APPENDIX E
USLE GENERATED UPLAND EROSION CORRECTED FOR EXISTING AND POTENTIAL RIPARIAN HEALTH

Introduction

Upland sediment loading due to hillslope erosion was modeled using the Universal Soil Loss Equation (USLE) and sediment delivery to the stream was predicted using a sediment delivery ratio. The model report and associated output are located in **Appendix D**. This modeling effort did not, however, take into account the effect that vegetated riparian buffers have on reducing the upland sediment load delivered to streams. **Figure E-1** depicts the USLE modeling process without the influence of riparian buffers included. That is, 100 percent of the USLE generated annual sediment load, adjusted via the sediment delivery ratio as defined in **Appendix D**, was delivered to the stream network. Because the modeling process did not account for the sediment reduction efficiency of the vegetated riparian buffer, a secondary effort to qualify and quantify this influence was undertaken and is presented here.

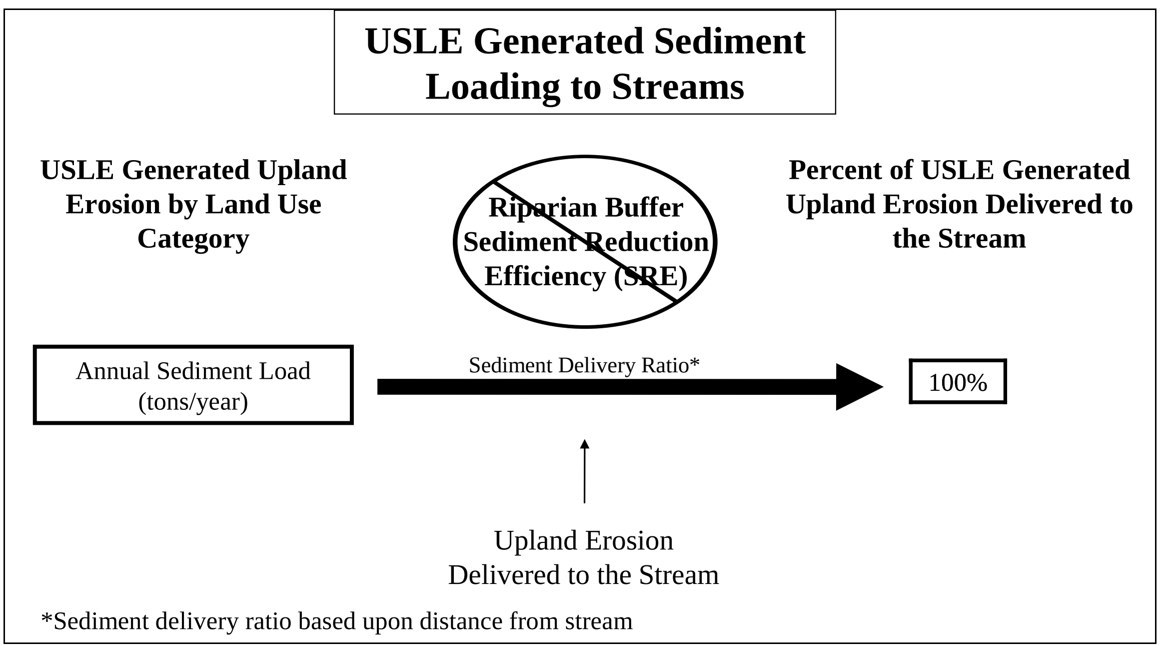

Figure E-1. USLE Upland Sediment Model Excluding the Influence of the Riparian Buffer

The USLE modeling effort (**Appendix D**) estimated existing upland sediment loads and potential reductions in loading associated with the implementation of Best Management Practicies (BMPs). Incorporating a riparian health component improves the estimate of upload loading by routing the modeled existing upland sediment load through the existing riparian buffer condition, routing the modeled reductions associated with upland BMPs through the existing riparian buffer condition, and estimating the overall potential sediment loading reductions associated with routing upland BMP loads through an improved riparian buffer (via BMPs).

