APPENDIX C - ANALYSIS OF BASE PARAMETER DATA AND EROSION INVENTORY DATA FOR SEDIMENT TMDL DEVELOPMENT WITHIN THE ROCK TPA

Appendix C is based on a report prepared for the DEQ by Water & Environmental Technologies, PC, June 2012, which is on file in the DEQ WQPB Library.

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C1.0 INTRODUCTION

The Rock TPA encompasses an area of approximately 569,320 acres, or approximately 890 square miles, in Granite and Missoula counties of southwestern Montana (**Attachment C1, Figure C1-1**). This TPA comprises the entire Rock Creek watershed. Waterbodies in this TPA flow through both publicly-owned (United States Forest Service, State of Montana and Bureau of Land Management) and privately-owned land. The streams in the Rock TPA are within the 4th code HUC 17010202, and they have been assigned a B-1 beneficial use classification (ARM 17.30.623). Rock Creek is located in the Pend Oreille River Basin (Accounting Unit 170102) and drains from the Anaconda Range to the Clark Fork River near Clinton. The watershed is located in the Middle Rockies and Idaho Batholith Level III Ecoregions. Flow in Rock Creek is reduced by an inter-basin diversion from the East Fork Reservoir on East Fork Rock Creek into Trout Creek, a tributary of Flint Creek.

Under Montana law, an impaired waterbody is defined as a waterbody for which sufficient and credible data indicates non-compliance with applicable water quality standards (MCA 75-5-103). Section 303 of the Federal Clean Water Act requires states to submit a list of impaired water bodies or stream segments to the U.S. Environmental Protection Agency (EPA) every two years. Prior to 2004, this list was referred to as the “303(d) list”, but is now named the “Integrated Report”. The Montana Water Quality Act further directs states to develop TMDLs for all water bodies appearing on the 303(d) list as impaired or threatened by “pollutants” (MCA 75-5-703).

Within the Rock TPA, there are 9 waterbody segments listed on the 2012 303(d) List for sediment-related impairments: Brewster Creek, East Fork Rock Creek, Eureka Gulch, Flat Gulch, Miners Gulch, Quartz Gulch, Scotchman Gulch, Sluice Gulch, and South Fork Antelope Creek. Streams identified in this sampling strategy include all of the streams listed above as well as Upper Willow Creek (which is impaired due to habitat alteration), Antelope Creek, and West Fork Rock Creek.

In 2011, Montana Department of Environmental Quality (DEQ) initiated an effort to collect data to support the development of sediment TMDLs for streams within the Rock TPA. This data collection effort involved assessing sediment and habitat conditions within the Rock Creek watershed, including stream stratification, sampling design, ground surveys, and sediment and habitat analyses. These data are intended to assist DEQ in evaluating the condition of tributary streams in the TPA and developing TMDLs where necessary.

A stream stratification process was previously completed by DEQ on stream segments in the Rock TPA. The stratification process is intended to develop similar waterbody characterizations that can be applied across watersheds, accounting for localized ecological and hydrologic variations. Stratification enables comparison between observed and expected values for various sediment and habitat parameters, and helps quantify the effects of anthropogenic influences. Stratification for streams in the Rock TPA began by dividing the water bodies into reaches and sub-reaches based on aerial photo interpretation of stream characteristics, landscape conditions, and land-use factors.

Following the initial primary reach stratification, representative reaches were chosen by DEQ for data collection. A two-day sampling reach reconnaissance was conducted in July 2011, and field personnel completed full site surveys in August 2011. Field personnel visited the selected reaches and recorded bank erosion sites, vegetation, and channel characteristic data as detailed in this report. Data were later compiled and analyzed resulting in full descriptions of sediment and habitat conditions for all of the surveyed reaches and the ability to extrapolate to non-surveyed reaches.

C2.0 Aerial Assessment Reach Stratification

C2.1 Methods

An aerial photo assessment of streams in the Rock TPA was conducted by Montana DEQ using geographic information systems (GIS) software and 2009 color aerial imagery. Relevant geographic data layers were acquired from the U.S. Geological Survey (USGS), the U.S. Environmental Protection Agency (USEPA) and the Montana State National Resource Information System (NRIS) database. Layers include the following data sets.

- Ecoregion (USEPA)
- Scanned and Rectified Topographic Maps, 1:24,000 and 1:100,000 (USGS)
- National Hydrography Dataset Lakes and Streams (USGS)
- 2009 National Aerial Image Program (NAIP – NRIS)

GIS data layers were used to stratify streams into primary reaches based on stream characteristics, landscape and land-use factors. The stream reach stratification methodology applied in this study is described in *Watershed Stratification Methodology for TMDL Sediment and Habitat Investigations* (Montana Department of Environmental Quality, 2008). The reach stratification methodology involves delineating a waterbody stream segment into stream reaches and sub-reaches. This process was completed for the following stream segments in the Rock TPA: Antelope Creek, Brewster Creek, East Fork Rock Creek, Flat Gulch, Miners Gulch, Quartz Gulch, Scotchman Gulch, South Fork Antelope Creek, Sluice Gulch, Upper Willow Creek, and West Fork Rock Creek. Although Eureka Gulch was stratified, no sites were assessed on the stream during the sediment and habitat data collection in 2011 because access was not granted.

C2.2 Stream Reaches

Waterbody segments are delineated by a water use class designated by the State of Montana, e.g. A-1, B-3, C-3 (Administrative Rules of Montana Title 17 Chapter 30, Sub-Chapter 6). Although a waterbody segment is the smallest unit for which an impairment determination is made, the stratification approach described in this document initially stratifies individual waterbody segments into discrete assessment reaches that are delineated by landscape controls including Ecoregion, Strahler stream order, valley gradient, and valley confinement. The reason for this stratification is that the inherent differences in landscape controls between stream reaches often prevents a direct comparison from being made between the physical attributes of one stream reach to another. By initially stratifying waterbody segments into stream reaches having similar landscape controls, it is feasible to make broad comparisons between similar reaches with regards to observed versus expected channel morphology. Likewise, when land use is used as an additional stratification category (e.g. grazed vs. non-grazed sub-reaches), sediment and habitat parameters for impaired stream reaches can be more readily compared to reference reaches that meet the same geomorphic stratification criteria.

Once stream reaches have been stratified, reaches are further divided based on the surrounding vegetation and land-use characteristics as observed in the color aerial imagery using GIS. The result is a series of stream reaches and sub-reaches delineated by landscape and land-use factors. Stream reaches with similar landscape factors can then be compared based on the character of surrounding land-use practices.

For ease of labeling, each listed stream in the assessment was assigned an abbreviation based on the stream name. These labels were used in the individual stream reach classification. **Table C2-1** shows the abbreviations developed for each waterbody.

Table C2-1. Waterbody naming key.

Waterbody	Label Abbreviation
Antelope Creek	ANTE
Brewster Creek	BREW
East Fork Rock Creek	EFRK
Flat Gulch	FLAT
Miners Gulch	MINE
Quartz Gulch	QUTZ
Scotchman Gulch	SCOT
South Fork Antelope Creek	SFAN
Sluice Gulch	SLUI
Upper Willow Creek	UWIL
West Fork Rock Creek	WFRK

C2.3 Reach Types

Individual stream reaches were delineated by reach type based on four watershed characteristics. For the purposes of this report, a "reach type" is defined as a unique combination of Ecoregion, valley gradient, Strahler stream order, and valley confinement, and is designated using the following naming convention based on the reach type identifiers provided in **Table C2-2**:

Level III Ecoregion – Valley Gradient – Strahler Stream Order – Confinement

The Rock TPA exists within the Middle Rockies (Ecoregion 17) and Idaho Batholith (Ecoregion 16) Level III Ecoregions. Only a small portion of West Fork of Rock Creek is within Ecoregion 16, including one sample site (WFRK 14-03). For the purpose of analysis within this report this site will be categorized as being in the Middle Rockies Ecoregion even though it lies partially within the Idaho Batholith Ecoregion. The Middle Rockies Ecoregion includes three Level IV Ecoregions within the Rock TPA, including the Deer Lodge-Philipsburg-Avon Grassy Intermontane Hills and Valleys (17ak), the Flint Creek-Anaconda Mountains (17am), and the Rattlesnake-Blackfoot-South Swan-Northern Garnet-Sapphire Mountains (17x). The Idaho Batholith Ecoregion includes only one Level IV Ecoregion, the Eastern Batholith (16a). Present reach type combinations for the Rock TPA are provided in **Table C2-3**, including the number of sites monitored of each reach type. Overall, 22 monitoring sites were selected for field evaluation.

Table C2-2. Reach type identifiers.

Watershed Characteristic	Stratification Category	Reach Type Identifier
Level III Ecoregion	Middle Rockies	MR
Valley Gradient	0-2%	0
	2-4%	2
	4-10%	4
	> 10%	10
Strahler Stream Order	first order	1
	second order	2
	third order	3
	fourth order	4
Confinement	confined	C
	unconfined	U

Table C2-3. Stratified reach types within the Rock TPA.

Level III Ecoregion	Valley Gradient	Strahler Stream Order	Confine-ment	Reach Type	Total Number of Reaches	Number of Monitoring Sites
Middle Rockies	<2%	1	U	MR-0-1-U	2	
		2	U	MR-0-2-U	17	
		3	C	MR-0-3-C	1	
			U	MR-0-3-U	45	6
		4	U	MR-0-4-U	9	2
	2-4%	1	C	MR-2-1-C	3	
			U	MR-2-1-U	9	1
		2	C	MR-2-2-C	8	1
			U	MR-2-2-U	18	2
		3	C	MR-2-3-C	5	
			U	MR-2-3-U	15	2
	4-10%	1	C	MR-4-1-C	25	1
			U	MR-4-1-U	40	3
		2	C	MR-4-2-C	10	1
			U	MR-4-2-U	12	2
		3	C	MR-4-3-C	1	
			U	MR-4-3-U	2	
	>10%	1	C	MR-10-1-C	21	
			U	MR-10-1-U	20	1
		2	C	MR-10-2-C	3	
Totals:					**266**	**22**

Table C2-4 shows the assessed water bodies and monitored reaches included within each reach type. A map of monitoring site locations is provided as **Attachment C1 – Figure C1-1**.

Table C2-4. Monitoring sites in assessed reach types.

Reach Type	waterbody	Monitoring Sites
MR-0-3-U	Antelope Creek, Brewster Creek, Upper Willow Creek, West Fork Rock Creek	ANTE 21-01, BREW 06-01, UWIL 11-05, WFRK 14-03, WFRK 27-03, WFRK 30-02
MR-0-4-U	East Fork Rock Creek, Upper Willow Creek	EFRK 03-03, UWIL 15-01
MR-10-1-U	Flat Gulch	FLAT 13-01

Table C2-4. Monitoring sites in assessed reach types.

Reach Type	waterbody	Monitoring Sites
MR-2-1-U	Scotchman Gulch	SCOT 08-01
MR-2-2-C	Sluice Gulch	SLUI 14-01
MR-2-2-U	Miners Gulch, Sluice Gulch	MINE 14-02, SLUI 18-02
MR-2-3-U	Brewster Creek, East Fork Rock Creek	BREW 05-01, EFRK 01-02
MR-4-1-C	Quartz Gulch	QUTZ 09-01
MR-4-1-U	Flat Gulch, Miners Gulch, Scotchman Gulch	FLAT 12-01, MINE 10-02, SCOT 16-02
MR-4-2-C	South Fork Antelope Creek	SFAN 06-01
MR-4-2-U	Antelope Creek, South Fork Antelope Creek	ANTE 07-01, SFAN 13-01

C3.0 Sediment and Habitat Dataset Review

C3.1 Field Methodology

The following sections describe the field methodologies employed during the stream assessments. The methods follow standard DEQ protocols for sediment and habitat assessment as presented in the document *Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments* (Montana Department of Environmental Quality, 2011a). For most survey sites, a minimum of 5 team members were present, which were always divided into 3 teams, referred to as the “Greenline”, “Longitudinal Profile” or “Long-Pro”, and “Cross-Section” teams. The teams worked independently moving upstream through the survey site and in a pre-established order to facilitate accurate data collection and to create the least possible instream disturbance. All field data were collected on DEQ standard forms for sediment and habitat assessments, and are summarized and provided in tabular format in the original report, which is available from the DEQ WQPB library.

C3.1.1 Survey Site Delineation

Stream survey sites were delineated beginning at riffle crests at the downstream end of each surveyed reach. Survey sites were measured moving upstream at pre-determined lengths based on the bankfull width at the selected downstream riffle. Survey lengths of 500 ft were used for bankfull widths less than 10 ft, survey lengths of 1,000 ft were used for bankfull widths between 10 ft and 50 ft, and survey lengths of 1,500 ft were used for bankfull widths of 51-75 ft. Each survey site was divided into 5 equally sized study cells. For each site, the field team leader identified the appropriate downstream riffle crest to begin a reach. Where no riffles were present or the stream was dry, the field team leader identified the appropriate starting point. The GPS location of the downstream and upstream ends of the survey site was recorded on the **Sediment and Habitat Assessment Site Information Form**. Digital photographs were taken at both upstream and downstream ends of the survey site, looking both upstream and downstream. Photo numbers and a brief description were recorded in a Photo Log.

C3.1.2 Field Determination of Bankfull

All members of the field crew participated in determining the bankfull elevation prior to breaking into their respective teams. Indicators that were used to estimate the bankfull channel elevation included scour lines, changes in vegetation types, tops of point bars, changes in slope, changes in particle size and distribution, stained rocks and inundation features. Multiple locations and indicators were examined, and bankfull elevation estimates and their corresponding indicators were recorded in the **Bankfull Elevation and Slope Assessment Field Form** by the field team leader. Final determination of the appropriate bankfull elevation was determined by the team leader, and informed by the team experience and notes from the field form.

C3.1.3 Channel Cross-Sections

The "Cross-Section team" was composed of two members of the assessment crew, who also performed pebble counts, riffle grid tosses, and riffle stability index. Channel cross-section surveys were performed at the first riffle in each cell moving upstream using a line level and a measuring rod. Channel surveys were recorded in the **Channel Cross-section Field Form**. Cross-sections were surveyed in each cell containing a riffle. In the case that riffles were present in only 1 or 2 cells, but those cells contained multiple riffles, additional cross-sections were performed at the most downstream unmeasured riffle, such that a minimum of three cross-sections were surveyed. If only 1 or 2 riffles were present in the entire reach, all riffle cross-sections were surveyed.

To begin each survey, the Cross-Section team placed a bank pin at the pre-determined bankfull elevation (using bankfull indicators as guides) on the right and left banks. A measuring tape was strung perpendicular to the stream channel at the most well-defined portion of the riffle and tied to the bank pins. Where mid-channel bars or other features were present which prevented a clean line across the channel, the protocol provided in the field methodology document was followed (Montana Department of Environmental Quality, 2011a). Bankfull depth measurements were collected to the nearest tenth of a foot across the channel at regular intervals depending on channel width. The thalweg depth was recorded at the deepest point of the channel independent of the regularly spaced intervals. From the recorded data, the following information was calculated for each cross-section:

Bankfull channel width = with of the channel measured at bankfull height.

Cross-sectional area = the sum of the calculated areas from each measured cross-section cell. This value is estimated in the field and later calculated in a spreadsheet.

Mean bankfull depth = cross-section area/bankfull channel width. This value is estimated in the field and later calculated in a spreadsheet.

Width/depth ratio = bankfull width / mean bankfull depth.

Entrenchment ratio = flood prone width / bankfull width.

The flood prone depth was determined by doubling the maximum channel depth. The flood prone width was then determined by stringing a tape from the bankfull channel margin on both right and left banks until the tape (pulled tight and flat) touched ground at the flood prone elevation. The total flood prone width was calculated by adding the bankfull channel width to the distances on each end of the channel to the flood prone elevation. When dense vegetation or other features prevented a direct line of tape from being strung, best professional judgment was used to determine the flood prone width. GPS coordinates for each cross-section were recorded. Photos were taken upstream and downstream of the cross section from the middle of the channel. A photo was also taken across the channel, showing the tape across the stream.

C3.1.3.1 Riffle Pebble Count

A Wolman pebble count (Wolman, 1954) was performed by the Cross-Section team at the first riffle encountered in cells 1, 2, 3 and 5 as the team progressed upstream for a total count of at least 400 particles. These data were recorded in the **Riffle Pebble Count Field Form**. Particle sizes were measured along their intermediate length axis (*b-axis*) and results were grouped into size categories. The team progressed from bankfull edge to bankfull edge using the "heel to toe" method, measuring particle size at the tip of the boot at each step. More specific details of the pebble count methodology can be found in the field methods document (Montana Department of Environmental Quality, 2011a).

