EVALUATING RIPARIAN HEALTH ASSESSMENT METHODS FOR PERENNIAL STREAMS IN MONTANA

by

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TABLE OF CONTENTS

TABLE OF CONTENTS – CONTINUED

LIST OF TABLES

LIST OF FIGURES

Figure Page

ABSTRACT

The purpose of this study was to evaluate current riparian assessment protocols and to determine if they reflect ecosystem function and/or water quality across large spatial scales, and are they congruent in their assessment of stream health. Objectives for this study include: 1) to compare three riparian assessment protocols in their agreement of evaluation of stream health, 2) to compare each protocol and a bank stability measure (Greenline) to a measure of aquatic macroinvertebrate diversity and richness, 3) to compare how well these protocols reflect water quality and instream conditions on perennial streams located in western and eastern Montana, and 4) determine how sensitive the protocols are to different geological provinces and water source. Five streams were located in western Montana where the water originated from high elevation snow pack. Five more streams were measured in eastern Montana with water originating from prairie springs. Aquatic macroinvertebrates and environmental parameters were measured along four reaches on each stream. All aquatic macroinvertebrates were keyed to family, and orders Ephemeroptera-Plecoptera-Trichoptera (EPT) were keyed to genera. Three lotic assessment protocols (Proper Functioning Condition (PFC), Riparian Assessment for Lotic systems (NRCS) and Stream Visual Assessment Protocol (SVAP)) were used at each of the reaches measured to assess riparian health. Following data analysis the Stream Visual Assessment Protocol (SVAP) was the only method that had a significant correlation with geological province and aquatic biotic integrity. The SVAP assessment could distinguish differences between western and eastern geological provinces ($P < 0.01$), reflected EPT diversity ($R^2 = 0.75$), EPT richness ($R^2 = 0.87$), and water quality ($R^2 = 0.80$) better than the other methods. However, the PFC and NRCS assessment protocols were the most similar in stream health ratings (*kappa* = 0.52). Overall the SVAP most accurately reflected instream conditions across Montana. Only the SVAP reflected taxonomic distributions with a correlation coefficient > 0.90. Substrate composition, discharge (CFS), elevation, average annual precipitation, water quality, and glide habitat types were correlated (≥ 0.70) with macroinvertebrate taxonomic distribution and composition. Results of this study suggest that SVAP should be used when management goals are focused on perennial streams and whether or not those streams can support a particular fishery in Montana.

INTRODUCTION

The evaluation of streamside or riparian health as part of land management decisions has become a major focus of government agencies, private land owners, and public users (Fleming et al. 2001). These interests coincide with the desire to maintain or restore stream ecosystem stability and biotic integrity (Resh et al. 1995). Throughout the past decade numerous stream and riparian monitoring methods have been developed by federal and state agencies interested in characterizing the health of these systems. Approximately 90% of the states have, or are developing, biological monitoring methods and water quality programs (Southerland and Stribling 1995). Federal agencies that currently use a combination of biological and physical criteria for stream and riparian monitoring methods include the Natural Resources Conservation Service (NRCS), Bureau of Land Management (BLM), U.S. Forest Service (FS), and Environmental Protection Agency (EPA). Many of these monitoring methods were incorporated into assessment protocols, which provide a qualitative rating of a stream and riparian system's health in relation to its potential natural community (Prichard 1998; NRCS 2004a). Furthermore, many of the current assessment protocols primarily quantify the status and trend of physical instream habitat and channel conditions (Henderson et al. 2002; Gallo 2002).

Because these assessment protocols are visual estimates or subjective classification of physical parameters of stream systems (Poole et al. 1997), their use provides an indirect assessments of riparian health and biotic integrity. Not only may different assessment protocols produce different stream health assessment ratings, but observers using the same protocol may differ in their evaluation of stream health within the same stream reach (Roper et al. 2002; Ward et al. 2003; Coles-Ritchie et al. 2004). Furthermore, assessment protocols are applied statewide, regionally and nationally, which may not consider potential differences in riparian ecosystems due to climate and physiographic province (Resh et al. 1995; Ward et al. 2003). The question arises: do current assessment protocols reflect ecosystem function and/or water quality across large spatial scales, and are they comparable in their assessment of stream condition?

The purposes of this study were to apply different riparian assessment protocols on perennial stream systems located in western and eastern Montana, and evaluate their ability to reflect ecosystem function and aquatic macroinvertebrate distribution across different climatic and physiographic provinces. Objectives for this study are: 1) to compare three riparian assessment protocols, 2) to compare each protocol with a bank stability measure (Greenline; Winward 2000), and aquatic macroinvertebrate assemblages in the same stream reach, 3) to determine how well these protocols reflect water quality and instream conditions, and 4) to determine how sensitive the selected protocols are to different geological provinces and water sources. The null hypotheses assume that quantitative measures of environmental parameters, aquatic macroinvertebrate assemblages, bank stability and qualitative measures of stream health assessment protocols will not differ across the state of Montana.

LITERATURE REVIEW

Assessment Protocols

Stream and riparian assessment protocols are qualitative monitoring methods developed to make land management decisions (Prichard 1998; Fleming et al. 2001). While based on quantitative science they are designed to serve as a starting point to evaluate stream and riparian health, and to identify and prioritize stream reaches or watershed systems that may require more in-depth study to prevent further degradation (BLM 2003; NRCS 2004a)

Assessment protocols are used to evaluate the conditions of key indicators that represent riparian and stream health (Fleming et al. 2001). Indicators generally include some combination of streambed geology and embeddedness, width/depth ratio, bank stability, stream channel characteristics, pool/riffle ratio, riparian area and flood plain characteristics, vegetation characteristics, canopy shading, and anthropogenic activity (Prichard 1998; NRCS 1998; Fleming et al. 2001; BLM 2003; NRCS 2004a). These stream and riparian characteristics help identify the system's state of resistance that will allow a riparian-wetland to maintain itself during high-flow events (Prichard 1998). Greater levels of resistance provide a stream system the opportunity to produce management goals for habitat, biotic diversity and production, trap sediment, dissipate energy, build streambank, store floodplain water, and aquifer recharge over long periods of time (Prichard 1998; NRCS 1998; BLM 2003; NRCS 2004a). Stream and riparian health scores and condition ratings are based primarily on the status of a system's physical and vegetative properties relative to the site's potential natural community (Prichard et al. 1998; NRCS 1998; BLM 2003; NRCS 2004a)

Criteria for these protocols have been based on quantitative measures and land management experience. However, agreement amongst assessment protocols is limited. Protocols that address similar stream and riparian attributes may have better correlations and agreements than protocols that emphasize other physical and vegetative features. One example includes results from a comparison among three assessment protocols (U.S. Department of Agriculture's Natural Resources Conservation Service's (NRCS), Stream Visual Assessment (SVAP), Environmental Protection Agency's (EPA) Habitat Assessment Field Data Sheet (HAFDS), and U.S. Department of Interior Bureau of Land Management's (BLM) Proper Functioning Condition (PFC)) applied to 234 rangeland riparian areas in California (Ward et al. 2003). The SVAP and HAFDS are habitat driven assessments and had the best positive correlation (r = 0.81) between stream and riparian scores. Proper Functioning Condition ratings of stream and riparian health on the other hand had a weak correlation with SVAP and HAFDS (r = 0.58 and 0.54) (Ward et al. 2003). A second example includes a comparison of six different protocols used by the USDA Forest Service and the Environmental Protection Agency, which was conducted on three streams in Oregon and Idaho (Whitacre 2004). Combined results from Oregon and Idaho streams indicated that 8 of 11 attributes differed amongst the protocols (Whitacre 2004). In addition to differences in assessments of stream and riparian health, riparian identification teams assessed the same reach differently even when using the same protocol and/or monitoring the same stream and riparian physical attributes (Poole et al. 1997; Roper et al. 2002; Coles-Ritchie et al. 2004). Their results suggest that identification teams evaluated physical and vegetative attributes along the same reach differently.

Local versus Catchment Scale

Another source of potential bias in assessment outcomes is the link between local and watershed conditions. Local and catchment scale features within watersheds influence a stream's and riparian area's biotic and abiotic dynamics. Instream habitat structure and organic inputs are influenced primarily by local conditions such as riparian vegetative cover at a site (reach) (Allan et al. 1997). Local vegetative characteristics influence stream channel stability and sediment retention along banks adjacent to the channel (Clary and Leininger 2000). The structure of riparian vegetation not only provides stability but strongly influences aquatic biota, amphibians, and fish by increasing habitat diversity and water quality (Winward 2000; Kauffman et al. 2001).

Catchment scale landscape geologic features, vegetative cover, and land use have a greater influence on the nutrient supply, sediment delivery, hydrology and channel dimensions within a stream system than local conditions (Richards et al. 1996; Allan et al. 1997). For example the Index of Biotic Integrity (IBI) and Habitat Index (HI) were influenced more by catchment scale features and management practices (IBI with % area with agriculture, $r^2 = 0.50$, HI with agriculture, $r^2 = 0.76$), whereas correlations with local scales were weak and non-significant (Roth et al. 1996). Hence, catchment scale features and regional land use may be the primary determinant of stream conditions, which should be considered to both monitor and manage biodiversity rather than simply assessing local conditions (Richards et al. 1996; Roth et al. 1996; Harding et al. 1998; Nerbonne and Vondracek 2001). Information such as catchment interactions within a stream ecosystem is important when considering the development of assessment protocols and their ability to reflect catchment scale features and catchment level management practices.

Aquatic Macroinvertebrates

Aquatic macroinvertebrates are a commonly used tool to evaluate catchment and stream health. They are used more often than any other freshwater organisms to assess the health of a stream system on both local and catchment scales (Voshell 2002). Because these taxa consist of a variety of species with different life histories, sensitivities to degradation, and function in the ecosystem, they respond to shifts in catchment geological features and pollution sources such as urbanization (Wiggins 1996; Bollman 2002; Wang and Kanehl 2003; Wang and Lyons 2003). Measured assemblages of these organisms also represent a cumulative measure of a watershed that reflects influences of hydrology, channel morphology and geology, and water quality and quantity. Consequently the cumulative measures are proven indicators of overall quality and health of stream ecosystems (Karr and Chu 1999; Wang and Lyons 2003). Inventories of aquatic macroinvertebrates have become a popular method because fewer samples through time and space need to be collected versus the number of samples needed to measure diurnal variations in water chemistry (Nimick et al. 2003).

Because of the apparent utility of aquatic macroinvertebrates numerous methods have been developed for freshwater and salt water ecosystems. For example, the Field Biotic Index (FBI) is a formula developed to measure water quality that uses tolerance/intolerance values of freshwater taxa (Hilsenhoff 1988). Tolerance/intolerance values represent a family, genus, or species sensitivity to organic water pollutants (Barbour et al. 1999). Community assemblages and functional feeding groups are also used as indicators of water quality, trophic feeding groups, and the river continuum concept (Allan 1995; Barbour et al. 1999).

Three orders of aquatic insects have gained much attention by resource managers which include: Mayflies (Ephemeroptera), Stoneflies (Plecoptera), and Caddisflies (Trichoptera). These orders typically referred to as EPT are generally identified to genera and/or species to strengthen measures of sensitivity, functional feeding groups, diversity, and richness in streams. These three orders have been thoroughly studied, and are considered reliable indicators of organic and sediment pollutants in stream ecosystems (Barbour et al. 1999).

Species diversity and richness measures represent another measure for evaluating aquatic sustainability. Species diversity can be used to indicate an ecosystem's physical and biological condition (Magurran 1987), and is often summarized with either the Shannon's or Simpson's diversity indexes. The Shannon's index of diversity measures equality in frequency of all species present within the community, whereas the Simpson's index is used to express the relative concentration of dominance of species within a community (Peet 1974; Gurevitch et al. 2000). Multimetric correlations of aquatic macroinvertebrate taxonomic presence and distribution in relation to environmental variables are also methods used for describing the ecology of a stream ecosystem. These methods improve our understanding of organisms relative to their environmental conditions (Wang and Kanehl 2003).

Many studies that measured aquatic macroinvertebrate assemblages have identified several environmental variables that correlate with presence/absence and distribution of these organisms. One key variable is watershed condition, which may have the greatest influence on aquatic macroinvertebrate taxonomic distributions (Weigel et al. 1999). This includes geological and regional management practices at the catchment level that dictate physical environmental variables such as stream substrate composition, channel morphological features, and water chemistry.

