# APPENDIX C
# TOTAL MAXIMUM DAILY LOADS

## C.1 Sediment

### C.1.1 Overview

A percent reduction based on average yearly loading was used as the primary approach for expressing the sediment TMDLs within this document because there is uncertainty associated with the loads derived from the source assessment, and using the estimated sediment loads alone creates a rigid perception that the loads are absolutely conclusive. However, in this appendix the TMDL is expressed using daily loads to satisfy an additional EPA required TMDL element. Daily loads should not be considered absolutely conclusive and may be refined in the future as part of the adaptive management process. The TMDLs may not be feasible at all locations within the watershed but if the allocations are followed, sediment loads are expected to be reduced to a degree that the sediment targets are met and beneficial uses are no longer impaired. It is not expected that daily loads will drive implementation activities.

### C.1.2 Approach

In order to determine a daily load, the means of daily mean values for suspended sediment discharge in tons per day were reviewed from USGS gage stations in the Upper Clark Fork TPA. The USGS station on the Clark Fork at Deer Lodge (12324200) was selected to represent the daily variability in sediment loading in the Upper Clark Fork TPA. Although the Clark Fork River is larger than the tributaries of interest, this site was selected primarily due to the lack of daily flow and sediment data available for the tributaries. Furthermore, the size of the Clark Fork is of less concern in this case because it is the relationship between sediment load (a function of sediment concentration and flow) and the day of the year that is the primary focus for this analysis. It is assumed that the hydrologic properties and rate of loading on a given day is similar throughout the watershed, regardless of the stream, and therefore is appropriate to use for these purposes.

The mean of daily mean values for suspended sediment discharge, in tons per day, was calculated based on 23 years of record (October 1, 1984 - September 30, 2008) (**Table C-1**). The mean annual suspended sediment load for USGS gage 12324200, based on a summation of the mean of daily mean values, is 8741.1 tons per year. Although the suspended sediment load is only a fraction of the total load from the source assessment, it provides an approximation of the relationship between sediment and flow in the Upper Clark Fork Tributaries. Using the mean of daily mean sediment loads, a daily percentage relative to the mean annual suspended sediment load was calculated for each day (**Table C-2**). **Figure C-1** visually represents the average daily percentage of the total yearly sediment load for each day of the calendar year.

To conserve resources, this appendix only provides the base data from the USGS stream gage, and the daily percentages of the total annual load. For specific streams, all daily TMDLs may be derived by using the daily percentages in **Table C-2** and the TMDLs expressed as an average annual load, which are discussed in **Section 5.6**. For instance, the total allowable annual sediment load for Antelope Creek is 200 tons. To determine the TMDL for January 1, 200 is multiplied by 1.2698% which provides a daily load for January 1st for Peterson Creek of 2.5. The daily loads are a composite of the allocations, but as allocations are not feasible on a daily basis, they are not contained within this appendix. If desired, daily allocations may be obtained by applying allocations provided in **Section 5.6** to the daily load.

