Clackamas County Water Environment Services

Surface Water Management Agency of Clackamas County

Benthic Macroinvertebrate and Geomorphological Monitoring Report 2017

REPORT- June 29, 2018

prepared by

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1.0 INTRODUCTION

Clackamas County Water Environment Services (WES) is one of several agencies responsible for wastewater and stormwater management in the region. 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 its watershed health focus and integrated watershed management approach. The main purposes of WES' monitoring programs include: meeting permit requirements, assessing existing conditions, documenting trends, determining the effectiveness of water resources management programs, informing the public, and providing guidance on the needs for future work.

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 (hereafter referred to as the Districts). Stream monitoring by the Districts includes water quality sampling, biotic surveys, streamflow and other hydrologic measurements, and monitoring the physical condition of streams (geomorphology). Among these, macroinvertebrate and geomorphic monitoring have been carried out every few years. Due to the close relationships between the physical habitat and the macroinvertebrate community, WES has arranged for the two investigations to be carried out in conjunction with one another in 2009, 2011, and 2014 (Lemke and Cole 2010a; Lemke and Cole 2010b; Lemke et al. 2012a; Lemke et al. 2012b; Waterways 2015a; Waterways 2015b). Together, this report and a companion report (Waterways, 2018) document the results of the 2017[1] geomorphic and macroinvertebrate monitoring event in the two districts. This is the monitoring report for SWMACC.

1.1 MONITORING NETWORK

Macroinvertebrate monitoring has been conducted at many sites since 2002, and geomorphic monitoring since 2009. Macroinvertebrate sampling work – including identification of macroinvertebrate communities, physical habitat characterization, and water chemistry – occurred within the Districts 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), 2014 (Waterways 2015a; Waterways 2015b), and in 2017.

Starting in 2009, following the development of basin plans for the Kellogg-Mt. Scott and Rock Creek Watersheds, WES expanded their efforts to include assessments of stream geomorphology, which occurred in 2009, 2011, 2014, and 2017.

The sampling network has changed and expanded over the years; however, most of the monitoring sites have remained consistent. There was some overlap in macroinvertebrate and geomorphic monitoring reaches in the 2009 monitoring event, but an effort was made in 2011 to co-locate more of the geomorphic and macroinvertebrate monitoring reaches. Macroinvertebrate monitoring within both districts expanded for the 2014 monitoring event (Waterways and Cole Ecological 2015a, Waterways and Cole Ecological 2015b). In 2017, the geomorphic monitoring network was further

[1]Field work for the current monitoring project mostly occurred in fall 2017, but the geomorphic monitoring for 2 sites in CCSD#1 sites occurred in January 2018. All SWMACC sites were surveyed in November 2017. For simplicity and consistency with previous years' programs, in this report the current monitoring event is referred to as the 2017 monitoring event.

extended to include additional sites that were selected for scoring within the context of a Stream Health Index program being implemented by WES (Waterways, 2018).

1.2 SETTING

The SWMACC district encompasses the area draining into the lowermost 12 kilometers of the Tualatin River (downstream of Interstate 5) (Figure 1). This area within northern Clackamas County contains small and medium sized tributary watersheds bounded by rolling topography with low to moderate topographic relief. Significant tributaries included in this assessment enter the Tualatin River between river kilometers 4 and 10.2, the largest of which is Saum Creek at RK 10.2, directly across the Tualatin River from the Oswego Canal, which drains Oswego Lake.

Land use in this area is mostly dominated by rural and suburban residential and commercial development with a mosaic of small tracts of forested land and agriculture. Most of the area encompassing the SWMACC survey streams occurs outside of the current Urban Growth Boundary (UGB). Many of the stream reaches occur in lightly developed residential areas and others occur adjacent to larger parcels that are managed for farmland or grazing. More intensive subdivision development occurs at both the upper and lower ends of this 6.2-km length of Tualatin River.

In most cases, stream channels within the study area have been impacted by past land uses and direct channel modification, which have somewhat altered the natural hydrology and morphology. 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 SWMACC service area from urban and suburban development and a trend towards increasing hydromodification.

1.3 PROJECT OBJECTIVES

Much of the SWMACC service area occurs along the periphery of the Portland metropolitan area, where urban land uses transition to rural land uses. Much of the service area has been or is in the process of being urbanized. SWMACC is adjacent to four Portland suburbs: Wilsonville, Tualatin, Lake Oswego, and West Linn. Historically, much of the watershed was converted from forest to agriculture; stream channels have been straightened and channelized in places, and wetlands have been filled. Urbanization has resulted in an increase in the amount of impervious area on the landscape. Collectively, these land-use changes have modified the timing and magnitude of delivery of stormwater to stream channels, and have therefore altered streamflows, a process called hydromodification. Hydromodification has the potential to affect the morphologic character of stream channels that receive affected stormflows. The effects of hydromodification are often observed throughout the channel network since, in part, the geometry of a stream channel (e.g. – channel width, channel depth) responds to the discharge during flood stages (Dunne and Leopold, 1978).

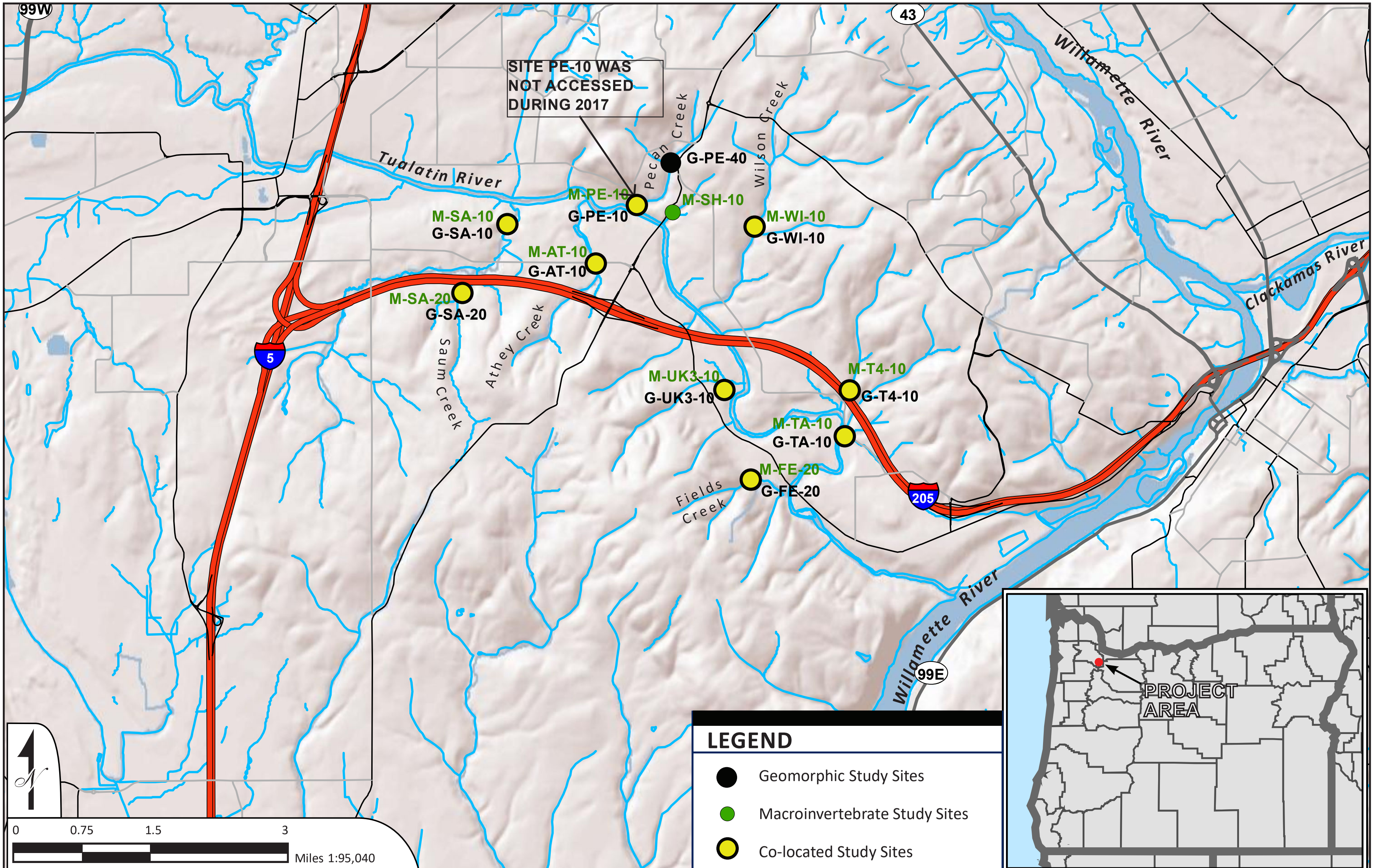

FIGURE 1

Geomorphic and Macroinvertebrate Study Sites for 2017 for the Surface Water Management Agency of Clackamas County (SWMACC) near Portland, Oregon.

WES MONITORING

SWMACC FINAL REPORT
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When the hydrology of a watershed is modified, the changes may have a strong impact on the character of stream channels, both spatially and temporally. Headwater channels may incise, widen, and may experience headward migration. Erosion in these headwater channels can mobilize sediment that results in aggradation and widening of channels downstream. When the upstream reaches adjust and the sediment supply decreases, the downstream channels may then narrow and incise, resulting in a situation with high, unstable banks and a disconnected floodplain terrace lacking mature vegetation. Typically, bank erosion is a significant issue in main stem channels in urbanizing areas as they aggrade and widen, and also when they narrow and incise. Ultimately, these hydrologic and geomorphic changes contribute to degradation of physical habitat and water quality conditions necessary to support healthy, diverse, native aquatic communities (fish and macroinvertebrates, in particular).

Evaluating the effects of hydromodification on stream channels requires a characterization of channel conditions over time. While a one-time evaluation provides some 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.

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 the SWMACC service area. 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 2017, as well as comparisons with previous years' monitoring programs. These results are used to identify changes in resource conditions over time and evaluate the need for management actions, particularly in relation to hydromodification, improving the capacity of streams to support diverse, native aquatic communities, and to improving overall watershed health.

2.0 METHODS

The assessment methodology was designed to establish and evaluate discrete sampling areas, or reaches, distributed throughout the SWMACC 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. Though some of the results may, in part, reflect site specific effects from particular activities, the overall results are meant for general examination and detection of broad longitudinal (upstream to downstream) trends resulting from the cumulative net effects of both disturbance and restoration activities. The data from this study should not be used to make inferences regarding reach-specific conditions, channel instability, or degradation occurring *outside* of the discrete study reaches, without any field verification. 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, ten reaches were sampled within the SWMACC area in 2017 (Figure 1, Table 1). Macroinvertebrate assessments were conducted in 9 reaches, and geomorphic assessments were conducted in 9 reaches, and the two types of surveys were co-located in 8 of the 10 reaches.

2.1 SITE SELECTION

A preliminary list of possible survey sites was prepared in 2009 based upon existing WES biological assessment sites. 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 the assessment team 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 13 targeted survey sites was agreed upon in 2009. Three of the sites initially selected for survey were dropped in 2009 because landowner access was not granted (MAC-G4) and heavy vegetation, primarily composed of blackberry, were present at two other sites (MAC-G2 and MAC-G10).

In 2011, all of the sites surveyed in 2009 were resurveyed with the exception of site G-NY-10 (MAC-G5), which was not resurveyed in 2011 or 2014 because it was determined that it was not a suitable location for long-term monitoring. In addition, site G-T4-10 (MAC-G13) was abandoned and moved upstream to align the location with a parcel owned and managed by Clackamas County. In 2017, the Pecan Creek site was relocated upstream approximately 1500 m, from private property to a property owned by Metro, and renamed from G-PE-10 to G-PE-40. Otherwise, all of the macroinvertebrate and geomorphic reaches that were sampled in 2011 and 2014 were sampled again in 2017. Six of the nine reaches sampled for macroinvertebrates in 2017 were sampled for macroinvertebrates in each monitoring year since 2002; 2017 represented the sixth macroinvertebrate sampling year on these six reaches (Table 1). The other four SWMACC survey reaches were sampled for the second time in 2014, each having been sampled concurrently for both geomorphology and macroinvertebrates for the first time in 2011 (Table 1). Geomorphic data were also collected in 2017 from all reaches other than the Shipley Creek reach (M-SH-10). Table 1 provides site information for the 2017 target project 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 have been consistently applied since 2011. 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. Thus higher numbers indicate upstream sites on the same stream. Example:

G-SA-10

G: Geomorphic Reach
SA: Saum Creek
10: Approximately 10 percent of the total distance from the mouth to the upstream end of the channel

Table 1. Site information for stream reaches where channel morphology assessment was conducted in Surface Water Management Agency of Clackamas County (SWMACC), Oregon.

Reach IDs	Previous Site Codes	Stream	Reach Description	Longitude/Latitude*	Years Sampled:
G-AT-10 M-AT-10	MAC-G11 LT-M11	Athey Creek	Upstream of SW Borland Rd	-122.708147 / 45.374606	M: 02,07,09,11,14,17 G: 09,11,14,17
G-FE-20 M-FE-20	MAC-G1 LT-M1	Fields Creek	Upstream of Bosky Dell Lane	-122.683348 / 45.350794	M: 02,07,09,11,14,17 G: 09,11,14,17
G-PE-10 M-PE-10	MAC-G8 LT-M8	Pecan Creek	Upstream of SW Mossy Brae Rd	-122.700935 / 45.381314	M: 02,07,09,11,14 G: 09,11,14 Site Moved Upstream to G-PE-40 in 2017
G-PE-40	-	Pecan Creek	Metro Property near SW Stafford Rd	-122.696008 / 45.386348	G: 17
G-SA-10 M-SA-10	MAC-G6 LT-M6	Saum Creek	Upstream of SW Halcyon Rd	-122.721694 / 45.379128	M: 02,07,09,11,14,17 G: 09,11,14,17
G-SA-20 M-SA-20	MAC-G7 LT-M7	Saum Creek	Upstream of HWY 205	-122.729730 / 45.371685	M: 02*,07*,11,14,17 G: 09,11,14,17
M-SH-10	LT-M10	Shipley Creek	Upstream of Shadow Wood Drive	-122.69596 / 45.38083	M: 02,07,09,11,14,17
G-T4-10 M-T4-10	MAC-G13 LT-M13a	Unnamed Tributary #4	Upstream of SW Johnson Rd	-122.667769 / 45.361212	M: 02*,07*,09*,11,14,17 G: 09,11,14,17
G-TA-10 M-TA-10	MAC-G9 LT-M9a	Tate Creek	Downstream of SW Johnson Rd	-122.668313 / 45.356101	M: 02,07,09,11,14,17 G: 09,11,14,17
G-UK3-10 M-UK3-10	MAC-G12 LT-M12	Unnamed Tributary #2	Upstream of SW Ribera Ln	-122.687655 / 45.360927	M: 02,07,09,11,14,17 G: 09,11,14,17
G-WI-10 M-WI-10	MAC-G3	Wilson Creek	Upstream of SW Johnson Rd	-122.682889 / 45.378362	M: 02*,07*,11,14,17 G: 09,11,14,17

Table 1. Site information for stream reaches where channel morphology assessment was conducted in Surface Water Management Agency of Clackamas County (SWMACC), Oregon.

Reach IDs	Previous Site Codes	Stream	Reach Description	Longitude/Latitude*	Years Sampled:

* Latitude/Longitude listed corresponds to the site benchmark recorded using a hand held GPS unit.

** Site moved upstream between 2009 and 2011.

"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
5) Assessment of bank conditions at various sites throughout the SWMACC service area.

The following sections provide detailed descriptions of the methods used for conducting the geomorphic monitoring.

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 2017 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 adjustments were made, where necessary, to account for any new monumentation that was established.

2.2.2 Geomorphic Field Data Collection

For the 2017 geomorphic monitoring year, field data was collected in the SWMACC district mostly between 1 November 2017 and 29 November 2017[2]. 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.

[2] Due to site access issues one reach (G-PE-40) was surveyed on 19 March 2018.

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 locations 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[3]. 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. Three cross sections were measured at each site, and where possible, each cross section was located near the head of a riffle. 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 the technique outlined by Wolman (1954). Assessments were conducted during low flow and counts were restricted to exposed depositional bar features. 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 to a lack of exposed depositional features or where the streambed was dominated by sand, fines, or 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".

[3] 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).

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 pool tail, a location that is important to salmonids. 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 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 incised and formed a more homogeneous bed profile, or scoured to bedrock, and there are few 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. Furthermore, WES' Stream Health Index (2018) uses a metric that quantifies "pool availability" as the function of the frequency and depth of pools in the survey reach.

To measure the availability of pools, both the 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 stadia rod was used to measure pool depth. This approach provides important information about pool quality, the implications of hydromodification, and sediment transport conditions, but 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.

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 trend line to all points collected during the survey. Longitudinal profiles from 2009, 2011, 2014 and 2017 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

Each cross-section profile is presented in a figure in Appendix A oriented "looking downstream," with a station of 0 ft. being the river left start of the cross section. In 2017, bankfull width and depth were determined for each cross section by identifying the bank tops on each side of the channel primarily based on slope breaks. In previous years' surveys, the bankfull channel was identified in the field based on a combination of geomorphic evidence, vegetation breaks, and indications from other cross sections within that reach. The approach of using the slope break at the top of the banks as the primary bankfull indicator was adopted in the current monitoring year because this approach is judged to be less subjective and more repeatable without requiring field judgement, and is the approach used in computing WES' new "geomorphic health index" (Waterways, 2018) for some of the WES monitoring reaches. Bankfull depth was estimated as the difference between the average elevation of the two bank points and the average elevation of all the survey points located in the channel bed. A bankfull width to depth ratio (W/D) was calculated for each cross section. Bankfull values shown in Table7 represent the average of all three cross sections surveyed at that site. Though the change in the bankfull criteria adopted in the current monitoring year may affect the estimated W/D ratio for a given cross section or reach, it is not clear how the new criteria affects the overall results. The W/D ratio in some of the the monitoring reaches increased in 2017 compared with previous years, and the ratio decreased in other reaches.

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. The D_{16} is an indicator of the size of the finer sediment in the bed, the D_{84} is a commonly used indicator of the size of the coarsest particles, and D_{50} is the median grain size.

Bulk Sediment Sample Collection

All bulk sediment samples were collected in the field and evaluated based upon methods outlined in McNeil and Ahnell (1964). 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). For the 2017 monitoring year, the 63 µm sieve (No. 230 sieve) was added to the grain size analysis to more accurately define the percent of fine-grained sediment in the bed material[4].

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. Through 2014, bulk sample results were evaluated to determine percent of sediment matrix less than 6.30 mm and percent of matrix less than 0.85 mm. Starting in 2017, the table in Appendix A reports the percent of sediment smaller than 2.36 mm (representing the mass percent of sand and fines, since 2.36 mm sieve is the closest sieve to 2 mm, the size threshold separating gravel and sand), and the percent smaller than 0.063 mm (representing the mass percent of silt and clay)

Pools Survey

Data collected for pools was an overall tally observed at each site and a maximum depth and maximum residual depth for each pool. Maximum residual pool depth is defined as the maximum pool depth minus the depth of the pool at its tail and represents a measure of pool depth that is independent of discharge. Average maximum pool depth and average maximum residual pool depth for each site are summarized 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

[4] By geological definition, 62.5 µm is the size threshold separating sand (0.0625 – 2 mm) from silt (.004 – 0.0625 mm).

a. Field sampling

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

2.3.1 Macroinvertebrate Field Data Collection

Macroinvertebrate communities, physical habitat, and water chemistry were sampled at the 10 survey reaches between 18 September and 24 September 2017. 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 Clackamas County (SWMACC), Oregon, in the fall of 2017.

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 percent 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 percent slope and rarely up to 6 percent.

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 percent slope and occasionally 7.0–8.0 percent. 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 percent 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 percent, 50 percent, and 75 percent 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 percent, 30 percent, 50 percent, 70 percent, and 90 percent 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 percent 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, and was calibrated for conductivity at the commencement of the project using 1,000 μS conductivity calibrator solution according to the manufacturer's instructions.

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 percent 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, macroinvertebrates were identified to standard levels of taxonomic resolution developed by the Pacific Northwest Aquatic Monitoring Partnership (PNAMP 2015). (WQIW 1999). Aquatic insects were keyed using Merritt, Cummins, and Berg (2008), Wiggins (1995), Stewart and Stark (2002), Thorp and Rogers (2015) and a number of regional and taxa-specific keys.

