APPENDIX C – UPLAND EROSION SEDIMENT ASSESSMENT

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ACRONYM LIST

Acronym	Definition
BMP	Best Management Practices
DEM	Digital Elevation Model
DEQ	Department of Environmental Quality (Montana)
GIS	Geographic Information System
LS	Length and Slope Factors
NAIP	National Agricultural Imagery Program
NCSL	Non-Cumulative Slope Length
NLCD	National Land Cover Dataset
NRCS	Natural Resources Conservation Service
RUSLE	Revised Universal Soil Loss Equation
SCAS	Spatial Climate Analysis Service
SDR	Sediment Delivery Ratio
SMZ	Streamside Management Zone
SRE	Sediment Reduction Efficiency
SSURGO	Soil Survey Geographic database
TMDL	Total Maximum Daily Load
TPA	TMDL Planning Area
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation

C1.0 INTRODUCTION

An assessment of the sediment loading from hillslope erosion within the Kootenai-Fisher Total Maximum Daily Load (TMDL) Project Area (Project Area) was performed to facilitate the development of sediment TMDLs for 303(d) listed stream segments with sediment as a documented impairment. Upland sediment loading from hillslope erosion was modeled using a Universal Soil Loss Equation (USLE) based model, which was combined with a sediment delivery ratio (SDR) and riparian health assessment to predict the amount of sediment delivered to streams in the Kootenai-Fisher Project Area. The USLE based model was implemented as a watershed-scale, raster-based, GIS model using ArcGIS software.

C1.1 SEDIMENT IMPAIRMENTS

The Kootenai-Fisher Project Area encompasses an area of approximately 2,511 square miles in Lincoln and Flathead counties in northwestern Montana. The Kootenai-Fisher Project Area includes both the Kootenai TMDL Planning Area (TPA) (1,667 square miles) and the Fisher TPA (844 square miles). The Kootenai TPA encompasses the majority of the Upper Kootenai River HUC8 (17010104), while the Fisher TPA aligns with the Fisher River HUC8 (17010101). Within the Kootenai-Fisher Project Area, there are six waterbody segments listed on the 2012 303(d) List for sediment-related impairments (**Table C1-1**). Bristow Creek, Libby Creek, Lake Creek and Quartz Creek are listed as impaired due to sediment in the Kootenai TPA, while Wolf Creek and Raven Creek are listed as impaired due to sediment in the Fisher TPA.

Table C1-1. Waterbody Segments Addressed during the USLE Assessment

TPA	Segment ID	Waterbody Description
Fisher	MT76C001_020	WOLF CREEK, headwaters to mouth (Fisher River)
Fisher	MT76C001_030	RAVEN CREEK, headwaters to mouth (Pleasant Valley Fisher River)
Kootenai	MT76D002_110	BRISTOW CREEK, the headwaters to mouth at Lake Koocanusa
Kootenai	MT76D002_062	LIBBY CREEK, from the highway 2 bridge to mouth (Kootenai River)
Kootenai	MT76D002_070	LAKE CREEK, Bull Lake outlet to mouth (Kootenai River)
Kootenai	MT76D002_090	QUARTZ CREEK, headwaters to confluence with the Kootenai River

C2.0 METHODS

Upland sediment loading from hillslope erosion was modeled using a Universal Soil Loss Equation (USLE) based model, which was combined with a sediment delivery ratio (SDR) and riparian health assessment to predict the amount of sediment delivered to streams in the Kootenai-Fisher Project Area. USLE is a soil erosion prediction tool that was originally developed for cropland and rangeland and was later modified for application to forested environments (Croke and Nethery, 2006). USLE has been widely used for sediment TMDL development and is a component of numerous more advanced models that are also used for TMDL development (e.g., SWMM, SWAT, GWLF, BASINS, AGNPS). This empirical model was selected for this source assessment because it is well suited for large watersheds since it incorporates local climate and landscape data, but is not overly data-intensive. For this project, the most simplistic uncalibrated version of the USLE model was selected because it meets the needs of the TMDL source assessment and provides the appropriate level of detail for the project. Methods used in this assessment are described in *Quality Assurance Project Plan: Assessment of Upland Sediment Sources for TMDL Development (Task Order 18: Task 2c) (U.S. Environmental Protection Agency and Montana Department of Environmental Quality, 2011)* and summarized in the following sections.

C2.1 Subwatershed Delineation

Prior to USLE model development, subwatersheds were delineated in which the Kootenai-Fisher Project Area upland sediment assessment would be conducted. Subwatersheds were delineated on the basis of the United States Geological Survey (USGS) 6th Hydrologic Unit Code (HUC12) layer and modified where necessary to delineate the subwatersheds of interest (**Table C2-1** and **Figure C2-1**). Delineated subwatersheds include the Upper Lake Creek HUC12, which was split into areas draining upstream (above) and downstream (below) the Bull Lake outlet, along with the Raven Creek subwatershed, which was delineated using watershed delineation tools in ArcGIS and a 30-meter DEM. The Raven Creek watershed is identified with a subwatershed ID of 'sub6code' in **Table C2-1** and **Figure C2-1** since it is located within the Pleasant Valley Fisher River-Loon Lake HUC12. While a portion of the sediment derived from the Upper Lake Creek watershed is likely retained in Bull Lake, no adjustment was made to sediment loading estimates since this assessment is focused on identifying areas where human sources of sediment loading can be reduced.

Table C2-1. Subwatersheds in the Kootenai-Fisher Project Area

HUC10 Name	HUC12 Name	Subwatershed ID
Bristow Creek-Rainy Creek	Bristow Creek	Bristow Creek
Flower Creek-Quartz Creek	Quartz Creek	Quartz Creek
Lake Creek	Keeler Creek	Keeler Creek
	Lower Lake Creek	Lower Lake Creek
	Ross Creek	Ross Creek
	Stanley Creek	Stanley Creek
	Upper Lake Creek	Upper Lake Creek_above Bull Lake
		Upper Lake Creek_below Bull Lake
Libby Creek	Big Cherry Creek	Big Cherry Creek
	Granite Creek	Granite Creek
	Lower Libby Creek	Lower Libby Creek
	Swamp Creek-Cowell Creek	Swamp Creek-Cowell Creek
	Upper Libby Creek	Upper Libby Creek
Wolf Creek	Dry Fork Creek	Dry Fork Creek
	Little Wolf Creek	Little Wolf Creek
	Lower Wolf Creek	Lower Wolf Creek
	Middle Wolf Creek	Middle Wolf Creek
	Upper Wolf Creek	Upper Wolf Creek
	Weigel Creek	Weigel Creek
Pleasant Valley Fisher River	Pleasant Valley Fisher River-Loon Lake	Raven Creek_sub6code

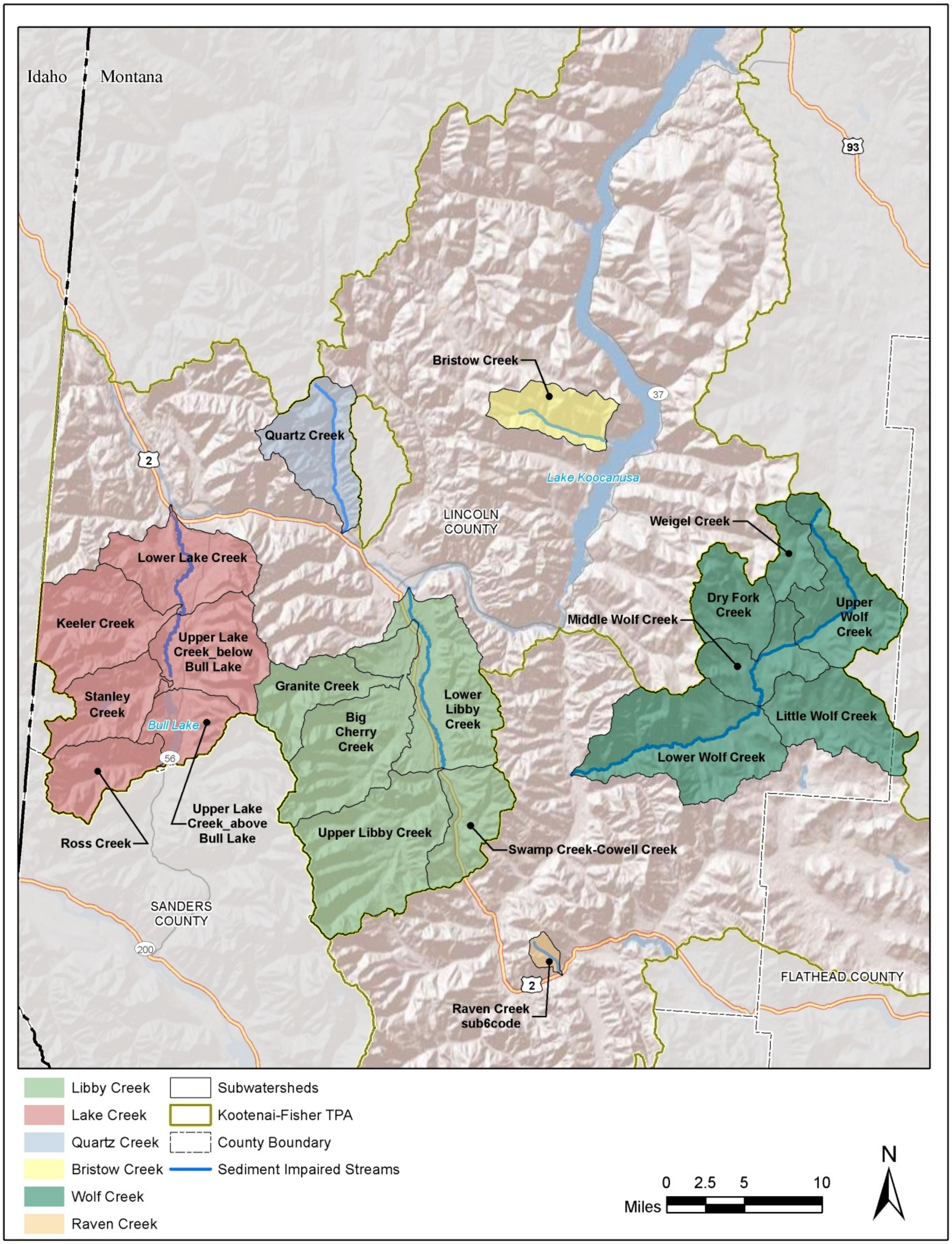

Figure C2-1. Subwatersheds in the Kootenai-Fisher Project Area

C2.2 ULSE Model Input Parameters

The USLE model requires five landscape factors that are combined to predict upland soil loss, including a rainfall factor (R), soil erodibility factor (K), length and slope factors (LS), cropping factor (C), and management practices factor (P). The general form of the USLE equation has been widely used for upland sediment erosion modeling and is presented as (Brooks et al., 1997):

$$A = RK(LS)CP \text{ (in tons per acre per year)}$$

For this assessment, the USLE based model was parameterized using a number of published data sources, including information from: (1) U.S. Geological Survey (USGS), (2) Spatial Climate Analysis Service (SCAS), and (3) Natural Resource Conservation Service (NRCS). Additionally, local information regarding specific land cover was acquired from the U.S. Forest Service (USFS) and the NRCS. Specific GIS data layers used in the modeling effort are presented in the following sections.

C2.2.1 R-Factor

The **R-factor** characterizes the effect of raindrop impact and runoff rates associated with a rainstorm, which is reported in 100s of ft-tons rainfall/ac-yr. The rainfall and runoff factor grid was prepared by the Spatial Climate Analysis Service of Oregon State University at a 4 km grid cell resolution based on Parameter-elevation Regressions on Independent Slopes Model (PRISM) precipitation data. The R-factor is determined using the kinetic energy of a rainfall event and the maximum 30-minute rainfall intensity for an area. For the purposes of this analysis, the SCAS R-factor grid was projected to Montana State Plane Coordinates and interpolated to a 10m grid cell (**Figure C2-2**).

