ESCHERICHIA COLI BACTERIA TOTAL MAXIMUM DAILY LOAD (TMDL) FOR THE BELLE FOURCHE RIVER, SEGMENT 1, BUTTE COUNTY, SOUTH DAKOTA

South Dakota Department of
Environment and Natural Resources

Protecting South Dakota's Tomorrow ... Today

South Dakota Department of
Environment and Natural Resources
Water Resources Assistance Program

March, 2012

Total Maximum Daily Load Summary

Waterbody Type:	Stream
303(d) Listing Parameter:	*Escherichia coli* (*E. coli*) bacteria
Designated Uses:	Warmwater permanent fish life propagation waters, immersion recreation waters, fish and wildlife propagation, recreation, and stock watering, and irrigation water
Size of Impaired Waterbody:	Approximately 64.2 km in length
Size of Watershed:	24,348 acres
Indicator(s):	Concentrations of *E. coli* bacteria
Analytical Approach:	Load Duration Curve
Location:	Hydrologic Unit Codes (12-digit HUC): 101202020109 101202020201
Goal:	Meet applicable water quality standards for fecal coliform bacteria
Target (Water Quality Standards):	Maximum daily concentration of ≤ 400 cfu/100mL and a geometric mean of 5 samples over a 30 day period ≤ 200 cfu/100mL. These criteria apply from May 1st through September 30th.
Reach Number:	SD-BF-R-BELLE_FOURCHE_01
Load Allocations based on Geometric Mean:	
High Flow Zone WLA (cfu/day):	0
High Flow Zone LA (cfu/day):	6.04E+15
High Flow Zone MOS (cfu/day):	4.47E+11
High Flow Zone TMDL (cfu/day):	6.04E+15

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1.0 Introduction

The intent of this document is to clearly identify the components of the TMDL, support adequate public participation, and facilitate the US Environmental Protection Agency (US EPA) review. The TMDL was developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by US EPA. This TMDL document addresses the *Escherichia coli* bacteria impairment of Belle Fourche River from the Wyoming/South Dakota border to the Redwater River confluence (SD-BF-R-BELLE_FOURCHE_01), which was assigned priority category 5 (high-priority) in the 2010 impaired waterbodies list (SDDENR, 2010) and the upcoming 2012 list.

1.1 Watershed Characteristics

The Belle Fourche River is a natural stream that originates in Wyoming, drains parts of Butte, Lawrence and Meade Counties in South Dakota, and flows to the Cheyenne River in Meade County and ultimately to the Missouri River (Figure 1). Within Wyoming the Belle Fourche River drains portions of Crook, Weston, and Campbell Counties. The Belle Fourche River also drains a small portion of Carter County within Montana.

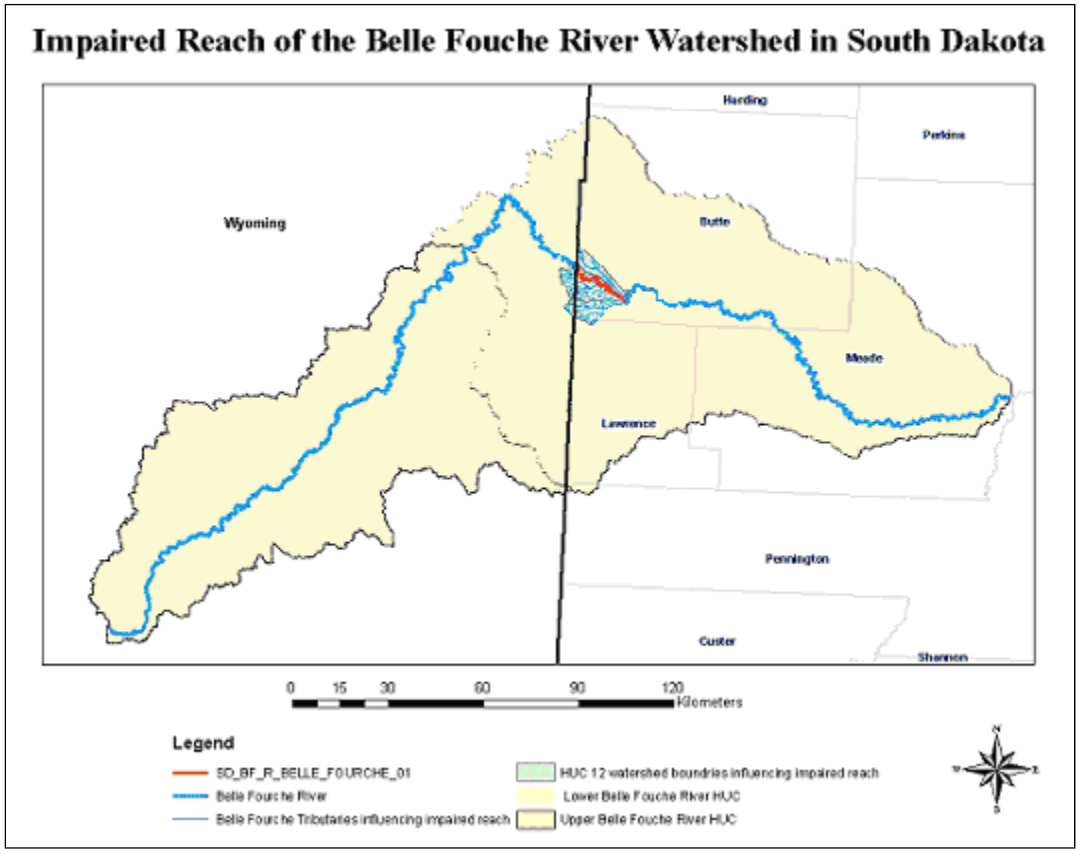

Figure 1. Impaired reach of the Belle Fourche River watershed in South Dakota and Wyoming.

The Belle Fourche River watershed is approximately 2,100,000 acres (3,300 sq. miles) in size in South Dakota and approximately 2,400,000 acres (3,700 sq. miles) in Wyoming. The majority of the Segment 1 watershed is comprised of range land (Table 1) with cropland making up the next largest land use.

Table 1. Land use characteristics for the Belle Fourche Segment 1 watershed.

	Percent	Area (acres)
Range	90.7	22084
Cropland	6.5	1583
Urban	1.2	292
Forest	0.9	219
Barren	0.7	170

The South Dakota portion of the Belle Fourche watershed, shown in Figure 2, is comprised of seven level IV ecoregions. Ecoregion designations include: Black Hills Foothills, Black Hills Plateau, Black Hills Core Highlands, River Breaks, Semiarid Pierre Shale Plains, Dense Clay Prairie, and Missouri Plateau Figure 2.

Two level IV ecoregions (Semiarid Pierre Shale Plains and Black Hills Foothills) directly influence the impaired reach of the Belle Fourche River (Figure 3).

The Black Hills Foothills are un-glaciated features which comprise a ring of hills surrounding the Black Hills mountainous core. The Dakota Hogback separates the foothills from the plains and the Red Valley is inside the Hogback and encircles the Black Hills Dome. The geology is Mesozoic sandstone and shale. The Hogback is composed of Lakota Sandstone, Fall River Sandstone, Fuson Shale and Minnewasta Limestone. The Red Valley is composed of the Spearfish Formation and red sandy shale. The soil types are Butche, Canyon, Enning, Nevee, Spearfish, Grummit, Tilford, Vale and Rekop. The mean annual precipitation in this area is 15-17 inches, supporting a vegetation cover of ponderosa pine woodlands with a grass under story of little bluestem, grama grasses, and leadplant. Land use includes cattle grazing and ranching with low density suburban development.

The Semiarid Pierre Shale Plains are undulating to rolling plains and is the dominant ecoregion within the watershed, representing 40% of the area. Steep-sided, incised stream channels dominate this ecoregion. The geology is predominately Cretaceous Pierre Shale. The soils include Pierre, Samsil, Lismas, Satanta and Nunn. The mean annual precipitation is 14 inches. Vegetation includes short grass prairie grasses such as western wheat grass, green needle grass, blue grama and buffalo grass. Land use is predominantly cattle grazing, rangeland and dry land farming.

