# ATTACHMENT B – FLINT CREEK WATERSHED SEDIMENT ASSESSMENT: UPLAND SEDIMENT ASSESSMENT AND MODELING AND BMP EFFECTIVENESS AND PERCENT REDUCTION POTENTIAL

# Flint Creek Watershed Sediment Assessment: Upland Sediment Assessment and Modeling and BMP Effectiveness and Percent Reduction Potential

*Final Modeling Summary Report*

Prepared for:

Montana Department of Environmental Quality
Water Quality Planning Bureau
P.O. Box 200901
Helena, MT 59620-0901

Prepared by:

Water & Environmental Technologies, PC
480 East Park Street, #200
Butte, MT 59701

September 2010

# ERRATA SHEET FOR THE FLINT CREEK WATERSHED SEDIMENT ASSESSMENT: UPLAND SEDIMENT ASSESSMENT AND MODELING AND BMP EFFECTIVENESS AND PERCENT REDUCTION POTENTIAL

The public comment period for the Draft Flint Creek Planning Area Sediment and Metals TMDLs and Framework Water Quality Improvement Plan occurred from February 17th, 2012 to April 2nd, 2012. During that time the DEQ received a number of comments on information presented within that document. The report Flint Creek Watershed Sediment Assessment : Upland Sediment Assessment and Modeling And BMP Effectiveness and Percent Reduction Potential was included in the TMDL document as Attachment B, and served as the basis for the upland sediment load quantification. One comment in particular called to question the attribution of land as “Cultivated Crops” throughout the Flint watershed. Based on their review, the acreage attributed to Cultivated Crops was significantly in error. As a result of this comment, a review was conducted and it was determined that acreage described as Cultivated Crops, was by and large incorrect, and should have been attributed as “Pasture/Hay”. This errata sheet presents revised tables where acreage previously attributed to Cultivated Crops has been converted to Pasture/Hay. For each subwatershed, the loading rate from the original Pasture/Hay category was applied to the Cultivated Crops to simulate that land use as Pasture/Hay, and calculate the corresponding sediment load. This was done for both existing and BMP scenarios. The tables below reflect these changes in loads and percent reductions and should be used in lieu of the original document tables.

**Table 2-1. Land-Use Types Present in the Flint Creek Watershed.**

| Land-Use Type | Area (acres) | Percent |
|---|---|---|
| Barren Land (Rock/Sand/Clay) | 92.76 | 0.0% |
| ~~Cultivated Crops~~* | ~~16662.05~~* | ~~5.4%~~* |
| Deciduous Forest | 20.26 | 0.0% |
| Developed, Low Intensity | 782.98 | 0.3% |
| Developed, Medium Intensity | 58.98 | 0.0% |
| Developed, High Intensity | 5.24 | 0.0% |
| Developed, Open Space | 3512.65 | 1.1% |
| Evergreen Forest | 159659.61 | 51.8% |
| Grasslands/Herbaceous | 53786.34 | 17.4% |
| Mixed Forest | 2.69 | 0.0% |
| Open Water | 3243.28 | 1.1% |
| Pasture/Hay | 31865.37 | 10.3% |
| Shrub/Scrub | 53844.24 | 17.5% |
| Woody Wetlands | 1519.83 | 0.5% |
| **Total** | **308424.26** | **100.0%** |