C2.2.2 K-Factor

The **K-factor** is a soil erodibility factor that quantifies the susceptibility of soil to erosion. It is a measure of the average soil loss from a particular soil in continuous fallow derived from experimental data (tons soil/100 ft tons rainfall). Polygon data of K-factor values in the Kootenai-Fisher Project Area was obtained from the NRCS General Soil Map (STATSGO) database and the NRCS Soil Survey Geographic (SSURGO) database. While the SSURGO database is more detailed and more current than the STATSGO database, the SSURGO database for the Kootenai-Fisher Project Area did not contain the required K-factor values for Quartz Creek, Bristow Creek, Raven Creek, or Wolf Creek. When the SSURGO database lacked K-factor values, the K-factor was derived from the STATSGO database in which the USLE K-factor is a standard component. Soils polygon data was summarized and interpolated to a 10m grid cell (**Figure C2-2**).

C2.2.3 LS-Factor

The **LS-factor** is a function of the slope and flow length of the eroding slope or cell (units are dimensionless). The LS-factor was derived from 10m USGS digital elevation model (DEM) grid data and interpolated to a 10m grid cell. For the purpose of computing the LS-factor, slope is defined as the average land surface gradient per cell, while the flow length refers to the distance between where overland flow originates and runoff reaches a defined channel or depositional zone. The equation used for calculating the slope length and slope factor is given in the Revised Universal Soil Loss Equation (RUSLE), which provides improved slope length and steepness analysis applicable to mountainous terrain, as published in United States Department of Agriculture (USDA) handbook #703 (Renard et al., 1997). According to McCuen (1998), flow lengths are seldom greater than 400 feet or less than 20 feet.

L, the slope length factor in the RUSLE equation, serves to reference the erosion estimate for a horizontally projected slope length to the experimentally measured erosion for a 72.6 foot (22.1 meters) plot.

$L = (\lambda/72.6)^m$

where:

λ = the horizontal projection of slope length

72.6 = the RUSLE unit plot length in feet

m = the variable slope length component, related to the ratio (β) of rill erosion (caused by flow) to interrill erosion (caused by raindrop impact) defined in the following equation: $= \beta/(1 + \beta)$

And $\beta = (\sin \Theta/0.0896) / [3.0(\sin \Theta)^{0.8} + 0.56]$

Soil loss increases more rapidly with slope steepness than it does with slope length. This is quantified by S, the slope steepness factor of the RUSLE.

S $= 10.8 \sin \theta + 0.03$ for $\theta < 9\%$

$= 16.8 \sin \theta - 0.50$ for $\theta \geq 9\%$

where:

θ = the slope angle

Combined, these factors can be written:

$$LS = S_i (\lambda_i^{m+1} - \lambda_{i-1}^{m+1}) / (\lambda_I - \lambda_{i-1}) (72.6)^m$$

where:

λ_i = length in feet from top of slope to lower end of the ith segment. This value was determined by applying GIS based surface analysis procedures to the each DEM, calculating total upslope length for each 10m grid cell, and converting the results to feet from meters.

S_i = slope steepness factor for the segment

$= 10.8 \sin \theta + 0.03$ for $\theta < 9\%$

$= 16.8 \sin \theta - 0.50$ for $\theta \geq 9\%$

The LS-Factor examines the topography of the area, identifying areas of steepness, flow paths, flow lengths, areas of deposition, and ultimately the concentrated sediment yield. The LS-Factor was calculated using a C++ program which automatically processes the DEM input (Van Remortel et al., 2004). The program evaluates each individual grid cell based on the LS factors mentioned above. The C++ program begins with a fill function of any depressions or sinks found on the DEM input. The highest elevation points on the DEM are then identified by the program and the flow direction is determined. In situations of converging flow, the flow direction of steepest decent takes precedence. The distance between the centers of one grid cell to the next grid cell is then calculated by the C++ program as the non-cumulative slope length (NCSL). A cumulative slope length is then computed by summing the NCSL from each grid cell, beginning at a high point and moving down along the direction of steepest descent.

The calculated slope angle of each cell is first examined by the C++ program, and a sub-routine calls for a table lookup function. The range in which the slope angle falls within the table is indentified and a corresponding slope length exponent (m) is assigned. The program has a function called the cutoff slope angle and is defined as the ratio of change in slope angle from one grid cell to the next along the flow direction. When the slope angle decreases sufficiently, the cumulative slope length calculation stops and then resumes when the land surface extends further downhill in order to recognize areas of deposition versus erosion. The final grid produced combines the effect of these topographic factors into the LS-factor given in the formula above (**Figure C2-2**).

C2.2.3.1 Digital Elevation Model

The digital elevation model (DEM) is the base layer used for developing the LS-factor for the USLE analysis. The USGS 10m (1/3 Arc-second) DEM was used for this analysis. The 10m DEM was projected into Montana State Plan Coordinates and interpolated to a 10m grid cell to render the delineated stream network more representative of the actual size of Kootenai-Fisher Project Area streams and to minimize resolution dependent stream network anomalies. The resulting interpolated 10m DEM was subjected to standard hydrologic preprocessing, including filling of sinks to create a positive drainage condition for all areas of the watershed (**Figure C2-2**).

C2.2.3.2 Stream Network Delineation

The stream network for each subwatershed in the Kootenai-Fisher Project Area was derived from the 10m DEM using TauDEM (**T**errain **A**nalysis **U**sing **D**igital **E**levation **M**odels) software developed by the Utah State University Hydrology Research Group (http://hydrology.usu.edu/taudem/taudem5.0/index.html). The stream network was generated using TauDEM with the threshold adjusted to most closely mirror the 1:24,000 National Hydrography Dataset (NHD) stream layer.

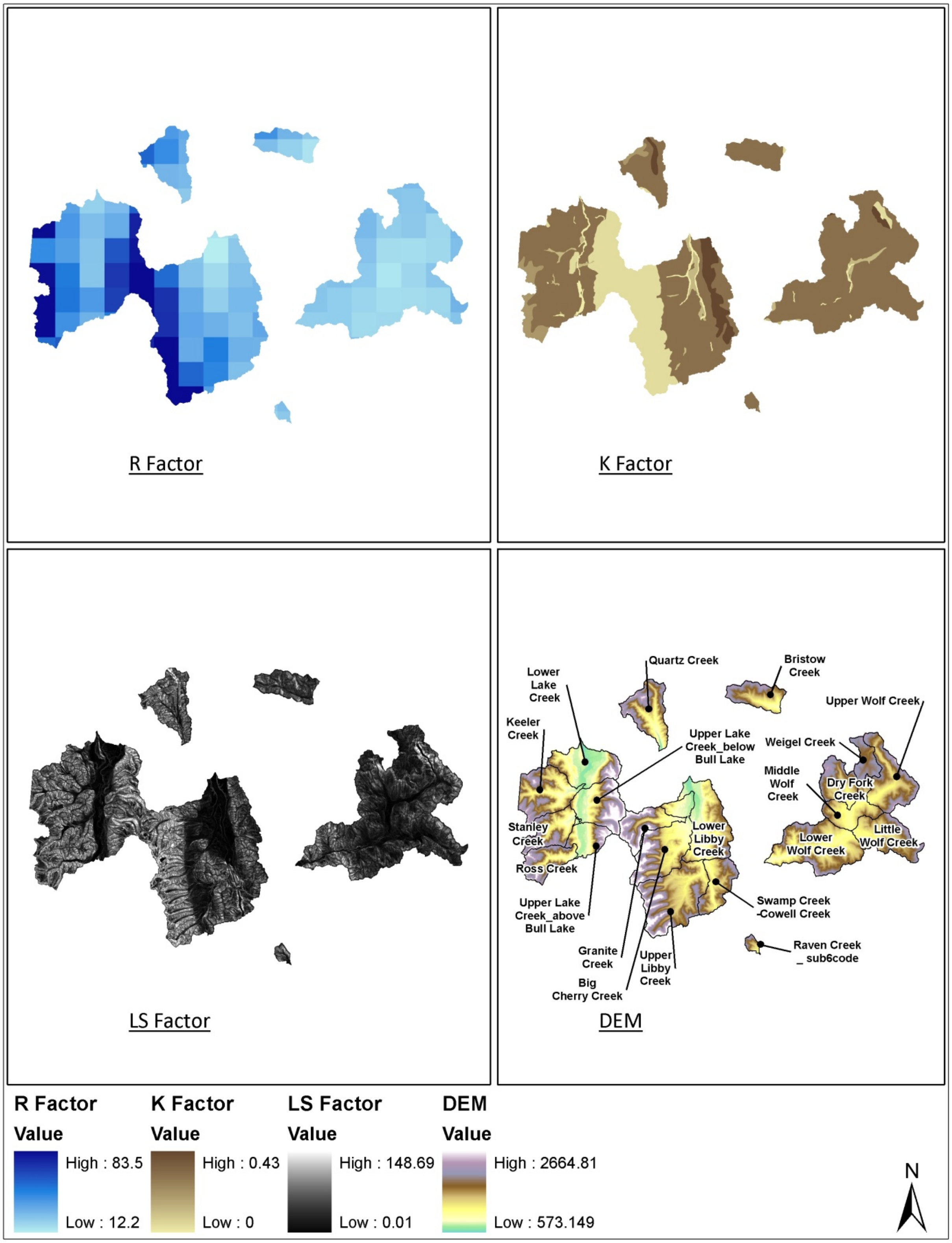

Figure C2-2. R-Factor, K-Factor, LS-Factor, and DEM for the Kootenai-Fisher Project Area

C2.2.4 C-Factor

The **C-factor** is a crop management value that represents the ratio of soil erosion from a specific cover type compared to the erosion that would occur on a clean-tilled fallow under identical slope and rainfall. The C-factor integrates a number of variables that influence erosion including vegetative cover, plant litter, soil surface, and land management. Original ULSE C-factors were experimentally determined for agricultural crops and have since been modified to include rangeland and forested land cover types. For this assessment, the C-factor was estimated for various land cover types using the National Land Cover Database and C-factor interpretations applied during previous USLE modeling projects conducted for sediment TMDL development. C-factors are intended to be conservatively representative of conditions within the Kootenai-Fisher Project Area.

C2.2.4.1 National Land Cover Database

The 2006 National Land Cover Database (NLCD) was obtained from the Multi-Resolution Land Characteristics (MRLC) Consortium and used for establishing USLE C-factors in the Kootenai-Fisher Project Area. The 2006 NLCD is a categorized 30 meter Landsat Thematic Mapper image shot in 2006. The NLCD image was projected to Montana State Plane Coordinates and interpolated to a 10m grid cell (**Figure C2-3**). For this analysis, areas described as ‘cultivated crops’ in the NLCD database were redefined as ‘hay/pasture’ to better represent agricultural practices in the Kootenai-Fisher Project Area based on input from the local Natural Resources Conservation Service representative (Fiest, Don, personal communication). NLCD land cover types for the Kootenai-Fisher Project Area are described in **Attachment CA**.

