APPENDIX E - STREAMBANK EROSION SOURCE ASSESSMENT

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E1.0 INTRODUCTION

This appendix presents an assessment of sediment loading due to streambank erosion in the Tobacco River TMDL Planning Area (TPA) located in Lincoln and Flathead Counties of Montana. Most of the information within this appendix is derived directly from an April, 2009 streambank erosion report prepared by Water & Environmental Technologies, PC (Water & Environmental Technologies, 2009; River Design Group, 2011; Water & Environmental Technologies, 2009). Sediment loads due to streambank erosion were estimated based on field data collected at 32 monitoring sites in August and September 2008. Streambank data collected at field monitoring sites were extrapolated to the stream reach, stream segment, and watershed scales based on reach type and land use characteristics identified in the aerial assessment database, which was compiled in a geographic information system (GIS) prior to field data collection. Detailed data from the GIS aerial assessment and other sediment and habitat parameters are presented in **Appendix D**. Streambank erosion data were also used to estimate potential sediment reductions to human influenced reaches through the application of all reasonable land, soil, and water conservation practices.

E2.0 METHODS

The streambank erosion assessment involved several procedures. First, streams were stratified into similar reaches using an aerial assessment performed in GIS. Streambank erosion data was then collected in the field at selected monitoring sites, and sediment loads were estimated based on field conditions. Sediment loads from field assessed monitoring sites were then extrapolated to the stream reach, stream segment, and watershed. Finally, the potential for reducing human influenced streambank erosion was evaluated. Detailed methods describing each procedure are provided in the following sections.

E2.1 AERIAL ASSESSMENT REACH STRATIFICATION

Prior to field data collection, an aerial assessment of streams in the Tobacco River TPA was conducted using GIS. Data layers were used to stratify streams into distinct reaches based on landscape and land-use factors following techniques described in *Watershed Stratification Methodology for TMDL Sediment and Habitat Investigations(Montana Department of Environmental Quality, 2008)*.

The reach stratification process was completed for the mainstem segments of the following sediment-listed streams in the Tobacco River TPA: Deep Creek, Edna Creek, Fortine Creek, Grave Creek, Lime Creek, Swamp Creek, Theriault Creek, and Tobacco River. In addition to these streams, Sinclair Creek was included due to stakeholder and DEQ interest in evaluating this stream. A TMDL and water quality restoration plan has already been prepared for the Grave Creek watershed (Montana Department of Environmental Quality, et al., 2005), but the stream was included in the reach stratification effort for the purposes of consistency and extrapolation of sediment loads at the watershed scale. Stream segments stratified during the aerial assessment are considered “stratified”, while streams not stratified are considered “unstratified” for the purposes of this report. Meadow Creek and Indian Creek were not listed for sediment impairment, were not included in the stratification effort, and will be considered “unassessed” streams.

The aerial assessment reach stratification process involved dividing each stream into distinct reaches based on four watershed characteristics. A reach type is defined as a unique combination of EPA Ecoregion, valley gradient, Strahler stream order, and valley confinement, and is designated using the following naming convention based on the reach type identifiers provided in **Table E2-1**:

Level III Ecoregion – Valley Gradient – Strahler Stream Order – Confinement

Table E2-1. Reach type identifiers.

Watershed Characteristic	Stratification Category	Reach Type Identifier
Level III Ecoregion	Northern Rockies	NR
	Canadian Rockies	CR
Valley Gradient	0-2%	0
	2-4%	2
	4-10%	4
	> 10%	10
Strahler Stream Order	first order	1
	second order	2
	third order	3
	fourth order	4
	fifth order	5
Confinement	confined	C
	unconfined	U

For example, a reach identified as NR-0-3-U is in the Northern Rockies Level III Ecoregion, has a valley gradient of 0-2%, is a 3rd order stream, and is within an unconfined valley.

E2.2 FIELD DATA COLLECTION

Field data collection utilized the approach described the in *Longitudinal Field Methods for the Assessment of TMDL Sediment and Habitat Impairments* (Montana Department of Environmental Quality, 2007). Streambank erosion data was collected at each field assessed monitoring site, which was 500, 1000, or 2000 feet long based on bankfull width of the stream: the larger the bankfull width, the longer the monitored reach.

At each monitoring site, all streambanks were assessed for erosion severity and categorized as either "actively/visually eroding" or "slowly eroding/vegetated/undercut". At each eroding bank, Bank Erosion Hazard Index (BEHI) measurements were performed and the Near Bank Stress (NBS) was estimated or determined based on field measurements (Rosgen, 2006). Bank erosion severity was rated from "very low" to "extreme" based on the BEHI score, which was determined by the following six parameters: bank height, bankfull height, root depth, root density, bank angle, and surface protection. Near Bank Stress was rated from "very low" to "extreme" depending on the shape of the channel at the toe of the bank and the force of the water (i.e. "stream power") along the bank.

In addition, the source or underlying cause of streambank erosion was evaluated based on current or observed human disturbances within the riparian corridor, as well as historic land-use practices in the surrounding landscape. The following near-stream source categories were used: transportation (roads), grazing, cropland, mining, logging, irrigation, natural, and "other". Naturally eroding streambanks were considered those with no observed or known historic human impacts, while the "other" category was

chosen when streambank erosion resulted from a source not specifically identified in the list. If multiple sources were observed, then a percent of the total was estimated for each source.

E2.3 SEDIMENT LOAD CALCULATIONS

For each eroding streambank, the average annual sediment load was estimated based on the bank's length, mean height, and estimated annual retreat rate. The length and mean height were measured in the field, while the annual retreat rate was determined based on the BEHI and NBS ratings. Annual retreat rates were estimated based on those measured from the Lamar River in Yellowstone National Park (Rosgen, 1996) (**Table E2-2**).

Table E2-2. Streambank erosion retreat rates (ft/year), Lamar River, YNP.

BEHI	Near Bank Stress					
	very low	low	moderate	high	very high	extreme
very Low	0.002	0.004	0.009	0.021	0.050	0.12
low	0.02	0.04	0.10	0.24	0.57	1.37
moderate	0.10	0.17	0.28	0.47	0.79	1.33
high - very high	0.37	0.53	0.76	1.09	1.57	2.26
extreme	0.98	1.21	1.49	1.83	2.25	2.76

The annual sediment load in cubic feet was then calculated from the field data (annual retreat rate x mean bank height x bank length), converted into cubic yards, and finally converted into tons per year based on the bulk density of streambank material. The bulk density of streambank material was assumed to average 1.3 tons/cubic yard as identified in *Watershed Assessment of River Stability and Sediment Supply* (WARSSS) (Rosgen, 2006). This process resulted in a sediment load from each eroding bank expressed in tons/year. Loads from each eroding bank were summed to produce a monitoring site sediment loading rate, expressed in tons/year/1000-feet of stream.

E2.4 SEDIMENT LOAD EXTRAPOLATION

Annual sediment loads from monitoring sites were extrapolated to the stream reach and stream segment scales based on similar reach type characteristics as identified in the aerial assessment database. Sediment load extrapolations were performed for monitoring sites, stream reaches, and stream segments, which are defined as follows:

Monitoring Site - *A 500, 1000, or 2000 foot section of a stream reach where field monitoring was conducted*

Stream Reach -*Subdivision of the stream segment based on Ecoregion, stream order, gradient and confinement as evaluated in GIS*

Stream Segment -*303(d) listed segment* (Note: several additional non-listed streams were included within this assessment)

The extrapolation of annual bank erosion sediment loads was completed according to the following criteria:

1. Monitoring site sediment loading rates were extrapolated directly to the stream reach in which the monitoring site was located.
2. For reaches not assessed in the field, the average sediment loading rate for all monitoring sites within a given reach type was applied, provided that a representative number of monitoring sites were assessed for that reach type.

3. All 1st order streams, both stratified and unstratified, were assigned a sediment load of zero due to their relatively small size, steep gradient and large substrate. These streams are not considered a significant source of controllable sediment load in this watershed. Therefore, they are excluded to focus on the controllable sediment loads.
4. Unstratified, non-1st order streams within the Northern Rockies Ecoregion were assigned the 25th percentile of sediment loading rates from all stratified streams in the NR Ecoregion (negating the Tobacco River due to its size). These streams were given a sediment loading rate of 11 tons/year/1000' of stream.
5. Unstratified, non-1st order streams within the Canadian Rockies Ecoregion were assigned the 25th percentile of sediment loading rates from all stratified streams in the CR Ecoregion (negating site DEP 9-2 due to its large non-typical sediment load). These streams were assigned a sediment loading rate of 5 tons/year/1000' of stream.
6. For reaches with field-assessed monitoring sites, the field-identified sources replaced the sources identified during the aerial assessment.

Exceptions to these criteria were made based on review of color aerial imagery and field experience within the Tobacco River watershed, including:

1. In select situations, the sediment loading rate derived for a specific reach was extrapolated directly to another reach, often when the two reaches were within close proximity or had similar land-use characteristics.
2. For reach types with confined valley types, the reach type average of the unconfined valley type may be applied.
3. If a certain reach type was not assessed within a major Ecoregion (Northern Rockies or Canadian Rockies), the reach type average from the other Ecoregion may be applied.
4. For steep reaches (valley gradient >10%), the 25^{th} percentile loading rate from that Ecoregion was applied since no steep reaches were assessed in the field.

When human disturbances were evident at the stream reach scale but not observed at the monitoring site, the sources identified in the aerial assessment were retained.

E2.5 SEDIMENT LOAD REDUCTION POTENTIAL

The sediment load reduction potential was evaluated for human influenced monitoring sites. This evaluation was performed by reducing all high, very high, and extreme BEHI ratings to the level of "moderate" at sites with human-caused sources of erosion. This provides an estimate of bank erosion reductions from the implementation of land, soil, and water conservation practices. Examples of these conservation practices may include riparian grazing management practices, physical adjustments to channel form via restoration projects, limiting harvest or removal of riparian vegetation or near-stream trees, or active revegetation efforts that improve riparian condition. Sediment load reductions at monitoring sites were extrapolated to the reach, segment, and watershed scales using the following methodology:

1. All field-assessed monitoring sites which had a human influenced sediment source were identified. Only sites with >5% human sources were considered for reduction.
2. For the monitoring sites identified in item 1, the load reduction potential was evaluated by reducing BEHI ratings of all streambanks down to "moderate", adjusting the bank erosion retreat rate, and calculating a reduced sediment loading rate for the reach. Only banks with a BEHI rating greater than "moderate" were adjusted. Though this approach may underestimate

potential load reductions in places, it focuses on the most likely and desirable locations for reducing bank erosion.

3. The potential load reduction percentage for each monitoring site was calculated by comparing the reduced sediment loading rate to the original sediment loading rate. All adjusted monitoring sites were then combined to calculate an average potential reduction percentage for human influenced sites.
4. The average potential reduction percentage calculated in item 3 was then multiplied by the existing human influenced load of all stratified reaches that had >5% human sources, thereby calculating the potential sediment load reduction in these reaches. The potential reduction to human influenced sediment load was then subtracted from the original reach load in these reaches.
5. The potential reduced sediment load was then calculated for each stream segment and for the entire watershed. All unstratified streams retained their original sediment load since land-use and erosion source information was unavailable for these streams. Sites with less than 5% human sediment sources also retained their existing sediment load.

E3.0 RESULTS

This section provides results of the aerial photo assessment, reach stratification process, a summary of field data collection sites, and the estimated average annual sediment loads due to streambank erosion at the monitoring site, stream segment and watershed scales. Potential sediment reductions were also examined by estimating reduced sediment loads for banks influenced by human activities.