Substrate composition especially in relation to the proportion of sediment and embeddedness is a primary determinant of aquatic community structure, and has a negative correlation with aquatic macroinvertebrate diversity and presence/abundance of taxa with low tolerance values (Beisel et al. 1998; Lammert and Allan 1999). Percent fines and the resulting stream embeddedness an organic pollutant and results in the lowest representation of EPT taxa and a reduction in aquatic biota diversity (Waters 1995; Weigel et al. 1999; Nerbonne and Vondracek 2001). In contrast, large stream ecosystems with high flow and substantial flow events have the highest community stability to maintain aquatic populations especially for Ephemeroptera, because accumulations of sediment are flushed from the channels, flood plains are maintained, and gravel bars are rebuilt (Naiman et al. 2000; Scarsbrook 2002). Besides fine sediments, water temperature has a high correlation with dissolved oxygen which is an important component in water quality, aquatic macroinvertebrate and fish taxa presence and distribution within and across stream ecosystems (Turak et al. 1999; Wang and Kanehl 2003). Higher water temperatures reduce concentrations of dissolved oxygen within the water (Wetzel 2001), which can be detrimental to aquatic species. All of these environmental variables have a high correlation with aquatic macroinvertebrates, which in turn reflect water quality and function of the stream ecosystem.

Reaches as the Replicate

Sampling multiple reaches or sites per stream is used to capture the inherent variability that may exist within a stream system. Comparison of streams or stream reaches may also be necessary when funds and other available resources are scarce to achieve maximum effectiveness when monitoring land management outcomes (Myers and Swanson 1992). However, autocorrelation and stochastic inhomogeneity are difficult to avoid when measuring attributes along streams. To avoid autocorrelation reach lengths should be approximately 30 channel widths or 10 transects spaced about 3 channel widths apart per transect to optimize sampling efficiency (Myers and Swanson 1997).

Similar methods that use multiple reaches per stream have been applied to many of the experimental designs reported within the literature. Consequently, ecological and riparian studies often differ in the total number of streams and reaches per stream sampled (Richards et al. 1996; Turak et al. 1999). For example in northeastern France, 12 reaches across 6 streams were measured (Beisel et al. 1998). In a second study in the River Raisin watershed, 18 reaches across 3 streams were measured (Lammert and Allan 1999). A similar approach was used on the upper and middle River Raisin watershed where 23 sites or reaches across 7 streams were measured (Roth et al. 1996). On the Whitewater River watershed, 27 reaches across 6 streams were measured (Nerbonne and Vondracek 2001). For each of these studies the reach (site) rather than the stream was used as the sampling unit in their statistical analyses to detect changes in morphological characteristics and/or changes in management practices.

Kappa Coefficients

The kappa coefficient is primarily used in the medical field of sciences as a way to test the level of agreement among individuals rating or scoring a patient's state of health (SAS/STAT 1999). This method compares percent agreement among observers and/or the reliability of different methodologies used to measure a state of condition such as patients' diagnosis of cancer (Landis and Koch 1977; Friedman and Margo 2000; Hoehler 2000; Raitanen et al. 2002). Kappa is used in reliability studies that involve the analysis of categorical data (Hripcsak and Heitjan 2002). Kappa percent agreement is always less than or equal to one, where values of 1 implies perfect agreement and values less than 1 implies less than perfect agreement (Landis and Koch 1977). Kappa values can be negative, which indicates that the two observers or methodologies agreed less than what would be expected. The interpretation of Kappa coefficients is a range where values < 0.00 = poor agreement, 0.00 – 0.20 = slight agreement, 0.21 – 0.40 fair agreement, 0.41 – 0.60 = moderate agreement, 0.61 – 0.80 = substantial agreement, and 0.81 – 1.00 = almost perfect agreement (Landis and Koch 1977).

MATERIALS AND METHODS

Site Descriptions

Ten streams were randomly selected across Montana; 5 streams were located in eastern Montana and 5 in western Montana. Streams were selected based on four criteria: 1) streams were located in Montana, 2) streams were low gradient (< 0.02%) and perennial, 3) streams located in western Montana derived their source from the major mountain ranges, and 4) streams located in eastern Montana derived their source from prairie watersheds.

The five western study reaches were classified as Rosgen C type morphologies typical of open meadows (Rosgen 1996). Western streams were located on private property and subject to annual grazing and hay production. These streams were Cottonwood Creek, Lower and Upper Nevada Creek, South Boulder Creek, and South Willow Creek. South Boulder and South Willow Creek sections had similar average annual precipitation (460 mm) and base elevations ranging between 1,615 m – 1,737 m (WRCC 1999). Both of these streams have deep to very deep well drained soils with a texture that is predominantly sandy to course sandy loam. Parent material consists of granite, limestone, and igneous rock (NRCS 2004b). The other three western study reaches have similar elevations (1,250 m – 1,433 m), and deep to very deep, poor to well drained soils (NRCS 2004b). Cottonwood Creek has the highest average annual precipitation (530 mm) of the western streams, and a soil texture that is predominately a gravelly loam (NRCS 2004b; WRCC 2004f). Cottonwood Creek along with the 2

Nevada Creek sections drain landscapes dominated by glacial till and drift parent material. Nevada Creek has an average annual precipitation of 470 mm, and a loam to a silty clay loam soil texture (NRCS 2004b; WRCC 2004c). The Nevada Creek sections are divided by the Nevada Creek Reservoir. Upper Nevada Creek is located three miles above the reservoir, whereas Lower Nevada Creek is located four miles below the reservoir. For more information see Appendix A.

Perennial eastern streams were more difficult to locate due to limited numbers in the prairie environment. The five stream sections selected were located on private property with Rosgen stream classifications ranging from E to G type morphologies (Rosgen 1996). C type stream morphology is rare to nonexistent in the prairie environment. Streams systems that did resemble C types were typically larger rivers that derived their source from mountainous terrain more than 160 km from the study site. The five eastern streams, Little Spring Creek, Louse Creek, Mission Spring Creek, Rosebud Creek, and Otter Creek were subject to both annual grazing and hay production. Louse Creek, the northern most of the eastern Montana streams, has an elevation of 1,192 m and an average annual precipitation of 390 mm (WRCC 2004e). Soils are very deep, well drained loam to silty clay loams with parent materials that consist of limestone and marly shale (NRCS 2004b). Little Spring Creek is located at an elevation of 1,341-m and receives about 390 mm of annual precipitation (WRCC 2004a). Soils are moderate to deep, well drained loam and clay loams, and parent materials consist of mudstone, siltstone, and sedimentary beds (NRCS 2004b). Mission Spring Creek derives its source from the Yellowstone River through hyphoreic flow and resurfaces in hay meadows at an elevation of 1,323 m, and receives an average annual precipitation of 420 mm (WRCC 2004d). Soils are very deep, poor to well drained loam and silty clay loams, and parent material is predominantly derived from alluvium deposition (NRCS 2004b). Otter and Rosebud Creeks are located in the southeastern corner of Montana with elevations at 884 m – 975 m. Rosebud Creek soils are very deep, well to moderately drained loams, formed primarily from sandstone and shales (NRCS 2004b). The area receives about 360 mm of annual precipitation (WRCC 2004b). Otter Creek soils are very deep, well drained loams, formed from parent materials of scoria and sandstone (NRCS 2004b). Annual precipitation averages 330 mm (WRCC 2001). For more information see Appendix B.

Stream and Riparian Assessment Protocols and Bank Stability Ratings

In this study we evaluated 3 commonly used riparian assessment protocols: Proper Functioning Condition, the Stream Visual Assessment, and the Riparian Assessment for Lotic Systems. Assessment protocols were used to rate riparian and stream ecological function and health of lotic systems. We used identification teams consisting of local NRCS and BLM employees to assess each reach to avoid researcher bias. The researcher measured bank stability and instream biotic and abiotic parameters.

Proper Functioning Condition (PFC)

This assessment protocol is a modified version of the original PFC (Prichard 1998), and was developed by the USDI Bureau of Land Management (BLM) in the states of Montana and Idaho. The protocol is described in the US Lotic Wetland Health Assessment for Streams and Small Rivers (*Survey*) (BLM 2003). It is a first approximation designed to provide a rapid visual assessment of a stream's health and condition. Proper Functioning Condition assessment is based on a combination of physical, hydrologic, and vegetative factors. These factors address a stream's or reaches's ability to perform certain functions such as: trap sediment, build and maintain banks, store water in the flood plain, recharge aquifers, dissipate flow energy, maintain biotic diversity, and primary production. The condition of a reach is ranked by scores totaled for the 11 factors evaluated and that total is divided by the possible maximum score and multiplied by 100. The resulting score is used to select a rating category: proper functioning (80% – 100%), functioning at risk (60% – 79%), or nonfunctioning (< 60%). For more information see Appendices C and D.

Riparian Assessment for Lotic Systems (NRCS)

This assessment protocol was developed by the Montana Natural Resource Conservation Service in 2004, to provide a rapid assessment of sustainability and function of lotic riparian systems (NRCS 2004a). The NRCS protocol is similar to PFC protocol, and is designed as a "first cut" visual evaluation of a lotic riparian system health and condition. Scores are based on reach similarity to the highest ecological status or potential natural community of that system. This assessment protocol is used primarily to evaluate factors that support critical riparian functions such as: trap sediment, build and maintain banks, store water in the flood plain, recharge aquifers, dissipate flow energy, maintain biotic diversity, and primary production. The NRCS protocol rates specific stream locations or reaches by dividing the summed scores of 10 factors by the potential score and multiplying it by 100. The rating is then categorized as sustainable (80% – 100%), at risk (50% – 80%), or not sustainable (< 50%). For more information see Appendices C and D.

Stream Visual Assessment Protocol (SVAP)

This assessment protocol was developed by the Aquatic Assessment Workgroup (NRCS), to evaluate condition of aquatic environments associated with lotic systems (NRCS 1998). The SVAP is based primarily on physical conditions that relate riparian and instream attributes to ecological health criteria. The SVAP assesses ecosystem complexity and diversity of habitat for organisms and related functional hydrologic properties. This protocol was designed to be an easy to use visual assessment for landowners to evaluate lotic conditions and trend through continued monitoring on their lands. The SVAP rates sites or reaches by dividing the summed scores of 15 factors by the number of actual factors scored. The rating is then categorized as excellent (> 9), good (7.5 – 8.9), fair (6.1 – 7.4), or poor (< 6). For more information see Appendices C and D.

US Forest Service Greenline Bank Stability (GL)

This measure evaluates the first vegetative community types on or near the water's edge and their ability to buffer against forces of moving water (Winward 2000). Riparian vegetative community structure measured adjacent to the stream channel is the basis for this methodology assuming that each community type is an indicator of channel and bank stability. Assessment of individual reaches were summarized by a stability rating of excellent (9 – 10), good (7 – 8), moderate (5 – 6), poor (3 – 4), or very poor (0 – 2) (Winward 2000). For more information see Appendices C and D.

Study Design

Selected stream sections were divided into 4 individual reaches, each approximately 30 channel widths in thalweg length to avoid stochastic inhomogeneity (Myers and Swanson 1997). Multiple reaches per stream were used to capture the inherent variability within stream systems (Myers and Swanson 1992; Roth et al. 1996; Beisel et al. 1998; Lammert and Allan 1999; Turak et al. 1999; Nerbonne and Vondracek 2001). However, to maintain the same number of reaches for each private land ownership we were unable to achieve the study reach length recommended by Myers and Swanson (1997) on South Boulder Creek, Cottonwood Creek, South Willow Creek, and Otter Creek. Reach lengths on these streams were set at approximately 110 m in thalweg length. For the remaining 6 streams 110 m in reach length was more than sufficient. Individual reaches were separated by a minimum distance of 6 times channel width or if a reach could not fit within management boundaries (i.e. fences) it was placed on the other side of the boundary so that it would not be divided to avoid autocorrelation (Myers and Swanson 1997). On some streams all reaches were exposed to the same management practice, whereas others were separated by fenced boundaries and exposed to different livestock and irrigation management practices. Streams where reaches differed in management were Cottonwood Creek, South Willow Creek, Louse Creek, Little Spring Creek, and Mission Spring Creek. Each reach was designated the sampling unit.

Riparian and Instream Measures

We measured riparian and stream channel characteristics to compare with aquatic biotic integrity, and to distinguish which assessment protocol consisted of environmental parameters that best reflected distributions of aquatic macroinvertebrates. Riparian and instream measurements consisted of channel and floodplain cross-section morphologic characteristics, substrate composition, discharge, instream habitat, riparian vegetative composition, and aquatic macroinvertebrate assemblages. All variables were measured during base flow to reduce variability.

