APPENDIX H - SEDIMENT LOAD ESTIMATES AND BMP SCENARIO REDUCTIONS FOR THE BITTERROOT

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

H1.0 UPLAND SEDIMENT

Nonpoint source pollution is pollution that originates over many varied and diffuse sources, as opposed to pollution delivered directly from a specific point or outlet, such as an end of pipe. Typically, this type of pollution is carried to streams and lakes through erosion via surface water (in the form of rainfall or snowmelt), ground water, or wind. It is often difficult to accurately quantify pollutant loads from the landscape when so much variability may exist across a watershed with regard to weather, vegetation, land use practices, soil types, geology, riparian condition, etc. However, while many complex processes are intertwined that determine this load, models with varying levels of complexity can be employed to represent the landscape and simulate the processes that occur that allow us to reasonably estimate sediment loads, identify where on the landscape those loads are coming from, and suggest how those loads could be reduced.

In the Bitterroot TPA, three main categories of pollution sources for sediment have been identified: sediment from roads, sediment from bank erosion, and sediment from upland sources. A model is used to determine sediment from upland sources, and refers to the sediment from the landscape that is delivered to the stream via overland runoff from rainfall and snowmelt.

H2.0 QUANTIFYING SEDIMENT FROM UPLAND SOURCES USING SWAT

H2.1 MODEL DEVELOPMENT

The tool used in the Bitterroot TPA to determine the sediment loads from upland sources is the hydrologic simulation model known as SWAT (Soil and Water Assessment Tool). SWAT is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds. It incorporates hydrologic, climactic, and water chemistry data with detailed land cover/land use and topography information to predict pollutant loading for seasonal and annual time frames.

A SWAT model for the Bitterroot, currently underway for evaluation of sediment and nutrient loads, is being used to represent the typical land uses and associated conditions affecting sediment production. The workings of the model are detailed as part of an initial calibration report (Van Liew, unpublished), however, finalization of this tool will be complete as it is refined as part of the nutrient TMDL. Even in its initial form, the tool is useful for estimation of landscape sediment yields. Because the model and associated sedimentation results are only preliminary, a simplified approach was implemented for the TMDL analysis. This consisted of the following:

1. Use of the preliminary SWAT model for estimating existing condition baseline upland sediment sources for impaired tributaries in the Bitterroot watershed.
2. Subsequent scenario analysis outside of the model, where loads from the preliminary SWAT model are multiplied by a literature based BMP efficiency to establish the load reductions for the TMDL.

An initial existing condition scenario was used that incorporated some basic assumptions regarding land use management practices to estimate current existing loads. Changes were then made to parameters in the model to represent potential land use management practice improvements and thereby estimate the sediment loads that could be expected if those practices were adopted.

To simulate pollutant loading at the watershed scale, SWAT first partitions a watershed into a number of subbasins. Each subbasin delineated within the model is simulated as a homogeneous area in terms of climatic conditions, but with additional subdivisions within each subbasin to represent various soils and land use types. Each of these subdivisions is referred to as a hydrologic response unit (HRU) and is assumed to be spatially uniform in terms of soils, land use, topographic and climatic data (Van Liew, 2009). HRU categories used in the Bitterroot sediment SWAT model are listed in **Table H-1**.

Table H-1. SWAT HRU Categories

SWAT Code	Land Cover/LandUse Description
AGRL	Alfalfa/Grass/Hay/Cultivated Crops
BARN	Small Rural Properties
FRST	Deciduous Forest, Evergreen Forest, Wetland
RNGB	Range Brush
RNGE	Range Grass
URML	Medium/Low Density Urban

Once the hydrologic response unit (HRU) categories have been defined, the model then introduces the hydrologic and land management information in order to generate the sediment loads from the landscape. Sediment loadings for the baseline watershed condition were taken directly from HRU output of the preliminary SWAT model. HRU loads are reflective of only landscape-based loadings (e.g. prior to channel routing), and are the direct output of the Modified Universal Soil Loss Equation (MUSLE). Simulated values reflect the integrated effects of soil erodibility, slope length and steepness, vegetative cover, and sediment delivery ratio. They are comparable to an uncalibrated GIS Universal Soil Loss Equation (USLE) model, similar to what DEQ would employ if nutrients were not of interest in the watershed. Thus the approach is adequate for this particular application.