E3.1 AERIAL ASSESSMENT REACH STRATIFICATION

During the aerial assessment, a total of 550 miles of stream were identified in the Tobacco River watershed, with 116 miles included in the aerial assessment reach stratification process. Of the remaining 434 miles of stream not included in the aerial assessment, 334 miles are 1st order headwater streams, and 100 miles are non-1st order streams. A total of 186 reaches were delineated in GIS and reach-specific data were compiled into a database. A total of 29 reach types were identified in the Tobacco River watershed, 11 of which were assessed in the field. Possible reach type combinations identified in the Tobacco River watershed are presented in **Table E3-1**, along with the number of reaches assessed in the field for each reach type.

Table E3-1. Reach types within the Tobacco River watershed

Reach Type	Number of Stratified Reaches	Number of Sampled Reaches	Percent Sampled
CR-0-2-U	17	4	24%
CR-0-3-U	1		
CR-0-4-C	1		
CR-0-4-U	9		
CR-2-1-U	3		
CR-2-2-C	1		
CR-2-2-U	7		
CR-2-3-U	6	1	17%
CR-2-4-U	2		
CR-4-1-U	6		

Table E3-1. Reach types within the Tobacco River watershed

Reach Type	Number of Stratified Reaches	Number of Sampled Reaches	Percent Sampled
CR-4-2-C	3		
CR-4-2-U	6	3	50%
CR-4-3-U	5	1	20%
CR-4-4-U	1		
CR-10-1-C	2		
CR-10-1-U	6		
CR-10-2-U	2		
NR-0-1-U	1		
NR-0-2-U	4		
NR-0-3-U	24	5	21%
NR-0-4-U	32	7	22%
NR-0-5-U	11	4	36%
NR-2-1-U	3		
NR-2-2-U	5	1	20%
NR-2-3-U	12	2	17%
NR-4-1-U	3		
NR-4-2-U	7	2	29%
NR-4-3-U	4	2	50%
NR-10-1-U	2		
Total	**186**	**32**	**17%**

E3.2 FIELD DATA COLLECTION

A total of 32 monitoring sites within the Tobacco River TPA were assessed in August and September 2008 (**Attachment A**). Monitoring sites were identified through an assessment of aerial images and field reconnaissance to capture the variability in land use and watershed characteristics that may be contributing to sediment impairment. At 18 of the monitoring sites, a complete sediment and habitat assessment was performed, while the remaining 14 monitoring sites were assessed only for streambank erosion. A total of 199 individual streambanks were assessed. The following streams were included in the Tobacco River TPA sediment assessment (specific reaches identified in parentheses):

- Deep Creek (13-2, 9-1, 7-1)
- Edna Creek (11-1, 10-2, 8-1, 7-2)
- Fortine Creek (15-3, 15-2, 13-1, 12-9, 12-7, 12-2, 9-3, 7-2, 6-1, 4-3, 4-1)
- Lime Creek (6-1)
- Sinclair Creek (10-3, 8-2, 5-1)
- Swamp Creek (9-1, 5-1, 3-1)
- Theriault Creek (14-1, 9-5)
- Tobacco (2-6, 2-3, 1-1)
- Clarence Creek (Clarence Creek is an unstratified Grave Creek tributary that was inadvertently sampled instead of the stratified Grave Creek mainstem)

E3.3 SEDIMENT LOAD CALCULATIONS AT MONITORING SITES

Sediment loads for each field-assessed eroding streambank were summed to provide a sediment load for each monitoring site. A total annual sediment load of 1,223 tons/year was attributed to the 199 eroding banks within the 32 field-assessed monitoring sites (**Table E3-2**). Approximately 41% of the bank erosion sediment load was attributed to historic or current human activities, while approximately 59% was attributed to natural erosion processes and sources. Monitoring site assessments indicate that roads (14%), riparian grazing (11%), cropland (<1%), recent logging (3%), and "other" (13%) are the main types of human activities in the Tobacco River TPA. The "other" category primarily describes impacts due to railroads and urban influences. Bank erosion impacts from mining and irrigation were not observed as sources during this assessment.

Table E3-2. Summary of monitoring site sediment loads.

Source	Sediment Load (Tons/Year)	Sediment Load (Percent)
Roads	172	14
Riparian Grazing	129	11
Cropland	0.1	<1
Logging	40.3	3
Natural Sources	719	59
Other	163	13
Total	**1223**	**100%**
Anthropogenic	**504**	**41%**
Natural	**719**	**59%**

Average annual sediment loads from each monitoring site were normalized to a length of 1,000 feet for comparison and extrapolation purposes. Estimated annual sediment loads for each monitoring site are presented in **Table E3-3**, and estimated sediment loads by source are provided in **Table E3-4**.

Table E3-3. Estimated sediment loads by monitoring site.

Stream	Reach ID	Reach Type	Number of Eroding Banks	Length of Eroding Banks (Feet)	Monitoring Site Length (Feet)	Eroding Bank (% of reach)	Reach Sediment Load (Tons/Year)	Sediment Load per 1000 Feet (Tons/Year)
Clarence Creek	Clarence	CR-4-2-U	5	249	1000	12.5	14.1	14.1
Deep Creek	DEP 13-2	CR-2-3-U	5	131	1000	6.6	2.8	2.8
	DEP 7-1	CR-4-2-U	0	0	1000	0.0	0.0	0.0
	DEP 9-2	CR-4-3-U	5	458	1000	22.9	155.5	155.5
Edna Creek	ENA 10-2	NR-4-3-U	7	181	1000	9.1	7.9	7.9
	ENA 11-1	NR-0-3-U	5	62	1000	3.1	0.1	0.1
	ENA 7-2	NR-4-2-U	5	187	1000	9.4	13.6	13.6
	ENA 8-1	NR-2-2-U	4	73	1000	3.7	8.3	8.3

Table E3-3. Estimated sediment loads by monitoring site.

Stream	Reach ID	Reach Type	Number of Eroding Banks	Length of Eroding Banks (Feet)	Monitoring Site Length (Feet)	Eroding Bank (% of reach)	Reach Sediment Load (Tons/Year)	Sediment Load per 1000 Feet (Tons/Year)
Fortine Creek	FTN 12-2	NR-0-4-U	9	467	1000	23.4	35.5	35.5
	FTN 12-7	NR-0-4-U	6	734	1000	36.7	77.8	77.8
	FTN 12-9	NR-0-4-U	5	198	1000	9.9	19.4	19.4
	FTN 13-1	NR-0-4-U	5	329	1000	16.5	58.0	58.0
	FTN 15-2	NR-0-4-U	6	439	1000	22.0	11.9	11.9
	FTN 15-3	NR-0-4-U	4	195	1000	9.8	4.9	4.9
	FTN 4-1	NR-0-3-U	11	395	1000	19.8	46.5	46.5
	FTN 4-3	NR-0-3-U	8	691	1000	34.6	21.3	21.3
	FTN 6-1	NR-0-3-U	5	487	1000	24.4	43.4	43.4
	FTN 7-2	NR-2-3-U	6	203	1000	10.2	37.7	37.7
	FTN 9-3	NR-0-4-U	3	457	1000	22.9	21.3	21.3
Lime Creek	LME 6-1	NR-4-3-U	8	111	500	11.1	9.9	19.8
Sinclair Creek	SNC 10-3	CR-0-2-U	4	228	1000	11.4	53.5	53.5
	SNC 5-1	CR-4-2-U	3	140	1000	7.0	11.7	11.7
	SNC 8-2	CR-0-2-U	14	321	1000	16.1	42.0	42.0
Swamp Creek	SWP 3-1	NR-4-2-U	7	117	1000	5.9	1.0	1.0
	SWP 5-1	NR-0-3-U	5	242	1000	12.1	13.4	13.4
	SWP 9-1	NR-2-3-U	7	535	1000	26.8	51.6	51.6
Theriault Creek	THR 14-1	CR-0-2-U	8	134	1000	6.7	7.9	7.9
	THR 9-5	CR-0-2-U	13	274	1000	13.7	21.4	21.4
Tobacco River	TOB 1-1	NR-0-5-U	8	1587	2000	39.7	108.5	54.3
	TOB 1-3	NR-0-5-U	5	1035	2000	25.9	136.7	68.4
	TOB 2-3	NR-0-5-U	6	440	2000	11.0	18.8	9.4
	TOB 2-6	NR-0-5-U	8	990	2000	24.8	166.4	83.2

Table E3-4. Estimated sediment loads by individual source.

Stream	Reach ID	Monitoring Site Length (Feet)	Reach Sediment Load (Tons/Yr)	Road Load		Grazing Load		Cropland Load		Logging Load		Natural Load		"Other" Load	
				(Tons/ Yr)	(%)	(Tons / Yr)	(%)	(Tons / Yr)	(%)	(Tons / Yr)	(%)	(Tons/ Yr)	(%)	(Tons / Yr)	(%)
Clarence Creek	Clarence	1000	14.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.14	100.0	0.0	0.0
Deep Creek	DEP 13-2	1000	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.79	100.0	0.0	0.0
	DEP 7-1	1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	DEP 9-2	1000	155.5	126.4	81.3	0.0	0.0	0.0	0.0	0.0	0.0	29.05	18.7	0.0	0.0
Edna Creek	ENA 10-2	1000	7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.87	100.0	0.0	0.0
	ENA 11-1	1000	0.1	0.0	0.0	0.0	0.0	0.1	100.0	0.0	0.0	0.00	0.0	0.0	0.0
	ENA 7-2	1000	13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.59	100.0	0.0	0.0
	ENA 8-1	1000	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.27	100.0	0.0	0.0
Fortine Creek	FTN 12-2	1000	35.5	0.0	0.0	0.0	0.0	0.0	0.0	13.6	38.3	21.89	61.7	0.0	0.0
	FTN 12-7	1000	77.8	0.0	0.0	75.9	97.6	0.0	0.0	0.0	0.0	1.88	2.4	0.0	0.0
	FTN 12-9	1000	19.4	0.0	0.0	0.8	4.3	0.0	0.0	0.3	1.3	18.35	94.4	0.0	0.0
	FTN 13-1	1000	58.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.01	100.0	0.0	0.0
	FTN 15-2	1000	11.9	5.7	48.3	0.0	0.0	0.0	0.0	0.0	0.0	6.14	51.7	0.0	0.0
	FTN 15-3	1000	4.9	0.0	0.0	1.3	25.7	0.0	0.0	0.0	0.0	3.67	74.3	0.0	0.0
	FTN 4-1	1000	46.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.55	100.0	0.0	0.0
	FTN 4-3	1000	21.3	0.0	0.0	5.0	23.5	0.0	0.0	0.0	0.0	16.30	76.5	0.0	0.0
	FTN 6-1	1000	43.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.50	58.7	17.9	41.3
	FTN 7-2	1000	37.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	37.72	100.0	0.0	0.0
	FTN 9-3	1000	21.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.32	100.0	0.0	0.0
Lime Creek	LME 6-1	500	9.9	3.0	30.4	0.0	0.0	0.0	0.0	0.7	7.3	6.17	62.4	0.0	0.0
Sinclair Creek	SNC 10-3	1000	53.5	26.7	50.0	0.0	0.0	0.0	0.0	0.0	0.0	10.69	20.0	16.0	30.0
	SNC 5-1	1000	11.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.68	100.0	0.0	0.0
	SNC 8-2	1000	42.0	0.0	0.0	42.0	100.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0
Swamp Creek	SWP 3-1	1000	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	9.2	0.88	90.8	0.0	0.0
	SWP 5-1	1000	13.4	0.0	0.0	0.0	0.0	0.0	0.0	12.4	92.9	1.0	7.1	0.0	0.0
	SWP 9-1	1000	51.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.57	100.0	0.0	0.0
Theriault Creek	THR 14-1	1000	7.9	0.0	0.0	0.6	7.3	0.0	0.0	0.5	6.5	4.89	61.8	1.9	24.4
	THR 9-5	1000	21.4	0.0	0.0	0.0	0.0	0.0	0.0	12.7	59.6	8.64	40.4	0.0	0.0

Table E3-4. Estimated sediment loads by individual source.

