APPENDIX G
STREAM TEMPERATURE ASSESSMENT FOR PETERSON CREEK UPPER CLARK FORK TMDL PLANNING AREA

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October 2008

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INTRODUCTION

Temperature impairments were assessed within Peterson Creek using a combination of in-stream temperature measurements, riparian shading assessments, mid-summer streamflow measurements, and modeling. The Peterson Creek temperature assessment was conducted to aid in the development of Total Maximum Daily Loads (TMDLs) in the Upper Clark Fork TMDL Planning Area (TPA). Data collected during this assessment were used in the QUAL2K model to assess the influence of shading and streamflow on stream temperatures in Peterson Creek. The results of this assessment were compared to Montana's water quality standards for temperature to evaluate beneficial use support and potential restoration strategies.

1.1 Montana Water Quality Standards

Montana's water quality standard for temperature addresses a maximum allowable increase above the "naturally occurring" temperature to protect the existing thermal regime for fish and aquatic life. For waters classified as B-1, the maximum allowable increase over the naturally occurring temperature (if the naturally occurring temperature is less than 66º Fahrenheit) is 1°F. In the naturally occurring range of 66-66.5 ºF, an increase cannot exceed 67ºF. If the naturally occurring temperature is greater than 66.5ºF, the maximum allowable increase is 0.5º F [ARM 17.30.622(e) and ARM 17.30.623(e)]. Temperature monitoring and modeling indicated that naturally occurring stream temperatures in Peterson Creek are likely greater than 66.5°F during portions of the summer months. Thus, the maximum allowable increase due to unmitigated human causes is 0.5°F (0.23°C).

SECTION 2.0
TEMPERATURE ASSESSMENT

The Peterson Creek temperature assessment was performed in order to identify existing conditions and to determine if anthropogenic disturbances have led to increased stream water temperatures. This assessment utilized field data and computer modeling to assess stream temperatures in relation to Montana's water quality standards.

2.1 Field Data collection

Field data used in this assessment were collected by Montana DEQ staff during the 2007 field season and included temperature measurements, streamflow measurements, and an assessment of riparian shading along Peterson Creek and selected tributaries. Field methods are described in *Upper Clark Fork TMDL Planning Area Temperature and Instantaneous Flow Monitoring Sampling and Analysis Plan* (MDEQ 2007).

2.1.1 Temperature Measurements

Temperature monitoring was conducted on Peterson Creek over a two-month timeframe in the summer of 2007. The study timeframe examined stream temperatures during the period when streamflows tend to be lowest, water temperatures are warmest, and negative affects to the cold water fishery and aquatic life beneficial uses are likely most pronounced. Temperature monitoring consisted of placing temperature data logging devices at 11 sites in the Peterson Creek watershed during the summer of 2007. Temperature monitoring sites were selected to bracket stream reaches with similar hydrology, riparian vegetation type, valley type, stream aspect, and channel width so that the temperature data collected during this assessment could be utilized in the QUAL2K model. A summary of temperature data is presented in **Attachment A**.

2.1.2 Streamflow Measurements

Streamflow was measured at 11 sites on Peterson Creek and selected tributary streams where temperature data logging devices were deployed. Streamflow data were collected during temperature data logger deployment and again during retrieval. Streamflow data collected during this assessment were used in the QUAL2K model to help determine if in-stream temperatures exceed Montana standards. Streamflow data is presented in **Attachment B**.

2.1.3 Riparian Shading

Riparian shading was assessed at five sites along Peterson Creek using a Solar Pathfinder which measures the amount of shade at a site in one-hour intervals. The Solar Pathfinder was utilized to assess riparian shading using the August template for the path of the sun. Shade was measured three times over a 200-foot reach at each site. In addition to the Solar Pathfinder readings, the following measurements were performed at each site in which riparian shading was assessed:

- Stream azimuth

- Bankfull width
- Wetted width
- Dominant tree species

Riparian shading data were used to assess existing and potential riparian shading conditions relative to the level of anthropogenic disturbance at a site. Measurements obtained with the Solar Pathfinder were utilized in the QUAL2K model to help determine if in-stream temperatures exceed Montana standards. Solar Pathfinder data are presented in **Attachment C**.

2.2 QUAL2K Model

The QUAL2K model was used to determine if human caused disturbances within the watershed have increased the water temperature above the "naturally occurring" level and, if so, to what degree. The QUAL2K model is available at: http://www.epa.gov/ATHENS/wwqtsc/html/qual2k.html. Stream temperature, riparian shading and streamflow data collected in the summer of 2007 were used to calibrate the QUAL2K model for existing conditions. The potential to reduce stream temperatures was then modeled based on five scenarios, including:

- Baseline scenario (existing conditions)
- Increased shade scenario
- Decreased water consumptive use scenario
- Natural condition scenario (no anthropogenic impacts)
- Naturally occurring scenario (full application of BMPs to present uses)

2.2.1 Data Sources and Model Assumptions

Data sources and model assumptions made during this assessment include:

1. Temperature data loggers were placed at 11 sites in the Peterson Creek watershed during the summer of 2007, including eight mainstem locations and three tributaries. Data loggers were deployed between July 16th and 18th and retrieved on September 26th. One mainstem temperature data logger was lost (PTR-04) and one tributary data logger did not work properly (PTR-02) resulting in temperature data for seven Peterson Creek sites and two tributary streams (**Table 2-1**). The maximum daily temperature and the 7-day average maximum temperature data were reviewed to identify the warmest day of the season. Maximum daily temperatures occurred between July 19th and 28th, depending on the site, while the 7-day average maximum temperature occurred between July 20th and 22nd (**Attachment A**). Based on this data set, the QUAL2K model was run for July 21st, 2007 conditions.

2. Streamflow data were collected at 11 sites during temperature data logger deployment and retrieval, with eight measurements on Peterson Creek and three measurements on tributary streams (**Table 2-1, Attachment B**). Streamflows collected during data logger deployment were applied in the QUAL2K model since the deployment date (July 16th – 18th) was near the date for which maximum temperatures were modeled (July 21st).

Depth and velocity measurements at each streamflow measurement site were used to develop a rating curve for use in the QUAL2K model. The upper site (PTR-01) was excluded when developing the rating curve for depth since this flow measurement was much lower than all the other measurements.

Table 2-1. Temperature Data Logger and Streamflow Measurement Sites.

Temperature Data Logger Site	Stream	Deployment Flow (cfs)
PTR-01	Peterson Creek	0.1
PTR-02	Tributary 1, data invalid	0.6
PTR-03	Peterson Creek	1.6
PTR-04	Peterson Creek, data logger lost	1.7
PTR-05	Jack Creek	0.6
PTR-07	Peterson Creek	1.7
PTR-08 (no data logger)	Peterson Creek	2.0
PTR-09	Peterson Creek	N/A
PTR-11	Burnt Hollow Creek	0.1
PTR-12	Peterson Creek	2.1
PTR-13	Peterson Creek	0.6
PTR-14	Peterson Creek	0.4

3. Streamside shading was assessed at five sites corresponding to the location of temperature data loggers. Four sites were located on Peterson Creek, while one site was located on a headwater tributary stream. Riparian shade was assessed using the August template for the solar pathfinder, which measures the amount of shade at one-hour intervals. Since the QUAL2K model was run for July 21st, shade measurements based on the August path of the sun may be slightly higher than the actual shade on July 21st due to the fact that sun is slightly lower in the sky during August than during July. However, based on the relatively small size of the riparian shade dataset, any additional error introduced based on slightly different sun angles in July and August is likely negligible. At each site where shade was assessed, the riparian vegetation type was also described and the average daily shade at each site was calculated (**Table 2-2**). Average daily shade ranged from 34% at PTR-08 to 92% at PTR-07. The majority of the solar pathfinder measurements documented relatively dense shrub cover which was observed along much of Peterson Creek and measured at sites PTR-03, PTR-04 and PTR-07. Forested conditions in the headwaters were documented at the PTR-02 site, while open pasture conditions in areas of irrigated agriculture were documented at the PTR-08 site.

Table 2-2. Solar Pathfinder Sites.