C2.2.4.2 C-Factor Derivation

USLE C-factors for existing conditions were assigned to the NLCD land cover types in the Kootenai-Fisher Project Area based on ground cover percentages in *Table 10 – Factor C for permanent pasture, range, and idle land* as presented in Predicting Rainfall Erosion Losses: A Guide to Conservation Planning (Wischmeier and Smith, 1978) and summarized in **Table C2-2** and **Attachment CB**. In order to estimate the potential sediment reduction that might be achieved under a Best Management Practices (BMP) scenario, the USLE-based model was also run using C-factors representing desired conditions. Land cover types identified as ‘grasslands/ herbaceous’ and ‘hay/pasture’ were conservatively adjusted to reflect a 10% improvement in ground cover over existing conditions based on input from the local Natural Resources Conservation Service representative as depicted in **Table C2-3** (Fiest, Don, personal communication).

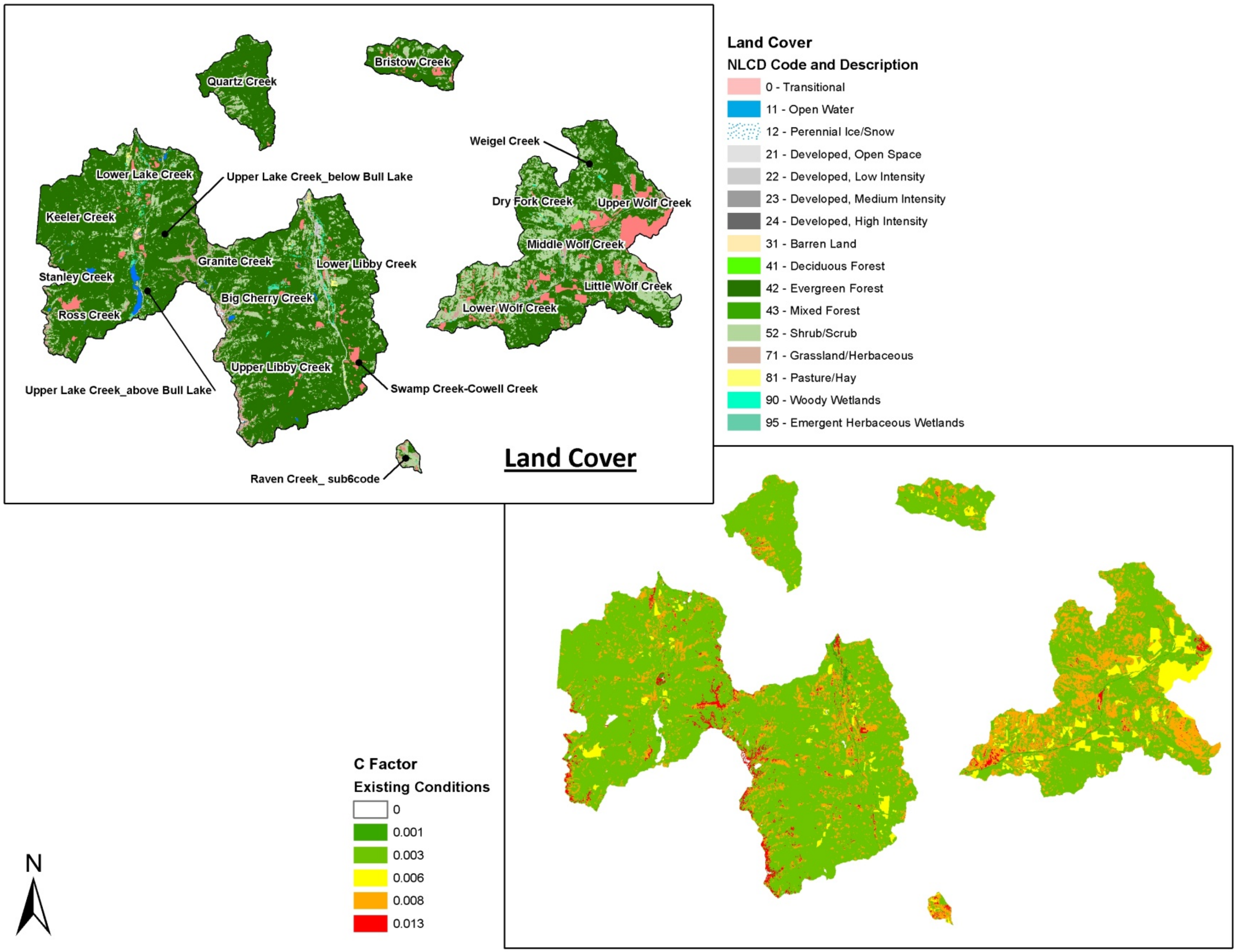

Figure C2-3. Land Cover and C-Factors for the Kootenai-Fisher Project Area

Table C2-2. C-factors for Existing and Desired Conditions

NLCD Code	Description	C-Factor Existing Conditions	C-Factor Desired Conditions
0*	Transitional*	0.006	0.006
11	Open Water*	-	-
12	Perennial Ice/Snow*	-	-
21	Developed, Open Space	0.003	0.003
22	Developed, Low Intensity	0.001	0.001
23	Developed, Medium Intensity	0.001	0.001
24	Developed, High Intensity	0.001	0.001
31	Barren Land	0.001	0.001
41	Deciduous Forest	0.003	0.003
42	Evergreen Forest	0.003	0.003
43	Mixed Forest	0.003	0.003
52	Shrub/Scrub	0.008	0.008
71	Grassland/Herbaceous	0.013	0.008
81	Hay/Pasture	0.013	0.008
90	Woody Wetlands	0.003	0.003
95	Emergent Herbaceous Wetlands	0.003	0.003

* A code of "0" and a description of "Transitional" was developed to describe areas of Fire or Timber Harvest
**Water and ice/snow classes will not be counted as surfaces contributing erosion

Table C2-3. Percent Ground Cover for Existing and Desired Land Cover Types

Land Cover	Existing % ground cover	Desired % ground cover
Grassland/Herbaceous	80	90
Hay/Pasture	80	90

It is acknowledged that land cover is variable within and across watersheds and changes seasonally. The C-factors used for the USLE-based model are intended to represent typical annual conditions at a coarse scale and the percent of improvement achievable via the implementation of BMPs.

C2.2.4.3 Fire and Timber Harvest Adjustments

The 2006 NLCD layer was adjusted to quantify the amount of fire and timber harvest that have occurred since 2006 and also to identify previously disturbed areas that have become reforested over that same period. Adjustments on U.S. Forest Service lands were performed based on fire and timber harvest polygons provided by the U.S. Forest Service. Areas with fire or timber harvest within the past five years (2006-2011) we coded as ‘transitional’, while areas older than five years (pre-2006) were coded based on the NLCD cover type (**Figure C2-4**). On non-USFS property, a polygon layer of fire and timber harvest was digitized in GIS by comparing the 2006 NLCD layer with the 2011 National Agricultural Imagery Program (NAIP) aerial imagery. As with National Forest lands, areas with fire or timber harvest identified within the past five years (2006-2011) were coded as ‘transitional’ (**Figure C2-4**). Adjustments for reforestation were also examined by comparing the 2006 NLCD layer with the 2011 NAIP aerial imagery, though no areas of reforestation were observed.

Areas identified as ‘transitional’ due to recent fire or timber harvest were assigned a C-factor of 0.006 (**Table C2-2** and **Figure C2-3**). This C-factor is slightly higher than a ‘deciduous/evergreen forest’ and was used for logged areas (i.e. ‘transitional’) because logging intensity within the watershed is generally low and because practices, such as riparian clearcutting, that tend to produce high sediment yields have not been used since at least 1991, when the Montana Streamside Management Zone (SMZ) law was enacted. However, since timber harvest has the potential to double the background erosion rate from an undisturbed forest (Elliot, 2007), a conservative C-factor was applied. Additionally, the USLE model is intended to reflect long-term average sediment yield, and while a sediment pulse typically occurs in the first year after logging, sediment production after the first year rapidly declines (Elliot and Robichaud, 2001; Elliot, 2006; Rice et al., 1972). Thus, the 'transitional' value was applied to areas of timber harvest under the assumption that a portion of a given watershed is always being harvested while other areas are recovering. The same C-factor was applied for both the existing conditions and BMP scenarios to indicate that logging will continue sporadically on public and private land within the watershed and will produce sediment at a rate slightly higher than an undisturbed forest. This is not intended to imply that additional best management practices beyond those in the SMZ law should not be used for logging activities.

While upland erosion following fire tends to be greater than erosion following timber harvest (Elliot and Robichaud, 2001), the same C-factor was applied to both disturbance types because of the unpredictable nature of wildfire and the difficulty of estimating the long term average sediment inputs from it. As with timber harvest, the C-factor for fire is the same for both management scenarios since disturbance is expected from periodic forest fires.

C2.2.5 P-Factor

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

C2.3 Distance and Riparian Health Assessment based Sediment Delivery Ratio

The USLE assessment estimates the amount of sediment generated from the landscape, but the distance that sediment must travel to the stream channel, as well as the sediment removal capacity (i.e., the health) of the riparian vegetation, are important factors for estimating the sediment load that actually enters the stream network. Therefore, results from the USLE hillslope erosion assessment were combined with a sediment delivery ratio (SDR) and riparian health assessment to predict the amount of sediment delivered to streams in the Kootenai-Fisher Project Area. Soil lost from one area on a hillslope due to erosive processes is typically re-deposited a short distance downslope and therefore not all of the sediment produced from a hillslope erosion event is delivered to a stream channel. In the Kootenai-Fisher Project Area, sediment re-deposition is accounted for through the application of a sediment delivery ratio (SDR) which estimates the percentage of hillslope sediment produced that is ultimately delivered to the stream. This distance based sediment delivery ratio reflects the relationship between downslope travel distance and ultimate sediment delivery. In addition to sediment re-deposition during hillslope transport processes, riparian zones also reduce sediment inputs to stream channels. The width and quality of the riparian vegetation buffer zone determines its effectiveness as a sediment filter. Thus, a riparian health-based loading reduction was performed along with the distance based sediment delivery analysis.

C2.3.1 Riparian Health Assessment

A riparian health assessment was conducted during the aerial assessment reach stratification process in which reaches were delineated based on a combination of physical attributes (ecoregion, valley slope, valley confinement, and stream order) and the presence and degree of adjacent human activity. For each reach, a riparian health assessment was performed using aerial photos, field notes, and best professional judgment. Riparian health for each reach was designated as ‘poor’, ‘poor/fair’, ‘fair’, ‘fair/good’, or ‘good’ based on adjacent land use practices, streamside vegetation, and the presence or absence of human activities (**Figure C2-5**). The health classifications were then ground-truthed and modified based on field observations during July 2011. The cumulative length of the reaches within each riparian health category was tallied for each stream segment and the percent of stream length in each riparian health category was calculated. This information was then used to refine estimates of sediment delivery to streams from upland sources by incorporating the results of the riparian health assessment into the distance based sediment delivery ratio calculation.

