ANALYSIS OF BASE PARAMETER DATA AND EROSION INVENTORY DATA FOR SEDIMENT TMDL DEVELOPMENT WITHIN THE BOULDER-ELKHORN TPA

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1.0 INTRODUCTION

The Boulder-Elkhorn TPA encompasses an area of approximately 760 square miles in Jefferson County of southwestern Montana (**Attachment A - Figure 1**). The TPA is bounded by the continental divide to the west, Boulder Hill to the north, the Elkhorn Mountains to the northeast, and the Bull Mountains to the southwest. Elevations in the Boulder TPA range from approximately 1,304 to 2,868 meters (4,275 - 9,415 feet) above mean sea level. The lowest point is the confluence of the Boulder and Jefferson Rivers. The highest point is Crow Peak, at the northeast corner of the TPA in the Elkhorn Mountains. Much of the TPA is rugged and mountainous, with three distinct valleys: Elk Park, a long, narrow valley drained by Bison Creek; the Boulder Valley near Boulder, a high basin hemmed in by mountains; and the Boulder River valley below Elkhorn Creek, a broad river valley opening to the Jefferson River Valley. The uplands are characterized by steep-sided valleys with gently sloping ridgelines and peaks. The Boulder River itself flows a distance of approximately 70 miles, and the TPA (which includes the entire Boulder River watershed) contains 374 miles of named streams. An estimated 2,245 persons live within the TPA. Basin and Boulder had reported populations of 255 and 1,300 in the 2000 census, respectively. The remainder of the population is sparsely distributed throughout rural areas, and much of the TPA is unpopulated.

Mining, timber and agriculture were historically major economic components of the Boulder-Elkhorn TPA. Current land use within the TPA is dominated by forest and agriculture. Agriculture in the lowlands is primarily related to the cattle industry, including irrigated hay pasture and dryland grazing. Mining remains a major economic activity within Jefferson County, but active mining sites are predominantly located outside the TPA. Slightly more than one-third (37%) of the TPA is privately owned, and approximately half (51%) is administered by the US Forest Service. The remainder of the TPA is administered by the US Bureau of Land Management (8%) or Montana State Trust land (3%). Private land is generally concentrated in the valley bottoms and foothills and public land in the uplands, although patented mining claims are scattered throughout the mountains.

Under Montana law, an impaired water body is defined as a water body 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. This list of impaired waters, known as the 303(d) list, is included within the DEQ's biannual "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).

In 2010, Montana Department of Environmental Quality (DEQ) initiated an effort to collect data to support the development of sediment TMDLs for streams within the Boulder-Elkhorn TPA. The data collection effort involved assessing sediment and habitat conditions within the Boulder-Elkhorn watershed, including stream stratification, sampling design, ground surveys, and sediment and habitat analyses. The data collection effort is intended to assist DEQ in evaluating the condition of tributary streams in the TPA and developing TMDLs where necessary.

A total of thirteen streams in the Boulder-Elkhorn TPA were included in the sediment and habitat investigation, including Basin Creek, Bison Creek, Cataract Creek, Elkhorn Creek, High Ore Creek, Little Boulder River, Lowland Creek, McCarty Creek, Muskrat Creek, North Fork of the Little Boulder River, Nursery Creek, Uncle Sam Creek, and the mainstem of the Boulder River. All of these streams were listed on the 2008 303(d) list for sediment except, Bison Creek, Little Boulder River, Lowland Creek, and Muskrat Creek (which are listed for habitat alterations).

A stream stratification process was previously completed on stream segments in the Boulder-Elkhorn TPA and is intended to develop similar water body characterizations that can be applied across watersheds, accounting for localized ecological and hydrologic variations. The 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 Boulder-Elkhorn 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 on July 19 and 20, 2010, and field personnel completed full site surveys from August 31 to September 10, 2010. Field personnel visited the selected reaches and recorded bank erosion sites, vegetation, and channel characteristic data. 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.

2.0 AERIAL ASSESSMENT REACH STRATIFICATION

2.1 Methods

An aerial assessment of streams in the Boulder-Elkhorn 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* (DEQ 2008). The reach stratification methodology involves delineating a water body stream segment into stream reaches and sub-reaches. This process was completed for the following stream segments in the Boulder-Elkhorn TPA: Basin Creek, Bison Creek, Cataract Creek, Elkhorn Creek, High Ore Creek, Little Boulder River, Lowland Creek, McCarty Creek, Muskrat Creek, North Fork of the Little Boulder River, Nursery Creek, Uncle Sam Creek, and the mainstem of the Boulder River.

2.2 Stream Reaches

Water body 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 water body segment is the smallest unit for which an impairment determination is made, the stratification approach described in this document initially stratifies individual water body 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 water body segments into stream reaches having similar landscape controls, it is feasible to make comparisons between similar reaches in regards to observed versus expected channel morphology. Likewise, when land use is used as an additional stratification (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.

The aerial photograph reach stratification methodology involves dividing a stream segment into distinct reaches based on four primary watershed characteristics: Ecoregion, valley gradient, Strahler stream order, and valley confinement. Once stream reaches have been classified by the four watershed characteristics, 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 use in the individual stream reach classification. **Table 2-1** shows the abbreviations developed for each water body.

Table 2-1. Water body naming key.

Water Body	Label Abbreviation
Basin Creek	BASI
Bison Creek	BISO
Boulder River	BLDR
Cataract Creek	CATA
Elkhorn Creek	ELKH
High Ore Creek	HIOR
Little Boulder River	LBLR
Lowland Creek	LOWL
McCarty Creek	MCCA
Muskrat Creek	MUSK
North Fork Little Boulder River	NFLB
Nursery Creek	NURS
Uncle Sam Gulch	USGU

2.3 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 2-2**:

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

The Boulder-Elkhorn TPA exists solely within the Middle Rockies Level III Ecoregion (Ecoregion 17), which includes three Level IV Ecoregions within the Boulder-Elkhorn TPA, including the Elkhorn Mountains-Boulder Batholith (17ai), the Townsend-Horseshoe-London Sedimentary Hills (17y), and the Townsend Basin (17w). Present reach type combinations for the Boulder-Elkhorn TPA are provided in **Table 2-3**, including the number of sites monitored of each reach type. Overall, 23 monitoring sites were selected for field evaluation.

Table 2-2. 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 2-3. Stratified reach types within the Boulder-Elkhorn 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	9	
		2	C	MR-0-2-C	3	
			U	MR-0-2-U	42	3
		3	C	MR-0-3-C	2	
			U	MR-0-3-U	57	4
		4	U	MR-0-4-U	40	5
	2-4%	1	C	MR-2-1-C	1	1
			U	MR-2-1-U	23	1
		2	C	MR-2-2-C	6	
			U	MR-2-2-U	46	2
		3	C	MR-2-3-C	5	2
			U	MR-2-3-U	28	1
	4-10%	1	C	MR-4-1-C	12	
			U	MR-4-1-U	50	
		2	C	MR-4-2-C	15	1
			U	MR-4-2-U	34	3
		3	C	MR-4-3-C	5	
			U	MR-4-3-U	12	
	>10%	1	C	MR-10-1-C	14	
			U	MR-10-1-U	32	
		2	C	MR-10-2-C	8	
			U	MR-10-2-U	6	
		3	C	MR-10-3-C	2	
				Totals:	**452**	**23**

Table 2-4 shows the assessed water bodies and monitored reaches included within each reach type. A map of monitoring site locations is provided as **Attachment A – Figure 2**.

Table 2-4. Monitoring sites in assessed reach types.

Reach Type	Water body	Monitoring Sites
MR-0-2-U	Basin Creek, Bison Creek, Lowland Creek	BASI 08-02, BISO 04-01, LOWL 08-01
MR-0-3-U	Basin Creek, Bison Creek, Little Boulder River, Muskrat Creek	BASI 15-02, BISO 11-01, LBLR 37-01, MUSK 22-08
MR-0-4-U	Boulder River	BLDR 12-04, BLDR 13-04, BLDR 13-10, BLDR 13-23, BLDR 13-33
MR-2-1-C	Nursery Creek	NURS 07-01
MR-2-1-U	Uncle Sam Gulch	USGU 10-01
MR-2-2-U	Cataract Creek, Muskrat Creek	CATA 18-01, MUSK 18-01
MR-2-3-C	Elkhorn Creek, Little Boulder River	ELKH 23-01, LBLR 32-01
MR-2-3-U	Elkhorn Creek	ELKH 28-01
MR-4-2-C	North Fork Little Boulder River	NFLB 42-01
MR-4-2-U	High Ore Creek, McCarty Creek	HIOR 09-01, HIOR 15-01, MCCA 22-01

3.0 SEDIMENT AND HABITAT DATASET REVIEW

3.1 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* (DEQ 2010). 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 in-stream disturbance. All field data were collected on DEQ standard forms for sediment and habitat assessments, and are summarized and provided in tabular format in **Attachment B**.

3.1.1 Survey Site Delineation

Stream survey sites were delineated beginning at riffle crests at the downstream end of each surveyed reach. Survey sites were measured 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 45 ft; and survey lengths of 1,500 or 2,000 ft were used for bankfull widths greater than 45 ft depending on stream size and the homogeneity of features within the reach. The two Boulder River sites lowest in the watershed were surveyed as 2,000' reaches, while the three upper Boulder River sites were surveyed as 1,500' reaches. 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 the **Photo Log**, which is included in **Attachment C**.

3.1.2 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.

3.1.3 Channel Cross-Sections

The "Cross-Section team" was composed of two members of the assessment crew, who also performed pebble counts, riffle stability index, and riffle grid tosses. 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 (DEQ 2010b). 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 = floodprone width / bankfull width.

The floodprone depth was determined by doubling the maximum channel depth. The floodprone 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 floodprone elevation. The total floodprone width was calculated by adding the bankfull channel width to the distances on each end of the channel to the floodprone elevation. When dense vegetation or other features prevented a direct line of tape from being strung, best professional judgment was used to determine the floodprone 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.

3.1.4 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 stream features were recorded. Features were considered dominant when occupying over 50% of the stream width for riffles and 33% for pools. 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 (DEQ 2010b).

3.1.4.1 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 3.1.4.2**).

3.1.4.2 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:

1. Pool types were determined to be either Scour (S) or Dammed (D).
2. Pool size was estimated relative to bankfull channel width was recorded as Small (S), Medium (M), or Large (L). Small pools were defined as <1/3 of the bankfull channel width; medium pools were >1/3 and <2/3 of the bankfull channel with; and large pools were determined to be those >2/3 of the bankfull channel width or >20 feet wide.
3. Pool formative features were recorded as lateral scour (LS), plunge (P), boulder (B), or woody debris (W).
4. 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
5. When undercut banks were present, their depths were measured to the nearest tenth of a foot by inserting a measuring rod horizontally into the undercut bank.

3.1.4.3 Fine Sediment in Depositional Spawning Areas

A measurement of the percent of fine sediment in depositional spawning areas was taken using the grid toss method at the first and second scour pool of 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, following the methodology in *Longitudinal Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments* (DEQ 2010b). 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.

3.1.4.4 Fine Sediment in Riffles

Measurements of fine sediment in riffles were recorded by the Cross-Section team using the same grid toss method as used in pools (**Section 3.1.4.3**). 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 3.1.4.6**) to avoid disturbances to fine sediments. These measurements were recorded in the **Riffle Pebble Count Field Form.**

3.1.4.5 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* (DEQ 2010b).

3.1.4.6 Riffle Pebble Count

A Wolman pebble count (Wolman 1954) was performed by the Cross-Section team at the first riffle encountered in cells 1, 3 and 5 as the team progressed upstream. 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 (DEQ 2010b).

3.1.4.7 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.

3.1.5 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.

3.1.6 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 4.2** and **4.3**.

3.1.7 Water Surface Slope

Where possible, water surface slope measurements were estimated and recorded in the **Elevation & Water Surface Slope Field Form**. Two crew members, usually part of the Cross-Section team, stood distant from each other within direct line-of-sight at the water's surface between two similar stream features, and estimated slope with a clinometer.

3.1.8 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.

3.1.9 Quality Assurance/Quality Control

Quality assurance and quality control (QA/QC) was achieved through strict adherence to the project's Sampling and Analysis Plan (DEQ 2010a). 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 Sampling and Analysis Plan (SAP), some deviations did occur while in the field and during data processing. Additionally, parameters used for sediment loading calculations were adjusted during data processing and following review of field photos to better represent actual field conditions. These adjustments and any deviations from the SAP are described in the Quality Assurance/Quality Control Review provided in **Attachment D**.

3.2 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 2-3**.

Data provided for each parameter include statistical box plots and data tables organized by each reach type and a total that includes all monitored sites. The box plots and data tables provide the minimum and maximum observed values, and the 25^{th} (Q1), 50^{th} (median), and 75^{th} (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.

3.2.1 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 over-widened streams may have an artificially high channel width.

The measured bankfull channel widths are presented in **Figure 3-1** by reach type, and summary statistics are provided in **Table 3-1**. All surveyed cross sections are included in the data generated for each reach type**.**

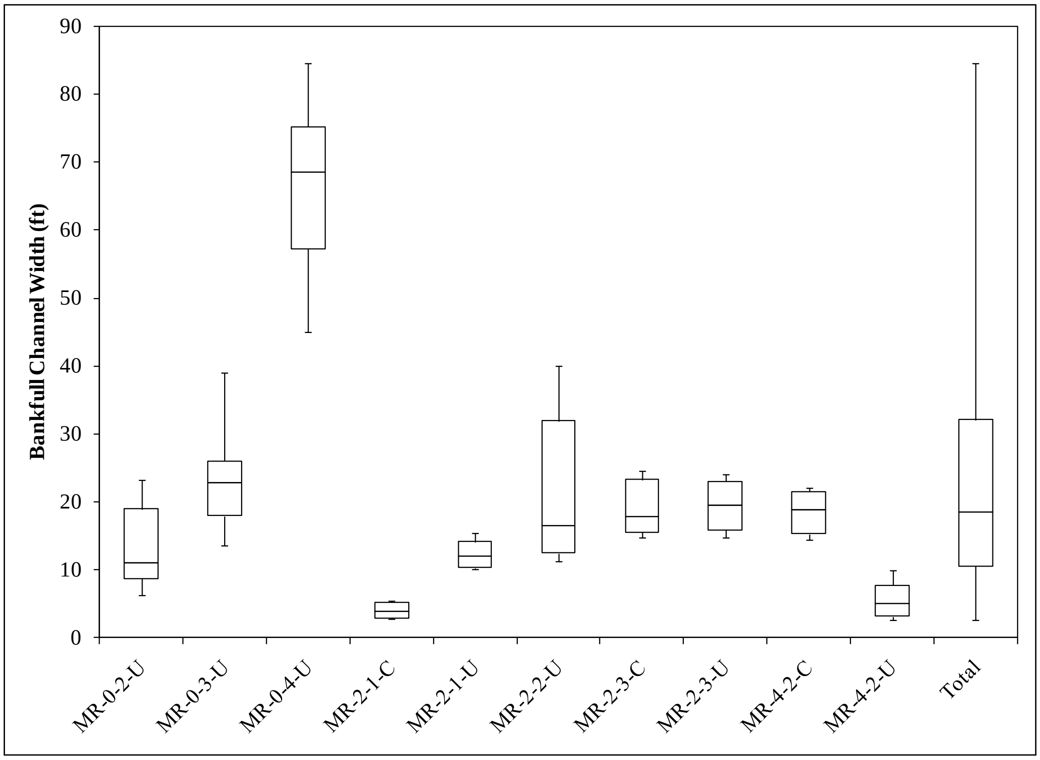

Figure 3-1. Bankfull channel width by reach type.

Table 3-1. Summary statistics of bankfull channel width by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	15	6.3	8.7	11.0	19.0	23.3
MR-0-3-U	4	19	13.6	18.0	22.8	26.0	39.0
MR-0-4-U	5	22	45.0	57.3	68.5	75.3	84.5
MR-2-1-C	1	5	2.8	2.9	3.8	5.3	5.5
MR-2-1-U	1	5	10.1	10.4	12.0	14.1	15.4
MR-2-2-U	2	9	11.3	12.5	16.5	32.0	40.0
MR-2-3-C	2	10	14.8	15.6	17.8	23.3	24.5
MR-2-3-U	1	4	14.8	15.9	19.5	23.0	24.0
MR-4-2-C	1	4	14.5	15.3	18.9	21.6	22.0
MR-4-2-U	3	15	2.7	3.2	5.0	7.7	10.0
Total	**23**	**108**	**2.7**	**10.5**	**18.5**	**32.1**	**84.5**

3.2.2 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 channel width/depth ratio is one of several standard measurements used to classify stream channels, making it a useful variable for comparing conditions on reaches within the same stream type. A comparison of observed and expected width/depth ratio is a useful indicator of channel over-widening and aggradation, which are often linked to excess streambank erosion or acute or chronic erosion from sources upstream of the study reach. Channels that are over-widened often are associated with excess sediment deposition and streambank erosion, contain shallower, warmer water, and provide fewer deepwater habitat refugia for fish.

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

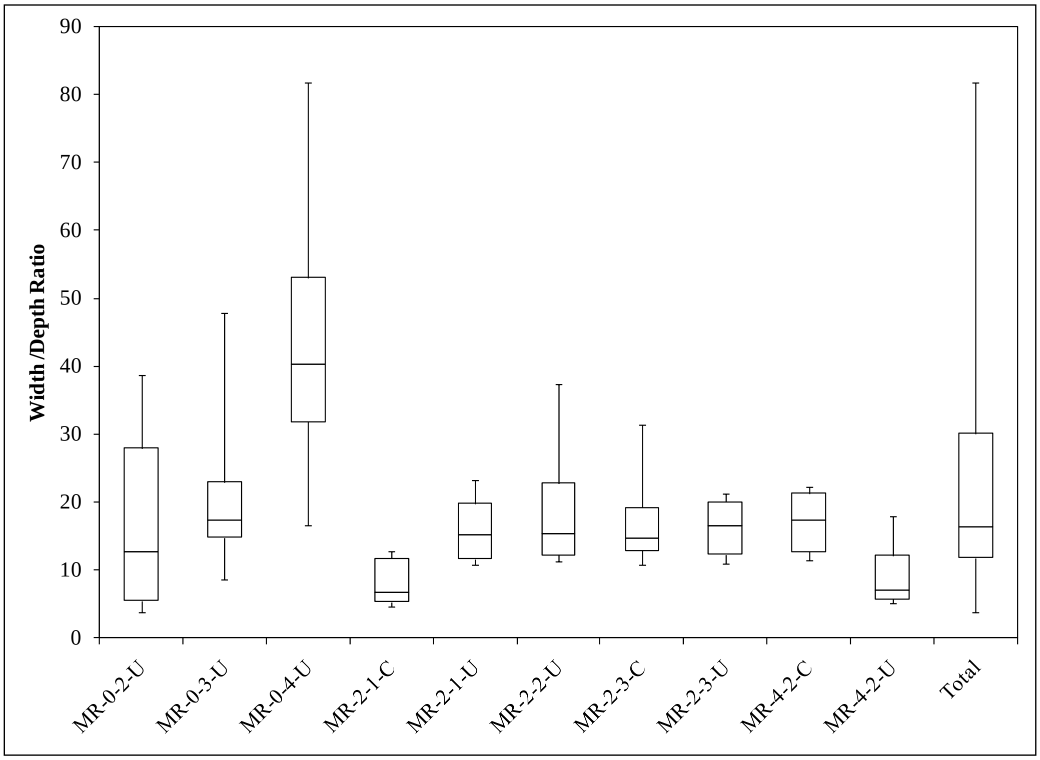

Figure 3-2. Width/depth ratio by reach type.

