APPENDIX B - SEDIMENT AND HABITAT DATA COLLECTION METHODS

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B1.0 INTRODUCTION

This appendix summarizes sediment and habitat data collected and analyzed for the stream segments evaluated in the Madison TPA. Twenty-one stream segments in the Madison TPA were evaluated for sediment impairments based on existing impairment listings, reconnaissance, and input from local stakeholders (**Table B-1 and Figure B-1**). Of the twenty-one, thirteen were found to be impaired and TMDLs were written (See **Section 5.4.3** in this document for summary information on these thirteen stream segments). Seven stream segments were found not impaired by sediment and are summarized within this Appendix; along with the lower Madison River where the impairment remains but did not have a TMDL written. Several of the twenty-one stream segments, including some of the streams with no sediment impairment, have a habitat alteration, which is a non-pollutant impairment commonly associated with sediment impairment (**Table B-1**). TMDLs are limited to pollutants, but implementation of land, soil, and water conservation practices to reduce pollutant loading will inherently address some non-pollutant impairments. Such approaches are highlighted in Montana DEQ's Nonpoint Source Management Plan (DEQ 2017)

Table B-1. Stream Segments Evaluated for Sediment Impairment

Stream Segment	Segment ID	Sediment TMDL Developed
Antelope Creek	MT41F004_140	Yes*
Bear Creek	MT41F004_021	Yes
Blaine Spring Creek	MT41F004_010	Yes
Buford Creek	MT41F004_150	No
Cherry Creek	MT41F002_010	Yes
Elk Creek	MT41F002_020	Yes*
Elk River	MT41F004_110	No
Gazelle Creek	MT41F004_120	No
Hot Springs Creek	MT41F002_030	Yes*
Indian Creek	MT41F004_040	No*
Jack Creek	MT41F004_050	No*
Lower Madison River[1]	MT41F001_010	No*
Moore Creek	MT41F004_130	Yes*
North Meadow Creek	MT41F004_060	Yes*
O'Dell Spring Creek	MT41F004_020	No*
Red Canyon Creek	MT41F006_020	Yes*
Ruby Creek	MT41F004_080	Yes*
South Meadow Creek	MT41F004_070	Yes
Watkins Creek	MT41F006_030	Yes*
West Fork Madison River	MT41F004_100	No
Wigwam Creek	MT41F004_160	Yes

*Non-pollutant listing/s associated with sediment impairment on 2018 303(d) List

[1] PPL, Montana 2013

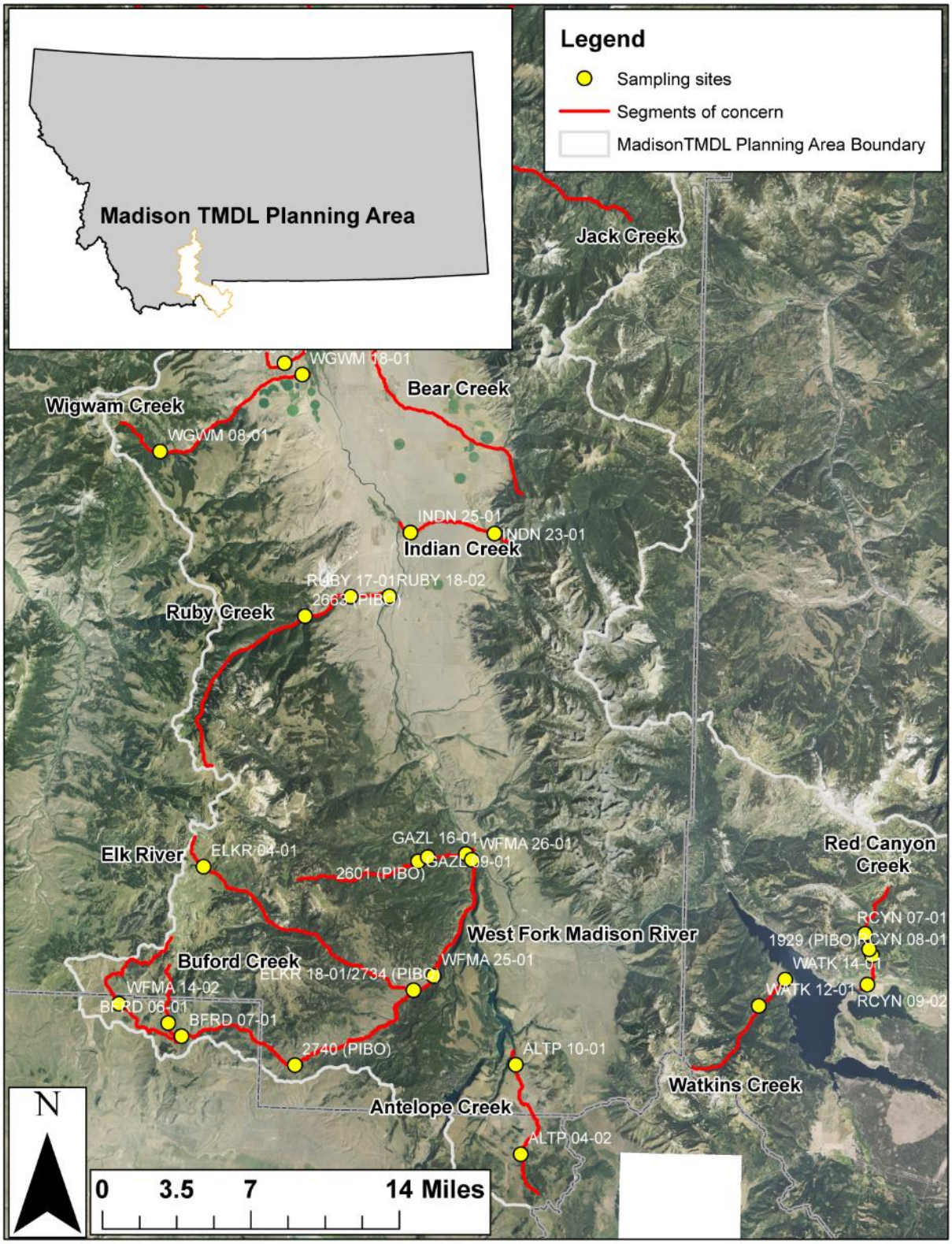

Figure B-1. Stream segments upstream of Indian Creek evaluated in this document and sampling sites on these segments

