ROAD SEDIMENT ASSESSMENT & MODELING
LOWER GALLATIN RIVER TPA

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1.0 INTRODUCTION

This report presents a sediment load analysis and culvert assessment of the road network within listed watersheds of the Lower Gallatin River TMDL Planning Area (TPA). This assessment was performed as part of the development of sediment TMDLs for 303(d) listed stream segments with sediment as a documented impairment. Roads located near stream channels can impact stream function through degradation of riparian vegetation, channel encroachment, and sediment loading. The degree of impact is determined by a number of factors, including road type, construction specifications, drainage, soil type, topography, precipitation, and the use of Best Management Practices (BMPs). Through a combination of GIS analysis, field assessment, and computer modeling, estimated sediment loads were developed for road crossings and unpaved parallel segments. Existing road conditions were modeled and future road conditions were estimated after the application of sediment reducing Best Management Practices (BMPs). Existing culverts were also assessed for fish passage and failure potential.

The 2008 303(d) List includes the following stream segments for sediment / siltation impairment: Bear Creek, Camp Creek, Dry Creek, Godfrey Creek, Jackson Creek, Rocky Creek, Smith Creek, Sourdough (Bozeman) Creek, Stone Creek and Thompson Creek. These watersheds will be the focus of modeling efforts to quantify sediment loads. The Smith Creek watershed is subdivided into areas draining into Ross, Reese and Smith creeks.

2.0 DATA COLLECTION

The Lower Gallatin Sediment Assessment consisted of four primary tasks: 1) GIS summary of road crossings and statistics, 2.) field assessment and sediment modeling for crossings and parallel segments in sediment listed watersheds, 3.) sediment load calculations and load reduction allocations for sediment listed watersheds, and 4.) Traction sand assessment on paved road surfaces. The first task was completed by MDEQ and results are included in this report. Additional information on assessment techniques is available in the following prior reports for this project: *Road GIS Layers and Summary Statistics* (MDEQ 2010), and *Task 2. Sampling and Analysis Plan* (MDEQ 2010).

2.1 Spatial Analysis

Using road layers derived from the State of Montana Base Map Service Center Transportation Framework Theme and stream layers from the National Hydrography Dataset (NHD) high-resolution (1:24,000) flowline layer, crossings and parallel segments in the road network were identified and classified relative to 6^{th} code subwatershed, Level IV Ecoregion, ownership, and road surface type. Land ownership recorded in the cadastral database may not correlate with ownership / road maintenance responsibility. This was commonly observed in cases where county roads intersect private property. To address this, a GIS roads layer was downloaded from the Gallatin County website, which identifies the agency responsible for road maintenance. This Gallatin County layer was compared to the MDT roads layer to provide better information on road ownership. Ownership areas not included in the Gallatin County layer or listed as “To Be

Determined" were based off of Cadastral ownership. Five maintenance categories were included: USFS, State, County, City of Bozeman and Private. Maintenance categories were assigned after the field data collection.

All crossings were labeled automatically by GIS in Task 2 to include the 6th Code HUC name, Level IV Ecoregion, road surface type and site type (crossing or parallel segment). This will allow site names to be consistent within the GIS database and within all tables in this report. Crossing and parallel sites were named with the first two to three letters representing the 6th code HUC, the following three letters and numbers represents the Level IV Ecoregion, the following letter represents the road surface type (Paved, Gravel, or Native) and the final letter represents the site type (crossing, X, or parallel segment, P). The last three numbers were automatically assigned through GIS software to ensure that each site is unique.

An example of the naming convention is RCC-17g-G-X-108:

- RCC = Rocky Creek;
- 17g = Level IV Ecoregion 17g;
- G = Gravel road surfacing;
- X = Road crossing;
- 108 = Unique numerical identifier.

Using GIS, a random subset of 25 of the total 438 crossing sites (5.7%) was generated for field assessment based on the proportion of road surface types. Four sites were relocated during the field effort due to private ownership access limitations (gate), or due to dry stream channels. The goal of the field effort was to characterize approximately five percent of the road network.

A summary of road crossings in the Lower Gallatin River TPA is shown in **Table 2-1** and the field assessed crossing sites by maintenance ownership are shown in **Table 2-2.**

Table 2-1. Assessment Sites by Road Type

Road Class	Unpaved Crossings	Paved Crossings	Total Crossings	Number of Sites Randomly Selected with GIS	Number of Actual Field Assessed Sites (Crossing / Parallel)
Paved	-	105	105	7	4* / 0
Gravel	277	-	277	13	14 / 4
Native	56	-	56	5	6 / 2
Total	**333**	**105**	**438**	**25**	**24 / 6**
*Three additional paved crossings were visited but were deemed of negligible sediment contribution.					

Table 2-2. Assessment Sites by Maintenance Ownership

County	County	County	Private
BC-17g-G-X-34	DC-17w-G-X-353	DC-P-5	LJC-17i-N-X-204
BZC-17w-P-X-62[A]	DC-17w-G-X-383	DC-P-6	REC-17w-G-X-308
BZC-17w-P-X-63[A]	DC-17w-G-X-389	DC-P-7	TC-17w-G-X-432
CC-17w-G-X-242	DC-17w-G-X-399	**City**	LJC-P-3
CC-17w-G-X-249	DC-17w-G-X-410	BZC-17w-P-X-167[A]	RCC-P-4
CC-17w-N-X-219	GC-17w-G-X-172	**Federal**	**State**
CC-17w-N-X-231	LJC-17w-X-160[B]	LJC-17i-N-X-223	GC-17w-P-X-230
CC-17w-N-X-247	REC-17w-G-X-323	RCC-17g-G-X-38	RCC-17g-G-X-108
DC-17w-G-X-335	DC-P-1		REC-17w-X-324
[A] Paved site determined to have negligible sediment load [B] GIS error, site name should read LJC-17w-**P**-X-160			RSC-17w-X-304

Parallel road segments were identified as areas where roads encroach upon the stream channel, and total road lengths within 150-foot stream buffer zones were generated. There is a total of 60 miles of unpaved parallel road segments within 150 feet of stream channels. Parallel sites were named in the field with the abbreviated HUC name and a unique number.

2.2 Field Data Collection

A total of twenty four (24) road crossings and six (6) parallel segments were evaluated in the field (**Figures 2, 3, Attachment B, and D**). Three additional paved road crossings were visited and were deemed to contribute negligible sediment.

In the field, parallel segments were selected based on best professional judgment while traveling roads on which specific crossings were selected for assessment. Parallel segments were evaluated on gravel or native surfaced roads.

Traction sand was also assessed on paved crossings and parallel segments. Sites are shown in **Figure 4**.

2.3 Sediment Assessment Methodology

The road sediment assessment was conducted using the WEPP:Road forest road erosion prediction model (http://forest.moscowfsl.wsu.edu/fswepp/). WEPP:Road is an interface to the Water Erosion Prediction Project (WEPP) model (Flanagan and Livingston, 1995), developed by the USDA Forest Service and other agencies, and is used to predict runoff, erosion, and sediment delivery from forest roads. The model predicts sediment yields based on specific soil, climate, ground cover, and topographic conditions. Specifically, the following model input data was collected in the field: soil type, percent rock, road surface, road design, traffic level, and specific road topographic values (road grade, road length, road width, fill grade, fill length, buffer grade, and buffer length). In addition, supplemental data was collected for evidence of erosion from the road system or traction sand, the presence of road BMPs, and potential for fish passage and culvert failure.

Site specific climate profiles were created using data from the Western Regional Climate Center (http://www.wrcc.dri.edu). Climate stations within the Lower Gallatin TPA encompass a wide range of annual precipitation, with quantities ranging from 11.56 to 34.62 inches per year. The sites assessed in the field ranged in precipitation from 13.45 inches to 39.21 inches. The individual sites were divided into three climate stations that best described the elevation and precipitation at the specific road crossing or parallel segment (**Table A-1)**. Due to the elevation difference and impact from rain-on-snow events, the medium precipitation class produces greater runoff than the higher elevation and higher precipitation class.

Per WEPP:Road documentation, 30 year simulations were run for road crossings and parallel segments within the Bozeman 12NE climate station since the quantity of precipitation exceeded 500 millimeters (19.69 inches). Fifty (50) year simulations were run for crossings and parallel segments within the Belgrade Airport and Bozeman Montana State University climate stations.

Some road conditions encountered in the field are not accurately represented in the WEPP:Road design options; as a result, some adjustments were made to the model to more appropriately represent these types of roads. **Attachment C** contains a description of model or site condition adjustments, as recommended by WEPP:Road technical documentation, the model author or by best professional judgment. **Attachment C** also includes a summary of each climate station model.

2.4 Field Adjustments

Field conditions required that a number of sites be moved to different locations due to lack of access (landowner permission, road condition, or accessibility by vehicle). In the *Task 2-Sampling and Analysis Plan*, twenty-five stream crossing field sites were identified. Parallel segments were not identified prior to the field assessment. The resulting twenty-four crossings and 6 parallel (30 total) assessment sites were selected in the field as shown in **Table A-3** and in **Figures 2 and 3**. One site was added on Bear Canyon Creek Road that was not selected randomly and is further discussed in Section 2.6. The results from this site were not used in the extrapolation process; however, the culvert was included in fish crossing and failure potential analysis.

2.5 Mean Sediment Loads from Field Assessed Sites –Stream Crossings

Field assessment data and WEPP:Road modeling results were used to develop existing sediment loads based on various watershed criteria. A standard statistical breakdown of loads from the road network within each sediment-listed watershed was generated using the applicable dataset of field assessed crossing and parallel sites. Mean sediment load and contributing length, median load, maximum and minimum loads, and 25^{th} and 75^{th} percentile loads were calculated for road crossings within each road surface type that was the basis of the field assessment. Mean sediment loads from road crossings were estimated at 0.20 tons/year on native surfaced roads, 0.34 tons/year on gravel roads, and 0.03 tons/year on paved roads (**Table 2-3**). Paved roads are further discussed in Section 2.6.

Table 2-3. Sediment Load Summary for Field Assessed Crossings by Road Surface

Statistical Parameter	Native	Gravel	Paved	Total of Field Assessed Crossings
Number of Sites (n),	6	13[A]	4[B]	23
Mean Contributing Length (ft)	735.5	641.2	805.0	
Mean Load (tons/year)	0.20	0.34	0.06[B]	
Median Load (tons/year)	0.08	0.14	0.03	
Maximum Load (tons/year)	0.67	0.98	0.17	
Minimum Load (tons/year)	0.00	0.00	0.00	
25th Percentile (tons/year)	0.05	0.04	0.01	
75th Percentile (tons/year)	0.19	0.48	0.07	

[A] Site BC-17g-G-X-34 is not included.
[B] Three more paved crossings were visited in the field but deemed of negligible sediment contribution. Including these three sites, the mean load is reduced to **0.03 tons/year.**

The annual sediment loads shown in Table 2-3 are a function of the predicted average annual runoff as a result of elevation and annual precipitation at each crossing as shown in **Tables 2-4 and 2-5**. Listed HUCs were subdivided based on high, medium and low precipitation quantities, in similar categories to the climate stations (**Table A-1**):

- High Precipitation Class: 26 – 40 Average Annual Inches;
- Medium Precipitation Class: 16 – 25 Average Annual Inches; and
- Low Precipitation Class: 13 – 15 Average Annual Inches.

These precipitation quantities are used to extrapolate average sediment loads across road surface type in each listed watershed.

Table 2-4. Sediment Load Summary for Field Assessed Native and Gravel Crossings by Precipitation Class and Road Surface

Statistical Parameter	High Precip Native	Medium Precip Native	Low Precip Native	High Precip Gravel	Medium Precip Gravel	Low Precip Gravel
Number of Sites (n)	2	-[A]	4	3[B]	4	6
Mean Contributing Length (ft)	645	645	781	594	728	675
Mean Load (tons/year)	0.36	0.48	0.08	0.37	0.55	0.17
Median Load (tons/year)	0.36	0.48	0.07	0.14	0.65	0.12
Maximum Load (tons/year)	0.67	0.89	0.19	0.98	0.88	0.42
Minimum Load (tons/year)	0.05	0.06	0.00	0.00	0.04	0.02
25th Percentile (tons/year)	0.20	0.27	0.04	0.07	0.37	0.05
75th Percentile (tons/year)	0.51	0.69	0.11	0.56	0.83	0.27

[A] The random selection of sample sites did not include crossings in the Medium Precip Class for native surfaces. The two sites that were assessed in the High Precip Class were modeled with WEPP:Road under the Medium Precip Climate Station.
[B] Site BC-17g-G-X-34 is not included.

Table 2-5. Sediment Load Summary for Field Assessed Paved Crossings by Precipitation Class and Road Surface

Statistical Parameter	High Precip Paved	Medium Precip Paved	Low Precip Paved
Number of Sites (n)	1	2	1
Mean Contributing Length (ft)	1000	310	1000
Mean Load (tons/year)	0.17	0.02	0.02
Median Load (tons/year)	0.17	0.02	0.02
Maximum Load (tons/year)	0.17	0.04	0.02
Minimum Load (tons/year)	0.17	0.00	0.02
25th Percentile (tons/year)	0.17	0.01	0.02
75th Percentile (tons/year)	0.17	0.03	0.02

The sediment load summary shows similar values between the median and mean statistics. This is most likely due to the low sample numbers in each precipitation class. Due to the similar values for the gravel sites and native sites for high and medium precipitation classes, the mean load will be averaged for unpaved roads in those precipitation classes. This will result in the following values:

- Unpaved high precipitation class: 0.37;
- Unpaved medium precipitation class: 0.53; and
- Native low precipitation class: 0.08
- Gravel low precipitation class: 0.17

Based on the lack of sediment delivery from three out of the seven assessed paved crossing sites and the low sample numbers within each precipitation class, the extrapolated load will be based on the mean annual sediment load from all seven paved crossings. This was listed in **Table 2-3** as 0.03 tons/year**.**

For the purposes of estimating the sediment load from each road crossing in the Lower Gallatin River TPA, the average of all field sites by road type and precipitation class assumes that the random subset of crossings assessed as part of this study is representative of road crossing conditions in the TPA.

2.6 Additional Assessment of Bear Canyon Creek Stream Crossing

There was one crossing (BC-17g-G-X-34) that was not randomly selected according to the *Task 2. Sampling and Analysis Plan* (MDEQ 2009), but was purposely assessed in the field due to the listed sediment impairment from road-related sediment in Bear Canyon Creek and due to the minimal number of overall crossings. The specific site was chosen due to field observations during the sediment and habitat assessment field work. Bear Creek Canyon is a listed stream with only six total road crossings. This area is heavily used for recreation; the United States Forest Service closed motorized access to much of the upper watershed and will likely reopen access in the future to recreational vehicles. The model results from BC-17g-G-X-34 are elevated and warrant further discussion; however, this crossing was not included in the dataset used for extrapolation. The site location is shown in the following two photographs.

Photograph 1. BC-17g-G-X-34 View from Crossing Looking Upgradient

The long road contributing length, steep fill slope and lack of a buffer indicated that the road would have an elevated annual average sediment load. Half of the road width was modeled in order to separate the parallel segment and the road crossing sediment quantity. This result is slightly higher but similar to the randomly chosen dataset for high precipitation, gravel surfaced roads (**Table 2-4**, 0.98 tons/year maximum load).

2.7 Sediment Loads from Field Assessed Sites – Paved Stream Crossings

Seven paved crossings were assessed as part of the field effort. Of the seven sites, three were in the Bozeman Creek watershed and had existing curbs or grass berms to prevent sediment from entering Sourdough (Bozeman) Creek. The remaining four sites were located in Bozeman Creek, Lower Jackson Creek, Godfrey Creek, Ross Creek and Reese Creek watersheds. Each site had heavily vegetated swales as shown in the photographs below.

Photograph 2. Vegetated ditch on RSC-17W-P-X-304

Photograph 3. Vegetated ditch on GC-17W-P-X-230

The WEPP Forest Road model allows for a paved surface option. Four of the seven field sites were assessed for WEPP:Road variables (as shown in **Attachment D**). The results of the four sites are summarized below in **Table 2-6.**

Table 2-6. WEPP:Road Results for Assessed Paved Sites

WEPP:Road Input variables and Results	GC-17W-P-X-230	LJC-17W-P-X-160	REC-17W-G-324	RSC-17W-X-304
Road Design	Outsloped, unrutted	Insloped, vegetated ditch	Outsloped, unrutted	Insloped, vegetated ditch
Precipitation Class	Low	High	Medium	Medium
Contributing Length (ft)	1000	1000	20	60
Mean Road Gradient (%)	<1	6.5	4	0.5
Mean Fill Length (ft)	1	1	7	1
Mean Fill Gradient (%)	42	80	100	27
Mean Buffer Length (ft)	11.75	86.5	1	8
Mean Buffer Gradient (%)	42	20	0.3	27
Mean Sediment Load (tons/year)	0.02	0.17	0.004	0.04

It may be observed that the overall sediment contribution from paved roads is low; except for the crossing modeled in the high precipitation class with a long contributing road length and steep gradient. The annual sediment load from site LJC-17W-P-X-160 with out model adjustments, had the highest sediment load of all assessed sites, both paved and unpaved (2.8 tons/year).

WEPP:Road guidance on paved roads is included below.