* Added to Pasture/Hay totals

| Table 3-1. Base Results of the USLE Model for the Flint Creek Watershed. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Sub-Watershed** | **Land Use Type** | **Area (acres)** | **Percent of Watershed** | **Existing Conditions Load (Tons/Year)** | **Existing Conditions Load (Tons/Acre/Year)** | **Desired Conditions Load (Tons/Year)** | **Desired Conditions Load (Tons/Acre/Year)** | **Percent Reduction from Existing to Desired** |
| **Barnes Creek** | Cultivated Crops* | 725 | 7% | 17.10 | 0.02 | 11.12 | 0.02 | 35% |
| | Developed, Low Intensity | 6 | 0% | 0.04 | 0.01 | 0.04 | 0.01 | 0% |
| | Developed, Open Space | 172 | 2% | 1.50 | 0.01 | 1.50 | 0.01 | 0% |
| | Evergreen Forest | 2015 | 20% | 77.25 | 0.04 | 77.25 | 0.04 | 0% |
| | Grasslands/ Herbaceous | 4589 | 45% | 564.64 | 0.12 | 470.53 | 0.10 | 17% |
| | Pasture/Hay | 645 | 6% | 15.21 | 0.02 | 9.89 | 0.02 | 35% |
| | Shrub/Scrub | 2096 | 20% | 631.65 | 0.30 | 489.53 | 0.23 | 22% |
| | Woody Wetlands | 49 | 0% | 0.79 | 0.02 | 0.79 | 0.02 | 0% |
| | **Total Sub-Watershed** | **10298** | **100%** | **1308.17** | **0.13** | **1060.64** | **0.10** | **19%** |
| **Boulder Creek** | Barren Land | 72 | 0% | 0.22 | 0.00 | 0.22 | 0.00 | 0% |
| | Cultivated Crops* | 3 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Developed, Low Intensity | 22 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Open Space | 24 | 0% | 0.14 | 0.01 | 0.14 | 0.01 | 0% |
| | Evergreen Forest | 39068 | 92% | 732.95 | 0.02 | 732.95 | 0.02 | 0% |
| | Grasslands/ Herbaceous | 555 | 1% | 51.95 | 0.09 | 43.29 | 0.08 | 17% |
| | Open Water | 71 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 28 | 0% | 0.96 | 0.03 | 0.62 | 0.02 | 35% |
| | Shrub/Scrub | 2352 | 6% | 406.31 | 0.17 | 314.89 | 0.13 | 23% |
| | Woody Wetlands | 45 | 0% | 0.33 | 0.01 | 0.33 | 0.01 | 0% |
| | **Total Sub-Watershed** | **42240** | **100%** | **1192.86** | **0.03** | **1092.45** | **0.03** | **8%** |
| **Douglas Creek North** | Cultivated Crops* | 27 | 0% | 0.59 | 0.02 | 0.38 | 0.01 | 35% |
| | Developed, Low Intensity | 2 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Med. Intensity | 1 | 0% | 0.01 | 0.01 | 0.01 | 0.01 | 0% |
| | Developed, Open Space | 75 | 1% | 4.24 | 0.06 | 4.24 | 0.06 | 0% |
| | Evergreen Forest | 5122 | 55% | 194.84 | 0.04 | 194.84 | 0.04 | 0% |
| | Grasslands/ Herbaceous | 2086 | 22% | 313.68 | 0.15 | 261.40 | 0.13 | 17% |
| | Open Water | 3 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 65 | 1% | 1.41 | 0.02 | 0.92 | 0.01 | 35% |
| | Shrub/Scrub | 1992 | 21% | 549.40 | 0.28 | 425.79 | 0.21 | 22% |
| | Woody Wetlands | 2 | 0% | 0.01 | 0.00 | 0.01 | 0.00 | 0% |
| | **Total Sub-Watershed** | **9376** | **100%** | **1064.18** | **0.11** | **887.58** | **0.09** | **17%** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Douglas Creek-Philipsburg** | Barren Land | 3 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Cultivated Crops* | 57 | 1% | 0.11 | 0.00 | 0.07 | 0.00 | 35% |
| | Developed, High Intensity | 1 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Low Intensity | 28 | 1% | 0.07 | 0.00 | 0.07 | 0.00 | 0% |
| | Developed, Med. Intensity | 7 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Open Space | 109 | 3% | 1.82 | 0.02 | 1.82 | 0.02 | 0% |
| | Evergreen Forest | 3382 | 83% | 37.67 | 0.01 | 37.67 | 0.01 | 0% |
| | Grasslands/ Herbaceous | 85 | 2% | 8.73 | 0.10 | 7.28 | 0.09 | 17% |
| | Pasture/Hay | 47 | 1% | 0.09 | 0.00 | 0.06 | 0.00 | 35% |
| | Shrub/Scrub | 378 | 9% | 54.43 | 0.14 | 42.19 | 0.11 | 22% |
| | **Total Sub-Watershed** | **4096** | **100%** | **102.93** | **0.03** | **89.16** | **0.02** | **13%** |
| **Fred Burr Creek** | Barren Land | 2 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Cultivated Crops* | 68 | 1% | 1.76 | 0.03 | 1.14 | 0.02 | 35% |
| | Developed, Low Intensity | 6 | 0% | 0.01 | 0.00 | 0.01 | 0.00 | 0% |
| | Developed, Open Space | 33 | 0% | 0.19 | 0.01 | 0.19 | 0.01 | 0% |
| | Evergreen Forest | 9218 | 92% | 113.01 | 0.01 | 113.01 | 0.01 | 0% |
| | Grasslands/ Herbaceous | 128 | 1% | 4.47 | 0.03 | 3.73 | 0.03 | 17% |
| | Open Water | 140 | 1% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 63 | 1% | 1.61 | 0.03 | 1.05 | 0.02 | 35% |
| | Shrub/Scrub | 329 | 3% | 30.66 | 0.09 | 23.76 | 0.07 | 22% |
| | Woody Wetlands | 65 | 1% | 0.51 | 0.01 | 0.51 | 0.01 | 0% |
| | **Total Sub-Watershed** | **10053** | **100%** | **152.22** | **0.02** | **143.40** | **0.01** | **6%** |
| **Georgetown Lake** | Barren Land | 4 | 0% | 0.03 | 0.01 | 0.03 | 0.01 | 0% |
| | Cultivated Crops* | 16 | 0% | 0.92 | 0.06 | 0.37 | 0.02 | 35% |
| | Deciduous Forest | 4 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Low Intensity | 17 | 0% | 0.20 | 0.01 | 0.20 | 0.01 | 0% |
| | Developed, Med. Intensity | 4 | 0% | 0.18 | 0.04 | 0.18 | 0.04 | 0% |
| | Developed, Open Space | 105 | 0% | 1.06 | 0.01 | 1.06 | 0.01 | 0% |
| | Evergreen Forest | 15767 | 72% | 125.93 | 0.01 | 125.93 | 0.01 | 0% |
| | Grasslands/ Herbaceous | 959 | 4% | 38.40 | 0.04 | 32.00 | 0.03 | 17% |
| | Open Water | 2877 | 13% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 15 | 0% | 0.84 | 0.06 | 0.54 | 0.04 | 35% |
| | Shrub/Scrub | 1983 | 9% | 126.84 | 0.06 | 98.30 | 0.05 | 22% |
| | Woody Wetlands | 24 | 0% | 0.03 | 0.00 | 0.03 | 0.00 | 0% |
| | **Total Sub-Watershed** | **21776** | **100%** | **294.41** | **0.01** | **258.86** | **0.01** | **12%** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Lower Flint Creek** | Barren Land | 9 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Cultivated Crops* | 6886 | 17% | 84.17 | 0.01 | 54.71 | 0.01 | 35% |
| | Deciduous Forest | 6 | 0% | 0.01 | 0.00 | 0.01 | 0.00 | 0% |
| | Developed, Low Intensity | 258 | 1% | 0.17 | 0.00 | 0.17 | 0.00 | 0% |
| | Developed, Med. Intensity | 8 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Open Space | 992 | 2% | 3.26 | 0.00 | 3.26 | 0.00 | 0% |
| | Evergreen Forest | 5282 | 13% | 158.40 | 0.03 | 158.40 | 0.03 | 0% |
| | Grasslands/ Herbaceous | 13659 | 34% | 2314.75 | 0.17 | 1928.96 | 0.14 | 17% |
| | Mixed Forest | 1 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 68% |
| | Open Water | 4 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 5642 | 14% | 68.96 | 0.01 | 44.82 | 0.01 | 35% |
| | Shrub/Scrub | 7108 | 18% | 1830.75 | 0.26 | 1418.83 | 0.20 | 23% |
| | Woody Wetlands | 572 | 1% | 3.25 | 0.01 | 3.25 | 0.01 | 0% |
| | **Total Sub-Watershed** | **40427** | **100%** | **4463.71** | **0.11** | **3612.41** | **0.09** | **19%** |
| **Lower Willow Creek** | Cultivated Crops* | 2900 | 13% | 74.27 | 0.03 | 48.27 | 0.02 | 35% |
| | Deciduous Forest | 4 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Low Intensity | 22 | 0% | 0.01 | 0.00 | 0.01 | 0.00 | 0% |
| | Developed, Open Space | 302 | 1% | 1.45 | 0.00 | 1.45 | 0.00 | 0% |
| | Evergreen Forest | 2555 | 12% | 24.41 | 0.01 | 24.41 | 0.01 | 0% |
| | Grasslands/ Herbaceous | 8354 | 39% | 1217.10 | 0.15 | 1014.25 | 0.12 | 17% |
| | Open Water | 134 | 1% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 1810 | 8% | 46.37 | 0.03 | 30.14 | 0.02 | 35% |
| | Shrub/Scrub | 5322 | 25% | 896.94 | 0.17 | 695.13 | 0.13 | 23% |
| | Woody Wetlands | 108 | 1% | 0.47 | 0.00 | 0.47 | 0.00 | 0% |
| | **Total Sub-Watershed** | **21511** | **100%** | **2261.01** | **0.11** | **1814.13** | **0.08** | **20%** |
| **Middle Flint Creek** | Cultivated Crops* | 2796 | 6% | 59.50 | 0.02 | 38.68 | 0.01 | 35% |
| | Developed, High Intensity | 4 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Low Intensity | 306 | 1% | 1.10 | 0.00 | 1.10 | 0.00 | 0% |
| | Developed, Med. Intensity | 32 | 0% | 0.01 | 0.00 | 0.01 | 0.00 | 0% |
| | Developed, Open Space | 971 | 2% | 7.98 | 0.01 | 7.98 | 0.01 | 0% |
| | Evergreen Forest | 21036 | 43% | 600.22 | 0.03 | 600.22 | 0.03 | 0% |
| | Grasslands/ Herbaceous | 9693 | 20% | 1790.51 | 0.18 | 1492.09 | 0.15 | 17% |
| | Mixed Forest | 2 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Open Water | 12 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 2853 | 6% | 60.72 | 0.02 | 39.47 | 0.01 | 35% |
| | Shrub/Scrub | 10645 | 22% | 3740.73 | 0.35 | 2899.07 | 0.27 | 22% |
| | Woody Wetlands | 348 | 1% | 4.25 | 0.01 | 4.25 | 0.01 | 0% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Total Sub-Watershed** | **48696** | **100%** | **6265.02** | **0.13** | **5082.86** | **0.10** | **19%** |
| **Princeton Gulch** | Evergreen Forest | 2819 | 96% | 131.56 | 0.05 | 131.56 | 0.05 | 0% |
| | Grasslands/ Herbaceous | 8 | 0% | 1.63 | 0.22 | 1.36 | 0.18 | 17% |
| | Shrub/Scrub | 110 | 4% | 135.15 | 1.23 | 104.74 | 0.95 | 23% |
| | **Total Sub-Watershed** | **2937** | **100%** | **268.34** | **0.09** | **237.66** | **0.08** | **11%** |
| **Smart Creek** | Barren Land | 4 | 0% | 0.01 | 0.00 | 0.01 | 0.00 | 0% |
| | Cultivated Crops* | 221 | 1% | 7.38 | 0.03 | 4.79 | 0.02 | 35% |
| | Developed, Low Intensity | 3 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Open Space | 46 | 0% | 0.25 | 0.01 | 0.25 | 0.01 | 0% |
| | Evergreen Forest | 9321 | 60% | 218.55 | 0.02 | 218.55 | 0.02 | 0% |
| | Grasslands/ Herbaceous | 1774 | 11% | 212.29 | 0.12 | 176.91 | 0.10 | 17% |
| | Pasture/Hay | 203 | 1% | 6.77 | 0.03 | 4.40 | 0.02 | 35% |
| | Shrub/Scrub | 4015 | 26% | 1051.10 | 0.26 | 814.61 | 0.20 | 22% |
| | Woody Wetlands | 38 | 0% | 0.23 | 0.01 | 0.23 | 0.01 | 0% |
| | **Total Sub-Watershed** | **15626** | **100%** | **1496.59** | **0.10** | **1219.76** | **0.08** | **18%** |
| **Trout Creek** | Cultivated Crops* | 2064 | 9% | 90.10 | 0.04 | 58.56 | 0.03 | 35% |
| | Developed, Low Intensity | 40 | 0% | 0.08 | 0.00 | 0.08 | 0.00 | 0% |
| | Developed, Open Space | 325 | 1% | 2.71 | 0.01 | 2.71 | 0.01 | 0% |
| | Evergreen Forest | 5890 | 26% | 21.85 | 0.00 | 21.85 | 0.00 | 0% |
| | Grasslands/ Herbaceous | 5212 | 23% | 1022.73 | 0.20 | 852.27 | 0.16 | 17% |
| | Open Water | 2 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 2718 | 12% | 118.63 | 0.04 | 77.11 | 0.03 | 35% |
| | Shrub/Scrub | 6260 | 28% | 1852.35 | 0.30 | 1435.57 | 0.23 | 22% |
| | Woody Wetlands | 49 | 0% | 0.82 | 0.02 | 0.82 | 0.02 | 0% |
| | **Total Sub-Watershed** | **22560** | **100%** | **3109.26** | **0.14** | **2448.97** | **0.11** | **21%** |
| **Upper Flint Creek** | Cultivated Crops* | 713 | 5% | 9.44 | 0.01 | 6.13 | 0.01 | 35% |
| | Developed, Low Intensity | 67 | 0% | 0.10 | 0.00 | 0.10 | 0.00 | 0% |
| | Developed, Med. Intensity | 2 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Open Space | 353 | 3% | 2.09 | 0.01 | 2.09 | 0.01 | 0% |
| | Evergreen Forest | 9028 | 66% | 50.26 | 0.01 | 50.26 | 0.01 | 0% |
| | Grasslands/ Herbaceous | 945 | 7% | 140.56 | 0.15 | 117.13 | 0.12 | 17% |
| | Pasture/Hay | 1004 | 7% | 13.30 | 0.01 | 8.64 | 0.01 | 35% |
| | Shrub/Scrub | 1506 | 11% | 134.52 | 0.09 | 104.25 | 0.07 | 23% |
| | Woody Wetlands | 69 | 1% | 0.57 | 0.01 | 0.57 | 0.01 | 0% |
| | **Total Sub-Watershed** | **13687** | **100%** | **350.84** | **0.03** | **289.19** | **0.02** | **18%** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Upper Willow Creek** | Cultivated Crops* | 196 | 0% | 6.72 | 0.03 | 4.37 | 0.02 | 35% |
| | Deciduous Forest | 5 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Evergreen Forest | 29213 | 65% | 851.54 | 0.03 | 851.54 | 0.03 | 0% |
| | Grasslands/ Herbaceous | 5735 | 13% | 829.06 | 0.14 | 690.88 | 0.12 | 17% |
| | Pasture/Hay | 153 | 0% | 5.27 | 0.03 | 3.42 | 0.02 | 35% |
| | Shrub/Scrub | 9726 | 22% | 3440.31 | 0.35 | 2666.24 | 0.27 | 22% |
| | Woody Wetlands | 152 | 0% | 0.77 | 0.01 | 0.77 | 0.01 | 0% |
| | **Total Sub-Watershed** | **45180** | **100%** | **5133.67** | **0.11** | **4217.23** | **0.09** | **18%** |
| **Total Flint Creek Watershed** | | **308461** | **100%** | **27463.23** | **0.089** | **22454.29** | **0.07** | **18%** |

*Cultivated Crops treated as Pasture/Hay. Loading rates mirror that of Pasture/Hay.

**Table 3-2. Results of the USLE Model with Riparian Health Incorporation.**

| **Sub-Watershed** | **Existing Condition Load (tons/yr)** | **Desired Condition Load (tons/yr)** | **Scenario 1** | | **Scenario 2** | | **Scenario 3** | | **Total Load Reduction with use of Upland and Riparian BMPs** |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Existing Upland Load with Existing Riparian Condition (tons/yr)** | **Percent Load Reduction with use of Riparian Condition** | **Desired Upland Load with Existing Riparian Condition (tons/yr)** | **Percent Load Reduction with use of Upland BMPs** | **Desired Upland Load with Improved Riparian Health (tons/yr)** | **Percent Load Reduction with use of Riparian BMPs** | |
| Barnes Creek | 1308.17 | 1060.64 | 605 | 54% | 491 | 19% | 265 | 46% | 56% |
| Boulder Creek | 1192.86 | 1092.45 | 494 | 59% | 452 | 8% | 279 | 38% | 44% |
| Douglas Creek - North | 1064.18 | 887.58 | 535 | 50% | 446 | 17% | 244 | 45% | 54% |
| Douglas Creek- | 102.93 | 89.16 | 58 | 44% | 50 | 13% | 34 | 33% | 42% |
| Fred Burr | 155.22 | 143.40 | 61 | 61% | 57 | 8% | 36 | 36% | 41% |
| Georgetown Lake | 294.41 | 258.86 | 146 | 50% | 129 | 12% | 74 | 42% | 49% |
| Lower Flint | 4463.71 | 3612.41 | 2276 | 49% | 1842 | 19% | 948 | 49% | 58% |
| Lower Willow Creek | 2261.01 | 1814.13 | 1121 | 50% | 900 | 20% | 467 | 48% | 58% |
| Middle Flint Creek | 6265.02 | 5082.86 | 3195 | 49% | 2592 | 19% | 1334 | 49% | 58% |
| Princeton | 268.34 | 237.66 | 124 | 54% | 110 | 11% | 62 | 44% | 50% |
| Smart Creek | 1496.59 | 1219.76 | 685 | 54% | 558 | 18% | 305 | 45% | 55% |
| Trout Creek | 3109.26 | 2448.97 | 1555 | 50% | 1224 | 21% | 612 | 50% | 61% |
| Upper Flint | 350.84 | 289.19 | 179 | 49% | 147 | 18% | 76 | 49% | 58% |
| Upper Willow Creek | 5133.67 | 4217.23 | 2554 | 50% | 2098 | 18% | 1212 | 42% | 53% |
| **Total Watershed** | **27463.23** | **22454.29** | **15104** | **50%** | **11171** | **18%** | **6456** | **42%** | **53%** |

**TABLE OF CONTENTS**



**LIST OF FIGURES**



**LIST OF TABLES**

## 1.0 Introduction

This report presents results of the Flint Creek Watershed upland sediment modeling assessment. This upland sediment model was developed to provide Total Maximum Daily Load (TMDL) estimations of existing annual sediment loads from each of the various upland land cover/land use types in the watershed, and to estimate potential sediment reduction that may occur through land use changes and implementation of best management practices (BMPs) designed to improve upland land condition or riparian health.