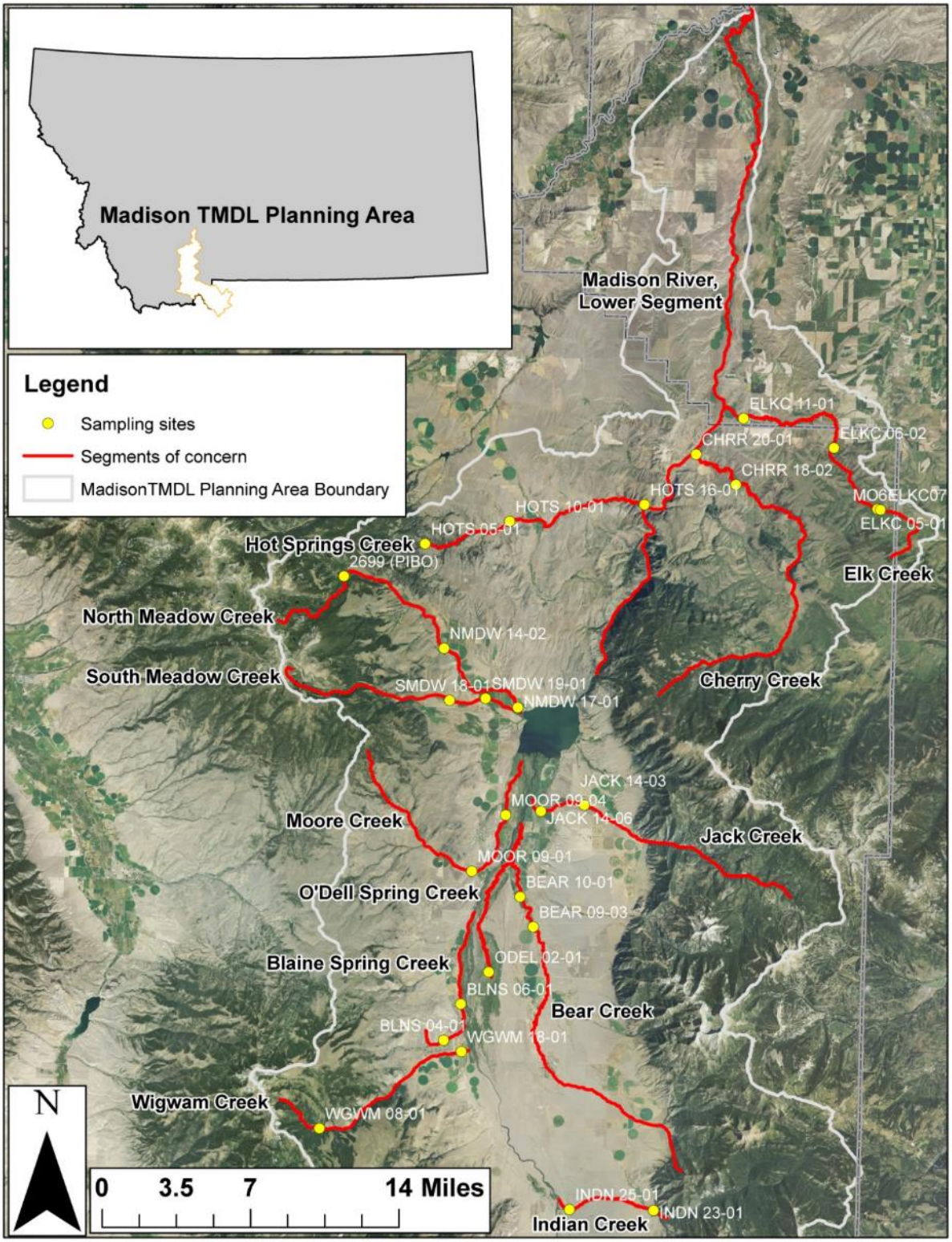

Figure B-2. Stream segments downstream of Indian Creek evaluated in this document and sampling sites on these segments

B2.0 DEQ SEDIMENT AND HABITAT ASSESSMENT

To aid in TMDL development, the DEQ performed field measurements of channel morphology, riparian and instream habitat parameters, and bank erosion during the summers of 2013 and 2014 from 43 sites within 20 of the 21 segments of concern (the Madison River downstream of Ennis Lake was not sampled by DEQ; **Figures B-1** and **B-2**).

B2.1 Aerial Assessment Reach Stratification

Prior to field data collection, DEQ completed a stream stratification process on stream segments in the Madison TPA. The stratification methodology can be found in *Sediment – Habitat Reach Stratification and Riparian Assessment Procedure* (DEQ, 2015b). The reason for this stratification is that the inherent differences in landscape controls between stream reaches often prevents a direct comparison from being made between the physical attributes of one stream reach to another. By initially stratifying waterbody segments into stream reaches having similar landscape controls, it is possible to make broad comparisons between similar reaches with regards to observed versus expected channel morphology. Likewise, when land use is used as an additional stratification category (e.g. grazed vs. non-grazed sub-reaches), sediment and habitat parameters for impaired stream reaches can be more readily compared to reference reaches that meet the same geomorphic stratification criteria.

B2.1.1 Stream Reaches

Waterbody segments are delineated by a water use class designated by the State of Montana, e.g. A-1, B-3, C-3 (Administrative Rules of Montana Title 17 Chapter 30, Sub-Chapter 6). Although a waterbody segment is the smallest unit for which an impairment determination is made, the stratification approach described in this document initially stratifies individual waterbody segments into discrete assessment reaches that are delineated by landscape controls including Ecoregion, Strahler stream order, valley gradient, and valley confinement. These attributes represent main factors influencing stream morphology, which in turn influence sediment transport and deposition. Relevant geographic data layers were acquired from the U.S. Geological Survey (USGS), the U.S. Environmental Protection Agency (USEPA) and the Montana State National Resource Information System (NRIS) database.

Once stream reaches have been stratified, reaches are further divided based on the surrounding vegetation and land-use characteristics as observed in the color aerial imagery using GIS. The result is a series of stream reaches and sub-reaches delineated by landscape and land-use factors. Stream reaches with similar landscape factors can then be compared based on the character of surrounding land-use practices.

For ease of labeling, each listed stream in the assessment was assigned an abbreviation based on the stream name. These labels were used in the individual stream reach classification. **Table B-2** shows the abbreviations developed for each waterbody.

Table B-2. Waterbody naming key

Waterbody	Label Abbreviation
Antelope Creek	ALTP
Bear Creek	BEAR
Blaine Spring Creek	BLNS
Buford Creek	BFRD
Cherry Creek	CHRR
Elk Creek	ELKC
Elk River	ELKR
Gazelle Creek	GAZL
Hot Springs Creek	HOTS
Indian Creek	INDN
Jack Creek	JACK
Moore Creek	MOOR
North Meadow Creek	NMDW
O'Dell Spring Creek	ODEL
Red Canyon Creek	RCYN
Ruby Creek	RUBY
South Meadow Creek	SMDW
Watkins Creek	WATK
West Fork Madison River	WFMA
Wigwam Creek	WGWM

B2.1.2 Reach Types

For the purposes of this report, a "reach type" is defined as a unique combination of Ecoregion, valley gradient, Strahler stream order, and valley confinement, and is designated using the following naming convention based on the reach type identifiers:

Level III Ecoregion – Valley Gradient – Strahler Stream Order – Confinement

The Madison TPA exists within the Middle Rockies Level III Ecoregion (Ecoregion 17). There are eleven Level IV Ecoregions within the Madison TPA: Absaroka-Gallatin Volcanic Mountains (17i), Alpine Zone (17h), Barren Mountains (17e), Dry Gneissic-Schistose-Volcanic Hills (17ab), Dry Intermontane Sagebrush Valleys (17aa), Eastern Gravelly Mountains (17d), Gneissic-Schistose Forested Mountains (17l), Mid-elevation Sedimentary Mountains (17g), Tobacco Root Mountains (17z), Townsend Basin (17w), Yellowstone Plateau (17j).