2.3.2 Macroinvertebrate Data Analysis

The 2017 SWMACC macroinvertebrate assessment marked the 6th year of sampling under WES's current macroinvertebrate monitoring program. With six years of data, temporal aspects of summarizing, analyzing, and interpreting the data are increasingly important and potentially informative. As such, all WES macroinvertebrate data from 2002 through 2017 were maintained and updated in a single database for consistency in naming conventions (as taxonomic names change over the years) and coding. Then, all multi-metric analyses were performed in R and the results were cross-validated with calculations performed in Excel. These results ensured thorough consistency in all aspects of data management and analysis across all WES monitoring years and facilitated examination of the data for temporal trends or other patterns.

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 Tualatin 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.

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 (SWMACC), Oregon, in the fall of 2017.

	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

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 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 percent 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 (a reference condition). 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.

Table 5. Metric set used to assess condition of macroinvertebrate communities sampled from glides in Clackamas County (SWMACC), Oregon in the fall of 2017.
Metric
Taxa richness
EPT taxa richness
% Dominant (1 taxon)
Modified HBI
% Sediment tolerant taxa
% Tolerant taxa
% Chironomidae
% Mollusca
% Oligochaeta

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). Using the MWCF biological condition thresholds (Hubler 2008), higher-gradient streams with O/E scores ≤0.85 (≤10th percentile of reference site scores) were classified as "most disturbed", 0.86 to 0.91 (>10th to 25th percentile) as "moderately disturbed", and 0.92 to 1.24 (25th to 95th percentile) as "least disturbed."

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.

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. As an additional analysis, benthic community conditions were examined in relation to land use (calculated in 2012 using land use classes from National Land Cover Dataset, NLCD 2006) using correlation analysis. To increase the power of these statistical tests, the reaches where riffles were sampled were pooled across both SWMACC and CCSD #1 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 SWMACC service area streams and to identify potential causative factors of impairment. Correlation analysis focused on instream variables previously known to correlate with macroinvertebrate community conditions (Cole et al. 2006).

As in 2011, weighted-average inference models developed by the DEQ (Huff et al. 2006) and elements of 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 by DEQ 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 the distribution of values derived from 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 18.4 °C for temperature and 19% of fine sediment (90th 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 from both 2011 and 2014 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 site-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.

Athey Creek: G-AT-10, M-AT-10

Geomorphology. The survey reach on Athey Creek was located upstream of SW Borland Road on property owned by the Rolling Hills Community Church. This moderate gradient channel exhibits a pool and riffle morphology with signs of historic channel modification including a section of rip rapped bank, a straightened area upstream of the Borland Road Bridge, and a section of the left channel bankline composed of unstable fill material on the steep bank bordering the channel. Bed conditions are dominated by bedrock with depositional features consisting of mixed gravels and sand with a D_{50} of 42mm in 2009, 78mm in 2011, and 65mm in 2014. The channel may have aggraded slightly from 2011 to 2014 and again to 2017; the width to depth ratio has increased between 2009 (9.7) to 2014 (14.5). The reduction in the width to depth ratio in 2017 is likely due to the change in the definition of bankfull width implemented in 2017 (Section 2). The apparent slight aggradation may be due to the inability of the stream to incise due to the presence of bedrock or a coarsely armored bed. Active bank erosion was observed in a small area of low activity at the downstream end. Overall, the site's morphology changed little between the survey years. The straightened portion of the survey reach runs along a tall and steep bank. Part of this bank is partially covered in riprap that is beginning to fall into the stream channel. Another large portion of this bank is composed largely of trash and other debris. This debris is old, decaying and covered by ivy, and contains sharp objects, so care should be taken when working on or nearby this portion of the stream channel.

Macroinvertebrates. Instream physical habitat consisted primarily of riffles (62.0 percent of reach length) interceded by glides and pools. Substrate in riffle habitats where macroinvertebrate samples were collected was dominated by coarse gravel (34.8 percent) and cobble (44.2 percent) substrates; substrate embeddedness was 14.9 percent. The riparian area adjacent to the reach is mature with trees of varying sizes; small- to medium- sized woody shrubs, and various types of ground cover. English ivy and Himalayan blackberry are also present. The riparian zone averages approximately 40-m wide between both banks with an upland forest adjacent to this zone. Riparian overhead cover averaged 94 percent through the reach. Large-woody debris loading in this reach tended towards the low end of the range measured across the SWMACC reaches, averaging 3.9 pieces per 100 m. Physical habitat conditions were generally similar to those measured and observed in 2014, with no significant changes from the previous survey noted.

Macroinvertebrate communities were classified as slightly disturbed using the western Oregon multimetric index, and as moderately disturbed using the MWCF model (Table 12). DEQ stressor model results suggest that macroinvertebrate communities marginally show indications of stress induced by elevated fine sediment deposition (fine sediment stress score = 19.9 versus 19.0 "stressed" threshold), and even less so by water temperature (temperature stress score = 18.5 versus 18.4 "stressed" threshold). Based on these results, field substrate data, and the high proportion of the upstream drainage areas in urban and agricultural land uses (85.4 percent), both stream temperature and fine sediment were once again classified as potential stressors to aquatic biological communities in this reach. The Athey Creek sample supported 36 total macroinvertebrate taxa and 15 EPT, each higher than their group means across the seven higher-gradient SWMACCC reaches, and an indication that physical conditions in this reach are not particularly unstable or degraded. A modified HBI score of 3.9 indicates no significant water quality issues, particularly as they may relate to nutrient enrichment. Furthermore, an abundance of the small shredder stonefly, *Zapada cinctipes*, in the 2017 sample speaks to the intact riparian zone and tree canopy enclosing this section of Athey Creek. This stonefly feeds on leaves, needles, and other coarse organic materials derived from the trees in this reach, and its presence reveals the ongoing contributions from the riparian zone to the instream food base in this section of Athey Creek.

Based on comparisons with biological data from previous years, biological conditions in the Athey Creek reach have varied from year to year, but show no sign of longer-term decline in condition since sampling was initiated in this reach in 2002. MM scores have ranged from 22 to 34, with the highest scores of 32 and 34 occurring in 2007 and 2009, respectively. MWCF O/E scores have also varied among years and have not shown any evidence of longer-term degradation in biological condition. Apparent declines in biological condition from 2009 to 2011 highlighted the need for additional data collection to determine whether the apparent downward trending was occurring or simply year-to-year variation. 2014 sampling provides a strong indication of the latter.

Site Access. Access to this site is located behind the youth ministry services offices of the Rolling Hills Community Church.

Fields Creek: G-FE-20, M-FE-20

Geomorphology. The Fields Creek site is a small channel with a steep gradient of 5 percent to 6 percent. The survey reach is located within land owned by Bosky Dell Nursery in a rural residential area. The site has experienced past manipulation, such as a manmade pond upstream of the reach, a bridge in the middle of the reach, and a culvert at the downstream end of the reach. The reach experienced deposition at all cross sections between 2009 and 2011, and between 2011 and 2014, with minimal change in overall pool-riffle morphology. The 2017 data shows very little change in the bed profile or cross-sections from 2014, but the repeat longitudinal profile suggests the reach may be considered to be aggrading over the past decade. The banks of the channel are steep and are actively eroding in many locations, though the data suggests a trend of decreasing bank erosion as the riparian restoration conducted by the property owner matures. Given that the channel has cut down to bedrock in many locations, the banks may continue to erode laterally and deposit fine sediments in the channel, however the overall impact of these changes is expected to be minimal. Bulk sediment was not collected at this site due to the bedrock and there were no depositional features from which to measure pebble counts. The channel is incised, with a capacity estimated at greater than the 100-year event. The adjacent infrastructure would likely limit the opportunity to reconnect the floodplain.

Although we did not investigate channel conditions much beyond the relatively small survey area, the presence of a historic dam and evidence of the potential for headcutting through, and failure of, the dam prompted us to evaluate conditions upstream as part of a separate feasibility study to evaluate the need for stabilization measures. In addition, the owner had mentioned during previous surveys that the outlet of the pond had shifted and she was experiencing occasional flooding onto her access road and property during high flows. Based on a quick, reconnaissance-level evaluation, it appeared that a significant amount of coarse bedload had deposited in the historic pond located upstream of the monitoring reach, causing a partial blocking of the original outlet channel. This condition has the potential to cause the dam to fail and result in movement of a knickpoint upstream that would be on the order of 7 to 10 feet high. Rapid knickpoint migration could result in mobilization of a significant amount of bedload and debris downstream, which could potentially block the downstream culvert and cause the stream to alter its course and flow down Bosky Dell Road. In 2017, little to no water was flowing through the pond, suggesting that aggradation at the upstream of the pond limits flow into the pond area, potentially reducing the risk of dam failure. Despite these changes, the risk is still present during a high flow event, and we still recommend that restoration at this site be considered if an opportunity presents itself.

Macroinvertebrates. Owing to the higher-gradient nature of this reach, instream physical habitat is dominated by riffles (80.3 percent of reach length). Substrate in riffle habitats where macroinvertebrate samples were collected was dominated by coarse gravel (42.3 percent) and cobble (39.4 percent) substrates, with substrate embeddedness of 16.2 percent. The survey reach passes through an area owned and managed by a native plant nursery for propagation and as such consists of a thick and diverse riparian area dominated by native vegetation. While this riparian zone is narrow (16 m approximate average), the reach is well shaded by a canopy averaging 96 percent overhead cover throughout the reach.

The Fields Creek reach (M-FE-20) has received the highest multimetric scores in 2002 (34 points), 2007 (40 points), 2009 (32 points), 2011 (36 points), 2014 (44 points), and 2017 (40 points). Corresponding disturbance classes have changed between slightly disturbed and not disturbed during this time. This reach received a 2017 MWCF O/E score corresponding to "least disturbed", indicating good correspondence between MM and O/E scores for this site. Using this predictive model approach, the Fields Creek reach has ranged between least disturbed and most disturbed, and has received O/E scores corresponding to "most disturbed" conditions, even when MM scores suggested only slightly disturbed conditions. MWCF O/E scores from Fields Creek generally indicate much more variable conditions than do MM scores. This higher variability in the O/E scores results from the sensitivity of the O/E index to the absence of *specific taxa* from the sample. MM scores likely more accurately reflect overall community condition because the index is less sensitive to changes in the composition of taxa specific to the MWCF model.

The Fields Creek reach sample supported 19 EPT taxa, the highest number of EPT taxa occurring in any SWMACC study reach in 2017. Considered together, forty total taxa and only 14 percent dominance by the most abundant taxon, suggest that this section of Fields Creek provides a diverse habitat template. Three sensitive and three sediment sensitive taxa were sampled from this reach, also representing the best performance of the sediment-sensitive metric across all study reaches in 2017. Also, 7 caddisfly taxa were sampled from this reach, further suggesting that stream substrates in this reach are not appreciably fouled by fine sediment. Fields Creek's modified HBI score of 3.6 was the lowest among the SWMACC samples, suggesting no significant water quality issues particularly as they relate to nutrient enrichment.

DEQ stressor model results across all years consistently suggest that the macroinvertebrate community in this reach is not stressed by elevated water temperatures (Figure 9). The relatively heavily forested condition of the drainage area (72.9 percent) upstream of this reach supports this finding. DEQ fine sediment stressor model results indicate no fine sediment-induced community shifts in most years (2017 fine sediment stress score = 12.6), excepting the 2011 results, when the reach received an inferred fine sediment score of 25.6 percent. Field-derived substrate data have generally suggested low riffle substrates embeddedness in this reach; however, the geomorphic survey results suggest that this reach is potentially unstable, particularly given the location and condition of the small dam within the survey reach. Based on these results, fine sediment was classified as a potential stressor to aquatic life in this reach.

Site Access. This site is easily accessed via the Bosky Dell Nursery with permission. Note that the riparian area is actively used for plant propagation so care should be taken to minimize impact during future surveying activities.

Pecan Creek: G-PE-10, M-PE-10

The survey reach PE-10 on Pecan Creek was the site of macroinvertetebrate sampling from 2002 through 2014, and geomorphic survey from 2009 through 2014. However, site access was not granted by the property owner in 2017. The geomorphic monitoring was moved upstream to property owned by Metro and a new site G-PE-40 (described next) was established.

Geomorphology. No geomorphic monitoring survey was conducted in lower Pecan Creek (G-PE-10) in 2017 due to access constraints.

Macroinvertebrates. No macroinvertebrate monitoring survey was conducted in lower Pecan Creek (G-PE-10) in 2017 due to access constraints.

Pecan Creek: G-PE-40

Geomorphology. The 2017 survey reach on Pecan Creek was moved upstream because site access was not allowed by the property owner at the site that had previously been monitored since 2009. The new site is located on property owned by Metro, which is likely to allow access in perpetuity. Geomorphically, the new monitoring location is very different than the previously monitored site G-PE-10, preventing direct comparisons with earlier surveys. The gradient of the channel is steeper than at the previous monitoring location (gradient of about 8 percent) and the bed material is coarser. The channel is moderately incised into the floodplain, and the floodplain alternates between segments that are wide (on the order of three to four times the active channel width) and narrower than this. The channel was estimated to be incised approximately 1 to 2 feet, which likely limits flow interaction with the floodplain, except in sections where debris has accumulated in the channel causing local aggradation. Active bank erosion was only noted in areas of debris accumulation where flows may begin to flank the accumulated debris. The channel incision is probably caused by hydromodification and potentially past logging activities, which would have reduced wood loading that can act as grade control. The bed is composed of primarily coarse, subangular rock with some gravel and fines, suggesting that the bed material is primarily derived from local colluvial sources and has not been reworked in the channel for very long. Bedrock is exposed in parts of the channel bed, suggesting that the alluvial layer across much of the valley bottom is relatively thin. The riparian canopy is well developed and consists primarily of cedar and maple, which provide a good source of wood to the channel. There is very little understory which may suggest the presence of significant elk and deer browse.

Macroinvertebrates. No macroinvertebrate surveys have been conducted in this reach.

Site Access. The site is accessed from SW Stafford Road or the end of SW Ecotopia Ln in Lake Oswego. Metro permit permission is required to access the site.

Lower Saum Creek: G-SA-10, M-SA-10

Geomorphology. Site G-SA-10 is located upstream of the Halcyon Road crossing. The survey reach consists of a large meander bend around a floodplain peninsula on which an unoccupied house is located. This channel is low gradient (0.4 percent slope) and somewhat incised, cutting through recent floodplain deposits, possibly caused during a large event in the backwater of the undersized culvert at the end of the survey reach. The bed is completely submerged at low flow due in part to the culvert backwater condition. The bed material is dominated by unconsolidated sands and silts with no recent depositional features exposed above the low water level. The stream banks were mostly well vegetated but appear to be shifting laterally. In 2014, cross section two appeared to be aggrading on the inner portion bend on the left and eroding on the outer bend on the right, and this trend appears to have continued through 2017. The apparent lateral shift in the channel at cross section three is likely due to the loss and re-installation of the monument on the right end of the cross section. A pool that appears to have begun to form in 2014 at about 440 feet on the longitudinal profile appears to have become about two feet deeper in 2017. The bed elevation appears to fluctuate spatially and temporally, aggrading and scouring at different locations at different times; however, the 2017 survey suggests that the amplitude of downstream changes in bed elevation may be increasing.

The bulk sediment sample from 2017 had a similar amount of fine gravel (<6.3 mm) as the 2014 sample, but a smaller proportion of sand. This difference is more likely due to randomness of sampling sediment in a submerged bed where riffles are not clearly defined, than it is a clear indication of changes in sediment sources upstream. Overall, the reach has a high percentage of sand and fines within the gravel matrix. In 2014, the channel capacity was estimated to fall between the 2-year and 5-year event, indicating that the house on the property may be prone to frequent flooding. The 2017 survey does not show any changes to the channel capacity compared with 2014. The riparian area consisted of a "manicured" lawn along the left bank with an extensive riparian zone along the right bank consisting of a diverse array of vegetation including large trees, grasses along with English ivy and blackberry.

Macroinvertebrates. The entire survey reach exhibits a shallow glide character interspersed with deep, slack-water pools. The reach exclusively comprised these slow-water habitat units in 2017, yet one of the run habitat units was noted as approaching a riffle condition. Macroinvertebrates were sampled from the few shallower glide habitats in this reach that contained coarser substrates such as gravels and cobbles, which composed 57 percent of the bed substrate in sampled habitat units. Substrate embeddedness in these sampled units was high, averaging 36.9 percent. Further, a high degree of fine sediment intrusion was noted for this reach. These instream physical characteristics result from the above described geomorphic processes and conditions.

Macroinvertebrates were sampled from glides, including one glide that approached a riffle condition – the most productive habitat from which to sample in this stream reach of relatively homogeneous physical character. Forty-two macroinvertebrate taxa were sampled from this reach in 2017, including 8 EPT taxa, representing the highest richness of these three orders of generally sensitive taxa sampled from lower Saum Creek since sampling was initiated here in 2002. While these results suggest that no significant degradation in biological condition has occurred in this reach in the last ~16 years, the reach has consistently supported a community that is comprised largely of organisms that are tolerance to disturbance and degraded water quality. Even among the EPTs, the caddisfly *Cheumatopsyche* sp. was the dominant taxon, representing 24.3 percent of the total organism abundance in the sample from this reach. *Cheumatopsyche* is known to be tolerant to warm water, nutrient enrichment, sediment intrusion, and other disturbance. While it may naturally occur in abundance in larger streams in the Willamette Valley, its present dominance in lower Saum suggests potential problems with nutrient enrichment. A modified HBI of 5.46 from this reach – the highest measured among the SWMACC reaches in 2017 – further implicates nutrient enrichment as a potential stressor in this reach. In each year since 2009, approximately half of the organisms sampled were classified as generally tolerant to disturbance (2009: 50.2 percent, 2011: 52.4 percent, 2014: 43.8 percent, 2017: 57.4 percent). These metric values generally suggest a biological community under significant duress, corroborated by the current geomorphic and physical character of the reach.

Site Access. This site is easily accessed via a pedestrian access bridge at the property entrance on Halcyon Road. We expect that this property will be reoccupied in the future requiring access permission.

Tributary to Saum Creek: G-SA-20, M-SA-20

Geomorphology. The survey reach on a tributary to Saum Creek is located along Prosperity Park Road upstream of Prindle Road. The channel in this survey reach is small (less than 10 feet wide), mostly straightened, and with a gradient less than 1 percent containing pools separated by riffles and glides. The dominant bed condition is bedrock with accumulations of small gravel, sand and silt, with 99 percent of particles by volume less than 6.30mm in 2014. No sample was collected in 2017 because the channel is bedrock with only limited fresh sediment deposits. The bulk sample data shows an increase in fine sediment intrusion from 2009 to 2014; however, this could be due to spatial differences in the sample location or temporal changes in bed material that was sampled. The survey reach is slightly incised, likely due to the presence of Prosperity Park Road and residential properties, which have constricted the channel and focused flows. The 2017 data suggests that some aggradation occurred at the upstream end of the reach which is evident in the longitudinal profile and XS 3. This is primarily due to local fine sediment accumulations behind small debris jams. The bank erosion data from 2017 suggests an increase in bank erosion in the reach, especially along the left bank adjacent to Prosperity Park Road. This may be a response to lateral movement of the straightened channel in response to scouring of the channel to bedrock. Little active bank erosion has been observed over the survey years. The 2014 monitoring report estimated that the channel can contain a discharge equivalent to a peak flow between the 5-year and 10-year events. The riparian area along much of the survey reach is limited to a small strip of grasses and other low growing vegetation along the adjacent road. Where the creek flows away from the road the riparian area is much more extensive and includes numerous cedar, fern and other native riparian species.

Macroinvertebrates. For the macroinvertebrate study, this reach was shifted upstream one property in 2014 and was surveyed here again in 2017, where the creek flows away from the Prosperity Park Road and the riparian area is much more extensive and includes native riparian species. As a result of this shift in 2014, the macroinvertebrate reach now occurs immediately upstream of the geomorphic survey reach. Instream physical habitat in this reach consisted primarily of glides and pools (82.6 percent of the reach length) and also included 17.4 percent riffle habitat. This riffle habitat primarily occurred immediately below the driveway culvert at the upper end of the reach. As stated above, the geomorphic survey results indicated that the degree of fine sediment intrusion in this reach is high. No changes in riparian conditions since the previous survey were noted. Overhead canopy cover once again averaged 99 percent through the reach. The riparian area along the left bank of the survey reach is limited to a narrow wooded area extending to the adjacent road. The right bank riparian area is more extensively forested for a significant distance extending upslope from the reach.

