APPENDIX H – TEMPERATURE CONDITIONS FOR LOWER MADISON RIVER AND WEST FORK MADISON RIVER

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H1.0 Introduction

Cherry Creek, Elk Creek, and Moore Creek were found to be temperature impaired through the Madison TMDL Planning Area temperature study, and TMDLs were written for those streams, details of which can be found in Section 6.0 of the main TMDL document. Jack Creek was not identified prior to this study as having a temperature impairment but was evaluated based on field reconnaissance and stakeholder concern. Data collected during this effort indicates Jack Creek is not impaired for temperature and no TMDL was written and a summary of the Jack Creek data is not included in this appendix. This appendix details stream conditions in the Madison River below Madison Dam (Assessment Unit MT41F001_010) and the West Fork Madison River (Assessment Unit MT41F004_100), both of which currently remain listed for temperature impairment in Montana's 2018 Water Quality Integrated Report (DEQ, 2018).

H2.0 Madison River (Madison Dam to Mouth) Temperature Conditions

The Madison River downstream of Ennis Lake (Madison Dam), also referred to as the lower Madison River, has a hydrologic regime that is modified by the presence of two major reservoirs, Hebgen Lake and Ennis Lake (Madison Reservoir). The Madison River flows from its headwaters in Yellowstone National Park into Hebgen Lake, which is located just outside of the Yellowstone National Park boundary. Hebgen Lake was created in 1914 with the construction of Hebgen Dam, and is used to control streamflow for the downstream Madison River system. From Hebgen Lake, the river has a short freH-flowing stretch before it enters Quake Lake, a lake that was formed in 1959 by an earthquake-induced landslide. Downstream of Quake Lake, the Madison River flows approximately 59 miles to Ennis Lake. Ennis Lake is a shallow reservoir that was created by Madison Dam in 1906, and is normally operated as a run of the river dam. Because Madison Dam is operated as run of the river, the outflow from Madison Dam is regulated by upstream flow and dam operations at Hebgen Dam. Downstream of Madison Dam, the Madison River travels approximately 41.3 miles to the mouth, which forms the headwaters of the Missouri River. The lower Madison River is listed as impaired by temperature in the 2018 Integrated Report.

Riparian Health/Shade
The lower Madison River, like many other large river systems, has a wide channel where shade produced by riparian vegetation may not have a significant cooling effect on the entire width of the stream. Downstream of Madison Dam, the Madison River flows through a large canyon which provides significant topographical shade to the stream. Because the stream is contained in this confined canyon, the existing riparian vegetation is likely at or near its potential.

Dam Operations
Northwestern Energy (FERC licensee), formerly PPL Montana and Montana Power Company, currently operates Hebgen Dam for water storage and Madison Dam for hydropower generation. As a part of Northwestern Energy's Federal Energy Regulatory Commission (FERC) licensing and Clean Water Act §401 certification through DEQ for these facilities, Northwestern Energy monitors the effects on water quality that these facilities may have. In 1989, the FERC licensee installed multiple long-term air and water temperature monitoring stations, and river timH-of-travel and fisheries studies were conducted along the lower Madison River. The FERC licensee also developed a Madison thermal statistical model

that used data collected each half-hour at these stations between 1989 and 1995. The model described the thermal character of the lower Madison River by river mile with and without the influence of Madison Dam. Thermal model data showed that the lower Madison River with or without the influence of Madison Dam and Reservoir would produce summer thermal conditions much higher than optimal for resident trout (Jourdonnais 2004).

Madison statistical model results showed that Madison Reservoir (Ennis Lake), during the hot, dry summer of 1988, increased mean river temperature by 2.5°F in the lower Madison River at Black's Ford and increased maximum river temperature by 5.7°F, compared to a theoretical reservoir absence condition. In cooler, wetter summers (e.g. 1993) Madison Reservoir raised maximum lower Madison River temperature by only 2.3°F and raised mean temperatures by 1.9°F, compared to reservoir absence. Hence, the Madison thermal model statistically quantified thermal effects of Madison Reservoir on lower river temperatures for the first time and provided definitive guidance on the scope of thermal impacts and potential for mitigative solutions (Jourdonnais 2004).