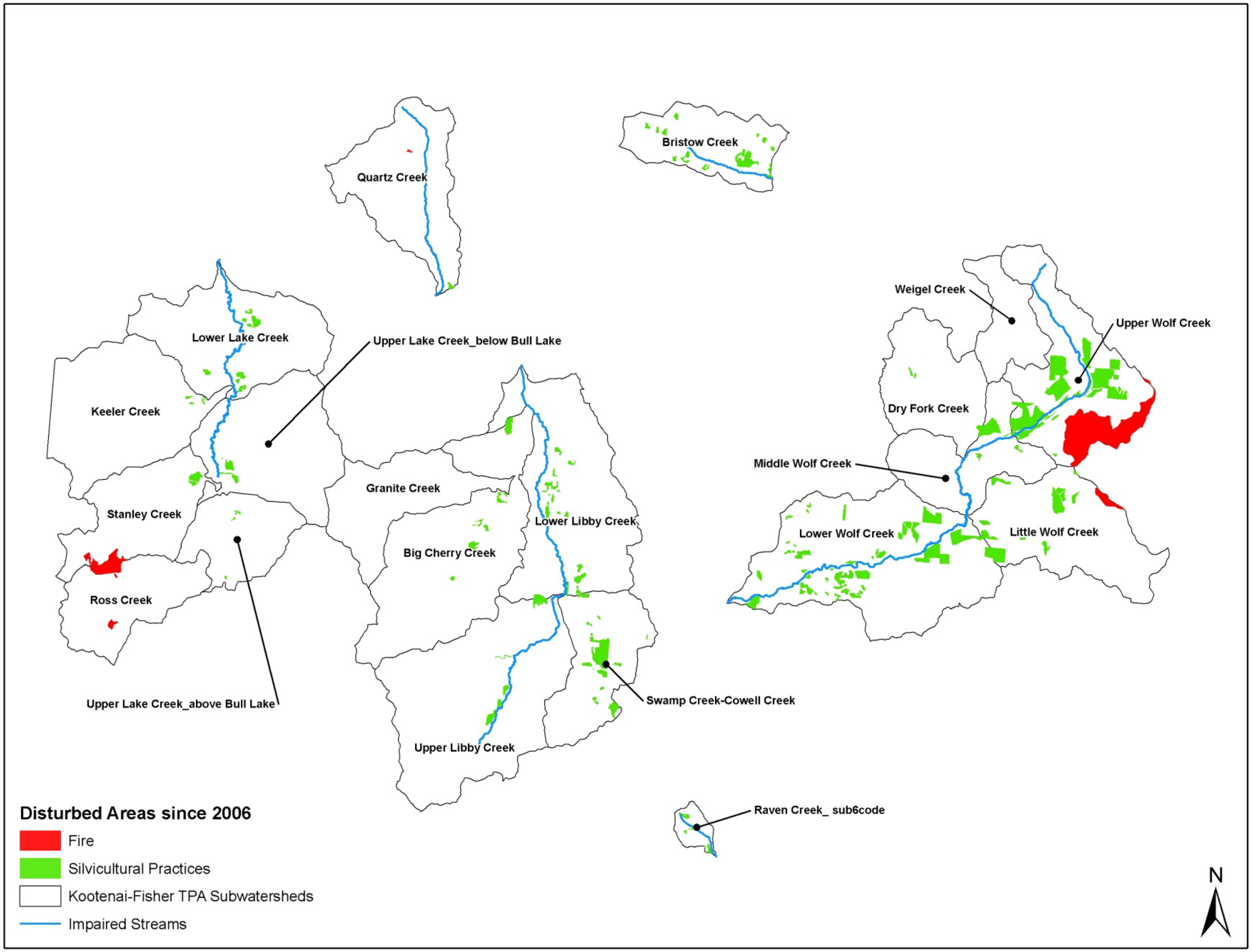

Figure C2-4. Fire and Timber Harvest Areas in the Kootenai-Fisher Project Area since 2006

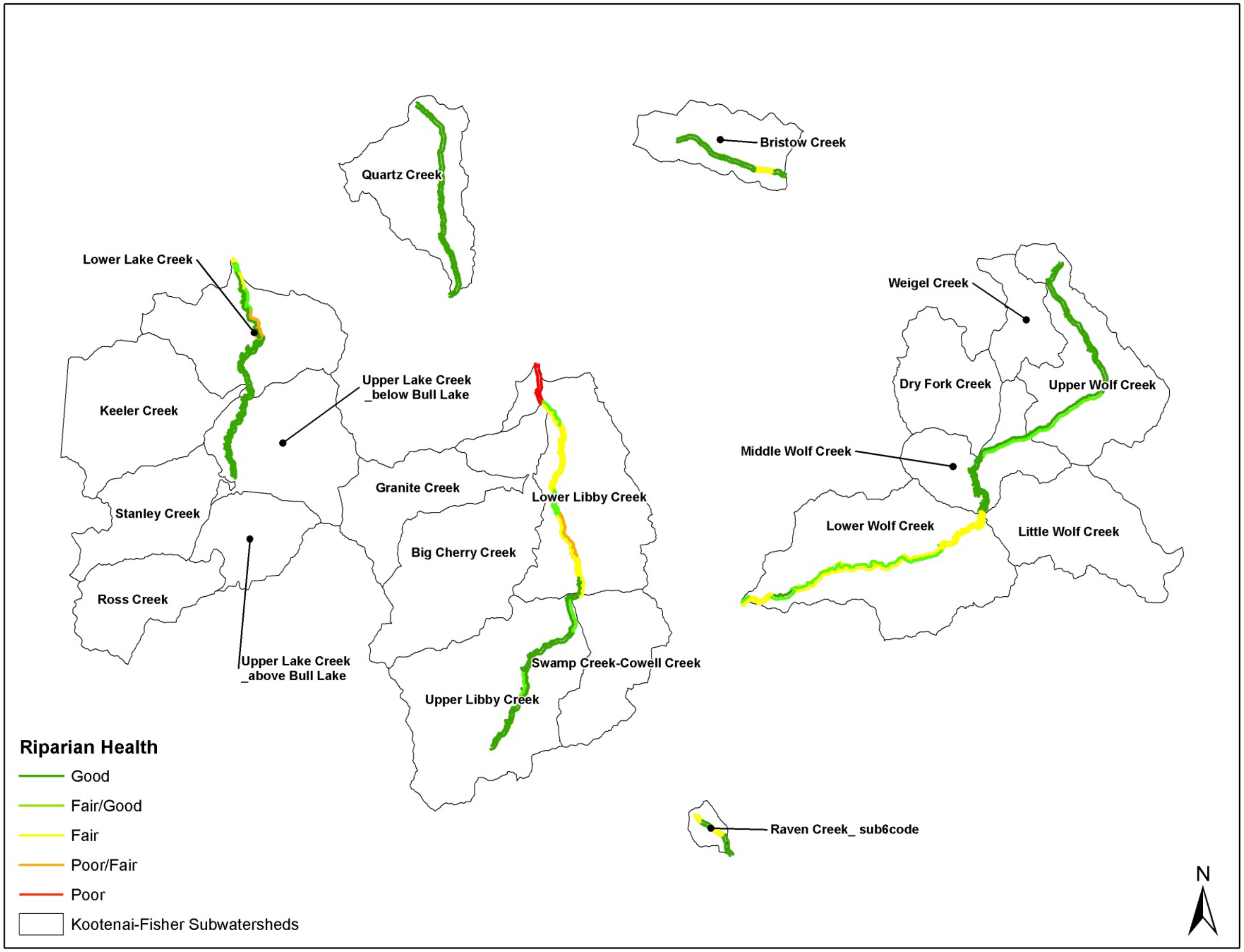

Figure C2-5. Aerial Assessment Reach Stratification Riparian Health Assessment

C2.3.2 Distance based Sediment Delivery Ratio

The distance based sediment delivery ratio was calculated in the model for each grid cell based on the observed relationship between the distance from the delivery point to the stream and the percent of eroded sediment delivered to the stream using an equation developed by Megahan and Ketcheson (1996). Megahan and Ketcheson (1996) found that the relationship between the percentage (by volume) of sediment that travels a given percentage of the maximum distance is as shown in **Figure C2-6**. Megahan and Ketcheson's logarithmic regression of the data permits this relationship to be expressed by the equation presented in **Figure C2-6**, which may be restated as a function of three variables:

Volume % = or 103.62*EXP(-((D/Dtotal)*100)/32.88))-5.55

where:

Volume% = the percentage of sediment mobilized from a source that travels at least distance D from that source

D = distance from the sediment source, and

Dtotal = the maximum distance that sediment travels from the source.

As the Megahan and Ketcheson equation is dimensionless, to serve as an SDR it was scaled to the field conditions of the Kootenai-Fisher TPA by evaluating the equation with site-specific values for D and Volume% at a single point and then solving for Dtotal. Having established a site-specific Dtotal, the Megahan and Ketcheson equation reduces to the two variables that define a distance based SDR: distance and percent sediment delivered beyond that distance. This SDR was then used to estimate sediment delivery at all points on the sediment delivery path extending from the streambank to a distance Dtotal. A sediment delivery ratio example calculation is provided in **Attachment CC**.

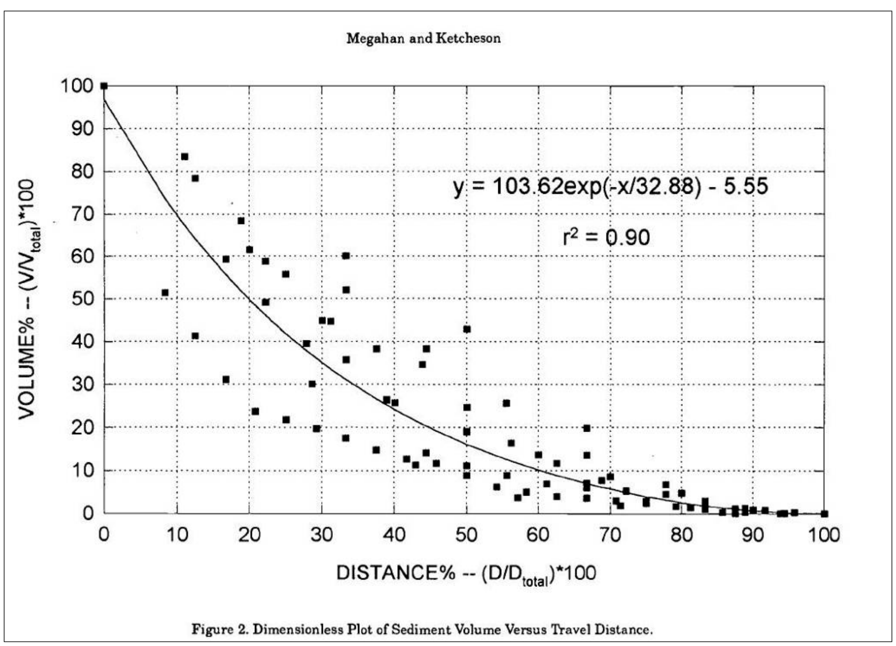

Figure C2-6. Sediment Volume vs. Travel Distance (Megahan and Ketcheson, 1996)

C2.3.3 Subwatershed Specific Sediment Delivery Ratio Scale Factors

Riparian zone sediment filtering capacity is typically expressed as a given percent reduction in delivery of sediment entering a riparian zone of a given buffer width. This rating of a known percent delivery (Volume%) from a known distance from the stream (D) permits scaling of the Megahan and Ketcheson's dimensionless equation (**Section C2.3.2**) for use in predicting percent delivery from other distances. Thirty five feet is the minimum buffer width recommended by NRCS (Natural Resource Conservation Service, 2011b; 2011a) and 50 feet is the minimum width of the streamside management zone in Montana (Montana Department of Natural Resources and Conservation, 2006). Although buffer widths of 30 to 50 feet help reduce upland sediment loading to surface waters, the ability of riparian buffers to effectively filter sediment increases with increasing buffer width. For instance, a 100 foot wide, well-vegetated riparian buffer is a common recommended buffer width (Cappiella et al., 2006; Mayer et al., 2005) and has been found to filter 75-90% of incoming sediment from reaching the stream channel (Wegner, 1999; Knutson and Naef, 1997) .