H2.2 ESTABLISHING THE TOTAL ALLOWABLE LOAD

From the model output, the average annual sediment load delivered to the stream is determined for each subbasin, (or listed stream watershed). The average annual upland sediment load is the sum of the average annual loads from each land cover/ landuse type (HRU category). This sediment load represents the best estimation of current conditions resulting in sediment from upland sources. **Table H-2** below presents the existing sediment load from the preliminary SWAT model, with additional information to provide comparisons in severity of sediment loading among subbasins.

Table H-2. Sediment Load from Upland Sources and Comparison Among Watersheds

Subbasin	Delivered Sediment Load (T/year)	Subbasin Area (sq. miles)	Normalized to tons per square mile
Ambrose	590	21.1	28.0
Bass	369	15.3	24.1
Lick	3	8.5	0.4
Lolo 11 (Lower)	199	3.6	55.6
Lolo 12 (Middle)	2690	132.6	20.3
Lolo 13 (Upper)	2256	135.6	16.6
McClain	78	4.1	19.2
Miller	131	47.3	2.8
Muddy Spring Creek	17	1.7	10.3
North Burnt Fork	2279	85.9	26.5
Rye	10	41.7	0.2
Sleeping Child	243	89.5	2.7

Table H-2. Sediment Load from Upland Sources and Comparison Among Watersheds

Subbasin	Delivered Sediment Load (T/year)	Subbasin Area (sq. miles)	Normalized to tons per square mile
Sweathouse	127	28.3	4.5
Threemile	1384	49.6	27.9
Willow	621	48.3	12.8

H2.3 SCENARIO ANALYSIS

Following simulation of the existing condition baseline, scenarios were developed to estimate load reductions for particular best management practices in the watershed. Specific management practices that DEQ wishes to evaluate as part of the TMDL include the following: (1) agricultural best management practices (BMPs) and (2) riparian buffer strip or corridor enhancements. BMP efficiencies were taken directly from the literature when applicable, or were established using reasonable scientific judgment. To determine load reductions, the BMP efficiency was multiplied by the initial landcover load calculated from SWAT (Eq. 1), and the difference between the baseline and subsequent calculation became the load reduction for the proposed scenario (Eq. 2). Numerically, these calculations are shown below.

$$ScenarioX_{load} = \sum_{lulc=i}^{n} SWAT_{load\,i} \times BMP_{eff\,i} + SWAT_{load\,i+1} \times BMP_{eff\,i+1} \ldots SWAT_{load\,n} \times BMP_{eff\,n} \quad \text{(Eq. 1)}$$

$$Load_{reduction} = Baseline_{load} - ScenarioX_{load} \quad \text{(Eq. 2)}$$

Where:

$Baseline_{load}$ = Load for baseline scenario
$ScenarioX_{load}$ = Load for scenario
$SWAT_{load\,i}$ = Load from SWAT for a specific landcover type
$BMP_{eff\,I}$ = BMP efficiency applied to specific landcover type

Given that the baseline loadings will likely change as a result of refinement during the nutrient TMDL, all sediment loading reductions are formulated around the BMP efficiency factor, which can be directly transferred to the final loads at a later date (if desired). The scenario analyses and methods for which this factor were derived are described in subsequent sections.