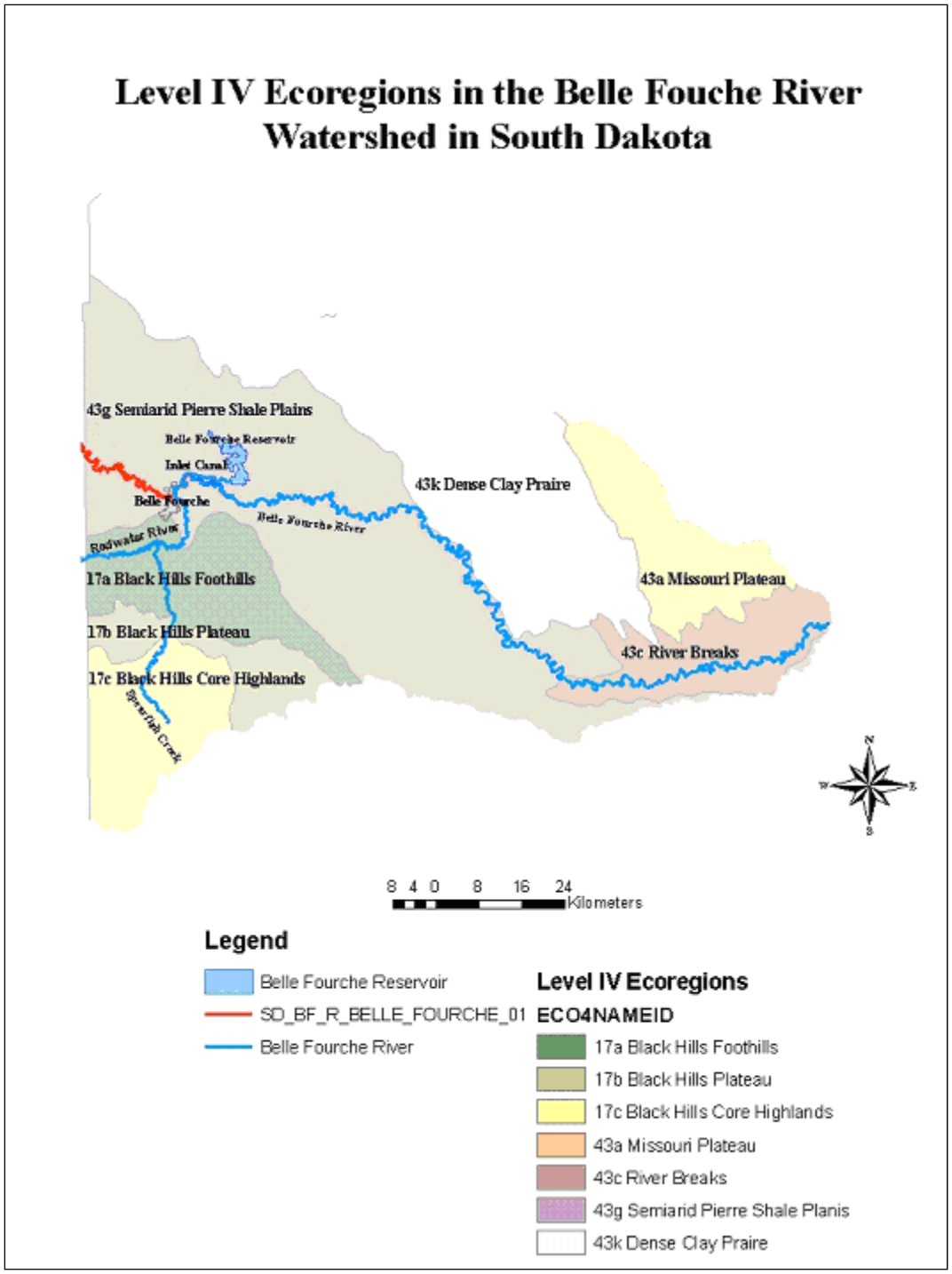

Figure 2. Belle Fourche River watershed in South Dakota including Level IV ecoregions.

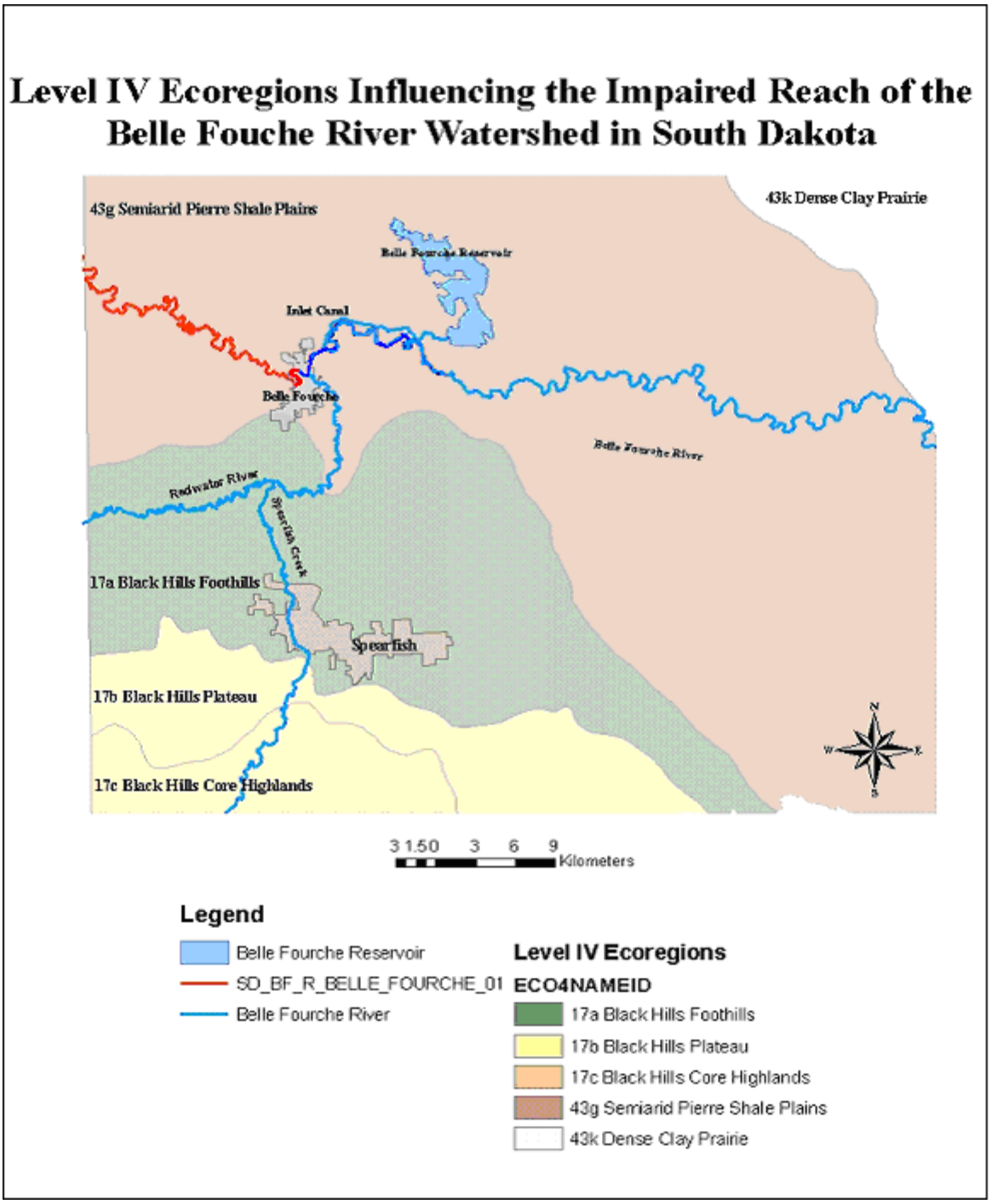

Figure 3. Level IV ecoregions influencing the fecal coliform impaired reach of the Belle Fourche watershed in South Dakota.

1.2 Problem Identification

Belle Fourche River Segment 1 was first listed for pathogens (fecal coliform bacteria) in the 2002 South Dakota Report to Congress 305(b) Water Quality Assessment (SD DENR, 2002) and continued to be listed for fecal coliform in successive Integrated Report (combined 305(b) and 303(d) reports) listing cycles (SD DENR 2004, 2006, 2008, and 2010). In 2001 through 2002, a watershed assessment and TMDL study of the Belle Fourche River in South Dakota was completed to evaluate existing and potential pollution problems and develop a TMDL for Total Suspended Solids (TSS) (SD DENR, 2005). During the assessment exceedences in the fecal coliform criteria were observed along the Belle Fourche River from the Wyoming border (monitoring sites BF01) to the assessment monitoring site (monitoring site BF02) just above the confluence with the Redwater River (Figure 3). In 2012 the segment was listed for *Escherichia coli* bacteria in the South Dakota Integrated Report to Congress 305(b) Water Quality Assessment (SD DENR, 2012).

Since 1999, the South Dakota Department of Environment and Natural Resources (SD DENR) have collected fecal coliform bacteria samples at WQM 130 (460130) in Belle Fourche. Since 2009 *E. coli* bacteria samples have been collected at WQM 130 (460130) and paired fecal coliform and *E. coli* samples were used to model *E. coli* concentrations on unpaired fecal coliform data.

1.3 Description of Applicable Water Quality Standards & Numeric Water Quality Targets

Each waterbody within South Dakota is assigned beneficial uses. All waters (both lakes and streams) are designated with the use of fish and wildlife propagation, recreation, and stock watering, while all streams and select lakes (to include Belle Fourche Reservoir) are assigned the use of irrigation. Additional uses are assigned by the state based on a beneficial use analysis of each waterbody. Water quality standards have been defined in South Dakota state statutes in support of these uses. These standards consist of suites of criteria that provide physical and chemical benchmarks from which management decisions can be developed.

Belle Fourche River has been assigned the following beneficial uses: warmwater permanent fish life propagation, immersion recreation, limited contact recreation, fish and wildlife propagation, recreation and stock watering, and irrigation. Table 2 lists the criteria that must be met to support the specified beneficial uses. When multiple criteria exist for a particular parameter, the most stringent criterion is used.

Individual parameters, determine the support of these beneficial uses. South Dakota has narrative standards that may be applied to the undesired eutrophication of lakes and streams. Administrative Rules of South Dakota (ARSD) Article 74:51 contains language that prohibits the presence of materials causing pollutants to form, visible pollutants, taste and odor producing materials, and nuisance aquatic life.

The numeric TMDL target established for SD-BF-R-BELLE_FOURCHE_01 reach of the Belle Fourche River is based on the current daily maximum criteria for *E. coli* bacteria. Water quality criteria for the immersion recreation beneficial use requires that 1) no sample exceeds 235 cfu/100 mL and 2) during a 30-day period, the geometric mean of a minimum of 5 samples collected during separate 24-hour periods must not exceed 126 cfu/100 mL. This criterion is applicable from May 1 through September 30 (SD DENR, 2002b).

Immersion recreation standards for fecal coliform in the impaired reach of the Belle Fourche River were exceeded 32 percent of the time during the project. Of 48 recent *E. coli* samples that have been collected from Segment 1 of the Belle Fourche River, 14.6 percent exceeded the acute Immersion Recreation *E. coli* water quality standard from 2007 to 2012. The Belle Fourche River in South Dakota has a US EPA approved TMDL for TSS (SD DENR, 2005) and fecal coliform (SD DENR, 2011).

This document will use the immersion recreation beneficial use chronic threshold value for *E. coli* of 126 cfu/100 ml as a management goal. By using the chronic threshold of immersion recreation there is increased confidence that acute and chronic water quality criteria for immersion recreation and limited contact recreation will be achieved.

Table 2. State surface water quality standards for the Belle Fourche River, Butte County, South Dakota.