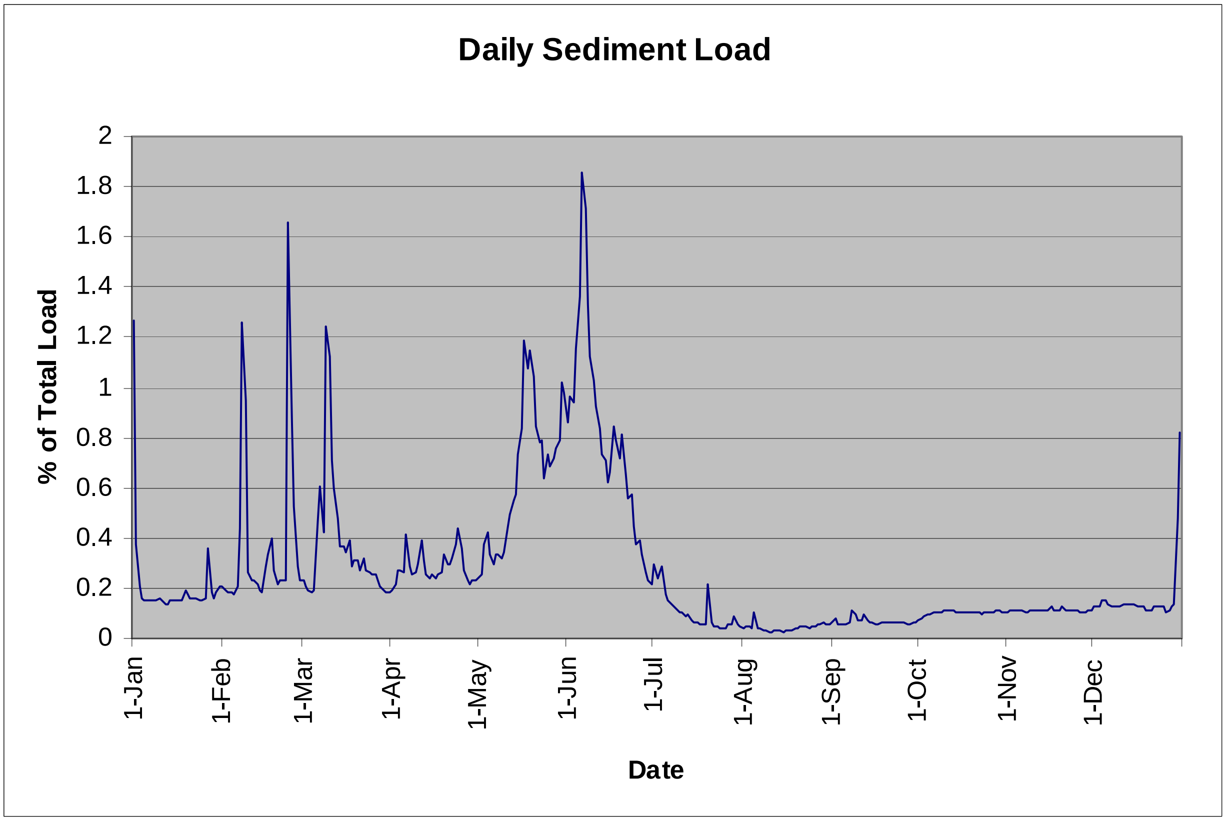


**Figure C-1. Average Percentage of Total Daily Sediment Loading Throughout the Calendar Year.**

The percent of total daily sediment loading from the Clark Fork @ Deer Lodge USGS gage station information in **Figure C-1** illustrates the fluctuating nature of sediment loads, driven by climate and precipitation, in many western Montana streams. In general, it appears that elevated sediment loading is linked to spring runoff, with occasional sporadic elevated loads, probably as the result of individual runoff events, mostly in winter and early spring, potentially as a result of wet spring snows with rapid melting or rain-on-snow events.

**Table C-1. USGS Stream Gage 12324200 (Clark Fork @ Deer Lodge) - Mean of daily mean suspended sediment values for each day of record in tons/day (Calculation Period 1984-10-01 -> 2008-09-30)**