C3.1.3.2 Riffle Grid Toss

Measurements of fine sediment in riffles were recorded by the Cross-Section team using the same grid toss method as used in pools (**Section C3.1.4.3**). Grid tosses were performed approximately within the right, middle, and left third of the riffle. Grid tosses were performed in the same general location but before the pebble counts (**Section C3.1.3.1**) to avoid disturbances to fine sediments. These measurements were recorded in the **Riffle Pebble Count Field Form.**

C3.1.3.3 Riffle Stability Index

In stream reaches that had well developed point bars downstream of riffles, a riffle stability index (RSI) was performed to determine the average size of the largest recently deposited particles, and to calculate an RSI which evaluates riffle particle stability (Kappesser, 2002). For stream reaches in which well-developed gravel bars were present, a RSI was determined by first measuring the intermediate axis (*b-axis*) of 15 of the largest recently deposited particles on a depositional bar. This information was recorded in the **Riffle Pebble Count Field Form**. During post-field data processing, the arithmetic mean of the largest recently deposited particles is calculated. This value is then compared to the cumulative particle size distribution of an adjacent riffle, as determined by the Wolman pebble count. The RSI is reported as the cumulative percentile of the particle size classes that are smaller than the arithmetic mean of the largest recently deposited particles. The RSI value generally represents the percent of mobile particles within the riffle that is adjacent to the sampled bar.

C3.1.4 Channel Bed Morphology

A variety of channel bed morphology features were measured and recorded by the "Long-Pro" team, which consisted of one team member experienced in identifying these features, and who could consult with the field team leader when needed. The length of the survey site occupied by pools and riffles was identified and recorded in the **Pools, Riffles and Large Woody Debris Field Form.** Beginning from the downstream end of the survey site, the upstream and downstream stations of dominant riffle and pool features were recorded. Riffles were considered dominant when occupying over 50% of the stream width. A pool is defined as a depression in the streambed that is concave in profile, is bounded by a "head crest" at the upstream end and "tail crest" at the downstream end, and that typically has a maximum depth that is 1.5 times the pool-tail depth. Pools and riffles were measured from the downstream to upstream end of each feature. Runs and glides were not recorded in the field form. Stream features were identified using standard methods (Montana Department of Environmental Quality, 2011a).

C3.1.4.1 Residual Pool Depth

For this assessment, a pool is defined as a depression in the streambed that is concave in profile, is bounded by a "head crest" at the upstream end and a "tail crest" at the downstream end, and has a maximum depth that is 1.5 times the pool-tail depth. Backwater pools were not measured. The station (distance in feet) of each measured pool was recorded beginning at the downstream end of the survey site. At all pools, the maximum pool depth and pool tail depth were measured, the difference of which provides the residual pool depth. In the case of dry channels, readings were taken from channel bed surface to bankfull height. No pool tail crest depth was recorded for dammed pools (see **Section C3.1.4.2**).

C3.1.4.2 Pool Habitat Quality

Qualitative assessments of each pool feature were undertaken and recorded in the **Pools, Riffles and Large Woody Debris Field Form** as follows:

Pool types were determined to be either Scour (S) or Dammed (D).
Pool size was estimated relative to bankfull channel width was recorded as Small (S) or Large (L). Small pools were defined as <1/2 of the bankfull channel width and large pools were determined to be those >1/2 of the bankfull channel width or >20 feet wide.
Pool formative features were recorded as lateral scour (LS), plunge (P), boulder (B), or woody debris (W).
The primary pool cover type was recorded using the following codes:

- V = Overhanging Vegetation
- D = Depth
- U = Undercut
- B = Boulder
- W = Woody Debris
- N = No apparent cover

C3.1.4.3 Fine Sediment in Depositional Spawning Areas

A measurement of the percent of fine sediment in depositional spawning areas was conducted using the grid toss method at all scour pools encountered within each cell. Grid toss readings were focused in those gravels that appeared to be suitable or potentially suitable for trout spawning. Measurements were taken within the “arc” just upstream of the pool tail crest or other pool locations suitable for spawning, following the methodology in *Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments* (Montana Department of Environmental Quality, 2011a). Three measurements were taken across the channel with specific attention given to measurements in gravels determined to be of appropriate size for salmonid spawning. The presence of spawning gravels was recorded as Yes (Y), No (N) or Unknown (?) at each pool location.

C3.1.4.4 Woody Debris Quantification

The amount of large woody debris (LWD) was recorded by the Long-Pro team along the entire assessment reach in the **Pools, Riffles and Large Woody Debris Field Form**. Large pieces of woody debris within the bankfull channel and which were relatively stable as to influence the channel form were counted as either single, aggregate or willow bunch. For this assessment, a piece of large woody debris is defined as being greater than 9 feet long or two-thirds of the wetted stream width, and at least 4 inches in diameter at the small end. An aggregate is comprised of two or more single pieces of large woody debris. Further description of these categories is provided in *Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments* (Montana Department of Environmental Quality, 2011a).

C3.1.5 Riparian Greenline Assessment

After the entire survey station length was measured by the “Greenline” team member, an assessment of riparian vegetation cover was performed. The reach was walked by the “Greenline” team member who noted the general vegetation community type of the groundcover, understory and overstory on both banks. Vegetation types were recorded in the **Riparian Greenline Field Form** at intervals of 10’, 15’ or 20’ depending on the length of the reach.

The *ground cover* vegetation (<1.5 feet tall) was described using the following categories:

W = Wetland vegetation, such as sedges and rushes
G = Grasses or forbs, rose, snowberry (vegetation lacking binding root structure)
B = Bare/disturbed ground
R = Rock, when a large cobble or bolder is encountered
RR = Riprap

The *understory* (1.5 to 15 feet tall) and *overstory* (>15 feet tall) vegetation was described using the following categories:

C = Coniferous
D = Deciduous, riparian shrubs and trees with sufficient rooting mass and depth to provide protection to the streambanks
M = mixed coniferous and deciduous

At 50-foot intervals, riparian buffer width was estimated for both banks by evaluating the belt of riparian vegetation buffering the stream from adjacent land uses. Upon conclusion of the Greenline measurements, the total numbers of each type of vegetation were tallied.

C3.1.6 Streambank Erosion Assessment

An assessment of all actively/visually eroding and slowly eroding/undercut/vegetated streambanks was conducted along each survey site. This assessment consisted of the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) estimation which are used to quantify sediment loads from bank erosion. All streambank measurements were recorded in the **Streambank Erosion Field Form** and **Additional Streambank Erosion Measurements Form.** Further information related to the streambank erosion assessment methodology and results is included in **Sections C4.2** and **C4.3**.

C3.1.7 Water Surface Slope

The water surface slope was measured using a transit level and stadia rod using methods described in the field methods document (Montana Department of Environmental Quality, 2011a) and recorded on the **Slope Worksheet Field Form**. In areas where line of sight is not possible due to interference of vegetation or topography, slope was estimated between similar stream features using a clinometer.

C3.1.8 Field Notes

At the completion of data collection at each survey site, field notes were collected by the field team leader with inputs from the entire field team. The following four categories contributed to field notes, which served to provide an overall context for the condition of the stream channel relative to surrounding and historical uses:

- Description of human impacts and their severity;
- Description of stream channel conditions;
- Description of streambank erosion conditions; and

- Description of riparian vegetation conditions.

C3.1.9 Quality Assurance/Quality Control

Quality assurance and quality control (QA/QC) was achieved through strict adherence to the project's Sampling and Analysis Plan (SAP) (Montana Department of Environmental Quality, 2011b). During each stream assessment, the field team leader and most experienced crew members led the separate teams. Equipment checks were done each morning and field maps were reviewed with drivers before approaching field sites. Field forms were distributed and double-checked before teams left the vehicles to the survey sites. At the conclusion of each stream assessment, all field forms were reviewed for completeness and accuracy. Any questions that arose from field teams were brought to the attention of the field team leader until resolved to the leader's satisfaction.

Despite the best efforts to adhere to the project's SAP, some deviations did occur while in the field. Any deviations from the SAP are described in the Quality Assurance/Quality Control Review in the original report (Water & Environmental Technologies, 2012).

C3.2 Sampling Parameter Descriptions and Summaries by Reach Type

The following sections provide definitions of sampling parameters that were measured at each reach, and basic statistical summaries of data for each parameter organized by reach type. Parameters described in this section include bankfull channel width, width/depth ratio, entrenchment ratio, percent understory shrub cover, percent bare/disturbed ground, riffle pebble count data (% <2 mm and <6 mm, D50), riffle grid toss data (% <6 mm), riffle stability index (RSI), mean pool depth, pool frequency, pool grid toss data (% <6 mm), and large woody debris (LWD) frequency. Data for each individual measurement site were used in the statistical analysis (i.e. data from each of the individual cross sections in one assessment reach were used), and then sample reaches and water bodies were grouped into reach types as shown in **Table C2-3**.

Data provided for each parameter include statistical box plots and data tables organized by each reach type and a total that includes data from all monitored sites. The box plots and data tables provide the minimum and maximum observed values, and the 25th (Q1), 50th (median), and 75th (Q3) percentile values. The statistics tables also provide the number of reaches sampled and the number of data cases available for each parameter. Parameters with a limited number of cases (N<4) or with little variability may appear as a single line on the box plots.

C3.2.1 Bankfull Channel Width

Bankfull is a concept used by hydrologists to define a regularly occurring, channel-forming high flow. One of the first generally accepted definitions of bankfull was provided by Dunne and Leopold (1978):

> *"The bankfull stage corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels."*

Bankfull channel width is measured at each surveyed cross-section as the width of the channel at bankfull height. In general, bankfull channel width will increase with stream order, although overwidened streams may have an artificially high channel width.

The measured bankfull channel widths are presented in **Figure C3-1** by reach type, and summary statistics are provided in **Table C3-1**. All surveyed cross sections are included in the data generated for each reach type**.**

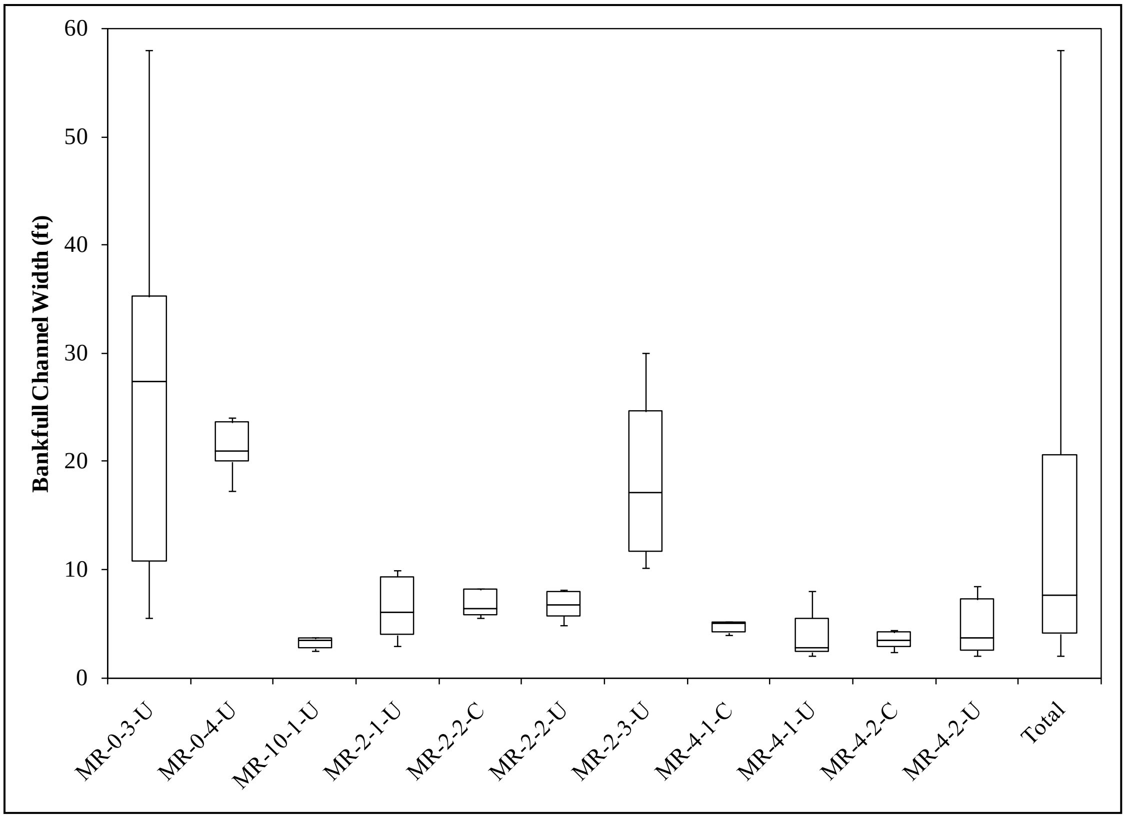

Figure C3-1. Bankfull channel width by reach type.

Table C3-1. Summary statistics of bankfull channel width by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	28	5.5	10.8	27.4	35.3	58.0
MR-0-4-U	2	10	17.3	20.1	21.0	23.6	24.0
MR-10-1-U	1	5	2.5	2.8	3.5	3.7	3.8
MR-2-1-U	1	5	3.0	4.0	6.1	9.4	10.0
MR-2-2-C	1	5	5.5	5.9	6.4	8.2	8.3
MR-2-2-U	2	10	4.9	5.8	6.8	8.0	8.2
MR-2-3-U	2	10	10.2	11.8	17.2	24.6	30.0
MR-4-1-C	1	5	4.0	4.3	5.0	5.1	5.2
MR-4-1-U	3	15	2.0	2.4	2.8	5.5	8.0
MR-4-2-C	1	5	2.4	3.0	3.5	4.2	4.4
MR-4-2-U	2	10	2.0	2.6	3.7	7.3	8.5
Total	**22**	**108**	**2.0**	**4.1**	**7.7**	**20.7**	**58.0**

C3.2.2 Width/Depth Ratio

The stream channel width/depth ratio is defined as the channel width at bankfull height divided by the mean bankfull depth (Rosgen, 1996). The width/depth ratio is one of several measurements used to classify stream channels, making it useful for comparing conditions on reaches within the same stream type. A comparison of observed and expected width/depth ratio is an indicator of channel overwidening and aggradation, which are often linked to excess streambank erosion or acute or chronic erosion from sources upstream. Channels that are overwidened often are associated with excess deposition and erosion, contain shallow warm water, and provide fewer deepwater refugia for fish. Width to depth ratios were calculated using mean segment depths instead of field measured depths, meaning that for each segment (the distance between any two adjacent field measured points on the cross section), the two field measured depths that make up the boundaries of that segment were averaged together (thereby estimating the midpoint for that segment of the cross- section's depth).

The measured width/depth ratios are presented in **Figure C3-2** by reach type, and summary statistics are provided in **Table 3-2**. All surveyed cross sections are included for each reach type**.**

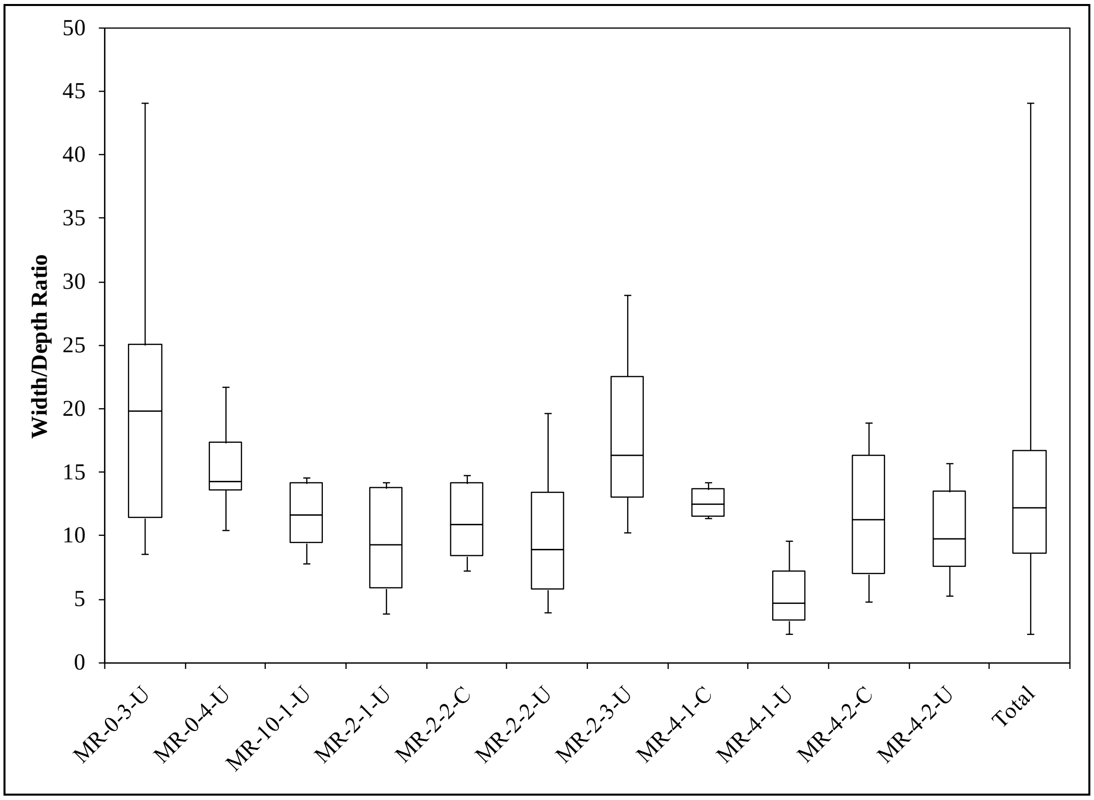

Figure C3-2. Width/depth ratio by reach type.