Cross-sections randomly located were established as the starting point for each reach. Methods used to measure channel and floodplain cross-section morphology are based on Rosgen (1996). Variables measured were entrenchment ratio, gradient, Wolman pebble count, and discharge measured in cubic feet per second (CFS). Entrenchment ratio describes the stream's ability to access its floodplain during high flow events, which enables the stream to dissipate energy, reduce bank erosion, and store water in the flood plain. Gradient was measured using a survey transit by taking stream water surface elevation measures 30-m upstream and 30-m downstream from the permanent reach cross-section and dividing the difference in elevation by 60-m. The Wolman pebble count was developed to characterize substrate composition of percent fines and course material (Wolman 1954). A grid was also used to calculate percent surface-fines, which estimated stream bed coverage by particle sizes less than 2-mm in size (Overton et al. 1997; T. McMahon, Montana State University, personal communication). Grid measurements were measured in the tail-outs of three different pools within a reach to calculate a mean for percent fines.

Instream habitat structures selected for measurement were based on Overton et al. (1997). Measured structural habitat components were pools, riffles, and glides. Width depth ratios, surface area and volume were measured for each habitat component within the entire length of each reach. Habitat measures for cover were based on undercut banks, vegetative overhang, and large wood and boulders along and within the stream channel throughout the length of the reach. Bank stability (Greenline) was measured on each side of the stream for the length of each reach.

Aquatic macroinvertebrates were sampled in three different riffle habitat types or glides when riffle habitats were not available in each reach. This produced 12 samples per stream. Samples were collected in September in 2003 and 2004. Insects were collected using a D-frame dip net constructed of 800 x 900 µm mesh nylon net bag, and kicking the streambed material for one minute per sample per habitat. Samples were then stored in whirl packs with 2 x Kahles solution, and were taken to a lab for sorting and identification. Samples were picked and sorted to approximately 500 organisms. Identification to the family level was done except for Ephemeroptera-Plecoptera-Trichoptera (EPT), which were identified to genus following Merritt and Cummins (1996).

Once the aquatic macroinvertebrates were identified they were then placed into functional feeding groups and tolerance values to organic pollutants (Barbour et al. 1999). Tolerance values were used to calculate the field biotic index (FBI) to identify water quality of each reach (Hilsenhoff 1988). The aquatic macroinvertebrate assessment was also used to determine biotic diversity. Family and EPT diversity were measured by Shannon's H' (Peet 1974; Gurevitch et al. 2002). For more information see Appendices E through K.

Data Analysis

Individual reaches were considered the sample unit (sample size $n = 40$ units), and a significance level ≤ 0.05 was used in all statistical analyses. A two sample *t*-test of the mean assessment scores between western ($n = 20$) and eastern ($n = 20$) stream reaches were compared to see if any of the assessment protocols and/or GL distinguished catchment geological shifts within the state. Assessment protocols and GL were left in their numerical scores for this analysis. A simple *kappa* coefficient was used to measure interrator agreement between assessment protocols and GL (Hoehler 2000; Hripcsak and Heitjan 2002). First assessment protocols and GL were placed into their functional rating categories: proper functioning/sustainable/good-excellent, at risk/fair/moderate, and nonfunctioning/not sustainable/poor-very poor. The functional rating categories were set at 3 for good condition, 2 for moderate condition, and 1 for poor condition for each protocol and GL. When *kappa* is positive the observed agreement exceeds chance agreement, and its magnitude reflects the strength of the agreement (SAS/STAT 1999).

If *kappa* is negative the observed agreement is less than the chance agreement. Agreement measures for categorical data are poor < 0.00, slight 0.00 – 0.20, fair 0.21 – 0.40, moderate 0.41 – 0.60, substantial 0.61 – 0.80, almost perfect 0.81 – 1.00 (Landis and Koch 1977). The test of symmetry, probability > than the statistic ($Pr > S$), specifies the level of agreement between protocols. If $Pr > S$ are greater than α of 0.05 then the agreement is considered to be similar.

Simple linear regression models (SLRM) were used to identify assessment protocols that best reflect EPT diversity, EPT richness, and tolerance/intolerance measures (FBI) (R Development Core Team 2004). The sample size for the SLRM was reduced to $n = 10$ using an average of the four reaches for each stream as the sample unit. This corrected for psuedoreplication of the predictor variables so that streams instead of reaches serve as the independent unit.

Conical Correspondence Analysis (CCA) was used to determine the importance of environmental variables that best correlate to the projected scatter diagram of aquatic macroinvertebrate taxa distributions sampled (R Development Core Team 2004). Taxonomic composition is directly related to the environmental variables where the individual taxa are the dependent variables and the environmental factors are independent variables (Ter-Braak 1986; Palmer 1993; Austin 2002). Inertia explained, correlation coefficients (CC), and eigenvalues of the first two axes were used to determine the importance of the specific environmental parameters and the model. Conical Correspondence Analysis was also used to determine the correlation between aquatic macroinvertebrates, assessment protocols and GL.

Two reaches measured on Otter Creek were not included in the CCA analysis due to difficulty in collecting aquatic macroinvertebrates on reaches 2 and 4 during drought conditions in September 2004. This produced a sample size of $n = 38$ for the CCA analyses. Other analyses remained the same as described above.

RESULTS

The SVAP was the only assessment protocol that differentiated between eastern and western stream reaches in the state of Montana (Table 1). Assessments from all other protocols including the GL did not differ between western and eastern provinces. Greenline did not differ ($P = 0.07$) between eastern and western stream reaches, but eastern stream reach health scores were usually higher.

Table 1. Two sample *t* test of assessment protocols and greenline scores for western and eastern stream reaches ($n = 40$)

	Location		
Protocol	West ± *SE*[5]	East ± *SE*	*P*
SVAP[1]	7.1± 0.2	5.0 ± 0.2	< 0.01
NRCS[2]	68.4 ± 1.7	75.0 ± 3.9	0.20
PFC[3]	76.1 ± 15.5	72.5 ± 13.6	0.40
GL[4]	6.9 ± 0.1	7.3 ± 0.2	0.07

[1]Stream Visual Assessment Protocol; [2]Riparian Assessment for Lotic Systems; [3]U.S. Lotic Wetland Health Assessment for Streams and Small Rivers (*Survey*); [4]Greenline; [5]Standard Error

The simple kappa coefficients for agreement between protocol ratings of reach condition are represented in Table 2. The PFC and NRCS were the only assessment protocols that agreed on stream reach health condition. However, the relationship between PFC and NRCS is moderate (*kappa* = 0.52), and there were differences between condition ratings of 1 and 2. All other kappa coefficients resulted in non-similar scores between protocol conditional ratings among the stream reaches.

Table 2. Kappa Coefficient agreements between NRCS, PFC, SVAP and GL categorical ratings (3, 2, and 1) of stream reach condition ($n = 40$)

Comparisons	*Kappa*	Agreement	95% CL (L)[1]	95% CL (U)[2]	Pr > S[3]
NRCS[4] vs. PFC[5]	0.52	Moderate	0.31	0.73	0.15
NRCS vs. SVAP[6]	- 0.11	Poor	- 0.29	0.07	0.01
NRCS vs. GL[7]	- 0.15	Poor	- 0.35	0.06	< 0.01
PFC vs. SVAP	0.21	Slight	0.002	0.41	< 0.01
PFC vs. GL	- 0.21	Poor	- 0.44	0.02	0.03
SVAP vs. GL	- 0.11	Poor	- 0.30	0.05	< 0.01

[1] Lower Confidence Limit; [2] Upper Confidence Limit; [3] Probability > Statistic; [4] Riparian Assessment for Lotic Systems; [5] U.S. Lotic Wetland Health Assessment for Streams and Small Rivers (*Survey*); [6] Stream Visual Assessment Protocol; [7] Greenline

The simple linear regression models for SVAP had highest R^2 and lowest residual variance throughout the data for EPT diversity, richness, and FBI scores for all streams (Table 3). The PFC assessment protocol had a significant linear relationship ($P \leq 0.05$) with the response variables; however, the R^2 was low indicating a high degree of unexplained variance within the models. The NRCS assessment protocol and GL did not produce linear relationships and an adequate R^2 between EPT diversity, richness, and water quality across stream reaches.

Table 3. Simple linear regression comparison of assessment protocol and greenline scores for all streams with EPT diversity, EPT richness, and FBI (n = 10)

	[1]EPT Diversity		[2]EPT Richness		[3]FBI	
Protocol	P	R^2	P	R^2	P	R^2
[4]PFC	0.04	0.43	0.13	0.27	< 0.01	0.36
[5]NRCS	0.63	0.03	0.93	0.01	0.66	0.03
[6]SVAP	< 0.01	0.82	< 0.01	0.89	< 0.01	0.89
[7]GL	0.37	0.10	0.29	0.14	0.43	0.08

[1]Ephemeroptera–Plecoptera–Trichoptera Diversity; [2]Ephemeroptera–Plecoptera–Trichoptera Richness; [3]Field Biotic Index; [4]U.S. Lotic Wetland Health Assessment for Streams and Small Rivers (*Survey*); [5]Riparian Assessment for Lotic Systems; [6]Stream Visual Assessment Protocol; [7]Greenline

The CCA identified 7 environmental parameters where the correlation coefficients (CC) were ≥ 0.70. These parameters were percent fines in pool tail-outs (Grid), percent fines (Fine), discharge (CFS), average annual precipitation (precip), elevation (elev), water quality (FBI), and glide proportions (GP) (Fig. 1). The primary environmental variables with a CC ≥ 0.90 were Grid and FBI. The secondary environmental variables with $0.90 < CC \geq 0.80$ were percent fines, precip, and CFS. The tertiary environmental variables with $0.80 < CC \geq 0.70$ were GP and elevation.

The inertia explained in Figure 1 was 0.59 and the eigenvalues of the first two axes are 0.58 (axis 1) and 0.51 (axis 2). This indicates that substrate composition, water quality, discharge, and average annual precipitation had the greatest correlation with aquatic macroinvertebrate distribution and community composition across all study sites. Figure 2 represents a model that illustrates the primary and secondary environmental variables.

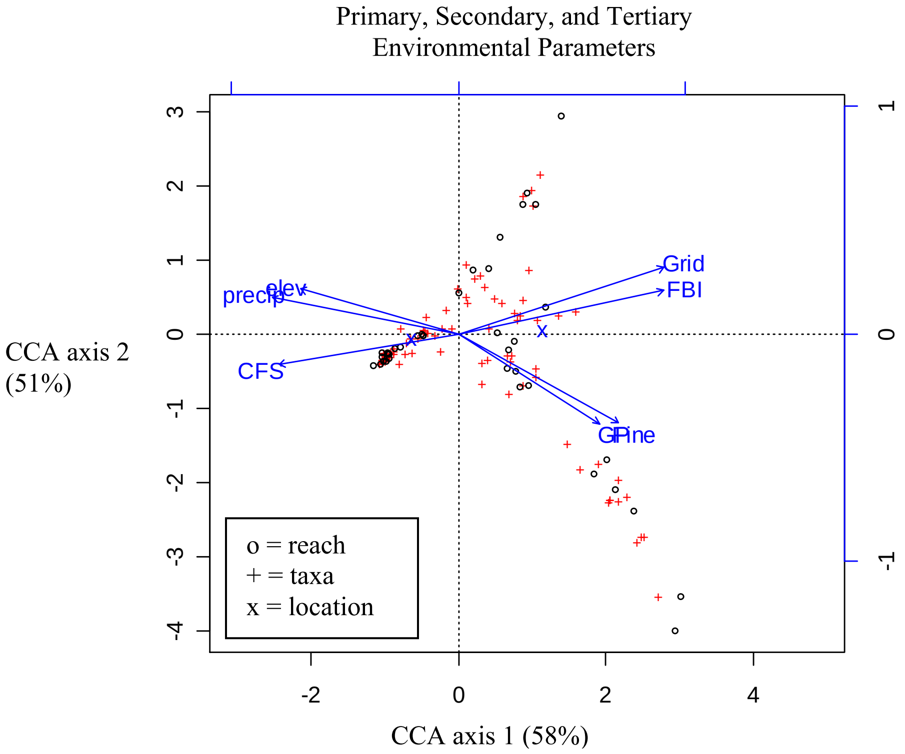

Figure 1. CCA of environmental parameters: Grid (CC = 0.95), FBI (CC = 0.92), precip (CC = 0.84), Fine (CC = 0.81), CFS (CC = 0.80), GP (CC = 0.74), elev (CC = 0.72); inertia explained = 0.59; eigenvalues for axis 1 = 58% and axis 2 = 51%. Red + = individual taxa families and genera, o = circles are individual sampled reaches, and x = location (left = west and right = east).

