Fecal Coliform Bacteria Total Maximum Daily Load (TMDL) for Beaver Creek, Fall River County, South Dakota

South Dakota Department of
Environment and Natural Resources

Protecting South Dakota's Tomorrow ... Today

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

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Total Maximum Daily Load Summary Table

Water Body Name/Description:	Beaver Creek (from Wyoming/South Dakota state boundary to its confluence with the Cheyenne River)
Assessment Unit ID:	SD-CH-R-Beaver_01
Size of Impaired Waterbody:	Approximately 25 km in length
Size of Watershed:	4,325 square km
Location:	Hydrologic Unit Codes (12-digit HUC): 101201070307 and 101201070504
Impaired Designated Use(s):	Limited-contact recreation
Cause(s) of Impairment:	Fecal coliform bacteria
Cycle Most Recently Listed:	2008

TMDL End Points

Indicator Name:	Fecal coliform bacteria
Threshold Values:	Maximum daily concentration of ≤ 2000 CFU/100mL and a geometric mean of at least 5 samples over a 30 day period ≤ 1000 CFU/100mL. These criteria apply from May through September.
Analytical Approach:	Load Duration Curve, Bacterial Indicator Tool and HSPF modeling

TMDL Allocations (CFU*10^9/day) for High Flow Zone (77-834 cfs)

Wasteload Allocations (WLAs):	0
Load Allocations (LAs):	21,991
Margin of Safety (MOS):	3,366
TMDL:	25,357

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 fecal coliform bacteria impairment of Beaver Creek from the WY/SD boundary to the confluence with the Cheyenne River (SD-CH-R-Beaver_01), which was assigned to priority category 2 (low-priority) in the 2008 impaired waterbodies list.

1.1 Watershed Characteristics

The Beaver Creek watershed is approximately 4,325 square km (1670 square miles); 71% of the watershed is in Wyoming, and 29% is in South Dakota. The watershed drains much of the eastern portion of Weston County in Wyoming and portions of Pennington, Custer, and Fall River Counties in South Dakota before discharging to the Cheyenne River south of Burdock, SD in Fall River County (Figure 1). The impaired (Section 303(d) listed) segment of Beaver Creek has a length of approximately 25 km and begins at the Wyoming / South Dakota border and ends at the mouth of stream.

According to state climate records (http://climate.sdstate.edu/archives/data/pptnormals.shtm), average annual precipitation at Hot Springs, SD is 17.3 inches with approximately 70% occurring during the months of April through August and approximately 50% occurring during the months of May through July.

Watershed landuse is predominantly herbaceous rangeland (56%) and forest (38%) with a small amount of cropland (5%).

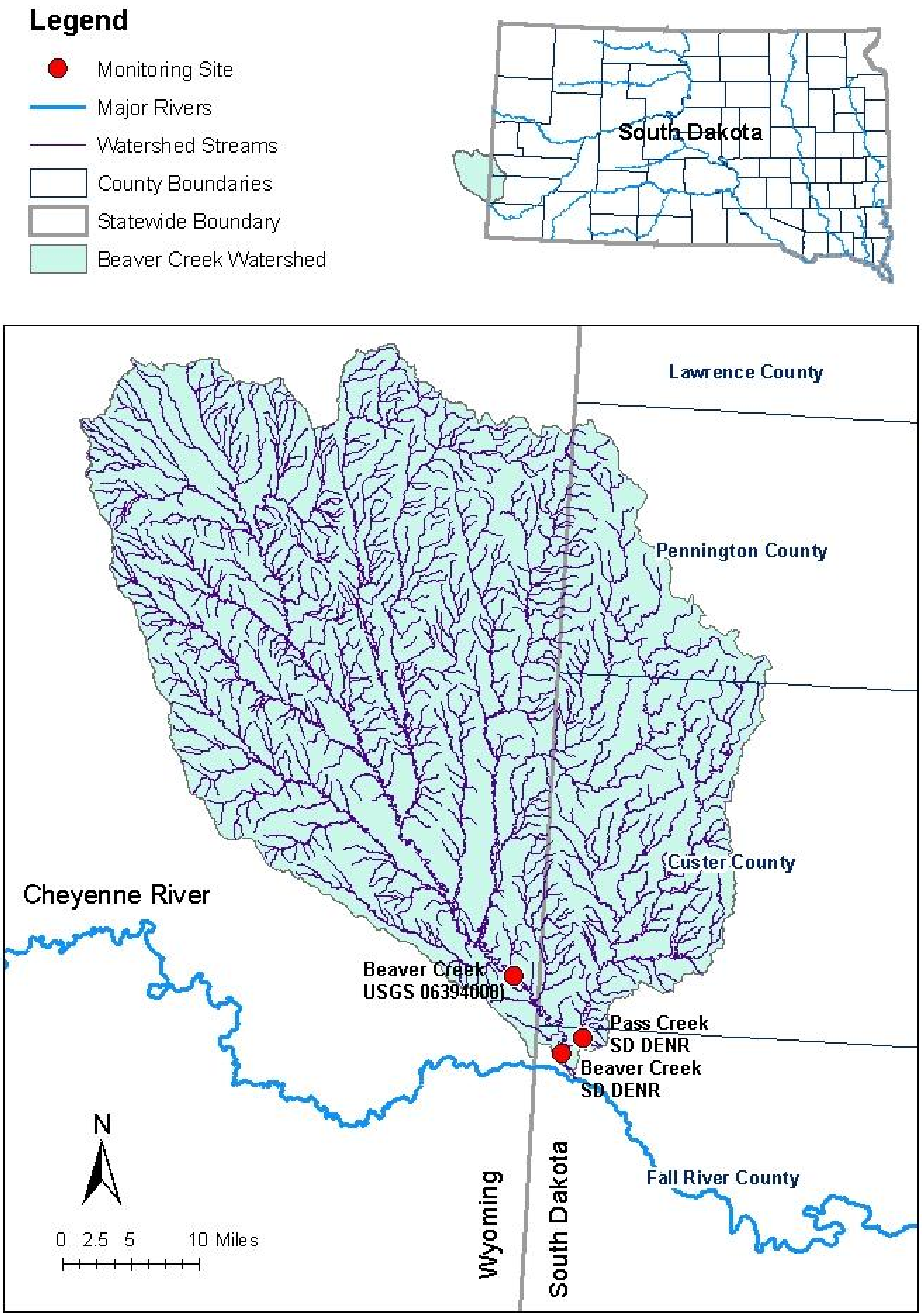

Figure 1. Location of the Beaver Creek watershed within Pennington, Custer and Fall River Counties, South Dakota. The location of the water quality monitoring site (Site ID 460128) is also shown.

1.2 CWA Section 303(d) Listing Information

Beaver Creek was first listed in South Dakota's 2006 303(d) list (SD DENR 2006) as impaired due to sample concentrations of fecal coliform bacteria that exceeded the daily maximum criterion for the protection of the limited contact recreation use. In the 2008 303(d) list, Beaver Creek's limited contact recreation use is assigned a "threatened" classification based on historical data, as insufficient information was available to determine whether or not the limited contact recreation use was supported during the 2008 reporting cycle. Beaver Creek is not a listed as an impaired waterbody in Wyoming's most current 303(d) list (SD DENR 2008a).

1.3 Available Water Quality Data

Since 1999, the South Dakota Department of Environment and Natural Resources (SD DENR) has collected quarterly bacteria samples at the Beaver Creek ambient monitoring station (STORET Site ID 460128) shown in Figure 1. In addition to ongoing ambient monitoring, SD DENR also sampled this site monthly and during rain events from September 2003 - August 2005 during the TMDL assessment project for the Upper Cheyenne River watershed. More recent sampling at this site was conducted by RESPEC Consulting and Services from July 2007 through June 2008. Fecal coliform bacteria concentration data collected at this site to date show that five out of 26 samples (19%) collected from May 1 to September 30 (effective criterion period) exceeded the daily maximum fecal coliform bacteria criterion of 2,000 colony-forming units per 100 mL (CFU/100ml). Concentrations ranged from <10 CFU/100mL to 21,000 CFU/100mL.

Bacteria samples have also been collected from Pass Creek, a tributary of Beaver Creek, as well as from Beaver Creek near Newcastle, WY at the USGS gaging station 06394000 (Table 1). Data from these sites were used in watershed model calibration. Bacteria sample data are presented in Appendix A.

Table 1. Water quality stations in the Beaver Creek watershed used for TMDL development and watershed model calibration

Water Quality Station	Period of Record	Number of Samples
Beaver Creek West of Burdock, SD (SD DENR 460128)	1999-2008	54
Beaver Creek near Newcastle, WY (USGS 06394000)	2007-2008	12
Pass Creek	2003-2007	16

2.0 Water Quality Standards and TMDL 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. All streams are assigned the use of irrigation. Additional uses may be 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 (ARSD 74:51:01 – 74:51:03).

Additional "narrative" standards that may apply can be found in the "Administrative Rules of South Dakota: Articles 74:51:01:05; 06; 08; and 09." These contain language that generally prohibits the presence of materials causing pollutants to form, visible pollutants, and nuisance aquatic life.

Beaver Creek has been assigned the following beneficial uses: warmwater semi-permanent fish life propagation, limited contact recreation, fish and wildlife propagation, recreation and stock watering, and irrigation. Table 2 lists water quality criteria that must be met to support the beneficial uses currently assigned to Beaver Creek. As part of the TMDL assessment, a Use Attainability Assessment (UAA) was completed for Beaver Creek (SD DENR 2008b). The limited contact recreation use currently assigned to Beaver Creek was confirmed by the UAA (i.e. no recommendation was made to upgrade to the immersion recreation use) due to incised channel morphology and sustained periods of low water depth.

Current fecal coliform criteria for the limited contact recreation use require that 1) no sample exceeds 2,000 CFU/100 mL and 2) the geometric mean of a minimum of 5 samples collected during separate 24-hour periods for any 30-day period must not exceed 1,000 CFU/100 mL. Since only one or two water samples were collected during any 30-day period, compliance with the geometric mean criterion was evaluated using the HSPF model-predicted, daily concentrations. The geometric mean, as defined in ARSD § 74:51:01:01, is the nth root of a product of n factors. The fecal coliform criteria are applicable from May 1 through September 30.

South Dakota has recently adopted *Escherichia coli* criteria for the protection of the limited contact and immersion recreation uses. However, Beaver Creek does not require an *E. coli* TMDL because the parameter is not currently listed as a cause of impairment to this stream. One of 25 samples (4%) exceeded the acute *E. coli* criterion (1,178 CFU/100ml). Greater than 10% of samples must exceed water quality criteria for that parameter to be included as a cause of impairment on the 303(d) impaired waters list.

Bacteria sample data collected to date in Beaver Creek at the SD DENR monitoring station (Site ID 460128) show a statistically significant correlation (Spearman r_s, = 0.75; $p < 0.05$) between fecal coliform bacteria and *E. coli* concentrations. Because the two indicators are closely related, the fecal coliform bacteria TMDL and associated implementation strategy described in this document are expected to address both the fecal coliform bacteria and possible future *E. coli* impairments to the limited contact recreation use of Beaver Creek. If a TMDL must be established for *E. coli* in the future, the paired fecal coliform and *E. coli* data can be used to develop a translator function to convert fecal coliform loading estimates to *E. coli* loading estimates.

In Wyoming, Beaver Creek is classified as a "2ABww" water, which indicates that the stream is a primary recreation water that supports warm water game fish. During the designated summer recreation season (May 1 through September 30), all Wyoming waters designated for primary contact recreation shall not exceed a geometric mean of 126 organisms per 100 milliliters of *E. coli* bacteria based on a minimum of not less than 5 samples obtained during separate 24 hour periods for any 30-day period. Sufficient data were not available to determine compliance with this criterion. Wyoming surface water quality standards also include a single-sample maxima *E. coli* criterion for primary recreation waters; however, the standards state that "an exceedence of the single-sample maxima shall not be cause for listing a water body on the State 303(d) list or development of a TMDL or watershed plan." (http://soswy.state.wy.us/Rules/RULES/6547.pdf)

The numeric TMDL target established for Beaver Creek's limited contact recreation use impairment was determined for each of five flow conditions or zones and based on either the acute (2,000 CFU/100ml) or chronic (1,000 CFU/100ml) fecal coliform bacteria criterion, depending on which criterion required the greatest load reduction.

Table 2. State surface water quality standards for Beaver Creek, Custer and Fall River County, SD.

Parameter	Criteria	Unit of Measure	Special Conditions
Total alkalinity as calcium carbonate [1]	≤ 750	mg/L	30-day average
	≤ 1313	mg/L	Daily maximum
Total dissolved solids [1]	≤ 2,500	mg/L	30-day average
	≤ 4,375	mg/L	Daily maximum
Total petroleum hydrocarbon [1]	≤ 10	mg/L	Daily maximum
Oil and grease [1]	≤ 10	mg/L	Daily maximum
Nitrates as N [1]	≤ 50	mg/L	30-day average
	≤ 88	mg/L	Daily maximum
Dissolved oxygen [2]	≥ 5.0	mg/L	Daily minimum
Total Suspended Solids [2]	≤ 90	mg/L	30-day average
	≤ 158	mg/L	Daily maximum
Temperature [2]	≤ 90	°F	Daily maximum
pH [2]	≥ 6.5 and ≤ 9.0	Standard units	
Undisassociated hydrogen sulfide [2]	≤ 0.002	mg/L	Daily maximum
Total ammonia nitrogen as N [2]	See Equation 3 in Appendix A	mg/L	30-day average (Mar 1 – Oct 31)
	See Equation 4 in Appendix A	mg/L	30-day average (Nov 1 – Feb 29)
	See Equation 2 in Appendix A	mg/L	Daily maximum
Fecal coliform [3, 4]	≤ 1,000	CFU /100 mL	Geometric mean (May 1 – Sep 30)
	≤ 2,000	CFU /100 mL	Daily maximum (May 1 – Sep 30)
Escherichia coli [3, 4]	≤ 630	CFU /100 mL	Geometric mean (May 1 – Sep 30)
	≤ 1,178	CFU /100 mL	Daily maximum (May 1 – Sep 30)
Conductivity at 25°C [5]	≤ 2,500	micromhos/cm	30-day average
	≤ 4,375	micromhos/cm	Daily maximum
Sodium adsorption ratio [5]	≤ 10		Daily maximum

[1] Criteria for fish and wildlife propagation, recreation and stock watering use

[2] Criteria for warmwater semi-permanent fish life propagation use

[3] Criteria for limited contact recreation use

[4] Geometric mean must be based on a minimum of five samples obtained during separate 24-hour periods for any 30-day period

[5] Criteria for irrigation use

3.0 Significant Sources

3.1 Point Sources

No permitted point source dischargers are located in the South Dakota portion of the Beaver Creek watershed. One permitted wastewater treatment facility (NPDES ID WY0020605) is located in Upton, Wyoming in Weston County. This facility has fecal coliform bacteria permit limits for one outfall. This discharge is greater than 50 stream miles upstream of the WY/SD border. Thus, the bacteria load from this facility likely does not reach the impaired segment of Beaver Creek in South Dakota.

3.2 Nonpoint Sources

Based on review of available information and communication with state and local authorities, the primary nonpoint sources of fecal coliform within the Beaver Creek watershed include agricultural runoff, as well as wildlife and human sources. Using the best available information, loadings were estimated from each of these sources using the EPA's Bacterial Indicator Tool (BIT) based on the density and distribution of animals (livestock and wildlife) and failing septic systems in the watershed (USEPA 2000).

3.2.1 Agriculture

Manure from livestock is a potential source of fecal coliform to the stream. Livestock in the basin are predominantly beef cattle, sheep, and horses. Other livestock in the basin include dairy cattle, bison, chickens and swine. Livestock population densities in the watershed were estimated using Census of Agriculture data, which is summarized by county. Livestock contribute bacteria loads to the Beaver Creek directly by defecating while wading in the stream and indirectly by defecating on rangelands that are washed off during precipitation events. Both the indirect and direct sources of bacteria loads from livestock were represented in the modeling applications.

