Lower Gallatin Watershed Tributary Sediment Assessment: Upland Sediment Assessment and Modeling

Final Modeling Summary Report

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1.0 Introduction

This report presents results of the Upland Sediment Assessment and Modeling Effort for the Lower Gallatin Watershed Tributary Sediment Assessment. Upland sediment loading from hillslope erosion was modeled using a Universal Soil Loss Equation (USLE) based model which was combined with a sediment delivery ratio (SDR) and a riparian health assessment to predict the amount of sediment delivered to streams. The USLE based model was implemented as a watershed-scale, raster-based, GIS model using ArcView GIS software. The USLE model requires five landscape factors which are combined to predict upland soil loss, including a rainfall factor (R), soil erodibility factor (K), length and slope factors (LS), a cropping factor (C), and a management practices factor (P). Details and data sources of each factor are described in subsequent sections of this report. Three separate management scenarios were modeled in this study to evaluate the potential sediment reduction from implementation of best management practices (BMPs).

The study area is located in southwest Montana near the communities of Bozeman, Belgrade, and Manhattan (**Figure 1-1**). The individual watersheds evaluated in this study include streams listed for sediment impairment on the 2008 303(d) list, including Bear, Sourdough, Camp, Dry, Godfrey, Jackson, Reese, Rocky, Smith, Stone and Thompson Springs Creeks, shown below in **Figure 1-2**.

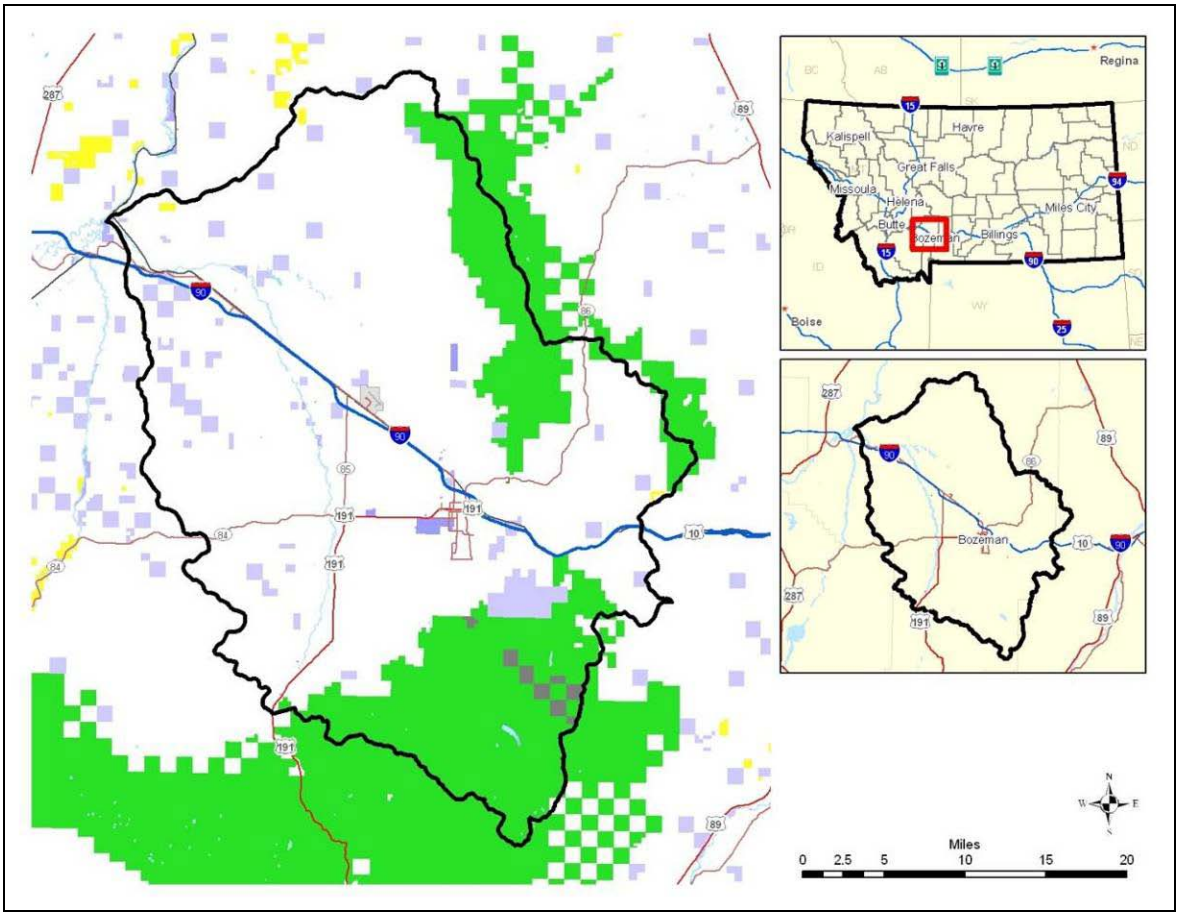

Figure 1-1. Lower Gallatin River Watershed Site Location Map.

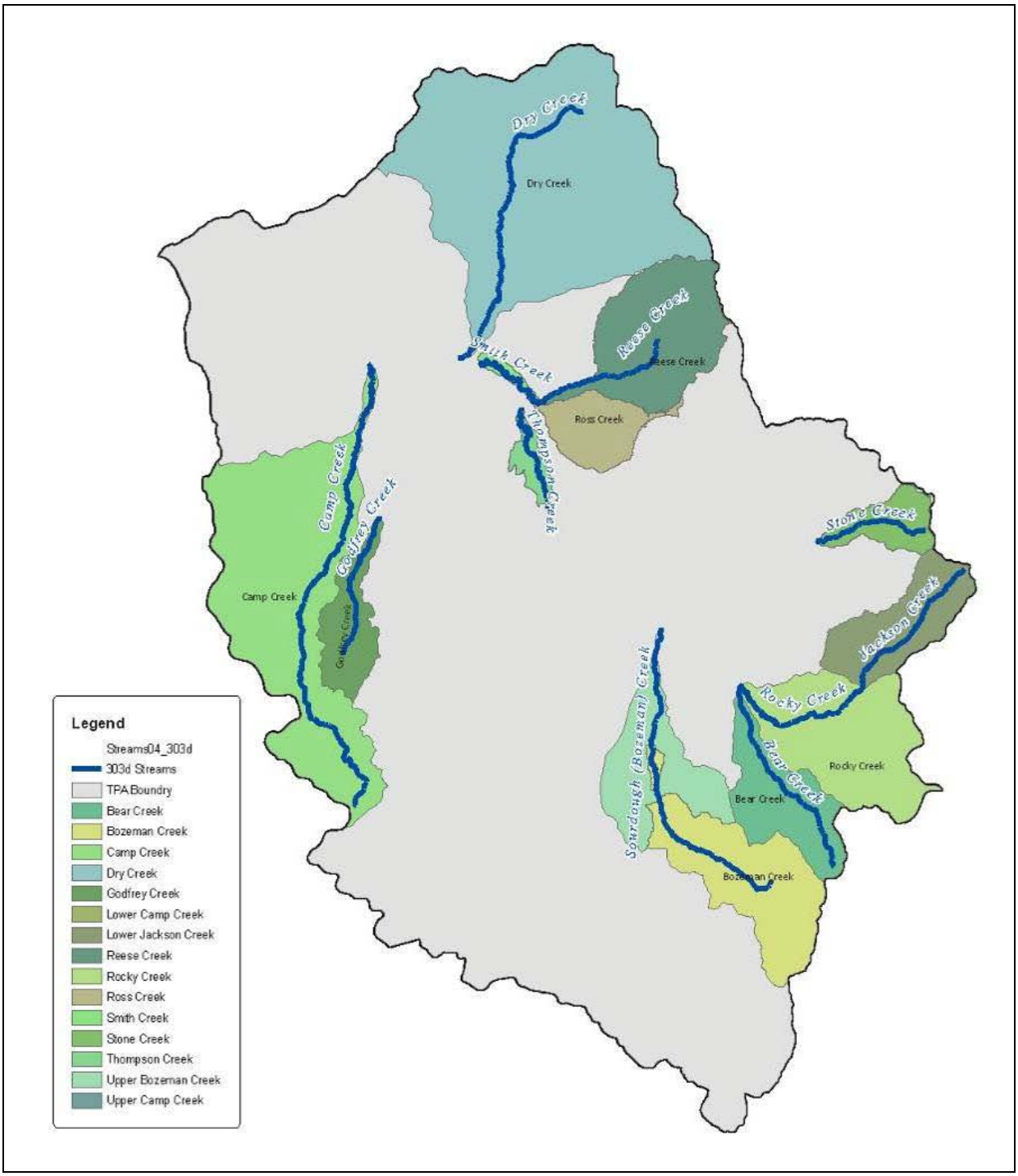

Figure 1-2. 2008 303(d) Sediment Listed Streams of the Lower Gallatin River Watershed.

