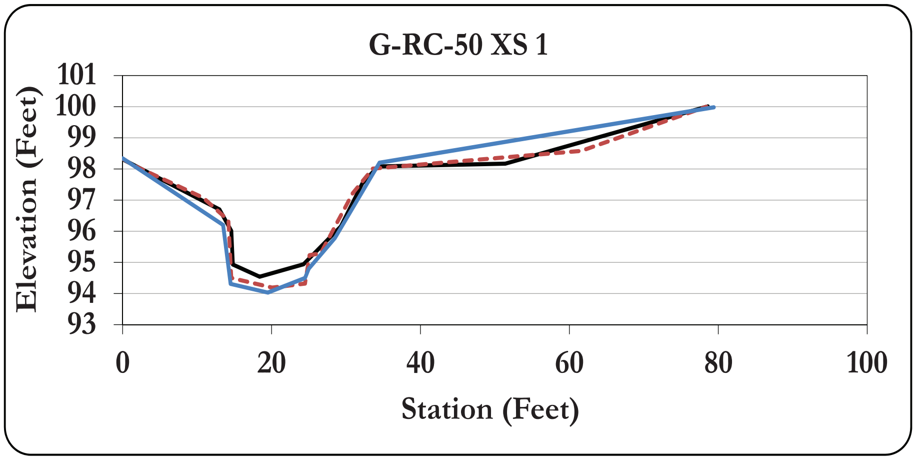
Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	18.7	2.1	9.2
2011	19.7	2.2	11.3
2014	19.0	2.4	7.7

WATERWAYS CONSULTING, INC.

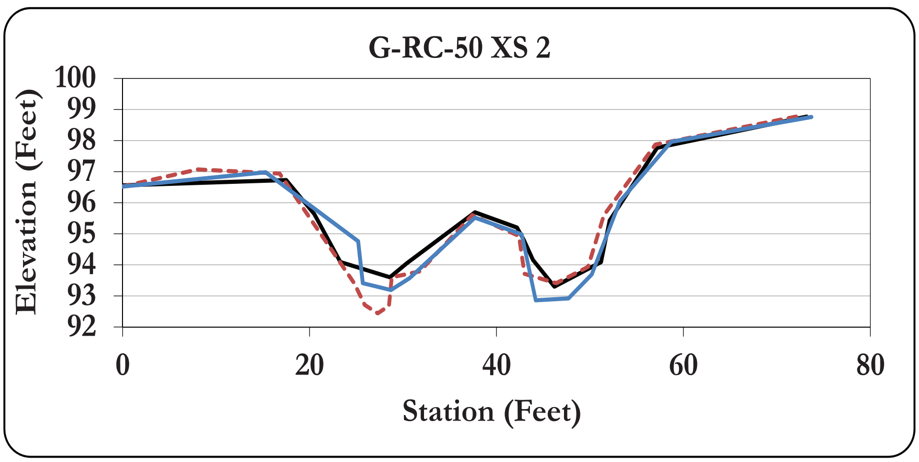
Santa Cruz, CA | watways.com | Portland, OR

FIGURE A26
Results of analysis for site G-RC-40 Rock Creek and picture of reach.

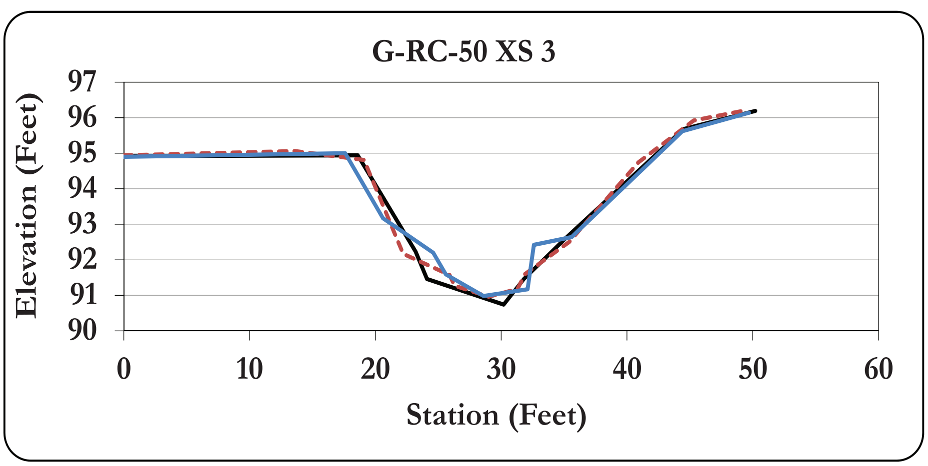




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.1	0.010	0.001
		0.011	
2011-2014	-0.3	0.011	0.000
		0.011	
2009-2014	-0.4	0.010	0.001
		0.011	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.2	0.009	0.002
		0.011	
2011-2014	-0.3	0.011	0.000
		0.011	
2009-2014	-0.5	0.009	0.002
		0.011	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.4	0.012	-0.001
		0.011	
2011-2014	-0.4	0.011	0.000
		0.011	
2009-2014	0.0	0.012	-0.001
		0.011	

FIGURE A27

Survey data results for site G-RC-50 Rock Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.

*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

ANALYSIS RESULTS - Rock Creek (G-RC-50)

Channel Capacity Flow: Between the **10-year and 100-year** Events (Calculated at XS 1)

Pebble Counts and Bulk Sediment:

Year	Pebble Count			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	N/A			46%	11%
2011	N/A			26%	10%
2014	N/A			55%	33%

*N/A: Sample not taken due to lack of depositional features or conditions in study area.

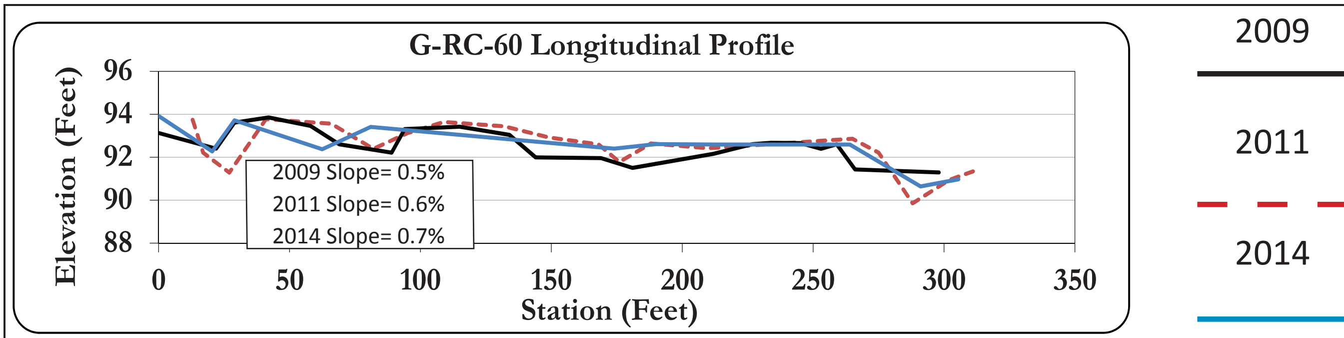
Pools and Bank Erosion:

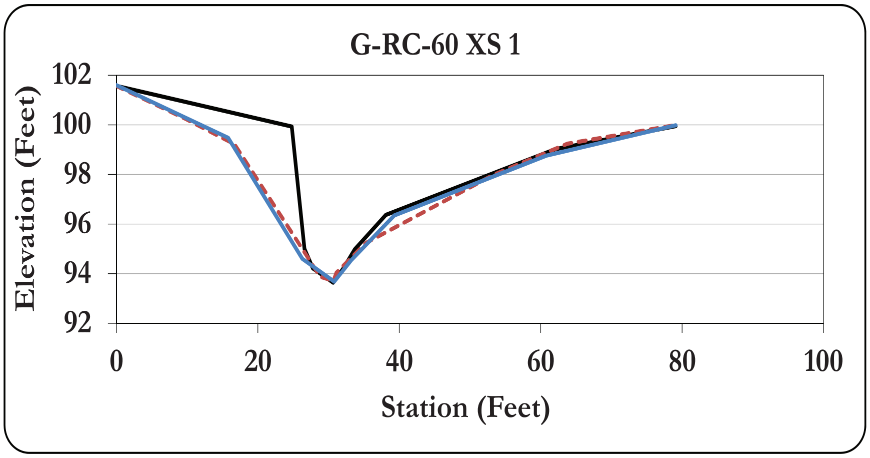
Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	4	1.4 ft	0.9 ft	0%	0%
2011	5	1.1 ft	0.9 ft	5.1%	5.1%
2014	2	1.3 ft	0.8 ft	6.8%	7.4%

Average Bankfull Width, Depth and Width/Depth Ratio:

Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	12.2	1.7	7.2
2011	13.2	1.9	7.3
2014	11.5	1.3	9.2

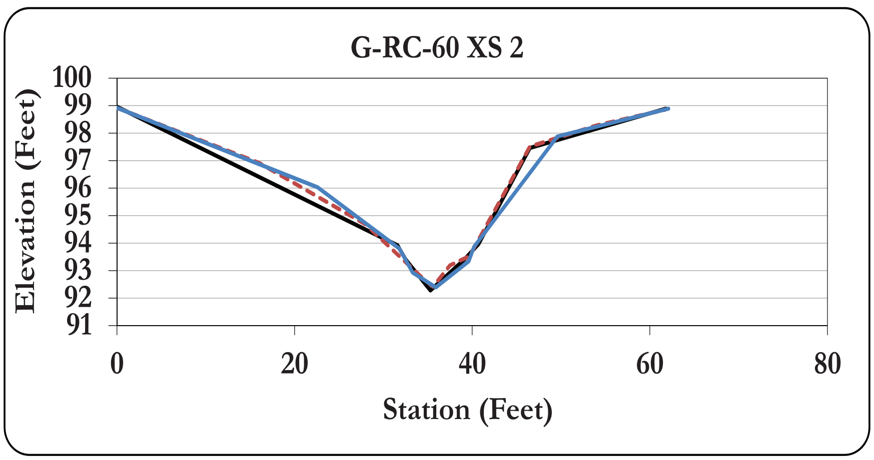
FIGURE A28
Results of analysis for site G-RC-50 Rock Creek and picture of reach.