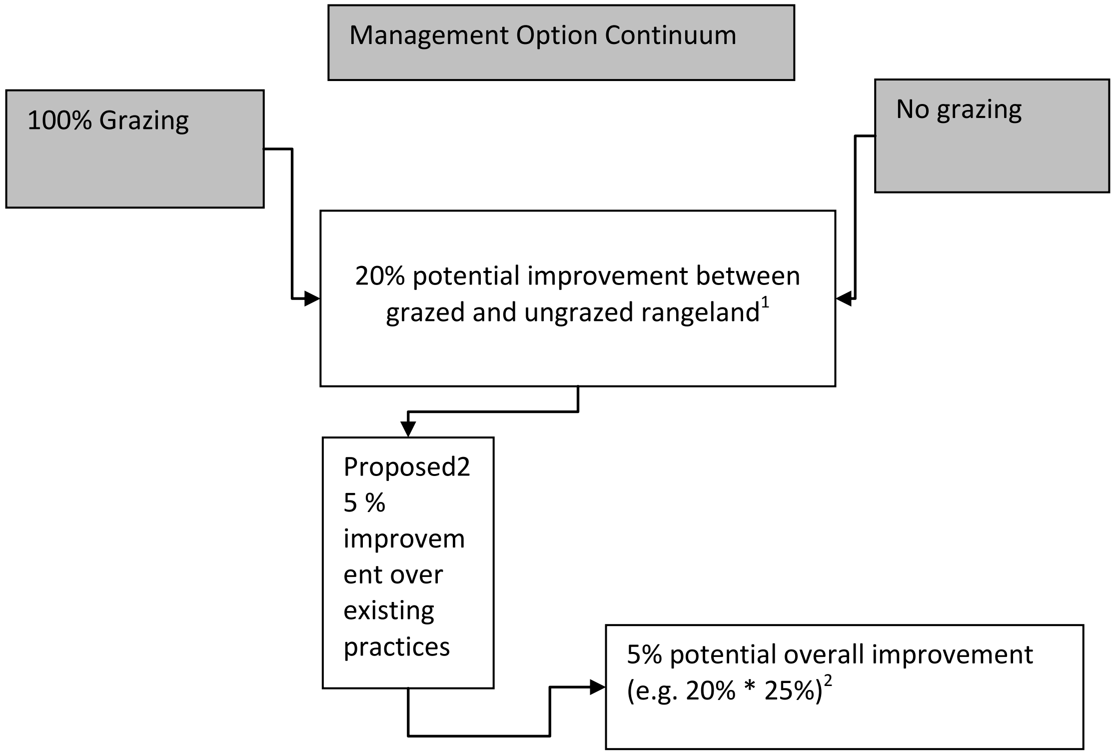
H2.3.1 Agricultural Best Management Practice Scenario

Agricultural best management practices (BMPs) are proposed to reduce agricultural non-point source loads and improve overall stream water quality in the Bitterroot watershed. Agouridis et al. (2005) provide a comprehensive review of common agricultural BMP implementation practices in the United States. In general, at least one aspect of stream water quality has improved after receiving one or more of the following BMP treatments: off-stream water, alternate shade, rotational grazing, supplemental feeding, buffer strips, or livestock exclusion. As such, DEQ believes that implementation of at least one or more of these practices could cost-effectively reduce sediment loads, and improve water quality in the Bitterroot watershed. While application and effectiveness of such practices are site-specific, the agricultural BMP scenario was formulated to evaluate the hypothetical load reductions from the following BMPs: (1) improved upland range management, (2) better barnyard management, and (3) reduced tillage.

H2.3.1.1 Upland Range Improvement Scenario

The upland range improvement scenario was developed to reflect improved grazing management practices in the agricultural portions of watershed. It is well known that grazing reduces groundcover, and excellent review of regional studies has been presented by Thrift (2006). In her thesis, she concludes that domestic animals (e.g. cattle and sheep) reduce ground cover through both grazing and trample. Generally, this could be linked to increased rill and interill erosion. Plot studies on the Beaverhead National Forest near Dillon, MT suggest similar conclusions, finding sites that received heavy, moderate, and light grazing had 14.9, 18.6, and 6.8 percent more bare ground than plots with no cattle (Evanko and Peterson, 1955). Similarly, in an exclusion study on foothill sheep ranges in Meagher County near White Sulpher Springs, MT, total cover (e.g. foliage and litter) was 16.9 percent higher on protected plots than on those that received grazing (Vogel and Van Dyne, 1966).