2.0 Modeling Approach

The general form of the USLE equation has been widely used for upland sediment erosion modeling and is presented as (Brooks et al. 1997):

A = RK(LS)CP (in tons per acre per year).

The **R-factor** characterizes the effect of raindrop impact and runoff rates associated with a rainstorm. It is a determined using the kinetic energy of a rainfall event (measured in hundreds of ft-tons per acre per year) and the maximum 30-minute rainfall intensity (inches per hour) for an area. The total kinetic energy of a rain event is obtained by multiplying the kinetic energy per inch of rainfall by the depth of rainfall during each intensity period.

The **K-factor** is a soil erodibility factor that quantifies the susceptibility of soil to erosion. It is a measure of the average soil loss (tons per acre per hundreds of ft-tons per acre of rainfall intensity) from a particular soil in continuous fallow, and has been derived from previous experimental data.

The **LS-factor** is a function of the slope and flow length of the eroding slope or cell. For the purpose of computing the LS-factor, slope is defined as the average land surface gradient per cell. The flow length refers to the distance between where overland flow originates and runoff reaches a defined channel or depositional zone. The equation used for calculating the length and slope factor (LS) was provided by Lim, et al. (2005) using a method developed by Moore and Burch (1986 a, b). The equation used to calculate LS is provided below; where A is flow length multiplied by cell size, and Θ is slope angle in degrees.

$$LS = \left(\frac{A}{22.13}\right)^{0.4} * \left(\frac{\sin\Theta}{0.0896}\right)^{1.3}$$

The **C-factor** is a crop management value that represents the ratio of soil erosion from a specific cover type compared to the erosion that would occur on a clean-tilled fallow under identical slope and rainfall. The C-factor integrates a number of variables that influence erosion including vegetative cover, plant litter, soil surface, and land management. The original C-factor of the USLE was experimentally determined for agricultural crops and has since been modified to include rangeland and forested cover.

The **P-factor** or conservation practice factor is a function of the interaction of the supporting land management practice and slope. It incorporates the use of erosion control practices such as strip-cropping, terracing and contouring, and is applicable only to agricultural lands. Values of the P-factor compare straight-row farming practices with that of certain agriculturally based conservation practices. This factor was set to one for this analysis based on existing practices within the watershed.

Results from the USLE equation were combined with a **sediment delivery ratio** (**SDR**) to predict the amount of sediment delivered to streams. The sediment delivery ratio was derived

within the model for each cell based on the relationship between the distance from the delivery point to the stream and the percent of eroded sediment delivered to the stream.

A **riparian health condition** was also applied to the USLE model to determine the amount of sediment that could be delivered to streams based on the condition of their riparian vegetation.

Three management scenarios were modeled for the Lower Gallatin River watershed including:

1) an existing conditions scenario using sediment loads derived for the existing upland land condition and the existing riparian health condition,
2) a desired conditions scenario using sediment loads derived for the desired upland land condition and the existing riparian health condition, and
3) an improved conditions scenario using sediment loads derived for the desired upland land condition and an improved riparian health condition.

The results of these modeling efforts include the annual sediment load for each stream listed for sediment on the state's 2008 303(d) List, the annual sediment load from each land cover type, and the potential sediment load reduction from each sediment listed stream with the implementation of land-use BMPs and improved riparian health condition.

2.1 Data Sources

The following sections describe the data sources used to obtain the appropriate spatial data required for this model. The results of each specific parameter are shown graphically.

2.1.1 R-Factor

The rainfall and runoff factor grid was prepared by the Spatial Climate Analysis Service (SCAS) of Oregon State University at 4 km grid cell resolution. For the purposes of this analysis, the SCAS R-factor grid was projected to Montana State Plane Coordinates (NAD83, meters), resampled to a 10m analytic cell size and clipped to the extent of the Lower Gallatin River watershed to match the project's standard grid definition. The R-Factor for the Lower Gallatin River Watershed is shown below in **Figure 2-1**.

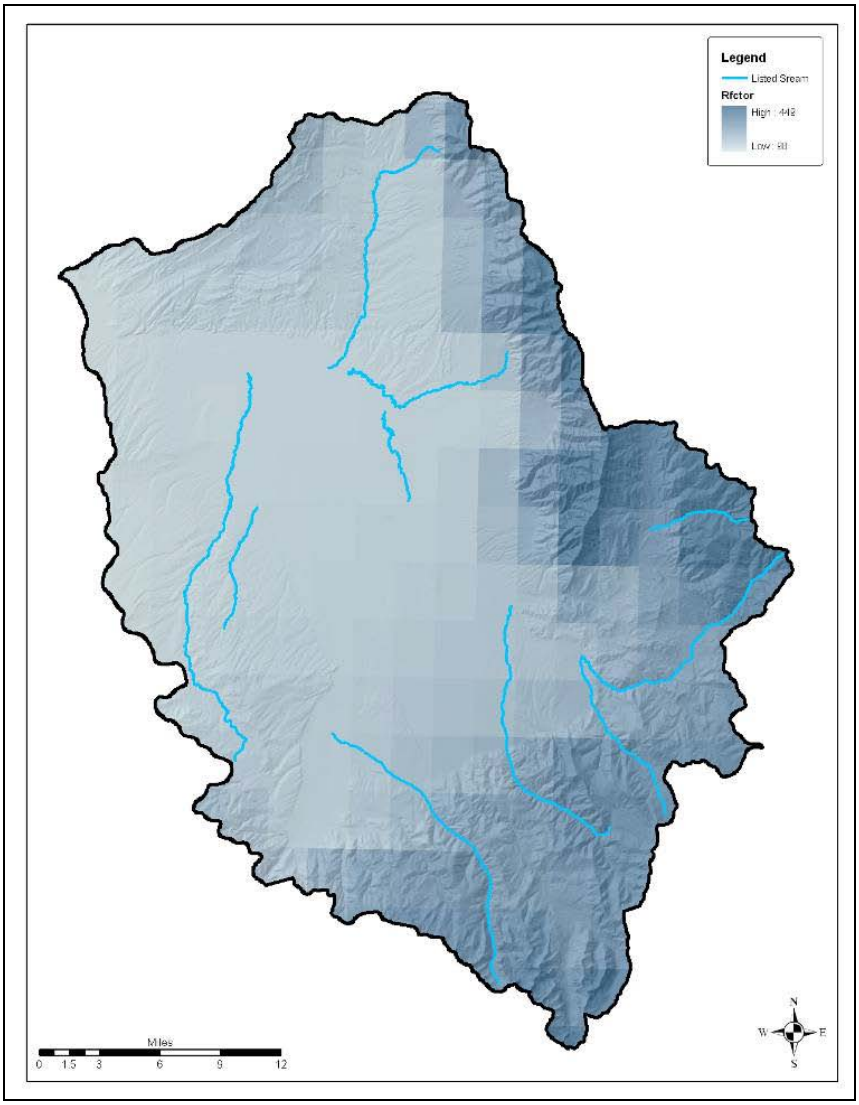

Figure 2-1. USLE R-factor for the Lower Gallatin River Watershed.