Stream	Reach ID	Monitoring Site Length (Feet)	Reach Sediment Load (Tons/Yr)	Road Load		Grazing Load		Cropland Load		Logging Load		Natural Load		"Other" Load	
				(Tons/ Yr)	(%)	(Tons / Yr)	(%)	(Tons / Yr)	(%)	(Tons / Yr)	(%)	(Tons/ Yr)	(%)	(Tons / Yr)	(%)
Tobacco River	TOB 1-1	2000	108.5	0.0	0.0	1.3	1.2	0.0	0.0	0.0	0.0	107.17	98.8	0.0	0.0
	TOB 1-3	2000	136.7	1.6	1.1	1.6	1.1	0.0	0.0	0.0	0.0	133.60	97.7	0.0	0.0
	TOB 2-3	2000	18.8	8.6	45.7	0.0	0.0	0.0	0.0	0.0	0.0	5.86	31.1	4.4	23.2
	TOB 2-6	2000	166.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.04	26.5	122.3	73.5

E3.4 STREAMBANK EROSION SEDIMENT LOAD EXTRAPOLATION

Sediment loading rates derived from the monitoring sites were extrapolated to the stream reach, stream segment and watershed scales based on the aerial assessment reach type analysis. Sediment loading rates were applied to each reach using the criteria provided in **Section E2.4**, and a total load was then calculated for each stream segment and subwatershed. The following sections provide summaries of sediment load extrapolation results by reach type, stream segment, and watershed.

E3.4.1 Reach Type Sediment Loads

Sediment loading rates from each monitoring site were averaged within each reach type to derive a reach type sediment loading rate. Overall, 11 reach types were identified in the Tobacco River TPA, including 4 in the Canadian Rockies Ecoregion (CR) and 7 in the Northern Rockies Ecoregion (NR). Reach type averages of sediment loading rates ranged from 3 to 155 tons/year/1000-feet; however, many reach type averages include only one assessed reach and may not be representative of conditions throughout the watershed. A summary of reach type sediment loading rates is provided in **Table E3-5**.

Table E3-5. Reach type sediment loading rates.

Reach Type	Description	Reach ID	Sediment Load per 1000 Feet (Tons/Year)	Average Reach Type Sediment Load per 1000 Feet (Tons/Year)
CR-0-2-U	Canadian Rockies, low gradient, 2nd order streams	SNC 10-3	53.5	31.2
		SNC 8-2	42.0	
		THR 14-1	7.9	
		THR 9-5	21.4	
CR-2-3-U	Canadian Rockies, moderate gradient, 3rd order streams	DEP 13-2	2.8	2.8
CR-4-2-U	Canadian Rockies, steep gradient, 2nd order streams	Clarence	14.1	8.6
		DEP 7-1	0.0	
		SNC 5-1	11.7	
CR-4-3-U	Canadian Rockies, steep gradient, 3rd order streams	DEP 9-2	155.5	155.5
NR-0-3-U	Northern Rockies, low gradient, 3rd order streams	ENA 11-1	0.1	24.9
		FTN 4-1	46.5	
		FTN 4-3	21.3	
		FTN 6-1	43.4	
		SWP 5-1	13.4	
NR-0-4-U	Northern Rockies, low gradient, 4th order streams	FTN 12-2	35.5	32.7
		FTN 12-7	77.8	
		FTN 12-9	19.4	
		FTN 13-1	58.0	
		FTN 15-2	11.9	
		FTN 15-3	4.9	
		FTN 9-3	21.3	
NR-0-5-U	Northern Rockies, low gradient, 5th order streams	TOB 1-1	54.3	53.8
		TOB 1-3	68.4	
		TOB 2-3	9.4	
		TOB 2-6	83.2	
NR-2-2-U	Northern Rockies, moderate gradient, 2nd order streams	ENA 8-1	8.3	8.3

Table E3-5. Reach type sediment loading rates.

Reach Type	Description	Reach ID	Sediment Load per 1000 Feet (Tons/Year)	Average Reach Type Sediment Load per 1000 Feet (Tons/Year)
NR-2-3-U	Northern Rockies, moderate gradient, 3rd order streams	FTN 7-2	37.7	44.6
		SWP 9-1	51.6	
NR-4-2-U	Northern Rockies, steep gradient, 2nd order streams	ENA 7-2	13.6	7.3
		SWP 3-1	1.0	
NR-4-3-U	Northern Rockies, steep gradient, 3rd order streams	ENA 10-2	7.9	13.8
		LME 6-1	19.8	

E3.4.2 Stream Segment Sediment Loads

Stream segment sediment loads were estimated for all Tobacco River TPA streams impaired for sediment per Montana's 2008 Integrated Report (reference), including Deep Creek, Edna Creek, Fortine Creek, Grave Creek, Lime Creek, Swamp Creek, Theriault Creek, and Tobacco River. Because of stakeholder interest, Sinclair Creek was fully evaluated for sediment TMDL development purposes including a bank erosion assessment. Although bank erosion loading were determined for the Grave Creek watershed during previous TMDL development (Montana Department of Environmental Quality, et al., 2005), DEQ decided to estimate bank erosion loading again for the Grave Creek watershed using the information presented in this appendix.

Overall, sediment loads were estimated for a total stratified length of 116 miles. A total annual sediment load of 15,423 tons/year was attributed to streambank erosion at the stream segment scale (**Table E3-6**). Approximately 34% of this sediment load was attributed to human sources, while approximately 66% was attributed to natural sources. This assessment indicates that roads (10%), riparian grazing (10%) and "other" (8%) are the greatest human related contributors of streambank sediment loading at the stream segment scale. The "other" category includes impacts from railroads and urban influences.

Table E3-6. Summary of stream segment sediment loads.

Source	Sediment Load (Tons/Year)	Sediment Load (Percent)
Roads	1547	10
Grazing	1529	10
Cropland	693	4
Logging	264	2
Natural Sources	10,141	66
Other	1248	8
Total	**15,423**	**100**
Human Influenced	**5282**	**34**
Natural	**10,141**	**66**

Total stream segment loads were calculated by summing the cumulative sediment load of all reaches within each segment by using the sediment load extrapolation procedure detailed in **Section E2.4**. Stream segment sediment loads are discussed below for each stratified stream in the Tobacco River TPA. The total sediment load is provided for individual reaches, for the total stratified stream segment, for unstratified tributary streams, and for each subwatershed. The streambank erosion rate assigned to each reach during the extrapolation process is provided along with the bank erosion source. Any assumptions made in the selection of sediment loading rates are discussed on a reach by reach basis.

Reaches which were assessed in the field were assigned their measured sediment loading rate, and are shown on summary tables in **bold**.

E3.4.2.1 Deep Creek Sediment Loads

A total of 18 reaches were delineated for the mainstem of Deep Creek, and three monitoring sites were assessed in the field. Reach 9-2 was further broken into two sub-reaches (DEP 9-2a and DEP 9-2b) due to extreme erosion observed within the assessed monitoring site. The four upper reaches (1-1 to 4-1) were 1st order streams which were assigned a sediment load of zero. Reach 5-1 was reach type CR-4-2-U and received the reach type average as a loading rate. Reach 6-1 was a steep reach (>10%) and received the 25th percentile loading rate for Canadian Rockies Ecoregion since no other steep reaches were visited during the field assessment. Five reaches were reach type CR-4-3-U; however, the only field-assessed reach of this type was DEP 9-2a, which was determined to have an extreme load which was uncharacteristically high. As a result, the average sediment loading rate from reach type CR-4-2-U was applied to these reaches. The six reaches furthest downstream were all of reach type CR-2-3-U or CR-0-3-U, and received the field-assessed loading rate from adjacent reach DEP 13-2, which had similar land use characteristics.

The total estimated sediment load for the Deep Creek watershed was estimated to be 453 tons/year, including 405 tons/year from the mainstem, and 48 tons/year from unstratified non-1st order tributary streams. The estimated annual sediment loads for Deep Creek are provided below in **Table E3-7.**

Table E3-7. Estimated annual sediment loads for Deep Creek.

Reach ID	Reach Type	Sediment Loading Rate	Loading Rate Source	Reach Length	Total Reach Load	Roads	Grazing	Cropland	Logging	Natural	Other
		(tons/yr /1000')		(miles)	(tons /year)	(%)	(%)	(%)	(%)	(%)	(%)
DEP 1-1	CR-10-1-U	0	zero load (1st order)	0.5	0	0	0	0	0	100	0
DEP 2-1	CR-4-1-U	0	zero load (1st order)	1.1	0	0	0	0	0	100	0
DEP 3-1	CR-10-1-U	0	zero load (1st order)	0.3	0	0	0	0	0	100	0
DEP 4-1	CR-4-1-U	0	zero load (1st order)	0.1	0	0	0	0	0	100	0
DEP 5-1	CR-4-2-U	9	RT avg (N=3)	0.7	34	0	0	0	40	60	0
DEP 6-1	CR-10-2-U	5	CR 25th percentile	0.4	11	0	0	0	40	60	0
DEP 7-1	**CR-4-2-U**	**0**	**assessed value**	**0.5**	**0**	**0**	**0**	**0**	**0**	**100**	**0**
DEP 8-1	CR-4-3-U	9	CR-4-2-U avg (N=3)	0.3	14	0	0	0	50	50	0
DEP 8-2	CR-4-3-U	9	CR-4-2-U avg (N=3)	0.3	14	0	0	0	0	100	0
DEP 9-1	CR-4-3-U	9	CR-4-2-U avg (N=3)	0.6	29	0	0	0	20	80	0
DEP 9-2a	**CR-4-3-U**	**155**	**assessed value**	**0.2**	**156**	**81**	**0**	**0**	**0**	**19**	**0**
DEP 9-2b	CR-4-3-U	9	CR-4-2-U avg (N=3)	2.1	93	0	0	0	0	100	0
DEP 10-1	CR-4-3-U	9	CR-4-2-U avg (N=3)	0.1	5	0	0	0	0	100	0
DEP 11-1	CR-2-3-U	3	DEP 13-2 load	0.2	3	0	0	0	0	100	0
DEP 11-2	CR-2-3-U	3	DEP 13-2 load	0.3	4	0	0	0	0	100	0
DEP 12-1	CR-0-3-U	3	DEP 13-2 load	1.5	23	20	10	10	10	50	0
DEP 13-1	CR-2-3-U	3	DEP 13-2 load	0.3	4	40	20	0	0	40	0
DEP 13-2	**CR-2-3-U**	**3**	**assessed value**	**0.8**	**11**	**0**	**0**	**0**	**0**	**100**	**0**
DEP 13-3	CR-2-3-U	3	DEP 13-2 load	0.4	5	10	20	20	0	50	0
			Total Stream Segment	**10.6**	**405**	**33**	**1**	**1**	**8**	**57**	**0**
Unstratified 1st Order		0	no load (1st order)	12.6	0						
Unstratified non-1st Order		5	CR 25th percentile	1.7	48						
			Total Deep Creek Watershed	**24.9**	**453**						

E3.4.2.1 Edna Creek Sediment Loads

Eighteen reaches were delineated on the mainstem of Edna Creek, and 4 monitoring sites were evaluated in the field. The four 1st order reaches of Edna Creek were all assigned a sediment load of

zero. Reaches with types NR-4-2-U or NR-2-2-U received their reach type average sediment loading rate, which was comparable to assessed values found in Edna Creek. Sediment loading rates from field assessed reaches were applied to adjacent stream reaches since they were often a similar reach type or land use. The total estimated annual sediment load for the Edna Creek watershed was 452 tons/year, including 324 tons/year from the mainstem, and 128 tons/year from unstratified non-1st order streams. The estimated annual sediment loads for Edna Creek are provided below in **Table E3-8.**

Table E3-8. Estimated annual sediment loads for Edna Creek.