Given that the relationship between ground cover and erosion is apparent, and that regional studies tend to suggest that ground cover is approximately 15-20 percent higher on ungrazed rangeland than sites receiving grazing (note: this is a relative change in percent cover not an absolute percentage), a scenario was developed to evaluate improvements in rangeland condition. However, because the BMP implementation described previously reflects only the difference between grazed and excluded plots, a fractional adjustment is necessary to reflect reasonable grazing practices (e.g. it is unrealistic to evaluate an ungrazed condition). A 25% improvement over the existing condition is proposed which calculates out to a 5% relative potential improvement in groundcover as illustrated in **Figure H-1**. Note this is not an absolute change in cover, rather it needs to be multiplied by the existing groundcover to come up with the actual percent change in cover. A similar procedure was completed for range-brush (e.g. sagebrush land); although it was assumed that only 50% of the land had grass forage therefore the percent improvement in cover would only be 2.5%.



[1] A 20% relative potential change over the existing cover condition, not a 20% absolute change in cover.
[2] A 5% relative potential change over the existing cover condition based on the previous assumption (e.g.20% x proposed 25% improvement is 5% potential improvement).

Figure H-1. Rangeland cover improvement scenario management option propagated on the SWAT model output.

BMP efficiency factors for this scenario were formulated using the multiplicative nature of MUSLE and the straightforward relationship between percent cover and c-factor. Assumptions used in this estimation procedure for the rangeland management scenario are shown in Table H-3. A similar approach was taken for the tillage and confined animal management scenario, as described in subsequent sections (also shown in the table).

Table H-3. Assumptions used in development of agricultural best management scenario.

Cover Type	Assumptions	Existing Condition Cover (%)	Annual USLE C-factor, (minimum c-factor in parenthesis)	Improved Condition Cover (%)	Annual USLE C-factor	BMP efficiency (%)
Barnyard[1]	Heavily compacted soil; no cover	0	1.000 (1.0)	20	0.5	50%
Cultivated Crops[1]	Intensive tillage practices	<15% residue	0.230 (0.13)	15-30% residue (reduced tillage)	0.15	35%
Range Grass[2]	Grass cover type; no canopy cover	57	0.050 (0.014)	60	0.042	16%
Range Brush[2]	50% grass cover, 50% brush canopy; 0.5 m fall height	56	0.042 (0.0107)	57	0.037	12%

[1] From McCuen (1998)
[2] From Brooks et al. (1997)

H2.3.1.2 Reduced tillage scenario

According to the 2002 Census of Agriculture for Montana, Ravalli County produced approximately 1,789 acres of wheat (both winter and spring grains). While exact tillage practices are not apparent, it is believed that intensive ones are most likely used in the watershed. This constitutes less than 15% surface residue left, or <500 lbs/acre stubble mulch. Therefore, as part of the agricultural best management practice scenario, a reduced tillage system was evaluated which resulted in a BMP reduction efficiency of 35% per the cover management practice factors in McCuen (1998). This represents between 500-1000 lb/acre stubble mulch, or15-30% surface residue.

H2.3.1.3 Confined Animal Management Scenario

Rural development in the Bitterroot watershed has been on the rise, much of which has taken the form of small-scale residential acreages. Based on windshield surveys conducted by Montana DEQ, one in four of these areas typically has a confined animal area, e.g. a corralled and/or fenced area where livestock are present. Because bare soil in these areas is an erosion risk, a scenario was developed to address the potential sediment reduction from these practices. An increase from 0 to 20 percent ground cover was proposed which translates to a direct BMP efficiency of approximately 50%.