Temperature Data Logger Site	Stream	Site Description	Average Daily Shade	Average Azimuth	Average Bankfull Width (Feet)	Average Wetted Width (Feet)
PTR-02	Tributary 1	Conifers with graminoid understory, relatively narrow and flat valley, headwater tributary, grazed	71%	183%	7.8	4.7

Table 2-2. Solar Pathfinder Sites.

Temperature Data Logger Site	Stream	Site Description	Average Daily Shade	Average Azimuth	Average Bankfull Width (Feet)	Average Wetted Width (Feet)
PTR-03	Peterson Creek	Dense willow and alder in valley bottom, sparse cottonwoods, graminoid understory, influenced by beaver ponds, grazed	87%	39%	14.0	8.5
PTR-04	Peterson Creek	Alders, willow, sparse cottonwood, graminoid understory, conifers on hillslopes, grazed, evidence of pugging and hummocking	77%	33%	9.8	5.1
PTR-07	Peterson Creek	Willows with graminoid understory, entrenched gulch, grazed	92%	28%	8.0	6.9
PTR-08	Peterson Creek	Tall grass hayfield with buffer	34%	23%	8.1	5.0

4. Following field data collection, a GIS project was initiated to evaluate riparian conditions along Peterson Creek using National Agricultural Imagery Program (NAIP) color aerial imagery from 2005, along with high-resolution color orthophotographs from May 20th, 2004 collected in the vicinity of Deer Lodge. Information prepared during Montana DEQ's recent Upper Clark Fork TPA Aerial Assessment Reach Stratification project was also reviewed. For this project, the 1:24,000 USGS NHD layer was used for Peterson Creek, while the 1:100,000 NHD layer was used to identify tributary streams. A total of 10 reaches were delineated along Peterson Creek based on changes in vegetation type, changes in stream aspect, and tributary inputs. These 10 reaches were used to break Peterson Creek into 10 stream segments in the QUAL2K model. QUAL2K model segments were identified as "PCT" in this report, which indicates "Peterson Creek Temperature" reaches **(Table 2-3, Figure 2-1**).

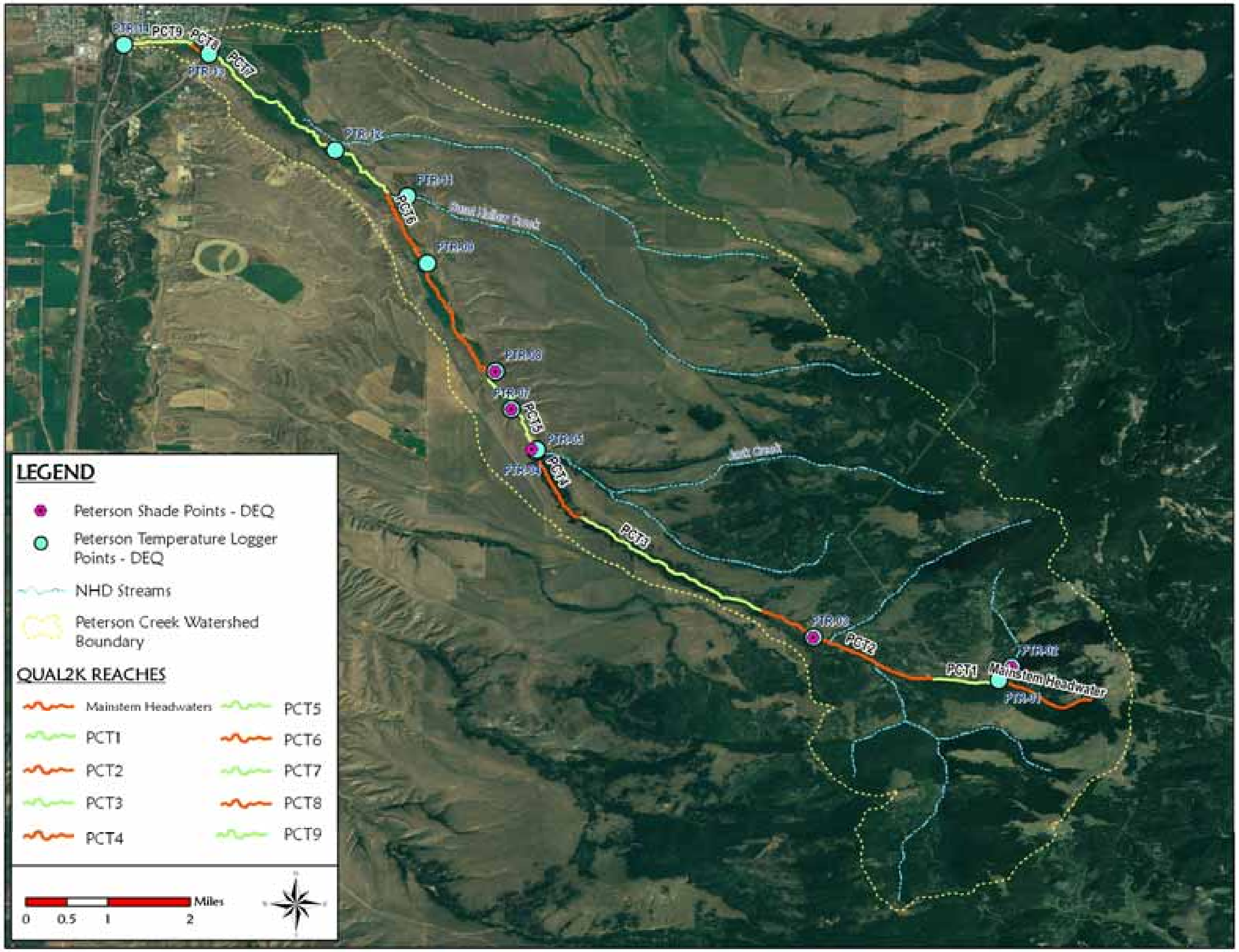
Table 2-3. Peterson Creek Temperature (PCT) Reach Descriptions.

Reach	Description
Mainstem headwater	The Mainstem Headwater Reach extended from the headwaters downstream to the confluence with Tributary 1. The data logger PTR-01 was located at the break between the Mainstem Headwater Reach and Reach PCT1. Vegetation included conifers in the overstory with shrubs in the understory.
PCT1	Reach PCT1 extended from Tributary 1 downstream to a road crossing that is associated with a slight aspect change as well as a change in riparian vegetation. Water from Tributary 1 was added to this reach at the same temperature as recorded at PTR-01. Tributary 1 is apparently larger than Peterson Creek at the confluence. Vegetation included conifers in the overstory with shrubs in the understory.
PCT2	Reach PCT2 extends from the road crossing downstream past data logger PTR-03 to a change in vegetation. Tributary 2 and Tributary 3 enter this reach upstream of the PTR-03 data logger. Temperatures were elevated at the PTR-03 data logger, so the two tributary streams were added in at the same temperature that was recorded in Jack Creek (PTR-05). There was an irrigation withdrawal that appeared to be downstream of the PTR-03 logger. Vegetation included shrubs in the valley bottom and conifers on the hillslopes. Beaver ponds were observed during the 2007 field assessment.
PCT3	Reach PCT3 extended from a vegetation break to an aspect break. There are no data loggers and no tributary inputs. Vegetation included sparse deciduous trees and shrubs in the valley bottom and conifers on the hillslopes.

Table 2-3. Peterson Creek Temperature (PCT) Reach Descriptions.