Parameter	Criteria	Unit of Measure	Special Conditions
Total ammonia nitrogen as N (Warmwater Permanent Fish Life Propagation)	Equal to or less than the result from Equation 3 in Appendix A	mg/L	30-day average March 1 - October 31
	Equal to or less than the result from Equation 4 in Appendix A	mg/L	30 day average November 1 - February 29
	Equal to or less than the result from Equation 2 in Appendix A	mg/L	daily maximum
[1]**Fecal coliform** (May 1 – September 30) (Immersion Recreation) [2]***Escherichia coli*** (May 1 – September 30) (Immersion Recreation)	[1]≤ 200 [2]≤ 126	/100 mL	geometric mean based on a minimum of 5 samples obtained during separate 24-hour periods for any 30-day period, and they may not exceed this value in more than 20 percent of the samples examined in this same 30-day period
	[1]≤ 400 [2]≤ 235		in any one sample
Dissolved oxygen (Warmwater Permanent Fish Life Propagation)	≥ 5.0	mg/L	
Undisassociated hydrogen sulfide (Warmwater Permanent Fish Life Propagation)	≤ 0.002	mg/L	
pH (Warmwater Permanent Fish Life Propagation)	≥ 6.5 - ≤ 9.0	units	see § 74:51:01:07
Total Suspended Solids (Warmwater Permanent Fish Life Propagation)	≤ 90	mg/L	30-day average
	≤ 158	mg/L	daily maximum
Total alkalinity as calcium carbonate (Fish, Wildlife, Propagation, Recreation and Stock Watering)	≤ 750	mg/L	30-day average
	≤ 1313	mg/L	daily maximum
Total dissolved solids (Fish, Wildlife, Propagation, Recreation and Stock Watering)	≤ 2,500	mg/L	30-day average
	≤ 4,375	mg/L	daily maximum
Conductivity at 25°C (Irrigation)	≤ 2,500	micromhos/cm	30-day average
	≤ 4,375	micromhos/cm	daily maximum
Nitrates as N (Fish, Wildlife, Propagation, Recreation and Stock Watering)	≤ 50	mg/L	30-day average
	≤ 88	mg/L	daily maximum
Total petroleum hydrocarbon (Fish, Wildlife, Propagation, Recreation and Stock Watering)	≤ 10	mg/L	see § 74:51:01:10
Oil and grease (Fish, Wildlife, Propagation, Recreation and Stock Watering)	≤ 10	mg/L	see § 74:51:01:10
Sodium Adsorption Ratio (Irrigation)	≤ 6		see definition
Temperature (Warmwater Permanent Fish Life)	≤ 80	°F	see § 74:51:01:31

2.0 Pollutant Assessment

2.1 Boundary Conditions

BF01 is located along the Belle Fourche at the Wyoming/South Dakota border. Conditions at this site reflect land use within Wyoming and serve as a boundary condition for Segment 1 of the Belle Fourche River. Exceedences of the acute standard only occur in the upper 40% of the flow regime (Figure 4). Reductions to meet the chronic threshold in the high flow and moist condition were both 94% (Table 3). A reduction of 3% of *E. coli* loading is needed to meet the chronic threshold in the dry flow zone. Wyoming does not have their segment of the Belle Fourche River (which is upstream of SD-BF-R-BELLE_FOURCHE_01) listed in their 303(d) as being impaired by *E. coli*.

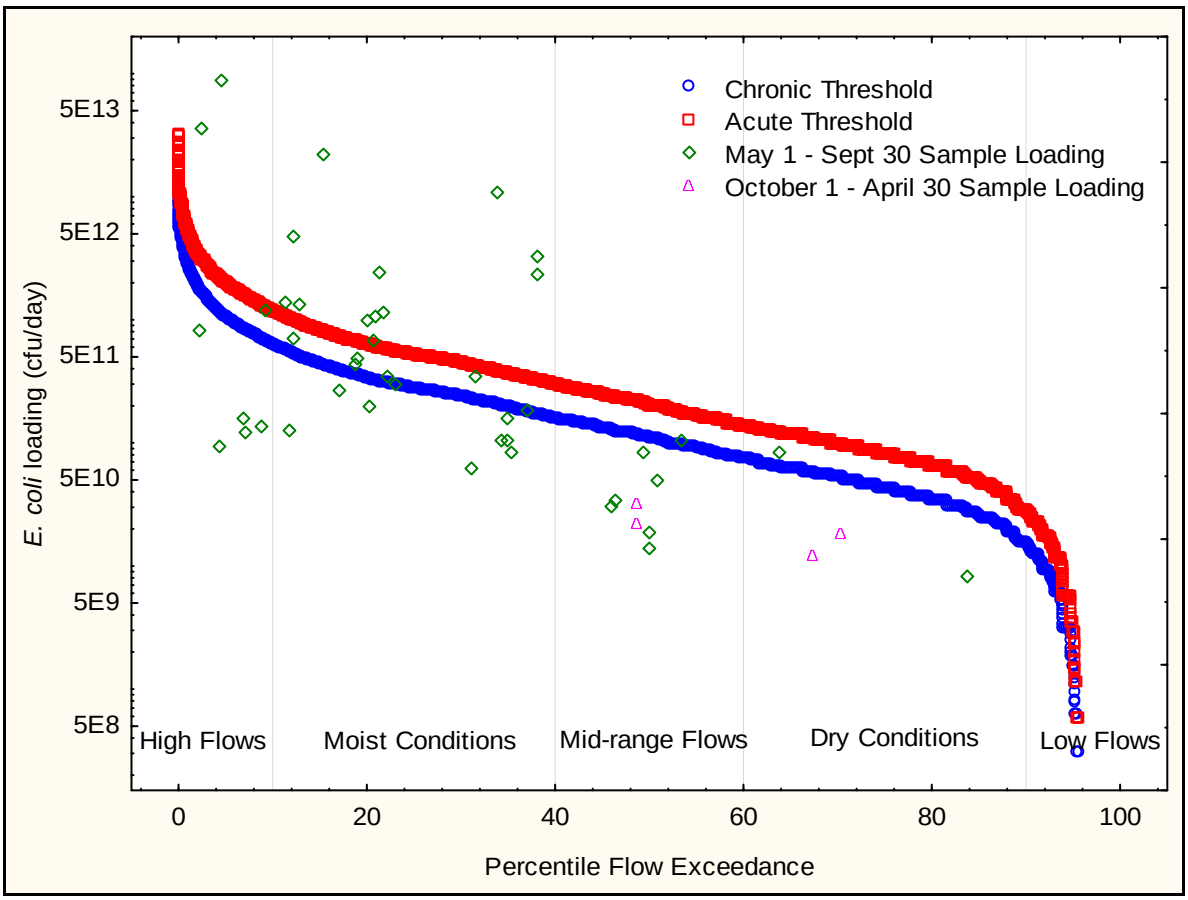

Figure 4. Boundary Conditions for the Belle Fourche River Segment 1.

Table 3. Boundary conditions at the Wyoming/South Dakota border.

Flow Zone	High	Moist Condition	Mid-Range Conditions	Dry	Low Flow
CFS	≥ 205	52 - 204	24 - 52	24-May	≤ 5
TMDL	6.04E+15	1.02E+14	7.71E+12	1.63E+12	6.24E+10
MOS	4.47E+11	1.17E+11	3.70E+10	2.77E+10	1.54E+09
LA	6.04E+15	1.02E+14	7.67E+12	1.60E+12	6.09E+10
Load Reduction (%)	94	94	0	3	-

2.2 Point Sources

The City of Belle Fourche is located at the end of the impaired reach; approximately four river kilometers are in the city limits before the reach ends at the confluence with the Redwater River. The City of Belle Fourche uses a multiple lagoon municipal sewage treatment system located approximately 5 r-km downstream of the impaired reach. A waste load allocation of 0 *E. coli* cfu/100 ml has been assigned to Segment 1 of the Belle Fourche River.

2.3 Nonpoint Sources

Based on review of available land use information and communication with local land owners and representatives from Belle Fourche, the primary nonpoint sources of fecal coliform within the impaired reach of the Belle Fourche River is agricultural (Figure 5). Urban runoff, as well as wildlife and human sources may also be present. Using the best available information, loadings were estimated from each of these sources based on the number of units (e.g. numbers of animals, failing septic systems, etc.) representative of each source.

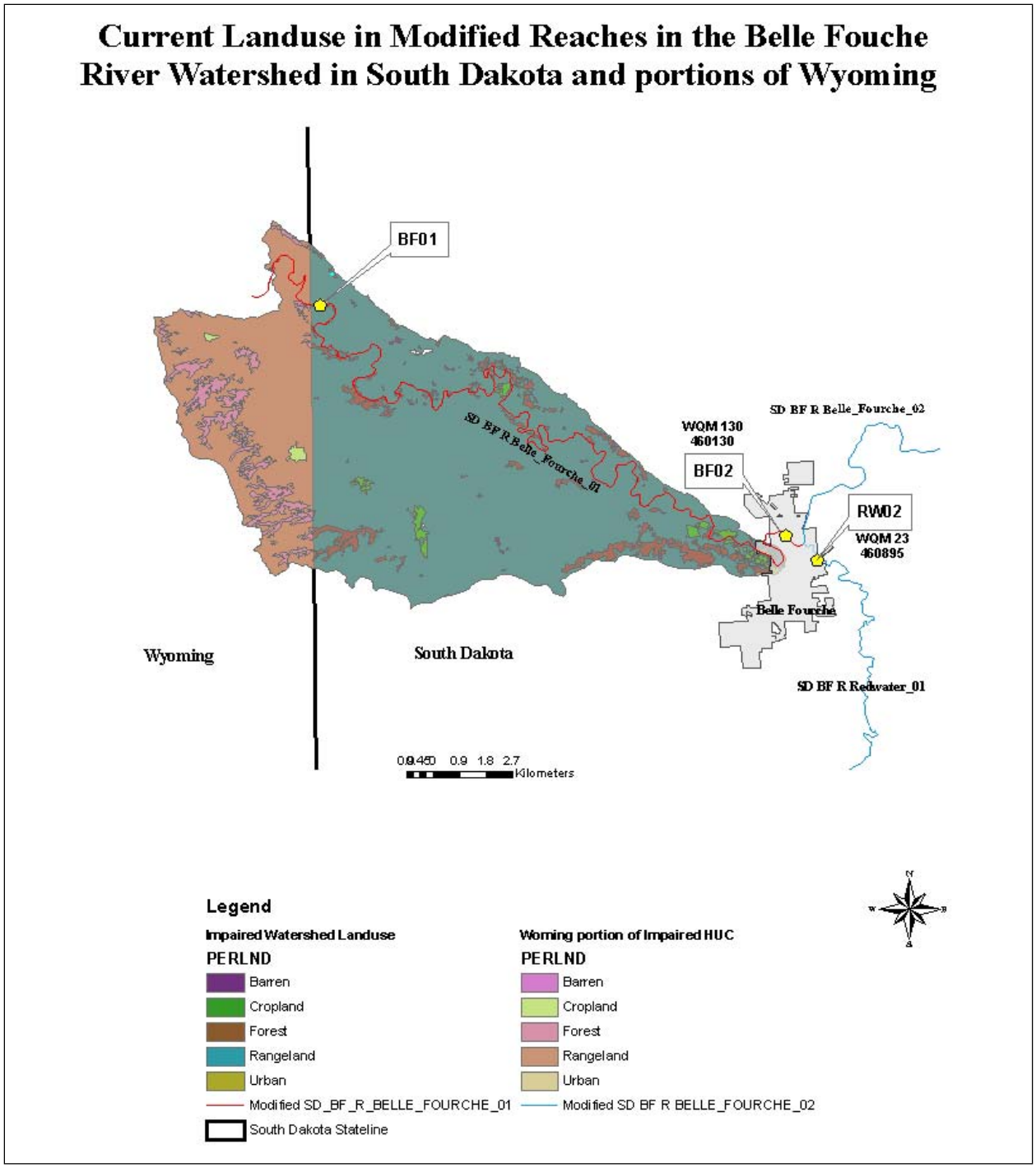

Figure 5. Land use in impaired reach SD BF R Belle_Fourche_01 of the Belle Fourche River in South Dakota and Wyoming 2009.