Effect of Riparian Buffers on Sediment Loading to Streams

Vegetated riparian buffers function as filters that protect adjoining streams and downstream receiving waters (Martin 1999). Riparian buffers utilize filtration, adsorption, and entrainment to remove sediments, nutrients, and a range of contaminants. Vegetated riparian buffers disperse concentrated or channelized runoff, increasing infiltration, slowing surface runoff, and enhancing the deposition of sediment and sediment associated contaminants from both overland flows and overbank floodwaters (CRWP 2006; Leeds-Harrison 1999; Burt 1999).

Vegetated riparian buffers maintain the connectivity and exchange of surface water and groundwater between rivers and uplands. Maintaining riparian zones and effective land use practices within these zones are widely recognized as two valuable strategies to prevent the degradation of water quality services provided by these essential riparian processes (Hancock, 2002). Because of their ability to reduce upland sources of pollutants, the influence of riparian corridors on water quality is proportionately much greater than the relatively small area in the landscape they occupy.

In general, the effectiveness of vegetated riparian buffers is proportional to their width and overall health. Sediment removal efficiency relationships developed by Castelle and Johnson (2000) estimated near 80 percent sediment removal and 65 percent particulate organic matter removal across a comparable buffer width. Other research in southwest Montana reported greater than 90 percent removal of coarse textured sediment with a six meter buffer on bunchgrass uplands (Hook 2003).

For this analysis, a sediment reduction efficiency of 75 percent was assumed to represent the loading condition for a healthy (Excellent / Good) vegetated riparian buffer. This value reflects those reported in the literature while allowing for some hillslope loading from developed and disturbed land. With 75 percent removal, 25 percent of the USLE generated upland hillslope load is delivered to the stream and assumed to be the natural occurring annual maximum load from upland hillslope erosion. The remaining 75 percent of the load is assumed to be controllable by riparian health and associated buffering capacity.

As the condition of the riparian buffer declines or is degraded, sediment reduction efficiencies of 50 percent and 25 percent are then assumed to represent the loading condition for moderately (Fair) and heavily (Poor) disturbed conditions. That is, as the overall health of the vegetated riparian buffer is degraded, hence reducing its buffering capacity (sediment reduction efficiency), sediment loading delivered to the stream from upland sources increases. With 50 percent and 25 percent removal, 50 percent and 75 percent of the USLE generated upland erosion is delivered to the stream (**Figure E-2**).