3.2.2 Human

Human fecal coliform bacteria were identified from bacterial source tracking tests. The Beaver Creek watershed is largely rural, with few centralized wastewater collection and treatment facilities. Thus, septic systems are assumed to be the primary human source of bacteria loads to Beaver Creek. Densities of septic systems in the watershed were derived from the 1990 U.S. Census septic data and the 2004 U.S. Census population data.

3.2.3 Natural background/wildlife

Wildlife within the watershed is a natural background source of fecal coliform bacteria. For watershed modeling purposes, wildlife population density estimates were obtained from the Wyoming Game and Fish Department and the South Dakota Department of Game, Fish and Parks.

3.3 Bacterial Source Tracking

Bacteria samples were analyzed to determine sources of fecal coliform bacteria within the watershed. Pulsed-field gel electrophoresis (PFGE), a DNA testing procedure, was used to link bacteria from samples to known sources. From each water sample with a fecal coliform bacteria concentration ≥50 cfu/100ml, laboratory staff attempted to isolate five *E. coli* bacteria to test using the PFGE technique.

Twenty-three *E. coli* isolates were successfully cultured from Beaver Creek samples. DNA from these isolates was compared to a reference database of known-DNA isolates from other samples collected in Northwestern Great Plains Ecoregion (primarily western South Dakota). The results of this source tracking assessment indicate the following sources and relative percent contributions: agricultural livestock (74%), domestic animals (18%), human (4%) and unknown (4%). A more detailed report of the PFGE results can be found in Appendix B.

3.4 Source Assessment Modeling Results

The Hydrologic Simulation Program Fortran (HSPF) model was used to determine the contribution of fecal coliform bacteria from identified sources in the Beaver Creek watershed and evaluate the implementation of Best Management Practices (BMPs) to control these sources. The Beaver Creek drainage basin was represented in the model using 12 subwatersheds. The nonpoint sources in the study area were modeled in HSPF by estimating per acre fecal coliform accumulation rates and maximum fecal coliform storage rates for each source. The buildup and wash-off of fecal coliform was simulated based on these rates and precipitation. The accumulation and storage rates were calculated using the Bacterial Indicator Tool. Failing septic systems and livestock in streams are direct sources that were modeled as point sources, because the bacteria loads that they produce are independent of rainfall/runoff processes. The BIT was used to calculate flow rates and fecal coliform bacteria densities that represent livestock in streams and human sources, which were then used as inputs to the HSPF model. A detailed report explaining the watershed model development and calibration can be found in Appendix C.

Source assessment modeling results were summarized by landuse categories for nonpoint sources and separately for livestock in streams and septic tank failures (direct sources). Results show that rangelands contribute the highest proportion (approximately 97%) of the bacteria load to the impaired segment of Beaver Creek (Table 3). In addition, BIT loading estimates indicate that, on average, approximately 98% of the load from rangelands is attributed to livestock and approximately 2% is attributed to wildlife.

Table 3. Fecal coliform bacteria loading sources based on HSPF model results.

Land Use / Source	Load Contribution (%)
Nonpoint Sources	
Rangeland	96.57%
Impervious Urban	2.94%
Groundwater Recharge Zone	0.17%
Barren	0.14%
Forest	0.13%
Pervious Urban	0.01%
Cropland	0.01%
Direct Sources*	
Livestock Direct Defecation	0.03%
Septic Tank Failures	0.00%

* Livestock direct defecation and septic tank failures were modeled as direct sources of bacteria loads; however, these sources are considered nonpoint source discharges under the Clean Water Act and are not regulated as point sources of pollution.

4.0 Technical Analyses

4.1 Load Duration Curve Analysis

The TMDL was developed using the Load Duration Curve (LDC) approach, resulting in a flow-variable target that considers the entire flow regime within the recreational season (May 1 – September 30). The LDC is a dynamic expression of the allowable load for any given day within the recreation season. To aid in interpretation and implementation of the TMDL, the LDC flow intervals were grouped into five flow zones: high flows (0–10%), moist conditions (10–40%), mid-range flows (40–60%), dry conditions (60–90%), and low flows (90–100%) according to EPA's *An Approach for Using Load Duration Curves in the Development of TMDLs* (USEPA 2006).

Instantaneous or "observed" loads were calculated by multiplying the fecal coliform sample concentrations from SD DENR ambient water quality data (site number 460128), the measured flow at the time the water sample was collected, and a unit conversion factor. When measured flow data were not available, simulated daily average flow data (as predicted by the HSPF model for the date of the sample) were used for the instantaneous load calculation. The location of the SD DENR water quality monitoring site on Beaver Creek is shown in Figure 1.

When the instantaneous loads are plotted on the LDC, characteristics of the water quality impairment are shown. Instantaneous loads that plot above the solid curve are exceeding the daily maximum water quality criterion, while those below the curve are in compliance. As the plot shows, fecal coliform samples collected from Beaver Creek exceed the daily maximum criterion during high, moist, and low flow conditions (Figure 2). Loads exceeding the criteria in the low flow zone indicate potential point source load contributions or sources in close proximity to the stream, such as failing septic systems or livestock in the stream channel, while those further left on the plot (i.e. high and moist flow conditions) generally reflect potential nonpoint source contributions from storm water runoff (USEPA, 2006).

The LDC shown in Figure 2 represents a dynamic expression of the fecal coliform bacteria TMDL for Beaver Creek that is based on the daily maximum fecal coliform criterion, resulting in a unique maximum daily load that corresponds to a measured average daily flow.

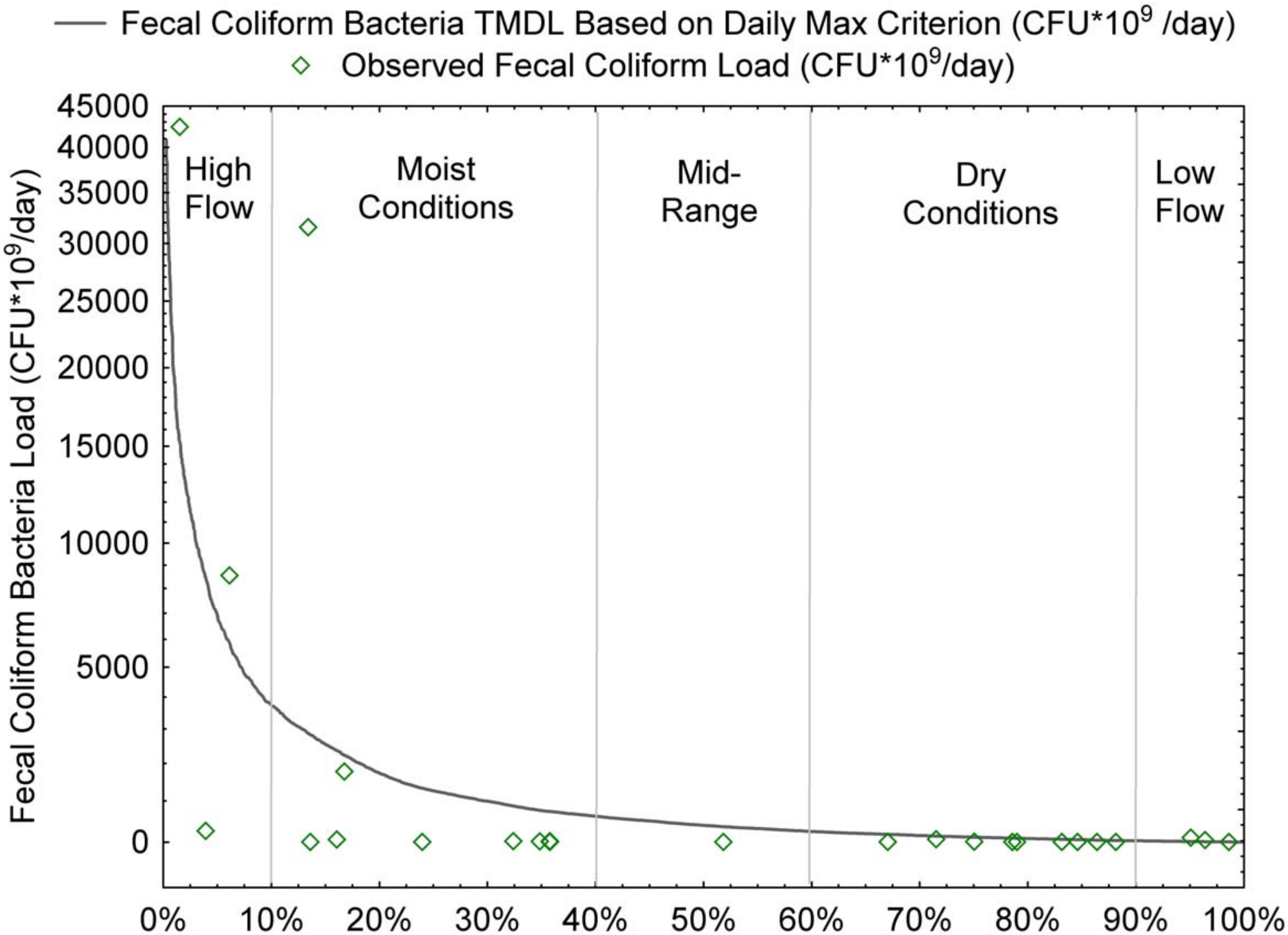

Figure 2. Load duration curve representing allowable daily fecal coliform loads based daily maximum fecal coliform criteria (≤ 2000 mg/L) and simulated stream flow during the recreations seasons 1990 to 2008. Observed fecal coliform loads for the same time period are also displayed.

5.0 TMDL and Allocations

To ensure that all applicable fecal coliform criteria are met and aid in the implementation of the TMDL, load allocations were calculated for each of the five flow zones using both the acute and chronic criteria. The criterion requiring the greatest load reduction from baseline conditions, which varies by flow zone, was used to establish the TMDL allocations. Methods used to calculate the TMDL allocations are discussed in more detail below.

The TMDL is in effect from May 1 through September 30, as the fecal coliform criteria are applicable only during this period. In addition, only data from this time period were used to develop the TMDL allocations and load reduction goals.

5.1 Load Allocation (LA)

To develop the fecal coliform bacteria load allocation (LA), the loading capacity (LC) was first determined. Both the daily maximum criterion (2,000 CFU/100ml) and the geometric mean criterion (1,000 CFU/100ml) were used for the calculation of the LC. The LC for Beaver Creek based on the acute criterion was calculated by multiplying the acute fecal coliform bacteria criterion by the simulated daily average flow at the Beaver Creek outlet as predicted by the HSPF model. The LC based on the chronic criterion was calculated by multiplying the chronic criterion by the monthly average model-predicted flows.

For each of the five flow zones, the 95th percentile of the range of LCs within a zone was set as the flow zone goal. Bacteria loads experienced during the largest stream flows (e.g. top 5%) can not be feasibly controlled by practical management practices. Thus, setting the flow zone goal at the 95th percentile of the range of LCs will protect the limited contact recreation beneficial use and allow for the natural variability of the system.

The TMDL (and LC) is the sum of WLA, LA, and MOS. Portions of the LC were allocated to nonpoint sources as a load allocation (LA) and 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 waste load allocation (WLA) is assigned a zero value, as no point sources of fecal coliform bacteria discharge into the impaired segment of Beaver Creek. The overall LA was determined by subtracting the WLA and MOS from the LC.

The load allocation was further divided to assign a portion of the load allocation to South Dakota and Wyoming based on the proportion of the model-predicted current total load contributed by each state. Using the HSPF model, the contributions from Wyoming were estimated by simulating the removal of all loadings from the South Dakota portion of the watershed, and vice versa. Then, the estimated daily load contributions for each state were summed by flow zone, and the percent contribution from each state was used to determine flow zone load allocations.

5.2 Baseline Conditions

Measured sample concentrations and flow data were used to estimate current daily loads (CFU*10^9/day). The product of fecal coliform sample concentrations (CFU/100 ml) from SD DENR monitoring site number 460128, the measured flow (cfs) at the time the water sample was collected, and a unit conversion factor (0.0245). When measured flow data were not available for a sample date, simulated daily average flow data were used for the daily load calculation. A total of 26 observed (instantaneous) load estimates were calculated. The 95% percentile of the range of these estimates within each flow zone was defined as the baseline daily load.

Baseline conditions for the 30-day averaging period were calculated differently than the daily averaging period. To estimate current monthly geometric mean loads (CFU*10^9/month), the product of the monthly geometric mean concentrations (CFU/100ml) and monthly average stream flows (cfs), calculated from the model's daily time series data, was multiplied by a conversion factor (0.7339). A total of 90 monthly geometric mean load estimates were calculated. The 95% percentile of the range of these estimates within each flow zone was defined as the baseline monthly geometric mean load.

Table 4 presents a combination of allocations based on the acute criterion for each flow zone, showing that load reductions are required for all flow zones, except the mid-range and dry flow zones (i.e. stream flows of 0.5 to 12 cfs). Table 5 list monthly allocations based on the chronic criterion, showing that, except for the low flow zone, no load reductions of the monthly geometric mean loads are required to meet the chronic criterion. The low flow zone allocations based on the chronic criterion require slightly greater reductions than the allocations based on the acute criterion. Thus, the allocations listed for the high, moist, mid-range, and dry flow zones in Table 4 (using the acute criterion) and the low flow zone in Table 5 (using the chronic criterion) represent the TMDL goals to attain compliance with all applicable water quality standards. To arrive at a daily expression of the low flow zone goal, the monthly geometric mean TMDL allocations were simply divided by 30 (Table 6).

Table 4. Beaver Creek fecal coliform bacteria TMDL based on the daily maximum criterion. The table lists daily allocations by flow zone, including load allocations for both South Dakota and Wyoming portions of the watershed.

TMDL Component	Flow Zone (expressed as $CFU*10^9$/day)				
	High	Moist	Mid-range	Dry	Low
	77-834 cfs	13-76 cfs	5.0-12 cfs	0.6-5.0 cfs	0-0.5 cfs
LA_{SD}*	10,345	1,564	300	76	9
LA_{WY}*	11,646	1,040	150	75	10
WLA	0	0	0	0	0
MOS	3,366	773	140	78	6
TMDL	25,357	3,378	589	229	25
Current Load**	42,389	31,525	1	60	99
Load Reduction	40%	89%	0%	0%	74%

* Load allocations are provided for both South Dakota (LA_{SD}) and Wyoming (LA_{WY}).
** Current load is the 95th percentile of observed fecal coliform bacteria load for each flow zone.

Table 5. Beaver Creek fecal coliform bacteria TMDL based on the geometric mean criterion. The table lists monthly allocations by flow zone, including load allocations for both South Dakota and Wyoming portions of the watershed.

TMDL Component	Flow Zone (expressed as $CFU*10^9$/month)				
	High	Moist	Mid-range	Dry	Low
	77-834 cfs	13-76 cfs	5.0-12 cfs	0.6-5.0 cfs	0-0.5 cfs
LA_{SD}*	96,120	23,928	10,076	2,112	118
LA_{WY}*	108,214	15,912	5,035	2,090	129
WLA	0	0	0	0	0
MOS	58,579	20,462	3,978	1,691	255
TMDL	262,913	60,301	19,089	5,894	503
Current Load**	817	671	980	1,373	2,633
Load Reduction	0%	0%	0%	0%	81%

* Load allocations are provided for both South Dakota (LA_{SD}) and Wyoming (LA_{WY}).
** Current load is the 95th percentile of model-predicted monthly geometric mean loads for each flow zone.

Table 6. Daily expression of low flow zone monthly allocations, calculated by dividing the monthly allocations in Table 5 by 30.

TMDL Component	Flow Zone (expressed as CFU*10^9/day)
	Low
	0-0.5 cfs
LA_{SD}*	4
LA_{WY}*	4
WLA	0
MOS	9
TMDL	17
Current Load**	88
Load Reduction	81%

5.3 Waste Load Allocation (WLA)

No point sources of fecal coliform bacteria discharge directly to the impaired segment or tributary of the impaired segment of Beaver Creek, so the WLA is assigned a zero value. Only one point source discharge (City of Upton, WY) is located in the Beaver Creek watershed. This discharge is more than 50 stream miles upstream of the WY/SD border. The bacteria load from this facility likely does not reach the impaired segment of Beaver Creek in South Dakota due to the travel time and die-off rates of the bacteria.

6.0 Margin of Safety and Seasonality

6.1 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.