Reach type combinations for the Madison TPA are provided in **Table B-3**, and following the initial primary reach stratification, representative reaches were chosen by DEQ for monitoring sites.

Table B-3. Stratified reach types within the Madison TPA.

Level III Ecoregion	Valley Gradient	Strahler Stream Order	Confine-ment	Reach Type	Total Number of Reaches	Number of Monitoring Sites
Middle Rockies	<2%	1	U	MR-0-1-U	1	-
		2	C	MR-0-2-C	7	1
			U	MR-0-2-U	13	1
		3	C	MR-0-3-C	3	1
			U	MR-0-3-U	68	10
		4	C	MR-0-4-C	2	1
			U	MR-0-4-U	25	5
		5	U	MR-0-5-U	1	-
		6	C	MR-0-6-C	5	-
			U	MR-0-6-U	17	-
	2-4%	1	U	MR-2-1-U	11	1
		2	C	MR-2-2-C	17	-
			U	MR-2-2-U	32	4
		3	C	MR-2-3-C	21	1
			U	MR-2-3-U	47	10
		4	C	MR-2-4-C	1	-
			U	MR-2-4-U	8	1
		6	C	MR-2-6-C	1	-
			U	MR-2-6-U	2	-
	4-10%	1	C	MR-4-1-C	21	-
			U	MR-4-1-U	49	2
		2	C	MR-4-2-C	16	-
			U	MR-4-2-U	45	3
		3	C	MR-4-3-C	18	-
			U	MR-4-3-U	14	-
		4	C	MR-4-4-C	5	-
			U	MR-4-4-U	2	-
	>10%	1	C	MR-10-1-C	16	-
			U	MR-10-1-U	34	-
		2	C	MR-10-2-C	11	1
			U	MR-10-2-U	7	-
		3	C	MR-10-3-C	4	-
			U	MR-10-3-U	2	-
Totals:					**526**	**42**

Table B-4 shows the assessed water bodies and monitored reaches included within each reach type. A map of monitoring site locations is provided in **Figures B-1** and **B-2**, above.

Table B-4. Monitoring sites in assessed reach types.

Reach Type	waterbody	Monitoring Sites
MR-0-2-C	West Fork Madison River	WFMA 14-02
MR-0-2-U	O'Dell Spring Creek	ODEL 02-01
MR-0-3-C	Indian Creek	INDN 25-01
MR-0-3-U	Cherry Creek, Elk Creek, Hot Springs Creek, Jack Creek, Moore Creek, South Meadow Creek	CHRR 18-02, CHRR 20-01, ELKC 05-01, ELKC 11-01, HOTS 10-01, JACK 14-03, JACK 14-06, MOOR 09-01, MOOR 09-04, SMDW 19-01
MR-0-4-C	West Fork Madison River	WFMA 25-01
MR-0-4-U	Bear Creek, Blaine Spring Creek, North Meadow Creek, West Fork Madison River	BEAR 09-03, BEAR 10-01, BLNS 06-01, NMDW 17-01, WFMA 26-01
MR-2-1-U	Buford Creek	BFRD 07-01
MR-2-2-U	Antelope Creek, Elk River, Red Canyon Creek	ALTP 04-02, ELKR 04-01, RCYN 08-01, RCYN 09-02
MR-2-3-C	Ruby Creek	RUBY 17-01
MR-2-3-U	Blaine Spring Creek, Elk Creek, Elk River, Indian Creek, North Meadow Creek, Ruby Creek, South Meadow Creek, Watkins Creek, Wigwam Creek	BLNS 04-01, ELKC 06-02, ELKR 18-01, INDN 23-01 NMDW 14-02, RUBY 18-02, SMDW 18-01, WATK 12-01, WATK 14-01, WGWM 18-01
MR-2-4-U	Hot Springs Creek	HOTS 16-01
MR-4-1-U	Buford Creek, Hot Springs Creek	BFRD 06-01, HOTS 05-01
MR-4-2-U	Gazelle Creek, Red Canyon Creek, Wigwam Creek	GAZL 16-01, RCYN 07-01, WGWM 08-01
MR-10-2-C	Gazelle Creek	GAZL 09-01

B2.2 Field Work

Substrate character and stream habitat conditions were evaluated by performing a stream channel assessment in tributaries listed in **Table B-2**. Longitudinal surveys including pebble counts, grid toss, cross sections, pool data collection, riparian greenline surveys, and eroding streambank measurements were performed at each of the selected monitoring sites during the summers of 2013 and 2014; following methods presented in *The Montana Department of Environmental Quality Sediment Assessment Method: Considerations, Physical and Biological Parameters, and Decision Making* (Kusnierz et al., 2013) and *Field Methodology for Sediment and Habitat Source Assessment* (DEQ, 2012) .

Field assessment reaches were selected in relatively low-gradient portions of the listed streams to facilitate the evaluation of sediment loading impacts. The monitoring locations were chosen to represent various reach characteristics, land-use categories, and human-caused influences, but their representativeness relative to other reaches of the same slope, order, confinement and ecoregion, as well as ease of access, were also considered. There was a preference toward sampling those reaches where human influences would most likely lead to impairment conditions, since it is a primary goal of sediment TMDL development to further characterize sediment impairment conditions. Thus, it is not a random sampling design intended to sample stream reaches representing all potential impairment and non-impairment conditions. Instead, it is a targeted sampling design that aims to assess a representative

subset of reach types, while ensuring that reaches within each 303(d) listed waterbody with potential sediment impairment conditions are incorporated into the overall evaluation.

B2.2.1 Sediment and Habitat field Methods

Sediment and habitat assessments were performed at 43 field monitoring sites, which were selected based on the aerial assessment in GIS and on-the-ground reconnaissance using the factors discussed above. Sediment and habitat data was collected along all stream segments cited in **Table B-2**. Sediment and habitat data was collected within fifteen reach types (**Table B-3**). Field monitoring sites were assessed progressing in an upstream direction and the length of the monitoring site was based on the bankfull channel width.

After a minimum site length was determined, DEQ identified pools, riffles, and pool-forming woody debris; mapped the site; and set up an "EMAP" reach for collecting biological samples. The crew then performed channel form and instream sediment and habitat measurements:

Biological Measurements (EMAP)

- Periphyton samples

Channel Form and Stability Measurements

- Field Determination of Bankfull
- Channel Cross-sections
    - Bankfull Width
    - Channel Bed Morphology
    - Width/Depth Ratio
    - Floodprone Width
    - Entrenchment Ratio
- Water Surface Slope

Fine Sediment Measurements

- Sitewide Riffle Pebble Count
- Pool Tail Grid Toss

In-stream Habitat Measurements

- Residual Pool Depth

General Site Information

- Notes
- GPS Coordinates
- Photographs

An in-depth description of the methods are available in *The Montana Department of Environmental Quality Sediment Assessment Method: Considerations, Physical and Biological Parameters, and Decision Making* (Kusnierz et al., 2013).