Table 3-2. Summary statistics of width/depth ratio by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	15	3.8	5.5	12.7	27.9	38.8
MR-0-3-U	4	19	8.6	14.8	17.3	23.0	47.8
MR-0-4-U	5	22	16.5	31.8	40.4	53.0	81.7
MR-2-1-C	1	5	4.7	5.4	6.7	11.7	12.8
MR-2-1-U	1	5	10.8	11.7	15.2	19.8	23.2
MR-2-2-U	2	9	11.3	12.2	15.3	22.8	37.4
MR-2-3-C	2	10	10.8	12.9	14.6	19.2	31.4
MR-2-3-U	1	4	10.9	12.3	16.5	20.1	21.2
MR-4-2-C	1	4	11.5	12.7	17.4	21.3	22.2
MR-4-2-U	3	15	5.1	5.7	7.0	12.1	18.0
Total	**23**	**108**	**3.8**	**11.9**	**16.4**	**30.1**	**81.7**

3.2.3 Entrenchment Ratio

Stream entrenchment ratio is equal to the floodprone 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 (down-cutting), 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 3-3**, and summary statistics are provided in **Table 3-3**. All surveyed cross sections are included in the statistics generated within each reach type**.**

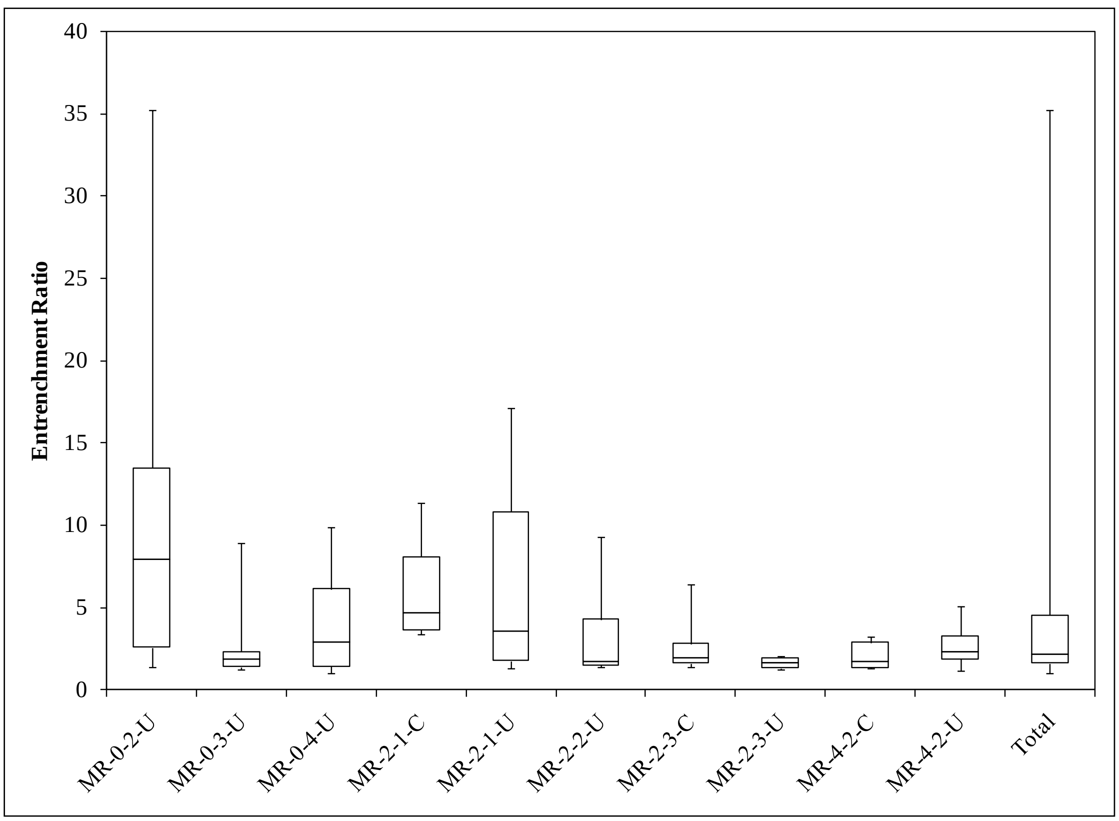

Figure 3-3. Entrenchment ratio by reach type.

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

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	15	1.4	2.6	7.9	13.5	35.2
MR-0-3-U	4	19	1.2	1.4	1.8	2.3	8.9
MR-0-4-U	5	22	1.0	1.4	2.9	6.1	9.9
MR-2-1-C	1	5	3.4	3.7	4.7	8.1	11.4
MR-2-1-U	1	5	1.4	1.8	3.6	10.8	17.1
MR-2-2-U	2	9	1.4	1.5	1.7	4.3	9.3
MR-2-3-C	2	10	1.4	1.6	1.9	2.8	6.4
MR-2-3-U	1	4	1.3	1.3	1.6	1.9	2.1
MR-4-2-C	1	4	1.3	1.4	1.7	2.9	3.2
MR-4-2-U	3	15	1.2	1.9	2.3	3.3	5.1
Total	**23**	**108**	**1.0**	**1.6**	**2.2**	**4.6**	**35.2**

3.2.4 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 cold water 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 3-4**, and summary statistics are provided in **Table 3-4**.

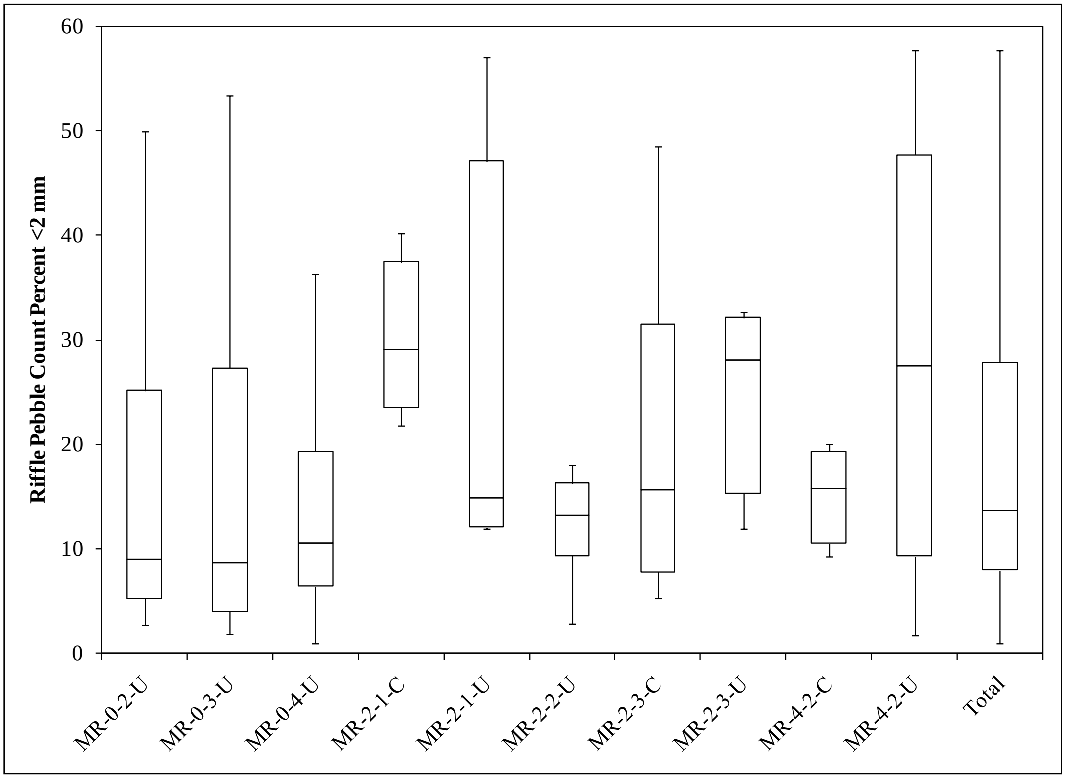

Figure 3-4. Riffle pebble count (% <2 mm) by reach type.

Table 3-4. Summary statistics of riffle pebble count (% <2 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	12	2.8	5.3	9.0	25.2	50.0
MR-0-3-U	4	16	1.9	4.0	8.7	27.3	53.4
MR-0-4-U	5	20	1.0	6.4	10.5	19.4	36.4
MR-2-1-C	1	4	21.8	23.6	29.1	37.5	40.2
MR-2-1-U	1	4	12.0	12.1	14.9	47.1	57.0
MR-2-2-U	2	8	2.9	9.4	13.2	16.3	18.0
MR-2-3-C	2	8	5.3	7.8	15.6	31.5	48.6
MR-2-3-U	1	4	11.9	15.4	28.1	32.1	32.7
MR-4-2-C	1	4	9.3	10.5	15.8	19.3	20.0
MR-4-2-U	3	12	1.8	9.3	27.5	47.7	57.7
Total	**23**	**92**	**1.0**	**8.0**	**13.7**	**27.9**	**57.7**

3.2.5 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 cold water 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.

The pebble count measurements for sediment fines (% <6 mm) by reach type are presented below in **Figure 3-5** and summary statistics are provided in **Table 3-5**.

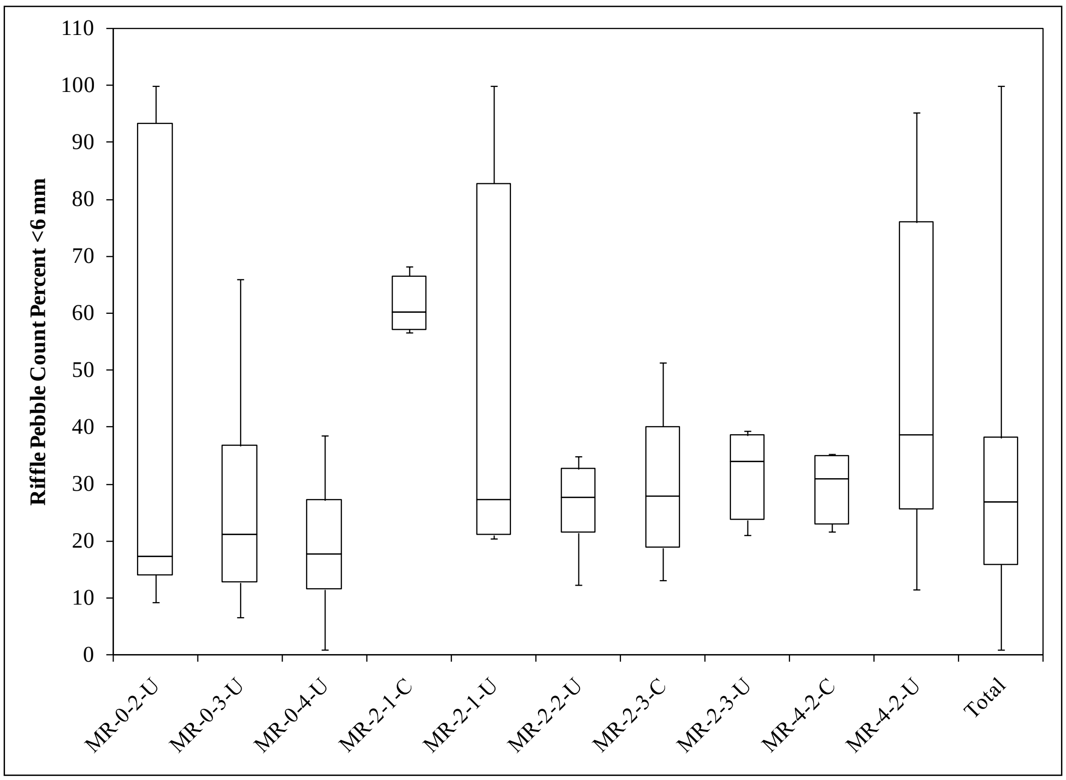

Figure 3-5. Riffle pebble count (% <6 mm) by reach type.

Table 3-5. Summary statistics of riffle pebble count (% <6 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	12	9.3	14.1	17.3	93.4	100.0
MR-0-3-U	4	16	6.7	12.8	21.2	36.8	66.0
MR-0-4-U	5	20	1.0	11.6	17.7	27.3	38.5
MR-2-1-C	1	4	56.7	57.2	60.2	66.6	68.2

Table 3-5. Summary statistics of riffle pebble count (% <6 mm) by reach type.							
MR-2-1-U	1	4	20.4	21.1	27.3	82.8	100.0
MR-2-2-U	2	8	12.4	21.5	27.7	32.8	35.0
MR-2-3-C	2	8	13.3	18.9	27.9	40.1	51.4
MR-2-3-U	1	4	21.1	23.8	34.0	38.6	39.4
MR-4-2-C	1	4	21.7	23.1	31.0	35.0	35.2
MR-4-2-U	3	12	11.6	25.7	38.7	76.0	95.2
Total	**23**	**92**	**1.0**	**16.0**	**27.0**	**38.2**	**100.0**

3.2.6 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, 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 3-6** and summary statistics are provided in **Table 3-6**.

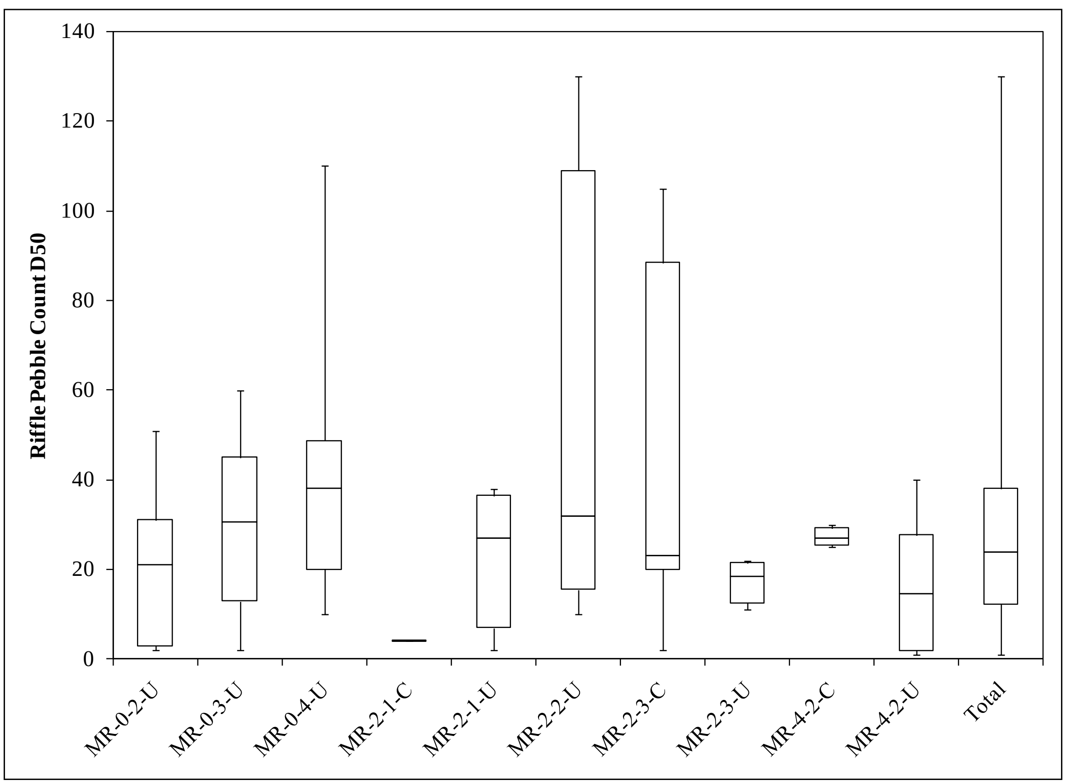

Figure 3-6. Riffle pebble count D50 (mm) by reach type.

Table 3-6. Summary statistics of riffle pebble count D50 (mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	12	2	3	21	31	51
MR-0-3-U	4	16	2	13	31	45	60
MR-0-4-U	5	20	10	20	38	49	110
MR-2-1-C	1	4	4	4	4	4	4
MR-2-1-U	1	4	2	7	27	37	38
MR-2-2-U	2	8	10	16	32	109	130
MR-2-3-C	2	8	2	20	23	89	105
MR-2-3-U	1	4	11	13	19	22	22
MR-4-2-C	1	4	25	26	27	29	30
MR-4-2-U	3	12	1	2	15	28	40
Total	**23**	**92**	**1**	**12**	**24**	**38**	**130**

3.2.7 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 stabile 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 3-7**.

Table 3-7. Riffle stability index results for all reaches.

Reach ID	Cell	Reach Type	Arithmetic Mean (cm)	Riffle Stability Index
BASI 15-02	1	MR-0-3-U	99	96
BLDR 13-04	3	MR-0-4-U	77	67
BLDR 13-10	2	MR-0-4-U	79	90

3.2.8 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 3-7** and summary statistics are provided in **Table 3-8**. One reach (HIOR 09-01, reach type MR-4-2-U) was unable to be assessed due to murky water.

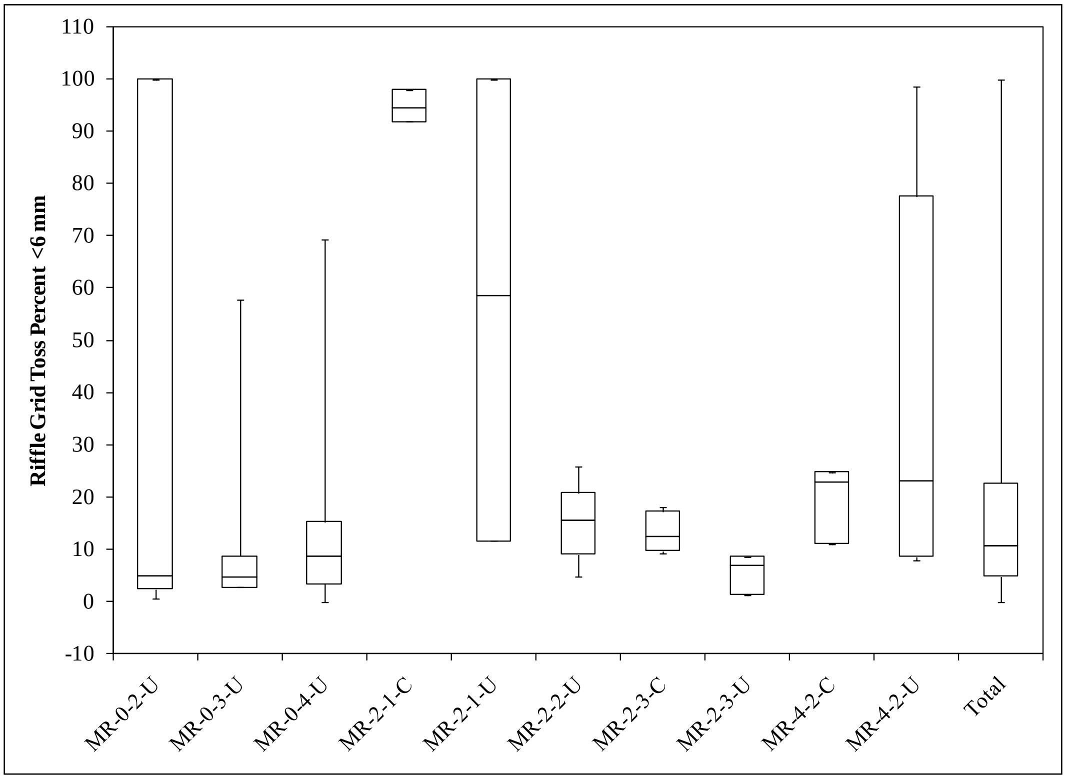

Figure 3-7. Riffle grid toss (% <6 mm) by reach type.