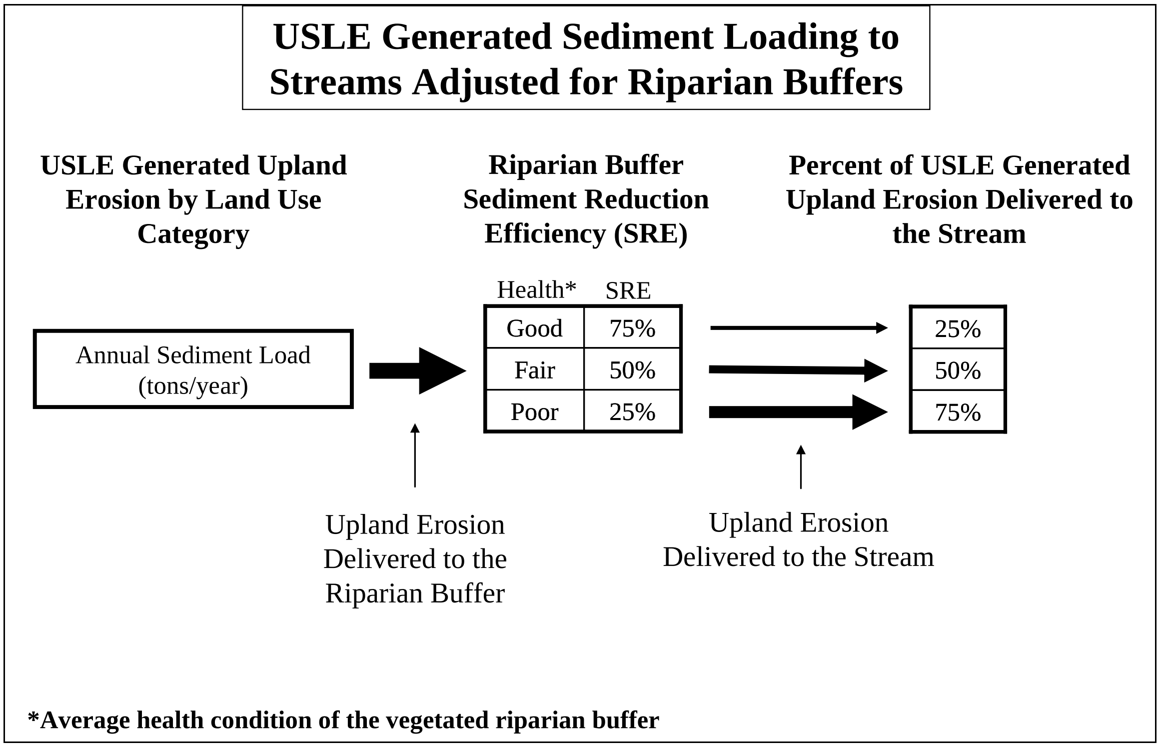

Figure E-2. USLE Upland Sediment Load Adjusted for Riparian Buffer Capacity

Riparian Health

Prior to modeling, a watershed scale riparian health assessment was undertaken to estimate the existing riparian condition of all listed tributary streams within the planning area. This process utilized data and information available within **Appendix C**, Aerial Photo Review and Field Source Assessment. As such, a data set was generated that quantified the existing riparian condition as a percent of the total stream length within each sub-watershed. Riparian health was qualified as Good, Fair or Poor (**Table E-1** and **Figure E-3**). For more information regarding the riparian health assessment see **Appendix C**.

Watershed	Existing Buffer Condition	Stream Length (mi)	Percent of Total Length	Watershed	Existing Buffer Condition	Stream Length (mi)	Percent of Total Length
Big Pipestone Creek	Good	0.0	0	**Halfway Creek**	Good	4.2	55
	Fair	14.6	72		Fair	3.4	45
	Poor	5.7	28		Poor	0.0	0
	Total	20.2	100		Total	7.6	100
Cherry Creek	Good	0.6	9	**Hells Canyon Creek**	Good	4.0	32
	Fair	4.8	70		Fair	7.9	61
	Poor	1.5	21		Poor	0.9	7
	Total	6.9	100		Total	12.8	100
Fish Creek	Good	3.2	14	**Little Pipestone Creek**	Good	1.5	9
	Fair	14.1	62		Fair	4.0	25
	Poor	5.4	24		Poor	10.7	66
	Total	22.7	100		Total	16.2	100
Fitz Creek	Good	0.0	0	**Whitetail Creek**	Good	4.8	21
	Fair	4.8	100		Fair	10.2	44
	Poor	0.0	0		Poor	8.2	35
	Total	4.8	100		Total	23.2	100

Using the information from Big Pipestone Creek as an example:

Along Big Pipestone Creek's 20.2 miles, the existing health condition of the riparian buffer was defined as consisting of 0.0 miles of Good, 14.6 miles of Fair and 5.7 miles of Poor riparian areas. Thus, the three health categories represent 0, 72 and 28 percent of the total stream length, respectfully (**Table E-1** and **Figure E-3**). This data was then used to evaluate the sediment reduction scenarios presented below.