Under Montana law, an impaired water body is defined as a water body for which sufficient and credible data indicates non-compliance with applicable water quality standards (MCA 75-5-103). Section 303 of the Federal Clean Water Act requires states to submit a list of impaired water bodies or stream segments to the U.S. Environmental Protection Agency (EPA) every two years. Prior to 2004, this list was referred to as the "303(d) list", but is now named the "Integrated Report". The Montana Water Quality Act further directs states to develop TMDLs for all water bodies appearing on the 303(d) list as impaired or threatened by "pollutants" (MCA 75-5-703). If sufficient credible data exists to support the sediment impairment determinations for the 1996 listed streams, then sediment TMDLs will be developed. If sufficient data does not exist, then data will be collected to confirm or deny the 1996 listings and TMDLs will be developed for all streams determined to be impaired. In 2009, Montana Department of Environmental Quality (DEQ) initiated an effort to collect data to support the development of sediment TMDLs for listed streams within the Flint Creek TMDL Planning Area (TPA). This included data collection efforts to estimate sediment delivery to streams from both streambank erosion and from upland sediment production, which is described within this report. The data provided in this report is intended to assist DEQ in evaluating the impairment status of tributary streams in the Flint Creek TPA and for developing TMDLs where necessary.

The Flint Creek TPA encompasses an area of approximately 500 square miles in southwestern Montana (**Figure 1-1**) and lies almost entirely in Granite County with a small portion in Deer Lodge County. The Flint Creek watershed originates in the Flint Creek Mountains to the east, the Pintlar Mountains to the south, and the Sapphire and John Long Mountains to the west. Flint Creek drains from Georgetown Lake and bisects two large agricultural valleys, the Philipsburg Valley and the Drummond Valley, which are separated by a narrow bedrock canyon. Flow in upper Flint Creek is primarily controlled by the outlet structure at Georgetown Lake, and flow is seasonally augmented by a trans-basin diversion from the East Fork of Rock Creek. Approximately 2,200 residents reside within the Flint Creek TPA, with Philipsburg (pop. 911) and Drummond (pop. 315) as the largest towns. Other population centers include Maxville and Hall. Land ownership in the Flint Creek TPA is primarily private and U.S. Forest Service (Beaverhead-Deer Lodge National Forest), with a small amount of land managed by Bureau of Land Management (BLM) and the State of Montana. Private lands are located predominantly in the lower elevation areas where wide, low-gradient valleys are conducive to agriculture and development. The land use of the Flint TPA is dominated by evergreen forest (52%), shrub/scrub land (17%), and grassland/herbaceous land (17%).

The 303(d) streams listed for sediment in the Flint Creek watershed include Barnes Creek, Douglas Creek (near Philipsburg), Smart Creek, and Flint Creek. For the purposes of this project, the Flint Creek TPA was partitioned into smaller sub-watersheds in order to spatially evaluate upland sediment loading. The sub-watersheds evaluated in this study include Georgetown Lake, Upper Flint Creek, Trout Creek, Fred Burr Creek, Douglas Creek-Philipsburg, Middle Flint Creek, Boulder Creek, Princeton Gulch, Smart Creek, Lower Flint Creek, Douglas Creek-North, Upper Willow Creek, Lower Willow Creek, and Barnes Creek, as shown below in **Figure 1-2**.

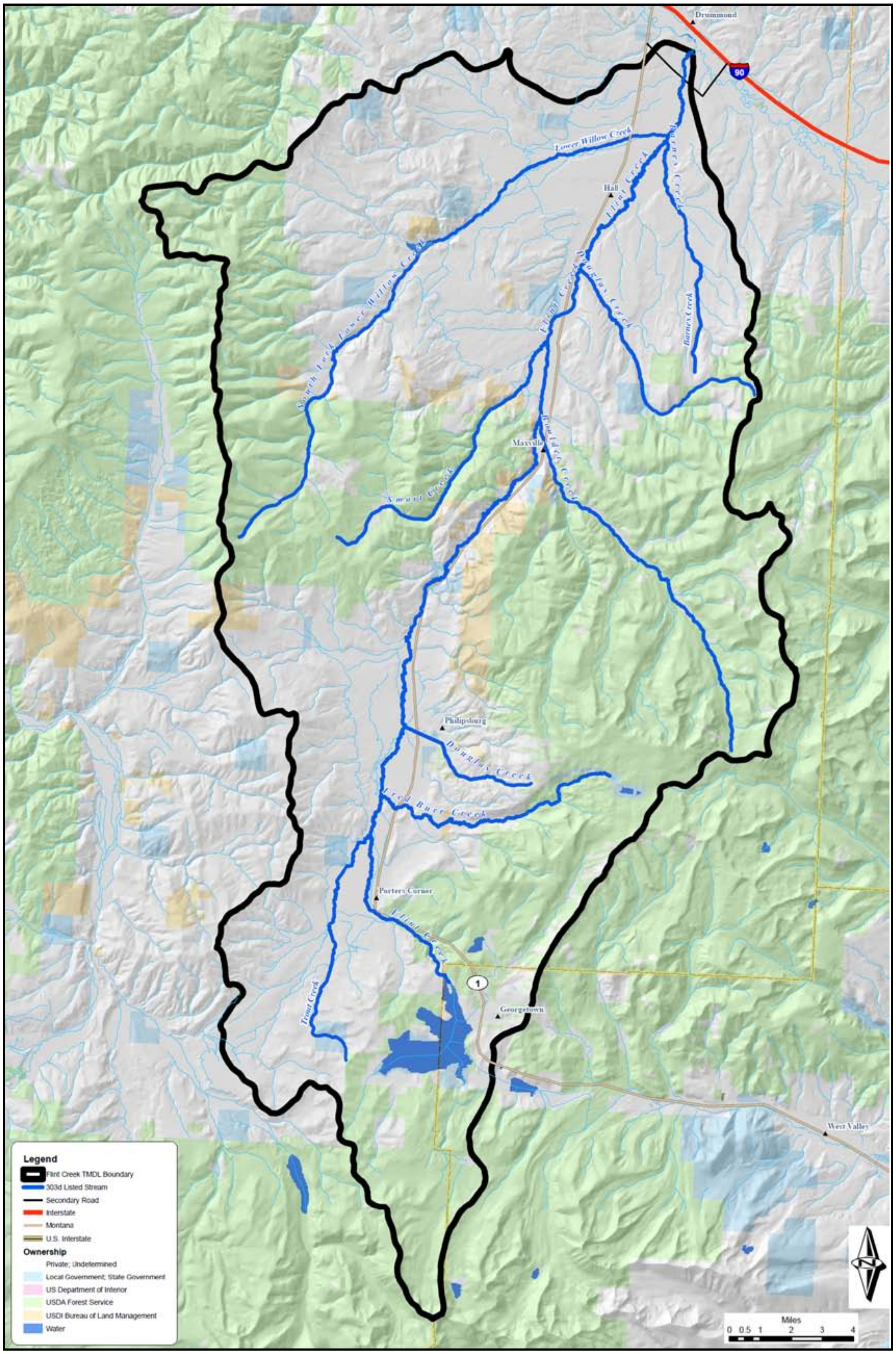


**Figure 1-1. Flint Creek Watershed.**

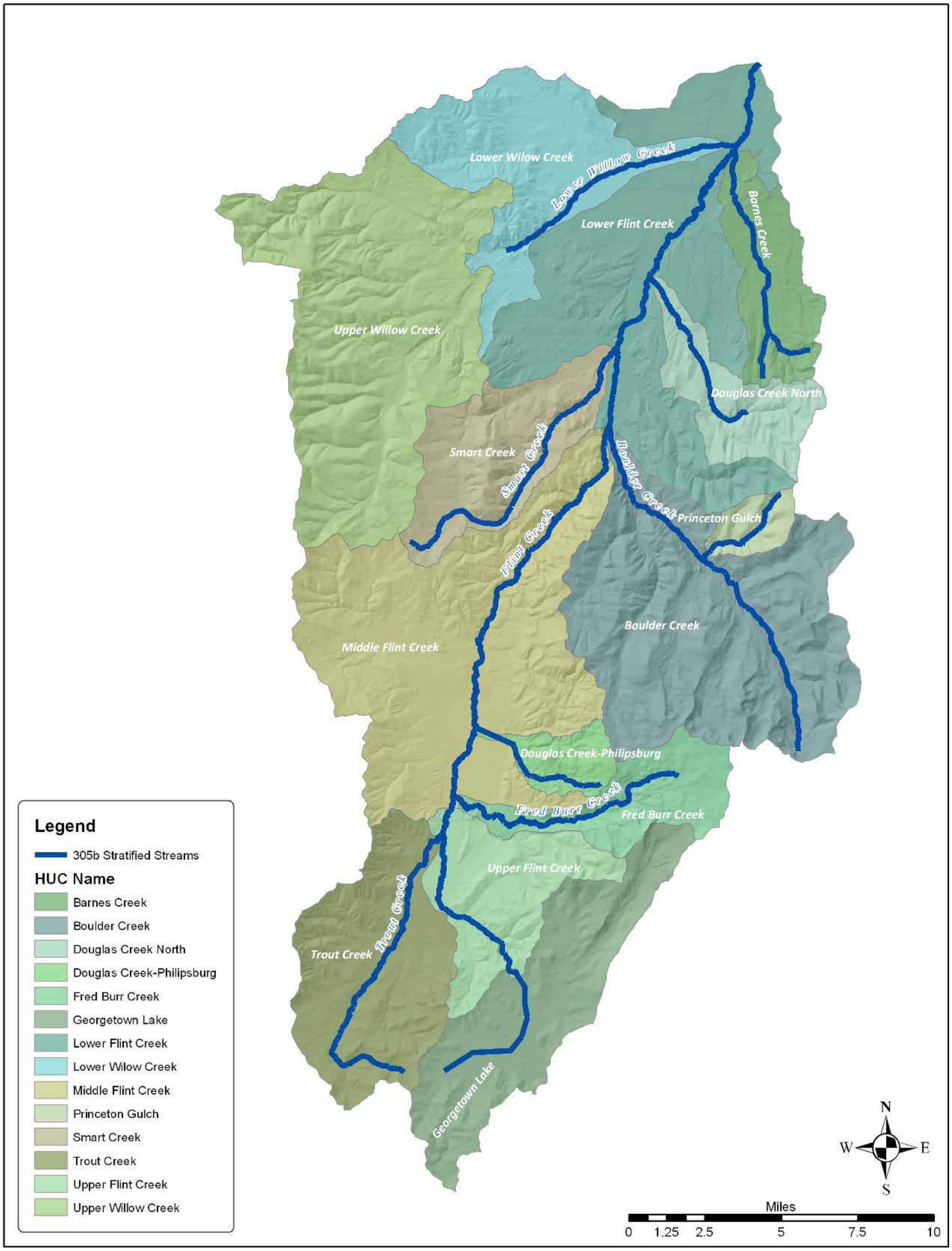


**Figure 1-2. Sub-Basins of the Flint Creek Watershed.**

## 2.0 Model Approach

Sediment delivery from upland erosion was modeled using a Universal Soil Loss Equation (USLE) based model. The USLE was originally developed by the USDA Agricultural Research Service based on data from agricultural plots under natural rainfall, and later incorporated data from simulated rainfall experiments to evaluate the effectiveness of conservation tillage and construction practices for controlling soil erosion. The USLE model was later refined to include non-agricultural settings, such as developed land, forests, and rangeland. For this modeling effort, the USLE was implemented as a watershed-scale, raster-based, GIS model using ArcView software. The USLE model requires five landscape factors which are combined to predict upland soil loss, including a rainfall factor (R), soil erodibility factor (K), length and slope factors (LS), a cropping factor (C), and a management practices factor (P). The general form of the USLE equation has been widely used for upland sediment erosion modeling and is presented as (Brooks et al. 1997):

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

The USLE model estimates sediment production from upland erosion sources. However, in order to extrapolate to the watershed scale, results of the model were combined with a sediment delivery ratio (SDR) to estimate the quantity of sediment that actually reaches the stream. Previous studies (Dube et al. 2004) have determined that the percent of sediment delivered to streams decreases with distance, so a distance-based sediment delivery ratio was applied to the USLE model results. Furthermore, the USLE model does not evaluate the effect of vegetated riparian buffers at removing sediment, so model results were combined with a riparian health condition to evaluate the effect of existing and improved riparian buffers at filtering sediment.