Reach	Description
PCT4	Reach PCT4 extended down to the confluence with Jack Creek. A small input of groundwater was added to this reach. Vegetation includes deciduous trees and shrubs in the valley bottom and conifers on the hillslopes. This reach marked the lowest extend of coniferous vegetation.
PCT5	Reach PCT5 extended from the confluence with Jack Creek downstream to the upstream end of the hayfield and the start of irrigated agriculture. This reach included data logger PTR-07. Jack Creek was smaller than Peterson Creek at their confluence. Temperature data (PTR-05) and flow data from Jack Creek were applied to the model. Flows in this reach decreased due to irrigation withdrawals as documented by streamflow measurements at data logger PTR-07. Streamflows then increase again by the lower end of the reach (PTR-08) likely due to irrigation return flows. Irrigation return flows were modeled at the same temperature as measured in Jack Creek (PTR-05). Vegetation included shrubs in the valley bottom.
PCT6	Reach PCT6 included the irrigated hayfield through which this entire reach flows. Data logger PTR-09 was located in this reach along with the PTR-08 shade assessment site. No irrigation withdrawals were identified in this reach due to a lack of streamflow data. An assessment of aerial imagery indicated there were irrigation withdrawals within this reach. Vegetation included open pasture and irrigated agriculture.
PCT7	Reach PCT7 began at the confluence with Burnt Hollow Creek which was smaller than Peterson Creek. Reach PCT7 flows through an area of irrigated agriculture and includes PTR-12. Streamflows increased slightly at the upper end of the reach as documented at PTR-12 and this was attributed to downstream irrigation return flows. Progressing through the reach, streamflow then decreased likely due to irrigation withdrawals. The measured temperatures at PTR-12 were the highest of the study area. Vegetation included shrubs alternating with open pasture areas and sparse deciduous trees. Beaver dams were apparent in the 2004 aerial imagery.
PCT8	Reach PCT8 extended downstream from the I-90 crossing to where the channel became channelized along the east side of Deer Lodge. No losses or gains in streamflow were identified within this reach. Vegetation included shrubs and sparse deciduous trees.
PCT9	Reach PCT 9 was channelized along the east side of Deer Lodge. Vegetation included shrubs and sparse deciduous trees alternative with open pasture areas.

Figure 2-1. Peterson Creek Monitoring Sites and Reaches.



5. Solar pathfinder data collected at five sites in the Peterson Creek watershed were used to assign shading values to assessed reaches in the QUAL2K model. Reaches in which the solar pathfinder data were applied directly included PCT2, PCT4 and PCT6 based on solar pathfinder sites PTR-03, PTR-04 and PTR-08, respectively. For reaches in which no solar pathfinder data were collected, shade values were extrapolated from assessed reaches based on similar riparian vegetation characteristics as observed in GIS using color aerial imagery from 2004 and 2005 (**Table 2-4**). In addition, reaches PCT5, PCT7 and PCT8 were assigned hourly shade values based on the average of shade measurements at sites PTR-07 and PTR-08 since the aerial assessment indicated that these reaches alternated between dense riparian vegetation and open areas. Combining data from sites PTR-07 and PTR-08 resulted in a reach average shade value of 63% (**Attachment C**).

Table 2-4. Solar Pathfinder Shade Data Applied in QUAL2K.

Reach	QUAL2K Reach Identifier	Solar Pathfinder Measurement Performed	Solar Pathfinder Measurement Applied
1	Mainstem headwater	No	PTR-02
2	PCT1	No	PTR-02
3	PCT2	PTR-03	PTR-03
4	PCT3	No	PTR-04
5	PCT4	PTR-04	PTR-04
6	PCT5	PTR-07	PTR-07/08
7	PCT6	PTR-08	PTR-08
8	PCT7	No	PTR-07/08
9	PCT8	No	PTR-07/08
10	PCT9	No	PTR-08

6. Climatic data inputs for the QUAL2K model were obtained from the Pacific Northwest Cooperative Agricultural Weather Network (AgriMet) site in Deer Lodge, Montana (http://www.usbr.gov/pn/agrimet/webaghrread.html) and included air temperature, dew point temperature and wind speed. Wind speed was reduced to 0 m/s under the assumption that this small stream is relatively sheltered from the wind. The dew point temperature was adjusted by increasing the relative humidity by 15% based on local conditions within the stream corridor as measured in a similar assessment in the Big Hole River watershed (Flynn et. al. 2008). Cloud cover was assumed to be 0% in the QUAL2K model.

7. To evaluate tributary and groundwater inputs and water withdrawals along Peterson Creek, a hydrologic balance was created (**Table 2-5**). Flows were balanced at the outlet of each reach and at each data logger site where flows were measured. Where tributaries were present in a reach, increases in streamflow were entirely attributed to the tributary inflows. When no tributaries were present, inputs were attributed to groundwater discharge in the upper watershed and to irrigation return flows in the lower watershed. Groundwater inputs were assigned a temperature of 11.0°C based on the results of a similar modeling effort in the Big Hole River watershed, which shares a hydrologic boundary with the Upper Clark Fork River watershed in which Peterson Creek is located

(Flynn et. al. 2008). Streamflow decreases were considered due to irrigation withdrawals, which are evident in the aerial imagery. Inflows were treated as follows:

- Trib 1 enters at the same temperature as PTR-1 (Peterson mainstem headwater)
- Tribs 2 and 3 enter at the same temperature as PTR-05 (Jack Creek)
- Trib 4 enters at the same temperature as PTR-11 (Burnt Hollow Creek)
- Inflows in Reaches 6 and 8 enter at the same temperature as PTR-11

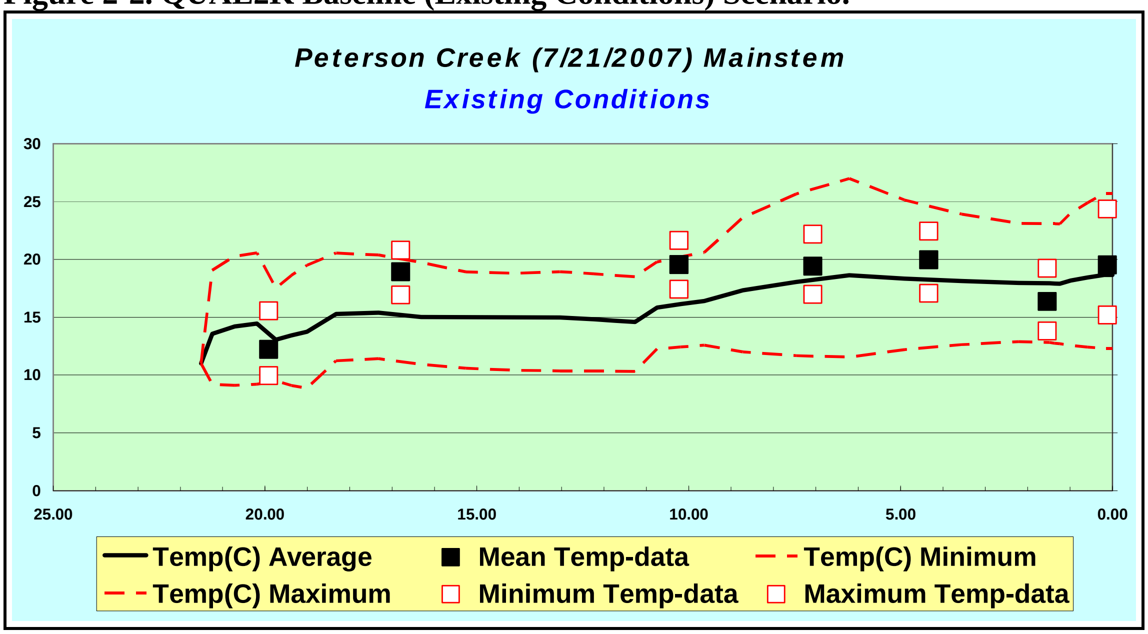
Table 2-5. Hydrologic Balance for Peterson Creek.

Reach ID	Hydrologic Balance (cms)	
Mainstem headwaters	0.0010	headwaters (GW temp)
	0.0027	groundwater gain
	0.0037	**flow at outlet of 1**
	0.0037	PTR-01
PCT1	0.0156	PTR-02, trib 1
	0.0193	**flow at outlet of 2**
PCT2	0.0163	trib 2
	0.0082	trib 3
	0.0438	**flow at outlet of 3**
	0.0438	PTR-03
PCT3	**0.0438**	**flow at outlet of 4**
PCT4	0.0054	groundwater gain
	0.0492	**flow at outlet of 5**
	0.0492	PTR-04
PCT5	0.0164	PTR-05, Jack Creek
	0.0656	**sum of Peterson and Jack Creek**
	0.0209	irrigation loss
	0.0447	PTR-07
	0.0107	irrigation return
	0.0554	**flow at outlet of 6**
	0.0554	PTR-08
PCT6	**0.0554**	**flow at outlet of 7**
PCT7	0.0027	PTR-11, Burnt Hollow Creek
	0.0581	**sum of Peterson and Burnt Hollow Creek**
	0.0024	irrigation return
	0.0605	PTR-12
	0.0014	trib 4
	0.0619	**sum of Peterson and trib 4**
	0.0443	irrigation loss
	0.0176	**flow at outlet of 8**
	0.0176	PTR-13
PCT8	**0.0176**	**flow at outlet of 9**
PCT9	0.0057	irrigation loss
	0.0119	**flow at outlet of 10**
	0.0119	PTR-14