> *A paved road greatly decreases road surface erosion, but increases the runoff. Increased runoff from the road surface can cause increased erosion on fillslopes, ditches, and flow paths leading from the road to the forest. Sediment eroded on the fillslopes is more likely to be transported to streams with the increased runoff from a paved road.*
>
> *Paved roads show the best benefit on outsloped roads, or roads with armored ditches with minimal buffers. They are least beneficial on scenarios with insloped roads, or roads a moderate distance from the stream. On roads a long way from the stream, it makes little difference what the road treatment is, as all of the runoff is absorbed by the forest, and hence most of the sediment from the road prism is deposited in the buffer.*

Per review of the photographs and discussions between WET and MDEQ field team members, the results appear to be elevated. Site LJC-17W-P-X-160 consisted of two segments (from the south and from the northwest) contributing to a crossing in the low point of the road. Evidence of erosion and scour was noted in the field on the south side of the contributing length at the slope break between the ditch, fillslope and buffer. This contributing length resulted in 0.15 tons/year annual average sediment load. The contributing length from the northwest did not show evidence of scour or sediment deposits on the buffer length; however, the model results from this segment contributed 2.65 tons/year average annual sediment load. Due to the site conditions and lack of evidence of 2.8 tons/year sediment erosion, the segment from the North West was modeled as an outsloped, unrutted road design. This reduced the total sediment load from this site to 0.17 tons/year. Even with these model changes, the site continues to be the highest contributor of sediment of the four assessed paved crossings; however, the results better reflect actual site conditions.

Photograph 4. Site LJC-17W-P-X-160 view to North West

Photograph 5. Site LJC-17W-P-X-160 view to South

2.8 Mean Sediment Loads from Field Assessed Sites – Parallel Segments

Mean sediment loads were calculated for parallel road segments, and loads were then normalized to a per-mile value to account for differences in contributing road length. Parallel segments were only assessed for native and gravel surfacing types. Mean sediment loads from unpaved parallel road segments were estimated at 0.06 tons/year/mile on gravel roads and 0.08 tons/year/mile on native roads (**Table 2-7**). Parallel sites were either evaluated at the delivery point (cross drain) or as a random sampling at set distances. The results were summed for a delivery point and averaged across the set distances so that there was one load value for each parallel segment. A summary of modeling results from field assessed sites is located in **Attachment D**.

Table 2-7. Sediment Load Summary from Unpaved Field Assessed Parallel Sites

Statistical Parameter	Native	Gravel
Number of Sites (n)	3	3
Mean Contributing Length (ft)	791	764
Mean Road Gradient (%)	5.0	3.6
Mean Buffer Length (ft)	115	48.3
Mean Buffer Gradient (%)[A]	25.3	2.3
Mean Load (tons/year/mile)	0.08	0.06
Median Load (tons/year/mile)	0.08	0.03
Maximum Load (tons/mile/ year)	0.10	0.16
Minimum Load (tons/year/mile)	0.07	0.02

Paved parallel segments were not assessed with the field effort. The contribution was determined from the average of paved crossings from Table 2-3, and the gravel and native parallel segments from Table 2-7. Based on the results between paved and unpaved road crossing results, it was more representative to include the paved crossing average sediment contribution in the calculation even though these units were not per mile.

$$\text{Average Sediment Contribution} = \frac{0.03 + 0.06 + 0.08}{3} = 0.06 \text{ tons per year per mile}$$

For the purposes of estimating the sediment load from each parallel segment in the Lower Gallatin River TPA, the average of all field sites by road type assumes that the random subset of crossings assessed as part of this study is representative of the parallel segment conditions in the listed watersheds.

2.9 Paved Roads – Traction Sand

Traction sand was visually assessed in the field at seven sites. Findings are classified as:

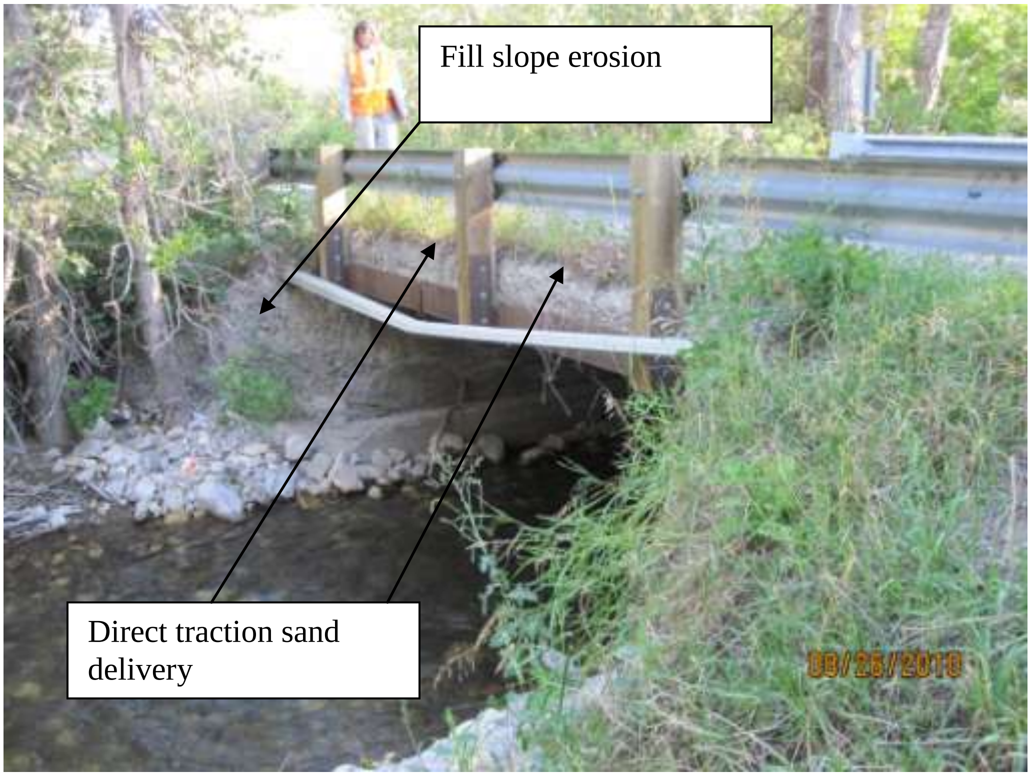
1.) City of Bozeman; and
2.) Interstate 90.

City of Bozeman
Per telephone conversation with the City of Bozeman Streets Department, 3,500 to 5,000 tons per year of traction sand is applied in and near the city streets. The traction sand is applied mostly to troubled traffic areas and to intersections. The City of Bozeman maintains 218 miles

of streets and alleys and includes these areas in the street sweeper program. Using these estimates, approximately 16 to 23 tons/mile/year is applied in the populated areas.

Due to the late summer field assessment and a comprehensive street sweeper program, traction sand accumulation in the City of Bozeman was negligible. The majority of crossings had curbs and / or storm water infrastructure installed to limit delivery; however, a few sites were observed to have direct delivery from a bridge surface (**Photograph 7**).

Photograph 6. Example of Curb on Bridge – Sourdough Creek



Photograph 7. Example of Traction Sand Direct Delivery from Bridge Surface

I-90

The Montana Department of Transportation provided data to calculate that an average of 67 yard^3 per lane mile (87 tons/lane mile/year or 348 tons/mile/year[A]) were applied over the past three seasons for the section from mile markers 288 to 323. The department is employing best management practices to reduce sand application. The current model is to effectively use a deicer / traction sand mix. Since 2008, traction sand application has decreased approximately 14% with the increased usage of deicer.

In order to determine traction sand contributions per HUC for the Lower Gallatin River watershed, the GIS database was queried for paved parallel road lengths within 150 feet of streams. The distance to surface water was not further refined into smaller increments due to the inherent inaccuracies between the GIS road and stream layers.

The field assessment focused on the listed watersheds between Bear Creek and Rocky Creek on I-90. Traction sand was measured at several distances from the shoulder of the road.

Field results were compared to the traction sand assessment performed in the St. Regis TPA report (MDEQ, 2008). Both highways are four-lane roads maintained by MDT. The traction sand application rate as provided by MDT in the TPA is near the mean annual traction sand application rates along Interstate 90 between Saltese and St. Regis and the rates are

[A] Bulk density 1.3 tons per cubic yard (Traction Sand MSDS, 2006) approximately 70% lower than those provided between Lookout Pass and Saltese (Table K-2 in MDEQ, 2008). The St. Regis TMDL results had an average fill slope of 45%; the furthest distance traveled at each site was observed at a minimum (25 feet), mean (33 feet) and maximum (45 feet) from the shoulder. Depths of traction sand in the St. Regis study varied from 7.9 inches to unobservable. Results from crossings in the Lower Gallatin are described in **Table 2-8.**

Table 2-8. Lower Gallatin TPA Traction Sand Assessment Results

Site (East or West Bound)	Fill Slope (%)	Distance from Road Surface (ft)	Depth (inches)
RCC-17g-G-X-84	57	9	2.25
RCC-17W-P-X-74 EB	46.5	14.5	1 inch
RCC-17W-P-X-74 EB	46.5	25 near culvert	1-2 inches above rock
RCC-17W-P-X-90	92	20	minimal
RCC-17W-P-X-80 WB	71	35	1 inch
RCC-17W-P-X-74 WB	Not Assessed	45	Minimal
RCC-17W-P-X-120 WB	1.5	15	Minimal

These results corroborate the findings in the St. Regis study regarding the distance of travel. All of the sites near I-90 had evidence of recent chip sealing activities. Traction sand was deposited on top of the excess chip seal indicating at least one winter has passed since the road resurfacing. The deposition of excess chip seal may have impacted traction sand mobility due to larger particles on the fill slope surface (**Photograph 8**) and due to the creation of berms on the road shoulders (**Photograph 10**).

Photograph 8. Chip Seal and Traction Sand Material at RCC-17W-P-X-74 EB

Photograph 9. Depth of Traction Sand at RCC-17W-P-X-80

Photograph 10. Chip Seal at Guardrail and Berm near RCC-17W-P-X-80 West Bound

Photograph 11. Vegetation above RCC-17g-P-X-90 West Bound

Many of the fill slope lengths and buffer lengths were greater than the extent of the traction sand travel distance as noted in the field. Although there will be periodic loading of traction sand, based on the measurements in the field, it will not be a significant source of sediment in the watersheds. As a result, sediment loads from traction sand were not included in the load analysis..

3.0 ROAD NETWORK LOAD ANALYSIS

The annual mean sediment loads for field assessed road crossings and parallel segments were extrapolated to all sites in sediment listed watersheds to determine the total sediment load in the TPA. Results indicate that the greatest sediment load is produced from County-maintained road crossings due to the large quantity of unpaved county roads compared to other road types (**Tables A-5** and **A-6**).

A fish passage evaluation was completed for field-assessed culverts using the criteria listed in Table 1 of the document *A Summary of Technical Considerations to Minimize the Blockage of Fish at Culverts on National Forests in Alaska* (USFS, 2002). Few culverts passed the fish passage evaluation due to steep culvert gradients. Culvert failure potential was also evaluated using USGS 2004 regression equations. Based on basin characteristic equations, culverts appear to be sized for the Q10 storm event.

3.1 Sediment Load from Road Crossings and Parallel Segments-Extrapolation to Watershed Scale

Mean sediment loads from field assessed sites were used to extrapolate existing loads throughout the sediment-listed watersheds. Crossing load with road surface types within specific precipitation classes were applied to the total number of crossings within the specific watersheds, and further classified by 6th code HUC and land ownership. The existing total sediment load from road crossings for listed watersheds within Lower Gallatin River TPA is estimated at 119.12 tons/year, and the total existing load from parallel road segments is estimated at 3.81 tons/year (**Table 3-1**). Paved crossings and parallel segments were not further classified into precipitation classes due to the overall low number of samples sites (seven and six respectively).

Table 3-1. Extrapolated Sediment Load Summary from Road Crossings and Parallel Segments– Existing Conditions

Road Feature	Road Surface – Precipitation Class	Total Number of Crossings	Mean Sediment Load (Tons/year)	Total Sediment Load (Tons/year)
Crossing	Paved - L, M, & H	105	0.03	3.15
Crossing	Unpaved – H	97	0.37	35.89
Crossing	Unpaved - M	112	0.53	59.36
Crossing	Native - L	4	0.08	0.32
Crossing	Gravel - L	120	0.17	20.40
Total:		**438**		**119.12**
Road Feature	**Landscape Type**	**Total Parallel Distance w/in 150-feet (Mi)**	**Mean Sediment Load (Tons/year/mile)**	**Total Sediment Load (Tons/year)**
Parallel	Paved – L, M, & H	8.50	0.06	0.51
Parallel	Gravel – L, M, & H	37.37	0.06	2.24
Parallel	Native – L, M, & H	14.23	0.08	1.14
Total:		**22.8**		**3.89**
Total Existing Sediment Load – Listed Lower Gallatin River TPA watersheds:				**123.01**

Detailed sediment loads for road crossings classified by ownership, precipitation class and road surface type within each 6th code/303(d) subwatershed are included in **Tables A-5 and A-6**. Detailed sediment loads for parallel segments classified by ownership and landscape type within each 6th code/303(d) subwatershed are included in **Tables A-7 and A-8**.

3.2 Sediment Load Analysis from Road Crossings

Road crossing results showed that Dry Creek (31.28 tons/year), Rocky Creek (20.62 tons/year) and Camp Creek (22.71 tons/year) HUCs contained the three highest sediment loads from road crossings (**Table A-6**). This was due to the large number of crossings in each watershed, as well as the higher precipitation classes present in the Rocky Creek HUC. The total number of crossings was as follows: Dry Creek (81), Rocky Creek (66) and Camp Creek (104 crossings).

3.3 Culvert Assessment – Fish Passage

Culverts were analyzed for their ability to allow for fish passage. Measurements were collected at each field assessed crossing site, and these values were used to determine if culverts represented potential fish passage barriers at various flow conditions. Of the 24 field assessed road crossing sites, sites with bridges, sites with intermittents or ephemeral channels, and any other sites where the required screening data could not be accurately collected, were removed from the dataset. After removing these sites, fifteen (15) culverts were determined to be suitable for fish passage assessment. The nine crossings that could not be assessed for fish passage were due to: dry channel (4), the lack of a culvert (2 crossings), the culvert slope could not be determined (culvert plugged, 1 crossing), or the presence of a bridge (2 crossings).

The fish passage evaluation was completed using the criteria listed in Table 1 of the document *A Summary of Technical Considerations to Minimize the Blockage of Fish at Culverts on National Forests in Alaska* (USFS, September 27, 2002). The analysis uses site-specific information to classify culverts as green (passing all lifestages of salmonids), red (partial or total barrier to salmonids), or grey (needs additional analysis). Indicators used in the classification are the ratio of the culvert width to bankfull width (constriction ratio), culvert slope, and outlet drop, with large (>48-inches) and small (<48-inches) culvert groups evaluated differently. Failure of any one of the three indicators results in a red classification. Using the Alaska fish passage analysis, 13 of 15 culverts (87%) were classified as partial or total fish barriers (red), and 2 of 15 (13%) were classified as needing additional evaluation (grey). None of the field assessed culverts were classified as capable of passing fish at all flows and life stages (**Table 3-2, Table A-9**). The predominant cause for preventing fish passage was (relatively) steep culvert gradient. It is important to note that this fish passage assessment is a coarse level evaluation; further study may be necessary to more accurately determine fish passage conditions.

Table 3-2. Fish Passage Analysis for Selected Culverts Using Alaska Region Criteria

Culvert Classification or Indicator	Definition of Indicator	Number of Culverts	Percentage of Total Culverts Assessed (n = 15)
Green	High certainty of meeting juvenile fish passage at all flows	0	0%
Grey	Additional and more detailed analysis is required to determine juvenile fish passage ability	2	13%
Red	High certainty of not providing juvenile fish passage at all desired stream flows	13	87%

3.4 Culvert Assessment – Failure Potential

Each culvert with available data was evaluated to determine peak flow capacity using USGS regression equations as presented in the USGS Water-Resources Investigation Report 03-4308, *Methods for Estimating Flood Frequency in Montana Based on Data through Water Year 1998*, and flow estimates using Manning's equation. Using the regression equations, peak discharge flows were developed for the 2-, 5-, 10-, 25-, 50-, and 100-year recurring intervals for each selected culvert. Montana is divided into eight hydrologic regions, with a unique set of equations developed for each region. The Lower Gallatin River TPA is located in the Upper Yellowstone-Central Mountain Region, and independent variables within these equations are drainage area (square miles) and percentage of drainage basin above 6000 feet elevation (percentage). Drainage area above each culvert was calculated using a digital elevation model (DEM) and the ArcSwat extension in GIS.

Using site-specific culvert information collected in the field (including culvert dimensions and slope) a peak flow was also calculated using Manning's equation. Variables in Manning's equation are culvert cross sectional area, hydraulic radius, slope, and roughness coefficient (based on culvert material). The peak flow calculated using Manning's equation was compared with USGS regression equation values to estimate the maximum storm event that each culvert could convey without water backup. Nineteen (19) culverts were analyzed for failure potential. The number of culverts passing each specific storm event is shown in **Table 3-3** and **Table A-10**.

Table 3-3. Percent of Culverts Passing Design Storm Events

Design Storm Event	Number of Culverts Passing	Number of Culverts Failing Design Flow	Cumulative Percent Passing
Total Culverts	19		100%
Q2	19	0	100%
Q5	17	2	89%
Q10	13	6	68%
Q25	6	13	32%
Q50	1	18	5%
Q100	0	19	0%

Potential road fill volume at risk for delivery in the event of a culvert failure was calculated using field measurements of the road prism over the culvert. The volumes calculated are conservatively, assuming that the entire road prism above the culvert fails to bankfull width and is delivered to the stream, which will likely not always be the case. In some instances only part of the road fill may be delivered, and in other cases water may simply overtop the road and the culvert will stay intact If bankfull width was not available due to the lack of a channel then twice the width of the culvert diameter was used. In the instances of multiple culverts, the width of the culverts plus one half of the diameter on each side was used as the road prism width. Bulk density was assumed to be 1.3 tons/yd^3 for all sites[B]. Results show an average of 61.9 tons of fill at risk per road crossing (**Table A-10**).