Three scenarios were modeled during this analysis to quantify sediment delivery under existing and improved conditions. These scenarios were chosen to estimate the reduction of upland erosion that may be accomplished with the implementation of BMPs that are intended to improve upland erosion conditions or riparian health. An example of a BMP practice intended to improve upland condition would be a reduction of grazing that increased the percent ground cover. A BMP strategy to improve riparian health might include riparian fencing that is designed to exclude grazing animals and increase the quality and size of the vegetated riparian buffer. The three scenarios modeled in this exercise include:

- Scenario 1) an Existing Conditions scenario that quantifies sediment delivery under the existing upland land cover and the existing riparian health condition,

- Scenario 2) an Upland BMP Conditions scenario that quantifies sediment delivery using a desired upland land cover that represents the implementation of upland management BMPs and the existing riparian health condition, and

- Scenario 3) an Improved Riparian and Upland BMP Conditions scenario using the desired upland land cover with implementation of BMPs and an improved riparian health condition with use of riparian BMPs.

### 2.1 Data Sources

The following sections provide data sources and results of the individual parameter data collected for the Flint Creek USLE model.

#### 2.1.1 R – Rainfall Factor

The R-factor characterizes the effect of raindrop impact and runoff rates associated with a rainstorm. It is determined using the kinetic energy of a rainfall event (hundreds of ft-tons per acre per year) and the maximum 30-minute rainfall intensity (inches per hour) for an area. The total kinetic energy of a rain event is obtained by multiplying the kinetic energy per inch of rainfall by the depth of rainfall during each intensity period. The rainfall and runoff factor grid for the Flint Creek watershed was obtained from the NRCS and is based on PRISM (Parameter-elevation Regressions on Independent Slopes Model) precipitation data developed by the Spatial Climate Analysis Service at Oregon State University (SCAS) at 4 km grid cell resolution. For the purposes of this analysis, the SCAS R-factor grid was projected to Montana State Plane Coordinates (NAD83), resampled to a 10m analytic cell size and clipped to the extent of the Flint Creek watershed to match the project's standard grid definition. The R-Factor for the Flint Creek watershed is shown below in **Figure 2-1**.

#### 2.1.2 K – Soil Erodibility Factor

The K-factor is a soil erodibility factor that quantifies the susceptibility of soil to resist erosion. It is a measure of the average soil loss (tons per acre per hundreds of ft-tons per acre of rainfall intensity) from a particular soil in continuous fallow, and has been derived from previous experimental data. A high value K-factor will result in more erosion than a low value K-factor. Polygon data for the K-factor were obtained from the NRCS Soil Survey Geographic database (SSURGO), which is the most detailed level of soil data developed by the National Cooperative Soil Survey. Soils data were summarized and interpolated to 10m grid format. The K-factor for the Flint Creek watershed is shown below in **Figure 2-2.**

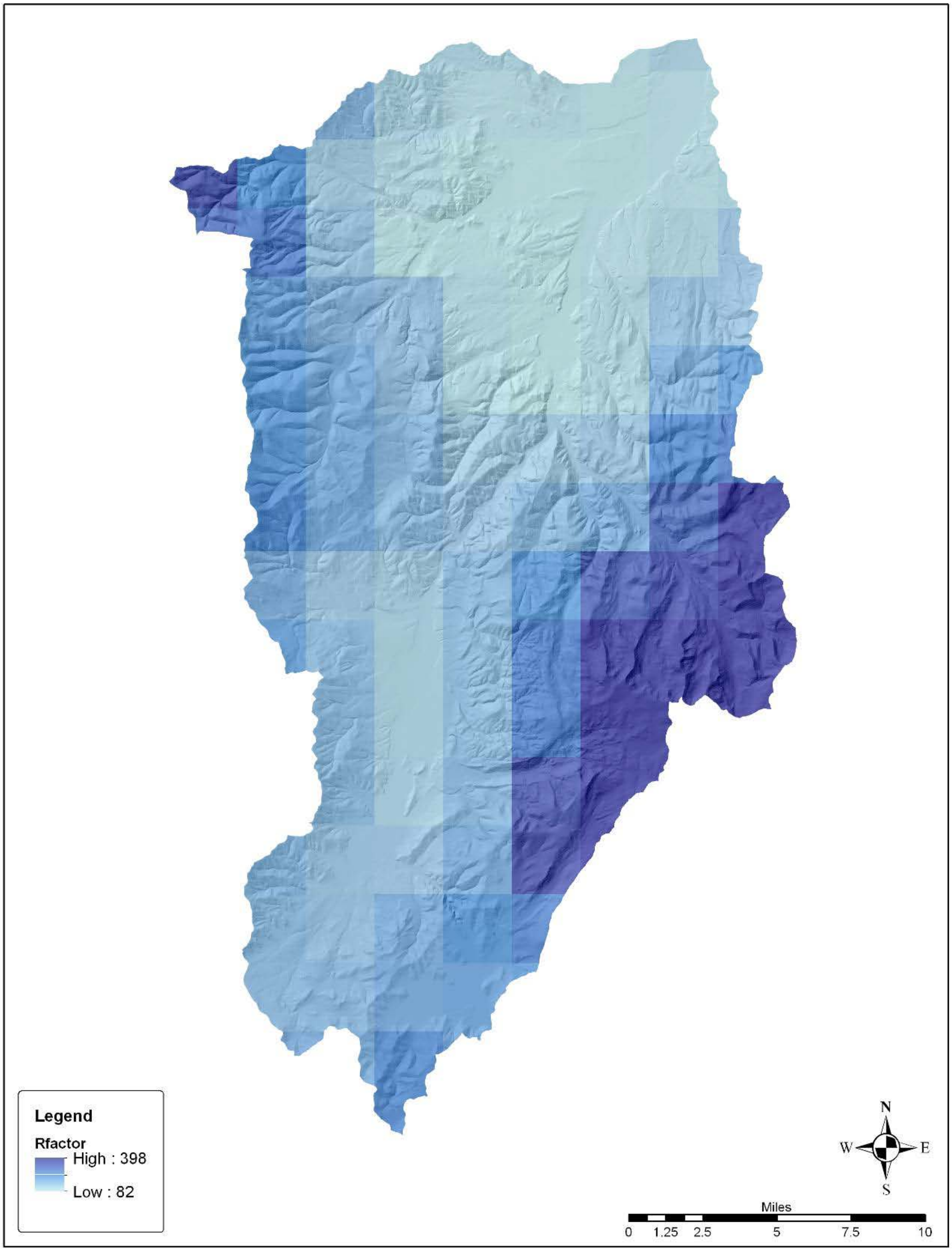


**Figure 2-1. USLE R-factor for the Flint Creek Watershed.**

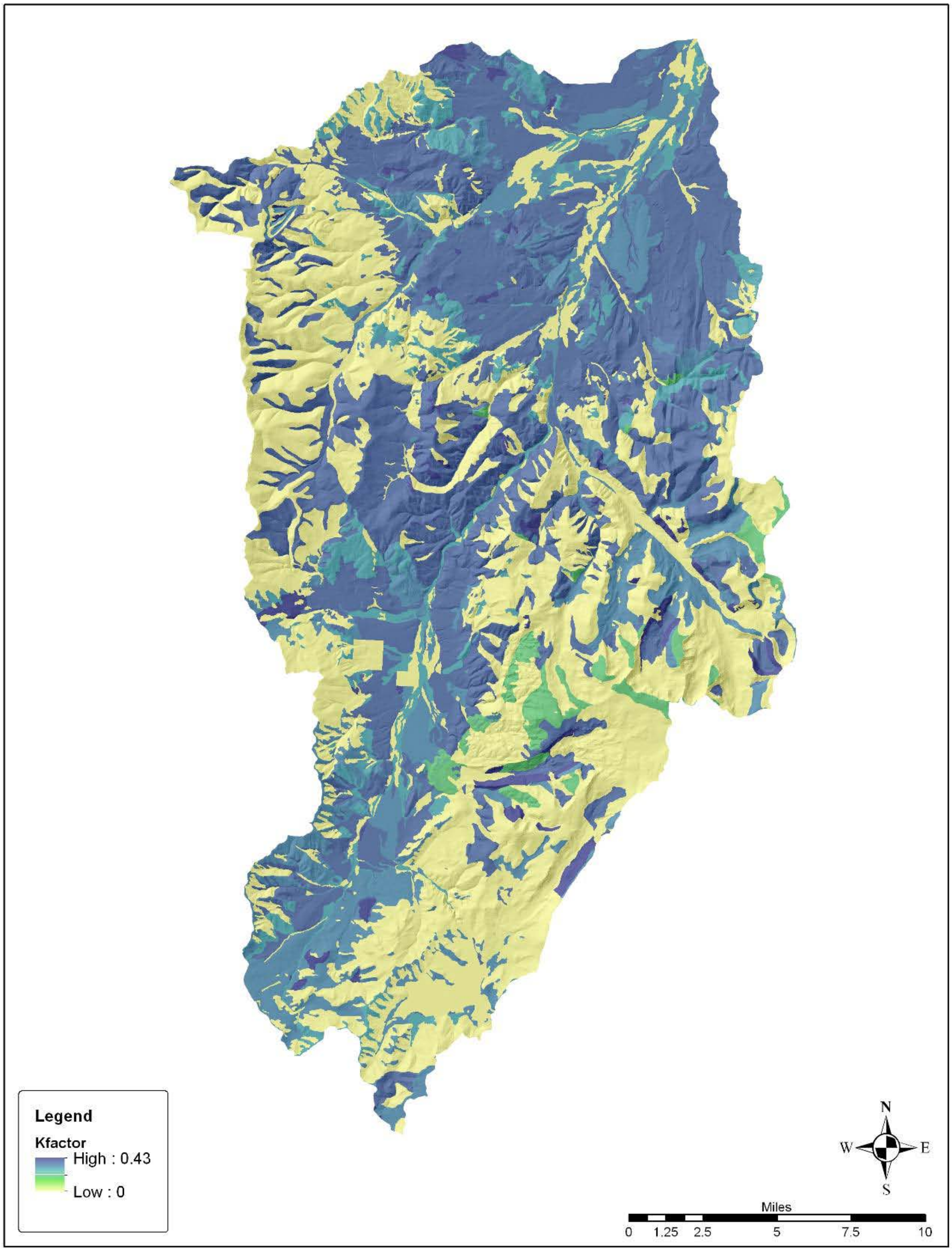


**Figure 2-2. USLE K-factor for the Flint Creek Watershed.**

### 2.1.3 LS – Length and Slope Factors

The LS-factor is a function of the slope and flow length of the eroding slope or cell. For the purpose of computing the LS-factor, slope is defined as the average land surface gradient across the cell based on the elevations of neighboring cells. The flow length refers to the distance between where overland flow originates and runoff reaches a defined channel or depositional zone. A longer slope length and steeper slopes translates into higher soil erosion rates. The equation used for calculating the length and slope factor (LS) was provided by Lim, et al. (2005) using a method developed by Moore and Burch (1986 a, b). The equation used to calculate LS is provided below; where A is flow length multiplied by cell size, and $\Theta$ is slope angle in degrees.