Although sediment removal efficiency is affected by factors such as ground slope, buffer health, and buffer composition, the literature values for a 100 foot buffer were used as the basis for applying a 75% sediment reduction efficiency (SRE) to buffers classified as 'good' and then scaling down the SRE based on the health classification (i.e., the SRE declines as buffer health/width declines) (**Figure C2-7**). The actual sediment removal efficiency is likely greater than shown in **Figure C2-7**, but conservative values from the literature were used as part of an implicit margin of safety. Note: Even though the health classifications assigned to streams in the Kootenai-Fisher Project Area roughly correspond to different widths, and vegetative condition, density, and potential were considered during field verification of the classifications, the loading reductions based on riparian health are predominantly intended to highlight the importance of maintaining healthy riparian zones in reducing loading from upland sediment erosion. The values were not calibrated and do not necessarily reflect actual loading reductions associated with the riparian zone.

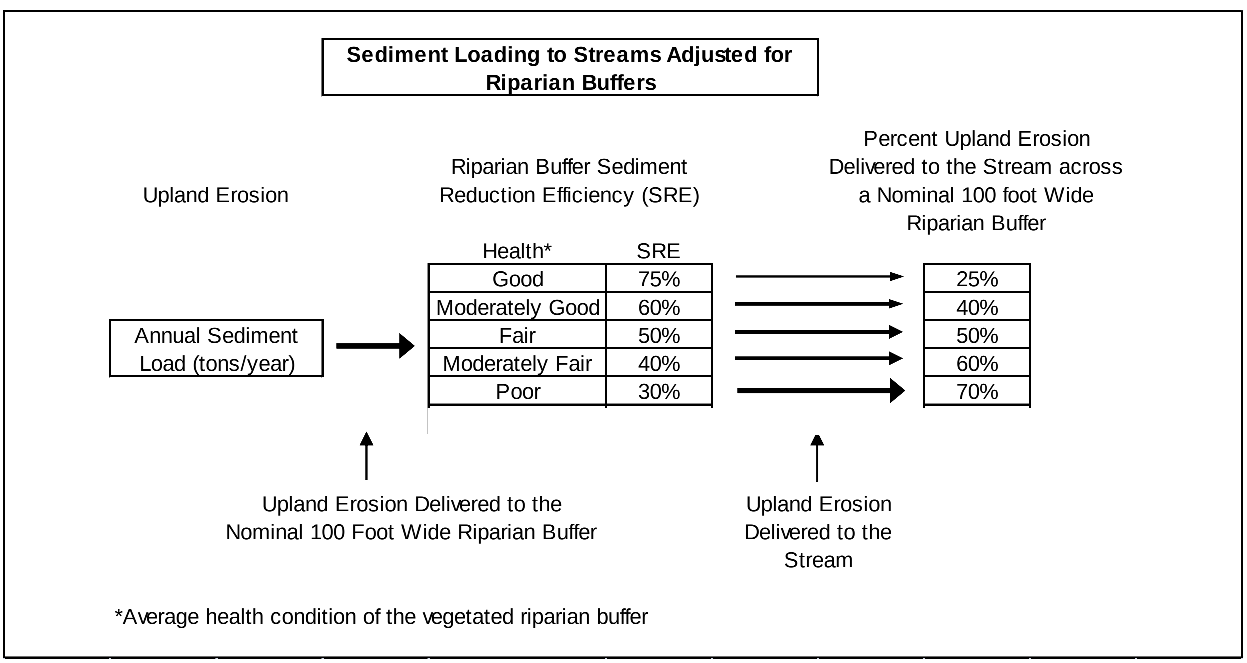

Figure C2-7. USLE Upland Sediment Load Delivery Adjusted for Riparian Buffer Capacity

The Kootenai-Fisher Project Area riparian health assessment was used to develop a riparian health score based on the sediment reduction percentage for each individual stream segment subwatershed. This value represents the percent reduction in sediment delivery under existing conditions. For the BMP scenario, it was assumed that the implementation of BMPs on those activities that affect the overall health of the vegetated riparian buffer will increase riparian health. The potential to improve riparian health was evaluated for each reach based on best professional judgment through a review of color aerial imagery from 2009 and on-the-ground verification during July 2011.

C2.4 Model Scenarios

Management scenarios include: (1) an existing conditions scenario that considers the current land cover, management practices, and riparian health in the watershed; (2) an upland BMP conditions scenario that reflects improved grazing and cover management; and (3) a riparian health BMP and upland BMP conditions scenario that considers improved riparian buffer zones and grazing and cover management. For each scenario, erosion was differentiated into two source categories: (1) natural erosion that occurs on the time scale of geologic processes and (2) anthropogenic erosion that is accelerated by human-caused activity. For scenarios 2 and 3, land cover types identified as 'grasslands/ herbaceous' and 'hay/pasture' were conservatively adjusted to reflect a 10% improvement in ground cover over existing conditions as discussed in **Section C2.2.4.2** and depicted in **Table C2-3**. For scenario 3, the riparian health score was adjusted to reflect improvements in riparian health as discussed in **Section C2.3.3**.

C3.0 Results

The results of this assessment are summarized by subwatershed in **Table C3-1**, with the complete modeling results presented by land cover category for each subwatershed in **Table C3-2**.

Table C3-1. Summary of Delivered Sediment Load by Land Cover Type in the Kootenai-Fisher Project Area

Subwatershed	Area (Acres)	Scenario 1		Scenario 2 (BMP 1)			Scenario 3 (BMP 2)		
		Upland Erosion Sediment Load for **Existing Conditions** and **Existing Riparian** Health		Upland Erosion Sediment Load for **BMP Conditions** and **Existing Riparian** Health		**Percent Reduction**	Upland Erosion Sediment Load for **BMP Conditions** and **BMP Riparian** Health		**Percent Reduction**
		(Tons/Year)	(Tons/Acre/Year)	(Tons/Year)	(Tons/Acre/Year)		(Tons/Year)	(Tons/Acre/Year)	
Ross Creek	16,111	327.1	0.020	322.1	0.020	2%	292.0	0.018	11%
Upper Lake - Above Bull Lake	12,925	96.4	0.007	96.3	0.007	<1%	87.5	0.007	9%
Upper Lake - Below Bull Lake	25,177	36.4	0.001	36.4	0.001	<1%	32.6	0.001	11%
Stanley Creek	17,869	310.4	0.017	307.2	0.017	1%	278.8	0.016	10%
Keeler Creek	28,571	352.0	0.012	351.0	0.012	<1%	317.0	0.011	10%
Lower Lake Creek	25,608	87.2	0.003	86.9	0.003	<1%	77.4	0.003	11%
Lake Creek Total	**126,262**	**1,209**	**0.010**	**1,200**	**0.010**	**1%**	**1,085**	**0.009**	**10%**
Upper Libby Creek	42,877	303.9	0.007	303.2	0.007	<1%	245.7	0.006	19%
Swamp Creek-Cowell Creek	17,217	173.5	0.010	172.4	0.010	1%	140.3	0.008	19%
Big Cherry Creek	37,491	128.3	0.003	126.6	0.003	1%	103.3	0.003	19%
Granite Creek	17,327	18.4	0.001	18.4	0.001	0%	14.5	0.001	21%
Lower Libby Creek	34,734	251.5	0.007	250.4	0.007	<1%	205.1	0.006	18%
Libby Creek Total	**149,646**	**876**	**0.006**	**871**	**0.006**	**1%**	**709**	**0.005**	**19%**
Upper Wolf Creek	28,166	192.6	0.007	186.6	0.007	3%	165.7	0.006	14%
Weigel Creek	9,368	29.8	0.003	29.7	0.003	<1%	25.8	0.003	13%
Dry Fork Creek	16,803	98.3	0.006	98.1	0.006	<1%	86.8	0.005	12%
Middle Wolf Creek	16,511	61.1	0.004	60.9	0.004	<1%	54.1	0.003	12%
Little Wolf Creek	24,239	134.0	0.006	133.6	0.006	<1%	118.1	0.005	12%
Lower Wolf Creek	42,748	291.2	0.007	290.0	0.007	0%	254.1	0.006	13%
Wolf Creek Total	**137,836**	**807**	**0.006**	**799**	**0.006**	**1%**	**705**	**0.005**	**13%**
Bristow Creek	**14,849**	**82**	**0.005**	**82**	**0.005**	**<1%**	**74**	**0.005**	**10%**
Raven Creek	**2,202**	**31.1**	**0.014**	**30.5**	**0.014**	**2%**	**25.6**	**0.012**	**18%**
Quartz Creek	**22,855**	**271**	**0.012**	**271**	**0.012**	**<1%**	**271**	**0.012**	**<1%**

Table C3-2. Delivered Sediment Load by Land Cover Type in the Kootenai-Fisher Project Area

Sub-watershed	Land Cover Classification	Area (Acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (Tons/Year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (Tons/Year)	Percent Reduction	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (Tons/Year)	Percent Reduction
Ross Creek	Transitional	648	22.134	22.134	0%	19.994	10%
	Open Water	5	0.000	0.000	0%	0.000	0%
	Perennial Snow	1	0.000	0.000	0%	0.000	0%
	Developed, Low Intensity	3	0.119	0.119	0%	0.111	7%
	Barren Land	3	0.000	0.000	0%	0.000	0%
	Evergreen Forest	13,036	232.265	232.265	0%	211.345	9%
	Shrub/Scrub	1,693	59.497	59.497	0%	53.569	10%
	Grassland/Herbaceous	676	12.193	7.504	38%	6.423	47%
	Pasture/Hay	7	0.855	0.526	38%	0.491	43%
	Woody Wetlands	14	0.006	0.006	0%	0.006	10%
	Emergent Herbaceous Wetlands	24	0.013	0.013	0%	0.012	7%
	Total	**16,111**	**327.1**	**322.1**	**2%**	**292.0**	**11%**
Upper Lake Creek - Above Bull Lake	Transitional	44	0.489	0.489	0%	0.431	12%
	Open Water	1,126	0.000	0.000	0%	0.000	0%
	Developed, Open Space	165	0.120	0.120	0%	0.105	12%
	Developed, Low Intensity	76	0.022	0.022	0%	0.020	10%
	Deciduous Forest	4	0.000	0.000	0%	0.000	0%
	Evergreen Forest	10,316	83.282	83.282	0%	75.830	9%
	Shrub/Scrub	839	11.930	11.930	0%	10.694	10%
	Grassland/Herbaceous	192	0.234	0.144	38%	0.131	44%
	Woody Wetlands	76	0.041	0.041	0%	0.037	9%
	Emergent Herbaceous Wetlands	86	0.249	0.249	0%	0.221	11%
	Total	**12,925**	**96.4**	**96.3**	**<1%**	**87.5**	**9%**

Table C3-2. Delivered Sediment Load by Land Cover Type in the Kootenai-Fisher Project Area

Sub-watershed	Land Cover Classification	Area (Acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (Tons/Year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (Tons/Year)	Percent Reduction	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (Tons/Year)	Percent Reduction
Upper Lake Creek - Below Bull Lake	Transitional	209	0.547	0.547	0%	0.474	13%
	Open Water	28	0.000	0.000	0%	0.000	0%
	Developed, Open Space	62	0.033	0.033	0%	0.030	11%
	Developed, Low Intensity	75	0.012	0.012	0%	0.011	9%
	Developed, Medium Intensity	4	0.000	0.000	0%	0.000	0%
	Barren Land	168	0.006	0.006	0%	0.006	8%
	Deciduous Forest	23	0.017	0.017	0%	0.014	18%
	Evergreen Forest	19,895	30.395	30.395	0%	27.241	10%
	Mixed Forest	16	0.001	0.001	0%	0.001	26%
	Shrub/Scrub	3,035	5.198	5.198	0%	4.627	11%
	Grassland/Herbaceous	1,468	0.081	0.050	38%	0.045	44%
	Pasture/Hay	14	0.007	0.005	38%	0.004	45%
	Woody Wetlands	129	0.111	0.111	0%	0.099	11%
	Emergent Herbaceous Wetlands	50	0.008	0.008	0%	0.007	9%
	Total	**25,177**	**36.4**	**36.4**	**<1%**	**32.6**	**11%**
Stanley Creek	Transitional	487	5.507	5.507	0%	4.727	14%
	Open Water	336	0.000	0.000	0%	0.000	0%
	Barren Land	10	0.000	0.000	0%	0.000	14%
	Deciduous Forest	25	0.003	0.003	0%	0.003	20%
	Evergreen Forest	15,449	237.229	237.229	0%	215.273	9%
	Shrub/Scrub	1,300	59.345	59.345	0%	54.341	8%
	Grassland/Herbaceous	232	8.277	5.094	38%	4.433	46%
	Woody Wetlands	15	0.003	0.003	0%	0.002	38%
	Emergent Herbaceous Wetlands	16	0.012	0.012	0%	0.011	8%
	Total	**17,869**	**310.4**	**307.2**	**1%**	**278.8**	**10%**