| Day of Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 111 | 18 | 20 | 17 | 21 | 75 | 26 | 3.7 | 5.3 | 6 | 9.3 | 11 |
| **2** | 33 | 17 | 18 | 19 | 22 | 84 | 21 | 3.9 | 7 | 7.2 | 9.5 | 11 |
| **3** | 18 | 16 | 17 | 24 | 33 | 82 | 23 | 3.9 | 5.1 | 7.9 | 9.8 | 11 |
| **4** | 14 | 16 | 16 | 24 | 37 | 101 | 25 | 3.8 | 4.6 | 8.4 | 10 | 13 |
| **5** | 13 | 15 | 17 | 23 | 29 | 119 | 15 | 8.9 | 4.7 | 8.6 | 10 | 13 |
| **6** | 13 | 18 | 41 | 36 | 26 | 162 | 13 | 3.8 | 4.7 | 8.9 | 10 | 12 |
| **7** | 13 | 38 | 53 | 25 | 29 | 150 | 12 | 3.4 | 5.6 | 8.9 | 9.2 | 11 |
| **8** | 13 | 110 | 37 | 22 | 29 | 116 | 11 | 2.9 | 10 | 9.2 | 8.9 | 11 |
| **9** | 13 | 83 | 109 | 23 | 28 | 98 | 10 | 2.6 | 8.5 | 9.1 | 9.5 | 11 |
| **10** | 14 | 23 | 98 | 26 | 30 | 90 | 9 | 2.3 | 6.1 | 9.9 | 9.8 | 11 |
| **11** | 13 | 20 | 62 | 34 | 39 | 81 | 9.2 | 2.3 | 6 | 10 | 9.9 | 12 |
| **12** | 12 | 20 | 52 | 27 | 43 | 73 | 7.9 | 2.5 | 8.2 | 9.8 | 10 | 12 |
| **13** | 12 | 19 | 42 | 22 | 48 | 64 | 8.2 | 2.7 | 6.5 | 9.6 | 9.9 | 12 |
| **14** | 13 | 17 | 32 | 21 | 50 | 62 | 6.6 | 2.5 | 5.8 | 9.2 | 10 | 12 |
| **15** | 13 | 16 | 32 | 22 | 64 | 54 | 5.4 | 2.4 | 5.9 | 8.9 | 10 | 12 |
| **16** | 13 | 25 | 30 | 21 | 73 | 58 | 5.5 | 2.6 | 5.2 | 9.1 | 11 | 11 |
| **17** | 13 | 29 | 34 | 22 | 104 | 74 | 5 | 2.7 | 5 | 8.9 | 10 | 11 |
| **18** | 13 | 35 | 25 | 23 | 94 | 69 | 5.1 | 2.9 | 5.5 | 8.9 | 10 | 11 |
| **19** | 17 | 24 | 27 | 29 | 100 | 63 | 4.9 | 3.3 | 5.6 | 8.8 | 10 | 10 |
| **20** | 15 | 19 | 27 | 26 | 91 | 71 | 19 | 3.4 | 5.5 | 8.8 | 11 | 10 |
| **21** | 14 | 20 | 24 | 26 | 74 | 57 | 5.8 | 4.1 | 5.5 | 9 | 10 | 10 |
| **22** | 14 | 20 | 28 | 28 | 68 | 49 | 4.5 | 4.1 | 5.4 | 8.8 | 10 | 11 |
| **23** | 14 | 20 | 24 | 33 | 69 | 50 | 4.2 | 3.9 | 5.6 | 8.6 | 10 | 11 |
| **24** | 13 | 145 | 23 | 38 | 56 | 39 | 3.8 | 3.7 | 5.4 | 8.9 | 10 | 11 |
| **25** | 13 | 76 | 22 | 31 | 64 | 33 | 3.2 | 3.9 | 5.5 | 9.2 | 9.6 | 11 |
| **26** | 14 | 46 | 22 | 24 | 60 | 34 | 3.6 | 4.4 | 5.4 | 9 | 9.4 | 9.3 |
| **27** | 31 | 25 | 20 | 20 | 63 | 29 | 4.8 | 4.9 | 5.2 | 9.4 | 9 | 9.9 |
| **28** | 16 | 20 | 18 | 19 | 66 | 23 | 5.1 | 4.6 | 5.2 | 9.7 | 9.4 | 11 |
| **29** | 14 | 15 | 17 | 20 | 69 | 20 | 8 | 5.3 | 5.3 | 9.5 | 9.9 | 12 |
| **30** | 16 | | 16 | 20 | 89 | 19 | 5.1 | 5.1 | 5.3 | 8.9 | 10 | 42 |
| **31** | 18 | | 16 | | 86 | | 3.9 | 4.7 | | 9.1 | | 72 |