Reach ID	Reach Type	Sediment Loading Rate	Loading Rate Source	Reach Length	Total Reach Load	Roads	Grazing	Cropland	Logging	Natural	Other
		(tons/yr /1000')		(miles)	(tons /year)	(%)	(%)	(%)	(%)	(%)	(%)
ENA 1-1	NR-2-1-U	0	no load (1st order)	0.6	0	40	0	0	40	20	0
ENA 1-2	NR-2-1-U	0	no load (1st order)	0.5	0	30	0	0	30	40	0
ENA 2-1	NR-4-1-U	0	no load (1st order)	1.2	0	25	0	0	0	75	0
ENA 3-1	NR-4-2-U	7	RT avg (N=2)	0.2	6	0	0	0	0	100	0
ENA 3-2	NR-4-2-U	7	RT avg (N=2)	0.1	5	0	0	0	0	100	0
ENA 4-1	NR-2-2-U	8	RT avg (N=1)	0.8	34	0	0	0	0	100	0
ENA 5-1	NR-4-2-U	7	RT avg (N=2)	0.3	13	0	0	0	0	100	0
ENA 6-1	NR-2-2-U	8	RT avg (N=1)	0.2	10	0	0	0	0	100	0
ENA 6-2	NR-2-2-U	8	RT avg (N=1)	0.5	21	25	0	0	0	75	0
ENA 7-1	NR-4-2-U	14	ENA 7-2 load	0.3	25	20	0	0	0	80	0
ENA 7-2	**NR-4-2-U**	**14**	**assessed value**	**1.3**	**91**	**0**	**0**	**0**	**0**	**100**	**0**
ENA 8-1	**NR-2-2-U**	**8**	**assessed value**	**0.7**	**28**	**0**	**0**	**0**	**0**	**100**	**0**
ENA 9-1	NR-2-3-U	8	ENA 8-1 load	0.6	26	10	0	0	0	90	0
ENA 9-2	NR-2-3-U	8	ENA 10-2 load	0.4	16	10	0	0	20	70	0
ENA 10-1	NR-4-3-U	8	ENA 10-2 load	0.2	9	0	0	0	0	90	10
ENA 10-2	**NR-4-3-U**	**8**	**assessed value**	**0.9**	**38**	**0**	**0**	**0**	**0**	**100**	**0**
ENA 11-1	**NR-0-3-U**	**0**	**assessed value**	**0.7**	**0**	**0**	**0**	**100**	**0**	**0**	**0**
ENA 12-1	NR-0-3-U	0	ENA 11-1 load	0.7	0	0	60	0	0	40	0
			Total Stream Segment	**10.2**	**324**	**4**	**0**	**0**	**1**	**94**	**0**
Unstratified 1st Order		0	no load (1st order)	23.0	0						
Unstratified non-1st Order		11	NR 25th percentile	2.2	128						
			Total Edna Creek Watershed	**35.4**	**452**						

E3.4.2.3 Fortine Creek Sediment Loads

A total of 52 reaches were delineated on the mainstem of Fortine Creek, and 11 monitoring sites were assessed in the field. The one 1st order reach was assigned a sediment load of zero, and the two 2nd order reaches (reach type NR-0-2-U) received the 25th percentile rate of all assessed reaches within the Northern Rockies Ecoregion, since no sites in this reach type were evaluated in the field. The remaining reaches along Fortine Creek were reach type NR-0-3-U or NR-0-4-U, and received the average sediment loading rate for their respective reach type, most of which were derived from field assessments in Fortine Creek. Reach 7-1 was reach type NR-2-3-U, and received the sediment loading rate from adjacent reach 7-2, which was the same reach type.

The total estimated annual sediment load for the Fortine Creek watershed was 7287 tons/year, including 5175 tons/year from the mainstem, and 2112 tons/year from unstratified non-1st order streams. The estimated annual sediment loads for Fortine Creek are provided below in **Table E3-9.** Note that these results to not include all bank erosion loading from all watersheds contributing to Fortine Creek, but instead represent only those loads along Fortine Creek and from associated unstratified non-1st order streams.

Table E3-9. Estimated annual sediment loads for Fortine Creek.

Reach ID	Reach Type	Sediment Loading Rate	Loading Rate Source	Reach Length	Total Reach Load	Roads	Grazing	Cropland	Logging	Natural	Other
		(tons/yr /1000')		(miles)	(tons /year)	(%)	(%)	(%)	(%)	(%)	(%)
FTN 1-1	NR-0-1-U	0	no load (1st order)	0.3	0	20	0	0	0	80	0
FTN 2-1	NR-0-2-U	11	NR 25th percentile	0.1	6	0	0	0	0	100	0
FTN 2-2	NR-0-2-U	11	NR 25th percentile	1.2	72	10	0	0	0	90	0
FTN 3-1	NR-0-3-U	25	RT avg (N=5)	0.2	21	20	0	0	0	80	0
FTN 3-2	NR-0-3-U	25	RT avg (N=5)	0.2	30	10	0	0	0	90	0
FTN 3-3	NR-0-3-U	25	RT avg (N=5)	0.1	14	10	0	0	0	90	0
FTN 3-4	NR-0-3-U	25	RT avg (N=5)	0.1	12	40	0	0	0	60	0
FTN 3-5	NR-0-3-U	25	RT avg (N=5)	0.3	33	0	0	0	0	100	0
FTN 4-1	**NR-0-3-U**	**47**	**assessed value**	**0.6**	**154**	**0**	**0**	**0**	**0**	**100**	**0**
FTN 4-2	NR-0-3-U	25	RT avg (N=5)	0.2	32	0	0	0	0	100	0
FTN 4-3	**NR-0-3-U**	**21**	**assessed value**	**0.7**	**75**	**0**	**24**	**0**	**0**	**76**	**0**
FTN 4-4	NR-0-3-U	25	RT avg (N=5)	0.2	21	20	0	0	20	60	0
FTN 5-1	NR-0-3-U	25	RT avg (N=5)	0.3	42	60	0	0	0	20	20
FTN 5-2	NR-0-3-U	25	RT avg (N=5)	0.2	23	80	0	0	0	0	20
FTN 5-3	NR-0-3-U	25	RT avg (N=5)	0.1	17	20	0	0	40	40	0
FTN 5-4	NR-0-3-U	25	RT avg (N=5)	0.2	21	0	0	0	0	100	0
FTN 6-1	**NR-0-3-U**	**43**	**assessed value**	**2.3**	**517**	**0**	**0**	**0**	**0**	**59**	**41**
FTN 7-1	NR-2-3-U	38	FTN 7-2 load	0.4	80	40	0	0	0	60	0
FTN 7-2	**NR-2-3-U**	**38**	**assessed value**	**0.2**	**33**	**0**	**0**	**0**	**0**	**100**	**0**
FTN 8-1	NR-0-3-U	25	RT avg (N=5)	0.2	29	0	0	0	0	100	0
FTN 9-1	NR-0-4-U	33	RT avg (N=7)	0.3	44	0	0	0	0	0	100
FTN 9-2	NR-0-4-U	33	RT avg (N=7)	0.2	35	10	0	0	0	50	40
FTN 9-3	**NR-0-4-U**	**21**	**assessed value**	**0.7**	**74**	**0**	**0**	**0**	**0**	**100**	**0**
FTN 9-4	NR-0-4-U	33	RT avg (N=7)	0.9	159	20	0	0	0	80	0
FTN 9-5	NR-0-4-U	33	RT avg (N=7)	0.3	59	0	0	0	0	90	10
FTN 10-1	NR-0-4-U	33	RT avg (N=7)	2.1	365	20	0	0	0	80	0
FTN 10-2	NR-0-4-U	33	RT avg (N=7)	0.9	153	10	20	40	0	30	0
FTN 11-1	NR-0-4-U	33	RT avg (N=7)	0.3	58	10	0	0	0	90	0
FTN 11-2	NR-0-4-U	33	RT avg (N=7)	0.3	60	0	25	25	0	50	0
FTN 11-3	NR-0-4-U	33	RT avg (N=7)	0.8	143	10	0	0	0	70	20
FTN 12-1	NR-0-4-U	33	RT avg (N=7)	0.1	23	10	0	0	0	90	0
FTN 12-2	**NR-0-4-U**	**35**	**assessed value**	**1.2**	**230**	**0**	**0**	**0**	**38**	**62**	**0**
FTN 12-3	NR-0-4-U	33	RT avg (N=7)	0.6	102	10	0	0	0	80	10
FTN 12-4	NR-0-4-U	33	RT avg (N=7)	1.6	271	10	0	0	0	90	0
FTN 12-5	NR-0-4-U	33	RT avg (N=7)	0.4	67	0	0	40	0	60	0
FTN 12-6	NR-0-4-U	33	RT avg (N=7)	0.5	83	0	0	0	0	100	0
FTN 12-6	NR-0-4-U	33	RT avg (N=7)	0.4	66	10	0	20	0	70	0
FTN 12-7	**NR-0-4-U**	**78**	**assessed value**	**0.7**	**292**	**0**	**98**	**0**	**0**	**2**	**0**
FTN 12-8	NR-0-4-U	33	RT avg (N=7)	0.2	34	0	0	0	0	100	0
FTN 12-9	**NR-0-4-U**	**19**	**assessed value**	**0.7**	**73**	**0**	**4**	**0**	**1**	**94**	**0**
FTN 12-10	NR-0-4-U	33	RT avg (N=7)	1.4	246	0	0	0	0	100	0
FTN 12-11	NR-0-4-U	33	RT avg (N=7)	1.3	222	10	0	30	10	50	0
FTN 12-12	NR-0-4-U	33	RT avg (N=7)	0.6	101	30	0	40	0	30	0
FTN 13-1	**NR-0-4-U**	**58**	**assessed value**	**0.8**	**243**	**0**	**0**	**0**	**0**	**100**	**0**
FTN 13-2	NR-0-4-U	33	RT avg (N=7)	0.2	35	0	0	0	0	100	0
FTN 14-1	NR-0-4-U	33	RT avg (N=7)	0.1	22	10	0	0	0	90	0
FTN 14-2	NR-0-4-U	33	RT avg (N=7)	1.8	313	50	0	0	0	50	0
FTN 14-3	NR-0-4-U	33	RT avg (N=7)	0.7	129	10	0	0	0	70	20
FTN 14-4	NR-0-4-U	33	RT avg (N=7)	0.4	77	10	0	0	0	90	0
FTN 15-1	NR-0-4-U	33	RT avg (N=7)	0.4	70	10	0	0	0	80	10
FTN 15-2	**NR-0-4-U**	**12**	**assessed value**	**1.4**	**88**	**48**	**0**	**0**	**0**	**52**	**0**
FTN 15-3	**NR-0-4-U**	**5**	**assessed value**	**0.3**	**7**	**0**	**26**	**0**	**0**	**74**	**0**
			Total Stream Segment	**30.7**	**5175**	**11**	**7**	**4**	**2**	**68**	**7**
Unstratified 1st Order		0	no load (1st order)	105.9	0						
Unstratified non-1st Order		11	NR 25th percentile	36.7	2112						
Total Fortine Creek				**173.4**	**7287**						

E3.4.2.4 Grave Creek Sediment Loads

Sixteen reaches were stratified on the mainstem of Grave Creek, although no sites were assessed in the field. The upper mainstem reaches of Grave Creek above the confluence of Clarence Creek were assigned the sediment loading rate from the monitoring site on Clarence Creek, which was similar in size and land-use characteristics. Mainstem portions of Grave Creek downstream of Clarence Creek are primarily reach type CR-2-4-U or CR-0-4-U. These reaches were given the average loading rate from reach type NR-0-4-U (33 tons/year/1000'), which is similar in size and power to Grave Creek. All 1st order reaches in the Grave Creek watershed were assigned a sediment load of zero. Non-1st order tributaries to Grave Creek were assigned the 25th percentile loading rate from assessed reaches in the Canadian Rockies Ecoregion (negating site DEP 9-2). The estimated sediment load from the Grave Creek watershed was 2,730 tons/year, including 2,350 tons/year from the mainstem, and 380 tons/year from unstratified non-1st order streams (**Table E3-10**).

