APPENDIX E
TEMPERATURE DAILY TMDLS AND INSTANTANEOUS LOADS

A TMDL is the sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources (**Equation E-1**). 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 E-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 thermal daily loads (TMDLs) and instantaneous thermal load (ITLs) presented in this appendix apply to all the temperature impaired waters in Upper and North Fork Big Hole River watersheds. This appendix provides daily and instantaneous heat loading limits for the Big Hole River above Pintlar Creek. All waters in this planning area are classified as A-1. Montana's temperature standard for A-1 classified waters is depicted in **Figure E-1**.

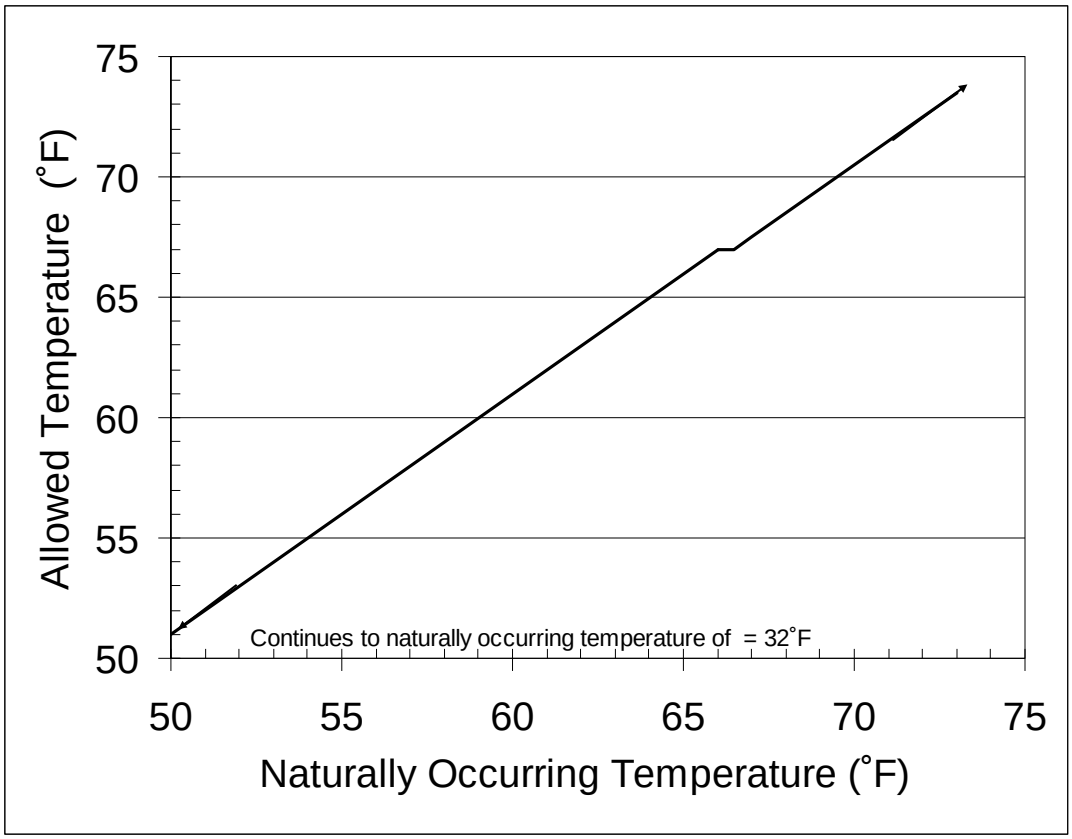

Figure E-1. In-stream Temperatures Allowed by Montana's A-1 Classification Temperature Standard

Daily Thermal Load

The allowed temperature can be calculated using Montana's A-1 classification temperature standards (**Figure E-1**) 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 in **Equation E-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 E-1**.

Equation E-2

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

Where:

Δ = allowed temperatures from **Figure E-1** 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 E-3**.