B2.2.2 Bank Erosion and Greenline Field Methods

A separate field crew set up sites to perform greenline and bank erosion assessments, typically downstream from the in-stream assessment crew or in the same location as the in-stream crew when the in-stream crew had completed their monitoring. The bank data is used to estimate loading to streams from bank erosion, as well as give an indication of the causes of bank erosion and composition of sediment entering the streams. The greenline data helps establish the composition and condition of riparian vegetation along the streams and provides location information of healthy and degraded areas,

and from where sources of riparian degradation are coming. More details regarding the greenline and bank erosion methodologies can be found in *Field Methodology for Sediment and Habitat Source Assessment* (DEQ, 2012). The data collected is below:

Riparian Health Measurements

- Riparian Greenline Assessment

Bank Erosion

- Field Determination of Bankfull
- Bank Erosion Hazard Measurements
- Near Bank Stress
- Source Information

General Site Information

- Notes
- GPS Coordinates
- Photographs
- Slope

B2.3 Other Information Sources

As indicated in **Section 5.3** of this document, DEQ compiled available sediment data and performed additional field investigations during 2013 and 2014 to characterize sediment conditions for TMDL development purposes. Other data sources listed below were also used to help characterize water quality and/or develop TMDL targets.

- DEQ Assessment Files (cwaic.mt.gov)
- US Forest Service Pacfish/Infish Biological Opinion (PIBO) Program Data
- DEQ reference site data
- Data and reports

B2.3.1 DEQ Assessment Files

The DEQ assessment files contain information used to make sediment impairment determinations. The assessment files include a summary of physical, biological, and habitat data collected and/or compiled by DEQ. The files also include information on sediment water quality characterization and potentially significant sources of sediment, as well as information on non-pollutant impairment determinations and associated rationales. This information is available at cwaic.mt.gov.

B2.3.2 US Forest Service PIBO Program Data

The US Forest Service PACFISH/INFISH Biological Opinion Effectiveness (PIBO) monitoring program annually collects sediment and habitat data from watersheds throughout the northwestern United States. Data collected from “reference” sites (minimally impacted by human activities) was used to develop the targets described in **Section 5.4**. The protocols for collection of this data are found in Archer et al. (2012) and are analogous to those used by DEQ when collecting sediment and habitat data.

B2.3.3 DEQ Reference Site Data

Data collected by DEQ at reference sites was used in conjunction with PIBO data to develop water quality targets. DEQ reference sites are located in watersheds with minimal human impacts (Suplee et al. 2005). The protocols for data collected from DEQ reference sites are found in Kusnierz et al. (2013).

B2.3.4 Data and Reports

Several other documents that provided historical context to sediment sources, described the sensitivity of watersheds to disturbance, provide information about current conditions or sources, and described restoration work that has taken place were also used to help evaluate conditions within the stream segments of concern. These documents were written by state and federal agencies, the Madison Conservation District, and non-profit and private entities.

B3.0 SUMMARIES FOR WATERBODIES WITH NO TMDL WRITTEN

B3.1 Buford Creek MT41F004_150

Buford Creek (MT41F004_150) is not listed for any sediment- or habitat-related issues on the 2016 303(d) List. The segment flows 4.36 miles from the headwaters to the confluence with the West Fork Madison River through sedimentary geology and a shrub/scrub landscape with pockets of evergreen forest and willows growing in the wider riparian areas.

Physical Condition and Sediment Sources

In 2014 DEQ collected sediment and habitat data from two sites on Buford Creek (BFRD 06-01, BFRD 07-01; **Figure B-3**). BFRD 06-01 was the upstream site in this segment and had no sign of human impacts (DEQ 2014). The site was well vegetated with willows, sedges, and native grasses and forbs with about 50% of the vegetation being grass/forbs, and 45.5% being shrub/tree; 4.5% of the ground cover was rock (DEQ 2014, 2015; **Figure B-3**). No disturbed bare ground or hummocking was observed at the site. Streambanks were stable at the site and were composed of sand/clay (10-100%) and fine gravel (0-90%) (DEQ 2015). About 34% of the site length had eroding banks with all being attributed to natural processes. A periphyton sample from the site yielded a 55% probability of the site having excess fine sediment.

Figure B-3. Healthy riparian vegetation conditions at BFRD 06-01

BFRD 07-01 was located about 1.1 miles downstream of BFRD 06-01 near the confluence with the West Fork Madison River and had little evidence of human impacts other than a trail/road ford (DEQ 2014). The site was vegetated with sedges, native grasses and forbs, and some willows with about 83% of the vegetation being wetland species, 16% grass/forbs and 1% being shrub/tree (DEQ 2014, 2015). No disturbed bare ground or hummocking was observed at the site. Streambanks were stable at the site and were composed primarily of sand/clay (90-100%) with some fine gravel (0-10%) (DEQ 2015). About 42% of the site length had eroding banks with 88% being attributed to natural processes and the remainder being riparian grazing. A periphyton sample from the site yielded a 38.1% probability of the site having excess fine sediment.

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for Buford Creek are summarized in **Table B-5**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, both sites fail to meet the target for riffle pebble count < 6 mm. With regards to the channel form and instream habitat variables, one site fails to meet the target for residual pool depth. These results indicate that the creek is generally meeting targets.

Table B-5. Existing sediment-related data for Buford Creek relative to targets
Values that do not meet the target are in bold and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
BFRD 06-01	2014	*NM (<15)*	1.7	B	**25**	17	8	*NM*	*NM*	0.7	19.8
BFRD 07-01	2014	4.2	0.7	E	**21**	16	10	3.8	10.2	**0.4**	25

Summary and TMDL Development Determination
Data collected by DEQ in 2014 (DEQ 2014, 2015) indicate that while riparian grazing is a potential source contributing some fine sediment to the segment, the predominant source is natural processes. The physical data indicate that fine sediment targets are generally being met. The lack of sediment- and habitat-related listings is supported based on current land management practices in place, the general lack of human-caused erosion observed, the apparent improvement in conditions since the last DEQ evaluation, and the few instream target failures; a TMDL will not be written.

B3.2 Elk River MT41F004_110

Elk River (MT41F004_110) is not listed for any sediment- or habitat-related issues on the 2016 303(d) List. The segment flows 15.59 miles from the headwaters to the mouth at the West Fork Madison River through sedimentary, intrusive, and volcanic geology and an evergreen landscape interspersed with shrub/scrub vegetation.

Physical Condition and Sediment Sources
Sediment and habitat data were collected from the Elk River by PIBO at one site in 2009 and 2014 and by DEQ at one site in 2013 and another in 2014 (ELKR 04-01, ELKR 18-01/2734 (PIBO)); **Figure B-1**). ELKR 04-01 was the upstream site sampled by DEQ in this segment. Vegetation at the site consisted of willow, sedges, grass, and forbs with about 52% of the vegetation being wetland species, 1% grass/forbs, and 36% being shrub/tree (DEQ 2014, 2015;
5-7). Disturbed ground and rock comprised about 6% and 5% of the site respectively with no hummocking observed. Streambanks were composed primarily of sand/clay (60-70%) with lesser amounts of fine gravel (10-20%) and coarse gravel or larger sediment (20-30%) (DEQ 2015). About 25% of the site length had eroding banks with 100% being attributed to natural processes. A periphyton sample from the site yielded a 55.7% probability of the site having excess fine sediment.