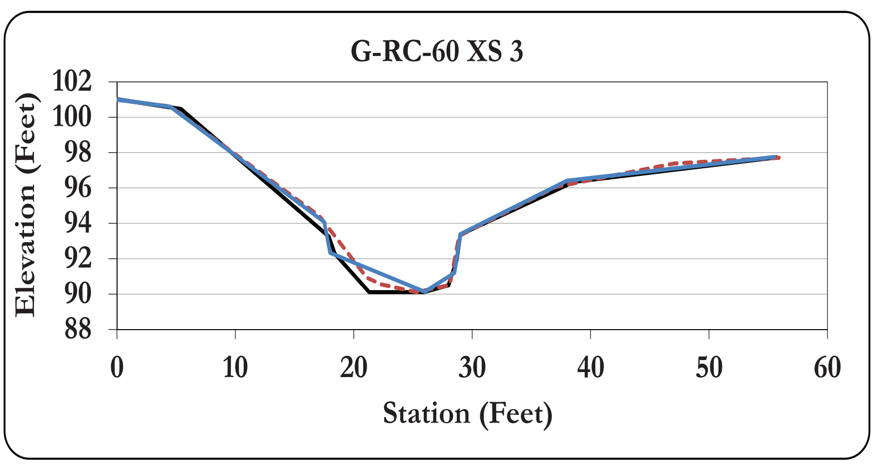
Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.2	0.016	0.000
		0.016	
2011-2014	+0.1	0.016	0.000
		0.016	
2009-2014	+0.3	0.016	0.000
		0.016	

(Area Calculated from Station 16 to 64 ft)



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.3	0.014	0.001
		0.015	
2011-2014	+0.1	0.015	-0.001
		0.014	
2009-2014	-0.2	0.014	0.000
		0.014	

(Area Calculated from Station 10 to 47 ft)



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.2	0.022	0.001
		0.023	
2011-2014	+0.7	0.023	-0.001
		0.022	
2009-2014	+0.9	0.022	0.000
		0.022	

(Area Calculated from Station 13 to 37 ft)

FIGURE A29

Survey data results for site G-RC-60 Upper Rock Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.

*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

ANALYSIS RESULTS - Upper Rock Creek (G-RC-60)

Channel Capacity Flow: Less than the **2-year** Event (Calculated at XS 2)

Pebble Counts:

Year	Pebble Count			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	N/A			46%	11%
2011	N/A			N/A	
2014	N/A			N/A	

*N/A: Sample not taken due to lack of depositional features or conditions in study area.

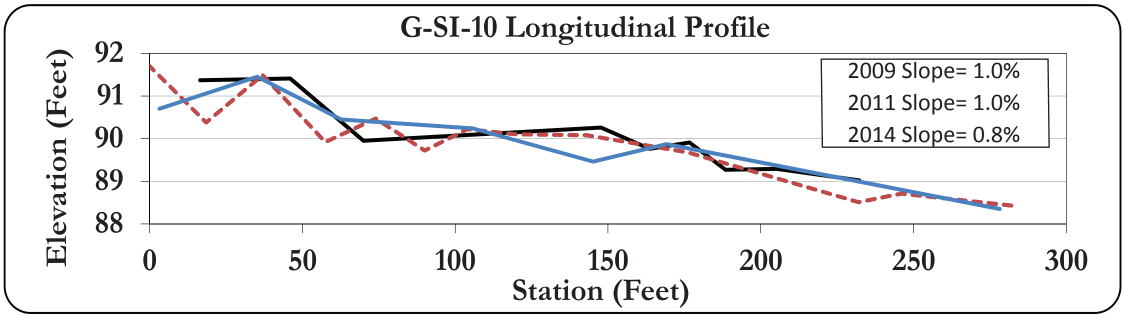
Pools:

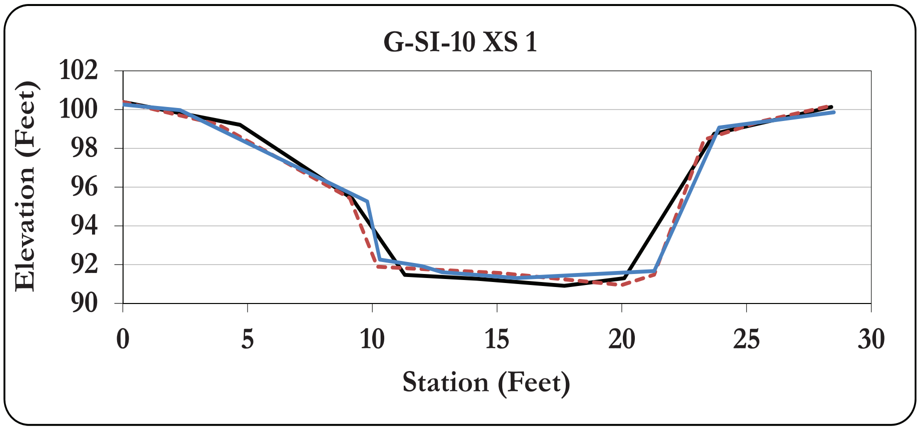
Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	3	3.0 ft	1.9 ft	0%	0%
2011	0	No flow at time of survey		16.7%	13.4%
2014	3	2.6 ft	1 ft	0%	0%

Average Bankfull Width, Depth and Width/Depth Ratio:

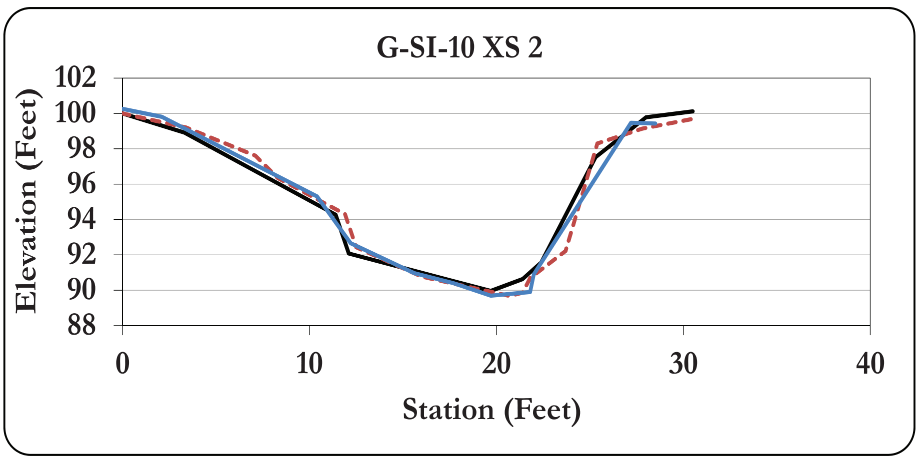
Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	9.1	2.1	4.7
2011	11.0	2.3	5.5
2014	11.6	2.3	5.2

FIGURE A30
Results of analysis for site G-RC-60 Upper Rock Creek and picture of reach.

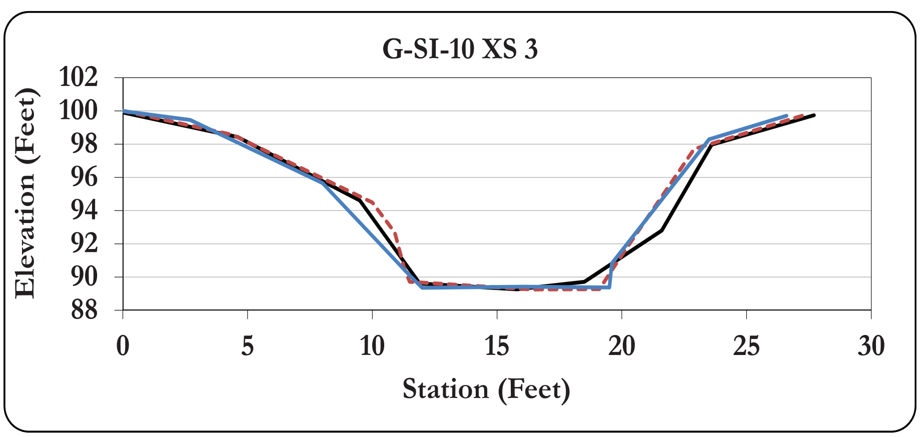




Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.1	0.023	0.002
		0.025	
2011-2014	-0.3	0.025	-0.004
		0.021	
2009-2014	-0.2	0.023	-0.002
		0.021	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	-0.2	0.024	-0.001
		0.023	
2011-2014	0	0.023	0.002
		0.025	
2009-2014	-0.2	0.024	0.001
		0.025	



Variable	Bed Elev. Change (ft)	GINI Coeff*	GINI Change
2009-2011	+0.3	0.025	-0.003
		0.022	
2011-2014	+0.3	0.022	0.004
		0.026	
2009-2014	+0.6	0.025	0.001
		0.026	

FIGURE A31

Survey data results for site G-SI-10 Sieben Creek taken in 2009, 2011, and 2014. Cross section profiles are shown as looking downstream.