Table C3-2. Summary statistics of width/depth ratio by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	28	8.6	11.4	19.8	25.0	44.1
MR-0-4-U	2	10	10.5	13.6	14.2	17.3	21.7
MR-10-1-U	1	5	7.8	9.5	11.7	14.2	14.6
MR-2-1-U	1	5	3.9	5.9	9.3	13.8	14.2
MR-2-2-C	1	5	7.2	8.4	10.9	14.2	14.8
MR-2-2-U	2	10	4.0	5.8	8.9	13.5	19.7
MR-2-3-U	2	10	10.3	13.1	16.3	22.6	29.0
MR-4-1-C	1	5	11.4	11.6	12.5	13.7	14.2
MR-4-1-U	3	15	2.2	3.3	4.7	7.2	9.6

Table C3-2. Summary statistics of width/depth ratio by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-4-2-C	1	5	4.8	7.0	11.3	16.4	18.9
MR-4-2-U	2	10	5.3	7.6	9.8	13.5	15.7
Total	**22**	**108**	**2.2**	**8.6**	**12.2**	**16.7**	**44.1**

C3.2.3Entrenchment Ratio

Stream entrenchment ratio is equal to the flood prone width divided by the bankfull width (Rosgen, 1996). Entrenchment ratio is used to help determine if a stream shows departure from its natural stream type. It is an indicator of stream incision, and therefore indicates how easily a stream can access its floodplain. Streams are often incised due to detrimental land management or may be naturally incised due to landscape characteristics. A stream that is overly entrenched generally is more prone to streambank erosion due to greater energy exerted on the banks during flood events. Greater scouring energy in incised channels results in higher sediment loads derived from eroding banks. If the stream is not actively degrading (downcutting), the sources of human caused incision may be historical in nature and may not currently be present, although sediment loading may continue to occur. The entrenchment ratio is an important measure of channel condition as it relates to sediment loading and habitat condition, due to the long-lasting impacts of incision and the large potential for sediment loading in incised channels.

The entrenchment ratios by reach type are presented in **Figure C3-3**, and summary statistics are provided in **Table C3-3**. All surveyed cross sections are included in the statistics generated within each reach type**.**

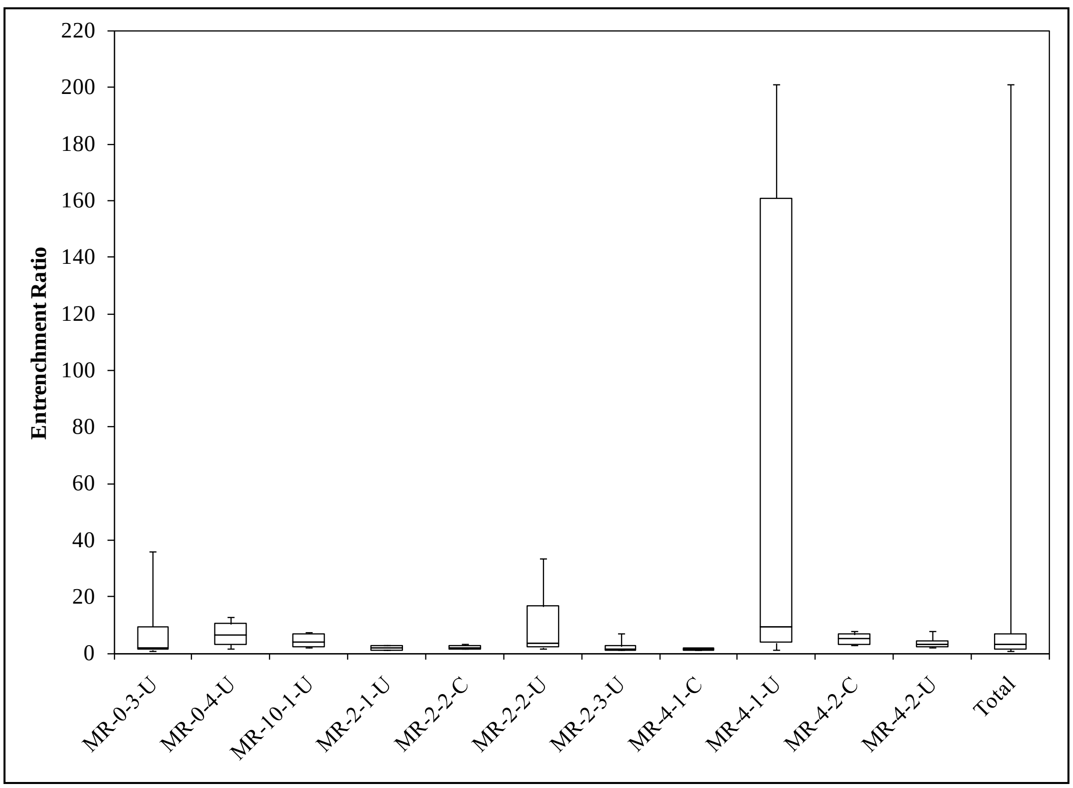

Figure C3-3. Entrenchment ratio by reach type.

Table C3-3. Summary statistics of entrenchment ratio by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	28	1.1	1.4	2.0	9.4	36.0
MR-0-4-U	2	10	1.6	3.2	6.7	10.6	12.7
MR-10-1-U	1	5	2.3	2.3	4.2	7.0	7.7
MR-2-1-U	1	5	1.2	1.3	1.9	2.9	3.0
MR-2-2-C	1	5	1.6	1.7	1.9	2.9	3.4
MR-2-2-U	2	10	1.9	2.2	3.7	16.8	33.5
MR-2-3-U	2	10	1.2	1.2	1.6	2.6	7.0
MR-4-1-C	1	5	1.2	1.2	1.4	1.5	1.5
MR-4-1-U	3	15	1.5	4.0	9.2	161.0	201.0
MR-4-2-C	1	5	3.0	3.1	5.3	6.8	8.1
MR-4-2-U	2	10	2.0	2.4	3.3	4.6	7.9
Total	**22**	**108**	**1.1**	**1.6**	**3.0**	**7.0**	**201.0**

C3.2.4 Riffle Pebble Count: Substrate Fines (% <2 mm)

Clean stream bottom substrates are essential for optimum habitat for many fish and aquatic insect communities. The most obvious forms of degradation occur when critical habitat components such as spawning gravels (Chapman and McLeod, 1987) and cobble surfaces are physically covered by fines, thereby decreasing inter-gravel oxygen and reducing or eliminating the quality and quantity of habitat for fish, macroinvertebrates and algae (Lisle, 1989; Waters, 1995). Chapman and McLeod found that size of bed material is inversely related to habitat suitability for fish and macroinvertebrates and that excess sediment decreased both density and diversity of aquatic insects. Specific aspects of sediment-invertebrate relationships may be described as follows: 1) invertebrate abundance is correlated with substrate particle size; 2) fine sediment reduces the abundance of original populations by reducing interstitial habitat normally available in large-particle substrate (gravel, cobbles); and 3) species type, species richness, and diversity all change as particle size of substrate changes from large (gravel, cobbles) to small (sand, silt, clay) (Waters, 1995).

The percent of fine sediment in a stream channel provides a measure of the siltation occurring in a river system and is an indicator of stream channel condition. Although it is difficult to correlate percent surface fines with sediment loading directly, the Clean Water Act allows “other applicable measures” for the development of TMDL water quality restoration plans. Percent surface fines have been used successfully in other TMDLs in western Montana addressing sediment related to stream bottom deposits, siltation, and aquatic life uses. Surface fine sediment measured in the Wolman pebble count is one indicator of aquatic habitat condition and can indicate excessive sediment loading. The Wolman pebble count method provides a survey of the particle distribution of the entire channel width, allowing investigators to calculate a percentage of the surface substrate (as frequency of occurrence) composed of fine sediment.

In addition to being a direct measure of impairment to the aquatic macroinvertebrate community, riffle percent surface fines can be used as an indicator of possible impairment condition to coldwater fish since the elevated riffle surface fines are likely an indicator of elevated subsurface fines within spawning gravels.

The pebble count measurements for particles <2 mm by reach type are presented in **Figure C3-4**, and summary statistics are provided in **Table C3-4**.

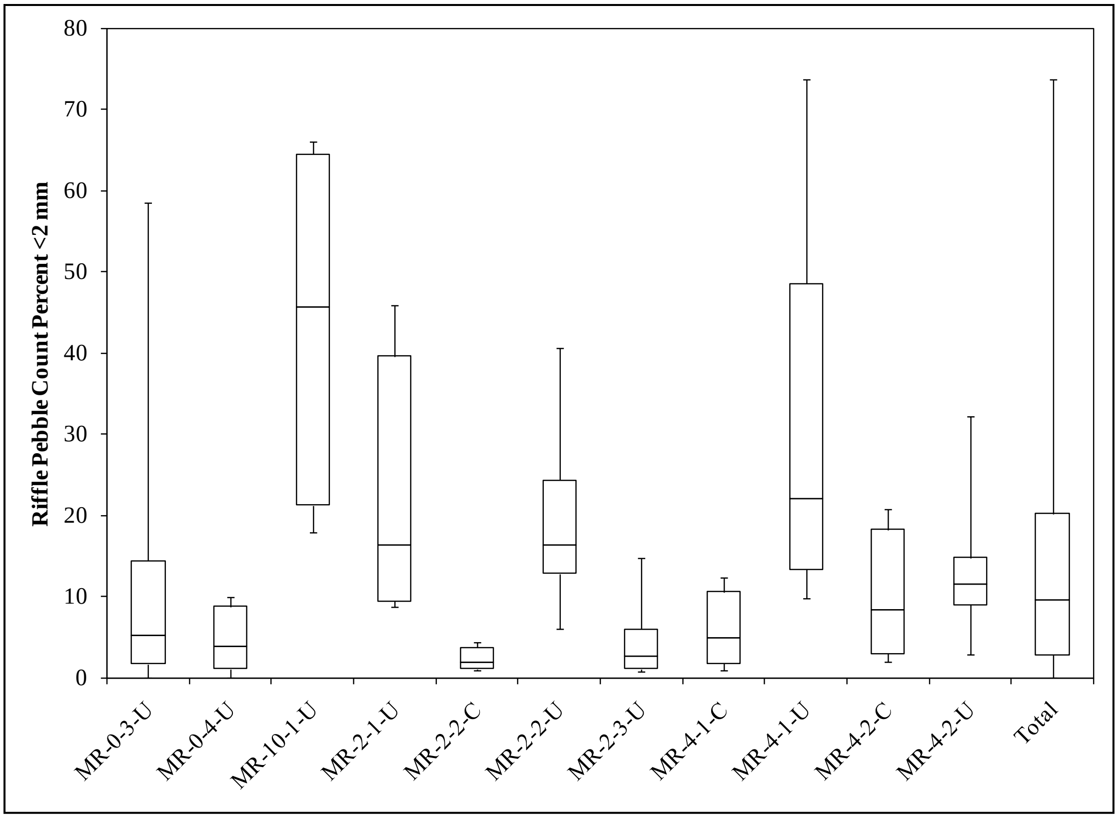

Figure C3-4. Riffle pebble count (% <2 mm) by reach type.

Table C3-4. Summary statistics of riffle pebble count (% <2 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	24	0.0	1.7	5.3	14.5	58.5
MR-0-4-U	2	8	0.0	1.2	3.8	8.8	9.9
MR-10-1-U	1	4	17.9	21.3	45.7	64.5	66.0
MR-2-1-U	1	4	8.7	9.5	16.3	39.6	45.9
MR-2-2-C	1	4	0.9	1.1	1.9	3.8	4.4
MR-2-2-U	2	8	6.0	12.8	16.3	24.4	40.6
MR-2-3-U	2	8	0.8	1.1	2.7	6.0	14.7
MR-4-1-C	1	4	0.9	1.8	4.9	10.6	12.4
MR-4-1-U	3	12	9.8	13.4	22.0	48.6	73.8
MR-4-2-C	1	4	2.0	3.0	8.4	18.3	20.8
MR-4-2-U	2	8	2.9	9.0	11.5	14.8	32.2
Total	**22**	**88**	**0.0**	**2.8**	**9.5**	**20.3**	**73.8**

C3.2.5 Riffle Pebble Count: Substrate Fines (% <6 mm)

As with surface fine sediment smaller than 2 mm diameter, an accumulation of surface fine sediment less than 6 mm diameter may also indicate excess sedimentation and has the potential to negatively impact the spawning success of coldwater fish. The size distribution of substrate material in the streambed is also indicative of habitat quality for salmonid spawning and incubation. Excess surface fine substrate may have detrimental impacts on aquatic habitat by cementing spawning gravels, thus reducing their accessibility, preventing flushing of toxins in egg beds, reducing oxygen and nutrient delivery to eggs and embryos, and impairing emergence of fry (Meehan, 1991).

Weaver and Fraley (1991) observed a significant inverse relationship between the percentage of material less than 6.35 mm and the emergence success of westslope cutthroat trout and bull trout. Weaver (1996) noted that bull trout spawning is threatened in streams when the percent of riffle substrate <6.35mm exceeds 35% (Weaver, 1996).

The pebble count measurements for sediment fines (% <6 mm) by reach type are presented below in **Figure C3-5** and summary statistics are provided in **Table C3-5**.

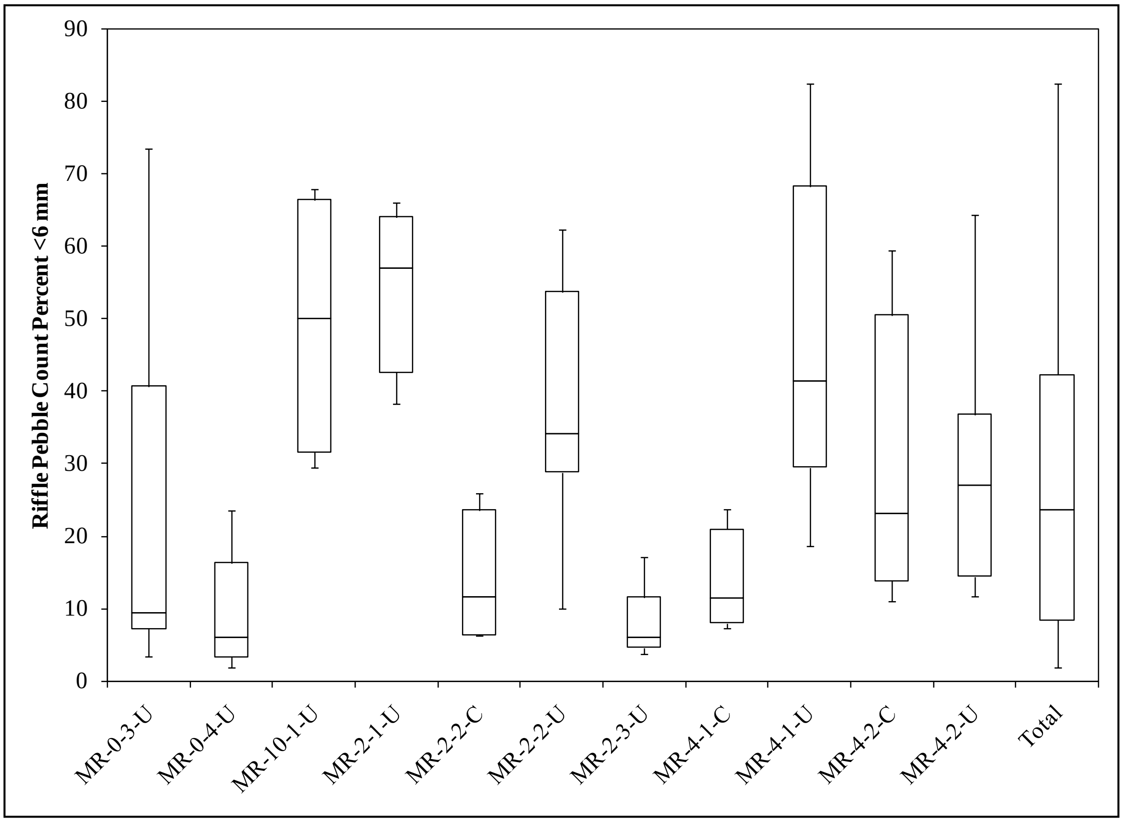

Figure C3-5. Riffle pebble count (% <6 mm) by reach type.

Table C3-5. Summary statistics of riffle pebble count (% <6 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	24	3.5	7.3	9.5	40.7	73.5
MR-0-4-U	2	8	1.8	3.4	6.0	16.3	23.6
MR-10-1-U	1	4	29.5	31.6	50.0	66.5	68.0
MR-2-1-U	1	4	38.3	42.7	57.1	64.1	66.1
MR-2-2-C	1	4	6.4	6.4	11.6	23.6	26.0
MR-2-2-U	2	8	10.0	28.9	34.1	53.8	62.4
MR-2-3-U	2	8	3.8	4.7	6.1	11.6	17.1
MR-4-1-C	1	4	7.3	8.1	11.5	21.0	23.8
MR-4-1-U	3	12	18.7	29.5	41.5	68.3	82.5
MR-4-2-C	1	4	11.0	13.9	23.2	50.5	59.4
MR-4-2-U	2	8	11.8	14.5	27.1	36.8	64.4
Total	**22**	**88**	**1.8**	**8.4**	**23.7**	**42.3**	**82.5**

C3.2.6 Riffle Pebble Count: D50

The D50 represents the median (50th percentile) particle size of a riffle as determined by the Wolman pebble count. This value can be used to evaluate the suitability of a riffle as spawning gravel for salmonids. Kondolf and Wolman (1993) state that the appropriate size of spawning gravels varies based on stream size and fish species, since larger fish are capable of moving larger particles. In general, fish can spawn in gravels with a median diameter up to about 10% of their body length (Kondolf, 2000). Appropriate sized spawning gravels should be less than approximately 40 mm for salmonids.