6.2 Seasonality

Stream flows in Beaver Creek (USGS gage 06394000, Beaver Creek near Newcastle, WY) displayed seasonal variation for the period of record (1/1/90 to 12/31/97). Highest stream flows typically occur in the spring with highest mean monthly average stream flow reported in March (84 cfs), and lowest stream flows occur during the fall and winter months with lowest mean monthly average stream flow reported in September (8.9 cfs). Fecal coliform concentrations also displayed seasonal variation. While a statistically significant correlation between sample concentration and stream flow did not exist, samples collected during or shortly after a rain event exceeded the daily maximum criterion. Short duration, high-intensity rainstorms are common during the summer months. These localized summer storms can cause significant runoff and increased bacteria concentrations for a relatively short period of time, while only slightly increasing stream flows. However, by using the LDC approach to develop the TMDL allocations, seasonal variability in fecal coliform loads is taken into account, as stream flow is related to seasonal changes in precipitation.

In addition, this fecal coliform bacteria TMDL is seasonal, as it is effective only during the period of May 1 through September 30. Since the criteria for fecal coliform bacteria concentrations are in effect from May 1 through September 30, the TMDL is also applicable only during this time period.

Critical conditions occur during the moist flow conditions (13-76 cfs) as the greatest load reductions are required during this flow regime. Summer is also a critical time period due to seasonal differences in precipitation patterns and landuses. Typically, livestock are allowed to graze along the streams 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.

7.0 Public Participation

Efforts taken to gain public education, review, and comment during development of the Beaver Creek fecal coliform bacteria TMDL involved presentations to local groups in the watershed on the findings of the assessment and a 30-day public notice period for public review and comment. The findings from these public meetings and comments have been taken into consideration in development of the TMDL.

8.0 Monitoring Strategy

During and after the implementation of management practices, monitoring will be necessary to assure attainment of the TMDL. Stream water quality monitoring will be accomplished through SD DENR’s ambient water quality monitoring station on Beaver Creek (STORET ID: 460654), which is sampled on a monthly basis.

Additional monitoring and evaluation efforts should be targeted toward the effectiveness of implemented BMPs. Monitoring locations should be based on the location and type of BMPs installed.

SD DENR may adjust the load and/or wasteload allocations in this TMDL to account for new information or circumstances that develop during the implementation phase of the TMDL. New information generated during TMDL implementation may include monitoring data, BMP effectiveness information and land use information. SD DENR 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. SD DENR will notify EPA of any adjustments to this TMDL within 30 days of their adoption. Adjustment of the load and waste load allocation will only be made following an opportunity for public participation.

9.0 Restoration Strategy

A variety of BMPs could be considered in the development of a water quality management implementation plan for the South Dakota portion of the Beaver Creek watershed. While several types of control measures are available for reducing fecal coliform bacteria loads, the practicable control measures listed and discussed below are recommended to address the identified sources in South Dakota. Based on water quality monitoring, bacterial source tracking and HSPF model results, the recommended control measures to be implemented in South Dakota are expected to achieve the required load reductions and attain the TMDL goal.

Four management scenarios were simulated using the HSPF model: 1) reduced Wyoming bacteria loads to comply with South Dakota water quality criteria, 2) removal of septic system bacteria loads, 3) exclusion of cattle from streams, and 4) general rangeland management.

Model results show that reducing Wyoming loads to meet South Dakota water quality criteria (scenario 1) would result in only a 4% reduction in the average recreation season (May 1 through September 30) load in Beaver Creek. Similarly, the model predicts that the daily maximum criterion would be exceeded only 4% of the time in Beaver Creek at the Wyoming/South Dakota border. Of the five bacteria samples collected during the recreation season at the USGS gage in Wyoming (Beaver Creek near Newcastle, WY; USGS 06394000), none exceeded South Dakota water quality standards. For these reasons, bacteria loads from Wyoming do not appear to significantly contribute to the recreation use impairment of Beaver Creek.

The model also shows that the removal of the septic system bacteria load (scenario 2) would result in no reduction to the average annual recreation season load in Beaver Creek. In addition, only one bacteria isolate (4% of all isolates) from bacteria source tracking samples was identified as human in origin. Thus, septic system BMPs are recommended for only those systems in the South Dakota portion of the watershed that are in close proximity to Beaver Creek.

Exclusion of cattle from streams (scenario 3) appears to be the most effective management practice for the Beaver Creek watershed. Based on the simulation, approximately 26% of the average recreation season bacteria load in Beaver Creek could be reduced by implementing livestock exclusion practices, such as installing fence to exclude livestock from streams and off-stream water supplies.

Lastly, grazing management practices (scenario 4) were simulated using a uniform reduction factor of 87% based on observed bacteria concentration reductions from a previous study (Sheffield et al. 1997). In the model, the reduction factor was applied to all pastureland. With this implementation scenario, the predicted average recreation season loads delivered to Beaver Creek were reduced by approximately 15%. Grazing practices, such as seasonal access or rotational grazing, reduce the intensity and duration of grazing. These practices result in improved rangeland health, thereby increasing water infiltration and reducing runoff.

On average, an estimated 53% load reduction is required to meet water quality standards based on the overall percent difference between the current loads and TMDL targets across all flow conditions. With the implementation of livestock exclusion and grazing management practices (scenarios 3 and 4, respectively), the model predicted a reduction in average recreation season bacteria loads of approximately 41%, slightly less than the required load reduction of 53%. A difference of 12% is within the model error and the explicit margin of safety of the TMDL. Thus, implementation of scenarios 3 and 4 are expected to achieve the TMDL goal.

Funds to implement watershed water quality improvements can be obtained through SD DENR. SD DENR administers three major funding programs that provide low interest loans and grants for projects that protect and improve water quality in South Dakota. They include: Consolidated Water Facilities Construction program, Clean Water State Revolving Fund (SRF) program, and the Section 319 Nonpoint Source program.

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APPENDIX A: Bacteria Sample Data

STATION ID	Station Name	Sample Date	Parameter	Result (CFU/100ml)
BVR020	Beaver Creek at USGS 06394000 (near Newcastle)	07/24/2007	F-Coliform	110
BVR020	Beaver Creek at USGS 06394000 (near Newcastle)	06/17/2008	F-Coliform	44
BVR020	Beaver Creek at USGS 06394000 (near Newcastle)	12/11/2007	F-Coliform	10
BVR020	Beaver Creek at USGS 06394000 (near Newcastle)	05/26/2008	F-Coliform	1200
BVR020	Beaver Creek at USGS 06394000 (near Newcastle)	08/20/2007	F-Coliform	350
BVR020	Beaver Creek at USGS 06394000 (near Newcastle)	03/09/2008	F-Coliform	36
BVR020	Beaver Creek at USGS 06394000 (near Newcastle)	03/09/2008	F-Coliform	32
BVR020	Beaver Creek at USGS 06394000 (near Newcastle)	04/14/2008	F-Coliform	<2
BVR020	Beaver Creek at USGS 06394000 (near Newcastle)	10/17/2007	F-Coliform	62
BVR020	Beaver Creek at USGS 06394000 (near Newcastle)	11/19/2007	F-Coliform	2
BVR020	Beaver Creek at USGS 06394000 (near Newcastle)	01/11/2008	F-Coliform	4
BVR020	Beaver Creek at USGS 06394000 (near Newcastle)	09/28/2007	F-Coliform	12
BVR030	Beaver Creek Near Burdock, SD	07/16/2007	F-Coliform	140
BVR030	Beaver Creek Near Burdock, SD	05/14/2003	F-Coliform	2
BVR030	Beaver Creek Near Burdock, SD	06/10/2003	F-Coliform	50
BVR030	Beaver Creek Near Burdock, SD	07/15/2003	F-Coliform	70
BVR030	Beaver Creek Near Burdock, SD	08/18/2003	F-Coliform	11000
BVR030	Beaver Creek Near Burdock, SD	12/01/2003	F-Coliform	10
BVR030	Beaver Creek Near Burdock, SD	07/12/1999	F-Coliform	32
BVR030	Beaver Creek Near Burdock, SD	11/17/2003	F-Coliform	40
BVR030	Beaver Creek Near Burdock, SD	10/28/2003	F-Coliform	50
BVR030	Beaver Creek Near Burdock, SD	01/12/2004	F-Coliform	<10
BVR030	Beaver Creek Near Burdock, SD	07/12/2000	F-Coliform	730
BVR030	Beaver Creek Near Burdock, SD	07/12/2001	F-Coliform	1600
BVR030	Beaver Creek West of Burdock, SD	11/17/2004	F-Coliform	30
BVR030	Beaver Creek West of Burdock, SD	06/13/2005	F-Coliform	21000
BVR030	Beaver Creek West of Burdock, SD	06/27/2005	F-Coliform	110
BVR030	Beaver Creek West of Burdock, SD	07/11/2005	F-Coliform	70
BVR030	Beaver Creek West of Burdock, SD	08/01/2005	F-Coliform	10
BVR030	Beaver Creek West of Burdock, SD	05/23/2005	F-Coliform	30
BVR030	Beaver Creek West of Burdock, SD	08/01/2005	F-Coliform	10

STATION ID	Station Name	Sample Date	Parameter	Result (CFU/100ml)
BVR030	Beaver Creek West of Burdock, SD	10/28/2003	F-Coliform	50
BVR030	Beaver Creek West of Burdock, SD	11/17/2003	F-Coliform	40
BVR030	Beaver Creek West of Burdock, SD	12/15/2003	F-Coliform	10
BVR030	Beaver Creek West of Burdock, SD	05/17/2004	F-Coliform	120
BVR030	Beaver Creek West of Burdock, SD	06/09/2004	F-Coliform	160
BVR030	Beaver Creek West of Burdock, SD	07/13/2004	F-Coliform	170
BVR030	Beaver Creek West of Burdock, SD	08/16/2004	F-Coliform	40
BVR030	Beaver Creek West of Burdock, SD	04/21/2005	F-Coliform	30
BVR030	Beaver Creek West of Burdock, SD	05/12/2005	F-Coliform	4400
BVR030	Beaver Creek West of Burdock, SD	05/16/2005	F-Coliform	170
BVR030	Beaver Creek West of Burdock, SD	05/23/2005	F-Coliform	30
BVR030	Beaver Creek West of Burdock, SD	05/17/2004	F-Coliform	130
BVR030	Beaver Creek West of Burdock, SD	05/17/2004	F-Coliform	120
BVR030	Beaver Creek West of Burdock, SD	05/23/2005	F-Coliform	10
BVR030	Beaver Creek West of Burdock, SD	01/13/2004	F-Coliform	10
BVR030	Beaver Creek West of Burdock, SD	03/08/2004	F-Coliform	10
BVR030	Beaver Creek West of Burdock, SD	03/23/2004	F-Coliform	30
BVR030	Beaver Creek West of Burdock, SD	04/21/2004	F-Coliform	24.6
BVR030	Beaver Creek West of Burdock, SD	09/14/2004	F-Coliform	20
BVR030	Beaver Creek West of Burdock, SD	12/13/2004	F-Coliform	10
BVR030	Beaver Creek West of Burdock, SD	02/22/2005	F-Coliform	10
BVR030	Beaver Creek West of Burdock, SD	03/24/2005	F-Coliform	10
BVR030	Beaver Creek West of Burdock, SD	04/19/2005	F-Coliform	10
BVR030	Beaver Creek near Burdock	05/26/2008	F-Coliform	5700
BVR030	Beaver Creek near Burdock	04/14/2008	F-Coliform	2
BVR030	Beaver Creek near Burdock	01/11/2008	F-Coliform	16
BVR030	Beaver Creek near Burdock	03/09/2008	F-Coliform	2
BVR030	Beaver Creek near Burdock	07/24/2007	F-Coliform	68
BVR030	Beaver Creek near Burdock	08/20/2007	F-Coliform	2500
BVR030	Beaver Creek near Burdock	12/11/2007	F-Coliform	6
BVR030	Beaver Creek near Burdock	11/19/2007	F-Coliform	30
BVR030	Beaver Creek near Burdock	12/11/2007	F-Coliform	14
BVR030	Beaver Creek near Burdock	09/26/2007	F-Coliform	<2
BVR030	Beaver Creek near Burdock	10/17/2007	F-Coliform	76
BVR030	Beaver Creek near Burdock	06/17/2008	F-Coliform	44
PSC010	Pass Creek	03/08/2004	F-Coliform	10
PSC010	Pass Creek	03/23/2004	F-Coliform	10
PSC010	Pass Creek	06/09/2004	F-Coliform	30
PSC010	Pass Creek	09/14/2004	F-Coliform	10
PSC010	Pass Creek	11/17/2003	F-Coliform	10
PSC010	Pass Creek	08/16/2004	F-Coliform	100

STATION ID	Station Name	Sample Date	Parameter	Result (CFU/100ml)
PSC010	Pass Creek	07/13/2004	F-Coliform	130
PSC010	Pass Creek	01/13/2004	F-Coliform	60
PSC010	Pass Creek	02/09/2004	F-Coliform	10
PSC010	Pass Creek	08/16/2004	F-Coliform	30
PSC010	Pass Creek	04/21/2004	F-Coliform	10
PSC010	Pass Creek	05/17/2004	F-Coliform	10
PSC010	Pass Creek	08/16/2004	F-Coliform	30
PSC010	Pass Creek	10/28/2003	F-Coliform	50
PSC010	Pass Creek	12/15/2003	F-Coliform	10
PSC010	Pass Creek downstream of Spencer Ranch	07/19/2007	F-Coliform	4000
BVR030	Beaver Creek Near Burdock, SD	12/01/2003	E-Coli	6.3
BVR030	Beaver Creek Near Burdock, SD	11/17/2003	E-Coli	21.3
BVR030	Beaver Creek Near Burdock, SD	10/28/2003	E-Coli	74.9
BVR030	Beaver Creek Near Burdock, SD	01/12/2004	E-Coli	1
BVR030	Beaver Creek West of Burdock, SD	11/17/2004	E-Coli	10.9
BVR030	Beaver Creek West of Burdock, SD	09/14/2004	E-Coli	5.1
BVR030	Beaver Creek West of Burdock, SD	06/13/2005	E-Coli	2420
BVR030	Beaver Creek West of Burdock, SD	06/27/2005	E-Coli	23.8
BVR030	Beaver Creek West of Burdock, SD	07/11/2005	E-Coli	10.9
BVR030	Beaver Creek West of Burdock, SD	08/01/2005	E-Coli	1
BVR030	Beaver Creek West of Burdock, SD	05/23/2005	E-Coli	6.2
BVR030	Beaver Creek West of Burdock, SD	08/01/2005	E-Coli	1
BVR030	Beaver Creek West of Burdock, SD	10/28/2003	E-Coli	74.9
BVR030	Beaver Creek West of Burdock, SD	11/17/2003	E-Coli	21.3
BVR030	Beaver Creek West of Burdock, SD	12/15/2003	E-Coli	6.3
BVR030	Beaver Creek West of Burdock, SD	05/17/2004	E-Coli	173
BVR030	Beaver Creek West of Burdock, SD	06/09/2004	E-Coli	144
BVR030	Beaver Creek West of Burdock, SD	07/13/2004	E-Coli	14.2
BVR030	Beaver Creek West of Burdock, SD	08/16/2004	E-Coli	1
BVR030	Beaver Creek West of Burdock, SD	04/21/2005	E-Coli	206
BVR030	Beaver Creek West of Burdock, SD	05/12/2005	E-Coli	168
BVR030	Beaver Creek West of Burdock, SD	05/16/2005	E-Coli	132
BVR030	Beaver Creek West of Burdock, SD	05/23/2005	E-Coli	6.2
BVR030	Beaver Creek West of Burdock, SD	05/17/2004	E-Coli	185
BVR030	Beaver Creek West of Burdock, SD	05/17/2004	E-Coli	173
BVR030	Beaver Creek West of Burdock, SD	05/23/2005	E-Coli	6.1
BVR030	Beaver Creek West of Burdock, SD	01/13/2004	E-Coli	1
BVR030	Beaver Creek West of Burdock, SD	03/08/2004	E-Coli	2
BVR030	Beaver Creek West of Burdock, SD	03/23/2004	E-Coli	25.6
BVR030	Beaver Creek West of Burdock, SD	04/21/2004	E-Coli	5

STATION ID	Station Name	Sample Date	Parameter	Result (CFU/100ml)
BVR030	Beaver Creek West of Burdock, SD	12/13/2004	E-Coli	7.4
BVR030	Beaver Creek West of Burdock, SD	02/22/2005	E-Coli	1
BVR030	Beaver Creek West of Burdock, SD	03/24/2005	E-Coli	1
BVR030	Beaver Creek West of Burdock, SD	04/19/2005	E-Coli	12
PSC010	Pass Creek	10/28/2003	E-Coli	40.8
PSC010	Pass Creek	11/17/2003	E-Coli	1
PSC010	Pass Creek	12/15/2003	E-Coli	2
PSC010	Pass Creek	01/13/2004	E-Coli	77.1
PSC010	Pass Creek	02/09/2004	E-Coli	1
PSC010	Pass Creek	03/08/2004	E-Coli	17.3
PSC010	Pass Creek	03/23/2004	E-Coli	2
PSC010	Pass Creek	04/21/2004	E-Coli	4.1
PSC010	Pass Creek	05/17/2004	E-Coli	39.3
PSC010	Pass Creek	06/09/2004	E-Coli	42.6
PSC010	Pass Creek	07/13/2004	E-Coli	60.1
PSC010	Pass Creek	08/16/2004	E-Coli	17.3
PSC010	Pass Creek	09/14/2004	E-Coli	6.3
PSC010	Pass Creek	08/16/2004	E-Coli	79.8
PSC010	Pass Creek	08/16/2004	E-Coli	17.3

APPENDIX B: Results of Fecal Coliform Bacteria Source Tracking

Samples were analyzed with a bacterial source tracking technique known as pulsed-field gel electrophoresis (PFGE), which uses DNA to identify sources of fecal bacteria. From each sample that contained at least 50 cfu/100ml, laboratory staff attempted to isolate five *E. coli* bacteria to test using the PFGE technique. A total of 23 *E. coli* isolates were successfully cultured from Beaver Creek samples. DNA from these isolates was compared to a reference database of known-DNA isolates from other samples collected in Ecoregion 43 (primarily western South Dakota). Of the 23 isolates that were tested, approximately 4% were unidentifiable. Among the isolates for which the source could be identified, 26% were equine (horse) and 30% were ovine (sheep). Other identified animal sources include porcine (pig), bovine (cow), canine (dog), feline (cat) and human (Figure 1).