Table E3-10. Estimated annual sediment loads for Grave Creek.

Reach ID	Reach Type	Sediment Loading Rate (tons/yr /1000')	Loading Rate Source	Reach Length (miles)	Total Reach Load (tons /year)	Roads (%)	Grazing (%)	Cropland (%)	Logging (%)	Natural (%)	Other (%)
GRV 1-1	CR-2-2-U	14.1	Clarence Creek load	1.3	100	5	0	0	0	95	0
GRV 1-2	CR-2-2-U	14.1	Clarence Creek load	1.3	100	25	0	0	0	75	0
GRV 2-1	CR-2-3-U	14.1	Clarence Creek load	1.3	94	5	0	0	0	95	0
GRV 3-1	CR-2-4-U	32.7	NR-0-4-U RT avg (N=7)	1.6	278	10	0	0	0	90	0
GRV 3-2	CR-2-4-U	32.7	NR-0-4-U RT avg (N=7)	0.2	27	10	0	0	0	90	0
GRV 4-1	CR-4-4-U	32.7	NR-0-4-U RT avg (N=7)	0.5	94	0	0	0	0	100	0
GRV 5-1	CR-0-4-U	32.7	NR-0-4-U RT avg (N=7)	1.6	278	0	0	0	0	100	0
GRV 6-1	CR-0-4-U	32.7	NR-0-4-U RT avg (N=7)	0.4	63	0	0	0	0	100	0
GRV 6-2	CR-0-4-U	32.7	NR-0-4-U RT avg (N=7)	0.7	119	10	0	0	0	90	0
GRV 6-3	CR-0-4-U	32.7	NR-0-4-U RT avg (N=7)	1.4	237	10	0	0	0	90	0
GRV 7-1	CR-0-4-C	32.7	NR-0-4-U RT avg (N=7)	0.8	132	0	0	0	0	100	0
GRV 8-1	CR-0-4-U	32.7	NR-0-4-U RT avg (N=7)	0.4	66	30	0	0	0	70	0
GRV 8-2	CR-0-4-U	32.7	NR-0-4-U RT avg (N=7)	2.4	414	10	10	30	0	50	0
GRV 8-3	CR-0-4-U	32.7	NR-0-4-U RT avg (N=7)	0.4	63	10	0	0	10	80	0
GRV 8-4	CR-0-4-U	32.7	NR-0-4-U RT avg (N=7)	0.4	63	10	0	0	0	50	40
GRV 8-5	CR-0-4-U	32.7	NR-0-4-U RT avg (N=7)	1.3	223	10	20	30	0	30	10
			Total Stream Segment	**15.9**	**2350**	**8**	**4**	**8**	**0**	**78**	**2**
Unstratified 1st Order		0.0	no load (1st order)	57.9	0						
Unstratified non-1st Order		5.3	CR 25th percentile	13.6	380						
			Total Grave Creek Watershed	**87.4**	**2730**						

E3.4.2.5 Lime Creek Sediment Loads

Thirteen reaches were delineated on the mainstem of Lime Creek, and one monitoring site was assessed in the field. The three 1st order reaches on Lime Creek were assigned a sediment load of zero. Reaches 5-1 to 9-1 were assigned the sediment loading rate measured at adjacent site LME 6-1, which displayed similar land-use characteristics. The bottom two reaches were of reach type NR-0-3-U and were assigned the reach type average sediment loading rate. The total estimated annual sediment load for the Lime Creek watershed was 530 tons/year, including 383 tons/year from the mainstem, and 146 tons/year from unstratified non-1st order streams. Estimated annual sediment loads for Lime Creek are provided below in **Table E3-11.**

Table E3-11. Estimated annual sediment loads for Lime Creek.

Reach ID	Reach Type	Sediment Loading Rate	Loading Rate Source	Reach Length	Total Reach Load	Roads	Grazing	Cropland	Logging	Natural	Other
		(tons/yr /1000')		(miles)	(tons /year)	(%)	(%)	(%)	(%)	(%)	(%)
LME 1-1	NR-10-1-U	0	no load (1st order)	0.1	0	0	0	0	0	100	0
LME 2-1	NR-4-1-U	0	no load (1st order)	0.4	0	10	0	0	0	90	0
LME 3-1	NR-10-1-U	0	no load (1st order)	0.2	0	0	0	0	0	100	0
LME 4-1	NR-4-1-U	0	no load (1st order)	0.3	0	0	0	0	0	100	0
LME 5-1	NR-4-2-U	20	LME 6-1 load	0.2	19	0	0	0	0	100	0
LME 6-1	**NR-4-3-U**	**20**	**assessed value**	**0.6**	**64**	**30**	**0**	**0**	**7**	**62**	**0**
LME 7-1	NR-2-3-U	20	LME 6-1 load	0.1	12	0	0	0	0	100	0
LME 7-2	NR-2-3-U	20	LME 6-1 load	0.1	7	0	0	0	0	100	0
LME 8-1	NR-2-3-U	20	LME 6-1 load	0.6	61	0	30	0	0	70	0
LME 8-2	NR-2-3-U	20	LME 6-1 load	0.4	37	10	0	0	0	80	10
LME 9-1	NR-2-3-U	20	LME 6-1 load	0.1	11	0	0	0	0	100	0
LME 10-1	NR-0-3-U	25	RT avg (N=5)	0.7	95	20	40	0	0	40	0
LME 10-2	NR-0-3-U	25	RT avg (N=5)	0.6	78	10	20	0	0	70	0
			Total Stream Segment	**4.3**	**383**	**13**	**19**	**0**	**1**	**66**	**1**
Unstratified 1st Order		0	no load (1st order)	8.9	0						
Unstratified non-1st Order		11	NR 25th percentile	2.5	146						
			Total Lime Creek Watershed	**15.8**	**530**						

E3.4.2.6 Sinclair Creek Sediment Loads

Fourteen reaches were delineated for the mainstem of Sinclair Creek, and 3 monitoring sites were assessed in the field. The two 1st order streams received a load of zero, and the adjacent steep headwaters reach (3-1) received the 25th percentile loading rate for the Canadian Rockies Ecoregion. Reaches 4-1 to 6-1 were all similar reach type and land use, and received the field-assessed loading rate from reach 5-1. Reaches 7-1 and 8-1 were both forested reaches of type CR-0-2-U, and received the reach type average sediment loading rate. Reaches 8-2 to 10-2 were of similar reach type and land use (rural residential/hobby farm), so they received the field-assessed loading rate from reach 8-2. The total sediment load for the Sinclair Creek watershed was estimated to be 1381 tons/year, all from the mainstem. The watershed has 6.61 miles of unstratified 1st order streams, but no unstratified streams larger than 1st order. The estimated annual sediment loads for Sinclair Creek are provided below in **Table E3-12.**

Table E3-12. Estimated annual sediment loads for Sinclair Creek.

Reach ID	Reach Type	Sediment Loading Rate	Loading Rate Source	Reach Length	Total Reach Load	Roads	Grazing	Cropland	Logging	Natural	Other
		(tons/yr /1000')		(miles)	(tons /year)	(%)	(%)	(%)	(%)	(%)	(%)
SNC 1-1	CR-10-1-C	0	no load (1st order)	0.5	0	0	0	0	0	100	0
SNC 2-1	CR-10-1-U	0	no load (1st order)	0.6	0	0	0	0	0	100	0
SNC 3-1	CR-10-2-U	5	CR 25th percentile	1.0	27	0	0	0	0	100	0
SNC 4-1	CR-4-2-U	12	SNC 5-1 load	0.7	41	10	0	0	0	90	0
SNC 5-1	**CR-4-2-U**	**12**	**assessed value**	**0.8**	**47**	**0**	**0**	**0**	**0**	**100**	**0**
SNC 5-2	CR-4-2-U	12	SNC 5-1 load	1.3	80	10	0	0	0	80	10
SNC 6-1	CR-2-2-U	12	SNC 5-1 load	0.7	44	10	20	0	10	60	0
SNC 7-1	CR-0-2-U	31	RT avg (N=4)	0.4	67	10	0	0	0	90	0
SNC 8-1	CR-0-2-U	31	RT avg (N=4)	0.1	14	20	0	0	0	60	20
SNC 8-2	**CR-0-2-U**	**42**	**assessed value**	**1.7**	**378**	**0**	**100**	**0**	**0**	**0**	**0**
SNC 9-1	CR-2-2-U	42	SNC 8-2 load	0.5	105	20	40	0	0	20	20
SNC 10-1	CR-0-2-U	42	SNC 8-2 load	0.9	208	10	70	20	0	0	0
SNC 10-2	CR-0-2-U	42	SNC 8-2 load	0.5	109	20	50	10	0	0	20
SNC 10-3	**CR-0-2-U**	**53**	**assessed value**	**0.9**	**259**	**50**	**0**	**0**	**0**	**20**	**30**
			Total Stream Segment	**10.6**	**1381**	**16**	**46**	**4**	**0**	**25**	**10**
Unstratified 1st Order		0	no load (1st order)	6.6	0						
Unstratified non-1st Order		5	CR 25th percentile	0.0	0						
			Total Sinclair Creek Watershed	**17.2**	**1381**						

E3.4.2.7 Swamp Creek Sediment Loads

Fourteen reaches were delineated on the mainstem of Swamp Creek, and 3 monitoring sites were assessed in the field. The one 1st order reach was assigned a sediment load of zero, and the four 2nd order reaches (SWP 3-1 to 5-1) received the field-assessed sediment loading rate from reach 3-1. Reaches 6-1 and 6-2 received the field-assessed sediment loading rate from adjacent reach 5-1. Reaches 7-1 to 8-2 were all of reach type NR-0-3-U, and received the average reach type loading rate. The furthest downstream reach (SWP 10-1) was reach type NR-4-3-U, and also received its reach type average loading rate. The total estimated annual sediment load for the Swamp Creek watershed was 1408 tons/year, including 1080 tons/year from the mainstem, and 329 tons/year from unstratified non-1st order streams. The estimated annual sediment loads for Swamp Creek are provided below in **Table E3-13.**

Table E3-13. Estimated annual sediment loads for Swamp Creek.