A riffle/glide composite macroinvertebrate sample collected from this reach supported a rich community for this habitat type, as 40 taxa were collected, including 15 EPT taxa, or nearly twice as many EPT taxa as were sampled downstream at M-SA-10. Furthermore, four taxa classified as sensitive to disturbance were sampled. The MWCF O/E score was 0.728 in both 2014 and 2017, and is among the highest recently observed from glide-dominated samples in the area. Furthermore, the 2017 MM score for this reach was 34, which corresponds to only slightly disturbed biological conditions from riffle-dominated samples. Because this sample was a riffle-glide composite, the score would be expected to be lower than that from a riffle-only sample. These results collectively suggest a community less disturbed than would be expected given the current physical habitat and geomorphic condition of the reach. Glide-only samples collected in 2007 and 2009 from nearby this reach (a riffle was sampled in 2011) contained far fewer EPT taxa (3 and 4, respectively) than did the 2014 and 2017 samples. This large increase in EPT richness in recent years is likely the result of sampling from more productive habitats in the newer reach location and should be interpreted carefully, as the influence of the riffle is evident in the 2014 and 2017 results.

Site Access. The site is easily accessed along Prosperity Park Road.

Shipley Creek: M-SH-10

Geomorphology. No geomorphology surveys have been conducted in this reach.

Macroinvertebrates. The macroinvertebrate and physical habitat survey reach on Shipley Creek is located upstream of Shadow Wood Drive (erroneously referred to in past reports as Hillside Drive). A geomorphic assessment was not conducted within this reach. Himalayan blackberry has only continued to proliferate and overtake the sampling reach. While in 2014, the location of this reach was shifted upstream by approximately 50 m to allow sampling throughout a sufficient channel length of at least 75 m, the 2017 survey was restricted to a very short section of stream, bound both upstream and downstream by exceedingly heavy blackberry growth. The 2017 survey and sampling occurred exclusively in this short section of Shipley Creek that spanned only approximately 20 m.

The reach is bound on each bank by riparian forest that provides greater than 90 percent canopy cover to the sampled reach. The riparian buffer width averages approximately 63 m between the two banks. Bank erosion in this reach was 42 percent. The small (WW= 0.7 m, BFW = 1.8 m), moderate gradient channel is comprised predominately of riffle (45.8 percent) and pool (30.0 percent) habitat. Distributions of substrate particles in sampled riffles were similar to those measured in past years, with a high percentage of gravel substrates (90.4 percent).

Macroinvertebrates were sampled from riffles in 2007, 2011, 2014, and 2017. Macroinvertebrates were sampled from glides in 2002 and 2009 due to the apparent lack of riffle habitat (10.1 percent of the reach in 2009), suggesting a potentially unstable geomorphic condition in this reach. Multimetric scores for samples collected from across both glide and riffle habitats since 2002 have ranged from 22 to 30, with the lowest score of 22 occurring in the 2007 riffle sample and the 2009 glide sample. The highest MM score of 30 was measured in 2014, while the 2017 score was 28. Macroinvertebrate and physical habitat data from this reach both continue to indicate a period of reduced physical and biological conditions during 2007-2009, followed by more recent improvement, as evidenced by higher biological condition scores. As further evidence, the percent tolerant taxa metric continued to decrease from 72.5 percent in 2007 to 6.0 percent in 2011 and to 1.8 percent in 2014, and remained low at 7.8 percent in 2017. While the reach supported a low percentage of tolerant taxa (7.8 percent) and sediment tolerant taxa (7.7 percent) relative to the group means of 21.2 percent and 10.0 percent, respectively. The sample was dominated by one taxon, *Ramellogammarus* sp. (Order: Amphipoda) accounting for 45.3 percent of the organisms in the sample. While not specifically classified in the Pacific Northwest as tolerant to disturbance, *Ramellogammarus* is known to be generally tolerant of warmer water and can occur in disturbed locations in abundance.

Site Access. This reach is readily accessed from a small pull-out on the north side of the stream crossing along Shadow Wood Drive.

Unnamed Tributary #4: G-T4-10, M-T4-10

In 2011, a new survey reach was established on this stream due to difficulties securing access permission for reach sampled from 2002 through 2009. The 2011-2017 survey reach is located upstream of S. Grapevine Road, approximately 150 m upstream of the previously sampled reach.

Geomorphology. This survey reach is located on an unnamed creek along Johnson Road near the intersection of Woodbine Road. The site is located near a portion of the channel where a large perched culvert flows under Johnson Road. The culvert is likely a fish passage barrier. The reach is a moderate gradient channel with a slope of about 0.8 percent that flows through a low gradient floodplain interspersed with wetlands. The low slope, small channel, and relatively broad valley results in frequent flow interaction between the channel and the floodplain, on the order of several times a year. In fact, much of the floodplain is saturated during the winter and would likely be classified as wetland. There are no apparent trends such as aggradation or degradation apparent in the survey data from 2009 to 2017, and little to no bank erosion. Minor changes in channel location and bed profile are likely due to small shifts in the location of the active channel in response to debris accumulations and the fact that the overall reach is depositional, though much of that deposition occurs on the floodplain.

Macroinvertebrates. The Unnamed Tributary 4 reach is dominated by depositional habitats; together, glides and pools accounted for 74.7 percent of the instream habitat, while riffles accounted for 25.3 percent. As macroinvertebrate samples have been collected from riffles from this reach and the former downstream reach in all years, riffles were again sampled in 2017. Substrate in riffle habitats from which macroinvertebrates were collected was dominated by fine gravel (30.7 percent) and coarse gravel (66.3 percent), with a substrate embeddedness of 15.5 percent. The riffle substrate embeddedness in this reach has varied from 7.5 percent to 25.5 percent from 2011 through 2017, but this variation is likely a primarily a function of the differing substrate composition among specific habitat units from which samples were collected in each year.

Bed conditions consist of clays and silts with a few small gravels. The bulk sediment sample showed a slight increase in fine sediments in the reach. No large exposed depositional features were observed. The riparian area is dominated by grasses, with numerous large trees, small trees and other riparian plants. Some of the small trees and shrubs were likely planted as part of landscaping.

As in 2011 and 2014, the macroinvertebrate community sampled from riffles within the reach was again classified as slightly disturbed using the western Oregon multimetric index, and as most disturbed using the MWCF model. These results are also similar to the 2007 and 2009 results from the downstream reach. Both MM and MWCF O/E 2002 results from the downstream reach indicated a more disturbed biological condition, suggesting potential improvement in condition in this larger section of this creek since 2002 (Figure 6). The Unnamed Tributary 4 reach (M-T4-10) riffle sample supported 12 EPT taxa in 2017, including 1 mayfly (*Neoleptophlebia* sp.), 5 stoneflies, and 6 caddisflies. The low richness of mayfly taxa relative to that of stoneflies and caddisflies is unique among the SWMACC sites and is noteworthy because a loss of mayfly taxa without a corresponding loss of stonefly and caddisfly taxa can result from heavy metals pollution, as some mayfly groups are known to be particularly sensitive to metals (e.g. Clements 1999, Clements 2004, Fore 2003). Four sensitive taxa (*Glutops* sp., immature Leuctridae, immature Capniidae, and *Anagapetus* sp.) and 2 sediment sensitive taxa (*Anagapetus* sp. and *Wormaldia* sp.) were also present. DEQ stressor models continue to suggest that the macroinvertebrate community in this reach is potentially stressed by elevated water temperatures (TS score = 18.6) and is likely showing stress related to elevated fine sediment loading (FSS score = 22.5).

Site Access. This site is accessed via a pull out on Woodbine Road upstream of Johnson Road and an overpass. The survey reach is accessed by descending a steep slope on the creek side of Woodbine Road. Note that traffic here can be heavy at times and care should always be taken.

Tate Creek: G-TA-10, M-TA-10

Geomorphology. The site on Tate Creek is located downstream of a crossing beneath Johnson Road and runs roughly parallel to Johnson Road toward the Tualatin River. The survey reach is a highly incised channel actively cutting through what appears to be an historic floodplain terrace of the Tualatin River. The current condition of the upstream portion of the survey reach suggests that past incision and headcutting were severe, and rock was placed in the channel to limit further incision. The installed rock has resulted in the formation of a series of steps with deep plunge pools. Site conditions also suggest that channel incision is migrating from downstream to upstream, as evidenced by several large, active headcuts, visible in the longitudinal profile (Appendix A). A small tributary with numerous active headcuts also enters the Tate Creek survey reach at the downstream end. In 2009, the largest headcut was located between cross section two and cross section three, but has moved upstream approximately 40 feet and is now located between cross-sections one and two with an estimated annual migration rate of approximately 5 feet per year. The movement of the headcut past cross section two is clearly evident in the repeat cross sections, which showed 2 to 3 feet of incision at that cross section but not at the upstream or downstream sections. At the current rate it will create a risk to the property access culvert in approximately 18 years unless the placed rock limits its continued upstream movement.

Bank material throughout the entire survey reach is clay and silt, and these sediment types also dominate the bed material. With the exception of some areas containing placed rock, most of the channel consists of sands and fines with no clear recent depositional features. Based on the bulk sample from 2017, 61 percent of the sediment by mass is sand or finer, and 21 percent is silt or finer. Upstream of the large, active headcuts, the channel and banks appear stable and no active bank erosion was observed. The portion of the survey reach downstream of the major headcut exhibited numerous areas of highly active bank erosion and undercutting.

Macroinvertebrates. Instream physical habitat consisted primarily of pools (41.3 percent of reach length) interceded by riffles (29.3 percent of reach length) and glides (6.7 percent of reach length; a culvert occupied ~22 percent of the reach length). Substrate in riffle habitats where macroinvertebrate samples were collected was dominated by fine gravel (54.1 percent) and coarse gravel (33.3 percent) substrates. Cobble was notably absent from sampled riffles in this reach in 2017, resulting in generally unstable habitat conditions for macroinvertebrates. Riffle substrate embeddedness was 20.5 percent, approximately the average embeddedness of targeted habitats across the seven higher-gradient SWMACC macroinvertebrate survey reaches. Rural residential properties occupy the floodplain, where vegetation is dominated by maintained lawn, ruderal grasses and non-native ground covers such as English ivy and Himalayan blackberry.

As in 2011 and 2014, the macroinvertebrate community sampled from riffles within the reach in 2017 was classified as moderately disturbed using the western Oregon multimetric index, and as most disturbed using the MWCF model. One taxon classified as sensitive by DEQ was collected from this reach in 2017, the mayfly genus *Cinygma*. An HBI score of 5.3 is the highest measured among the SWMACC sites in 2017 and is indicative of a benthic community that is relatively tolerant to low dissolved oxygen and other problems attendant with organic enrichment.

DEQ stressor model results once again indicated that macroinvertebrate communities show compositional indications of stress likely induced by both elevated water temperatures (TS score = 18.9) and elevated sediment deposition (FS score = 29.7). Fine sediment stress scores measured in 2011, 2014, and 2017 from this site are among the highest measured across all years and sites in the SWMACC study area (Figure 8). The absence of sediment sensitive taxa and the low caddisfly richness further suggests reduced integrity of coarse substrates, likely from fouling with deposited sediments. Also noteworthy was the low total macroinvertebrate abundance of 750 individuals/m^2 calculated for this site, the lowest among the 2017 SWMACC samples. In the absence of a recent storm or dewatering event (none such had occurred prior to sampling this reach), such low macroinvertebrate abundance likely results from the poor and unstable substrate conditions in the reach. Based on these results and field substrate data from both the physical habitat and geomorphic surveys, both stream temperature and sediment continue to be classified as likely stressors to aquatic communities in this reach.

Site Access. This site is easily reached via Johnson Rd.

Unnamed Tributary #2: G-UK3-10, M-UK3-10

Geomorphology. The survey reach for this unnamed creek is located from the Ribera Lane road culvert, upstream through residential property. The moderate gradient channel, with a slope of 2 percent, appears to be historically straightened along the property boundaries and is bisected by a log and debris jam. Upstream of the debris jam, the channel exhibits incision with areas of active bank erosion. The upstream portion exhibits riffle structure, with some possible headcuts, with bed conditions consisting of relatively clean gravels and sand. The longitudinal profile for 2017 and the data for cross-section one suggests that the headcut in the middle of the reach has migrated upstream, causing apparent incision in the upstream part of the reach. The headcut is being stabilized by live roots and debris. If those elements were to fail, there is a potential that the headcut would migrate upstream rapidly. Despite these impacts, the 2017 bank erosion data suggests there has been a reduction in the amount of bank erosion. The downstream section is composed mainly of finer grained silt that covers any gravels or sands present. As with the upstream section, there were no depositional features present in the downstream portion of the survey reach. The upstream cross-section experienced scour between 2011 and 2014, while the downstream section experienced a small degree of deposition. The increase in bank erosion is due to the incision at the upstream end which has led to exposed bank with only grass for vegetation. This site is located in a rural residential area and contains little to no riparian canopy. The stream is bordered by manicured grasses along most of the survey reach. Numerous cedar trees are present that shade the upstream portion of the survey reach, which extends approximately 25 m further than the geomorphic survey reach.

Macroinvertebrates. Physical habitat conditions in this reach were generally very similar to those last measured in 2014. Instream physical habitat consisted primarily of riffles (52.0 percent of reach length) and glides (30.7 percent of reach length). Substrate in riffle habitats where macroinvertebrate samples were collected was dominated by fine gravel (33.9 percent) and coarse gravel (57.1 percent) substrates, with substrate embeddedness of 23.2 percent.

Macroinvertebrate communities have been sampled from riffles in this reach since 2011, after having been sampled from glides in 2002, 2007, and 2009. A higher proportion of riffle was observed in 2011 than in previous years, allowing for the collection of samples from this habitat type. The macroinvertebrate community sampled from riffles within the reach was classified as slightly/moderately disturbed using the western Oregon multimetric index, representing a classification intermediate of those assigned in 2011 and 2014. As noted previously, despite this apparent change in condition, 2011-2014 MM scores differed by only 4 points, a size not unexpected even for replicate samples. Accordingly, the condition of this reach has remained consistent among the three sampling rounds since 2011. As further evidence of any lack of significant change, MWCF scores have also remained similar between 2011 and 2017, ranging only between 0.727 and 0.776.

Twelve EPT taxa were present as well as 3 sensitive taxa and 1 sediment sensitive taxon. 2011 through 2017 DEQ stressor model results consistently suggest that the macroinvertebrate community in this reach is not currently stressed by water temperatures (2017 TS score = 17.7). While the fine sediment stress score was lower in 2017 (18.3 percent) than it has been the past two rounds (27 percent and 23 percent in 2011 and 2014, respectively), field substrate data and a high proportion of eroding banks in the reach (69 percent) result in sediment continuing to be deemed a likely stressor in this reach. Moreover, the presence of only two caddisfly taxa and one sediment sensitive taxon lends further evidence of sediment-induced stress on the benthic community. Stream temperature was once again determined not likely to be a biological stressor in this reach.

Site Access. This site is easily reached via Ribera Lane.

Upper Wilson Creek: G-WI-10, M-WI-10

Geomorphology. The site on Upper Wilson Creek is located within Portland METRO property (Landover Natural Area) that that was the site of a stabilization and restoration project implemented in 2011. The survey reach flows through a portion of the valley where the valley bottom is wider, compared with upstream and downstream reaches. In 2009, prior to restoration, the downstream portion of the site had incised down to bedrock and exhibited moderate erosion on both banks. The incised conditions transitioned to an active headcut area in the middle of the survey reach ending in a more natural alluvial channel upstream that included multiple side channels and groundwater flow. Downstream of the active headcut region the stream was transport dominated with few depositional features such as gravel bars. Upstream of the headcut, however, multiple side channels contained extensive depositional features including coarse bedload deposits. Those coarse deposits have been mobile over the monitoring period but had a relatively constant grain size distribution, with a D_{50} of 70mm in 2009, 78mm in 2011, 70 mm in 2014, and 87 mm in 2017. The entire channel has a relatively steep gradient with a slope of 3.7 percent in 2017. At the time of the 2011 survey METRO was completing a project to introduce large wood to the incised reach downstream to encourage bed aggradation, increase floodplain connection, and limit upstream movement of the headcuts. Upon resurvey in 2014, all three cross sections show aggradation, with the greatest amounts in the lower cross section. The trend continued in 2017, and it was clear in the field that sediment was accumulating behind the installed wood structures, halting headcuts and reversing some of the historic channel incision. All, or nearly all, of the large wood pieces counted in this reach in 2017 were from the restoration project. In 2014, the channel capacity was estimated to fall between the 5 year and 10 year events, indicating that more aggradation is required before floodplain connectivity is achieved; however, the frequency of overbank flow has increased since 2014 as the channel has continued to aggrade.

Macroinvertebrates. Instream habitat was notably similar to that measured and observed in this reach in previous years. As in 2011 and 2014, instream physical habitat consisted primarily of riffles (74.7 percent of reach length). Substrate in riffle habitats where macroinvertebrate samples were collected was dominated by coarse gravel (33.0 percent) and cobble (57.5 percent) substrates. Riffle substrate embeddedness was 12.4 percent, very similar to the 13.4 percent measured in 2014. An intact, mature riparian buffer remains present on the left bank, while a younger stand of trees and recently planted saplings was present on the right bank.

While this reach on Wilson Creek was sampled for the first time in 2011, another reach was sampled only 250 m upstream from this reach in 2002 and 2007. As no significant tributaries or land-use changes occur along that intervening length of creek, macroinvertebrate results are combined from both locations in this report to examine longer-term trends in conditions. Macroinvertebrate communities were classified by the multimetric index as not disturbed in this reach for the first time in 2017, receiving a total MM score of 40, the highest score this site has received since sampling was initiated in 2011. In both 2011 and 2014 the site had received a total MM score of 34 and a corresponding condition class of slightly disturbed. However, the 2017 MWCF O/E of 0.873 resulted in a classification of moderately disturbed, a decrease from the 2014 score of 0.939 and least-disturbed classification. These results once again indicate that the MWCF O/E model is more prone to variation influenced by subtle changes in taxonomic composition that might not necessarily be indicative of increased stress on the system. As such, conditions between 2014 and 2017 have likely remained similar, if not slightly improved, as evidenced by the numerous metrics composing the multimetric index.

An EPT richness of 17 taxa in 2017 is the highest measured among the three years; as 15 EPT taxa were observed in both 2011 and 2014. Other individual community metrics constituting the multimetric index generally performed well in this reach in 2017; the HBI score of 3.6 was among the lowest measured in the 2017 SWMACC samples, and suggests no significant water quality issues related to nutrient enrichment in this reach. Eight caddisfly taxa and two sediment sensitive taxa suggest that fouling of course substrates largely does not impede colonization by sensitive invertebrate taxa. However, Wilson Creek's sample supported one of the lowest densities of macroinvertebrates (888 individuals/m^2) among the 2017 SWMACC samples. In this case, the most likely cause is the relative instabilities of the coarse substrates in this reach: while deposition of fine sediment into this reach is not presently a problem, storm events likely result in significant mobilization of gravel and cobble substrates throughout this length of Wilson Creek. Geomorphic surveys of this section of stream have revealed significant aggradation of bed materials. Such recurring bedload movement through this reach is likely precluding macroinvertebrates from presently achieving higher densities. The lower macroinvertebrate density could also reflect a transitional situation, and it may take time for macroinvertebrate communities to adjust to the post-restoration condition.

Consistent with previous years, DEQ stressor models suggest that the macroinvertebrate community in this reach is not currently stressed by elevated water temperatures (TS score = 18.1) but is showing stress related to elevated fine sediment loading (FSS score = 25.5). Based on these results and field substrate data, stream temperature was again determined not likely to be a biological stressor in this reach, while sediment was again classified as a potential stressor.

Site Access. This site can be accessed from Johnson Road through METRO property (with a special use permit) along a farm road and down a steep slope to the valley bottom.