Table 3-8. Summary statistics of riffle grid toss (% <6 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	9	0.7	2.4	5.0	100.0	100.0
MR-0-3-U	4	12	2.7	2.8	4.8	8.7	57.8
MR-0-4-U	5	13	0.0	3.4	8.6	15.3	69.4
MR-2-1-C	1	3	91.8	91.8	94.6	98.0	98.0
MR-2-1-U	1	3	11.6	11.6	58.5	100.0	100.0
MR-2-2-U	2	6	4.9	9.1	15.5	20.8	25.9
MR-2-3-C	2	8	9.2	9.7	12.4	17.2	18.2
MR-2-3-U	1	3	1.4	1.4	7.0	8.6	8.6

Table 3-8. Summary statistics of riffle grid toss (% <6 mm) by reach type.							
Reach Type	**Reaches**	**Count**	**Minimum**	**Q1**	**Median**	**Q3**	**Maximum**
MR-4-2-C	1	3	11.1	11.1	22.8	24.8	24.8
MR-4-2-U	2	6	7.9	8.6	23.0	77.6	98.6
Total	**22**	**64**	**0.0**	**4.8**	**10.7**	**22.8**	**100.0**

3.2.9 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 less than 6.35mm and the emergence success of westslope cutthroat trout and bull trout.

Grid toss results for sediment fines (% <6 mm) found within depositional spawning areas are provided below in **Figure 3-8** and summary statistics are provided in **Table 3-9**. The data presented represents only pool tails that were identified as having the appropriate sized gravels to support spawning. There were four assessed reaches (BASI 15-02, BISO 04-02, BLDR 13-33, and HIOR 09-01) where spawning gravels did not exist in pool tails.

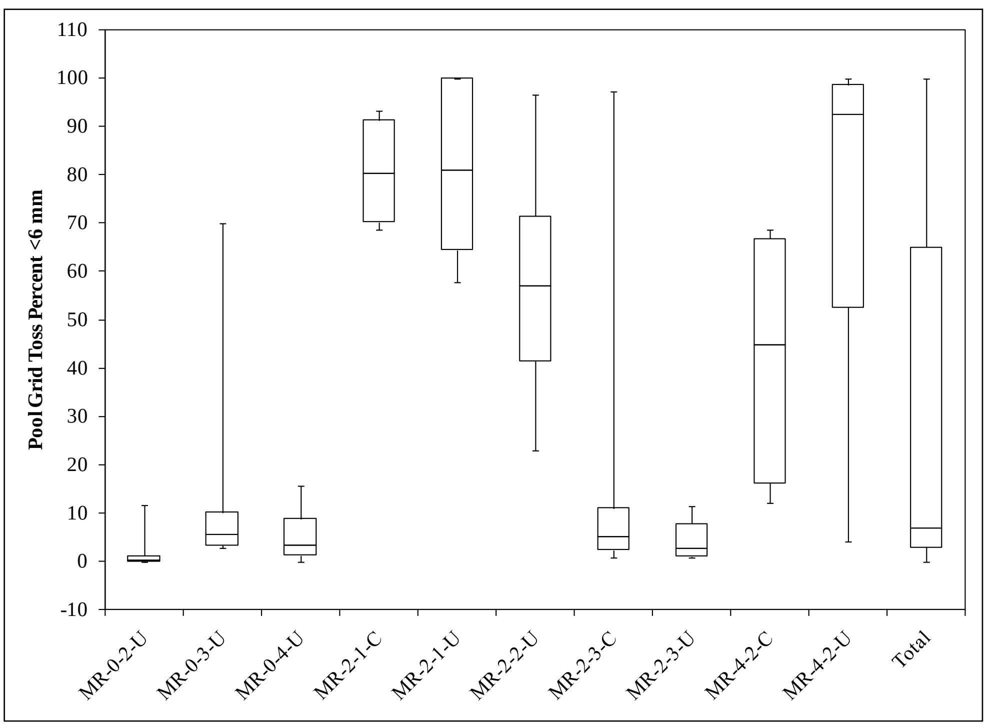

Figure 3-8. Pool grid toss (% <6 mm) by reach type.

Table 3-9. Summary statistics of pool grid toss (% <6 mm) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	2	16	0.0	0.0	0.3	1.2	11.7
MR-0-3-U	3	19	2.7	3.4	5.5	10.2	70.1
MR-0-4-U	4	15	0.0	1.4	3.5	8.8	15.6
MR-2-1-C	1	4	68.7	70.2	80.3	91.3	93.2
MR-2-1-U	1	6	57.8	64.5	81.0	100.0	100.0
MR-2-2-U	1	7	23.1	41.5	57.0	71.4	96.6
MR-2-3-C	2	10	0.7	2.4	5.1	11.0	97.3
MR-2-3-U	1	5	0.7	1.1	2.7	7.9	11.6
MR-4-2-C	1	4	12.2	16.3	44.9	66.8	68.7
MR-4-2-U	3	13	4.2	52.6	92.5	98.6	100.0
Total	**19**	**99**	**0.0**	**3.0**	**7.0**	**65.0**	**100.0**

3.2.10 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 3-9** and **Table 3-10**. 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.

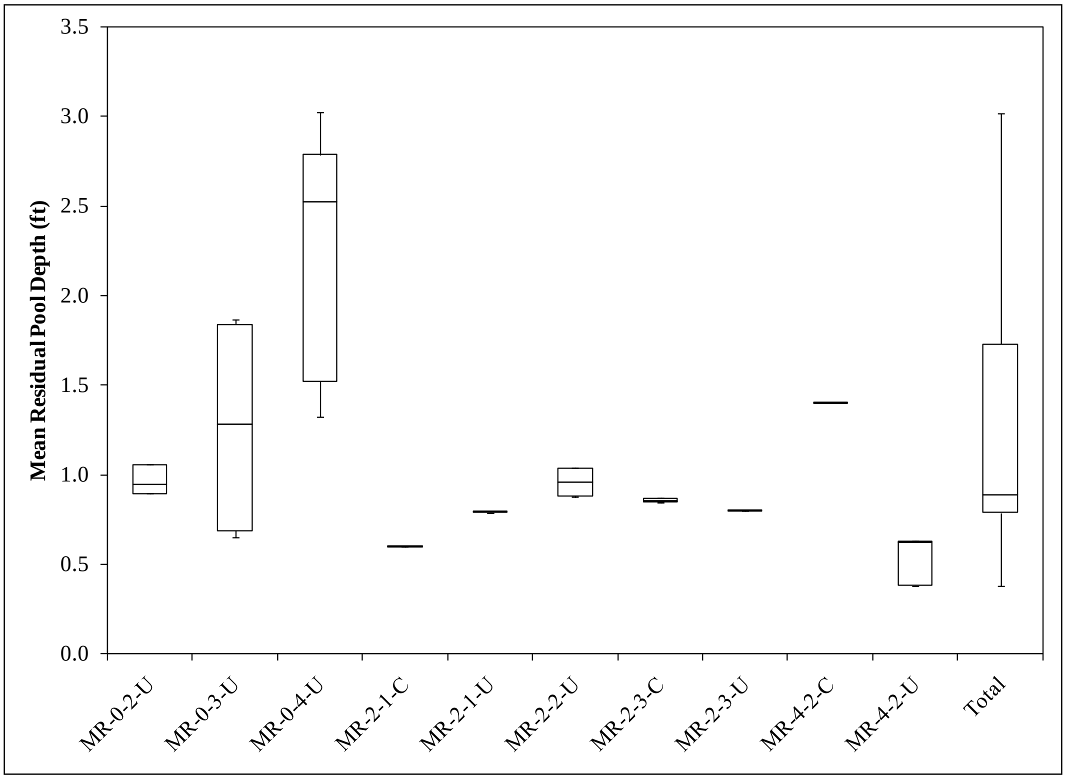

Figure 3-9. Residual pool depth (ft) by reach type.

Table 3-10. Summary statistics of residual pool depth (ft) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	3	0.9	0.9	0.9	1.1	1.1
MR-0-3-U	4	4	0.7	0.7	1.3	1.8	1.9
MR-0-4-U	5	5	1.3	1.5	2.5	2.8	3.0
MR-2-1-C	1	1	0.6		0.6		0.6
MR-2-1-U	1	1	0.8		0.8		0.8
MR-2-2-U	2	2	0.9		1.0		1.0
MR-2-3-C	2	2	0.8		0.9		0.9
MR-2-3-U	1	1	0.8		0.8		0.8
MR-4-2-C	1	1	1.4		1.4		1.4
MR-4-2-U	3	3	0.4	0.4	0.6	0.6	0.6
Total	**23**	**23**	**0.4**	**0.8**	**0.9**	**1.7**	**3.0**

3.2.11 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 3-10** and summary statistics are provided in **Table 3-11**. As with residual pool depth, some reach types are represented by only a single value.

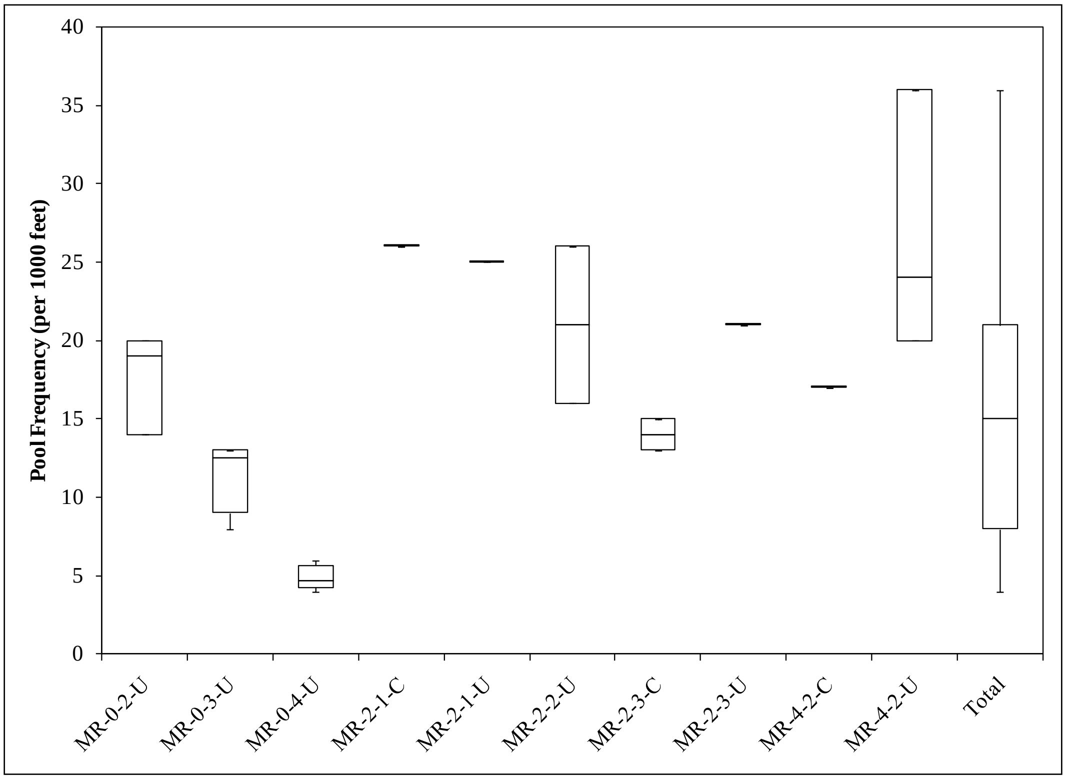

Figure 3-10. Pool frequency (per 1,000 ft) by reach type.

Table 3-11. Summary statistics of pool frequency by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	3	14.0	14.0	19.0	20.0	20.0
MR-0-3-U	4	4	8.0	9.0	12.5	13.0	13.0
MR-0-4-U	5	5	4.0	4.3	4.7	5.7	6.0
MR-2-1-C	1	1	26.0		26.0		26.0
MR-2-1-U	1	1	25.0		25.0		25.0
MR-2-2-U	2	2	16.0		21.0		26.0
MR-2-3-C	2	2	13.0		14.0		15.0
MR-2-3-U	1	1	21.0		21.0		21.0
MR-4-2-C	1	1	17.0		17.0		17.0
MR-4-2-U	3	3	20.0	20.0	24.0	36.0	36.0
Total	**23**	**23**	**4.0**	**8.0**	**15.0**	**21.0**	**36.0**

3.2.12 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. A guideline value of approximately 150 pieces of LWD per mile, or approximately 28 pieces of LWD per 1000 feet, represents an average of target values from other studies. 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 3-11** and summary statistics are provided in **Table 3-12**.

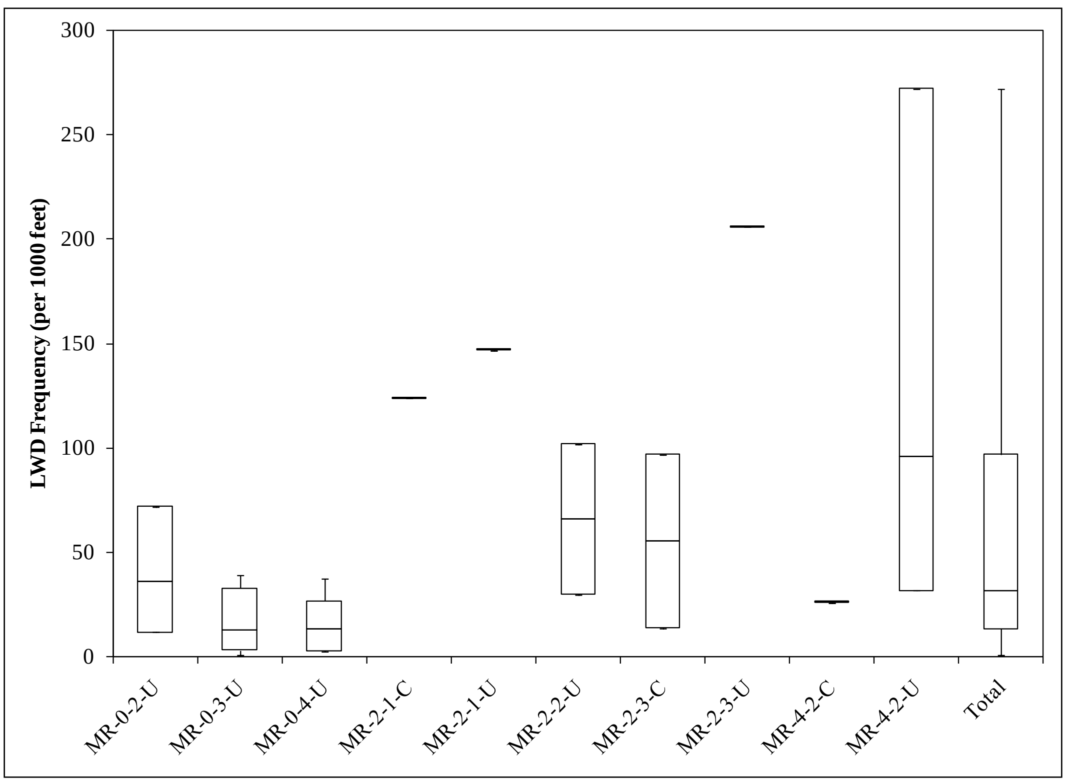

Figure 3-11. LWD frequency (per 1,000 ft) by reach type.

Table 3-12. Summary statistics of LWD frequency by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	3	12	12	36	72	72
MR-0-3-U	4	4	1	4	13	33	39

Table 3-12. Summary statistics of LWD frequency by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-4-U	5	5	3	3	14	27	37
MR-2-1-C	1	1	124		124		124
MR-2-1-U	1	1	147		147		147
MR-2-2-U	2	2	30		66		102
MR-2-3-C	2	2	14		56		97
MR-2-3-U	1	1	206		206		206
MR-4-2-C	1	1	26		26		26
MR-4-2-U	3	3	32	32	96	272	272
Total	**23**	**23**	**1**	**14**	**32**	**97**	**272**

3.2.13 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.

The Greenline understory shrub cover percentages by reach type are presented in **Figure 3-12**. The summary data are also presented in **Table 3-13**.

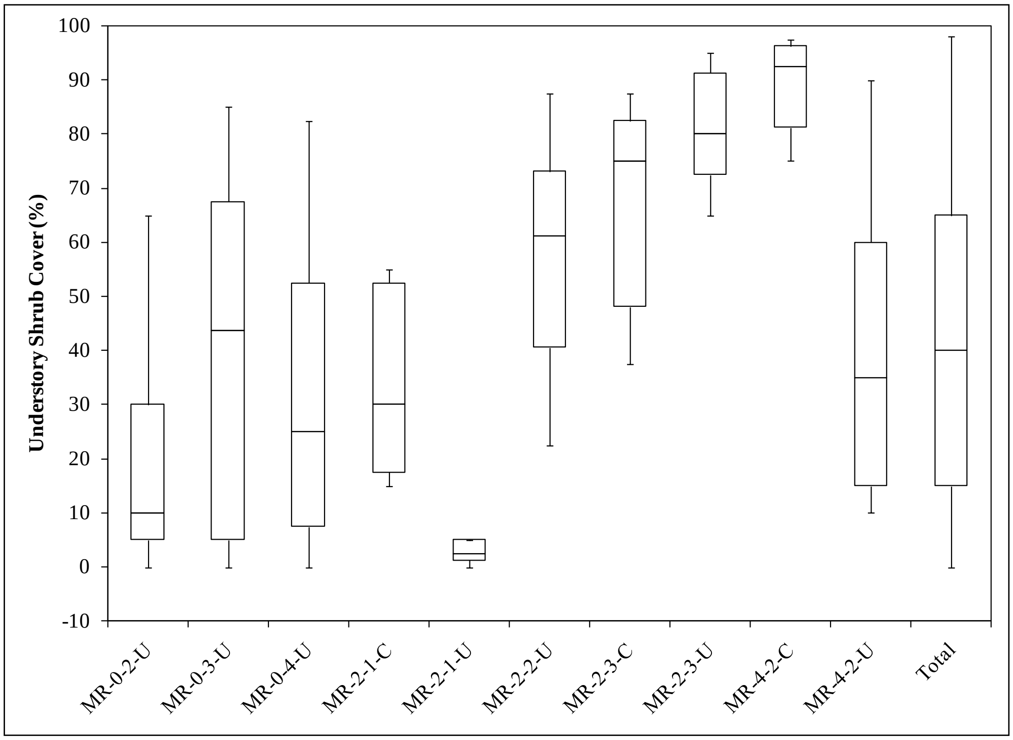

Figure 3-12. Greenline understory shrub cover (%) by reach type.