$$LS = \left( \frac{A}{22.13} \right)^{0.4} * \left( \frac{\sin \Theta}{0.0896} \right)^{1.3}$$

The LS-factor was derived from the digital elevation model (DEM) of the Flint Creek watershed. The USGS 30m DEM was used for these analyses, which was later interpolated to a 10m analytic grid cell to render the delineated stream network more representative of the actual size of Flint Creek watershed streams and to minimize resolution dependent stream network anomalies. The National Elevation Dataset (NED) is the primary elevation data product produced and distributed by the USGS and provides the best available public domain raster elevation data of the conterminous United States, Alaska, Hawaii, and territorial islands in a seamless format. The length and slope factors are calculated from the DEM within the model. Results of the DEM for the Flint Creek watershed is provided below in **Figure 2-3.**

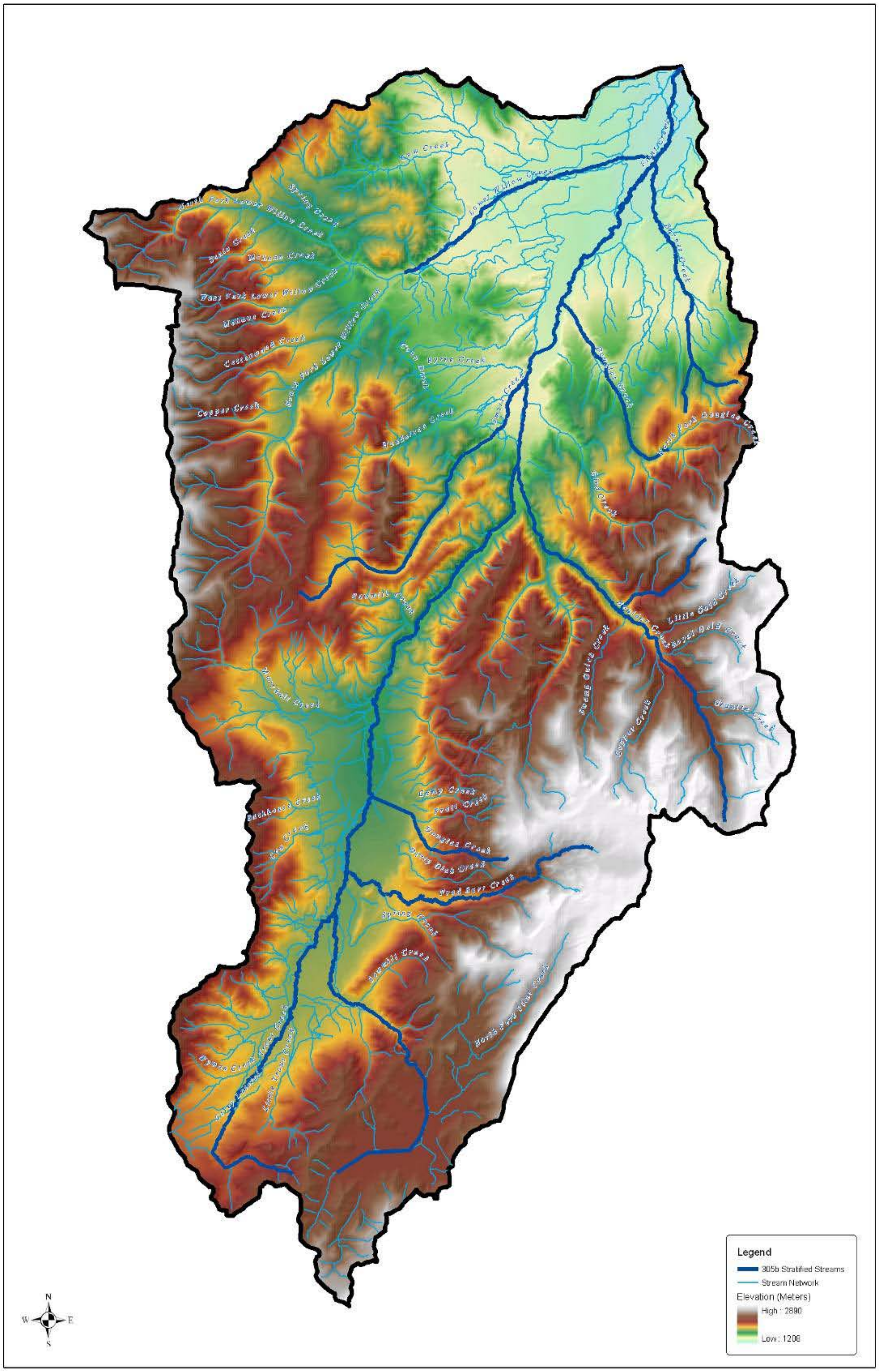


**Figure 2-3. Digital Elevation Model (DEM) of the Flint Creek Watershed.**

### 2.1.4 NLCD – National Land Cover Dataset

The 2001 National Land Cover Dataset (NLCD) was obtained from USGS and is developed through a cooperative project conducted by the Multi-Resolution Land Characteristics (MRLC) Consortium, a partnership of nine federal agencies. This layer provides land-use categories that are used to establish USLE C-factors for the Flint Creek watershed. The NLCD is a categorized 30 meter Landsat Thematic Mapper image shot in 2001. The NLCD image was reprojected to Montana State plane projection/coordinate system, and resampled to the project standard 10m grid. Results of the NLCD are shown below in **Figure 2-4.** NLCD land cover classification codes present in the Flint Creek watershed are described below and the percent distribution of each category is provided in **Table 2-1**.

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

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

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

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

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

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

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

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

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

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

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

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

82. Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

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

**Table 2-1. Land-Use Types Present in the Flint Creek Watershed.**

| Land-Use Type | Area (acres) | Percent |
|---|---|---|
| Barren Land (Rock/Sand/Clay) | 92.76 | 0.0% |
| Cultivated Crops | 16662.05 | 5.4% |
| Deciduous Forest | 20.26 | 0.0% |
| Developed, Low Intensity | 782.98 | 0.3% |
| Developed, Medium Intensity | 58.98 | 0.0% |
| Developed, High Intensity | 5.24 | 0.0% |
| Developed, Open Space | 3512.65 | 1.1% |
| Evergreen Forest | 159659.61 | 51.8% |
| Grasslands/Herbaceous | 53786.34 | 17.4% |
| Mixed Forest | 2.69 | 0.0% |
| Open Water | 3243.28 | 1.1% |
| Pasture/Hay | 15233.32 | 4.9% |
| Shrub/Scrub | 53844.24 | 17.5% |
| Woody Wetlands | 1519.83 | 0.5% |
| **Total** | **308424.26** | **100.0%** |

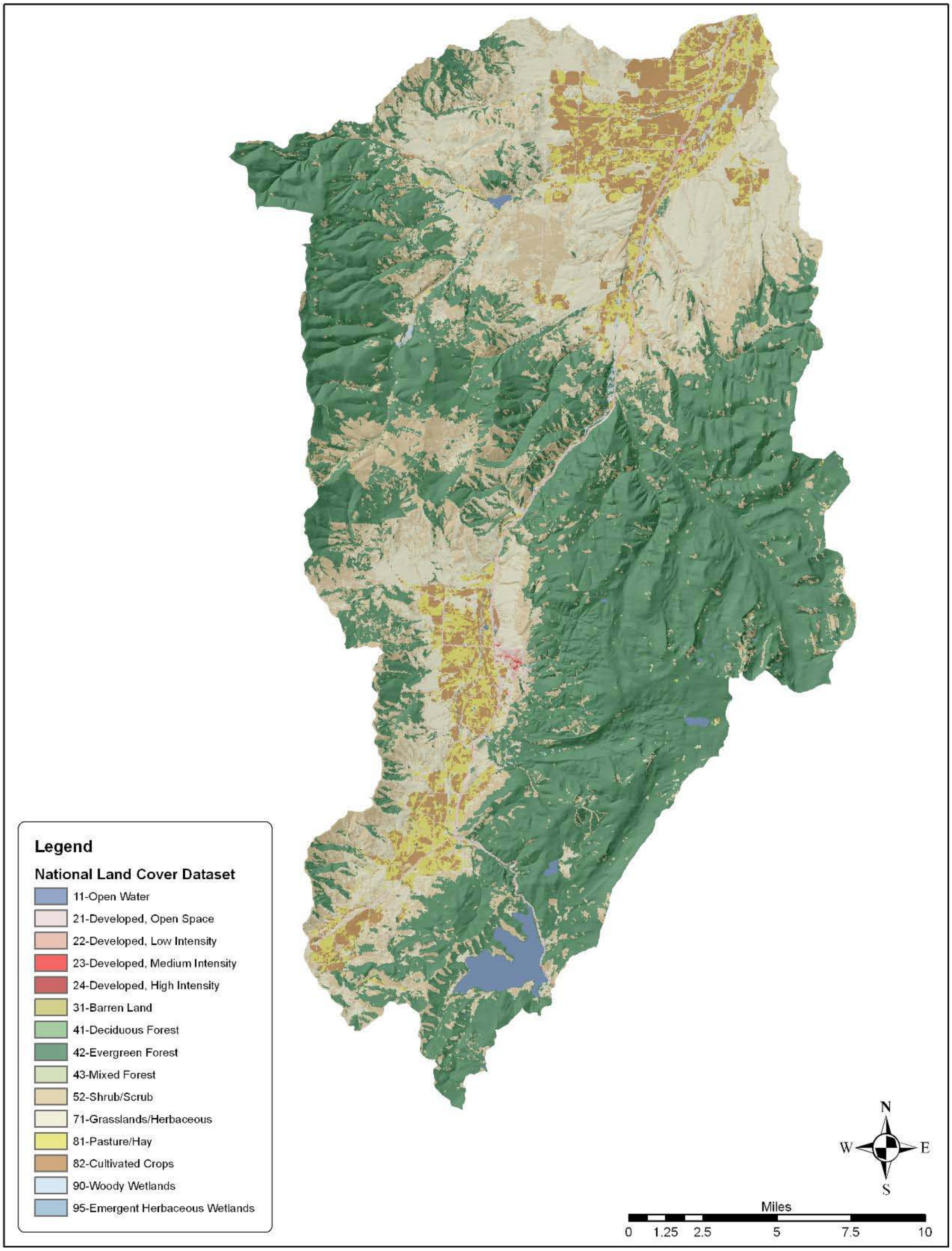


**Figure 2-4. National Land Cover Dataset (2001) for the Flint Creek Watershed.**

### 2.1.5 C – Crop Management Factor

The C-factor is a crop management value that represents the ratio of soil erosion from a specific cover type compared to the erosion that would occur on a clean-tilled fallow under identical slope and rainfall. A high value C-factor will result in more soil erosion than a low value C-factor. The C-factor integrates a number of variables that influence erosion, including vegetative cover, plant litter, soil surface, and land management. The original C-factors for USLE were experimentally determined for agricultural crops, and have since been modified to include rangeland and forest cover. It is now referred to as the vegetation management factor (VM) for non-agricultural settings (Brooks et al. 1997). Three primary variables are considered when determining the VM-factor, including: (1) canopy cover effects, (2) effects of low-growing vegetal cover, mulch, and litter, and (3) rooting structure.