*(A GINI of zero indicates a flat/wide channel, a GINI of one indicates a deep/narrow channel)

WATERWAYS CONSULTING, INC.
Santa Cruz, CA | watways.com | Portland, OR

ANALYSIS RESULTS - Sieben Creek (G-SI-10)

Channel Capacity Flow: Greater than the **100-year** Event (Calculated at XS)

Pebble Counts and Bulk Sediment:

Year	Pebble Count			Bulk Sediment	
	D_{16}	D_{50}	D_{84}	< 6.30 mm	<0.85 mm
2009	10 mm	39 mm	72 mm	46%	11%
2011	N/A			25%	12%
2014	N/A			20%	8%

*N/A: Sample not taken due to lack of depositional features or conditions in study area.

Pools and Bank Erosion:

Year	Pools			Erosion	
	Number	Average Max Depth	Average Residual Max Depth	Left Bank	Right Bank
2009	4	0.9 ft	0.7 ft	0%	53.3%
2011	2	1.3 ft	0.9 ft	17.7%	31.9%
2014	1	1.7 ft	1.3 ft	0%	49.1%

Average Bankfull Width, Depth and Width/Depth Ratio:

Year	Average W_{BF}	Average D_{BF}	Average W/D
2009	10.7	2.5	4.6
2011	11.6	3.5	3.4
2014	8.8	1.2	7.8

FIGURE A32
Results of analysis for site G-SI-10 Sieben Creek and picture of reach.

WATERWAYS CONSULTING, INC.

Clackamas County Service District #1
2014 WES Monitoring

APPENDIX B

Macroinvertebrate Summary Figures

Reach Assessment Summary

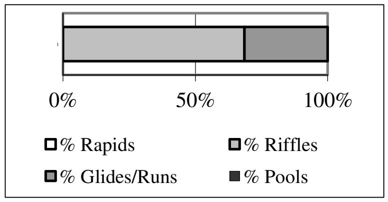
Stream Name: **Kellogg Creek**
Location: Upstream of Kellogg Lake; Rowe Middle School
County, State: Clackamas, Oregon
Date sampled: 9/17/2014
Field Personnel: MBC, CB

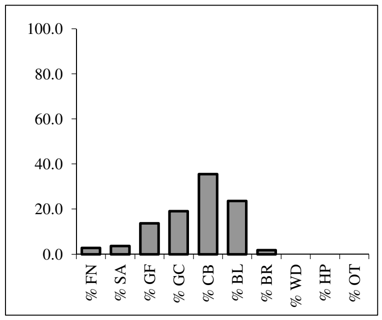
Site ID: M-KL-10
Reach ID: SD1-M18
Latitude: 45.43192
Longitude: -122.62812
Reach Length: 105 m

Physical and Chemical Conditions Summary

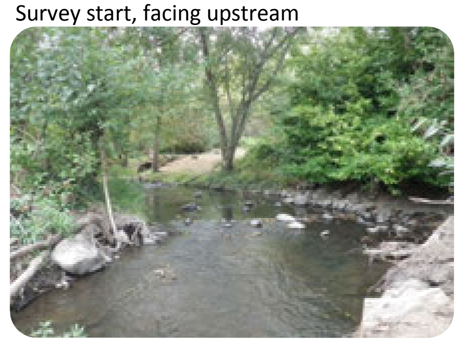
Instream Physical Characteristics

Reach Gradient (%)	1.1
Wetted Width (m)	7.9
Bankfull Width (m)	8.7
% Rapids	0.0
% Riffles	68.6
% Glides/Runs	31.4
% Pools	0.0
Substrate	
% Fines (FN)	2.7
% Sand (SA)	3.6
% Gravel, Fine (GF)	13.6
% Gravel, Coarse (GC)	19.1
% Cobble (CB)	35.5
% Boulder (BL)	23.6
% Bedrock (BR)	1.8
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	21.6
Large Wood Tally (pieces/m)	0.12
Eroding Banks (%)	12
Undercut Banks (%)	3





Survey start, facing upstream

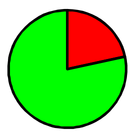


Survey end, facing downstream

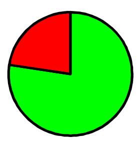
Riparian Zone Characteristics

Canopy Cover (%)	77
Riparian Buffer Width (m)	5
Riparian Zone Tree Cover (%)	45
Riparian Zone Non-Native Cover (%)	20
Dom Adjacent Land Use	RES

Embeddedness



Canopy Cover



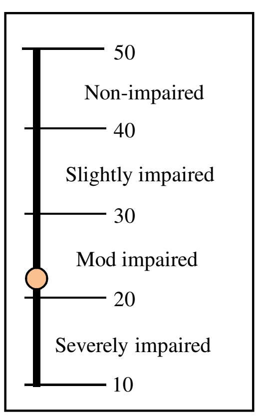
Chemical Characteristics

Time of measurement	9:45
Water Temperature (°C)	16.05
Dissolved Oxygen (%)	86.8
Dissolved Oxygen (mg/L)	8.55
Specific Cond. (µS/cm)	218

Biological Conditions Summary

CE Sample ID: 14-121-11
Habitat(s) Sampled: Riffles
Sample Method: OR DEQ 8-kick composite

DEQ Metric Scores	Raw	Stand.
Richness	24	1
Mayfly Richness	3	3
Stonefly Richness	0	1
Caddisfly Richness	3	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	5.0	3
% Tolerant Taxa	44.2	3
% Sed Tol Taxa	1.6	5
% Dominant (1)	24.2	3
TOTAL		**22**



PREDATOR MWCF O/E Scores:

Yr/Habitat	O/E Score	Classification
2002		
2007		
2009/R	0.242	MOST
2011/R	0.630	MOST
2014/R	0.436	MOST

DEQ Multimetric Scores

Yr/Habitat	MM Score	Classification
2002		
2007		
2009/R	16	SEVERE
2011/R	22	MOD
2014/R	22	MOD

5 MOST ABUNDANT TAXA

Taxon	Count
Cheumatopsyche	123
Baetis tricaudatus	112
Hydropsyche	92
Ramellogammarus	51
Orthocladiinae	40

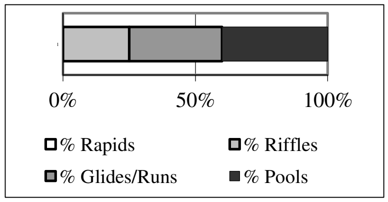
Reach Assessment Summary

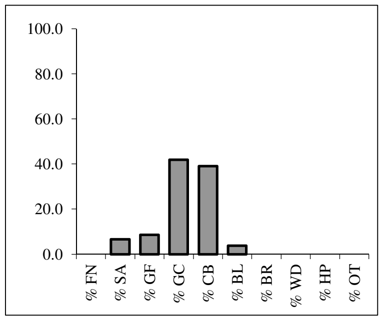
Stream Name:	**Kellogg Creek**	Site ID:	M-KL-20
Location:	Upstream of SE Rusk Road	Reach ID:	SD1-M13
County, State:	Clackamas, Oregon	Latitude:	45.42295
Date sampled:	9/22/2014	Longitude:	-122.60388
Field Personnel: MBC		Reach Length:	100 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

Reach Gradient (%)	0.6
Wetted Width (m)	2.7
Bankfull Width (m)	3.8
% Rapids	0.0
% Riffles	25.0
% Glides/Runs	35.0
% Pools	40.0
Substrate	
% Fines (FN)	0.0
% Sand (SA)	6.7
% Gravel, Fine (GF)	8.6
% Gravel, Coarse (GC)	41.9
% Cobble (CB)	39.0
% Boulder (BL)	3.8
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	17.4
Large Wood Tally (pieces/m)	0.00
Eroding Banks (%)	5
Undercut Banks (%)	32





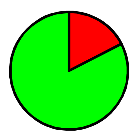
Survey start, facing upstream

Survey end, facing downstream

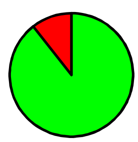
Riparian Zone Characteristics

Canopy Cover (%)	89
Riparian Buffer Width (m)	4
Riparian Zone Tree Cover (%)	75
Riparian Zone Non-Native Cover (%)	30
Dom Adjacent Land Use	RES

Embeddedness



Canopy Cover



Chemical Characteristics

Time of measurement	13:30
Water Temperature (°C)	15.17
Dissolved Oxygen (%)	74.7
Dissolved Oxygen (mg/L)	7.5
Specific Cond. (µS/cm)	204

PREDATOR MWCF O/E Scores:

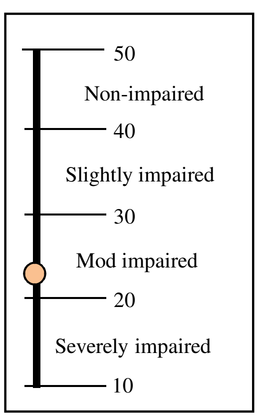
Yr/Habitat	O/E Score	Classification
2002/R		
2007/R		
2009/R		
2011/R	0.533	MOST
2014/R	0.581	MOST

Biological Conditions Summary

CE Sample ID: 14-121-12 Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

DEQ Metric Scores	Raw	Stand.
Richness	23	1
Mayfly Richness	2	3
Stonefly Richness	0	1
Caddisfly Richness	4	3
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	5.6	1
% Tolerant Taxa	36.7	3
% Sed Tol Taxa	21.3	3
% Dominant (1)	18.1	5
TOTAL		**22**