Table 3-13. Summary statistics of understory shrub cover (%) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	15	0.0	5.0	10.0	30.0	65.0
MR-0-3-U	4	20	0.0	5.0	43.8	67.5	85.0
MR-0-4-U	5	25	0.0	7.5	25.0	52.5	82.5
MR-2-1-C	1	5	15.0	17.5	30.0	52.5	55.0
MR-2-1-U	1	5	0.0	1.3	2.5	5.0	5.0
MR-2-2-U	2	10	22.5	40.6	61.3	73.1	87.5
MR-2-3-C	2	10	37.5	48.1	75.0	82.5	87.5
MR-2-3-U	1	5	65.0	72.5	80.0	91.3	95.0
MR-4-2-C	1	5	75.0	81.3	92.5	96.3	97.5
MR-4-2-U	3	15	10.0	15.0	35.0	60.0	90.0
Total	**23**	**115**	**0.0**	**15.0**	**40.0**	**65.0**	**98.0**

3.2.14 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.

Results of the Greenline survey for percent bare/disturbed ground are provided by reach type below in **Figure 3-13**, and tabular data are presented in **Table 3-14**.

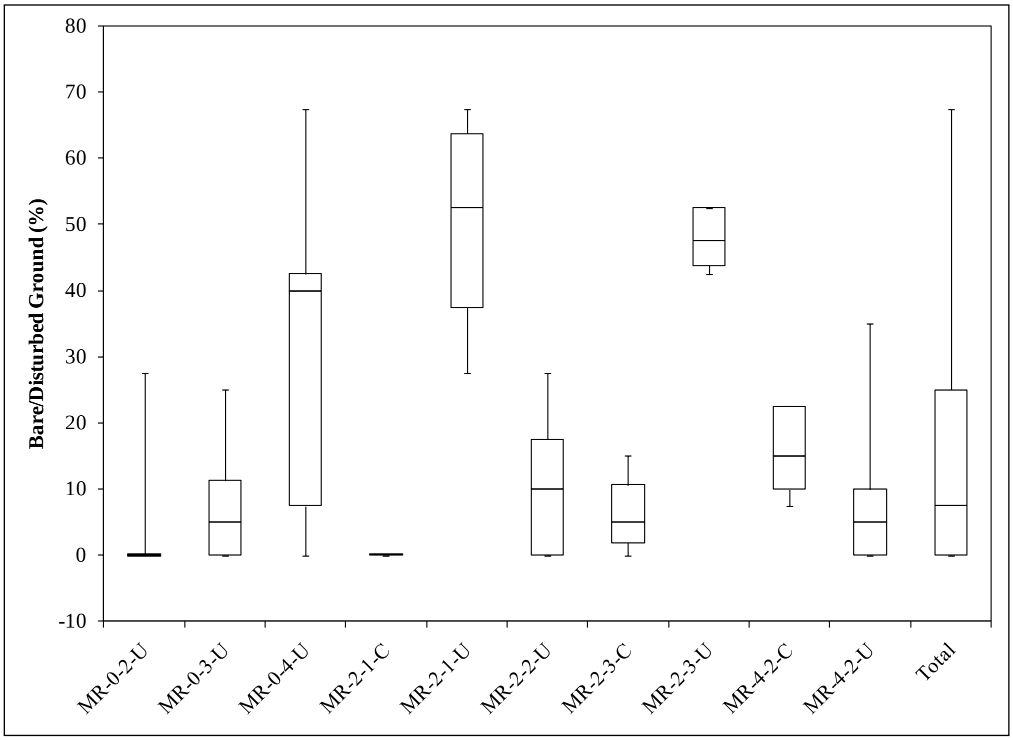

Figure 3-13. Greenline bare/disturbed ground (%) by reach type.

Table 3-14. Summary statistics of bare/disturbed ground (%) by reach type.

Reach Type	Reaches	Count	Minimum	Q1	Median	Q3	Maximum
MR-0-2-U	3	15	0.0	0.0	0.0	0.0	27.5
MR-0-3-U	4	20	0.0	0.0	5.0	11.3	25.0
MR-0-4-U	5	25	0.0	7.5	40.0	42.5	67.5
MR-2-1-C	1	5	0.0	0.0	0.0	0.0	0.0
MR-2-1-U	1	5	27.5	37.5	52.5	63.8	67.5
MR-2-2-U	2	10	0.0	0.0	10.0	17.5	27.5
MR-2-3-C	2	10	0.0	1.9	5.0	10.6	15.0
MR-2-3-U	1	5	42.5	43.8	47.5	52.5	52.5
MR-4-2-C	1	5	7.5	10.0	15.0	22.5	22.5
MR-4-2-U	3	15	0.0	0.0	5.0	10.0	35.0
Total	**23**	**115**	**0.0**	**0.0**	**7.5**	**25.0**	**67.5**

3.3 Assessment Reach Field Descriptions

The following sections provide brief descriptions of each sampled reach. Descriptions are provided for human impacts, stream channel conditions, and riparian vegetation conditions. Stream bank erosion conditions are provided with sediment loading results in **Section 4.6**. Assessment reaches are organized by water body and reach location starting at the upstream end and moving downstream.

3.3.1 Basin Creek

BASI 08-02

Description of human impacts and their severity:

This stream has been heavily affected by human activity. A road parallels the stream for much of the reach on river right. Placer tailings are also evident in places throughout the reach, particularly the berms that confine the stream at the uppermost end. Some banks in the section have little vegetation and appear to be a loosely consolidated collection of cobbles, sand, and overlying duff. The stream has found some semblance of a stable form; however, the channel is easily diverted and braided by tree fall in areas with loose cobble banks and steeper slopes.

Description of stream channel conditions:

Stream reach is a B4 type channel dominated by riffles with a stream bottom comprised of mostly small to mid-sized angular cobble, gravel and sand. Little pool formation exists in most of the reach; however, some lateral scour pools occur at bends. Where LWD does exist some stream variability also occurs, with braided channels and pool formation (cell 3). In general, stream appears significantly over-widened as a result of human alterations and impacts throughout. This reach has very little spawning gravel, with only two spawning gravel locations observed in LWD pools.

Description of streambank erosion conditions:

Despite the obvious alteration and historic disturbance to the stream, little stream bank erosion was witnessed; however, eroding banks may not exist because the stream corridor has been so over-widened that not many discernable banks exist anymore. Plus, where eroding banks do exist they are comprised of cobbles and gravel that effectively armor the bank. Only where the stream was directed into the old placer pilings did the banks become unstable. In cell 3, where the stream became braided, the large wood and natural vegetation through this section helped maintain stable banks. This was the only section that appeared to have a better vegetation community.

Description of riparian vegetation conditions:

Ground cover was predominantly sedges along stream edge with some rushes. Some grasses were also present but up-gradient of stream edge. Forbs are in abundance throughout the area. Understory consisted of lodgepole saplings, a few large willows, and a few smaller bushes along the stream edge. Overstory consisted of lodgepole/spruce mix with abundant beetle kill.

BASI 15-02

Description of human impacts and their severity:

The stream through this reach definitely appears to have had some anthropogenic impacts. Upstream of the reach the valley has been cleared for a small plane landing strip and a residence exists on river left in the lower part of the reach. Large size cobbles occupy multiple gravel bars and point bars and these features are often over a foot deep with this type of substrate. Multiple transverse bars also occur throughout the reach. The area surrounding the stream is occupied by transitional and young size class vegetation suggesting historic logging or potentially mining, as occurred upstream. The excess cobbles and expansive point bars suggest strong spring runoff capable of moving larger material. The cobbles are possibly resulting from the upstream conditions affected by historic mining, logging and road building.

Description of stream channel conditions:

This reach is predominantly a high energy B4 type channel. Multiple transverse bars and deep, large point bars indicate an aggrading system. Where transverse bars or large wood occur, deep scour pools result often exerting near bank stress leading to eroding banks. Stream width/depth ratios appear variable, with frequent overwidening and pinch points where gravel bars constrict channel into deeper run features at the beginning of bends. Substrate is dominated by coarse cobbles with little suitability for spawning. Not much fine material exists within the substrate. LWD and deep bends provide good cover. A fair amount of algae was noted throughout the reach.

Description of streambank erosion conditions:

This reach has a number of long, actively eroding banks corresponding with bends or transverse bars that direct flow into the bank. Banks have poor stabilizing vegetation, possibly as a result of historic logging and mining or more recent residential development. Bank material is typically loosely consolidated large angular cobble within sand/clay matrix. Where slowly eroding banks occurred they were often accompanied by dense, mature vegetation on the bank, including established willow and fir trees.

Description of riparian vegetation conditions:

Ground cover is predominantly rushes and sedges along stream edge. Grasses are more abundant up gradient from stream edge. Moderate forb growth exists throughout the area. Understory has good recruitment of lodgepole and spruce saplings along stream bank with multiple age classes. Willow exists throughout area, but none over 15 feet tall. Few old and mature conifers are present. The overstory is mostly lodgepole pine and spruce with moderate beetle kill. Spruce is more prevalent in riparian areas.

3.3.2 Bison Creek

BISO 04-02

Description of human impacts and their severity:

Site is actively grazed and shows signs of historic grazing. A dirt road exists approximately 150’ upstream of reach top. The interstate and a paved frontage road exist within 0.5 miles of the stream. Some logging and historic mining has occurred in the upper watershed.

Description of stream channel conditions:
The stream channel in this reach is a meandering E5 type channel that is completely filled with coarse sand. Some small gravel (11.3 -16 mm size) exists in the lower part of the reach, but mostly fines occur. Lots of undercut banks exist, and pools are mostly lateral scour pools with some willow bunches. Spawning gravels do not exist in pool tails. Much of the coarse sand is likely naturally derived from weathered granite of the Boulder batholith. The reach exists within a glacial outwash area with a large amount of sediment delivered from neighboring foothills.

Description of streambank erosion conditions:
This site has mostly natural/slowly eroding banks with low NBS in lower reach. Upper reach has more hoof shear, trampling, and actively eroding banks with some slowly eroding banks on outside bends. Reach has low root density and root depth, with good access to floodplain.

Description of riparian vegetation conditions:
Ground cover is almost all sedges with few grasses. Site has been lightly grazed. Understory is predominantly cinquefoil, willows, and a few weed species with little evidence of browse. No overstory exists throughout the reach.

BISO 11-01
Description of human impacts and their severity:
Transportation has played a significant role in confining the stream throughout this reach. The interstate highway parallels the streams on river left in some places as close as 100 feet. There is evidence of a former railroad grade within the reach, and bank/floodplain material appears to be non-native fill material in places. A tall berm influences confinement on the bottom end of the reach.

Description of stream channel conditions:
Stream reach has a slightly steeper slope with riffle/pool system despite the relative confinement, although the reach is mostly riffle with only a few lateral scour pools at meanders and some small step pool formation intermixed. The slope and confinement has created a B4 type channel, although the stream would likely be a C4 type channel without the presence of the highway. Very few pools exist with suitable spawning gravels. Substrate is mostly fine particles, and stream is highly embedded. No significant woody debris noted in this reach.

Description of streambank erosion conditions:
Eroding streambanks in this reach occur on bends and are usually tall with medium to large cobbles mixed with silt and clays. Cobbles provide some limited bank protection at the toe of these banks. Vegetation is mixed, although little vegetation is suitable for bank stabilization. Non-native floodplain material and modifications from the transportation corridor may also be affecting the unconsolidated nature of the banks and increasing bank erosion rate.

Description of riparian vegetation conditions:
Ground cover consists of rushes, sedges, and snake grass along bank edges with grasses and forbs on low lying benches. Understory consists of willow, dogwood, and small cottonwoods in

the riparian area, and cinquefoil along the stream edge. Canopy consists of large conifers along the riparian buffer. All willow species were less than 15’ tall.

3.3.3 Boulder River

BLDR 12-04

Description of human impacts and their severity:

This reach is significantly confined and altered from the interstate highway on river right and the local access road on river left. These two transportation corridors have left the channel as a high gradient chute with limited sinuosity, armored banks, and high width/depth ratios. Debris and garbage from the two roads are in the banks and stream channel. Road sanding in the winter may also be affecting the system due to the road’s proximity to the stream. Historic mining activity has occurred in the immediate local watershed.

Description of stream channel conditions:

Stream channel is overwidened, entrenched, and mostly homogeneous in character throughout the 1500’ reach. The stream in this reach is a F4/B4c type channel, although the potential stream type is likely C4 if the stream were able to access its entire floodplain. Large cobble and boulders dominate the substrate. Very little pool habitat exists due to lack of LWD and meanders. Pools that do exist are typically small and formed downstream from large boulders. Suitable spawning gravels are very uncommon. Substrate is embedded and coated with a film of brown algae. Stream is entrenched with very little room for lateral movement due to the roads and bank armor.

Description of streambank erosion conditions:

This site has essentially no streambank erosion. Only two eroding banks were recorded, both in the lowest cell. The lack of eroding banks is due to heavy armoring from rip-rap and large cobbles, and due to channel straightening. One eroding bank occurs where the stream meets a section of old road fill, and the other is a slowly eroding clayey bank bound by alder and rushes.

Description of riparian vegetation conditions:

This site has almost no preferable wetland species. Vegetation is non-existent throughout the left bank with only a few alder, birch and willow. River right has slightly better vegetation with mixed willows at the stream edge. Invasive weeds and grasses are common throughout the reach, likely as a result of the stream’s proximity to roads.

BLDR 13-04

Description of human impacts and their severity:

This site has irrigated hay ground and grazing present throughout the reach. Several banks have been armored with rip-rap to slow erosion, with varying levels of success. An automobile has been dumped in the river just upstream of the reach. Noxious weeds are present within the riparian area. The watershed has historically been mined, although impacts are not observed in the reach. Two irrigation returns near the top of the reach may be influencing erosion locally.

Description of stream channel conditions:
Stream is a meandering C4 type channel with short, poorly developed riffles and long lateral scour pools on outside meander bends. The channel is slightly overwidened in places, and evidence of braiding exists in the upper part of the reach. The lower end of the reach has pools with poorly developed tails and minimal spawning gravels; however, the upper reach has pools with well developed tails and good spawning gravels. Substrate has a high percentage of fines and is moderately embedded. Site has minimal woody debris and good point bar development.

Description of streambank erosion conditions:
Site has numerous long, near vertical, actively eroding banks, mainly occurring on outside meander bends. Several attempts have been made to slow erosion with rip-rap, but in several places the river has undercut the rip-rap, causing it to slump into the stream channel. Very little stabilizing vegetation exists along the riparian corridor, and predominantly fine bank material is exacerbating erosion throughout the reach. NBS is generally moderate to high on bends, but straight sections with low NBS also show evidence of streambank erosion.

Description of riparian vegetation conditions:
Ground cover has rushes where banks are not eroding and few sedges. Grasses are prevalent on higher banks. Understory is fairly sparse with some areas populated by mature willow and birch. The canopy has large cottonwoods throughout the riparian corridor.

BLDR 13-10
Description of human impacts and their severity:
This site is heavily impacted by grazing. The riparian corridor contains almost all grass with very few willow and cottonwoods. The downstream end of the reach is just upstream of a road crossing, although road effects do not appear to impact the reach. Irrigation is prevalent throughout the Boulder River watershed, and flow fluctuations and changes in stream energy may be impacting streambank stability throughout the watershed.

Description of stream channel conditions:
This reach is a meandering C4 type channel that is split in cells 2 and 5 due to large woody debris. Riffles are typically short and poorly developed, although better riffle habitat exists in split channels. Most pools are long lateral scour pools on outside meander bends. Pool tails generally have good spawning habitat; however, most pool tails are used as animal crossings and there is evidence of excess fines due to trampling. Large woody debris is found throughout the reach, and is affecting channel form in cells 2 and 5. Reach has good point bar development with lots of evidence of braiding.

Description of streambank erosion conditions:
Near vertical eroding banks exist throughout almost the entire 1500 foot reach, especially on long outside meander bends. Two primary bank types exist, including one with predominantly silty/clayey substrate, and one with cobble substrate near the toe. NBS is consistent throughout the reach except where it is affected by LWD or transverse bars. Riparian fencing exists in the upper cells, but erosion is threatening to remove the fence within several years, and the riparian area within the fence appears to be more heavily grazed than the area outside. No naturally

occurring erosion exists within this reach. All streambank erosion is attributed to riparian grazing or possibly flow impacts related to irrigation.

Description of riparian vegetation conditions:
Ground cover is predominantly grasses on the high banks, although many banks are sloughing into the stream channel. Sedges and rushes are rare. Understory is moderately populated by willow, although little recruitment exists due to grazing. Canopy is dominated by cottonwood with a few tall willows. Lower portion of the reach has a dense understory which became thinner in the upper cells.

BLDR 13-23

Description of human impacts and their severity:
This reach is in the valley bottom of the Boulder River and is largely affected by agricultural practices in the area. Irrigated hay production exists directly adjacent to the stream, and irrigation practices upstream of this reach may affect bank stability in this area. Cattle paths exist in some parts of the reach with isolated bank trampling.

Description of stream channel conditions:
The stream is a C4 type channel dominated by pool and run conditions. Outside bends are characterized by compound pools that have limited spawning gravel in pool tails. Substrate is predominantly fine except for gravels in riffles and a few pool tails. A few transverse bars exist on inside bends. One rip-rap structure exists in cell 3 to protect an outside bend.

Description of streambank erosion conditions:
Site has several near vertical actively eroding banks on outside meander bends that have almost all fine substrate and little supporting vegetation. Most banks are actively eroding, although one slowly eroding bank occurs where willow vegetation stabilizes the banks. One extremely tall (14.5’) eroding bank contributes a large amount of sediment to the stream.

Description of riparian vegetation conditions:
This reach generally has good ground cover with grasses on upper banks and sedges/rushes on sloping banks near the stream edge. Understory has willow, birch and alder, predominantly in the upper part of the reach. Understory vegetation has been cleared in lower portions of the reach to accommodate agricultural practices. Canopy is generally lacking, although some cottonwood and aspen occur within the reach.

BLDR 13-33

Description of human impacts and their severity:
This reach occurs in the valley bottom of the Boulder River, and may be affected by irrigation practices upstream. The road on river left encroaches the stream in several places. Riparian grazing was not evident within this reach, but may have historically occurred. The road is the primary human influence within this reach.

Description of stream channel conditions:
This reach is dominated by pool/run conditions with deep compound pools on outside meander bends. Pool tails have embedded cobbles and gravels with very little suitable spawning habitat. Riffles were uncommon and typically very short.

Description of streambank erosion conditions:
Four bank types were noted in this reach, dominated by long actively eroding streambanks on outside meander bends with limited surface protection. Some slowly eroding banks exist on straight channel sections with significant vegetation and high root density. One tall (11’) eroding bank occurs where the road closely parallels the stream.

Description of riparian vegetation conditions:
Ground cover is sedges and rushes on sloping banks near the stream edge, and grasses and forbs on upper banks where understory vegetation does not cause significant shading. Understory is dominated by dense willows along stream edge. The canopy is almost non-existent throughout the reach, but some spruce occurs in the upper part of the reach. The reach is mostly dominated by dense willow vegetation.

3.3.4 Cataract Creek

CATA 18-01
Description of human impacts and their severity:
Some riparian logging has occurred on river right of this reach, and historic placer mining has occurred as evidenced by large rock piles within the floodplain. The immediate watershed has a significant amount of historic mining activity, although recent human disturbance appears to be relatively minor. Trenches, pits, rock walls and abandoned roads occur throughout the reach.