The CCA correlations between aquatic macroinvertebrate taxa with assessment protocols and GL (Fig. 3), implicated that SVAP had the greatest CC (0.96). The PFC protocol had the second highest CC (0.84), which fits a similar pattern of the simple linear regression analyses where PFC had a tendency to have a significant relationship, but with little of the variance accounted for water quality and EPT diversity and richness. The NRCS protocol and GL had very low CC values, which would indicate a weak correlation with aquatic taxonomic composition across sample sites.

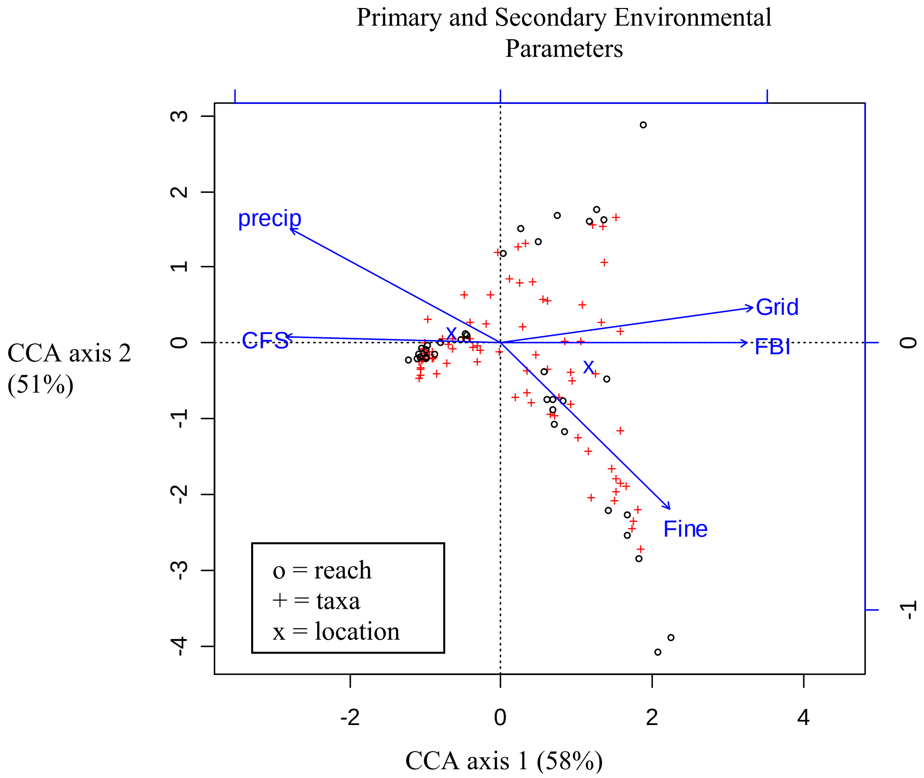

Figure 2. CCA of primary and secondary environmental parameters: Grid (CC = 0.95), FBI (CC = 0.92), precip (CC = 0.89), Fine (CC = 0.89), and CFS (CC = 0.81); inertia explained = 0.51; eigenvalues for axis 1 = 58% and axis 2 = 51%; + = individual taxa families and genera, o = individual sampled reaches, and x = location (left = west and right = east).

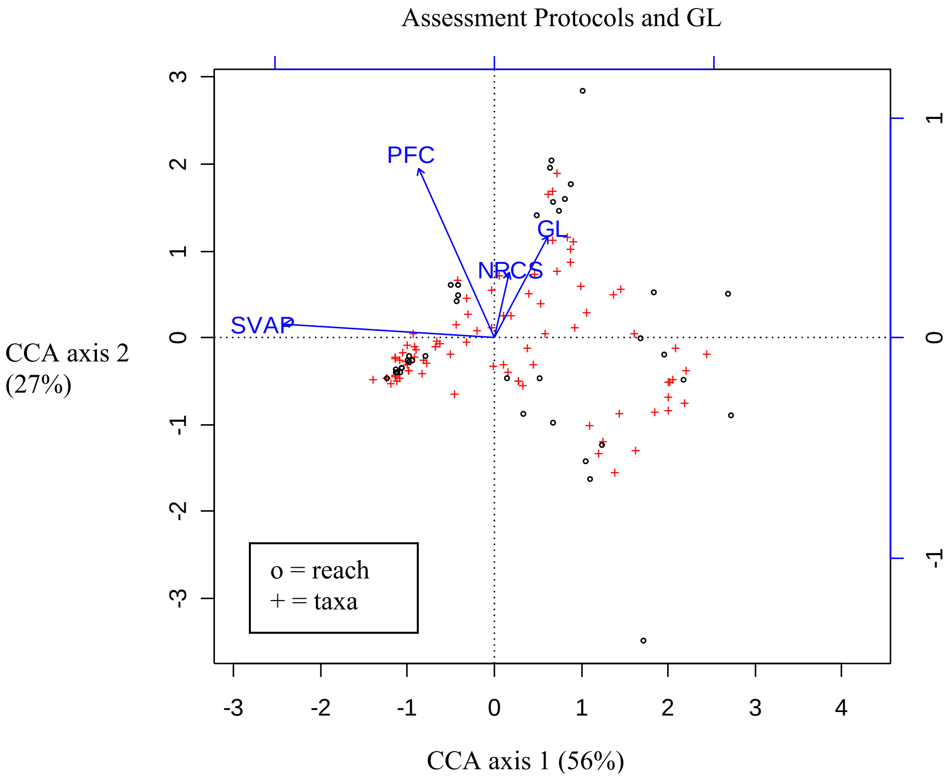

Figure 3. CCA of assessment protocols and greenline: SVAP (CC = 0.96), PFC (CC = 0.84), GL (CC = 0.52), and NRCS (CC = 0.30); inertia explained = 0.33; eigenvalues for axis 1 = 56% and axis 2 = 27%; + = individual taxa families and genera, and o = individual sampled reaches.

DISCUSSION

The SVAP was the only assessment protocol that distinguished between streams in western and eastern geological provinces. Stream Visual Assessment Protocol reach scores were greater on western streams indicating differences in instream characteristics between the provinces. Dissimilarities amongst protocols and GL agreement of reach ratings were evident in the results, and only PFC and NRCS protocols had a significant relationship to each other with a moderate kappa coefficient. PFC and NRCS should be similar because they emphasize and evaluate similar characteristics within a stream system. A similar relationship was also found by Ward et al. (2003). They found that the SVAP and Habitat Assessment Field Data Sheet (HAFDS), which target similar parameters resulted in a strong positive correlation ($r = 0.81$) between stream health scores. The original PFC which focuses more on hydrologic functions, had a weak correlation with SVAP and HAFDS ($r = 0.58$ and 0.54). Whitacre (2004) found means among protocols for 8 of the 10 physical attributes evaluated differed ($P \leq 0.05$) across three Oregon and three Idaho streams when comparing the Aquatic and Riparian Effectiveness Monitoring Program (AREMP), the Environmental Monitoring and Assessment Program (EMAP), and PACFISH/INFISH effectiveness monitoring program (PIBO).

Not only are there potential differences between protocols, but potential variability amongst observers of stream and riparian condition (Roper et al. 2002). Coles-Ritchie et al. (2004) discovered high variability among observers when conducting GL surveys on different reaches with different community types and stability conditions.

The mean agreement for all observers was 38%, and the maximum and minimum were 49% and 29%. Hannaford and Resh (1995) found that individual riparian site assessments varied considerably among college student groups. Thus, it must be assumed that differences in assessment scores may have occurred between the different ID teams that evaluated stream reaches in this study. Observations suggest that differences in familiarity with the various assessment tools and riparian monitoring experience among the teams may have resulted in variable assessments of stream reaches across the state.

The differences found in assessment protocols did not only reflect variability in stream reach condition, but also each assessment protocol's ability to predict aquatic macroinvertebrate diversity, richness, and water quality. The data collected suggests that SVAP was the only assessment protocol that had a significant and strong linear relation with these three aquatic parameters. SVAP best estimates instream conditions because it considers not only vegetative and hydrologic characteristics, but also substrate composition, instream habitat types, water clarity, and aquatic macrophyte production. The SVAP addresses parameters suggested by Resh et al. (1995) that are needed to capture the stream's ability to influence resistance and water quality. Furthermore assessment protocols that reflect aquatic macroinvertebrate assemblages may indicate direct responses to changes in water quality, chemistry, and geological regions (Resh et al. 1995; Wang and Lyons 2003).

Environmental variables that have been found to have some of the most significant relationships to aquatic macroinvertebrate assemblages are substrate composition and annual stream flow (Allan 1995; Scarsbrook 2002). Beisel et al. (1998) measured seven environmental variables in northeastern France; substrate was the dominant factor that influenced the community structure of aquatic taxa, and found that current velocity and water depth were secondary factors. Substrate composed of medium particle sizes such as gravel and cobble generally increases the abundance and richness of aquatic benthic invertebrates whereas excessive sediment is considered a pollutant in streams and can have negative affects on aquatic biota (Waters 1995). Percent fines and embeddedness of the substratum has been observed to have a negative correlation with aquatic macroinvertebrate assemblages (Nerbonne and Vondracek 2001). These findings related to substrate composition and aquatic macroinvertebrates are similar to stream characteristics measured in this study suggesting that western stream reaches typically had fewer fines, greater CFS, and a greater presence of low tolerant taxa, EPT diversity, and EPT richness measures. Eastern stream reaches typically had greater proportions of fines, lower CFS, presence of moderate to high tolerant taxa, and lower EPT diversity and richness measures.

Vegetative characteristics influence stream channel stability and sediment retention, especially buffer widths, along banks adjacent to the channel (Clary and Leininger 2000). The structure of riparian vegetation not only provides stability but strongly influences aquatic biota, amphibians, and fish by increasing habitat diversity and water quality (Kauffman et al. 2001). While the GL measures in this study typically had moderate to good ratings, there was a weak correlation with aquatic biotic integrity. Even though most assessment scores from PFC and NRCS ranged between “at-risk” to “sustainable,” Allan et al. (1997) found local riparian vegetation to be a secondary predictor of habitat quality and aquatic biotic integrity.

Substratum composition is an important characteristic when evaluating instream conditions and aquatic biotic integrity. While the modified PFC and NRCS may give valuable information on proper functioning condition and sustainability of flood plain communities, they lack the ability to reflect water quality and aquatic biotic integrity. The SVAP, a more detailed evaluation of instream characteristics such as substrate composition, resulted in stream reach evaluations that best predicted water quality and aquatic biotic integrity. The components within SVAP and the results of this study correspond with the environmental parameters found in other studies that resulted in significant correlations with aquatic biotic integrity.

IMPLICATIONS

The SVAP is an example of an assessment protocol that characterizes instream environmental parameters and reflects water quality, aquatic diversity, and stability better than other developed protocols such as PFC and NRCS. The results indicate that SVAP is sensitive to changes in geologic province, and may differentiate between western and eastern streams in Montana. If management goals are focusing on perennial streams, and whether those streams have higher water quality and can support a particular fishery then this study would suggest the application of the SVAP or other protocols that assess substrate characteristics. The application of PFC, NRCS, or GL along with the SVAP could be a valuable addition to evaluate stream reaches that may provide a more in-depth measure of interactions between vegetative features and hydrologic function. The integration of SVAP and NRCS, for example, would result in little additional effort and cost when applied to a stream reach, and would provide a better understanding of the aquatic and terrestrial conditions within a stream system.