A classification scheme was used to assign USLE C-factors to the NLCD land-use types present in the Flint Creek watershed. This classification scheme was initially developed based on ground and canopy cover percentages established by the Soil Conservation Service (USDA 1977, published in Brooks et al. 1997), and has been refined for the Flint Creek watershed based on recommendations from NRCS and/or other local land management agency staff and best professional judgment.

In order to estimate the potential sediment reduction that might be accomplished under BMP scenarios, the model was run using C-factors assigned to both the existing and desired upland condition. To determine C-factors for the desired upland condition, C-factors for the existing upland condition were adjusted to reflect the ground and canopy cover that best represents an improved land condition in the Flint Creek watershed with implementation of BMPs. For example, ground and canopy cover percentages for shrub/scrub and grassland/herbaceous land would increase 10% with the reduction of grazing pressure, while ground cover percentages for mixed forest would increase 5%. Ground cover percentages for pasture/hay and cultivated crop land would increase 10% and 20%, respectively, with the implementation of BMP practices designed to reduce erosion, such as conservation tillage or crop stripping. C-factor values for the existing and improved condition are provided below in **Table 2-2**, along with their respective canopy and ground cover percentages.

**Table 2-2. C-Factor Classification Scheme for the Flint Creek Watershed.**

| Land-Use Description | Canopy Cover (%) | | Ground Cover (%) | | C-Factor | |
|---|---|---|---|---|---|---|
| | Existing | Improved | Existing | Improved | Existing | Improved |
| Barren Land (Rock) | - | - | - | - | 0.001 | 0.001 |
| Developed, Open Space | 0 | 0 | 95 | 95 | 0.003 | 0.003 |
| Developed Land (Low, Medium, or High Intensity) | - | - | - | - | 0.001 | 0.001 |
| Deciduous or Evergreen Forest | 75 | 75 | 90 | 90 | 0.003 | 0.003 |
| Mixed Forest | 75 | 75 | **90** | **95** | **0.003** | **0.001** |
| Shrub/Scrub | **25** | **35** | **55** | **65** | **0.04** | **0.031** |
| Grasslands/Herbaceous | **0** | **10** | **55** | **65** | **0.042** | **0.035** |
| Pasture/Hay | 0 | 0 | **70** | **80** | **0.02** | **0.013** |
| Cultivated Crops | 0 | 0 | **20** | **40** | **0.24** | **0.15** |
| Woody Wetlands | 35 | 35 | 70 | 70 | 0.003 | 0.003 |

### 2.1.6 P – Conservation Practices Factor

The P-factor is a conservation practices factor that considers interaction of supporting land management practices and slope. This factor incorporates the use of erosion control practices such as strip-cropping, terracing and contouring, and is applicable only to agricultural lands. The P-factor will be set to one for this analysis since land-management practices designed to reduce upland erosion are not heavily used within the Flint Creek watershed, and alterations in C-factor values for agricultural land use categories are used to represent the BMP applications.

### 2.1.7 SDR – Sediment Delivery Ratio

USLE model results were combined with a sediment delivery ratio (**SDR**) to predict sediment delivery to streams. The USLE model was derived from experimental data on small agricultural plots, and the SDR enables us to extrapolate sediment delivery from upland sources to the watershed scale. The SDR is derived for each grid cell based on the distance from the cell to the nearest stream. This distance-based relationship was established during development of the WARSEM road sediment model by integrating previous studies which evaluated sediment delivery down slope of forest roads (Dube et al. 2004). These studies determined that the percent of sediment delivered to streams decreases with distance based on the relationship shown in **Table 2-3**. This relationship has been applied in previous USLE models for TMDL development, and is considered to be a conservative estimate of sediment delivery from upland erosion. For this exercise, the SDR is incorporated into the GIS model and is included in the USLE base results prior to the incorporation of the riparian health condition.

**Table 2-3. Sediment Delivery vs. Distance from Stream.**

| Distance from Stream (ft) | Percent of Sediment Delivered to Stream |
|---|---|
| 0 | 100 |
| 35 | 70 |
| 70 | 50 |
| 105 | 35 |
| 140 | 25 |
| 175 | 18 |
| 210 | 10 |
| 245 | 4 |
| 280 | 3 |
| 315 | 2 |
| 350 | 1 |

### 2.1.8 Riparian Health Incorporation

Well vegetated riparian buffers act as filters that effectively trap sediment from overland flow. The ability of riparian buffers to trap sediment is generally proportional to their width and overall health. Previous studies (Castelle and Johnson 2000) have estimated that approximately 80% of sediment and 65% of particulate organic matter can be removed across a healthy riparian buffer. Studies within Montana suggest that sediment generated from upland erosional sources can be reduced by 25% (Middle Blackfoot TMDL) to 90% (Hook 2003). The USLE model does not specifically incorporate riparian function of stream corridors, but rather looks at the land use and land cover as a whole. Since we are viewing sediment production at the watershed scale and determining the ultimate sediment load delivered to streams, the existing riparian health condition and potential changes to riparian health are included within these estimations.

A riparian health factor was applied to the base results of the USLE model to evaluate the reduction of sediment input to streams based on the condition of their riparian vegetation. A coarse level riparian health assessment was previously conducted for the Flint Creek watershed by Montana DEQ. Ratings of poor, fair, and good were assigned to the left and right bank of all delineated reaches on each surveyed stream. Results of this analysis are shown below in **Table 2-4**. For this analysis, the Upper, Middle, and Lower Flint Creek sub-watersheds were given the riparian health condition derived for all of Flint Creek. The Upper Willow Creek and Georgetown Lake sub-watersheds were not evaluated for riparian health condition, and were assigned the watershed wide riparian health condition for the purposes of this incorporation.

**Table 2-4. Riparian Health Condition of the Flint Creek Watershed.**

| Watershed | Riparian Condition Percent Distribution | | |
|---|---|---|---|
| | **Good** | **Fair** | **Poor** |
| Barnes Creek | 15 | 85 | - |
| Boulder Creek | 36 | 62 | 2 |
| Douglas Creek (North) | 7 | 83 | 10 |
| Douglas Creek (Philipsburg) | 15 | 34 | 51 |
| Flint Creek | 0 | 95 | 5 |
| Fred Burr | 43 | 56 | 1 |
| Lower Willow Creek | 4 | 93 | 3 |
| Princeton Gulch | 18 | 78 | 4 |
| Smart Creek | 17 | 83 | - |
| Trout Creek | - | 100 | - |
| **Watershed Wide Average** | **19** | **76** | **10** |

To incorporate riparian health data into the base USLE results, riparian condition estimates identified in the stream stratification effort are tallied for each watershed of interest, and a buffering efficiency (i.e. sediment delivery reduction) is assumed for each riparian category (good=75%, fair=50%, poor=30%). This value was multiplied to the sediment load corresponding to the percentage of riparian condition within each watershed. For example, Barnes Creek was found to have 15% "good" riparian condition and 85% "fair" riparian condition. If 100 tons/year of sediment were determined from the base USLE model to enter the stream from upland sources, then 15 tons would be reduced by 75% (a total of 3.75 tons remaining) to account for the "good" riparian condition, and 85 tons would be reduced by 50% (42.5 tons remaining) to account for the "fair" riparian condition. This leaves a total buffered sediment load of 46.25 tons delivered to the stream, or a reduction of 53.75% as a result of riparian buffer conditions.

To estimate sediment delivery under improved riparian conditions that would result from implementation of riparian BMPs, the riparian buffer conditions of each stream are increased from "fair" to "good" and from "poor" to "fair". In the case above for Barnes Creek, the improved riparian buffer would be adjusted to reflect 100% "good" riparian condition, and therefore, a 75% reduction would be applied to the total sediment load. The concept is that through the application of riparian BMPs, the health of the vegetated riparian buffer will increase, hence increasing its sediment reduction efficiency.

### 2.1.9 Management Scenarios

The results of the USLE model with the riparian health incorporation form the basis for TMDL estimations and potential sediment reductions. Three scenarios were modeled in order to provide TMDL estimations for upland sediment delivery under existing and improved conditions. These scenarios were chosen to estimate the reduction of upland erosion that may be accomplished with the implementation of BMPs that are intended to improve upland erosion conditions or riparian health. An example of a BMP practice intended to improve upland condition would be a reduction of grazing pressure that increased the percent ground cover. A BMP strategy to improve riparian health might include riparian fencing that is designed to exclude grazing animals and increase the quality and size of the vegetated riparian buffer. The three scenarios modeled in this exercise include:

- Scenario 1) an Existing Conditions scenario that quantifies sediment delivery under the existing upland land cover and the existing riparian health condition,

- Scenario 2) an Upland BMP Conditions scenario that quantifies sediment delivery using a desired upland land cover that represents the implementation of upland management BMPs and the existing riparian health condition, and

- Scenario 3) an Improved Riparian and Upland BMP Conditions scenario using the desired upland land cover with implementation of BMPs and an improved riparian health condition with use of riparian BMPs.

## 3.0 Results

Sediment loading results for the existing and desired upland conditions are provided below in **Table 3-1**. This table presents the base results of the USLE model (including the SDR) before the incorporation of the riparian health condition. Results of the USLE model with the riparian health incorporation follow in **Table 3-2**. Results are presented by sub-watershed and land-use type. It should be noted that the sub-watersheds listed are not additive of watershed areas upstream, and include only the total for the sub-watershed listed. Sediment loads for existing upland conditions in individual sub-watersheds ranged from 107.9 tons/year (Douglas Creek - Philipsburg) to 6740.4 tons/year (Middle Flint Creek), with a total watershed sediment load of 30,360 tons/year. Using the desired upland condition, minimum and maximum sediment loads for individual sub-watersheds were reduced to 92.3 tons/year (Douglas Creek - Philipsburg) and 5378.5 tons/year (Middle Flint Creek), with a total watershed sediment load of 24,256 tons/year. Sediment loading rates for existing upland conditions ranged from 0.014 tons/acre/year in the Georgetown Lake sub-watershed to 0.18 tons/acre/year in Trout Creek, with a total watershed average of 0.098 tons/acre/year. Under desired upland conditions, these values were reduced to 0.012 and 0.14 tons/acre/year for Georgetown Lake and Trout Creek sub-watersheds, respectively, with a total watershed average of 0.079 tons/acre/year.