Description of stream channel conditions:
The stream is a B4 type channel through this reach, characterized by a step-pool system with large gravel, cobble, and boulder substrate. Because of the high gradient, this reach is basically one long riffle/run with intermixed pocket pools formed by boulders and LWD. Pools provide good habitat for fish due to their depth, but little spawning gravels exist. Fine substrate exists in the few slow water areas with some embeddedness.

Description of streambank erosion conditions:
This site has very little streambank erosion, with only one evaluated eroding streambank. Banks were heavily armored and composed of hard packed clay, binding root mass and overgrown mosses throughout. The banks are typical of what would be expected in a high gradient, coarse bed stream.

Description of riparian vegetation conditions:
Ground cover was dominated by moss and grasses with a few sedges and forbs. Willow and birch were prevalent in the understory, especially on river right. The canopy was dominated by late successional forest of lodgepole and spruce, with good recruitment of young spruce trees.

3.3.5 Elkhorn Creek

ELKH 23-01

Description of human impacts and their severity:

Human impacts are evident throughout this reach, including a forest road parallel to and downstream of the reach, and a rough access road that parallels the stream as close as 5'. Fire pits and camp sites are scattered throughout the reach, and signs of cattle or animal trampling occur on both sides of the stream. Tree stumps in the riparian and upland areas suggest logging or mining activity has previously occurred in the area. The stream appears to have been altered or confined to its present channel, possibly to accommodate the construction of the forest road.

Description of stream channel conditions:

The stream channel is a typical B4 type channel with long riffles and small step-pool features associated with LWD and boulders. The channel appears slightly overwidened in several places. Pools are generally not well developed with only a few good pools created by LWD jams or boulders. Substrate is a mix of large gravel and cobble with some large boulders. Some spawning gravels do exist, but fines are also collecting in some pool tails.

Description of streambank erosion conditions:

Streambank erosion is relatively minor and characterized by small, slowly eroding, undercut banks that occur at knick points from boulders, LWD, or tight meander bends. The erosion is likely influenced by the reduction of riparian vegetation and animal crossings within the stream. Hoof shear was observed, and some banks appeared to be trampled more than others.

Description of riparian vegetation conditions:

The ground cover contained sedges, rushes, grasses and forbs throughout the reach, with evidence of hummocking. The understory includes a diverse mix of birch, alder, willow and aspen. The canopy is dominated by mature spruce with cottonwoods and aspen in the upper portion of the reach.

ELKH 28-01

Description of human impacts and their severity:

Evidence of cattle grazing occurs throughout this reach, with multiple cattle paths crossing the stream. A clearing occurred on river left in the lower portion of the reach, possibly to accommodate cattle. A large crib structure was also observed in the upper reach which may have served as a cattle pen. A road parallels the stream on river left, and another road crosses the stream at the bottom end of the reach.

Description of stream channel conditions:

Stream is a B4 type channel with lateral scour pools and poorly developed riffles. The channel is overwidened in places due to trampling, and may also be downcutting as evidenced by decadent alder and willow on high banks. Most surveyed cross sections occurred at cattle crossings that resembled riffles. Substrate consists of large gravel and cobble with a few large boulders. Very few pools had suitable spawning gravels.

Description of streambank erosion conditions:
Eroding streambanks typically occur where cattle paths create low angle crossings with poor stabilizing vegetation. Several tall eroding banks also occur where riparian vegetation has died and is falling into the channel. Dead woody vegetation provides some surface protection, but the banks often have poor root depth and density and are composed of fine substrate.

Description of riparian vegetation conditions:
Ground cover is a mix of sedges and grasses with some forbs. Most of the ground cover was classified as wetland species. Understory is dominated by alder and willow with some birch and aspen. Understory is dense and provides significant shading. Canopy is composed of alder and birch with some aspen, juniper, and spruce in the lower cells.

3.3.6 High Ore Creek

HIOR 09-01
Description of human impacts and their severity:
Human impacts exist throughout this reach; including a road parallel to the stream, hoof shear from cattle grazing, fire rings, an outhouse, an old road crossing, and various debris. The area around the reach appears to have been cleared at some point, possibly for logging or mining, and there is evidence of historic placer mining. Stream clarity was very murky at the time of sampling. Forest fires, mining, and reclamation activities in the upper watershed may also be affecting streambank stability at this reach.

Description of stream channel conditions:
Stream is a narrow C4b type channel dominated by long, fast riffles and few pools. Occasional channel braids were observed. Substrate is a mix of small to mid-size gravel and cobble with a few boulders. Fines were common in areas of slower water.

Description of streambank erosion conditions:
Only one eroding streambank was identified in this reach, which was a tall, poorly vegetated bank where LWD directs stream flow into the bank. Banks were quite stable despite limited riparian vegetation, possibly because the floodplain has been significantly flattened and few true banks exist. Hoof shear and human traffic is evident along the stream, although it doesn't appear to significantly affect stream erosion.

Description of riparian vegetation conditions:
Ground cover is lush with rushes, sedges and moss along the stream edge and grasses and forbs on upper banks. Understory was sparse in the lower reach, but becomes denser upstream with aspen, alder and willow. The canopy is dominated by mature spruce forest with good aspen recruitment and mature aspens in the upper reach.

HIOR 15-01

Description of human impacts and their severity:
A road parallels the stream for the duration of this reach, typically within 30'. Historic mining or logging may have occurred within the reach, and was prevalent in the upper watershed. Very little streamside vegetation exists. The stream channel was previously restored, and there is still evidence of coir fabric and wooden stakes along the stream. The reach is fenced on both sides and there is no evidence of current grazing.

Description of stream channel conditions:
This reach contains a narrow reconstructed stream that resembles an E4b type channel with numerous boulders and plunge pools and very little LWD. Most pools were short and were followed by long riffles. Substrate is predominately large gravels that are embedded with fines. Very few spawning gravels exist in pool tails.

Description of streambank erosion conditions:
Infrequent short stretches of slowly eroding bank were observed, but overall, banks were well vegetated and stable. Eroding banks were typically found at bends or where LWD or boulders confine flow to one side of the channel.

Description of riparian vegetation conditions:
Ground cover has abundant grass throughout the reach, with sedges and rushes in the lower portions, and some knapweed, mustard and sagebrush. Understory was moderately populated with willow, aspen and birch. The canopy was predominantly spruce with some juniper and aspen.

3.3.7 Little Boulder River

LBLR 32-01

Description of human impacts and their severity:
This reach is paralleled by a forest road on river left within 10-100'. Signs of light cattle grazing exist in the upper reach. Historic logging and mining likely occurred in the upper watershed, although there is no direct evidence near the stream. A high percentage of fines occur in the stream channel, which may be from the adjacent road or naturally derived from the weathered granitic geology.

Description of stream channel conditions:
Stream is a cascading B4 type channel with many large boulders, cobbles, and infrequent LWD that has a large influence on channel form where it does occur. Pools are poorly developed with minimal spawning gravels. Two terraces were noted at approximately 4' and 10' in height, suggesting the stream has been downcutting. A high percentage of fine substrate occurred in pools and slower water; however, it may be sourced from local geology. Undercut banks provide good cover in some places. The stream splits in the upper cell. This reach appears in relatively good condition for this type of B channel.

Description of streambank erosion conditions:
This reach has several slowly eroding banks that generally occur at meander bends or where LWD and boulders have deflected flow into the bank. Banks are well vegetated with a dense root structure that helps stability. Undercut banks are not uncommon, especially in areas where the stream is altered by large boulders or stabilized by mature coniferous trees. NBS is increased by mid-channel boulders and LWD that deflects flow.

Description of riparian vegetation conditions:
Ground cover is predominantly rushes and mosses with some grasses and forbs on higher banks. Understory includes a diverse group of deciduous species, including willow, gooseberry, birch, aspen and snowberry. Overstory includes mature spruce with juniper, cottonwood and birch.

LBLR 37-01
Description of human impacts and their severity:
Most human impacts in this reach are associated with the forest road that parallels the stream and recreational activities in the area. A stream ford occurs at station 600 that was accessed by ATVs during the stream survey. Man-made debris was also found in many places, including road signs and tires. Historic logging or mining activity in the upper watershed may also affect this reach.

Description of stream channel conditions:
The stream channel is entrenched by the road on river left and an elevated sandy terrace on river right, creating an F4 type stream channel (although the potential stream type is likely C4). Substrate is predominantly small gravel with a high percentage of fines. Stream has wide meanders with deep pools on outside bends and interspersed riffles. Reach has deep transverse bars that directly flow into deep scouring troughs in some of the straight portions of the reach. Spawning gravels do exist, although they are often marginal and somewhat embedded. Pool habitat is good, and LWD was infrequent.

Description of streambank erosion conditions:
Reach has numerous eroding banks, typically occurring on outside meander bends. A tall sandy terrace occurs on river right that is actively eroding in several places. Most eroding banks are provided some surface protection from living and dead willows.

Description of riparian vegetation conditions:
Ground cover is predominantly sedges and rushes with grasses prevalent in the upper part of the reach. Spotted knapweed was present throughout. Understory is dominated by birch and willow, with dead willows common along the bank. The canopy was non-existent, with no individual tree taller than 15’.

3.3.8 Lowland Creek

LOWL 08-01
Description of human impacts and their severity:
Human impacts in this reach appear to be minimal; however, the impoundment upstream (Maney Lake) may have some effect on the flow regime of this reach. Some cattle grazing is evident, but

effects appear to be minimal. Willow growth appears to be unaffected by grazing. A road parallels the stream on river left, but does not appear to be confining the stream. Upper hillslopes show evidence of historic logging, but are presently well vegetated.

Description of stream channel conditions:
Stream is a small C4 type channel, although its potential stream type is likely E4. Stream has tight meander bends with deep pool formation that is generally associated with mid-channel boulders. Substrate is mostly medium sized gravels with sporadic boulders and little embeddedness. Some transverse bar formation occurs in the lower cells of this reach.

Description of streambank erosion conditions:
Banks are predominantly stable throughout this reach, with dense vegetation and some willow growth. Most bank erosion appears naturally derived, with undercut banks on outside meander bends that occasionally slump into the stream. The most severe erosion occurs where transverse bars or mid-channel boulders deflect flow into the streambank.

Description of riparian vegetation conditions:
Ground cover is dense with abundant grasses, rushes and sedges. A large number of forbs also exist. Understory is predominantly willow ranging from 1’ to 15’ tall. Canopy included a few coniferous trees at riparian edge, but no willows were taller than 15’.

3.3.9 McCarty Creek

MCCA 22-01
Description of human impacts and their severity:
Signs of grazing exist throughout this reach, particularly in the lower sections. Historic beaver activity is also noted. A road is not far from the riparian channel on river right, and power lines cross the stream just below the reach. Upper watershed may have historically been logged, although no direct evidence exists within the reach. A small reservoir exists upstream which may have some impact on the entrenchment and downcutting of this reach.

Description of stream channel conditions:
Stream is a narrow, shallow, entrenched, B5/G5 type channel, although it should potentially be a B4 type channel. The stream has decent riffle and pool habitat for its size. Stream has good cover from woody vegetation, and it periodically runs subsurface where mature root masses hold the bank together. The site has abundant woody debris, but much of it is dead vegetation that has been abandoned by the downcutting stream channel. The immediate riparian corridor is thick with brush, and many undercut banks exist throughout the reach.

Description of streambank erosion conditions:
This reach has many slowly and actively eroding banks which are near vertical or undercut. Eroding banks generally occur where woody vegetation has died, or on tight meander bends. Erosion appears partially due to the severe downcutting observed in this reach.

Description of riparian vegetation conditions:
Ground cover is mostly grasses and forbs where the understory has not shaded out the ground cover. Bull thistle was observed within the reach. The understory was very thick, with living and dead willow, birch, aspen and juniper. Understory appears to be dying from age or abandonment by the downcutting stream channel. The canopy is dominated by aspen, with a few birch and juniper over 15' tall. The riparian corridor is primarily spruce.

3.3.10 Muskrat Creek

MUSK 18-01-02
Description of human impacts and their severity:
This site is located on USFS land with a forest road within 100 yards of the reach. A campsite exists at the top end of the reach within a clearing. Hoof shear was observed in several places along this reach, and old stumps on adjacent hill slopes indicate past logging. Cleared or grazed vegetation has left the banks unstable at a few locations in the upper portion of the reach, although these are rare.

Description of stream channel conditions:
Reach is a B4 type channel with large boulders throughout long riffles. Short pools exist with poorly developed tails and minimal spawning gravels that are typically embedded with fines. Some fish habitat is provided by small pocket pools near boulders. LWD exists throughout the reach and appears to influence channel form. The channel splits in the lower portion of the cell due to a LWD jam.

Description of streambank erosion conditions:
This reach has a mix of slowly and actively eroding banks. Slowly eroding banks are generally well vegetated undercut banks with natural sources of erosion. Actively eroding banks are generally found on outside meander bends and are influenced by LWD. One large mass wasting site occurs within this reach that is presently separated from the main channel. However, during high flow the stream will likely reach this bank and continue erosion unless flow is directed elsewhere.

Description of riparian vegetation conditions:
Ground cover is mostly grasses and forbs with a few sedges and rushes, although many areas are shaded out by dense understory. The understory is thickest in the upper cells, and dominated by alder, willow and birch. The canopy in the upper reach is moderately sparse with cottonwood and spruce, and is thicker in the lower reach with spruce and Ponderosa pine.

MUSK 22-08
Description of human impacts and their severity:
The stream in this reach has been moved from its natural channel to accommodate the adjacent hay pasture. Evidence of the excavated channel exists along river left. Some debris was observed within the stream, including lumber and bricks. A road runs perpendicular to the channel downstream of the reach, which may be restricting movement of groundwater and creating seeps

with the stream channel. Several seeps or irrigation returns were observed in the lower end of the reach.

Description of stream channel conditions:
This reach is a straight, man-made channel that presently resembles a C4 type channel, although its potential stream type is likely a meandering E4 type channel. Reach has poorly developed features, including very few riffles, long runs with some micro-pool habitat, significant fine substrate, low sinuosity, and very little spawning habitat. Shallow groundwater seepage was noted throughout the reach.

Description of streambank erosion conditions:
This site has numerous slowly eroding banks that are characterized by thick vegetation, fine substrate, and low NBS due to the straight channel. Some eroding banks occur where groundwater seepage is softening the streambank.

Description of riparian vegetation conditions:
Ground cover in this reach is very thick with intermixed grasses and sedges along the stream edge. No rushes were observed. Grass is over 3’ tall in some places, but traditional understory is generally absent. No canopy exists within the reach, although tall willows were observed downstream of the reach and left of the river channel where the stream’s historic channel likely resides.

3.3.11 North Fork Little Boulder River

NFLB 42-01
Description of human impacts and their severity:
A forest road parallels the stream closely on river left, and a short access road also parallels the stream on river right. Metal piping was found in the lower portions of the reach, and a non-functioning diversion structure or dam was found in the upper portion of the reach. Other signs of human activity were observed within this reach, including fire rings, concrete, lumber and fence posts. The reach is naturally confined by the steep valley type, but confinement is further exacerbated by the two neighboring roads.

Description of stream channel conditions:
The stream is a steep (4-10% slope), cascading, B4a type stream channel with numerous large boulders. The potential stream type is likely an A4, but entrenchment is presently more similar to a B type channel. Not many true riffles occur, and pools were often deep with poorly developed tails and minimal spawning gravel. Multiple split channels exist due to boulders and LWD. Fine material occurs in pools and slow water, but it is likely naturally derived from the local granitic geology.

Description of streambank erosion conditions:
This reach has eleven actively eroding streambanks that are generally associated with LWD or boulders that direct streamflow into the bank. Eroding banks are generally short and near vertical or overhanging. The boulder dominated system provides good surface protection, along with the abundant LWD and dense natural vegetation.

Description of riparian vegetation conditions:
Ground cover along this reach is mostly rock or bare ground due to the high amount of shading, although some grasses do occur. Understory is composed of a diverse variety of shrubs and deciduous trees. Overstory is predominantly spruce with some aspen and birch.

3.3.12 Nursery Creek

NURS 07-01
Description of human impacts and their severity:
A forest fire passed through this site approximately 5-10 years ago, and the reach now has many standing or fallen dead trees. Cattle trampling is also evident within this reach, along with signs of browse. Despite the human impacts, the stream channel appears relatively healthy with only moderate grazing impacts.

Description of stream channel conditions:
This reach is potentially a B4 type stream channel, although it currently resembles an E5b type channel with moderate entrenchment, low width/depth ratio, and sandy substrate. The reach has long riffles and short plunge pools created by wood. Numerous LWD exists throughout the channel, which seems to have an effect on channel form. Pool tails had marginal spawning gravels, but may be appropriate for the small fish that would occupy this size of stream.

Description of streambank erosion conditions:
This reach has seven slowly eroding streambanks that are generally associated with seeps, LWD, or cattle trampling, although eroding banks within this reach are generally quite short in length. Lush wetland vegetation stabilizes the banks throughout most of the reach.

Description of riparian vegetation conditions:
The ground cover on this side is predominantly dense sedges with few grasses or rushes. Thistle was also observed within the reach. Understory is mostly alder and scrub maple, although aspen and Ponderosa pine were observed outside the riparian corridor. The canopy is lacking through most of the reach due to previous fire, although a few tall Ponderosa pines do occur.

3.3.13 Uncle Sam Gulch

USGU 10-01
Description of human impacts and their severity:
Human impacts are abundant in this reach, including evidence of past grazing, riparian logging, an old road bed, wood structures, and campfire rings. LWD appears to be intentionally fallen into the stream channel, possible to divert the stream.

Description of stream channel conditions:
This reach currently resembles a C4b type channel, although its potential stream type is likely B4. The stream channel is dominated by a series of LWD controlled step pools, some of which may be natural, but others that appear to be intentionally located. Channel pattern is slightly

sinuous with few true riffles. Most of the stream is pool/run type features with a high percentage of fines. The stream is braided in the upper portion of the reach, and there is evidence of a historic stream channel on river right. Substrate is highly embedded throughout the reach.

Description of streambank erosion conditions:
This reach has eight slowly eroding streambanks that are bound by clay substrate and dense root mass from mature coniferous trees. Eroding banks generally occur in isolated sections at knick points from LWD.

Description of riparian vegetation conditions:
Ground cover in this reach is mostly thick duff with a few bunch grasses and sedges. Understory is composed of small willow with some birch and coniferous trees. Canopy consists of lodgepole and spruce with some beetled-killed trees present.

3.4 Sampling Parameter Summaries by Individual Reach

The following **Figures 3-13** to **3-21** display statistical boxplots of stream channel and riparian zone 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.