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APPENDICES

APPENDIX A

ENVIRONMENTAL VARIABLES FOR WESTERN STREAM REACHES

A: Environmental variables for western stream reaches

Stream	Precip[a]	Elev[b]	Reach	CFS[c]	W:D[d]	Entrench[e]	P:R[f]	Cover[g]	Grid[h]	Fines[i]	Course[j]	RP[k]	PP[l]	GP[m]
	mm	m		ft^3/s	----------- Ratio -----------			----------------------------- % -----------------------------						
South Boulder	460	1743	1	3.71	41	10.0	1.0	7	9	5	87	57	43	0
			2	3.50	26	10.0	4.0	8	17	10	78	9	91	0
			3	3.43	23	2.2	3.0	5	14	5	88	39	49	0
			4	4.06	34	10.0	4.0	9	19	8	84	15	71	15
South Willow	460	1615	1	2.13	31	7.4	1.0	6	14	13	72	34	49	0
			2	2.13	31	2.5	1.3	7	12	17	74	55	45	0
			3	2.13	26	2.7	1.5	16	23	9	77	35	65	0
			4	2.13	26	3.0	2.5	43	30	7	83	31	69	0
Cottonwood	530	1244	1	1.73	22	2.2	1.3	18	10	20	71	22	78	0
			2	1.82	24	2.4	1.5	25	9	29	46	80	20	0
			3	1.87	42	10.0	0.3	21	12	32	59	94	6	0
			4	1.83	22	10.0	4.0	23	10	15	70	13	87	0
Lower Nevada	470	1329	1	0.76	14	1.5	3.0	13	80	15	74	6	84	10
			2	0.76	13	2.4	2.5	15	89	12	73	30	70	0
			3	0.78	12	2.5	0.0	29	98	29	49	0	67	33
			4	0.95	13	5.5	3.0	11	75	47	46	7	64	29
Upper Nevada	470	1426	1	1.02	19	5.7	2.0	2	36	13	70	27	67	8
			2	0.98	29	1.2	1.3	1	44	10	80	23	66	10
			3	0.92	15	10.0	3.0	2	28	19	64	18	82	0
			4	0.95	22	10.0	2.0	1	41	12	76	17	83	0

[a]Average Annual Precipitation; [b]Elevation; [c]Discharge; [d]Width/Depth Ratio; [e]Entrenchment Ratio; [f]Pool/Riffe Ratio; [g]Vegetative & Bank Overhang; [h]Pool tail out Fines; [i]Wholman Pebble Count; [j]Wholman Pebble Count; [k]Riffle Proportion; [l]Pool Proportion; [m]Glide Proportion

APPENDIX B

ENVIRONMENTAL VARIABLES FOR EASTERN STREAM REACHES

B: Environmental variables for eastern stream reaches

Stream	Precip[a]	Elev[b]	Reach	CFS[c]	W:D[d]	Entrench[e]	P:R[f]	Cover[g]	Grid[h]	Fines[i]	Course[j]	RP[k]	PP[l]	GP[m]
	mm	m		ft^3/s	----------- Ratio -----------			---------------------------- % ----------------------------						
Rosebud	360	988	1	NA	10	1.9	0.0	4	100	100	0	0	0	90
			2	0.07	20	1.7	0.4	5	100	55	10	10	24	60
			3	0.07	8	1.9	0.0	12	100	100	0	0	34	66
			4	0.13	13	1.4	4.0	2	100	72	2	25	37	38
Otter	330	887	1	NA	42	1.3	0.0	0	100	100	0	0	0	100
			2	NA	41	1.8	0.0	0	100	100	0	0	0	100
			3	NA	33	1.2	0.0	2	100	100	0	0	0	100
			4	NA	31	1.2	0.0	2	100	100	0	0	0	100
Louse	390	1192	1	0.11	18	10.0	1.0	0	65	35	50	29	71	0
			2	0.11	19	2.1	1.0	0	60	45	47	37	63	0
			3	0.10	23	5.8	0.8	0	79	44	42	20	63	14
			4	0.08	12	4.3	1.0	0	87	85	15	12	9	79
Little Spring	390	1341	1	0.19	10	4.6	1.3	0	45	50	39	53	33	14
			2	0.18	5	10.4	4.0	0	100	57	31	7	14	79
			3	0.30	6	3.7	0.0	0	100	100	0	0	14	86
			4	0.63	4	3.0	2.0	0	100	100	0	6	14	80
Mission Spring	420	1323	1	0.38	14	1.3	2.5	20	100	36	57	24	76	0
			2	0.41	15	1.6	2.0	9	100	11	83	4	96	0
			3	0.25	18	1.3	2.0	6	100	16	68	5	95	0
			4	0.39	15	1.4	4.0	1	100	25	61	3	97	0

[a]Average Annual Precipitation; [b]Elevation; [c]Discharge; [d]Width/Depth Ratio; [e]Entrenchment Ratio; [f]Pool/Riffe Ratio; [g]Vegetative & Bank Overhang; [h]Pool tail out Fines; [i]Wholman Pebble Count; [j]Wholman Pebble Count; [k]Riffle Proportion; [l]Pool Proportion; [m]Glide Proportion

APPENDIX C

ASSESSMENT PROTOCOL AND GREENLINE SCORES AND CONDITIONS FOR WESTERN STREAM REACHES

C: Assessment protocol and greenline scores and conditions for western stream reaches

		SVAP[a]		NRCS[b]		PFC[c]		GL[d]	
Stream	Reach	Score	Condition	Score	Condition	Score	Condition	Score	Condition
South Boulder	1	7.7	Good	72	At Risk	88	PFC*	6.7	Moderate
	2	7.7	Good	77	At Risk	82	PFC	6.8	Moderate
	3	7.7	Good	78	At Risk	79	At Risk	7.9	Good
	4	7.7	Good	63	At Risk	74	At Risk	6.3	Moderate
South Willow	1	7.7	Good	80	Sustainable	81	PFC	6.7	Moderate
	2	8.1	Good	77	At Risk	77	At Risk	7.5	Good
	3	7.9	Good	78	At Risk	79	At Risk	6.9	Moderate
	4	8.0	Good	63	At Risk	74	At Risk	6.9	Moderate
Cottonwood	1	7.7	Good	83	Sustainable	82	PFC	6.5	Moderate
	2	7.5	Fair	85	Sustainable	88	PFC	6.9	Moderate
	3	7.5	Good	82	Sustainable	84	PFC	6.8	Moderate
	4	7.9	Good	82	Sustainable	84	PFC	6.3	Moderate
Lower Nevada	1	6.1	Fair	67	At Risk	63	At Risk	7.3	Good
	2	6.1	Fair	70	At Risk	67	At Risk	7.6	Good
	3	6.2	Fair	72	At Risk	72	At Risk	7.6	Good
	4	6.1	Fair	72	At Risk	72	At Risk	7.2	Good
Upper Nevada	1	6.2	Fair	33	Not Sust[x]	67	At Risk	6.2	Moderate
	2	6.2	Fair	55	At Risk	67	At Risk	6.7	Moderate
	3	6.2	Fair	47	Not Sust	75	At Risk	6.4	Moderate
	4	6.1	Fair	33	Not Sust	67	At Risk	5.8	Moderate

[a]Stream Visual Assessment Protocol; [b]Riparian Assessment for Lotic Systems; [c]Proper Functioning Condition: US Lotic Wetland Health Assessment for Streams and Small Rivers; [d]Greenline; *Proper Functioning Condition; [x]Not Sustainable

APPENDIX D

ASSESSMENT PROTOCOL AND GREENLINE SCORES AND CONDITIONS FOR EASTERN STREAM REACHES

D: Assessment protocol and greenline scores and conditions for eastern stream reaches

		SVAP[a]		NRCS[b]		PFC[c]		GL[d]	
Stream	Reach	Score	Condition	Score	Condition	Score	Condition	Score	Condition
Rosebud	1	4.4	Poor	78	At Risk	63	At Risk	6.7	Moderate
	2	4.5	Poor	73	At Risk	61	At Risk	6.8	Moderate
	3	4.4	Poor	73	At Risk	61	At Risk	7.9	Good
	4	4.4	Poor	65	At Risk	51	Non Fun[†]	6.3	Moderate
Otter	1	3.4	Poor	58	At Risk	56	Non Fun	6.7	Moderate
	2	3.4	Poor	58	At Risk	58	Non Fun	7.5	Good
	3	3.4	Poor	58	At Risk	58	Non Fun	6.9	Moderate
	4	3.4	Poor	60	At Risk	60	At Risk	6.9	Moderate
Louse	1	6.5	Fair	90	Sustainable	93	PFC[*]	6.5	Moderate
	2	5.9	Poor	83	Sustainable	91	PFC	6.9	Moderate
	3	5.6	Poor	75	At Risk	80	PFC	6.8	Moderate
	4	5.9	Poor	94	Sustainable	91	PFC	6.3	Moderate
Little Spring	1	6.3	Fair	98	Sustainable	91	PFC	7.3	Good
	2	6.4	Fair	100	Sustainable	100	PFC	7.6	Good
	3	5.9	Poor	81	Sustainable	96	PFC	7.6	Good
	4	5.9	Poor	81	Sustainable	96	PFC	7.2	Good
Mission Spring	1	5.3	Poor	78	At Risk	67	At Risk	6.2	Moderate
	2	5.0	Poor	67	At Risk	60	At Risk	6.7	Moderate
	3	5.0	Poor	72	At Risk	67	At Risk	6.4	Moderate
	4	4.6	Poor	57	At Risk	51	Non Fun	5.8	Moderate

[a]Stream Visual Assessment Protocol; [b]Riparian Assessment for Lotic Systems; [c]Proper Functioning Condition: US Lotic Wetland Health Assessment for Streams and Small Rivers; [d]Greenline; *Proper Functioning Condition; †Non Functioning

APPENDIX E

AQUATIC MACROINVERTEBRATE DATA FOR WESTERN STREAM REACHES

E: Aquatic macroinvertebrate data measures for western stream reaches

		FBI[a]						
Stream	Reach	Score	Condition	EPT Div. [b]	EPT Richness[c]	SC[e]	SH[f]	OM[g]
						------------------ %	------------------	
South Boulder	1	4.1	Very Good	1.07	20	14	6	0
	2	3.7	Very Good	1.05	20	15	6	0
	3	4.8	Good	1.11	21	8	6	0
	4	4.1	Very Good	1.19	23	13	7	0
South Willow	1	3.3	Excellent	1.11	22	19	5	0
	2	2.8	Excellent	1.03	21	27	3	0
	3	3.0	Excellent	1.07	23	21	3	0
	4	3.1	Excellent	1.03	21	18	4	0
Cottonwood	1	3.6	Very Good	0.89	18	10	3	0
	2	3.1	Excellent	0.82	15	21	1	0
	3	3.5	Excellent	0.88	16	16	2	0
	4	3.9	Very Good	0.96	16	12	3	0
Lower Nevada	1	4.3	Very Good	0.75	15	3	1	0
	2	4.7	Good	0.77	13	8	1	5
	3	5.7	Fair	0.43	12	3	1	2
	4	4.8	Good	0.59	11	0	1	1
Upper Nevada	1	4.7	Good	0.75	17	21	6	0
	2	3.7	Very Good	0.93	17	11	5	0
	3	3.6	Very Good	0.95	17	12	6	0
	4	3.6	Very Good	0.84	17	23	8	0

[a] Field Biotic Index; [b] Ephemeroptera-Plecoptera-Trichoptera Genera Diversity (Shannon); [c] Ephemeroptera-Plecoptera-Trichoptera Genera Richness; [e] Scrapers; [f] Shredders; [g] Omnivores

APPENDIX F

AQUATIC MACROINVERTEBRATE DATA FOR WESTERN STREAM REACHES

F: Aquatic macroinvertebrate data measures for eastern stream reaches

Stream	Reach	FBI[a]		EPT Div. [b]	EPT Richness[c]	SC[d]	SH[e]	OM[f]
		Score	Condition					
							----------------- % -----------------	
Rosebud	1	6.5	Fair	0.06	2	6	0	22
	2	6.5	Fair	0.16	3	4	0	20
	3	7.0	Fairly Poor	0.02	2	2	0	26
	4	6.5	Fair	0.09	3	10	0	28
Otter	1	7.3	Fairly Poor	0.17	2	0	0	3
	2	NA	NA	NA	NA	NA	NA	NA
	3	8.1	Poor	0.19	2	0	0	1
	4	NA	NA	NA	NA	NA	NA	NA
Louse	1	4.4	Very Good	0.81	12	7	0	28
	2	4.1	Very Good	1.08	11	1	0	34
	3	4.5	Very Good	1.03	13	2	0	23
	4	5.0	Good	0.66	10	0	0	32
Little Spring	1	5.1	Good	0.74	11	12	0	16
	2	6.3	Fair	0.62	11	32	0	0
	3	5.6	Fair	0.67	8	20	0	12
	4	4.6	Good	0.60	8	18	0	22
Mission Spring	1	6.3	Fair	0.77	6	1	0	12
	2	5.7	Fair	0.60	7	1	0	18
	3	6.1	Fair	0.60	6	2	0	11
	4	7.0	Fairly Poor	0.42	6	4	0	9

[a]Field Biotic Index; [b]Ephemeroptera-Plecoptera-Trichoptera Genera Diversity (Shannon); [c]Ephemeroptera-Plecoptera-Trichoptera Genera Richness; [e]Scrapers; [f]Shredders; [g]Omnivores