Table C3-2. Delivered Sediment Load by Land Cover Type in the Kootenai-Fisher Project Area

Sub-watershed	Land Cover Classification	Area (Acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (Tons/Year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (Tons/Year)	Percent Reduction	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (Tons/Year)	Percent Reduction
Keeler Creek	Transitional	61	0.044	0.044	0%	0.041	6%
	Open Water	38	0.000	0.000	0%	0.000	0%
	Developed, Open Space	3	0.000	0.000	0%	0.000	0%
	Developed, Low Intensity	9	0.004	0.004	0%	0.004	8%
	Barren Land	6	0.000	0.000	0%	0.000	0%
	Deciduous Forest	7	0.063	0.063	0%	0.060	4%
	Evergreen Forest	26,172	301.221	301.221	0%	272.085	10%
	Shrub/Scrub	2,043	47.599	47.599	0%	42.960	10%
	Grassland/Herbaceous	175	2.232	1.374	38%	1.183	47%
	Pasture/Hay	4	0.386	0.237	38%	0.217	44%
	Woody Wetlands	44	0.407	0.407	0%	0.378	7%
	Emergent Herbaceous Wetlands	9	0.083	0.083	0%	0.076	8%
	Total	**28,571**	**352.0**	**351.0**	**<1%**	**317.0**	**10%**
Lower Lake Creek	Transitional	696	0.358	0.358	0%	0.316	12%
	Open Water	138	0.000	0.000	0%	0.000	0%
	Developed, Open Space	145	0.205	0.205	0%	0.183	11%
	Developed, Low Intensity	150	0.022	0.022	0%	0.019	11%
	Developed, Medium Intensity	20	0.003	0.003	0%	0.003	18%
	Barren Land	1	0.000	0.000	0%	0.000	0%
	Deciduous Forest	19	0.000	0.000	0%	0.000	0%
	Evergreen Forest	19,940	73.578	73.578	0%	65.598	11%
	Mixed Forest	2	0.004	0.004	0%	0.004	11%
	Shrub/Scrub	3,612	11.647	11.647	0%	10.270	12%
	Grassland/Herbaceous	244	0.363	0.223	38%	0.208	43%
	Pasture/Hay	175	0.334	0.205	38%	0.190	43%
	Woody Wetlands	313	0.442	0.442	0%	0.402	9%
	Emergent Herbaceous Wetlands	152	0.195	0.195	0%	0.174	11%
	Total	**25,608**	**87.2**	**86.9**	**<1%**	**77.4**	**11%**

Table C3-2. Delivered Sediment Load by Land Cover Type in the Kootenai-Fisher Project Area

Sub-watershed	Land Cover Classification	Area (Acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (Tons/Year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (Tons/Year)	Percent Reduction	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (Tons/Year)	Percent Reduction
Lake Creek Total	Transitional	2,145	29.080	29.080	0%	25.983	11%
	Open Water	1,672	0.000	0.000	0%	0.000	0%
	Perennial Snow	1	0.000	0.000	0%	0.000	0%
	Developed, Open Space	375	0.359	0.359	0%	0.318	11%
	Developed, Low Intensity	312	0.179	0.179	0%	0.165	8%
	Developed, Medium Intensity	24	0.003	0.003	0%	0.003	18%
	Barren Land	189	0.006	0.006	0%	0.006	8%
	Deciduous Forest	79	0.084	0.084	0%	0.077	8%
	Evergreen Forest	104,809	957.970	957.970	0%	867.372	9%
	Mixed Forest	18	0.005	0.005	0%	0.004	13%
	Shrub/Scrub	12,522	195.217	195.217	0%	176.461	10%
	Grassland/Herbaceous	2,988	23.381	14.388	38%	12.423	47%
	Pasture/Hay	200	1.582	0.973	38%	0.902	43%
	Woody Wetlands	591	1.009	1.009	0%	0.924	8%
	Emergent Herbaceous Wetlands	336	0.559	0.559	0%	0.502	10%
	Total	**126,262**	**1209.4**	**1199.8**	**1%**	**1,085.1**	**10%**
Upper Libby Creek	Transitional	375	1.862	1.862	0%	1.316	29%
	Open Water	63	0.000	0.000	0%	0.000	0%
	Perennial Snow	49	0.000	0.000	0%	0.000	0%
	Developed, Open Space	20	0.139	0.139	0%	0.114	18%
	Developed, Low Intensity	15	0.010	0.010	0%	0.008	20%
	Developed, Medium Intensity	4	0.004	0.004	0%	0.003	17%
	Barren Land	106	0.000	0.000	0%	0.000	0%
	Evergreen Forest	36,685	247.913	247.913	0%	202.544	18%
	Shrub/Scrub	3,893	51.669	51.669	0%	40.434	22%
	Grassland/Herbaceous	1,514	1.638	1.008	38%	0.759	54%
	Pasture/Hay	21	0.000	0.000	0%	0.000	0%

Table C3-2. Delivered Sediment Load by Land Cover Type in the Kootenai-Fisher Project Area

Sub-watershed	Land Cover Classification	Area (Acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (Tons/Year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (Tons/Year)	Percent Reduction	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (Tons/Year)	Percent Reduction
	Woody Wetlands	49	0.099	0.099	0%	0.079	21%
	Emergent Herbaceous Wetlands	83	0.526	0.526	0%	0.434	17%
	Total	**42,877**	**303.9**	**303.2**	**<1%**	**245.7**	**19%**
Swamp Creek-Cowell Creek	Transitional	1,114	4.210	4.210	0%	3.300	22%
	Developed, Open Space	277	3.243	3.243	0%	2.515	22%
	Developed, Low Intensity	63	0.111	0.111	0%	0.085	23%
	Developed, Medium Intensity	0.34	0.000	0.000	0%	0.000	100%
	Evergreen Forest	14,075	138.042	138.042	0%	112.952	18%
	Shrub/Scrub	1,509	24.700	24.700	0%	19.702	20%
	Grassland/Herbaceous	52	2.483	1.528	38%	1.296	48%
	Pasture/Hay	64	0.597	0.368	38%	0.303	49%
	Woody Wetlands	20	0.048	0.048	0%	0.043	11%
	Emergent Herbaceous Wetlands	44	0.109	0.109	0%	0.094	14%
	Total	**17,217**	**173.5**	**172.4**	**1%**	**140.3**	**19%**
Big Cherry Creek	Transitional	446	1.151	1.151	0%	0.878	24%
	Open Water	146	0.000	0.000	0%	0.000	0%
	Perennial Snow	76	0.000	0.000	0%	0.000	0%
	Developed, Open Space	57	0.036	0.036	0%	0.029	19%
	Developed, Low Intensity	111	0.004	0.004	0%	0.003	16%
	Developed, Medium Intensity	28	0.002	0.002	0%	0.002	9%
	Developed, High Intensity	3	0.000	0.000	0%	0.000	13%
	Barren Land	48	0.000	0.000	0%	0.000	0%
	Deciduous Forest	13	0.044	0.044	0%	0.038	15%
	Evergreen Forest	28,802	103.526	103.526	0%	84.531	18%
	Shrub/Scrub	5,867	17.751	17.751	0%	14.347	19%
	Grassland/Herbaceous	1,343	4.008	2.466	38%	2.033	49%
	Pasture/Hay	57	0.253	0.155	38%	0.138	45%
	Woody Wetlands	264	0.774	0.774	0%	0.650	16%
	Emergent Herbaceous Wetlands	229	0.733	0.733	0%	0.627	14%

Table C3-2. Delivered Sediment Load by Land Cover Type in the Kootenai-Fisher Project Area

Sub-watershed	Land Cover Classification	Area (Acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (Tons/Year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (Tons/Year)	Percent Reduction	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (Tons/Year)	Percent Reduction
	Total	**37,491**	**128.3**	**126.6**	**1%**	**103.3**	**19%**
Granite Creek	Transitional	0.13	0.000	0.000	0%	0.000	0%
	Open Water	109	0.000	0.000	0%	0.000	0%
	Perennial Snow	159	0.000	0.000	0%	0.000	0%
	Barren Land	20	0.000	0.000	0%	0.000	0%
	Deciduous Forest	9	0.014	0.014	0%	0.007	54%
	Evergreen Forest	13,897	15.512	15.512	0%	12.412	20%
	Shrub/Scrub	2,281	2.813	2.813	0%	2.046	27%
	Grassland/Herbaceous	791	0.000	0.000	0%	0.000	0%
	Woody Wetlands	52	0.028	0.028	0%	0.025	11%
	Emergent Herbaceous Wetlands	8	0.005	0.005	0%	0.005	7%
	Total	**17,327**	**18.4**	**18.4**	**0%**	**14.5**	**21%**
Lower Libby Creek	Transitional	692	1.554	1.554	0%	1.217	22%
	Open Water	71	0.000	0.000	0%	0.000	0%
	Developed, Open Space	475	0.230	0.230	0%	0.189	18%
	Developed, Low Intensity	726	0.081	0.081	0%	0.068	16%
	Developed, Medium Intensity	179	0.048	0.048	0%	0.041	15%
	Barren Land	2	0.002	0.002	0%	0.002	23%
	Deciduous Forest	13	0.000	0.000	0%	0.000	59%
	Evergreen Forest	25,228	206.078	206.078	0%	169.596	18%
	Shrub/Scrub	6,140	40.428	40.428	0%	32.231	20%
	Grassland/Herbaceous	360	2.396	1.474	38%	1.264	47%
	Pasture/Hay	317	0.264	0.162	38%	0.136	48%
	Woody Wetlands	462	0.233	0.233	0%	0.200	14%
	Emergent Herbaceous Wetlands	69	0.139	0.139	0%	0.120	13%
	Total	**34,734**	**251.5**	**250.4**	**<1%**	**205.1**	**18%**

Table C3-2. Delivered Sediment Load by Land Cover Type in the Kootenai-Fisher Project Area