It is difficult to develop a specific road crossing allocation for sediment delivered in the event of a culvert failure, as there are several factors that may impact the accuracy of the data. First, peak flows generated using the USGS regression equations are subject to large standard errors that may substantially over or underestimate peak discharge. In addition, peak flows generated using Manning's equation rely heavily on culvert slope. Slope values measured during field activities were estimated by measuring the height of a laser beam from a laser pointer and level on one side of the culvert to a tape measure on the other side of the culvert. When the culvert was submerged, plugged or experiencing high flows, the slope was estimated by using a handheld inclinometer from the top of the culvert. Visual estimates were recorded where access or use of an inclinometer was not possible. Variations in slope estimates may lead to differences in peak flow calculations. Second, the culvert assessment was conducted on a small subset of culverts,

[B] Caterpillar ®Performance Handbook, 2002. Peoria, IL, Bank density of Earth Loam, page 26-4, October, 2002.

which may or may not be representative of the sediment-listed watersheds Lower Gallatin River TPA. Third, it is difficult to estimate which culverts will fail in any given year, and what percentage of at-risk fill material will be delivered to the stream.

Due to these difficulties in sediment delivery estimation, a 25% probability of culvert failure was assigned in **Table A-11**. The annual potential sediment delivery is calculated based on the average fill at risk multiplied by the number of crossings multiplied by the frequency of failure based on the storm recurrence interval and the 25% probability. This probability assumes that large storm events (>Q25) occur annually across a quarter of the watershed area and that the fill at risk is replaced soon after a failure with the same culvert size and slope.

4.0 APPLICATION OF BEST MANAGEMENT PRACTICES

Sediment impacts are widespread throughout the listed watersheds in the Lower Gallatin River TMDL Planning Area, and sediment loading from the road network is one of several sources within the watershed. Application of Best Management Practices (BMPs) on the road network will result in decreased sediment loading to streams. BMP sediment reduction was evaluated for unpaved road crossings only. Due to the overall minimal contribution from paved crossings and from parallel segments (each approximately 3% of the total sediment load); BMP reduction scenarios were not developed.

The selected scenario for estimating sediment load reductions was calculated by assuming regular maintenance of the roads to prevent rutting for County, City, and State maintained road networks. A road length reduction was assumed for Federal and Private maintained road networks. A road length reduction represents the installation of water bars, drive through dips, or similar BMP at the designated road length.

Due to the extent of the road network and the resulting inability to assess it in its entirety, generalized assumptions are necessary for modeling the effects of BMPs. Restoration efforts would need to consider site-specific BMPs that, on average, would likely be represented by the modeling assumptions.

4.1 BMP: Road Maintenance Scenario

Based on discussions with the Gallatin County Road Department, regular road maintenance is the BMP most commonly used by Gallatin County. Gallatin County blades and re-grades gravel roads on average biannually (twice per year) or bimonthly depending on the condition. Native roads are resurfaced at most biannually. The City of Bozeman Street Department also similarly maintains their gravel roads on an as-needed basis.

A road maintenance scenario was selected to incorporate regular maintenance, which effectively reduces the length of time of road rutting for unpaved road crossings under City, State of Montana, or County maintenance responsibility. This BMP scenario is represented in the model through the upgrade of rutted roads to an insloped, vegetated road design. Results are included in

Attachment E. This scenario was extrapolated for all roads maintained by the State of Montana, Cities, Gallatin County and Park County. Although the unrutted maintenance level may not be achievable on all roads at all times; an equivalent reduction in sediment loading may be achieved through other BMPs such as water bars, cross drains, or check dams in the road ditches. These additional BMPs were not modeled and would require assessment on an individual basis.

Extrapolated summary load reductions by road surface type and precipitation class are shown in **Table 4-1**.

4.2 BMP: Road Length Reduction Scenario

Roads under private or Federal (USFS) ownership were modeled with a contributing road length reduction scenario. Road lengths were reduced to 200 feet (100-feet on each road for a crossing with two contributing road segments or 200 feet on crossings with one contributing segment) for all crossing locations in excess of this length reduction scenario. No changes were made to crossings where the contributing road length was less than the 200-foot BMP reduction scenario.

The 200-foot BMP scenario was evaluated using the WEPP:Road model, so potential sediment load reductions could be estimated. The model assumes that the contributing length above the BMP does not discharge into the ditch next to the road. Thus BMPs would have to include a break in runoff along the road and ditch surface. One example would be a water bar or drive through dip with a ditch sediment detention basin. There were five private or Federal unpaved crossings assessed in the field. . Of the five crossings, three had road lengths in excess of 200 feet. The overall average annual sediment load per crossing changed dramatically: 0.15 tons/year to 0.02 tons/year with the road length reduction. The results are heavily influenced from LJC-17i-N-X-204 which had a field road length of 1000 feet. Due to this influence, the percentage change from each of the five crossings (0%, 0%, 98%, 49% and 50%) were averaged to estimate the percentage improvement of BMPs on private and Federally maintained roads (39%). The averaged percentage improvement for the two Federally maintained sites equated to 25%. The road length reduction scenario results are included in **Attachment F**.

Extrapolated summary load reductions by road surface type and precipitation class are shown in **Table 4-1**. Paved crossings and parallel segments each contributed approximately three percent to the overall sediment contribution from unpaved roads; as a result, BMP reduction scenarios were not developed.

Table 4-1. Extrapolated Sediment Load Summary from Unpaved Road Crossings

Ownership-Road Surface – Precipitation Class	Total Number of Sites	Existing Conditions Mean Sediment Load (Tons/year)	BMP Conditions Mean Sediment Load (Tons/year)	Total Sediment Load (Tons/year)	Load Reduction (%)
City, County & State Maintenance Ownership – Insloped, Vegetated Road Design					
Unpaved – H	20	0.37	0.26	5.20	30%
Unpaved - M	88	0.53	0.43	37.84	19%
Native - L	2	0.08	0.04	0.08	50%
Gravel - L	112	0.17	0.15	16.80	12%
Federal and Private Maintenance Ownership – Road Length Reduction					
Unpaved – H	77	0.37	0.22	17.26	39%
Unpaved - M	24	0.53	0.32	7.71	39%
Native - L	2	0.08	0.05	0.10	39%
Gravel - L	8	0.17	0.10	0.82	39%
Total:	**333**			**85.81**	**26%**

Total sediment load from unpaved road crossings would be reduced from 115.97 tons/year to 85.81 tons/year (26% reduction), assuming all sites were fully BMP'd.

Estimated total sediment load reductions for crossings were also classified by 6th code HUC/303(d) watershed, ownership and precipitation class assuming all sites were fully BMP'd (**Table A-12**). Results by HUC are shown in **Table 4-2**.

Table 4-2. Percent Sediment Reduction per HUC: BMP Reduction Scenarios for Road Crossings

Sediment Listed USGS HUC 12	Annual Sediment Load (tons/year)	Road Length Reduction Annual Sediment Load (tons/year)	Load Reduction (%)
Bear Creek	1.02	0.7	31%
Bozeman Creek	8.65	6.26	28%
Camp Creek	22.71	18.89	17%
Dry Creek	31.28	25.17	20%
Godfrey Creek	5.75	4.77	17%
Lower Jackson Creek	15.29	9.39	39%
Reese Creek	6.09	4.59	25%
Rocky Creek	20.62	13.12	36%
Ross Creek	3.79	3.06	19%
Smith Creek	0.03	0.03	0%
Stone Creek	2.25	1.35	40%
Thompson Creek	0.71	0.58	18%
Upper Bozeman Creek	0.93	0.68	27%
Total	**119.12**	**88.59**	**26%**

4.3 Summary of Total Loads and Potential Reductions

Each potential sediment source from roads: crossings, parallel segments, and culvert failure, is summarized in **Table 4-3** and **A-13**. The potential sediment loads as modeled with the WEPP:Road software were extrapolated to the total number of crossings and parallel segments within each sediment listed 6th code subwatershed (USGS HUC 12). The overall sediment reduction, including no BMP improvement to parallel segments and paved crossings, is 24%.

Table 4-3. Total Annual Sediment Load and Potential BMP Percent Reduction

6th Code Subwatershed (USGS HUC 12)	Total Annual Sediment Load Crossings (t/y)	Total Annual Sediment Load Parallel Segments (t/y)	Sum (Crossings and Parallel Segments)	Sum with All Available Sediment Reductions (t/y)	Percent Reduction (%)
Column #	**1**	**2**	**3**	**4**	**5**
Bear Creek	1.02	0.28	1.3	0.98	25%
Bozeman Creek	8.65	0.18	8.72	6.44	26%
Camp Creek	22.71	0.46	23.15	19.35	16%
Dry Creek	31.28	0.85	32.13	26.02	19%
Godfrey Creek	5.75	0.22	5.85	4.99	15%
Lower Jackson Creek	15.29	0.52	15.72	9.91	37%
Reese Creek	6.09	0.05	6.11	4.64	24%
Rocky Creek	20.62	0.79	21.22	13.91	34%
Smith/Ross Creeks	3.82	0.03	3.85	3.12	19%
Stone Creek	2.25	0.09	2.33	1.44	38%
Thompson Creek	0.71	0.02	0.72	0.6	17%
Upper Bozeman Creek	0.93	0.40	1.27	1.08	15%
Sum	**119.12**	**3.89**	**122.33**	**92.48**	**24%**

Table A13 also includes sediment loading from potential culvert failure based on storm events. The average fill at risk from field measurements was extrapolated to the number of culverts passing design storm events and to a 25% probability of failing per year per USGS HUC 12. Due to the uncertainty associated with this extrapolation, the information is not included in the summary portion of the table (columns 3, 4, and 5).

As old or failed culverts are replaced, many regulations include guidance to accommodate the 25-year storm event: International Building Code Standards for 2006 (ICC 2006) and Water Quality BMPs for Montana Forests (DNRC 2006). USFS documentation (Inland Native Fish Strategy, Environmental Assessment, 1995) recommends that new culverts should be designed to pass the 100-year flow event. It is recommended that culvert replacements in the Lower Gallatin

TPA be upgraded to pass the Q25 flood event at a minimum. Approximately two thirds of the culverts that were assessed did not convey the 25-year event.

On fish bearing streams, it is also recommended that culvert replacements be completed in a manner that allows for full fish and Aquatic Organism Passage (AOP). Specifically, culverts would be sized with constriction ratios at 1.0 or greater, and with a goal of re-creating the stream channel through the crossing to match those channel conditions outside of the crossing influence.

The identification of priority culverts for replacement should be on the following factors:

1.) Inability to pass the Q25 design flow;
2.) Constriction ratio <0.70; and
3.) Location on a perennial fish bearing stream.

Achieving full culvert replacement will take many years to complete, and some culverts on private land may never be replaced. This will result in continued loads from culvert failures in the foreseeable future; however, continued investment in the replacement of culverts failing the above criteria will significantly reduce sediment loads over time.

4.4 Assessment of Existing BMPs

This was a unique assessment in that the only type of water-diversion BMP noted in the field assessment areas were cross drains. A reason for minimal BMP presence and variety may be the large percentage of low gradient, valley bottom roads, and roads within urban areas. Many cross drains were marked with reflectors or poles which might indicate planned maintenance. Of the field-assessed 24 crossings and six parallel segments, two crossings and three parallel segments had cross drains. However, the heavily vegetated road ditches and swales also represent important BMPs and should be maintained.

5.0 QUALITY ASSURANCE / QUALITY CONTROL RESULTS

5.1 Representativeness

Representativeness refers to the extent to which measurements represent an environmental condition in time and space. Spatial representation was achieved through the Lower Gallatin TPA Roads field assessment. Twenty five sites were randomly selected through GIS based on watershed and road surface type categories. A total of 27 road crossings were visited in the field, with complete model parameters for 24 of the 27 sites. Three sites were deemed minimal delivery sites due to the paved road surface and limited connectivity of runoff from the road to the stream. Spatial representation is shown in **Table A-3a**. Adequate coverage of road surface types was achieved in the watershed.

Temporal variations were not accounted for in this study, as the field data collected at road crossing locations does not change during the year.

5.2 Comparability

Comparability is the applicability of the project's data to the WEPP:Road model input data. The WEPP:Road model includes a high and low data value for each input parameter. Field data was compared to the model input range and sites with data outside these ranges were flagged for additional evaluation through the review of photographs, field comments, personal communication and other field data. No sites were determined to have unacceptable field data for the WEPP:Road model. A review of comparability of field data is shown in **Table A-14**.

5.3 Completeness

Completeness is a measure of the amount of data prescribed for assessment activities and the usable data actually collected, expressed as a percentage.

Completeness as % = (No. Valid Data Points or Samples / Total # Data Points or Samples) x 100

The overall project goal is 90% completeness. A total of 27 sites were assessed in the field. As documented in **Table A-12**, and **Attachment C,** all sites were deemed valid through data adjustments based on comments, conversations with the field crew and through analysis of photographs for input into the WEPP:Road model. This equates to a completeness of 100%.