**Table C-2. USGS Stream Gage 12324200 (Clark Fork @ Deer Lodge) – Percent of Mean Annual Suspended Sediment Load Based on Mean of Daily Mean Suspended Sediment Values for each Day of Record (Calculation Period 1984-10-01 -> 2008-09-30)**

| Day of Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.269863061 | 0.2059 | 0.2288 | 0.1945 | 0.2402 | 0.858 | 0.2974 | 0.0423 | 0.0606 | 0.0686 | 0.10639 | 0.125842 |
| 2 | 0.377526856 | 0.1945 | 0.2059 | 0.2174 | 0.2517 | 0.961 | 0.2402 | 0.0446 | 0.0801 | 0.0824 | 0.10868 | 0.125842 |
| 3 | 0.20592374 | 0.183 | 0.1945 | 0.2746 | 0.3775 | 0.9381 | 0.2631 | 0.0446 | 0.0583 | 0.0904 | 0.11211 | 0.125842 |
| 4 | 0.160162909 | 0.183 | 0.183 | 0.2746 | 0.4233 | 1.1555 | 0.286 | 0.0435 | 0.0526 | 0.0961 | 0.1144 | 0.148723 |
| 5 | 0.148722701 | 0.1716 | 0.1945 | 0.2631 | 0.3318 | 1.3614 | 0.1716 | 0.1018 | 0.0538 | 0.0984 | 0.1144 | 0.148723 |
| 6 | 0.148722701 | 0.2059 | 0.469 | 0.4118 | 0.2974 | 1.8533 | 0.1487 | 0.0435 | 0.0538 | 0.1018 | 0.1144 | 0.137282 |
| 7 | 0.148722701 | 0.4347 | 0.6063 | 0.286 | 0.3318 | 1.716 | 0.1373 | 0.0389 | 0.0641 | 0.1018 | 0.10525 | 0.125842 |
| 8 | 0.148722701 | 1.2584 | 0.4233 | 0.2517 | 0.3318 | 1.3271 | 0.1258 | 0.0332 | 0.1144 | 0.1052 | 0.10182 | 0.125842 |
| 9 | 0.148722701 | 0.9495 | 1.247 | 0.2631 | 0.3203 | 1.1211 | 0.1144 | 0.0297 | 0.0972 | 0.1041 | 0.10868 | 0.125842 |
| 10 | 0.160162909 | 0.2631 | 1.1211 | 0.2974 | 0.3432 | 1.0296 | 0.103 | 0.0263 | 0.0698 | 0.1133 | 0.11211 | 0.125842 |
| 11 | 0.148722701 | 0.2288 | 0.7093 | 0.389 | 0.4462 | 0.9267 | 0.1052 | 0.0263 | 0.0686 | 0.1144 | 0.11326 | 0.137282 |
| 12 | 0.137282493 | 0.2288 | 0.5949 | 0.3089 | 0.4919 | 0.8351 | 0.0904 | 0.0286 | 0.0938 | 0.1121 | 0.1144 | 0.137282 |
| 13 | 0.137282493 | 0.2174 | 0.4805 | 0.2517 | 0.5491 | 0.7322 | 0.0938 | 0.0309 | 0.0744 | 0.1098 | 0.11326 | 0.137282 |
| 14 | 0.148722701 | 0.1945 | 0.3661 | 0.2402 | 0.572 | 0.7093 | 0.0755 | 0.0286 | 0.0664 | 0.1052 | 0.1144 | 0.137282 |
| 15 | 0.148722701 | 0.183 | 0.3661 | 0.2517 | 0.7322 | 0.6178 | 0.0618 | 0.0275 | 0.0675 | 0.1018 | 0.1144 | 0.137282 |
| 16 | 0.148722701 | 0.286 | 0.3432 | 0.2402 | 0.8351 | 0.6635 | 0.0629 | 0.0297 | 0.0595 | 0.1041 | 0.12584 | 0.125842 |
| 17 | 0.148722701 | 0.3318 | 0.389 | 0.2517 | 1.1898 | 0.8466 | 0.0572 | 0.0309 | 0.0572 | 0.1018 | 0.1144 | 0.125842 |
| 18 | 0.148722701 | 0.4004 | 0.286 | 0.2631 | 1.0754 | 0.7894 | 0.0583 | 0.0332 | 0.0629 | 0.1018 | 0.1144 | 0.125842 |
| 19 | 0.194483532 | 0.2746 | 0.3089 | 0.3318 | 1.144 | 0.7207 | 0.0561 | 0.0378 | 0.0641 | 0.1007 | 0.1144 | 0.114402 |
| 20 | 0.171603116 | 0.2174 | 0.3089 | 0.2974 | 1.0411 | 0.8123 | 0.2174 | 0.0389 | 0.0629 | 0.1007 | 0.12584 | 0.114402 |
| 21 | 0.160162909 | 0.2288 | 0.2746 | 0.2974 | 0.8466 | 0.6521 | 0.0664 | 0.0469 | 0.0629 | 0.103 | 0.1144 | 0.114402 |
| 22 | 0.160162909 | 0.2288 | 0.3203 | 0.3203 | 0.7779 | 0.5606 | 0.0515 | 0.0469 | 0.0618 | 0.1007 | 0.1144 | 0.125842 |
| 23 | 0.160162909 | 0.2288 | 0.2746 | 0.3775 | 0.7894 | 0.572 | 0.048 | 0.0446 | 0.0641 | 0.0984 | 0.1144 | 0.125842 |
| 24 | 0.148722701 | 1.6588 | 0.2631 | 0.4347 | 0.6407 | 0.4462 | 0.0435 | 0.0423 | 0.0618 | 0.1018 | 0.1144 | 0.125842 |
| 25 | 0.148722701 | 0.8695 | 0.2517 | 0.3546 | 0.7322 | 0.3775 | 0.0366 | 0.0446 | 0.0629 | 0.1052 | 0.10983 | 0.125842 |
| 26 | 0.160162909 | 0.5262 | 0.2517 | 0.2746 | 0.6864 | 0.389 | 0.0412 | 0.0503 | 0.0618 | 0.103 | 0.10754 | 0.106394 |
| 27 | 0.35464644 | 0.286 | 0.2288 | 0.2288 | 0.7207 | 0.3318 | 0.0549 | 0.0561 | 0.0595 | 0.1075 | 0.10296 | 0.113258 |
| 28 | 0.183043324 | 0.2288 | 0.2059 | 0.2174 | 0.7551 | 0.2631 | 0.0583 | 0.0526 | 0.0595 | 0.111 | 0.10754 | 0.125842 |
| 29 | 0.160162909 | 0.1716 | 0.1945 | 0.2288 | 0.7894 | 0.2288 | 0.0915 | 0.0606 | 0.0606 | 0.1087 | 0.11326 | 0.137282 |
| 30 | 0.183043324 | | 0.183 | 0.2288 | 1.0182 | 0.2174 | 0.0583 | 0.0583 | 0.0606 | 0.1018 | 0.1144 | 0.480489 |
| 31 | 0.20592374 | | 0.183 | | 0.9839 | | 0.0446 | 0.0538 | | 0.1041 | | 0.823695 |