Results of the riffle pebble count D50 are presented below by reach type in **Figure C3-6** and summary statistics are provided in **Table C3-6**.

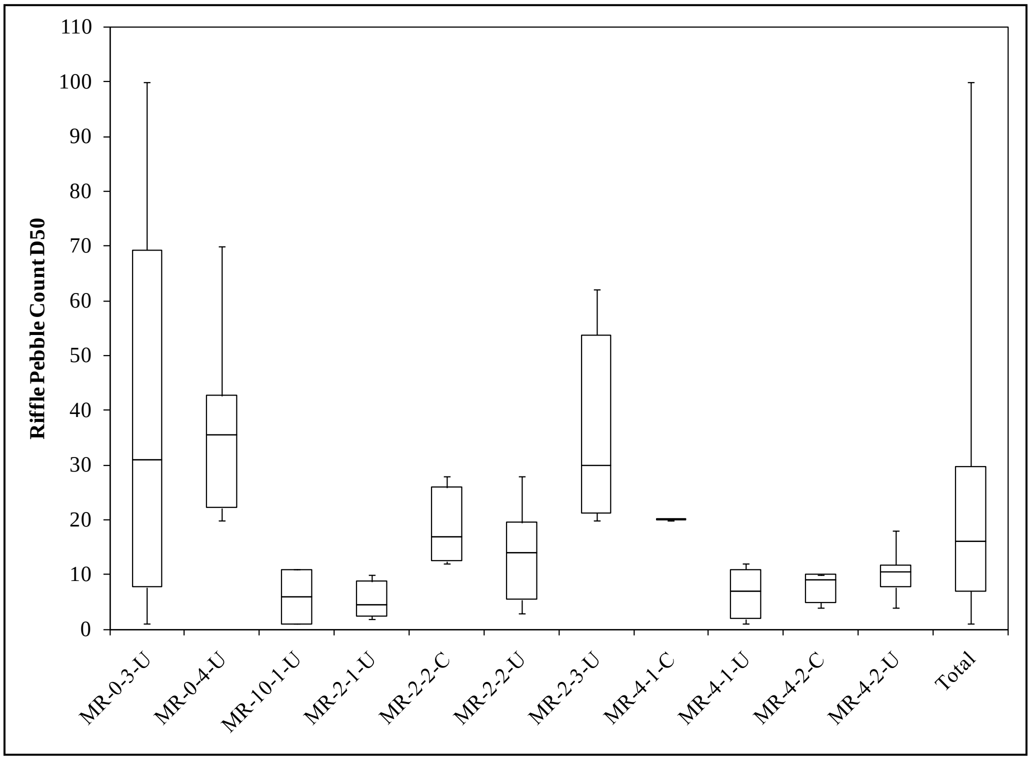

Figure C3-6. Riffle pebble count D50 (mm) by reach type.

Table C3-6. Summary statistics of riffle pebble count D50 (mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	24	1	8	31	69	100
MR-0-4-U	2	8	20	22	36	43	70
MR-10-1-U	1	4	1	1	6	11	11
MR-2-1-U	1	4	2	3	5	9	10
MR-2-2-C	1	4	12	13	17	26	28
MR-2-2-U	2	8	3	6	14	20	28
MR-2-3-U	2	8	20	21	30	54	62
MR-4-1-C	1	4	20	20	20	20	20
MR-4-1-U	3	12	1	2	7	11	12
MR-4-2-C	1	4	4	5	9	10	10
MR-4-2-U	2	8	4	8	11	12	18
Total	**22**	**88**	**1**	**7**	**16**	**30**	**100**

C3.2.7 Riffle Stability Index

The riffle stability index (RSI) is used to evaluate riffle particle mobility in an area receiving excessive sediment input (Kappesser, 2002). The mobile fraction in a riffle is estimated by comparing the particle sizes in the riffle to the arithmetic mean of the largest mobile particles on an adjacent depositional bar. Riffle particles of the size class smaller than the largest particles on a depositional bar are interpreted as mobile, and the RSI value represents the percent of mobile particles within a riffle. Riffles that have received excessive sediment from upstream eroding banks have a higher percent of mobile particles than riffles in equilibrium. The following breaks are provided as general guidelines for interpreting RSI values:

RSI Value	Description
< 40	High bedrock component to riffle (very stable system) or channel has been scoured
40 – 70	Stream is in dynamic equilibrium – good channel and watershed stability
70 – 85	Riffle is somewhat loaded with excessive sediment
> 85	Riffle is loaded with excessive sediment

Limited RSI data were collected during this field effort due to the frequency of poorly developed point bars downstream of riffles and actively eroding banks. The riffle stability index results for all reaches are provided below in **Table C3-7**.

Table C3-7. Riffle stability index results for all reaches.

Reach ID	Cell	Reach Type	Arithmetic Mean (mm)	Riffle Stability Index
QUTZ 09-01	2	MR-4-1-C	35	71
UWIL 15-01	1	MR-0-4-U	61	73
UWIL 15-01	5	MR-0-4-U	74	87
WFRK 30-02	1	MR-0-3-U	95	66

C3.2.8 Riffle Grid Toss: Substrate Fines (% <6 mm)

The wire grid toss is a standard procedure frequently used in aquatic habitat assessment to approximate the percent fine material in a stream. The grid toss measurement does not cover the entire channel width as in the Wolman pebble count, but rather provides a more focused measurement of surface fines in a subsample of the cross-section.

The riffle grid toss results for sediment fines (% <6 mm) are presented below in **Figure C3-7** and summary statistics are provided in **Table C3-8**. A great degree of variability exists for some reach types due to the high percent of fines in some individual reaches. Riffle grid toss data for individual reaches is shown in a latter section of this report (see **Figure C3-18**).

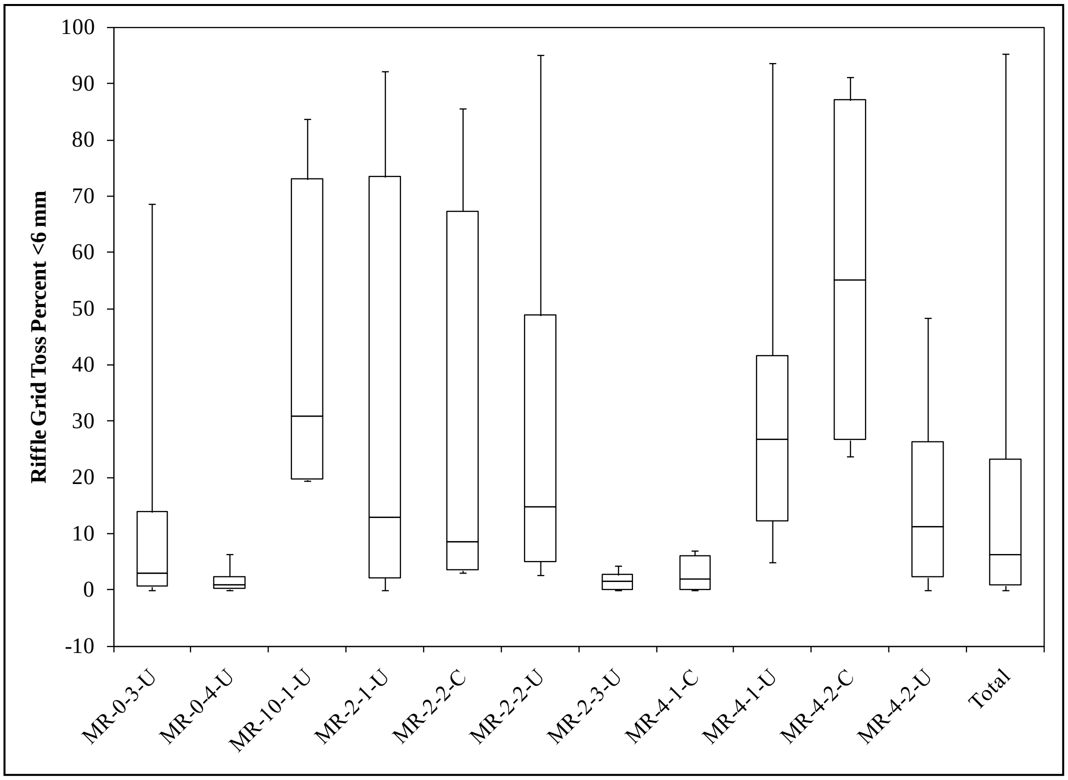

Figure C3-7. Riffle grid toss (% <6 mm) by reach type.

Table C3-8. Summary statistics of riffle grid toss (% <6 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	24	0.0	0.7	3.1	13.9	68.7
MR-0-4-U	2	8	0.0	0.2	0.8	2.4	6.3
MR-10-1-U	1	4	19.4	19.7	30.9	73.0	83.7
MR-2-1-U	1	4	0.0	2.2	12.9	73.5	92.3
MR-2-2-C	1	4	3.0	3.5	8.6	67.3	85.7
MR-2-2-U	2	8	2.7	5.1	14.7	48.8	95.2
MR-2-3-U	2	8	0.0	0.2	1.5	2.7	4.3
MR-4-1-C	1	4	0.0	0.2	2.0	6.1	7.0
MR-4-1-U	3	12	4.9	12.3	26.8	41.7	93.7
MR-4-2-C	1	4	23.8	26.7	55.1	87.1	91.2
MR-4-2-U	2	8	0.0	2.3	11.2	26.4	48.3
Total	**22**	**88**	**0.0**	**0.9**	**6.2**	**23.3**	**95.2**

C3.2.9 Pool Grid Toss within Depositional Spawning Areas: Sediment Fines (% <6 mm)

Grid toss measurements in depositional spawning areas provide a measure of fine sediment accumulation in potential spawning sites. Excess surface fines may have detrimental impacts on aquatic habitat by cementing spawning gravels, thus reducing their accessibility, preventing flushing of toxins in egg beds, reducing oxygen and nutrient delivery to eggs and embryos, and impairing emergence of fry (Meehan, 1991). Weaver and Fraley (1991) observed a significant inverse relationship between the percentage of material < 6.35mm and the emergence success of cutthroat and bull trout.

Grid toss results for sediment fines (% <6 mm) found within depositional spawning areas are provided below in **Figure C3-8** and summary statistics are provided in **Table C3-9**. The data presented here represents only pool tails that were identified as having the appropriate sized gravels to support spawning. There were four assessed reaches (FLAT 12-01, FLAT 13-01, UWIL 11-05, and WFRK 27-02) where spawning gravels did not exist in pool tails.

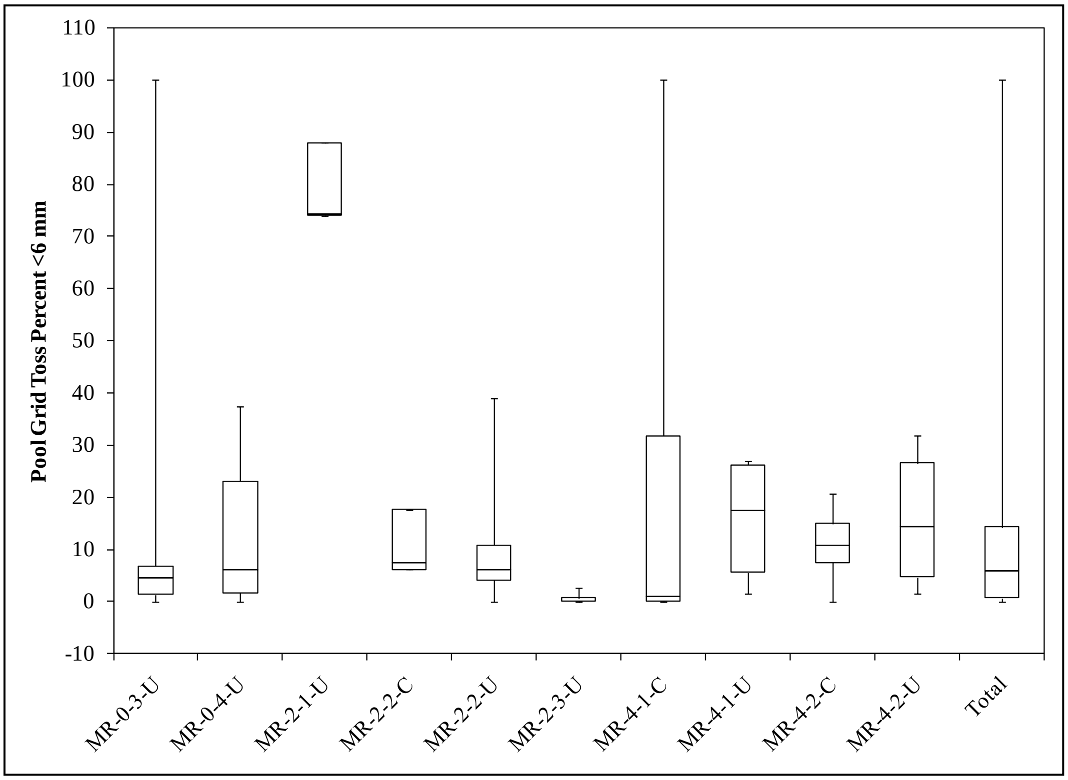

Figure C3-8. Pool grid toss (% <6 mm) by reach type.

Table C3-9. Summary statistics of pool grid toss (% <6 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	4	15	0	1	4	7	100
MR-0-4-U	2	18	0	2	6	23	38
MR-2-1-U	1	3	74	74	74	88	88
MR-2-2-C	1	3	6	6	7	18	18
MR-2-2-U	2	19	0	4	6	11	39
MR-2-3-U	2	19	0	0	0	1	3
MR-4-1-C	1	14	0	0	1	32	100
MR-4-1-U	2	6	1	6	18	26	27
MR-4-2-C	1	7	0	8	11	15	21
MR-4-2-U	2	11	1	5	14	27	32
Total	**18**	**115**	**0**	**1**	**6**	**14**	**100**

C3.2.10 Pool Residual Depth

Residual pool depth, defined as the difference between pool maximum depth and crest depth, is a discharge-independent measure of pool depth and an indicator of the quality of pool habitat. Deep pools are important resting and hiding habitat for fish, and provide refugia during temperature extremes and high flow periods. Pool residual depth is also an indirect measurement of sediment inputs to listed streams. An increase in sediment loading would be expected to cause pools to fill, thus decreasing residual pool depth over time.

Data are presented below in **Figure C3-9** and **Table C3-10**. Note that the data presented represents the mean residual pool depth for each reach, so some reach types have only one data point. Residual pool depths were not calculated for dammed pools.

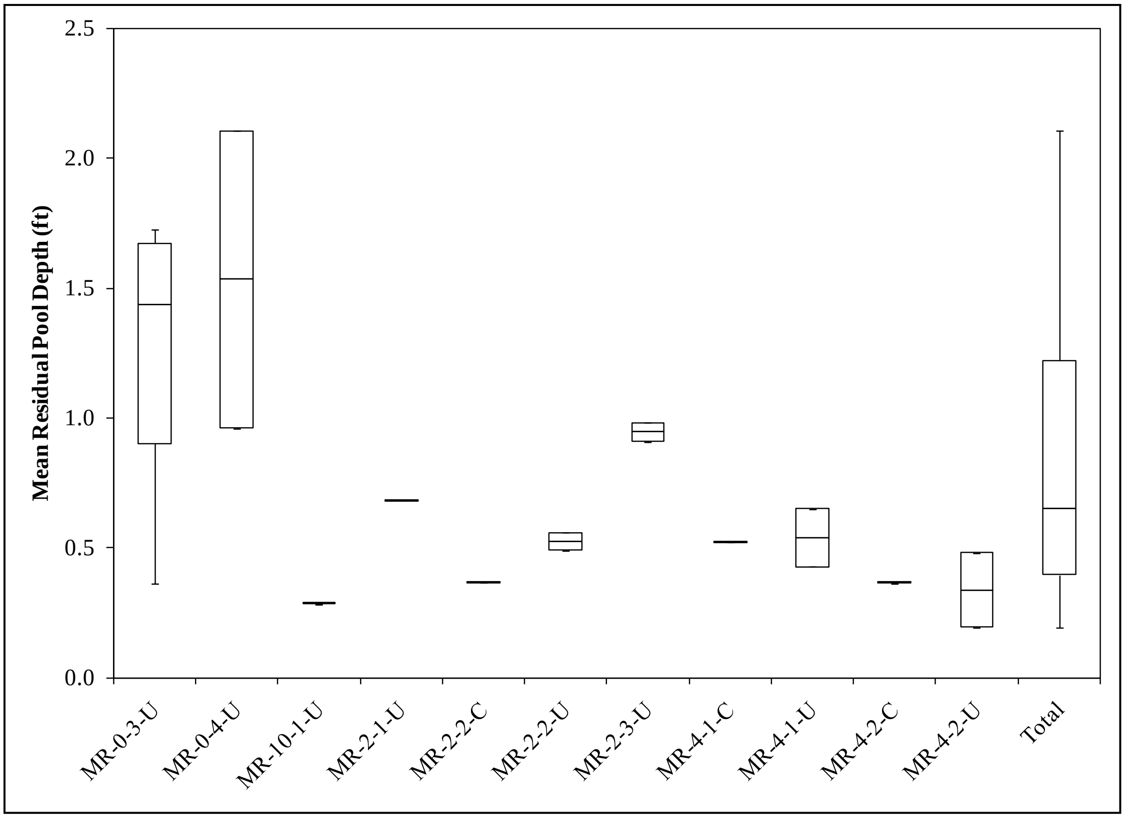

Figure C3-9. Residual pool depth (ft) by reach type.

