ATTACHMENT C - ROAD SEDIMENT ASSESSMENT & MODELING

Central Clark Fork Tributaries TMDL Project Area: Road Sediment Assessment & Modeling




Prepared by:

ATKINS
Water Resources Group
820 North Montana Avenue
Helena, MT 59601

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1.0 INTRODUCTION

An assessment of the road network within the Central Clark Fork Tributaries TMDL Project Area (Project Area) was performed as part of the development of sediment TMDLs for 303(d) listed stream segments with sediment as a documented impairment. This assessment employed GIS, field data collection, and sediment modeling to assess sediment inputs from the unpaved road network. In addition, because undersized and improperly installed and maintained culverts can be a substantial source of sediment to streams and a barrier to fish and other aquatic organisms, potential loading from undersized culverts was also evaluated, along with an evaluation of fish passage at assessed crossings.

1.1 SEDIMENT IMPAIRMENTS

The Central Clark Fork Tributaries Project Area encompasses an area of approximately 2,175 square miles in Granite, Missoula and Mineral counties in western Montana. The Central Clark Fork Tributaries Project Area includes two TMDL Planning Areas (TPAs): the Middle Clark Fork Tributaries TPA and the Clark Fork – Drummond TPA. Within the Central Clark Fork Tributaries Project Area, there are ten water body segments listed on the 2012 303(d) List for sediment related impairments (**Table 1-1**). Flat Creek, Petty Creek, Trout Creek, and West Fork Petty Creek are listed as impaired due to sediment in the Middle Clark Fork Tributaries TPA, while Cramer Creek, Deep Creek, Grant Creek, Mulkey Creek, Tenmile Creek, and Rattler Gulch are listed as impaired due to sediment in the Clark Fork – Drummond TPA.

Table 1-1. Waterbody Segments Addressed during the Road Assessment

TPA	List ID	Waterbody Description
Clark Fork - Drummond	MT76E004_020	CRAMER CREEK, headwaters to mouth (Clark Fork River)
Clark Fork - Drummond	MT76E004_070	DEEP CREEK, headwaters to mouth (Bear Creek, which is a tributary to Clark Fork River near Bearmouth)
Clark Fork - Drummond	MT76E004_050	MULKEY CREEK, headwaters to mouth (Clark Fork River)
Clark Fork - Drummond	MT76E004_060	RATTLER GULCH, headwaters to mouth (Clark Fork River), T11N R13W S22
Clark Fork - Drummond	MT76E004_030	TENMILE CREEK, headwaters to mouth (Bear Creek-Clark Fork River)
Middle Clark Fork Tributaries	MT76M002_180	FLAT CREEK, headwaters to mouth (Clark Fork)
Middle Clark Fork Tributaries	MT76M002_130	GRANT CREEK, headwaters to mouth (Clark Fork River)
Middle Clark Fork Tributaries	MT76M002_090	PETTY CREEK, headwaters to mouth (Clark Fork River)
Middle Clark Fork Tributaries	MT76M002_050	TROUT CREEK, headwaters to mouth (Clark Fork River)
Middle Clark Fork Tributaries	MT76M002_100	WEST FORK PETTY CREEK, headwaters to mouth (Petty Creek)

2.0 METHODS

Methods employed in this assessment are outlined in *Quality Assurance Project Plan and Sampling and Analysis Plan: Assessment of Unpaved Roads for TMDL Development (Task Order 18: Task 2b)* (EPA 2011) and *Road Sediment Assessment and Modeling: Central Clark Fork Tributaries TMDL Planning Area Road GIS Layers and Summary Statistics* (Atkins 2013) and summarized below.

2.1 Sediment Inputs from Unpaved Roads

Sediment inputs from unpaved roads were evaluated through a combination of GIS analysis, field data collection and computer modeling.

2.1.1 GIS Analysis

Prior to field data collection, GIS data layers representing land ownership, road attributes, stream network, watersheds, and ecoregions were used to summarize the road network in the Central Clark Fork Tributaries Project Area (Atkins 2013). Because unpaved road crossings and near-stream parallel segments are the most likely sources of sediment loading to streams from the road network, the GIS analysis focused on these areas. Land ownership was divided into five categories: U.S. Forest Service, U.S. Fish and Wildlife Service, Montana Fish, Wildlife and Parks, Montana State Trust Lands, and Private. The roads layer was primarily derived from the Travel Routes for Region 1 geodatabase developed by the U.S. Forest Service and available from the Northern Region Geospatial Library (http://www.fs.fed.us/r1/gis/), supplemented with the State of Montana Base Map Service Center Transportation Framework Theme data. Following the initial GIS analysis, Jurisdiction was assigned to each unpaved road crossing based on information in the U.S Forest Service Travel Routes for Region 1 layer and the Montana Public Lands layer. Stream layers were developed using the National Hydrography Dataset (NHD) 1:24,000 high-resolution flowline layer. The high-resolution NHD layer was used because it is the most conservative (i.e., inclusive) stream network layer. Flowlines were limited to streams/rivers and artificial paths; ditches and pipelines were not included. Watersheds were delineated on the basis of the USGS 6th Hydrologic Unit Code (HUC12) layer and modified where necessary to delineate the subwatersheds of interest (**Figure 2-1**). Landscapes were delineated according to the EPA 2002 level IV ecoregions (Woods, et al., 2002) (**Figure 2-2**). These GIS layers were utilized to develop a database of stream crossings and parallel road segments that includes land ownership, road surface type, subwatershed, and ecoregion attributes in one attribute table.

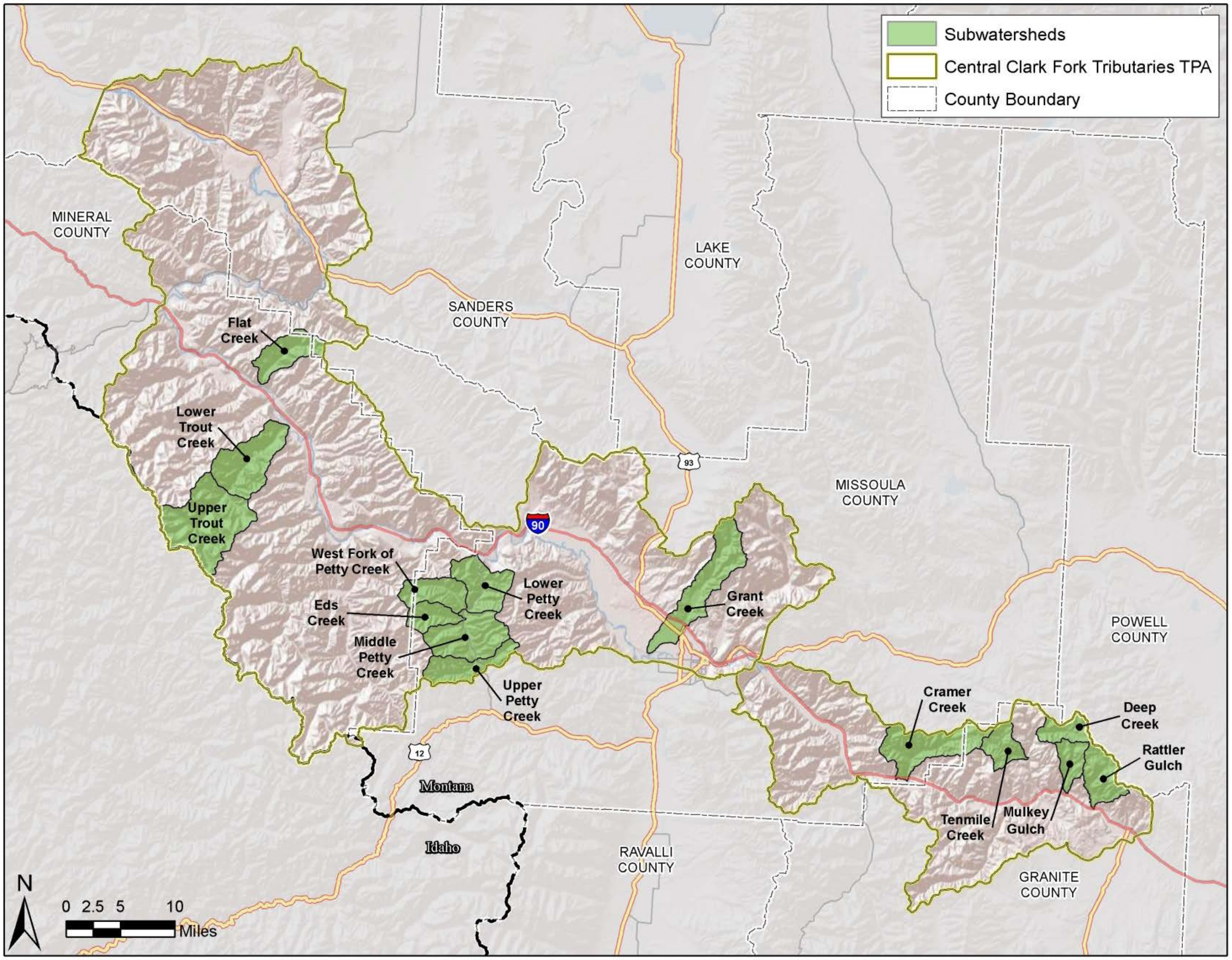

Figure 2-1. HUC12 Subwatersheds in the Central Clark Fork Tributaries Project Area

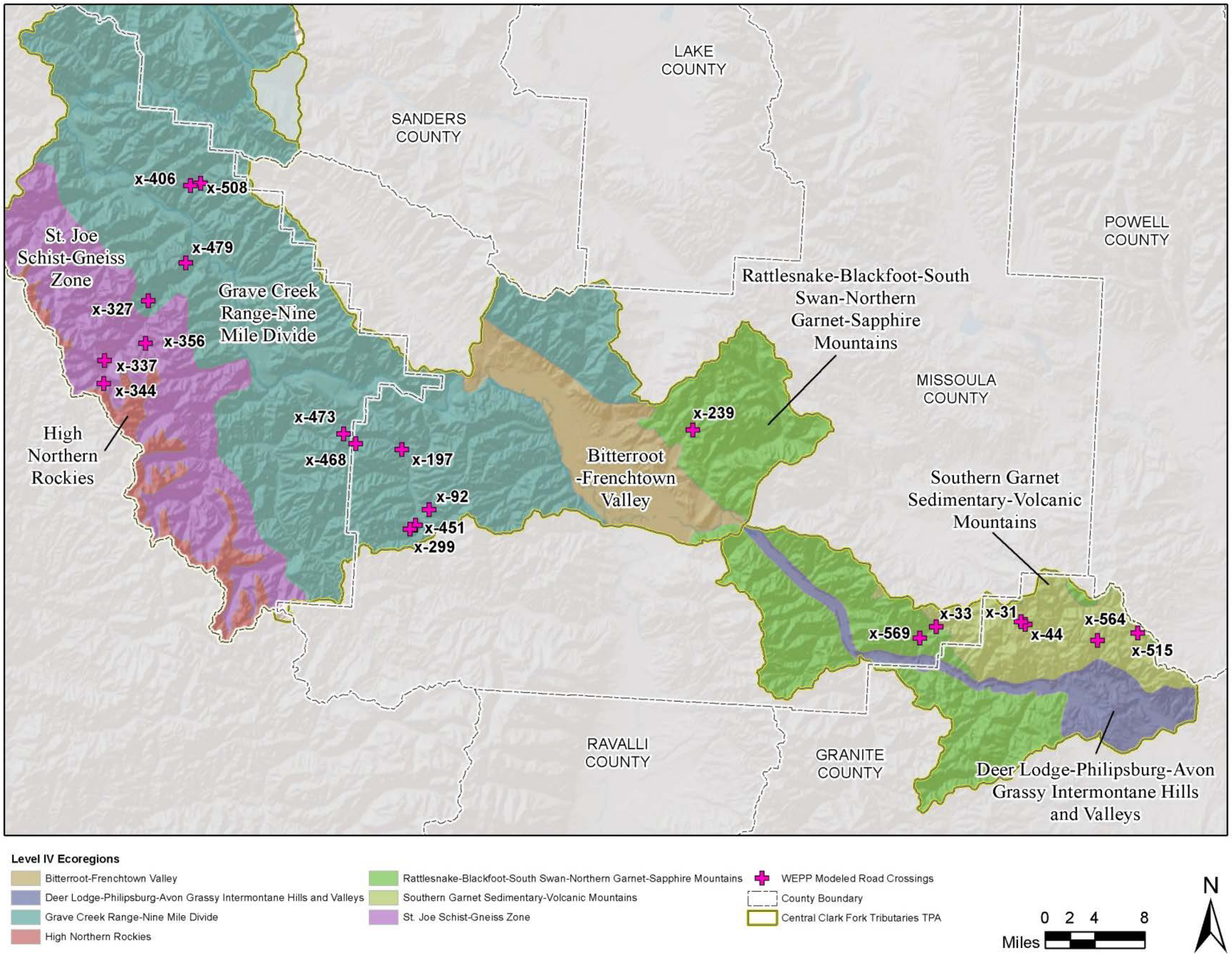

Figure 2-2. Level IV Ecoregions in the Central Clark Fork Tributaries Project Area