DEQ Multimetric Scores

Yr/Habitat	MM Score	Classification
2002/R		
2007/R		
2009/R		
2011/R	18	MOST
2014/R	22	MOD

5 MOST ABUNDANT TAXA

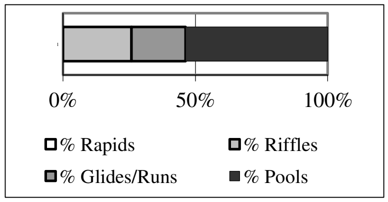
Taxon	Count
Juga	94
Orthocladiinae	90
Cheumatopsyche	76
Trombidiformes	38
Tanytarsini	36

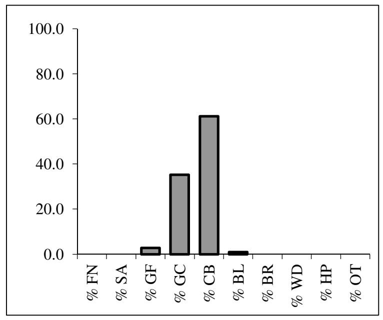
Reach Assessment Summary

Stream Name:	**Mt. Scott Creek**	Site ID:	M-MS-10
Location:	N. Clackamas Park	Reach ID:	SD1-M4
County, State:	Clackamas, Oregon	Latitude:	45.42668
Date sampled:	9/17/2014	Longitude:	-122.61233
Field Personnel:	MBC, CB	Reach Length:	201 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics	
Reach Gradient (%)	0.6
Wetted Width (m)	7.5
Bankfull Width (m)	8.7
% Rapids	0.0
% Riffles	25.9
% Glides/Runs	20.4
% Pools	53.7
Substrate	
% Fines (FN)	0.0
% Sand (SA)	0.0
% Gravel, Fine (GF)	2.8
% Gravel, Coarse (GC)	35.2
% Cobble (CB)	61.1
% Boulder (BL)	0.9
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	6.2
Large Wood Tally (pieces/m)	0.12
Eroding Banks (%)	25
Undercut Banks (%)	9



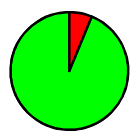


Survey start, facing upstream

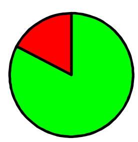
Survey end, facing downstream

Riparian Zone Characteristics	
Canopy Cover (%)	83
Riparian Buffer Width (m)	55
Riparian Zone Tree Cover (%)	65
Riparian Zone Non-Native Cover (%)	15
Dom Adjacent Land Use	RES

Embeddedness



Canopy Cover



Chemical Characteristics	
Time of measurement	7:40
Water Temperature (°C)	16.75
Dissolved Oxygen (%)	71.4
Dissolved Oxygen (mg/L)	6.94
Specific Cond. (µS/cm)	231

PREDATOR MWCF O/E Scores:

Yr/Habitat	O/E Score	Classification
2002/R	0.291	MOST
2007/R	0.338	MOST
2009/R	0.388	MOST
2011/R*	0.436	MOST
2014/R*	0.339	MOST

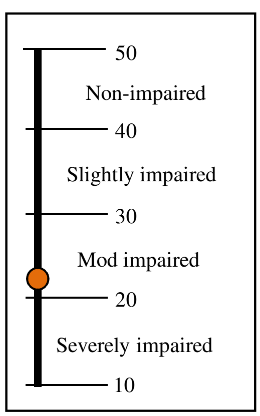
Biological Conditions Summary

CE Sample ID: 14-121-13 Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

DEQ Metric Scores	Raw	Stand.
Richness	22	1
Mayfly Richness	3	3
Stonefly Richness	0	1
Caddisfly Richness	3	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	5.0	3
% Tolerant Taxa	44.5	3
% Sed Tol Taxa	1.1	5
% Dominant (1)	38.3	3
TOTAL		**22**

* This reach was relocated approximately 200 m in 2011 to a restoration site in North Clackamas Park



DEQ Multimetric Scores

Yr/Habitat	MM Score	Classification
2002/R	16	SEVERE
2007/R	14	SEVERE
2009/R	16	SEVERE
2011/R*	18	SEVERE
2014/R*	22	MOD

5 MOST ABUNDANT TAXA

Taxon	Count
Cheumatopsyche	204
Orthocladiinae	64
Hydropsychidae	61
Baetis tricaudatus	58
Turbellaria	32

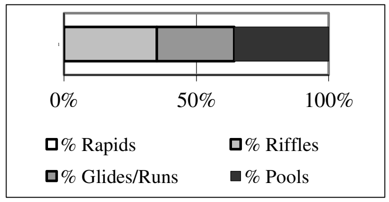
Reach Assessment Summary

Stream Name:	**Mt. Scott Creek**	Site ID:	M-MS-40
Location:	Three Creeks restoration site behind Aquatic Center	Reach ID:	SD1-M3
County, State:	Clackamas, Oregon	Latitude:	45.42988
Date sampled:	9/17/2014	Longitude:	-122.58236
Field Personnel: MBC, CB		Reach Length:	137 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

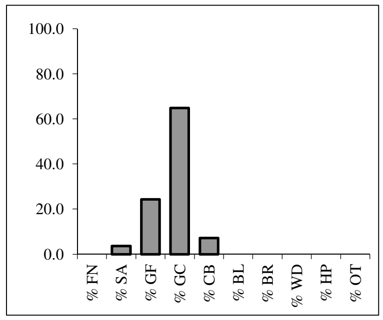
Reach Gradient (%)	0.4
Wetted Width (m)	5.3
Bankfull Width (m)	6.7
% Rapids	0.0
% Riffles	35.0
% Glides/Runs	29.2
% Pools	35.8



Survey start, facing upstream

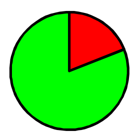
Substrate

% Fines (FN)	0.0
% Sand (SA)	3.6
% Gravel, Fine (GF)	24.3
% Gravel, Coarse (GC)	64.9
% Cobble (CB)	7.2
% Boulder (BL)	0.0
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	19.0
Large Wood Tally (pieces/m)	0.09
Eroding Banks (%)	69
Undercut Banks (%)	12



Survey end, facing downstream

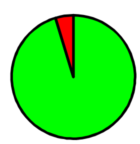
Embeddedness



Riparian Zone Characteristics

Canopy Cover (%)	95
Riparian Buffer Width (m)	63
Riparian Zone Tree Cover (%)	70
Riparian Zone Non-Native Cover (%)	10
Dom Adjacent Land Use	COM

Canopy Cover



Chemical Characteristics

Time of measurement	14:35
Water Temperature (°C)	17.1
Dissolved Oxygen (%)	77.3
Dissolved Oxygen (mg/L)	7.45
Specific Cond. (μS/cm)	195

PREDATOR MWCF O/E Scores:

Yr/Habitat	O/E Score	Classification
2002/R	0.291	MOST
2007/R	0.483	MOST
2009/R	0.533	MOST
2011/R	0.484	MOST
2014/R	0.581	MOST

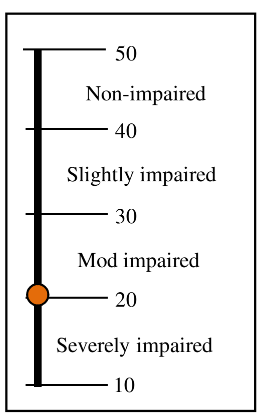
Biological Conditions Summary

CE Sample ID: 14-121-14 — Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

DEQ Metric Scores

	Raw	Stand.
Richness	22	1
Mayfly Richness	3	3
Stonefly Richness	0	1
Caddisfly Richness	4	3
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	5.3	1
% Tolerant Taxa	40.7	3
% Sed Tol Taxa	10.6	3
% Dominant (1)	27.6	3
TOTAL		**20**



DEQ Multimetric Scores

Yr/Habitat	MM Score	Classification
2002/R	16	SEVERE
2007/R	18	SEVERE
2009/R	18	SEVERE
2011/R	14	SEVERE
2014/R	20	MOD

5 MOST ABUNDANT TAXA

Taxon	Count
Cheumatopsyche	145
Baetis tricaudatus	63
Oligochaeta	53
Paraleptophlebia	40
Crangonyx	34

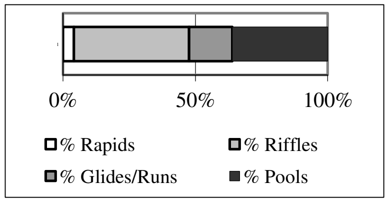
Reach Assessment Summary

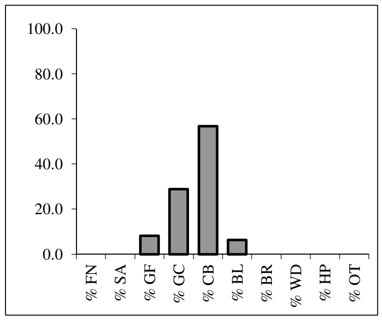
Stream Name:	**Mt. Scott Creek**	Site ID:	M-MS-80
Location:	US 122nd/Sunnyside, DS Spring Mt. Dam removal	Reach ID:	SD1-M2
County, State:	Clackamas, Oregon	Latitude:	45.435118
Date sampled:	9/17/2014	Longitude:	-122.5402
Field Personnel:	MBC, CB	Reach Length:	125 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