H2.3.2 Incorporating Improved Riparian Condition

Aerial assessment techniques using GIS and aerial photos were completed for each stream of interest to provide a coarse summary of riparian conditions in the subbasins. Delineated reaches were given a riparian condition category of good, fair, or poor based on land use adjacent to the stream, riparian vegetation type and density, and the presence or absence of human related activities near the stream corridor. Based on this, each stream investigated was given corresponding percentages of condition based on the total length of stream assessed.

Literature review (Wegner 1999, Knutson and Naef 1997) indicates that a 100 foot wide, well vegetated riparian buffer zone can be expected to filter 75-90% of incoming sediment from reaching its stream channel. Conversely, this analysis conservatively assumes that a riparian zone without vegetation cover (corresponding to a riparian health assessment of ‘none’) would only filter 10% of incoming sediment from reaching its stream.

Based on the above information, sediment reduction factors were chosen to account for the potential in sediment reduction efficiency from improved riparian conditions. The range between filtering capacity between ‘good’ and ‘none’ is roughly 65-80%. A conservative assumption was then made that sediment reduction potential representing ‘poor’ conditions may be close to 25%, ‘moderate’ riparian condition filters 50% of the sediment load, and ‘good’ riparian condition has the effect of reducing upland sediment load by 75%.

To then incorporate riparian filtering capacity, in addition to the load from the improved condition, the riparian condition and associated reduction potential for each stream is applied to simulate the total sediment reduction potential if all land management improvements across the landscape and within the riparian corridor are implemented. For instance, if stream A is determined by the SWAT model desired condition to have a sediment load of 100 tons/year, and 50% (50 tons/year) of the stream is considered to be in Good riparian condition, and 50% (50 tons/year) is considered to be Poor, than a total of 50% (25 tons/year) of the load from the Poor riparian could be buffered if the riparian condition was improved to Good, resulting in a total load for stream A of 75 tons/year when all best management practices are implemented (**Table H-4**). The filtering capacity of the buffers is only applied in the improvement scenarios. Since the model serves only as a representation of existing conditions, it is implied that additional reduction through riparian filters is only applicable once modifications in land management improve riparian condition.

Table H-4. Example Riparian Buffer Load Reduction Estimate

Riparian Condition			Buffering Capacity	
Category	**Percent Stream Length**	**Upland Load Distribution**	**Estimated Load Reduction with Buffer Improvement**	**Upland Load Reduction**
Good	50%	50	0%	50
Fair	-	-	25%	-
Poor	50%	50	50%	25
Upland Load From Model		100	Desired Load	75

No specified BMP practices were recommended by DEQ to reach these improvements. Rather it should be up to the stakeholders and watershed managers in the area to define what practices, and associated locations, will be most effective and cost-efficient for watershed restoration. Subsequently, more detailed set of practices should be tailored to each agricultural producer during actual watershed restoration planning.

H2.4 RESULTS - LOAD REDUCTION SUMMARIES

The following tables (**H-5 to H-19**) display the current estimated load based on SWAT, the load resulting when BMPs are applied to each specific land use, and the total load with land use BMPs and improved riparian areas in place to get the total possible percent upland reduction.

Table H-5. Ambrose Creek Upland Load Reductions

AMBROSE CREEK			Land Use BMP Efficiency Only		Combined Land Use and Riparian BMP Efficiency	
Sources		**Current estimated load based on SWAT (T/Year)**	**Land use BMP efficiency**	**Sediment load with land use BMP efficiency applied to current load (T/Year)**	**Resultant sediment load with 31% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)**	**Total possible upland % reduction**
Upland Erosion	Barnyard[1]	18	50%	9		
	Agriculture	101	35%	66		
	Range Grass[2]	211	16%	177		
	Range Brush[2]	182	12%	161		
	Forest	76	N/A	76		
	Low/Med Urban	2	N/A	2		
	Total	590		490	338	43%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-6. Bass Creek Upland Load Reductions