Overall, GIS analysis identified 653.18 miles of road within the Central Clark Fork Tributaries Area Project Area, with all but 48.30 miles (7.4%) being unpaved. Of the 719 road crossings identified within the Central Clark Fork Tributaries Project Area, 345 were unpaved (gravel or native material) based on attribute information contained in the GIS roads database (**Figure 2-3**). An additional 294 crossings were identified with an 'unknown' surface type. Based on attributes of proximal road segments, 256 of the crossings identified as 'unknown' are likely to be unpaved. Therefore, there are an estimated total of 601 unpaved road crossings in the Central Clark Fork Tributaries Project Area (**Table 2-1**). Approximately 32% of the crossings are on roads administered by the USFS, with the remainder being a mix of private, state, and county (**Table 2-2**).

Based on the analysis of near-stream parallel road segments, 50.61 miles (7.7%) are within 150 feet of a stream channel, and 19.60 of those miles are unpaved road segments (**Figure 2-4**). An additional 24.48 miles were classified as 'unknown' based on attribute information in the GIS roads database, the majority of which are likely unpaved.

Table 2-1. Road Surface Types in the Central Clark Fork Tributaries Project Area

Road Surface Type	Number of Crossings based on GIS Attribute Information	Number of Crossings Re-classified based on Attributes of Proximal Road Segments	Total Number of Crossings
Paved	80	38	118
Gravel	21	3	24
Native	324	253	577
Unknown	294		
Total Crossings	**719**	**294**	**719**
Total Unpaved Crossings	**345**	**256**	**601**

Table 2-2. Jurisdiction for Unpaved Road Crossings

Jurisdiction	Number of Crossings
Federal	229
Private	141
County/State	349
Total	**719**

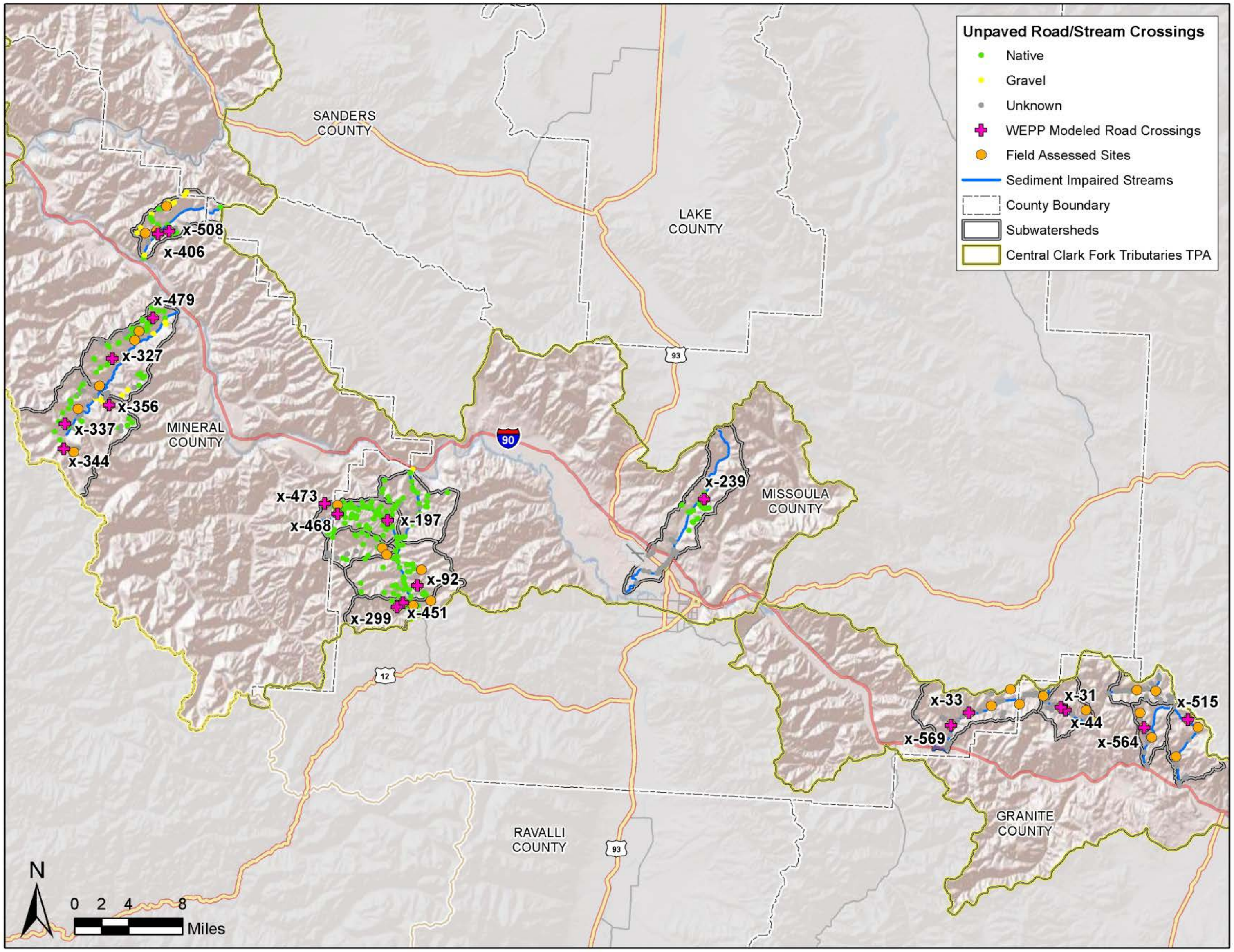

Figure 2-3. Unpaved Road Crossings and Road Surface Type in the Central Clark Fork Tributaries Project Area

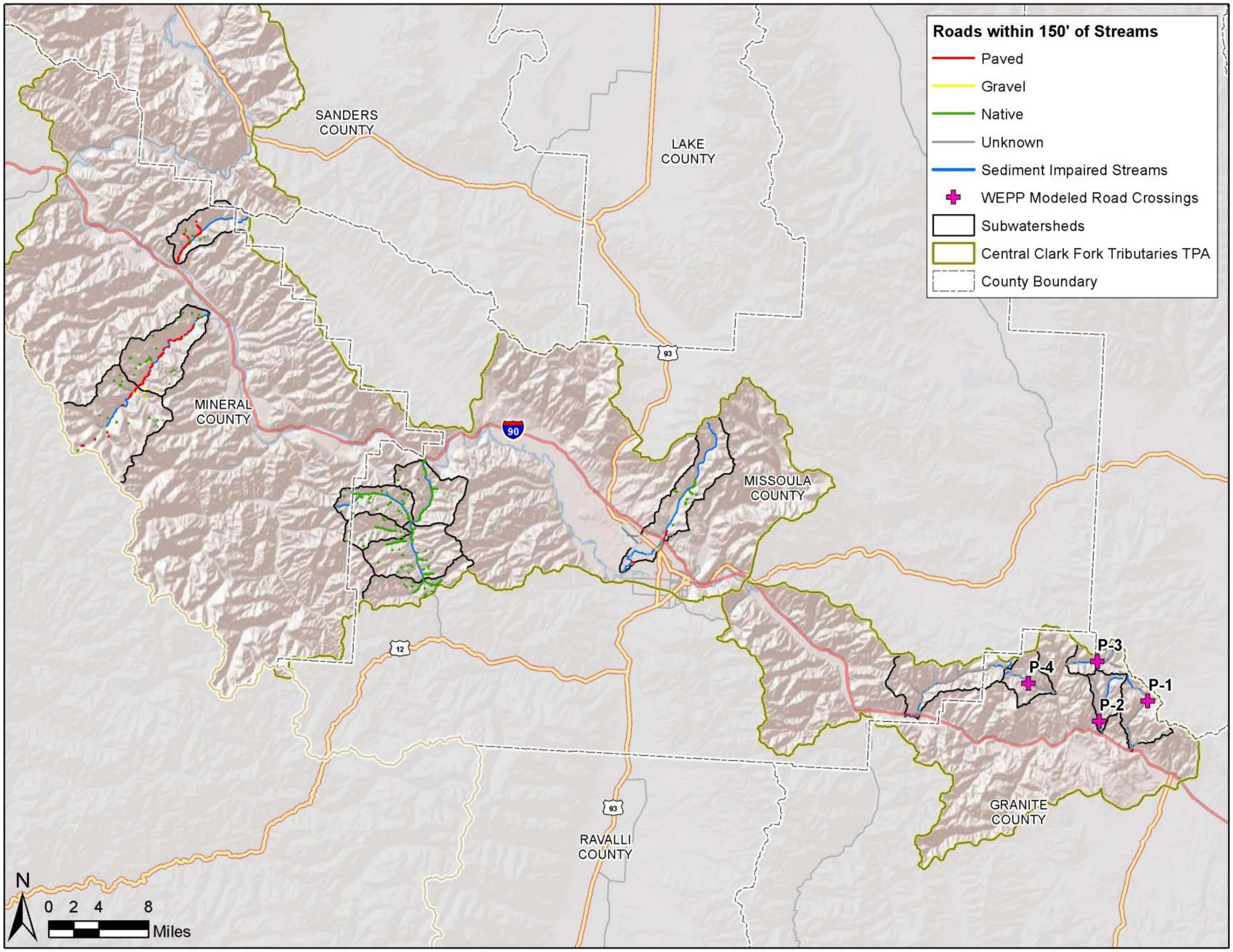

Figure 2-4. Unpaved Parallel Road Segments and Road Surface Type in the Central Clark Fork Tributaries Project Area

2.1.2 Field Data Collection

A field assessment of unpaved roads was conducted by performing an inspection of road crossings and parallel road segments throughout the Central Clark Fork Tributaries Project Area in October of 2012. For each unpaved crossing, a series of measurements were performed to characterize road design, maintenance level, condition, culvert size, and sediment loading potential. Measurements included the length, gradient, and width of road contributing sediment from each side of a stream crossing. Additional information was collected describing road design, road surface type, soil type, rock content, traffic level, and the presence of any Best Management Practices (BMPs).