6.0 REFERENCES

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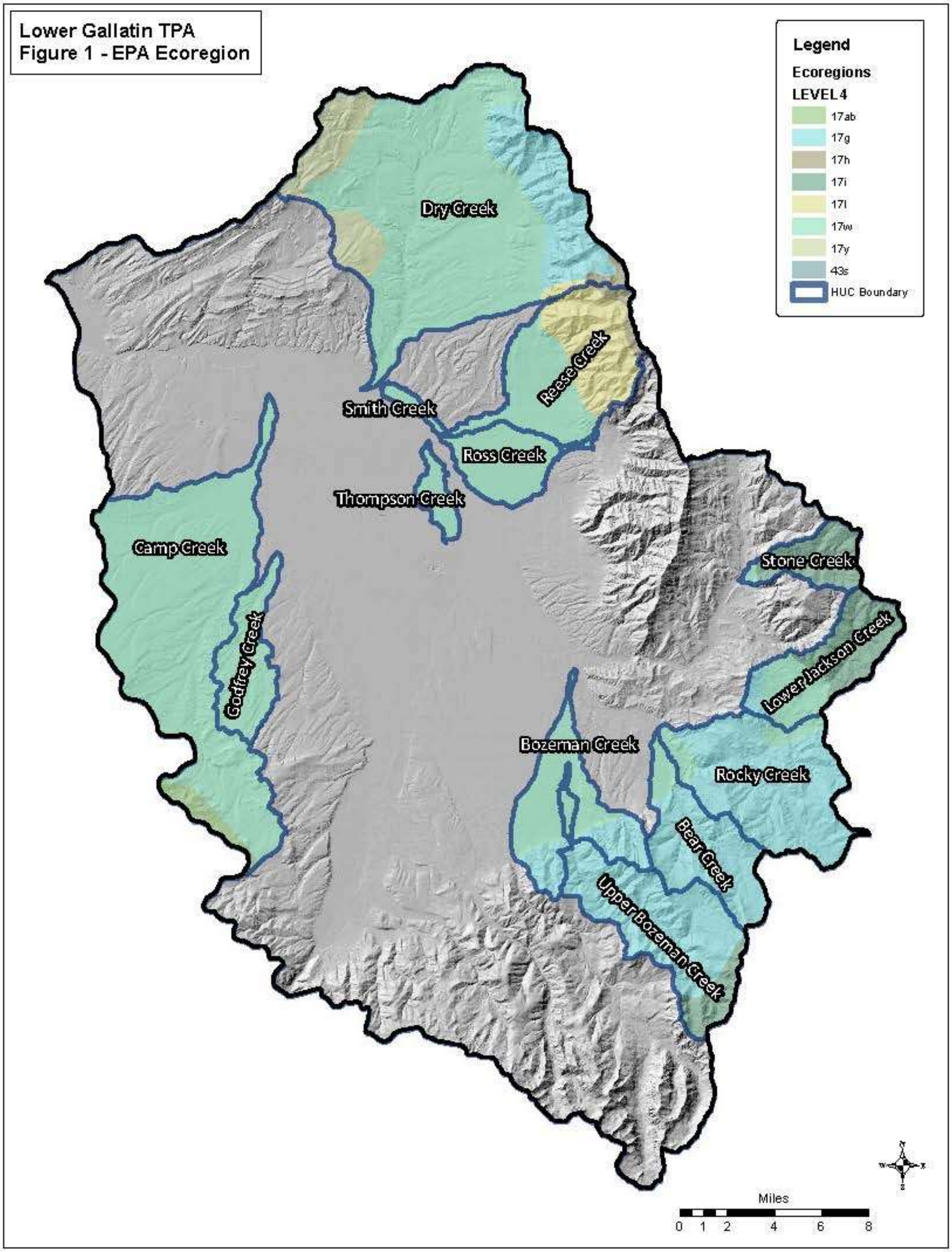
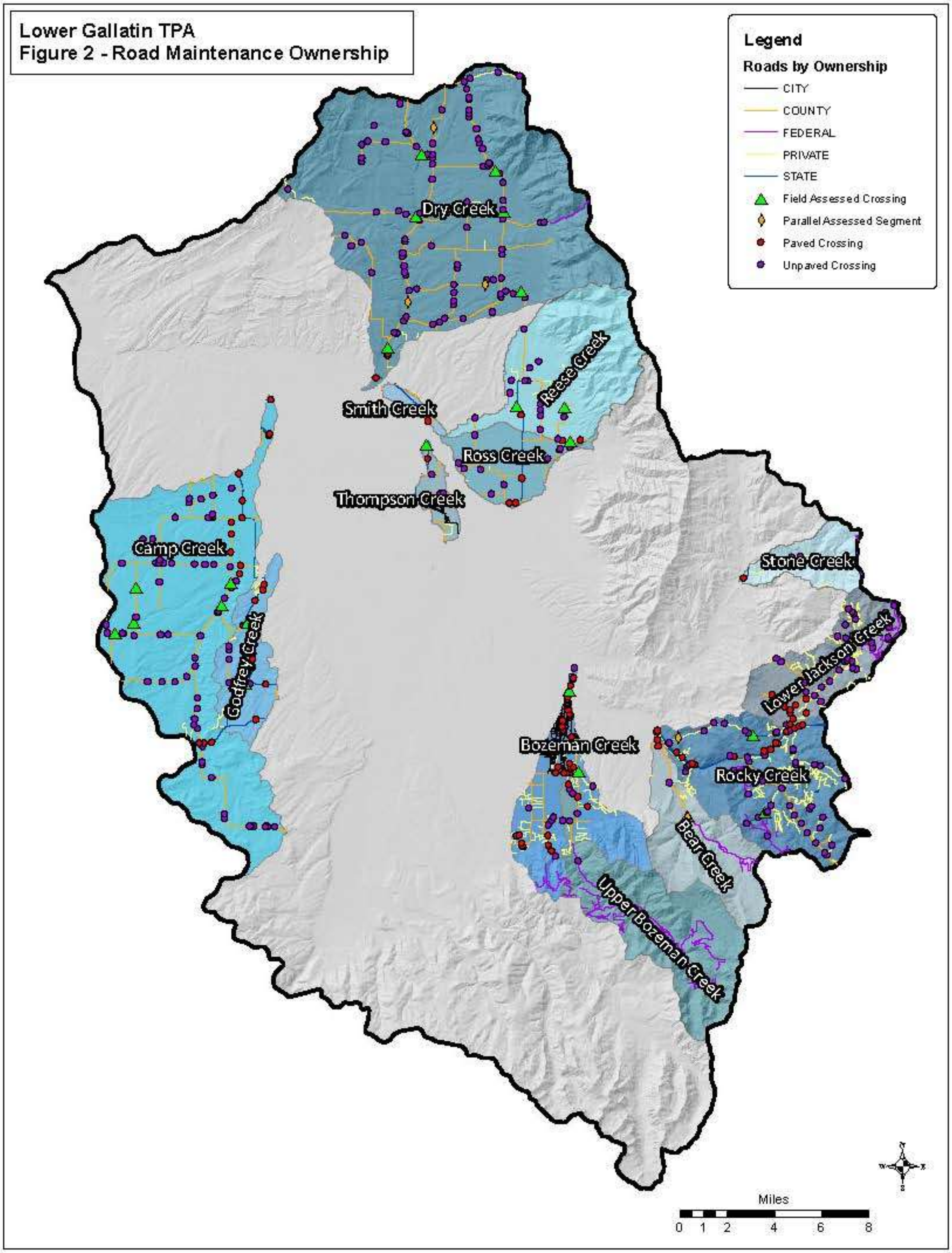
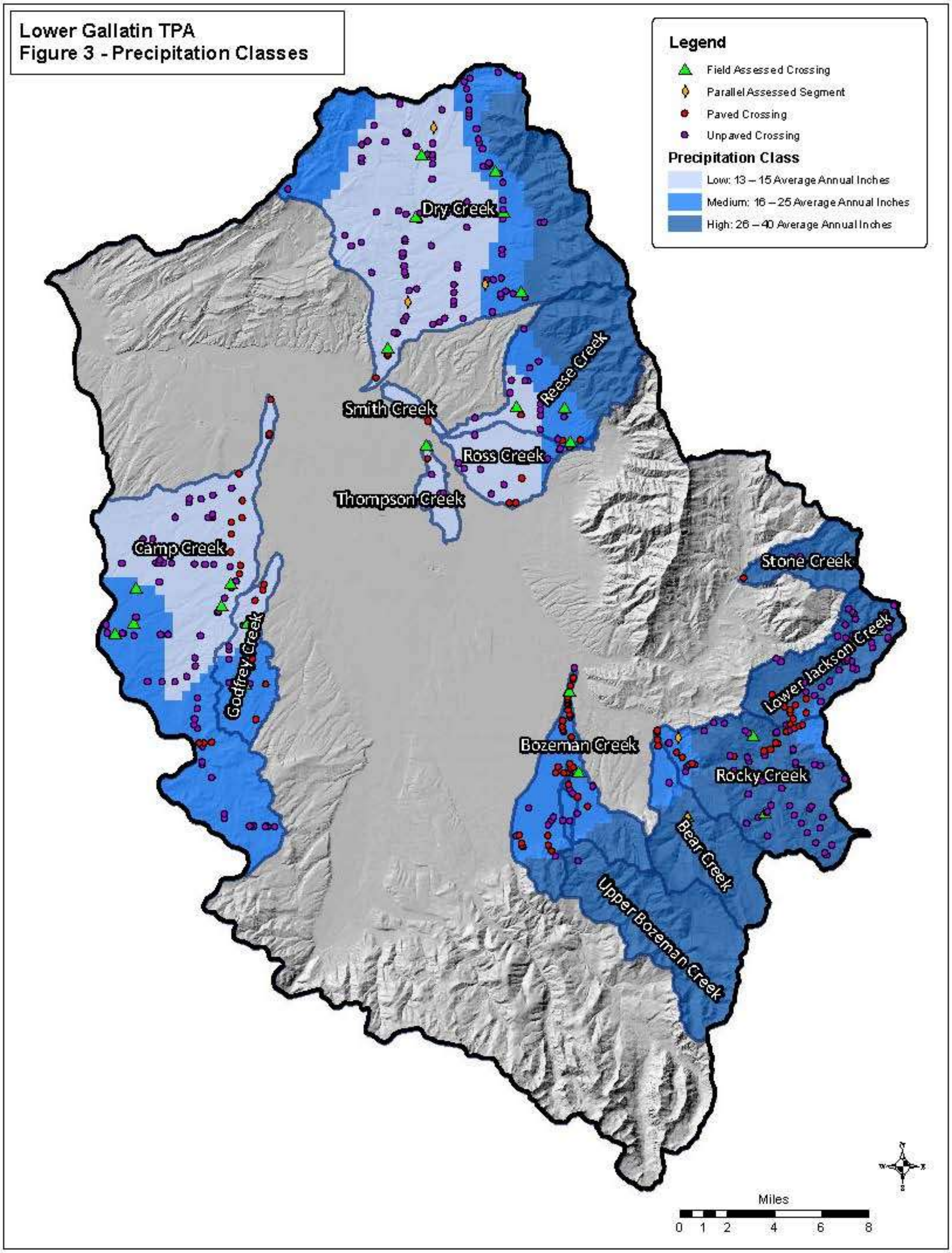
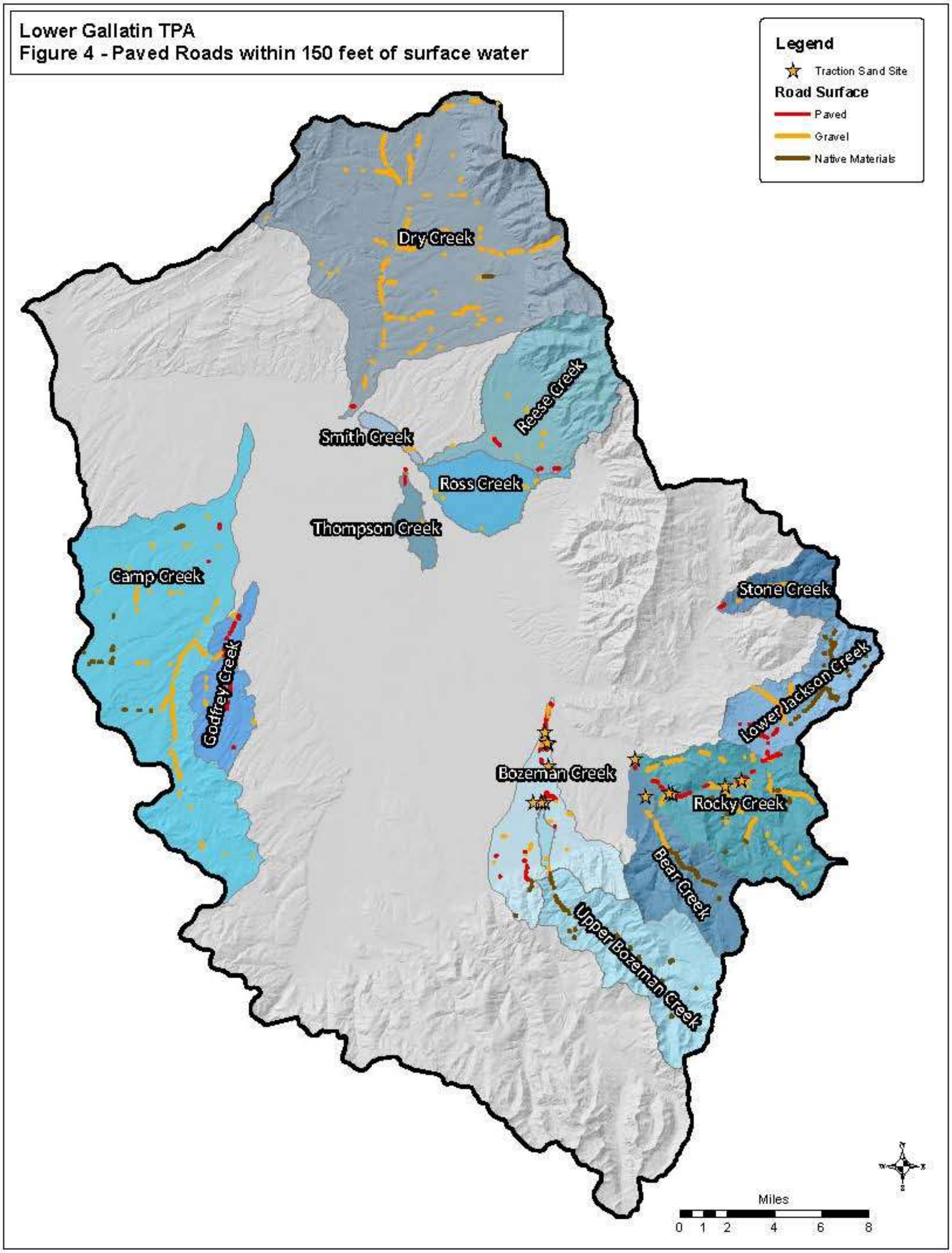
FIGURES



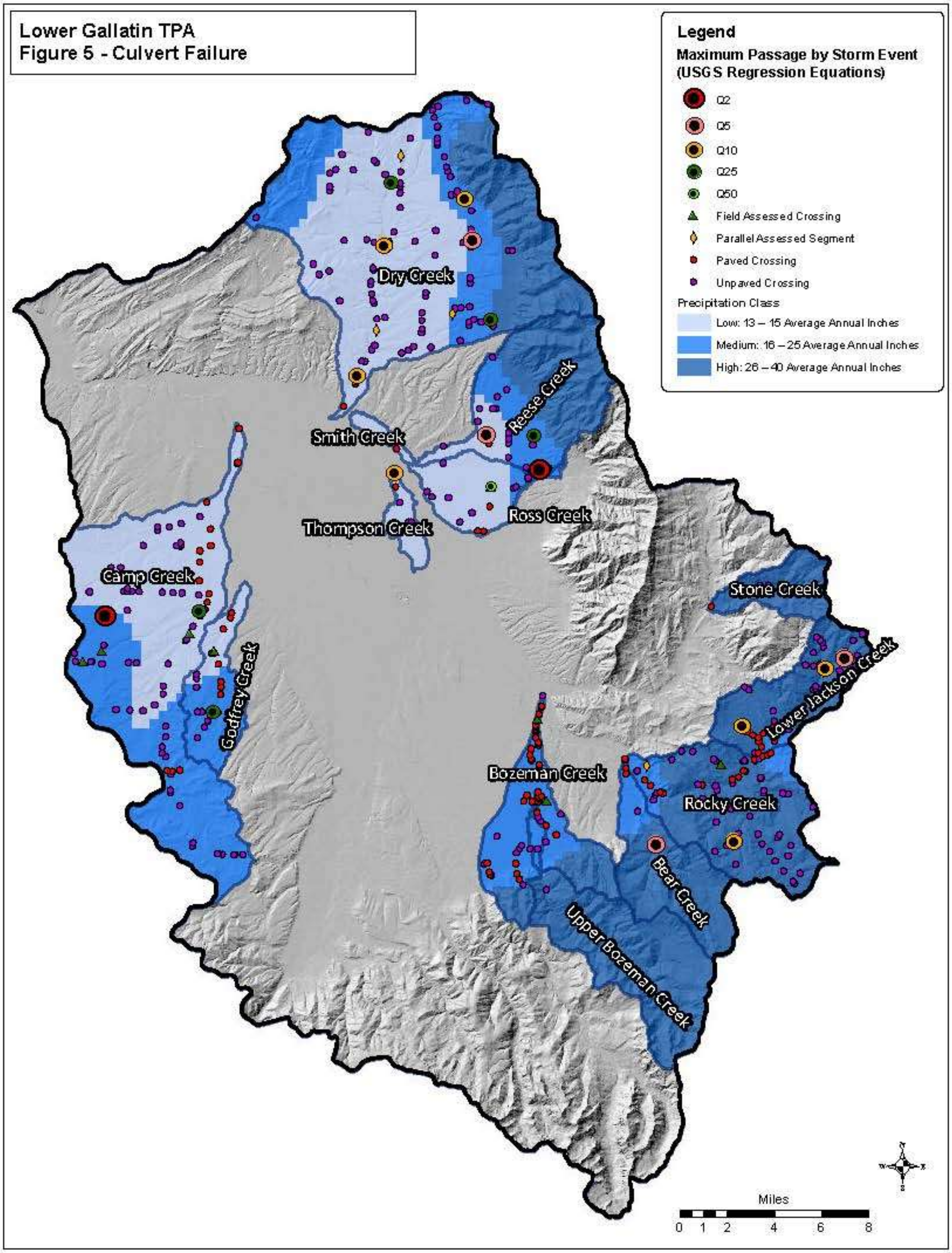
Lower Gallatin TPA
Figure 1 - EPA Ecoregion
Legend
Ecoregions
LEVEL4
17ab
17g
17h
17i
17l
17w
17y
43s
HUC Boundary
Dry Creek
Reese Creek
Smith Creek
Ross Creek
Thompson Creek
Camp Creek
Godfrey Creek
Stone Creek
Lower Jackson Creek
Bozeman Creek
Rocky Creek
Bear Creek
Upper Bozeman Creek
Miles
0 1 2 4 6 8


Lower Gallatin TPA
Figure 2 - Road Maintenance Ownership
Legend
Roads by Ownership
CITY
COUNTY
FEDERAL
PRIVATE
STATE
Field Assessed Crossing
Parallel Assessed Segment
Paved Crossing
Unpaved Crossing
Dry Creek
Reese Creek
Smith Creek
Ross Creek
Thompson Creek
Camp Creek
Godfrey Creek
Stone Creek
Lower Jackson Creek
Bozeman Creek
Rocky Creek
Bear Creek
Upper Bozeman Creek
Miles
0 1 2 4 6 8


Lower Gallatin TPA
Figure 3 - Precipitation Classes
Legend
Field Assessed Crossing
Parallel Assessed Segment
Paved Crossing
Unpaved Crossing
Precipitation Class
Low: 13 – 15 Average Annual Inches
Medium: 16 – 25 Average Annual Inches
High: 26 – 40 Average Annual Inches
Dry Creek
Reese Creek
Smith Creek
Ross Creek
Thompson Creek
Camp Creek
Godfrey Creek
Stone Creek
Lower Jackson Creek
Bozeman Creek
Rocky Creek
Bear Creek
Upper Bozeman Creek
Miles
0 1 2 4 6 8



Lower Gallatin TPA
Figure 4 - Paved Roads within 150 feet of surface water
Legend
Traction Sand Site
Road Surface
Paved
Gravel
Native Materials
Dry Creek
Reese Creek
Smith Creek
Ross Creek
Thompson Creek
Camp Creek
Godfrey Creek
Stone Creek
Lower Jackson Creek
Bozeman Creek
Rocky Creek
Bear Creek
Upper Bozeman Creek
Miles
0 1 2 4 6 8


Lower Gallatin TPA
Figure 5 - Culvert Failure
Legend
Maximum Passage by Storm Event
(USGS Regression Equations)
Q2
Q5
Q10
Q25
Q50
Field Assessed Crossing
Parallel Assessed Segment
Paved Crossing
Unpaved Crossing
Precipitation Class
Low: 13 – 15 Average Annual Inches
Medium: 16 – 25 Average Annual Inches
High: 26 – 40 Average Annual Inches
Dry Creek
Reese Creek
Smith Creek
Ross Creek
Thompson Creek
Camp Creek
Godfrey Creek
Stone Creek
Lower Jackson Creek
Bozeman Creek
Rocky Creek
Bear Creek
Upper Bozeman Creek
Miles
0 1 2 4 6 8

ATTACHMENT A

Attached Tables

Table A-1. Western Regional Climate Center (WRCC) Selected Climate Stations

Climate Station	Relative Precipitation Class	Climate Station Elevation (ft)	Climate Station Annual Precipitation (in)	Number of Field Assessment Sites	WEPP predicted average annual runoff from rainfall for clay loam (in)	WEPP predicted average annual runoff from snow melt or rain-on-snow event for clay loam (in)	Assessment Site Elevation Range (ft)	Assessment Site Annual Precipitation (in)
Belgrade Airport, Montana 240622	Low	4450	14.00	13	0.08	0.01	4398 - 5150	13.45 – 15.21
Bozeman Montana State Univ., 241044	Medium	4860	18.46	7	0.27	0.01	4717 - 5481	15.60 – 19.49
Bozeman 12NE, Montana 241050	High	5950	34.62	10[A]	0.18	0.04	5566 - 6990	24.99 – 39.21

[A] Includes BC-17G-G-X-34.