3.2 DATA SUMMARY

In Section 3.1, spatial and temporal trends in the data were interpreted for each site for both geomorphic and macroinvertebrate parameters, as appropriate. Geomorphic parameters are dominated by both local and watershed-wide controls and the monitoring has occurred since 2009. Because of the limited data and many controlling variables it is difficult to examine spatial and temporal trends quantitatively using statistical methods. Macroinvertebrates, conversely, are considered as a relatively robust environmental health indicator for streams, and monitoring has been occurring since 2002. Therefore the macroinvertebrate data sets provide more opportunity to assess longer-term changes and trends in biological conditions. In this section the summary geomorphic data from 2017 are summarized briefly, and this is followed by a more extensive statistical analysis of the macroinvertebrate data.

Both the geomorphic and macroinvertebrate data are affected by episodic flood events, so the recent flood history is summarized for context (Figure 2). Annual peak flow data was compiled from the USGS National Water Information System (NWIS) for a gage on Fanno Creek, near the mouth of the creek which flows into the Tualatin River ; this is the streamflow gage that is most representative of conditions within the SWMACC study area. The highest annual peak flow events in the past 25 years in Fanno Creek were in December 2007 (1,670 cfs), January 2009 (1,650 cfs), December 2015 (1,680 cfs). At least two of the highest four annual peaks over the past 25 years occurred between the 2014 and 2017 surveys. For that reason, it may be expected that the 2017 geomorphic and macroinvertebrate surveys represent conditions following flood events in which the bed material was recently mobilized.

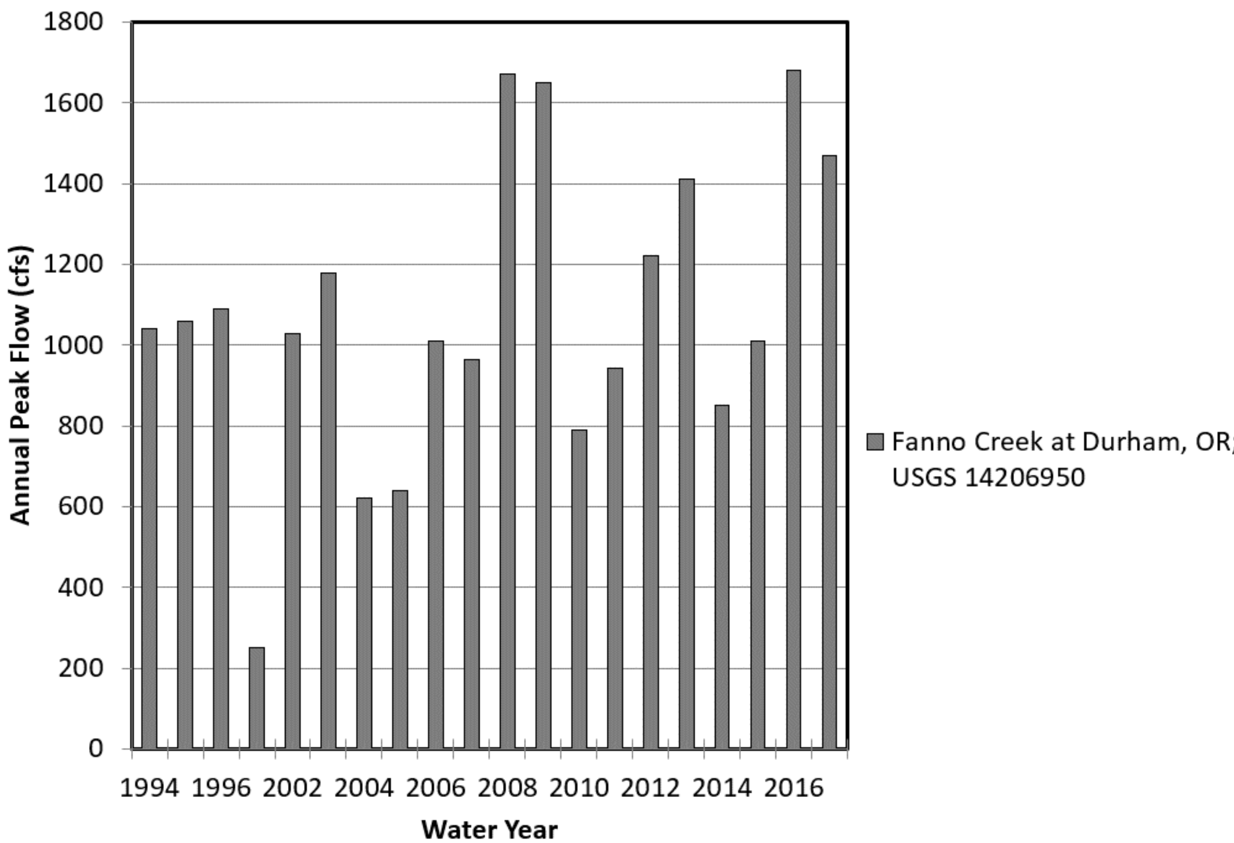


Figure 2. *Annual peak flow data for SWMACC*

Geomorphic Monitoring Data Summary

Table 6 lists the types of geomorphic information collected at each of the 9 SWMACC geomorphic monitoring sites in 2017. Key geomorphic data from all the site surveys are summarized in Tables 7 and 8, and some of the key geomorphic data for the SWMACC region are summarized graphically in Figure 3.

The variability in geomorphology among the sites reflects a wide array of factors, both natural and human-caused. Some of the geomorphic parameters may represent larger watershed-scale, cumulative effects, whereas others are reflecting localized conditions. Distinguishing watershed impacts from local-scale influences on channel geomorphology is a complex project that is beyond the scope of this monitoring report. WES recently developed a Stream Health Index (Waterways, 2018) in which a "geomorphic health index" is proposed for streams in the region. The index combines information on pools, banks, bed material, cross section shape, and longer-term trends to attempt to synthesize this type of data and used the WES geomorphic monitoring data through 2014. Measurements for one of the SWMACC sites, Pecan Creek (PE-10) is included in that analysis (Waterways, 2018).

As explained above, there are too many controlling variables and not enough data to permit a thorough statistical analysis of the geomorphic data. Nevertheless, some of the data are plotted in Figure 4, attempting to discern any dominant trends.

Figure 4A plots the percent sand, silt, and clay size sediment (collectively referred here as fines) in the gravel bed as the dependent variable against four potential explanatory variables. A high percent fines is generally considered to be a negative trait, as fines infiltration in gravel is a detriment to salmon spawning. Streams in Tualatin River drainage (SWMACC District) typically have a higher percent fines compared with those in the Clackamas River basin (CCSD#1), mostly due to the different geology underlying the two regions. In this data set, the width-to-depth ratio is the most powerful explanatory variable for fines infiltration in the bed (R^2=0.75), perhaps reflecting that narrow, deep channels supply more fines through bank erosion; however, the percent fines does not correlate to the amount of bank erosion (R^2=0.1) The percent fines does correlate with the average pool depth in the reach (R^2=0.65). The reason for this is not clear, but it implies that deeper pools in SWMACC may have more fines in their tails. Finally, the percent fines show a weak negative correlation with the channel gradient, reflecting higher ability of steeper reaches to transport fines. The correlation between gradient and percent fines is less strong than we expected.

Figure 4B examines correlations between the amount of bank erosion and several geomorphic variables. The amount of bank erosion does not correlate with the bankfull depth (R^2=0.05) as might be expected because higher banks are more likely to be unstable. Bank erosion does not strongly correlate with the channel gradient, pool depth, W/D ratio, or any of the other measured geomorphic parameters. Instead, based on our observations the amount of bank erosion in these streams is almost entirely determined by the intactness of the riparian buffer immediately along the bankline, or to the presence of riprap, which stabilize streambanks in the SWMACC area.

Table 6. Geomorphic data collected in 2017 for long-term monitoring -Surface Water Management Agency of Clackamas County (SWMACC), Oregon

Site ID	Longitudinal Profile	Cross Sections	Bank Erosion	Pool Depths	Bulk Sample**	Pebble Count***
Athey Creek Subbasin						
G-AT-10	X	X	X	X		
Fields Creek Subbasin						
G-FE-20	X	X	X	X		
Peacan Creek Subbasin						
G-PE-10	Site Discontinued in 2017					
G-PE-40*	X	X	X	X	X	
Saum Creek Subbasin						
G-SA-10	X	X	X	X	X	
G-SA-20	X	X	X	X		
Unnamed Tributary #4 Subbasin						
G-T4-10	X	X	X	X	X	
Tate Creek Subbasin						
G-TA-10	X	X	X	X	X	
Unnamed Tributary #2 Subbasin						
G-UK3-10	X	X	X	X	X	
Wilson Creek Subbasin						
G-WI-10	X	X	X	X	X	X

* Site added in 2017

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

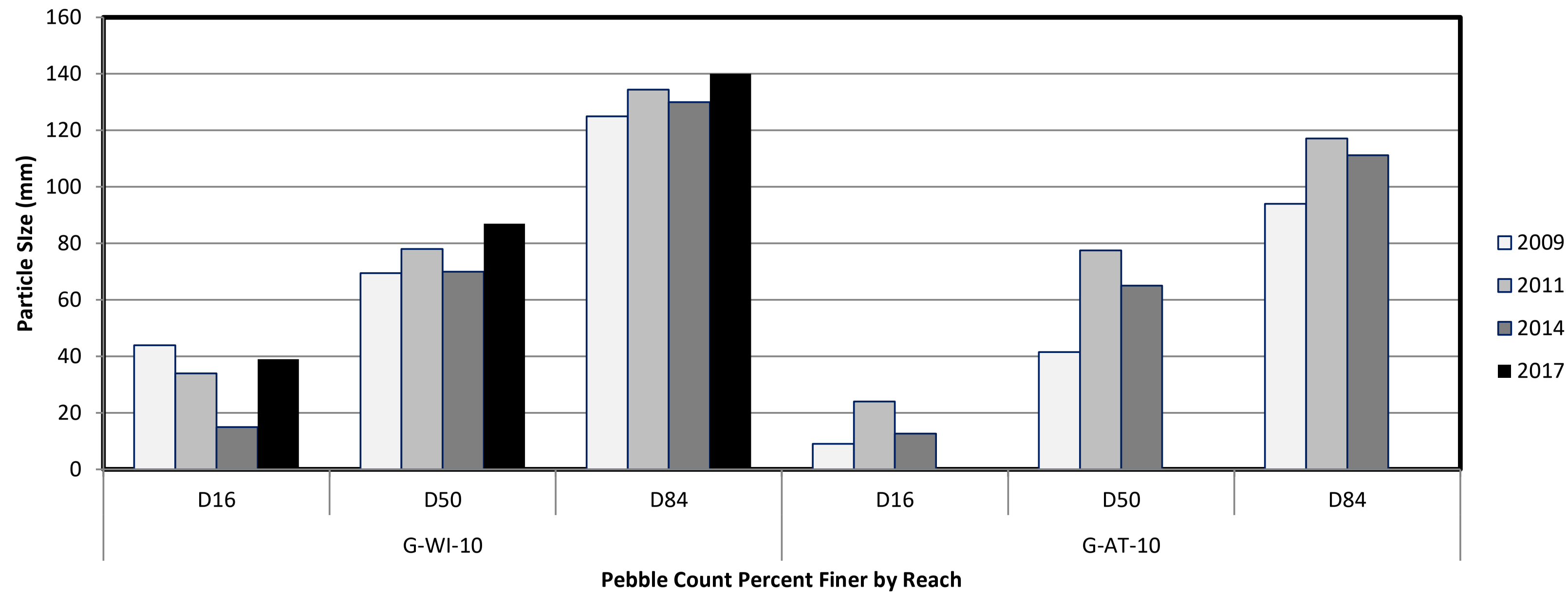
*** Pebble counts were only taken at sites where exposed depositional features were present.

Table 7. 2017 Channel geomorphology assessment parameters determined for reaches in Surface Water Management Agency of Clackamas County (SWMACC), Oregon.

Site Code	Slope (percent)	Bankfull Width (ft.)	Bankfull Depth (ft.)	Bankfull W/D Ratio	Avg. Max Pool Depth (ft.)	Avg. Max Res. Pool Depth (ft.)
Athey Creek Subbasin						
G-AT-10	2.7	23.3	4.3	5.7	1.4	1.2
Fields Creek Subbasin						
G-FE-20	6.0	13.6	3.7	3.6	1.2	0.8
Pecan Creek Subbasin						
G-PE-40	8.0	17.4	1.6	12.8	0.7	0.5
Saum Creek Subbasin						
G-SA-10	0.3	21.2	4.0	5.3	4.4	2.1
G-SA-20	0.6	10.1	3.0	3.4	1.8	0.9
Unnamed Tributary #4 Subbasin						
G-T4-10	1.0	16.5	1.1	19.2	1.2	0.7
Tate Creek Subbasin						
G-TA-10	3.3	16.0	5.3	3.0	2.9	2.1
Unnamed Tributary #2 Subbasin						
G-UK3-10	1.8	22.2	3.3	7.5	1.3	1.1
Wilson Creek Subbasin						
G-WI-10	3.7	18.2	1.7	11.0	1.1	0.7

Table 8. Bed substrate and bank conditions in 2017 for each study reach - Surface Water Management Agency of Clackamas County (SWMACC), Oregon.

Site Code	% Left Bank Erosion	% Right Bank Erosion	D_{16} (mm)	D_{50} (mm)	D_{84} (mm)	% Bulk Sample < 2.36 mm	% Bulk Sample < 0.063mm
Athey Creek Subbasin							
G-AT-10	0	0	-	-	-	-	-
Fields Creek Subbasin							
G-FE-20	21.6	10.8	-	-	-	-	-
Pecan Creek Subbasin							
G-PE-40	16.1	0	-	-	-	9	1
Saum Creek Subbasin							
G-SA-10	0	7.3	-	-	-	48	11
G-SA-20	10.2	11.9	-	-	-	-	-
Unnamed Tributary #4 Subbasin							
G-T4-10	3.8	0	-	-	-	28	3
Tate Creek Subbasin							
G-TA-10	28.4	17.0	-	-	-	61	21
Unnamed Tributary #2 Subbasin							
G-UK3-10	10.7	0	-	-	-	56	15
Wilson Creek Subbasin							
G-WI-10	0	8.4	39	87	140	10	2



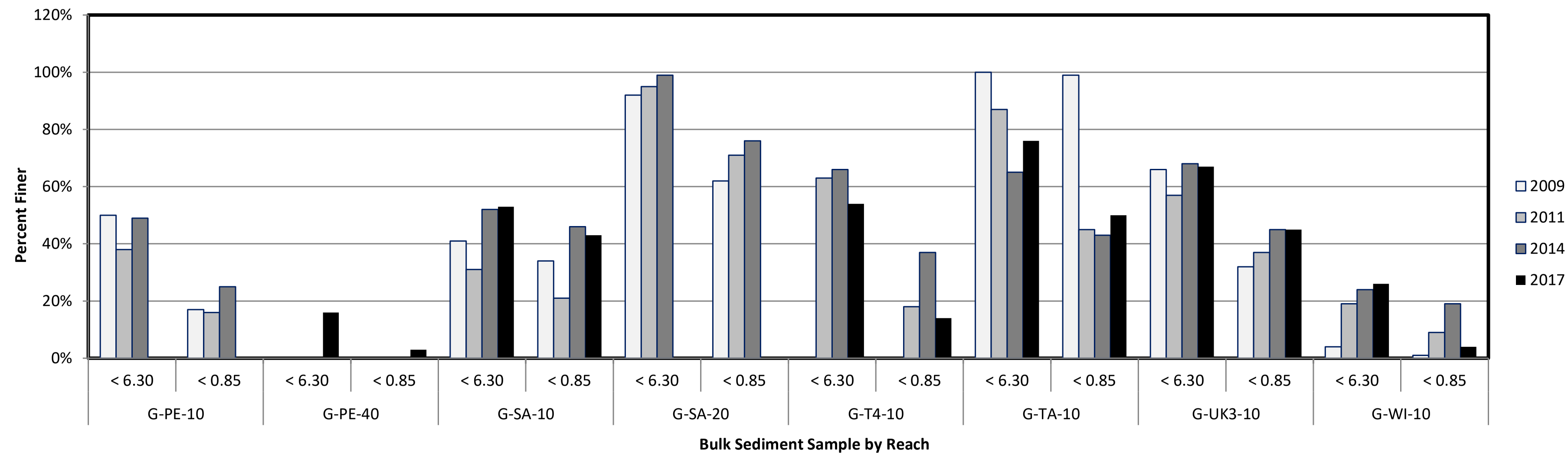


FIGURE 3

Bulk sample results (top graph) and pebble count results (bottom graph) sampled from reaches in Clackamas County (SWMACC), Oregon in the fall of 2009, 2011, 2014, and 2017

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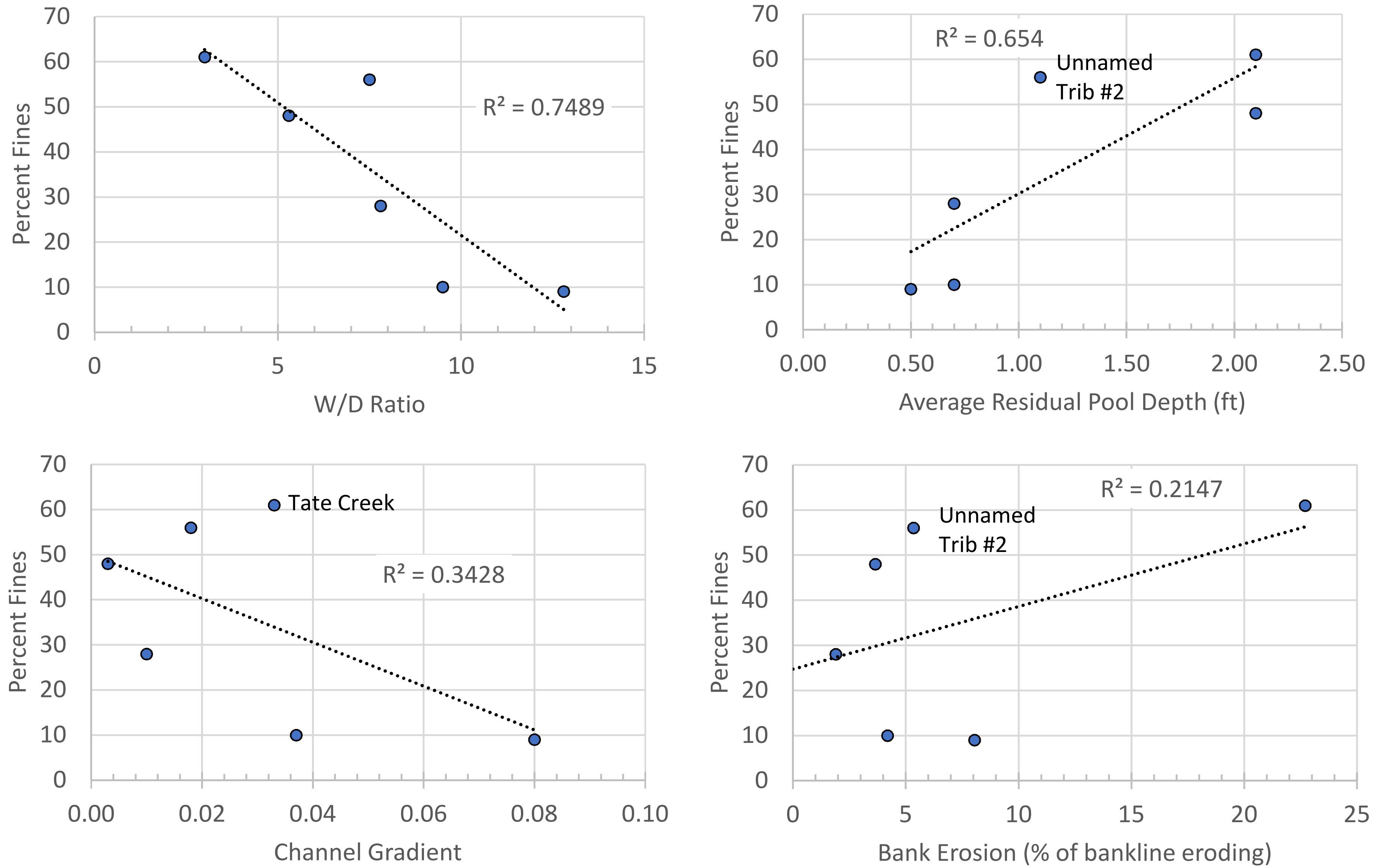