Reach Gradient (%)	4.2
Wetted Width (m)	1.8
Bankfull Width (m)	6.8
% Rapids	4.0
% Riffles	42.4
% Glides/Runs	16.0
% Pools	35.2
Substrate	
% Fines (FN)	0.0
% Sand (SA)	0.0
% Gravel, Fine (GF)	8.1
% Gravel, Coarse (GC)	28.8
% Cobble (CB)	56.8
% Boulder (BL)	6.3
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	18.6
Large Wood Tally (pieces/m)	0.05
Eroding Banks (%)	2.08
Undercut Banks (%)	2.24





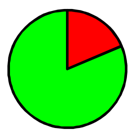
Survey start, facing upstream

Survey end, facing downstream

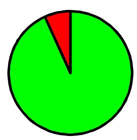
Riparian Zone Characteristics

Canopy Cover (%)	93.24
Riparian Buffer Width (m)	50
Riparian Zone Tree Cover (%)	80
Riparian Zone Non-Native Cover (%)	10
Dom Adjacent Land Use	RES

Embeddedness



Canopy Cover



Chemical Characteristics

Time of measurement	12:15
Water Temperature (°C)	16.36
Dissolved Oxygen (%)	90.9
Dissolved Oxygen (mg/L)	8.89
Specific Cond. (µS/cm)	161

PREDATOR MWCF O/E Scores:

Yr/Habitat	O/E Score	Classification
2002/R	0.387	MOST
2007/R	0.532	MOST
2009/R	0.533	MOST
2011/R	0.580	MOST
2014/R	0.484	MOST

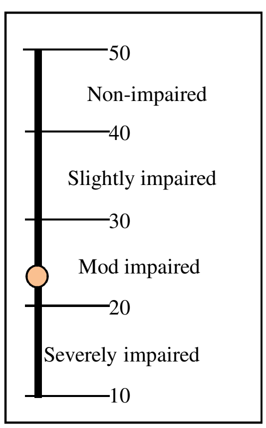
Biological Conditions Summary

CE Sample ID: 14-121-15

Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

DEQ Metric Scores	Raw	Stand.
Richness	24	1
Mayfly Richness	3	3
Stonefly Richness	0	1
Caddisfly Richness	3	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	5.0	3
% Tolerant Taxa	44.2	3
% Sed Tol Taxa	1.6	5
% Dominant (1)	24.2	3
TOTAL		**22**



DEQ Multimetric Scores

Yr/Habitat	MM Score	Classification
2002/R	16	SEVERE
2007/R	16	SEVERE
2009/R	24	MOD
2011/R	20	MOD
2014/R	24	MOD

5 MOST ABUNDANT TAXA

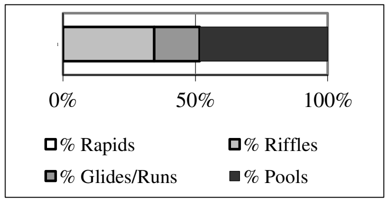
Taxon	Count
Baetis tricaudatus	103
Cheumatopsyche	79
Simulium	79
Paraleptophlebia	65
Orthocladiinae	39

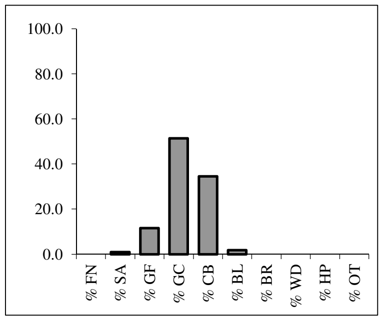
Reach Assessment Summary

Stream Name:	**Phillips Creek**	Site ID:	M-PH-10
Location:	Upstream of SE 84th Avenue	Reach ID:	SD1-M5
County, State:	Clackamas, Oregon	Latitude:	45.42834
Date sampled:	9/23/2014	Longitude:	-122.57676
Field Personnel:	MBC, CB	Reach Length:	93 m

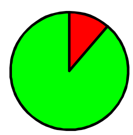
Physical and Chemical Conditions Summary

Instream Physical Characteristics	
Reach Gradient (%)	2.8
Wetted Width (m)	2.9
Bankfull Width (m)	6.6
% Rapids	0.0
% Riffles	34.4
% Glides/Runs	17.2
% Pools	48.4
Substrate	
% Fines (FN)	0.0
% Sand (SA)	0.9
% Gravel, Fine (GF)	11.5
% Gravel, Coarse (GC)	51.3
% Cobble (CB)	34.5
% Boulder (BL)	1.8
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	11.2
Large Wood Tally (pieces/m)	0.08
Eroding Banks (%)	6
Undercut Banks (%)	14



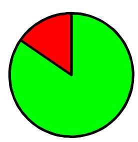


Embeddedness



Riparian Zone Characteristics	
Canopy Cover (%)	85
Riparian Buffer Width (m)	9
Riparian Zone Tree Cover (%)	53
Riparian Zone Non-Native Cover (%)	43
Dom Adjacent Land Use	COM

Canopy Cover



Chemical Characteristics	
Time of measurement	15:00
Water Temperature (°C)	17.52
Dissolved Oxygen (%)	85.2
Dissolved Oxygen (mg/L)	8.13
Specific Cond. (µS/cm)	201

Survey start, facing upstream

Survey end, facing downstream

PREDATOR MWCF O/E Scores:

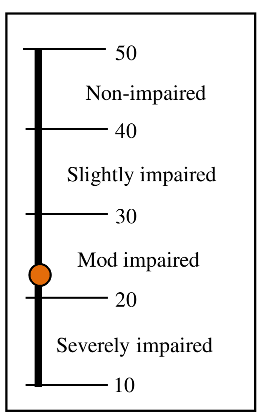
Yr/Habitat	O/E Score	Classification
2002/R		
2007/R		
2009/R		
2011/R	0.387	MOST
2014/R	0.436	MOST

Biological Conditions Summary

CE Sample ID: 14-121-16 Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

DEQ Metric Scores	Raw	Stand.
Richness	27	1
Mayfly Richness	2	3
Stonefly Richness	1	1
Caddisfly Richness	3	1
# Sensitive Taxa	1	1
# Sed Sens Taxa	0	1
Modified HBI	5.9	1
% Tolerant Taxa	12.7	5
% Sed Tol Taxa	9.8	5
% Dominant (1)	34.0	3
TOTAL		**22**



DEQ Multimetric Scores

Yr/Habitat	MM Score	Classification
2002/R		
2007/R		
2009/R		
2011/R	16	SEVERE
2014/R	22	MOD

5 MOST ABUNDANT TAXA

Taxon	Count
Baetis tricaudatus	176
Crangonyx	112
Orthocladiinae	55
Simulium	45
Oligochaeta	44

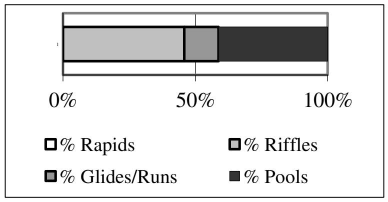
Reach Assessment Summary

Stream Name:	**Rock Creek**	Site ID:	M-RC-10
Location:	~120 M Upstream of confluence with Trillium Creek	Reach ID:	SD1-M10
County, State:	Clackamas, Oregon	Latitude:	45.4091
Date sampled:	9/16/2014	Longitude:	-122.50836
Field Personnel:	MBC, CB	Reach Length:	201 m

Physical and Chemical Conditions Summary

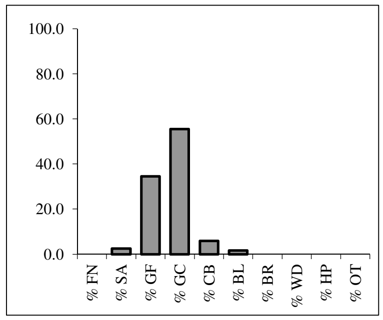
Instream Physical Characteristics

Reach Gradient (%)	1.0
Wetted Width (m)	3.5
Bankfull Width (m)	9.5
% Rapids	0.0
% Riffles	45.8
% Glides/Runs	12.9
% Pools	41.3

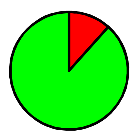


Substrate

% Fines (FN)	0.0
% Sand (SA)	2.5
% Gravel, Fine (GF)	34.5
% Gravel, Coarse (GC)	55.5
% Cobble (CB)	5.9
% Boulder (BL)	1.7
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	11.6
Large Wood Tally (pieces/m)	0.04
Eroding Banks (%)	57
Undercut Banks (%)	1



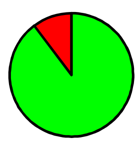
Embeddedness



Riparian Zone Characteristics

Canopy Cover (%)	90
Riparian Buffer Width (m)	75
Riparian Zone Tree Cover (%)	70
Riparian Zone Non-Native Cover (%)	5
Dom Adjacent Land Use	COM/RES

Canopy Cover



Chemical Characteristics

Time of measurement	12:15
Water Temperature (°C)	13.65
Dissolved Oxygen (%)	98.9
Dissolved Oxygen (mg/L)	10.26
Specific Cond. (µS/cm)	180

Survey start, facing upstream

Survey end, facing downstream

PREDATOR MWCF O/E Scores:

Yr/Habitat	O/E Score	Classification
2002/R	0.532	MOST
2007/R	0.918	LEAST
2009/R	0.775	MOST
2011/R*	0.774	MOST
2014/R*	0.871	MOD

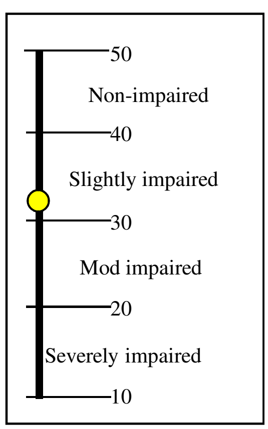
Biological Conditions Summary

CE Sample ID: 14-121-17 Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

DEQ Metric Scores	Raw	Stand.
Richness	31	3
Mayfly Richness	6	3
Stonefly Richness	6	5
Caddisfly Richness	3	1
# Sensitive Taxa	1	1
# Sed Sens Taxa	1	3
Modified HBI	4.1	3
% Tolerant Taxa	8.7	5
% Sed Tol Taxa	2.1	5
% Dominant (1)	34.8	3
TOTAL		**32**

* This reach was relocated approximately 90 m upstream in 2011.