Reach ID	Reach Type	Sediment Loading Rate (tons/yr /1000')	Loading Rate Source	Reach Length (miles)	Total Reach Load (tons /year)	Roads (%)	Grazing (%)	Cropland (%)	Logging (%)	Natural (%)	Other (%)
SWP 1-1	NR-2-1-U	0	no load (1st order)	1.4	0	10	0	0	40	50	0
SWP 2-1	NR-2-2-U	1	SWP 3-1 load	0.1	1	0	0	0	0	100	0
SWP 3-1	**NR-4-2-U**	**1**	**assessed value**	**0.5**	**2**	**0**	**0**	**0**	**9**	**91**	**0**
SWP 4-1	NR-0-2-U	1	SWP 3-1 load	2.4	12	30	0	0	0	70	0
SWP 4-2	NR-0-2-U	1	SWP 3-1 load	0.1	1	0	0	0	0	100	0
SWP 5-1	**NR-0-3-U**	**13**	**assessed value**	**0.9**	**60**	**0**	**0**	**0**	**93**	**7**	**0**
SWP 6-1	NR-2-3-U	13	SWP 5-1 load	0.2	13	0	0	0	50	50	0
SWP 6-2	NR-2-3-U	13	SWP 5-1 load	0.5	38	0	0	0	10	90	0
SWP 7-1	NR-0-3-U	25	RT avg (N=5)	0.1	12	10	0	0	0	80	10
SWP 7-2	NR-0-3-U	25	RT avg (N=5)	0.9	118	20	20	40	0	20	0
SWP 8-1	NR-0-3-U	25	RT avg (N=5)	1.0	131	10	20	50	0	20	0
SWP 8-2	NR-0-3-U	25	RT avg (N=5)	0.6	80	10	0	0	0	90	0
SWP 9-1	**NR-2-3-U**	**52**	**assessed value**	**2.2**	**590**	**0**	**0**	**0**	**0**	**100**	**0**
SWP 10-1	NR-4-3-U	14	RT avg (N=2)	0.3	20	0	0	0	0	80	20
			Total Stream Segment	**11.1**	**1080**	**5**	**5**	**10**	**6**	**74**	**0**
Unstratified 1st Order		0	no load (1st order)	29.7	0						
Unstratified non-1st Order		11	NR 25th percentile	5.7	329						
			Total Swamp Creek Watershed	**46.5**	**1408**						

E3.4.2.8 Theriault Creek Sediment Loads

A total of 31 reaches were delineated for Theriault Creek, and 2 monitoring sites were assessed in the field. The upper 12 reaches were 1st order streams or lake sections and were assigned zero load. Thirteen reaches were reach type CR-0-2-U or CR-2-2-U. These reaches received the average of the 2 reaches assessed on Theriault Creek, since stream conditions observed for Theriault Creek indicated a lower loading rate than the average for streams of type CR-0-2-U. Reaches of type CR-4-2-U or CR-4-2-C received the CR-4-2-U reach type average sediment loading rate. The total sediment load for Theriault Creek was estimated to be 433 tons/year, including 375 tons/year from the mainstem, and 57 tons/year from unstratified non-1st order streams. The estimated annual sediment loads for Theriault Creek are provided below in **Table E3-14.**

Table E3-14. Estimated annual sediment loads for Theriault Creek.

Reach ID	Reach Type	Sediment Loading Rate	Loading Rate Source	Reach Length	Total Reach Load	Roads	Grazing	Cropland	Logging	Natural	Other
		(tons/yr /1000')		(miles)	(tons /year)	(%)	(%)	(%)	(%)	(%)	(%)
THR 1-1	CR-10-1-C	0	no load (1st order)	0.5	0	5	0	0	0	95	0
THR 2-1	CR-10-1-U	0	no load (1st order)	0.9	0	5	0	0	0	95	0
THR 3-1	CR-4-1-U	0	no load (1st order)	0.6	0	0	0	0	0	100	0
THR 3-2	CR-4-1-U	0	no load (1st order)	0.2	0	5	0	0	0	95	0
THR 4-1	lake	0	no load (lake segment)	0.2	0	10	0	0	30	60	0
THR 5-1	CR-4-1-U	0	no load (1st order)	0.4	0	5	0	0	0	95	0
THR 5-2	CR-4-1-U	0	no load (1st order)	0.3	0	30	0	0	0	70	0
THR 6-1	CR-10-1-U	0	no load (1st order)	0.1	0	25	0	0	0	75	0
THR 6-2	CR-10-1-U	0	no load (1st order)	0.1	0	0	0	0	0	100	0
THR 7-1	CR-2-1-U	0	no load (1st order)	0.6	0	10	0	0	0	90	0
THR 7-2	CR-2-1-U	0	no load (1st order)	0.2	0	0	0	0	0	100	0
THR 7-3	CR-2-1-U	0	no load (1st order)	0.1	0	0	0	0	0	100	0
THR 8-1	CR-2-2-U	15	avg of THR reaches (N=2)	0.1	4	0	0	0	30	70	0
THR 9-1	CR-0-2-U	15	avg of THR reaches (N=2)	0.1	5	0	0	0	20	80	0
THR 9-2	CR-0-2-U	15	avg of THR reaches (N=2)	0.1	12	20	0	0	0	80	0
THR 9-3	CR-0-2-U	15	avg of THR reaches (N=2)	0.4	32	10	10	30	0	50	0
THR 9-4	CR-0-2-U	15	avg of THR reaches (N=2)	0.2	18	20	0	0	0	80	0
THR 9-5	**CR-0-2-U**	**21**	**assessed value**	**0.2**	**24**	**0**	**0**	**0**	**60**	**40**	**0**
THR 10-1	CR-4-2-U	9	RT avg (N=3)	0.3	14	10	0	0	50	40	0
THR 11-1	CR-4-2-C	9	CR-4-2-U avg (N=3)	0.0	2	0	0	0	0	100	0
THR 11-2	CR-4-2-C	9	CR-4-2-U avg (N=3)	0.1	5	10	0	0	0	90	0
THR 12-1	CR-2-2-C	15	avg of THR reaches (N=2)	0.2	19	10	0	0	0	90	0
THR 13-1	CR-2-2-U	15	avg of THR reaches (N=2)	0.5	38	0	0	0	0	90	10
THR 13-2	CR-2-2-U	15	avg of THR reaches (N=2)	0.2	15	0	0	0	0	100	0
THR 14-1	**CR-0-2-U**	**8**	**assessed value**	**0.3**	**12**	**0**	**7**	**0**	**6**	**62**	**24**
THR 14-2	CR-0-2-U	15	avg of THR reaches (N=2)	0.7	51	10	20	20	0	50	0
THR 14-3	CR-0-2-U	15	avg of THR reaches (N=2)	0.1	11	10	0	0	0	90	0
THR 14-4	CR-0-2-U	15	avg of THR reaches (N=2)	0.2	14	25	0	0	0	75	0
THR 15-1	CR-4-2-C	9	CR-4-2-U avg (N=3)	0.3	13	25	0	0	0	75	0
THR 16-1	CR-0-2-U	15	avg of THR reaches (N=2)	0.1	8	25	0	0	0	75	0
THR 16-2	CR-0-2-U	15	avg of THR reaches (N=2)	1.0	80	10	25	25	0	40	0
			Total Stream Segment	**9.0**	**375**	**10**	**9**	**11**	**6**	**63**	**2**
Unstratified 1st Order		0	no load (1st order)	20.6	0						
Unstratified non-1st Order		5	CR 25th percentile	2.1	57						
			Total Theriault Creek Watershed	**31.7**	**433**						

E3.4.2.9 Tobacco River Sediment Loads

A total of 11 reaches were delineated on the mainstem of the Tobacco River, and 4 monitoring sites were assessed in the field. All reaches on the Tobacco River were reach type NR-0-5-U. All field-assessed were assigned their measured sediment loading rate, while the remaining six reaches received the NR-0-5-U reach type average loading rate, all of which were on the Tobacco River. The total estimated annual sediment load for the Tobacco River watershed was 4,830 tons/year, including 3,949 tons/year from the mainstem, and 880 tons/year from unstratified non-1st order streams. The estimated annual sediment loads for Tobacco River are provided below in **Table E3-15.** Note that these results to not include all bank erosion loading from all watersheds contributing to the Tobacco River, but instead represent only those loads along the Tobacco River and from associated unstratified non-1st order streams.

Table E3-15. Estimated annual sediment loads for Tobacco River.

Reach ID	Reach Type	Sediment Loading Rate	Loading Rate Source	Reach Length	Total Reach Load	Roads	Grazing	Cropland	Logging	Natural	Other
		(tons/yr /1000')		(miles)	(tons /year)	(%)	(%)	(%)	(%)	(%)	(%)
TOB 1-1	**NR-0-5-U**	**54**	**assessed value**	**1.3**	**372**	**0**	**1**	**0**	**0**	**99**	**0**
TOB 1-2	NR-0-5-U	54	RT avg (N=4)	1.0	283	15	0	0	0	85	0
TOB 1-3	**NR-0-5-U**	**68**	**assessed value**	**1.2**	**429**	**1**	**1**	**0**	**0**	**98**	**0**
TOB 1-4	NR-0-5-U	54	RT avg (N=4)	3.2	918	10	0	0	0	90	0
TOB 2-1	NR-0-5-U	54	RT avg (N=4)	0.3	78	10	0	0	0	90	0
TOB 2-2	NR-0-5-U	54	RT avg (N=4)	1.0	280	10	25	25	0	40	0
TOB 2-3	**NR-0-5-U**	**9**	**assessed value**	**1.4**	**71**	**46**	**0**	**0**	**0**	**31**	**23**
TOB 2-4	NR-0-5-U	54	RT avg (N=4)	0.4	108	15	0	0	0	85	0
TOB 2-5	NR-0-5-U	54	RT avg (N=4)	0.8	240	10	50	0	0	40	0
TOB 2-6	**NR-0-5-U**	**83**	**assessed value**	**2.1**	**916**	**0**	**0**	**0**	**0**	**26**	**74**
TOB 2-7	NR-0-5-U	54	RT avg (N=4)	0.9	253	10	40	0	0	50	0
			Total Stream Segment	**13.6**	**3949**	**7**	**8**	**2**	**0**	**66**	**17**
Unstratified 1st Order		0	no load (1st order)	33.5	0						
Unstratified non-1st Order		11	NR 25th percentile	15.3	880						
Total Tobacco River				**62.4**	**4830**						

E3.4.3 Sediment Loads from Meadow Creek and Indian Creek

This section presents the approach used to estimate bank erosion for two major streams in the Tobacco River watershed not listed as impaired and not otherwise included in the above analyses: Meadow Creek and Indian Creek. All of Meadow Creek is within the Northern Rockies Ecoregion. The upper portions of the Indian Creek watershed are in the Canadian Rockies Ecoregion; however, the watershed will be considered part of the Northern Rockies Ecoregion for the extrapolation process since the majority falls in the Northern Rockies Ecoregion and the watershed is bracketed by the lower portions of the Tobacco River watershed.