BASS CREEK			Land Use BMP Efficiency Only		Combined Land Use and Riparian BMP Efficiency	
Sources		Current estimated load based on SWAT (T/Year)	Land use BMP efficiency	Sediment load with land use BMP efficiency applied to current estimated load (T/Year)	Resultant sediment load with 6% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)	Total possible upland % reduction
Upland Erosion	Barnyard[1]	0	50%	0		
	Agriculture	20	35%	13		
	Range Grass[2]	212	16%	178		
	Range Brush[2]	131	12%	115		
	Forest	6	N/A	6		
	Low/Med Urban	0	N/A	0		
	Total	369		313	294	20%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-7. Lick Creek Upland Load Reductions

LICK CREEK			Land Use BMP Efficiency Only		Combined Land Use and Riparian BMP Efficiency	
Sources		Current estimated load based on SWAT (T/Year)	Land use BMP efficiency	Sediment load with land use BMP efficiency applied to current estimated load (T/Year)	Resultant sediment load with 8% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)	Total possible upland % reduction
Upland Erosion	Barnyard[1]	0	50%	0		
	Agriculture	0	35%	0		
	Range Grass[2]	0	16%	0		
	Range Brush[2]	0	12%	0		
	Forest	2	N/A	2		
	Low/Med Urban	1	N/A	1		
	Total	3		3	2	32%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-8. Lolo Creek 11 (Lower) Upland Load Reductions

LOLO CREEK 11 (LOWER)			Land Use BMP Efficiency Only		Combined Land Use and Riparian BMP Efficiency	
Sources		Current estimated load based on SWAT (T/Year)	Land use BMP efficiency	Sediment load with land use BMP efficiency applied to current estimated load (T/Year)	Resultant sediment load with 25% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)	Total possible upland % reduction
Upland Erosion	Barnyard[1]	4	50%	2		
	Agriculture	57	35%	37		
	Range Grass[2]	83	16%	70		
	Range Brush[2]	42	12%	37		
	Forest	10	N/A	10		
	Low/Med Urban	3	N/A	3		
	Total	199		159	119	40%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-9. Lolo Creek 12 (Middle) Upland Load Reductions

LOLO CREEK 12 (MIDDLE)			**Land Use BMP Efficiency Only**		**Combined Land Use and Riparian BMP Efficiency**	
Sources		**Current estimated load based on SWAT (T/Year)**	**Land use BMP efficiency**	**Sediment load with land use BMP efficiency applied to current estimated load (T/Year)**	**Resultant sediment load with 26% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)**	**Total possible upland % reduction**
Upland Erosion	Barnyard[1]	11	50%	6		
	Agriculture	126	35%	82		
	Range Grass[2]	415	16%	349		
	Range Brush[2]	1074	12%	945		
	Forest	1057	N/A	1057		
	Low/Med Urban	7	N/A	7		
	Total	2690		2445	1809	33%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-10. Lolo Creek 13 (Upper – Includes Upper Lolo TPA) Upland Load Reductions

LOLO CREEK 13 (UPPER – Includes Upper Lolo TPA)			**Land Use BMP Efficiency Only**		**Combined Land Use and Riparian BMP Efficiency**	
Sources		**Current estimated load based on SWAT (T/Year)**	**Land use BMP efficiency**	**Sediment load with land use BMP efficiency applied to current estimated load (T/Year)**	**Resultant sediment load with 21% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)**	**Total possible upland % reduction**
Upland Erosion	Barnyard[1]	1	50%	0		
	Agriculture	2	35%	1		
	Range Grass[2]	98	16%	82		
	Range Brush[2]	1022	12%	899		
	Forest	1125	N/A	1125		
	Low/Med Urban	8	N/A	8		
	Total	2256		2116	1672	26%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-11. McClain Creek Upland Load Reductions