DEQ Multimetric Scores

Yr/Habitat	MM Score	Classification
2002/R	22	MOD
2007/R	32	SLIGHT
2009/R	34	SLIGHT
2011/R*	30	SLIGHT
2014/R*	32	SLIGHT

5 MOST ABUNDANT TAXA

Taxon	Count
Baetis tricaudatus	197
Zapada cinctipes	64
Rhithrogena	49
Orthocladiinae	42
Paraleptophlebia	36

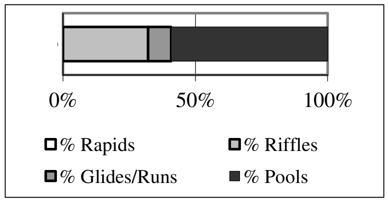
Reach Assessment Summary

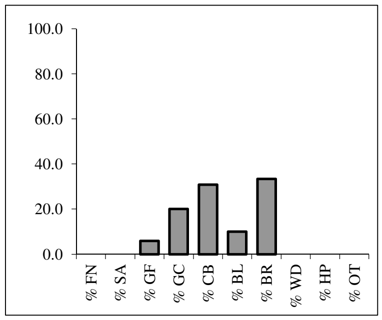
Stream Name:	**Rock Creek**	Site ID:	M-RC-30
Location:	Downstream of Sunnyside Road	Reach ID:	SD1-M11
County, State:	Clackamas, Oregon	Latitude:	45.42555
Date sampled:	9/23/2014	Longitude:	-122.49398
Field Personnel:	MBC, CB	Reach Length:	136 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

Reach Gradient (%)	1.8
Wetted Width (m)	2.9
Bankfull Width (m)	5.4
% Rapids	0.0
% Riffles	32.4
% Glides/Runs	8.8
% Pools	59.6
Substrate	
% Fines (FN)	0.0
% Sand (SA)	0.0
% Gravel, Fine (GF)	5.8
% Gravel, Coarse (GC)	20.0
% Cobble (CB)	30.8
% Boulder (BL)	10.0
% Bedrock (BR)	33.3
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	5.3
Large Wood Tally (pieces/m)	0.06
Eroding Banks (%)	16
Undercut Banks (%)	0





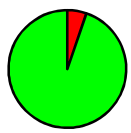
Survey start, facing upstream

Survey end, facing downstream

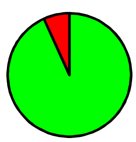
Riparian Zone Characteristics

Canopy Cover (%)	93
Riparian Buffer Width (m)	75
Riparian Zone Tree Cover (%)	73
Riparian Zone Non-Native Cover (%)	45
Dom Adjacent Land Use	RES

Embeddedness



Canopy Cover



Chemical Characteristics

Time of measurement	10:20
Water Temperature (°C)	15.26
Dissolved Oxygen (%)	86.7
Dissolved Oxygen (mg/L)	8.69
Specific Cond. (µS/cm)	162

PREDATOR MWCF O/E Scores:

Yr/Habitat	O/E Score	Classification
2002/R	0.629	MOST
2007/R	0.870	MOD
2009/R	0.678	MOST
2011/R	0.822	MOD
2014/R	0.967	LEAST

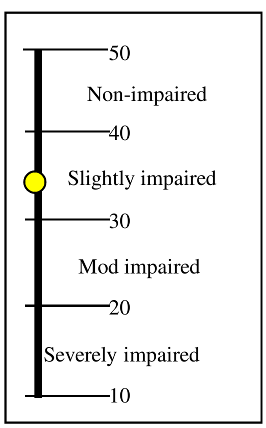
Biological Conditions Summary

CE Sample ID: 14-121-18

Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

DEQ Metric Scores	Raw	Stand.
Richness	42	5
Mayfly Richness	9	5
Stonefly Richness	5	3
Caddisfly Richness	4	3
# Sensitive Taxa	1	1
# Sed Sens Taxa	0	1
Modified HBI	4.2	3
% Tolerant Taxa	21.8	3
% Sed Tol Taxa	4.8	5
% Dominant (1)	17.8	5
TOTAL		**34**



DEQ Multimetric Scores

Yr/Habitat	MM Score	Classification
2002/R	22	MOD
2007/R	28	MOD
2009/R	26	MOD
2011/R	28	MOD
2014/R	34	SLIGHT

5 MOST ABUNDANT TAXA

Taxon	Count
Paraleptophlebia	97
Orthocladiinae	79
Optioservus	46
Zapada cinctipes	40
Baetis tricaudatus	32

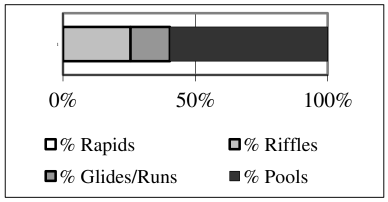
Reach Assessment Summary

Stream Name:	**Rock Creek**	Site ID:	M-RC-50
Location:	Along Troge Road downstream of Foster Road	Reach ID:	SD1-M17
County, State:	Clackamas, Oregon	Latitude:	45.436101
Date sampled:	9/24/2014	Longitude:	-122.47398
Field Personnel:	MBC, CB	Reach Length:	80.5 m

Physical and Chemical Conditions Summary

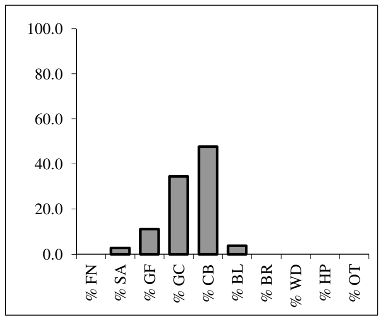
Instream Physical Characteristics

Reach Gradient (%)	1.0
Wetted Width (m)	1.6
Bankfull Width (m)	3.3
% Rapids	0.0
% Riffles	25.5
% Glides/Runs	14.9
% Pools	59.6

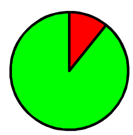


Substrate

% Fines (FN)	0.0
% Sand (SA)	2.8
% Gravel, Fine (GF)	11.2
% Gravel, Coarse (GC)	34.6
% Cobble (CB)	47.7
% Boulder (BL)	3.7
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	10.7
Large Wood Tally (pieces/m)	0.04
Eroding Banks (%)	15
Undercut Banks (%)	11



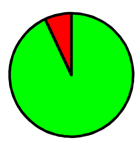
Embeddedness



Riparian Zone Characteristics

Canopy Cover (%)	93.01
Riparian Buffer Width (m)	6
Riparian Zone Tree Cover (%)	45
Riparian Zone Non-Native Cover (%)	10
Dom Adjacent Land Use	RES

Canopy Cover



Chemical Characteristics

Time of measurement	8:45
Water Temperature (°C)	16.13
Dissolved Oxygen (%)	74.2
Dissolved Oxygen (mg/L)	7.29
Specific Cond. (µS/cm)	134

Survey start, facing upstream

Survey end, facing downstream

PREDATOR MWCF O/E Scores:

Yr/Habitat	O/E Score	Classification
2002/R		
2007/R		
2009/R	0.823	MOD
2011/R	0.822	MOD
2014/R	0.774	MOST

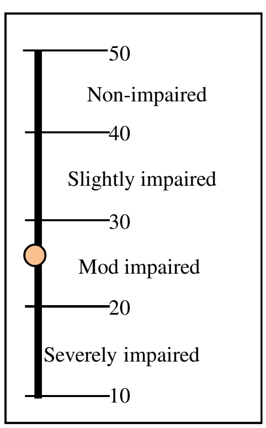
Biological Conditions Summary

CE Sample ID: 14-121-20

Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

DEQ Metric Scores	Raw	Stand.
Richness	33	3
Mayfly Richness	7	3
Stonefly Richness	3	3
Caddisfly Richness	4	3
# Sensitive Taxa	1	1
# Sed Sens Taxa	0	1
Modified HBI	4.4	3
% Tolerant Taxa	29.6	3
% Sed Tol Taxa	13.0	3
% Dominant (1)	25.5	3
TOTAL		**26**



DEQ Multimetric Scores

Yr/Habitat	MM Score	Classification
2002/R		
2007/R		
2009/R	26	MOD
2011/R	20	MOD
2014/R	26	MOD

5 MOST ABUNDANT TAXA

Taxon	Count
Paraleptophlebia	137
Zapada cinctipes	74
Chironomini	67
Optioservus	65
Juga	64