2.1.2.1 Crossing Assessment Sites

Fifty crossing assessment sites were randomly selected for field data collection. Field measurements included the length, gradient, and width of road contributing sediment from each side of a stream crossing. Additional information was collected describing road design, road surface type, soil type, rock content, traffic level, and the presence of any BMPs, while notes were made regarding road condition at all sites visited. Since the high-resolution NHD layer used to identify road crossings includes intersections of roads with intermittent and ephemeral channels that may not be conduits for road-related sediment, many of the randomly selected sites lacked an actual crossing when visited in the field. As outlined in the project QAPP (EPA 2011), crossings randomly chosen for field assessment that did not have a defined channel (and were unlikely to be pathways for road-related sediment) were excluded from field measurements, and the percentage of randomly selected field sites that had an undefined channel relative to the total number of randomly selected field sites were later factored into the extrapolation process.

Out of the 50 pre-selected sites, 44 crossings were visited in the field in October 2012 and field forms were completed at 18 pre-selected sites where unpaved road crossings of streams were observed. Of the 44 sites visited, 23 lacked defined stream crossings, had become re-vegetated due to road closures, or were inaccessible due to road closures; no measurements were taken at these sites, but notes were made regarding road condition. Measurements were taken and field forms completed at two alternate sites. One additional alternate site was visited, though no data were collected because it lacked a defined channel. Therefore, out of the 47 field assessed sites (i.e., 44 + 3 alternates), field forms were completed at a total of 20 unpaved road crossing sites, and those data were used in the Water Erosion Prediction Project (WEPP) soil erosion model (**Figures 2-2** and **2-3**). Of the remaining 27 sites, 14 had no defined stream channel, nine were inaccessible due to closure, two were on paved roads, and two sites did not exist due to GIS errors (**Attachment A**).

2.1.2.2 Parallel Road Segment Assessment Sites

To account for the contribution of sediment from parallel road segments, field data was collected at four sites identified during field data collection. All four sites were located in the Clark Fork – Drummond TPA.

2.1.3 WEPP Modeling

Sediment loading from unpaved road crossings was estimated using the WEPP:Road soil erosion model version 2012.10.30 (http://forest.moscowfsl.wsu.edu/fswepp/). WEPP:Road is an interface to the Water Erosion Prediction Project (WEPP) model developed by the U.S. Forest Service and other agencies, and is used to predict runoff, erosion, and sediment delivery from forest roads. The WEPP:Road model predicts sediment yields based on specific soil, climate, ground cover, and topographic conditions. Field data collected from each field assessed site provided the following input data necessary to run the WEPP:Road model:

- Road design: insloped, bare ditch; insloped, vegetated or rocked ditch; outsloped, rutted; outsloped unrutted
- Road surface: native, graveled, paved
- Traffic level: high, low, none
- Soil texture: clay loam, silt loam, sandy loam, loam
- Rock content
- Gradient, length and width of the road, fill and buffer
- Climate data
- Years to simulate

The WEPP:Road model was used to evaluate existing conditions at each road crossing based on the field collected data. The WEPP:Road model was also used to estimate the potential to reduce sediment loads through the application of BMPs. During field data collection, the location of potential BMPs, such as water bars and rolling dips, were identified and the distance to the stream crossing was measured. During the BMP modeling scenario, the contributing road length was reduced from the existing length to the potential BMP length based on the field measured values.

2.1.3.1 Model Input Parameters

Road condition data collected throughout the Central Clark Fork Tributaries Project Area in October of 2012 were input directly into the WEPP:Road model following guidance outlined in *WEPP Interface for Predicting Forest Road Runoff, Erosion and Sediment Delivery Technical Documentation*, which is available on the Internet at http://forest.moscowfsl.wsu.edu/fswepp/docs/wepproaddoc.html (**Attachment B**). In addition to field collected data, the WEPP:Road model requires the selection of a climate station to provide an estimate of mean annual precipitation. The WEPP:Road model contains 55 custom climate stations for Montana. Out of these 55 custom climate stations, three were selected to represent the range of precipitation conditions at field assessed sites in the Central Clark Fork Tributaries Project Area: LIBBY 1 NE RS MT, TROUT CREEK RS MT, and DRUMMOND AVIATION MT. Precipitation in the Central Clark Fork Tributaries Project Area ranges from 13”-85” annually based on data collected from 1971 to 2000 and compiled by the PRISM Group at Oregon State University (http://nris.mt.gov/nsdi/nris/precip71_00.html) (**Figure 2-5**). Road crossing assessments in the Central Clark Fork Tributaries Project Area were conducted at sites located in precipitation zones ranging from 18” to 70”, which covers over 95% of the unpaved road crossings identified in GIS. Because precipitation is a significant factor in erosion, modeled loads for stream crossings were grouped into three precipitation zones for the purposes of sediment load modeling and extrapolation in WEPP:Road: <20”, 20-26”, and >26”. In order to improve the representation of conditions within each precipitation zone, all assessed road sites were modeled in WEPP:Road for each precipitation zone. It is assumed that the range of road conditions associated with all of the sites visited would be seen throughout the watershed, and is not dependent on the precipitation zone. Therefore, modeling the entire data set in each precipitation zone provides a better estimate for the range of sediment production that would be seen for that zone. In the Middle Clark Fork Tributaries TPA, the mean precipitation value of 17.18" at the LIBBY NE RS MT climate station was utilized for the <20" precipitation zone, while the mean precipitation value of 28.58" at the TROUT CREEK RS MT climate station was utilized for the >26" precipitation zone. For the 20-26" precipitation zone, the mean precipitation value of 28.58" at the TROUT CREEK RS MT climate station was reduced by 20% to a value of 22.71". In the Clark Fork-Drummond TPA, the mean precipitation value of 12.87" was increased by 30% (16.72") for the <20" precipitation zone, increased by 80% (23.16") for the 20-26" precipitation zone, and increased by 120% (28.17") for the >26" precipitation zone (**Table 2-3** and **Figure 2-5)**.

Table 2-3. Precipitation Data Applied in the WEPP:Road Model

Middle Clark Fork Tributaries TPA				
Climate Station	**Mean Precipitation (Inches)**	**Percent Adjustment**	**Adjusted Mean Precipitation (Inches)**	**PRISM Precipitation Zone (Inches)**
LIBBY 1 NE RS MT	17.18	0%	No adjustment	<20
TROUT CREEK RS MT	28.58	-20%	22.71	20-26
TROUT CREEK RS MT	28.58	0%	No adjustment	>26
Clark Fork – Drummond TPA				
DRUMMOND AVIATION MT	12.87	30%	16.62	<20
DRUMMOND AVIATION MT	12.87	80%	23.16	20-26
DRUMMOND AVIATION MT	12.87	120%	28.17	>26

2.1.4 Potential Culvert Failures

A coarse assessment for each culvert was performed on-site to calculate its conveyance capacity and the amount of sediment at-risk for eroding into the stream channel during culvert failure. The assessment included measurements of structure type, structure diameter, and structure gradient, bankfull width upstream of the culvert, fill height, fill length, fill width, outlet invert, and the presence of streambed materials in the culvert. At each culvert assessed in the field, flood frequencies for the 2, 5, 10, 25, 50, and 100-year events were determined based on the bankfull width upstream of the culvert using U.S. Geological Survey Montana Region regression equations (Parrett and Johnson, 1998). The Urban Drainage and Flood Control District Sewer and Culvert Hydraulics Version 2.0 (http://www.udfcd.org/) spreadsheet model was then utilized to establish the flow capacity of each field assessed culvert. The amount of sediment contributed during a culvert failure was calculated conservatively, assuming that culvert failure would erode sediment to a width equal to the bankfull width of the stream channel upstream of the culvert. For this analysis, an estimated soil weight of 1.66 tons/yard^3 was utilized based on the maximum unit weight for dry well-graded subangular sand presented in Table 1:4 of *Introductory Soil Mechanics and Foundations: Geotechnical Engineering Forth Edition* (Sowers 1979).

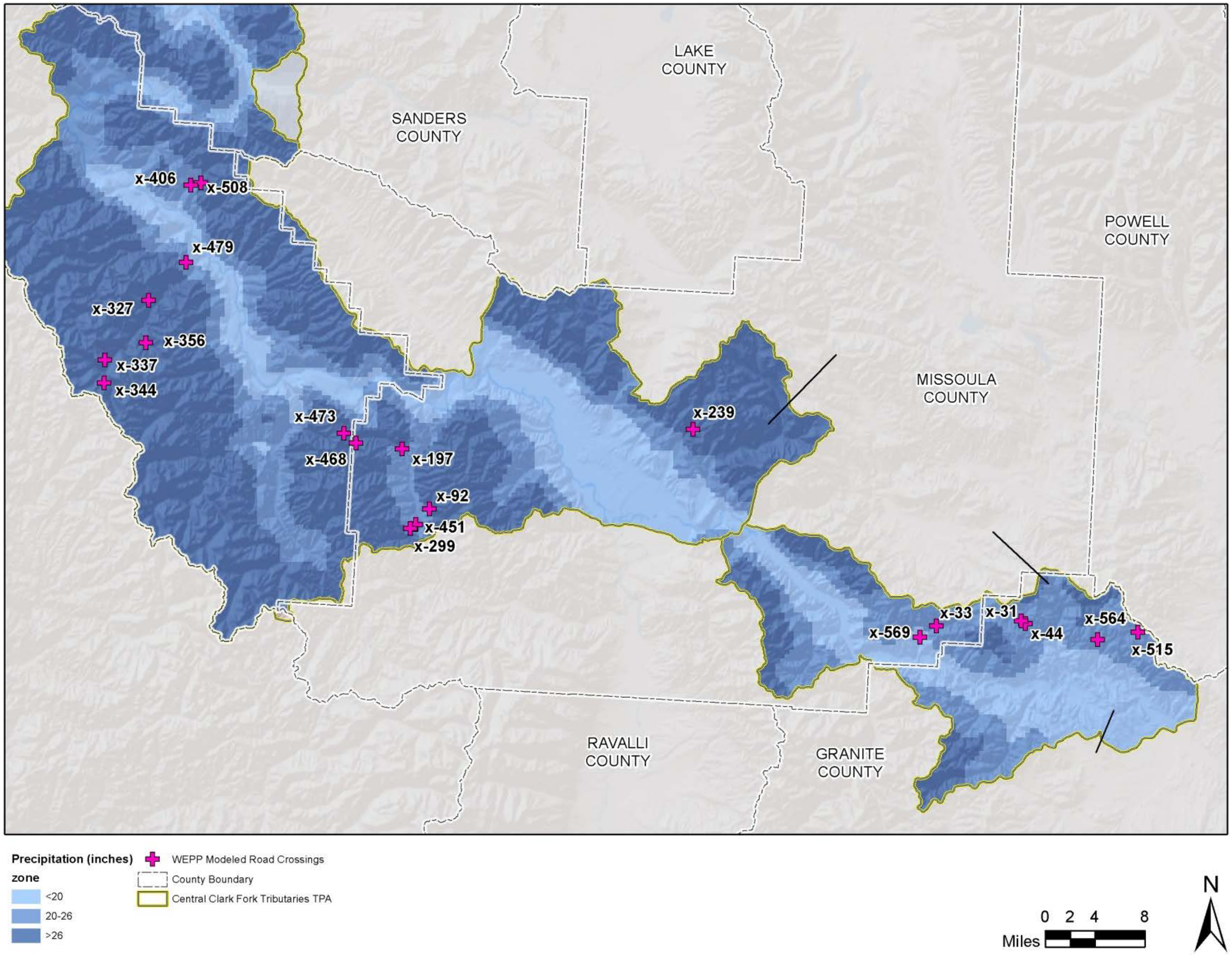

Figure 2-5. Precipitation Patterns in the Central Clark Fork Tributaries Project Area

2.2 Fish Passage Analysis

Measurements were collected at each of the field assessed road crossing sites, and these values were used to determine if culverts represented potential fish passage barriers at various flow conditions. 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 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 diameter (>48 in) and small (<48 in) culvert groups evaluated differently. Failure of any one of the three indicators results in a red classification.