FIGURE 4A

Correlation between geomorphic parameters and percent fines in riverbed sampled from reaches in Clackamas County (SWMACC), Oregon in the fall of 2017

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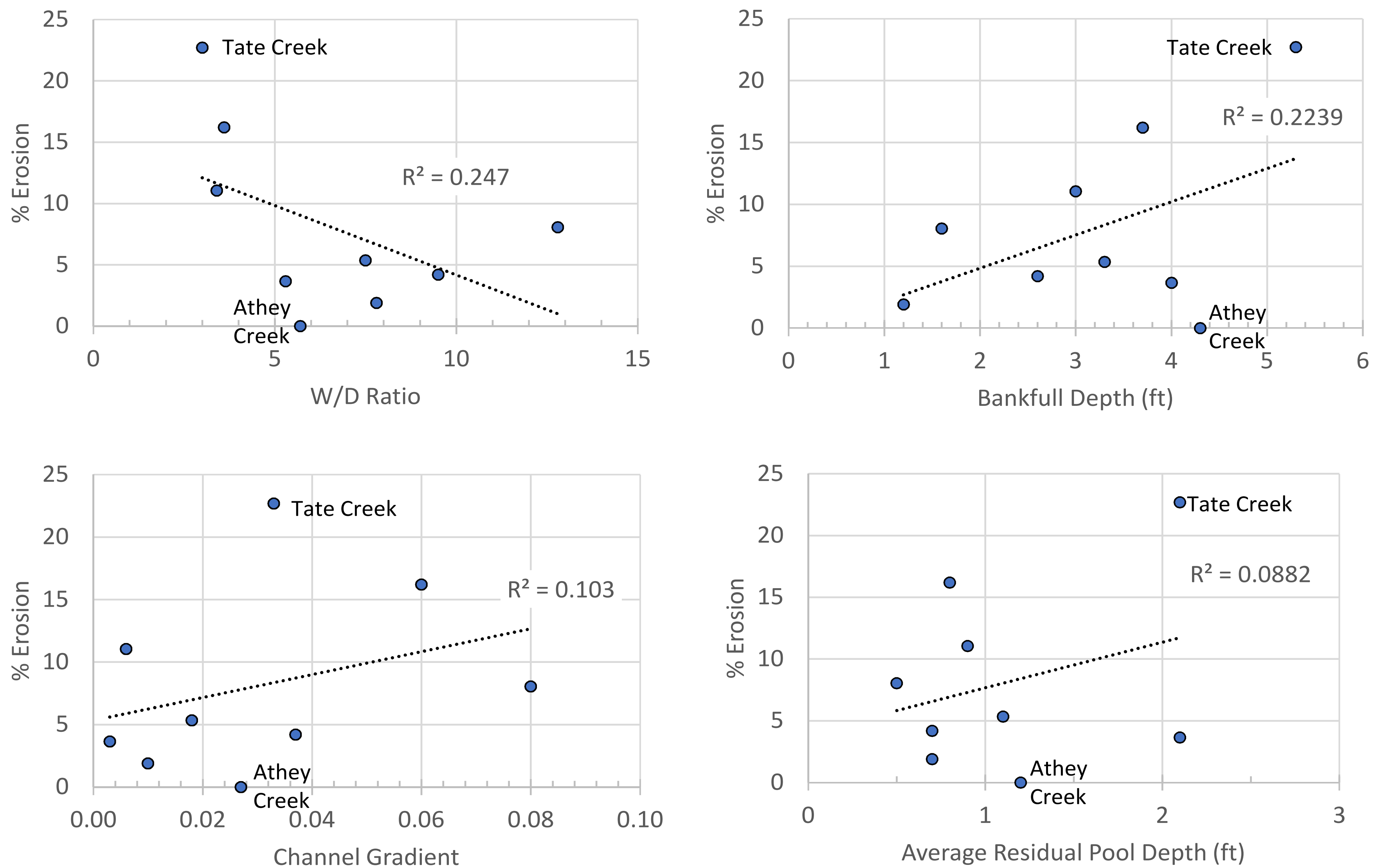

FIGURE 4B

Correlation between geomorphic parameters and percent of eroding bankline sampled from reaches in Clackamas County (SWMACC), Oregon in the fall of 2017

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Macroinvertebrate Monitoring Data Summary

Instream Physical Habitat and Associated Environmental Conditions

Seven of the nine macroinvertebrate survey reaches were classified as higher-gradient reaches and had channel slopes ranging from 0.7 to 7.1 percent (mean: 2.6 percent) with riffles comprising 25.3 to 80.3 percent (mean: 52.6 percent) of the instream habitat. The lower Saum Creek reach (M-SA-10) and middle Saum Creek reach (M-SA-20) were classified as lower-gradient reaches with channel slopes of 0.3 percent and 0.4 percent, respectively. Each of these two reaches was heavily dominated by slow-water habitats (Table 9).

The seven higher-gradient reaches had a high proportion of coarse substrates from riffle habitats sampled for macroinvertebrates (mean: 93.8 percent; range: 87.4 to 99.1 percent) and a low proportion of fine substrates in these targeted habitats (mean: 5.1 percent; range: 0.9 to 8.9 percent). Substrate embeddedness in target habitats from the higher-gradient reaches averaged 19.1 percent and ranged from a low of 12.4 percent in M-WI-10 to a high of 31.1 in M-SH-10.

Table 9. Environmental conditions of two lower-gradient and eight higher-gradient stream reaches sampled in Clackamas County (SWMACC), Oregon in the fall of 2017.

	Lower Gradient		Higher-gradient (n = 7)			
Environmental parameter	M-SA-10	M-SA-20	Mean	SD	Min	Max
Channel slope (%)	0.3	0.4	2.6	2.3	0.7	7.1
Wetted width (m)	2.0	0.9	1.0	0.2	0.5	1.3
Bankfull width (m)	3.3	2.6	2.2	0.7	1.7	3.6
Percent pools	52.9	67.4	29.1	19.0	10.5	65.8
Percent glides/runs	47.1	15.2	15.0	9.8	6.3	30.7
Percent riffles	0.0	17.4	52.6	21.1	25.3	80.3
Percent other	0.0	0.0	3.2	8.6	0.0	22.7
Target Habitat Percent coarse substrate	77.8	75.0	93.8	4.8	87.4	99.1
Target Habitat Percent fine substrate	16.3	25.0	5.1	3.7	0.9	8.9
Target Habitat Substrate embeddedness	36.9	NA	19.1	6.4	12.4	31.1
Reach-Wide Substrate embeddedness	89.7	89.1	47.6	22.9	18.5	75.8
Eroding banks	81	89	49	21	11	73
Undercut banks	1	4	4	6	0	14
Large wood tally (#/100 m)	33.8	7.6	6.9	5.2	1.3	16.5
Overhead cover (%)	78	99	93	5	84	100
Mean riparian width (m)	25	65	39	27	10	83
Riparian zone tree cover (%)	30	75	69	14	50	93
Riparian zone non-native Veg. Cover (%)	55	45	24	16	5	50
Water temperature (°C)	14.13	13.28	12.8	0.9	11.6	14.12
Dissolved oxygen (%)	79.4	76.4	90.4	6.3	79.8	98.1
Dissolved oxygen (mg/L)	8.16	8.00	9.59	0.80	8.44	10.67

Among all reaches, riparian zone buffer widths ranged from 10 to 83 m (mean: 39 m), while canopy cover ranged from 74 to 100 percent (mean: 93 percent). Across the seven higher-gradient reaches, instream large woody debris was generally low, averaging 6.9 pieces/100-m and ranging from 1.3 pieces/100-m in Unnamed Tributary 4 (M-T4-10) to 16.5 pieces/100-m in Wilson Creek (M-WI-10).

A number of water chemistry parameters were measured within each reach. Water temperatures were generally low to moderate, ranging from 11.6ºC to 14.2ºC (Table 9). Specific conductance ranged only between 83 and 205 µS/cm. Dissolved oxygen concentrations ranged from 8.4 to 10.7 mg/L.

Land use in the lower Tualatin River basin includes rural and suburban residential areas, commercial development, agriculture, and small tracts of forested land. Average percent land use among the drainage basins upstream of the 9 reaches sampled was relatively evenly split among urban (mean: 33.3 percent), agriculture (mean: 32.1 percent), and forest (mean: 34.5 percent), but these percentages very widely among individual drainages. Urban land use is lowest in the drainage basin upstream of Fields Creek (M-FE-20) and highest in the drainage basin upstream of lower Saum Creek (M-SA-10; Table 10). Agricultural land use is highest upstream of the upper Wilson Creek reach (M-WI-10) and Shipley Creek reach (M-SH-10).

Table 10. Land uses in the drainage basin upstream of monitoring reaches sampled in Clackamas County (SWMACC), Oregon in the fall of 2017.

	Percent				
Reach Code	**Urban**	**Forest**	**Agriculture**	**Water**	**Total**
M-SA-10	53.1	22.4	24.3	0.3	100.0
M-SA-20	31.7	34.9	33.4	0.0	100.0
M-AT-10	38.1	14.5	47.3	0.0	100.0
M-PE-10	41.5	27.2	31.2	0.0	100.0
M-SH-10	24.5	25.3	50.2	0.0	100.0
M-WI-10	22.3	21.4	56.1	0.2	100.0
M-T4-10	31.0	48.1	20.9	0.0	100.0
M-TA-10	43.9	42.2	13.3	0.6	100.0
M-FE-20	8.8	72.9	18.3	0.0	100.0
M-UK3-10	38.3	36.2	25.5	0.0	100.0

As in previous sampling years, the highest-quality habitat occurred in the Fields Creek reach (M-FE-20). This reach supported a large proportion of fast-water habitat (80.3 percent), a high percentage of coarse substrate in targeted sampling habitats (93.3 percent), and intact riparian buffers with a high percentage of tree cover (93 percent) and overhead canopy cover (96 percent). The riparian area was almost entirely comprised of native plant species. The drainage area upstream of this reach, at 72 percent forested, is the most heavily forested drainage among the SWMACC study reaches.

Macroinvertebrate Community Conditions – Riffle Samples

Riffle samples were collected from seven higher-gradient stream reaches. Stream flow conditions were generally at their seasonal averages for at least three months prior to macroinvertebrate sampling in 2017. A storm event did occur on September 20, after which both Shipley Creek and Unnamed Tributary 2 were sampled. However, results of 2017 macroinvertebrate surveys from those two streams were very similar to those from past years, suggesting that 2017 results were still comparable with past years' sampling.

DEQ multimetric (MM) scores of macroinvertebrate communities sampled from riffles in 2017 ranged from 22 in M-MA-10 to 40 in M-FE-20 and M-WI-10, as compared to a range of 26 to 44 from these same reaches in 2014. The average 2017 MM score from these seven reaches (32.3) was within 0.6 points of the average 2014 MM score (32.9). Three reaches received MM scores indicating slightly disturbed conditions, and two reaches received MM scores indicating moderately disturbed conditions; two reaches, Fields Creek (M-FE-20) and Wilson Creek (M-WI-10), each received an MM score of 40, indicating no biological impact (Table 12 and Table 13). MM scores showed no noteworthy declines in biological condition in any reaches between 2014 and 2017 (Table 13). Tate Creek (M-TA-10) exhibited the largest decrease in MM score, decreasing from 28 in 2014 to 22 in 2017, but this 6-point decline does not result in a change in condition class, and the MWCF O/E for this site was slightly higher in 2017 than in 2014. MM scores increased from 2014 to 2017, albeit modestly, in 3 reaches, including an increase of 6 MM points each in M-WI-10 (Table 13).

Table 11. Habitats from which macroinvertebrate samples were collected in monitoring reaches sampled in Clackamas County (SWMACC), Oregon in the fall of 2002, 2007, 2009, 2011, 2014, and 2017.

	Year Sampled					
Reach Code	**2002**	**2007**	**2009**	**2011**	**2014**	**2017**
M-AT-10	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle
M-FE-20	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle
M-PE-10	Glide	Glide	Glide	Glide	Glide	NS
M-SA-10	Glide	Glide		Riffle	Glide	Riffle/Glide
M-SA-20	Glide	Riffle	Glide	Riffle	Riffle	Riffle/Glide
M-SH-10	Riffle/Glide	Riffle/Glide	Riffle/Glide	Riffle/Glide	Riffle	Riffle
M-T4-10				Riffle	Riffle	Riffle
M-TA-10	Glide	Glide	Glide	Riffle	Riffle	Riffle
M-UK3-10	Pool	Riffle		Riffle	Riffle	Riffle
M-WI-10	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle

Table 12. Western Oregon multimetric scores and PREDATOR MWCF O/E scores calculated from macroinvertebrate samples collected from riffles in eight stream reaches in Clackamas County (SWMACC), Oregon, in the fall of 2017.

Reach Code	MM Score	MM Disturbance Class	O/E Score	O/E Disturbance Class
M-AT-10	36	Slight	0.873	Mod
M-FE-20	40	None/Slight	0.970	Least
M-SH-10	28	Mod	0.533	Most
M-T4-10	30	Slight/Mod	0.776	Most
M-TA-10	22	Mod	0.776	Most
M-UK3-10	30	Slight/Mod	0.727	Most
M-WI-10	40	None/Slight	0.873	Mod

As another measure of overall biological condition in western Oregon streams, the PREDATOR MWCF O/E scores from riffle samples ranged from 0.533 in M-SH-10 to 0.970 in 2017, as compared to 0.631 to 0.969 in 2014 (Table 12 and Table 14). Unlike the MM score results, MWCF O/E score results suggest that biological conditions in 4 of these 7 reaches are "most disturbed", while only one reach, Fields Creek (M-FE-20), is "least disturbed". Two reaches, Athey Creek (M-AT-10) and Wilson Creek (M-WI-10), were each classified as moderately disturbed from MWCF O/E scores (Table 12). Using combined 2011 through 2017 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 from 2011 through 2017 and classified by the MWCF model as "most disturbed", none of these received a corresponding "severely disturbed" MM score, 10 received a "moderately disturbed" MM score, 7 received a "slightly disturbed" MM scores, and 1 received a "not disturbed" MM score (Figure 5). While the PREDATOR MWCF model is generally considered to be more robust than the multimetric index, these comparisons of results with those from the MMI suggest that the MWCF model potentially underperforms the MMI. As previously explained, this underperformance likely results from the MWCF model's very specific list of taxa predicted to occur at the test site. If any of these particular taxa are absent, the site score suffers. However, the MMI relies on broader community attributes, such as the number of sensitive taxa or the number of mayfly taxa. As long as a sufficient number of taxa in an attribute class are present, irrespective of the occurrence specific taxa, the sample scores favorably. Because the two tools use alternative approaches to evaluating community condition and sometimes perform differently the results of both assessment tools should be carefully examined to ascertain biological conditions, potential causation of observed conditions, and spatial and temporal patterns in those conditions.

Furthermore, future assessments of macroinvertebrate communities will include the use of yet a third assessment tool that is presently in its last stages of development (Jen Stamp, Tetra Tech, personal communication). This new tool, known as the Biological Condition Gradient (BCG), is a scientific framework that can be used by practitioners of water quality monitoring to better interpret biological responses from the cumulative effects of stressors than allowed by present tools. In some respects, the BCG is much like the western Oregon multimetric index used in the present and other studies. However, much larger data sets were used and numerous experts (including Dr. Cole) were convened to inform the development of this tool, which is intended to more precisely define and measure biological condition in Willamette Valley Ecoregion streams. The BCG was first proposed in 2006 as a conceptual framework developed by EPA in partnership with scientists from states, USGS and the academic community; the BCG framework and process have been implemented in a number of states and regions across the country with the oversight of EPA and their consultants. Much like the western Oregon multimetric index, the Willamette Valley/Puget Sound Lowlands BCG utilizes a series of metrics – or community attributes – that are known to be responsive to the degradation of freshwater resources. However, the scoring criteria are developed to align assignment of condition classes by the tool with expert opinion of what constitutes various levels of disturbance by the panel of experts involved in model development. Furthermore, the assessment tools development consistently model their condition classes on the BCG framework, which includes six levels of biological condition, based on a uniformly-applied definition of each of those condition classes. While the application of the new regional BCG tool to WES macroinvertebrate won't occur until the next round of monitoring, it is sure to provide excellent additional context for assessing biological conditions in Clackamas County streams.

Among the three reaches sampled in each assessment year since 2002 (M-AT-10, M-FE-20, and M-T4-10), multimetric scores suggest variable, yet unchanged or potentially improving biological conditions (Figure 6). MWCF O/E scores suggest a similar lack of any downward trending for the reaches (Figure 6). Considering all reaches monitored in each year, both MM scores and MWCF O/E scores suggest steady, if not slightly improved, biological conditions in all streams sampled since 2002 (Figure 7). Including only the 3 reaches sampled each assessment year since 2002, the same trend of potentially improving biological conditions is evident with the MM scores, but less so with the MECF O/E scores (Figure 7).

The Fields Creek reach (M-FE-20) has received the highest multimetric scores in each assessment year since 2002 (Table 13). Both MM and MWCF O/E scores have been variable in this reach, but MM scores have consistently indicated only slightly disturbed or better conditions (Figure 6). Fields Creek has also received the highest MWCF O/E scores among all reaches in all years since 2011, scoring 0.970 in 2017.

Table 13. Multimetric scores calculated for riffle samples collected from stream reaches in Clackamas County (SWMACC), Oregon, in the fall of 2002, 2007, 2009, 2011, 2014, and 2017.

Reach Code	Year Sampled					
	2002	2007	2009	2011	2014	2017
M-AT-10	24	32	22	22	34	36
M-FE-20	34	40	32	36	44	40
M-SA-20				24		
M-PE-10	18	24	24	20	26	
M-SH-10		22		28	30	28
M-T4-10	16	32	28	34	32	30
M-TA-10				24	28	22
M-UK3-10				32	28	30
M-WI-10		34		34	34	40

Table 14. MWCF O/E scores calculated for riffle samples collected from stream reaches in Clackamas County (SWMACC), Oregon, in the fall of 2002, 2007, 2009, 2011, 2014, and 2017.

Reach Code	Year Sampled					
	2002	2007	2009	2011	2014	2017
M-AT-10	0.679	0.871	0.873	0.727	0.825	0.873
M-FE-20	0.533	0.870	0.825	1.017	0.824	0.970
M-SA-20				0.775		
M-SH-10		0.387		0.484	0.678	0.533
M-T4-10	0.533	0.725	0.873	0.775	0.824	0.776
M-TA-10				0.678	0.727	0.776
M-UK3-10				0.775	0.776	0.727
M-WI-10		0.726		0.775	0.969	0.873

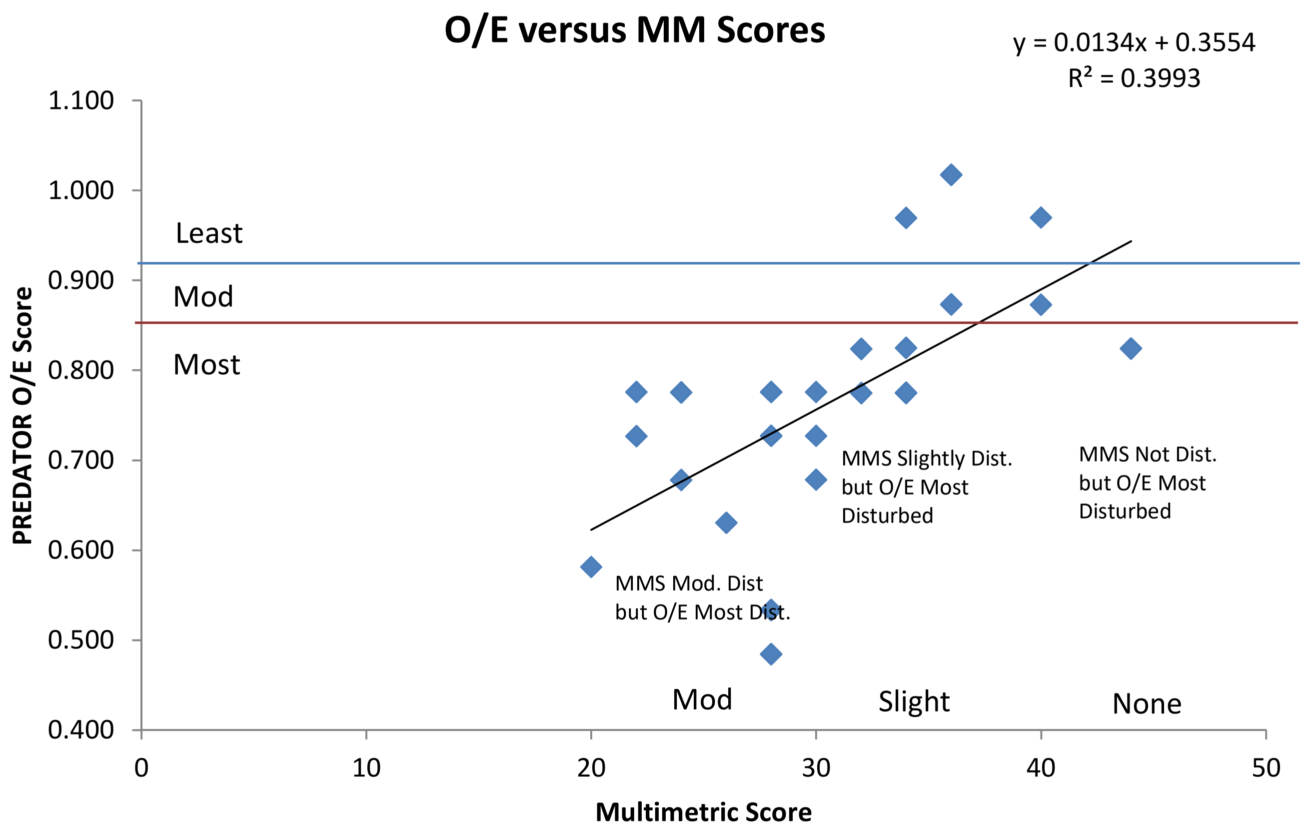

FIGURE 5

Relationships between multimetric scores and PREDATOR O/E model scores of macroinvertebrate communities sampled from riffles in stream reaches in Clackamas County (SWMACC), Oregon in the fall of 2017.