Figure B-4. Willow growth within the riparian zone at ELKR 04-01

ELKR 18-01 was located about 12.5 miles downstream of ELKR 04-01 near the confluence with the West Fork Madison River within an upland area that was lightly grazed (DEQ 2013). Vegetation and bank erosion data was collected just upstream of ELKR 18-01 at a site named ELKR 17-01. Vegetation at this location consisted of about 15% of the vegetation being wetland species, 39.5% grass/forbs, and 22% being shrub/tree (DEQ 2015). Disturbed bare ground was present at 0.5% of the site with rock comprising 23%; no hummocking was observed. Streambanks were composed primarily of sand/clay (50-70%) with lesser amounts of fine gravel (10%) and coarse gravel or larger sediment (20-40%) (DEQ 2015). About 25% of the site length had eroding banks with half being attributed to natural processes and the other half being riparian grazing. A periphyton sample from ELKR 18-01 yielded a 45.6% probability of the site having excess fine sediment.

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for the Elk River are summarized in **Table B-6**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, both sites fail to meet the targets for riffle pebble count < 6 mm and < 2 mm. The target for < 6 mm is exceeded by three percentage points at both sites and the target for < 2 mm is exceeded by one percentage point at one site and three at the other. The only other variable that fails to meet its respective target is residual pool depth at the upper site. These results indicate that there may be excessive fine sediment in the Elk River; however, both riffle fines targets are exceeded by a small margin and the pool tail fines at both sites are very low.

Table B-6. Existing sediment-related data for Elk River relative to targets
Values that do not meet the target are in bold and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
ELKR 04-01	2014	10.1	1	C	**21**	**20**	4	11	2.3	**0.6**	20.2
ELKR 18-01, 2734 (PIBO)	2009, 2013, 2014	26.8	1.8	C	**21**	**18**	5	15.0	6.6	1.3	8.5

[1]PIBO site 2734 is co-located with ELKR 18-01, values are averages from sampling events in 2009, 2013, and 2014

Summary and TMDL Development Determination
Data collected by DEQ in 2013 and 2014 (DEQ 2013, 2014, 2015) indicate that most of the erosion observed on the Elk River was attributed to natural processes and that continued implementation of best management practices will maintain the existing sediment loading to the Elk River. The lack of sediment- and habitat-related listings is supported based on the current land management practices that are limiting sediment sources, the apparent improvement in conditions since the 2003 DEQ evaluation, the minimal human-caused erosion observed, and the borderline failures of instream sediment ; a TMDL will not be written.

B3.3 Gazelle Creek MT41F004_120

Gazelle Creek (MT41F004_120) is not listed for any sediment- or habitat-related issues on the 2016 303(d) List. The segment flows 9.65 miles from the headwaters to the mouth at the West Fork Madison River through metamorphic and volcanic geology and an evergreen landscape interspersed with shrub/scrub vegetation.

Physical Condition and Sediment Sources
Sediment and habitat data were collected from Gazelle Creek by PIBO at one site in 2008 and 2013 and by DEQ at two sites in 2014 (2601 (PIBO), GAZL 09-01, GAZL 16-01; **Figure B-1**). GAZL 09-01 was the upstream site in this segment and was located in a lightly grazed setting (DEQ 2014). The site was well vegetated with currant, conifer, sedge, thimbleberry, willow, and dogwood with about 31% of the vegetation being wetland species, 36% grass/forbs and 18% being shrub/tree (DEQ 2014, 2015; **Figure B-5**). Large woody debris was prevalent within the site and limited cattle access to riparian areas. Rock covered about 15% of the site and there was hummocking within 1%; no disturbed bare ground was observed. Streambanks were composed entirely of sand/clay (DEQ 2015). About 90% of the site length had eroding banks with 90% being attributed to natural processes and the remainder being riparian grazing. A periphyton sample from the site yielded a 42.9% probability of the site having excess fine sediment.

Figure B-5. Vegetation and large woody debris at GAZL 09-01

GAZL 16-01 was located about 2.6 miles downstream of GAZL 09-01 near the confluence with the West Fork Madison River. The site was well vegetation with conifer, grasses, forbs, willow, and dogwood with about 28% of the vegetation being wetland species, 9% grass/forbs and 26% being shrub/tree (DEQ 2014, 2015). There was limited cattle access to riparian areas though livestock paths were observed along the channel. Rock covered about 31% of the site and there was hummocking within 2%; 6% was disturbed bare ground. Streambanks were composed primarily of sand/clay (70%) with lesser amounts of fine gravel (10%) and coarse gravel or larger sediment (20%) (DEQ 2015). About 27% of the site length had eroding banks with 100% being attributed to natural processes. A periphyton sample from the site yielded a 27.9% probability of the site having excess fine sediment.

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for Gazelle Creek are summarized in **Table B-7**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, both DEQ sites meet the targets for riffle pebble count < 6 mm and < 2 mm and pool tail grid toss. The target for pool tail grid toss is exceeded at the PIBO site. The only other failure is for W/D ratio at a single site. These results indicate that while there may be some localized deposits of fine sediment (i.e., PIBO site) in general, fine sediment loading, channel form, and instream habitat quality appear to be appropriate for the creek.

Table B-7. Existing sediment-related data for Gazelle Creek relative to targets
Values that do not meet the target are in bold and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
2601 (PIBO)[1]	2008, 2013	18.6	0.2	*NM*	*NM*	*NM*	**34**	13.6	*NM*	1.65	22.2
GAZL 09-01	2014	14.9	2.3	B	10	6	9	**11.3**	2.1	0.9	54.6
GAZL 16-01	2014	16.5	3.4	B	6	4	5	16.7	1.8	1	25.0

[1]Values are averages from sampling events in 2008 and 2013; PIBO site 2601 is located on stratified reach GAZL 11-01 downstream of GAZL 09-01

Summary and TMDL Development Determination
Data collected by DEQ in 2014 (DEQ 2014, 2015) indicate that natural processes dominate the sediment source load, there is limited potential loading from riparian grazing, and that continued implementation of best management practices will maintain the existing sediment loading to Gazelle Creek. The lack of sediment- and habitat-related listings is supported based on the current land management practices that are limiting sediment sources, the apparent improvement in conditions since the 2003 evaluation, the limited human-caused erosion observed, and the healthy riparian vegetation conditions observed at the sampling sites; a TMDL will not be written.

B3.4 Indian Creek MT41F004_040

Indian Creek (MT41F004_040) is listed for alteration in stream-side or littoral vegetative covers on the 2016 303(d) List. The segment flows 6.34 miles from the Lee Metcalf Wilderness to the mouth at the Madison River through sedimentary geology and a grass and shrub/scrub landscape with pockets of evergreen forest.