2.1.2 K-Factor

Polygon data for the K-factor were obtained from the NRCS Soil Survey Geographic database (SSURGO). The K-factor for the Lower Gallatin River watershed is shown below in **Figure 2-2.**

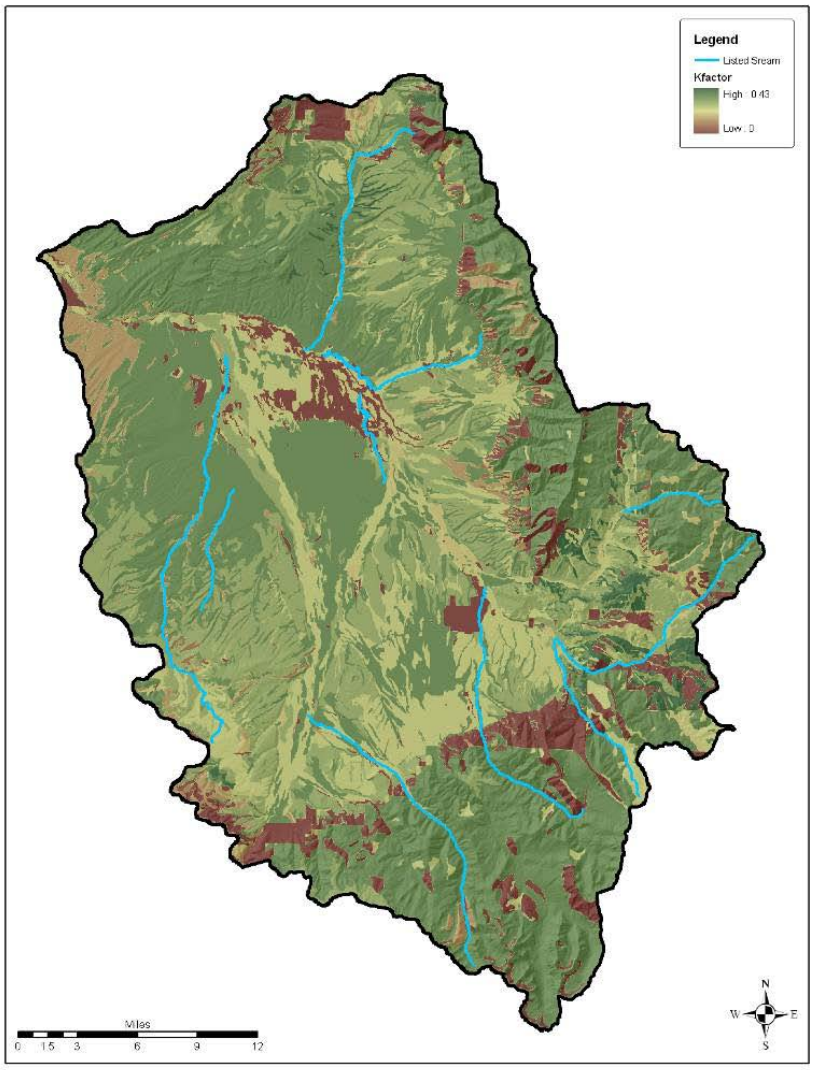

Figure 2-2. USLE K-factor for the Lower Gallatin River Watershed.

2.1.3 Digital Elevation Model (DEM)

The digital elevation model (DEM) of the Lower Gallatin River watershed is the base layer used for developing the LS factor, defining the extent of the bounds of the analysis area, and delineating areas where the USLE model is not valid (i.e. the flow channels of the stream network). The USGS 30m DEM for the Lower Gallatin River watershed was used for these analyses. The DEM was interpolated to a 10m analytic grid cell to render the delineated stream network more representative of the actual size of Lower Gallatin River watershed streams and to minimize resolution dependent stream network anomalies. Results of the DEM for the Lower Gallatin River watershed is provided below in **Figure 2-3.**

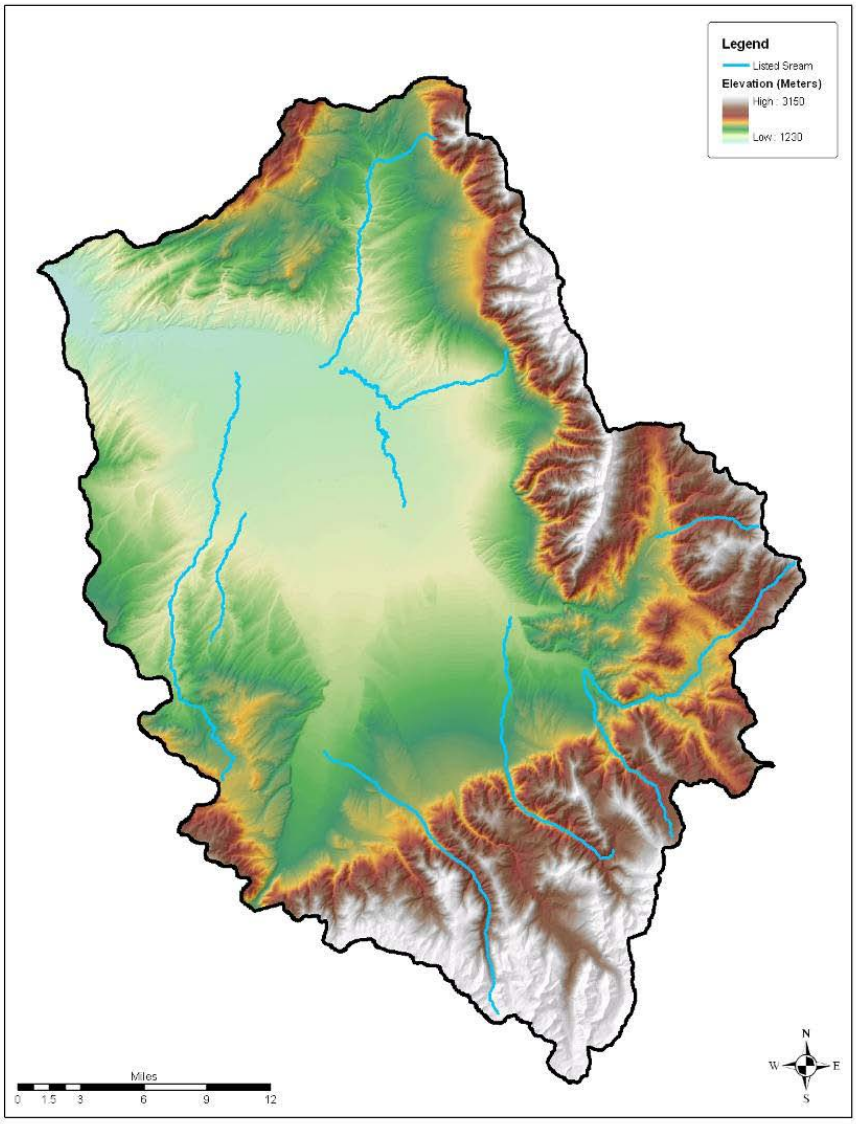

Figure 2-3. Digital Elevation Model (DEM) of the Lower Gallatin River Watershed.

2.1.4 National Land Cover Dataset (NLCD)

The 2001 National Land Cover Dataset (NLCD) was obtained from USGS and is developed through a cooperative project conducted by the Multi-Resolution Land Characteristics (MRLC) Consortium, a partnership of nine federal agencies. This layer is used to establish USLE C-factors for the Lower Gallatin River watershed. The NLCD is a categorized 30-meter Landsat Thematic Mapper image from 2001. The NLCD image was reprojected to Montana State plane projection/coordinate system, and resampled to the project standard 10-meter grid size. Results of the NLCD are shown below in **Figure 2-4.**