The Climate Station Annual Precipitation as taken from the Western Regional Climate Center changes slightly when entered into the WEPP Custom Climate Program. Results are shown in Tables C-2 through C-7.

Table A-2. Road Summary by Subwatershed, Road Class, Road Maintenance Ownership, and Level IV Ecoregion

Table A-2a. Lower Gallatin River TPA Road Summary by 6th Code Subwatershed (USGS HUC 12)

6th Code Subwatershed (USGS HUC 12)	Area (Mi^2)	Stream Miles (Mi)	Unpaved Crossings	Unpaved Crossing Density (Crossing / Mi^2)	Paved Crossings	Total Crossings	Total Road Length (Mi)	Total Road Density (Mi/Mi^2)	% of Total Roads which are unpaved	Total Unpaved Road Length w/in 150 ft Streams (Mi)	Field Assessed Crossing Sites	Field Assessed Parallel Segment Sites
Bear Creek	19.85	26.75	2	0.10	4	6	13.90	0.70	33%	3.84	1	1
Bozeman Creek	20.71	35.46	2	0.10	1	3	39.22	1.89	67%	2.89	-*	-
Upper Bozeman Creek	31.27	46.22	14	0.45	41	55	90.10	2.88	25%	5.09	-	-
Camp Creek	74.75	180.54	69	0.92	12	81	67.28	0.90	85%	7.34	5	-
Dry Creek	106.35	255.33	103	0.97	1	104	80.78	0.76	99%	14.11	6	3
Godfrey Creek	12.64	31.04	13	1.03	10	23	18.55	1.47	57%	3.65	2	-
Lower Jackson Creek	18.79	42.23	40	2.13	11	51	46.95	2.50	78%	7.22	3	1
Reese Creek	31.13	61.23	17	0.55	4	21	17.10	0.55	81%	0.88	3	-
Rocky Creek	34.51	64.03	52	1.51	14	66	95.02	2.75	79%	12.73	2	1
Smith/Ross Creeks	13.71	26.85	11	0.80	5	16	21.94	1.60	69%	0.53	1	-
Stone Creek	8.75	17.32	6	0.69	1	7	5.20	0.59	86%	1.43	-	-
Thompson Creek	3.84	9.44	4	1.04	1	5	14.10	3.67	80%	0.37	1	-
Total	**376.28**	**796.44**	**333**	**0.88**	**105**	**438**	**1587.43**	**4.22**	**76%**	**60.10**	**24***	**6**

* Three paved sites in Bozeman Creek were deemed to deliver negligible sediment upon field assessment and were not evaluated for WEPP input variables.

Table A-3a. Road Crossing Summary by Road Class, Road Maintenance Ownership, and Level IV Ecoregion

Road Class	Unpaved Crossings	Paved Crossings	Total Crossings	% of Total Crossings which are unpaved	Number of Sites Randomly Selected with GIS	Number of Actual Field Assessed Sites Crossings
Paved	0	105	105	0	7	4
Gravel	277	0	277	100	13	14
Native	56	0	56	100	5	6
Total	**333**	**105**	**438**	**76**	**25**	**24**
Road Maintenance Ownership	**Unpaved Crossings**	**Paved Crossings**	**Total Crossings**	**% of Total Roads which are unpaved**	**Number of Sites Randomly Selected with GIS**	**Number of Actual Field Assessed Sites (Crossing / Parallel)**
Federal	23	0	23	100	1	2
State	8	44	52	15	5	4
County	212	24	286	74	15	15
City	2	16	26	8	2	-
Private	88	21	60	147	2	3
Total	**333**	**105**	**438**	**76**	**25**	**24**
Level IV Ecoregion	**Unpaved Crossings**	**Paved Crossings**	**Total Crossings**		**Number of Sites Randomly Selected with GIS**	**Number of Actual Field Assessed Sites (Crossing / Parallel)**
17ab	0	0	0	-	-	-
17g	46	5	51	90	2	3
17i	37	0	37	100	2	2
17y	5	0	5	100	0	-
17w	245	100	345	71	21	19
43s	0	0	0	-	-	-
Total	**333**	**105**	**438**	**76**	**25**	**24**

Table A-3b. Parallel Segment Summary by Road Class, Road Maintenance Ownership, and Level IV Ecoregion

Road Class	Total Road Length w/in 150 ft Streams (Mi)	Total Road Length across all Listed Watersheds	% of Total Roads which are parallel segments	Number of Actual Field Assessed Sites Parallel Seg.
Paved	8.50	141.66	6%	-
Gravel	37.76	259.63	15%	3
Native	14.23	108.41	13%	3
Total	**60.09**	**509.70**	**12%**	**6**
Road Maintenance Ownership	**Total Road Length w/in 150 ft Streams (Mi)**	**Total Road Length across all Listed Watersheds**		**Number of Actual Field Assessed Sites (Crossing / Parallel)**
Federal	10.82	76.69	14%	-
State	6.59	52.59	13%	-
County	27.16	197.14	14%	4
City	0.79	44.61	2%	-
Private	14.74	138.66	11%	2
Total	**60.09**	**509.70**	**12%**	**6**
Level IV Ecoregion	**Total Road Length w/in 150 ft Streams (Mi)**	**Total Road Length across all Listed Watersheds**		**Number of Actual Field Assessed Sites (Crossing / Parallel)**
17ab	-	0.29	-	-
17g	20.60	128.52	16%	2
17i	6.11	37.50	16%	1
17w	33.27	336.59	10%	3
17y	0.12	6.10	2%	-
43s	-	0.70	-	-
Total	**60.09**	**509.70**	**12%**	**6**

Table A-5. Road Crossings by HUC/303(d) Subwatershed, Precipitation Class and Road Surface Type

Ownership	Federal - USFS					State					County					City					Private					Total Cross-ings
6th Code/303(d) Subwatershed	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	
Precipitation Class	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	
Bear Creek	-	-	-	-	-	2	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	-	1	-	-	6
Bozeman Creek	-	-	1	-	-	7	-	-	-	-	8	-	3	-	-	16	-	2	-	-	10	-	8	-	-	55
Camp Creek	-	-	-	-	-	9	-	-	-	-	3	-	30	37	2	-	-	-	-	-	-	-	-	-	-	81
Dry Creek	-	-	-	-	-	1	-	-	-	-	-	3	32	56	-	-	-	-	-	-	-	-	5	5	2	104
Godfrey Creek	-	-	-	-	-	9	-	4	-	-	1	-	5	4	-	-	-	-	-	-	-	-	-	-	-	23
Lower Jackson Creek	-	11	-	-	-	-	-	-	-	-	7	4	-	-	-	-	-	-	-	-	4	24	1	-	-	51
Reese Creek	-	-	-	-	-	2	-	-	-	-	2	1	5	6	-	-	-	-	-	-	-	-	3	2	-	21
Rocky Creek	-	10	-	-	-	8	4	-	-	-	-	7	2	-	-	-	-	-	-	-	6	25	4	-	-	66
Ross Creek	-	-	-	-	-	3	-	-	-	-	1	-	4	6	-	-	-	-	-	-	-	-	1	-	-	15
Smith Creek	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Stone Creek	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	7
Thompson Creek	-	-	-	-	-	1	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	1	-	5
Upper Bozeman Creek	-	1	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	3
Total	**0**	**22**	**1**	**0**	**0**	**44**	**4**	**4**	**0**	**0**	**24**	**16**	**82**	**112**	**2**	**16**	**0**	**2**	**0**	**0**	**21**	**55**	**23**	**8**	**2**	**438**

Table A-6. Detailed Extrapolated Sediment Load From Road Crossings by HUC/303(d) Subwatershed, Precipitation Class and Road Surface Type – Existing Conditions

Ownership	Federal - USFS					State					County					City					Private					Total Load t/y
6th Code/303(d) Subwatershed	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	Paved	Unpaved		Gravel	Native	
Precipitation Class	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	
Bear Creek	0	0	0	0	0	0.06	0	0	0	0	0.03	0.37	0	0	0	0	0	0	0	0	0.03	0	0.53	0	0	1.02
Bozeman Creek	0	0	0.53	0	0	0.21	0	0	0	0	0.24	0	1.59	0	0	0.48	0	1.06	0	0	0.3	0	4.24	0	0	8.65
Camp Creek	0	0	0	0	0	0.27	0	0	0	0	0.09	0	15.9	6.29	0.16	0	0	0	0	0	0	0	0	0	0	22.71
Dry Creek	0	0	0	0	0	0.03	0	0	0	0	0	1.11	16.96	9.52	0	0	0	0	0	0	0	0	2.65	0.85	0.16	31.28
Godfrey Creek	0	0	0	0	0	0.27	0	2.12	0	0	0.03	0	2.65	0.68	0	0	0	0	0	0	0	0	0	0	0	5.75
Lower Jackson Creek	0	4.07	0	0	0	0	0	0	0	0	0.21	1.48	0	0	0	0	0	0	0	0	0.12	8.88	0.53	0	0	15.29
Reese Creek	0	0	0	0	0	0.06	0	0	0	0	0.06	0.37	2.65	1.02	0	0	0	0	0	0	0	0	1.59	0.34	0	6.09
Rocky Creek	0	3.7	0	0	0	0.24	1.48	0	0	0	0	2.59	1.06	0	0	0	0	0	0	0	0.18	9.25	2.12	0	0	20.62
Ross Creek	0	0	0	0	0	0.09	0	0	0	0	0.03	0	2.12	1.02	0	0	0	0	0	0	0	0	0.53	0	0	3.79
Smith Creek	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03
Stone Creek	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.22	0	0	0	2.25
Thompson Creek	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0.51	0	0	0	0	0	0	0	0	0	0.17	0	0.71
Upper Bozeman Creek	0	0.37	0	0	0	0	0	0	0	0	0.03	0	0.53	0	0	0	0	0	0	0	0	0	0	0	0	0.93
Total	**0**	**8.14**	**0.53**	**0**	**0**	**1.32**	**1.48**	**2.12**	**0**	**0**	**0.72**	**5.92**	**43.46**	**19.04**	**0.16**	**0.48**	**0**	**1.06**	**0**	**0**	**0.63**	**20.35**	**12.19**	**1.36**	**0.16**	**119.12**

Table A-7. Parallel Segments by HUC/303(d) Subwatershed and Road Surface Type – Existing Conditions

Ownership	Federal - USFS			State			County			City			Private			Total
6th Code/303(d) Subwatershed	Paved	Gravel	Native	Paved	Gravel	Native	Paved	Gravel	Native	Paved	Gravel	Native	Paved	Gravel	Native	Miles
Bear Creek	-	-	2.34	0.00	-	-	-	1.46	-	-	-	-	0.03	0.02	-	3.84
Bozeman Creek	-	-	0.44	0.24	0.03	-	0.79	0.05	-	0.46	0.27	-	0.29	0.32	-	2.89
Camp Creek	-	-	-	0.14	-	-	0.00	6.38	0.78	-	-	-	-	0.03	-	7.34
Dry Creek	-	1.39	-	0.03	-	-	-	11.37	0.40	-	-	-	-	0.91	-	14.11
Godfrey Creek	-	-	-	1.95	0.95	-	0.01	0.60	-	-	-	-	0.00	0.14	-	3.65
Lower Jackson Creek	-	-	0.78	-	-	-	0.64	1.40	-	-	-	-	-	0.89	3.50	7.22
Reese Creek	-	-	-	0.33	-	-	0.26	0.14	-	-	-	-	-	0.14	-	0.88
Rocky Creek	-	0.24	0.79	2.23	0.27	-	-	2.11	-	-	-	-	0.64	6.08	0.36	12.73
Ross Creek	-	-	-	-	-	-	-	0.22	-	-	-	-	-	-	-	0.22
Smith Creek	-	-	-	-	-	-	-	0.31	-	-	-	-	-	-	-	0.31
Stone Creek	-	-	-	0.14	-	-	-	-	-	-	-	-	-	1.29	-	1.43
Thompson Creek	-	-	-	0.27	-	-	-	0.05	-	-	0.05	-	-	-	-	0.37
Upper Bozeman Creek	-	-	4.83	-	-	-	-	0.16	-	-	-	-	0.03	0.06	-	5.09
Total	**0.00**	**1.64**	**9.19**	**5.34**	**1.25**	**0.00**	**1.70**	**24.27**	**1.18**	**0.46**	**0.33**	**0.00**	**0.99**	**9.89**	**3.86**	**60.10**

Table A-8. Detailed Extrapolated Sediment Load From Unpaved Parallel Segments by HUC/303(d) Subwatershed and Road Surface Type – Existing Conditions

Ownership	Federal - USFS			State			County			City			Private			Total
6th Code/303(d) Subwatershed	Paved	Gravel	Native	Paved	Gravel	Native	Paved	Gravel	Native	Paved	Gravel	Native	Paved	Gravel	Native	Load t/y
Bear Creek	0	0	0.19	0.00	0	0	0	0.09	0	0	0	0	0.00	0.00	0	0.28
Bozeman Creek	0	0	0.04	0.01	0.002	0	0.05	0.00	0	0.03	0.02	0	0.02	0.02	0	0.18
Camp Creek	0	0	0	0.01	0	0	0.00	0.38	0.06	0.00	0	0	0	0.00	0	0.46
Dry Creek	0	0.08	0	0.00	0	0	0	0.68	0.03	0.00	0	0	0	0.05	0	0.85
Godfrey Creek	0	0	0	0.12	0.057	0	0.00	0.04	0	0	0	0	0.00	0.01	0	0.22
Lower Jackson Creek	0	0	0.06	0	0	0	0.04	0.08	0	0	0	0	0.00	0.05	0.28	0.52
Reese Creek	0	0	0	0.02	0	0	0.02	0.01	0	0	0	0	0	0.01	0	0.05
Rocky Creek	0	0.01	0.06	0.13	0.016	0	0	0.13	0	0	0	0	0.04	0.36	0.03	0.79
Ross Creek	0	0	0	0	0	0	0	0.01	0	0	0	0	0.00	0	0	0.01
Smith Creek	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
Stone Creek	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0.08	0	0.09
Thompson Creek	0	0	0	0.02	0	0	0	0.00	0	0	0.00	0	0	0	0	0.02
Upper Bozeman Creek	0	0	0.39	0	0	0	0.00	0.01	0	0	0	0	0.00	0.00	0	0.40
Total	**0.00**	**0.10**	**0.73**	**0.32**	**0.08**	**0.00**	**0.10**	**1.46**	**0.09**	**0.03**	**0.02**	**0.00**	**0.06**	**0.59**	**0.31**	**3.89**

Table A-9. Fish Passage Analysis for Selected Road Crossings Using Alaska Region Criteria

Location ID	Structure Type	Structure Diameter or Dimensions (in)	Width (ft)	Culvert Slope (%)	Bf in Riffle Above Culvert (ft)[A]	Constriction Ratio: Culvert I.D. / BF width	Perch (in)	Streambed Materials in Culvert	Final Classification	Notes/Comments Specific to Fish Crossing Model
Fish passage evaluation criteria: Circular CMP 48" span and smaller										
RCC-17G-G-X-108	cmp	10"	0.83	3	5	0.17	0	no	**RED**	
DC-P-17W-G-X-399	cmp	18"	1.5	2	1	1.50	0	yes	**RED**	
RCC-17G-G-X-38	cmp	2'	2	3	2.5	0.80	36	no	**RED**	
DC-P-17W-G-X-389	cmp	2'	2	2	2	1.00	13	no	**RED**	
REC-17W-G-X-308	cmp	24"	2	1	8	0.25	0	N/A	**RED**	Culvert flowing full, could not assess streambed materials.
LJC-17I-N-X-223	cmp	30"	2.5	1	8.5	0.29	0	no	**RED**	
GC-17W-G-X-172	2 culverts	3	3	2	2.5	2.40	25.2	no	**RED**	culvert / bf ratio calculated with width of two culverts
GC-17W-G-X-172	2 culverts	3	3	2	2.5	2.40	19.2	no	**RED**	culvert / bf ratio calculated with width of two culverts
DC-17W-G-X-353	cmp	36"	3	3	5	0.60	4	no	**RED**	
LJC-17I-N-X-204	2 arched culverts	41 x 28"	3.42	3	7	0.96	6	no	**RED**	culvert / bf ratio calculated with width of two culverts
LJC-17I-N-X-204	2 arched culverts	40 x 25"	3.33	3	7	0.96	6	no	**RED**	culvert / bf ratio calculated with width of two culverts
Fish passage evaluation criteria: Circular CMP greater than 48" and less than 100% substrate cover										
CC-17W-G-X-249	3 arch culverts	4 x 6	6	3	4.5	1.33	0	minimal	**RED**	
LJC-17W-P-X-160	cmp	48"	4	1	3.5	1.14	18	no	**RED**	
BC-17G-G-X-34	cmp	60"	5	3	12	0.42	0	no	**RED**	
TC-17W-G-X-432	2 squash culverts	4.5 x 4	4.5	1	24	0.38	0	yes	**RED**	culvert / bf ratio calculated with width of two culverts
TC-17W-G-X-432	2 squash culverts	4.5 x 4	4.5	1	24	0.38	0	yes	**RED**	culvert / bf ratio calculated with width of two culverts
REC-17W-G-X-324	arch cmp	8' x 6.5	8	1	8	1.00	0	yes	**GREY**	
DC-P-17W-G-X-383	arch cmp / bridge	4' x 13'	13	2	9	1.44	0	yes	**GREY**	