## C.2 Temperature

The temperature TMDLs are the sum of waste load allocations (WLAs) for point sources, and load allocations (LAs) for nonpoint sources (**Equation C-1**). Although there are no point sources in this watershed and therefore are no WLAs. In addition, the TMDL includes a margin of safety (MOS) that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream.

**Equation C-1.**

$$TMDL = \Sigma WLA + \Sigma LA + MOS.$$

Where:

ΣWLA = Waste Load Allocation = Pollutants from NPDES Point Sources
ΣLA = Load Allocation = Pollutants from Nonpoint Sources + Natural Sources
MOS = Margin of Safety

Total maximum daily loads are based on the loading of a pollutant to a water body. Federal Codes indicate that for each thermally listed water body the total maximum daily thermal load cannot be exceeded in order to assure protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife. Such estimates shall take into account the water temperatures, flow rates, seasonal variations, existing sources of heat input, and the dissipative capacity of the identified waters. The following approach for setting numeric temperature TMDLs considers all of the factors listed above.

The numeric daily thermal loads (TMDLs) and instantaneous thermal load (ITLs) presented in this appendix apply to all portions of the temperature impaired waters in the Upper Clark Fork TPA. This appendix provides daily and instantaneous heat loading limits for the upper and lower segments of Peterson Creek. Peterson Creek is classified as B-1. Montana's temperature standard for B-1 water body classifications are depicted in **Figure C-2**.