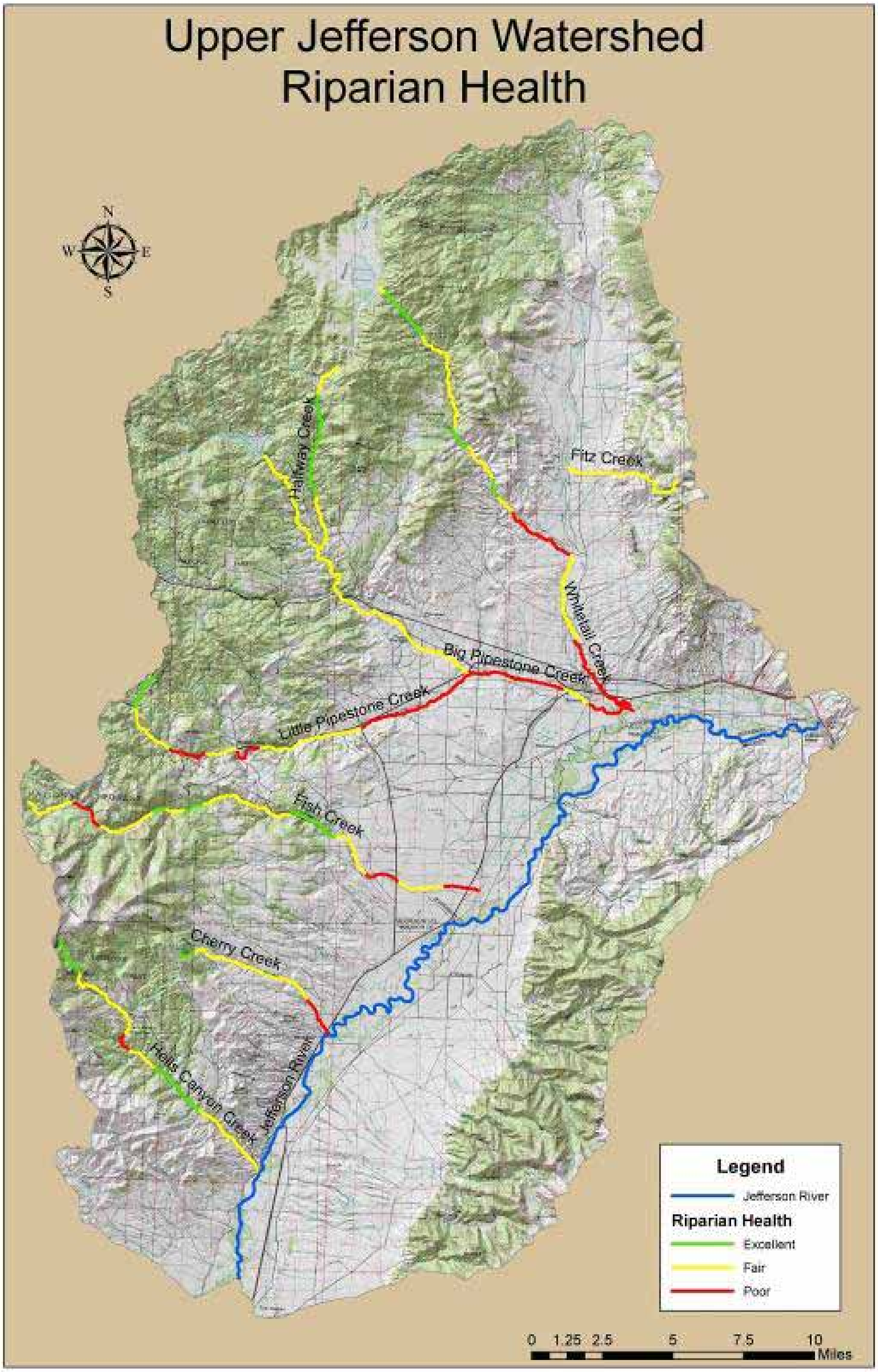

Figure E-3. Upper Jefferson River TMDL Planning Area: Existing Riparian Buffer Condition

Scenario Development

This section outlines the modeling approach that was implemented to evaluate the effect that vegetated riparian buffers have on sediment production and delivery to the stream network within the Upper Jefferson TPA. Results from this effort include the development and assessment of three scenarios:

Scenario 1: Existing Condition
This scenario evaluates the existing condition by routing the existing upland erosion USLE generated sediment load (calculated in **Appendix D**) through the existing condition of the riparian buffer (**Table E-1**). The results of this scenario then represent the existing upland sediment load delivered to the stream.