2.2.2 Baseline Scenario

Once the above calibration steps were performed, the QUAL2K model was run for the baseline scenario which is intended to represent existing conditions in Peterson Creek on July 21st, 2007 (**Figure 2-2**). This model run utilized all measured field data, with the assumptions described in **Section 2.2.1** of this document. The model failed to accurately predict the dramatic increase in temperatures that were actually measured between sites PTR-01 and PTR-03 at the upper end of Peterson Creek. Poor model calibration between sites PTR-01 and PTR-03 was thought to be primarily due to the small size of this stream relative to the influence of riparian shading. Hydraulic output in the model accurately reflected measured conditions, indicating that water routing and channel morphology were adequately calibrated. Several additional model calibration steps were taken in an attempt to increase temperatures between site PTR-01 and PTR-03. Decreasing shade to 0% was required to accomplish this task. Since this appeared unrealistic based on a review of aerial imagery and on-the-ground observations, the decision was made to retain the baseline scenario as depicted in **Figure 2-2** with the understanding that it does not accurately represent temperature values measured in the field, especially in the upper reaches of Peterson Creek. Model scenarios were compared to the results of the baseline model and not to the field measured values to assure consistency when evaluating the potential to reduce stream temperatures.

Figure 2-2. QUAL2K Baseline (Existing Conditions) Scenario.



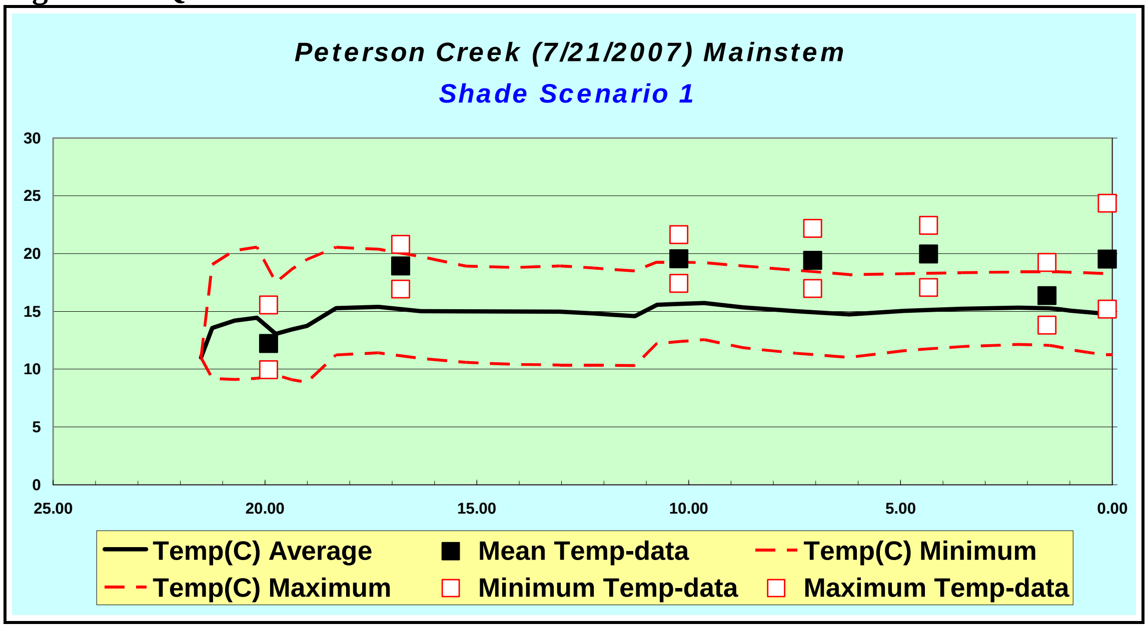
Point measurements progressing downstream: PTR-01, PTR-03, PTR-07, PTR-09, PTR-12, PTR-13, and PTR-14. Jack Creek confluence above PTR-07. Burnt Hollow Creek above PTR-12. I-90 crossing at PTR-13.

The baseline scenario model run indicated that stream temperatures remained relatively cool downstream to the confluence with Jack Creek and the PTR-07 data logger. In contrast, actual temperature measurements in 2007 indicated water temperature increases near the PTR-03 data logger followed by relatively constant temperatures progressing downstream all the way to the mouth. Modeled stream temperatures increased between Jack Creek and Burnt Hollow Creek, followed by downstream temperatures decreases. The maximum measured temperature was recorded at the PTR-12 data logger, which was located downstream of the confluence with Burnt Hollow Creek. Both the modeled and measured temperatures decreased as Peterson Creek approached the I-90 crossing. This may have been due to what appeared to be a large beaver complex within reach PCT7. Downstream of the I-90 crossing, both modeled and measured temperatures again increased. Thus, the results of the baseline modeling effort and 2007 field temperature measurements indicated that Peterson Creek from the Jack Creek confluence and continuing downstream past Burnt Hollow Creek, and Peterson Creek downstream of the I-90 crossing, may be negatively influenced by elevated water temperatures.

2.2.3 Shade Scenario

In the shade modeling scenario, areas with presently diminished shade conditions were changed to an unperturbed reference condition based on field measured shade values. Reaches of Peterson Creek extending from the headwaters to Jack Creek (through reach PCT4) were considered to be at their potential shade levels, with reach average shade values of 71-87%. Reaches of Peterson Creek from the confluence with Jack Creek downstream to the mouth, Reaches PCT5 through PCT9, were assigned an estimated reference shade value of 86% based on the average of the hourly measurements at sites PTR-03, PTR-04 and PTR-07 (**Attachment C**). Since no actual measurements were made for reference conditions where dense riparian vegetation covered the channel, the 85% value was applied as an estimate of reference conditions. If additional data become available for reference conditions, the 85% value may be adjusted accordingly. All other parameters from the baseline scenario were retained. The results of shade scenario 1 indicated a dramatic decrease in maximum temperatures, particularly in reaches PCT6 and PCT9 which were generally lacking woody shrub cover (**Figure 2-3**). The dramatic modeled temperature reductions were likely influenced by the minimal flow and associated small buffering capacity of this small stream.

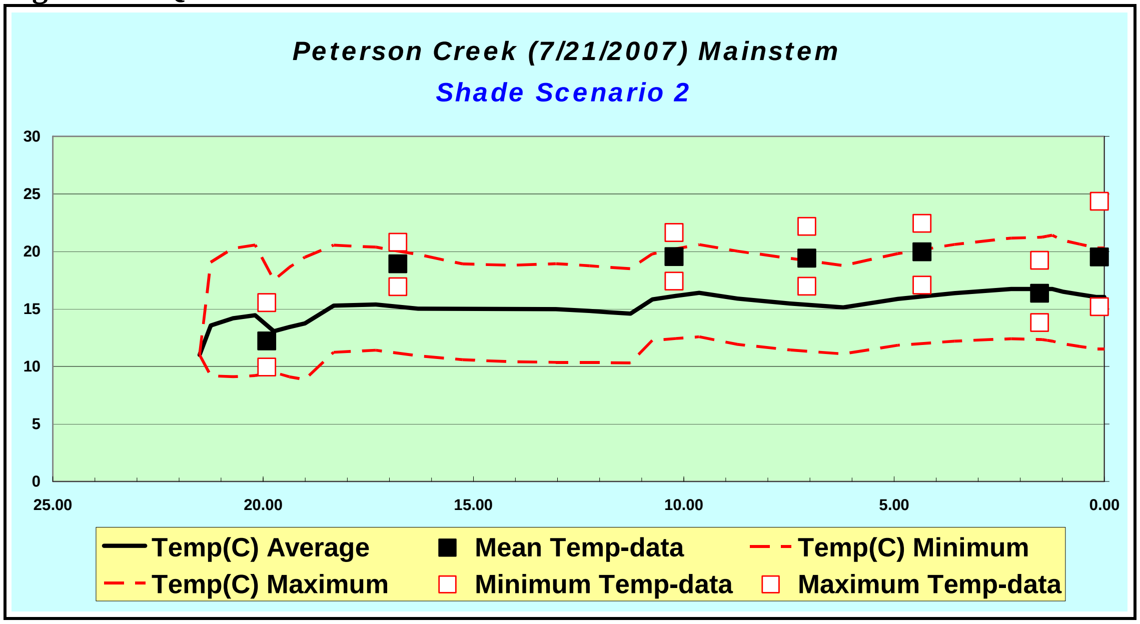
Figure 2-3. QUAL2K Shade Scenario 1.