In 1993 and 1994, the FERC licensee, in consultation with resource agencies and the public, investigated the feasibility of 14 thermal alternatives to reduce water temperature in the lower Madison River. The selected alternative involved cooling the lower Madison River by pulsing river flows during the heat of the day, effectively reducing peak water temperatures. Pulse flows are based on the well-known principle that a greater mass of water has a greater resistance to heating than a smaller mass of water given the same thermal input. Hence, the lower Madison River at higher flow volumes (1,400 cfs to 2,100 cfs) are expected to warm more slowly and reach lower maximum temperatures on a given hot summer day compared to minimum (1,100 cfs) baseflow rates. Pulse flow releases from Madison Dam, ramped at 200 cfs per hour to protect fisheries resources, are timed so that the increased flow reaches the downstream target area near Black's Ford during peak water temperature hours in late afternoon. Between flow pulses, the lower river is ramped to baseflow at night. Lower river pulsed flows are drafted from Madison Reservoir, which refills on the baseflow cycle. Upper Madison River flows from Hebgen Dam are slightly increased (though ramped slowly and stabilized) to backfill Madison Reservoir during extended pulsing events. Minimal flow changes in the upper Madison River are important both to protect important riverine aquatic resources and angling success and to minimize water level fluctuations in Hebgen Reservoir to protect recreation and biological resources there (Jourdonnais 2004).

To further improve the thermal program, the FERC licensee, resource agencies, and HARZA developed a state-of-the-art pulse flow Decision Support System (DSS) Plan for the lower Madison River using the data, technologies, and models employed during the licensing period since 1989 (Jourdonnais 2004). The goal of the DSS is to maintain maximum daily water temperature in the Madison River at or below 80°F to protect brown and rainbow trout. The DSS monitors air and water temperature, weather forecasts, and employs pulse flows from Madison Dam whenever lower Madison River temperatures are predicted to exceed 80°F at Sloan Meteorological Station. The Madison River DSS has operated every summer from 2001 through present. Daily data are publicly available online at http://www.madisondss.com.

Discussion

The lower Madison River is a large river system that has its hydrologic and thermal regimes modified by the presence of two large reservoirs upstream, Hebgen Lake and Ennis Lake (Madison Reservoir). Due to the wide channel width of the Madison River, improvements in riparian vegetation, where possible, will likely have minimal influence on effective stream shade and water temperatures. Dam operations however, play a significant role in water temperatures of the lower Madison River. Programs have been implemented by the FERC licensee of these dams (currently Northwestern Energy), to mitigate any negative effects of water temperature increases that these reservoirs may cause. Successful implementation of the pulse flow program maintains water temperatures of below 80°F in the lower Madison River to prevent fish kills.

Developing a sediment TMDL for the Lower Madison River requires a complex modeling effort due to the presence of Hebgen Dam and Madison Dam. A sediment TMDL for the Lower Madison River was not developed as part of this document.

H3.0 West Fork Madison River Temperature Conditions

The West Fork Madison River flows from its headwaters in the Gravelly Range to its mouth at the Madison River south of Cameron, Montana. The West Fork Madison River is listed as impaired by temperature in the 2018 Integrated Report.

In the West Fork Madison River watershed, riparian health/shade, channel width/depth ratio, and instream discharge are the three main variables that contribute to human-caused sources of stream temperature. Each of these variables in relation to the West Fork Madison River is described below.

Riparian Health/Shade

ShadH-related data, including Solar Pathfinder data were collected at 17 sites and used in conjunction with aerial photography to model the existing effective shade using the Shade Tool (Washington State Department of Ecology 2007). Shade targets were developed based on level IV ecoregion and the expected riparian vegetation community for that ecoregion. That vegetation community was then compared to shade curves developed for the near-by Targhee National Forest for reference riparian vegetation conditions (Shumar and de Varona 2009). **Figure H-1** compares the existing effective shade to its respective shade targets, while **Figure H-2** plots the difference between the existing effective shade and the shade targets. The plots are displayed in an upstream (left) to downstream (right) orientation to easily correlate targets and existing shade to location on the stream. Positive numbers in **Figure H-2** indicate that the existing effective shade exceeds the shade targets, while negative numbers indicate areas where existing effective shade is deficient. The West Fork Madison River generally meets shade targets throughout most of the length of the stream. Portions of the upper West Fork Madison River are naturally intermittent, which may be leading to the lack of shade in those areas, but overall, the riparian shade conditions are meeting or exceeding target shade (**Figure H-2**) (conversation with USFS Range Manager, Ennis Office, Kevin Suzuki on June 26, 2014).