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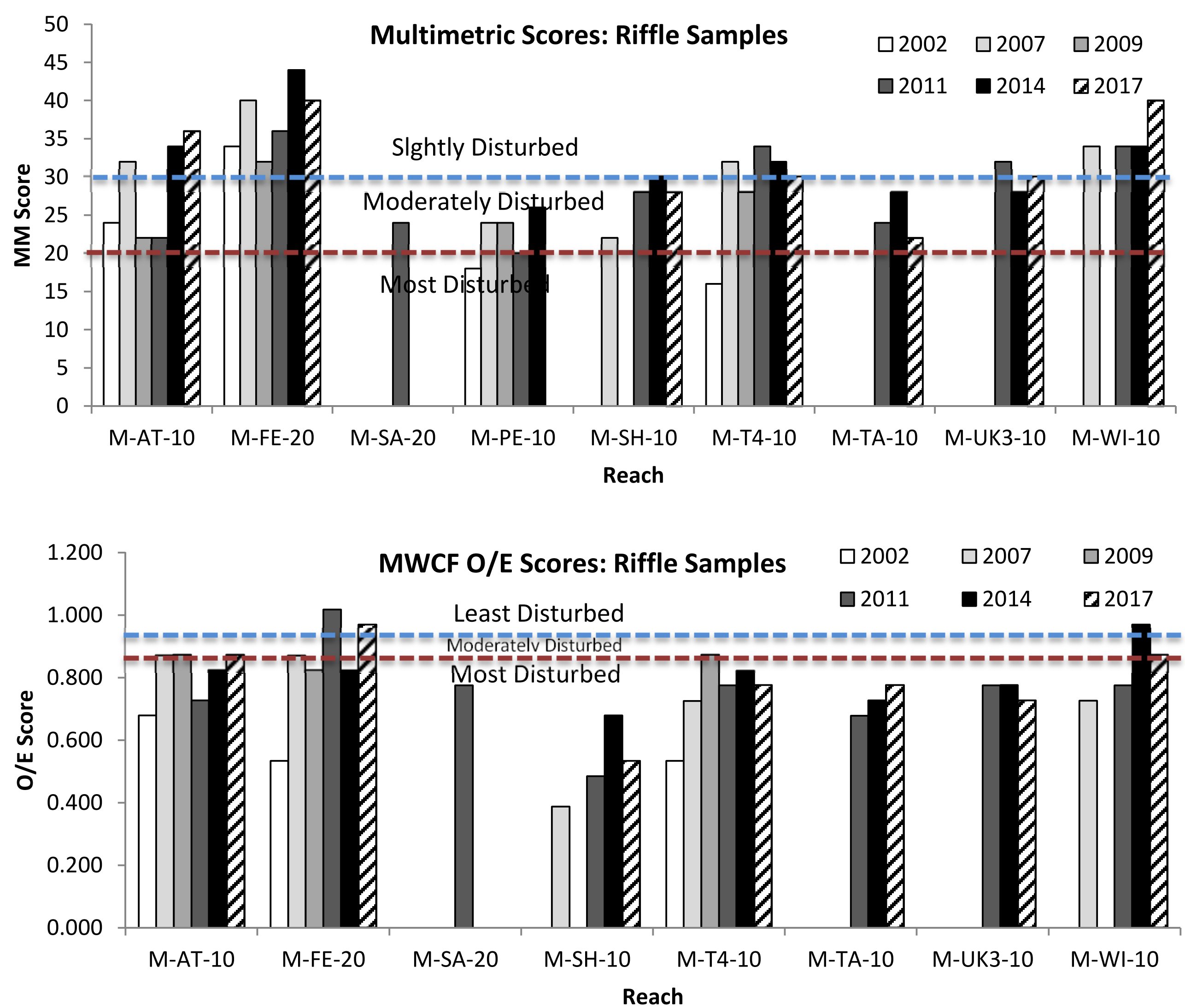

FIGURE 6

Multimetric scores (top panel) and PREDATOR MWCF O/E scores (bottom panel) of macroinvertebrate communities sampled from riffles in Clackamas County (SWMACC), Oregon in the fall of 2002, 2007, 2009, 2011, 2014, and 2017.

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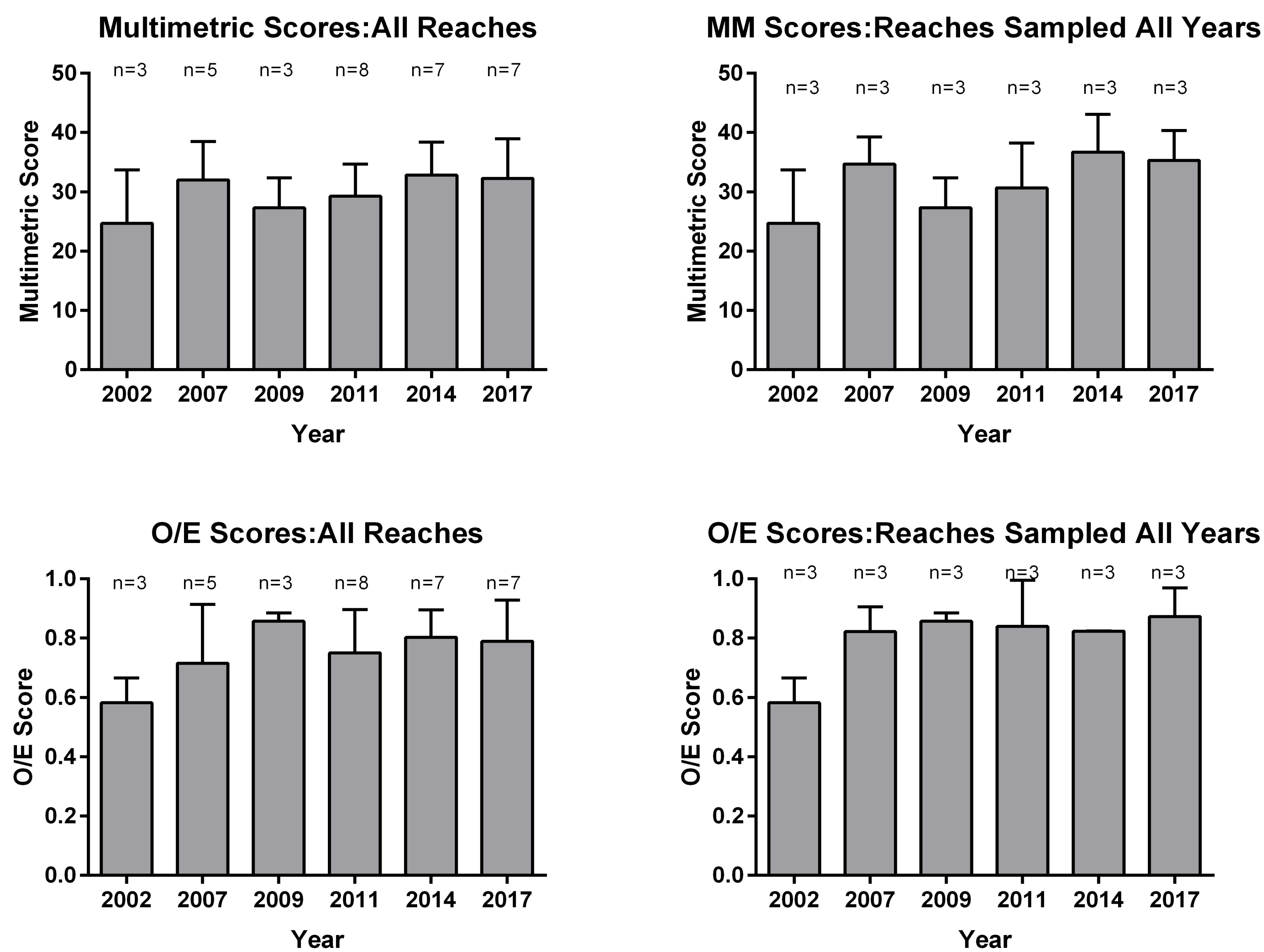

FIGURE 7

Mean multimetric (upper panels) and mean MWCF O/E (bottom panels) scores of macroinvertebrate communities sampled from riffles in Clackamas County (SWMACC), Oregon in the fall of 2002, 2007, 2009, 2011, 2014, and 2017. 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=4).

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Individual measures of community condition (using individual metrics) once again varied among riffle samples (Table 15). Total taxa richness ranged from 23 taxa in Shipley Creek (M-SH-10) to 40 taxa in both Fields Creek (M-FE-20) and Wilson Creek (M-WI-10) and averaged 32.6 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 Fields Creek reach supported the highest number of EPT taxa in 2017 (19 taxa), while upper Wilson Creek (M-WI-10) supported 17 EPT taxa. At least one sensitive taxon was present in each of the 7 reaches where riffles were sampled. Similar to past years, the Heptageniidae mayfly genus *Cingyma* was the most common sensitive taxon observed, and was present at 5 of the 7 reaches in which riffles were sampled. *Cingyma* was not sampled from the Fields Creek reach or the Unnamed tributary 4 reach, but has been sampled from these reaches in the past. The dipteran genus *Glutops*, also classified as sensitive, also occurred in five riffle-sampled reaches.

Table 15. Macroinvertebrate community metrics calculated for riffle samples collected from stream reaches in Clackamas County (SWMACC), Oregon, in the fall of 2017 (n= 7).

Metric	Mean	SD	Min	Max
Taxa richness	32.6	6.8	23	40
Mayfly richness	4.3	1.8	1	6
Stonefly richness	4.7	2.6	2	8
Caddisfly richness	4.4	1.4	3	7
Number sensitive taxa	2.4	1.0	1	4
Number sediment sensitive taxa	1.4	1.0	0	3
Modified HBI	4.1	0.6	3.6	5.3
Tolerant taxa (%)	21.2	7.1	7.8	28.2
Sediment tolerant taxa (%)	10.0	4.2	2.3	15.6
Dominant (%)	24.5	10.7	14.4	45.3
Total MM Score	32.3	6.7	22	40

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 among the SWMACC streams (Table 15). In 2011 and 2017, the Shipley Creek reach (M-SH-10) supported the lowest percentage of tolerant taxa (7.7 percent) and sediment tolerant taxa (1.2 percent) relative to the group mean of 21.2 percent. However, the sample was once again dominated by one taxon, (Order: Amphipoda; Genus: *Ramellogammarus*) accounting for 49.5 percent of the organisms in the sample (Table 15).

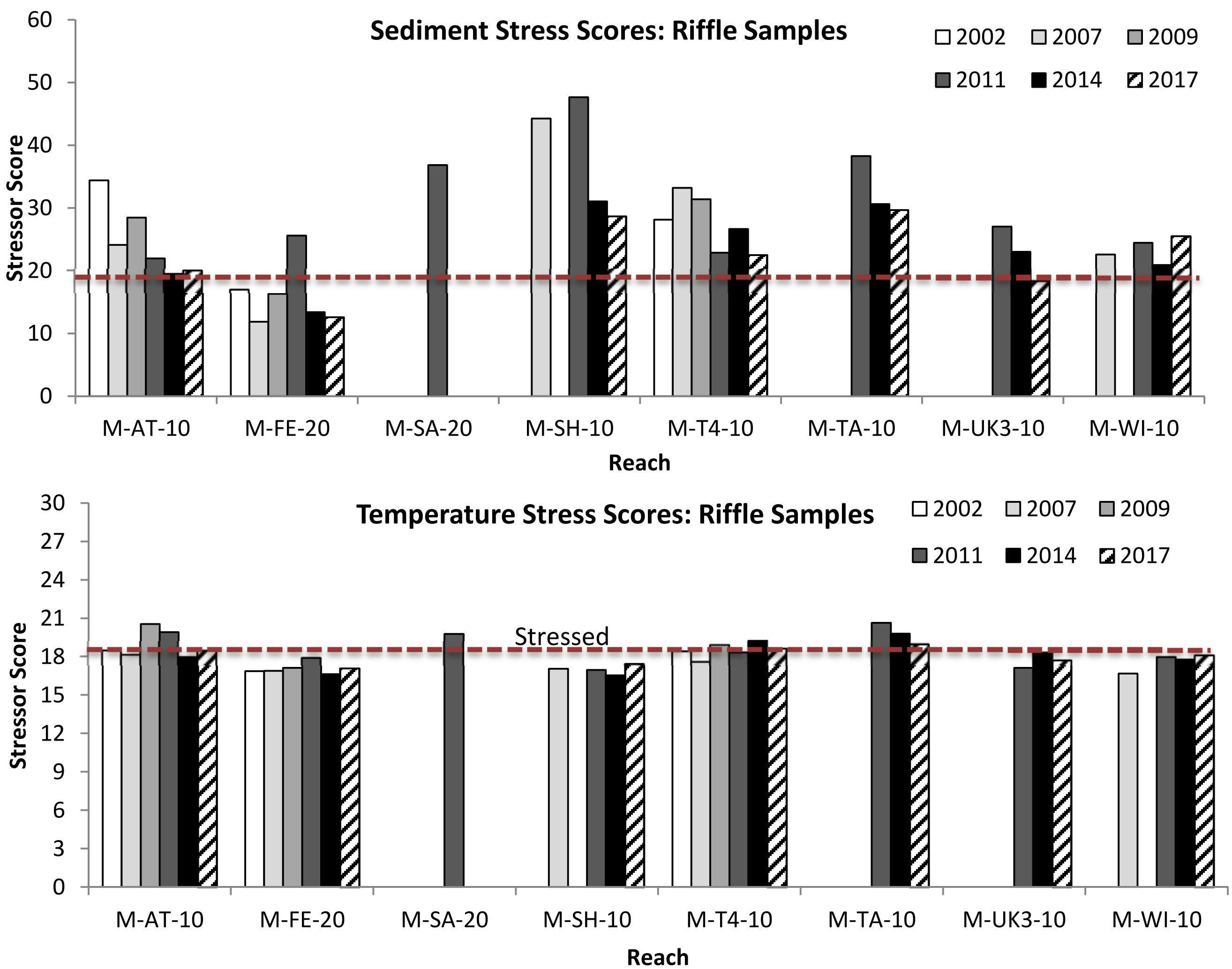
Fine-sediment stressor (FSS) model results indicated that macroinvertebrate communities from 6 of the 7 higher-gradient reaches exceeded the DEQ fine sediment stress threshold of 19 percent for the Willamette Valley (Figure 8), resulting in fine sediment being listed as a likely stressor to these two reaches (Table 16). FSS model results have also consistently indicated that M-T4-10 and M-UK3-10 exceed the DEQ Willamette Valley criterion of 19 percent (Figure 8); accordingly, sediment is listed in this report as a likely stressor for these two reaches (Table 16).

Both M-SA-10 and M-SA-20 are listed as undergoing a high degree of sediment intrusion. As such, fine sediment is classified as a likely biological stressor for each of these two reaches (Table 16). FSS results show that inferred fine sediment levels for Fields Creek (M-FE-10) are below the "stressed" threshold in most years, including 2017. Accordingly, fine sediment remained classified as a potential stressor in this reach in 2017 (Table 16). The upper Wilson Creek reach (M-WI-10) FSS scores have consistently exceeded the 19 percent threshold, but this reach shows relatively low substrate embeddedness in riffles (12.4 percent in 2017); as such, fine sediment remained classified as a potential stressor in this reach (Table 16).

Table 16. Summary of stressor identification results for macroinvertebrate communities sampled from nine stream reaches in Clackamas County (SWMACC), Oregon, fall 2017. Stressors include elevated levels of fine sediment, elevated water temperature (Temp), and low dissolved oxygen.

Reach Code	Likely Stressors	Potential Stressors	Not Likely Stressors
M-AT-10	-	Fine sediment, Temp	-
M-FE-20	-	Fine sediment	Temp
M-SA-10	Fine sediment, Temp	Dissolved oxygen	
M-SA-20	Fine sediment, Temp	Dissolved oxygen	-
M-SH-10	Fine sediment	-	Temp
M-T4-10	Fine sediment	Temp, Dissolved oxygen	Dissolved oxygen
M-TA-10	Fine sediment, Temp	-	-
M-UK3-10	Fine sediment	-	Temp, Dissolved oxygen
M-WI-10		Fine sediment	Temp, Dissolved oxygen

Temperature stressor (TS) model results suggested that macroinvertebrate communities from only 3 of the 7 higher-gradient reaches, likely showed elevated temperature stress (Figure 8)., In addition, macroinvertebrate assemblages from Tate Creek (M-TA-10) received inferred temperature stressor scores higher than the Willamette Valley threshold of 18.4 °C (Huff et al. 2006). The Tate Creek reach has exceeded the 18.4ºC threshold in both years sampled, resulting in a likely temperature stressed classification. The Unnamed Tributary 4 reach (M-T4-10) has consistently received TS scores immediately above or below the threshold (Figure 8), resulting in temperature being listed as a potential stressor for this reach (Table 16). Similarly, the Athey Creek reach (M-AT-10) TS scores have either narrowly missed or exceeded the 18.4ºC threshold also warranting classification of this reach as potentially temperature stressed (Figure 8, Table 16). Four reaches – M-FE-20, M-UK3-10, M-SH-10, and M-WI-10, have consistently received TS scores below the temperature threshold, resulting in temperature stress being classified as not likely occurring (Table 16).