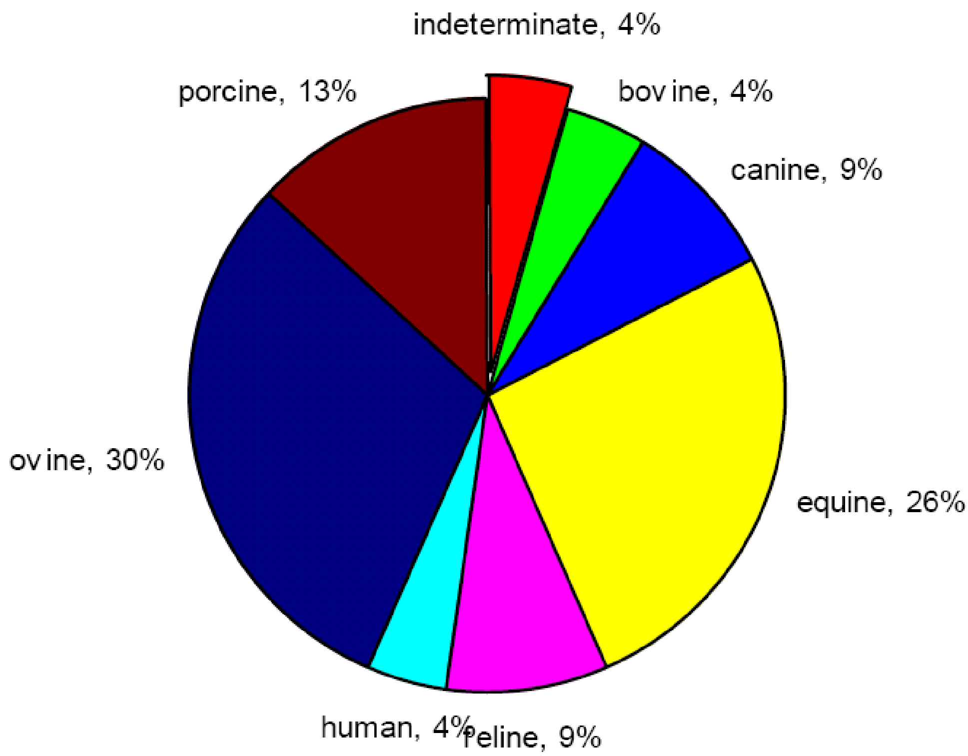

Figure 1. Relative percent of *E. coli* sources as determined from 23 tested isolates.

Several restrictions must be placed on the interpretation of source tracking results. The small number of isolates successfully identified allows a high margin of error when identifying sources of E. coli. The average rate of correct classification of DNA when using the Ecoregion 43 library varies from about 55% (horses and human) to 90% (feline and canine). Also, when compared with the statewide DNA database, sources are identified much differently, with 39% beef cow, 17% sheep, 13% dog, 9% indeterminate, 9% cat, 9% horse and 4% human. These discrepancies suggest that source-tracking technology is not perfected, and that results should not be taken as absolute. Increasing the size of the database would improve the average rate of correct classifications and reduce the number of indeterminate-source classifications. Increasing the number of bacteriological samples collected at Beaver Creek would increase the accuracy of source tracking results, and sampling multiple locations on Beaver Creek would help define spatial distribution of bacteriological contamination.

APPENDIX C: Upper Cheyenne River Watershed Model Development and Calibration

— DRAFT —

UPPER CHEYENNE RIVER WATERSHED MODEL DEVELOPMENT AND CALIBRATION

Topical Report RSI-2054
Rev. 2

prepared for

South Dakota Department of Environment
and Natural Resources
523 East Capitol
Joe Foss Building
Pierre, South Dakota 57501

July 2009

RESPEC
CONSULTING & SERVICES

UPPER CHEYENNE RIVER WATERSHED MODEL DEVELOPMENT AND CALIBRATION

Topical Report RSI-2054
Rev. 2

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July 2009

— DRAFT —

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1.0 INTRODUCTION

The *2008 South Dakota Integrated Report for Surface Water Quality Assessment* [South Dakota Department of Environmental and Natural Resources, 2008] listed Beaver Creek, from the Wyoming border to the mouth (SD-CH-R-Beaver_01), as impaired for fecal coliform as well as various other constituents. The Beaver Creek Watershed is located within the Upper Cheyenne River Watershed and drains approximately 1,664 square miles with 706 square miles draining from the state of Wyoming (Figure 1-1). The nature of the impairment lends this analysis to a more broad-based approach addressing the watershed as a whole, with evaluations sufficient to establish localized loadings coming from both the Wyoming and South Dakota portions of the Beaver Creek Watershed.

The purpose of this project was to gather and evaluate data pertinent to the impairment and to develop and calibrate a **Hydrological Simulation Program-FORTRAN** (**HSPF**) model application to simulate the existing hydrologic conditions and fecal coliform loadings within Beaver Creek. An **HSPF** model application was created to simulate the Upper Cheyenne River Watershed (from the Cheyenne River at Spencer, WY downstream to the Angostura Reservoir) and will be used to complete future modeling tasks for the Cheyenne River project. This report will discuss various aspects of the inventory of bacteria sources and loads, how the model application was developed, as well as the calibration approach and results. This report will also explain the hydrology results for the entire Upper Cheyenne River Watershed **HSPF** model application with the model deliverables focused specifically on the Beaver Creek Watershed. The products from this project are being provided to support the Beaver Creek fecal coliform Total Maximum Daily Load (TMDL) document development.

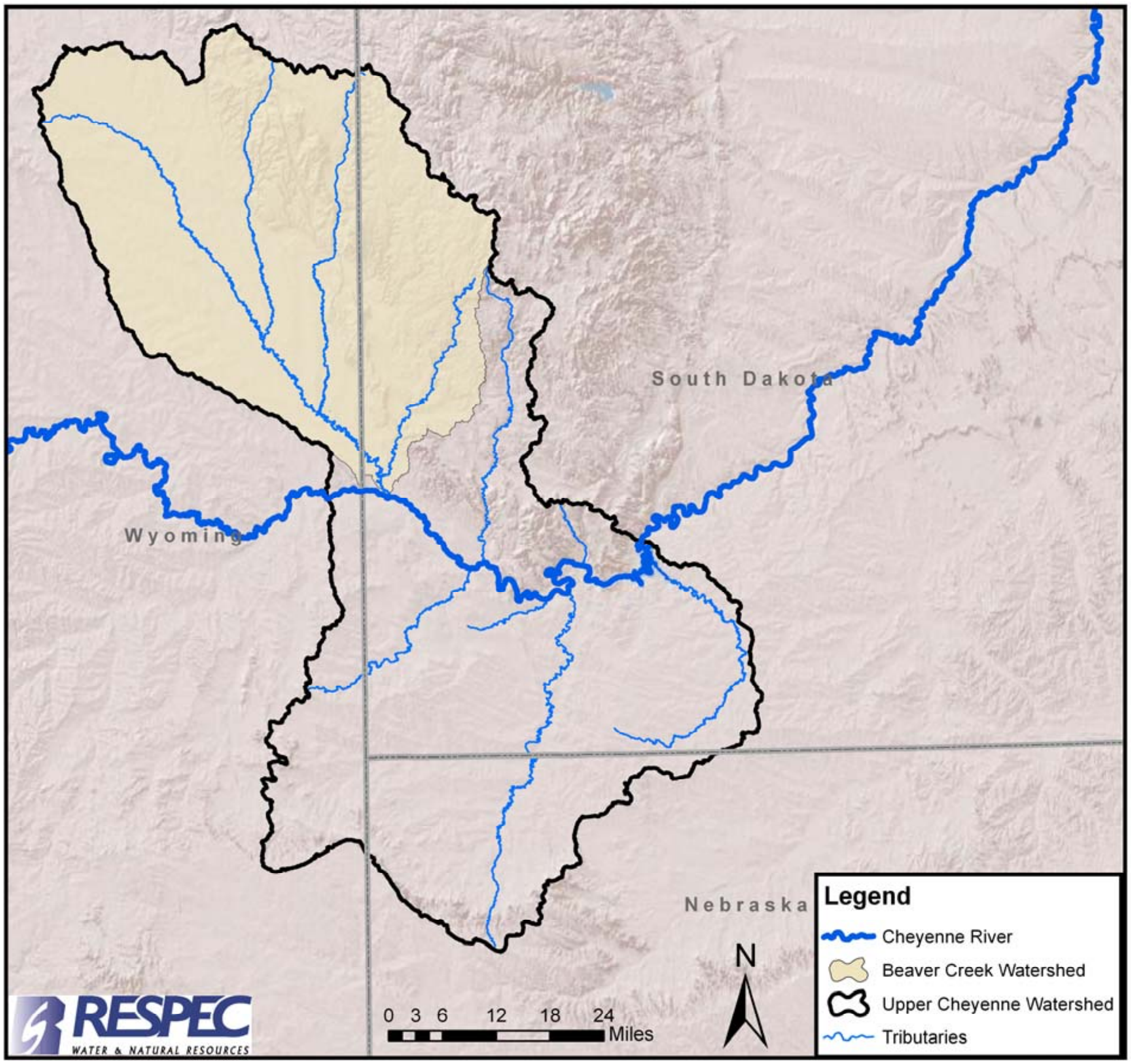

Figure 1-1. Beaver Creek Watershed Within the Upper Cheyenne River Watershed.

2.0 INVENTORY OF BACTERIAL SOURCES

The purpose of this task was to provide a comprehensive accounting of all potential bacterial sources within the watershed. Bacteria sources in the Beaver Creek Watershed include failed septic tank systems, wildlife, pastured livestock, runoff from fields where manure has been applied, and direct defecation by cattle into streams. These sources can be categorized as indirect or direct. Indirect sources of bacteria are associated with rainfall events; whereas, direct sources of bacteria usually discharge continuously (Figure 2-1).

Recently, the South Dakota Department of Environmental and Natural Resources (SD DENR) converted from fecal coliform to E *coli* bacteria as the indicator for limited and immersion recreation assessment. By definition, E *coli* are a subset of fecal coliform. Even though E *coli* may be a better indicator of human health issues for primary contact recreation assessment, historical data are predominately for fecal coliform and most of the pollutant source reference material, particularly for the **Bacteria Indicator Tool** (**BIT**) spreadsheet, used fecal coliform as the pathogen indicator. U.S. Environmental Protection Agency's (EPA's) **BIT** [U.S. Environmental Protection Agency, 2001] was used in conjunction with the EPA's **HSPF** model [Bicknell et al., 2001] to estimate pollutant source loading (see Chapter 3.0 for additional details). The load estimates are currently expressed as fecal coliform. A relationship (i.e., a translator function) can be developed between E *coli* and fecal coliform using available paired data, if necessary. The remainder of this chapter discusses the available data and methods used to quantify the direct and indirect source loadings of fecal coliform bacteria throughout the watershed.

2.1 DIRECT SOURCES

Direct sources are bacteria loadings that are discharged to waterbodies on a continuous basis, with no association with rainfall runoff. Septic systems and direct defecation were the only direct sources that were simulated within the model application. Information was acquired to estimate historical loadings that originate from these direct sources.

2.1.1 Failing Septic Systems

Septic systems deliver bacteria to nearby waterbodies through malfunctions, undetected system failures, piped discharges. Since a precipitation event is not required to deliver bacteria to nearby waterbodies, failures and discharges from septic systems are considered a direct source with ongoing discharges. The Beaver Creek Watershed was considered rural (either individual systems or collectively as part of an unsewered community) where the residents would not have access to a wastewater treatment plant. Although the exact number and locations of septic systems are unknown, the number can be estimated from the 1990 U.S. Census septic data and the 2004 population data. The 1990 U.S. Census septic data are presented by county. A percentage of the number of people using septic systems was calculated

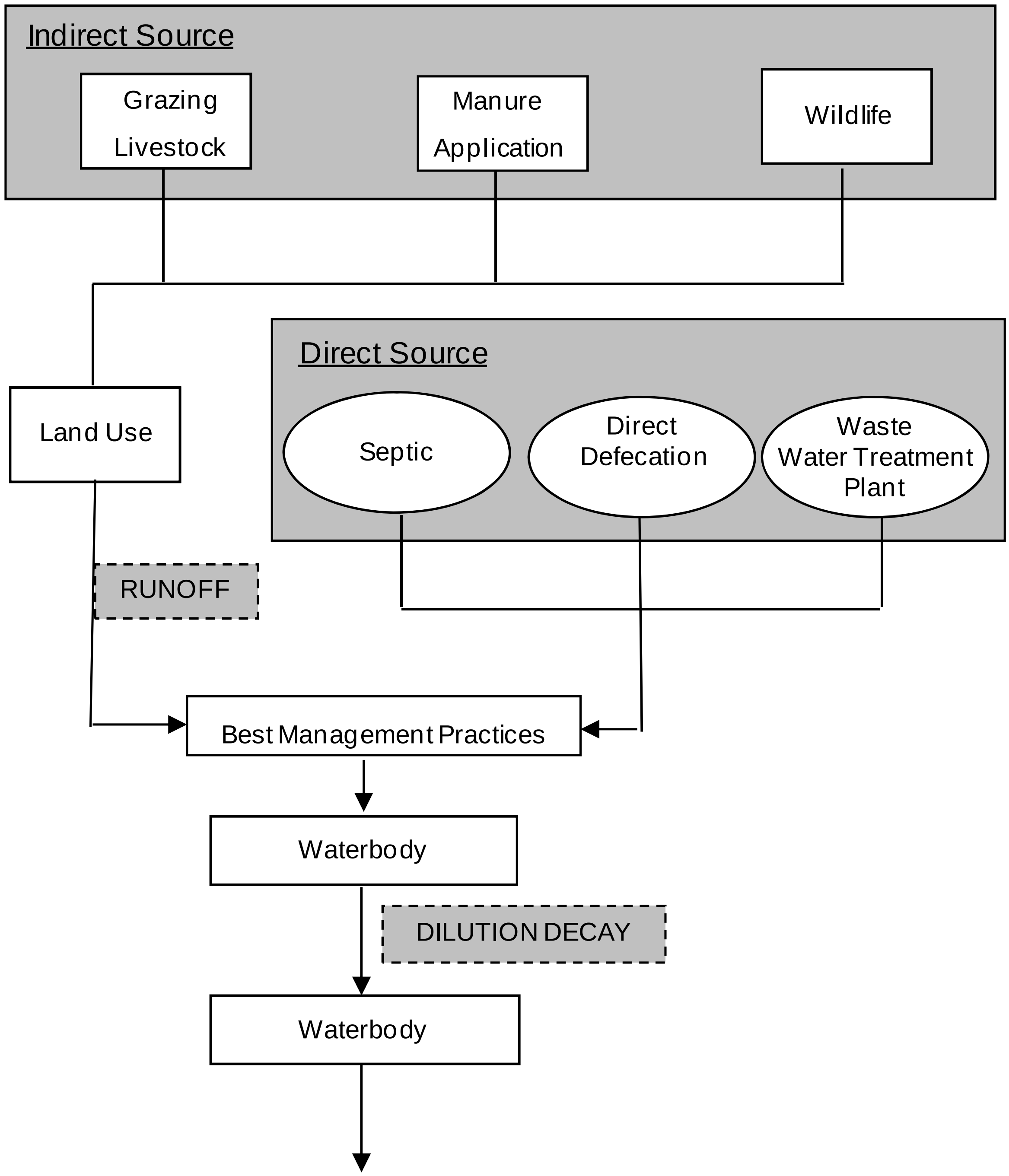

Figure 2-1. Sources of Bacteria.

from the 1990 Census data. The 2004 population was then multiplied by this percentage to determine the number of people using septic systems accounting for recent growth. The method used estimates the number of septic systems for each subwatershed by reducing the county population by the percent of the subwatershed within the county. A 20 percent failure rate was assumed based on previous **BIT** efforts and research [Hipple, 2008]. Impacts from septic system failures generally occur from nearby perennial waterbodies. Since not all septic systems are located near a stream, a reduction factor was used to reduce the original **BIT** loading during model calibration.