Physical Condition and Sediment Sources
INDN 25-01 was located about 4.5 miles downstream of INDN 23-01 in a lightly grazed setting (DEQ 2015). The site was vegetated with cottonwood, conifer, alder, dogwood, cedar, and grass with about 3% of the vegetation being wetland species, 28.5% grass/forbs and 44% being shrub/tree (DEQ 2014, 2015). Disturbed bare ground and rock each made up 2.5% and 14% of the site respectively with hummocking observed at less than 1% of the site. Streambanks were well armored and were composed of 40% sand/silt, 20% fine gravel, and 40% coarse gravel or larger sediment (DEQ 2015). About 7% of the site length had eroding banks with 74% being attributed to natural processes, 16% to historical riparian grazing, and the remainder being from an old bridge. A periphyton sample from the site yielded a 14.7% probability of the site having excess fine sediment.

Comparison to Water Quality Targets
The existing physical data in comparison with the targets for Indian Creek are summarized in **Table B-8**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, both sites meet the targets for riffle pebble

count < 6 mm and < 2 mm and pool tail grid toss. The only target failure is for residual pool depth at one site. These results indicate that fine sediment loading, channel form, and instream habitat quality appear to be appropriate for the creek.

Table B-8. Existing sediment-related data for Indian Creek relative to targets
Values that do not meet the target are in bold and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
INDN 23-01	2014	37.8	2.0	B	9	7	0	20.5	1.4	1.9	20.3
INDN 25-01	2014	36.0	2.1	B	7	3	1	22.7	1.7	**1.0**	16.6

Summary and TMDL Development Determination
Data collected by DEQ in 2014 (DEQ 2014, 2015) indicate that there are limited potential sources (historical grazing, an old bridge) contributing excess fine sediment to the segment and that continued implementation of best management practices will maintain the existing sediment loading to Indian Creek. The lack of a sedimentation/siltation listing for Indian Creek is supported based on the current land management practices that are limiting sediment sources and the lack of human-caused erosion observed. The alteration in stream-side or littoral vegetative covers listing is supported by site visits indicating that the riparian community is not meeting potential. Because "alteration in stream-side or littoral vegetative covers" is a non-pollutant listing and there is no listing for sedimentation/siltation, a TMDL will not be written for Indian Creek.

B3.5 Jack Creek MT41F004_050

Jack Creek (MT41F004_050) is listed for alteration in stream-side or littoral vegetative covers on the 2016 303(d) List. The segment flows 15.18 miles from the headwaters to the mouth at the Madison River primarily through sedimentary geology and a shrub/scrub and evergreen-dominated landscape in the headwaters with a grass-dominated landscape with willows and sedges growing in riparian areas near the mouth.

Physical Condition and Sediment Sources
The Jack Creek watershed has been the focus of a monitoring project since 2006 (Madison Conservation District 2014). The goals of the project include collecting baseline water quality data, identifying changes in water quality, and providing opportunities for the public (youth and adults) to learn about and participate in water quality data collection. The effects of development in the Jack Creek watershed on water quality are a concern and the Jack Creek monitoring projects has the potential to evaluate such impacts.

In addition to regular sampling, Jack Creek has been the location of restoration work. In 2003 about 880 feet of new channel were constructed on Jack Creek and 50 acres of wetlands were created adjacent to the creek (Madison Conservation District 2015). Since 2010, the Madison Conservation District has

performed monitoring nearby. There are two bank restoration projects planned for Jack Creek in 2016; both involve the use of willow soil lifts to replace hard bank structures (Madison Conservation District 2015).

Sediment and habitat data were collected from Jack Creek at two sites by DEQ in 2014 (JACK 14-03, JACK 14-06; **Figure B-2**). JACK 14-03 was the upstream site in this segment and was located in a non-grazed riparian setting (except for at water gaps) (DEQ 2015). The site was vegetated with cottonwood, alder, willow, and reed canary grass with about 12.5% of the vegetation being wetland species, 77% grass/forbs, and 9% being shrub/tree (DEQ 2014, 2015). Disturbed bare ground and rock each made up 0.5% and 1% of the site respectively; no hummocking was observed. Streambanks were eroding in locations where vegetation was lacking and were primarily composed of sand/clay (60-80%) with lesser amounts of fine gravel (10-20%), and coarse gravel or larger sediment (10-30%) (DEQ 2015). About 51% of the site length had eroding banks with 81% being attributed to historical grazing and channel manipulation and the remainder to natural processes. A periphyton sample from the site yielded a 24.9% probability of the site having excess fine sediment.

JACK 14-06 was located about 2.3 miles downstream of JACK 14-03 and has had recent restoration work including adding channel meanders and planting willows, cottonwoods, and aspen (DEQ 2014,2015). The site was vegetated with cottonwood, aspen, willow, reed canary grass and other grasses with about 78% of the vegetation being grass/forbs and 11.5 being shrub/tree (DEQ 2014, 2015). Disturbed bare ground and rock each made up 2.5% and 0.5% of the site respectively; no hummocking was observed. Streambanks had riprap in places and were composed of primarily sand/clay (65-80%) with lesser amounts of fine gravel (10%), and coarse gravel or larger sediment (10-30%) (DEQ 2015). About 47% of the site length had eroding banks with about 57% being attributed to natural processes, 35% being attributed to existing historical channelization, and the remainder being due to roads. A periphyton sample from the site yielded a 27.3% probability of the site having excess fine sediment.

In addition to the DEQ data collection, the Madison Conservation District collected pebble counts from four sites on Jack Creek in July, 2014; percent fines < 2 mm were 10%, 14%, 14%, and 18% (Madison Conservation District 2014).

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for Jack Creek are summarized in **Table B-9.** All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, both DEQ sites meet the targets for riffle pebble count < 6 mm and < 2 mm and pool tail grid toss. One site fails to meet the targets for channel form; both of these failures are considered borderline because the site is within 1.3 feet of being in the next class for the W/D target and the entrenchment ratio is only one unit less than the target. These results indicate that fine sediment loading, channel form, and instream habitat quality appear to be appropriate for the creek.

Table B-9. Existing sediment-related data for Jack Creek relative to targets
Values that do not meet the target are in bold and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
JACK 14-03	2014	30.4	0.3	C	11	8	4	27.3	2.8	2.0	11.3
JACK 14-06	2014	28.7	0.2	C	16	13	4	**26.9**	**1.9**	2.4	9.7

Summary and TMDL Development Determination
Data collected by DEQ in 2014 (DEQ 2014, 2015) indicate that there are limited potential sources (historical grazing and channel manipulation) contributing fine sediment to the segment and that continued restoration and implementation of best management practices and additional restoration will maintain and potentially reduce the existing sediment loading to Jack Creek. The lack of a sedimentation/siltation listing for Jack Creek is supported based on the current land management practices that are limiting sediment sources, the apparent improvement in conditions since the 2000 DEQ evaluation, and the limited human-caused erosion observed. The alteration in stream-side or littoral vegetative covers listing is supported by site visits indicating that a lack of vegetation is resulting in some bank erosion. Because "alteration in stream-side or littoral vegetative covers" is a non-pollutant listing and there is no listing for sedimentation/siltation, a TMDL will not be written for Jack Creek. With the current developed state of the watershed, continuing to seize opportunities for stream restoration projects will be an important component of maintaining a properly functioning Jack Creek. And with anticipated further development in the watershed, implementation of management practices throughout the watershed will be important for maintaining the sediment loading in Jack Creek at a healthy level.