Fine sediment stressor model scores (top panel) and temperature stressor scores (bottom panel) of macroinvertebrate communities sampled from riffles in Clackamas County (SWMACC), Oregon in the fall of 2002, 2007, 2009, 2011, 2014, and 2017. Red lines indicate thresholds above which values indicate a stressed

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FIGURE
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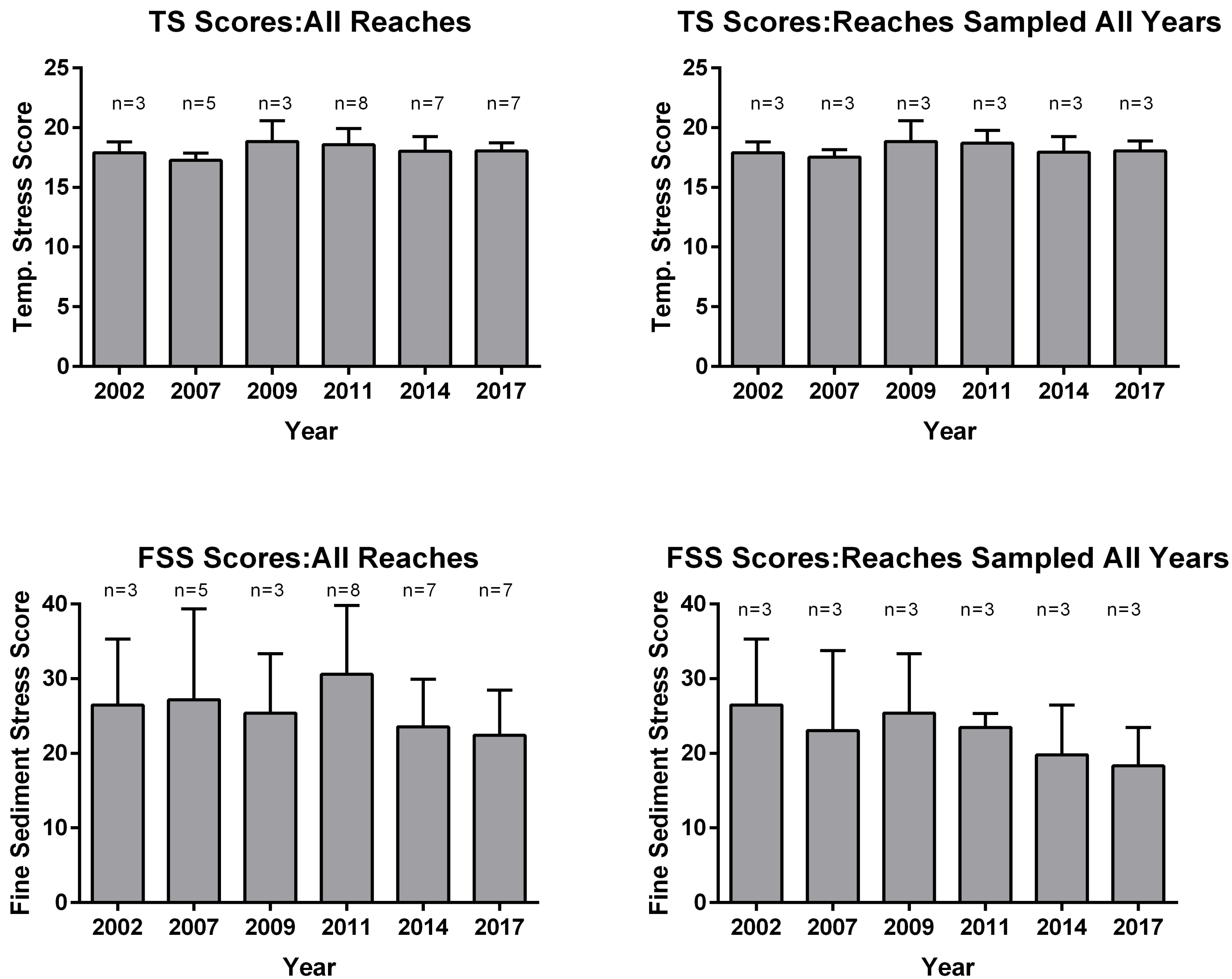

FIGURE 9

Mean temperature stressor scores (upper panels) and mean fine sediment stressor scores (bottom panels) of macroinvertebrate communities sampled from riffles in Clackamas County (SWMACC), Oregon in the fall of 2002, 2007, 2009, 2011, 2014, and 2017. 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=4).

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Macroinvertebrate Community Conditions –Glide Samples

Composite riffle/glide samples were collected from the Saum Creek reaches M-SA-10 and M-SA-20. The lower Saum Creek reach (M-SA-10) sample received an MM score of 18 (versus 20 in 2014), while the upper Saum Creek reach received an MM sores of 34 (versus 26 in 2014; Table 17). MWCF O/E scores for the two samples were 0.679 (versus 0.534 in 2014) and 0.728 (same score as in 2014), respectively (Table 18). Longer-term data derived from glides in each of these two reaches suggest that conditions have remained stable, if not slightly improved since monitoring was initiated in 2002; 2002 to 2011 MM scores ranged from 12 to 14 in M-SA-10, but this reach received an MM score of 18 in 2017 and 20 in 2014. Similarly, M-SA-20 glide samples received MM scores of 16 in 2007, 18 points lower than the 2017 MM score.

Macroinvertebrate communities sampled from the glides in these two low-gradient reaches were characterized as having a higher proportion of tolerant organisms, percent sediment tolerant organisms, and higher HBI scores than did the riffle samples collected in this study. While the lower Saum Creek reach (M-SA-10) had fewer EPT taxa than any of the riffle samples, the middle Saum Creek reach (M-SA-20) supported 15 EPT taxa, comparing favorably to the mean EPT richness of 13.4 collected from riffle samples. The upper end of this reach supported a riffle created by road fill, and some of the sample kicks were collected within this riffle. The influence of this riffle may be evident in these sample results and suggests that the macroinvertebrate community is not heavily disturbed in middle Saum Creek.

Table 17. Multimetric scores calculated for glide samples collected from stream reaches in Clackamas County (SWMACC), Oregon, in the fall of 2002, 2007, 2009, 2011, 2014, and 2017.

	Year Sampled					
Reach Code	**2002**	**2007**	**2009**	**2011**	**2014**	**2017**
M-SA-10	12	14	12	12	20	18*
M-SA-20	18	16			26	34*
M-SH-10	26		22			
M-T4-10	20	28	24	16		
M-UK3-10	18	22	24			
M-WI-10	16					

*composite riffle/glide sample (riffle was underdeveloped)

Table 18. MWCF O/E scores calculated for glide samples collected from stream reaches in Clackamas County (SWMACC), Oregon, in the fall of 2002, 2007, 2009, 2011, 2014, and 2017.

	Year Sampled					
Reach Code	**2002**	**2007**	**2009**	**2011**	**2014**	**2017**
M-SA-10	0.388	0.145	0.485	0.291	0.534	0.679*
M-SA-20	0.388	0.290			0.728	0.728*
M-SH-10	0.436		0.291			
M-T4-10	0.485	0.484	0.630	0.533		
M-UK3-10	0.533	0.435	0.582			
M-WI-10	0.291					

*composite riffle/glide sample (riffle was underdeveloped)

Correlation of Community Conditions with Environmental Conditions

As in previous years, both riffle sample multimetric scores and MWCF O/E scores were significantly correlated with land use composition in the upstream drainage area, including percent urban (MM score: Spearman rho = -0.8191, $p < 0.0001$; O/E score: Spearman rho = -0.7749, $p < 0.0001$), percent agriculture (MM score: Spearman rho = 0.8059, $p = <0.0001$; O/E score: Spearman rho = 0.7276, $p < 0.0001$), percent urban and agriculture land uses combined (MM Score: Spearman rho = -0.6369, $p = 0.0004$; O/E score: Spearman rho = -0.7615, $p = <0.0001$), and percent forest (MM Score: Spearman rho = 0.6383, $p = 0.0004$; O/E score: Spearman rho = 0.7635, $p = <0.0001$; Figure 10 and Figure 11).

Among measured physical habitat attributes, only wetted width was significantly correlated with both MM and O/E scores (MM Score: Spearman rho = -0.3936, $p = 0.0258$, O/E Score: Spearman rho = -0.5082, $p = 0.0047$). Bankfull width was also significantly correlated with O/E scores (Spearman rho = -0.4096, $p = 0.021$; Figure 10 and Figure 11) while the percentage of the reach comprised of riffle habitat (MM Score: Spearman rho = 0.3505, $p = 0.0429$) and the mean stream gradient (MM Score: Spearman rho = 0.3748, $p = 0.0325$) were each significantly correlated with only MM scores (Figure 10 and Figure 11).

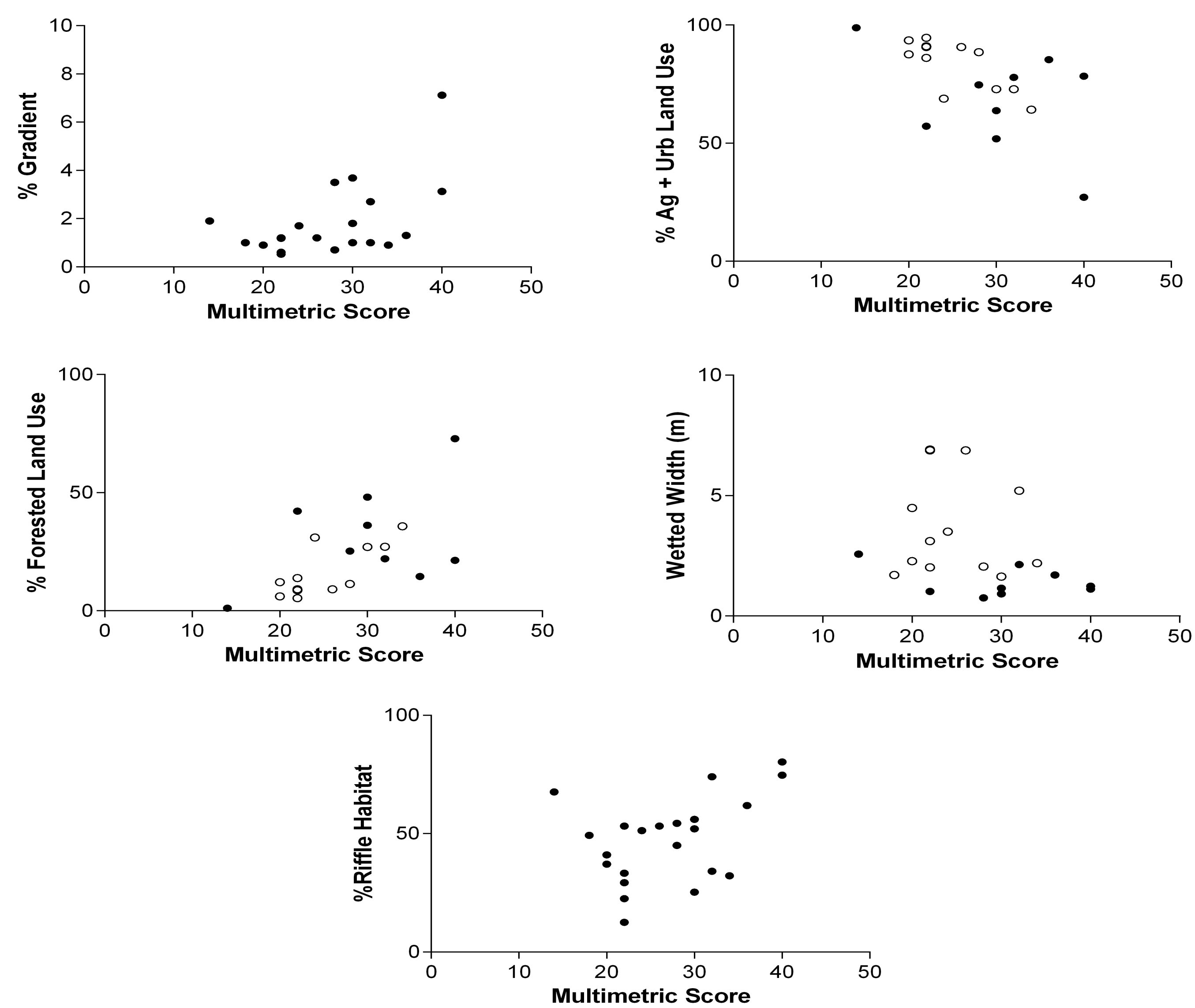

FIGURE 10

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 2017.

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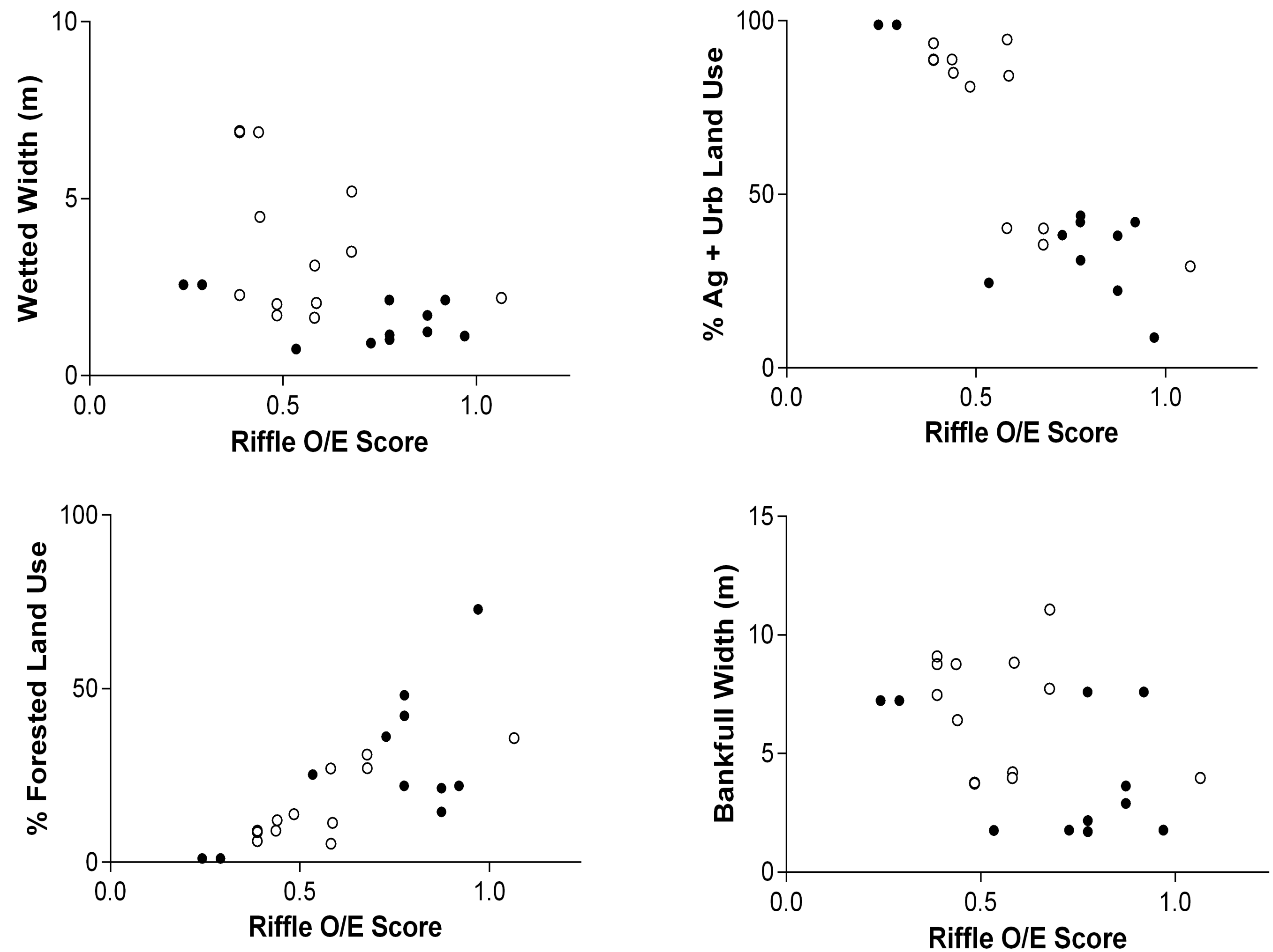

FIGURE 11

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 2017.

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4.0 DISCUSSION

4.1 DISCUSSION OF GEOMORPHIC SURVEY

The results from the geomorphic monitoring may be best viewed within the context of a "sediment budget" of each study reach. Geomorphic changes seen in the monitoring data reflect changes in the timing and magnitude of water and sediment supply from the watershed. Slow growth, deforestation and urbanization have increased the size and frequency of floods available to transport sediment, leading to erosion in stream channels throughout the region. These impacts have already affected most, if not all, of the channels within the SWMACC service area, and all of the channels that were surveyed in SWMACC are impaired to some extent due to lack of large wood supply, channel straightening, modified hydrology, and channel incision. The discussion focuses on two aspects of the geomorphic data: identifying areas of instability within the SWMACC monitoring area; and examining the impact of geomorphology on the macroinvertebrate communities.

Areas of Geomorphic Instability in SWMACC Monitoring Reaches

The geomorphic survey identified both stable and unstable reaches. Geomorphically stable reaches are those in which the sediment balance is about neutral over time. Stable reaches may be dynamic, moving laterally but maintaining the same approximate channel shape and elevation over time. Unstable reaches are those in which either erosion or deposition predominate. The geomorphic survey identified three main types of instability in the channels: aggrading reaches, degrading (incising) reaches, and active headcuts.

The unstable reaches in the SWMACC area are identified in Table 19, based on the geomorphic data in Appendix A and the site descriptions in Section 3.1.

The watershed-scale causes, impacts, and options for dealing with the three types of channel instability are summarized below:

1. ***Aggradation***. One type of geomorphic instability is a reach-scale change in the elevation in the streambed, either an increase (aggradation) or decrease (incision). Reach-scale channel aggradation is caused by a positive imbalance between the supply of sediment and the reach's transport capacity of sediment (oversupply of sediment). Under these conditions sediment will deposit in the channel bed, building gravel or sand bars. Aggradation in channels is typically accompanied by channel widening, because more of the flow energy is deflected towards the banks. Aggrading channels typically have more topographic complexity, and therefore better habitat. Also, since an aggrading bed is approaching the elevation of the floodplain, aggrading channels also flood more frequently (a condition that is considered beneficial for ecosystems and for protecting downstream properties, but worse for landowners if structures are built nearby). Although the causes of channel aggradation are complex and site-specific, in general it is caused by an increase in the sediment supply, a reduction in the size and(or) frequency of floods, or an increase in the base level of the stream. Unless there is a risk to infrastructure, aggrading channels are considered to be beneficial to ecosystems.
2. ***Degradation (incision).*** When the sediment balance is negative (transport capacity exceeds supply), streams and rivers incise. Incising, or degrading, streams are commonly encountered

in urbanizing environments, because more rainfall runs off of impervious surfaces and enters streams quickly, leading to higher peak flows and a resulting increase in the sediment transport capacity. Due to the increase in transport capacity, streams incise, usually becoming narrower and deeper. In this situation, much of the topographic complexity in the channel bed is removed by erosion. Also, incised streams often become "disconnected" from the adjacent floodplain, flooding infrequently or never. The steep, high banks caused by incision become unstable and collapse, increasing the supply of fine sediment to the stream. In some areas the incision may also cause groundwater levels in the floodplain to drop, impacting groundwater wells. In contrast to headcuts, which can be stabilized relatively easily, reversing or preventing reach-scale incision over the long term could potentially require changes at the scale of the entire watershed.

3. ***Active Headcut.*** A third type of geomorphic instability seen in many of these reaches is a headcut, which is a sharp geomorphic transition from a stable reach upstream to a degrading reach downstream. Headcuts commonly migrate upstream, increasing the size of the instability. Headcuts are initiated by a variety of causes – both watershed-scale and local-scale factors – but most often are caused by local events, such as the removal of a grade control feature. Downstream of headcuts, erosion predominates, starting with incision of the channel, which may in turn destabilize banks, often leading to an increase in the supply of fine sediment to the stream, causing detrimental impacts to downstream areas. One common method of treating headcuts uses natural channel design methods, such as wood or boulder installations to halt the continued upstream migration. To do this at the scale of the SWMACC service area, areas of active headcutting must be identified. Although headcuts have been be identified at some of the monitoring sites through observations in the field or analysis of the longitudinal profile (Table 18 and Section 3.1), we have not mapped headcuts outside the surveyed reaches.

Geomorphic Impact on Macroinvertebrates

The geomorphic data were also used to try to explain some of the variability in macroinvertebrate communities in tributaries of the lower Tualatin River basin. The highest O/E score in the 2017 data set for the SWMACC service area is in Athey Creek (M-AT-10) (0.87), and the lowest is at lower Saum Creek (M-SA-10) (0.68). The O/E score has a closer correlation with stream gradient (R^2=0.62) than any of the other geomorphic variables (Figure 12). This is not surprising and suggests that conditions are better in the surveyed reaches that are steeper (> 2 percent), presumably because the steeper reaches have more oxygenated gravel riffles that contain a smaller content of fines. The second strongest explanatory geomorphic variable controlling the O/E score is the percent fines in the bulk sample (R^2=0.53). This is not surprising, since infiltration of fines in the gravel bed is generally considered detrimental to the aquatic ecosystem.