MCCLAIN CREEK			**Land Use BMP Efficiency Only**		**Combined Land Use and Riparian BMP Efficiency**	
Sources		**Current estimated load based on SWAT (T/Year)**	**Land use BMP efficiency**	**Sediment load with land use BMP efficiency applied to current estimated load (T/Year)**	**Resultant sediment load with 21% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)**	**Total possible upland % reduction**
Upland Erosion	Barnyard[1]	0	50%	0		
	Agriculture	3	35%	2		
	Range Grass[2]	4	16%	3		
	Range Brush[2]	39	12%	34		
	Forest	32	N/A	32		
	Low/Med Urban	0	N/A	0		
	Total	78		72	57	28%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-12. Miller Creek Upland Load Reductions

MILLER CREEK			Land Use BMP Efficiency Only		Combined Land Use and Riparian BMP Efficiency	
Sources		Current estimated load based on SWAT (T/Year)	Land use BMP efficiency	Sediment load with land use BMP efficiency applied to current estimated load (T/Year)	Resultant sediment load with 34% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)	Total possible upland % reduction
Upland Erosion	Barnyard[1]	0	50%	0		
	Agriculture	0	35%	0		
	Range Grass[2]	53	16%	45		
	Range Brush[2]	42	12%	37		
	Forest	35	N/A	35		
	Low/Med Urban	0	N/A	0		
	Total	131		117	77	41%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-13. Muddy Spring Creek Upland Load Reductions

MUDDY SPRING CREEK			Land Use BMP Efficiency Only		Combined Land Use and Riparian BMP Efficiency	
Sources		Current estimated load based on SWAT (T/Year)	Land use BMP efficiency	Sediment load with land use BMP efficiency applied to current estimated load (T/Year)	Resultant sediment load with 1% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)	Total possible upland % reduction
Upland Erosion	Barnyard[1]	0	50%	0		
	Agriculture	0	35%	0		
	Range Grass[2]	7	16%	6		
	Range Brush[2]	8	12%	7		
	Forest	2	N/A	2		
	Low/Med Urban	0	N/A	0		
	Total	17		15	15	14%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-14. North Burnt Fork Creek Upland Load Reductions

NORTH BURNT FORK CREEK			Land Use BMP Efficiency Only		Combined Land Use and Riparian BMP Efficiency	
Sources		Current estimated load based on SWAT (T/Year)	Land use BMP efficiency	Sediment load with land use BMP efficiency applied to current estimated load (T/Year)	Resultant sediment load with 37% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)	Total possible upland % reduction
Upland Erosion	Barnyard[1]	23	50%	12		
	Agriculture	165	35%	107		
	Range Grass[2]	1592	16%	1337		
	Range Brush[2]	487	12%	429		
	Forest	11	N/A	11		
	Low/Med Urban	1	N/A	1		
	Total	2279		1897	1195	48%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-15. Rye Creek Upland Load Reductions

RYE CREEK			Land Use BMP Efficiency Only		Combined Land Use and Riparian BMP Efficiency	
Sources		Current estimated load based on SWAT (T/Year)	Land use BMP efficiency	Sediment load with land use BMP efficiency applied to current estimated load (T/Year)	Resultant sediment load with 19% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)	Total possible upland % reduction
Upland Erosion	Barnyard[1]	0	50%	0		
	Agriculture	1	35%	1		
	Range Grass[2]	5	16%	4		
	Range Brush[2]	4	12%	4		
	Forest	0	N/A	0		
	Low/Med Urban	0	N/A	0		
	Total	10		9	7	33%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-16. Sleeping Child Creek Upland Load Reductions

SLEEPING CHILD CREEK			Land Use BMP Efficiency Only		Combined Land Use and Riparian BMP Efficiency	
Sources		Current estimated load based on SWAT (T/Year)	Land use BMP efficiency	Sediment load with land use BMP efficiency applied to current estimated load (T/Year)	Resultant sediment load with 10% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)	Total possible upland % reduction
Upland Erosion	Barnyard[1]	3	50%	2		
	Agriculture	1	35%	1		
	Range Grass[2]	61	16%	51		
	Range Brush[2]	101	12%	89		
	Forest	77	N/A	77		
	Low/Med Urban	0	N/A	0		
	Total	243		219	197	19%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-17. Sweathouse Creek Upland Load Reductions