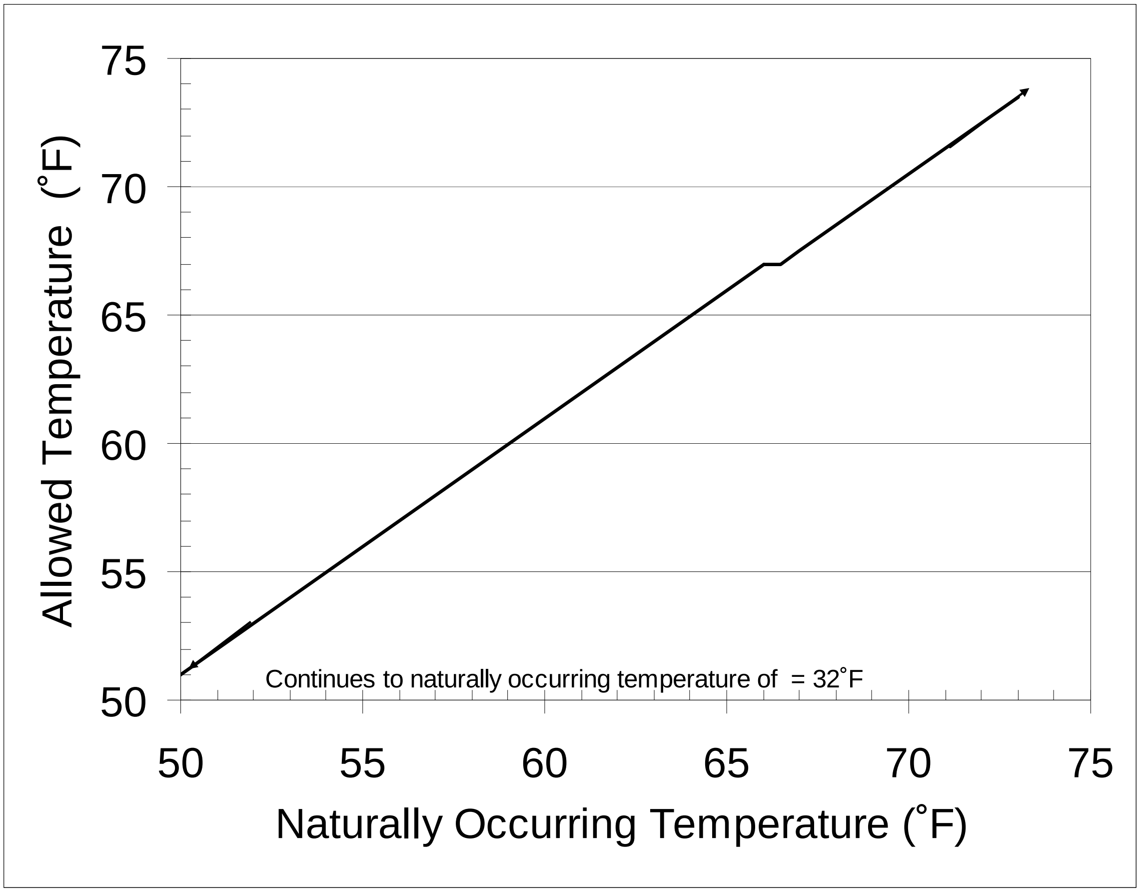


**Figure C-2. In-stream Temperatures Allowed by Montana's B-1 Classification Temperature Standard**

## C.2.1 Daily Thermal Load

The allowed temperature can be calculated using Montana's B-1 classification temperature standards (**Figure C-2**) and using a modeled or estimated naturally occurring daily average temperature. The daily average total maximum load at any location in the water body is provided **Equation C-2**. The daily allowable loading is expressed as the allowable loading to the liquid form of the water in the stream. This is defined as the kilocalorie increase associated with the warming of the water from 32°F to the temperature that represents compliance with Montana's temperature standard as determined from **Figure C-2**.