B3.6 Madison River, lower segment MT41F001_010

The Madison River, lower segment (MT41F001_010) is listed for sedimentation/siltation on the 2018 303(d) List. In addition, this segment is listed for alteration in stream-side or littoral vegetative covers which is a non-pollutant listing that can often be linked to sediment impairment. The segment flows 41.31 miles from Ennis Dam to the mouth at the Missouri River through sedimentary geology and a landscape consisting of grass-dominated landscape with willows and sedges growing in riparian areas.

Physical Condition and Sediment Sources
The previous DEQ assessment file indicated that there was moderate impairment from impacts to riparian vegetation and sedimentation, found by comparing aerial photos from 1990 to 1950. The files indicated these impacts could be mitigated by release of flushing flows from Hebgen Dam. Sources were listed as Dam Construction (Other than Upstream Flood Control Projects), Dam or Impoundment, Impacts from Abandoned Mine Lands (Inactive), and Agriculture.

DEQ did not conduct sediment fieldwork on this segment in 2013 or 2014 due to the size of the river and in light of the 2013 report authorized by Pacific Power and Light (PPL)) on flushing flow needs in the

river as part of their FERC license renewal (PPL Montana, 2013). The lower segment of the Madison River is wide and shallow, with fines found in depositional areas. The PPL document reports that data collection of various sediment parameters started in 1994 and have occurred with fair regularity in the years since. In June 1996, there was a large flushing flow event from natural events that resulted in a three-day period averaged flow from Madison Dam (at Ennis) of ~7,600 cfs. This flushing event resulted in a significant reduction in the percentage of fines at the two monitoring locations in the lower river (Norris Bridge and Greycliff FAS). Attempting to recreate the 1996 event and its results, PPL released flushing flows from Hebgen Dam in 2006, 2008, and 2010. Given the operational constraints of the FERC license, which includes a maximum flow limit of 3,500 cfs at Kirby Ranch to limit erosion from the outlet of Quake Lake, PPL is unable to release enough flow to the mainstem to fully recreate the June 1996 event. Reservoir modeling by the consultant determined the upward limit of a PPL-generated flushing flow to be ~5,400 cfs. The PPL study also determined that fine sediment is trapped by Ennis Lake and the upper reach is not a significant source of fines to the Lower Madison. Ultimately, sampling has determined that while the PPL-generated flushing flows are providing some benefits to the Lower Madison River, flushing flows are not enough to transport the fines out of the reach, and may also contribute to excess stream bank erosion.

Summary and TMDL Development Determination

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 TMDL document.

B3.7 O'Dell Spring Creek MT41F004_020

O'Dell Spring Creek (MT41F004_020) is listed for other anthropogenic substrate alterations, physical substrate habitat alterations, and alteration in stream-side or littoral vegetative covers on the 2016 303(d) List. These are non-pollutant listing that can often be linked to sediment impairment. The segment flows 13.19 miles from the headwaters to the mouth at the Madison River through sedimentary geology and a landscape consisting of interspersed grasses, shrub/scrub, and wetlands.

Physical Condition and Sediment Sources

The DEQ assessment file indicates that channelization and eroding banks and channel widening as a result of cattle trampling were observed on O'Dell Spring Creek. A range of riparian vegetative conditions were observed from there being no vegetation to willows present. Some areas of the stream were heavily grazed while others had fencing and little grazing pressure. Up to 50% of the stream bottom was covered by silt.

Since 2005 restoration work on O'Dell Creek has involved the filling of ditches, creation of wetlands, planting vegetation, and reconstruction of at least nine miles of channel (Madison Conservation District 2015).

Sediment and habitat data were collected from O'Dell Spring Creek at one site by DEQ in 2014 (ODEL 02-01; **Figure B-2**). The site was located in an area within a recent restoration project and had no evidence of grazing (DEQ 2014). The site was vegetated with sedges and grasses and had some cottonwood plantings with about 64% of the vegetation being wetland species and 36% grass/forbs (DEQ 2014, 2015). Disturbed bare ground and hummocking were not observed at the site. Banks were composed of 100% sand/clay (DEQ 2015). About 59% of the site length had eroding banks with 80% being attributed

to natural processes and the remainder to recent restoration work. A periphyton sample from the site yielded a 40.1% probability of the site having excess fine sediment.

In addition to the DEQ data collection, the Madison Conservation District collected pebble counts from two sites on O'Dell Spring Creek in July, 2014; percent fines < 2 mm were 38% and 59% (Madison Conservation District 2014).

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for O'Dell Spring Creek are summarized in **Table B-10**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. Although the existing stream type for the sampled site is a Rosgen C, it is believed that the W/D ration has been increased because of human impacts and the potential and expected channel type given the opportunity to recover is a Rosgen E. The only target failure at the sampled site was for riffle pebble count < 2 mm. These results indicate that sediment loading, channel form (except with regards to the potential Rosgen E channel type), and instream habitat appear to be appropriate for the site.

Table B-10. Existing sediment-related data for O'Dell Spring Creek relative to targets

Values that do not meet the target are in bold and shaded; values were compared to the targets for a Rosgen E channel type

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
ODEL 02-01	2014	33.3	0.5	C	33	**33**	12	19.6	9.6	2.5	6.0

Summary and TMDL Development Determination

Data collected by DEQ in 2014 (DEQ 2014, 2015) indicate that predominantly natural processes are contributing fine sediment to the segment and that continued restoration and implementation of best management practices will reduce sediment input from any historical sources. Most targets were met and it appears that conditions in O'Dell Spring Creek have improved since the last DEQ evaluation. In addition, insufficient information was collected to fully evaluate this creek. Therefore, a TMDL will not be written.

B3.8 West Fork Madison River MT41F004_100

West Fork Madison River (MT41F004_100) is not listed for any sediment- or habitat-related issues on the 2016 303(d) List. The segment flows 39.41 miles from the headwaters to the mouth at the Madison River through predominantly volcanic geology with sedimentary geology in the headwaters and a shrub/scrub-dominated landscape with pockets of conifers.

Physical Condition and Sediment Sources

Restoration activities were initiated on the West Fork Madison River in 2014. This work involved installing riparian fencing, installing hardened crossings, and closing unauthorized off highway vehicle trails in the National Forest (Madison Conservation District 2015).

Sediment and habitat data were collected from the West Fork Madison River at one site by PIBO in 2009 and 2014, one site by DEQ in 2013 and two sites by DEQ in 2014 (2740 (PIBO), WFMA 14-02, WFMA 25-01, WFMA 26-01; **Figure B-1**). WFMA 14-02 was the most upstream site visited by DEQ in this segment and was located in an area that was heavily grazed in the past; cattle are now excluded from the riparian area (DEQ 2015). The site had a healthy riparian vegetation community that consisted of willow, sedges, and forbs with about 34% of the vegetation being wetland species, 4% grass/forbs, and 50% being shrub/tree (DEQ 2014, 2015; **Figure B-6**). Disturbed bare ground and rock each made up 4% and 8% of the site respectively; hummocking covered about 10% of the site. Streambanks were primarily composed of sand/clay (50-80%) with lesser amounts of fine gravel (5-10%) and coarse gravel or larger sediment (15-40%) (DEQ 2015). About 20% of the site length had eroding banks with 62% being attributed to natural processes and the remainder to riparian grazing.