Table 19. Summary of Geomorphic Condition of SWMACC Monitoring Reaches[1]

	Measured Parameters			Interpretation			
Reach	**Bank Stability** (% bankline actively eroding)	**Substrate** (% sand+ fines in pool tail)	**Channel Cross Section** (W/D ratio)	**Incising** Yes (Y), No (N), or Maybe (?)	**Aggrading** Y, N, ?	**Active Headcut(s)** Y, N, ?	**Key Features of Reach**
G-AT-10	0		5.7				Stable channel in small canyon; left bank lined by fill slope of dumped garbage; floodplain choked with ivy
G-FE-20	16		3.6			Y	Incised channel may be aggrading
G-PE-40	8	9	12.8				Monitoring reach moved upstream in 2017, to steeper area with less fines
G-SA-10	4	48	5.3				Water ponded behind culvert allows deposition of fines; single house surrounded by meander loop on fenced property
G-SA-20	11		3.4		?	Y	Channelized reach along road
G-T4-10	2	28	7.8				Frequent flooding and high water table; perched culvert
G-TA-10	23	61	3	Y		Y	Channel incised to bedrock with headcuts
G-UK3-10	5	56	7.5	Y		Y	Headcut migration currently prevented by roots that could be destabilized
G-WI-10	4	10	9.5		Y		Restoration project installed in 2011 to reverse incision and stabilize headcuts

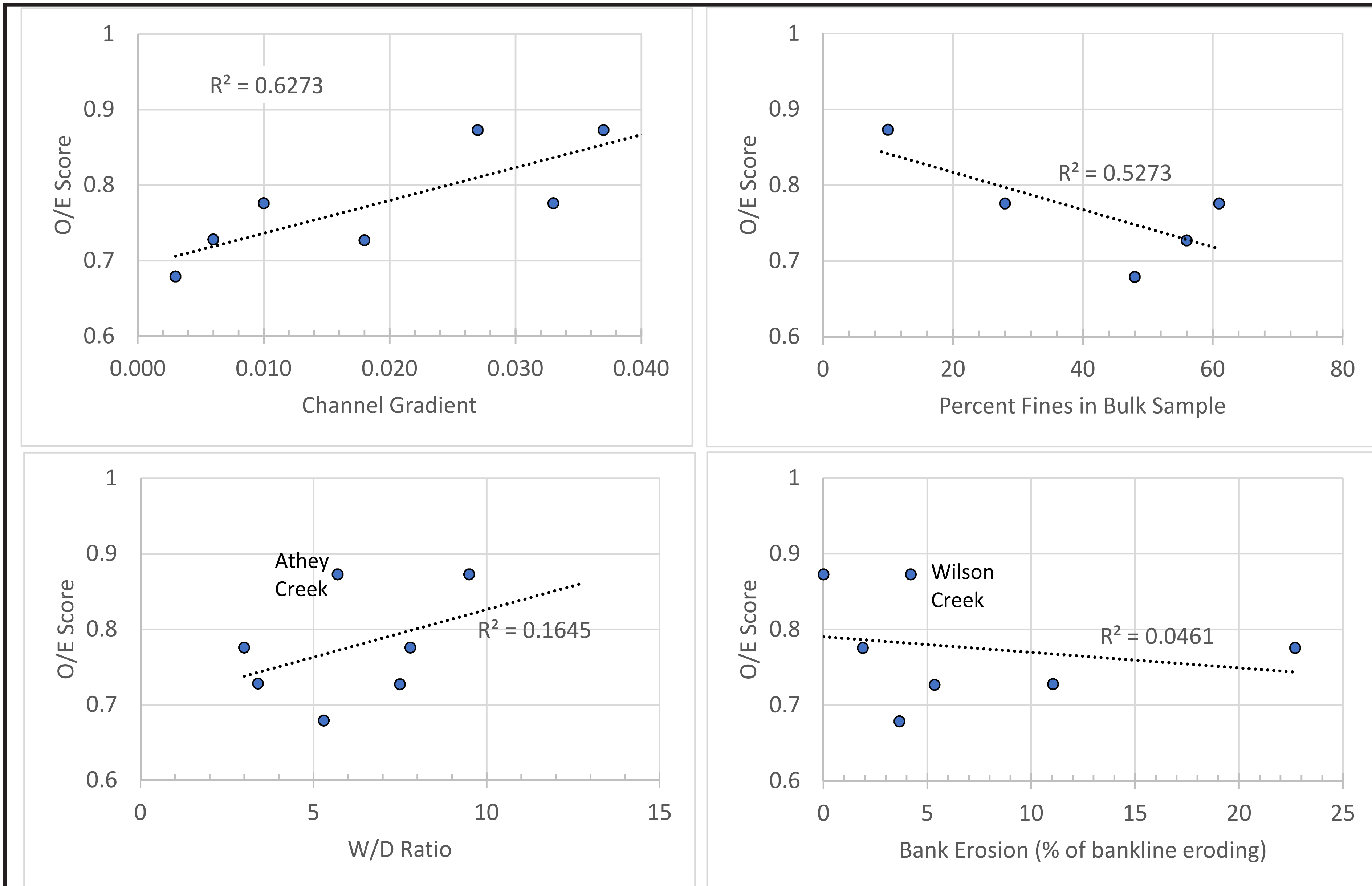

FIGURE 12

Correlation between geomorphic parameters and O/E scores sampled from reaches in Clackamas County (SWMACC), Oregon in the fall of 2017

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4.2 DISCUSSION OF MACROINVERTEBRATE SURVEY

As in previous assessments of macroinvertebrate communities in tributaries of the lower Tualatin River basin, macroinvertebrate community conditions varied among stream reaches sampled in 2017. All streams in the survey continue to show evidence of current or past instabilities and varying degrees of elevated sediment loading, likely resulting from hydromodification. Similarly, most of the higher-gradient streams in the study score as slightly or moderately disturbed using the western Oregon multi-metric index, but two stream reaches marginally scored as not disturbed using the index. Among the seven higher-gradient reaches included in the macroinvertebrate assessment for this study, fine sediment was identified as a "likely stressor" in four reaches and as a "potential stressor" in three reaches, based on the inferred fine sediment values produced by the fine sediment stressor model and as supported by geomorphic and physical habitat data.

Conversely, water temperature once again did not appear as common a factor contributing to degradation of macroinvertebrate communities in the SWMACC service area. Temperature stressor model results from across multiple monitoring years suggested that the macroinvertebrate community from only one (M-TA-10) of the seven higher-gradient reaches was likely stressed by elevated water temperature, while an additional two reaches were potentially being stressed by elevated temperatures. The apparently larger influence of sediment than of temperature on degradation of macroinvertebrate communities in the SWMACC area is likely related to the small size of these tributaries and the dominance of fine sediment conditions along the valley bottoms of these tributary streams. Despite altered hydrology and degraded habitat conditions in most or all of these systems, the streams are sufficiently small and support suitably intact near-bank riparian conditions so as to preclude excessive warming of water temperatures before emptying into the Tualatin River. Conversely, altered hydrology, channel, and bank conditions will lead to increased sediment loading, irrespective of stream size. Therefore, while temperature-induced stress to aquatic communities is not likely to occur in these small streams, sediment induced stress appears to be common among them, and also indicated by the geomorphic results.

2017 marked the sixth year of macroinvertebrate sampling in the SWMACC service area by WES since this monitoring was initiated in 2002. Only three streams - Athey Creek, Fields Creek, and Unnamed tributary 4 – have been sampled each assessment year (2002, 2007, 2009, 2011, 2014, and 2017) for macroinvertebrate community conditions consistently in riffles. Collectively, their results suggest that macroinvertebrate conditions in these streams largely appear to have remained unchanged, if not slightly improved, in some cases. The average multimetric score across these three reaches has increased from 24.7 to 35.3 from 2002 to 2017. Continued monitoring will be necessary to determine whether this apparent trend "holds", thereby providing stronger weight-of-evidence that a change has in fact occurred.

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 (6 of 9) received an overall geomorphic condition rating of "stable – at risk" or "stable", and conditions of macroinvertebrate communities in most reaches were deemed to be stable or even slightly improving. Three reaches included in both the geomorphic and macroinvertebrate studies received geomorphic condition ratings of "At Risk", "Unstable", or "At Risk – Unstable". G-TA-10/M-TA-10 received the only "unstable", and while monitoring hasn't occurred here long enough to know whether the biology may presently be in decline, fine sediment stressor model results and

MWCF model results both suggest a presently stressed condition. G-SA-10/M-SA-10 received the only "At Risk" overall channel condition rating. This lower-gradient and partially backwatered reach does not support sufficient riffle habitat for macroinvertebrate sampling. As such, sampling occurs in glides resulting in uniformly low MWCF O/E scores and MMI scores across all years.

Fields Creek (G-FE-20/M-FE-20) received the only geomorphic condition rating of "At Risk – Unstable". Fields Creek presents a unique set of circumstances among the SWMACC-area streams. Occurring primarily in a forested setting until flowing through the sample reach at Bosky Dell Nursery, this reach, despite its local geomorphic instability, supports a diverse macroinvertebrate community. This reach has consistently received among the highest MMI and O/E scores, likely the result of generally good water quality and habitat conditions. Furthermore, when there are localized disturbances to the banks and bed in this reach, the upstream sections of this creek serve as an immediate source of recolonization. Accordingly, occasional localized geomorphic instabilities in this reach are likely to have few long-term detrimental effects to the benthic community. In general, future monitoring should continue to examine overall geomorphic condition ratings in relation to apparent trends in 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 any lack of correspondence between these two aspects of the work may simply indicate that other factors are at play in affecting biological conditions.

Once again, MM and O/E scores often did not produce congruent biological condition classes. All reaches from which riffles were collected scored between no disturbance and moderate disturbance using the multimetric index, yet almost half of these reaches scored as most disturbed using the MWCF predictive model. As in previous years, the 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 by the MWCF O/E model to occur at more than half of the sites under least-disturbed conditions. This across-the-board absence of specific taxa from all or nearly all SWMACC samples results in lower O/E scores than 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 specific 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, with no consideration to *which* of those taxa within a class or category is present or absent. In some studies, O/E scores and multimetric scores have shown generally good correspondence, but when they don't correspond, the O/E scores tend to be lower than the multimetric scores. This same finding occurred in the 2011 and 2014 WES studies of macroinvertebrates in the SWMACC area. Considered together in Figure 6, MWCF O/E scores consistently underperform the corresponding MM scores. Because correspondence in condition classes often does not 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 SWMACC 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 type and certain physical habitat characteristics. Pooling the 2017 sample data across both service areas (SWMACC and CCSD #1) once again 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 for riffles samples were highly correlated with percent urban, agriculture, urban/agriculture, and forest land use types. These same correlative relationships have occurred in each study year. Scores were once again 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. The Fields Creek reach (M-FE-20), which shared the highest multimetric score among all reaches in both services districts, had the lowest percentage of urban land use in the drainage basin upstream of the reach (8.8 percent). Conversely, the Carli Creek reach (M-CA-10; CCSD #1), which received the lowest multimetric score among all reaches in both services districts, had the highest percentage of urban land use in the drainage basin upstream of the reach (98.9 percent).

As in previous years of sampling SWMACC stream reaches for macroinvertebrates, no freshwater mussels were sampled in 2017. This does not demonstrate that they are absent from SWMACC 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 SWMACC streams.

Urban development results in large impervious surface areas that modify hydrologic patterns and 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 modified 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. 2016). 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. Among the streams sampled by Carpenter et al. (in prep) for pesticides, none were included in this study.

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 constructed wetlands and retention facilities also serve to remove pollutants through physical, chemical, or biological processes. Further development within the lower Tualatin River basin 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 re-assess geomorphic and biological conditions at stream monitoring stations throughout Clackamas County's SWMACC Service Area, and provide some general and specific recommendations based on the observations. In 2017 we revisited geomorphic and macroinvertebrate monitoring stations on tributary streams to the lower Tualatin River that were previously surveyed in 2002, 2007, 2009, 2011, and 2014. Changes in channel morphology influence instream physical habitat; for example, geomorphic patterns determine the distribution of slow- and fast-water habitat units, as well as substrate composition associated with the various types of habitats.

Summary Observations

All of the stream channels evaluated in this assessment have been impacted in some way by land use changes and hydromodification. In most study reaches, hydromodification has resulted in moderately incised stream channels that are inset into wider valley bottoms. This incision restricts access to historic floodplain areas, which in turn confines higher flows to the primary channel, resulting in more energy being concentrated on the bed and banks of the channel. Because historic floodplain deposits in the lower Tualatin River drainage basin are composed primarily of fine grained sediment, streambanks comprised of these materials are particularly vulnerable to erosion.

In the SWMACC study area, 3 of the 9 geomorphic monitoring sites have severe bank erosion exceeding 10 percent of the total bank length: Fields Creek, Middle Saum Creek, and Tate Creek. In addition, 4 of the 6 sites where bulk samples were collected have riffles composed of more than 25 percent sand. This may be a reflection of the local geology and topography, but may also reflect accelerated rates of erosion and the locations of some of the monitoring reaches in areas backwatered by culverts.

Table 19, which summarizes the geomorphic condition of SWMACC Monitoring reaches, identified two incising reaches: Tate Creek (G-TA-10) and Unnamed Tributary #2 (G-UK3-10). One of the reaches –Wilson Creek (G-WI-10) – appears to be aggrading now, as a result of a restoration project, after having been previously incised reaches. Active headcuts were documented in four of the reaches, signifying that headcuts are common throughout these watersheds.

Efforts to reverse incisional trends and the impacts of hydromodification would benefit channel morphology, substrate, and physical habitat.

Table 20 summarizes categorical stream "conditions" for several geomorphic measures of stability published in the literature, and the corresponding scores for the SWMACC geomorphic monitoring reaches from the 2014 survey[5]. Channel condition for each study reach is presented in Table 21. This assessment has not changed in 2017. Throughout the 9 reaches with geomorphic monitoring, none were rated with low floodplain connectivity, 5 were rated 'At Risk' for bank stability, and 6 had high sediment intrusion ratings. Qualitative assessment and professional best judgement led to an overall rating of 'At Risk,' 'Unstable,' or 'At Risk – Unstable' geomorphic rating for three of the sites.

[5] Because of some updates in the 2017 field survey methodology, field data were not collected to determine the floodplain width; so the 2014 data was used to estimate "Entrenchment".

The most at-risk geomorphically unstable sites are listed below with some recommendations on how they may be addressed or monitored.

Table 20. 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 21. Qualitative assessment of 2017 channel conditions for each study reach - Surface Water Management Agency of Clackamas County SWMACC Area, Oregon.

Site ID	Floodplain Connectivity	Bed Morphology	Stream Bank Conditions	Degree of Fine Sediment Intrusion	Overall Channel Condition
G-AT-10	Moderate	Plane Bed	Stable	NA	Stable
G-FE-20	Moderate	Pool-Riffle	At Risk	NA	**At Risk - Unstable**
G-PE-10	Moderate	Plane Bed	At Risk	High	Stable - At Risk
G-SA-10	Moderate	Backwatered	At Risk	High	**At Risk**
G-SA-20	Moderate	Plane Bed	Stable - At Risk	High	Stable - At Risk
G-T4-10	High	Plane Bed	Stable - At Risk	High	Stable
G-TA-10	High	Plane Bed	At Risk	High	**Unstable**
G-UK3-10	High	Plane Bed	At Risk	High	Stable – At Risk
G-WI-10	High	Pool-Riffle	Stable - At Risk	Moderate	Stable

Monitoring Recommendations

To further this dataset's value for understanding long-term changes in channel morphology and ecological conditions, we make the following recommendations:

- The geomorphic monitoring effort described in this report continue to be updated every three years and following storm events that exceed a 10-year recurrence. Geomorphic data collected in the future should be compared to the baseline data collected in the first few years of this monitoring effort to assess long term trends.
- Consider adding potential "reference sites" that have not been significantly impacted, and where additional impacts associated with hydromodification are not expected to occur. Reference sites will provide a metric for comparison with impaired reaches. Because of limited existence of unimpacted reference sites west of the Willamette River and within the SWMACC Service Area, it may be possible to use a site such as SWMACC-G3 (Upper Wilson Creek) as a reference site. Although this site has experienced considerable impacts associated with hydromodification, METRO has developed a strategy to protect the Wilson Creek watershed for the long-term. WES could partner with METRO within this watershed to ensure that any development that does occur carefully considers the potential impacts of hydromodification on creek function and establishes goals for Low Impact Development (LID) or other stringent controls on stormwater runoff in the watershed that could be a pilot for development elsewhere in the SWMACC Service Area.
- Macroinvertebrate monitoring should continue at the same interval (every three years) as the geomorphic monitoring. The biological data collected ultimately reveals the overall ecological conditions of SWMACC streams (as affected by both the physical and chemical environment). To the extent possible, geomorphic and macroinvertebrate monitoring reaches should continue to be co-located to allow further examination of relationships between stream stability, geomorphic condition, habitat quality, and ecological condition.
- 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 likely causes of measured degradation to biological conditions in SWMACC 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.
- Detection of longer-term trends in biological conditions in the SWMACC 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. As of 2017, eight reaches have been monitored for biological condition since 2002 (and some of some reaches have been shifted short distances owing to access issues or habitats sampled have changed). Continued co-location of monitoring activities and consistency in station

selection will allow for larger numbers of streams to amass numerous years of comprehensive data sets. Monitoring activities currently being conducted within the SWMACC service area include the biological (macroinvertebrates) and geomorphic monitoring detailed here, as well as water chemistry and stream flow monitoring. WES administers a creek water quality and flow monitoring program within the SWMACC. 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. The macroinvertebrate and geomorphic survey reach within Pecan Creek is clustered with the WES#11 monitoring location. The water quality monitoring site in Pecan Creek is visited nine times per year.

Site-Specific Recommendations

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

Fields Creek (G-FE-20): Although the bank and bedforms present in this reach are relatively stable, there is a significant risk to channel conditions through this reach due to the presence of an unmaintained pond and associated dam upstream. Evidence suggests that the dam that creates the pond is at risk. A catastrophic failure of the dam is unlikely, but there is a high potential that a channel could erode around the dam itself resulting in rapid upstream migration of an existing knickpoint that could deliver a large amount of coarse bedload to downstream reaches. An undersized culvert at the downstream end of the reach at Elderberry Road would likely be overwhelmed, quickly aggrading the project reach and causing flow to exit the channel with unknown consequences. In 2013, WES funded a more detailed evaluation of this site to understand the failure of risk at the site and assess opportunities to either stabilize the site or develop a more comprehensive restoration plan. The assessment identified a list of alternatives to address the observed conditions. The landowner was not willing to allow a restoration project on the property.

Tate Creek (G-TA-10): This site can be characterized by the following attributes: 1) There is clear evidence of active incision and headcut, and 2) Future incision is not limited by the presence of bedrock in the bed of the channel. Consequently, existing and/or future development in this watershed could increase the rate of incision and eventually lead to lateral erosion once resistant bed material is reached and vertical, exposed, fine-grained bank materials begin to erode. The 2014 and 2017 monitoring data showed that the active headcut migrated upstream an average of approximately 5 feet per year. Assuming this rate continues into the future, the headcut will likely undermine the upstream culvert and associated road fill in approximately 10 years. This channel should be closely evaluated to record changes in bed elevation and acceleration of incision or lateral movement of the channel. Where structures are present, incision and/or lateral channel movement can result in risks to life and property.

Lower Saum Creek (G-SA-10): Although this site does not present a significant risk to the regional stability of lower Saum Creek, in 2014, Waterways recommended that site conditions warranted consideration of the site for restoration. The single family residence located adjacent to the stream channel had been unoccupied since monitoring began in 2009, presumably due to the flooding hazard at the site. In 2017, however, there is a new occupant of the house who may experience flooding and erosion on the property. The creek surrounds the house on 3 sides with two bridges crossing the channel, and the house and associated infrastructure may be at risk from flooding. Much of the riparian vegetation and ground cover is non-native, with large amounts of ivy covering mature trees. Given site conditions, the property may present an opportunity to address bank stability, restoration of a more intact floodplain, removal of non-native vegetation and restoration of a native riparian corridor. Any work on this site, which is on private property, would have to be approved by the new homeowner and care taken not to further increase the risk. However, a project might be able to be designed there that could benefit stream quality while also reducing this homeowner's flood and erosion hazard.

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APPENDIX A

Geomorphic Summary Figures

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APPENDIX B

Macroinvertebrate Summary Figures

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APPENDIX C

Completed Geomorphic Field Data Sheets

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APPENDIX D

PSI, Inc. Laboratory Report

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APPENDIX E

Response to Comments (RTC) Table