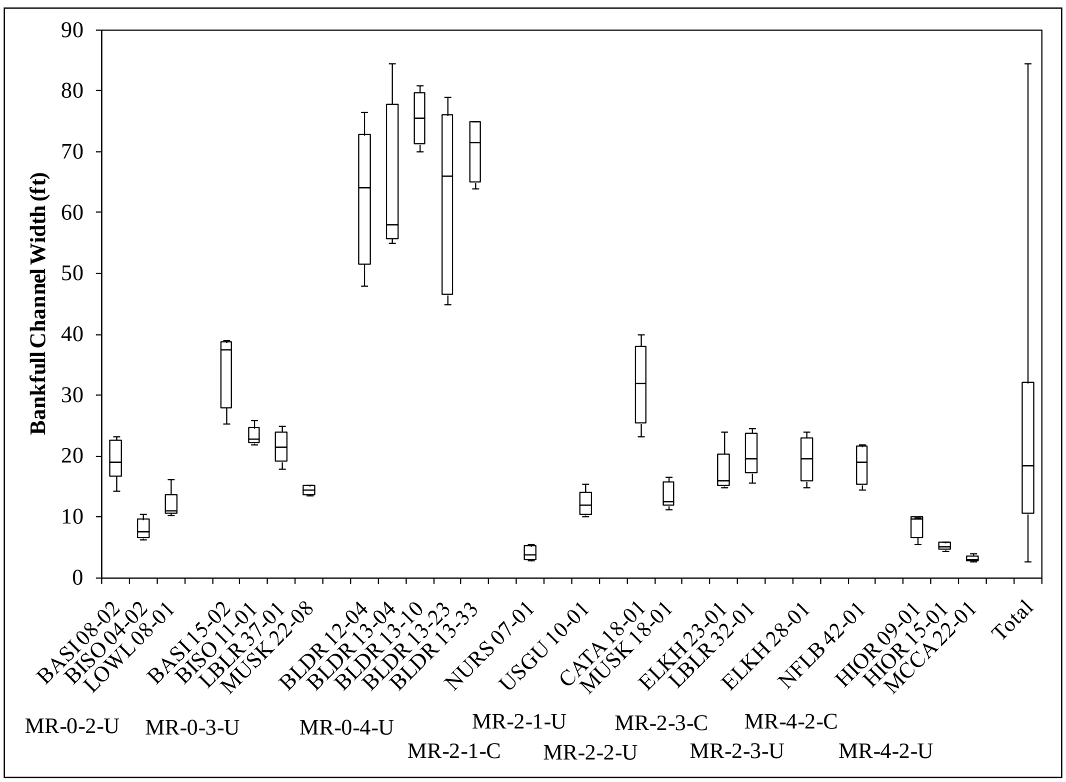

Figure 3-13. Bankfull channel width by reach.

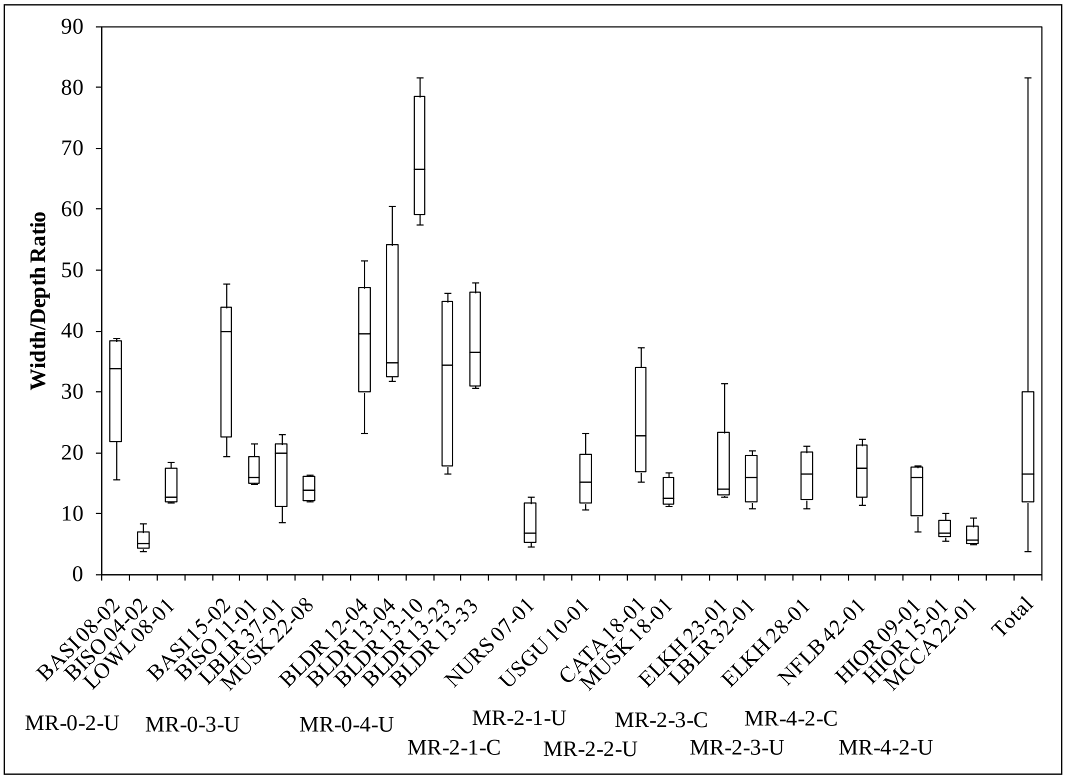

Figure 3-14. Width/depth ratio by reach.

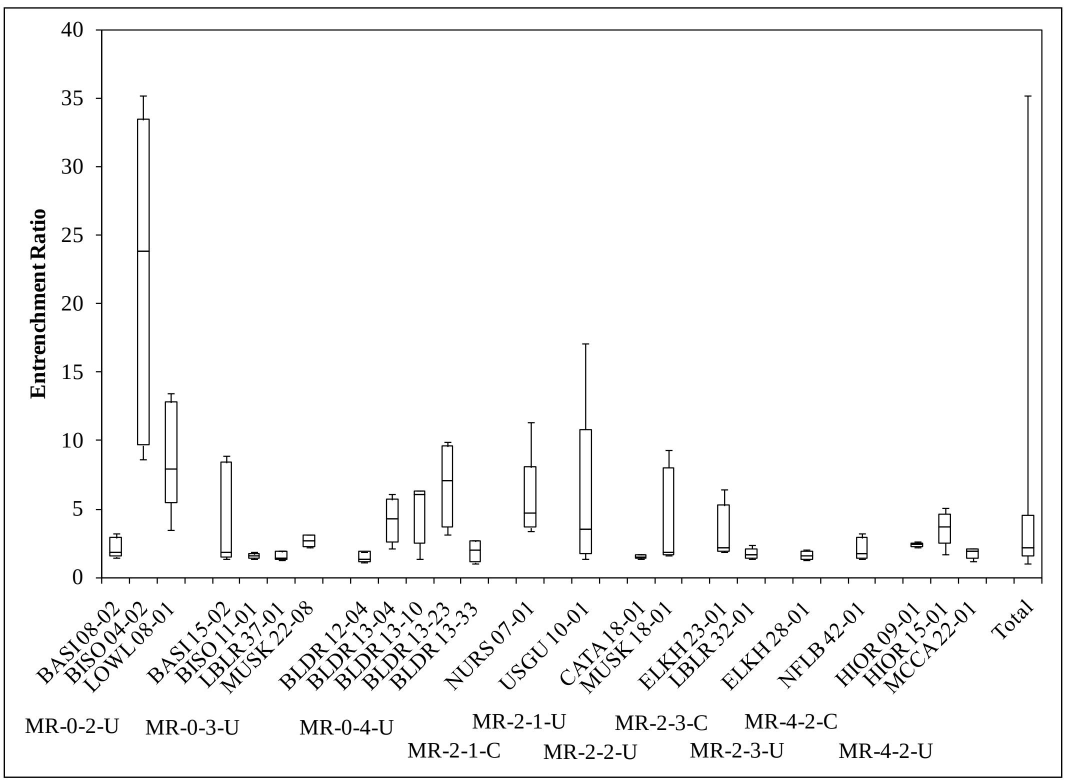

Figure 3-15. Entrenchment ratio by reach.

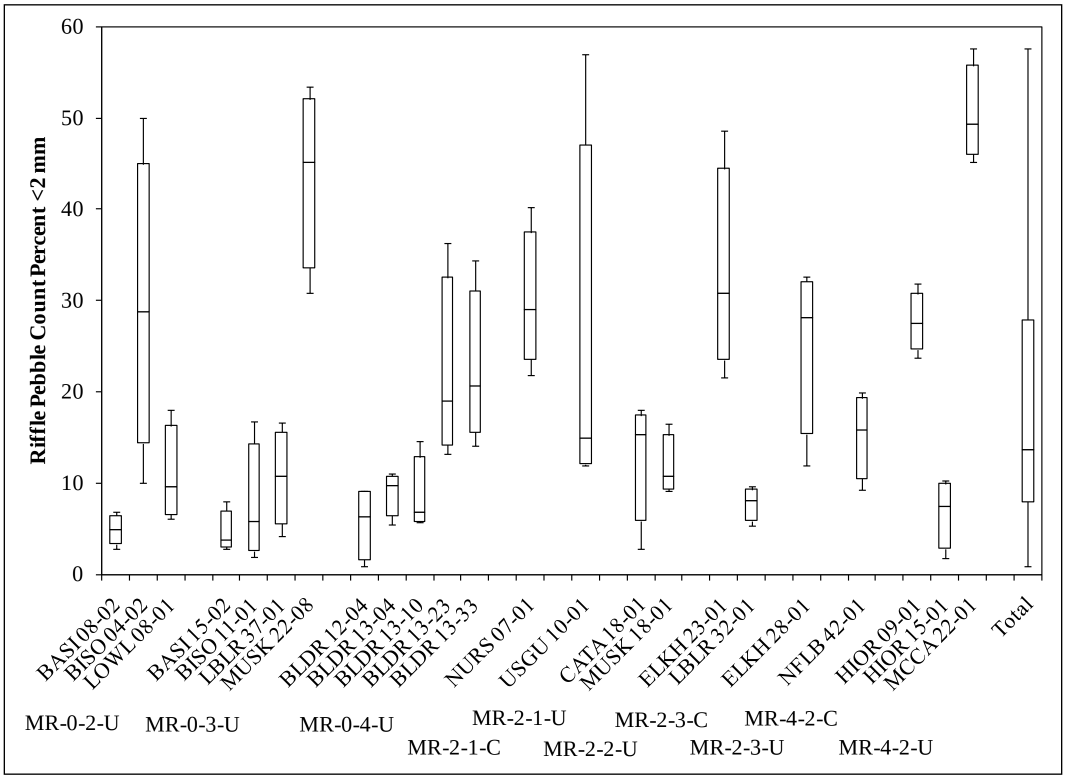

Figure 3-16. Riffle pebble count (% <2 mm) by reach.

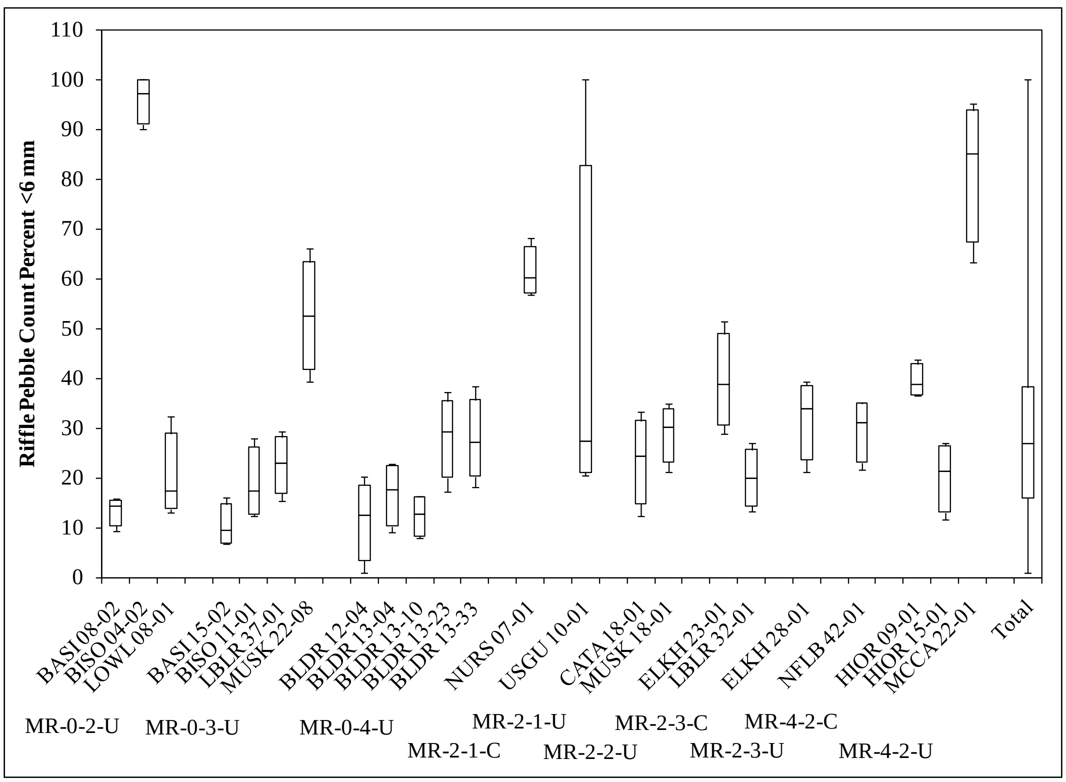

Figure 3-17. Riffle pebble count (% <6 mm) by reach.

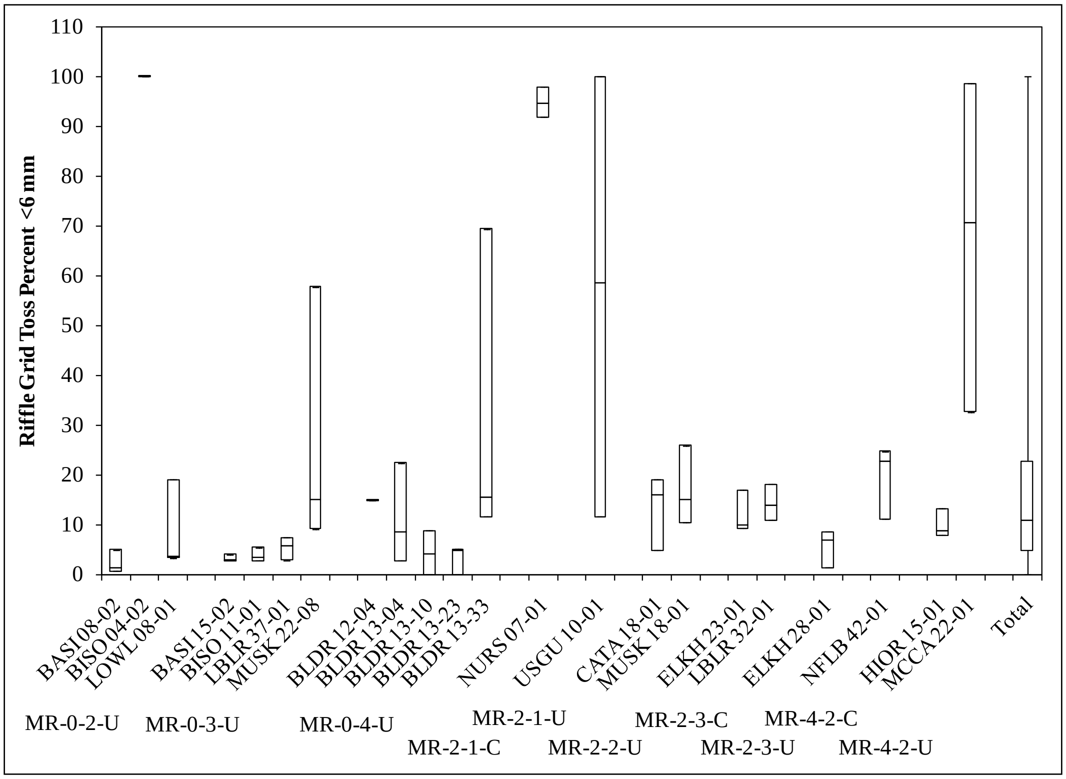

Figure 3-18. Riffle grid toss (% <6 mm) by reach.

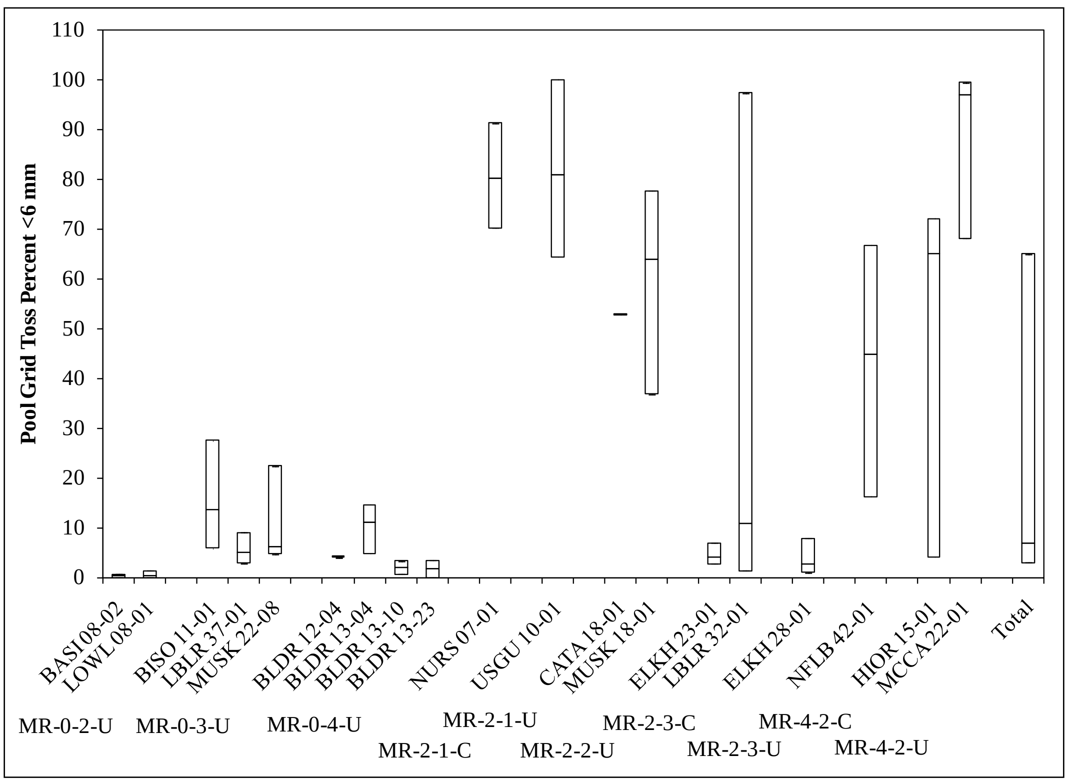

Figure 3-19. Pool grid toss (% <6 mm) by reach.