3.0 Results

3.1 Sediment Inputs from Unpaved Roads

The results of the field and WEPP modeling assessment examining sediment loading from roads to streams within the Central Clark Fork Tributaries Project Area are presented in the following sections.

3.1.1 Summary of BMPs and Contributing Length

Because allocations for sediment TMDLs are based on improving management practices, identifying the current practices and areas where improvements are needed is a significant component of the unpaved roads assessment. Out of the 20 unpaved crossings modeled using WEPP:Road, potential BMPs that would reduce the contributing road length were identified at 15 crossings, while sufficient BMPs were observed at four crossings and the addition of gravel to the road bed was recommended at one crossing (**Attachment B**). The most common BMPs observed were rolling dips and water bars. Both of these BMPs interrupt the flow of water, reducing the amount of road surface that water can erode as it moves towards the stream channel (i.e., the contributing length). The contributing length was evaluated separately for each side of a crossing and the average contributing length at sites where all reasonable BMPs have been implemented was 69 feet. During the field assessment, BMPs to reduce the contributing road length were identified at 15 crossings. At each of these 15 crossings, the optimal location (i.e., distance from the stream) of BMP placement to reduce contributing length was identified. This technique incorporated conditions specific to this project area and allowed for loads at each site to be modeled under a BMP scenario to determine achievable reductions in sediment loading from unpaved roads. The average contributing length at the sites needing additional BMPs was 289 feet (**Table 3-1**), and based on field measurements, BMPs could reduce the average contributing length to 106 feet. Although a reduction in contributing length was used for the BMP scenario for the model, other BMPs for unpaved roads include design and siting considerations of topography, soils, and stream crossings; routine maintenance; seasonal usage modification; and filter strips.

Table 3-1. Contributing Road Lengths at Sites with the Potential for Additional BMPs

GIS Site ID	Segment of Road Contributing Sediment (Facing Downstream)	Existing Contributing Length (Feet)	BMP Contributing Length (Feet)	Percent Reduction in Contributing Length
X-515 (C)	left	300	100	67%
X-33 (C)	left	70	40	43%
X-406 (P)	left	350	110	69%
X-508 (F)	left	400	130	68%
X-344 (C)	left	130	90	31%
X-92 (P)	left	140	50	64%
X-299 (F)	left	175	55	69%
X-451 (F)	left	110	55	50%
X-451 (F)	right	295	100	66%
X-564 (C)	right	650	200	69%
X-44 (C)	right	650	200	69%
X-327 (F)	right	250	130	48%
X-356 (F)	right	125	50	60%
X-337 (F)	right	450	215	52%
X-479 (F)	right	275	90	67%
X-239 (P)	right	250	75	70%
Average		**289**	**106**	**63%**

F = Federal, P = Private, C = County, S = State

3.1.2 WEPP Modeled Sediment Loads at Unpaved Road Crossings

The average load per crossing was used during the extrapolation process to estimate sediment loading associated with road crossings at a watershed scale. Unpaved road sediment loads were initially grouped by precipitation zone for modeling, but then the output was evaluated to determine the most appropriate approach for extrapolation. Considerations included ecoregion, precipitation zone, and jurisdiction. The approach selected was to use the three precipitation zones but to group the crossings into two categories based on jurisdiction: unpaved road crossings with federal jurisdiction were grouped into one category and those with private, county, or state jurisdiction were grouped into a second category. WEPP:Road model results for these two categories are presented by precipitation zone in **Attachment C** and summarized in **Table 3-2** and **Figure 3-1.** As expected, loads for both jurisdictional categories generally increase with increasing precipitation zone.

Table 3-2. Unpaved Road Crossing Mean Annual Sediment Loads

Jurisdiction	PRISM Precipitation Zone (Inches)	Number of Sites Assessed	Mean Annual Load (Tons)	Standard Error (Tons)	Minimum (Tons)	Maximum (Tons)	Mean Annual Load with BMP's (Tons)	Standard Error (Tons)	Minimum (Tons)	Maximum (Tons)
Federal	<20	10	0.0190	0.0118	0.0000	0.1149	0.0070	0.0039	0.0000	0.0328
Federal	20-26	10	0.0225	0.0145	0.0000	0.1453	0.0077	0.0043	0.0000	0.0369
Federal	>26	10	0.0320	0.0207	0.0000	0.2081	0.0101	0.0054	0.0000	0.0447
Private	<20	10	0.0141	0.0072	0.0001	0.0708	0.0031	0.0013	0.0000	0.0110
Private	20-26	10	0.0218	0.0126	0.0001	0.1285	0.0044	0.0019	0.0001	0.0169
Private	>26	10	0.0205	0.0090	0.0001	0.0877	0.0059	0.0025	0.0001	0.0231

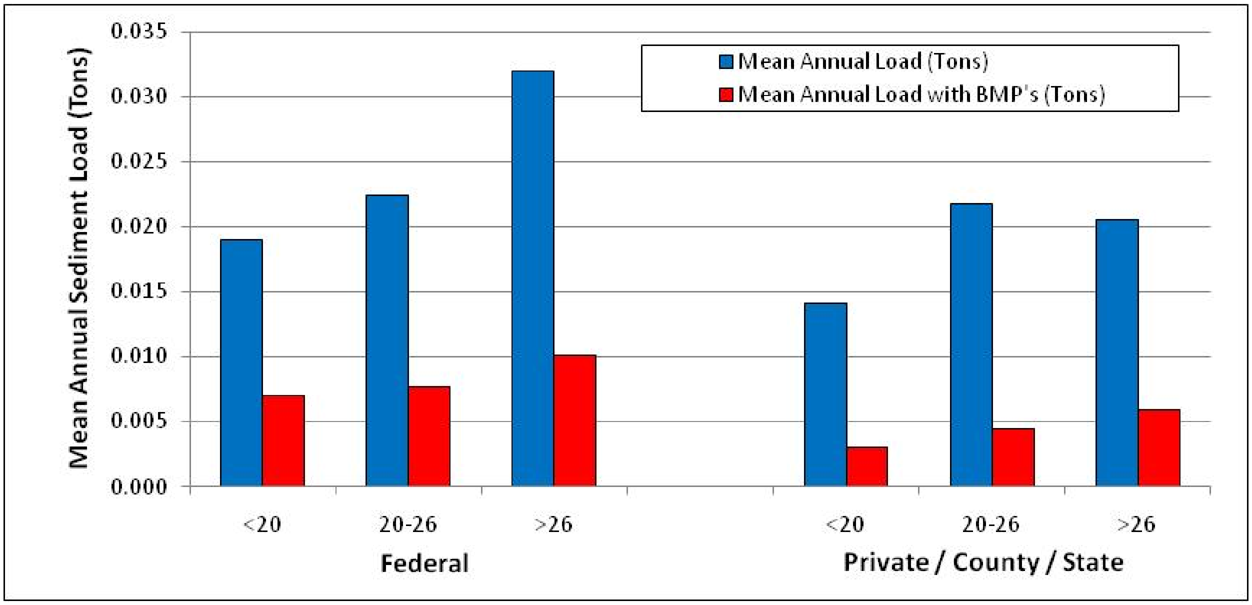

Figure 3-1. Unpaved Road Crossing Mean Annual Sediment Loads

3.1.3 Unpaved Road Crossing Sediment Load Extrapolation

The 20 unpaved road crossings modeled in WEPP:Road were grouped based on jurisdiction and precipitation zone as presented in **Table 3-2** for extrapolation to the subwatershed scale and the total number of crossings was adjusted to account for crossings over undefined channels (**Attachment D**). A total of 601 unpaved road crossings were identified during GIS analysis. A total of 14 out of 47 (30%) of all the visited crossing sites were at undefined channels. Thus, the number of unpaved road crossings identified in the GIS analysis was adjusted downward during the extrapolation process to account for crossings assumed to be over undefined channels that are not contributing road-related sediment to streams. Since 30% of the crossings were excluded for this reason, the total number of unpaved road crossings identified in GIS in each subwatershed was reduced by 30%, for an estimate of 421 unpaved road crossings.

3.1.4 Unpaved Road Parallel Segment Sediment Loads Extrapolation

A total of 44.1 miles of unpaved parallel road segments were identified during GIS analysis. For each of the four field assessed parallel road segments, the sediment load in pounds/foot of contributing road length was calculated based on the site specific precipitation zone. For existing conditions, parallel segments averaged 0.0155 pounds/foot, while for BMP conditions parallel segments averaged 0.0063 pounds/foot. The average sediment load from these four sites was then extrapolated to the subwatershed scale based on the length of unpaved parallel road segments in each subwatershed (**Attachment E**). Since a smaller dataset was used in this analysis, no differentiation was made between roads under federal jurisdiction and roads under private, state or county jurisdiction.

3.1.5 Unpaved Road Sediment Loads by Subwatershed

Both the GIS identified number of unpaved road crossings and the corrected number of unpaved road crossings are presented in **Table 3-3** by jurisdiction for each subwatershed, along with the mean annual sediment load for existing conditions and the mean annual sediment load achievable through the application of BMPs. Mean annual sediment contributions from unpaved road crossings total 10.23 tons per year. Through the application of BMPs, it is estimated that this sediment load can be reduced to 2.77 tons per year. Sediment loading from unpaved road crossings could be reduced between 68% and 80% with additional BMPs, which averages to a 73% reduction across the project area. In addition to the sediment load from unpaved road crossings, the mean annual sediment contribution from unpaved parallel road segments is estimated to be 1.80 tons per year. Through the application of BMPs, it is estimated that the parallel segment sediment loads in the project area can be reduced to 0.73 tons per year, which is a 59% reduction (**Table 3-4**). Although the field assessment is a limited sampling of all road crossings, based on observations while completing the field work, the sampled population of road crossings is representative of conditions throughout the project area. Overall, conditions for unpaved roads within the project area are good. In general, it appears most road sediment comes from a limited number of crossings with inadequate or improperly maintained BMPs. A more detailed accounting of sediment loads from unpaved road crossings at the HUC12 subwatershed scale by precipitation zone and ownership is presented in **Attachment D**.