All 1st order streams were assigned a sediment loading rate of zero. Non-1st order streams on Meadow Creek and Indian Creek were assigned the 25th percentile loading rate from all assessed reaches in the Northern Rockies Ecoregion (negating the Tobacco River due to its size). Overall, the estimated annual sediment load from unassessed streams was 1,181 tons/year, including 719 tons/year from the Meadow Creek watershed and 462 tons/year from the Indian Creek watershed. A summary of sediment loads from unassessed streams is provided below in **Table E3-16**.

Table E3-16. Estimated annual sediment loads from unassessed streams.

Watershed	Reach Type	Sediment Loading Rate	Loading Rate Source	Reach Length	Total Reach Load
		(tons/yr /1000')		(miles)	(tons /year)
Meadow Creek	1st order	0	no load (1st order)	22.5	0
	non-1st order	11	NR 25th percentile	12.5	719
	Total Stream Length			**35.0**	**719**
Indian Creek	1st order	0	no load (1st order)	12.3	0
	non-1st order	11	NR 25th percentile	8.0	462
	Total Stream Length			**20.4**	**462**
Total of Unassessed Streams				**55.4**	**1181**

E3.4.4 Watershed Sediment Loads

Streambank sediment loads were calculated for the entire Tobacco River watershed based on estimated loads from each subwatershed, including both stratified and unstratified streams. Overall, 550 miles of streams were evaluated, including 116 miles of stratified mainstem streams, 334 miles of unstratified 1st order streams, and 100 miles of unstratified non-1st order streams. The total estimated annual sediment load due to streambank erosion in the Tobacco River watershed was 20,685 tons/year, including 15,423 tons/year from listed mainstem streams, and 5,261 tons/year from unstratified non-1st order streams. As previously discussed, all 1st order streams were assigned a sediment loading rate of zero since they are not considered a significant source of controllable sediment load. A summary of estimated annual sediment loads are provided below for each sub-watershed and for the entire Tobacco River watershed (**Table E3-17**).

Note that the total load for Fortine Creek watershed is not identified within **Table E3-17**. The total watershed load would include the load from Fortine Creek plus the loads from Deep, Edna, Lime, Swamp, and Meadow Creeks for a total Fortine Creek watershed load of 10,849 tons/year.

Table E3-17. Estimated annual sediment loads for the entire Tobacco River watershed.

Stream	Reach Type	Stream Length	Total Sediment Load	Average Sediment Loading Rate	
		(miles)	(tons /year)	(tons/year/mile)	(tons/year/1000')
Deep Creek	Mainstem	10.6	405	38	7
	Unstratified 1st Order	12.6	0	0	0
	Unstratified Non-1st Order	1.7	48	28	5
	Total Deep Creek Watershed	**24.9**	**453**	**18**	**3**
Edna Creek	Mainstem	10.2	324	32	6
	Unstratified 1st Order	23.0	0	0	0
	Unstratified Non-1st Order	2.2	128	58	11
	Total Edna Creek Watershed	**35.4**	**452**	**13**	**2**
Fortine Creek	Mainstem	30.7	5175	168	32
	Unstratified 1st Order	105.9	0	0	0
	Unstratified Non-1st Order	36.7	2112	58	11
	Total Fortine Creek *	**173.4**	**7287**	**42**	**8**
Lime Creek	Mainstem	4.3	383	88	17
	Unstratified 1st Order	8.9	0	0	0
	Unstratified Non-1st Order	2.5	146	58	11
	Total Lime Creek Watershed	**15.8**	**530**	**33**	**6**
Sinclair Creek	Mainstem	10.6	1381	131	25
	Unstratified 1st Order	6.6	0	0	0
	Unstratified Non-1st Order	0.0	0	NA	NA
	Total Sinclair Creek Watershed	**17.2**	**1381**	**80**	**15**
Swamp Creek	Mainstem	11.1	1080	97	18
	Unstratified 1st Order	29.7	0	0	0
	Unstratified Non-1st Order	5.7	329	58	11
	Total Swamp Creek Watershed	**46.5**	**1408**	**30**	**6**
Theriault Creek	Mainstem	9.0	375	42	8
	Unstratified 1st Order	20.6	0	0	0
	Unstratified Non-1st Order	2.1	57	28	5
	Total Theriault Creek Watershed	**31.7**	**433**	**14**	**3**
Tobacco River	Mainstem	13.6	3949	290	55
	Unstratified 1st Order	33.5	0	0	0
	Unstratified Non-1st Order	15.3	880	58	11
	Total Tobacco River	**62.4**	**4830**	**77**	**15**
Grave Creek	Mainstem	15.9	2350	148	28
	Unstratified 1st Order	57.9	0	0	0
	Unstratified Non-1st Order	13.6	380	28	5
	Total Grave Creek Watershed	**87.4**	**2730**	**31**	**6**
Meadow Creek	Unstratified 1st Order	22.5	0	0	0
	Unstratified Non-1st Order	12.5	719	58	11
	Total Meadow Creek Watershed	**35.0**	**719**	**21**	**4**
Indian Creek	Unstratified 1st Order	12.3	0	0	0
	Unstratified Non-1st Order	8.0	462	58	11
	Total Indian Creek Watershed	**20.4**	**462**	**23**	**4**
Entire Tobacco River Watershed	Total Listed Mainstem Sites	116.1	15423	133	25
	Total Unstratified 1st Order	333.6	0	0	0
	Total Unstratified Non-1st Order	100.3	5261	52	10
	Total Tobacco River Watershed	**550.1**	**20684**	**38**	**7**

E3.5 STREAMBANK EROSION SEDIMENT LOAD REDUCTIONS

The potential to reduce sediment loads from streambanks with identified human impacts was evaluated to simulate the implementation of Best Management Practices (BMPs) and other reasonable land, soil, and water conservation practices. This evaluation was performed by adjusting BEHI values in reaches with identified human sources using methods described in **Section E2.5**. Results are presented in **Table E3-18** for individual monitoring sites.

Overall, the average potential reduction to the human related sediment load was 33% for all monitoring sites. Five monitoring sites with observed sources had low BEHI scores which could not be reduced, resulting in no potential reduction from these sites. The greatest potential reduction was seen in sites SNC 10-3 (87%) and DEP 9-2a (83%), both of which had extreme BEHI ratings in at least one eroding bank.

Table E3-18. Potential sediment load reductions at monitoring sites.

Reach ID	Reach Type	Human Related Sources (%)	Number of Eroding Banks	Number of Adjusted Banks	Original Sediment Loading Rate (tons/year /1000')	Reduced Sediment Loading Rate (tons/year /1000')	Potential Reduction to Human Sediment Load
SNC 10-3	CR-0-2-U	80%	4	1	53	7	87%
SNC 8-2	CR-0-2-U	100%	14	11	42	22	48%
THR 14-1	CR-0-2-U	38%	8	7	8	3	63%
THR 9-5	CR-0-2-U	60%	13	7	21	10	56%
DEP 9-2a	CR-4-3-U	81%	5	4	155	27	83%
ENA 11-1	NR-0-3-U	100%	5	0	0	0	0%
FTN 4-3	NR-0-3-U	24%	8	1	21	20	8%
FTN 6-1	NR-0-3-U	41%	5	3	43	19	57%
SWP 5-1	NR-0-3-U	93%	5	1	13	13	5%
FTN 12-2	NR-0-4-U	38%	9	2	35	30	15%
FTN 12-7	NR-0-4-U	98%	6	5	78	30	61%
FTN 12-9	NR-0-4-U	6%	5	1	19	9	52%
FTN 15-2	NR-0-4-U	48%	6	0	12	12	0%
FTN 15-3	NR-0-4-U	26%	4	0	5	5	0%
TOB 2-3	NR-0-5-U	69%	6	0	9	9	0%
TOB 2-6	NR-0-5-U	74%	8	4	83	44	47%
SWP 3-1	NR-4-2-U	9%	7	0	1	1	0%
LME 6-1	NR-4-3-U	38%	8	5	20	16	18%
Average Potential Reduction for all Human Influenced Sites							**33%**

The average potential reduction from human influenced monitoring sites (33%) was used to calculate sediment load reductions throughout the watershed. This reduction percentage was applied to the existing human load of all reaches identified in the aerial assessment process with >5% human load source. These reduced reach loads were then extrapolated to the stream segment and watershed scales (**Table E3-19)**. It is estimated that the total Tobacco River TPA sediment load can be reduced by approximately 1,700 tons/year through implementation of conservation practices and BMPs.

Not included in **Table E3-19** is the cumulative summary information applicable to the whole Fortine Creek watershed. Of the 10,849 tons/year within the Fortine Creek watershed, 2,243 tons/year were

linked to human loading. Application of a 33% reduction results in a total potential load reduction of 740 tons. This equates to a 10,109 tons/year load after reductions were applied, or a 7% total reduction for the whole Fortine Creek watershed consistent with the results for Fortine Creek only.

Table E3-19. Potential sediment load reductions by stream segment and watershed.

Stream	Reach Type	Reach Length (miles)	Original Reach Load (tons/year)	Original Human-Related Reach Load (tons/year)	Potential Reduction to Human-Related Reach Load (tons/year)	Reach Load w/ Human-Related Sources Reduced (tons/year)	Potential Reduction to Original Load (%)
Deep Creek	Total Stream Segment	10.6	405	174	57	348	14
	Unstratified 1st Order Streams	12.6	0	0	0	0	0
	Unstratified non-1st Order Streams	1.7	48	0	0	48	0
	Total Watershed	**24.9**	**453**	**174**	**57**	**396**	**13**
Edna Creek	Total Stream Segment	10.2	324	19	6	317	2
	Unstratified 1st Order Streams	23.0	0	0	0	0	0
	Unstratified non-1st Order Streams	2.2	128	0	0	128	0
	Total Watershed	**35.4**	**452**	**19**	**6**	**446**	**1**
Fortine Creek	Total Stream Segment	30.7	5175	1635	540	4636	10
	Unstratified 1st Order Streams	105.9	0	0	0	0	0
	Unstratified non-1st Order Streams	36.7	2112	0	0	2112	0
	Total Fortine Creek	**173.4**	**7287**	**1635**	**540**	**6748**	**7**
Lime Creek	Total Stream Segment	4.3	383	130	43	340	11
	Unstratified 1st Order Streams	8.9	0	0	0	0	0
	Unstratified non-1st Order Streams	2.5	146	0	0	146	0
	Total Watershed	**15.8**	**530**	**130**	**43**	**487**	**8**
Sinclair Creek	Total Stream Segment	10.6	1381	1037	342	1039	25
	Unstratified 1st Order Streams	6.6	0	0	0	0	0
	Unstratified non-1st Order Streams	0.0	0	0	0	0	0
	Total Watershed	**17.2**	**1381**	**1037**	**342**	**1039**	**25**
Swamp Creek	Total Stream Segment	11.1	1080	285	94	986	9
	Unstratified 1st Order Streams	29.7	0	0	0	0	0
	Unstratified non-1st Order Streams	5.7	329	0	0	329	0
	Total Watershed	**46.5**	**1408**	**285**	**94**	**1314**	**7**
Theriault Creek	Total Stream Segment	9.0	375	141	46	329	12
	Unstratified 1st Order Streams	20.6	0	0	0	0	0
	Unstratified non-1st Order Streams	2.1	57	0	0	57	0
	Total Watershed	**31.7**	**433**	**141**	**46**	**386**	**11**
Tobacco River	Total Stream Segment	13.6	3949	1334	435	3514	11
	Unstratified 1st Order Streams	33.5	0	0	0	0	0
	Unstratified non-1st Order Streams	15.3	880	0	0	880	0
	Total Tobacco River	**62.4**	**4830**	**1334**	**435**	**4394**	**9**
Grave Creek	Total Stream Segment	15.9	2350	528	174	2176	7
	Unstratified 1st Order Streams	57.9	0	0	0	0	0
	Unstratified non-1st Order Streams	13.6	380	0	0	380	0
	Total Watershed	**87.4**	**2730**	**528**	**174**	**2555**	**6**
Meadow Creek	Unstratified 1st Order Streams	22.5	0	**0**	**0**	0	0
	Unstratified non-1st Order Streams	12.5	719	0	0	719	0
	Total Watershed	**35.0**	**719**	**0**	**0**	**719**	**0**
Indian Creek	Unstratified 1st Order Streams	12.3	0	**0**	**0**	0	0
	Unstratified non-1st Order Streams	8.0	462	0	0	462	0
	Total Watershed	**20.4**	**462**	**0**	**0**	**462**	**0**
Entire Tobacco River Watershed	Total Stream Segment	116.1	15423	5282	1738	13685	11
	Unstratified 1st Order Streams	333.6	0	0	0	0	0
	Unstratified non-1st Order Streams	100.3	5261	0	0	5261	0
	Total Watershed	**550.1**	**20684**	**5282**	**1738**	**18946**	**8**