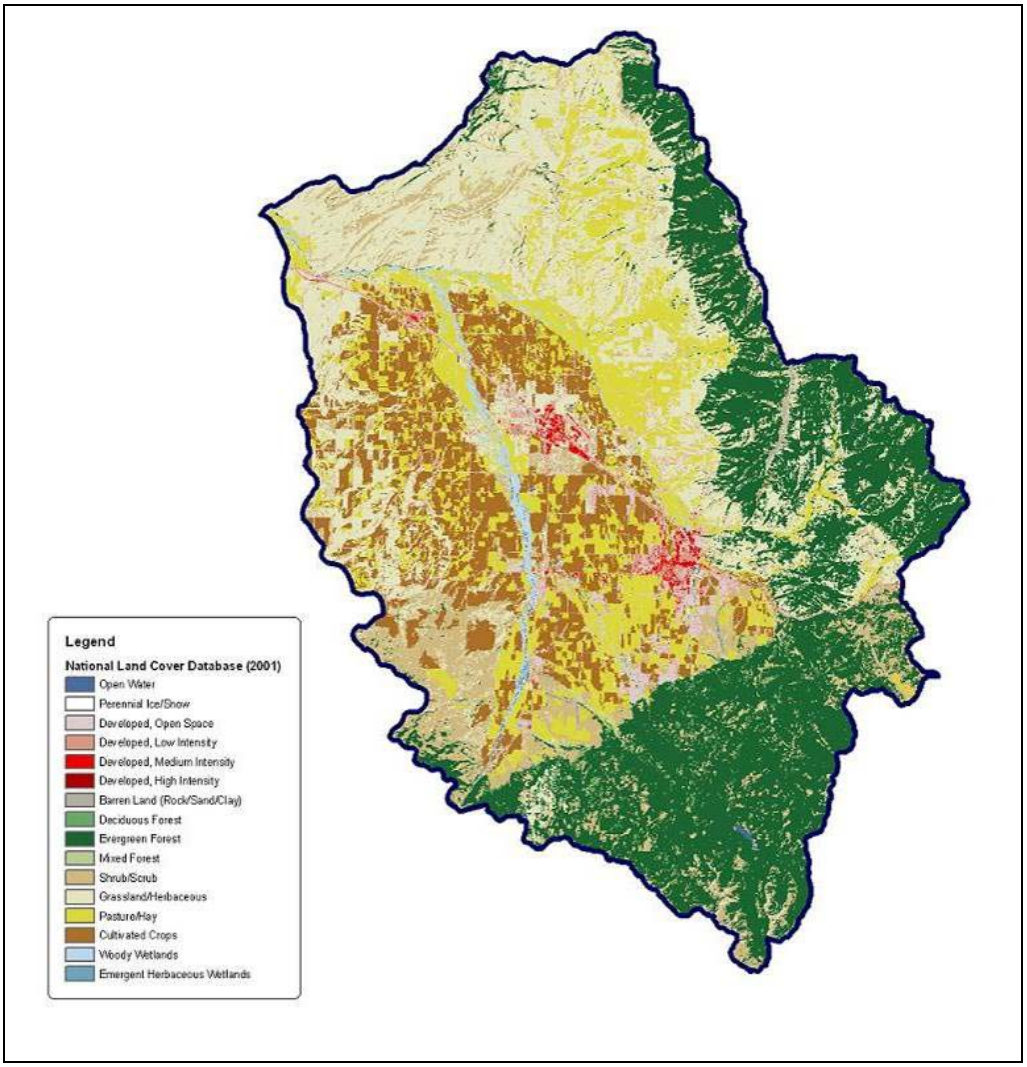

Figure 2-4. National Land Cover Dataset (2001) for the Lower Gallatin River Watershed.

Descriptions for the NLCD land cover classification codes present in the Lower Gallatin watershed are provided below, followed by the percent of each land-use type in **Table 2-1**.

11. Open Water - Areas of open water, generally with less than 25% cover of vegetation or soil.

12. Perennial Ice/Snow - All areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.

21. Developed, Open Space - Includes areas with a mixture of constructed materials, but mostly vegetation in the form of lawn. Impervious surfaces account for less than 20 percent of total cover. These areas commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes.

22. Developed, Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

23. Developed, Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.

24. Developed, High Intensity - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80-100 percent of the total cover.

31. Barren Land (Rock/Sand/Clay) – Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other earthen material. Generally, vegetation accounts for less than 15 percent of total cover.

41. Deciduous Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

42. Evergreen Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

43. Mixed Forest - Areas dominated by trees generally taller than 5 m, and greater than 20% of total cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.

52. Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes tree shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

71. Grasslands/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

81. Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

82. Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

90. Woody Wetlands - Areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated or covered with water.

95. Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Table 2-1. Percent of Land-Use Types Present in the Lower Gallatin River Watershed.

Land-Use Type	Remaining Lower Gallatin Watershed	Bear Creek	Rocky Creek	Lower Bozeman Creek	Upper Bozeman Creek	Camp Creek	Godfrey Creek	Smith Creek	Ross Creek	Thompson Creek
Barren Land	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cultivated Crops	14.1	3.0	0.0	1.4	12.7	34.0	45.5	0.0	0.0	61.5
Deciduous Forest	0.6	3.5	1.6	1.4	1.6	0.0	0.0	0.0	0.0	0.1
Developed High Intensity	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Developed Low Intensity	1.9	0.8	0.8	0.1	7.4	0.6	1.8	1.0	0.3	0.4
Developed Med. Intensity	0.6	0.1	0.1	0.0	2.5	0.1	0.1	0.0	0.0	0.0
Developed Open Space	4.2	1.3	1.1	1.2	18.5	2.4	3.5	9.4	3.6	6.4
Emergent Herb. Wetlands	0.2	0.0	0.1	0.1	0.4	0.0	0.0	0.0	0.0	0.0
Evergreen Forest	23.9	71.4	55.0	83.8	20.3	0.3	0.0	0.0	0.2	0.0
Hay/Pasture	17.1	5.1	2.3	1.6	18.5	15.0	19.8	51.8	47.8	23.6
Herbaceous/ Grassland	21.8	1.3	12.7	1.1	1.6	31.7	26.3	36.5	43.8	4.9
Mixed Forest	0.1	0.2	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Open Water	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.1	0.0
Shrub/Scrub	13.1	13.0	25.8	8.8	15.4	15.5	2.8	0.5	3.9	1.7
Woody Wetlands	2.0	0.4	0.2	0.5	0.6	0.3	0.0	0.6	0.2	1.3

2.1.5 C-Factor Derivation

A classification scheme was used to assign USLE C-factors to the NLCD land-use types present in the Lower Gallatin River watershed (**Table 2-2**). This scheme was initially developed based on ground cover percentages established by the USDA Soil Conservation Service (1977), and has been refined based on present land cover conditions in the Lower Gallatin River watershed as determined between DEQ and NRCS staff. Land-use categories of developed land (medium and high intensity), barren land, and open water were present in small amounts within the Lower Gallatin River watershed (<1% combined) and were assigned a C-factor of zero. In order to estimate the potential sediment reduction that might be accomplished under a best management practices scenario, the model was also run using C-factors assigned to the desired condition. To determine C-factors for the desired conditions, existing condition C-factors for anthropogenic land-use types were changed to reflect the ground cover that best represents an improved land

condition in the Lower Gallatin River watershed. Land cover types identified as shrub/scrub, grasslands/ herbaceous, pasture/hay, and cultivated crops were conservatively changed to reflect a 10 percent increase in ground cover over existing conditions, shown below in **Table 2-3**. It is acknowledged that land cover is variable within and across watersheds, and changes seasonally; the C-factors used for the model are intended to represent typical annual conditions at a coarse scale and the percent of improvement achievable via the implementation of BMPs.

Table 2-2. Lower Gallatin C-Factors for Existing and Desired Management Conditions.

NLCD Code	Description	Land Use Category	C-Factor	
			Existing Condition	Desired Condition
21, 22	Developed, Open Space /Low Intensity	Residential/Urban Development	0.0001	0.0001
41, 42, 43	Deciduous/ Evergreen/ Mixed Forest	Natural Sources	0.001	0.001
52	Shrub/Scrub	Grazing	0.040	0.027
71	Grasslands/Herbaceous	Grazing	0.035	0.019
81	Pasture/Hay	Cropland	0.020	0.013
82	Cultivated Crops	Cropland	0.15	0.10
90	Woody Wetlands	Natural Source	0.0001	0.0001

Table 2-3. Percent Ground Cover for Existing and Desired Land Cover Types.

Land Cover	Existing % Ground Cover	Desired % Ground Cover
Shrub/Scrub	60	70
Grasslands/Herbaceous	65	75
Pasture /Hay	65	75
Cultivated Crops	30	40

2.1.6 Sediment Delivery Ratio

USLE model results were combined with a sediment delivery ratio (**SDR**) to predict sediment delivery to streams. The SDR was derived for each grid cell based on the distance from the cell to the nearest stream. This distance-based relationship was established during development of the WARSEM road sediment model by integrating previous studies which evaluated sediment delivery down slope of forest roads (Dube et al. 2004). These studies determined that the percent of sediment delivered to streams decreases with distance from the stream based on the relationship shown in **Table 2-4**. This relationship has been applied in previous USLE models for TMDL development, and is considered to be a conservative estimate of sediment delivery from upland erosion.

Table 2-4. Sediment Delivery vs. Distance from Stream.