Point measurements progressing downstream: PTR-01, PTR-03, PTR-07, PTR-09, PTR-12, PTR-13, and PTR-14. Jack Creek confluence above PTR-07. Burnt Hollow Creek above PTR-12. I-90 crossing at PTR-13.

To further evaluate the influence of shade, a second scenario was assessed in which the estimated reference value derived from the average hourly measurements at sites PTR-03, PTR-04 and PTR-07 were applied only to reaches PCT6 and PCT9. These two reaches had extensive areas of open pasture and minimal riparian shrub cover as observed on aerial imagery from 2004 and 2005. All other parameters from the baseline scenario were retained, including shade values along PCT7 since aerial imagery indicated there was a relatively dense band of riparian vegetation along much of this reach. In addition, a more detailed assessment of riparian vegetation along one 500-foot reach within reach PCT7 in 2007 found that riparian shrub cover along the channel margin averaged 53% and ranged from 35% to 65%. The second shade scenario also led to a substantial decrease in maximum temperatures (**Figure 2-4**). This scenario was determined to best represent the potential to decrease stream temperatures by increasing shade along selected reaches of Peterson Creek.

Figure 2-4. QUAL2K Shade Scenario 2.



Point measurements progressing downstream: PTR-01, PTR-03, PTR-07, PTR-09, PTR-12, PTR-13, and PTR-14. Jack Creek confluence above PTR-07. Burnt Hollow Creek above PTR-12. I-90 crossing at PTR-13.

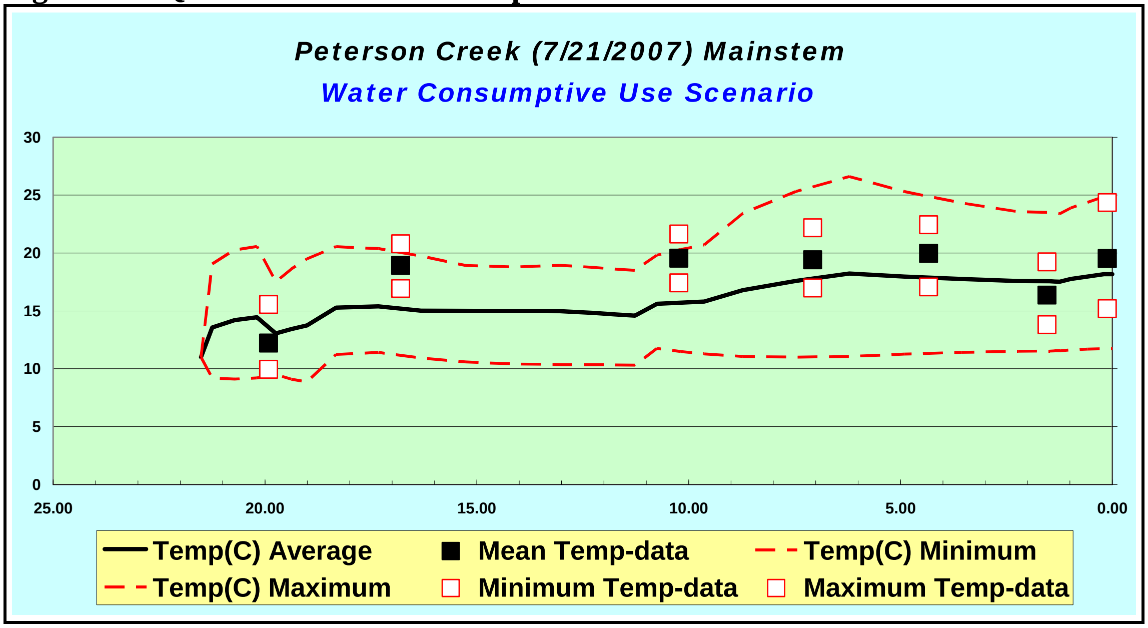
2.2.4 Channel Morphology Scenario

When applying the QUAL2K model in temperature assessments, a channel morphology scenario that examines the influence of channel over-widening is often applied. However, field data collected in 2007 documented low width/depth ratios, suggesting there was minimal potential to further reduce stream channel width. Thus, the channel morphology modeling scenario was not applied to the Peterson Creek temperature assessment.

2.2.5 Water Consumptive Use Scenario

The water consumptive use scenario describes the thermal effect of irrigation and domestic water uses on water temperatures in Peterson Creek. This scenario was modeled by removing existing water diversions from the study reach as identified in the hydrologic balance (**Table 2-5**). The current modeling effort included irrigation withdrawals identified in three reaches: PCT5, PCT7 and PCT9. Warm water irrigation return flows were also removed from reaches PCT5 and PCT7. Additional irrigation withdrawals not identified through field measurements in 2007 may be present, but were not accounted for in this modeling exercise. These included observed withdrawals in reaches PCT2 and PCT6. All other parameters from the baseline scenario were retained. This scenario indicated that water withdrawals have a lesser potential impact on stream temperatures than riparian shading (**Figure 2-5**). The model indicated that slight decreases in temperature could be achieved through water conservation in reach PCT6 upstream of the confluence with Burnt Hollow Creek and reach PCT9 through the City of Deer Lodge. Due to a lack of measurements of irrigation withdrawals throughout the system, the results of the water consumptive use scenario should be interpreted with caution. If more detailed flow data for the irrigation network becomes available, this scenario may need to be reevaluated.

Figure 2-5. QUAL2K Water Consumptive Use Scenario.



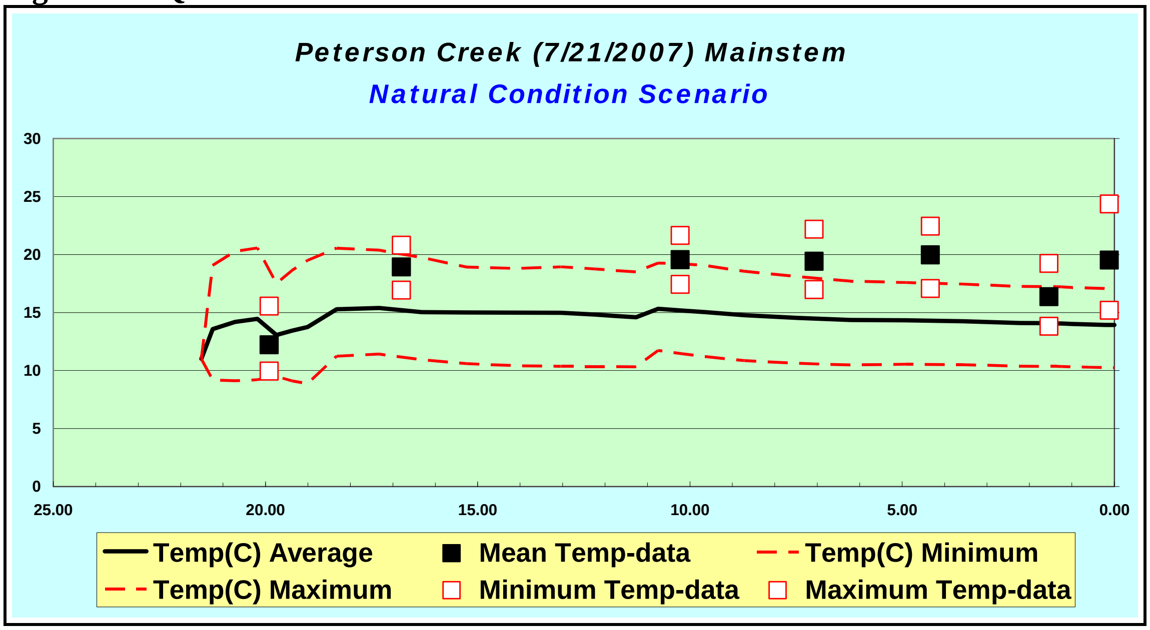
Point measurements progressing downstream: PTR-01, PTR-03, PTR-07, PTR-09, PTR-12, PTR-13, and PTR-14. Jack Creek confluence above PTR-07. Burnt Hollow Creek above PTR-12. I-90 crossing at PTR-13.