E4.0 DISCUSSION AND CONCLUSIONS

The streambank erosion source assessment included a combination of GIS analysis, aerial photograph assessment, field data collection, and detailed extrapolation procedures. Results of the assessment identify roads, riparian grazing, railroad encroachment, and urban influences as the primary sources of sediment loading in the Tobacco River TPA, with logging and crop production identified as minor sources. However, it should be noted that significant historic logging activities took place in the watershed that have likely impacted streambank erosion processes. Due to the historic nature of these activities, residual impacts may not have been difficult to identify through this assessment process.

It is estimated that 15,423 tons/year of sediment are delivered at the stream segment scale, which includes the stratified reaches of all listed streams within the Tobacco River TPA, in addition to Sinclair Creek. Approximately 5,282 tons/year (34%) of this sediment load is attributed to human sources. An additional 5,261 tons/year is delivered from unstratified and/or unassessed portions of the watershed, including 719 tons/year from Meadow Creek and 462 tons/year from Indian Creek.

For the entire Tobacco River TPA, it is estimated that 20,684 tons/year of sediment are delivered to the stream network from bank erosion. Through the implementation of all reasonable land, soil, and water conservation practices on sites with observed non-natural sources, it is estimated that the total human related sediment load be reduced by 1,738 tons/year (33%), which represents an 8% reduction in streambank sediment erosion for the entire watershed.

E5.0 COMPARISON BETWEEN GRAVE CREEK BANK EROSION STUDIES

Bank erosion was previously estimated for the 2005 Grave Creek sediment TMDL (Montana Department of Environmental Quality, et al., 2005) using a similar BEHI method applied to data collected during the 2003 summer field season. The results within the 2005 document show that most of the bank erosion in the Grave Creek watershed was along the lower mainstem portion of Grave Creek. **Table E3-10** of this appendix also shows a similar conclusion when looking at the 0-2% valley slope reaches where the lower Grave Creek mainstem is located. The lower Grave Creek mainstem results from both analyses, along with human impact and potential load reduction information, are presented in **Table E5-1**.

Table E5-1. Lower Grave Creek Mainstem Bank Erosion Loading Analyses

Measure	2005 Grave Creek TMDL Bank Erosion Analysis (using 2003 field data)	Tobacco Watershed TMDL Bank Erosion Analysis (using 2008 field data)
Bank Erosion Load	9,433 tons/yr	1,658 tons/yr (**Table E3-10** reaches with 0-2% valley slope)
Human Caused Percentage	99%	22% (**Table E3-10**)
Potential Load Reduction	63%	7% (**Table E3-19**)
Load after Reduction	3,475 tons/yr (based on 63% reduction from 9,433 tons/yr)	1,541 tons/yr (based on 7% reduction from 1,658 tons/year)

The **Table E5-1** results vary for several reasons:

- Lower Grave Creek mainstem has a history of instability linked to historical channelization and associated high levels of bank erosion. Field crews evaluated a significant portion of lower Grave Creek in 2003 and documented many highly erodible banks with an equivalent of high, very high

and extreme BEHI ratings. These erodible banks were primarily linked to human activity because of the human caused channelization. The more recent results from 2008 are based on an aerial assessment which probably did not capture human impacts from channelization as well as a field assessment.

- Significant restoration work was completed for about 8000 feet of the lower Grave Creek mainstem since the 2003 BEHI field work. Bank erosion rates have significantly decreased along many of the reaches where highly erodible banks were documented in 2003 (River Design Group, 2011). The more recent assessment likely captures some of this reduced bank erosion.
- The 63% reduction potential value for the 2003 Grave Creek work was based on bank erosion from a reference reach within Grave Creek and an estimate of achievable loading reduction. The extrapolation approach within this appendix resulted in a much lower percent reduction (7%) because of the lower estimate of human caused bank erosion in lower Grave Creek mainstem combined with a lower bank erosion reduction potential applied throughout the Tobacco watershed.

The resulting bank erosion values for lower Grave Creek mainstem, after applying reductions, are 3,475 tons/year based on the 2003 analysis, and 1,541 tons/year based on the 2008 analyses. These values compare favorably given the level of uncertainty associated with determining total loading, percent human influence, and reduction potential. The 3,475 tons/year value reported in the 2005 Grave Creek TMDL document is perhaps the more accurate achievable sediment loading values since it is based more on field data collection versus aerial assessment and extrapolation.

For the recent 2008 analysis, the resulting bank erosion load estimate in the upper portions of Grave Creek watershed is 1,072 tons/year. For the upper portions of the Grave Creek watershed, the 2005 sediment load estimate was 2,299 tons/year based on a combination of sediment loading from bank erosion and mass wasting along stream channels. The mass wasting was included in the Grave Creek sediment assessment because of the susceptibility of mass wasting within the Grave Creek watershed, and it was combined with bank erosion since it was difficult to separate mass wasting from bank erosion when it occurred along stream channels. The resulting load values after applying reductions are 1,526 tons/year from the 2005 analysis versus 997 tons/year based on the more recent 2008 information. Since the 1,526 tons/year also includes mass wasting, it may reflect a more accurate total achievable load, but cannot be compared directly to the 997 tons/year value since the 997 tons/year is based more on extrapolated bank erosion values and associated aerial assessment of human impact.

E6.0 REFERENCES

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Rosgen, David L. 1996. Applied River Morphology, Pagosa Springs, CO: Wildland Hydrology.

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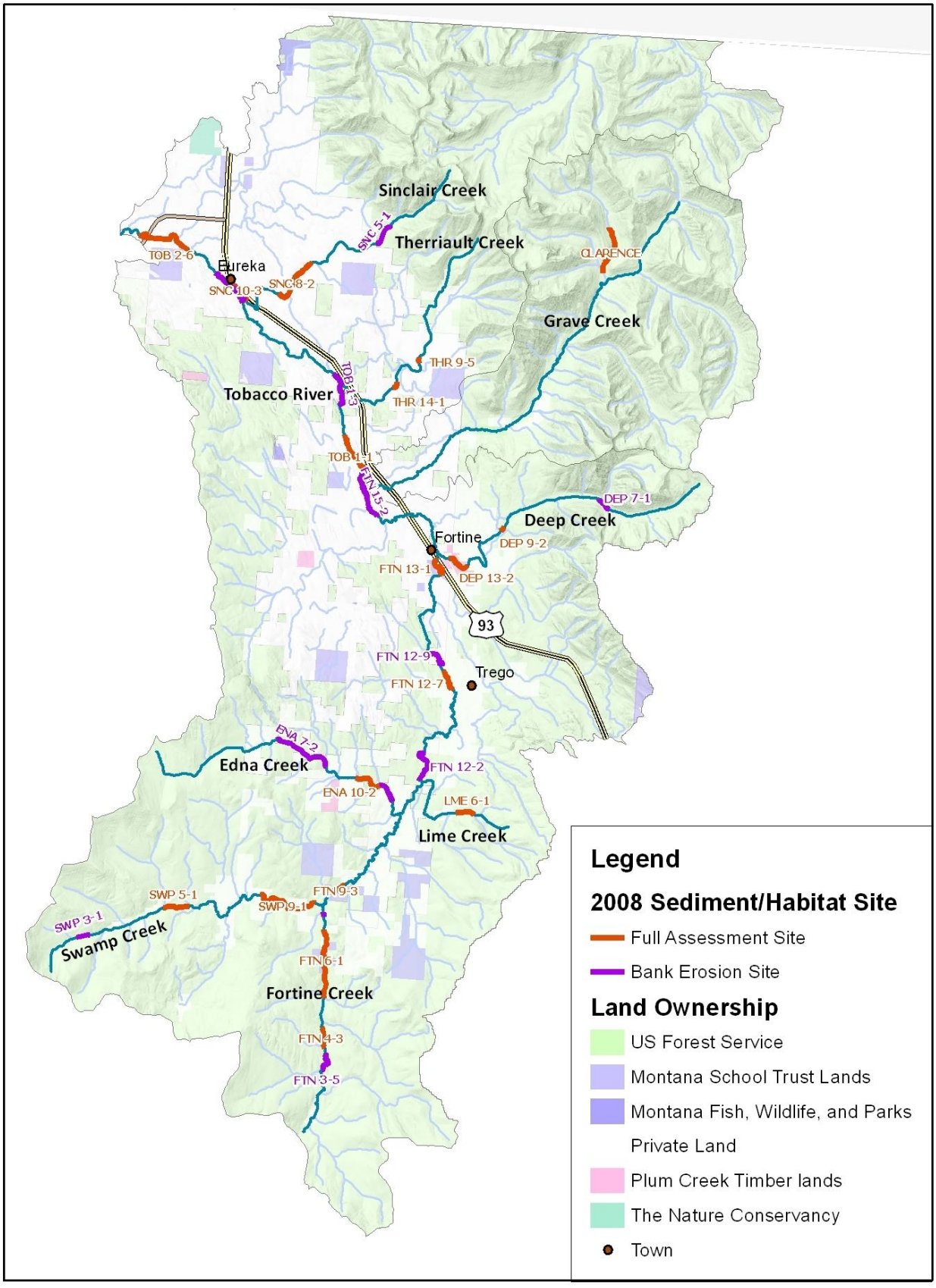
ATTACHMENT A – MONITORING SITE LOCATION MAP


Sinclair Creek
Therriault Creek
Grave Creek
Tobacco River
Deep Creek
Edna Creek
Lime Creek
Swamp Creek
Fortine Creek
Eureka
Fortine
Trego
93
SNC 5-1
TOB 2-6
SNC 8-2
SNC 10-3
THR 9-5
THR 14-1
TOB 1-3
TOB 1-1
FTN 15-2
CLARENCE
DEP 7-1
DEP 9-2
DEP 13-2
FTN 13-1
FTN 12-9
FTN 12-7
ENA 7-2
ENA 10-2
FTN 12-2
LME 6-1
SWP 5-1
SWP 3-1
SWP 9-1
FTN 9-3
FTN 6-1
FTN 4-3
FTN 3-5
Legend
2008 Sediment/Habitat Site
Full Assessment Site
Bank Erosion Site
Land Ownership
US Forest Service
Montana School Trust Lands
Montana Fish, Wildlife, and Parks
Private Land
Plum Creek Timber lands
The Nature Conservancy
Town