Table 3-3. Unpaved Road Crossing Mean Annual Sediment Loads by Subwatershed

Subwatershed	Number of Crossings Identified in GIS	Corrected Number of Crossings based on Field Data	Mean Annual Load (Tons)	Mean Annual Load with BMPs (Tons)	Percent Reduction
Cramer Creek	**55**	**39**	**0.785**	**0.161**	**80%**
Deep Creek	**58**	**41**	**0.862**	**0.207**	**76%**
Mulkey Gulch	**35**	**25**	**0.523**	**0.107**	**80%**
Rattler Gulch	**16**	**11**	**0.201**	**0.042**	**79%**
Tenmile Creek	**23**	**16**	**0.351**	**0.071**	**80%**
Flat Creek	**37**	**26**	**0.649**	**0.187**	**71%**
Grant Creek	**24**	**17**	**0.354**	**0.089**	**75%**
Upper Petty Creek	15	11	0.228	0.068	70%
Middle Petty Creek	49	34	0.774	0.206	73%
Lower Petty Creek	37	26	0.542	0.131	76%
Eds Creek	27	19	0.471	0.131	72%
Petty Creek Total (excluding West Fork Petty Creek)	**128**	**90**	**2.015**	**0.535**	**73%**
West Fork Petty Creek	**93**	**65**	**1.635**	**0.468**	**71%**
Upper Trout Creek	59	41	1.322	0.416	69%
Lower Trout Creek	73	51	1.529	0.488	68%
Trout Creek Total	**132**	**92**	**2.851**	**0.904**	**68%**
Central Clark Fork Tributaries Project Area Total	**601**	**421**	**10.23**	**2.77**	**73%**

Table 3-4. Unpaved Parallel Road Segment Mean Annual Sediment Loads by Subwatershed

Subwatershed	Road Length (Miles)	Mean Annual Load (Tons)	Mean Annual Load with BMPs (Tons)	Percent Reduction
Cramer Creek	**6.30**	**0.26**	**0.10**	**59%**
Deep Creek	**3.06**	**0.12**	**0.05**	**59%**
Mulkey Gulch	**3.49**	**0.14**	**0.06**	**59%**
Rattler Gulch	**4.67**	**0.19**	**0.08**	**59%**
Tenmile Creek	**2.87**	**0.12**	**0.05**	**59%**
Flat Creek	**0.94**	**0.04**	**0.02**	**59%**
Grant Creek	**2.12**	**0.09**	**0.04**	**59%**
Upper Petty Creek	3.45	0.14	0.06	59%
Middle Petty Creek	4.35	0.18	0.07	59%
Lower Petty Creek	2.97	0.12	0.05	59%
Eds Creek	1.93	0.08	0.03	59%
Petty Creek Total (excluding West Fork Petty Creek)	**12.70**	**0.52**	**0.21**	**59%**
West Fork of Petty Creek	**3.59**	**0.15**	**0.06**	**59%**
Upper Trout Creek	2.40	0.10	0.04	59%
Lower Trout Creek	1.93	0.08	0.03	59%
Trout Creek Total	**4.32**	**0.18**	**0.07**	**59%**
Central Clark Fork Tributaries Project Area Total	**44.08**	**1.80**	**0.73**	**59%**

3.1.6 Potential Culvert Failures

Out of the 20 field assessed crossings in the Central Clark Fork Tributaries Project Area, 17 crossings had culverts, while two sites located at bridges and one site lacked a culvert where a small dry gulch flowed over the road. While 11 of the culverts had flowing water at the time that field data was collected, all 17 culverts assessed in the field were evaluated for culvert failure to provide a conservative estimate of sediment loading. Of the 17 culverts assessed in the field, 94% are capable of passing the two-year flood event and 88% are capable of passing a 100-year flood event (**Tables 3-5** and **3-6**, **Attachment E**). Once a culvert's carrying capacity is exceeded, the potential for culvert failure increases, though the point at which a given culvert will fail remains uncertain. Hydraulic analysis of a culvert is extremely complex and potential sediment loads from the eroding fill as presented in **Table 3-5** are estimates assuming the entire height and length of road fill are eroded to a width equal to the bankfull width of the stream.

Table 3-5. Culvert Failure and Potential Sediment Load Evaluation

Location ID	Q2	Q5	Q10	Q25	Q50	Q100	Estimated Maximum Culvert Capacity (cfs)	Potential Sediment Load if Culvert Fails (Tons)
X-515	17	32	45	63	79	94	15	55
X-44	13	25	35	50	63	76	133	90
X-31	7	14	19	28	36	43	9	2
X-569	13	25	35	50	63	76	76	52
X-33	4	9	13	19	24	30	31	15
X-406	13	25	35	50	63	76	143	72
X-508	0	1	1	2	2	3	18	11
X-327	17	32	45	63	79	94	222	236
X-337	7	14	19	28	36	43	46	92
X-344	27	49	67	92	115	137	202	400
X-479	2	5	8	12	15	19	57	138
X-197	1	2	4	6	8	9	20	8
X-473	1	1	2	4	5	6	78	83
X-468	7	14	19	28	36	43	87	74
X-92	13	25	35	50	63	76	259	103
X-299	2	5	8	12	15	19	25	30
X-451	1	2	4	6	8	9	23	35

grey cells indicate culvert fails to pass a given discharge

Table 3-6. Culvert Failure Summary

Flood Frequency	Number of Culverts Passing	Number of Culverts Failing	Percent Passing	Percent Failing
Q2	16	1	94%	6%
Q5	15	2	88%	12%
Q10	15	2	88%	12%
Q25	15	2	88%	12%
Q50	15	2	88%	12%
Q100	15	2	88%	12%

If a culvert fails for a given event, the replacement culvert should address several issues. First, culverts typically cause changes in the upstream elevation and the new culvert should mitigate these effects to ensure that culvert placement does not negatively affect the surrounding habitat. Next, environmental considerations such as fish passage need to be accurately predicted. New three-sided culverts, where the bottom of the culvert is typically the natural channel bottom, allow better holding habitat and maintain a continuous stream channel bottom. The hydrology of the area should also be determined and directly related to the culvert design size for the given watershed. Following these principals will help improve the stream system, increase fish habitat, and reduce potential sediment loads from failed culverts.

3.2 FISH PASSAGE ANALYSIS

In the Central Clark Fork Tributaries Project Area, none of the 12 culverts assessed at crossings with flowing water had a high probability of allowing fish passage and all 12 culverts were classified as fish passage barriers (**Table 3-7**, **Attachment F**). The majority of these culverts were located on streams containing fish as evaluated by Montana Fish, Wildlife and Parks, though this was not considered when evaluating a culverts ability to pass fish (**Figure 3-2**). In general, too steep of slope led to most of these culverts being classified as fish passage barriers. Recent research suggests fish can pass steeper culverts than indicated by the Alaska criteria (Burford et al. 2009; Peterson et al. 2013), particularly if there is no outlet drop (Peterson et al. 2013). When gradients up to 8% are considered at culverts with no outlet perch, two of the assessed culverts may pass some fish. As this is a very coarse assessment, additional evaluations should be conducted at any culvert that may be replaced to facilitate fish passage.

Table 3-7. Fish Passage Evaluation

Fish Passage Evaluation Categories	Fish Passage Evaluation Criteria	Number of Culverts	Percentage of Total Culverts Assessed
green	conditions that have a high certainty of meeting juvenile fish passage at all desired stream flows	0	0%
red	conditions that have a high certainty of not providing juvenile fish passage at all desired stream flows	12	100%
grey	conditions are such that additional and more detailed analysis is required to determine their juvenile fish passage ability	0	0%

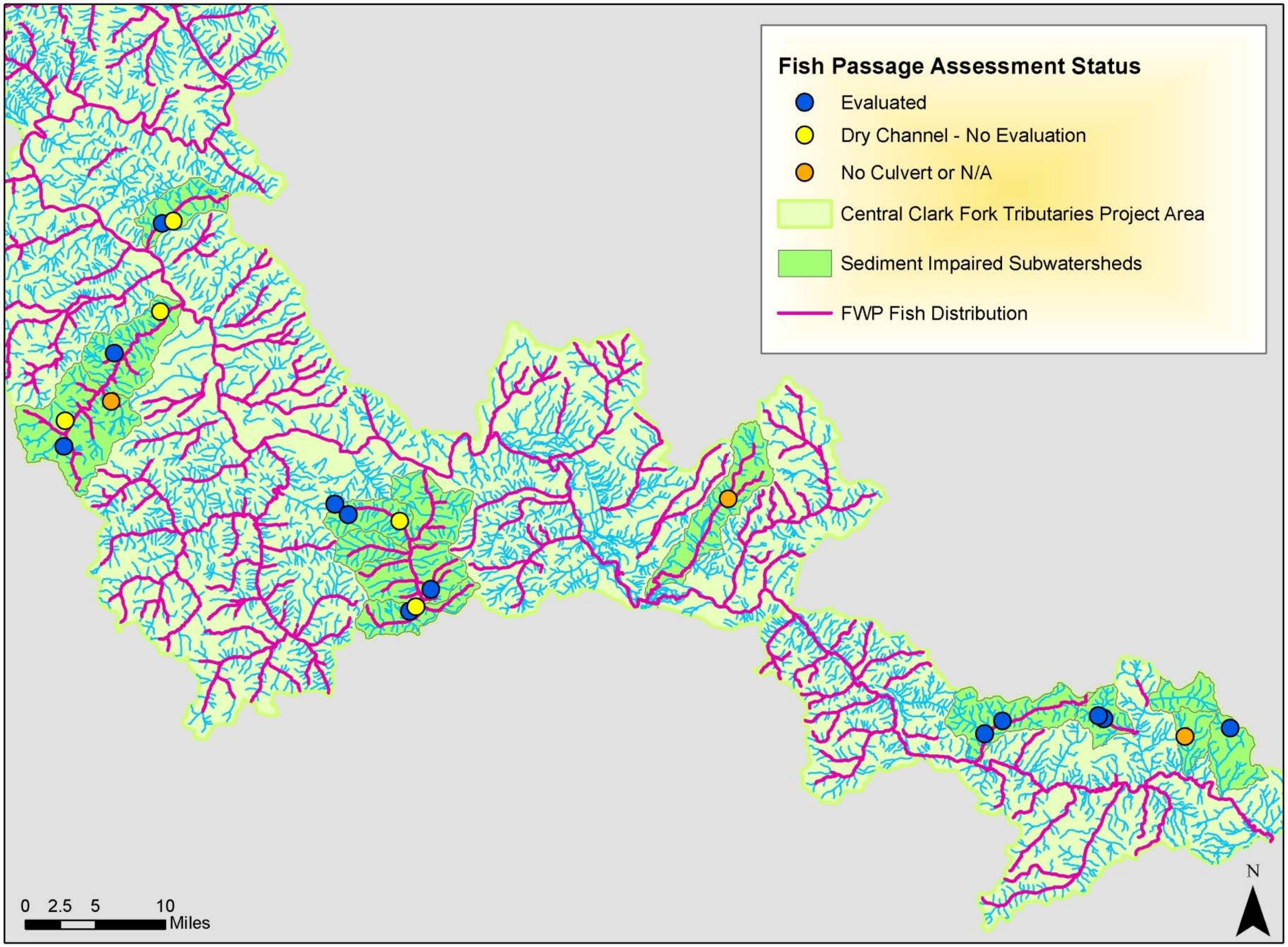

Figure 3-2. Montana Fish, Wildlife and Parks Fish Distribution in the Central Clark Fork Tributaries Project Area

4.0 Assumptions and Uncertainty

The Central Clark Fork Tributaries road assessment assumes that the crossings assessed in the field are representative of crossings throughout the project area. Since only a subset of the unpaved road crossings within the Central Clark Fork Tributaries Project Area were assessed in the field, a degree of uncertainty is unavoidable when extrapolating data from assessed sites to un-assessed sites. The largest potential sources of inaccuracy within the project are the small sample size, which was selected based on available resources, and potential errors in the GIS data layers. These are minimized by performing a random selection of representative monitoring sites and by adjusting the results of the GIS data analysis to account for sites where no crossing was observed during field data collection. Since sediment source modeling may under-estimate or over-estimate sediment inputs due to selection of sediment monitoring sites and the extrapolation methods used, model results should not be taken as an absolutely accurate account of sediment production within each sub-watershed. Instead, the unpaved road assessment model results should be considered an instrument for estimating existing sediment loads and making general comparisons of road sediment loads under different management scenarios. In addition, the fish passage assessment and culvert failure assessment are intended to highlight the importance of proper culvert design and installation and the results should be considered as coarse estimates.