APPENDIX G

AQUATIC MACROINVERTEBRATE ASSEMBLAGES FOR
SOUTH BOULDER CREEK AND
SOUTH WILLOW CREEK

G: Aquatic macroinvertebrate assemblages for South Boulder Creek and South Willow Creek

Order	Family	*Genera*	TV[a]	FFG[b]	SB1[c]	SB2	SB3	SB4	SW1[d]	SW2	SW3	SW4
Ephemeroptera	Ephemerallidae	*Drunella*	0	SC	5	5	12	27	55	31	64	26
		Ephemerella	1	GC	3	2	6	32	33	22	20	12
		Serratella	2	GC	58	69	60	53	48	49	58	57
	Baetidae	*Baetis*	5	GC	59	31	29	81	161	147	144	130
		Callibaetis	9	GC	0	0	0	0	0	0	0	0
		Diphetor	5	GC	0	0	0	0	0	0	0	0
	Heptageniidae	*Cinygmula*	4	SC	15	20	17	25	0	0	0	0
		Epeorus	0	SC	92	89	41	69	37	100	68	36
		Nixe	4	SC	0	0	0	0	0	0	0	0
		Rhithrgena	0	SC	23	24	5	45	87	33	59	36
	Leptophlebiidae	*Paraleptophlebia*	1	GC	0	0	0	0	2	0	1	0
	Ameletidae	*Ameletus*	0	GC	0	2	2	5	13	7	5	3
	Tricorythidae	*Tricorythides*	5	GC	0	0	0	0	0	0	0	0
	Caenidae	*Caenis*	7	GC	0	0	0	0	0	0	0	0
Plecoptera	Perlidae	*Doroneuria*	1	PR	12	12	2	22	5	2	1	5
		Hesperoperla	1	PR	18	36	18	28	0	2	1	2
	Perlodidae	*Diura*	2	PR	0	0	0	0	8	8	7	4
		Kogotus	2	PR	1	0	1	8	8	8	7	6
		Skwala	2	PR	1	3	4	7	13	1	9	1
	Nemouridae	*Zapada*	2	SH	35	28	34	69	27	5	5	8
	Chloroperlidae	*Sweltsa*	1	PR	11	2	13	10	17	11	8	4
	Capniidae/Leuctridae		1	SH	0	3	0	2	1	1	1	1
	Pteronarcyidae	*Pteronarcella*	0	SH	0	0	0	0	0	0	0	0
Trichoptera	Glossosomatidae	*Glossosoma*	0	SC	15	9	6	16	90	140	100	66
	Brachycentridae	*Brachycentrus*	1	FC	0	0	0	0	1	0	1	4
		Micrasema	1	SH	5	6	17	13	23	15	32	4
	Rhyacophilidae	*Rhyacophila*	0	PR	12	11	3	3	89	73	68	55

(continued)

G: *(Continued)*

Order	Family	*Genera*	TV[a]	FFG[b]	SB1[c]	SB2	SB3	SB4	SW1[d]	SW2	SW3	SW4
Trichoptera	Hydropsychidae	*Arctopsyche*	1	FC	50	80	18	80	61	73	118	96
		Ceratopsyche	4	FC	0	0	0	0	0	0	0	0
		Cheumatopsyche	5	FC	0	0	0	0	0	0	0	0
		Hydropsyche	4	FC	0	0	0	0	0	0	0	0
	Uenoidae	*Neophylax*	3	SC	0	0	0	0	0	0	0	0
	Limnephilidae	*Asynarchus*	NA	NA	0	0	0	0	0	0	0	0
		Ecclisomyia	2	GC	0	0	0	1	0	0	0	0
		Psychologlypha	1	GC	2	0	2	4	3	3	1	0
	Philopotamidae	*Dolophilodes*	1	GC	3	7	2	11	8	12	18	23
	Leptoceridae	*Oecetis*	8	PR	0	0	0	0	0	0	0	0
	Helicopsychidae	*Helicopsyche*	3	SC	0	0	0	0	0	0	0	0
	Hydroptilidae	*Agraylea*	8	NA	9	7	59	43	0	0	0	0
		Hydroptila	6	SC	0	0	0	0	0	0	0	0
		Oxyethira	NA	NA	0	0	0	0	0	0	0	0
	Physchomyiidae	*Physchomyia*	2	SC	0	0	0	0	0	0	0	0
	Phryganeidae	*Phryganea*	4	OM	0	0	0	0	0	0	0	0
		Ptilostmis	5	SH	0	0	0	0	0	0	0	0
Diptera	Chironomidae		6	GC	546	430	651	699	366	245	323	168
	Tipulidae		3	SH	27	24	16	25	28	8	9	24
	Simuliidae		6	FC	8	26	2	3	26	8	5	94
	Psychodidae		10	GC	0	0	0	0	23	7	7	3
	Pelecorhynchidae		NA	NA	0	0	0	0	0	0	0	0
	Ceratopogonidae		6	PR	8	2	14	17	10	2	2	0
	Blephariceridae		0	SC	0	0	0	0	3	3	0	13
	Empididae		6	PR	1	2	7	4	0	0	0	0
	Deuterophlebiidae		NA	SC	0	0	1	0	0	0	0	0
	Ephydridae		6	GC	0	0	0	0	0	0	0	0
	Tabanidae		8	PR	0	0	0	0	1	1	0	0

(continued)

G: *(Continued)*

Order	Family	*Genera*	TV[a]	FFG[b]	SB1[c]	SB2	SB3	SB4	SW1[d]	SW2	SW3	SW4
Diptera	Chaoboridae		8	PR	0	0	0	0	0	0	0	0
	Dixidae		1	GC	0	0	0	0	0	0	0	0
	Stratiomyidae		8	GC	0	0	0	0	0	0	0	0
	Muscidae		6	PR	0	0	0	0	0	0	0	0
Coleoptera	Elmidae		4	GC	23	27	32	27	198	115	269	109
	Carbaidae		4	PR	0	0	0	0	0	0	0	0
	Curculionidae		NA	SH	0	0	0	0	0	0	0	0
	Dytiscidae		5	PR	1	0	1	1	0	0	0	0
	Halipidae		7	NA	0	0	0	0	0	0	0	0
	Hydrophilidae		5	PR	0	0	0	0	0	0	0	0
Anisoptera	Aeshnidae		3	PR	0	0	0	0	0	0	0	0
	Libellulidae		9	PR	0	0	0	0	0	0	0	0
	Gomphidae		1	PR	0	0	0	0	0	0	0	0
Zygotera	Coenagrionidae		9	PR	0	0	0	0	0	0	0	0
Megaloptera	Sialidae	*Sialis*	4	PR	0	0	0	0	0	0	0	0
Hemiptera	Corixidae		10	PR	0	0	0	0	0	0	0	0
	Belostomatidae		NA	PR	0	0	0	0	0	0	0	0
	Notonectidae		NA	PR	0	0	0	0	0	0	0	0
Tricladida	Planariidae		1	OM	1	1	0	0	2	0	0	0
Amphipoda	Grammaridae	*Grammarus*	4	OM	0	0	0	0	0	0	0	0
Isopoda	Asellidae		8	GC	0	0	0	0	0	0	0	0
Gastropoda	Lymnaeidae		6	GC	0	0	0	0	0	0	0	0
	Physidae		8	SC	0	0	0	0	0	0	0	0
	Planorbidae		7	SC	0	0	0	0	0	0	0	0
Bibalvia	Sphaeriidae		8	FC	2	0	0	0	2	0	1	2
Oligochaeta			5	GC	0	0	0	0	0	0	0	0
Hirudinea	Hirudinidea		7	PR	0	0	0	0	0	0	0	0

[a]Tolerance Values; [b]Functional Feeding Group; [c]South Boulder reach 1; [d]South Willow reach 1

APPENDIX H

AQUATIC MACROINVERTEBRATE ASSEMBLAGES
FOR COTTONWOOD CREEK AND
UPPER NEVADA CREEK

H: Aquatic macroinvertebrate assemblages for Cottonwood Creek and Upper Nevada Creek

Order	Family	*Genera*	TV[a]	FFG[b]	CW1[c]	CW2	CW3	CW4	UN1[d]	UN2	UN3	UN4
Ephemeroptera	Ephemerallidae	*Drunella*	0	SC	43	68	53	99	1	0	0	0
		Ephemerella	1	GC	0	0	0	0	1	3	1	2
		Serratella	2	GC	26	17	25	14	0	0	0	0
	Baetidae	*Baetis*	5	GC	355	189	123	159	34	67	21	42
		Callibaetis	9	GC	0	0	0	0	0	0	0	0
		Diphetor	5	GC	0	2	0	0	0	0	0	0
	Heptageniidae	*Cinygmula*	4	SC	3	0	0	0	1	0	2	1
		Epeorus	0	SC	1	0	0	0	0	0	0	0
		Nixe	4	SC	0	0	0	0	2	0	0	0
		Rhithrgena	0	SC	0	0	0	0	0	0	0	0
	Leptophlebiidae	*Paraleptophlebia*	1	GC	4	1	5	9	13	82	49	23
	Ameletidae	*Ameletus*	0	GC	0	0	0	0	0	0	0	0
	Tricorythidae	*Tricorythides*	5	GC	0	0	0	0	5	2	2	1
	Caenidae	*Caenis*	7	GC	0	0	0	0	0	0	0	0
Plecoptera	Perlidae	*Doroneuria*	1	PR	0	0	0	0	0	0	0	0
		Hesperoperla	1	PR	10	0	1	0	4	9	6	4
	Perlodidae	*Diura*	2	PR	0	0	0	0	0	0	0	0
		Kogotus	2	PR	3	0	10	11	0	0	0	0
		Skwala	2	PR	9	6	1	5	22	31	45	47
	Nemouridae	*Zapada*	2	SH	26	2	10	4	0	2	0	0
	Chloroperlidae	*Sweltsa*	1	PR	4	2	5	9	0	4	13	5
	Capniidae/Leuctridae		1	SH	0	0	0	0	0	0	0	0
	Pteronarcyidae	*Pteronarcella*	0	SH	0	0	0	0	16	23	13	20
Trichoptera	Glossosomatidae	*Glossosoma*	0	SC	97	257	173	86	14	8	14	26
	Brachycentridae	*Brachycentrus*	1	FC	135	63	55	98	269	206	171	202
		Micrasema	1	SH	20	8	8	26	38	43	31	82
	Rhyacophilidae	*Rhyacophila*	0	PR	125	85	76	58	0	0	0	0

(continued)

H: *(Continued)*

Order	Family	*Genera*	TV[a]	FFG[b]	CW1[c]	CW2	CW3	CW4	UN1[d]	UN2	UN3	UN4
Trichoptera	Hydropsychidae	*Arctopsyche*	1	FC	107	114	133	54	0	0	0	2
		Ceratopsyche	4	FC	0	0	0	0	0	32	38	36
		Cheumatopsyche	5	FC	0	0	0	0	0	0	0	0
		Hydropsyche	4	FC	0	0	0	0	27	51	40	48
	Uenoidae	*Neophylax*	3	SC	21	9	1	8	0	0	0	0
	Limnephilidae	*Asynarchus*	NA	NA	0	0	0	0	0	0	0	0
		Ecclisomyia	2	GC	4	0	0	0	0	0	0	0
		Psychologlypha	1	GC	0	2	1	10	0	2	0	0
	Philopotamidae	*Dolophilodes*	1	GC	0	0	0	0	0	0	0	0
	Leptoceridae	*Oecetis*	8	PR	0	0	0	0	14	6	7	9
	Helicopsychidae	*Helicopsyche*	3	SC	0	0	0	0	242	144	115	337
	Hydroptilidae	*Agraylea*	8	NA	0	0	0	0	0	0	0	0
		Hydroptila	6	SC	0	0	0	0	0	0	0	0
		Oxyethira	NA	NA	0	0	0	0	0	0	0	0
	Physchomyiidae	*Physchomyia*	2	SC	0	0	0	0	3	0	2	0
	Phryganeidae	*Phryganea*	4	OM	0	0	0	0	0	0	0	0
		Ptilostmis	5	SH	0	0	0	0	0	0	0	0
Diptera	Chironomidae		6	GC	375	335	449	670	379	398	337	439
	Tipulidae		3	SH	4	3	3	15	22	6	24	26
	Simuliidae		6	FC	89	22	9	6	0	32	4	9
	Psychodidae		10	GC	0	1	3	4	0	0	0	0
	Pelecorhynchidae		NA	NA	0	1	1	3	0	0	0	0
	Ceratopogonidae		6	PR	0	0	0	0	0	0	0	0
	Blephariceridae		0	SC	0	0	0	0	0	0	0	0
	Empididae		6	PR	0	0	0	0	1	1	0	0
	Deuterophlebiidae		NA	SC	0	0	0	0	0	0	0	0
	Ephydridae		6	GC	0	0	0	0	0	0	0	0
	Tabanidae		8	PR	0	0	0	0	0	0	0	0