2.1.2 Direct Defecation

Livestock spend some time directly in waterbodies, depending on the time of the year. Therefore, there is potential for direct defecation from livestock to waterbodies. This assessment will assume that only cattle spend time directly in waterbodies while other livestock will only defecate on rangeland where bacteria would be transported to waterbodies through precipitation events (indirect source). The amount of time cattle spend in the waterbodies depends on the availability of access, the availability of nonwaterbody watering facilities, the time of year, and the associated temperature. Grazing season is from April to November, but the time spent in the streams varies as the temperature changes. Typical values ranging from 0 to 5 percent were assigned to the percent of time cattle spend in the stream throughout the year. Wildlife also spend time directly in streams but were considered to be negligible. While calibrating the **HSPF** model, final cattle loadings from the **BIT** spreadsheet were adjusted by a reduction factor to account for the uncertainty associated with the data.

2.2 INDIRECT SOURCES

Indirect sources of bacteria include runoff generated from rainfall events from agriculture and other lands that receive contributions of bacteria from grazing livestock, wildlife, and manure application.

Livestock numbers for the Cheyenne River Watershed were estimated using the Census of Agriculture (Ag Census) data available by county. The wildlife population density estimates were also obtained for South Dakota and Wyoming. Wyoming classified some wildlife based on herd unit as opposed to a county basis. Some animal data were not available for Wyoming; therefore, reasonable estimates from adjacent South Dakota areas were applied. A land use distribution method was used to distribute livestock and wildlife based on land use categories where they typically reside. Animal populations for each subwatershed were estimated by reducing county (or herd unit) animal populations by the percent of each land use in the subwatershed within the county. Typically, cattle, sheep, horses, and bison graze (and defecate) on rangeland during the grazing season, that was defined as April to November. During the nongrazing season, livestock were considered to be confined. The manure generated while livestock are confined was applied to cropland.

3.0 MODEL DEVELOPMENT, CALIBRATION, AND VERIFICATION

The focus of this task was to develop a modeling framework to analyze the Upper Cheyenne River Watershed as a whole and to calibrate and verify hydrology and fecal coliform. The watershed modeling package selected for this project was **HSPF**. **HSPF** is a comprehensive watershed model of hydrology and water quality that includes modeling of both land surface and subsurface hydrologic and water-quality processes, linked and closely integrated with corresponding stream and reservoir processes. It is considered a premier, high-level model among those currently available for comprehensive watershed assessments. **HSPF** has benefited from widespread usage and acceptance since its initial release in 1980, as demonstrated through hundreds of applications across the United States and abroad. **HSPF** is jointly supported and maintained by both the EPA and the United Stated Geological Survey (USGS)—a rare occurrence where two federal agencies agree on support of a single modeling system. In addition, **HSPF** is the primary watershed model included in the EPA **Better Assessment Science Integrating Point and Nonpoint Sources** (**BASINS**) modeling system, and it has recently been incorporated into the U.S. Army Corps of Engineers **Watershed Modeling System** (**WMS**). This widespread usage and support has helped to ensure the continuing availability and maintenance of the code for more than 2 decades, in spite of varying federal priorities and budget restrictions. **HSPF** has been used extensively to develop bacteria TMDLs.

The **HSPF** model application was developed for the Cheyenne River from the Wyoming/South Dakota border to Angostura Reservoir. The stream flow and water quality of the Cheyenne River near Spencer, Wyoming, were represented as boundary conditions. The remainder of this chapter describes the development of the Upper Cheyenne River Watershed Model (UCRWM). This chapter identifies and describes the watershed characteristics and types of data required/available for the model and presents the approach that was followed in constructing and calibrating the model. The major steps in the model application process consist of:

1. Collection and development of time-series data.
2. Characterization and segmentation of the watershed.
3. Calibration and verification of the model.

These three steps will be discussed in detail in the following subsections. Section 3.1 describes hydrologic, meteorological, and other data needed for the simulation; Section 3.2 discusses other types of spatial data used to characterize and segment the watershed; and Section 3.3 describes the calibration/verification process and analysis of the simulation period for the UCRWM.

3.1 DATA NEEDS FOR WATERSHED HYDROLOGIC MODELING

Data requirements for developing and calibrating an **HSPF** model application are extensive, in both spatial and temporal detail. Data used in developing this model application included meteorological time-series, stream flow and water-quality boundary conditions, channel geometry, spring flow estimates, and estimated losses to deep groundwater aquifers. Continuous stream flow from USGS gaging stations and water-quality data from various monitoring sites were used to calibrate the model to existing observed conditions.

3.1.1 Meteorological Data

Precipitation (PREC) and potential evapotranspiration (PEVT) are the minimum requirements that drive the internal water balance. However, the Cheyenne River Watershed is greatly influence by the accumulation and melting of snow. Air temperature (ATEM), wind speed (WIND), solar radiation (SOLR), dew point temperature (DEWP), and cloud cover (CLOU) are needed for **HSPF** to calculate snow processes using an energy balance method. Although there is an option to compute snow processes based on temperature alone, the data needed for the energy balance method were available and complete for the simulation time period. The **BASINS** system through the EPA Web site provides all the previously mentioned time-series data already preprocessed in a watershed data management (WDM) file. The WDM file is accessed directly by **HSPF** during a simulation.

Eight meteorological stations were chosen based on the availability of necessary data and their proximity to the Upper Cheyenne River project area (Figure 3-1). Stations that did not have a particular meteorological constituent available were given the time-series data from the nearest station within the Upper Cheyenne River Watershed. Time-series data that were not complete for the simulation period were also appended with data from the nearest station. All meteorological time series were analyzed for consistency and practicality with various graphical plots and statistical analysis for the entire simulation period.

Point data from each meteorological station were extrapolated to represent the meteorological data of eight different hydrozones (Figure 3-1). A hydrozone is an area of land within the model that receives the same meteorological data. Hydrozone boundaries were based on locations of the meteorological station, Thiessen network boundaries, isohyetal contours, and physiography.

The annual precipitation within the Cheyenne River Watershed ranged from 36 inches to 13 inches (Figure 3-2). It is very difficult to capture large variability with limited meteorological stations that represent data from a specific point. The tendency to have high-intensity, localized thunderstorms can also cause uncertainty in the data and can make it difficult to accurately represent the short-term (e.g., hourly and daily) processes. However, the overall trends will be captured and can represent the long-term runoff processes that are consistent with the objectives of this project.

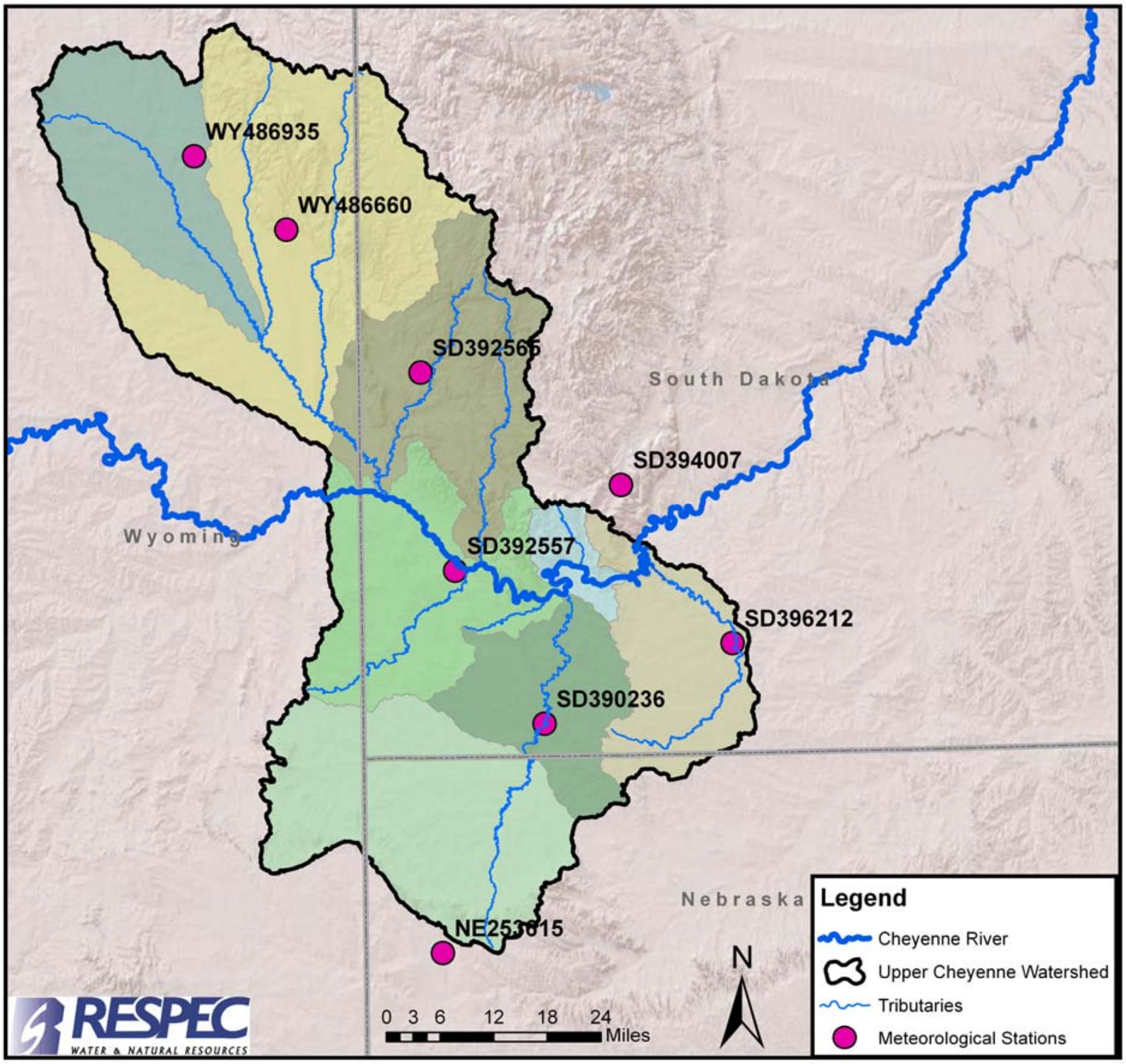

Figure 3-1. Precipitation Gages Used for the Upper Cheyenne River Watershed Model Application.

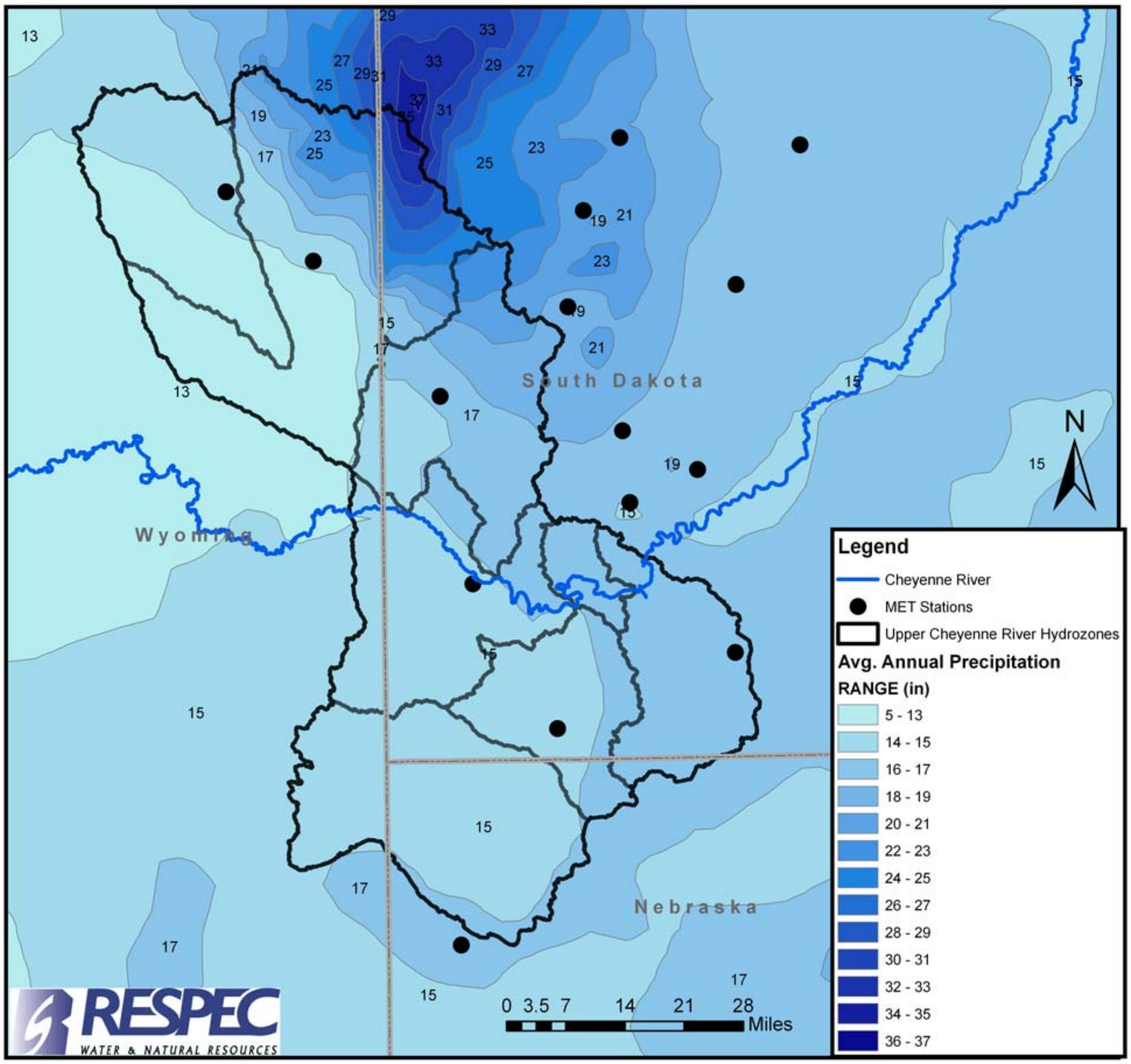

Figure 3-2. Precipitation Variability Within the Upper Cheyenne River Watershed.