2.4 Urban

Approximately 1.2 percent of the impaired study area is characterized as impervious area (urban). Most of the impervious area is located in the City of Belle Fourche; however, rural ranch areas located along the Belle Fourche River upstream of the City of Belle Fourche may also contribute to fecal coliform runoff to the Belle Fourche River during storm events.

Although several water quality samples taken from storm drains during storm events indicated that urban runoff could be a source of fecal coliform bacteria, the city is not large enough to require a stormwater discharge permit and the contributions from this source are considered insignificant (Table 4).

Table 4. Fecal source allocation to Belle Fourche River Segment 1 (based on information from Table 5).

Source	Percentage
Livestock on Grass	96.86%
Feedlots	2.33%
Wildlife	0.56%
Human	0.25%

2.5 Agriculture

Manure from livestock is a potential source of fecal coliform to the stream. Livestock in the basin are mainly beef cattle with sheep being the next abundant animals in the study area. Other livestock in the basin include dairy cattle, hogs, horses and chickens. Numbers of animals on private land were estimated through personal communication with landowners and NASS 2009 agricultural statistics in the watershed. The majority of the potential fecal coliform sources for livestock came from livestock on grass (rangland) and not from confined animal feeding operations, which were deemed insignificant (only 2.33%).

2.6 Human

The impaired HUC drainage contains an estimated 44 septic systems that are mostly located near tributaries to the Belle Fourche River (SD DENR, unpublished data). Septic systems located near drainages in the study area provide potential sources of human fecal coliform to the impaired segment of the Belle Fourche River. Limited information is available on the age and condition of these systems.

2.7 Natural background/wildlife

Wildlife within the watershed is a natural source of fecal coliform bacteria in the study area. County wildlife assessments provided the best available estimate of wildlife population densities. The wildlife assessment for Butte County was obtained from the South Dakota Department of Game, Fish and Parks. SD GF&P population estimates included counts of whitetail deer, mule deer, elk, antelope and turkey (Table 5) (Huxoll, 2002).

Table 5. Belle Fourche River Segment 1 potential nonpoint sources of fecal coliform.

Species	#/sq mile	#/acre	FC/Animal/Day	Fecal Coliform	Percent
Dairy Cow	0.51	< 0.01	1.01E+11	7.97E+07	1.59%
Cattle on Range	27.73	0.04	1.04E+11	4.51E+09	89.80%
Cattle on Feed	0.20	< 0.01	1.04E+11	3.31E+07	0.66%
Bison[6]	0.02	< 0.01	1.04E+11	2.89E+06	0.06%
Hog	0.23	< 0.01	1.08E+10	3.81E+06	0.08%
Sheep	18.72	0.03	1.20E+10	3.51E+08	6.99%
Horse	1.07	< 0.01	4.20E+08	7.00E+05	0.01%
Human	4.04	0.01	2.00E+09	1.26E+07	0.25%
All Wildlife	**Sum of all Wildlife**			2.82E+07	0.56%
Deer[3]	3.78	0.01	5.00E+08	2.95E+06	
Elk[6]	0.07	< 0.01	1.04E+11	1.08E+07	
Antelope[3]	3.65	0.01	5.00E+08	2.85E+06	
Turkey[1]	1.56	< 0.01	9.30E+07	2.26E+05	
Mink[5]	0.44	< 0.01	1.25E+08	8.69E+04	
Beaver[3]	0.89	< 0.01	2.50E+08	3.48E+05	
Muskrat[1]	0.78	< 0.01	1.25E+08	1.52E+05	
Skunk[5]	1.33	< 0.01	1.25E+08	2.61E+05	
Badger[5]	0.44	< 0.01	1.25E+08	8.69E+04	
Coyote[4]	0.06	< 0.01	4.09E+09	3.55E+05	
Fox[4]	0.18	< 0.01	4.09E+09	1.14E+06	
Raccoon[3]	2.00	< 0.01	1.25E+08	3.91E+05	
Bobcat[4]	0.11	< 0.01	4.09E+09	7.11E+05	
Jackrabbit[5]	8.89	0.01	1.25E+08	1.74E+06	
Mountain Lion[4]	< 0.01	< 0.01	4.09E+09	8.50E+03	
Cottontail Rabbit[5]	1.33	< 0.01	1.25E+08	2.61E+05	
Squirrel[5]	0.44	< 0.01	1.25E+08	8.69E+04	
Grouse[2]	1.76	< 0.01	1.36E+08	3.73E+05	
Partridge[2]	1.11	< 0.01	1.36E+08	2.36E+05	
Canada Goose[1]	0.07	< 0.01	4.90E+10	5.10E+06	

1 USEPA 2001

2 FC/Animal/Day copied from chicken (USEPA 2001) to provide an estimate of background affects of wildlife

3 Bacteria Indicator Tool worksheet

4 Best professional judgment based off of dogs

5 FC/Animal/Day copied from raccoon to provide a more conservative estimate of background effects of wildlife

6 Best professional judgment based off of cattle

2.8 Bacterial Source Tracking

Samples were collected on three different dates for bacteria source tracking: August 23, 2004; May 9, 2005; and July 5, 2005. These samples were not subject to runoff from storm events. In addition to sampling at WQM 130, samples were collected upstream and downstream of the city of Belle Fourche for bacteria source tracking on all three dates. Three different methods were used for bacteria source tracking for this project. On August 23, 2004, an *E. coli* ID™ test was run on samples from all three locations. On May 9, 2005, a Human *Bacteroidetes* ID™ test was run on samples from all three locations. On July 5, 2005, a Human *Bacteroidetes* ID™ test and a Cow *E. coli* ID™ test was performed on samples collected from samples collected upstream and downstream of the city of Belle Fourche. No bacteria source tracking test was run on the sample collected at WQM 130 on July 5, 2005, since an additional test was run on samples from the other two sample locations. All bacteria source tracking samples were analyzed by Source Molecular located in Miami, Florida. Due to cost a limited number of bacterial source tracking samples were collected.

An *E. coli* ID™ test, often referred to as a ribotyping test, uses a genetic fingerprint that comes from genes that code for ribosomal ribonucleic acids of *E. coli* to identify the source as either human or animal. This test does not distinguish cattle from other animal sources. A Human *Bacteroidetes* ID™ test uses organisms from the phylum *Bacteroidetes* as indicator species, instead of *E. coli* to identify sources of bacteria. *Bacteroidetes* are anaerobes and are, therefore, indicative of recent fecal contamination. The Human *Bacteroidetes* ID™ test filters and identifies the bacteria from an entire sample versus identifying a sub-sample that is cultured on a Petri dish. Specifically, the Human *Bacteroidetes* ID™ test identifies contamination from human sources only. Similar to the *E. coli* ID™ test, the Cow *E. coli* ID test uses *E. coli* as indicator species. The Cow *E. coli* ID test specifically identifies certain strains of *E. coli* that are specifically pathogenic in cattle to identify fecal contamination from cattle.

Source tracking samples from August 23, 2004, from all three sample locations indicated no contamination from human sources. Two isolates, one from upstream and one from downstream of the city of Belle Fourche, were indeterminate. All other samples were identified as being from animal sources. Similar to the August 2004 samples, the source tracking samples from May 9, 2005, showed no human sources of contamination. The Cow *E. coli* ID test was added for the final source tracking sampling on July 5, 2005, in order to identify the loading originating from cattle. The samples from the final source tracking sampling indicated no contamination from cattle or human sources. The complete list of results is shown in Table 6.

Table 6. Results of fecal coliform source tracking analysis.

Bacterial Source Tracking	Location	Energy Lab Fecal Coliform (CFU/100 ml)	Fecal Coliform (mpn/100ml)	Type of Test	Probable Source
08/23/2004	WQM 130	2,800	1,100	*E. coli* ID™	5 isolates animal
08/23/2004	U/S B.F.	–	93	*E. coli* ID™	4 isolates animal and 1 isolate indeterminate
08/23/2004	D/S B.F.	–	1,100	*E. coli* ID™	4 isolates animal and 1 isolate indeterminate
05/09/2005	WQM 130	46	–	Human *Bacteroidetes* ID™	No Human Gene Biomarker Detected
05/09/2005	U/S B.F.	–	–	Human *Bacteroidetes* ID™	No Human Gene Biomarker Detected
05/09/2005	D/S B.F.	–	–	Human *Bacteroidetes* ID™	No Human Gene Biomarker Detected
07/05/2005	WQM 130	460	–	–	–
07/05/2005	U/S B.F.	–	455 (*E.coli*)	Cow *E. coli* ID	No Cattle Gene Biomarker Detected
07/5/2005	D/S B.F.	–	293 (*E.coli*)	Cow *E. coli* ID	No Cattle Gene Biomarker Detected
07/5/2005	U/S B.F.	–	–	Human *Bacteroidetes* "Quatification" ID™	No Human Gene Biomarker Detected
07/5/2005	D/S B.F.	–	–	Human *Bacteroidetes* "Quatificatio" ID™	No Human Gene Biomarker Detected

Based on the results of the bacteria source tracking, it appears that human sources of fecal coliform bacteria are not a major portion of the fecal coliform load in the Belle Fourche River. No samples were identified from either human or cattle sources. However, because of the small sample size, the results do not mean that there is no loading of fecal coliform bacteria from either human or cattle sources. Possible sources of fecal contamination within samples tested for source tracking may come from domestic animals (pets) from the city of Belle Fourche as well as waterfowl and other avian life such as swallows occurring around bridges. Based on South Dakota agricultural bulletins, cattle make up the majority of the fecal source loading within the watershed. This data should be considered over bacteria source tracking in this case due to the small sample size of source tracking samples.