Note that streamflow measurements in July of 2007 document a maximum flow in Peterson Creek of 2.1 cfs at site PTR-12, with flows then decreasing to 0.4 cfs by the mouth (site PTR-14), which is a distance of approximately 2.6 miles. This section of Peterson Creek may be an appropriate area on which to focus water management activities since flows were observed to decrease by 80% in this reach, which extends from downstream of the confluence with Burnt Hollow Creek to the mouth.

2.2.6 Natural Condition Scenario

The natural condition scenario reflects the temperature regime that would be expected absent of the influence of man. This allows for the characterization of the extent of the departure from the natural condition. Factors applied in shade scenario 1 (reference shade) and the water consumptive use scenario (no irrigation withdrawals) were applied to run this scenario. All other parameters from the baseline scenario were retained. The natural condition scenario indicated that maximum temperatures at the mouth of Peterson Creek could be approximately 15°F cooler than the modeled maximum temperature of 78.3°F (**Figure 2-6**). The measured maximum temperature on July 21st of 2007 was 75.8°F at the mouth (PTR-14), while the natural condition scenario results in a maximum temperature of 62.7°F (**Attachment D**), suggesting water temperatures could be approximately 13°F cooler at the mouth of Peterson Creek. The seasonal maximum value at site PTR-14 was 78.0°F on July 22nd (**Attachment A**).

Figure 2-6. QUAL2K Natural Condition Scenario.

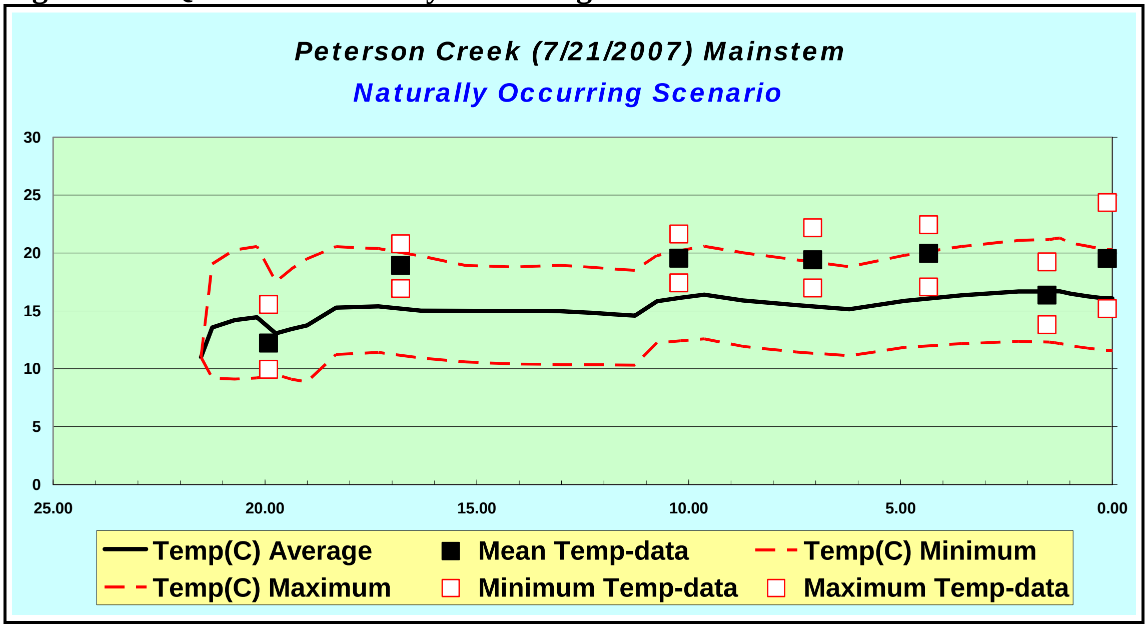


Point measurements progressing downstream: PTR-01, PTR-03, PTR-07, PTR-09, PTR-12, PTR-13, and PTR-14. Jack Creek confluence above PTR-07. Burnt Hollow Creek above PTR-12. I-90 crossing at PTR-13.

2.2.7 Naturally Occurring Scenario (ARM 17.30.602)

The naturally occurring scenario defines water temperature conditions resulting from the implementation of all reasonable land, soil and water conservation practices as outlined in ARM 17.30.602. This scenario identifies the "naturally occurring" temperature in water bodies of interest and establishes the temperatures to which a 0.23°C (0.5°F) temperature increase is allowable. This, in turn, can be used to identify the impairment status of a water body. This scenario included improved shading in reaches PCT6 and PCT9 as suggested by shade scenario 2 along with a 15% increase in irrigation and domestic water use efficiency. This was calculated by reducing the three identified irrigation withdrawals by 15%. The result of the naturally occurring scenario was similar to the result of shade scenario 2, with substantial reductions in temperature predicted in Peterson Creek downstream of the confluence with Jack Creek. Based on the naturally occurring scenario, a maximum temperature of 68.6°F was predicted at the mouth of Peterson Creek and there is the potential for an approximately 10°F reduction in in-stream temperatures relative to the baseline scenario (**Attachment D**).

Figure 2-7. QUAL2K Naturally Occurring Scenario.



Point measurements progressing downstream: PTR-01, PTR-03, PTR-07, PTR-09, PTR-12, PTR-13, and PTR-14. Jack Creek confluence above PTR-07. Burnt Hollow Creek above PTR-12. I-90 crossing at PTR-13.

2.3 Peterson Creek Modeled Temperature Relative to Montana Standards

The naturally occurring scenario indicated that water temperatures greater than 66.5°F can be expected in Peterson Creek. Thus, the maximum allowable increase in temperature due to unmitigated human causes is 0.5°F (0.23°C) (see **Section 1.1**). This standard was exceeded at the lower-most four monitoring sites on Peterson Creek, which represents Peterson Creek from downstream of Jack Creek to the confluence with the Clark Fork River (**Table 2-6**, results for each modeling scenario presented in **Attachment D**). The majority of the temperature reduction potential predicted by the QUAL2K model resulted from increased shade, as presented in shade scenario 2 (**Figure 2-4**), with an additional smaller reduction in temperatures resulting from improved irrigation and domestic water management. As discussed in **Section 2.2.3**, the dramatic modeled temperature reductions were likely a result of the minimal flow in this small stream. Due to the minimal amount of flow, there may be a substantial amount of error in the QUAL2K model. However, temperature data collected in 2007 and the results of this QUAL2K modeling effort suggest that Peterson Creek fails to meet Montana's standard for temperature during low flow periods in the middle of summer and that an increase in riparian shading, particularly along reaches PCT6 and PCT9 will likely lead to a decrease in water temperatures.

Table 2-6. Peterson Creek Temperatures Relative to Montana's Water Quality Standards.

Data Logger Site	Field Measured Data	QUAL2K Existing Conditions	Departure from Field Data (ºF)	QUAL2K Naturally Occurring Scenario	Departure from Existing Conditions Model (ºF)
	Maximum Temperature (ºF)	Maximum Temperature (ºF)		Maximum Temperature (ºF)	
PTR-01	60.0	63.5	3.53	63.5	0.00
PTR-03	69.4	67.5	-1.89	67.5	0.00
PTR-07	71.0	68.4	-2.54	68.4	0.00
PTR-09	71.9	78.2	6.23	66.9	**-11.21**
PTR-12	72.4	77.3	4.86	67.6	**-9.61**
PTR-13	66.6	73.6	6.97	70.1	**-3.47**
PTR-14	75.8	78.3	2.43	68.6	**-9.72**

Bold text indicates violation of Montana's water quality standard.

SECTION 3.0
CONCLUSIONS

This assessment indicated that Peterson Creek is impaired due to elevated water temperatures during low flow periods in the middle of summer. Overall, the results of this study indicated that Peterson Creek downstream of the confluence with Jack Creek should be the focus of restoration efforts directed towards decreasing water temperatures in Peterson Creek.

Major findings and restoration recommendations include:

- Temperature data collected in 2007 and the results of this QUAL2K modeling effort suggest that Peterson Creek fails to meet Montana's standard for temperature during low flow periods in the middle of summer.