Results of the USLE model with the riparian health incorporation are presented in **Table 3-2**, including results of the three model scenarios. These results form the basis for TMDL estimations and potential sediment reductions. Under Scenario 1, existing upland sediment loads were reduced by 44-61% when the buffering capacity of the existing riparian health condition is considered. Under Scenario 2, upland sediment loads were reduced by 8-25% with the use of upland management BMPs that result in the desired upland condition. Under Scenario 3, upland sediment loads were reduced by 33-50% with the use of BMPs that improve riparian health condition and increase the riparian buffering capacity. The total load reduction potential with the use of both upland and riparian BMPs ranged from 42-63% for the sub-watersheds.

**Table 3-1. Base Results of the USLE Model for the Flint Creek Watershed.**

| Sub-Watershed | Land Use Type | Area (acres) | Percent of Watershed | Existing Conditions Load (Tons/Year) | Existing Conditions Load (Tons/Acre /Year) | Desired Conditions Load (Tons/Year) | Desired Conditions Load (Tons/Acre /Year) | Percent Reduction from Existing to Desired |
|---|---|---|---|---|---|---|---|---|
| **Barnes Creek** | Cultivated Crops | 725 | 7% | 82.20 | 0.11 | 51.38 | 0.07 | 37% |
| | Developed, Low Intensity | 6 | 0% | 0.04 | 0.01 | 0.04 | 0.01 | 0% |
| | Developed, Open Space | 172 | 2% | 1.50 | 0.01 | 1.50 | 0.01 | 0% |
| | Evergreen Forest | 2015 | 20% | 77.25 | 0.04 | 77.25 | 0.04 | 0% |
| | Grasslands/Herbaceous | 4589 | 45% | 564.64 | 0.12 | 470.53 | 0.10 | 17% |
| | Pasture/Hay | 645 | 6% | 15.21 | 0.02 | 9.89 | 0.02 | 35% |
| | Shrub/Scrub | 2096 | 20% | 631.65 | 0.30 | 489.53 | 0.23 | 22% |
| | Woody Wetlands | 49 | 0% | 0.79 | 0.02 | 0.79 | 0.02 | 0% |
| | **Total Sub-Watershed** | **10298** | **100%** | **1373.27** | **0.13** | **1100.90** | **0.11** | **20%** |
| **Boulder Creek** | Barren Land | 72 | 0% | 0.22 | 0.00 | 0.22 | 0.00 | 0% |
| | Cultivated Crops | 3 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Developed, Low Intensity | 22 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Open Space | 24 | 0% | 0.14 | 0.01 | 0.14 | 0.01 | 0% |
| | Evergreen Forest | 39068 | 92% | 732.95 | 0.02 | 732.95 | 0.02 | 0% |
| | Grasslands/Herbaceous | 555 | 1% | 51.95 | 0.09 | 43.29 | 0.08 | 17% |
| | Open Water | 71 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 28 | 0% | 0.96 | 0.03 | 0.62 | 0.02 | 35% |
| | Shrub/Scrub | 2352 | 6% | 406.31 | 0.17 | 314.89 | 0.13 | 23% |
| | Woody Wetlands | 45 | 0% | 0.33 | 0.01 | 0.33 | 0.01 | 0% |
| | **Total Sub-Watershed** | **42240** | **100%** | **1192.86** | **0.03** | **1092.45** | **0.03** | **8%** |
| **Douglas Creek North** | Cultivated Crops | 27 | 0% | 3.96 | 0.15 | 2.48 | 0.09 | 38% |
| | Developed, Low Intensity | 2 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Med. Intensity | 1 | 0% | 0.01 | 0.01 | 0.01 | 0.01 | 0% |
| | Developed, Open Space | 75 | 1% | 4.24 | 0.06 | 4.24 | 0.06 | 0% |
| | Evergreen Forest | 5122 | 55% | 194.84 | 0.04 | 194.84 | 0.04 | 0% |
| | Grasslands/Herbaceous | 2086 | 22% | 313.68 | 0.15 | 261.40 | 0.13 | 17% |
| | Open Water | 3 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 65 | 1% | 1.41 | 0.02 | 0.92 | 0.01 | 35% |
| | Shrub/Scrub | 1992 | 21% | 549.40 | 0.28 | 425.79 | 0.21 | 22% |
| | Woody Wetlands | 2 | 0% | 0.01 | 0.00 | 0.01 | 0.00 | 0% |
| | **Total Sub-Watershed** | **9376** | **100%** | **1067.55** | **0.11** | **889.68** | **0.09** | **17%** |
| **Douglas Creek-Philipsburg** | Barren Land | 3 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Cultivated Crops | 57 | 1% | 5.07 | 0.09 | 3.17 | 0.06 | 38% |
| | Developed, High Intensity | 1 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Low Intensity | 28 | 1% | 0.07 | 0.00 | 0.07 | 0.00 | 0% |
| | Developed, Med. Intensity | 7 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Open Space | 109 | 3% | 1.82 | 0.02 | 1.82 | 0.02 | 0% |

Table 3-1. Base Results of the USLE Model for the Flint Creek Watershed.

| Sub-Watershed | Land Use Type | Area (acres) | Percent of Watershed | Existing Conditions Load (Tons/Year) | Existing Conditions Load (Tons/Acre /Year) | Desired Conditions Load (Tons/Year) | Desired Conditions Load (Tons/Acre /Year) | Percent Reduction from Existing to Desired |
|---|---|---|---|---|---|---|---|---|
| | Evergreen Forest | 3382 | 83% | 37.67 | 0.01 | 37.67 | 0.01 | 0% |
| | Grasslands/Herbaceous | 85 | 2% | 8.73 | 0.10 | 7.28 | 0.09 | 17% |
| | Pasture/Hay | 47 | 1% | 0.09 | 0.00 | 0.06 | 0.00 | 35% |
| | Shrub/Scrub | 378 | 9% | 54.43 | 0.14 | 42.19 | 0.11 | 22% |
| | **Total Sub-Watershed** | **4096** | **100%** | **107.90** | **0.03** | **92.26** | **0.02** | **14%** |
| **Fred Burr Creek** | Barren Land | 2 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Cultivated Crops | 68 | 1% | 23.10 | 0.34 | 14.44 | 0.21 | 37% |
| | Developed, Low Intensity | 6 | 0% | 0.01 | 0.00 | 0.01 | 0.00 | 0% |
| | Developed, Open Space | 33 | 0% | 0.19 | 0.01 | 0.19 | 0.01 | 0% |
| | Evergreen Forest | 9218 | 92% | 113.01 | 0.01 | 113.01 | 0.01 | 0% |
| | Grasslands/Herbaceous | 128 | 1% | 4.47 | 0.03 | 3.73 | 0.03 | 17% |
| | Open Water | 140 | 1% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 63 | 1% | 1.61 | 0.03 | 1.05 | 0.02 | 35% |
| | Shrub/Scrub | 329 | 3% | 30.66 | 0.09 | 23.76 | 0.07 | 22% |
| | Woody Wetlands | 65 | 1% | 0.51 | 0.01 | 0.51 | 0.01 | 0% |
| | **Total Sub-Watershed** | **10053** | **100%** | **173.56** | **0.02** | **156.69** | **0.02** | **10%** |
| **Georgetown Lake** | Barren Land | 4 | 0% | 0.03 | 0.01 | 0.03 | 0.01 | 0% |
| | Cultivated Crops | 16 | 0% | 0.59 | 0.04 | 0.37 | 0.02 | 38% |
| | Deciduous Forest | 4 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Low Intensity | 17 | 0% | 0.20 | 0.01 | 0.20 | 0.01 | 0% |
| | Developed, Med. Intensity | 4 | 0% | 0.18 | 0.04 | 0.18 | 0.04 | 0% |
| | Developed, Open Space | 105 | 0% | 1.06 | 0.01 | 1.06 | 0.01 | 0% |
| | Evergreen Forest | 15767 | 72% | 125.93 | 0.01 | 125.93 | 0.01 | 0% |
| | Grasslands/Herbaceous | 959 | 4% | 38.40 | 0.04 | 32.00 | 0.03 | 17% |
| | Open Water | 2877 | 13% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 15 | 0% | 0.84 | 0.06 | 0.54 | 0.04 | 35% |
| | Shrub/Scrub | 1983 | 9% | 126.84 | 0.06 | 98.30 | 0.05 | 22% |
| | Woody Wetlands | 24 | 0% | 0.03 | 0.00 | 0.03 | 0.00 | 0% |
| | **Total Sub-Watershed** | **21776** | **100%** | **294.09** | **0.01** | **258.63** | **0.01** | **12%** |
| **Lower Flint Creek** | Barren Land | 9 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Cultivated Crops | 6886 | 17% | 827.85 | 0.12 | 517.41 | 0.08 | 37% |
| | Deciduous Forest | 6 | 0% | 0.01 | 0.00 | 0.01 | 0.00 | 0% |
| | Developed, Low Intensity | 258 | 1% | 0.17 | 0.00 | 0.17 | 0.00 | 0% |
| | Developed, Med. Intensity | 8 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Open Space | 992 | 2% | 3.26 | 0.00 | 3.26 | 0.00 | 0% |
| | Evergreen Forest | 5282 | 13% | 158.40 | 0.03 | 158.40 | 0.03 | 0% |
| | Grasslands/Herbaceous | 13659 | 34% | 2314.75 | 0.17 | 1928.96 | 0.14 | 17% |