Equation E-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 Human Sources above naturally occurring conditions = (1/2°F)*($1.36*10^6$)*(Discharge (CFS))

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 heat of the day 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 A-1 classification temperature standards (**Figure E-1**) 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 E-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 E-1**.

Equation E-4

(Δ-32)*(Q)*(15.73) = Instantaneous Thermal Load (ITL)

Where:

Δ = allowed temperatures from **Figure E-1** 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

There are no point sources that increase water temperatures, and therefore, 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. See the main document for more information about surrogate allocations, which are more applicable to restoration approaches. The surrogate allocations should meet the ITL. 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 E-5**.

Equation E-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))

Margins of Safety, Seasonal Variations and Future Sources

See **Section 7** of the main document for this discussion.

Example Numeric TMDL Application for the Big Hole River above Pintlar Creek

Big Hole River Daily Thermal Load Example Application

Monitoring along with SSTEMP (Stream Segment Temperature Model) and SNTEMP (Stream Network Temperature Model) models were completed on the Big Hole River above Pintlar Creek (Appendicies B, C, D). A SNTEMP model scenario used reference riparian shade conditions throughout the watershed along with an estimated increase of 10cfs to estimate naturally occurring temperatures. Naturally occurring average daily temperature at the Big Hole River's confluence with Pintlar Creek during a hot day of summer 2006 was estimated at 67.3°F using SNTEMP modeling. This temperature is then used to determine the allowable temperature according to **Figure E-1**, Montana's temperature standard. The allowable mean daily temperature is estimated at 67.8°F during the hottest days of the summer. **Equation E-2** from above is used to calculate the Upper Big Hole River TMDL during the hottest days of the summer.

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

Where:

Δ = allowed temperatures from **Figure E-1** using daily temperature condition = **67.8°F**
Q = average daily discharge in cubic feet per second (CFS) = **101cfs**
TMDL = daily TMDL in Calories (kilocalories) per day above water's melting point = **$4.92*10^{9}$ kilocal/day**

The Upper Big Hole River load allocation to human caused heat sources not addressed by reasonable land, soil and water conservation practices for the TMDL is $6.87*10^{7}$ kilocalories per day. The remainder of the TMDL is appropriated to naturally occurring thermal load. Since there are no NPDES permits that affect water temperature, there is zero waste load allocation. During warm summer days the mean daily temperature of this site exceeds the average daily TMDL.

Big Hole River Instantaneous Thermal Load

The instantaneous thermal load (ITL) is described as the heat passing a monitoring location per second. The most sensitive timeframe for the fishery occurs during the heat of the day for the hottest period of the year. The same modeling described earlier in this appendix was used to model daily maximum temperatures. The naturally occurring daily maximum temperature at the confluence of the Big Hole River above Pintlar Creek's mouth during one of the hottest days of summer 2006 was estimated at 73.5°F using a SNTEMP model. This temperature is then used to determine the allowable temperature according to **Figure E-1**, Montana's temperature standard. Therefore, the allowable maximum temperature during this timeframe is estimated at 74.0°F during a hot summer day. **Equation E-4** from above is used to calculate the Upper Big Hole River's ITL during one of the hottest days of the summer.

Example:
(Δ-32)*(Q)*(15.73) = Instantaneous Thermal Load (ITL)

Where:
Δ = allowed temperatures from **Figure E-1** using instantaneous temperature condition = **74.0°F**
Q = average daily discharge in cubic feet per second (CFS) = **101cfs**
ITL = Allowed thermal load per second in kilocalories per day above water's melting point = **66,700 kilocal/second**

The Upper Big Hole River's load allocation to human caused heat sources not addressed by reasonable land, soil and water conservation practices for the ITL is 794 kilocalories per second. Since there are no NPDES permits that affect water temperature, there is zero waste load allocation. The remainder of the load allocation for the ITL is apportioned to naturally occurring thermal loading. During the hottest days of the summer the ITL is surpassed at the confluence with Pintlar Creek. This indicates that Montana's temperature standard at this site is not being met during an important timeframe for the most sensitive use.