3.0 Technical Analysis

3.1 Data Collection

Water samples were collected from two sites, BF01 and BF02 during the 2001-2002 Belle Fourche Assessment and Implementation projects (Figure 6). The samples were collected monthly with some occasional "event" sampling included to supplement the routine schedule.

Additionally, the SD DENR sampled these sites during 2009 on a weekly basis to provide more fecal coliform data for these sites.

BF01 is located near the Wyoming/South Dakota Border. BF02 is located within the town of Belle Fourche at the Highway 85 Bridge. BF01 represented boundary conditions. BF02 and ambient water quality monitoring station 460130 located near BF02 served to represent Segment 1 of the Belle Fourche River.

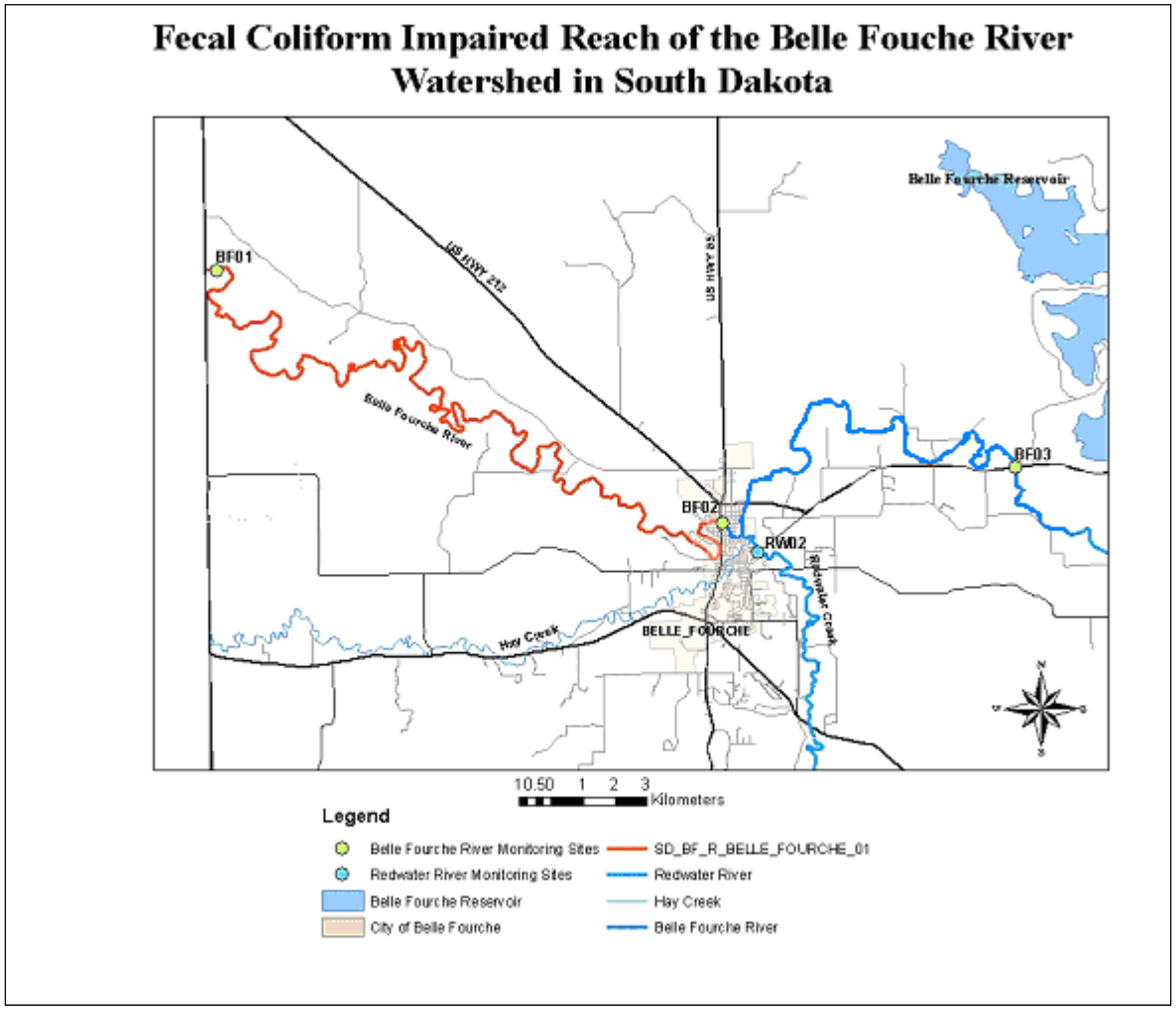

Figure 6. Monitoring sites.

E. coli and fecal coliform samples have also been collected on a monthly basis from ambient water quality monitoring station 460130 from 2009-present. However, only data from the recreational season (May through September) were used in this TMDL.

3.2 Sample Data

Paired *E. coli* and fecal coliform samples collected during 2009 were used to create a relationship to model *E. coli* concentration from unpaired fecal coliform samples (Figure 7). Comparing flow and concentration resulted in a very weak relationship that was inadequate for

use in predicting daily loads. Two out of 20 actual *E. coli* samples exceeded the acute threshold for immersion recreation from sites BF02 and 460130 (Table 7). Five of 29 actual *E. coli* samples exceeded the immersion recreation acute threshold from site BF01 (Table 8). On several dates duplicate samples were collected, these were removed from the load duration curve analysis because one sample should represent an instantaneous loading.

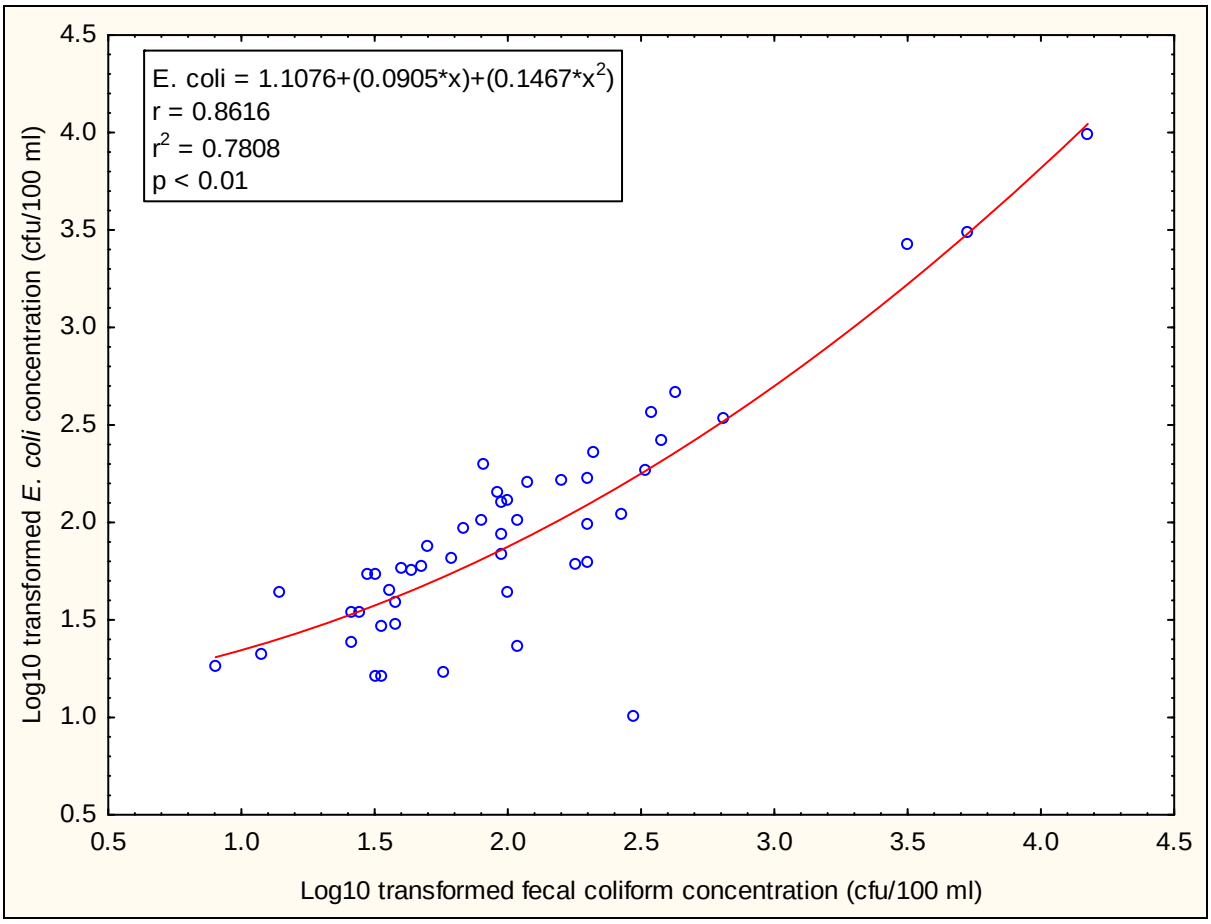

Figure 7. Fecal coliform/*E. coli* relationship.

Table 7. Samples obtained from site 460130 and BF2, modeled *E. coli* concentrations indicated by red text.