(continued)

H: *(Continued)*

Order	Family	*Genera*	TV[a]	FFG[b]	CW1[c]	CW2	CW3	CW4	UN1[d]	UN2	UN3	UN4
Diptera	Chaoboridae		8	PR	0	0	0	0	0	0	0	0
	Dixidae		1	GC	0	0	0	0	0	0	0	0
	Stratiomyidae		8	GC	0	0	0	0	0	0	0	0
	Muscidae		6	PR	0	0	0	0	0	0	0	0
Coleoptera	Elmidae		4	GC	196	374	206	251	146	221	186	255
	Carbaidae		4	PR	0	0	0	0	0	0	0	0
	Curculionidae		NA	SH	0	0	0	0	0	0	0	0
	Dytiscidae		5	PR	0	0	0	1	0	0	0	0
	Halipidae		7	NA	0	0	0	0	0	0	0	0
	Hydrophilidae		5	PR	0	0	0	0	0	0	0	0
Anisoptera	Aeshnidae		3	PR	0	0	0	0	0	0	0	0
	Libellulidae		9	PR	0	0	0	0	0	0	0	0
	Gomphidae		1	PR	0	0	0	0	9	5	8	13
Zygotera	Coenagrionidae		9	PR	0	0	0	0	0	0	0	0
Megaloptera	Sialidae	*Sialis*	4	PR	0	0	0	0	0	0	0	0
Hemiptera	Corixidae		10	PR	0	0	0	0	0	0	0	0
	Belostomatidae		NA	PR	0	0	0	0	0	0	0	0
	Notonectidae		NA	PR	0	0	0	0	0	0	0	0
Tricladida	Planariidae		1	OM	0	0	0	29	0	0	0	0
Amphipoda	Grammaridae	*Grammarus*	4	OM	0	0	0	0	0	0	0	0
Isopoda	Asellidae		8	GC	0	0	0	0	0	0	0	0
Gastropoda	Lymnaeidae		6	GC	0	0	0	0	0	0	0	0
	Physidae		8	SC	0	0	0	2	1	3	4	9
	Planorbidae		7	SC	0	0	0	0	0	1	1	1
Bibalvia	Sphaeriidae		8	FC	11	2	35	18	0	2	1	2
Oligochaeta			5	GC	0	0	0	12	0	15	11	7
Hirudinea	Hirudinidea		7	PR	0	0	0	0	0	0	0	0

[a]Tolerance Values; [b]Functional Feeding Group; [c]Cottonwood reach 1; [d]Upper Nevada reach 1

APPENDIX I

AQUATIC MACROINVERTEBRATE ASSEMBLAGES
FOR LOWER NEVADA CREEK AND
MISSION SPRING CREEK

I: Aquatic macroinvertebrate assemblages for Lower Nevada Creek and Mission Spring Creek

Order	Family	*Genera*	TV[a]	FFG[b]	LN1[c]	LN2	LN3	LN4	MS1[d]	MS2	MS3	MS4
Ephemeroptera	Ephemerallidae	*Drunella*	0	SC	0	1	0	0	0	0	0	0
		Ephemerella	1	GC	6	4	2	0	13	17	13	8
		Serratella	2	GC	0	0	0	0	0	0	0	0
	Baetidae	*Baetis*	5	GC	24	20	1	34	6	4	3	1
		Callibaetis	9	GC	0	0	0	2	0	0	0	0
		Diphetor	5	GC	0	6	0	0	0	0	0	0
	Heptageniidae	*Cinygmula*	4	SC	0	0	1	0	0	0	0	0
		Epeorus	0	SC	0	0	0	0	0	0	0	0
		Nixe	4	SC	5	17	0	2	0	0	0	0
		Rhithrgena	0	SC	0	0	0	0	0	0	0	0
	Leptophlebiidae	*Paraleptophlebia*	1	GC	21	31	8	2	0	0	0	0
	Ameletidae	*Ameletus*	0	GC	0	0	0	0	0	0	0	0
	Tricorythidae	*Tricorythides*	5	GC	231	389	274	194	0	1	0	0
	Caenidae	*Caenis*	7	GC	0	0	0	0	0	0	0	0
Plecoptera	Perlidae	*Doroneuria*	1	PR	0	0	0	0	0	0	0	0
		Hesperoperla	1	PR	0	0	0	0	0	0	0	0
	Perlodidae	*Diura*	2	PR	0	0	0	0	0	0	0	0
		Kogotus	2	PR	0	0	0	0	0	0	0	0
		Skwala	2	PR	139	94	2	54	0	0	0	0
	Nemouridae	*Zapada*	2	SH	0	0	1	1	0	0	0	0
	Chloroperlidae	*Sweltsa*	1	PR	1	0	0	0	0	0	0	0
	Capniidae/Leuctridae		1	SH	0	0	0	0	0	0	0	0
	Pteronarcyidae	*Pteronarcella*	0	SH	0	0	0	0	0	0	0	0
Trichoptera	Glossosomatidae	*Glossosoma*	0	SC	0	0	0	0	0	0	0	0
	Brachycentridae	*Brachycentrus*	1	FC	9	3	0	0	0	0	0	0
		Micrasema	1	SH	0	0	0	0	0	0	0	0
	Rhyacophilidae	*Rhyacophila*	0	PR	1	0	0	0	0	0	0	0

(continued)

I: *(Continued)*

Order	Family	*Genera*	TV[a]	FFG[b]	LN1[c]	LN2	LN3	LN4	MS1[d]	MS2	MS3	MS4
Trichoptera	Hydropsychidae	*Arctopsyche*	1	FC	0	0	0	0	0	0	0	0
		Ceratopsyche	4	FC	366	210	33	271	0	0	0	0
		Cheumatopsyche	5	FC	0	0	0	0	16	97	80	6
		Hydropsyche	4	FC	32	37	9	13	5	31	21	0
	Uenoidae	*Neophylax*	3	SC	0	0	0	0	0	0	0	0
	Limnephilidae	*Asynarchus*	NA	NA	0	0	0	0	0	0	0	0
		Ecclisomyia	2	GC	2	0	1	0	0	0	0	0
		Psychologlypha	1	GC	3	0	0	0	0	0	0	0
	Philopotamidae	*Dolophilodes*	1	GC	0	0	0	0	0	0	0	0
	Leptoceridae	*Oecetis*	8	PR	36	39	12	8	19	26	13	1
	Helicopsychidae	*Helicopsyche*	3	SC	40	90	19	4	2	0	0	0
	Hydroptilidae	*Agraylea*	8	NA	0	0	0	0	0	0	0	0
		Hydroptila	6	SC	0	0	0	0	9	8	22	44
		Oxyethira	NA	NA	0	0	0	0	0	0	0	2
	Physchomyiidae	*Physchomyia*	2	SC	0	0	0	0	0	0	0	0
	Phryganeidae	*Phryganea*	4	OM	0	0	0	0	0	0	0	0
		Ptilostmis	5	SH	0	0	0	0	0	0	0	0
Diptera	Chironomidae		6	GC	155	75	120	115	331	158	297	144
	Tipulidae		3	SH	17	13	8	10	1	1	1	0
	Simuliidae		6	FC	12	1	0	22	72	67	49	1
	Psychodidae		10	GC	0	0	0	0	0	0	0	0
	Pelecorhynchidae		NA	NA	0	0	0	0	5	0	0	0
	Ceratopogonidae		6	PR	0	0	0	0	0	2	0	1
	Blephariceridae		0	SC	0	0	0	0	0	0	0	0
	Empididae		6	PR	0	4	1	1	1	0	0	0
	Deuterophlebiidae		NA	SC	0	0	0	0	0	0	0	0
	Ephydridae		6	GC	0	0	0	0	0	0	0	0
	Tabanidae		8	PR	0	0	6	1	2	0	0	0

(continued)

I: *(Continued)*

Order	Family	*Genera*	TV[a]	FFG[b]	LN1[c]	LN2	LN3	LN4	MS1[d]	MS2	MS3	MS4
Diptera	Chaoboridae		8	PR	0	0	0	0	0	0	0	0
	Dixidae		1	GC	0	0	0	0	0	0	0	0
	Stratiomyidae		8	GC	0	0	0	0	5	0	1	0
	Muscidae		6	PR	0	0	0	0	1	1	4	5
Coleoptera	Elmidae		4	GC	222	137	22	43	8	35	16	5
	Carbaidae		4	PR	0	0	0	0	0	0	0	0
	Curculionidae		NA	SH	0	0	0	0	0	0	0	0
	Dytiscidae		5	PR	0	0	0	0	0	0	0	0
	Halipidae		7	NA	0	0	1	1	6	6	4	17
	Hydrophilidae		5	PR	0	0	0	0	0	0	0	0
Anisoptera	Aeshnidae		3	PR	0	1	0	0	0	0	0	0
	Libellulidae		9	PR	0	0	0	0	0	0	0	0
	Gomphidae		1	PR	0	0	0	0	0	0	0	0
Zygotera	Coenagrionidae		9	PR	0	0	1	0	0	0	0	0
Megaloptera	Sialidae	*Sialis*	4	PR	0	0	0	0	0	0	0	0
Hemiptera	Corixidae		10	PR	1	0	0	0	0	0	0	0
	Belostomatidae		NA	PR	0	0	0	0	0	0	0	0
	Notonectidae		NA	PR	0	0	0	0	0	0	0	0
Tricladida	Planariidae		1	OM	0	0	0	0	122	120	66	56
Amphipoda	Grammaridae	*Grammarus*	4	OM	5	77	17	9	26	57	46	43
Isopoda	Asellidae		8	GC	8	133	138	48	458	289	353	763
Gastropoda	Lymnaeidae		6	GC	7	8	5	1	0	0	0	0
	Physidae		8	SC	1	8	0	1	66	17	7	6
	Planorbidae		7	SC	0	0	0	0	13	23	1	0
Bibalvia	Sphaeriidae		8	FC	2	10	8	4	16	4	1	0
Oligochaeta			5	GC	1	9	4	0	45	7	19	21
Hirudinea	Hirudinidea		7	PR	3	6	9	7	8	4	10	4

[a]Tolerance Values; [b]Functional Feeding Group; [c]Lower Nevada reach 1; [d]Mission Spring reach 1

APPENDIX J

AQUATIC MACROINVERTEBRATE ASSEMBLAGES
FOR LOUSE CREEK AND
LITTLE SPRING CREEK

J: Aquatic macroinvertebrate assemblages for Rosebud Creek and Otter Creek

Order	Family	*Genera*	TV[a]	FFG[b]	RC1[c]	RC2	RC3	RC4	OC1[d]	OC3
Ephemeroptera	Ephemerallidae	*Drunella*	0	SC	0	0	0	0	0	0
		Ephemerella	1	GC	0	0	0	0	0	0
		Serratella	2	GC	0	0	0	0	0	0
	Baetidae	*Baetis*	5	GC	0	0	0	0	0	0
		Callibaetis	9	GC	166	80	237	142	5	113
		Diphetor	5	GC	0	0	0	0	0	0
	Heptageniidae	*Cinygmula*	4	SC	0	0	0	0	0	0
		Epeorus	0	SC	0	0	0	0	0	0
		Nixe	4	SC	0	0	0	0	0	0
		Rhithrgena	0	SC	0	0	0	0	0	0
	Leptophlebiidae	*Paraleptophlebia*	1	GC	0	0	0	0	0	0
	Ameletidae	*Ameletus*	0	GC	0	0	0	0	0	0
	Tricorythidae	*Tricorythides*	5	GC	0	0	0	0	0	0
	Caenidae	*Caenis*	7	GC	5	4	0	6	34	22
Plecoptera	Perlidae	*Doroneuria*	1	PR	0	0	0	0	0	0
		Hesperoperla	1	PR	0	0	0	0	0	0
	Perlodidae	*Diura*	2	PR	0	0	0	0	0	0
		Kogotus	2	PR	0	0	0	0	0	0
		Skwala	2	PR	0	0	0	0	0	0
	Nemouridae	*Zapada*	2	SH	0	0	0	0	0	0
	Chloroperlidae	*Sweltsa*	1	PR	0	0	0	0	0	0
	Capniidae/Leuctridae		1	SH	0	0	0	0	0	0
	Pteronarcyidae	*Pteronarcella*	0	SH	0	0	0	0	0	0
Trichoptera	Glossosomatidae	*Glossosoma*	0	SC	0	0	0	0	0	0
	Brachycentridae	*Brachycentrus*	1	FC	0	0	0	0	0	0
		Micrasema	1	SH	0	0	0	0	0	0
	Rhyacophilidae	*Rhyacophila*	0	PR	0	0	0	0	0	0