3.1.2 Evapotranspiration

HSPF generally uses measured pan evaporation (EVAP) to derive an estimate of lake evaporation, which is considered equal to the potential evapotranspiration (PET) required by **HSPF**; i.e., PET = (EVAP) × (pan coefficient). The actual simulated evapotranspiration (ET) is computed by the program based on the model algorithms that calculate dynamic soil moisture conditions, ET parameters, and the input PET data. Average annual lake evaporation is estimated at about 40 to 48 inches for the region [Farnsworth, 1982]. A pan coefficient of 0.74 is documented as a standard coefficient to estimate lake evaporation within the project area [Farnsworth, 1982]. Potential evapotranspiration (PET) values for all stations were compared to expected values from the National Oceanic and Atmospheric Administration (NOAA) evaporation atlas as well as the USGS hydrologic budgets report for the Black Hills [Carter and Driscoll, 2001a]. The USGS hydrologic budgets report estimated an annual total pan evaporation of 50 inches for the prairie and 30 inches for the Black Hills areas, which represents 37 and 22.2 inches of PET, respectively [Carter and Driscoll, 2001a].

BASINS PET data had annual totals from 20 to 25 inches which is lower than expected [Carter and Driscoll, 2001a]. The use of potential ET data from **BASINS** would result in higher simulated flows. Pan evaporation data were also made available through the South Dakota State University (SDSU) Climate & Weather Center. Pan evaporation data developed from SDSU were multiplied by the pan coefficient to obtain the corresponding PET time series. This daily time series only provided data from April through October with some additional missing days in between. The winter months were filled with **BASINS** PET data while other data gaps were filled by interpolation and long-term monthly averages.

3.1.3 Stream Flow

Historically, the USGS has collected long-term stream flow data at seven gages within the Upper Cheyenne River Watershed (Figure 3-3). The four primary gages (highlighted in green) and the two secondary gages (highlighted in orange) supported continuous calibration and verification over a wide range of hydrologic conditions. Flow data at the boundary condition gage (highlighted in red) were input directly into the model. Table 3-1 lists the stream flow gages and their period of record to support model calibration and verification of hydrology.

3.1.4 Water-Quality Data

Bacteria data have historically been collected by several agencies within the watershed. These data are typically stored within the EPA's **Storage and Retrieval** (**STORET**) system. Three fecal coliform gages within the Beaver Creek Watershed were identified and used for the fecal coliform calibration process (Figure 3-4). The fecal coliform data were primarily collected between 2003 and 2008, and the number of observed data points varied from 12 to 54 (Table 3-2).

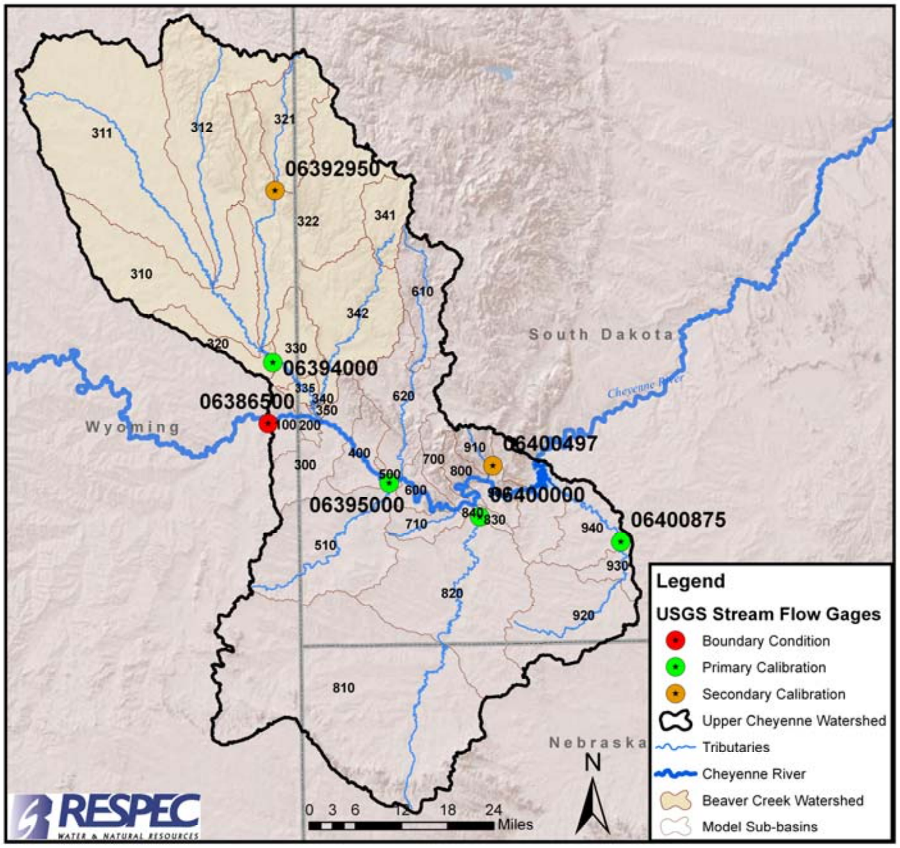

Figure 3-3. Flow Calibration Gages Within the Upper Cheyenne River Watershed.

Table 3-1. United States Geological Survey Stream Flow Gages Within the Upper Cheyenne River Watershed

USGS Stream Flow Gages	HSPF Reach I.D.	Data Availability	Calibration Gage Type
Beaver Creek Near Newcastle, WY (06394000)	320	1990–1997	Primary
Cheyenne River Near Edgemont, SD (06395000)	400	1990–1991	Primary
Hat Creek Near Edgemont, SD (06400000)	820	1990–1997	Primary
Horsehead Creek at Oelrichs, SD (06400875)	930	1990–Present	Primary
Stockade Beaver Creek Near Newcastle, WY (06392950)	321	1991–Present	Secondary
Cascade Springs Near Hot Springs, SD (06400497)	910	1990–1995	Secondary
Cheyenne River Near Spencer, WY (06386500)	N/A	2003–Present	Boundary Condition

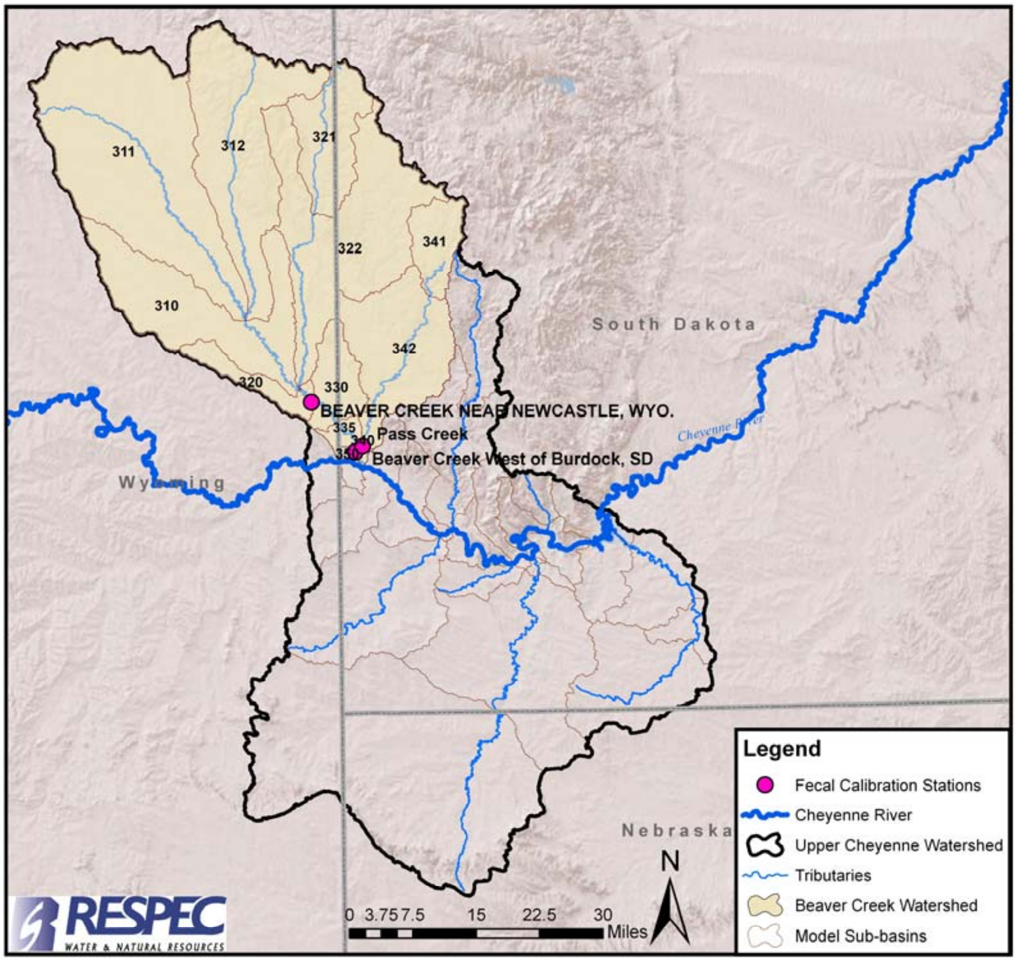

Figure 3-4. Fecal Coliform Calibration Gages Within the Beaver Creek Watershed.

Table 3-2. Fecal Coliform Calibration Gages Within the Beaver Creek Watershed

Fecal Coliform Calibration Stations	HSPF Reach I.D.	Data Availability	Number of Data Points
Beaver Creek Near Newcastle, WY (06394000)	320	2007–2008	12
Pass Creek	341	2003–2007	16
Beaver Creek West of Burdock, SD	340	2004–2008	54

3.1.5 Spring Flows and Losses

Spring flows, surface water losses, and in-stream water losses to groundwater aquifers were estimated using historical stream flow data and estimates from the Black Hills Hydrology Study [Carter and Driscoll, 2001a]. The amount of surface water losses was modeled as 0.04 inch to 0.29 inch based on land use which seemed reasonable for the project area. An 11 cubic feet per second (cfs) in-stream loss zone was also estimated for a reach on Stockade Beaver Creek based on flow comparisons. This loss zone represents the attenuation of streamflow within reservoirs along Stockade Beaver Creek and irrigation demands that were not explicitly simulated within the model application. Alluvial storage was represented in the model application for some reaches along the Cheyenne River based on researched values and calibration [Hortness and Driscoll, 1998].

3.2 SEGMENTATION AND CHARACTERIZATION OF THE WATERSHED

The purpose of watershed segmentation is to divide the study area into individual land and channel segments, or pieces, that are assumed to demonstrate relatively homogenous hydrologic/hydraulic and water-quality behavior. The segmentation provides the basis for assigning similar or identical input and/or parameter values or functions to where they can be applied logically to all portions of a land area or channel length contained within a model segment. Since **HSPF** and most watershed models differentiate between land and channel portions of a watershed and each is modeled separately, each watershed undergoes a segmentation process to produce separate land and channel segments that are linked together to represent the entire watershed area. The land and channel segmentation processes are discussed below.

3.2.1 River and Local Drainage Segmentation

The river reach segmentation requires consideration of river travel time, riverbed slope continuity, temporal and spatial cross section and morphologic changes or obstructions, confluence of tributaries, TMDL reach end points, and calibration/verification gage locations for flow and bacteria. Once the segmentation was finalized, each reach segment was analyzed to compute the tributary areas of the land use categories (discussed in Section 3.2.3) and the hydraulic characteristics of the reach. The reach hydraulic behavior is specified in an FTABLE, which contains the reach surface area, volume, and discharge as functions of depth; i.e., an expanded rating curve. FTABLEs were developed for each reach segment using Manning's equation from cross sections collected as a part of a physical habitat study performed previously by the Fall River Conservation District. Cross sections for unsurveyed tributaries were assigned the geometry of similar channels.

3.2.2 Land Segmentation

Land segmentation is used to assign unique parameters to areas of land within the HSPF model application. For the land segmentation, subbasins were delineated in a manner to capture hydrologic and water-quality variability. Land segmentation was based on the hydrozone boundaries which define meteorological characteristics.

3.2.3 Model Categories

Land use and land cover affect the hydrologic and water-quality response of a watershed. The land use and land cover affect infiltration, surface runoff, and water losses from evaporation or transpiration by vegetation. The movement of water through the system is affected significantly by vegetation (i.e., crops, pasture, or open) and associated characteristics. Land use clearly impacts the rate of accumulation of pollutants such as bacteria.

The 2002 National Land Cover Data categories were aggregated into five model categories (Figure 3-5). An additional category was created in the model to represent the groundwater recharge area. This category was developed to simulate the high infiltration rates and the losses to deep groundwater aquifers observed through the Black Hills Hydrology Study. The recharge model category includes the outcrop areas of the Madison, Minnelusa, and Deadwood Formations. The urban category was divided into pervious and impervious areas based on an estimated percent effective impervious area (EIA). The term “effective” implies that the impervious region is directly connected to a local hydraulic conveyance system (e.g., open channel, river) and the resulting overland flow will not run onto pervious areas and will not have the opportunity to infiltrate along its respective overland flow path before reaching a stream or waterbody.

3.3 CALIBRATION AND VERIFICATION

Once the initial model was developed, the calibration and verification process was initiated. The following sections discuss the time period for model calibration and verification and the procedures and comparisons that were performed as well as the overall results for hydrology and fecal coliform.

3.3.1 Calibration and Verification Time Periods

The principal time-series data needed for hydrologic calibration indicate that long-term calibration/verification simulations can be performed at the seven USGS gages shown in Table 3-1. Typically, calibration is performed over at least a 5-year period with a range of hydrologic conditions (wet and dry years) and then verified over a separate period of time; i.e., a split-sample verification. However, the process of calibration and verification is usually

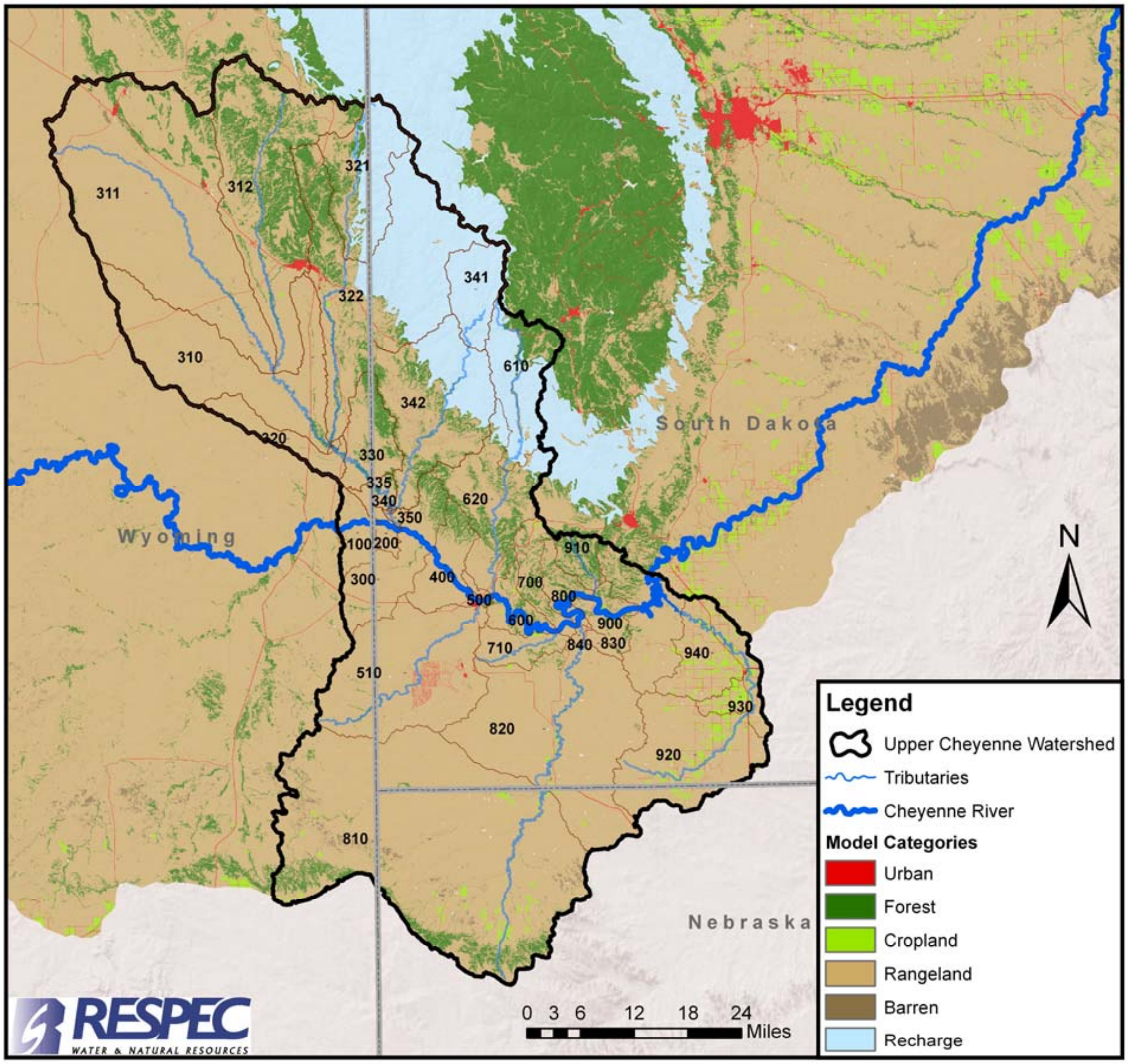

Figure 3-5. Map of the Upper Cheyenne River Watershed Model Categories.

repeated until the results are similar for both tasks. For this reason, the entire simulation period, excluding 1990, was used in the calibration of the model. The initial year (1990) was simulated to let the model adjust to existing conditions, and the years 1991 through 2006 were used as the calibration period. This time period has a very clear trend of exceptionally wet years in the 1990s to drought conditions in the 2000s, which makes it an ideal calibration/validation period. Subsequently, to achieving the best possible calibration, the model was verified by assessing the calibration in both wet and dry time periods.