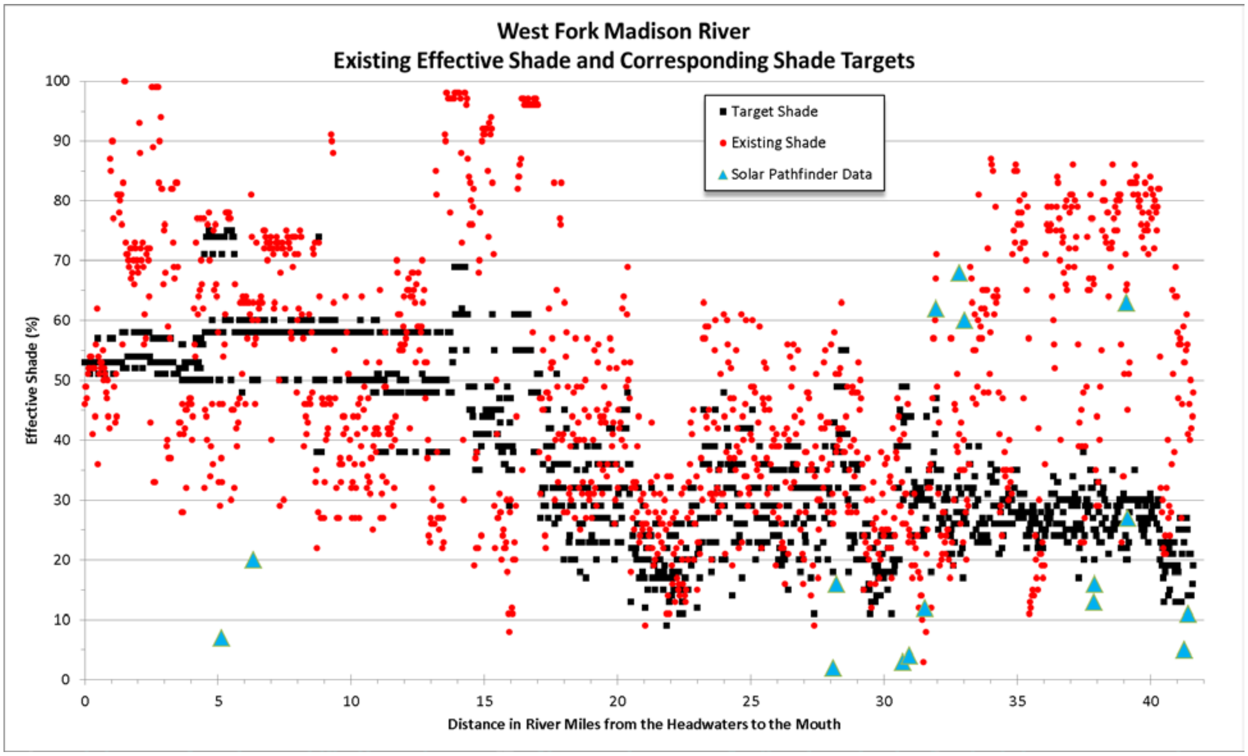

Figure H-1. Existing Effective Shade and Corresponding Shade Targets for the West Fork Madison River