Distance from Stream (ft)	Percent of Sediment Delivered to Stream
0	100
35	70
70	50
105	35
140	25
175	18
210	10
245	4
280	3
315	2
350	1

2.1.7 Riparian Health Assessment

Well vegetated riparian buffers act as filters that effectively trap sediment from overland flow. The ability of vegetated riparian buffers to trap sediment is generally proportional to the buffer width and overall health. Previous studies (Castelle and Johnson 2000) have estimated that approximately 80% of sediment and 65% of particulate organic matter can be removed across a healthy riparian buffer. Studies within Montana suggest that sediment generated from upland erosion sources can be reduced by 25% (Middle Blackfoot TMDL) to 90% (Hook 2003).

A riparian health assessment was previously conducted for the Lower Gallatin River watershed by Montana DEQ. Ratings of poor, fair, and good were assigned to the left and right bank of multiple reaches on each surveyed stream. The results of this assessment are provided below in **Table 2-5 a**nd shown graphically in **Figure 2-5**.

The USLE derived sediment loads for the Lower Gallatin River watershed were adjusted to compensate for riparian health conditions in the watershed. For this analysis, a sediment reduction efficiency of 75% was assumed for a healthy (good) riparian buffer. With 75% removal, 25% of the USLE-derived sediment load is delivered to the stream. As the condition of the riparian buffer declines or is degraded, sediment reduction efficiencies of 50% and 25% are assumed to represent moderately (fair) and heavily (poor) disturbed conditions.

Table 2-5. Riparian Health Statistics for the Lower Gallatin River Watershed.

Stream	Parameter	Riparian Condition		
		Poor	Fair	Good
Bear Creek	Length (mi)	0.00	14.76	5.51
	Percent	0%	73%	27%
Bozeman Creek	Length (mi)	2.28	18.56	10.74
	Percent	7%	59%	34%
Camp Creek	Length (mi)	14.97	35.43	0.28
	Percent	30%	70%	1%
Dry Creek	Length (mi)	2.06	29.94	0.46
	Percent	6%	92%	1%
Godfrey Creek	Length (mi)	12.10	2.14	0.00
	Percent	85%	15%	0%
Jackson Creek	Length (mi)	0.00	14.80	0.77
	Percent	0%	95%	5%
Reese Creek	Length (mi)	2.28	12.58	0.00
	Percent	15%	85%	0%
Rocky Creek	Length (mi)	1.98	12.00	1.10
	Percent	13%	80%	7%
Smith Creek	Length (mi)	0.62	11.98	0.00
	Percent	5%	95%	0%
Stone Creek	Length (mi)	0.00	10.83	0.31
	Percent	0%	97%	3%
Thompson Creek	Length (mi)	3.76	10.62	0.00
	Percent	26%	74%	0%

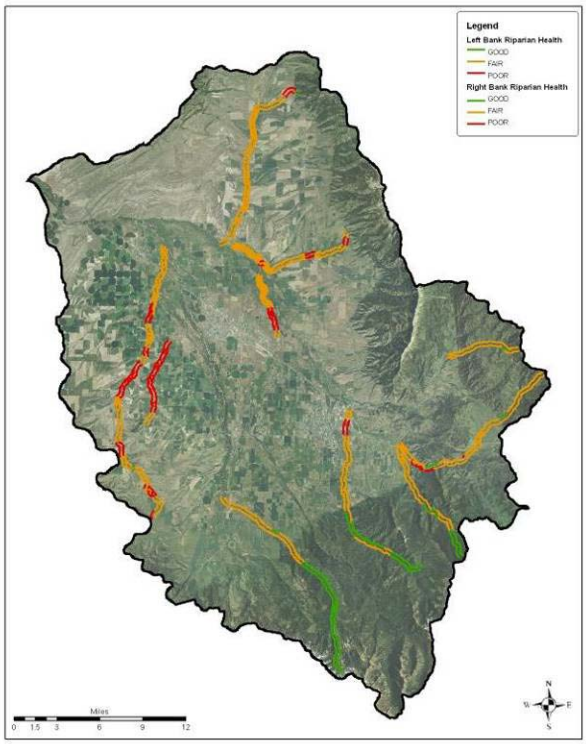

Figure 2-5. Riparian Health Condition of the Lower Gallatin River Watershed.

Riparian health data for the Lower Gallatin River watershed were incorporated into the USLE model by appropriating the calculated sediment load into the riparian condition categories for each watershed. This was accomplished by multiplying the USLE derived sediment load by the percent of each riparian condition present (poor, fair, good) and by the assumed delivery ratio (75% for poor, 50% for fair, 25% for good). Anthropogenic land-use categories were assigned the riparian condition that was previously determined for each watershed, while natural land-use categories were assigned a riparian condition of 75% good and 25% fair. This assumes that areas with natural sources of erosion have functioning riparian buffers that cannot be improved through the implementation of BMPs. For the purposes of this analysis, land-use categories considered anthropogenic include cultivated crops, developed land (low, medium and high density, open space), pasture/hay, grasslands/herbaceous land, and shrub/scrub land. Land-use categories considered natural include barren land, deciduous forest, emergent herbaceous wetland, evergreen forest, mixed forest, open water, and woody wetlands. The riparian health condition was not evaluated for Ross Creek; instead, the Ross Creek sub-watershed received the sediment delivery ratios calculated for Reese Creek, which is in close proximity to Ross Creek and has similar land-use. Examples of the sediment load calculations incorporating the riparian health condition are provided for each modeling scenario below in **Table 2-6.**

Table 2-6. Riparian Health Example for the Bear Creek Sub-Watershed.

Sub-Watershed	Land Use Type	Existing Upland Conditions Load (Tons/Year)	Desired Upland Conditions Load (Tons/Year)	Riparian Buffer Condition (%)			Appropriated Sediment Load (tons/year)			Total Adjusted Load (tons/yr)	Percent Load Reduction
				Good	Fair	Poor	Good	Fair	Poor		
Scenario 1 -Existing Upland Condition Load Adjusted for Existing Riparian Condition											
Bear Creek	Anthropogenic	378.8	251.9	27%	73%	0%	25.7	137.9	0.0	164	57%
	Natural	139.9	139.9	75%	25%	0%	26.2	17.5	0.0	44	69%
	Total	518.7	391.8	-	-	-	52.0	155.4	0.0	207	60%
Scenario 2 - Desired Upland Condition Load Adjusted for Existing Riparian Condition											
Bear Creek	Anthropogenic	378.8	251.9	27%	73%	0%	17.1	91.7	0.0	109	34%
	Natural	139.9	139.9	75%	25%	0%	26.2	17.5	0.0	44	0%
	Total	518.7	391.8	-	-	-	43.3	109.2	0.0	153	26%
Scenario 3 - Desired Upland Condition Load Adjusted for Improved Riparian Condition											
Bear Creek	Anthropogenic	378.8	251.9	75%	25%	0%	47.2	31.5	0.0	79	28%
	Natural	139.9	139.9	75%	25%	0%	26.2	17.5	0.0	44	0%
	Total	518.7	391.8	-	-	-	73.5	49.0	0.0	122	20%

For Scenario 1, loads were calculated using the USLE-based sediment loads derived for the existing upland condition, and the existing riparian health condition was applied to the anthropogenic land-use types. Natural land-use types were assigned riparian health condition of 75% good and 25% fair. This scenario evaluates the influence of the existing riparian condition on the existing USLE-derived upland sediment load.

For Scenario 2, loads were calculated using the USLE-based sediment loads for the desired upland condition, and the existing riparian health condition was applied to the anthropogenic

land-use types. Natural land-use types were assigned riparian health condition of 75% good and 25% fair. This scenario evaluates the effectiveness of the implementation of upland BMPs that improve land cover.

For Scenario 3, loads were calculated using the USLE-based sediment loads for the desired upland condition, and an improved riparian health condition was applied to the anthropogenic land-use types. In this calculation, the riparian health condition was changed to 75% good and 25% fair for anthropogenic land-use types, while natural land-use types remained at 75% good and 25% fair. The concept is that through the application of riparian BMPs, the health of the vegetated riparian buffers will increase, hence increasing their sediment reduction efficiency. This scenario evaluates the effectiveness of implementing BMPs that improve riparian condition.