SWEATHOUSE CREEK			Land Use BMP Efficiency Only		Combined Land Use and Riparian BMP Efficiency	
Sources		Current estimated load based on SWAT (T/Year)	Land use BMP efficiency	Sediment load with land use BMP efficiency applied to current estimated load (T/Year)	Resultant sediment load with 14% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)	Total possible upland % reduction
Upland Erosion	Barnyard[1]	7	50%	4		
	Agriculture	7	35%	5		
	Range Grass[2]	2	16%	2		
	Range Brush[2]	84	12%	74		
	Forest	27	N/A	27		
	Low/Med Urban	0	N/A	0		
	Total	127		111	95	25%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-18. Threemile Creek Upland Load Reductions

THREEMILE CREEK			Land Use BMP Efficiency Only		Combined Land Use and Riparian BMP Efficiency	
Sources		Current estimated load based on SWAT (T/Year)	Land use BMP efficiency	Sediment load with land use BMP efficiency applied to current estimated load (T/Year)	Resultant sediment load with 28% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)	Total possible upland % reduction
Upland Erosion	Barnyard[1]	40	50%	20		
	Agriculture	186	35%	121		
	Range Grass[2]	608	16%	511		
	Range Brush[2]	341	12%	300		
	Forest	204	N/A	204		
	Low/Med Urban	5	N/A	5		
	Total	1384		1161	836	40%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

Table H-19. Willow Creek Upland Load Reductions

WILLOW CREEK			Land Use BMP Efficiency Only		Combined Land Use and Riparian BMP Efficiency	
Sources		Current estimated load based on SWAT (T/Year)	Land use BMP efficiency	Sediment load with land use BMP efficiency applied to current estimated load (T/Year)	Resultant sediment load with 27% reduction from potential riparian improvement applied to load after land use BMP efficiency is in place (T/Year)	Total possible upland % reduction
Upland Erosion	Barnyard[1]	15	50%	8		
	Agriculture	18	35%	12		
	Range Grass[2]	201	16%	169		
	Range Brush[2]	297	12%	261		
	Forest	90	N/A	90		
	Low/Med Urban	0	N/A	0		
	Total	621		539	394	37%

[1] From McCuen (1998), [2] From Brooks et al. (1997)

3.0 REFERENCES

Agouridis, C.T., Workman, S.R., Warner, R.C., and G.D. Jennings. 2005. Livestock grazing management impacts on stream water quality: a review. Journal of American Water Resources Association. 2005 41(3). p.591-606

Brooks, K.N., Ffolliot, P.F., Gregerson, H.M., and DeBano, L.F. 1997. Hydrology and the management of watersheds. Iowa State University Press. Ames, Iowa.

Evanko, Anthony B.; Peterson, Roald A. 1955. Comparisons of protected and grazed mountain rangelands in southwestern Montana. Ecology. 36(1): 71-82.

Lacey, J.R., Marlow, C.B., and J.R. Lane. 1989. Influence of spotted knapweed (Centaurea maculosa) on surface runoff and sediment yield. Weed Technology. Volume 3: 627-631.

McCuen. R.H. 1998. Hydrologic Analysis and Design 2nd edition. Prentice-Hall, Inc. Upper Saddle River, New Jersey.

Thrift, T.M. 2006. Effects of long-term winter-spring grazing on foothill rangeland. Master's Thesis. Montana State University. Bozeman, Montana. April 2006.

Vogel, W. G.; Van Dyne, G. M. 1966. Vegetation responses to grazing management on a foothill sheep range. Journal of Range Management. 19: 80-85. [12263]