Table C3-10. Summary statistics of residual pool depth (ft) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	6	0.4	0.9	1.4	1.7	1.7
MR-0-4-U	2	2	1.0	1.0	1.5	2.1	2.1
MR-10-1-U	1	1	0.3	0.3	0.3	0.3	0.3
MR-2-1-U	1	1	0.7	0.7	0.7	0.7	0.7
MR-2-2-C	1	1	0.4	0.4	0.4	0.4	0.4
MR-2-2-U	2	2	0.5	0.5	0.5	0.6	0.6
MR-2-3-U	2	2	0.9	0.9	0.9	1.0	1.0
MR-4-1-C	1	1	0.5	0.5	0.5	0.5	0.5
MR-4-1-U	3	3	0.4	0.4	0.5	0.7	0.7
MR-4-2-C	1	1	0.4	0.4	0.4	0.4	0.4
MR-4-2-U	2	2	0.2	0.2	0.3	0.5	0.5
Total	**22**	**22**	**0.2**	**0.4**	**0.7**	**1.2**	**2.1**

C3.2.11 Pool Frequency

Pool frequency is a measure of the availability of pools within a reach to provide rearing habitat, cover, and refugia for salmonids. Pool frequency is related to channel complexity, availability of stable obstacles, and sediment supply. Excessive erosion and sediment deposition can reduce pool frequency by filling in smaller pools. Pool frequency can also be affected adversely by riparian habitat degradation resulting in a reduced supply of large woody debris or scouring from stable root masses in streambanks.

The pool frequencies per 1,000 ft for each reach type are presented in below **Figure C3-10** and summary statistics are provided in **Table C3-11**. As with residual pool depth, some reach types are represented by only a single value.

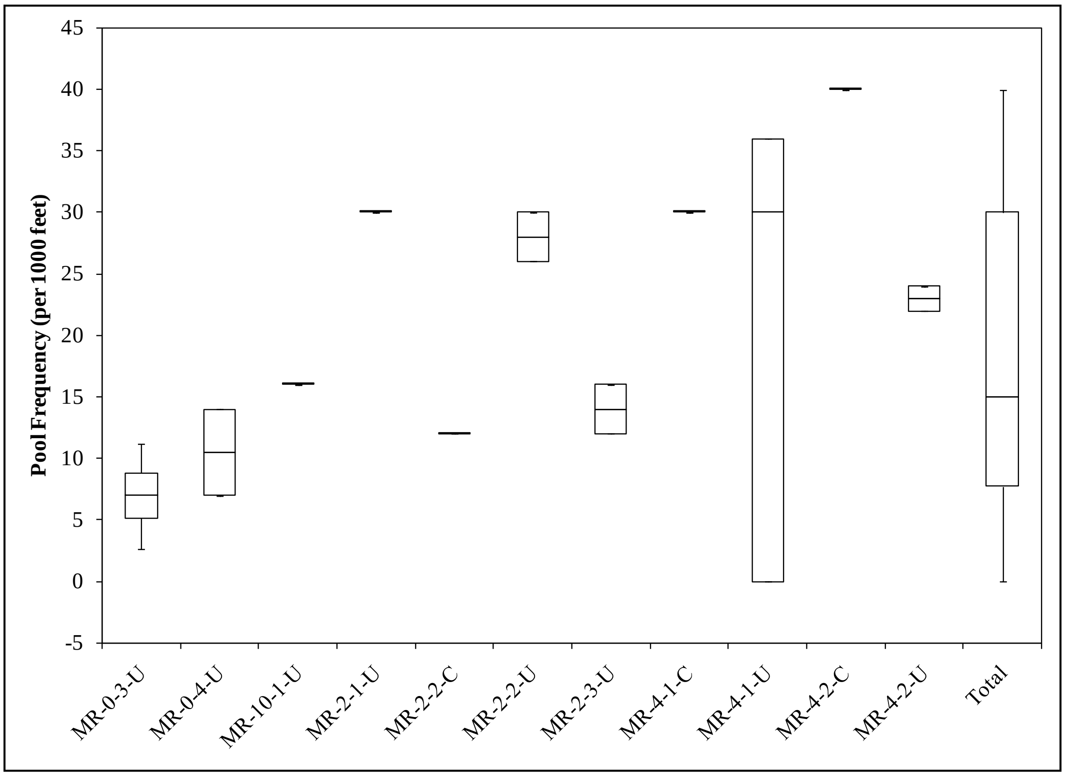

Figure C3-10. Pool frequency (per 1,000 ft) by reach type.

Table C3-11. Summary statistics of pool frequency by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	6	3	5	7	9	11
MR-0-4-U	2	2	7		11		14
MR-10-1-U	1	1	16		16		16
MR-2-1-U	1	1	30		30		30
MR-2-2-C	1	1	12		12		12
MR-2-2-U	2	2	26		28		30
MR-2-3-U	2	2	12		14		16
MR-4-1-C	1	1	30		30		30
MR-4-1-U	3	3	0	0	30	36	36
MR-4-2-C	1	1	40		40		40
MR-4-2-U	2	2	22		23		24
Total	**22**	**22**	**0**	**8**	**15**	**30**	**40**

C3.2.12 Large Woody Debris Frequency

Large woody debris (LWD) is a critical component of salmonid habitat, providing stream complexity, pool habitat, cover, and long-term nutrient inputs. LWD also constitutes a primary influence on stream function, including sediment and organic material transport, channel form, bar formation and stabilization, and flow dynamics (Bilby and Ward, 1989). LWD frequency can be measured and compared to reference reaches or literature values to determine if more or less LWD is present than would be expected under reference conditions. Too little or too much LWD may indicate riparian habitat impairment or upstream influences on habitat quality. Target values for LWD span a broad range of values, even for streams of similar size. Results for LWD should be interpreted with caution, as the guideline value for this parameter is tied to a high degree of variability due to land use, vegetative community and soils, among other factors.

The LWD frequencies for each reach type are provided below in **Figure C3-11** and summary statistics are provided in **Table C3-12**.

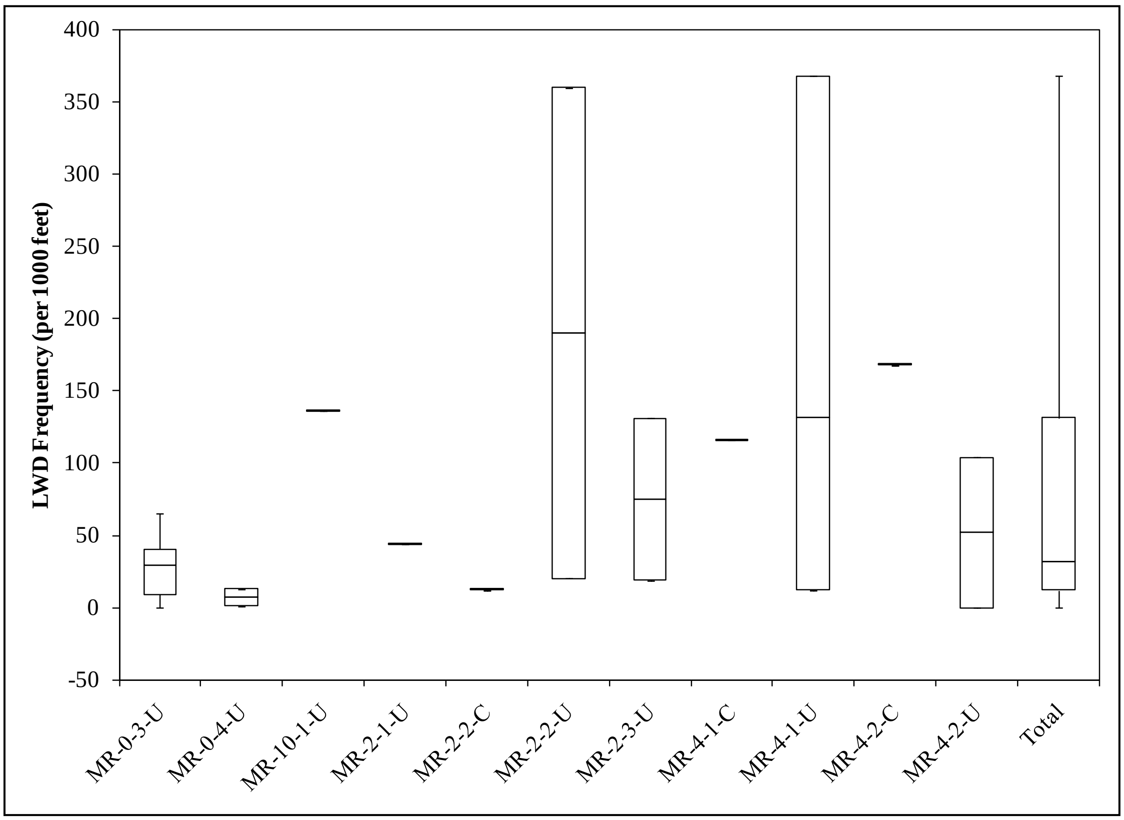

Figure C3-11. LWD frequency (per 1,000 ft) by reach type.

Table C3-12. Summary statistics of LWD frequency by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-3-U	6	6	0	9	29	41	65
MR-0-4-U	2	2	1		7		13
MR-10-1-U	1	1	136		136		136
MR-2-1-U	1	1	44		44		44
MR-2-2-C	1	1	12		12		12

Table C3-12. Summary statistics of LWD frequency by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-2-2-U	2	2	20		190		360
MR-2-3-U	2	2	19		75		131
MR-4-1-C	1	1	116		116		116
MR-4-1-U	3	3	12	12	132	368	368
MR-4-2-C	1	1	168		168		168
MR-4-2-U	2	2	0		52		104
Total	**22**	**22**	**0**	**12**	**32**	**131**	**368**

C3.2.13 Greenline Inventory: Percent Understory Shrub Cover

Riparian shrub cover is an important factor on streambank stability. Removal of riparian shrub cover can dramatically increase streambank erosion and increase channel width/depth ratios. Shrubs stabilize streambanks by holding soil and armoring lower banks with their roots, and reduce scouring energy of water by slowing flows with their branches. Good riparian shrub cover is also important for fish habitat. Riparian shrubs provide shade which reduce solar inputs and help maintain cooler water temperatures. The dense network of fibrous roots of riparian shrubs allows streambanks to remain intact while water scours the lowest portion of streambanks, creating important fish habitat in the form of overhanging banks and lateral scour pools. Overhanging branches of riparian shrubs provide important cover for aquatic species. In addition, riparian shrubs provide critical inputs of food for fish and other aquatic life. Terrestrial insects falling from riparian shrubs provide one main food source for fish. Organic inputs from shrubs, such as leaves and small twigs, provide food for aquatic macroinvertebrates, which are also an important food source for fish.

Summary statistics and boxplots from original report were removed because the data collected in the field was not correctly reported in the report.

C3.2.14 Greenline Inventory: Percent Bare/Disturbed Ground

Percent bare ground is an important indicator of erosion potential, as well as an indicator of land management influences on riparian habitat. Bare ground was noted in the Greenline inventory in cases where recent ground disturbance was observed, leaving bare soil exposed. Bare ground is often caused by trampling from livestock or wildlife, fallen trees, recent bank failure, new sediment deposits from overland or overbank flow, or severe disturbance in the riparian area, such as past mining, road-building, or fire. Ground cover on streambanks is important to prevent sediment recruitment to stream channels. Sediment can wash in from unprotected areas due to snowmelt, storm runoff, or flooding. Bare areas are also much more susceptible to erosion from hoof shear. Most stream reaches have a small amount of naturally-occurring bare ground. As conditions are highly variable, this measurement is most useful when compared to reference values from best available conditions within the study area or literature values.

Summary statistics and boxplots from original report were removed because the data collected in the field was not correctly reported in the report.

C3.3 Sampling Parameter Summaries by Individual Reach

The following **Figures C3-12** to **C3-18** display statistical boxplots of stream channel parameters that were measured in each of the monitored sites. Individual reaches are also grouped by reach type and displayed below the reach names on each boxplot.

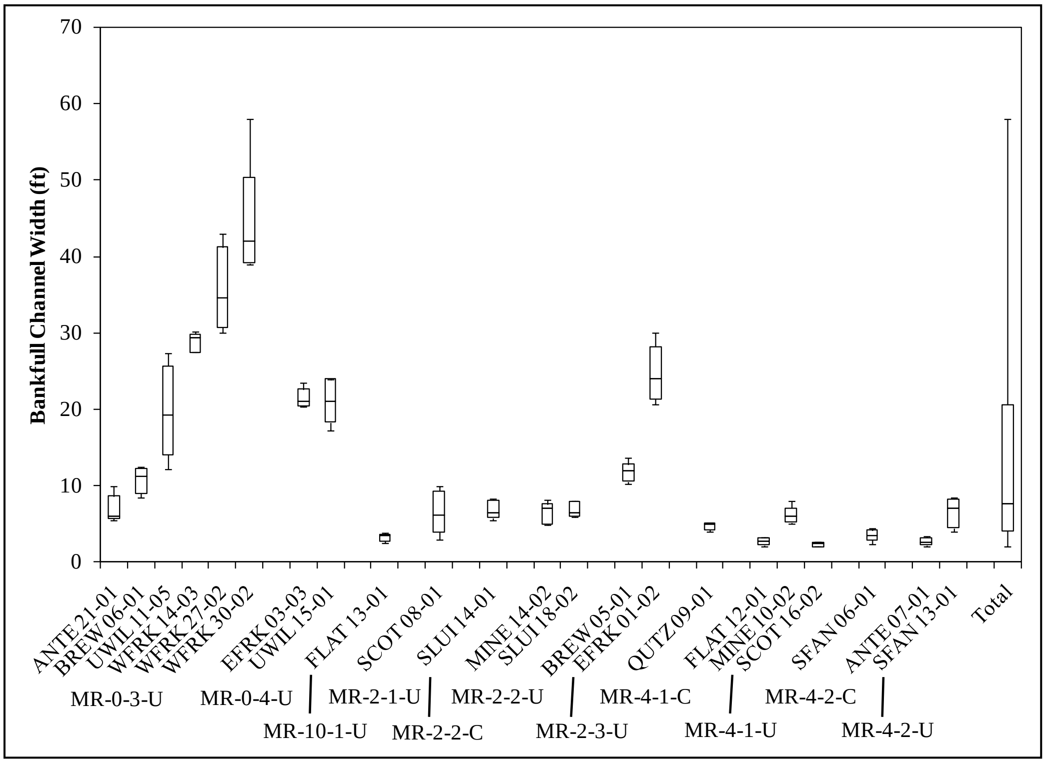

Figure C3-12. Bankfull channel width by reach.

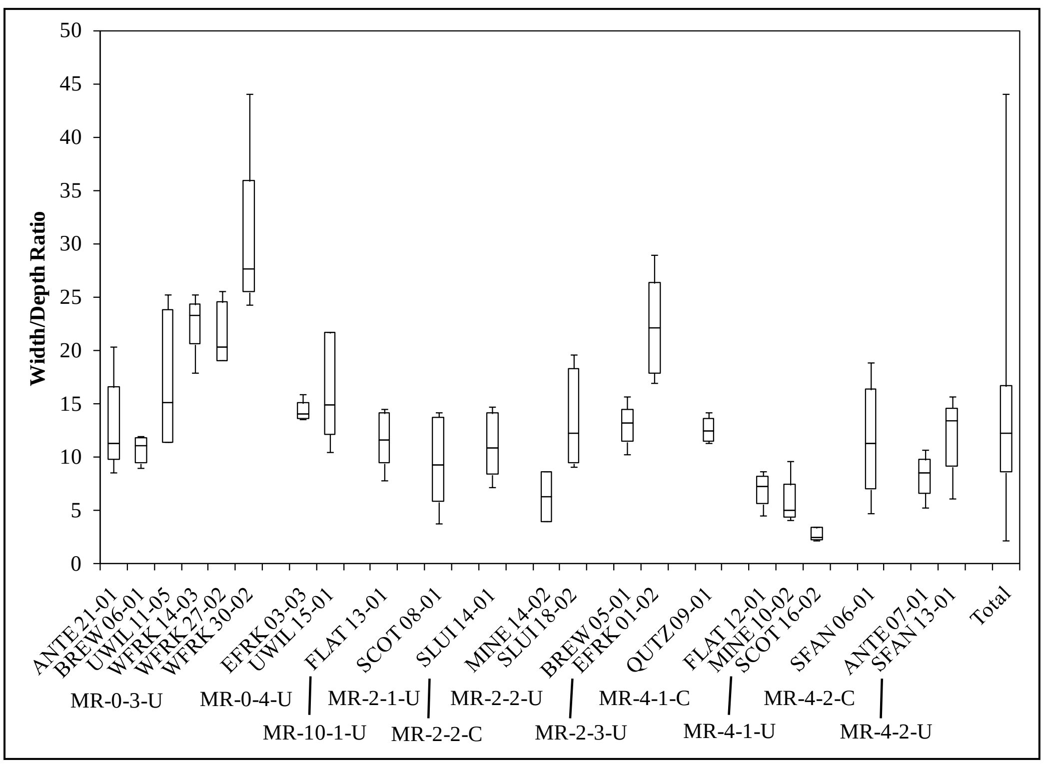

Figure C3-13. Width/depth ratio by reach.