3.0 Results

Sediment loading results for the existing and desired upland conditions are provided below in **Table 3-1**. This table presents results of the USLE model before the incorporation of the riparian health condition. Results are presented by sub-watershed and land-use type, and are further grouped by anthropogenic and natural sources. It should be noted that the sub-watersheds listed are not additive of watershed areas upstream, and include only the total for the sub-watershed listed. Total upland sediment loads for the sediment listed streams ranged from 1.0 tons/year (Smith Creek) to 13,258 tons/year (Dry Creek) for the existing upland condition, with an average sediment load of 3057 tons/year. Using the desired upland condition, minimum and maximum sediment loads for listed streams were reduced to 0.7 tons/year (Smith Creek) and 7856 tons/year (Dry Creek), with an average of 1924 tons/year.

Results of the riparian health incorporation are presented in **Table 3-2**, including results of the three model scenarios grouped by anthropogenic (labeled as “anthro”) and natural sources. Scenario 1 represents the sediment load delivered to streams under the existing upland condition and with existing riparian health conditions, Scenario 2 represents the desired upland condition with existing riparian health, and Scenario 3 represents the desired upland condition with improved riparian health. Anthropogenic sediment loads for the sediment listed streams were reduced by 33-43% with the implementation of upland management BMPs, and anthropogenic sources were reduced 28-56% with the use of BMPs that improve riparian health condition. The total load reduction potential with the use of both upland and riparian BMPs ranged from 41-72% for the sub-watersheds.

Table 3-1. Results of USLE Model for Lower Gallatin River Watershed (without riparian health).

Sub-Watershed	Land Use Type	Area (acres)	Percent of Watershed	Existing Condition Load (Tons/Year)	Existing Conditions Load (Tons/Acre/ Year)	Desired Conditions Load (Tons/Year)	Desired Conditions Load (Tons/Acre/ Year)
Bear Creek	Cultivated Crops	291	2%	32.5	0.11	21.7	0.07
	Deciduous Forest	397	3%	4.8	0.01	4.8	0.01
	Developed Low Intensity	26	0%	0.0	0.00	0.0	0.00
	Developed Open Space	112	1%	0.1	0.00	0.1	0.00
	Emergent Herb. Wetlands	9	0%	0.0	0.00	0.0	0.00
	Evergreen Forest	9590	76%	134.9	0.01	134.9	0.01
	Grasslands/Herbaceous	140	1%	25.3	0.18	13.7	0.10
	Mixed Forest	20	0%	0.1	0.01	0.1	0.01
	Pasture/Hay	587	5%	8.8	0.01	5.7	0.01
	Shrub/Scrub	1503	12%	312.2	0.21	210.7	0.14
	Woody Wetlands	20	0%	0.0	0.00	0.0	0.00
	Total Anthropogenic	**2658**	**21%**	**378.8**	**0.14**	**251.9**	**0.09**
	Total Natural	**10035**	**79%**	**139.9**	**0.01**	**139.9**	**0.01**
	Total Sub-Watershed	**12694**	**100%**	**518.7**	**0.04**	**391.8**	**0.03**
Camp Creek	Barren Land	6	0%	0.0	0.00	0.0	0.00
	Cultivated Crops	15200	32%	4997.2	0.33	3331.5	0.22
	Deciduous Forest	35	0%	0.4	0.01	0.4	0.01
	Developed High Intensity	3	0%	0.0	0.00	0.0	0.00
	Developed Low Intensity	291	1%	0.1	0.00	0.1	0.00
	Developed Med. Intensity	28	0%	0.0	0.00	0.0	0.00
	Developed Open Space	1115	2%	0.4	0.00	0.4	0.00
	Emergent Herb. Wetlands	5	0%	0.0	0.00	0.0	0.00
	Evergreen Forest	339	1%	3.2	0.01	3.2	0.01
	Grasslands/Herbaceous	15202	32%	2651.0	0.17	1439.1	0.09
	Mixed Forest	13	0%	0.2	0.01	0.2	0.01
	Open Water	9	0%	0.0	0.00	0.0	0.00
	Pasture/Hay	7021	15%	241.7	0.03	157.1	0.02
	Shrub/Scrub	8410	18%	1380.7	0.16	932.0	0.11
	Woody Wetlands	112	0%	0.0	0.00	0.0	0.00
	Total Anthropogenic	**47271**	**99%**	**9271.1**	**0.20**	**5860.1**	**0.12**
	Total Natural	**520**	**1%**	**3.8**	**0.01**	**3.8**	**0.01**
	Total Sub-Watershed	**47791**	**100%**	**9274.9**	**0.19**	**5864.0**	**0.12**
Dry Creek	Barren Land	93	0%	0.0	0.00	0.0	0.00
	Deciduous Forest	42	0%	0.4	0.01	0.4	0.01
	Developed Low Intensity	54	0%	0.0	0.00	0.0	0.00
	Developed Open Space	1431	2%	1.0	0.00	1.0	0.00
	Evergreen Forest	13235	19%	298.0	0.02	298.0	0.02
	Grasslands/Herbaceous	33712	50%	8891.5	0.26	4826.8	0.14
	Mixed Forest	16	0%	0.2	0.01	0.2	0.01
	Open Water	1	0%	0.0	0.00	0.0	0.00
	Pasture/Hay	11754	17%	640.2	0.05	416.1	0.04

Table 3-1. Results of USLE Model for Lower Gallatin River Watershed (without riparian health).

Sub-Watershed	Land Use Type	Area (acres)	Percent of Watershed	Existing Condition Load (Tons/Year)	Existing Conditions Load (Tons/Acre/ Year)	Desired Conditions Load (Tons/Year)	Desired Conditions Load (Tons/Acre/ Year)
	Shrub/Scrub	7454	11%	3426.9	0.46	2313.2	0.31
	Woody Wetlands	114	0%	0.1	0.00	0.1	0.00
	Total Anthropogenic	**54405**	**80%**	**12959.7**	**0.24**	**7557.2**	**0.14**
	Total Natural	**13501**	**20%**	**298.7**	**0.02**	**298.7**	**0.02**
	Total Sub-Watershed	**67905**	**100%**	**13258.4**	**0.20**	**7855.9**	**0.12**
Godfrey Creek	Barren Land	2	0%	0.0	0.00	0.0	0.00
	Cultivated Crops	3697	46%	2164.2	0.59	1442.8	0.39
	Developed High Intensity	1	0%	0.0	0.00	0.0	0.00
	Developed Low Intensity	120	1%	0.0	0.00	0.0	0.00
	Developed Med. Intensity	16	0%	0.0	0.00	0.0	0.00
	Developed Open Space	279	3%	0.2	0.00	0.2	0.00
	Evergreen Forest	1	0%	0.0	0.00	0.0	0.00
	Grasslands/Herbaceous	2232	28%	783.7	0.35	425.4	0.19
	Mixed Forest	1	0%	0.0	0.00	0.0	0.00
	Pasture/Hay	1410	17%	110.8	0.08	72.0	0.05
	Shrub/Scrub	330	4%	88.2	0.27	59.5	0.18
	Total Anthropogenic	**8085**	**100%**	**3147.2**	**0.39**	**2000.1**	**0.25**
	Total Natural	**4**	**0%**	**0.0**	**0.00**	**0.0**	**0.00**
	Total Sub-Watershed	**8089**	**100%**	**3147.2**	**0.39**	**2000.1**	**0.25**
Jackson Creek	Deciduous Forest	16	0%	0.1	0.01	0.1	0.01
	Developed Low Intensity	4	0%	0.0	0.00	0.0	0.00
	Developed Open Space	3	0%	0.0	0.00	0.0	0.00
	Evergreen Forest	6663	56%	175.8	0.03	175.8	0.03
	Grasslands/Herbaceous	3522	30%	1757.8	0.50	954.2	0.27
	Pasture/Hay	547	5%	56.5	0.10	36.7	0.07
	Shrub/Scrub	1092	9%	483.0	0.44	326.0	0.30
	Woody Wetlands	1	0%	0.0	0.00	0.0	0.00
	Total Anthropogenic	**5168**	**44%**	**2297.3**	**0.44**	**1317.0**	**0.25**
	Total Natural	**6681**	**56%**	**175.9**	**0.03**	**175.9**	**0.03**
	Total Sub-Watershed	**11849**	**100%**	**2473.2**	**0.21**	**1492.9**	**0.13**
Reese Creek	Barren Land	177	1%	0.0	0.00	0.0	0.00
	Deciduous Forest	46	0%	0.4	0.01	0.4	0.01
	Developed Low Intensity	6	0%	0.0	0.00	0.0	0.00
	Developed Open Space	218	1%	0.0	0.00	0.0	0.00
	Evergreen Forest	7834	39%	280.3	0.04	280.3	0.04
	Grasslands/Herbaceous	5690	29%	1621.2	0.28	880.1	0.15
	Mixed Forest	10	0%	0.1	0.01	0.1	0.01
	Pasture/Hay	4138	21%	132.5	0.03	86.1	0.02
	Shrub/Scrub	1710	9%	1291.8	0.76	871.9	0.51
	Woody Wetlands	89	0%	0.0	0.00	0.0	0.00
	Total Anthropogenic	**11762**	**59%**	**3045.5**	**0.26**	**1838.2**	**0.16**
	Total Natural	**8156**	**41%**	**280.8**	**0.03**	**280.8**	**0.03**

Table 3-1. Results of USLE Model for Lower Gallatin River Watershed (without riparian health).