Date	Sampling Time	Site	Average Daily/Instantaneous Flow	Fecal Coliform	*E. coli*
07/21/1999	08:00	460130	199/-	3800	2048.84
07/10/2000	08:00	460130	14/-	340	189.15
07/17/2001	08:00	460130	112/-	440	235.48
07/16/2002	08:00:00	460130	179/-	500	263.32
05/08/2003	08:40	460130	62/-	100	75.06
06/04/2003	11:00	460130	23/-	60	54.00
07/09/2003	10:55	460130	113/-	570	295.92
08/21/2003	09:05	460130	103/-	210	128.49
09/16/2003	10:05	460130	33/-	150	99.82
05/12/2004	10:55	460130	11/-	150	99.82
06/08/2004	11:35	460130	7.2/-	160	104.66
07/14/2004	12:50	460130	21/-	270	156.62
08/23/2004	11:25	460130	2.3/-	1300	648.50
08/23/2004	-	460130	2.3/-	2800	1454.75
09/14/2004	10:45	460130	52/-	340	189.15
05/09/2005	-	460130	28/-	46	46.10
05/24/2005	13:25	460130	19/-	120	85.10
06/21/2005	11:50	460130	9.3/-	150	99.82
07/05/2005	-	460130	51/-	460	244.75
07/13/2005	12:10	460130	46/-	110	80.11
08/24/2005	14:15	460130	111/-	150	99.82
09/21/2005	11:10	460130	9/-	160	104.66
05/17/2006	08:55	460130	87/-	330	184.51
06/20/2006	08:00	460130	22/-	78	63.68
07/26/2006	09:10	460130	70/-	70	59.43
08/23/2006	08:00	460130	106/-	150	99.82
09/20/2006	13:10	460130	19/-	2	14.06
05/13/2008	15:57	460130	521/-	1100	549.33
06/24/2008	15:25	460130	273/-	320	179.88
07/08/2008	14:42	460130	113/-	1000	500.50
08/13/2008	16:19	460130	72/-	440	235.48
09/10/2008	16:17	460130	40/-	60	54.00
05/05/2009	15:11	460130	401/-	100	44
06/16/2009	15:56	460130	556/-	5300	3020
07/14/2009	15:35	460130	113/-	330	185
08/19/2009	06:31	460130	64/-	200	96
09/15/2009	14:58	460130	37/-	58	17
05/03/2010	18:00	460130	206/-	200	62
06/22/2010	08:00	460130	172/-	270	109

Table 7 continued. Samples obtained from site 460130 and BF2, duplicate samples removed for LDC analysis indicated by *, modeled *E. coli* concentrations indicated by red text.

Date	Sampling Time	Site	Average Daily/Instantaneous Flow	Fecal Coliform	*E. coli*
07/14/2010	06:45	460130	113/-	350	365
08/10/2010	15:00	460130	78/-	180	61
09/13/2010	18:15	460130	38/-	48	59
05/18/2011	12:20	460130	448/-	120	160
06/15/2011	14:30	460130	452/-	160	164
07/07/2011	14:30	460130	214/-	110	102
08/23/2011	14:00	460130	89/-	38	39
09/14/2011	12:45	460130	71/-	36	45
06/14/2001	04:32	BF2	173/274	1500	749.69
07/24/2001	03:00	BF2	67/138	10000	6558.43
08/28/2001	0	BF2	31/31	66	57.27
08/28/2001*	0	BF2	31/31	7	19.45
09/27/2001	0	BF2	9.2/11	250	147.28
10/25/2001	0	BF2	17/19	23	31.83
04/23/2002	12:10	BF2	38/145	10	22.12
09/22/2009	11:30	BF2	36/-	50	75
09/22/2009	15:15	BF2	36/-	34	16
09/24/2009	14:00	BF2	36/-	30	54
09/24/2009*	15:00	BF2	36/-	14	44
09/24/2009	15:00	BF2	36/-	32	16

Table 8. Samples obtained from BF1, duplicate samples removed for LDC analysis indicated by *, modeled *E. coli* concentrations indicated by red text.

Date	Sampling Time	Site	Average Daily/Instantaneous Flow	Fecal Coliform	*E. coli*
06/14/2001	03:13	BF1	173/164.5	2200	1119.41
06/14/2001*	03:27	BF1	173/164.5	1600	801.04
07/13/2001	12:00	BF1	139/139	10000	6558.43
07/24/2001	02:00	BF1	67/67	10000	6558.43
08/28/2001	0	BF1	31/31	230	137.91
09/27/2001	0	BF1	9.2/9.6	30	36.42
10/25/2001	0	BF1	17/17	40	42.57
03/28/2002	11:42	BF1	38/197.7	27	34.49
04/23/2002	12:50	BF1	38/41.2	12	23.77
05/29/2002	11:04	BF1	21/19	280	161.28
06/06/2002	12:00	BF1	56/88	3200	1687.27
06/06/2002	02:30	BF1	56/99	4300	2361.43
06/07/2002	-	BF1	103/217	1900	958.04
06/08/2002*	12:00	BF1	105/106	860	432.96
06/08/2002	12:00	BF1	105/106	810	409.07
06/09/2002	12:00	BF1	110/201	710	361.63
06/10/2002	12:00	BF1	115/212	300	170.59
07/30/2002	01:10	BF1	184/212	600	309.94
08/27/2002	06:28	BF1	109/234	100	75.06
09/13/2002	07:25	BF1	117/364	260	151.96
10/23/2002	08:30	BF1	19/18	14	25.35
05/01/2009	11:00	BF1	600/-	44	56
05/06/2009	14:28	BF1	382/-	300	10
05/13/2009	11:50	BF1	281/-	110	23
05/14/2009	14:45	BF1	272/-	8	18
05/18/2009	13:30	BF1	231/-	26	24
05/28/2009	11:15	BF1	180/-	34	29
06/04/2009	11:30	BF1	173/-	200	168
06/16/2009	10:15	BF1	556/-	3200	2630
06/24/2009	14:40	BF1	219/-	210	226
06/30/2009	09:00	BF1	127/-	96	86
07/08/2009	09:45	BF1	97/-	96	127
07/16/2009	12:45	BF1	101/-	430	461
07/20/2009	13:50	BF1	106/-	380	263
07/21/2009	13:15	BF1	100/-	92	142
07/28/2009	12:30	BF1	73/-	82	195
07/30/2009	14:40	BF1	75/-	28	34
08/03/2009	11:30	BF1	63/-	32	54
08/05/2009	08:45	BF1	59/-	100	129
08/10/2009	10:00	BF1	375/-	15000	9678.4

Table 8 continued. Samples obtained from BF01.

Date	Sampling Time	Site	Average Daily/Instantaneous Flow	Fecal Coliform	*E. coli*
08/12/2009	10:45	BF1	164/-	650	336
08/18/2009	09:30	BF1	66/-	62	65
08/19/2009	14:40	BF1	64/-	80	102
08/19/2009	14:45	BF1	64/-	96	68
08/31/2009	13:30	BF1	42/-	38	30
09/01/2009	14:30	BF1	41/-	26	34
09/08/2009	10:15	BF1	37/-	68	93
09/21/2009	14:30	BF1	35/-	40	58
09/22/2009	13:00	BF1	36/-	12	21
09/24/2009	13:15	BF1	36/-	32	16

4.0 Linkage Analyses

4.1 Load Duration Curve Analysis

The TMDL was developed using the Load Duration Curve (LDC) approach that results in a flow-variable target that considers the entire flow regime (Figure 8). In the Belle Fourche River, *E. coli* concentrations are positively related to stream flow. Thus, the LDC approach was deemed an appropriate method for setting flow-variable fecal coliform bacteria TMDL for the Belle Fourche River.

The LDC is a dynamic expression of the allowable load for any given day. To aid in interpretation and implementation of the TMDL, the LDC flow intervals were grouped into five flow zones representing high flows (0–10 percent), moist conditions (10–40 percent), moderate flows (40–60 percent), dry conditions (60–90 percent), and low flows (90–100 percent) according to EPA's *An Approach for Using Load Duration Curves in the Development of TMDLs* (USEPA, 2006).

Instantaneous loads were calculated by multiplying *E. coli* sample concentrations from SD DENR ambient water quality data (site number 460130, WQM 130), the USGS daily average flow (gage number 06428500) and average daily discharge developed for watershed assessment monitoring site BF02 on the date of the sample and a unit conversion factor. The SD DENR water quality monitoring site, USGS flow gaging station and Belle Fourche River assessment monitoring site BF02 are co-located near the Highway 85 Bridge in the City of Belle Fourche (Figure 4).

When the instantaneous loads are plotted on the LDC, characteristics of the water quality impairment are shown (Figure 9). Instantaneous loads that plot above the curve are exceeding the TMDL, while those below the curve are in compliance. As the plot shows, the 95th percentile of fecal coliform samples collected from Belle Fourche River exceed the geometric mean criterion in the high, moist, moderate, dry and low flow conditions. Loads exceeding the criteria in the low flow zone typically indicate point source load contributions, while those further left on the plot generally reflect potential nonpoint source contributions (USEPA, 2006).

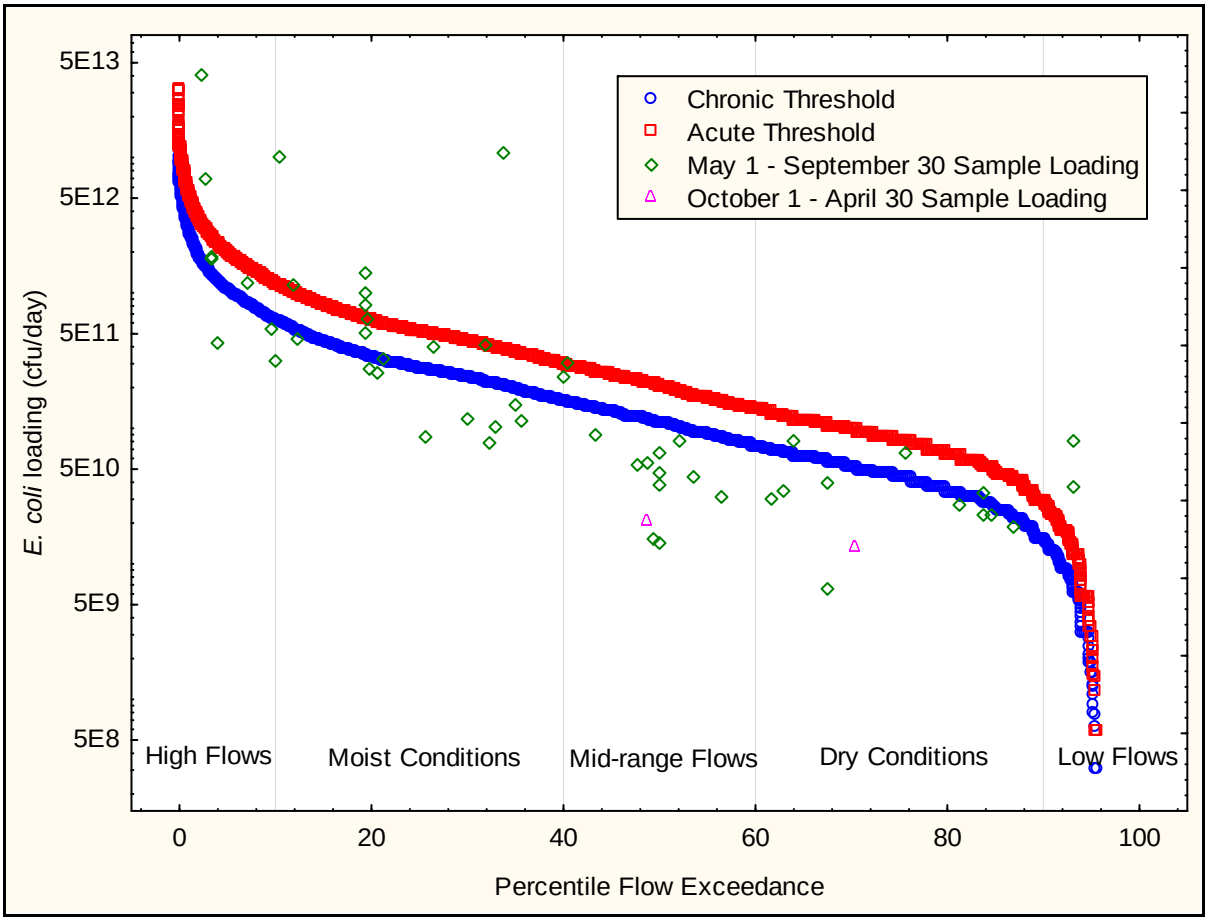

Figure 8. Load duration curve for the Belle Fourche River Segment 1.