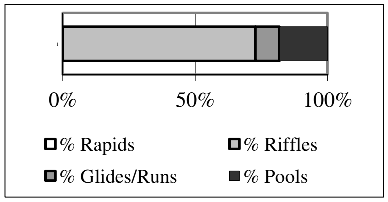
Reach Assessment Summary

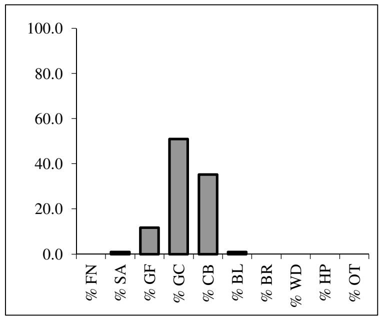
Stream Name:	**Trillium Creek**	Site ID:	M-TR-10
Location:	Near confluence with Rock Creek	Reach ID:	SD1-M7a
County, State:	Clackamas, Oregon	Latitude:	45.40831
Date sampled:	9/16/2014	Longitude:	-122.50912
Field Personnel: MBC, CB		Reach Length:	77 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

Reach Gradient (%)	2.8
Wetted Width (m)	1.5
Bankfull Width (m)	3.3
% Rapids	0.0
% Riffles	72.7
% Glides/Runs	9.1
% Pools	18.2
Substrate	
% Fines (FN)	0.0
% Sand (SA)	1.0
% Gravel, Fine (GF)	11.8
% Gravel, Coarse (GC)	51.0
% Cobble (CB)	35.3
% Boulder (BL)	1.0
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	25.0
Large Wood Tally (pieces/m)	0.22
Eroding Banks (%)	85
Undercut Banks (%)	11





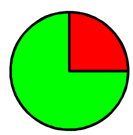
Survey start, facing upstream

Survey end, facing downstream

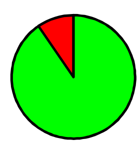
Riparian Zone Characteristics

Canopy Cover (%)	90
Riparian Buffer Width (m)	48
Riparian Zone Tree Cover (%)	65
Riparian Zone Non-Native Cover (%)	28
Dom Adjacent Land Use	COM/RES

Embeddedness



Canopy Cover



Chemical Characteristics

Time of measurement	10:15
Water Temperature (°C)	15.33
Dissolved Oxygen (%)	95.6
Dissolved Oxygen (mg/L)	9.57
Specific Cond. (µS/cm)	156

PREDATOR MWCF O/E Scores:

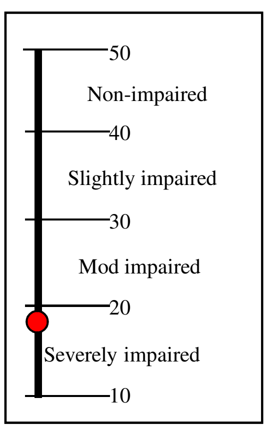
Yr/Habitat	O/E Score	Classification
2002/R		
2007/R		
2009/R	0.581	MOST
2011/R	0.629	MOST
2014/R	0.581	MOST

Biological Conditions Summary

CE Sample ID: 14-121-22 Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

DEQ Metric Scores	Raw	Stand.
Richness	30	1
Mayfly Richness	2	3
Stonefly Richness	1	1
Caddisfly Richness	3	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	5.4	1
% Tolerant Taxa	17.7	3
% Sed Tol Taxa	11.7	3
% Dominant (1)	24.7	3
TOTAL		**18**



DEQ Multimetric Scores

Yr/Habitat	MM Score	Classification
2002/R		
2007/R		
2009/R	24	MOD
2011/R	20	MOD
2014/R	18	SEVERE

5 MOST ABUNDANT TAXA

Taxon	Count
Baetis tricaudatus	70
Orthocladiinae	59
Simulium	25
Hydropsyche	16
Juga	16

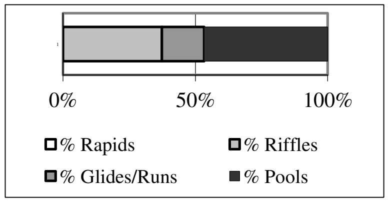
Reach Assessment Summary

Stream Name:	**Carli Creek**	Site ID:	M-CA-10
Location:	11814 Jennifer Street; downstream of outfall	Reach ID:	SD1-M16
County, State:	Clackamas, Oregon	Latitude:	45.40055
Date sampled:	9/22/2014	Longitude:	-122.54378
Field Personnel: MBC		Reach Length:	75 m

Physical and Chemical Conditions Summary

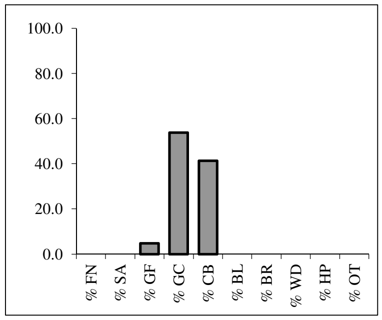
Instream Physical Characteristics

Reach Gradient (%)	2.7
Wetted Width (m)	1.9
Bankfull Width (m)	8.8
% Rapids	0.0
% Riffles	37.3
% Glides/Runs	16.0
% Pools	46.7



Substrate

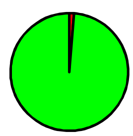
% Fines (FN)	0.0
% Sand (SA)	0.0
% Gravel, Fine (GF)	4.8
% Gravel, Coarse (GC)	53.8
% Cobble (CB)	41.3
% Boulder (BL)	0.0
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	1.2
Large Wood Tally (pieces/m)	0.01
Eroding Banks (%)	3
Undercut Banks (%)	8



Survey start, facing upstream

Survey end, facing downstream

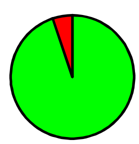
Embeddedness



Riparian Zone Characteristics

Canopy Cover (%)	94.85
Riparian Buffer Width (m)	11
Riparian Zone Tree Cover (%)	80
Riparian Zone Non-Native Cover (%)	30
Dom Adjacent Land Use	IND

Canopy Cover



Chemical Characteristics

Time of measurement	9:30
Water Temperature (°C)	16.74
Dissolved Oxygen (%)	84.8
Dissolved Oxygen (mg/L)	8.23
Specific Cond. (µS/cm)	253

PREDATOR MWCF O/E Scores:

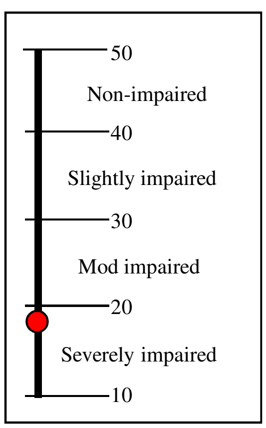
Yr/Habitat	O/E Score	Classification
2002/R		
2007/R	0.097	MOST
2009/R	0.242	MOST
2011/R	0.290	MOST
2014/R	0.387	MOST

Biological Conditions Summary

CE Sample ID: 14-121-24 Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

DEQ Metric Scores	Raw	Stand.
Richness	14	1
Mayfly Richness	1	1
Stonefly Richness	0	1
Caddisfly Richness	0	1
# Sensitive Taxa	0	1
# Sed Sens Taxa	0	1
Modified HBI	5.6	1
% Tolerant Taxa	4.4	5
% Sed Tol Taxa	3.1	5
% Dominant (1)	45.2	1
TOTAL		**18**



DEQ Multimetric Scores

Yr/Habitat	MM Score	Classification
2002/R		
2007/R	10	SEVERE
2009/R	12	SEVERE
2011/R	12	SEVERE
2014/R	18	SEVERE

5 MOST ABUNDANT TAXA

Taxon	Count
Baetis tricaudatus	249
Orthocladiinae	141
Turbellaria	47
Simulium	33
Oligochaeta	17

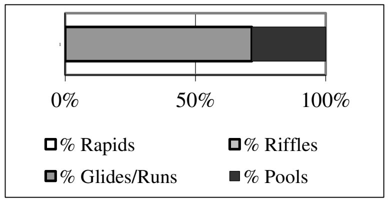
Reach Assessment Summary

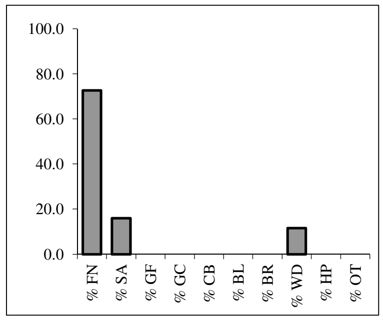
Stream Name:	**Cow Creek**	Site ID:	M-CO-20
Location:	Downstream of private driveway crossing	Reach ID:	SD1-M14a
County, State:	Clackamas, Oregon	Latitude:	45.39489
Date sampled:	9/22/2014	Longitude:	-122.57081
Field Personnel: MBC		Reach Length:	100 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

Reach Gradient (%)	0.7
Wetted Width (m)	1.8
Bankfull Width (m)	3.0
% Rapids	0.0
% Riffles	0.0
% Glides/Runs	71.7
% Pools	28.3
Substrate	
% Fines (FN)	72.6
% Sand (SA)	15.9
% Gravel, Fine (GF)	0.0
% Gravel, Coarse (GC)	0.0
% Cobble (CB)	0.0
% Boulder (BL)	0.0
% Bedrock (BR)	0.0
% Wood (WD)	11.5
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	92.7
Large Wood Tally (pieces/m)	0.12
Eroding Banks (%)	0
Undercut Banks (%)	0





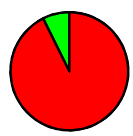
Survey start, facing upstream

Survey end, facing downstream

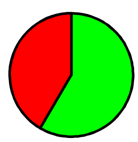
Riparian Zone Characteristics

Canopy Cover (%)	58
Riparian Buffer Width (m)	18
Riparian Zone Tree Cover (%)	0
Riparian Zone Non-Native Cover (%)	100
Dom Adjacent Land Use	AG/RES

Embeddedness



Canopy Cover



Chemical Characteristics

Time of measurement	11:15
Water Temperature (°C)	15.87
Dissolved Oxygen (%)	56.4
Dissolved Oxygen (mg/L)	5.57
Specific Cond. (µS/cm)	215