Sub-Watershed	Land Use Type	Area (acres)	Percent of Watershed	Existing Condition Load (Tons/Year)	Existing Conditions Load (Tons/Acre/ Year)	Desired Conditions Load (Tons/Year)	Desired Conditions Load (Tons/Acre/ Year)
	Total Sub-Watershed	**19918**	**100%**	**3326.3**	**0.17**	**2119.0**	**0.11**
Rocky Creek	Cultivated Crops	56	0%	15.9	0.29	10.6	0.19
	Deciduous Forest	421	2%	9.9	0.02	9.9	0.02
	Developed Low Intensity	219	1%	0.1	0.00	0.1	0.00
	Developed Med. Intensity	30	0%	0.0	0.00	0.0	0.00
	Developed Open Space	258	1%	0.3	0.00	0.3	0.00
	Emergent Herb. Wetlands	2	0%	0.0	0.00	0.0	0.00
	Evergreen Forest	12537	57%	187.3	0.01	187.3	0.01
	Grasslands/Herbaceous	1852	8%	874.4	0.47	474.7	0.26
	Mixed Forest	52	0%	0.5	0.01	0.5	0.01
	Pasture/Hay	485	2%	73.0	0.15	47.5	0.10
	Shrub/Scrub	6084	28%	2997.7	0.49	2023.5	0.33
	Woody Wetlands	60	0%	0.1	0.00	0.1	0.00
	Total Anthropogenic	**8984**	**41%**	**3961.6**	**0.44**	**2556.7**	**0.28**
	Total Natural	**13073**	**59%**	**197.7**	**0.02**	**197.7**	**0.02**
	Total Sub-Watershed	**22057**	**100%**	**4159.3**	**0.19**	**2754.4**	**0.12**
Ross Creek	Deciduous Forest	7	0%	0.1	0.01	0.1	0.01
	Developed Low Intensity	28	0%	0.0	0.00	0.0	0.00
	Developed Med. Intensity	2	0%	0.0	0.00	0.0	0.00
	Developed Open Space	319	4%	0.0	0.00	0.0	0.00
	Grasslands/Herbaceous	2917	38%	43.5	0.01	23.6	0.01
	Open Water	1	0%	0.0	0.00	0.0	0.00
	Pasture/Hay	4146	54%	36.4	0.01	23.7	0.01
	Shrub/Scrub	272	4%	4.7	0.02	3.2	0.01
	Woody Wetlands	15	0%	0.0	0.00	0.0	0.00
	Total Anthropogenic	**7683**	**100%**	**84.6**	**0.01**	**50.4**	**0.01**
	Total Natural	**23**	**0%**	**0.1**	**0.00**	**0.1**	**0.00**
	Total Sub-Watershed	**7706**	**100%**	**84.6**	**0.01**	**50.5**	**0.01**
Smith Creek	Developed High Intensity	2	0%	0.0	0.00	0.0	0.00
	Developed Low Intensity	10	1%	0.0	0.00	0.0	0.00
	Developed Open Space	60	6%	0.0	0.00	0.0	0.00
	Grasslands/Herbaceous	56	5%	0.1	0.00	0.0	0.00
	Open Water	2	0%	0.0	0.00	0.0	0.00
	Pasture/Hay	886	83%	1.0	0.00	0.6	0.00
	Shrub/Scrub	9	1%	0.0	0.00	0.0	0.00
	Woody Wetlands	40	4%	0.0	0.00	0.0	0.00
	Total Anthropogenic	**1023**	**96%**	**1.0**	**0.00**	**0.7**	**0.00**
	Total Natural	**42**	**4%**	**0.0**	**0.00**	**0.0**	**0.00**
	Total Sub-Watershed	**1066**	**100%**	**1.0**	**0.00**	**0.7**	**0.00**
Stone Creek	Deciduous Forest	6	0%	0.0	0.01	0.0	0.01
	Evergreen Forest	4632	83%	212.3	0.05	212.3	0.05
	Grasslands/Herbaceous	515	9%	523.2	1.02	284.0	0.55

Table 3-1. Results of USLE Model for Lower Gallatin River Watershed (without riparian health).

Sub-Watershed	Land Use Type	Area (acres)	Percent of Watershed	Existing Condition Load (Tons/Year)	Existing Conditions Load (Tons/Acre/ Year)	Desired Conditions Load (Tons/Year)	Desired Conditions Load (Tons/Acre/ Year)
	Mixed Forest	1	0%	0.0	0.00	0.0	0.00
	Pasture/Hay	23	0%	1.4	0.06	0.9	0.04
	Shrub/Scrub	422	8%	190.5	0.45	128.6	0.30
	Woody Wetlands	2	0%	0.0	0.00	0.0	0.00
	Total Anthropogenic	**961**	**17%**	**715.2**	**0.74**	**413.6**	**0.43**
	Total Natural	**4641**	**83%**	**212.3**	**0.05**	**212.3**	**0.05**
	Total Sub-Watershed	**5602**	**100%**	**927.6**	**0.17**	**625.9**	**0.11**
Thompson Creek	Cultivated Crops	1502	61%	5.9	0.00	4.0	0.00
	Deciduous Forest	3	0%	0.0	0.00	0.0	0.00
	Developed Low Intensity	17	1%	0.0	0.00	0.0	0.00
	Developed Open Space	133	5%	0.0	0.00	0.0	0.00
	Grasslands/Herbaceous	320	13%	0.2	0.00	0.1	0.00
	Pasture/Hay	390	16%	0.3	0.00	0.2	0.00
	Shrub/Scrub	75	3%	0.0	0.00	0.0	0.00
	Woody Wetlands	18	1%	0.0	0.00	0.0	0.00
	Total Anthropogenic	**2437**	**99%**	**6.5**	**0.00**	**4.3**	**0.00**
	Total Natural	**21**	**1%**	**0.0**	**0.00**	**0.0**	**0.00**
	Total Sub-Watershed	**2457**	**100%**	**6.5**	**0.00**	**4.3**	**0.00**
Lower Bozeman Creek	Cultivated Crops	277	1%	15.0	0.05	10.0	0.04
	Deciduous Forest	354	2%	7.1	0.02	7.1	0.02
	Developed Low Intensity	6	0%	0.0	0.00	0.0	0.00
	Developed Open Space	57	0%	0.0	0.00	0.0	0.00
	Emergent Herb. Wetlands	11	0%	0.0	0.00	0.0	0.00
	Evergreen Forest	16726	84%	405.8	0.02	405.8	0.02
	Grasslands/Herbaceous	269	1%	211.8	0.79	115.0	0.43
	Mixed Forest	8	0%	0.0	0.00	0.0	0.00
	Open Water	12	0%	0.0	0.00	0.0	0.00
	Pasture/Hay	296	1%	4.4	0.01	2.9	0.01
	Shrub/Scrub	1874	9%	1531.7	0.82	1033.9	0.55
	Woody Wetlands	106	1%	0.0	0.00	0.0	0.00
	Total Anthropogenic	**2779**	**14%**	**1762.9**	**0.63**	**1161.7**	**0.42**
	Total Natural	**17217**	**86%**	**413.0**	**0.02**	**413.0**	**0.02**
	Total Sub-Watershed	**19997**	**100%**	**2175.9**	**0.11**	**1574.7**	**0.08**
Upper Bozeman Creek	Cultivated Crops	1305	10%	96.6	0.07	64.4	0.05
	Deciduous Forest	270	2%	3.4	0.01	3.4	0.01
	Developed High Intensity	12	0%	0.0	0.00	0.0	0.00
	Developed Low Intensity	680	5%	0.0	0.00	0.0	0.00
	Developed Med. Intensity	187	1%	0.0	0.00	0.0	0.00
	Developed Open Space	2300	17%	0.4	0.00	0.4	0.00
	Emergent Herb. Wetlands	12	0%	0.0	0.00	0.0	0.00
	Evergreen Forest	4703	35%	36.1	0.01	36.1	0.01
	Grasslands/Herbaceous	179	1%	7.4	0.04	4.0	0.02

Table 3-1. Results of USLE Model for Lower Gallatin River Watershed (without riparian health).