4.1.1 High Flows

The high flow zone is composed of the highest 10% of flows that occur in Segment 1 of the Belle Fourche River. There were eight samples within this flow zone. Two were above both the chronic and acute standards and three were above the chronic but not the acute standard. The 95th percentile concentration of all samples in this zone was used to calculate the current load from which reductions were calculated. A load reduction of 85% will be needed to fully support designated beneficial uses to the chronic water quality standard. Table 9 depicts an example of a TMDL for a flow of 1400 cfs (95% flow in this zone) within the high flow zone regime. Higher or lower flows within this zone may acceptably carry higher or lower loads as long as the concentration does not exceed the state standard.

The concentration of 235 cfu/100 ml represents the acute standard and may make an appropriate goal for this flow zone because flows in excess of 205 cfs typically only last for short periods of time (peak runoff events).

While the 235 cfu/100 ml goal may have made an acceptable goal, the chronic threshold of 126 cfu/100 ml was chosen for the TMDL. Chronic violations are not likely in this flow zone, but using the 1000 cfu/100 ml threshold assurance is provided that the water quality standard will not be exceeded.

Table 9. TMDL calculation for the high flow zone.

	Flow Zone (expressed as CFU/day)	
	High Flows >205 cfs	
LA	6.04E+15	Remaining load after deducting WLA and MOS from TMDL
WLA	0.00E+00	
MOS	4.47E+11	
TMDL @126 cfu/100 ml	6.04E+15	Standard multiplied by 95th % flow for zone
Current Load	4.08E+16	95th Percentile of observed fecal coliform bacteria load for each zone multiplied by 95% flow for zone
Load Reduction	85%	Reduction required to reduce the current load to the load at the standard

4.1.2 Moist Conditions

Moist condition flows are characterized by above average moisture conditions in the watershed. Flows in this regime are generated by precipitation and snowmelt events. The moist condition flows extend from approximately 204 cfs down to 52 cfs. Table 10 depicts an example of a TMDL for a flow of about 182 cfs (95% flow in this zone) within the moist condition regime. Twenty one samples represent this flow zone. Eight samples exceed both the acute and the chronic water quality thresholds. Four samples exceed the chronic but not the acute water quality threshold. A load reduction of 94% is needed to meet the immersion recreation *E. coli* chronic threshold.

Table 10. TMDL calculation for the moist condition flow zone.

	Flow Zone (expressed as CFU/day)	
	Moist Conditions 204 - 52 cfs	
LA	1.02E+14	Remaining load after deducting WLA and MOS from TMDL
WLA	0.00E+00	
MOS	1.17E+11	
TMDL @126 cfu/100 ml	1.02E+14	Standard multiplied by 95th % flow for zone
Current Load	1.82E+15	95th Percentile of observed fecal coliform bacteria load for each zone multiplied by 95% flow for zone
Load Reduction	94%	Reduction required to reduce the current load to the load at the standard

4.1.3 Mid-range Flows

The midrange flows extend from approximately 52 cfs to 24 cfs. Thirteen samples represented this flow zone. One sample exceeded the acute and chronic water quality threshold. A load reduction of 13% will be needed to fully support designated beneficial uses to the chronic water quality standard. Table 11 depicts an example of a TMDL for a flow of 50 cfs (95% flow for this zone) within the midrange flow zone regime. Higher and lower flows within this zone may acceptably carry higher or lower loads as long as the concentration does not exceed the state standard.

Table 11. TMDL calculation for the mid-range flow zone.

	Flow Zone (expressed as CFU/day)	
	Mid-range Flows 52 - 24 cfs	
LA	7.67E+12	Remaining load after deducting WLA and MOS from TMDL
WLA	0.00E+00	
MOS	3.70E+10	
TMDL @126 cfu/100 ml	7.71E+12	Standard multiplied by 95th % flow for zone
Current Load	8.81E+12	95th Percentile of observed fecal coliform bacteria load for each zone multiplied by 95% flow for zone
Load Reduction	13%	Reduction required to reduce the current load to the load at the standard

4.1.4 Dry Conditions

The dry condition flows extend from 24 cfs to 5 cfs. Twelve samples were collected within this flow zone. No samples exceeded the acute threshold. Three samples exceeded the chronic threshold. A load reduction of 1% will be needed to fully support designated beneficial uses to the chronic water quality standard. Table 12 depicts an example of a TMDL for a flow of 23 cfs (95% flow for this zone) within the dry condition regime. Higher and lower flows within this zone may acceptably carry higher or lower loads as long as the concentration does not exceed the state standard.

Table 12. TMDL calculation for the dry conditions zone.

	Flow Zone (expressed as CFU/day)	
	Dry Conditions 24 - 5 cfs	
LA	1.60E+12	Remaining load after deducting WLA and MOS from TMDL
WLA	0.00E+00	
MOS	2.77E+10	
TMDL @126 cfu/100 ml	1.63E+12	Standard multiplied by 95th % flow for zone
Current Load	1.65E+12	95th Percentile of observed fecal coliform bacteria load for each zone multiplied by 95% flow for zone
Load Reduction	1%	Reduction required to reduce the current load to the load at the standard

4.1.5 Low Flows

The low flow zone consists of flow below 5 cfs. Two samples were collected that occurred within this zone. Both samples exceeded both the chronic and the acute threshold. A load reduction of 83% will be needed to fully support designated beneficial uses to the chronic water quality standard. Table 13 depicts an example of a TMDL for a flow of 4.5 cfs (95% flow for this zone) within the low flow regime. Higher and lower flows within this zone may acceptably carry higher or lower loads as long the concentration does now exceed the state standard.

Table 13. TMDL calculation for the low flow zone.

	Flow Zone (expressed as CFU/day)	
	Low Flows 5 - 0 cfs	
LA	6.09E+10	Remaining load after deducting WLA and MOS from TMDL
WLA	0.00E+00	
MOS	1.54E+09	
TMDL @126 cfu/100 ml	6.24E+10	Standard multiplied by 95th % flow for zone
Current Load	3.58E+11	95th Percentile of observed fecal coliform bacteria load for each zone multiplied by 95% flow for zone
Load Reduction	83%	Reduction required to reduce the current load to the load at the standard

5.0 TMDL Allocations

5.1 Waste Load Allocation (WLA)

There are no point discharges within the watershed of Segment 1. Belle Fourche has multi-cell ponded wastewater treatment facility (WWTF) with a no discharge permit (permit number SD0021628) located downstream of the listed segment. Any overflow discharges go directly into a constructed wetland with no connection to the Belle Fourche River.

The LDC represents the dynamic expression of the fecal coliform bacteria TMDL for the Belle Fourche River, resulting in a unique maximum daily load that corresponds to a measured average daily flow. To aid in the implementation of the TMDL and estimation of needed bacteria load reductions, Table 3 presents a combination of allocations for each of five flow zones. Methods

used to calculate the TMDL components are discussed below. This TMDL is in effect from May 1 through September 30, as the fecal coliform criteria are applicable only during this period.

5.2 Load Allocation (LA)

To develop the *E. coli* bacteria load allocation (LA), the loading capacity (LC) was first determined. The LC for the Belle Fourche River was calculated by multiplying the daily maximum *E. coli* bacteria criterion by the daily average flow measured at USGS gaging station 06428500 Belle Fourche River at Belle Fourche and assessment monitoring site BF02 in Belle Fourche.

The more stringent geometric mean criterion (126 cfu/100ml) was used, rather than the daily maximum criterion (235 cfu/100ml), because observed fecal coliform loads exceed the geometric mean criterion by flow zone. The geometric mean, as defined in ARSD § 74:51:01:01, is the nth root of a product of n factors. The geometric mean fecal coliform criteria (ARSD § 74:51:01:50) applies only under special conditions, where a minimum of five samples are obtained during separate 24-hour periods for any 30-day period, and the calculated geometric mean may not exceed the criterion in more than 20% of the samples collected in this same 30-day period. Since only one or two samples were collected during any 30-day period, the geometric mean criterion does not apply. However, a geometric mean concentration was calculated using all the samples within each flow zone to assess whether or not the geometric mean criterion would be exceeded within a flow zone if a sufficient number of samples are taken

Since the geometric mean criteria are exceeded in most flow zones, it was decided to use the geometric mean criterion to develop the loading capacity of the stream in order to ensure that the most stringent water quality standards are met. For each of the five flow zones, the 95th percentile of the range of assimilative capacity within a zone was set as the flow zone goal. Bacteria loads experienced during the largest stream flows (e.g. top 5 percent) cannot be feasibly controlled by practical management practices. Setting the flow zone goal at the 95th percentile of the range of LCs will protect the immersion recreation beneficial use and allow for the natural variability of the system.

In this TMDL the WLA was zero. A portion of the LC was allocated to nonpoint sources as a load allocation (LA). A fraction of the LC was also reserved as a margin of safety (MOS) to account for uncertainty in the calculations of these load allocations. The method used to calculate the MOS is discussed below. The LA was determined by subtracting the MOS from the LC. Thus, the TMDL (and LC) is the sum of LA, and MOS.