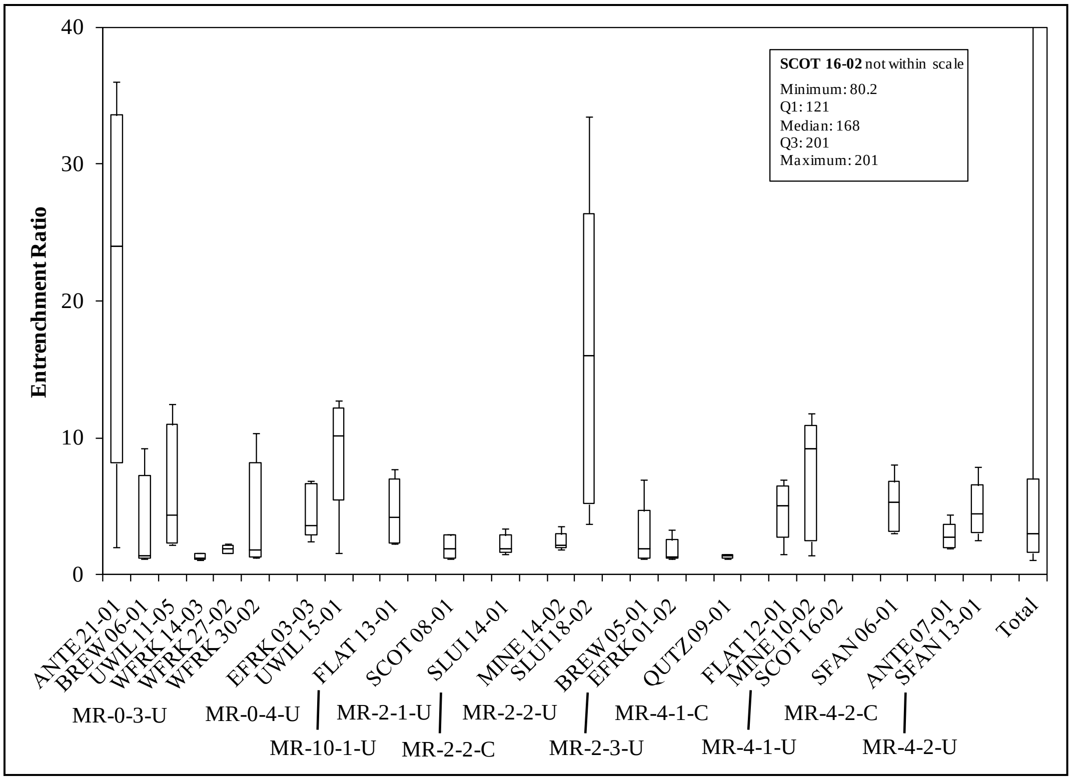

Figure C3-14. Entrenchment ratio by reach.

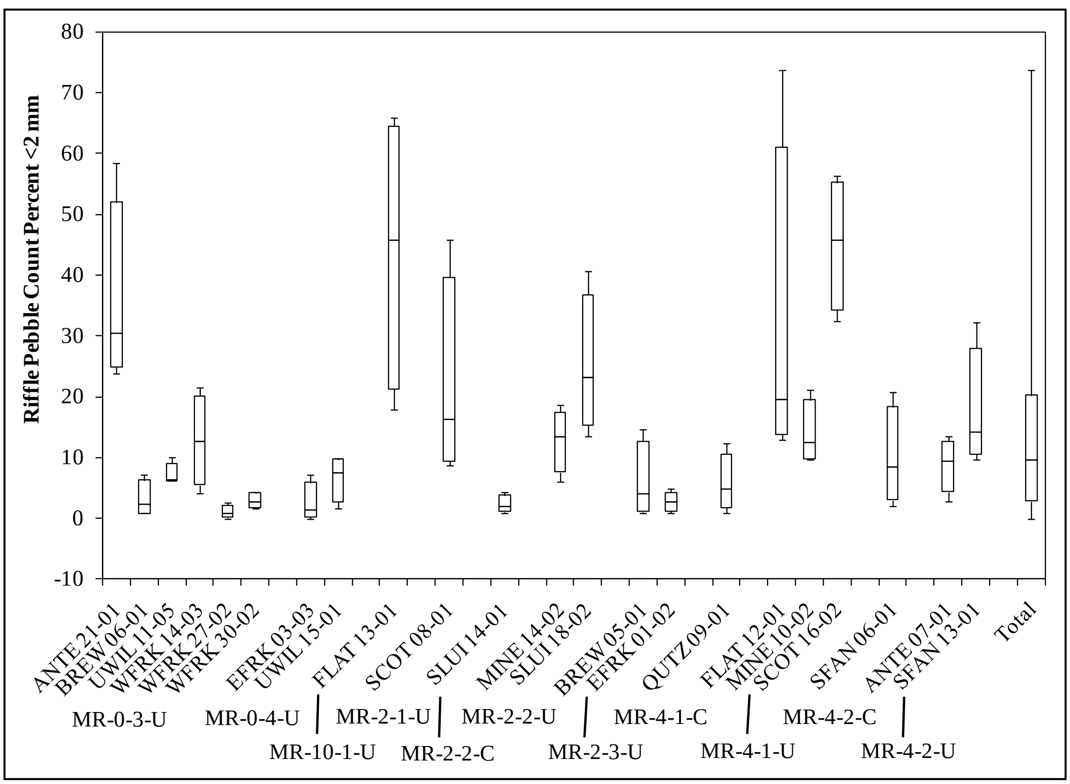

Figure C3-15. Riffle pebble count (% <2 mm) by reach.

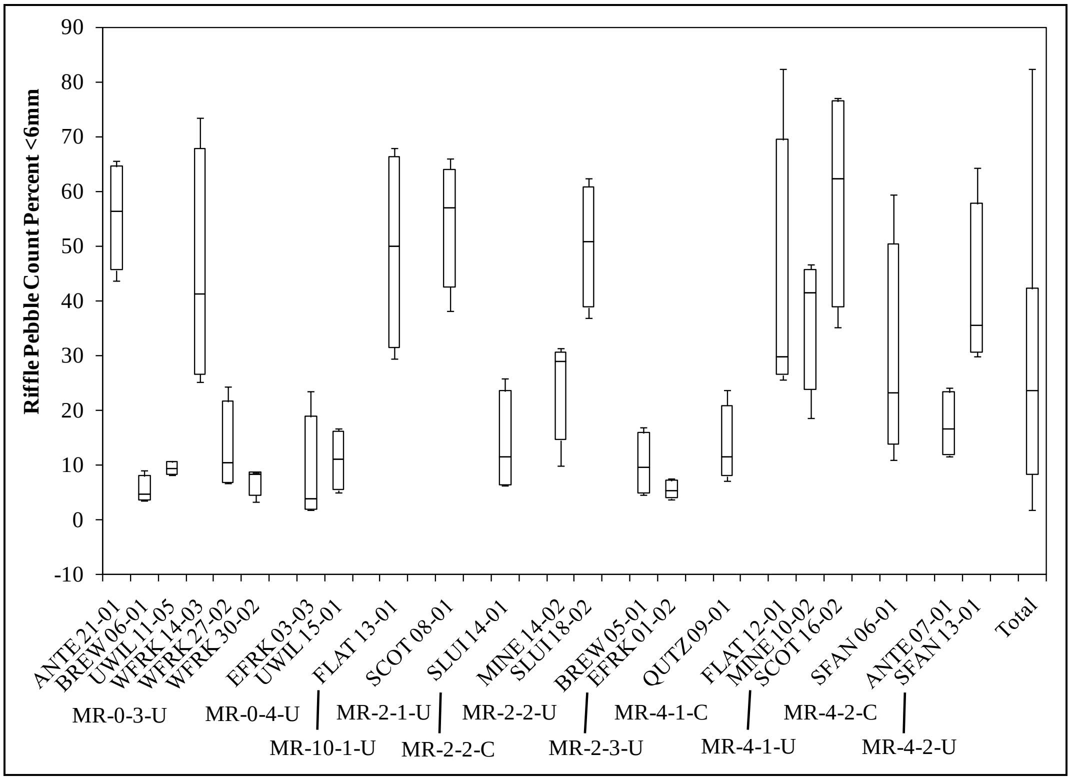

Figure C3-16. Riffle pebble count (% <6 mm) by reach.

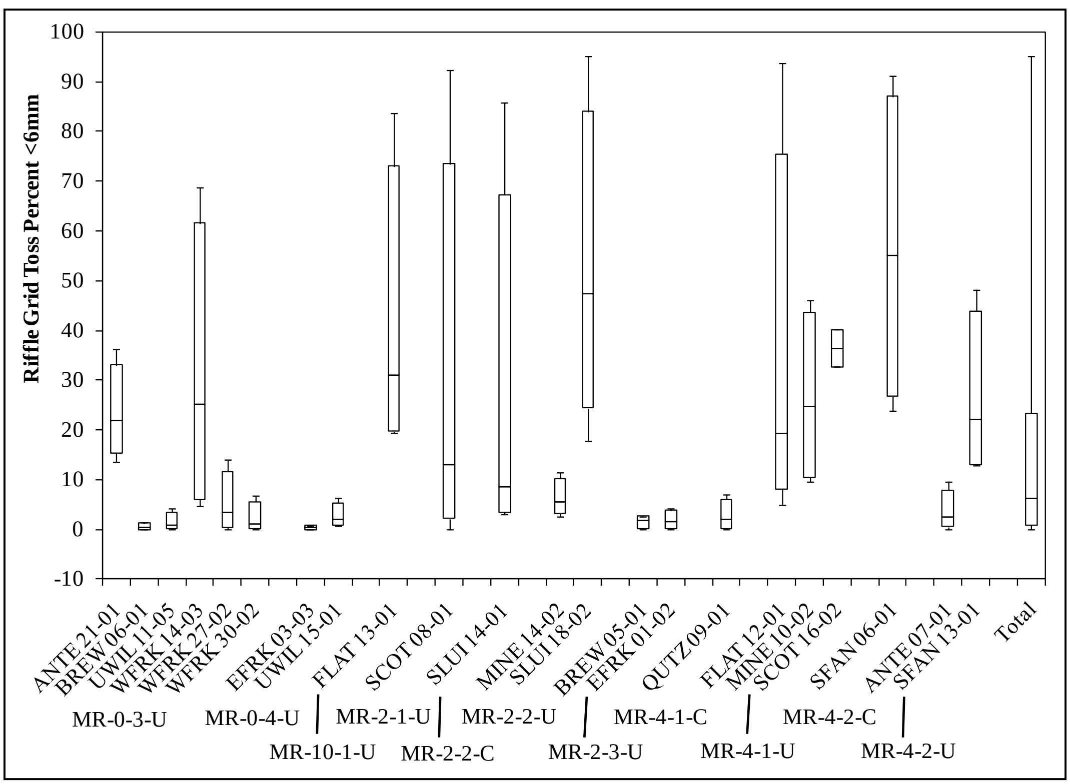

Figure C3-17. Riffle grid toss (% <6 mm) by reach.

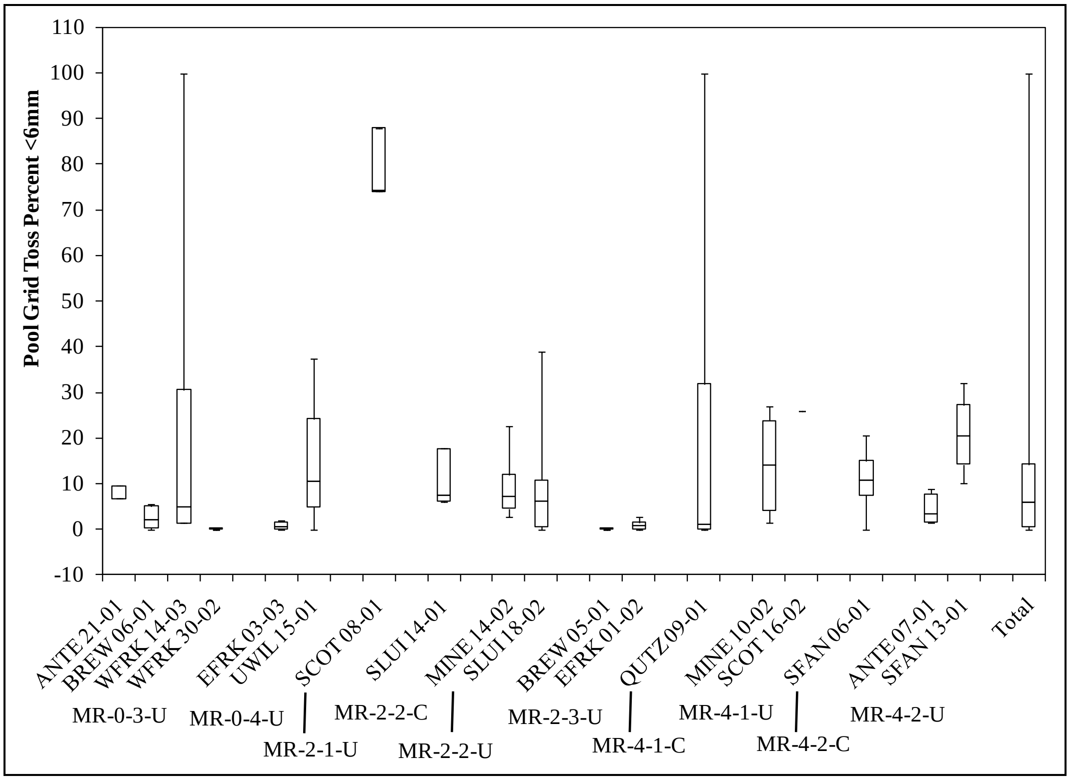

Figure C3-18. Pool grid toss (% <6 mm) by reach.

C4.0 Streambank Erosion Source Assessment

For each monitoring reach assessed during the study, measurements were collected to calculate the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) in accordance with guidelines provided in *Watershed Assessment of River Stability and Sediment Supply* (Rosgen, 2006). These measurements were used in conjunction with streambank length and erosion source notes to determine sediment loads per 1,000 feet within each surveyed reach.

For sites within the Rock TPA, eroding banks were identified as "actively eroding" or "slowly eroding" based on conditions observed in the field. Actively eroding banks typically show evidence of recent erosion, such as slumping banks, exposed soil, or trampling by animals. Slowly eroding banks show evidence of chronic erosion, but often have some form of surface protection, such as cobble or vegetation. The designation of "active" versus "slow" is independent of the BEHI or NBS determinations, so sediment loads from actively eroding banks may not necessarily be higher than loads from slowly eroding banks. The banks selected for evaluation provide a representative sample of conditions throughout the reach, and banks which are similar to the evaluated banks are measured and recorded as "additional banks". At each eroding bank, photos were taken from locations perpendicular and upstream/downstream of the streambank. Photos were labeled according to the streambank site and position of the photo.

C.4.1 Field Measurements and Loading Calculations

C4.1.1 Field Measurements

Within each sampled reach, eroding streambanks were identified by the field team and supporting measurements were recorded for the following metrics:

- Bank condition (includes actively eroding or slowly eroding/undercut/vegetated banks)
- Bank height
- Bankfull height
- Root depth
- Root density
- Bank angle
- Surface protection
- Material adjustments
- Bankfull mean depth
- Near bank maximum depth
- Stationing
- Mean height
- Bank composition (size classes)
- Hoof shear presence
- Sources of streambank instability (%)

C4.1.2 Determination of BEHI Scores

To determine the BEHI score for each eroding bank, the following parameters are used:

- Bank height/bankfull height
- Root depth/bank height
- Weighted root density (root density * root depth/bank height)
- Bank angle
- Surface protection

These bank erosion parameters are used to determine a numerical BEHI index score that ranks erosion potential from very low to extreme based on relationships provided by Rosgen (2006) (**Table C4-1**).

Table C4-1. BEHI score and rating system for individual parameters.

Parameter		Very Low	Low	Moderate	High	Very High	Extreme
Bank Height Ratio	Value	1.0 – 1.1	1.11 – 1.19	1.2 – 1.5	1.6 – 2.0	2.1 – 2.8	> 2.8
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Root Depth Ratio	Value	1.0 – 0.9	0.89 – 0.5	0.49 – 0.3	0.29 – 0.15	0.14 – 0.05	<0.05
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Weighted Root Density	Value	100 – 80	79 – 55	54 – 30	29 – 15	14 – 5	<5
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Bank Angle	Value	0 – 20	21 – 60	61 – 80	81 – 90	91 – 119	>119
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10
Surface Protection	Value	100 – 80	79 – 55	54 – 30	29 – 15	14 – 10	<10
	Index	1.0 – 1.9	2.0 – 3.9	4.0 – 5.9	6.0 – 7.9	8.0 – 9.0	10

After obtaining the BEHI index score for each individual parameter, the index scores are summed to produce a total BEHI score. Bank material factors are then considered, and total BEHI scores may be adjusted up or down. Banks comprised of bedrock, boulders, or cobble have very low erosion potential, and total BEHI scores for banks composed of these materials may be adjusted down by up to 10 points. Banks composed of cobble and/or gravel with a high fraction of sand have increased erosion potential, and total BEHI scores may be adjusted up by 5 to 10 points depending on the amount of sand present and whether the sandy material is exposed to erosion. Stratified banks containing layers of unstable material also have greater erosion potential, and total BEHI scores may be adjusted up by 5 to 10 points if stratified banks are present. After all material adjustments are made to the total BEHI score, the erosion potential is ranked from very low to extreme based on the scale provided below (**Table C4-2**).