**Table 3-1. Base Results of the USLE Model for the Flint Creek Watershed.**

| Sub-Watershed | Land Use Type | Area (acres) | Percent of Watershed | Existing Conditions Load (Tons/Year) | Existing Conditions Load (Tons/Acre /Year) | Desired Conditions Load (Tons/Year) | Desired Conditions Load (Tons/Acre /Year) | Percent Reduction from Existing to Desired |
|---|---|---|---|---|---|---|---|---|
| | Mixed Forest | 1 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 68% |
| | Open Water | 4 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 5642 | 14% | 68.96 | 0.01 | 44.82 | 0.01 | 35% |
| | Shrub/Scrub | 7108 | 18% | 1830.75 | 0.26 | 1418.83 | 0.20 | 23% |
| | Woody Wetlands | 572 | 1% | 3.25 | 0.01 | 3.25 | 0.01 | 0% |
| | **Total Sub-Watershed** | **40427** | **100%** | **5207.39** | **0.13** | **4075.10** | **0.10** | **22%** |
| **Lower Willow Creek** | Cultivated Crops | 2900 | 13% | 523.68 | 0.18 | 327.30 | 0.11 | 37% |
| | Deciduous Forest | 4 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Low Intensity | 22 | 0% | 0.01 | 0.00 | 0.01 | 0.00 | 0% |
| | Developed, Open Space | 302 | 1% | 1.45 | 0.00 | 1.45 | 0.00 | 0% |
| | Evergreen Forest | 2555 | 12% | 24.41 | 0.01 | 24.41 | 0.01 | 0% |
| | Grasslands/Herbaceous | 8354 | 39% | 1217.10 | 0.15 | 1014.25 | 0.12 | 17% |
| | Open Water | 134 | 1% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 1810 | 8% | 46.37 | 0.03 | 30.14 | 0.02 | 35% |
| | Shrub/Scrub | 5322 | 25% | 896.94 | 0.17 | 695.13 | 0.13 | 23% |
| | Woody Wetlands | 108 | 1% | 0.47 | 0.00 | 0.47 | 0.00 | 0% |
| | **Total Sub-Watershed** | **21511** | **100%** | **2710.43** | **0.13** | **2093.16** | **0.10** | **23%** |
| **Middle Flint Creek** | Cultivated Crops | 2796 | 6% | 534.82 | 0.19 | 334.26 | 0.12 | 38% |
| | Developed, High Intensity | 4 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Low Intensity | 306 | 1% | 1.10 | 0.00 | 1.10 | 0.00 | 0% |
| | Developed, Med. Intensity | 32 | 0% | 0.01 | 0.00 | 0.01 | 0.00 | 0% |
| | Developed, Open Space | 971 | 2% | 7.98 | 0.01 | 7.98 | 0.01 | 0% |
| | Evergreen Forest | 21036 | 43% | 600.22 | 0.03 | 600.22 | 0.03 | 0% |
| | Grasslands/Herbaceous | 9693 | 20% | 1790.51 | 0.18 | 1492.09 | 0.15 | 17% |
| | Mixed Forest | 2 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Open Water | 12 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 2853 | 6% | 60.72 | 0.02 | 39.47 | 0.01 | 35% |
| | Shrub/Scrub | 10645 | 22% | 3740.73 | 0.35 | 2899.07 | 0.27 | 22% |
| | Woody Wetlands | 348 | 1% | 4.25 | 0.01 | 4.25 | 0.01 | 0% |
| | **Total Sub-Watershed** | **48696** | **100%** | **6740.34** | **0.14** | **5378.45** | **0.11** | **20%** |
| **Princeton Gulch** | Evergreen Forest | 2819 | 96% | 131.56 | 0.05 | 131.56 | 0.05 | 0% |
| | Grasslands/Herbaceous | 8 | 0% | 1.63 | 0.22 | 1.36 | 0.18 | 17% |
| | Shrub/Scrub | 110 | 4% | 135.15 | 1.23 | 104.74 | 0.95 | 23% |
| | **Total Sub-Watershed** | **2937** | **100%** | **268.34** | **0.09** | **237.66** | **0.08** | **11%** |
| **Smart Creek** | Barren Land | 4 | 0% | 0.01 | 0.00 | 0.01 | 0.00 | 0% |
| | Cultivated Crops | 221 | 1% | 43.43 | 0.20 | 27.15 | 0.12 | 37% |
| | Developed, Low Intensity | 3 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |

**Table 3-1. Base Results of the USLE Model for the Flint Creek Watershed.**

| Sub-Watershed | Land Use Type | Area (acres) | Percent of Watershed | Existing Conditions Load (Tons/Year) | Existing Conditions Load (Tons/Acre /Year) | Desired Conditions Load (Tons/Year) | Desired Conditions Load (Tons/Acre /Year) | Percent Reduction from Existing to Desired |
|---|---|---|---|---|---|---|---|---|
| | Developed, Open Space | 46 | 0% | 0.25 | 0.01 | 0.25 | 0.01 | 0% |
| | Evergreen Forest | 9321 | 60% | 218.55 | 0.02 | 218.55 | 0.02 | 0% |
| | Grasslands/Herbaceous | 1774 | 11% | 212.29 | 0.12 | 176.91 | 0.10 | 17% |
| | Pasture/Hay | 203 | 1% | 6.77 | 0.03 | 4.40 | 0.02 | 35% |
| | Shrub/Scrub | 4015 | 26% | 1051.10 | 0.26 | 814.61 | 0.20 | 22% |
| | Woody Wetlands | 38 | 0% | 0.23 | 0.01 | 0.23 | 0.01 | 0% |
| | **Total Sub-Watershed** | **15626** | **100%** | **1532.65** | **0.10** | **1242.11** | **0.08** | **19%** |
| **Trout Creek** | Cultivated Crops | 2064 | 9% | 1033.23 | 0.50 | 645.77 | 0.31 | 37% |
| | Developed, Low Intensity | 40 | 0% | 0.08 | 0.00 | 0.08 | 0.00 | 0% |
| | Developed, Open Space | 325 | 1% | 2.71 | 0.01 | 2.71 | 0.01 | 0% |
| | Evergreen Forest | 5890 | 26% | 21.85 | 0.00 | 21.85 | 0.00 | 0% |
| | Grasslands/Herbaceous | 5212 | 23% | 1022.73 | 0.20 | 852.27 | 0.16 | 17% |
| | Open Water | 2 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Pasture/Hay | 2718 | 12% | 118.63 | 0.04 | 77.11 | 0.03 | 35% |
| | Shrub/Scrub | 6260 | 28% | 1852.35 | 0.30 | 1435.57 | 0.23 | 22% |
| | Woody Wetlands | 49 | 0% | 0.82 | 0.02 | 0.82 | 0.02 | 0% |
| | **Total Sub-Watershed** | **22560** | **100%** | **4052.40** | **0.18** | **3036.18** | **0.13** | **25%** |
| **Upper Flint Creek** | Cultivated Crops | 713 | 5% | 93.14 | 0.13 | 58.21 | 0.08 | 37% |
| | Developed, Low Intensity | 67 | 0% | 0.10 | 0.00 | 0.10 | 0.00 | 0% |
| | Developed, Med. Intensity | 2 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0% |
| | Developed, Open Space | 353 | 3% | 2.09 | 0.01 | 2.09 | 0.01 | 0% |
| | Evergreen Forest | 9028 | 66% | 50.26 | 0.01 | 50.26 | 0.01 | 0% |
| | Grasslands/Herbaceous | 945 | 7% | 140.56 | 0.15 | 117.13 | 0.12 | 17% |
| | Pasture/Hay | 1004 | 7% | 13.30 | 0.01 | 8.64 | 0.01 | 35% |
| | Shrub/Scrub | 1506 | 11% | 134.52 | 0.09 | 104.25 | 0.07 | 23% |
| | Woody Wetlands | 69 | 1% | 0.57 | 0.01 | 0.57 | 0.01 | 0% |
| | **Total Sub-Watershed** | **13687** | **100%** | **434.54** | **0.03** | **341.27** | **0.02** | **21%** |
| **Upper Willow Creek** | Cultivated Crops | 196 | 0% | 77.64 | 0.40 | 48.53 | 0.25 | 37% |
| | Deciduous Forest | 5 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | - |
| | Evergreen Forest | 29213 | 65% | 851.54 | 0.03 | 851.54 | 0.03 | 0% |
| | Grasslands/Herbaceous | 5735 | 13% | 829.06 | 0.14 | 690.88 | 0.12 | 17% |
| | Pasture/Hay | 153 | 0% | 5.27 | 0.03 | 3.42 | 0.02 | 35% |
| | Shrub/Scrub | 9726 | 22% | 3440.31 | 0.35 | 2666.24 | 0.27 | 22% |
| | Woody Wetlands | 152 | 0% | 0.77 | 0.01 | 0.77 | 0.01 | 0% |
| | **Total Sub-Watershed** | **45180** | **100%** | **5204.59** | **0.12** | **4261.38** | **0.09** | **18%** |
| **Total Flint Creek Watershed** | | **308461** | **100%** | **30359.91** | **0.098** | **24255.92** | **0.08** | **20%** |

**Table 3-2. Results of the USLE Model with Riparian Health Incorporation.**

| Sub-Watershed | Existing Condition Load (tons/yr) | Desired Condition Load (tons/yr) | Scenario 1 | | Scenario 2 | | Scenario 3 | | Total Load Reduction with use of Upland and Riparian BMPs |
|---|---|---|---|---|---|---|---|---|---|
| | | | Existing Upland Load with Existing Riparian Condition (tons/yr) | Percent Load Reduction with use of Riparian Condition | Desired Upland Load with Existing Riparian Condition (tons/yr) | Percent Load Reduction with use of Upland BMPs | Desired Upland Load with Improved Riparian Health (tons/yr) | Percent Load Reduction with use of Riparian BMPs | |
| Barnes Creek | 1373.27 | 1100.90 | 635 | 54% | 509 | 20% | 275 | 46% | 57% |
| Boulder Creek | 1192.86 | 1092.45 | 494 | 59% | 452 | 8% | 279 | 38% | 44% |
| Douglas Creek - North | 1067.55 | 889.68 | 536 | 50% | 447 | 17% | 245 | 45% | 54% |
| Douglas Creek-Philipsburg | 107.90 | 92.26 | 61 | 44% | 52 | 14% | 35 | 33% | 43% |
| Fred Burr Creek | 173.56 | 156.69 | 68 | 61% | 62 | 10% | 40 | 36% | 42% |
| Georgetown Lake | 294.09 | 258.63 | 146 | 50% | 129 | 12% | 74 | 42% | 49% |
| Lower Flint Creek | 5207.39 | 4075.10 | 2656 | 49% | 2078 | 22% | 1070 | 49% | 60% |
| Lower Willow Creek | 2710.43 | 2093.16 | 1344 | 50% | 1038 | 23% | 539 | 48% | 60% |
| Middle Flint Creek | 6740.34 | 5378.45 | 3438 | 49% | 2743 | 20% | 1412 | 49% | 59% |
| Princeton Gulch | 268.34 | 237.66 | 124 | 54% | 110 | 11% | 62 | 44% | 50% |
| Smart Creek | 1532.65 | 1242.11 | 701 | 54% | 568 | 19% | 311 | 45% | 56% |
| Trout Creek | 4052.40 | 3036.18 | 2026 | 50% | 1518 | 25% | 759 | 50% | 63% |
| Upper Flint Creek | 434.54 | 341.27 | 222 | 49% | 174 | 21% | 90 | 49% | 60% |
| Upper Willow Creek | 5204.59 | 4261.38 | 2589 | 50% | 2120 | 18% | 1225 | 42% | 53% |
| **Total Watershed** | **30359.91** | **24255.92** | **15104** | **50%** | **12067** | **20%** | **6974** | **42%** | **54%** |

## 4.0 References

Anderson, J.R, E.E Hardy, J.T. Roach, and R.E Witmer. (1976). A Land Use and Land Cover Classification System for Use with Remote Sensor Data. Geological Survey Professional Paper 964.

Brooks, K.N., P.F. Ffolliott, H.M. Gregersen, and L.F. DeBano. (1997) Hydrology and the Management of Watersheds – 2nd ed. Iowa State University Press. Ames, IA.

Castelle, A.J. and A.W. Johnson, (2000). Riparian Vegetation Effectiveness. Technical Bulletin No. 799, National Council for Air and Stream Improvement, Research Triangle Park, NC.

Dubé, K., W. Megahan and M. Mccalmon. (2004). Washington Road Surface Erosion Model (WARSEM) Manual. State of Washington, Department of Natural Resources.

Hook, Paul B. (2003). Sediment Retention in Rangeland Riparian Buffers. Journal of Environmental Quality. 32(3): 1130-1137.

Lim, K.J,, M. Sagong, B.A. Engel, Z.X. Tang, J. Choi, and K. Kim. (2005). GIS-based sediment assessment tool, Catena, 64:61-80.

Montana Code Annotated (MCA). (2007). Available online at http://data.opi.mt.gov/bills/mca_toc/index.htm

Moore, I. and G. Burch. (1986a). Physical basis of the length–slope factor in the universal soil loss equation. J. of Soil Science Society of America, 50:1294– 1298.

Moore, I. and G. Burch. (1986b). Modeling erosion and deposition: topographic effects. Transactions of the ASAE, 29(6):1624– 1630.

USDA Soil Conservation Service. (1977). Procedure for computing sheet and rill erosion on project areas. Technical Release No. 41 (Rev 2). 17 pg.