**Equation C-2**

$(\Delta-32)*(Q)*(1.36*10^{6}) = TMDL$

Where:

$\Delta$ = allowed temperatures from **Figure C-2** using daily temperature condition
Q = average daily discharge in cubic feet per second (CFS)
TMDL = daily TMDL in Calories (kilocalories) per day above water's melting point
Conversion factor = 1359209

There are no point sources that increase water temperatures, and therefore, no wasteload allocations for the watershed. The TMDL load allocation for each stream is a combination of the ½ °F allowable loading shared between the human caused sources without reasonable land, soil, and water conservation practices in addition to the naturally occurring loading as defined in state law. Because temperatures are estimated to be naturally above 66 °F at times, one-half degree allowable increase in temperature is used for the TMDL and allocations. See the main document for more information about surrogate allocations, which are more applicable to restoration approaches. The surrogate allocations should meet the daily thermal load. The daily numeric TMDL allocation is equal to the load allocation shared by all human-caused sources without reasonable land, soil, and water conservation practices plus the load allocated to naturally occurring temperatures as shown in **Equation C-3**.

**Equation C-3**

Load Allocation = Allowable Human Sources + Naturally Occurring Thermal Loads

Where:

Naturally Occurring Thermal Loads = (Naturally Occurring Temperature (°F) from Modeling Scenarios -32)*(Discharge (CFS))*($1.36*10^6$)

Allowable Load from Human Sources above naturally occurring conditions = (1/2°F)*($1.36*10^6$)*(Discharge (CFS))

## C.2.2 Instantaneous Thermal Load

Because of the dynamic temperature conditions during the course of a day, an instantaneous thermal load (ITL) is also provided for temperature. For temperature, the daily average thermal conditions are not always an effective indicator of impairment to fisheries. The peak height of the sun throughout the summer months is usually the most stressful timeframe for salmonids and char. Also, in high altitudes, thermal impacts that heat during the day may produce advanced cooling conditions during the night so that the daily temperature fluctuations increase greatly, with potentially significant negative impacts to fish without much impact on daily average temperature conditions. Therefore, Montana provides an instantaneous thermal load to protect during the hottest timeframes in mid to late afternoon when temperatures are most stressful to the fishery, which is the most sensitive use in reference to thermal conditions.

The instantaneous load is computed by the second. The allowed temperature can be calculated using Montana's B-1 classification temperature standards (**Figure C-2**) and using a modeled or estimated naturally occurring instantaneous temperature. The instantaneous total maximum load (per second) at any location in the water body is provided by **Equation C-4**. The allowable loading over a second is expressed as the allowable loading to the liquid form of the water in the stream. This is defined as the kCal increase associated with the warming of the water from 32°F to the temperature that represents compliance with Montana's temperature standard as determined from **Figure C-2**.

**Equation C-4**

$(\Delta\text{-}32)*(Q)*(15.73)$ = Instantaneous Thermal Load (ITL)

Where:

Δ = allowed temperatures from **Figure C-2** using daily temperature condition
Q = instantaneous discharge in CFS
ITL = Allowed thermal load per second in kilocalories per day above water's melting point
Conversion factor = 15.73

As mentioned earlier in the Daily Thermal Load description, no identified point sources exist in Peterson Creek that increase water temperatures, and therefore, no there are no instantaneous wasteload allocations for the watershed. The ITL load allocation for each stream is a combination of the 1/2°F allowable loading shared between the human caused sources without reasonable land, soil, and water conservation practices in addition to the naturally occurring loading as defined in state law. Because temperatures are estimated to be naturally above 66 °F at times, one-half degree allowable increase in temperature is used for the TMDL and allocations. The ITL allocation is equal to the load allocation shared by all human caused sources without reasonable land, soil and water conservation practices plus the load allocated to naturally occurring temperatures as shown in **Equation C-5**.

**Equation C-5**

Load Allocation = Allowable Human Sources + Naturally Occurring Thermal Loads

Where:

Naturally Occurring Thermal Loads = (Naturally Occurring Temperature (°F) from Modeling Scenarios -32)*(Discharge (CFS))*(15.73)

Allowable Human Sources above naturally occurring conditions = (1/2°F)*(15.73)*(Discharge (CFS))