Scenario 2: Upland BMP Scenario
This scenario evaluates how the application of BMPs on upland land uses can reduce the sediment loading to the stream. For this scenario, the upland erosion USLE generated BMP load (calculated in **Appendix D**) is routed through the existing condition of the riparian buffer. The resulting load then represents the upland BMP load corrected for the existing riparian health condition. It should be noted that the reductions gained through this modeling effort are the same as the reductions modeled in the USLE modeling effort (**Appendix D**). However, the final delivered loads are reduced via riparian filtering.

Scenario 3: Upland & Riparian BMP Scenario
This scenario provides an assessment of the additional sediment load reductions that could be gained through the application of BMPs applied to land use / land management activities within the riparian buffer. For this scenario the upland erosion USLE generated BMP load (calculated in Appendix D) is routed through the potential BMP condition of the riparian buffer. The resulting load then represents the upland BMP load corrected for the riparian health BMP condition.

Under this BMP scenario, it is assumed that the implementation of BMPs on those activities that affect the overall health of the vegetated riparian buffer increases the watershed scale riparian health condition from its existing condition to 75 percent of the total stream length with a Good riparian health condition and 25 percent of the total stream length with a Fair condition. The concept is that through the application of BMPs, the general health of the vegetated riparian buffer will increase, hence increasing its sediment reduction efficiency. Twenty five percent of the stream will be left in Fair condition because it is assumed that there will always be some reasonable level of disturbance within the vegetated riparian buffer.

Results

A simple spreadsheet modeling approach was formulated to facilitate data manipulation and to generate output for this report. The results and reductions associated with the three scenarios described above are presented by 303(d) Listed tributary in **Table E-2**.

A schematic diagram of all three scenarios described above is presented in **Figure E-4** for Big Pipestone Creek. The existing upland sediment load delivered to the stream network from grazing sources within the Big Pipestone Creek watershed is 1547 tons/year (**Scenario 1**). Through the application of upland BMPs , in this case grazing practices, it is estimated that the existing sediment load could be reduced by 25 percent to 1154 tons/year (**Scenario 2**). Furthermore, through the application of BMPs applied to land use / land management activities within the riparian buffer, it is estimated that the sediment load could be further reduced by an additional 45 percent to 633 tons/year (**Scenario 3**). In total, through implementation of upland and riparian BMPs the existing upland sediment load from grazing sources within the Big Pipestone Creek watershed was reduced by 59 percent, from 1547 to 633 tons/year.