Figure B-6. Riparian conditions at WFMA 14-02

WFMA 25-01 was located about 19.5 miles downstream of WFMA 14-02, downstream of the confluence with the Elk River. The site was vegetated with willow, conifer, grasses, and forbs with about 3.5% of the vegetation being grass/forbs and 64% being shrub/tree (DEQ 2014, 2015, **Figures B-6** and **B-7**). Disturbed bare ground and rock made up 17.5% and 15% of the site respectively; no hummocking was

observed. About 1000 feet of riparian fencing was recently installed downstream of the site (DEQ 2015). Streambanks were primarily composed of sand/clay (80%) with lesser amounts of fine gravel (10%), and coarse gravel or larger sediment (10%) (DEQ 2015; **Figure B-7**). About 12% of the site length had eroding banks with 98% being attributed to riparian grazing and the remainder to natural processes (**Figure B-8** and **Figure B-9**). A periphyton sample from the site yielded a 47% probability of the site having excess fine sediment.

Figure B-7. Relatively healthy riparian conditions at WFMA 25-01

Figure B-8. Grazed riparian conditions at WFMA 25-01

Figure B-9. Eroding streambank at WFMA 25-01

WFMA 26-01 was located about 6.3 miles downstream of WFMA 25-01 in a lightly grazed area upstream of the confluence with Gazelle Creek (DEQ 2013). The site had a healthy riparian vegetation community consisting of conifer, willow, rushes, tall grasses, and forbs with about 6.5% of the vegetation being wetland species, 67% grass/forbs, and 14% being shrub/tree (DEQ 2013, 2015). Disturbed bare ground and rock made up 8.5% and 4% of the site respectively; no hummocking was observed. Streambanks were composed primarily of sand/clay (75-100%) with lesser amounts of fine gravel (0-15%), and coarse gravel or larger sediment (0-10%) (DEQ 2015). About 40% of the site length had eroding banks with about 65% being attributed to natural processes and the remainder to historical timber harvest. A periphyton sample from the site yielded a 35% probability of the site having excess fine sediment.

In addition to the DEQ data collection, the Madison Conservation District collected pebble counts from three sites on the West Fork Madison River in July, 2014; percent fines < 2 mm were 5%, 10%, and 18% (Madison Conservation District 2014).

Comparison to Water Quality Targets

The existing physical data in comparison with the targets for West Fork Madison River are summarized in **Table B-11**. All bolded cells are not meeting the target; depending on the target parameter, this may equate to being below or above the target value. For fine sediment, none of the sites failed to meet targets. The upper DEQ site fails the targets for W/D ratio and pool frequency and the middle DEQ site fails the targets for entrenchment ratio and residual pool depth. These results indicate that sediment

loading is appropriate and that although the channel form and habitat quality in the West Fork Madison River fails to meet some targets, it overall appears healthy.

Table B-11. Existing sediment-related data for West Fork Madison River relative to targets
Values that do not meet the target are in bold and shaded

Reach/ Site ID	Assessment Year	Mean BFW (ft)	Gradient (%)	Existing Stream Type	Riffle Pebble Count		Grid Toss	Channel Form		Instream Habitat	
					% <6mm	% <2mm	Pool % <6mm	W/D Ratio	Entrenchment Ratio	Residual Pool Depth (ft)	Pools / 1000 ft
2740 (PIBO)[1]	2009, 2014	23.7	0.5	*NM*	*NM*	*NM*	14	12.8	*NM*	1.9	12.2
WFMA 14-02	2014	12.6	1.1	C	13	13	1	**13.9**	3.0	1.4	**12.3**
WFMA 25-01	2014	53.5	1.3	C	7	6	8	32.4	**1.5**	**1.0**	3.8
WFMA 26-01	2013	43.5	0.8	C	16	12	3	28.1	5.7	1.5	6.5

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

Summary and TMDL Development Determination

Data collected by DEQ in 2013 and 2014 (DEQ 2013, 2014, 2015) indicate that there are limited potential sources (riparian grazing, historical timber harvest) contributing excess fine sediment to the segment and that continued implementation of best management practices will maintain or improve the existing sediment loading to the West Fork Madison River. The lack of sediment- and habitat-related listings is supported based on the current land management practices that are limiting sediment sources, the apparent improvement in conditions since the last evaluation, and the limited human-caused erosion observed; a TMDL will not be written.

B4.0 REFERENCES

Archer, Eric K., Rebecca A. Scully, Richard Henderson, Brett P. Roper, and Jeremiah D. Heitke. 2012. Effectiveness Monitoring for Streams and Riparian Areas: Sampling Protocol for Stream Channel Attributes. Unpublished paper on file at: http://www.fs.fed.us/biology/fishecology/new.html#pibo_reports.

DEQ (Montana Department of Environmental Quality). 2012. Field Methodology for Sediment and Habitat Source Assessment. Helena, MT: Montana Dept. of Environmental Quality

DEQ (Montana Department of Environmental Quality). 2013. 2013 Sediment and Habitat Field Data. Helena, MT: Montana Department of Environmental Quality.

DEQ (Montana Department of Environmental Quality). 2014. 2014 Sediment and Habitat Field Data. Helena, MT: Montana Department of Environmental Quality.

DEQ (Montana Department of Environmental Quality). 2015. Madison TMDL Planning Area BEHI and Greenline Field Data. Helena, MT: Montana Department of Environmental Quality.

DEQ (Montana Department of Environmental Quality). 2015b. Sediment-Habitat Reach Stratification and Riparian Assessment Procedure. Helena, MT: Montana Department of Environmental Quality.

DEQ (Montana Department of Environmental Quality). 2017. Montana Nonpoint Source Management Plan. Helena, MT: Montana Dept. of Environmental Quality.

Kusnierz, P., A. Welch, and D. Kron. 2013. The Montana Department of Environmental Quality Sediment Assessment Method: Considerations, Physical and Biological Parameters, and Decision Making. Helena, MT: Montana Dept. of Environmental Quality.

Madison Conservation District. 2013. Stream Team Annual Report.

Madison Conservation District. 2014. Madison Stream Team and Jack Creek Project End of Season Update 2014. Ennis, MT: Madison Conservation District.

Madison Conservation District. 2015. Final Report for DEQ Contract 214034. Ennis, MT: Madison Conservation District.

Pacific Power and Light Montana. February 20, 2013. Beck, Stuart M. and Nightengale, Tim L., preparers. Flushing Flow Needs in the Madison River Montana 2008, 2009, 2010, 2011, and 2012: Streambed and Aquatic Invertebrate Monitoring Results and Comparison with 1994, 1995, 1996, 1997, 2002, and 2007 Results.

Suplee, M., R. Sada de Suplee, D. Feldman, T. Laidlaw 2005. Identification and assessment of Montana reference streams: a follow-up and expansion of the 1992 benchmark biology study. Helena, MT: Montana Dept. of Environmental Quality.