6.0 Margin of Safety (MOS)

An explicit MOS identified using a duration curve framework is basically unallocated assimilative capacity intended to account for uncertainty (e.g., loads from tributary streams, effectiveness of controls, etc). An explicit MOS was calculated as the difference between the loading capacity at the mid-point of each of the five flow zones and the loading capacity at the minimum flow in each zone. A substantial MOS is provided using this method, because the

loading capacity is typically much less at the minimum flow of a zone as compared to the mid-point.

Because the allocations are a direct function of flow, accounting for potential flow variability is an appropriate way to address the MOS. As new information becomes available and the TMDL is revisited, this unallocated capacity may be attributed to nonpoint sources and added to the load allocation, or the unallocated capacity may be attributed to point sources and become part of the waste load allocation.

7.0 Monthly Variation

Fecal coliform concentrations also displayed seasonal variation (Figure 9). June and July both had the highest *E. coli* concentration out of the months examined. During the month of May *E. coli* concentrations were higher at the reach endpoint than at the Wyoming/South Dakota border. June concentrations were higher at the boundary condition than at the end point (Figure 10). In addition, the TMDL is seasonal, as it is effective only during the period of May 1 through September 30. Since the *E. coli* criteria are in effect from May 1 through September 30, the TMDL is also applicable only during this time period.

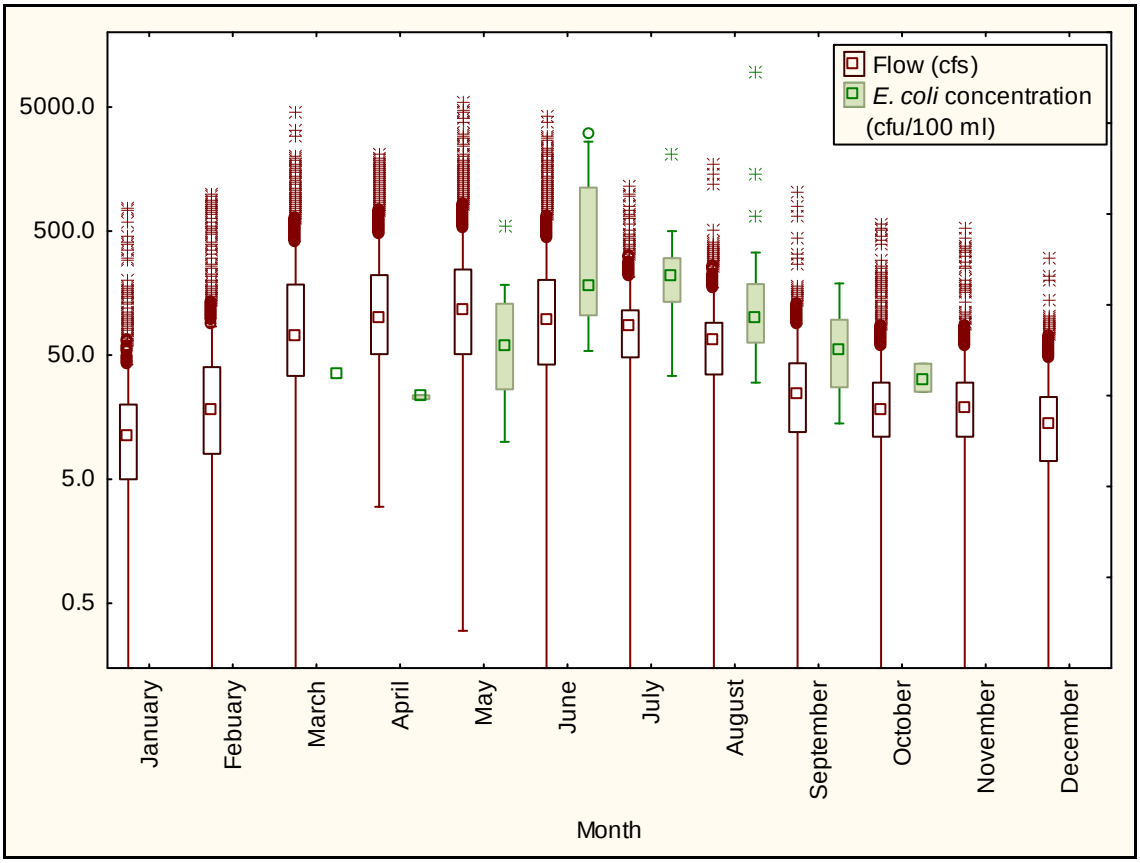

Figure 9. Monthly patterns in flow and *E. coli* concentration.

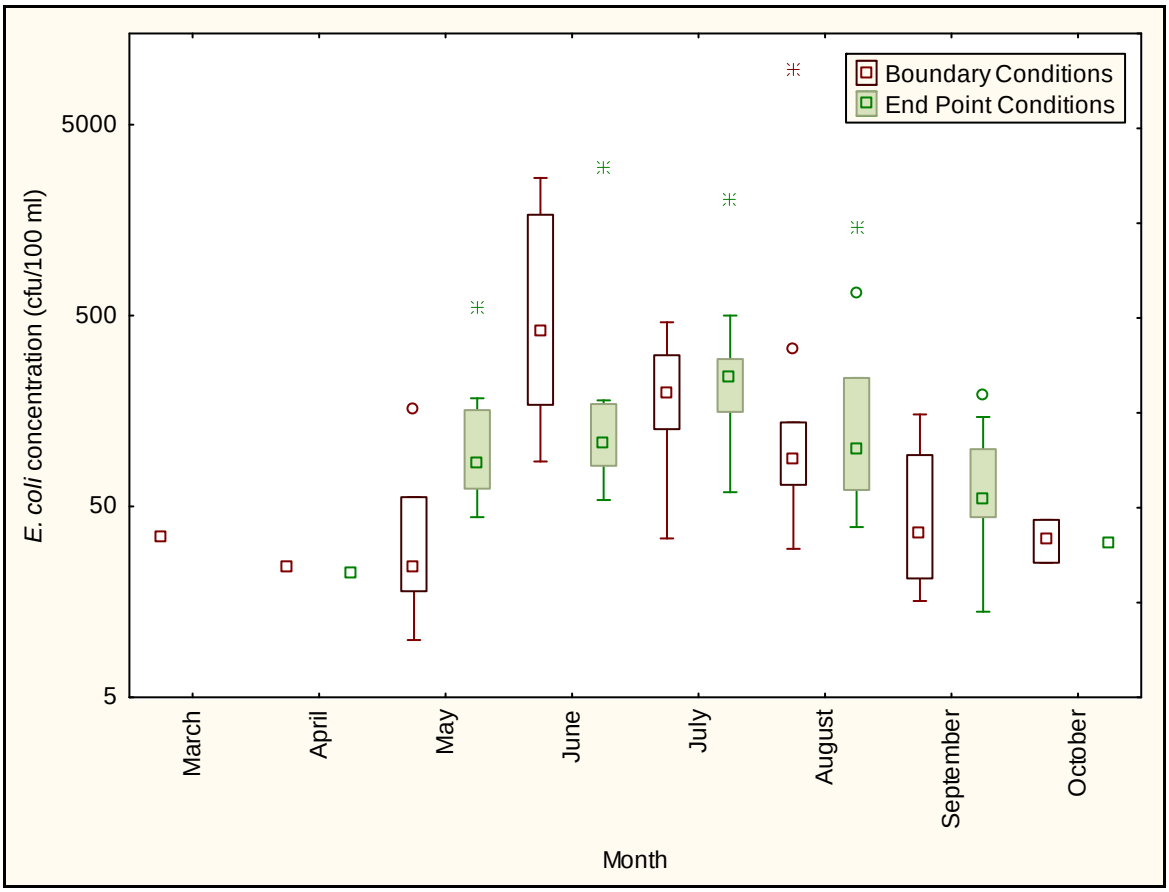

Figure 10. Monthly pattern in *E. coli* concentrations of boundary and segment end point sampling sites.

8.0 Critical Conditions

Critical conditions occur within the basin during the summer. Typically, greatest numbers of livestock and tourist activities are highest in the basin during the summer months. Combined with the peak in bacteria sources, high-intensity rainstorm events are common during the summer and produce a significant amount of fecal coliform load due to bacterial wash-off from the watershed.

9.0 Follow-Up Monitoring

The Department may adjust the load and/or waste load allocations in this TMDL to account for new information or circumstances that are developed or come to light during the implementation of the TMDL and a review of the new information or circumstances indicate that such adjustments are appropriate. Adjustment of the load and waste load allocation will only be made following an opportunity for public participation. New information generated during TMDL implementation may include, among other things, monitoring data, BMP effectiveness

information and land use information. The Department will propose adjustments only in the event that any adjusted LA or WLA will not result in a change to the loading capacity; the adjusted TMDL, including its WLAs and LAs, will be set at a level necessary to implement the applicable water quality standards; and any adjusted WLA will be supported by a demonstration that load allocations are practicable. The Department will notify EPA of any adjustments to this TMDL within 30 days of their adoption.

Monitoring will continue throughout the Belle Fourche River watershed and SDDENR WQM site 460130 will provide data for the upper reach of the river. Five other sites on the Belle Fourche River downstream of Segment 01 and one on Redwater Creek may also provide data to be used to judge the effectiveness of implementation activities. And the United States Geological Survey also has five sites within the Belle Fourche watershed that may provide additional water quality data.

10.0 Public Participation

Efforts taken to gain public education, review, and comment during development of the TMDL involved:

1. Four presentations to local groups on the findings of the assessment.
2. A webpage was developed and used during the course of the assessment and is currently used for the implementation effort. See www.bellefourchewatershed.org
3. 30-day public notice period for public review and comment. A public notice was published in the Rapid City Journal, Black Hills Pioneer, and Butte County Post. This public notice and the TMDL document has also been posted on the SD DENR Webpage http://denr.sd.gov/dfta/wp/tmdl.aspx

The findings from these public meetings and comments have been taken into consideration in development of the Belle Fourche Segment 1 TMDL.

11.0 Implementation

Several types of BMPs should be considered in the development of a water quality management implementation plan for watershed draining the impaired segment of the Belle Fourche River.

- Livestock access to streams should be reduced, and livestock should be provided sources of water away from streams.
- Unstable stream banks should be protected by enhancing the riparian vegetation that provides erosion control and filters runoff of pollutants into the stream.
- Filter strips should be installed along the stream bordering cropland and pastureland.
- Animal confinement facilities should implement proper animal waste management systems.

Funds to implement watershed water quality improvements can be obtained through SD DENR. This includes the Section 319 Nonpoint Source program.

12.0 Literature Cited

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