- Modeling indicated that increased shading in reaches PCT6 and PCT9 would likely have the greatest impact on water temperatures in Peterson Creek. Reach PCT6 extends upstream of the Burnt Hollow Creek confluence, while Reach PCT9 flows through the town of Deer Lodge. In 2007, maximum temperatures were observed at site PTR-12 in reach PCT7, which is located downstream of the Burnt Hollow Creek confluence. This further supports the need for improved riparian shading upstream of this site.

- Maximum streamflows were observed at PTR-12, which is located downstream of the Burnt Hollow Creek confluence. Streamflows decreased by 80% between this site and the confluence with the Clark Fork River. Thus, irrigation efficiency improvements should focus on Peterson Creek downstream of the confluence with Burnt Hollow Creek.

Limitations of this study include a lack of detailed flow measurements for the irrigation network, a lack of reference conditions data for riparian shading, and potential limitations of the QUAL2K model when working with such a small stream. Thus, the results of this assessment may need to be reevaluated as additional information becomes available.

SECTION 4.0 REFERENCES

Flynn, K., Kron, D., Granger, M. 2008. Modeling Streamflow and Water Temperature in the Big Hole River, Montana – 2006. Contributing authors K. Flynn, D. Kron and M. Granger, M. 2008. TMDL Technical Report DMS-2008-03. Montana Department of Environmental Quality. Helena, MT.

MDEQ 2007. Upper Clark Fork TMDL Planning Area Temperature and Instantaneous Flow Monitoring Sampling and Analysis Plan. Prepared by Montana Department of Environmental Quality. Helena, MT.

ATTACHMENT A
2007 TEMPERATURE DATA SUMMARY UPPER CLARK FORK TMDL PLANNING AREA

Site ID	Site Name	Lat	Long	Start Date	Stop date	Seasonal Maximum		Seasonal Minimum		Seasonal Max ΔT		7-Day averages			
						Date	Value	Date	Value	Date	Value	Date	Maximum	Minimum	Δ T
PTR-05	617318	46.3176	112.6628	07/18/07	09/25/07	07/20/07	72.5	09/25/07	38.2	08/11/07	14.9	07/21/07	71.1	59.8	11.3
PTR-12	617341	46.37078	112.69884	07/19/07	09/25/07	07/20/07	75.8	09/25/07	41.5	07/28/07	14.1	07/22/07	73.1	63.1	10.0
PTR-03	617386	46.2844	112.614	07/18/07	09/25/07	07/19/07	71.8	09/25/07	40.1	07/22/07	10.2	07/21/07	70.1	62.6	7.6
PTR-07	617400	46.3248	112.6673	07/18/07	09/25/07	07/20/07	73.4	09/25/07	41.5	08/11/07	14.2	07/21/07	71.8	63.2	8.6
PTR-09	650637	46.35066	112.6822	07/18/07	09/25/07	07/28/07	74.4	09/25/07	40.4	09/02/07	15.4	07/21/07	72.5	62.5	10.0
PTR-13	650641	46.3878	112.7207	07/18/07	09/25/07	07/19/07	73.4	09/25/07	41.0	09/11/07	15.7	07/21/07	68.1	57.5	10.6
PTR-01	650664	46.27683	112.58129	07/17/07	09/25/07	07/17/07	80.3	09/25/07	36.2	07/17/07	27.9	07/20/07	63.3	50.7	12.6
PTR-11	650710	46.3625	112.6857	07/18/07	09/25/07	07/22/07	76.0	09/25/07	43.2	07/22/07	18.6	07/21/07	74.0	59.5	14.5
PTR-14	650711	46.38944	112.73567	07/19/07	09/25/07	07/22/07	78.0	09/25/07	39.3	07/22/07	20.1	07/22/07	75.2	60.4	14.8

Site ID	Site Name	Days > 50 F	Days > 59 F	Days > 70 F	Hours > 50 F	Hours > 59 F	Hours > 70 F	Warmest day of 7-day max			Agency
								Date	Maximum	Minimum	
PTR-05	617318	65	47	9	1245.5	570.5	32.0	07/18/07	72.5	60.0	DEQ
PTR-12	617341	63	50	13	1406.5	757.0	86.5	07/20/07	75.8	62.5	DEQ
PTR-03	617386	64	47	7	1389.5	680.0	28.0	07/19/07	71.8	63.6	DEQ
PTR-07	617400	67	56	14	1456.0	849.0	76.5	07/18/07	73.4	61.4	DEQ
PTR-09	650637	65	52	14	1407.5	752.5	82.5	07/20/07	74.4	62.3	DEQ
PTR-13	650641	64	42	3	1193.5	327.0	14.0	07/19/07	73.4	62.3	DEQ
PTR-01	650664	52	16	1	818.0	56.5	11.5	07/17/07	80.3	52.4	DEQ
PTR-11	650710	69	60	16	1529.5	891.0	100.5	07/20/07	76.0	58.3	DEQ
PTR-14	650711	67	49	10	1326.5	612.5	67.5	07/22/07	78.0	57.9	DEQ

ATTACHMENT B
STREAMFLOW DATA UPPER CLARK FORK TMDL PLANNING AREA

Site Information				Deployment				Retrieval			
Site ID	Serial #	Latitude	Longitude	Date	Time	Flow (cfs)	Site Description	Date	Time	Flow (cfs)	Notes
PTR-01	650664	46.2768	112.5813	7/16/2007	11:24	0.131	just d/s of aspen	9/26/2007	9:40	0.015	Brick/logger in some sediment/slight sed in PVC
PTR-02	650682	46.2792	112.5790	7/16/2007	10:40	0.554	1st clearing, ~0.3 miles from PTR-01, under left bank	9/26/2007	8:40	0.052	Clean, bad file - only 10 days of results
PTR-03	617386	46.2844	112.6140	7/17/2007	12:03	1.553	btwn two cow crossings	9/26/2007	10:17	0.251	Logger in some sediment but no sed in PVC
PTR-04	530261	46.3172	112.6629	7/17/2007	13:33	1.743	Unshaded open bend	9/26/2007	13:00	0.182	No retrieval - lost
PTR-05	617318	46.3176	112.6628	7/17/2007	13:11	0.581	Under an alder tree ~150' u/s of cottonwood stand	9/26/2007	12:22	0.074	Some debris in PVC pipe but not clogged
PTR-07	617400	46.3248	112.6673	7/17/2007	16:19	1.688	just d/s of fence line, ~120' d/s of cattle xing in willow clearing	9/26/2007	16:40	0.308	PVC pipe covered w/ layer of sand, not clogged
PTR-08	n/a	46.3316	112.6701	7/17/2007	16:53	1.961	n/a	9/26/2007	n/a	0.296	n/a
PTR-09	650637	46.3507	112.6822	7/17/2007	17:26	N/A	deployed @ shuman ranch bridge crossing	9/26/2007	15:12		Logger was clean
PTR-11	650710	46.3625	112.6857	7/17/2007	NA	0.095	~10' d/s of manmade pond on Shiek house, d/s of culvert	9/26/2007	17:54	N/A	immeasurable flow but PVC not clogged. Some algae on brick/PVC
PTR-12	617341	46.3708	112.6984	7/18/2007	8:54	2.144	Rinsen property wooden bridge xing in cowfield adjacent to house	9/26/2007	18:15	0.326	PVC partially filled with fine sediment, but flow passing through
PTR-13	650641	46.3878	112.7207	7/17/2007	19:33	0.623	~ 10-15' u/s of culvert	9/26/2007	18:36		clean
PTR-14	650711	46.3894	112.7357	7/18/2007	9:52	0.420	on u/s side of culvert	9/26/2007	18:50	0.072	minimal sediment in PVC