5.0 Discussion

Within the Central Clark Fork Tributaries Project Area, there are ten water body segments listed on the 2012 303(d) List for sediment related impairments including Flat Creek, Pretty Creek, Trout Creek, and West Fork Petty Creek in the Middle Clark Fork Tributaries TPA, and Cramer Creek, Deep Creek, Grant Creek, Mulkey Creek, Tenmile Creek, and Rattler Gulch in the Clark Fork – Drummond TPA. Mean annual sediment contributions from unpaved road crossings total 10.23 tons per year (**Table 4-1**). Through the application of BMPs, it is estimated that this sediment load can be reduced to 2.77 tons per year, which is a 73% reduction in sediment load. The mean annual sediment contribution from unpaved parallel road segments is estimated to be 1.80 tons per year. Through the application of BMPs, it is estimated that the parallel segment sediment load can be reduced to 0.73 tons per year, which is a 59% reduction in sediment load. Overall, unpaved roads in the Central Clark Fork Tributaries Project Area are estimated to contribute 12.03 tons/year. Through the application of BMPs, it is estimated that this sediment load can be reduced to 3.50 tons per year, which is a 71% reduction in the overall sediment load.

Table 4-1. Potential Reduction in Sediment Loads from Unpaved Roads through Application of BMPs

Subwatershed	Mean Annual Load (Tons)	Mean Annual Load with BMPs (Tons)	Percent Reduction
Cramer Creek	**1.04**	**0.27**	**75%**
Deep Creek	**0.99**	**0.26**	**74%**
Mulkey Gulch	**0.67**	**0.16**	**75%**
Rattler Gulch	**0.39**	**0.12**	**69%**
Tenmile Creek	**0.47**	**0.12**	**75%**
Flat Creek	**0.69**	**0.20**	**71%**
Grant Creek	**0.44**	**0.12**	**72%**
Upper Petty Creek	**0.37**	0.13	66%
Middle Petty Creek	**0.95**	0.28	71%
Lower Petty Creek	**0.66**	0.18	73%
Eds Creek	**0.55**	0.16	70%
Petty Creek Total (excluding West Fork Petty Creek)	**2.53**	**0.75**	**71%**
West Fork Petty Creek	**1.78**	**0.53**	**70%**
Upper Trout Creek	**1.42**	0.46	68%
Lower Trout Creek	**1.61**	0.52	68%
Trout Creek Total	**3.03**	**0.98**	**68%**
Central Clark Fork Tributaries Project Area Total	**12.03**	**3.50**	**71%**

6.0 References

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Attachment A

Field Assessed Sites

Field Site ID	Stream Segment Subwatershed	Pre-selected / Alternate	WEPP Field Form Completed	Potential BMP Identified	Road Closed / Re-vegetated / Obliterated	No Defined Channel	Comment
X-267	Rattler Gulch	pre-selected	no			X	no channel, tributary gulch intercepted by road
X-272	Rattler Gulch	pre-selected	no			X	no channel, dry tributary gulch
X-515	Rattler Gulch	pre-selected	yes	yes			
P-1	Rattler Gulch	parallel segment	yes	yes			
X-9	Mulkey Gulch	pre-selected	no				not a crossing of Dry Mulkey, GIS error
X-563	Mulkey Gulch	pre-selected	no				not a crossing of Dry Mulkey, GIS error
X-564	Mulkey Gulch	alternate	yes	yes			
X-635	Mulkey Gulch	pre-selected	no			X	no channel, dry gulch, road criss-crosses valley bottom
P-2	Mulkey Gulch	parallel segment	yes	yes			
X-522	Deep Creek	pre-selected	no			X	no channel
X-293	Deep Creek	pre-selected	no			X	no channel, Gambler Creek
P-3	Deep Creek	parallel segment	yes	yes			
X-447	Tenmile Creek	pre-selected	no			X	no channel, field latlong plots poorly
X-690	Tenmile Creek	pre-selected	no		Road Closed - Administrative Use By Permit		
P-4	Tenmile Creek	parallel segment	yes	yes			
X-44	Tenmile Creek	pre-selected	yes	yes			
X-31	Tenmile Creek	pre-selected	yes	yes-gravel			road crosses wet meadow, add gravel, change % rock to 100%
X-569	Cramer Creek	pre-selected	yes	no			
X-33	Cramer Creek	pre-selected	yes	yes			
X-536	Cramer Creek	pre-selected	no			X	no channel, road up dry draw
X-38	Cramer Creek	pre-selected	no		Road Closed		
X-55	Cramer Creek	pre-selected	no			X	no channel
X-294	Cramer Creek	pre-selected	no			X	no channel, culvert drains roadside ditch
X-430	Flat Creek	pre-selected	no			X	no channel, 2-track road heading up narrow dry gulch
X-406	Flat Creek	pre-selected	yes	yes			
X-508	Flat Creek	pre-selected	yes	yes			no flow, very small channel
X-713	Flat Creek	pre-selected	no			X	no channel, dry gulch, native material, BST-BITUMINOUS in GIS database
X-428	Flat Creek	pre-selected	no		Road Decomissioned - Re-vegetated		dry gulch, AC-ASPHALT in GIS database
X-387	Trout Creek	pre-selected	no		Paved road		AC-ASPHALT in GIS database confirmed
X-327	Trout Creek	pre-selected	yes	yes			X-329 on photo log
X-372	Trout Creek	pre-selected	no		Road closed - Re-vegetated		
X-356	Trout Creek	pre-selected	yes	yes			bridge crossing of Windfall Creek
X-661	Trout Creek	pre-selected	no		Road closed - Re-vegetated		
X-337	Trout Creek	pre-selected	yes	yes			dry channel
X-328	Trout Creek	pre-selected	no		Semi-paved road		AC-ASPHALT in GIS database supported, appears to be "hardened gravel"
X-344	Trout Creek	pre-selected	yes	yes			well-maintained gravel road identified as AC-ASPHALT in GIS database, Lake Creek
X-479	Trout Creek	pre-selected	yes	yes			dry channel, field latlong plots poorly
X-378	Trout Creek	pre-selected	no			X	no channel
X-197	WF Petty Creek	pre-selected	yes	no			dry channel
X-474	WF Petty Creek	pre-selected	no			X	
X-473	WF Petty Creek	pre-selected	yes	yes	Road closed		
X-468	WF Petty Creek	pre-selected	yes	yes	Road closed		site accessed by walking up closed road
X-157	Petty Creek	alternate	no			X	no channel
X-146	Petty Creek	pre-selected	no		Road closed - Nature Conservancy		
X-445	Petty Creek	pre-selected	no		Road closed - converted to single track		PRINTERS CR TR NO 718
X-92	Petty Creek	pre-selected	yes	yes			2 culverts at crossing, pour point on more southerly culvert
X-299	Petty Creek	pre-selected	yes	yes			gate open
X-451	Petty Creek	pre-selected	yes	yes			dry channel
X-255	Petty Creek	pre-selected	no		Road closed		
X-50	Petty Creek	pre-selected	no		Road closed - Nature Conservancy		
X-239	Grant Creek	alternate	yes	yes			end of road at residence, East Fork Grant Creek

Attachment B

Unpaved Road Crossing and Parallel Segment Field Data

Waterbody	Stream Segment	Location ID	Date	Latitude	Longitude	Jurisdiction / Ownership	PRISM Precip 1971-2000 (inches)	Soil Type	% Rock	Insloped/ Outsloped	Road Surface	Traffic Level	Years Modeled	Gradient CRL1 (%)	Length CRL1 (Feet)	Width CRL1 (Feet)	Gradient Fill (%)	Length Fill (Feet)	Gradient Buffer (%)	Length Buffer (Feet)	WEPP LOAD (lbs)	Gradient CRL1 (%)	Length CRL1 (Feet)	Width CRL1 (Feet)	Gradient Fill (%)	Length Fill (Feet)	Gradient Buffer (%)	Length Buffer (Feet)	WEPP LOAD (lbs)	MEAN ANNUAL LOAD (lbs)	MEAN ANNUAL LOAD with BMPs (lbs)
														L	L	L	L	L	L	L	L	R	R	R	R	R	R	R	R		
Rattler Gulch	Rattler Gulch	X-515	10/8/12	46.76873	-113.21430	County	22-24	Silt L	20	Outsloped Unrutted	Native	Low	30	3	300	12	60	5	13.0	20	0.00	1	95	12	60	5	0.3	1	2.42	2.42	2.42
Rattler Gulch	Rattler Gulch	P-1	10/8/12	46.75520	-113.19849	not assigned	22-24	Silt L	20	Outsloped Unrutted	Native	Low	30	3	200	12	35	8	0.3	1	4.95	-	-	-	-	-	-	-	-	4.95	1.36
Dry Mulkey	Mulkey Gulch	X-564	10/8/12	46.75761	-113.28150	County	22-24	Silt L	60	Outsloped Rutted	Native	Low	30	-	-	-	-	-	-	-	-	16	650	10	0.3	1	0.3	1	86.30	86.30	0.40
Mulkey Gulch	Mulkey Gulch	P-2	10/8/12	46.72895	-113.27934	not assigned	14-16	Sand L	30	Outsloped Unrutted	Native	Low	50	6	350	12	0.3	1	0.3	1	0.00	-	-	-	-	-	-	-	-	0.00	0.00
Deep Creek	Deep Creek	P-3	10/8/12	46.79873	-113.28726	not assigned	26-30	Sand L	40	Outsloped Rutted	Native	Low	30	3	500	10	35	5	0.3	1	14.76	-	-	-	-	-	-	-	-	14.76	9.16
Tenmile Creek	Tenmile Creek	P-4	10/8/12	46.76903	-113.40175	not assigned	22-24	Sand L	40	Outsloped Rutted	Native	Low	30	4	1000	10	0.3	1	0.3	1	7.56	-	-	-	-	-	-	-	-	7.56	0.24
Tenmile Creek	Tenmile Creek	X-44	10/8/12	46.77230	-113.40528	County	22-24	Sand L	30	Outsloped Rutted	Native	Low	30	-	-	-	-	-	-	-	-	11	650	10	35	15	0.3	1	257.08	257.08	33.79
trib to Tenmile Creek	Tenmile Creek	X-31	10/8/12	46.77520	-113.41347	County	22-24	Sand L	5	Outsloped Rutted	Native	Low	30	-	-	-	-	-	-	-	-	4	135	10	0.3	1	0.3	1	0.27	0.27	0.22
trib to Cramer Creek	Cramer Creek	X-569	10/9/12	46.75019	-113.58292	County	18-20	Sand L	30	Outsloped Unrutted	Gravel	Low	50	0.5	50	16	80	3	0.3	1	1.07	0.5	5	16	80	3	0.3	1	0.11	1.18	1.18
trib to Cramer Creek	Cramer Creek	X-33	10/9/12	46.76442	-113.55662	County	20-22	Sand L	30	Outsloped Unrutted	Gravel	Low	30	2	70	14	40	3	0.3	1	2.65	-	-	-	-	-	-	-	-	2.65	1.51
Flat Creek	Flat Creek	X-406	10/9/12	47.22597	-114.87045	Private	20-22	Sand L	20	Outsloped Unrutted	Native	Low	30	8	350	14	45	10	0.3	1	32.82	0.5	30	14	45	10	0.3	1	1.64	34.46	11.95
Idaho Gulch	Flat Creek	X-508	10/9/12	47.22937	-114.85351	Federal	24-26	Sand L	20	Outsloped Unrutted	Native	Low	30	6	400	12	65	6	7.0	30	0.00	0.5	50	12	65	6	7.0	30	0.00	0.00	0.00
trib to Trout Creek	Trout Creek	X-327	10/9/12	47.08873	-114.92881	Federal	34-38	Sand L	50	Outsloped Rutted	Native	Low	30	-	-	-	-	-	-	-	-	4	250	10	70	18	4.0	8	55.69	55.69	23.79
Wind Fall Creek	Trout Creek	X-356	10/9/12	47.03857	-114.92853	Federal	55-60	Sand L	20	Outsloped Unrutted	Native	Low	30	2	100	12	0.3	1	0.3	1	0.60	4	125	12	0.3	1	0.3	1	0.77	1.37	0.91
trib to Trout Creek	Trout Creek	X-337	10/9/12	47.01517	-114.99600	Federal	55-60	Silt L	20	Outsloped Rutted	Native	Low	30	-	-	-	-	-	-	-	-	6	450	10	70	13	0.3	1	416.29	416.29	89.36
Lake Creek	Trout Creek	X-344	10/9/12	46.98853	-114.99535	County	60-70	Silt L	50	Outsloped Unrutted	Gravel	Low	30	8	130	24	70	20	0.3	1	43.40	1	65	24	70	20	0.3	1	16.06	59.46	46.11
trib to Trout Creek	Trout Creek	X-479	10/9/12	47.13475	-114.86366	Federal	22-24	Silt L	30	Outsloped Unrutted	Native	Low	30	3	150	18	75	20	0.3	1	35.00	4	275	18	75	20	0.3	1	66.51	101.51	56.76
trib to WF Petty Creek	WF Petty Creek	X-197	10/10/12	46.93496	-114.48123	Federal	24-26	Sand L	50	Outsloped Unrutted	Gravel	High	30	0.5	5	18	35	4	0.3	1	0.44	0.5	5	18	35	4	0.3	1	0.44	0.88	0.88
trib to WF Petty Creek	WF Petty Creek	X-473	10/10/12	46.94838	-114.58132	Federal	38-42	Sand L	20	Outsloped Unrutted	Native	None	30	2	60	4	0.3	1	80.0	30	0.07	3	180	4	0.3	1	80.0	30	0.29	0.36	0.36
West Fork Petty Creek	WF Petty Creek	X-468	10/10/12	46.93820	-114.55988	Federal	34-38	Sand L	40	Outsloped Unrutted	Native	None	30	0.5	20	2	0.3	1	90.0	10	0.03	5	105	2	0.3	1	90.0	10	0.44	0.47	0.47
Bill Creek	Petty Creek	X-92	10/10/12	46.86671	-114.42790	Private	30-34	Sand L	20	Outsloped Unrutted	Native	Low	30	3	140	10	120	8	0.3	1	14.45	0.5	75	12	120	8	0.3	1	8.95	23.40	14.11
trib to SF Petty Creek	Petty Creek	X-299	10/10/12	46.84259	-114.45805	Federal	24-26	Sand L	15	Outsloped Unrutted	Native	Low	30	4	175	8	45	9	0.3	1	5.16	0.5	50	8	45	9	0.3	1	0.90	6.06	2.52
trib to SF Petty Creek	Petty Creek	X-451	10/10/12	46.84765	-114.44902	Federal	22-24	Sand L	20	Outsloped Rutted	Native	Low	30	3	110	2	65	11	0.3	1	1.73	5	295	2	65	11	0.3	1	9.15	10.88	2.62
East Fork Grant Creek	Grant Creek	X-239	10/10/12	46.97815	-113.98796	Private	30-34	Sand L	20	Outsloped Unrutted	Gravel	Low	30	-	-	-	-	-	-	-	-	3	250	14	0.3	1	0.3	1	0.81	0.81	0.24