Biological Conditions Summary

CE Sample ID: 14-121-25 Habitat(s) Sampled: Glides

Sample Method: OR DEQ 8-kick composite

Glide Metrics	
Richness	29
EPT Richness	2
% Dominant	19.5
Modified HBI	6.6
% Sed Tolerant	19.1
% Tolerant	40
% Chironomidae	77.9
% Molluska	0.4
% Oligochaeta	14.9

*Reach was located approximately 630 m upstream of the location sampled in 2007 and 2009

PREDATOR O/E Score:

Sample	O/E Score
2007/G*	0.19
2009/G*	0.29
2011/G	0.29
2014/G	0.44

5 MOST ABUNDANT TAXA

Taxon	Count
Corynoneura	98
Micropsectra/Tanytarsus	89
Oligochaeta	75
Paratendipes	58
Cryptochironomus	54

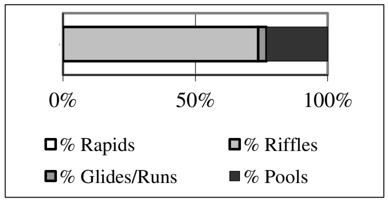
Reach Assessment Summary

Stream Name:	**Richardson Creek**	Site ID:	M-RI-10
Location:	Upstream of Highway 224	Reach ID:	SD1-M12
County, State:	Clackamas, Oregon	Latitude:	45.39766
Date sampled:	9/16/2014	Longitude:	-122.47236
Field Personnel: MBC, CB		Reach Length:	150 m

Physical and Chemical Conditions Summary

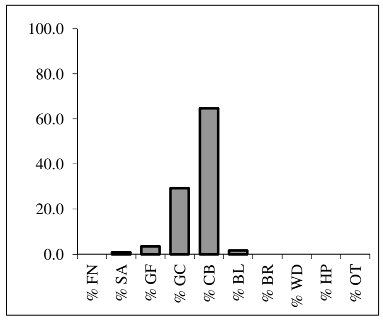
Instream Physical Characteristics

Reach Gradient (%)	3.4
Wetted Width (m)	2.5
Bankfull Width (m)	7.3
% Rapids	0.0
% Riffles	78.7
% Glides/Runs	3.3
% Pools	24.7



Substrate

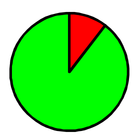
% Fines (FN)	0.0
% Sand (SA)	0.9
% Gravel, Fine (GF)	3.4
% Gravel, Coarse (GC)	29.3
% Cobble (CB)	64.7
% Boulder (BL)	1.7
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	10.4
Large Wood Tally (pieces/m)	0.09
Eroding Banks (%)	48
Undercut Banks (%)	1



Survey start, facing upstream

Survey end, facing downstream

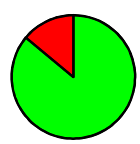
Embeddedness



Riparian Zone Characteristics

Canopy Cover (%)	86
Riparian Buffer Width (m)	100
Riparian Zone Tree Cover (%)	70
Riparian Zone Non-Native Cover (%)	30
Dom Adjacent Land Use	RES/FOR

Canopy Cover



Chemical Characteristics

Time of measurement	15:05
Water Temperature (°C)	15.33
Dissolved Oxygen (%)	93.7
Dissolved Oxygen (mg/L)	9.4
Specific Cond. (µS/cm)	90

PREDATOR MWCF O/E Scores:

Yr/Habitat	O/E Score	Classification
2002/R	0.774	MOST
2007/R	0.773	MOST
2009/R	0.823	MOD
2011/R	0.919	LEAST
2014/R	0.871	MOD

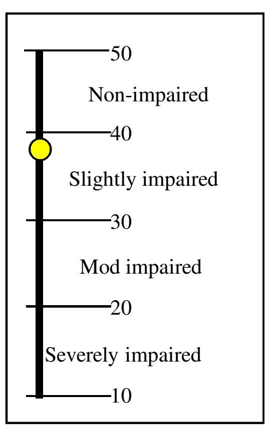
Biological Conditions Summary

CE Sample ID:

Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

DEQ Metric Scores	Raw	Stand.
Richness	34	3
Mayfly Richness	5	3
Stonefly Richness	9	5
Caddisfly Richness	6	3
# Sensitive Taxa	3	3
# Sed Sens Taxa	2	5
Modified HBI	3.9	5
% Tolerant Taxa	43.4	3
% Sed Tol Taxa	3.5	5
% Dominant (1)	35.4	3
TOTAL		**38**



DEQ Multimetric Scores

Yr/Habitat	MM Score	Classification
2002/R	30	SLIGHT
2007/R	34	SLIGHT
2009/R	38	SLIGHT
2011/R	32	SLIGHT
2014/R	38	SLIGHT

5 MOST ABUNDANT TAXA

Taxon	Count
Hydropsyche	190
Baetis tricaudatus	63
Zapada cinctipes	37
Glossosoma	34
Tanytarsini	34

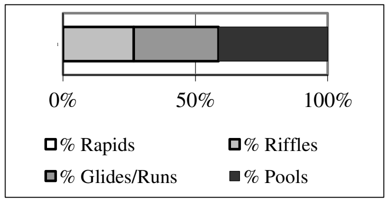
Reach Assessment Summary

Stream Name:	**Sieben Creek**	Site ID:	M-SI-10
Location:	Downstream of Highway 212/224	Reach ID:	SD1-M8
County, State:	Clackamas, Oregon	Latitude:	45.409521
Date sampled:	9/23/2014	Longitude:	-122.52207
Field Personnel: MBC, CB		Reach Length:	75 m

Physical and Chemical Conditions Summary

Instream Physical Characteristics

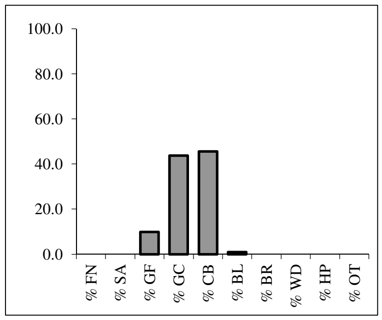
Reach Gradient (%)	1.5
Wetted Width (m)	2.0
Bankfull Width (m)	2.9
% Rapids	0.0
% Riffles	26.7
% Glides/Runs	32.0
% Pools	41.3



Survey start, facing upstream

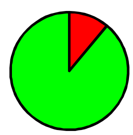
Substrate

% Fines (FN)	0.0
% Sand (SA)	0.0
% Gravel, Fine (GF)	9.8
% Gravel, Coarse (GC)	43.8
% Cobble (CB)	45.5
% Boulder (BL)	0.9
% Bedrock (BR)	0.0
% Wood (WD)	0.0
% Hardpan (HP)	0.0
% Other (OT)	0.0
% Embeddedness	11.0
Large Wood Tally (pieces/m)	0.05
Eroding Banks (%)	55
Undercut Banks (%)	5



Survey end, facing downstream

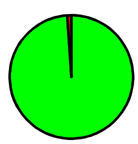
Embeddedness



Riparian Zone Characteristics

Canopy Cover (%)	99
Riparian Buffer Width (m)	8
Riparian Zone Tree Cover (%)	45
Riparian Zone Non-Native Cover (%)	70
Dom Adjacent Land Use	RES

Canopy Cover



Chemical Characteristics

Time of measurement	13:20
Water Temperature (°C)	15.99
Dissolved Oxygen (%)	91.6
Dissolved Oxygen (mg/L)	9.04
Specific Cond. (µS/cm)	189

PREDATOR MWCF O/E Scores:

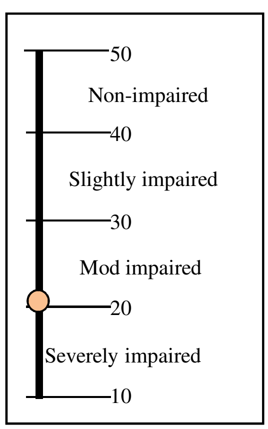
Yr/Habitat	O/E Score	Classification
2002/R	0.194	MOST
2007/R	0.338	MOST
2009/R	0.387	MOST
2011/R	0.436	MOST
2014/R	0.484	MOST

Biological Conditions Summary

CE Sample ID: 14-121-23 Habitat(s) Sampled: Riffles

Sample Method: OR DEQ 8-kick composite

DEQ Metric Scores	Raw	Stand.
Richness	19	1
Mayfly Richness	2	3
Stonefly Richness	1	1
Caddisfly Richness	2	1
# Sensitive Taxa	1	1
# Sed Sens Taxa	0	1
Modified HBI	5.3	1
% Tolerant Taxa	0.6	5
% Sed Tol Taxa	0.6	5
% Dominant (1)	55.0	1
TOTAL		**20**



DEQ Multimetric Scores

Yr/Habitat	MM Score	Classification
2002/R	24	MOD
2007/R	18	MOST
2009/R	20	MOD
2011/R	22	MOD
2014/R	20	MOD

5 MOST ABUNDANT TAXA

Taxon	Count
Orthocladiinae	291
Chironomini	40
Simulium	39
Tanytarsini	33
Tanypodinae	29

WATERWAYS
CONSULTING, INC.

Clackamas County Service District #1
2014 WES Monitoring

APPENDIX C

Completed Geomorphic Field Data Sheets

WATERWAYS
CONSULTING, INC.

Clackamas County Service District #1
2014 WES Monitoring

APPENDIX D

PSI, Inc. Laboratory Report