Legend:	High certainty of not providing juvenile fish passage	High certainty of providing juvenile fish passage	Additional and more detailed analysis is required	Flowing water noted at the time of the field assessment	

Table A-10. Peak Discharges Using USGS Equations WRIR-03-4308 (Upper Yellowstone-Central Mountain Region) and Manning's Equation

Site ID	Formula Variables		Site Information				Peak Discharges Using USGS Equations WRIR-03-4308 (Upper Yellowstone-Central Mountain Region						Peak Discharges Using Manning's Equation, pipes flowing full						
	Area (sqmi)	E_{6000}	Structure	Fill at Risk (tons)	CMP Diameter or Height (ft)	X-sect Area (ft2)	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)	Streambed Materials in Culvert	n^A	Slope %	Velocity (ft/sec)	Peak Flow (cfs)	Sum of Peak Flow (cfs)	Max. Conveyance Manning's > USGS
CC-17W-G-X-249	5.89	0.00	3 arch culverts	36.1	4 x 6	19.63	25.5	86.8	162.2	303.0	448.5	628.5	minimal	0.024	2.64	11.7	229.0	364.2	**Q25**
CC-17W-G-X-249	5.89	0.00	3 arch culverts	incl.	3 x 5	12.57	incl.	incl.	incl.	incl.	incl.	incl.	dry	0.023	1.00	6.5	81.2	incl.	incl.
CC-17W-G-X-249	5.89	0.00	3 arch culverts	incl.	3.25 x 3.5	8.95	incl.	incl.	incl.	incl.	incl.	incl.	dry	0.022	1.00	6.0	54.0	incl.	incl.
CC-17W-N-X-247	1.9	0.00	CMP	15.6	3	7.07	10.0	35.8	68.8	132.2	199.5	284.0	dry	0.018	0.1	2.2	15.2		**Q2**
GC-17W-G-X-172	1.69	0.00	2 culverts	83.6	3	7.07	9.0	32.7	63.0	121.3	183.5	261.6	no	0.018	1.94	9.5	67.0	135.1	**Q25**
GC-17W-G-X-172	1.69	0.00	2 culverts	incl.	3	7.07	incl.	incl.	incl.	incl.	incl.	incl.	no	0.018	2.00	9.6	68.1	incl.	incl.
TC-17W-G-X-432	3.78	0.00	2 squash culverts	16.8	4.5 x 4	14.19	17.7	61.4	115.9	218.9	326.5	460.3	yes	0.023	1.14	7.2	101.8	203.6	**Q10**
TC-17W-G-X-432	3.78	0.00	2 squash culverts	incl.	4.5 x 4	14.19	incl.	incl.	incl.	incl.	incl.	incl.	yes	0.023	1.14	7.2	101.8	incl.	incl.
DC-17W-G-X-335	0.65	0.00	cmp	2.7	2	3.14	4.1	15.5	30.5	60.2	92.6	133.8	no	0.015	2.80	10.5	32.8		**Q10**
RCC-17G-G-X-38	0.54	0.98	cmp	15.7	2'	3.14	3.7	13.1	28.2	47.5	71.6	101.7	no	0.015	2.8	10.4	32.7		**Q10**
LJC-17I-N-X-223	0.94	1.00	cmp	86.9	30"	4.91	5.9	20.3	43.0	71.2	106.3	149.7	no	0.017	1.1	6.7	33.1		**Q5**
LJC-17I-N-X-204	2.54	1.00	arched	128.0	40 x 25"	5.73	13.6	44.1	91.4	147.6	216.5	300.9	no	0.018	2.5	9.9	56.9	124.3	**Q10**
LJC-17I-N-X-204	2.54	1.00	arched	incl.	41 x 28"	6.49	13.6	44.1	91.4	147.6	216.5	300.9	no	0.018	2.5	10.4	67.3	incl.	incl.
LJC-17W-P-X-160	1.5	0.38	cmp	35.1	48"	12.57	8.4	29.5	59.2	106.0	158.9	224.8	no	0.023	0.7	5.3	66.4		**Q10**
RCC-17G-G-X-108	0.12	0.25	cmp	25.2	10"	0.55	1.0	4.1	8.7	16.9	26.5	39.0	no	0.014	0.1	1.2	0.6		**N/A**
BC-17G-G-X-34	10.31	0.93	cmp	228.7	60"	19.63	43.4	131.9	263.3	414.4	594.1	810.5	no	0.024	3.4	13.2	260.1		**Q5**
RSC-17W-X-304	0.36	0.00	cmp	72.8	43"	10.18	2.5	9.8	19.5	39.1	60.6	88.3	no	0.022	1	6.3	64.1		**Q50**
REC-17W-G-X-308	0.61	0.10	cmp	80.1	24"	3.14	3.9	14.7	29.3	56.7	86.9	125.4	no	0.015	0.5	4.4	13.9		**Q2**
REC-17W-G-X-323	2.15	0.80	cmp	96.3	42"	9.62	11.7	38.8	79.7	132.7	195.9	273.6	no	0.022	7.80	17.3	166.0		**Q25**
REC-17W-G-X-324	21.09	0.44	arch cmp	110.9	8' x 6.5	41.28	76.5	232.9	441.0	731.3	1046.1	1424.8	yes	0.027	1	8.2	337.8		**Q5**
DC-17W-G-X-353	0.84	0.43	cmp	60.2	36"	7.07	5.2	18.7	38.3	68.9	104.2	148.5	no	0.018	2.5	10.8	76.2		**Q25**
DC-P-17W-G-X-383	35.76	0.17	arch cmp / bridge	97.5	4' x 13'	56.75	116.3	354.2	645.7	1110.5	1585.6	2156.6	yes	0.027	2.0	12.9	730.0		**Q10**
DC-P-17W-G-X-389	0.95	0.19	cmp	6.6	2'	3.14	5.7	20.7	41.3	77.5	117.7	168.3	no	0.015	1.7	8.2	25.6		**Q5**
DC-P-17W-G-X-399	0.1	0.10	cmp	1.2	18"	1.77	0.9	3.6	7.4	15.1	23.8	35.2	yes	0.013	1.9	8.2	14.6		**Q10**
DC-P-17W-G-X-410	7.96	0.27	arch	37.0	6' x 9'	44.18	33.6	109.1	208.3	364.7	532.8	738.3	yes	0.027	1.0	8.4	369.7		**Q25**
GC-17W-P-X-230	9.4	0.00	bridge	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		**N/A**
CC-17W-G-X-242	33.12	0.00	bridge	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		**N/A**
CC-17-W-N-X-219	0.08	0.00	no culvert	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		**N/A**
CC-17W-N-X-231	0.7	0.00	no culvert	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		**N/A**
			Average	61.9															

Field notes were adjusted as follows: if slope was not recorded then 0.1% was used. No streambed materials assumed for REC-17W-G-X-308. Slope was recorded as 2-3% at DC-P-17W-G-X-353.

Manning's Equation Roughness Coefficient Reference (Assumed all Corrugated pipe had 2.66 x 0.5 inch corrugations for pipe 10-inch to 36 inch and 3 x 1 inch corrugations for pipe greater than 36-inch diameter: Modern Sewer Design, 4th Ed. 1999, American Iron and Steel Institute, Washington DC, Copyright 1980.

Table A-11. Culvert Failure Load Potential Per 25% Probability and Per Storm Event (tons/year)

6th Code Subwatershed (USGS HUC 12)	Number of Crossings	Q2	Q5	Q10	Q25	Q50	Q100
Percent of Culverts Failing Storm Event		**0%**	**11%**	**32%**	**68%**	**95%**	**100%**
Bear Creek	6	0	10	30	63	88	93
Bozeman Creek	3	0	5	15	32	44	46
Upper Bozeman Creek	55	0	94	272	579	809	851
Camp Creek	81	0	138	401	852	1191	1253
Dry Creek	104	0	177	515	1094	1529	1609
Godfrey Creek	23	0	39	114	242	338	356
Lower Jackson Creek	51	0	87	253	537	750	789
Reese Creek	21	0	36	104	221	309	325
Rocky Creek	66	0	112	327	695	970	1021
Smith/Ross Creeks	16	0	27	79	168	235	248
Stone Creek	7	0	12	35	74	103	108
Thompson Creek	5	0	9	25	53	74	77
Total	**438**	**0**	**746**	**2169**	**4609**	**6439**	**6778**

Sample calculation: Bear Creek, Q50 Storm Event

$$\text{Load} = (\text{probability}) \times (\text{percent\_failing}) \times (\#\text{crossings}) \times (\text{average fill at risk TableA} - 10)$$

$$\text{Load} = (0.25) \times (0.95) \times (6\ \text{crossings}) \times (61.9\ \text{tons}) = 88.2\ \frac{\text{tons}}{\text{year}}$$

Table A-12. Detailed Extrapolated Sediment Load from Road Crossings by HUC/303(d) Subwatershed, Precipitation Class and Road Surface Type – Insloped, Vegetated Road Design and Road Length Reduction based on Maintenance Ownership

Ownership	**Federal - USFS**					**State**					**County**					**City**					**Private**					**Total Load t/y**
6th Code/303(d) Subwatershed	**Paved**	**Unpaved**		**Gravel**	**Native**	**Paved**	**Unpaved**		**Gravel**	**Native**	**Paved**	**Unpaved**		**Gravel**	**Native**	**Paved**	**Unpaved**		**Gravel**	**Native**	**Paved**	**Unpaved**		**Gravel**	**Native**	
Precipitation Class	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	H/M/L	H	M	L	L	
Bear Creek	0	0	0	0	0	0.06	0	0	0	0	0.03	0.26	0	0	0	0	0	0	0	0	0.03	0	0.32	0	0	0.7
Bozeman Creek	0	0	0.32	0	0	0.21	0	0	0	0	0.24	0	1.29	0	0	0.48	0	0.86	0	0	0.3	0	2.56	0	0	6.26
Camp Creek	0	0	0	0	0	0.27	0	0	0	0	0.09	0	12.9	5.55	0.08	0	0	0	0	0	0	0	0	0	0	18.89
Dry Creek	0	0	0	0	0	0.03	0	0	0	0	0	0.78	13.76	8.4	0	0	0	0	0	0	0	0	1.6	0.5	0.1	25.17
Godfrey Creek	0	0	0	0	0	0.27	0	1.72	0	0	0.03	0	2.15	0.6	0	0	0	0	0	0	0	0	0	0	0	4.77
Lower Jackson Creek	0	2.42	0	0	0	0	0	0	0	0	0.21	1.04	0	0	0	0	0	0	0	0	0.12	5.28	0.32	0	0	9.39
Reese Creek	0	0	0	0	0	0.06	0	0	0	0	0.06	0.26	2.15	0.9	0	0	0	0	0	0	0	0	0.96	0.2	0	4.59
Rocky Creek	0	2.2	0	0	0	0.24	1.04	0	0	0	0	1.82	0.86	0	0	0	0	0	0	0	0.18	5.5	1.28	0	0	13.12
Ross Creek	0	0	0	0	0	0.09	0	0	0	0	0.03	0	1.72	0.9	0	0	0	0	0	0	0	0	0.32	0	0	3.06
Smith Creek	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03
Stone Creek	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.32	0	0	0	1.35
Thompson Creek	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0.45	0	0	0	0	0	0	0	0	0	0.1	0	0.58
Upper Bozeman Creek	0	0.22	0	0	0	0	0	0	0	0	0.03	0	0.43	0	0	0	0	0	0	0	0	0	0	0	0	0.68
Total	**0**	**4.84**	**0.32**	**0**	**0**	**1.32**	**1.04**	**1.72**	**0**	**0**	**0.72**	**4.16**	**35.26**	**16.8**	**0.08**	**0.48**	**0**	**0.86**	**0**	**0**	**0.63**	**12.1**	**7.36**	**0.8**	**0.1**	**88.59**

Table A-13. Total Annual Sediment Load from all Sources and Potential BMP Reduction

6th Code Subwatershed (USGS HUC 12)	Total Annual Sediment Load Crossings (t/y)	Total Annual Sediment Load Parallel Segments (t/y)	Sum [A] (Crossings and Parallel Segments)	Sum with All Available Sediment Reductions[B] (t/y)	Percent Reduction[C] (%)		Culvert Failure-per Storm Event (tons/year)					
							Q2	Q5	Q10	Q25	Q50	Q100
Column #	**1**	**2**	**3**	**4**	**5**		**6**	**7**	**8**	**9**	**10**	**11**
Bear Creek	1.02	0.28	1.3	0.98	25%		0	10	30	63	88	93
Bozeman Creek	8.65	0.18	8.72	6.44	26%		0	5	15	32	44	46
Camp Creek	22.71	0.46	23.15	19.35	16%		0	94	272	579	809	851
Dry Creek	31.28	0.85	32.13	26.02	19%		0	138	401	852	1191	1253
Godfrey Creek	5.75	0.22	5.85	4.99	15%		0	177	515	1094	1529	1609
Lower Jackson Creek	15.29	0.52	15.72	9.91	37%		0	39	114	242	338	356
Reese Creek	6.09	0.05	6.11	4.64	24%		0	87	253	537	750	789
Rocky Creek	20.62	0.79	21.22	13.91	34%		0	36	104	221	309	325
Smith/Ross Creeks	3.82	0.03	3.85	3.12	19%		0	112	327	695	970	1021
Stone Creek	2.25	0.09	2.33	1.44	38%		0	27	79	168	235	248
Thompson Creek	0.71	0.02	0.72	0.6	17%		0	12	35	74	103	108
Upper Bozeman Creek	0.93	0.40	1.27	1.08	15%		0	9	25	53	74	77
Sum	**119.12**	**3.89**	**122.33**	**92.48**	**24%**		**0**	**746**	**2169**	**4609**	**6439**	**6778**

[A]Sum = Column 1+2
[B]Sum = Sediment load per crossing (Table A-12 Total Load) + Column 2
[C]Percent Reduction = (Column 3-Column 4) / Column 3

Table A-14. Comparability of Field Data to WEPP:Road Parameters

WEPP:Road Variable	Road gradient (%)	Road length (ft)	Road width (ft)	Fill gradient (%)	Fill length (ft)	Buff gradient (%)	Buff length (ft)	Rock content (%)
Minimum Value	0.3%	3 ft	1 ft	0.3%	1 ft	0.3%	1 ft	0%
Maximum Value	40%	1000 ft	300 ft	150%	1000 ft	100%	1000 ft	100%
Measured Range from the Field Data	0.5 - 11%	20 – 1000 feet	10-36 ft	0.3 – 145 %	1 – 80 ft	0.3 – 90%	1 – 401 ft	10 – 50%
Non-compliant values	None.	None.	DC-17W-G-X-335 (36 feet – due to road and ditch)	Multiple entries (-)	Multiple entries (-) Heavy Vegetation	Multiple entries (-)	Multiple entries (-)	None.
Action Taken	None.	None.	None – automatically corrected to 33 feet on WEPP	Minimum values entered for (-) entries.	Minimum values entered for (-) entries. Fill slope length minimized for heavy vegetation (>>50%)	Minimum values entered for (-) entries.	Minimum values entered for (-) entries.	None.

ATTACHMENT B

Field Assessment Site Location Data

Table B-1. Field Assessment Site Location Information

Climate Station	HUC 12 Name	SITE ID	X	Y	Elevation (ft)	Average Precipitation (in)
Belgrade Airport, Montana 240622	Camp Creek	CC-17w-G-X-242	45.7336	-111.3376	4736	14.53
	Camp Creek	CC-17w-G-X-249	45.7474	-111.3305	4779	15.13
	Camp Creek	CC-17w-N-X-219	45.7148	-111.4302	5032	13.45
	Camp Creek	CC-17w-N-X-231	45.7216	-111.4143	4759	14
	Camp Creek	CC-17w-N-X-247	45.7429	-111.4129	4759	14
	Dry Creek	DC-17w-G-X-335	45.8942	-111.1966	4408	14.19
	Dry Creek	DC-17w-G-X-383	45.9747	-111.1751	4795	14.72
	Dry Creek	DC-17w-G-X-389	45.9790	-111.0978	4546	15.21
	Dry Creek	DC-17w-G-X-410	46.0133	-111.1703	4897	14.87
	Godfrey Creek	GC-17w-P-X-230	45.7230	-111.3153	4779	15.13
	Thompson Creek	TC-17w-G-X-432	45.8350	-111.1614	4398	14.43
	Dry Creek	DC-P-1	45.9222	-111.1806	4622	14.6
	Dry Creek	DC-P-7	46.0301	-111.1613	5150	15.21
Bozeman MSU, 241044	Dry Creek	DC-17w-G-X-399	46.0040	-111.1050	5481	17.98
	Godfrey Creek	GC-17w-G-X-172	45.6855	-111.3162	4972	15.94
	Reese Creek	REC-17w-G-X-308	45.8388	-111.0347	5179	19.49
	Reese Creek	REC-17w-G-X-323	45.8596	-111.0399	5179	19.49
	Reese Creek	REC-17w-X-324	45.8597	-111.0821	4766	15.6
	Ross Creek	RSC-17w-X-304	45.8277	-111.0767	4717	15.75
	Dry Creek	DC-P-6	45.9339	-111.1130	5373	18.55
Bozeman 12NE, Montana 241050	Bear Creek	BC-17g-G-X-34	45.6100	-110.9255	6796	35.3
	Dry Creek	DC-17w-G-X-353	45.9301	-111.0801	6990	39.21
	Lower Jackson Creek	LJC-17i-N-X-204	45.7198	-110.7807	6747	35.79
	Lower Jackson Creek	LJC-17i-N-X-223	45.7264	-110.7633	6747	35.79
	Lower Jackson Creek	LJC-17w-X-160	45.6838	-110.8520	5566	25.16
	Rocky Creek	RCC-17g-G-X-108	45.6601	-110.8695	5993	29.42
	Rocky Creek	RCC-17g-G-X-38	45.6127	-110.8579	6416	33.69
	Lower Jackson Creek	LJC-P-3	45.7184	-110.7813	6747	35.79
	Rocky Creek	RCC-P-4	45.6580	-110.9349	5894	24.99
	Bear Creek	BC-P-5	45.6097	-110.9252	6796	35.3

Latitude and Longitude obtained from GIS; Elevation data obtained from WEPP:Road PRISM

ATTACHMENT C

WEPP: Road Model Adjustments and Custom Climate Parameters

Heavily Vegetated Fill Slope

Heavily vegetated fill slope conditions are not properly represented in the standard WEPP:Road assumption. As a result, William J. Elliott, author of the model, was consulted to determine how best to represent these roads within the confines of the model.