Waterbody	Stream Segment	Location ID	Segment 1 Installed BMPs		Segment 1 Potential BMPs		Road Crossing and BMP Notes/Comments
			L	R	L	R	
Rattler Gulch	Rattler Gulch	X-515	none	rolling dip at 95 ft	rolling dip at 100 ft	none	existing rolling dips have lost effectiveness of river left
Rattler Gulch	Rattler Gulch	P-1					reduce length to 55 ft, deflect water to inside ditch
Dry Mulkey	Mulkey Gulch	X-564	-	none	-	rolling dip at 200 ft	stream crosses road, no fill or buffer, rocky road
Mulkey Gulch	Mulkey Gulch	P-2					reduce length to 115 ft using rolling dip
Deep Creek	Deep Creek	P-3					reduce length to 250 ft by installing a sediment basin
Tenmile Creek	Tenmile Creek	P-4					reduce length to 150 ft by installing a sediment basin, failing BMPs: silt fence, coir fabric wraps
Tenmile Creek	Tenmile Creek	X-44	-	failing rolling dip at 325 ft	-	rolling dip at 200 ft	repair failing rolling dip, steep hill
trib to Tenmile Creek	Tenmile Creek	X-31	-	none	-	add gravel: 100%	need to raise road bed and replace culvert, or decommission the road
trib to Cramer Creek	Cramer Creek	X-569	none	none	none	none	
trib to Cramer Creek	Cramer Creek	X-33	none	-	waterbar at 40 ft	-	bladed gravel road
Flat Creek	Flat Creek	X-406	none	none	rolling dip at 110 ft	none	well maintained road with signs of water transport
Idaho Gulch	Flat Creek	X-508	rolling dip at 400 ft	rolling dip at 50 ft	rolling dip at 130 ft	none	pour point approximately 50 ft from culvert location
trib to Trout Creek	Trout Creek	X-327	-	none	-	rolling dip or water bar at 130 ft	hardened road bed, two track with slight ruts
Wind Fall Creek	Trout Creek	X-356	rolling dip at 100 ft	rolling dip at 125 ft	none	waterbar at 50 ft	sediment inputs at bridge deck
trib to Trout Creek	Trout Creek	X-337	-	none	-	rolling dip at 215 ft	
Lake Creek	Trout Creek	X-344	none	none	waterbar at 90 ft	none	some form of dust control is necessary
trib to Trout Creek	Trout Creek	X-479	none	none	none	waterbar at 90 ft	
trib to WF Petty Creek	WF Petty Creek	X-197	none	none	none	none	
trib to WF Petty Creek	WF Petty Creek	X-473	none	rolling dip at 180 ft	none	none	vegetation covering fill, model as buffer
West Fork Petty Creek	WF Petty Creek	X-468	none	rolling dip at 105 ft	none	none	vegetation covering fill, model as buffer
Bill Creek	Petty Creek	X-92	rolling dip at 140 ft	none	waterbar at 50 ft	none	two culverts at crossing, pour point at southerly culvert
trib to SF Petty Creek	Petty Creek	X-299	none	none	waterbar at 55 ft	none	gate open on lightly traveled road with knapweed in the median
trib to SF Petty Creek	Petty Creek	X-451	none	none	waterbar at 55 ft	waterbar at 100 ft	lightly used road
East Fork Grant Creek	Grant Creek	X-239	-	none	-	waterbar at 75 ft	bladed gravel road sediment input at bridge

Attachment C

Unpaved Road Crossing WEPP Modeled Sediment Loads by Precipitation Zone

					<20	<20	20-26	20-26	>26	>26
Waterbody	Stream Segment	Location ID	Jurisdiction / Ownership	Estimated Mean Annual Precipitation (inches)	MEAN ANNUAL LOAD (lbs)	MEAN ANNUAL LOAD with BMPs (lbs)	MEAN ANNUAL LOAD (lbs)	MEAN ANNUAL LOAD with BMPs (lbs)	MEAN ANNUAL LOAD (lbs)	MEAN ANNUAL LOAD with BMPs (lbs)
Rattler Gulch	Rattler Gulch	X-515	Private / County / State	20-26	1.67	1.67	2.42	2.42	1.80	1.80
Rattler Gulch	Rattler Gulch	P-1	not assigned	20-26	3.23	0.89	4.95	1.36	3.33	0.92
Dry Mulkey	Mulkey Gulch	X-564	Private / County / State	20-26	71.99	0.60	86.30	0.40	86.91	0.19
Mulkey Gulch	Mulkey Gulch	P-2	not assigned	<20	0.00	0.00	1.30	0.43	0.78	0.26
Deep Creek	Deep Creek	P-3	Federal - USBLM	>26	14.38	7.23	22.98	11.32	14.76	9.16
Tenmile Creek	Tenmile Creek	P-4	not assigned	20-26	8.88	0.36	7.56	0.24	4.70	0.43
Tenmile Creek	Tenmile Creek	X-44	Private / County / State	20-26	141.67	21.93	257.08	33.79	175.46	26.37
trib to Tenmile Creek	Tenmile Creek	X-31	Private / County / State	20-26	0.18	0.01	0.27	0.16	0.25	0.15
trib to Cramer Creek	Cramer Creek	X-569	Private / County / State	<20	1.18	1.18	2.94	2.94	2.83	2.83
trib to Cramer Creek	Cramer Creek	X-33	Private / County / State	20-26	1.22	0.70	2.65	1.51	1.98	1.13
Flat Creek	Flat Creek	X-406	Private / County / State	20-26	28.77	9.66	34.46	11.95	57.76	19.90
Idaho Gulch	Flat Creek	X-508	Federal	20-26	0.00	0.00	0.00	0.00	0.00	0.00
trib to Trout Creek	Trout Creek	X-327	Federal	>26	37.65	15.13	39.73	16.27	55.69	23.79
Wind Fall Creek	Trout Creek	X-356	Federal	>26	0.18	0.14	0.24	0.24	1.37	0.91
trib to Trout Creek	Trout Creek	X-337	Federal	>26	229.88	65.69	290.51	73.74	416.29	89.36
Lake Creek	Trout Creek	X-344	Private / County / State	>26	24.40	18.55	34.28	26.40	59.46	46.11
trib to Trout Creek	Trout Creek	X-479	Federal	20-26	100.14	54.96	101.51	56.76	137.32	75.97
trib to WF Petty Creek	WF Petty Creek	X-197	Federal	20-26	0.56	0.56	0.88	0.88	2.04	2.04
trib to WF Petty Creek	WF Petty Creek	X-473	Federal	>26	0.00	0.00	0.00	0.00	0.36	0.36
West Fork Petty Creek	WF Petty Creek	X-468	Federal	>26	0.00	0.00	0.00	0.00	0.47	0.47
Bill Creek	Petty Creek	X-92	Private / County / State	>26	11.00	6.50	14.68	8.78	23.40	19.61
trib to SF Petty Creek	Petty Creek	X-299	Federal	20-26	3.39	1.34	6.06	2.52	9.59	4.23
trib to SF Petty Creek	Petty Creek	X-451	Federal	20-26	8.24	2.60	10.88	2.62	17.27	4.29
East Fork Grant Creek	Grant Creek	X-239	Private / County / State	>26	0.54	0.16	0.67	0.20	0.81	0.24