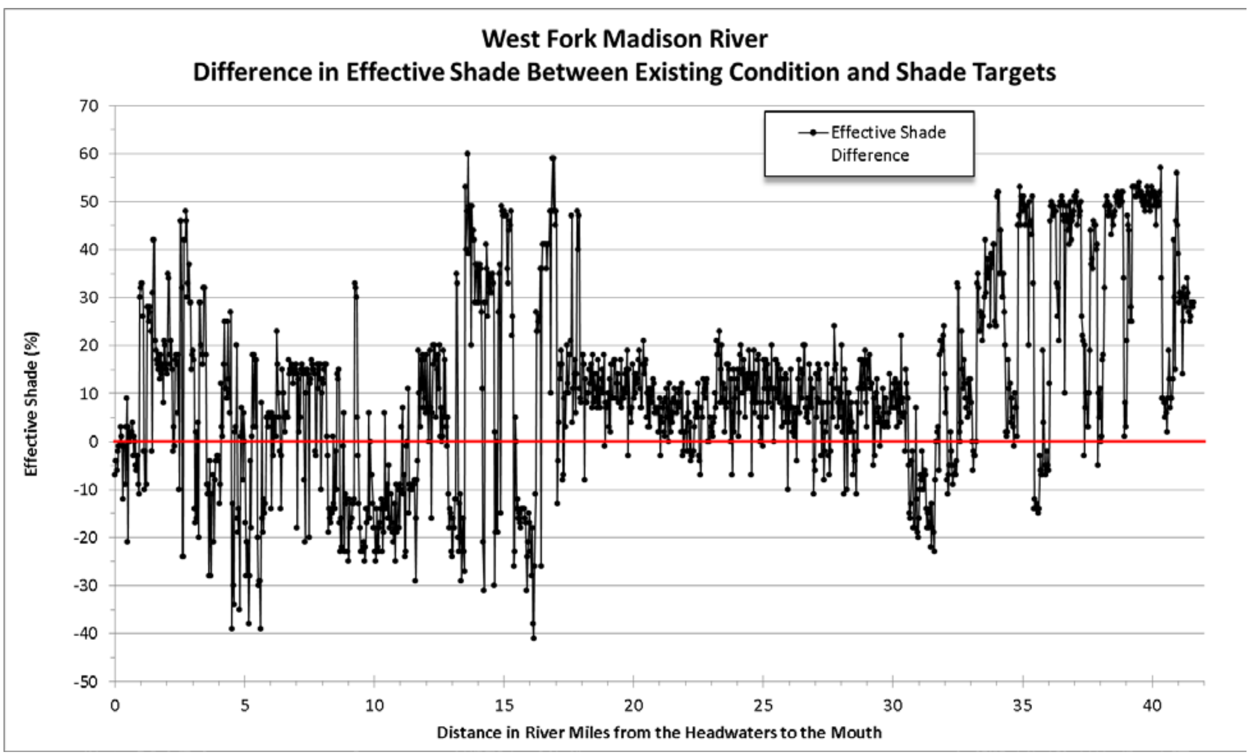

Figure H-2. Difference in Effective Shade between Existing Condition and Shade Targets for the West Fork Madison River

Channel Width/Depth Ratio

Channel width/depth ratio was measured at four sites along the West Fork Madison River as a part of the data collection effort to assess sediment impairment (**Section 5.0**). Data collected by DEQ in 2014 and the USFS in 2009 indicate that the West Fork Madison River is meeting the width/depth ratio targets at two of the four monitoring sites (**Table H-1**). Although this data was collected in four discrete locations, the locations of the monitoring sites were chosen because they are assumed to be representative of the West Fork Madison River as a whole. It is possible that the width/depth ratio may be exceeding targets in areas along the West Fork Madison River, especially in areas where land management practices are poor, but areas that have good land use management practices in place should not be negatively affecting the width/depth ratio of the West Fork Madison River.

Table H-1. West Fork Madison River Calculated Width/Depth Ratios in Comparison to Width/Depth Ratio Targets

Reach/Site ID	Year Data Collected	Mean BFW (ft)	W/D Ratio Target	W/D Ratio
2740 (PIBO)[1]	2009, 2014	23.7	≤ 24	12.8
WFMA 14-02	2014	12.6	≤ 11	13.9
WFMA 25-01	2014	53.5	≤ 30	32.4
WFMA 26-01	2013	43.5	≤ 30	28.1

[1] Values are averages from sampling events in 2009 and 2014

Although the West Fork Madison River fails to meet the width/depth ratio targets in two areas, it overall appears healthy. Data collected by DEQ in 2013 and 2014 indicate that there are limited potential human-caused sources contributing to channel instability, and that continued implementation of best management practices will maintain or improve the existing channel condition of the West Fork Madison River.

Instream Discharge (Streamflow Conditions)

There are no active water diversions on the West Fork Madison River. The Staudemeyer Canal, which previously diverted water from the upper West Fork Madison River to Metzel Creek in the Red Rock River watershed, is no longer in use and has not been in operation for over 30 years (conversation with USFS Range Manager, Ennis Office, Kevin Suzuki on June 26, 2014).

Discussion

There are relatively few current human-caused sources of temperature, and because of this, any elevated stream temperatures that may occur in the West Fork Madison River are likely due to historical human-caused sources that have since been removed and are now in recovery, and natural sources such as intermittent flow, thermal springs, wildland fire, and riparian grazing and browsing by wildlife. The comparison of recently collected data to the water quality targets outlined above indicate the river is at or near meeting targets and no TMDL was written at this time.

H4.0 References

DEQ (Montana Department of Environmental Quality). 2018. Montana Final 2018 Water Quality Integrated Report. Helena, MT: Montana Dept. of Environmental Quality.

Jourdonnais, J. June 21, 2004. A Winning Combination. Water Power and Dam Construction.

Suzuki, K. Personal Communication. June 25, 2014.