Sub-Watershed	Land Use Type	Area (acres)	Percent of Watershed	Existing Condition Load (Tons/Year)	Existing Conditions Load (Tons/Acre/ Year)	Desired Conditions Load (Tons/Year)	Desired Conditions Load (Tons/Acre/ Year)
	Mixed Forest	23	0%	0.0	0.00	0.0	0.00
	Pasture/Hay	2103	16%	43.3	0.02	28.2	0.01
	Shrub/Scrub	1425	11%	202.1	0.14	136.4	0.10
	Woody Wetlands	58	0%	0.0	0.00	0.0	0.00
	Total Anthropogenic	**8191**	**62%**	**349.9**	**0.04**	**233.4**	**0.03**
	Total Natural	**5065**	**38%**	**39.5**	**0.01**	**39.5**	**0.01**
	Total Sub-Watershed	**13257**	**100%**	**389.4**	**0.03**	**272.9**	**0.02**
Remaining Lower Gallatin Watershed	Barren Land	1048	0%	0.0	0.00	0.0	0.00
	Cultivated Crops	56000	14%	11632.6	0.21	7755.1	0.14
	Deciduous Forest	2217	1%	39.5	0.02	39.5	0.02
	Developed High Intensity	146	0%	0.0	0.00	0.0	0.00
	Developed Low Intensity	7733	2%	0.3	0.00	0.3	0.00
	Developed Med. Intensity	2308	1%	0.0	0.00	0.0	0.00
	Developed Open Space	16454	4%	3.0	0.00	3.0	0.00
	Emergent Herb. Wetlands	809	0%	0.0	0.00	0.0	0.00
	Evergreen Forest	98569	25%	2593.8	0.03	2593.8	0.03
	Grasslands/Herbaceous	84146	21%	25876.1	0.31	14047.0	0.17
	Mixed Forest	360	0%	4.3	0.01	4.3	0.01
	Open Water	707	0%	0.0	0.00	0.0	0.00
	Pasture/Hay	65632	17%	1686.3	0.03	1096.1	0.02
	Shrub/Scrub	53536	13%	23697.5	0.44	15995.8	0.30
	Woody Wetlands	7729	2%	1.1	0.00	1.1	0.00
	Total Anthropogenic	**285956**	**72%**	**62895.8**	**0.22**	**38897.3**	**0.14**
	Total Natural	**111438**	**28%**	**2638.7**	**0.02**	**2638.7**	**0.02**
	Total Sub-Watershed	**397394**	**100%**	**65534.5**	**0.16**	**41536.0**	**0.10**
Total Lower Gallatin River Watershed	**Total Anthro Load**	**447363**	**70%**	**100877.1**	**0.23**	**62142.6**	**0.14**
	Total Natural Load	**190418**	**30%**	**4400.5**	**0.02**	**4400.5**	**0.02**
	Total Watershed	**637781**	**100%**	**105277.6**	**0.17**	**66543.1**	**0.10**

Table 3-2. Results of USLE Model with Riparian Health Incorporation.

Sub-Watershed	Land Use Type	Existing Condition Load (tons/yr)	Desired Condition Load (tons/yr)	Scenario 1		Scenario 2		Scenario 3		Total Load Reduction w/ use of Upland and Riparian BMPs
				Existing Upland Load w/ Existing Riparian Condition (tons/yr)	Percent Load Reduction w/ use of Riparian Condition	Desired Upland Load w/ Existing Riparian Condition (tons/yr)	Percent Load Reduction w/ use of Upland BMPs	Desired Upland Load w/ Improved Riparian Health (tons/yr)	Percent Load Reduction w/ use of Riparian BMPs	
Bear Creek	Anthro	379	252	164	57%	109	34%	79	28%	52%
	Natural	140	140	44	69%	44	0%	44	0%	0%
	Total	519	392	207	60%	153	26%	122	20%	41%
Camp Creek	Anthro	9271	5860	5307	43%	3355	37%	1831	45%	65%
	Natural	4	4	1	69%	1	0%	1	0%	0%
	Total	9275	5864	5309	43%	3356	37%	1832	45%	65%
Dry Creek	Anthro	12960	7557	6640	49%	3872	42%	2362	39%	64%
	Natural	299	299	93	69%	93	0%	93	0%	0%
	Total	13258	7856	6733	49%	3965	41%	2455	38%	64%
Godfrey Creek	Anthro	3147	2000	2242	29%	1425	36%	625	56%	72%
	Natural	0	0	0	69%	0	0%	0	0%	0%
	Total	3147	2000	2242	29%	1425	36%	625	56%	72%
Jackson Creek	Anthro	2297	1317	1120	51%	642	43%	412	36%	63%
	Natural	176	176	55	69%	55	0%	55	0%	0%
	Total	2473	1493	1175	52%	697	41%	467	33%	60%
Reese Creek	Anthro	3046	1838	1640	46%	990	40%	574	42%	65%
	Natural	281	281	88	69%	88	0%	88	0%	0%
	Total	3326	2119	1727	48%	1077	38%	662	39%	62%
Rocky Creek	Anthro	3962	2557	2039	49%	1316	35%	799	39%	61%
	Natural	198	198	62	69%	62	0%	62	0%	0%
	Total	4159	2754	2100	50%	1377	34%	861	38%	59%
Ross Creek	Anthro	85	50	46	46%	27	40%	16	42%	65%
	Natural	0	0	0	69%	0	0%	0	0%	0%
	Total	85	51	46	46%	27	40%	16	42%	65%
Smith Creek	Anthro	1	1	1	49%	0	36%	0	39%	61%
	Natural	0	0	0	69%	0	0%	0	0%	0%
	Total	1	1	1	49%	0	36%	0	39%	61%
Stone Creek	Anthro	715	414	353	51%	204	42%	129	37%	63%
	Natural	212	212	66	69%	66	0%	66	0%	0%
	Total	928	626	419	55%	270	35%	196	28%	53%
Thompson Creek	Anthro	6	4	4	43%	2	34%	1	45%	63%
	Natural	0	0	0	69%	0	0%	0	0%	0%
	Total	6	4	4	43%	2	34%	1	45%	63%
Lower Bozeman Creek	Anthro	1763	1162	763	57%	503	34%	363	28%	52%
	Natural	413	413	129	69%	129	0%	129	0%	0%
	Total	2176	1575	892	59%	632	29%	492	22%	45%
Upper Bozeman Creek	Anthro	350	233	152	57%	101	33%	73	28%	52%
	Natural	40	40	12	69%	12	0%	12	0%	0%
	Total	389	273	164	58%	113	31%	85	25%	48%
Remaining Watershed	Anthro	62896	38897	31530	50%	19500	38%	12155	38%	61%
	Natural	2639	2639	825	69%	825	0%	825	0%	0%
	Total	65535	41536	32355	51%	20324	37%	12980	36%	60%
Lower Gallatin Watershed	Anthro	**100877**	**62143**	**50571**	**50%**	**31153**	**38%**	**19420**	**38%**	**62%**
	Natural	**4400**	**4400**	**1375**	**69%**	**1375**	**0%**	**1375**	**0%**	**0%**
	Total	**105278**	**66543**	**51946**	**51%**	**32528**	**37%**	**20795**	**36%**	**60%**

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