3.3.2 Calibration/Verification Procedures and Comparisons

Hydrology calibration was completed in a manner to match continuous daily simulated flow to daily observed flow records. Fecal coliform simulations are highly dependent on the hydrology process. Therefore, once the hydrology calibration was considered acceptable, calibration of fecal coliform began. The procedure used to calibrate and verify that the simulated results best represented the observed data as well as the overall processes.

The calibration of the **HSPF** model application was a cyclical process of making parameter changes, running the model and producing comparisons of simulated and observed values, and interpreting the results. The calibration process is greatly facilitated with the use of in-house **Matlab** scripts and functions that are capable of reading the **HSPF** binary output file and automating statistical and graphical tests to help assess the calibration.

The standard **HSPF** hydrologic calibration is divided into four phases:

- **Establish an annual water balance.** This consists of comparing the total annual simulated and observed flow (in inches) and is governed primarily by the input rainfall and evaporation and the parameters LZSN (lower zone nominal storage), LZETP (lower zone ET parameter), DEEPFR (deep groundwater recharge losses), and INFILT (infiltration index).
- **Adjust low flow/high flow distribution.** This is generally done by adjusting the groundwater or baseflow, because it is the easiest to identify in low flow periods. Comparisons of mean daily flow are utilized, and the primary parameters involved are INFILT, AGWRC (groundwater recession), and BASETP (baseflow ET index).
- **Adjust storm flow/hydrograph shape.** The storm flow, which is compared in the form of short-time-step (1-hour) hydrographs, is largely composed of surface runoff and interflow. Adjustments were made to the UZSN (upper zone storage), INTFW (interflow parameter), IRC (interflow recession), the overland flow parameters LSUR (length of the overland flow plane), NSUR (Manning's *n* for the overland flow plane), and SLSUR (slope of the overland flow plane). INFILT was also used for minor adjustments.
- **Make seasonal adjustments.** Differences in the simulated and observed total flow over summer and winter are compared to see if runoff needs to be shifted from one season to another. These adjustments are generally accomplished by using seasonal

(monthly variable) values for the parameters CEPSC (vegetal interception), LZETP, and UZSN. Adjustments to KVARY (variable groundwater recession) and BASETP are also used.

By iteratively adjusting specific calibration parameter values, within accepted ranges, the simulation results were changed until an acceptable comparison of simulated results and measured data was achieved. The procedures and parameter adjustments involved in these phases are more completely described in Donigian et al. [1984] and the **HSPF** hydrologic calibration expert system (**HSPEXP**) [Lumb et al., 1994].

A boundary condition was needed for the Cheyenne River Near Spencer, WY, to account for upstream stream flow and water-quality constituents from areas that were not modeled within this application. Historical USGS data provided flow at this site from October 2003 to present. A synthetic boundary condition from 1990 through September 2003 was developed to supplement missing flow data that was entered as a direct input into the model. This was completed by using an iterative process of calibrating and comparing flow results at Reach 400 (Cheyenne River at Edgemont, SD). Initially, the boundary condition was set to zero for the dates that had missing flow data. Beaver Creek was calibrated and a flow comparison was made downsteam at the Cheyenne River Near Edgemont, SD (Reach 400). The difference between the observed and simulated flow at the Cheyenne River Near Edgemont, SD, was calculated on a daily basis and these values were entered as the new boundary condition. This was completed after incorporating a 3-day lag time into the data which was estimated based on the estimated travel time from the Cheyenne River at Spencer, SD, to the Cheyenne River at Edgemont, SD. The process was repeated until satisfactory and reasonable results were obtained for Beaver Creek, the Cheyenne River at Edgemont, SD, and the Cheyenne River boundary condition at Spencer, SD.

3.3.3 Fecal Coliform Calibration Procedures

Several parameters are available for adjustment of bacteria loadings and concentrations in the model. To achieve calibration under baseflow conditions, adjustments are typically made to parameters that represent continuous discharges and are not dependent upon transport via runoff mechanisms; i.e., direct sources with estimated loadings. The direct sources category nominally includes contributions of fecal coliform from direct deposition from wildlife or livestock, but this type of continuous source could also include contributions of fecal coliform from failing septic systems and leaking wastewater collection system infrastructure. This direct source category could also represent other mechanisms that are difficult to quantify explicitly, including resuspension of bacteria associated with sediment and illicit discharges. Calibration under runoff conditions can be achieved through adjustment of parameters that relate to washoff of bacteria from land surfaces. The accumulation rate of bacteria on land surfaces (ACQOP) and the maximum accumulation (SQOLIM) are typically adjusted to render either more or less bacterial mass available for washoff. These bacterial accumulation rates represent the contributions from wildlife, livestock, and general urban loadings to the land surfaces in the watershed. The rate of surface runoff that will remove 90 percent of stored fecal coliform (WSQOP) is also adjusted, which affects the proclivity for washoff to occur. These key model parameters were adjusted based upon the site-specific bacteria concentration data collected in the Beaver Creek watershed. Calibration of the in-stream concentrations can also be accomplished by adjusting the first-order decay rate for bacteria (FSTDEC).

3.3.4 Weight of Evidence Comparisons

Calibration comparisons were made using a weight-of-evidence approach. This type of approach uses both visual and statistical methods to best define the performance of the model. Visual aids are evaluated using the modeler's experience and professional discretion. Statistical methods may give definitive answers but are still subject to the modeler's best judgment for the overall model performance.

Table 3-3 lists general calibration/verification tolerances or targets that were provided to model users as part of **HSPF** training workshops over the past 20 years [Donigian, 2000]). The values in the table attempt to provide some general guidance, in terms of the percent mean errors or differences between simulated and observed values, so that users can gage what level of agreement or accuracy (i.e., very good, good, fair) may be expected from the model application. The caveats at the bottom of the table indicate that the tolerance ranges should be applied to mean values and that individual event or observations may show larger differences and still be acceptable. In addition, the level of agreement to be expected depends on many site- and application-specific conditions, including the data quality, purpose of the study, available resources, and available alternative assessment procedures that could meet the study objectives. Given the uncertain state-of-the-art in model performance criteria, the inherent errors in input and observed data, and the approximate nature of model formulations, absolute criteria for watershed model acceptance or rejection are not generally considered appropriate by most modeling professionals. Most decision makers want definitive answers to the questions "How accurate is the model?" and "Is the model good enough for this evaluation?" Consequently, it is currently anticipated that a good to very good calibration can be achieved. However, this entirely depends on the available data to quantify bacterial loading rates and the accuracy and/or representative nature of the meteorological data.

3.3.4.1 Hydrology Comparisons

The specific model-data comparisons of simulated and observed values for the calibration period include:

- Annual and monthly runoff volumes (inches).
- Daily time series of flow.
- Storm event periods; e.g., hourly values (cfs).
- Flow frequency (flow duration) curves (cfs).

Table 3-3. General Calibration/Verification Targets or Tolerances for HSPF Applications

	Difference Between Simulated and Recorded Values (%)		
	Fair	**Good**	**Very Good**
Hydrology/Flow	15–25	10–15	<10
Bacteria	30–45	20–30	<20

Caveats: Relevant to monthly and annual values; storm peaks may differ more.
Quality and detail of input and calibration data.
Purpose of model application.
Availability of alternative assessment procedures.
Resource availability (i.e., time, money, personnel).

Source: Donigian [2000].

Annual and monthly plots were used to visually compare runoff volumes over the contributing area. This method included transferring the amount of flow measured at a gage to an amount of water in inches over the entire contributing area to normalize the data and create a more realistic picture. Plots were also developed to analyze the daily flow comparisons on a yearly basis. This allowed observations of individual storm events to be analyzed as well the snow accumulation/melt processes and the baseflow trends. Flow frequency curves, or flow duration curves, were used to characterize the flow conditions under which flows are occurring. The flow duration curve presents measured flow and simulated flow versus the corresponding percent of time the flow was exceeded. Thus the flow duration curves provide a clear way to evaluate model performance for various flow conditions (e.g., storm events or baseflow) and which parameters to adjust to better fit the data.

In addition to the above comparisons, the water balance components (input and simulated) were reviewed. This effort involved displaying model results for individual land uses for the following water balance components:

- Precipitation
- Total Runoff (sum of following components)
  - Overland flow
  - Interflow
  - Baseflow
- Potential Evapotranspiration
- Total Actual ET (sum of following components)
  - Interception ET

- Upper zone ET
- Lower zone ET
- Baseflow ET
- Active groundwater ET

• Deep Groundwater Recharge/Losses.

Although observed values are not available for each of the water balance components listed above, the average annual values must be consistent with expected values for the region, as impacted by the individual land use categories. This is a separate consistency, or reality, check with data independent of the modeling (except for precipitation) to ensure that land use categories and the overall water balance reflect local conditions. These comparisons relied primarily on information obtained from the Black Hills Hydrology Study [Carter and Driscoll, 2001a].

Figure 3-6 provides value ranges for both correlation coefficients (*R*) and coefficient of determination (R^2) for assessing model performance for both daily and monthly flows. The figure shows the range of values that may be appropriate for judging how well the model is performing based on the daily and monthly simulation results. As shown, the ranges for daily values are lower to reflect the difficulties in exactly duplicating the timing of flows, given the uncertainties in the timing of model inputs (mainly precipitation).

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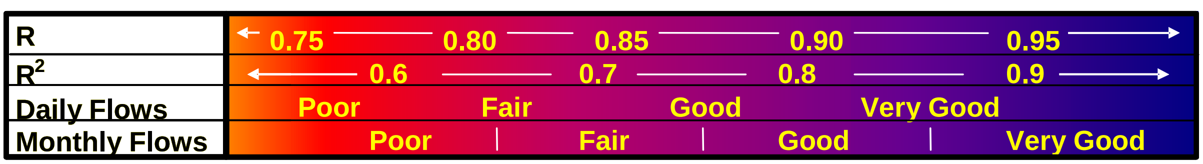

Figure 3-6. General Calibration/Verification *R* and R^2 Targets for HSPF Applications.

3.3.4.2 Fecal Coliform

For bacteria constituents, model performance was based largely on visual and graphical presentations since the frequency of data is often inadequate for accurate statistical measures. For each calibration station, calibration time series showing observed and modeled daily bacteria data for the simulation period were prepared with precipitation data included on each figure. Concentration duration curves were also developed to facilitate the calibration process. The concentration duration curves present measured concentrations and simulated concentrations versus the corresponding percent of time the concentration was exceeded. Concentration duration curves do not necessarily represent the flow condition in which the concentrations occur, but rather the overall trends in bacteria concentrations. Comparing both the concentration duration plots and the daily time-series plots together provides a clear way to evaluate model performance of loading processes and concentrations.

3.3.5 Hydrology Calibration Results

Using the weight-of-evidence approach the hydrology calibration was completed. Figures 3-7 through Figure 3-10 show the flow duration curves for the primary calibration gages located within the Upper Cheyenne River Watershed. These plots show a very good to good fit between the observed and simulated flows. Two tributaries, Hat Creek and Horsehead Creek, showed larger differences between observed and simulated flows. This is primarily due to the fact that there is very little runoff in the system and because localized irrigation practices within those watersheds were not modeled due to a lack of data. This made it difficult to accurately model flow during the summer irrigation months. Another important factor to consider is the variability in the precipitation and the limited number of meteorological gages within this watershed. There is a tendency to have high-intensity, localized thunderstorms within the project area. With these considerations, the model application was still capable of representing the overall runoff trends.

Figures 3-11 through Figure 3-14 show the average monthly runoff at the primary calibration reaches. With so little runoff in the watershed, what are viewed as large differences could be one misrepresented storm. These monthly plots verify that the model did exceptionally well at capturing the variability in the runoff between the watersheds and show that the snowfall/snowmelt processes were simulated accurately. Average yearly plots were also used during calibration to verify that the annual water balances were reasonable and to view the trends between the wet years in the 1990s and the dry years in the 2000s (Figure 3-15 through Figure 3-18).

The statistical weight of evidence shows an acceptable model performance (Table 3-4). Statistical results used to analyze the overall model performance showed a maximum percent difference between the observed and simulated volumes (normalized to inches over the contributing area) of 12.44 percent and a minimum value of 6.66 percent. The maximum and minimum residuals were 0.05 and 0.02, respectively. It is important when analyzing model performance to also look at the residual between the observed and simulated volume as it can show a more logical reasoning for the results. For instance, the maximum percent difference in volume correlates to a residual of only 0.03 inch, which is a very small amount of runoff. The coefficient of determination and the correlation coefficients tend to be better on a monthly basis rather than a daily basis which is expected because of the variability in precipitation patterns and amounts. Table 3-5 shows the statistical weight of evidence used to verify model performance during wet and dry periods. The overall hydrologic model performance was considered satisfactory and capable of simulating the rainfall-runoff responses within the Upper Cheyenne River Watershed.

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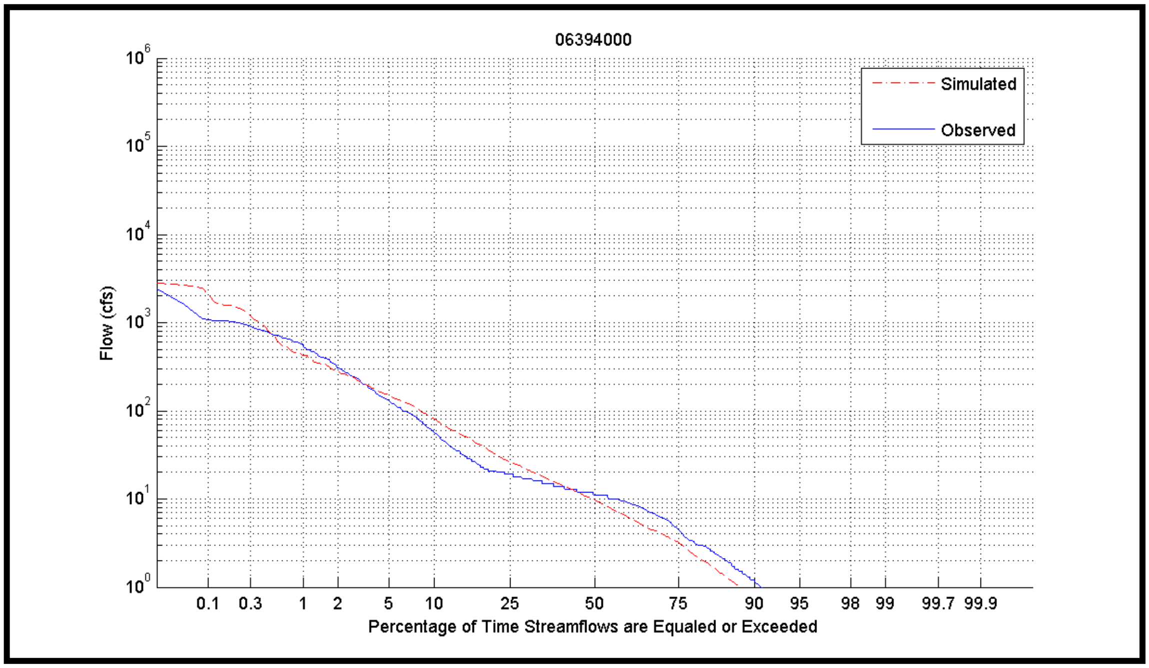

Figure 3-7. Flow Duration Curve at Reach 320 (Beaver Creek Near Newcastle, WY).