(continued)

J: *(Continued)*

Order	Family	*Genera*	TV[a]	FFG[b]	RC1[c]	RC2	RC3	RC4	OC1[d]	OC3
Trichoptera	Hydropsychidae	*Arctopsyche*	1	FC	0	0	0	0	0	0
		Ceratopsyche	4	FC	0	0	0	0	0	0
		Cheumatopsyche	5	FC	0	0	0	0	0	0
		Hydropsyche	4	FC	0	0	0	0	0	0
	Uenoidae	*Neophylax*	3	SC	0	0	0	0	0	0
	Limnephilidae	*Asynarchus*	NA	NA	0	0	0	0	0	0
		Ecclisomyia	2	GC	0	0	0	0	0	0
		Psychologlypha	1	GC	0	0	0	0	0	0
	Philopotamidae	*Dolophilodes*	1	GC	0	0	0	0	0	0
	Leptoceridae	*Oecetis*	8	PR	0	0	0	0	0	0
	Helicopsychidae	*Helicopsyche*	3	SC	0	0	0	0	0	0
	Hydroptilidae	*Agraylea*	8	NA	0	0	0	0	0	0
		Hydroptila	6	SC	0	0	0	0	0	0
		Oxyethira	NA	NA	0	0	0	0	0	0
	Physchomyiidae	*Physchomyia*	2	SC	0	0	0	0	0	0
	Phryganeidae	*Phryganea*	4	OM	0	4	2	1	0	0
		Ptilostmis	5	SH	0	0	0	0	0	0
Diptera	Chironomidae		6	GC	55	28	77	68	12	64
	Tipulidae		3	SH	0	0	0	0	0	0
	Simuliidae		6	FC	0	0	0	0	0	0
	Psychodidae		10	GC	0	0	0	0	0	0
	Pelecorhynchidae		NA	NA	0	0	0	0	0	0
	Ceratopogonidae		6	PR	1	1	9	6	4	1
	Blephariceridae		0	SC	0	0	0	0	0	0
	Empididae		6	PR	0	0	0	0	0	0
	Deuterophlebiidae		NA	SC	0	0	0	0	0	0
	Ephydridae		6	GC	0	0	1	0	1	0
	Tabanidae		8	PR	0	2	0	0	0	0

(continued)

J: *(Continued)*

Order	Family	*Genera*	TV[a]	FFG[b]	RC1[c]	RC2	RC3	RC4	OC1[d]	OC3
Diptera	Chaoboridae		8	PR	4	1	0	0	0	0
	Dixidae		1	GC	0	0	0	0	0	0
	Stratiomyidae		8	GC	0	0	0	0	0	0
	Muscidae		6	PR	0	0	0	0	0	0
Coleoptera	Elmidae		4	GC	72	65	18	35	0	1
	Carbaidae		4	PR	11	1	1	0	0	0
	Curculionidae		NA	SH	2	0	0	0	0	0
	Dytiscidae		5	PR	0	0	0	0	0	1
	Halipidae		7	NA	4	1	1	2	0	11
	Hydrophilidae		5	PR	0	1	0	0	22	5
Anisoptera	Aeshnidae		3	PR	8	1	1	2	0	4
	Libellulidae		9	PR	0	0	0	0	0	2
	Gomphidae		1	PR	0	0	0	0	0	0
Zygotera	Coenagrionidae		9	PR	34	28	43	38	6	100
Megaloptera	Sialidae	*Sialis*	4	PR	1	2	2	1	0	0
Hemiptera	Corixidae		10	PR	0	1	0	1	11	86
	Belostomatidae		NA	PR	0	0	0	0	0	0
	Notonectidae		NA	PR	7	3	1	5	0	16
Tricladida	Planariidae		1	OM	0	0	0	0	0	0
Amphipoda	Grammaridae	*Grammarus*	4	OM	123	63	151	161	3	6
Isopoda	Asellidae		8	GC	0	0	0	0	0	0
Gastropoda	Lymnaeidae		6	GC	0	0	0	0	0	0
	Physidae		8	SC	32	12	14	57	0	0
	Planorbidae		7	SC	9	4	5	10	0	0
Bibalvia	Sphaeriidae		8	FC	8	27	20	18	0	0
Oligochaeta			5	GC	7	0	0	27	0	0
Hirudinea	Hirudinidea		7	PR	0	0	0	0	0	0

[a]Tolerance Values; [b]Functional Feeding Group; [c]Rosebud Creek reach 1; [d]Otter Creek reach 1

K: Aquatic macroinvertebrate assemblages for Louse Creek and Little Spring Creek

Order	Family	*Genera*	TV[a]	FFG[b]	LC1[c]	LC2	LC3	LC4	LS1[d]	LS2	LS3	LS4
Ephemeroptera	Ephemerallidae	*Drunella*	0	SC	0	0	0	0	0	0	0	0
		Ephemerella	1	GC	5	48	144	156	0	0	0	0
		Serratella	2	GC	0	0	0	0	0	0	0	0
	Baetidae	*Baetis*	5	GC	23	49	84	34	72	47	9	10
		Callibaetis	9	GC	0	0	0	0	0	0	0	0
		Diphetor	5	GC	0	0	0	0	0	0	0	0
	Heptageniidae	*Cinygmula*	4	SC	0	0	0	0	0	0	0	0
		Epeorus	0	SC	0	0	0	0	0	0	0	0
		Nixe	4	SC	0	0	0	0	0	0	0	0
		Rhithrgena	0	SC	0	0	0	0	0	0	0	0
	Leptophlebiidae	*Paraleptophlebia*	1	GC	2	7	18	2	7	1	0	0
	Ameletidae	*Ameletus*	0	GC	0	0	0	0	0	0	0	0
	Tricorythidae	*Tricorythides*	5	GC	1	2	16	3	102	54	1	25
	Caenidae	*Caenis*	7	GC	17	30	31	6	0	0	0	0
Plecoptera	Perlidae	*Doroneuria*	1	PR	0	0	0	0	0	0	0	0
		Hesperoperla	1	PR	0	0	0	0	0	0	0	0
	Perlodidae	*Diura*	2	PR	0	0	0	0	0	0	0	0
		Kogotus	2	PR	0	0	0	0	0	0	0	0
		Skwala	2	PR	0	0	0	0	0	0	0	0
	Nemouridae	*Zapada*	2	SH	0	0	0	0	0	0	0	0
	Chloroperlidae	*Sweltsa*	1	PR	0	0	0	0	0	0	0	0
	Capniidae/Leuctridae		1	SH	0	0	0	0	0	0	0	0
	Pteronarcyidae	*Pteronarcella*	0	SH	0	0	0	0	0	0	0	0
Trichoptera	Glossosomatidae	*Glossosoma*	0	SC	0	0	0	0	0	0	0	0
	Brachycentridae	*Brachycentrus*	1	FC	4	6	17	9	0	0	0	0
		Micrasema	1	SH	0	0	0	0	0	0	0	0
	Rhyacophilidae	*Rhyacophila*	0	PR	0	0	0	0	0	0	0	0

(continued)

APPENDIX K

AQUATIC MACROINVERTEBRATE ASSEMBLAGES FOR ROSEBUD CREEK AND OTTER CREEK

K: *(Continued)*

Order	Family	*Genera*	TV[a]	FFG[b]	LC1[c]	LC2	LC3	LC4	LS1[d]	LS2	LS3	LS4
Trichoptera	Hydropsychidae	*Arctopsyche*	1	FC	0	0	0	0	0	0	0	0
		Ceratopsyche	4	FC	0	0	0	0	0	0	0	0
		Cheumatopsyche	5	FC	6	12	83	86	61	124	47	58
		Hydropsyche	4	FC	5	63	94	35	104	49	21	27
	Uenoidae	*Neophylax*	3	SC	0	0	0	0	0	0	0	0
	Limnephilidae	*Asynarchus*	NA	NA	0	0	1	1	0	0	0	0
		Ecclisomyia	2	GC	0	0	0	0	0	0	0	0
		Psychologlypha	1	GC	0	2	0	0	0	0	0	0
	Philopotamidae	*Dolophilodes*	1	GC	0	0	0	0	0	0	0	0
	Leptoceridae	*Oecetis*	8	PR	6	14	23	33	0	0	3	4
	Helicopsychidae	*Helicopsyche*	3	SC	37	8	22	1	112	0	29	141
	Hydroptilidae	*Agraylea*	8	NA	0	0	0	0	0	0	0	0
		Hydroptila	6	SC	0	0	0	0	18	0	0	1
		Oxyethira	NA	NA	0	0	2	1	3	0	0	0
	Physchomyiidae	*Physchomyia*	2	SC	0	0	0	0	0	0	0	0
	Phryganeidae	*Phryganea*	4	OM	0	0	0	0	0	0	0	0
		Ptilostmis	5	SH	0	1	1	0	0	0	0	4
Diptera	Chironomidae		6	GC	43	49	54	248	350	32	220	129
	Tipulidae		3	SH	0	0	0	0	0	0	0	0
	Simuliidae		6	FC	1	1	5	10	98	146	3	1
	Psychodidae		10	GC	0	3	4	0	0	0	0	0
	Pelecorhynchidae		NA	NA	0	0	0	0	0	0	0	0
	Ceratopogonidae		6	PR	6	9	6	14	8	6	0	0
	Blephariceridae		0	SC	0	0	0	0	0	0	0	0
	Empididae		6	PR	0	0	0	0	0	0	0	0
	Deuterophlebiidae		NA	SC	0	0	0	0	0	0	0	0
	Ephydridae		6	GC	0	0	0	0	0	0	0	0
	Tabanidae		8	PR	0	0	0	0	0	0	0	0

(continued)

K: *(Continued)*

Order	Family	*Genera*	TV[a]	FFG[b]	LC1[c]	LC2	LC3	LC4	LS1[d]	LS2	LS3	LS4
Diptera	Chaoboridae		8	PR	0	0	0	0	0	0	0	0
	Dixidae		1	GC	0	1	0	0	0	0	0	0
	Stratiomyidae		8	GC	0	1	3	1	0	0	0	0
	Muscidae		6	PR	0	0	0	0	0	0	0	0
Coleoptera	Elmidae		4	GC	73	140	196	153	83	1	66	130
	Carbaidae		4	PR	0	0	0	0	0	0	0	0
	Curculionidae		NA	SH	0	0	0	0	0	0	0	0
	Dytiscidae		5	PR	0	0	0	0	1	2	1	0
	Halipidae		7	NA	0	0	0	1	0	0	0	0
	Hydrophilidae		5	PR	0	0	0	0	0	0	0	0
Anisoptera	Aeshnidae		3	PR	0	0	0	0	0	0	0	0
	Libellulidae		9	PR	0	0	0	0	3	0	0	0
	Gomphidae		1	PR	0	0	0	0	0	0	0	1
Zygotera	Coenagrionidae		9	PR	20	11	7	17	19	27	23	8
Megaloptera	Sialidae	*Sialis*	4	PR	1	0	0	0	0	0	7	12
Hemiptera	Corixidae		10	PR	6	5	5	9	0	0	0	1
	Belostomatidae		NA	PR	8	8	3	3	0	0	7	27
	Notonectidae		NA	PR	0	0	0	0	0	0	0	0
Tricladida	Planariidae		1	OM	0	0	0	0	0	0	0	0
Amphipoda	Grammaridae	*Grammarus*	4	OM	148	263	251	413	238	1	97	204
Isopoda	Asellidae		8	GC	0	0	0	0	0	0	0	0
Gastropoda	Lymnaeidae		6	GC	0	0	0	0	0	0	0	0
	Physidae		8	SC	2	7	5	5	53	347	125	22
	Planorbidae		7	SC	0	0	0	0	0	0	2	0
Bibalvia	Sphaeriidae		8	FC	41	4	6	6	22	40	4	20
Oligochaeta			5	GC	59	11	16	19	130	176	109	84
Hirudinea	Hirudinidea		7	PR	12	15	10	14	11	16	2	7

[a]Tolerance Values; [b]Functional Feeding Group; [c]Louse Creek reach 1; [d]Little Spring reach 1