Sub-watershed	Land Cover Classification	Area (Acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (Tons/Year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (Tons/Year)	Percent Reduction	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (Tons/Year)	Percent Reduction
Libby Creek Total	Transitional	2,628	8.777	8.777	0%	6.710	24%
	Open Water	389	0.000	0.000	0%	0.000	0%
	Perennial Snow	283	0.000	0.000	0%	0.000	0%
	Developed, Open Space	829	3.649	3.649	0%	2.848	22%
	Developed, Low Intensity	914	0.205	0.205	0%	0.164	20%
	Developed, Medium Intensity	212	0.054	0.054	0%	0.046	15%
	Developed, High Intensity	3	0.000	0.000	0%	0.000	13%
	Barren Land	177	0.002	0.002	0%	0.002	23%
	Deciduous Forest	35	0.059	0.059	0%	0.044	24%
	Evergreen Forest	118,687	711.071	711.071	0%	582.034	18%
	Shrub/Scrub	19,690	137.361	137.361	0%	108.760	21%
	Grassland/Herbaceous	4,060	10.525	6.477	38%	5.352	49%
	Pasture/Hay	459	1.114	0.685	38%	0.578	48%
	Woody Wetlands	847	1.182	1.182	0%	0.997	16%
	Emergent Herbaceous Wetlands	433	1.512	1.512	0%	1.281	15%
	Total	**149,646**	**875.5**	**871.0**	**1%**	**708.8**	**19%**
Upper Wolf Creek	Transitional	8,152	66.137	66.137	0%	58.924	11%
	Developed, Open Space	119	0.284	0.284	0%	0.253	11%
	Developed, Low Intensity	115	0.071	0.071	0%	0.063	12%
	Developed, Medium Intensity	5	0.003	0.003	0%	0.002	22%
	Barren Land	1	0.000	0.000	0%	0.000	0%
	Deciduous Forest	5	0.033	0.033	0%	0.024	26%
	Evergreen Forest	15,347	73.192	73.192	0%	64.958	11%
	Shrub/Scrub	3,895	37.229	37.229	0%	32.929	12%
	Grassland/Herbaceous	463	15.571	9.582	38%	8.450	46%
	Woody Wetlands	35	0.064	0.064	0%	0.058	10%
	Emergent Herbaceous Wetlands	29	0.053	0.053	0%	0.048	11%

Table C3-2. Delivered Sediment Load by Land Cover Type in the Kootenai-Fisher Project Area

Sub-watershed	Land Cover Classification	Area (Acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (Tons/Year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (Tons/Year)	Percent Reduction	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (Tons/Year)	Percent Reduction
	Total	**28,166**	**192.6**	**186.6**	**3%**	**165.7**	**14%**
Weigel Creek	Evergreen Forest	6,932	20.280	20.280	0%	17.693	13%
	Shrub/Scrub	2,357	8.948	8.948	0%	7.676	14%
	Grassland/Herbaceous	11	0.122	0.075	38%	0.068	44%
	Pasture/Hay	3	0.047	0.029	38%	0.024	49%
	Woody Wetlands	57	0.295	0.295	0%	0.266	10%
	Emergent Herbaceous Wetlands	8	0.097	0.097	0%	0.086	11%
	Total	**9,368**	**29.8**	**29.7**	**<1%**	**25.8**	**13%**
Dry Fork Creek	Transitional	101	0.152	0.152	0%	0.122	19%
	Barren Land	2	0.000	0.000	0%	0.000	64%
	Deciduous Forest	23	0.035	0.035	0%	0.033	6%
	Evergreen Forest	10,825	48.029	48.029	0%	42.421	12%
	Shrub/Scrub	5,527	47.946	47.946	0%	42.470	11%
	Grassland/Herbaceous	36	0.071	0.044	38%	0.039	44%
	Pasture/Hay	40	0.312	0.192	38%	0.173	45%
	Woody Wetlands	79	0.599	0.599	0%	0.542	10%
	Emergent Herbaceous Wetlands	171	1.152	1.152	0%	1.034	10%
	Total	**16,803**	**98.3**	**98.1**	**<1%**	**86.8**	**12%**

Table C3-2. Delivered Sediment Load by Land Cover Type in the Kootenai-Fisher Project Area

Sub-watershed	Land Cover Classification	Area (Acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (Tons/Year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (Tons/Year)	Percent Reduction	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (Tons/Year)	Percent Reduction
Middle Wolf Creek	Transitional	594	1.921	1.921	0%	1.717	11%
	Open Water	5	0.000	0.000	0%	0.000	0%
	Developed, Open Space	73	0.047	0.047	0%	0.039	16%
	Developed, Low Intensity	97	0.027	0.027	0%	0.023	16%
	Developed, Medium Intensity	8	0.000	0.000	0%	0.000	73%
	Barren Land	4	0.003	0.003	0%	0.002	30%
	Deciduous Forest	68	0.001	0.001	0%	0.000	59%
	Evergreen Forest	9,467	20.504	20.504	0%	18.190	11%
	Shrub/Scrub	5,794	37.712	37.712	0%	33.469	11%
	Grassland/Herbaceous	236	0.423	0.260	38%	0.232	45%
	Pasture/Hay	10	0.095	0.058	38%	0.051	46%
	Woody Wetlands	64	0.230	0.230	0%	0.202	12%
	Emergent Herbaceous Wetlands	93	0.155	0.155	0%	0.136	12%
	Total	**16,511**	**61.1**	**60.9**	**<1%**	**54.1**	**12%**
Little Wolf Creek	Transitional	1,988	5.889	5.889	0%	5.143	13%
	Deciduous Forest	10	0.039	0.039	0%	0.032	17%
	Evergreen Forest	13,190	52.503	52.503	0%	46.366	12%
	Shrub/Scrub	8,643	73.654	73.654	0%	65.217	11%
	Grassland/Herbaceous	218	1.254	0.772	38%	0.672	46%
	Pasture/Hay	4	0.022	0.013	38%	0.012	46%
	Woody Wetlands	46	0.301	0.301	0%	0.271	10%
	Emergent Herbaceous Wetlands	139	0.387	0.387	0%	0.349	10%
	Total	**24,239**	**134.0**	**133.6**	**<1%**	**118.1**	**12%**

Table C3-2. Delivered Sediment Load by Land Cover Type in the Kootenai-Fisher Project Area

Sub-watershed	Land Cover Classification	Area (Acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (Tons/Year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (Tons/Year)	Percent Reduction	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (Tons/Year)	Percent Reduction
Lower Wolf Creek	Transitional	4,050	19.272	19.272	0%	16.659	14%
	Developed, Open Space	203	0.630	0.630	0%	0.533	15%
	Developed, Low Intensity	347	0.305	0.305	0%	0.259	15%
	Developed, Medium Intensity	59	0.027	0.027	0%	0.022	18%
	Barren Land	3	0.027	0.027	0%	0.024	12%
	Deciduous Forest	26	0.129	0.129	0%	0.117	9%
	Evergreen Forest	24,972	126.870	126.870	0%	112.209	12%
	Shrub/Scrub	12,267	140.158	140.158	0%	122.087	13%
	Grassland/Herbaceous	658	3.150	1.939	38%	1.582	50%
	Pasture/Hay	8	0.000	0.000	0%	0.000	0%
	Woody Wetlands	116	0.493	0.493	0%	0.439	11%
	Emergent Herbaceous Wetlands	40	0.174	0.174	0%	0.158	9%
	Total	**42,748**	**291.2**	**290.0**	**0%**	**254.1**	**13%**
Wolf Creek Total	Transitional	14,885	93.370	93.370	0%	82.564	12%
	Open Water	5	0.000	0.000	0%	0.000	0%
	Developed, Open Space	394	0.961	0.961	0%	0.826	14%
	Developed, Low Intensity	558	0.404	0.404	0%	0.344	15%
	Developed, Medium Intensity	72	0.030	0.030	0%	0.024	19%
	Barren Land	10	0.030	0.030	0%	0.026	14%
	Deciduous Forest	133	0.237	0.237	0%	0.207	13%
	Evergreen Forest	80,734	341.377	341.377	0%	301.838	12%
	Shrub/Scrub	38,483	345.647	345.647	0%	303.848	12%
	Grassland/Herbaceous	1,621	20.592	12.672	38%	11.043	46%
	Pasture/Hay	65	0.476	0.293	38%	0.260	45%
	Woody Wetlands	396	1.983	1.983	0%	1.778	10%
	Emergent Herbaceous Wetlands	480	2.018	2.018	0%	1.810	10%
	Total	**137,836**	**807.1**	**799.0**	**1%**	**704.6**	**13%**

Table C3-2. Delivered Sediment Load by Land Cover Type in the Kootenai-Fisher Project Area

Sub-watershed	Land Cover Classification	Area (Acres)	Scenario 1	Scenario 2 (BMP 1)		Scenario 3 (BMP 2)	
			Upland Erosion Sediment Load for Existing Conditions and Existing Riparian Health (Tons/Year)	Upland Erosion Sediment Load for BMP Conditions and Existing Riparian Health (Tons/Year)	Percent Reduction	Upland Erosion Sediment Load for BMP Conditions and BMP Riparian Health (Tons/Year)	Percent Reduction
Bristow Creek	Transitional	773	5.186	5.186	0%	4.696	9%
	Deciduous Forest	2	0.000	0.000	0%	0.000	0%
	Evergreen Forest	11,927	70.634	70.634	0%	63.748	10%
	Shrub/Scrub	2,072	5.681	5.681	0%	5.110	10%
	Grassland/Herbaceous	70	0.001	0.000	38%	0.000	77%
	Woody Wetlands	1	0.003	0.003	0%	0.003	7%
	Emergent Herbaceous Wetlands	4	0.016	0.016	0%	0.015	7%
	Total	**14,849**	**81.5**	**81.5**	**<1%**	**73.6**	**10%**
Raven Creek	Transitional	220	1.315	1.315	0%	1.022	22%
	Developed, Open Space	1	0.004	0.004	0%	0.003	8%
	Developed, Low Intensity	1	0.000	0.000	0%	0.000	17%
	Developed, Medium Intensity	0.26	0.001	0.001	0%	0.001	3%
	Barren Land	2	0.000	0.000	0%	0.000	65%
	Evergreen Forest	499	6.129	6.129	0%	5.305	13%
	Shrub/Scrub	1,211	21.812	21.812	0%	18.315	16%
	Grassland/Herbaceous	242	1.672	1.029	38%	0.785	53%
	Emergent Herbaceous Wetlands	28	0.210	0.210	0%	0.190	9%
	Total	**2,202**	**31.1**	**30.5**	**2%**	**25.6**	**18%**
Quartz Creek	Transitional	48	0.000	0.000	0%	0.000	0%
	Developed, Open Space	0.31	0.000	0.000	0%	0.000	0%
	Deciduous Forest	2	0.000	0.000	0%	0.000	0%
	Evergreen Forest	20,707	227.096	227.096	0%	227.096	0%
	Shrub/Scrub	1,943	42.789	42.789	0%	42.789	0%
	Grassland/Herbaceous	146	1.125	0.692	38%	0.692	38%
	Woody Wetlands	3	0.019	0.019	0%	0.019	0%
	Emergent Herbaceous Wetlands	4	0.018	0.018	0%	0.018	0%
	Total	**22,855**	**271.0**	**270.6**	**<1%**	**270.6**	**<1%**

C4.0 Assumptions and Uncertainty

USLE models have been widely used for TMDL development and it is assumed that it adequately estimates sediment from upland sources in the Kootenai Fisher project area. As stated in **Section C2.0**, the USLE model was selected for this source assessment because it is well suited for large watersheds since it incorporates local climate and landscape data, but is not overly data-intensive. It is assumed that the climate and landscape data sources used to build the model were appropriate. The C-factor is the input with the most uncertainty because it was the variable specified by the modeler and changed between the existing condition and BMP scenario. Efforts were made to minimize uncertainty by using a USDA research-based table (**Attachment CB**) and consulting with Montana NRCS personnel, project stakeholders, and Department of Environmental Quality (DEQ) modeling staff to select reasonable C-factors for each land cover type. Input parameters such as existing vegetative cover and the potential for vegetative cover improvement via BMP implementation for a particular land use are applied at the project area scale on an annual basis and are intended to reflect the long-term average condition. Therefore, there is no differentiation by season or ownership.