ATTACHMENT C
SOLAR PATHFINDER DATA UPPER CLARK FORK TMDL PLANNING AREA

		6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	TOTAL
Reach	**Potential**	**3**	**5**	**8**	**10**	**12**	**12**	**12**	**12**	**10**	**8**	**5**	**3**	
PTR02-1	Transect 1	3	5	8	10	12	12	12	8	5	1	5	3	84
PTR02-2	Transect 2	3	3.5	0	0	0	1	12	12	10	8	5	3	58
PTR02-3	Transect 3	3	5	8	9	3	0	0	0	5	8	5	3	49
PTR02	**Average %**	**100%**	**90%**	**67%**	**63%**	**42%**	**36%**	**67%**	**56%**	**67%**	**71%**	**100%**	**100%**	**71%**
PTR03-1	Transect 1	3	5	6	10	12	12	10	0	0	7	5	3	73
PTR03-2	Transect 2	3	5	6	2.5	2	10.5	12	12	10	8	5	3	79
PTR03-3	Transect 3	3	5	8	10	12	10	12	12	10	8	5	3	98
PTR03	**Average %**	**100%**	**100%**	**83%**	**75%**	**72%**	**90%**	**94%**	**67%**	**67%**	**96%**	**100%**	**100%**	**87%**
PTR04-1	Transect 1	3	5	8	6.5	1	0	0	0	3	8	4	2	41
PTR04-2	Transect 2	3	5	8	10	12	12	12	12	10	8	5	3	100
PTR04-3	Transect 3	3	5	0	0	3	12	12	12	10	8	5	3	73
PTR04	**Average %**	**100%**	**100%**	**67%**	**55%**	**44%**	**67%**	**67%**	**67%**	**77%**	**100%**	**93%**	**89%**	**77%**
PTR07-1	Transect 1	3	5	7	5	7	7	10	8	7.5	8	5	3	76
PTR07-2	Transect 2	3	5	8	10	12	12	12	12	10	8	5	3	100
PTR07-3	Transect 3	3	3.5	6	10	12	12	10	12	10	8	5	3	95
PTR07	**Average %**	**100%**	**90%**	**88%**	**83%**	**86%**	**86%**	**89%**	**89%**	**92%**	**100%**	**100%**	**100%**	**92%**
PTR08-1	Transect 1	3	1	0	0	0	0	0	0	0	0	0	2	6
PTR08-2	Transect 2	3	5	5	0	0	10.5	12	12	10	8	5	3	74
PTR08-3	Transect 3	2	0	0	0	0	0	0	0	0	0	0	1	3
PTR08	**Average %**	**89%**	**40%**	**21%**	**0%**	**0%**	**29%**	**33%**	**33%**	**33%**	**33%**	**33%**	**67%**	**34%**
PTR07/08	**Average %**	**94%**	**65%**	**54%**	**42%**	**43%**	**58%**	**61%**	**61%**	**63%**	**67%**	**67%**	**83%**	**63%**
PTR03/04/07	**Average %**	**100%**	**97%**	**79%**	**71%**	**68%**	**81%**	**83%**	**74%**	**78%**	**99%**	**98%**	**96%**	**85%**

ATTACHMENT D
QUAL2K MODEL SCENARIOS UPPER CLARK FORK TMDL PLANNING AREA

Baseline Scenario

	Field Measured Data			Q2K Existing Conditions			Departure from Field Data (ºF)
Data Logger Site	Distance (km)	Maximum Temperature (ºC)	Maximum Temperature (ºF)	Distance (km)	Maximum Temperature (ºC)	Maximum Temperature (ºF)	
PTR-01	19.91	15.54	60.0	19.74	17.50	63.5	3.53
PTR-03	16.80	20.79	69.4	16.32	19.74	67.5	-1.89
PTR-07	10.23	21.64	71.0	10.19	20.23	68.4	-2.54
PTR-09	7.07	22.18	71.9	7.47	25.64	78.2	6.23
PTR-12	4.43	22.44	72.4	4.91	25.14	77.3	4.86
PTR-13	1.54	19.22	66.6	1.48	23.09	73.6	6.97
PTR-14	0.12	24.36	75.8	0.20	25.71	78.3	2.43

Shade Scenario 1

	Q2K Existing Conditions			Q2K Shade Scenario 1			Departure from Existing Conditions Model (ºF)
Data Logger Site	Distance (km)	Maximum Temperature (ºC)	Maximum Temperature (ºF)	Distance (km)	Maximum Temperature (ºC)	Maximum Temperature (ºF)	
PTR-01	19.74	17.50	63.5	19.74	17.50	63.5	0.00
PTR-03	16.32	19.74	67.5	16.32	19.74	67.5	0.00
PTR-07	10.19	20.23	68.4	10.19	19.25	66.7	-1.76
PTR-09	7.47	25.64	78.2	7.47	18.55	65.4	-12.76
PTR-12	4.91	25.14	77.3	4.91	18.26	64.9	-12.38
PTR-13	1.48	23.09	73.6	1.48	18.42	65.2	-8.41
PTR-14	0.20	25.71	78.3	0.20	18.28	64.9	-13.37

Shade Scenario 2

	Q2K Existing Conditions			Q2K Shade Scenario 2			Departure from Existing Conditions Model (ºF)
Data Logger Site	Distance (km)	Maximum Temperature (ºC)	Maximum Temperature (ºF)	Distance (km)	Maximum Temperature (ºC)	Maximum Temperature (ºF)	
PTR-01	19.74	17.50	63.5	19.74	17.50	63.5	0.00
PTR-03	16.32	19.74	67.5	16.32	19.74	67.5	0.00
PTR-07	10.19	20.23	68.4	10.19	20.23	68.4	0.00
PTR-09	7.47	25.64	78.2	7.47	19.39	66.9	-11.25
PTR-12	4.91	25.14	77.3	4.91	19.81	67.7	-9.59
PTR-13	1.48	23.09	73.6	1.48	21.25	70.3	-3.31
PTR-14	0.20	25.71	78.3	0.20	20.32	68.6	-9.70

Water Consumptive Use Scenario

	Q2K Existing Conditions			Q2K Water Consumptive Use Scenario			Departure from Existing Conditions Model (ºF)
Data Logger Site	Distance (km)	Maximum Temperature (ºC)	Maximum Temperature (ºF)	Distance (km)	Maximum Temperature (ºC)	Maximum Temperature (ºF)	
PTR-01	19.74	17.50	63.5	19.74	17.50	63.5	0.00
PTR-03	16.32	19.74	67.5	16.32	19.74	67.5	0.00
PTR-07	10.19	20.23	68.4	10.19	20.30	68.5	0.13
PTR-09	7.47	25.64	78.2	7.47	25.30	77.5	-0.61
PTR-12	4.91	25.14	77.3	4.91	25.30	77.5	0.29
PTR-13	1.48	23.09	73.6	1.48	23.51	74.3	0.76
PTR-14	0.20	25.71	78.3	0.20	24.86	76.7	-1.53

Natural Condition Scenario

	Q2K Existing Conditions			Natural Condition Scenario			Departure from Existing Conditions Model (ºF)
Data Logger Site	Distance (km)	Maximum Temperature (ºC)	Maximum Temperature (ºF)	Distance (km)	Maximum Temperature (ºC)	Maximum Temperature (ºF)	
PTR-01	19.74	17.50	63.5	19.74	17.50	63.5	0.00
PTR-03	16.32	19.74	67.5	16.32	19.74	67.5	0.00
PTR-07	10.19	20.23	68.4	10.19	19.19	66.5	-1.87
PTR-09	7.47	25.64	78.2	7.47	18.09	64.6	-13.59
PTR-12	4.91	25.14	77.3	4.91	17.59	63.7	-13.59
PTR-13	1.48	23.09	73.6	1.48	17.25	63.1	-10.51
PTR-14	0.20	25.71	78.3	0.20	17.07	62.7	-15.55

Naturally Occuring Scenario

	Q2K Existing Conditions			Naturally Occurring Scenario			Departure from Existing Conditions Model (ºF)
Data Logger Site	Distance (km)	Maximum Temperature (ºC)	Maximum Temperature (ºF)	Distance (km)	Maximum Temperature (ºC)	Maximum Temperature (ºF)	
PTR-01	19.74	17.50	63.5	19.74	17.50	63.5	0.00
PTR-03	16.32	19.74	67.5	16.32	19.74	67.5	0.00
PTR-07	10.19	20.23	68.4	10.19	20.23	68.4	0.00
PTR-09	7.47	25.64	78.2	7.47	19.41	66.9	-11.21
PTR-12	4.91	25.14	77.3	4.91	19.80	67.6	-9.61
PTR-13	1.48	23.09	73.6	1.48	21.16	70.1	-3.47
PTR-14	0.20	25.71	78.3	0.20	20.31	68.6	-9.72