Table C4-2. Total BEHI score and rating system.

Rating	Very Low	Low	Moderate	High	Very High	Extreme
Score	<10	10 - 19.9	20 - 29.9	30 - 39.9	40 - 45	>45

C4.1.3 Near Bank Stress (NBS) Determination

To calculate Near Bank Stress (NBS) for each eroding bank, the following relationship is used:

NBS = Near Bank Maximum Bankfull Depth (ft) / Bankfull Mean Depth (ft)

As with the BEHI scores, the resulting NBS values correspond to a categorical rating that ranks the erosion potential from very low to extreme (**Table C4-3)**. The NBS rating is calculated in the field by collecting the near bank maximum bankfull depth at the eroding bank location and dividing this value by the average of five measurements across the bankfull channel. NBS can also be estimated in the field based on channel form or by using best professional judgment.

Table C4-3. Near bank stress (NBS) rating system.

NBS Value	Rating
< 1.0	very low
1.0 - 1.5	low
1.51 - 1.8	moderate
1.81 - 2.5	high
2.51 - 3.0	very high
> 3.0	extreme

C4.1.4 Retreat Rate

Once respective BEHI and NBS ratings are found for each eroding bank, the ratings are used to derive the average retreat rate of each streambank based on empirical relationships derived from Colorado by Rosgen (2006), which are applicable to areas with sedimentary and/or metamorphic geology like the Rock Creek TPA. The average retreat rates (ft/yr) based on BEHI and NBS ratings are provided below in **Table C4-4**.

Table C4-4. Streambank retreat rate (ft/yr) based on BEHI and NBS rating.

	Near Bank Stress					
BEHI	**Very Low**	**Low**	**Moderate**	**High**	**Very High**	**Extreme**
Low	0.02	0.04	0.07	0.16	0.32	0.67
Moderate	0.09	0.15	0.25	0.42	0.70	1.16
High-Very High	0.17	0.25	0.38	0.58	0.87	1.32

C4.1.5 Sediment Loading Calculation

Once retreat rate is determined from the BEHI and NBS ratings, the dimensions of the eroding streambank are used to find the total mass eroding from each bank per year. The total mass eroded from each streambank is calculated using the following equation:

*mass eroded (tons/yr) = bank length (ft) * bank height (ft) * retreat rate (ft/yr) * material density (tons/ft^3)*

The sediment load from each streambank is filtered into two bank erosion type categories including actively eroding banks or slowly eroding/undercut/vegetated banks. The total loads for each bank erosion type and for the entire reach are then calculated in tons of sediment per year per 1000 feet of reach.

C4.2 Sediment Loading Results by Assessment Reach

The following sections provide sediment loading results for each sampled stream. One data table is included for each stream which includes data from each reach summarizing bank erosion and sediment loading for each bank erosion type (active or slowly eroding) and for the total reach. Information provided includes the number of eroding banks, the mean BEHI rating for each erosion type, the percent of reach that has eroding banks, the sediment load per 1000 feet, and the percent contribution from each erosion source present. The percentage of reach with eroding streambanks was calculated by summing the total footage of eroding banks (active and slow) and dividing the total by the total bank footage in the reach, including both right and left banks. Identified sources of streambank erosion within the Rock TPA included transportation, riparian grazing, cropland, irrigation (or changes in stream energy), natural sources, or those classified as "other" (historical grazing and mining, rural residential, and recreation); however, each erosion source may not be present at all sample sites.

C4.2.1 Sediment Loading Results for Antelope Creek

C4.2.1.1 ANTE 07-01

Five eroding banks were identified in this reach, including one actively eroding bank and four slowly eroding banks. Banks are typically low, grass-covered and hummocky from cattle, although the actively eroding bank is taller. Typical eroding streambank conditions are depicted for this reach in **Figure C4-1** and sediment loading results are provided in **Table C4-5**.

Figure C4-1. Typical eroding streambank conditions in Antelope Creek Reach 07-01.

C4.2.1.2 ANTE 21-01

This reach had two slowly eroding banks. Eroding banks were low grass-covered banks which were heavily grazed this year, likely in spring. Hummocking occurs along the entire length of the reach. Typical eroding streambank conditions are depicted in **Figure C4-2** and sediment loading results are provided in **Table C4-5**.

Figure C4-2. Typical eroding streambank conditions in Antelope Creek Reach 21-01.

Table C4-5. Sediment loading results for Antelope Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Source (%)
						Riparian Grazing
ANTE 07-01	Active	1	high	3.6	1.8	100.0
	Slow	4	moderate	81.6	10.0	100.0
	Total	5	high	85.2	11.8	100.0
ANTE 21-01	Active	0				
	Slow	2	high	98.4	16.6	100.0
	Total	2	high	98.4	16.6	100.0

C4.2.2 Sediment Loading Results for Brewster Creek

C4.2.2.1 BREW 05-01

This reach has eleven slowly eroding banks. Eroding banks were typically well vegetated overhanging banks with cobble. Typical eroding streambank conditions are depicted for this reach in **Figure C4-3** and sediment loading results are provided in **Table C4-6**.

Figure C4-3. Typical eroding streambank conditions in Brewster Creek Reach 05-01.

C4.2.2.2 BREW 06-01

This reach had eleven slowly eroding banks with two bank types. Eroding banks are typically well vegetated with a high root density. Some banks are associated with the small bridges that cross the stream within the surveyed reach. Typical eroding streambank conditions are depicted for this reach in **Figure C4-4** and sediment loading results are provided in **Table C4-6**.

Figure C4-4. Typical eroding streambank conditions in Brewster Creek Reach 06-01.

Table C4-6. Sediment loading results for Brewster Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Transportation	Natural	Other
BREW 05-01	Active	0						
	Slow	11	low	37.7	3.4	3.4	96.6	0.0
	Total	11	low	37.7	3.4	3.4	96.6	0.0
BREW 06-01	Active	0						
	Slow	11	moderate	35.3	11.3	0.0	65.7	34.3
	Total	11	moderate	35.3	11.3	0.0	65.7	34.3

C4.2.3 Sediment Loading Results for East Fork Rock Creek

C4.2.3.1 EFRK 01-02

This reach has ten slowly eroding banks. Banks are generally slowly eroding, well-vegetated, undercut banks located on outside meander bends. Recreational trails have contributed to streambank erosion in some places. Typical eroding streambank conditions are depicted for this reach in **Figure C4-5** and sediment loading results are provided in **Table C4-7**.

Figure C4-5. Typical eroding streambank conditions in East Fork Rock Creek Reach 01-02.

C4.2.3.2 EFRK 03-03

This reach has six slowly eroding banks. Eroding banks are generally well-vegetated undercut banks located on outside meander bends. Typical eroding streambank conditions are depicted for this reach in **Figure C4-6** and sediment loading results are provided in **Table C4-7**.

Figure C4-6. Typical eroding streambank conditions in East Fork Rock Creek Reach 03-03.

Table C4-7. Sediment loading results for East Fork Rock Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Irrigation	Natural	Other
EFRK 01-02	Active	0						
	Slow	10	moderate	35.2	9.8	0.0	82.0	18.0
	Total	10	moderate	35.2	9.8	0.0	82.0	18.0
EFRK 03-03	Active	0						
	Slow	6	moderate	49.5	14.7	20.0	70.0	10.0
	Total	6	moderate	49.5	14.7	20.0	70.0	10.0

C4.2.4 Sediment Loading Results for Flat Gulch

C4.2.4.1 FLAT 12-01

Only two eroding streambanks were identified in this reach, but they extended throughout 87% of the reach length. Eroding banks were slowly eroding vegetated banks which were severely trampled by cattle. Typical eroding streambank conditions are depicted in **Figure C4-7** and sediment loading results are provided in **Table C4-8**.

Figure C4-7. Typical eroding streambank conditions in Flat Gulch Reach 12-01.

C4.2.4.2 FLAT 13-01

Six eroding streambanks were identified in this reach with one primary bank type. Eroding banks are low and well vegetated but show evidence of trampling. Typical eroding streambank conditions are depicted in **Figure C4-8** and sediment loading results are provided in **Table C4-8**.


Figure C4-8. Typical eroding streambank conditions in Flat Gulch Reach 13-01.

Table C4-8. Sediment loading results for Flat Gulch.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Riparian Grazing	Natural	Other
FLAT 12-01	Active	0						
	Slow	2	high	87.0	14.7	100.0	0.0	0.0
	Total	2	high	87.0	14.7	100.0	0.0	0.0
FLAT 13-01	Active	0						
	Slow	6	moderate	13.2	1.7	0.0	80.0	20.0
	Total	6	moderate	13.2	1.7	0.0	80.0	20.0

C4.2.5 Sediment Loading Results for Miners Gulch

C4.2.5.1 MINE 10-02

Four slowly eroding banks were identified in this reach. Eroding banks were typically slowly eroding well-vegetated banks with high root density. Typical eroding streambank conditions are depicted in **Figure C4-9** and sediment loading results are provided in **Table C4-9**.


Figure C4-9. Typical eroding streambank conditions in Miners Gulch Reach 10-02.

C4.2.5.2 MINE 14-02

This reach had two actively eroding banks and ten slowly eroding banks. Slowly eroding banks were typically low and well vegetated. Actively eroding banks were taller and occur where banks have sloughed into the stream channel. Typical eroding streambank conditions are depicted in **Figure C4-10** and sediment loading results are provided in **Table C4-9**.

Figure C4-10. Typical eroding streambank conditions in Miners Gulch Reach 14-02.

Table C4-9. Sediment loading results for Miners Gulch.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)
						Natural
MINE 10-02	Active	0				
	Slow	4	low	86.4	2.2	100.0
	Total	4	low	86.4	2.2	100.0
MINE 14-02	Active	2	low	1.2	0.2	100.0
	Slow	10	low	52.9	3.2	100.0
	Total	12	low	54.1	3.4	100.0

C4.2.6 Sediment Loading Results for Quartz Gulch

C4.2.6.1 QUTZ 09-01

This reach has five slowly eroding streambanks. Eroding banks are well vegetated and located on outside meander bends. Typical eroding streambank conditions are shown in **Figure C4-11** and sediment loading results are provided in **Table C4-10**.

Figure C4-11. Typical eroding streambank conditions in Quartz Creek Reach 09-01.

Table C4-10. Sediment loading results for Quartz Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)	
						Natural	Other
QUTZ 09-01	Active	0					
	Slow	5	high	39.6	30.6	50.0	50.0
	Total	5	high	39.6	30.6	50.0	50.0

C4.2.7 Sediment Loading Results for Scotchman Gulch

C4.2.7.1 SCOT 08-01

This site has eleven slowly eroding banks that are recovering from heavy grazing. Many banks are overhanging and sloughing into the stream channel. Typical eroding streambank conditions are depicted in **Figure C4-12** and sediment loading results are provided in **Table C4-11**.

Figure C4-12. Typical eroding streambank conditions in Scotchman Gulch Reach 08-01.

C4.2.7.2 SCOT 16-01

This reach has five slowly eroding streambanks which are well-vegetated, low, and occur on outside meander bends. Typical eroding streambank conditions are depicted in **Figure C4-13** and sediment loading results are provided in **Table C4-11**.

Figure C4-13. Typical eroding streambank conditions in Scotchman Gulch Reach 16-01.

Table C4-11. Sediment loading results for Scotchman Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Riparian Grazing	Natural	Other
SCOT 08-01	Active	0						
	Slow	11	moderate	82.9	19.1	83.2	15.6	1.2
	Total	11	moderate	82.9	19.1	83.2	15.6	1.2
SCOT 16-02	Active	0						
	Slow	5	low	96.6	4.4	0.0	100.0	0.0
	Total	5	low	96.6	4.4	0.0	100.0	0.0

C4.2.8 Sediment Loading Results for South Fork Antelope Creek

C4.2.8.1 SFAN 06-01

Three slowly eroding streambanks were identified in this reach, but they make up more than 73% of the entire reach. Banks are well vegetated but have been extensively trampled by cattle throughout the reach. Typical eroding streambank conditions are depicted in **Figure C4-14** and sediment loading results are provided in **Table C4-12**.

Figure C4-14. Typical eroding streambank conditions in South Fork Antelope Creek 06-01.

C4.2.8.1 SFAN 13-01

Just two slowly eroding streambanks were identified in this reach, but they comprise nearly 95% of the entire reach. Banks are slowly eroding and well vegetated with a dense root mass, but suffer from extensive cattle grazing. Typical eroding streambank conditions are depicted in **Figure C4-15** and sediment loading results are provided in **Table C4-12**.

Figure C4-15. Typical eroding streambank conditions in South Fork Antelope Creek 13-01.

Table C4-12. Sediment loading results for South Fork Antelope Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)
						Riparian Grazing
SFAN 06-01	Active	0				
	Slow	3	moderate	73.2	6.3	100.0
	Total	3	moderate	73.2	6.3	100.0
SFAN 13-01	Active	0				
	Slow	2	low	94.9	2.7	100.0
	Total	2	low	94.9	2.7	100.0

C4.2.9 Sediment Loading Results for Sluice Gulch

C4.2.9.1 SLUI 14-01

This reach has seven slowly eroding banks, which are recovering from historic grazing and are well vegetated with grasses and weeds with high surface protection. Typical eroding streambank conditions are depicted in **Figure C4-16** and sediment loading results are provided in **Table C4-13**.

Figure C4-16. Typical eroding streambank conditions in Sluice Gulch Reach 14-01.

C4.2.9.2 SLUI 18-02

This reach has two slowly eroding banks that extend throughout the entire reach length. Banks are stable and well vegetated with tall grasses. Signs of recent grazing exist which causes pugging along the entire reach. Typical eroding streambank conditions are depicted in **Figure C4-17** and sediment loading results are provided in **Table C4-13**.

Figure C4-17. Typical eroding streambank conditions in Sluice Gulch Reach 18-02.

Table C4-13. Sediment loading results for Sluice Gulch.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Riparian Grazing	Natural	Other
SLUI 14-01	Active	0						
	Slow	7	high	17.6	8.5	0.0	80.0	20.0
	Total	7	high	17.6	8.5	0.0	80.0	20.0
SLUI 18-02	Active	0						
	Slow	2	low	100.0	3.9	20.0	80.0	0.0
	Total	2	low	100.0	3.9	20.0	80.0	0.0

C4.2.10 Sediment Loading Results for Upper Willow Creek

C4.2.10.1 UWIL 11-05

This reach has one actively eroding bank and eleven slowly eroding banks. Slowly eroding banks are typically near vertical and well vegetated, typically occurring on outside meander bends. The actively eroding bank has a cobble bottom that is eroding away. Typical eroding streambank conditions are depicted in **Figure C4-18** and sediment loading results are provided in **Table C4-14**. A slowly eroding bank is shown on the left, and the actively eroding bank is shown on the right.

Figure C4-18. Typical eroding streambank conditions in Upper Willow Creek Reach 11-05.

C4.2.10.2 UWIL 15-01

This site has two distinct banks types, including actively eroding banks with large portions of bank sloughing into the stream, and slowly eroding well-vegetated banks with undercuts. Both occur on outside meander bends. Typical eroding streambank conditions are depicted in **Figure C4-19** and sediment loading results are provided in **Table C4-14**. An actively eroding bank is shown on the left, and a slowly eroding bank is shown on the right.

Figure C4-19. Typical eroding streambank conditions in Upper Willow Creek Reach 15-01.

Table C4-14. Sediment loading results for Upper Willow Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Riparian Grazing	Cropland	Natural
UWIL 11-05	Active	1	moderate	3.9	2.7	0.0	10.0	90.0
	Slow	12	low	43.8	3.7	0.0	1.5	98.5
	Total	13	low	47.6	6.4	0.0	5.0	95.0
UWIL 15-01	Active	4	moderate	21.2	18.5	25.0	25.0	50.0
	Slow	3	moderate	9.5	2.2	0.0	20.0	80.0
	Total	7	moderate	30.7	20.7	22.3	24.5	53.2

C4.2.11 Sediment Loading Results for West Fork Rock Creek

C4.2.11.1 WFRK 14-03

This reach has twelve slowly eroding streambanks that are generally well-vegetated and undercut. One large exposed bank appears to be created from an excavation area and has no vegetation or surface protection. Typical eroding streambank conditions are depicted in **Figure C4-20** and sediment loading results are provided in **Table C4-15**. Typical bank conditions are shown on the left, while the excavated bank is shown on the right.

Figure C4-20. Typical eroding streambank conditions in West Fork Rock Creek 14-03.

C4.2.11.2 WFRK 27-02

This reach has six slowly eroding banks and one actively eroding bank. Slowly eroding banks are typically well vegetated and undercut with dense tree roots. The one actively eroding bank is tall and has sloughed into the channel, but is well armored with large cobble and boulders. Typical eroding streambank conditions are depicted in **Figure C4-21** and sediment loading results are provided in **Table C4-15**. A slowly eroding bank is shown on the left and an actively eroding bank is shown on the right.