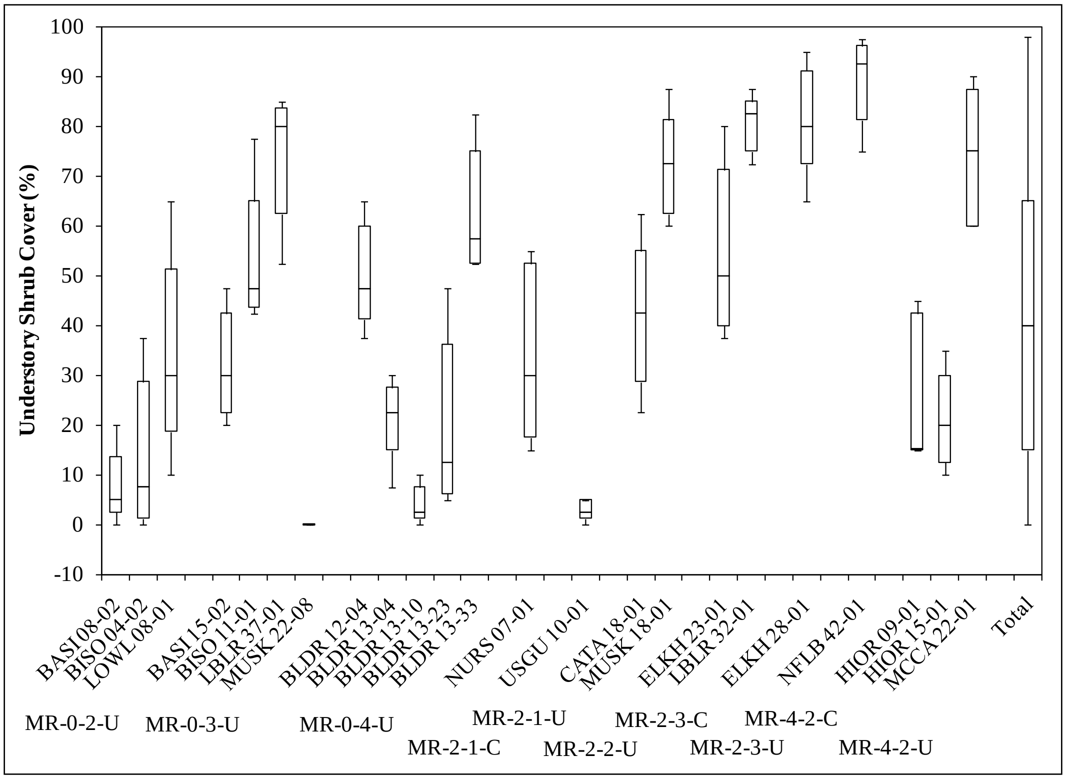

Figure 3-20. Greenline understory shrub cover (%) by reach.

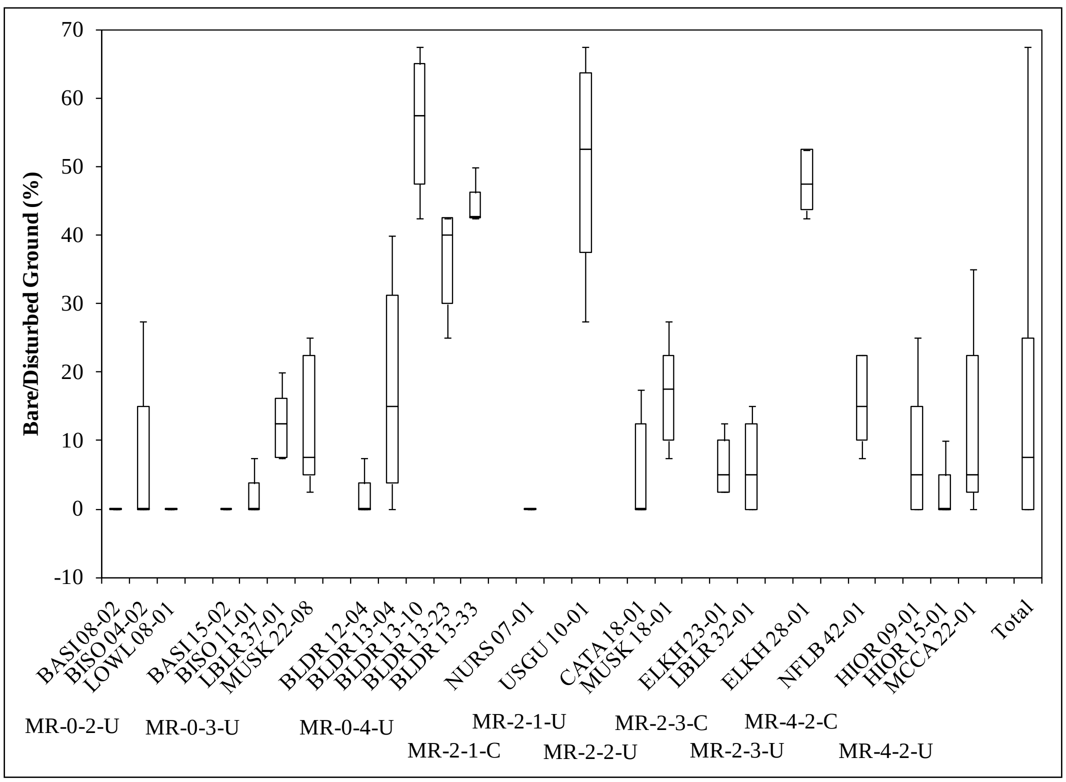

Figure 3-21. Greenline bare/disturbed ground (%) by reach.

4.0 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 Boulder-Elkhorn 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.

4.1 Field Measurements and Loading Calculations

4.1.1 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 (%): transportation, grazing, cropland, irrigation, natural, urban, railroad

4.1.2 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 five 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 4-1**).

Table 4-1. 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 4-2**). Photos of example streambanks with each BEHI rating are provided in **Attachment D**.

Table 4-2. 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

4.1.3 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 4-3)**. If appropriate measurements are not recorded for NBS determination, the NBS rating is estimated in the field or from photos using best professional judgment.

Table 4-3. 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

4.1.4 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 Yellowstone National Park by Rosgen (2006). The average retreat rates (ft/yr) based on BEHI and NBS ratings are provided below in **Table 4-4**.

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

	Near Bank Stress					
BEHI	Very Low	Low	Moderate	High	Very High	Extreme
Very Low	0.002	0.004	0.009	0.021	0.05	0.12
Low	0.02	0.04	0.10	0.24	0.57	1.37
Moderate	0.10	0.17	0.28	0.47	0.79	1.33
High-Very High	0.37	0.53	0.76	1.09	1.57	2.26
Extreme	0.98	1.21	1.49	1.83	2.25	2.76

4.1.5 Sediment Loading Calculation

Once retreat rate is determined from the BEHI and NBS ratings, the dimensions of the eroding stream bank 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.

4.2 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 identified, the mean BEHI rating for each erosion type, the percent of reach that has eroding streambanks, 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 (i.e., a 1000' reach has 2000' of bank). Identified sources of streambank erosion within the Boulder-Elkhorn TPA included transportation, riparian grazing, cropland, mining, silviculture, irrigation (or changes in stream energy), natural sources, or those classified as "other"; however, each erosion source may not be present at all sample sites.

4.2.1 Sediment Loading Results for Basin Creek

4.2.1.1 BASI 08-02

Only three eroding banks were identified in this reach, including two actively eroding banks and one slowly eroding bank. Banks are typically armored with cobbles and large gravel. The stream channel is overwidened through this reach. Typical eroding streambank conditions are depicted for this reach in **Figure 4-1** and sediment loading results are provided in **Table 4-5**.

Figure 4-1. Typical eroding streambank conditions in Basin Creek Reach 08-02.

4.2.1.2 BASI 15-02

This reach had seven eroding banks, including four actively eroding and three slowly eroding. Actively eroding banks were typically associated with meander bends that direct flow into the bank and have limited stabilizing vegetation, possibly as a result of prior logging activity. Slowly eroding banks were accompanied by dense mature vegetation on the banks, including established willow and fir trees. Typical eroding streambank conditions are depicted in **Figure 4-2** and sediment loading results are provided in **Table 4-5**.

Figure 4-2. Typical eroding streambank conditions in Basin Creek Reach 15-02.

Table 4-5. Sediment loading results for Basin Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)				
						Transpor-tation	Mining	Silvi-culture	Natural	Other
BASI 08-02	Slow	1	moderate	0.8	0.2	10.0	10.0	0.0	80.0	0.0
	Active	2	high	3.3	7.4	30.0	50.0	0.0	20.0	0.0
	Total	3	high	4.1	7.6	29.6	49.1	0.0	21.3	0.0
BASI 15-02	Slow	3	moderate	2.2	1.1	3.1	30.0	16.9	50.0	0.0
	Active	4	high	7.8	21.9	0.0	30.0	20.0	20.0	30.0
	Total	7	high	10.0	23.0	0.2	30.0	19.8	21.5	28.5

4.2.2 Sediment Loading Results for Bison Creek

4.2.2.1 BISO 04-02

This reach has four actively eroding banks and thirteen slowly eroding banks. Actively eroding banks were generally low angled with no surface protection and exposed sandy substrate. Some areas had hummocking from being trampled by cattle. Slowly eroding banks were typically overhanging but well vegetated. Typical eroding streambank conditions are depicted for this reach in **Figure 4-3** and sediment loading results are provided in **Table 4-6**.

Figure 4-3. Typical eroding streambank conditions in Bison Creek Reach 04-02.

4.2.2.2 BISO 11-01

This reach had one slowly eroding bank and seven actively eroding banks. Actively eroding banks are typically tall and located on meander bends with little stabilizing vegetation and large cobble substrate armoring the toe. Slowly eroding banks are overhanging but bound by roots of mature vegetation. Typical eroding streambank conditions are depicted for this reach in **Figure 4-4** and sediment loading results are provided in **Table 4-6**.

Figure 4-4. Typical eroding streambank conditions in Bison Creek Reach 11-01.

Table 4-6. Sediment loading results for Bison Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)		
						Transpor-tation	Riparian Grazing	Natural
BISO 04-02	Slow	13	high	9.5	8.7	0.0	50.0	50.0
	Active	4	high	2.4	1.6	0.0	72.4	27.6
	Total	17	high	11.9	10.3	0.0	53.6	46.4
BISO 11-01	Slow	1	moderate	2.6	1.5	80.0	0.0	20.0
	Active	7	high	10.4	19.1	80.0	0.0	20.0
	Total	8	high	13.0	20.6	80.0	0.0	20.0

4.2.3 Sediment Loading Results for Boulder River

4.2.3.1 BLDR 12-04

This reach has only two slowly eroding banks, mainly because the channel is armored with rip-rap and large cobbles to protect the neighboring roads. One eroding bank occurs where the stream hits an area of road fill, and the other contains hard packed clay and is bound by mature alders and rushes. Typical eroding streambank conditions are depicted for this reach in **Figure 4-5** and sediment loading results are provided in **Table 4-7**. The left photo shows an example of a slowly eroding bank within this reach, and the right photo shows an example of the rip-rap stabilization within this reach.

Figure 4-5. Typical eroding streambank conditions in Boulder River Reach 12-04.

4.2.3.2 BLDR 13-04

This reach has twelve eroding banks, including ten active and two slowly eroding. The actively eroding banks are typically long, near vertical banks, generally with a clayey composition but sometimes with poorly placed rip-rap material that has slumped into the stream channel. Slowly eroding banks were low angled and had some vegetative cover. Typical eroding streambank conditions are depicted for this reach in **Figure 4-6** and sediment loading results are provided in **Table 4-7**.

Figure 4-6. Typical eroding streambank conditions in Boulder River Reach 13-04.

4.2.3.3 BLDR 13-10

Reach BLDR 13-10 has thirteen actively eroding banks that typically occur along outside meander bends. Eroding banks are near vertical and have either a silty/clayey substrate that is slumping into the stream channel, or they have a cobble layer near the toe that provides some armoring against erosion. Typical eroding streambank conditions are depicted for this reach in **Figure 4-7** and sediment loading results are provided in **Table 4-7**.

Figure 4-7. Typical eroding streambank conditions in Boulder River Reach 13-10.

4.2.3.4 BLDR 13-23

This reach has ten eroding banks, nine of which were actively eroding. Eroding banks are generally near vertical slumping banks with silty/clayey substrate, and one bank is very tall

(14.5’). One slowly eroding bank was identified, which had substantial willow growth that helps stabilize the bank. This reach had the highest loading rate of all sampled reaches. Typical eroding streambank conditions are depicted for this reach in **Figure 4-8** and sediment loading results are provided in **Table 4-7**.

Figure 4-8. Typical eroding streambank conditions in Boulder River Reach 13-23.

4.2.3.5 BLDR 13-33

This reach has twelve actively eroding banks and three slowly eroding banks. Actively eroding banks were typically slumping banks that occur on outside meander bends with little surface protection. One tall (11’) actively eroding bank occurs where the stream closely parallels the road. The slowly eroding banks occur on straight sections where vegetation is established and root density is higher. Typical eroding streambank conditions are depicted for this reach in **Figure 4-9** and sediment loading results are provided in **Table 4-7**.

Figure 4-9. Typical eroding streambank conditions in Boulder River Reach 13-33.

Table 4-7. Sediment loading results for Boulder River.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)					
						Transp-ortation	Riparian Grazing	Crop-land	Irrig-ation	Natural	Other
BLDR 12-04	Slow	2	mod.	0.6	0.3	100.0	0.0	0.0	0.0	0.0	0.0
	Active	0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	2	mod.	0.6	0.3	100.0	0.0	0.0	0.0	0.0	0.0
BLDR 13-04	Slow	2	mod.	1.0	0.6	0.0	7.4	92.6	0.0	0.0	0.0
	Active	10	high	15.8	36.5	0.0	19.9	79.0	1.2	0.0	0.0
	Total	12	mod.	16.8	37.0	0.0	19.7	79.2	1.2	0.0	0.0
BLDR 13-10	Slow	0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Active	13	mod.	41.3	27.9	0.0	80.0	0.0	20.0	0.0	0.0
	Total	13	mod.	41.3	27.9	0.0	80.0	0.0	20.0	0.0	0.0
BLDR 13-23	Slow	1	mod.	1.6	0.8	0.0	30.0	30.0	20.0	20.0	0.0
	Active	9	high	30.8	78.8	0.0	30.0	30.0	20.0	20.0	0.0
	Total	10	high	32.4	79.6	0.0	30.0	30.0	20.0	20.0	0.0
BLDR 13-33	Slow	3	mod.	6.2	6.7	0.0	0.0	0.0	30.0	50.0	20.0
	Active	12	high	32.5	65.3	9.4	0.0	0.0	28.1	46.2	16.2
	Total	15	high	38.7	72.0	8.5	0.0	0.0	28.3	46.6	16.6

4.2.4 Sediment Loading Results for Cataract Creek

4.2.4.1 CATA 18-01

Only one eroding streambank was identified in this reach, which was a slowly eroding undercut bank. Most banks in this high gradient reach are composed of hard packed clay and are armored with binding root masses and overgrown moss. Typical eroding streambank conditions are depicted in **Figure 4-10** and sediment loading results are provided in **Table 4-8**.

Figure 4-10. Typical eroding streambank conditions in Cataract Creek Reach 18-01.

Table 4-8. Sediment loading results for Cataract Creek.						
Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)
						Mining
CATA 18-01	Slow	1	moderate	0.9	0.6	100.0
	Active	0		0.0	0.0	0.0
	Total	1	moderate	0.9	0.6	100.0

4.2.5 Sediment Loading Results for Elkhorn Creek

4.2.5.1 ELKH 23-01

Seven slowly eroding banks were identified in reach ELKH 23-01. Eroding banks were typically short in length, well vegetated, and occur at knick points coming from boulders, LWD, or tight stream meanders. In several places, the erosion is influenced by reduction of vegetation and bank trampling from hoof shear. Typical eroding streambank conditions are depicted in **Figure 4-11** and sediment loading results are provided in **Table 4-9**.

Figure 4-11. Typical eroding streambank conditions in Elkhorn Creek Reach 23-01.

4.2.5.2 ELKH 28-01

This reach had thirteen actively eroding banks with three primary bank types. Eroding banks included tall, steep banks that are partially protected by dead woody vegetation, low angle banks at stream crossings that are trampled by cattle, and a few slumping vegetated banks on outside meander bends. Typical eroding streambank conditions are depicted in **Figure 4-12** and sediment loading results are provided in **Table 4-9**.

Figure 4-12. Typical eroding streambank conditions in Elkhorn Creek Reach 28-01.

Table 4-9. Sediment loading results for Elkhorn Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)				
						Transpor-tation	Riparian Grazing	Irrigation	Natural	Other
ELKH 23-01	Slow	7	moderate	2.6	1.6	48.7	51.1	0.0	0.0	0.3
	Active	0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	7	moderate	2.6	1.6	48.7	51.1	0.0	0.0	0.3
ELKH 28-01	Slow	0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Active	13	moderate	8.7	8.6	0.0	70.9	5.9	9.7	13.4
	Total	13	moderate	8.7	8.6	0.0	70.9	5.9	9.7	13.4

4.2.6 Sediment Loading Results for High Ore Creek

4.2.6.1 HIOR 09-01

Only one eroding streambank was identified in this reach, which is a tall, poorly vegetated bank where LWD directs stream flow into the bank. Banks are quite stable despite limited riparian vegetation, possibly because floodplain has been significantly flattened and few tall banks exist. Typical eroding streambank conditions are shown in **Figure 4-13** and sediment loading results are provided in **Table 4-10**.

Figure 4-13. Typical eroding streambank conditions in High Ore Creek Reach 09-01.

4.2.6.2 HIOR 15-01

This reach has six slowly eroding banks and one actively eroding bank. Slowly eroding banks are short, overhanging banks with good riparian vegetation. The actively eroding bank is taller with exposed soil, but bound by roots. Typical eroding streambank conditions are shown in **Figure 4-14** and sediment loading results are provided in **Table 4-10**.

Figure 4-14. Typical eroding streambank conditions in High Ore Creek Reach 15-01.

Table 4-10. Sediment loading results for High Ore Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)			
						Transpor-tation	Riparian Grazing	Natural	Other
HIOR 09-01	Slow	0		0.0	0.0	0.0	0.0	0.0	0.0
	Active	1	high	0.6	1.3	20.0	60.0	0.0	20.0
	Total	1	high	0.6	1.3	20.0	60.0	0.0	20.0
HIOR 15-01	Slow	6	moderate	3.8	1.2	50.0	0.0	20.0	30.0
	Active	1	moderate	1.0	0.2	50.0	0.0	20.0	30.0
	Total	7	moderate	4.8	1.4	50.0	0.0	20.0	30.0

4.2.7 Sediment Loading Results for Little Boulder River

4.2.7.1 LBLR 32-01

This site has eleven slowly eroding banks that are typically near vertical with woody vegetation and a dense root mass that helps stabilize the banks. Undercut banks are not uncommon, especially in areas where stream is altered by large boulders or stabilized by mature coniferous trees. Typical eroding streambank conditions are depicted in **Figure 4-15** and sediment loading results are provided in **Table 4-11**.

Figure 4-15. Typical eroding streambank conditions in Little Boulder River Reach 32-01.

4.2.7.2 LBLR 37-01

This reach has ten eroding streambanks, including two actively eroding and eight slowly eroding. Slowly eroding banks are typically found on outside bends, but have significant surface protection from dead and living willows. One actively eroding bank occurs where the stream abuts a tall sandy terrace. Typical eroding streambank conditions are depicted in **Figure 4-16** and sediment loading results are provided in **Table 4-11**.

Figure 4-16. Typical eroding streambank conditions in Little Boulder River Reach 37-01.

Table 4-11. Sediment loading results for Little Boulder River.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)				
						Transpor-tation	Riparian Grazing	Mining	Silvi-culture	Natural
LBLR 32-01	Slow	11	low	7.5	1.6	18.6	0.0	18.7	16.3	46.3
	Active	0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	11	low	7.5	1.6	18.6	0.0	18.7	16.3	46.3
LBLR 37-01	Slow	8	moderate	7.9	16.1	80.0	9.1	0.0	0.0	10.9
	Active	2	high	2.2	9.4	79.4	1.3	0.0	0.0	19.4
	Total	10	moderate	10.0	25.5	79.7	6.2	0.0	0.0	14.0

4.2.8 Sediment Loading Results for Lowland Creek

4.2.8.1 LOWL 08-01

Fourteen slowly eroding streambanks were identified in this reach. Banks are typically well vegetated with sedges and grasses, but are often undercut and slumping into the stream channel on outside meander bends. Typical eroding streambank conditions are depicted in **Figure 4-17** and sediment loading results are provided in **Table 4-12**.