Attachment D

Unpaved Road Crossing Subwatershed Sediment Loads

Subwatershed	Jurisdiction	PRISM Precipitation Zone (Inches)	Number of Crossings Identified in GIS	Corrected Number of Crossings based on Field Data	MEAN ANNUAL LOAD per CROSSING (Tons)	MEAN ANNUAL LOAD per CROSSING with BMPs (Tons)	MEAN ANNUAL LOAD (Tons)	MEAN ANNUAL LOAD with BMPs (Tons)
Cramer Creek	County	<20	10	7	0.0141	0.0031	0.0989	0.0214
Cramer Creek	County	20-26	45	32	0.0218	0.0044	0.6864	0.1395
			55	39			0.7853	0.1609
Cramer Creek Total			**55**	**39**			**0.7853**	**0.1609**
Deep Creek	County	20-26	32	22	0.0218	0.0044	0.4881	0.0992
Deep Creek	County	>26	26	18	0.0205	0.0059	0.3737	0.1077
			58	41			0.8618	0.2069
Deep Creek Total			**58**	**41**			**0.8618**	**0.2069**
Mulkey Gulch	County	<20	2	1	0.0141	0.0031	0.0198	0.0043
Mulkey Gulch	County	20-26	33	23	0.0218	0.0044	0.5033	0.1023
			35	25			0.5231	0.1066
Mulkey Gulch Total			**35**	**25**			**0.5231**	**0.1066**
Rattler Gulch	County	<20	8	6	0.0141	0.0031	0.0791	0.0171
Rattler Gulch	County	20-26	8	6	0.0218	0.0044	0.1220	0.0248
			16	11			0.2012	0.0419
Rattler Gulch Total			**16**	**11**			**0.2012**	**0.0419**
Tenmile Creek	County	20-26	23	16	0.0218	0.0044	0.3508	0.0713
			23	16			0.3508	0.0713
Tenmile Creek Total			**23**	**16**			**0.3508**	**0.0713**
Flat Creek	Federal	20-26	9	6	0.0225	0.0077	0.1418	0.0485
Flat Creek	Federal	>26	13	9	0.0320	0.0101	0.2914	0.0916
			22	15			0.4331	0.1401
Flat Creek	Private	20-26	3	2	0.0218	0.0044	0.0458	0.0093
			3	2			0.0458	0.0093
Flat Creek	County	<20	2	1	0.0141	0.0031	0.0198	0.0043
Flat Creek	County	>26	2	1	0.0205	0.0059	0.0287	0.0083
			4	3			0.0485	0.0126
Flat Creek	State	20-26	8	6	0.0218	0.0044	0.1220	0.0248
			8	6			0.1220	0.0248
Flat Creek Total			**37**	**26**			**0.6494**	**0.1868**
Grant Creek	County	20-26	3	2	0.0218	0.0044	0.0458	0.0093
Grant Creek	County	>26	11	8	0.0205	0.0059	0.1581	0.0455
			14	10			0.2039	0.0548
Grant Creek	Private	20-26	7	5	0.0218	0.0044	0.1068	0.0217
Grant Creek	Private	>26	3	2	0.0205	0.0059	0.0431	0.0124
			10	7			0.1499	0.0341
Grant Creek Total			**24**	**17**			**0.3538**	**0.0890**
Upper Petty Creek	Federal	20-26	7	5	0.0225	0.0077	0.1103	0.0377
			7	5			0.1103	0.0377
Upper Petty Creek	Private	20-26	3	2	0.0218	0.0044	0.0458	0.0093
Upper Petty Creek	Private	>26	4	3	0.0205	0.0059	0.0575	0.0166
			7	5			0.1033	0.0259
Upper Petty Creek	County	>26	1	1	0.0205	0.0059	0.0144	0.0041
			1	1			0.0144	0.0041
Upper Petty Creek Total			**15**	**11**			**0.2279**	**0.0677**
Middle Petty Creek	Federal	20-26	8	6	0.0225	0.0077	0.1260	0.0431
Middle Petty Creek	Federal	>26	5	4	0.0320	0.0101	0.1121	0.0352
			13	9			0.2381	0.0784
Middle Petty Creek	Private	20-26	16	11	0.0218	0.0044	0.2440	0.0496
Middle Petty Creek	Private	>26	15	11	0.0205	0.0059	0.2156	0.0621
			31	22			0.4597	0.1117
Middle Petty Creek	County	20-26	5	4	0.0218	0.0044	0.0763	0.0155
			5	4			0.0763	0.0155
Middle Petty Creek Total			**49**	**34**			**0.7740**	**0.2056**
Lower Petty Creek	Federal	20-26	3	2	0.0225	0.0077	0.0473	0.0162
Lower Petty Creek	Federal	>26	2	1	0.0320	0.0101	0.0448	0.0141
			5	4			0.0921	0.0303
Lower Petty Creek	Private	<20	4	3	0.0141	0.0031	0.0396	0.0085
Lower Petty Creek	Private	20-26	12	8	0.0218	0.0044	0.1830	0.0372
Lower Petty Creek	Private	>26	6	4	0.0205	0.0059	0.0862	0.0248
			22	15			0.3088	0.0706
Lower Petty Creek	County	<20	2	1	0.0141	0.0031	0.0198	0.0043
Lower Petty Creek	County	20-26	7	5	0.0218	0.0044	0.1068	0.0217
Lower Petty Creek	County	>26	1	1	0.0205	0.0059	0.0144	0.0041
			10	7			0.1409	0.0301
Lower Petty Creek Total			**37**	**26**			**0.5419**	**0.1310**
Eds Creek	Federal	20-26	2	1	0.0225	0.0077	0.0315	0.0108
Eds Creek	Federal	>26	9	6	0.0320	0.0101	0.2017	0.0634
			11	8			0.2332	0.0742
Eds Creek	Private	20-26	8	6	0.0218	0.0044	0.1220	0.0248
Eds Creek	Private	>26	7	5	0.0205	0.0059	0.1006	0.0290
			15	11			0.2226	0.0538
Eds Creek	County	20-26	1	1	0.0218	0.0044	0.0153	0.0031
			1	1			0.0153	0.0031
Eds Creek Total			**27**	**19**			**0.4711**	**0.1311**
Petty Creek Total (excluding West Fork Petty Creek)			**128**	**90**			**2.0149**	**0.5354**
West Fork of Petty Creek	Federal	20-26	5	4	0.0225	0.0077	0.0788	0.0270
West Fork of Petty Creek	Federal	>26	34	24	0.0320	0.0101	0.7621	0.2397
			39	27			0.8408	0.2666
West Fork of Petty Creek	Private	20-26	20	14	0.0218	0.0044	0.3051	0.0620
West Fork of Petty Creek	Private	>26	33	23	0.0205	0.0059	0.4744	0.1366
			53	37			0.7794	0.1987
West Fork of Petty Creek	County	20-26	1	1	0.0218	0.0044	0.0153	0.0031
			1	1			0.0153	0.0031
West Fork Petty Creek Total			**93**	**65**			**1.6355**	**0.4684**
Upper Trout Creek	Federal	>26	59	41	0.0320	0.0101	1.3224	0.4159
			59	41			1.3224	0.4159
Upper Trout Creek Total			**59**	**41**			**1.3224**	**0.4159**
Lower Trout Creek	Federal	<20	3	2	0.0190	0.0070	0.0399	0.0147
Lower Trout Creek	Federal	20-26	12	8	0.0225	0.0077	0.1890	0.0647
Lower Trout Creek	Federal	>26	58	41	0.0320	0.0101	1.3000	0.4088
			73	51			1.5289	0.4883
Lower Trout Creek Total			**73**	**51**			**1.5289**	**0.4883**
Trout Creek Total			**132**	**92**			**2.8513**	**0.9042**
Central Clark Fork Tributaries Project Area Total			**601**	**421**			**10.2271**	**2.7713**

Attachment E

Culvert Failure Analysis

Location ID	Structure Type	Culvert Dimensions	Culvert Slope	Bankfull Width	Q2	Q5	Q10	Q25	Q50	Q100	Estimated Maximum Capacity at Cross Section	Headwater Hieght (Fill Hieght)	Field Measured Fill Width	Modeled Fill Width*	Fill Length	Fill Volume*	Fill Volume*	Potential Sediment Load if Culvert Fails*
		(ft)	(%)	(ft)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft³)	(CY)	(tons)
X-515	CMP	1.5	1	8	17	32	45	63	79	94	15	4	20	8	28	896	33	55
X-44	CMP	4	9	7	13	25	35	50	63	76	133	7	35	7	30	1470	54	90
X-31	metal pipe	1	0.5	5	7	14	19	28	36	43	9	0.5	5	5	10	25	1	2
X-569	squash CMP	3 x 4	2	7	13	25	35	50	63	76	76	4	15	7	30	840	31	52
X-33	CMP	1.5	7	4	4	9	13	19	24	30	31	2	10	4	30	240	9	15
X-406	double CMP	3	9	7	13	25	35	50	63	76	143	6	15	7	28	1176	44	72
X-508	CMP	1.5	9	1	0	1	1	2	2	3	18	5	15	1	36	180	7	11
X-327	CMP	4	8	8	17	32	45	63	79	94	222	12	50	8	40	3840	142	236
X-337	CMP	2	8	5	7	14	19	28	36	43	46	10	30	5	30	1500	56	92
X-344	flare CMP	4	9	10	27	49	67	92	115	137	202	13	35	10	50	6500	241	400
X-479	CMP	2	11	3	2	5	8	12	15	19	57	15	80	3	50	2250	83	138
X-197	CMP	2	4	2	1	2	4	6	8	9	20	3	10	2	22	132	5	8
X-473	CMP	2	25	1.5	1	1	2	4	5	6	78	15	20	1.5	60	1350	50	83
X-468	CMP	3	3	5	7	14	19	28	36	43	87	8	36	5	30	1200	44	74
X-92	2 squash CMP	3 x 4	6	7	13	25	35	50	63	76	259	6	85	7	40	1680	62	103
X-299	CMP	2	2	3	2	5	8	12	15	19	25	4	23	3	40	480	18	30
X-451	CMP	1.5	17	2	1	2	4	6	8	9	23	8	30	2	36	576	21	35

*assuming a fill width equal to the bankfull width

culvert fails to pass a given discharge

Attachment F

Fish Passage Assessment

Location ID	Structure Type	Evaluation Method	Culvert Dimensions (ft)	Width (ft)	Culvert Slope (%)	Bankfull Width (ft)	Culvert/ Bankfull Ratio	Outlet Perch (inches)	Final Classification (# of failures)
X-515	CMP	3	1.5	1.5	1	8	0.19	0	1
X-44	CMP	3	4	4	9	7	0.57	8	2
X-31	metal pipe	3	1	1	0.5	5	0.20	0	1
X-569	squash CMP	3	3 x 4	4	2	7	0.57	0	1
X-33	CMP	3	1.5	1.5	7	4	0.38	0	2
X-406	double CMP	3	3	3	9	7	0.43	7	3
X-327	CMP	3	4	4	8	8	0.50	72	2
X-344	flare CMP	3	4	4	9	10	0.40	12	3
X-473	CMP	3	2	2	25	1.5	1.33	0	1
X-468	CMP	3	3	3	3	5	0.60	18	2
X-92	2 squash CMP	3	3 x 4	4	6	7	0.57	0	1
X-299	CMP	3	2	2	2	3	0.67	6	2

Note: Evaluation Method based on Table:1 Fish Passage Evaluation Criteria located in *A Summary of Technical Considerations to Minimize the Blockage of Fish at Culverts on the National Forests of Alaska*

Green	conditions that have a high certainty of meeting juvenile fish passage at all desired stream flows
Gray	conditions are such that additional and more detailed analysis is required to determine their juvenile fish passage ability
Red	conditions that have a high certainty of <u>not</u> providing juvenile fish passage at all desired stream flows