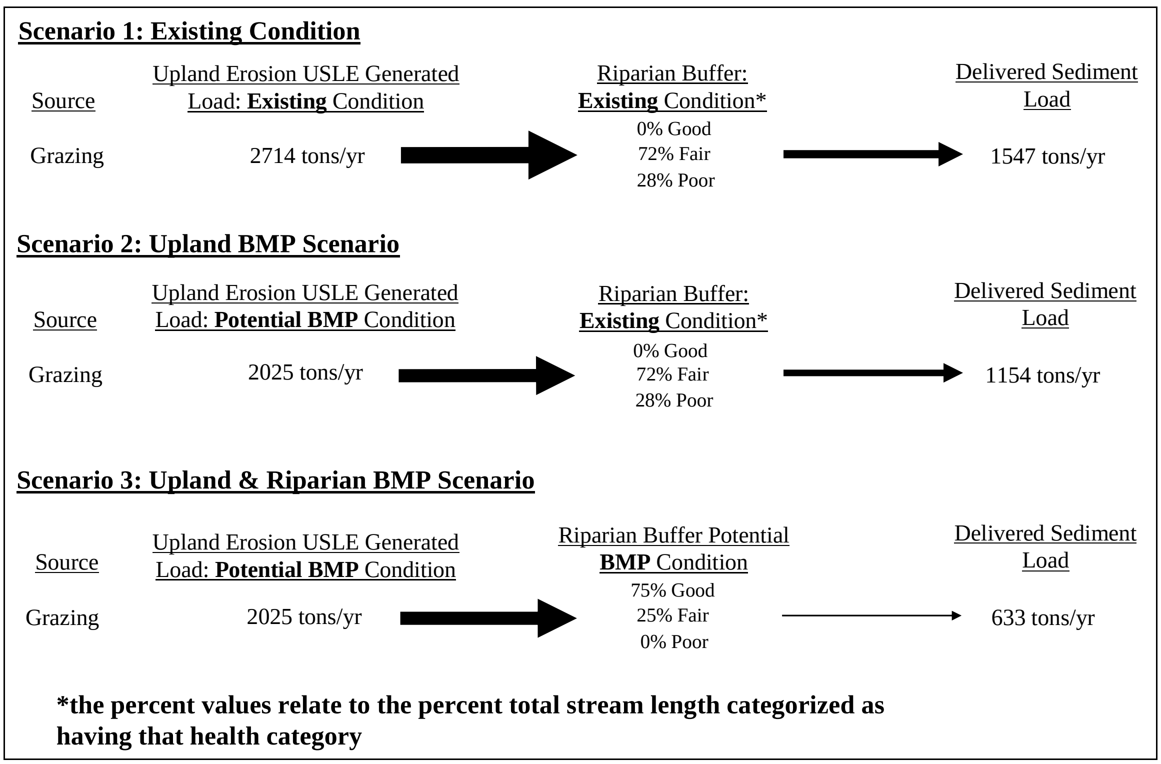

Figure E-4. Big Pipestone Creek Example of the three scenarios.

Table E-2- Upland sediment loading summary and percent reductions by watershed.

Watershed	Sources	Delivered Sediment Load (tons/year)					Overall Sediment Load Reduction
		Scenario 1	Scenario 2		Scenario 3		
		Upland Erosion USLE Load Corrected for Existing Riparian Health	Upland Erosion USLE BMP Load Corrected for Existing Riparian Health Condition (tons/yr)	Upland BMP Load Reduction	Upland Erosion USLE BMP Load Corrected for Riparian BMP Health Condition (tons/yr)	Riparian BMP Load Reduction	
Big Pipestone Creek	Grazing	1547	1154	25%	633	45%	59%
	Crops	46	7	84%	4	45%	91%
	Silviculture	2	2	0%	1	45%	45%
	Natural Sources	282	282	0%	155	45%	45%
	Total	**1877**	**1446**	**23%**	**793**	**45%**	**58%**
Cherry Creek	Grazing	234	179	23%	106	41%	55%
	Crops	0.34	0.22	35%	0.13	41%	62%
	Natural Sources	18	18	0%	11	41%	41%
	Total	**252**	**198**	**22%**	**117**	**41%**	**54%**
Fish Creek	Grazing	690	514	25%	306	40%	56%
	Crops	3	1	55%	1	40%	73%
	Silviculture	2	2	0%	1	40%	40%
	Natural Sources	122	122	0%	72	40%	41%
	Total	**817**	**640**	**22%**	**381**	**40%**	**53%**
Fitz Creek	Grazing	118	92	22%	58	38%	51%
	Crops	3.97	0.50	87%	0.31	38%	92%
	Natural Sources	8	8	0%	5	38%	38%
	Total	**130**	**101**	**22%**	**63**	**38%**	**51%**
Halfway Creek	Grazing	67	47	30%	40	14%	39%
	Natural Sources	19	19	0%	16	14%	14%
	Total	**85**	**66**	**23%**	**57**	**14%**	**34%**
Hells Canyon Creek	Grazing	668	520	22%	371	29%	44%
	Natural Sources	57	57	0%	41	29%	29%
	Total	**725**	**577**	**20%**	**412**	**29%**	**43%**
Little Pipestone Creek	Grazing	534	405	24%	197	51%	63%
	Crops	2	1	66%	0	51%	83%
	Silviculture	0.39	0.39	0%	0.19	51%	51%
	Natural Sources	73	73	0%	35	51%	51%
	Total	**609**	**479**	**21%**	**233**	**51%**	**62%**
Whitetail Creek	Grazing	2490	1920	23%	1122	42%	55%
	Crops	90	11	88%	6	42%	93%
	Silviculture	2	2	0%	1	42%	42%
	Natural Sources	270	270	0%	158	42%	42%
	Total	**2852**	**2203**	**23%**	**1287**	**42%**	**55%**