Figure 4-17. Typical eroding streambank conditions in Lowland Creek Reach 08-01.

Table 4-12. Sediment loading results for Lowland Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)	
						Natural	Other
LOWL 08-01	Slow	14	high	8.4	7.9	90.0	10.0
	Active	0		0.0	0.0	0.0	0.0
	Total	14	high	8.4	7.9	90.0	10.0

4.2.9 Sediment Loading Results for McCarty Creek

4.2.9.1 MCCA 22-01

This reach has eleven slowly eroding banks and seven actively eroding banks. Slowly eroding banks are typically near vertical or undercut with stabilizing vegetation. Actively eroding banks occur where woody vegetation has died, or on tight meander bends. Erosion appears partially due to the severe downcutting observed in this reach. Typical eroding streambank conditions are depicted in **Figure 4-18** and sediment loading results are provided in **Table 4-13**.

Figure 4-18. Typical eroding streambank conditions in McCarty Creek Reach 22-01.

Table 4-13. Sediment loading results for McCarty Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)		
						Riparian Grazing	Silvi-culture	Natural
MCCA 22-01	Slow	11	high	12.0	14.0	66.9	21.0	12.2
	Active	7	high	5.0	4.6	68.8	12.6	18.6
	Total	18	high	17.0	18.6	67.4	18.9	13.8

4.2.10 Sediment Loading Results for Muskrat Creek

4.2.10.1 MUSK 18-01-02

This reach has six slowly eroding banks and seven actively eroding banks. Slowly eroding banks are generally well vegetated undercut banks with natural sources of erosion. Actively eroding banks are generally found on outside meander bends and are influenced by LWD. One large mass wasting site occurs within this reach that is presently separated from the main channel. However, during high flow the stream will likely reach this bank and continue erosion unless flow is directed elsewhere. Typical eroding streambank conditions are depicted in **Figure 4-19** and sediment loading results are provided in **Table 4-14**. The left photo shows an example of slowly eroding conditions found within this reach and the right photos shows the mass wasting site that is presently separated from the main channel.

Figure 4-19. Typical eroding streambank conditions in Muskrat Creek Reach 18-01-02.

4.2.10.2 MUSK 22-08

This site has numerous slowly eroding banks that are generally well vegetated with low NBS due to the straight channel. Some eroding banks are associated with seeps that occur from irrigation recharge. Typical eroding streambank conditions are depicted in **Figure 4-20** and sediment loading results are provided in **Table 4-14**.

Figure 4-20. Typical eroding streambank conditions in Muskrat Creek Reach 22-08.

Table 4-14. Sediment loading results for Muskrat Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)		
						Riparian Grazing	Irrigation	Natural
MUSK 18-01-02	Slow	6	low	3.1	0.6	67.8	0.0	32.2
	Active	7	moderate	2.8	1.8	63.5	0.0	36.5
	Total	13	moderate	5.9	2.3	64.6	0.0	35.4
MUSK 22-08	Slow	30	moderate	17.7	6.1	0.0	100.0	0.0
	Active	0		0.0	0.0	0.0	0.0	0.0
	Total	30	moderate	17.7	6.1	0.0	100.0	0.0

4.2.11 Sediment Loading Results for North Fork Little Boulder River

4.2.11.1 NFLB 42-01

This reach has eleven actively eroding streambanks that are generally associated with LWD or boulders that direct streamflow into the bank. Eroding banks are generally short and near vertical or overhanging. Typical eroding streambank conditions are depicted in **Figure 4-21** and sediment loading results are provided in **Table 4-15**.

Figure 4-21. Typical eroding streambank conditions in North Fork Little Boulder 42-01.

Table 4-15. Sediment loading results for North Fork Little Boulder River.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)	
						Transpor-tation	Natural
NFLB 42-01	Slow	0		0.0	0.0	0.0	0.0
	Active	11	moderate	4.5	2.8	26.8	73.2
	Total	11	moderate	4.5	2.8	26.8	73.2

4.2.12 Sediment Loading Results for Nursery Creek

4.2.12.1 NURS 07-01

This reach has seven slowly eroding streambanks that are generally associated with seeps, LWD, or cattle trampling. Lush wetland vegetation stabilizes the banks throughout most of the reach. Typical eroding streambank conditions are depicted in **Figure 4-22** and sediment loading results are provided in **Table 4-16**.

Figure 4-22. Typical eroding streambank conditions in Nursery Creek Reach 07-01.

Table 4-16. Sediment loading results for Nursery Creek.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)	
						Riparian Grazing	Natural
NURS 07-01	Slow	7	moderate	2.4	0.4	30.1	69.9
	Active	0		0.0	0.0	0.0	0.0
	Total	7	moderate	2.4	0.4	30.1	69.9

4.2.13 Sediment Loading Results for Uncle Sam Gulch

4.2.13.1 USGU 10-01

This reach has eight slowly eroding streambanks that are bound by clay substrate and dense root mass from mature coniferous trees. Eroding banks generally occur in isolated sections at knick points from LWD. Typical eroding streambank conditions are depicted in **Figure 4-23** and sediment loading results are provided in **Table 4-17**.

Figure 4-23. Typical eroding streambank conditions in Uncle Sam Gulch Reach 10-01.

Table 4-17. Sediment loading results for Uncle Sam Gulch.

Reach ID	Erosion Type	Number of Banks	Mean BEHI Rating	Percent Eroding Bank	Sediment Load per 1000' (tons/yr)	Loading Source (%)			
						Transpor-tation	Mining	Natural	Other
USGU 10-01	Slow	8	moderate	3.9	1.7	30.0	30.0	17.7	22.3
	Active	0		0.0	0.0	0.0	0.0	0.0	0.0
	Total	8	moderate	3.9	1.7	30.0	30.0	17.7	22.3

4.3 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.

4.3.1 Sediment Loading Results for Reach Type MR-0-2-U

Three sites were sampled of reach type MR-0-2-U. This reach type is in the Middle Rockies Ecoregion, has low valley slope (<2%), and includes 2nd order streams within unconfined valleys. Loading results are provided below in **Table 4-18**.

Table 4-18. Sediment loading results for reach type MR-0-2-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
BASI 08-02	moderate	high	high	0.8	3.3	4.1	0.2	7.4	7.6
BISO 04-02	high	high	high	9.5	2.4	11.9	8.7	1.6	10.3
LOWL 08-01	high		high	8.4	0.0	8.4	7.9	0.0	7.9
Reach Type Average	**moderate**	**high**	**high**	**6.2**	**1.9**	**8.1**	**5.6**	**3.0**	**8.6**

4.3.2 Sediment Loading Results for Reach Type MR-0-3-U

Four 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 4-19**.

Table 4-19. 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
BASI 15-02	moderate	high	high	2.2	7.8	10.0	1.1	21.9	23.0
BISO 11-01	moderate	high	high	2.6	10.4	13.0	1.5	19.1	20.6
LBLR 37-01	moderate	high	moderate	7.9	2.2	10.0	16.1	9.4	25.5
MUSK 22-08	moderate		moderate	17.7	0.0	17.7	6.1	0.0	6.1
Reach Type Average	**moderate**	**high**	**high**	**7.6**	**5.1**	**12.7**	**6.2**	**12.6**	**18.8**

4.3.3 Sediment Loading Results for Reach Type MR-0-4-U

Five reaches were sampled of reach type MR-0-4-U, all on the Boulder River. 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 4-20**.

Table 4-20. 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
BLDR 12-04	moderate		moderate	0.6	0.0	0.6	0.3	0.0	0.3
BLDR 13-04	moderate	high	moderate	1.0	15.8	16.8	0.6	36.5	37.0
BLDR 13-10		moderate	moderate	0.0	41.3	41.3	0.0	27.9	27.9
BLDR 13-23	moderate	high	high	1.6	30.8	32.4	0.8	78.8	79.6
BLDR 13-33	moderate	high	high	6.2	32.5	38.7	6.7	65.3	72.0
Reach Type Average	**moderate**	**high**	**moderate**	**1.9**	**24.1**	**26.0**	**1.7**	**41.7**	**43.4**

4.3.4 Sediment Loading Results for Reach Type MR-2-1-C

One site was sampled of reach type MR-2-1-C. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 1st order streams within confined valleys. Loading results are provided below in **Table 4-21**.

Table 4-21. Sediment loading results for reach type MR-2-1-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
NURS 07-01	moderate		moderate	2.4	0.0	2.4	0.4	0.0	0.4
Reach Type Average	**moderate**		**moderate**	**2.4**	**0.0**	**2.4**	**0.4**	**0.0**	**0.4**

4.3.5 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 4-22**.

Table 4-22. 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
USGU 10-01	moderate		moderate	3.9	0.0	3.9	1.7	0.0	1.7
Reach Type Average	**moderate**		**moderate**	**3.9**	**0.0**	**3.9**	**1.7**	**0.0**	**1.7**

4.3.6 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 4-23**.

Table 4-23. 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
CATA 18-01	moderate		moderate	0.9	0.0	0.9	0.6	0.0	0.6
MUSK 18-01-02	low	moderate	moderate	3.1	2.8	5.9	0.6	1.8	2.3
Reach Type Average	**moderate**	**moderate**	**moderate**	**2.0**	**1.4**	**3.4**	**0.6**	**0.9**	**1.5**

4.3.7 Sediment Loading Results for Reach Type MR-2-3-C

Two reaches were sampled of reach type MR-2-3-C. This reach type is in the Middle Rockies Ecoregion, has moderate valley slope (2-4%), and includes 3rd order streams within confined valley types. Loading results are provided below in **Table 4-24**.

Table 4-24. Sediment loading results for reach type MR-2-3-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
ELKH 23-01	moderate		moderate	2.6	0.0	2.6	1.6	0.0	1.6
LBLR 32-01	low		low	7.5	0.0	7.5	1.6	0.0	1.6
Reach Type Average	**moderate**		**moderate**	**5.0**	**0.0**	**5.0**	**1.6**	**0.0**	**1.6**

4.3.8 Sediment Loading Results for Reach Type MR-2-3-U

One reach was 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 4-25**.

Table 4-25. 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
ELKH 28-01		moderate	moderate	0.0	8.7	8.7	0.0	8.6	8.6
Reach Type Average		**moderate**	**moderate**	**0.0**	**8.7**	**8.7**	**0.0**	**8.6**	**8.6**

4.3.9 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 4-26**.

Table 4-26. 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
NFLB 42-01		moderate	moderate	0.0	4.5	4.5	0.0	2.8	2.8
Reach Type Average		**moderate**	**moderate**	**0.0**	**4.5**	**4.5**	**0.0**	**2.8**	**2.8**

4.3.10 Sediment Loading Results for Reach Type MR-4-2-U

Three 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 4-27**.

Table 4-27. 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
HIOR 09-01		high	high	0.0	0.6	0.6	0.0	1.3	1.3
HIOR 15-01	moderate	moderate	moderate	3.8	1.0	4.8	1.2	0.2	1.4
MCCA 22-01	high	high	high	12.0	5.0	17.0	14.0	4.6	18.6
Reach Type Average	**moderate**	**high**	**high**	**5.3**	**2.2**	**7.5**	**5.1**	**2.0**	**7.1**

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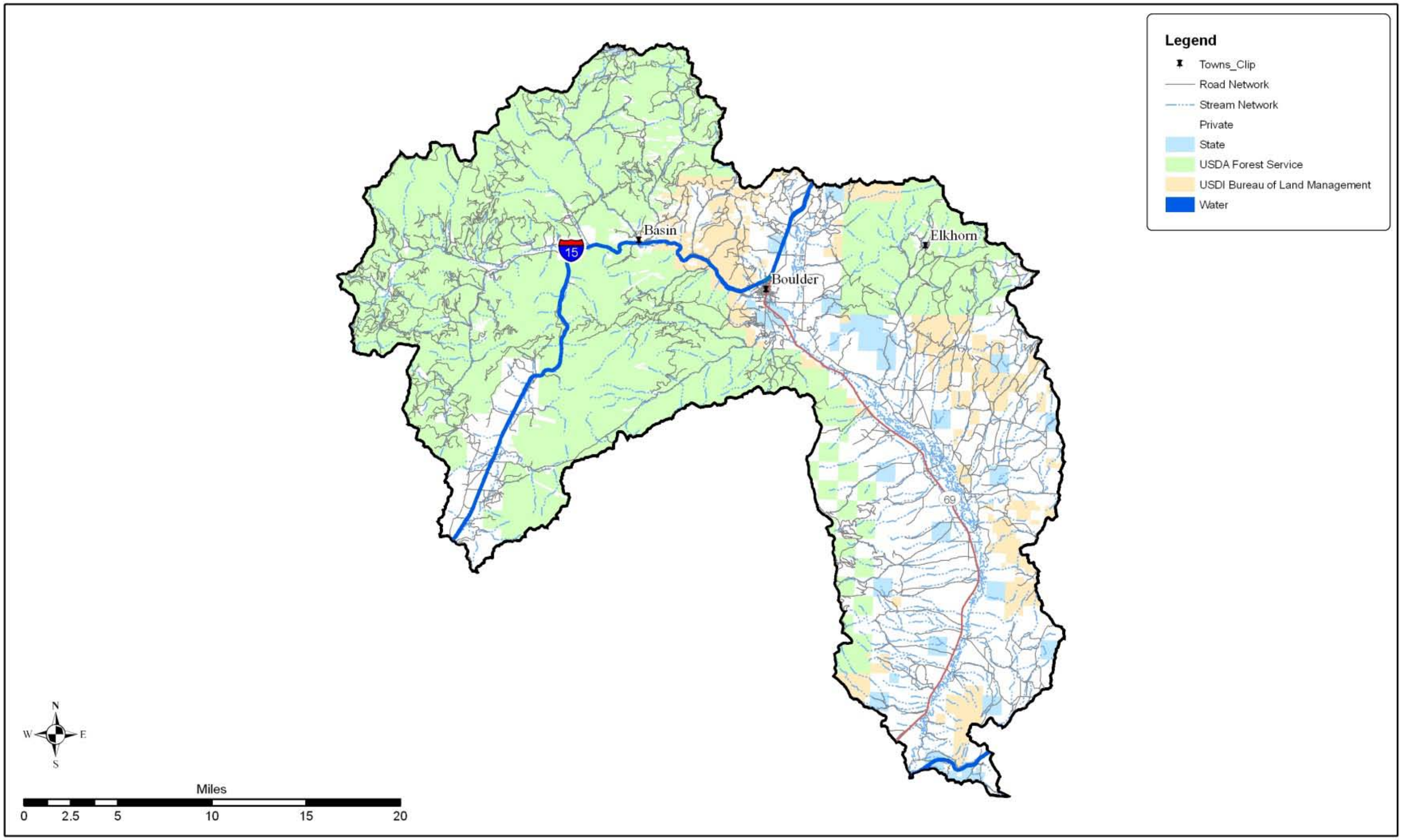
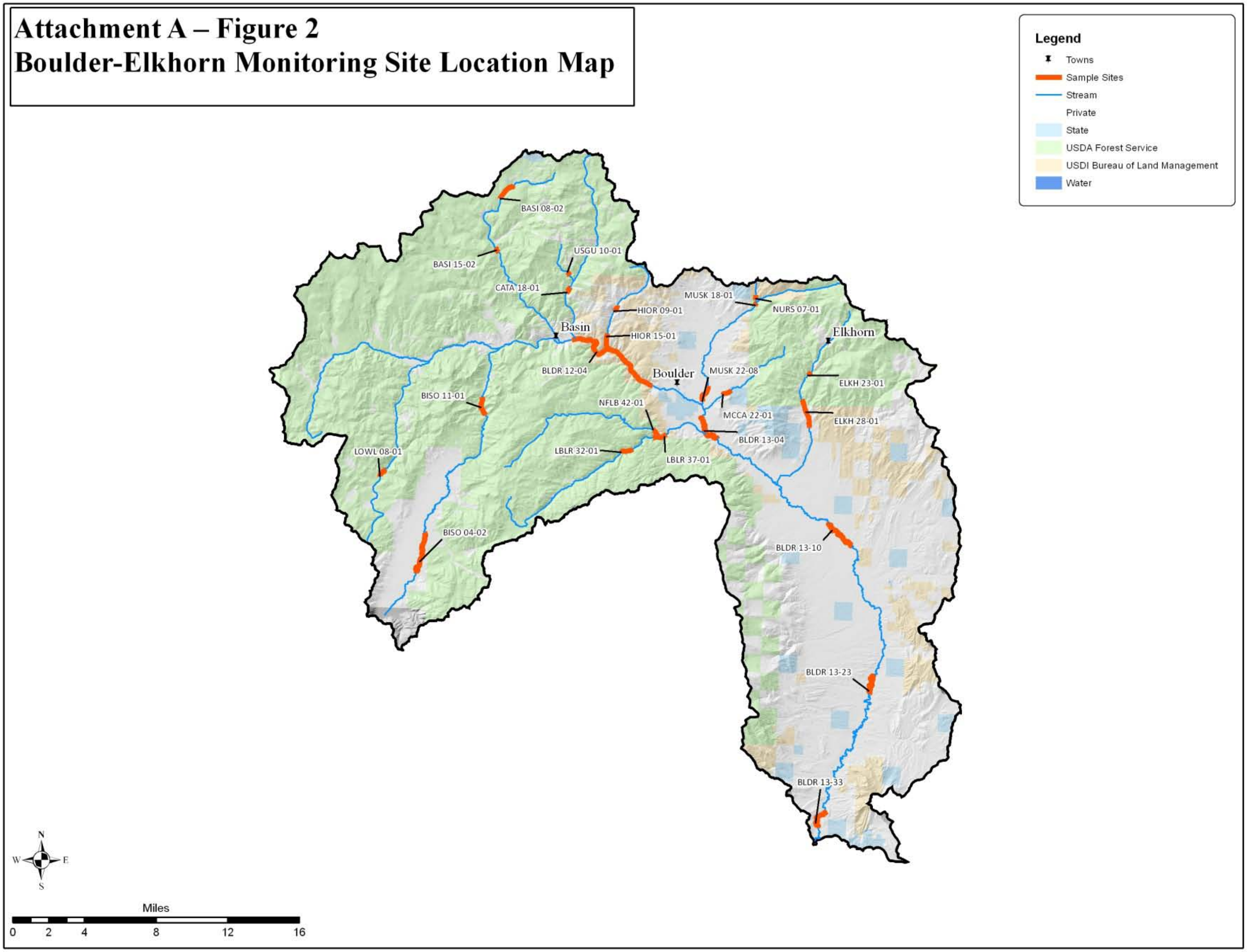
ATTACHMENT A – Maps



Attachment A – Figure 1
Boulder-Elkhorn TMDL Planning Area

Attachment A – Figure 2
Boulder-Elkhorn Monitoring Site Location Map



ATTACHMENT B – Field Data Sheets

ATTACHMENT C – Photo Log

ATTACHMENT D – Quality Assurance/Quality Control Review