The upland erosion model integrates sediment delivery based on riparian health; riparian health evaluations linked to the stream stratification work are discussed in **Attachment CA**. The riparian health classifications were performed using aerial imagery and a coarse classification system (i.e., poor, poor/fair, fair, fair/good, and good). There is uncertainty associated with classifying riparian health into such broad categories because vegetation type and health can vary greatly over small distances. Additionally, wetland vegetation, which has a high sediment removal capacity, can be difficult to distinguish from other grasses and is likely to be given a lower health rating than woody shrubs or trees. However, field verification of the original classifications as well as the potential improvement was conducted to help reduce the uncertainty. The riparian health classification is intended to be a general indicator of riparian condition within each watershed but is not detailed enough to identify where additional BMPs are necessary.

Each riparian health class was assigned a sediment reduction efficiency value based on literature values. There is high uncertainty that the reduction efficiencies applied are the actual reduction efficiencies because no field data were collected and they were based on ranges provided in literature. This uncertainty is acceptable for this project. The riparian health analysis was not performed with the expectation that it would identify specific locations for implementation of additional BMPs. Instead it was performed to simulate the buffering capacity of riparian vegetation and emphasize the importance of a healthy riparian buffer. Even with these uncertainties, the ability to reduce upland sediment erosion and delivery to nearby waterbodies is well documented in literature, and the estimated reductions are consistent with literature values for riparian buffers.

The riparian health classification was also used to scale the maximum travel distance for sediment within each watershed (i.e., beyond that distance, eroding sediment will not reach the channel). Watershed-specific scaling of the sediment delivery ratio is assumed to help reduce the uncertainty associated with a set maximum delivery distance. Nonetheless, values were intentionally chosen to be conservative (and potentially err on high side, allowing more sediment to be delivered) as part of the implicit margin of safety.

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ATTACHMENT CA - NATIONAL LAND COVER DATABASE LAND COVER TYPE DESCRIPTIONS

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

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

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

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

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

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

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

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

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

43. Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.

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

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

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

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

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

ATTACHMENT CB - ASSIGNMENT OF USLE C-FACTORS TO NLCD LAND COVER TYPES

TABLE 10.—*Factor* C *for permanent pasture, range, and idle land*[1]

Vegetative canopy: Type and height[2]	Vegetative canopy: Percent cover[3]	Cover that contacts the soil surface: Type[4]	Percent ground cover: 0	20	40	60	80	95+
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	.45	.24	.15	.091	.043	.011
Tall weeds or short brush with average drop fall height of 20 in	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes, with average drop fall height of 6½ ft	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but no appreciable low brush. Average drop fall height of 13 ft	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

[1] The listed **C** values assume that the vegetation and mulch are randomly distributed over the entire area.

[2] Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 ft.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[4] G: cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 in deep.

W: cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface) or undecayed residues or both.

C-Factors for land cover types in the Kootenai-Fisher TPA for Existing Conditions						
NLCD Code	**Description**	**Type and Height of Raised Canopy**	**Percent Canopy Cover**	**Type**	**Percent Ground Cover**	**C-Factor**
0*	Transitional*	no appreciable canopy	-	-		0.006
11	Open Water**			-		-
12	Perennial Ice/Snow**					-
21	Developed, Open Space	no appreciable canopy	-	G	95-100	0.003
22	Developed, Low Intensity	-	-	-	-	0.001
23	Developed, Medium Intensity	-	-	-	-	0.001
24	Developed, High Intensity	-	-	-	-	0.001
31	Barren Land	-	-	-	-	0.001
41	Deciduous Forest	trees	75	G	95-100	0.003
42	Evergreen Forest	trees	75	G	95-100	0.003
43	Mixed Forest	trees	75	G	95-100	0.003
52	Shrub/Scrub	appreciable brush	25	G	85	0.008
71	Grassland/Herbaceous	no appreciable canopy	-	G	80	0.013
81	Hay/Pasture	no appreciable canopy	-	G	80	0.013
90	Woody Wetlands	trees	25	G	95-100	0.003
95	Emergent Herbaceous Wetlands	tall grass	75	G	95-100	0.003
* A code of "0" and a description of "Transitional" was developed to describe areas of Fire or Timber Harvest						
**Water and ice/snow classes will not be counted as surfaces contributing erosion						

C-Factors for land cover types in the Kootenai-Fisher TPA for Desired Conditions						
NLCD Code	**Description**	**Type and Height of Raised Canopy**	**Percent Canopy Cover**	**Type**	**Percent Ground Cover**	**C-Factor**
0*	Transitional*	no appreciable canopy	-	-		0.006
11	Open Water**			-		-
12	Perennial Ice/Snow**					-
21	Developed, Open Space	no appreciable canopy	-	G	95-100	0.003
22	Developed, Low Intensity	-	-	-	-	0.001
23	Developed, Medium Intensity	-	-	-	-	0.001
24	Developed, High Intensity	-	-	-	-	0.001
31	Barren Land	-	-	-	-	0.001
41	Deciduous Forest	trees	75	G	95-100	0.003
42	Evergreen Forest	trees	75	G	95-100	0.003
43	Mixed Forest	trees	75	G	95-100	0.003
52	Shrub/Scrub	appreciable brush	25	G	85	0.008
71	Grassland/Herbaceous	no appreciable canopy	-	G	90	0.008
81	Hay/Pasture	no appreciable canopy	-	G	90	0.008
90	Woody Wetlands	trees	25	G	95-100	0.003
95	Emergent Herbaceous Wetlands	tall grass	75	G	95-100	0.003
* A code of "0" and a description of "Transitional" was developed to describe areas of Fire or Timber Harvest						
**Water and ice/snow classes will not be counted as surfaces contributing erosion						

ATTACHMENT CC - SEDIMENT DELIVERY RATIO EXAMPLE CALCULATION

SEDIMENT DELIVERY RATIO EXAMPLE CALCULATION – RAVEN CREEK

Existing Conditions

To create a final, subwatershed specific SDR, Megahan and Ketcheson's (1996) dimensionless equation relating percent sediment volume to percent travel distance was scaled to each subwatershed by using its riparian health assessment based 100-Foot Sediment Reduction Efficiency Percentage to derive a site-specific maximum sediment travel distance. For each subwatershed, the following method was applied as described below using Raven Creek as an example.

From the subwatershed's Riparian Health Assessment, determine the expected % sediment delivery across a nominal 100 foot wide riparian zone. The riparian health assessment based Sediment Reduction Efficiency Percentage (SRE) computed for the Raven Creek subwatershed is presented in **Table CC-1**.

Table CC-1. Raven Creek Sediment Reduction Efficiency Percentage for Existing Conditions.

Riparian Health	Stream Length (Feet)	Percent of Total	Riparian Buffer Sediment Reduction Efficiency Percentage	Weighted Sediment Reduction Efficiency Percentage (Existing Conditions)
Good	11,688	43	75	32
Fair/Good	0	0	60	0
Fair	15,450	57	50	28
Poor/Fair	0	0	40	0
Poor	0	0	30	0
No data	0	0	10	0
Total	27,138	100		**61**

Example:
Per **Table CC-1**, the Raven Creek subwatershed's expected sediment delivery across a **100**-foot wide riparian zone is (100%-61% reduction) = **39%** delivered.

Substitute the expected % sediment delivery across a **100**-foot wide riparian zone into Megahan and Ketcheson's dimensionless sediment volume vs travel distance equation.

Example:
Volume% = 103.62exp(-((D/Dtotal)*100)/32.88) -5.55 =

39% = 103.62exp(-((**100**/Dtotal)*100)/32.88) -5.55

Solve the equation for **Dtotal** to arrive at a representative maximum sediment travel distance for that subwatershed.

Example:
39% = 103.62exp(-((**100**/Dtotal)*100)/32.88) -5.55

Dtotal = **100**/(-0.3288*ln((**39**+5.55)/103.62))

Dtotal = **360** feet

Restate the equation using the subwatershed's calculated maximum sediment travel distance (Dtotal) to arrive at an integrated Distance and Riparian Health based Sediment Deliver Ratio (SDR) for that subwatershed.

Example:
Within the Raven Creek subwatershed, the SDR for an analytical pixel with a drainage path to the nearest stream of length **D** would be given by:

Volume% = 103.62exp(-((D/**360**)*100)/32.88) -5.55

So if the downslope distance (D) were 200 feet in this subwatershed, then

Volume % = 103.62exp(-((200/**360**)*100)/32.88) -5.55

Volume % = 13.5

By this method, the Sediment Delivery Ratio (SDR) for each analytical pixel in a Raven Creek subwatershed is obtained by evaluating this equation:

*SDR = (103.62*EXP(-((D/Dtotal)*100)/32.88)-5.55)/100*

Where:

SDR = the ratio of sediment generated from the pixel that is delivered to a stream,
D = the downslope distance from the pixel to the nearest stream channel, and
Dtotal = the subwatershed specific Riparian Health derived maximum sediment travel distance.

Therefore in the example above, that specific pixel would have an SDR value of 0.135 that will then be multiplied against the existing USLE soil loss to produce the final reduced soil loss rate for that cell.

Best Management Practices (BMP) Conditions

Table CC-2. Raven Creek Sediment Reduction Efficiency Percentage for BMP Conditions.

BMP Riparian Health	Stream Length (Feet)	Percent of Total	Riparian Buffer Sediment Reduction Efficiency Percentage	Weighted Sediment Reduction Efficiency Percentage (BMP Conditions)
Good	11,688	43	75	32
Fair/Good	15,450	57	60	34
Fair	0	0	50	0
Poor/Fair	0	0	40	0
Poor	0	0	30	0
No data	0	0	10	0
Total	27,138	100		**66**

Example:
Per **Table CC-2**, the Raven Creek subwatershed's expected sediment delivery across a **100**-foot wide riparian zone is (100%-66% reduction) = **34%** delivered.

Substitute the expected % sediment delivery across a **100**-foot wide riparian zone into Megahan and Ketcheson's dimensionless sediment volume vs travel distance equation.

Example:
Volume% = 103.62exp(-((D/Dtotal)*100)/32.88) -5.55 =

34% = 103.62exp(-((**100**/Dtotal)*100)/32.88) -5.55

Solve the equation for **Dtotal** to arrive at a representative maximum sediment travel distance for that subwatershed.

Example:
34% = 103.62exp(-((**100**/Dtotal)*100)/32.88) -5.55

Dtotal = **100**/(-0.3288*ln((**34**+5.55)/103.62))

Dtotal = **316** feet

Restate the equation using the subwatershed's calculated maximum sediment travel distance (Dtotal) to arrive at an integrated Distance and Riparian Health based Sediment Deliver Ratio (SDR) for that subwatershed.

Example:
Within the Raven Creek subwatershed, the SDR for an analytical pixel with a drainage path to the nearest stream of length **D** would be given by:

Volume% = 103.62exp(-((D/**316**)*100)/32.88) -5.55

So if the downslope distance (D) were 200 feet in this subwatershed, then

Volume % = 103.62exp(-((200/**316**)*100)/32.88) -5.55

Volume % = 9.6

By this method, the Sediment Delivery Ratio (SDR) for each analytical pixel in a Raven Creek subwatershed is obtained by evaluating this equation:

*SDR = (103.62*EXP(-((D/Dtotal)*100)/32.88)-5.55)/100*

Where:

SDR = the ratio of sediment generated from the pixel that is delivered to a stream,
D = the downslope distance from the pixel to the nearest stream channel, and
Dtotal = the subwatershed specific Riparian Health derived maximum sediment travel distance.

Therefore in the example above, that specific pixel would have an SDR value of 0.096 that will then be multiplied against the existing USLE soil loss to produce the final reduced soil loss rate for that cell.