There are three traffic scenarios available in the model that affect fillslope vegetation. All of the crossings and parallel segments in this report were low or high traffic levels. For roads where vegetation is 100% on the fill slope, the fill slope length was minimized and the remainder was added to the buffer length. The following table explains the model assumptions for the three traffic scenarios:

Traffic	**High**	**Low**	**None**
Erodibility	100%	25%	25%
Hydraulic Conductivity	100%	100%	100%
Vegetation on Road Surface	0	0	50%
Vegetation on fill	50%	50%	100% Forested
Buffer	Forested	Forested	Forested

Affected segments:

- CC-17W-N-X-247
- GC-17W-P-X-230
- GC-17W-G-X-172
- TC-17W-G-X-432
- LJC-17W-P-X-160
- RCC-17G-G-X-108
- RSC-17W-P-X-304
- REC-17W-G-X-323353
- DC-P-6
- DC-P-17W-G-X-383
- DC-P-17W-G-X-389
- DC-P-17W-G-X-399
- DC-P-7

Traffic Level

High traffic is described in WEPP:Road guidance as " generally associated with a timber sale, hauling numerous loads of logs over the road, or roads that receive considerable traffic during much of the year". Low traffic is described as "administrative or light recreational use during the dry season". Due to the proximity to Bozeman, Belgrade and Manhattan, almost all of the roads receive daily use. Thus all of the sites were updated to high traffic level with the exception of the high bank area of Camp Creek that receives occasional ranch traffic and the parallel segment in Rocky Creek. This area has few homes, two forms of egress, and a private property sign at the entrance.

Maximum Contributing Road Length

The WEPP:Road model has a maximum contributing road length of 1000-feet. According to Dr. Elliott, it is rare that the contributing road length ever exceeds this distance. As a result, any field assessed road crossing or parallel segment in excess of this distance was reduced to 1000-feet for modeling purposes. This includes multiple segments for the same crossing. If both of the segments exceeded 1000 feet, each was reduced to 500 feet. If only one segment exceeded the halfway mark, that segment was reduced so that the total road length was at the maximum.

Affected segments:

- DC-17W0G-X-335
- DC-P-17W-G-X-410
- DC-P-17W-G-X-389
- BC-17G-G-X-34
- DC-P-17W-G-X-399
- GC-17W-G-X-172
- LJC-17I-N-X-204
- CC-17W-N-X-231
- CC-17W-N-X-247
- GC-17W-P-X-230
- LJC-17W-P-X-160
- RSC-17W-P-X-304
- DC-P-1
- BC-P-5
- DC-P-7

Road Crossing Model Adjustments

Some road crossing locations had contributing road length on each side of the crossing, and road conditions were significantly different on each side. In these situations, each road segment was modeled separately and the two segments were then summed to get the total sediment load for the crossing. Also, some crossing locations were located at the convergence of two or more roads, with all roads contributing to sediment load at the crossing. In these cases, road segments were modeled separately and then summed to get the total sediment load for the crossing.

Crowned Roads

A crowned road is not a road design option in WEPP:Road. Each crossing must be considered as an inslope or outslope design with a rutted or unrutted surface. Photographs and field notes were reviewed prior to each assessment. The following is a summary of model changes.

Table C-1. Specific WEPP: Road Modeling Adjustments for Crowned Roads

Site Name	Road Design	Model Adjustments
CC-17W-G-X-249	IV	Two segments (both IV) modeled separately and summed
GC-17W-P-X-230	OU	Two paved segments (both OU) modeled separately and summed
RSC-17W-X-304	IV	One segment with two ditches. Modeled as one IV segment with half width of road and doubled result.
REC-17W-G-X-308	OR	One segment with ruts present. Modeled as OR per WEPP Guidance.
REC-17W-G-X-323	OR	Two segments with ruts present. Modeled as OR per WEPP Guidance and summed results.
REC-17W-G-324	OU	One paved segments modeled as OU.
DC-17W-G-X-353	OR	One segment with ruts present. Modeled as OR per WEPP Guidance.
DC-P-17W-G-X-389	OR	One segment with ruts present. Modeled as OR per WEPP Guidance.
DC-P-7	OR & IV	Four segments: one OR and three IV. Results averaged to represent the site.
Road crossings and parallel segments that are not listed above were not altered from the field worksheets when entered into the WEPP model. Road Design options: OU = Outslope unrutted road, OR = Outslope rutted road, IV = Inslope road with vegetated or rocked ditch, IB = Inslope road with bare ditch		

Table C-2 and C-3:
Climate parameters for Belgrade Airport 240622 1971-2 +

45.48°N 111.63°W; 4450 feet elevation
85 years of record[C]

Month	Mean Maximum Temperature (°F)	Mean Minimum Temperature (°F)	Mean Precipitation (in)	Number of wet days
January	30.0	7.4	0.56	8.0
February	36.3	13.3	0.64	7.1
March	45.4	21.6	1.00	9.1
April	55.3	29.3	1.40	10.0
May	64.5	37.3	2.30	12.1
June	74.2	44.1	2.42	12.1
July	83.2	48.7	1.26	7.9
August	82.3	47.7	1.13	8.1
September	70.4	38.5	1.43	8.0
October	57.8	28.9	1.13	7.1
November	39.4	16.6	0.79	7.9
December	30.6	7.6	0.56	7.0
Annual			14.63	104.3

INTERPOLATED DATA

Station	Weighting	Station	Weighting
Wind Stations		**Solar Radiation and Max .5 P Stations**	
BOZEMAN MT	45.3 %	HELENA, MONTANA	51.2 %
DILLON MT	29.1 %	BILLINGS, MONTANA	26.7 %
LIVINGSTON MT	25.6 %	POCATELLO, IDAHO	22.1 %
Dewpoint Stations		**Time-to-Peak Stations**	
BUTTE MT	61 %	CAMERON MT	43.3 %
BILLINGS MT	21.4 %	LOGAN MT	29.2 %
POCATELLO ID	17.5 %	WHITEFALLS 7 E MT	27.5 %

Modified by Rock:Clime on October 8, 2010 from NORRIS MADISON PH MT 246157 0

[C] All three climate stations were altered from the NORRIS MADISON PH MT 246157 site. Thus the interpolated data is exactly the same for each of the three climate stations (wind, dewpoint, solar radiation and time-to-peak) based on the NORRIS latitude, longitude and years of record. Temperature and Precipitation data is unique to each site.

Table C-4 and C-5:
Climate parameters for BZN MSU 241044 YR 1971-2000 +

45.48°N 111.63°W; 4860 feet elevation
85 years of record

Month	Mean Maximum Temperature (°F)	Mean Minimum Temperature (°F)	Mean Precipitation (in)	Number of wet days
January	33.6	14.0	0.81	9.0
February	38.8	18.3	0.79	7.9
March	46.5	24.4	1.41	10.1
April	55.5	31.4	2.10	11.1
May	64.4	39.4	2.98	13.0
June	73.6	46.3	2.84	12.9
July	81.6	51.6	1.52	8.9
August	81.2	50.6	1.45	8.1
September	71.1	42.0	1.83	8.0
October	58.6	33.1	1.57	7.9
November	41.2	21.8	1.11	7.9
December	33.9	14.6	0.89	8.1
Annual			19.30	112.7

INTERPOLATED DATA

Station	Weighting	Station	Weighting
Wind Stations		**Solar Radiation and Max .5 P Stations**	
BOZEMAN MT	45.3 %	HELENA, MONTANA	51.2 %
DILLON MT	29.1 %	BILLINGS, MONTANA	26.7 %
LIVINGSTON MT	25.6 %	POCATELLO, IDAHO	22.1 %
Dewpoint Stations		**Time-to-Peak Stations**	
BUTTE MT	61 %	CAMERON MT	43.3 %
BILLINGS MT	21.4 %	LOGAN MT	29.2 %
POCATELLO ID	17.5 %	WHITEFALLS 7 E MT	27.5 %

Modified by Rock:Clime on October 8, 2010 from NORRIS MADISON PH MT 246157 0

Table C-6 and C-7:
Climate parameters for Bozeman 12NE 241050 YR71-00 +

45.48°N 111.63°W; 5950 feet elevation
85 years of record

Month	Mean Maximum Temperature (°F)	Mean Minimum Temperature (°F)	Mean Precipitation (in)	Number of wet days
January	32.7	8.0	2.40	14.1
February	36.6	11.2	1.94	12.9
March	42.2	16.9	2.72	15.1
April	49.3	23.1	3.60	15.0
May	58.1	30.3	4.48	16.0
June	67.1	36.2	4.35	15.0
July	74.3	39.4	2.44	11.1
August	74.2	38.2	2.41	10.0
September	64.4	31.9	2.80	10.0
October	53.6	25.5	2.60	10.0
November	38.4	15.8	2.48	13.1
December	32.6	8.8	2.40	14.1
Annual			34.60	156.4

INTERPOLATED DATA

Station	Weighting	Station	Weighting
Wind Stations		**Solar Radiation and Max .5 P Stations**	
BOZEMAN MT	45.3 %	HELENA, MONTANA	51.2 %
DILLON MT	29.1 %	BILLINGS, MONTANA	26.7 %
LIVINGSTON MT	25.6 %	POCATELLO, IDAHO	22.1 %
Dewpoint Stations		**Time-to-Peak Stations**	
BUTTE MT	61 %	CAMERON MT	43.3 %
BILLINGS MT	21.4 %	LOGAN MT	29.2 %
POCATELLO ID	17.5 %	WHITEFALLS 7 E MT	27.5 %

Modified by Rock:Clime on October 8, 2010 from NORRIS MADISON PH MT 246157 0

ATTACHMENT D

WEPP: Road Modeling Results for Field Assessed Sites

Table D-1. WEPP: Road Modeling Results for Field Assessed Crossings

Comment	Precipitation Class	Soil	Years	Design	Surface, traffic	Road grad (%)	Road length (ft)	Road width (ft)	Fill grad (%)	Fill length (ft)	Buff grad (%)	Buff length (ft)	Rock cont (%)	Average annual rain runoff (in)	Average annual snow runoff (in)	Average annual sediment leaving road (lb/yr)	Average annual sediment leaving buffer (lb/yr)
Paved Roads																	
GC-17W-P-X-230	Belgrade	loam	50	Outsloped, unrutted	paved high	0.75	905	23	84	1	84	13.5	10	0.3	0	30	33
GC-17W-P-X-230	Belgrade	loam	50	Outsloped, unrutted	paved high	1	95	23	0.3	1	0.5	10	10	incl.	incl.	incl.	incl.
REC-17W-G-324	MSU	sand	50	Outsloped, unrutted	paved high	4	20	22	100	7	0.3	1	15	1.4	0.1	9	7
RSC-17W-X-304 PAVED	MSU	sand	50	Insloped, vegetated or rocked ditch	paved high	0.5	600	11.5	27	1	27	8	50	8.6	2.2	84	82
RSC-17W-X-304 PAVED	MSU	sand	50	Insloped, vegetated or rocked ditch	paved high	0.5	600	11.5	27	1	27	8	50	incl.	incl.	incl.	incl.
Paved: Medium and Low Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.01**	**75th Perc.**	**0.03**	**Median**	**0.02**	**Max**	**0.04**	**Min**	**0.00**	**Mean**	**0.02**
LJC-17W-P-X-160	BZN 12 NE	loam	30	Outsloped, unrutted	paved high	7	500	33	120	1	0.5	149	50	1	0.4	7538	335
LJC-17W-P-X-160	BZN 12 NE	loam	30	Insloped, vegetated or rocked ditch	paved high	6	500	29	40	1	40	24	50	incl.	incl.	incl.	incl.
Paved: High Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.17**	**75th Perc.**	**0.17**	**Median**	**0.17**	**Max**	**0.17**	**Min**	**0.17**	**Mean**	**0.17**
Gravel Roads																	
CC-17W-G-X-242	Belgrade	loam	50	Outsloped, rutted	graveled high	2.5	160	21	57	13	0.3	1	20	0.8	0.2	242	205
DC-17W-G-X-335	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	2	1000	36	48	3.5	0.3	1	30	0.7	0.2	902	838
DC-P-17W-G-X-383	Belgrade	loam	50	Outsloped, rutted	graveled high	5.5	369	19	46	1	0.3	11	20	0.6	0.2	1271	622
DC-P-17W-G-X-410	Belgrade	loam	50	Outsloped, rutted	graveled high	3	844	21	90	4	1	156	20	0.1	0	1773	75
DC-P-17W-G-X-410	Belgrade	loam	50	Outsloped, rutted	graveled high	3	156	21	0.3	1	1	79	20	incl.	incl.	incl.	incl.
DC-P-17W-G-X-389	Belgrade	sand	50	Outsloped, rutted	graveled high	2.5	1000	21	58	1	0.3	50	30	0.2	0.1	1140	283
CC-17W-G-X-249	Belgrade	silt loam	50	Insloped, vegetated or rocked ditch	graveled high	1	39	31.5	39	12	0.3	1	15	0.3	0.1	849	36
CC-17W-G-X-249	Belgrade	silt loam	50	Insloped, vegetated or rocked ditch	graveled high	4	480	28	0.3	1	2	230	15	incl.	incl.	incl.	incl.
Gravel: Low Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.05**	**75th Perc.**	**0.27**	**Median**	**0.12**	**Max**	**0.42**	**Min**	**0.02**	**Mean**	**0.17**
DC-17W-G-X-353	BZN 12 NE	sand	30	Outsloped, rutted	graveled high	4	288	20	65	1	0.3	16	30	0.6	0.1	624	279
RCC-17G-G-X-108	BZN 12 NE	sand	30	Outsloped, rutted	graveled high	5	306	16	65	1	65	4.5	35	1.9	0.4	1999	1951
RCC-17G-G-X-108	BZN 12 NE	sand	30	Outsloped, rutted	graveled high	3.5	633	16	41	1	41	5	35	incl.	incl.	incl.	incl.
RCC-17G-G-X-38	BZN 12 NE	sand	30	Outsloped, rutted	graveled high	5	148	23	0.3	1	8	108	50	0	0	198	8
BC-17G-G-X-34[A]	BZN 12 NE	loam	30	Insloped, bare ditch	graveled high	4	1000	11	85	6	0.3	1	50	1.1	0	2391	2261
Gravel: High Precipitation Class Statistics: Annual Sediment Load (tons/year) [A]**BC-17G-G-X-34 not included in statistics**						**25th Perc.**	**0.07**	**75th Perc.**	**0.56**	**Median**	**0.14**	**Max**	**0.98**	**Min**	**0.00**	**Mean**	**0.37**