Figure C4-21. Typical eroding streambank conditions in West Fork Rock Creek 27-02.

C4.2.11.3 WFRK 30-02

This reach has five slowly eroding banks and one actively eroding bank. Most slowly eroding banks are well-vegetated and undercut with a stratified cobble layer that leads to sloughing of banks. The actively eroding bank is taller with a steeper angle. Typical eroding streambank conditions are depicted in **Figure C4-22** and sediment loading results are provided in **Table C4-15**. A slowly eroding bank is shown on the left and an actively eroding bank is shown on the right.

Figure C4-22. Typical eroding streambank conditions in West Fork Rock Creek 30-02.

Table C4-15. Sediment loading results for West Fork Rock Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (Tons/Year)	Loading Source (%)		
						Riparian Grazing	Natural	Other
WFRK 14-03	Active	0						
	Slow	12	high	71.9	51.9	0.0	57.6	42.4
	Total	12	high	71.9	51.9	0.0	57.6	42.4
WFRK 27-02	Active	1	moderate	3.2	1.4	0.0	100.0	0.0
	Slow	6	moderate	64.2	19.9	10.0	90.0	0.0
	Total	7	moderate	67.4	21.3	9.3	90.7	0.0
WFRK 30-02	Active	1	high	7.0	5.9	0.0	100.0	0.0
	Slow	5	moderate	24.6	10.4	0.0	100.0	0.0
	Total	6	moderate	31.7	16.4	0.0	100.0	0.0

C4.3 Sediment Loading Results by Reach Type

The following sections provide sediment loading results organized by reach type. Data provided includes sediment load per 1000 feet for each bank type (active, slow and total) and the dominant influence (anthropogenic or natural). If <75% of the bank erosion-influenced load was attributed to natural sources, the load is considered to be anthropogenically influenced.

C4.3.1Sediment Loading Results for Reach Type MR-0-3-U

Six reaches were sampled of reach type MR-0-3-U. This reach type is in the Middle Rockies Ecoregion, has low valley slope (<2%), and includes 3rd order streams within unconfined valleys. Loading results are provided below in **Table C4-16**.

Table C4-16. Sediment loading results for reach type MR-0-3-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
ANTE 21-01	high		high	98.4	0.0	98.4	16.6	0.0	16.6
BREW 06-01	moderate		moderate	35.3	0.0	35.3	11.3	0.0	11.3
UWIL 11-05	low	moderate	low	43.8	3.9	47.6	3.7	2.7	6.4
WFRK 14-03	high		high	71.9	0.0	71.9	51.9	0.0	51.9
WFRK 27-02	moderate	moderate	moderate	64.2	3.2	67.4	19.9	1.4	21.3
WFRK 30-02	moderate	high	moderate	24.6	7.0	31.7	10.4	5.9	16.4
Reach Type Average	**moderate**	**moderate**	**moderate**	**56.4**	**2.4**	**58.7**	**19.0**	**1.7**	**20.7**

C4.3.2 Sediment Loading Results for Reach Type MR-0-4-U

Two reaches were sampled of reach type MR-0-4-U. This reach type is in the Middle Rockies Ecoregion, has low valley slope (<2%), and includes 4th order streams within unconfined valley types. Loading results are provided below in **Table C4-17**.

Table C4-17. Sediment loading results for reach type MR-0-4-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
EFRK 03-03	moderate		moderate	49.5	0.0	49.5	14.7	0.0	14.7
UWIL 15-01	moderate	moderate	moderate	9.5	21.2	30.7	2.2	18.5	20.7
Reach Type Average	**moderate**	**moderate**	**moderate**	**29.5**	**10.6**	**40.1**	**8.5**	**9.3**	**17.7**

C4.3.3 Sediment Loading Results for Reach Type MR-10-1-U

One reach was sampled of reach type MR-10-1-U. This reach type is in the Middle Rockies Ecoregion, has steep valley slope (>10%), and includes first order streams within unconfined valley types. Loading results are provided below in **Table C4-18**.

Table C4-18. Sediment loading results for reach type MR-10-1-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
FLAT 13-01	moderate		moderate	13.2	0.0	13.2	1.7	0.0	1.7
Reach Type Average	**moderate**		**moderate**	**13.2**	**0.0**	**13.2**	**1.7**	**0.0**	**1.7**

C4.3.4 Sediment Loading Results for Reach Type MR-2-1-U

One site was sampled of reach type MR-2-1-U. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 1st order streams within unconfined valley types. Loading results are provided below in **Table C4-19**.

Table C4-19. Sediment loading results for reach type MR-2-1-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
SCOT 08-01	moderate		moderate	82.9	0.0	82.9	19.1	0.0	19.1
Reach Type Average	**moderate**		**moderate**	**82.9**	**0.0**	**82.9**	**19.1**	**0.0**	**19.1**

C4.3.5 Sediment Loading Results for Reach Type MR-2-2-C

One reach was sampled of reach type MR-2-2-C. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 2nd order streams within confined valley types. Loading results are provided below in **Table C4-20**.

Table C4-20. Sediment loading results for reach type MR-2-2-C.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
SLUI 14-01	high		high	17.6	0.0	17.6	8.5	0.0	8.5
Reach Type Average	**high**		**high**	**17.6**	**0.0**	**17.6**	**8.5**	**0.0**	**8.5**

C4.3.6 Sediment Loading Results for Reach Type MR-2-2-U

Two sites were sampled of reach type MR-2-2-U. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 2nd order streams within unconfined valley types. Loading results are provided below in **Table C4-21**.

Table C4-21. Sediment loading results for reach type MR-2-2-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
MINE 14-02	low	low	low	52.9	1.2	54.1	3.2	0.2	3.4
SLUI 18-02	low		low	100.0	0.0	100.0	3.9	0.0	3.9
Reach Type Average	**low**	**low**	**low**	**76.5**	**0.6**	**77.1**	**3.5**	**0.1**	**3.6**

C4.3.7 Sediment Loading Results for Reach Type MR-2-3-C

Two reaches were sampled of reach type MR-2-3-U. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 3rd order streams within unconfined valley types. Loading results are provided below in **Table C4-22**.

Table C4-22. Sediment loading results for reach type MR-2-3-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
BREW 05-01	low		low	37.7	0.0	37.7	3.4	0.0	3.4
EFRK 01-02	moderate		moderate	35.2	0.0	35.2	9.8	0.0	9.8
Reach Type Average	**low**		**low**	**36.5**	**0.0**	**36.5**	**6.6**	**0.0**	**6.6**

C4.3.8 Sediment Loading Results for Reach Type MR-4-1-C

One reach was sampled of reach type MR-4-1-C. This reach type is in the Middle Rockies Ecoregion, has steep valley slope (4-10%), and includes 1st order streams within confined valley types. Loading results are provided below in **Table C4-23**.

Table C4-23. Sediment loading results for reach type MR-4-1-C.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
QUTZ 09-01	high		high	39.6	0.0	39.6	30.6	0.0	30.6
Reach Type Average	**high**		**high**	**39.6**	**0.0**	**39.6**	**30.6**	**0.0**	**30.6**

C4.3.9 Sediment Loading Results for Reach Type MR-4-1-U

Three reaches were sampled of reach type MR-4-1-U. This reach type is in the Middle Rockies Ecoregion, has steep valley slope (4-10%), and includes 1st order streams within unconfined valley types. Loading results are provided below in **Table C4-24**.

Table C4-24. Sediment loading results for reach type MR-4-1-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
FLAT 12-01	high		high	87.0	0.0	87.0	14.7	0.0	14.7
MINE 10-02	low		low	86.4	0.0	86.4	2.2	0.0	2.2
SCOT 16-02	low		low	96.6	0.0	96.6	4.4	0.0	4.4
Reach Type Average	**moderate**		**moderate**	**90.0**	**0.0**	**90.0**	**7.1**	**0.0**	**7.1**

C4.3.10 Sediment Loading Results for Reach Type MR-4-2-C

One reach was sampled of reach type MR-4-2-C. This reach type is in the Middle Rockies Ecoregion, has steep valley slope (4-10%), and includes 2nd order streams within confined valley types. Loading results are provided below in **Table C4-25**.

Table C4-25. Sediment loading results for reach type MR-4-2-C.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
SFAN 06-01	moderate		moderate	73.2	0.0	73.2	6.3	0.0	6.3
Reach Type Average	**moderate**		**moderate**	**73.2**	**0.0**	**73.2**	**6.3**	**0.0**	**6.3**

C4.3.11 Sediment Loading Results for Reach Type MR-4-2-U

Two reaches were sampled of reach type MR-4-2-U. This reach type is in the Middle Rockies Ecoregion, has steep valley slope (4-10%), and includes 2nd order streams within unconfined valley types. Loading results are provided below in **Table C4-26**.

Table C4-26. Sediment loading results for reach type MR-4-2-U.

Reach ID	Mean BEHI Rating			Percent of Reach with Eroding Bank			Total Sediment Load per 1000 Feet (Tons/Year)		
	Slow	Active	Total	Slow	Active	Total	Slow	Active	Total
ANTE 07-01	moderate	high	high	81.6	3.6	85.2	10.0	1.8	11.8
SFAN 13-01	low		low	94.9	0.0	94.9	2.7	0.0	2.7
Reach Type Average	**moderate**	**high**	**moderate**	**88.3**	**1.8**	**90.1**	**6.4**	**0.9**	**7.3**

C5.0 REFERENCES

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ATTACHMENT C1 – MAPS

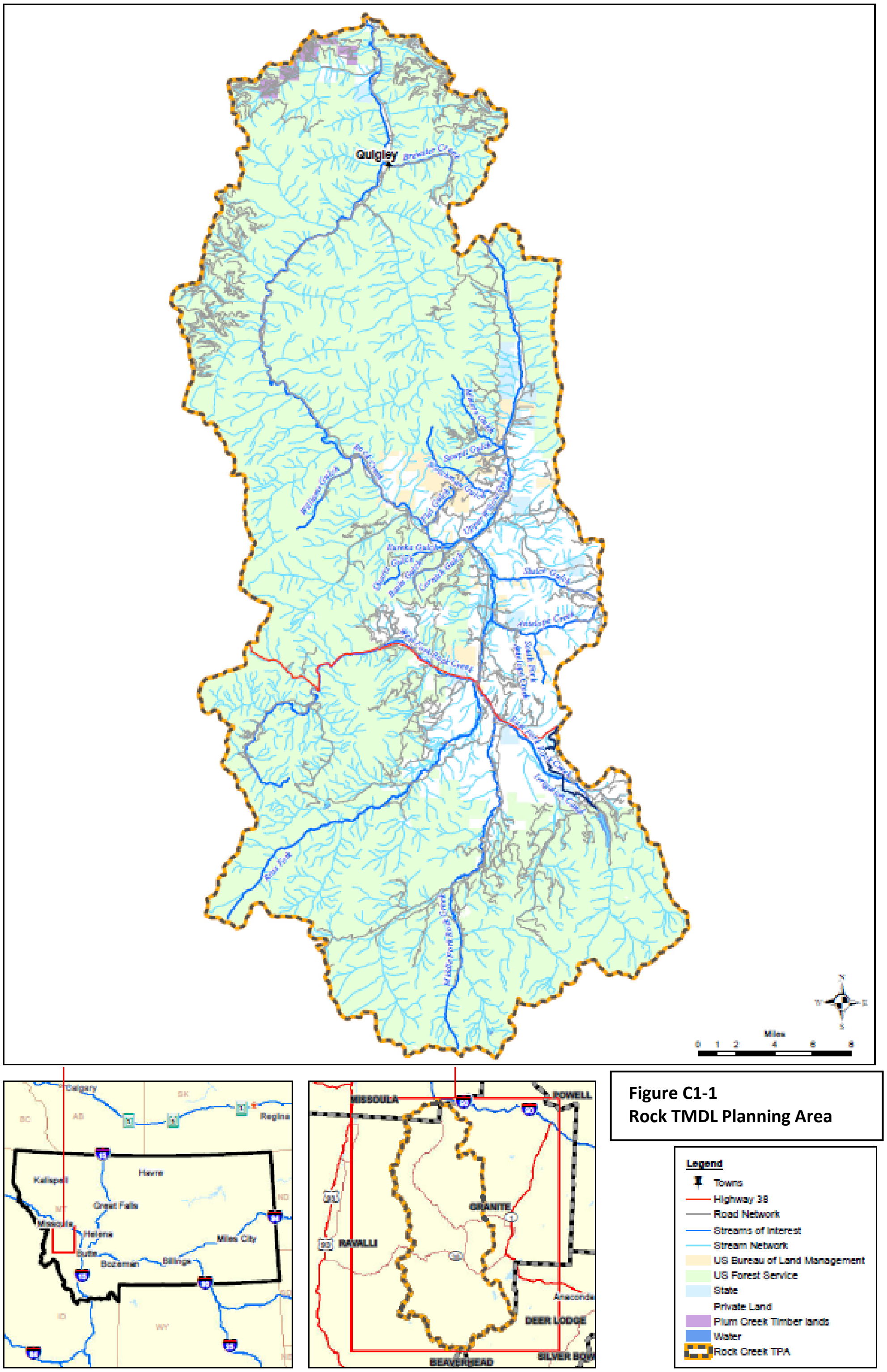

Figure C-1-1. Rock TMDL Planning Area

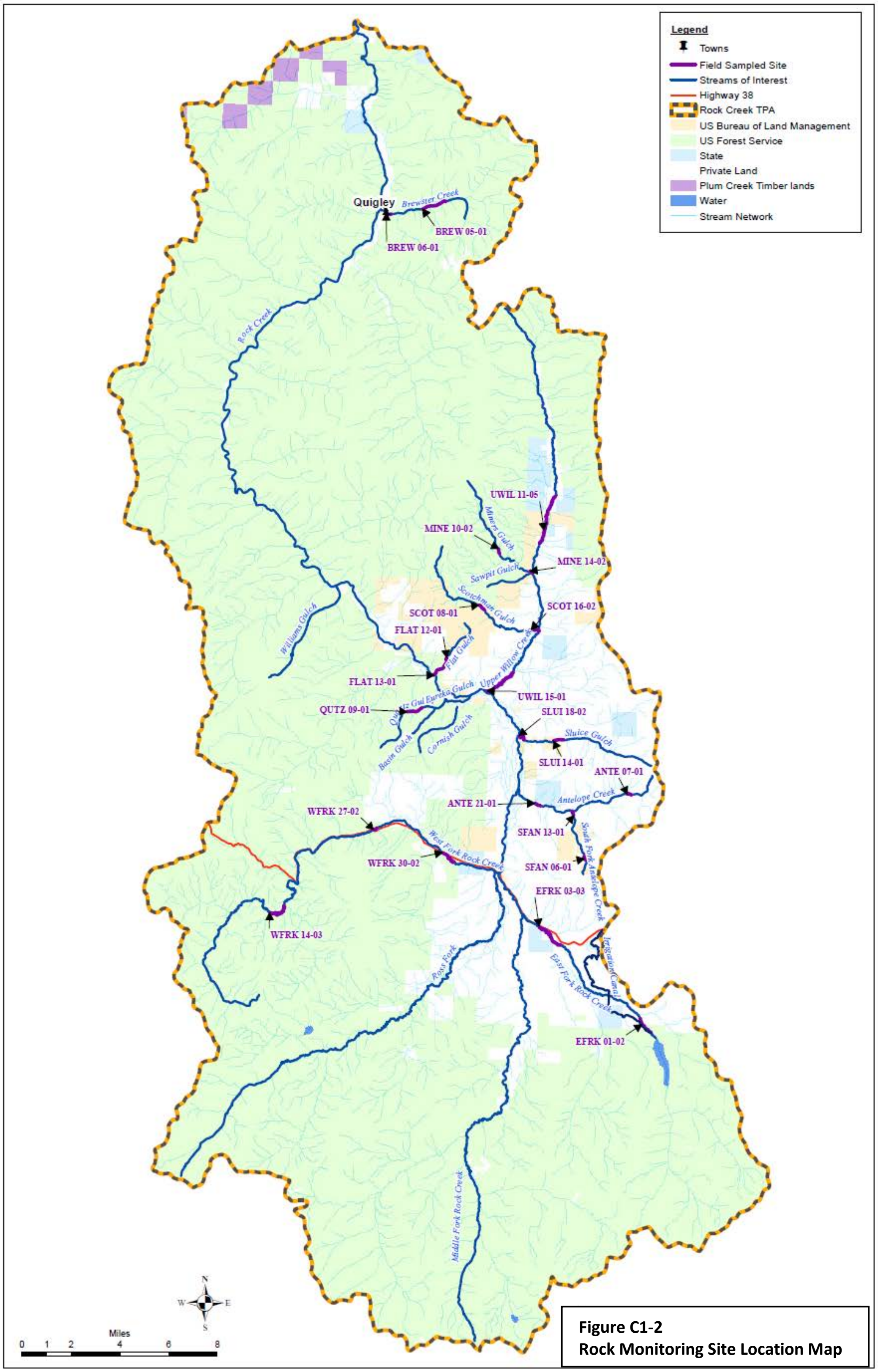

Figure C1-2. Rock Monitoring Site Location Map