Table D-1 Continued. WEPP: Road Modeling Results for Field Assessed Crossings

Comment	Precipitation Class	Soil	Years	Design	Surface, traffic	Road grad (%)	Road length (ft)	Road width (ft)	Fill grad (%)	Fill length (ft)	Buff grad (%)	Buff length (ft)	Rock cont (%)	Average annual rain runoff (in)	Average annual snow runoff (in)	Average annual sediment leaving road (lb/yr)	Average annual sediment leaving buffer (lb/yr)
DC-P-17W-G-X-399	MSU	sand	50	Outsloped, rutted	graveled high	2.5	1000	21	42	1	0.3	3	30	1.1	0	2017	1768
REC-17W-G-X-308	MSU	sand	50	Outsloped, rutted	graveled high	1.5	180	14	5	6	0.3	1	20	1.2	0	90	78
REC-17W-G-X-323	MSU	silt	50	Outsloped, rutted	graveled high	2.5	504	15	92	1	0.3	7	15	1.9	0	1335	965
REC-17W-G-X-323	MSU	silt	50	Outsloped, rutted	graveled high	1	228	15	92	1	0.3	7	15	incl.	incl.	incl.	incl.
GC-17W-G-X-172	MSU	silt loam	50	Outsloped, rutted	graveled high	2	155	21	90	12	90	11	15	1.3	0	9105	1623
GC-17W-G-X-172	MSU	silt loam	50	Outsloped, rutted	graveled high	8	484	21	70	1	6	60	15	incl.	incl.	incl.	incl.
GC-17W-G-X-172	MSU	silt loam	50	Outsloped, rutted	graveled high	11	361	21	100	1	4	126	15	incl.	incl.	incl.	incl.
Gravel: Medium Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.37**	**75th Perc.**	**0.83**	**Median**	**0.65**	**Max**	**0.88**	**Min**	**0.04**	**Mean**	**0.55**
Native Roads																	
LJC-17I-N-X-204	BZN 12 NE	loam	30	Outsloped, rutted	native high	9	500	13	2	25	1	26	25	1.4	1.1	13269	1332
LJC-17I-N-X-204	BZN 12 NE	loam	30	Outsloped, rutted	native high	7	500	11	7	80	1	26	25	incl.	incl.	incl.	incl.
LJC-17I-N-X-223	BZN 12 NE	sand	30	Outsloped, rutted	native high	3.5	122	12	0.3	1	0.3	1	30	1	0.5	250	97
LJC-17I-N-X-223	BZN 12 NE	sand	30	Outsloped, rutted	native high	2.5	167	16	0.3	1	6	70	30	incl.	incl.	incl.	incl.
Native: High Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.20**	**75th Perc.**	**0.51**	**Median**	**0.36**	**Max**	**0.67**	**Min**	**0.05**	**Mean**	**0.36**
TC-17W-G-X-432	Belgrade	loam	50	Outsloped, rutted	native high	0.5	89	16	31	1	0.5	100.5	50	0	0	293	2
TC-17W-G-X-432	Belgrade	loam	50	Outsloped, rutted	native high	2	260	16	9	1	0.5	266	50	incl.	incl.	incl.	incl.
CC-17-W-N-X-219	Belgrade	clay	50	Outsloped, rutted	native low	3	468	15	0.3	1	0.3	1	10	5.1	2.4	499	379
CC-17-W-N-X-219	Belgrade	clay	50	Outsloped, rutted	native low	3.5	307	15	0.3	1	0.3	1	10	incl.	incl.	incl.	incl.
CC-17W-N-X-231	Belgrade	clay	50	Outsloped, rutted	native low	5	770	10	0.3	1	1	50	50	3.4	1.7	1144	168
CC-17W-N-X-231	Belgrade	clay	50	Outsloped, rutted	native low	0.5	230	10	0.3	1	1	5	50	incl.	incl.	incl.	incl.
CC-17W-N-X-247	Belgrade	clay	50	Outsloped, rutted	native low	1	144	13	25	1	0.3	11	10	1.2	0.8	1268	105
CC-17W-N-X-247	Belgrade	clay	50	Outsloped, rutted	native low	6	428	13	58	1	1	401	40	incl.	incl.	incl.	incl.
CC-17W-N-X-247	Belgrade	clay	50	Outsloped, rutted	native low	6	428	13	58	1	1	50	40	incl.	incl.	incl.	incl.
Native: Low Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.04**	**75th Perc.**	**0.11**	**Median**	**0.07**	**Max**	**0.19**	**Min**	**0.00**	**Mean**	**0.08**

Table D-2. WEPP: Road Modeling Results for Field Assessed Parallel Segments

Comment	Precipitation Class	Soil	Years	Design	Surface, traffic	Road grad (%)	Road length (ft)	Road width (ft)	Fill grad (%)	Fill length (ft)	Buff grad (%)	Buff length (ft)	Rock cont (%)	Average annual rain runoff (in)	Average annual snow runoff (in)	Average annual sediment leaving road (lb/yr)	Average annual sediment leaving buffer (lb/yr)
Gravel Parallel Segments																	
DC-P-1	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	1.5	1000	24	58	7	1	18	30	0.4	0.1	1678	381
DC-P-1	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	2.5	1000	24	23	5	1	182	30	incl.	incl.	incl.	incl.
BC-P-5	BZN 12 NE	loam	30	Insloped, bare ditch	graveled high	4	1000	11	85	9	0.3	1	50	0.8	0.3	2213	2204
DC-P-6	MSU	sand	50	Outsloped, rutted	graveled high	2.5	500	20	33	1	8.75	23	30	0.4	0.00	1047.3	320.3
DC-P-6	MSU	sand	50	Outsloped, rutted	graveled high	3.5	500	20	23	1	3	126	30	avg'd	avg'd	avg'd	avg'd
DC-P-6	MSU	sand	50	Outsloped, rutted	graveled high	3.5	500	12	56	1	5	78.5	30	avg'd	avg'd	avg'd	avg'd
RCC-P-4	BZN 12 NE	loam	30	Outsloped, rutted	graveled low	5.5	556	16	24	13	5	48	20	0.4	0.1	814	411
Gravel: All Precipitation Classes Statistics: Annual Sediment Load (tons/year/mile)						**25th Perc.**	**0.03**	**75th Perc.**	**0.09**	**Median**	**0.03**	**Max**	**0.16**	**Min**	**0.02**	**Mean**	**0.06**
Gravel Parallel Segments																	
DC-P-7	Belgrade	sand	50	Outsloped, rutted	native high	6	1000	20	16	1	48	33	40	0.25	0.13	2853.8	1336.0
DC-P-7	Belgrade	sand	50	Outsloped, rutted	native high	6.5	1000	12	66	1	2	24	40	avg'd	avg'd	avg'd	avg'd
DC-P-7	Belgrade	sand	50	Outsloped, rutted	native high	7	1000	12	26	1	2	207	40	avg'd	avg'd	avg'd	avg'd
DC-P-7	Belgrade	sand	50	Outsloped, rutted	native high	0.5	1000	14	22	1	2	97	40	avg'd	avg'd	avg'd	avg'd
LJC-P-3	BZN 12 NE	loam	30	Outsloped, rutted	native high	2	582	17	22	1.5	26	105	15	0.4	0.3	1436	870
Native: All Precipitation Classes Statistics: Annual Sediment Load (tons/year/mile)						**25th Perc.**	**0.07**	**75th Perc.**	**0.09**	**Median**	**0.08**	**Max**	**0.10**	**Min**	**0.07**	**Mean**	**0.08**

Shaded cells in the Road Length column represent two upstream sections of the culvert. These cells were summed prior to calculating the average road length for each crossing within a watershed.
Cells with an "incl." in the last four columns were summed either because the road was crowned and was modeled as two widths (inslope and outslope portion) or because of the two contributing upstream road sections. Cells with an "avg'd" in the last four columns are parallel sections were averaged to present one normalized value for average sediment delivery in tons/mile/year.

ATTACHMENT E

WEPP: Road Modeling Results for Field Assessed Sites as Insloped, Vegetated Ditch Design

Table E-1. WEPP: Road Modeling Results for Field Assessed Crossings as Insloped, Vegetated Ditch Design

Comment	Precipitation Class	Soil	Years	Design	Surface, traffic	Road grad (%)	Road length (ft)	Road width (ft)	Fill grad (%)	Fill length (ft)	Buff grad (%)	Buff length (ft)	Rock cont (%)	Average annual rain runoff (in)	Average annual snow runoff (in)	Average annual sediment leaving road (lb/yr)	Average annual sediment leaving buffer (lb/yr)
Gravel Roads																	
CC-17W-G-X-242	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	2.5	160	21	57	13	0.3	1	20	0.8	0.2	223	185
DC-17W-G-X-335	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	2	1000	36	48	3.5	0.3	1	30	0.7	0.2	902	838
DC-P-17W-G-X-383	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	5.5	369	19	46	1	0.3	11	20	0.6	0.2	717	412
DC-P-17W-G-X-410	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	3	844	21	90	4	1	156	20	0.1	0	1125	77
DC-P-17W-G-X-410	Belgrade	loam	50	Insloped, vegetated or rocked ditch	graveled high	3	156	21	0.3	1	1	79	20	incl.	incl.	incl.	incl.
DC-P-17W-G-X-389	Belgrade	sand	50	Insloped, vegetated or rocked ditch	graveled high	2.5	1000	21	58	1	0.3	50	30	0.2	0.1	729	232
CC-17W-G-X-249	Belgrade	silt loam	50	Insloped, vegetated or rocked ditch	graveled high	1	39	31.5	39	12	0.3	1	15	0.3	0.1	849	36
CC-17W-G-X-249	Belgrade	silt loam	50	Insloped, vegetated or rocked ditch	graveled high	4	480	28	0.3	1	2	230	15	incl.	incl.	incl.	incl.
Gravel: Low Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.05**	**75th Perc.**	**0.18**	**Median**	**0.10**	**Max**	**0.42**	**Min**	**0.02**	**Mean**	**0.15**
DC-17W-G-X-353	BZN 12 NE	sand	30	Insloped, vegetated or rocked ditch	graveled high	4	288	20	65	1	0.3	16	30	0.5	0.1	359	191
RCC-17G-G-X-108	BZN 12 NE	sand	30	Insloped, vegetated or rocked ditch	graveled high	5	306	16	65	1	65	4.5	35	1.9	0.4	1141	1147
RCC-17G-G-X-108	BZN 12 NE	sand	30	Insloped, vegetated or rocked ditch	graveled high	3.5	633	16	41	1	41	5	35	incl.	incl.	incl.	incl.
RCC-17G-G-X-38	BZN 12 NE	sand	30	Insloped, vegetated or rocked ditch	graveled high	5	148	23	0.3	1	8	108	50	0	0	123	8
BC-17G-G-X-34[A]	BZN 12 NE	loam	30	Insloped, bare ditch	graveled high	4	1000	11	85	6	0.3	1	50	1.1	0	2391	2261
Gravel: High Precipitation Class Statistics: Annual Sediment Load (tons/year) **[A]BC-17G-G-X-34 not included in statistics**						**25th Perc.**	**0.05**	**75th Perc.**	**0.33**	**Median**	**0.10**	**Max**	**0.57**	**Min**	**0.00**	**Mean**	**0.22**

Table E-1 Continued. WEPP: Road Modeling Results for Field Assessed Crossings as Insloped, Vegetated Ditch Design

Comment	Precipitation Class	Soil	Years	Design	Surface, traffic	Road grad (%)	Road length (ft)	Road width (ft)	Fill grad (%)	Fill length (ft)	Buff grad (%)	Buff length (ft)	Rock cont (%)	Average annual rain runoff (in)	Average annual snow runoff (in)	Average annual sediment leaving road (lb/yr)	Average annual sediment leaving buffer (lb/yr)
DC-P-17W-G-X-399	MSU	sand	50	Insloped, vegetated or rocked ditch	graveled high	2.5	1000	21	42	1	0.3	3	30	1.1	0	1234	1166
REC-17W-G-X-308	MSU	sand	50	Insloped, vegetated or rocked ditch	graveled high	1.5	180	14	5	6	0.3	1	20	1.2	0	88	78
REC-17W-G-X-323	MSU	silt	50	Insloped, vegetated or rocked ditch	graveled high	2.5	504	15	92	1	0.3	7	15	1.9	0	898	682
REC-17W-G-X-323	MSU	silt	50	Insloped, vegetated or rocked ditch	graveled high	1	228	15	92	1	0.3	7	15	incl.	incl.	incl.	incl.
GC-17W-G-X-172	MSU	silt loam	50	Insloped, vegetated or rocked ditch	graveled high	2	155	21	90	12	90	11	15	1.3	0	6185	1528
GC-17W-G-X-172	MSU	silt loam	50	Insloped, vegetated or rocked ditch	graveled high	8	484	21	70	1	6	60	15	incl.	incl.	incl.	incl.
GC-17W-G-X-172	MSU	silt loam	50	Insloped, vegetated or rocked ditch	graveled high	11	361	21	100	1	4	126	15	incl.	incl.	incl.	incl.
Gravel: Medium Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.27**	**75th Perc.**	**0.63**	**Median**	**0.46**	**Max**	**0.76**	**Min**	**0.04**	**Mean**	**0.43**
Native Roads																	
LJC-17I-N-X-204	BZN 12 NE	loam	30	Insloped, vegetated or rocked ditch	native high	9	500	13	2	25	1	26	25	1.4	1.1	5376	1166
LJC-17I-N-X-204	BZN 12 NE	loam	30	Insloped, vegetated or rocked ditch	native high	7	500	11	7	80	1	26	25	incl.	incl.	incl.	incl.
LJC-17I-N-X-223	BZN 12 NE	sand	30	Insloped, vegetated or rocked ditch	native high	3.5	122	12	0.3	1	0.3	1	30	1	0.5	159	61
LJC-17I-N-X-223	BZN 12 NE	sand	30	Insloped, vegetated or rocked ditch	native high	2.5	167	16	0.3	1	6	70	30	incl.	incl.	incl.	incl.
Native: High Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.17**	**75th Perc.**	**0.44**	**Median**	**0.31**	**Max**	**0.58**	**Min**	**0.03**	**Mean**	**0.31**
TC-17W-G-X-432	Belgrade	loam	50	Insloped, vegetated or rocked ditch	native high	0.5	89	16	31	1	0.5	100.5	50	0	0	197	2
TC-17W-G-X-432	Belgrade	loam	50	Insloped, vegetated or rocked ditch	native high	2	260	16	9	1	0.5	266	50	incl.	incl.	incl.	incl.
CC-17-W-N-X-219	Belgrade	clay	50	Insloped, vegetated or rocked ditch	native low	3	468	15	0.3	1	0.3	1	10	5.1	2.4	139	91
CC-17-W-N-X-219	Belgrade	clay	50	Insloped, vegetated or rocked ditch	native low	3.5	307	15	0.3	1	0.3	1	10	incl.	incl.	incl.	incl.
CC-17W-N-X-231	Belgrade	clay	50	Insloped, vegetated or rocked ditch	native low	5	770	10	0.3	1	1	50	50	3.4	1.7	405	114
CC-17W-N-X-231	Belgrade	clay	50	Insloped, vegetated or rocked ditch	native low	0.5	230	10	0.3	1	1	5	50	incl.	incl.	incl.	incl.
CC-17W-N-X-247	Belgrade	clay	50	Insloped, vegetated or rocked ditch	native low	1	144	13	25	1	0.3	11	10	1.2	0.8	512	90
CC-17W-N-X-247	Belgrade	clay	50	Insloped, vegetated or rocked ditch	native low	6	428	13	58	1	1	401	40	incl.	incl.	incl.	incl.
CC-17W-N-X-247	Belgrade	clay	50	Insloped, vegetated or rocked ditch	native low	6	428	13	58	1	1	50	40	incl.	incl.	incl.	incl.
Native: Low Precipitation Class Statistics: Annual Sediment Load (tons/year)						**25th Perc.**	**0.03**	**75th Perc.**	**0.05**	**Median**	**0.05**	**Max**	**0.06**	**Min**	**0.00**	**Mean**	**0.04**

Shaded cells in the Road Length column represent two upstream sections of the culvert. These cells were summed prior to calculating the average road length for each crossing within a watershed.
Cells with an “incl.” in the last four columns were summed either because the road was crowned and was modeled as two widths (inslope and outslope portion) or because of the two contributing upstream road sections. .

ATTACHMENT F

WEPP: Road Modeling Results for Field Assessed Sites with Road Length Reductions

Table F-1. WEPP: Road Modeling Results for Field Assessed Crossings: 200 Feet Maximum Length

Comment	Precipitation Class	Soil	Years	Design	Surface, traffic	Road grad (%)	Road length (ft)	Road width (ft)	Fill grad (%)	Fill length (ft)	Buff grad (%)	Buff length (ft)	Rock cont (%)	Average annual rain runoff (in)	Average annual snow runoff (in)	Average annual sediment leaving road (lb/yr)	Average annual sediment leaving buffer (lb/yr)
Gravel Roads																	
RCC-17G-G-X-38	BZN 12 NE	sand	30	Insloped, vegetated or rocked ditch	graveled high	5	148	23	0.3	1	8	108	50	0	0	177	8
REC-17W-G-X-308	MSU	sand	50	Outsloped, rutted	graveled high	1.5	180	14	5	6	0.3	1	20	1.2	0	90	78
Native Roads																	
LJC-17I-N-X-204	BZN 12 NE	loam	30	Insloped, vegetated or rocked ditch	native high	9	100	13	2	25	1	26	25	0.3	0.1	283	26
LJC-17I-N-X-204	BZN 12 NE	loam	30	Insloped, vegetated or rocked ditch	native high	7	100	11	7	80	1	26	25	incl.	incl.	incl.	incl.
LJC-17I-N-X-223	BZN 12 NE	sand	30	Insloped, vegetated or rocked ditch	native high	3.5	122	12	0.3	1	0.3	1	30	1.0	0.5	114.2	49.3
LJC-17I-N-X-223	BZN 12 NE	sand	30	Outsloped, rutted	native high	2.5	78	16	0.3	1	6	70	30	incl.	incl.	incl.	incl.
TC-17W-G-X-432	Belgrade	loam	50	Outsloped, rutted	native high	0.5	89	16	31	1	0.5	100.5	50	0	0	119	1
TC-17W-G-X-432	Belgrade	loam	50	Outsloped, rutted	native high	2	111	16	9	1	0.5	266	50	incl.	incl.	incl.	incl.
All five crossings: Annual Sediment Load (tons/year)						**25th Perc.**	**0.01**	**75th Perc.**	**0.03**	**Median**	**0.02**	**Max**	**0.04**	**Min**	**0.00**	**Mean**	**0.02**

Shaded cells in the Road Length column represent two upstream sections of the culvert. These cells were summed prior to calculating the average road length for each crossing within a watershed.
Cells with an "incl." in the last four columns were summed either because the road was crowned and was modeled as two widths (inslope and outslope portion) or because of the two contributing upstream road sections.