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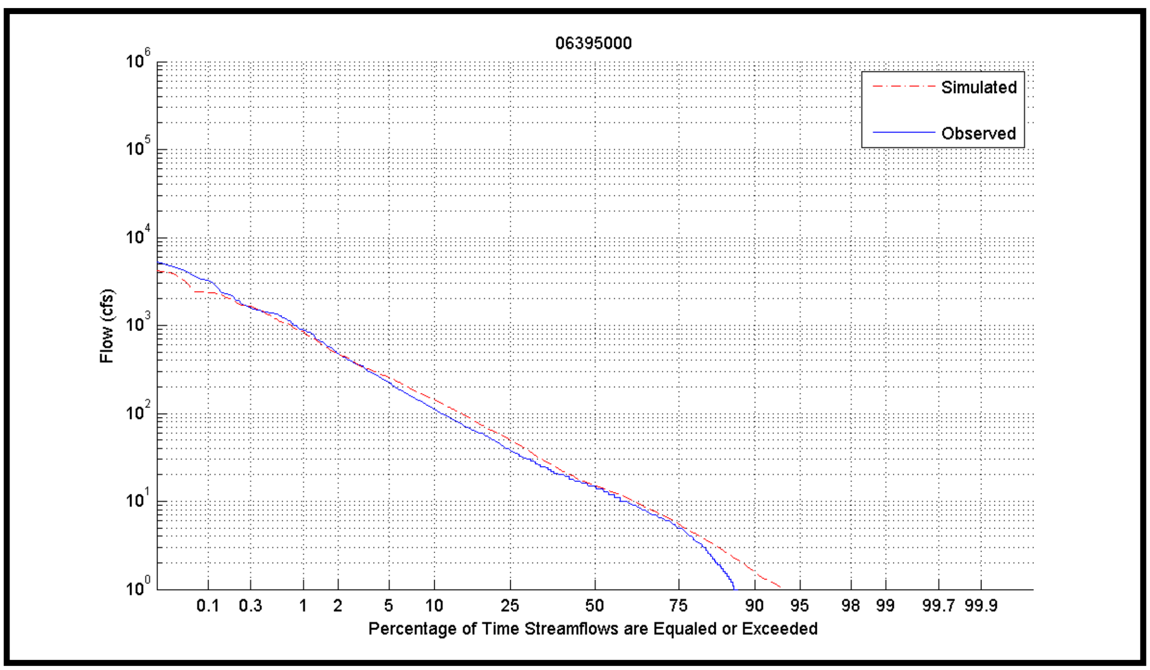

Figure 3-8. Flow Duration Curve at Reach 400 (Cheyenne River at Edgemont, SD).

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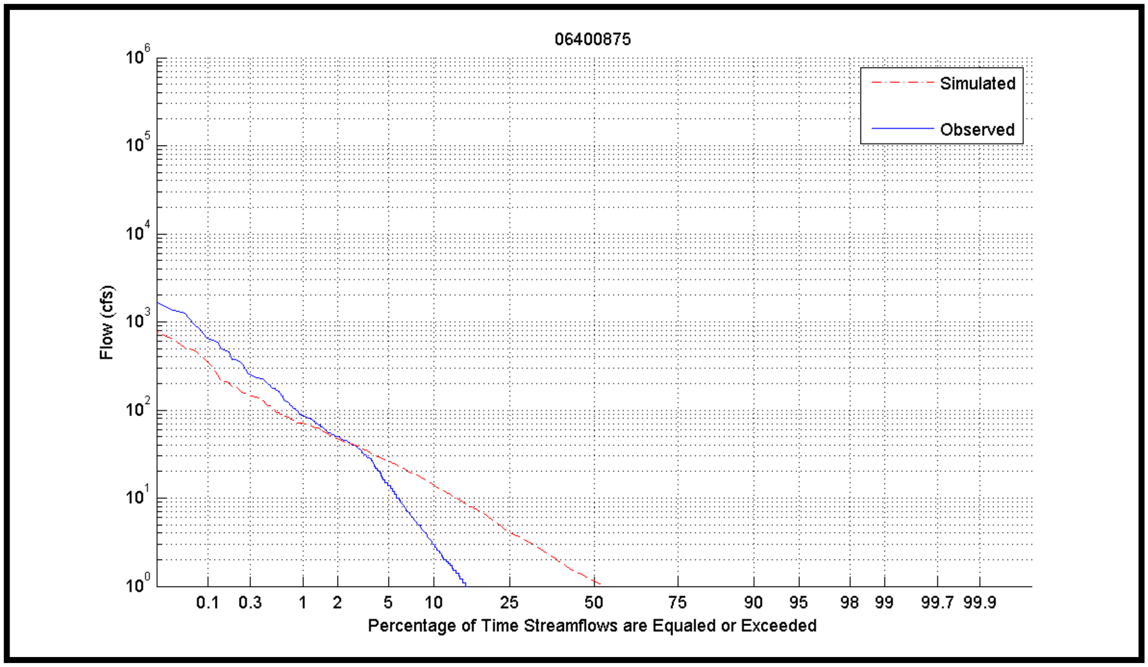

Figure 3-9. Flow Duration Curve at Reach 820 (Hat Creek Near Edgemont, SD).

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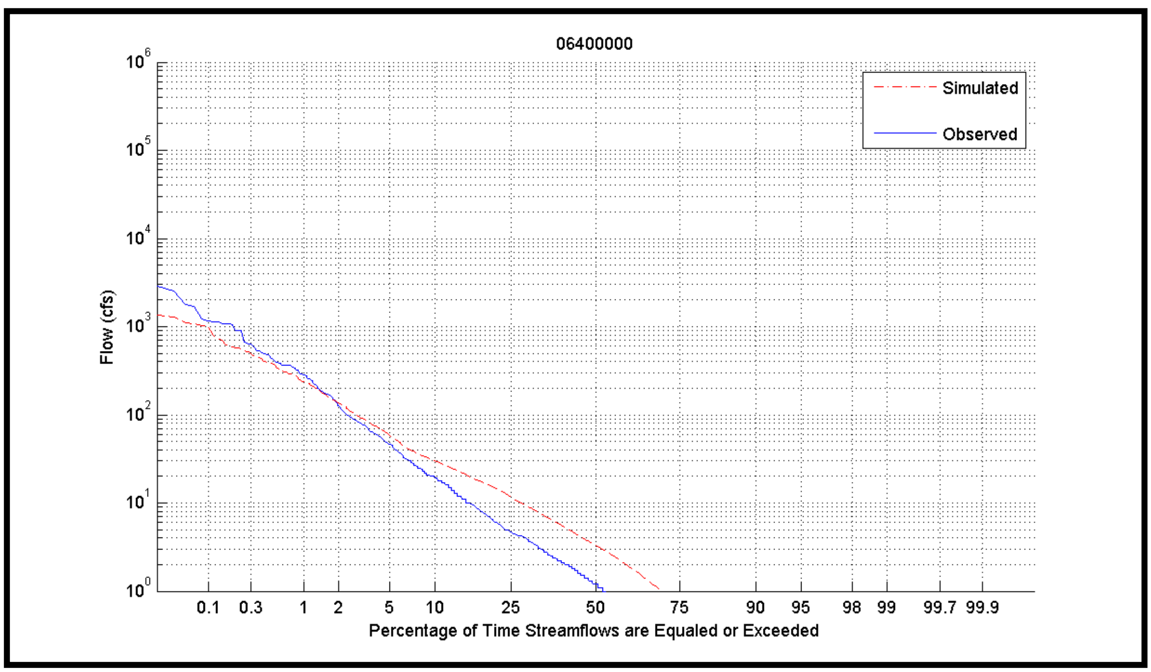

Figure 3-10. Flow Duration Curve at Reach 930 (Horsehead Creek at Oelrichs, SD).

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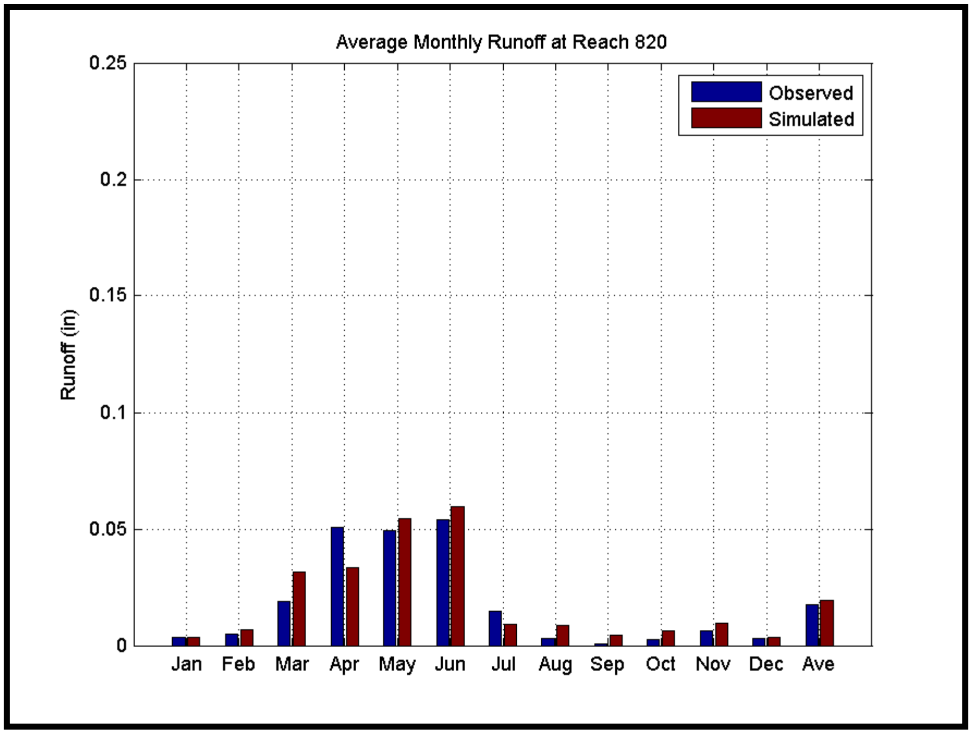

Figure 3-11. Average Monthly Runoff at Reach 320 (Beaver Creek Near Newcastle, WY).

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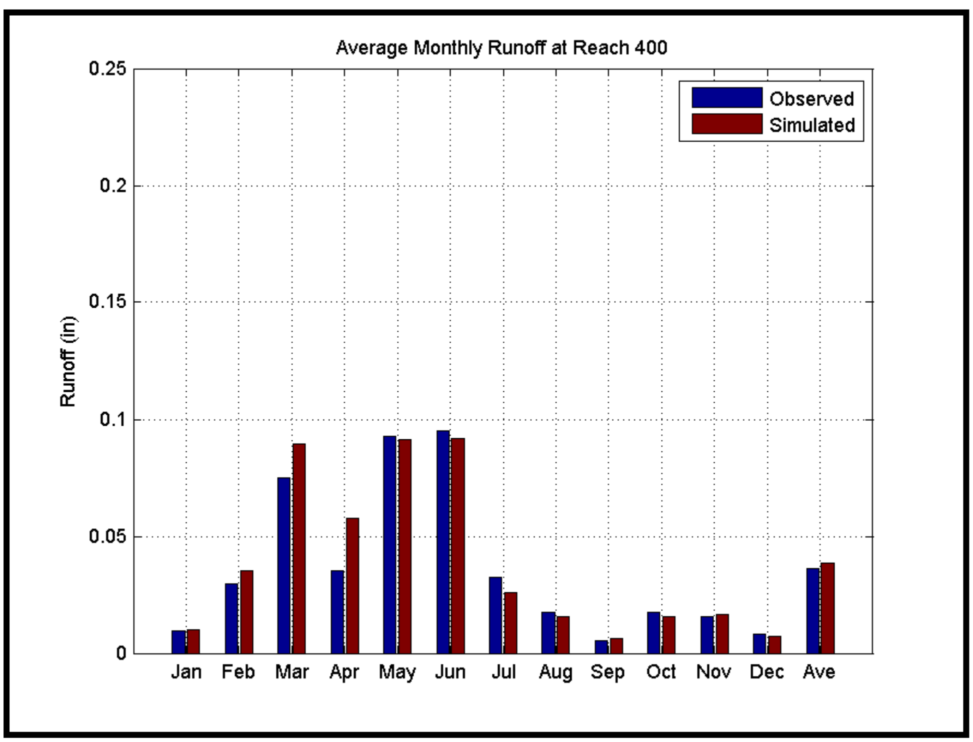

Figure 3-12. Average Monthly Runoff at Reach 400 (Cheyenne River at Edgemont, SD).

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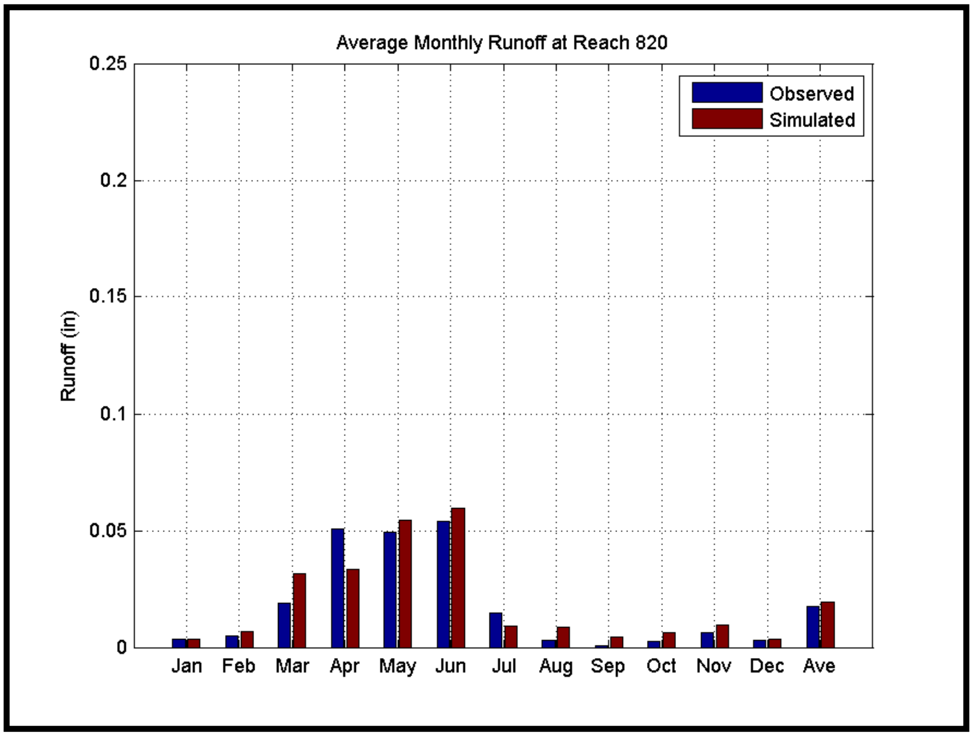

Figure 3-13. Average Monthly Runoff at Reach 820 (Hat Creek Near Edgemont, SD).

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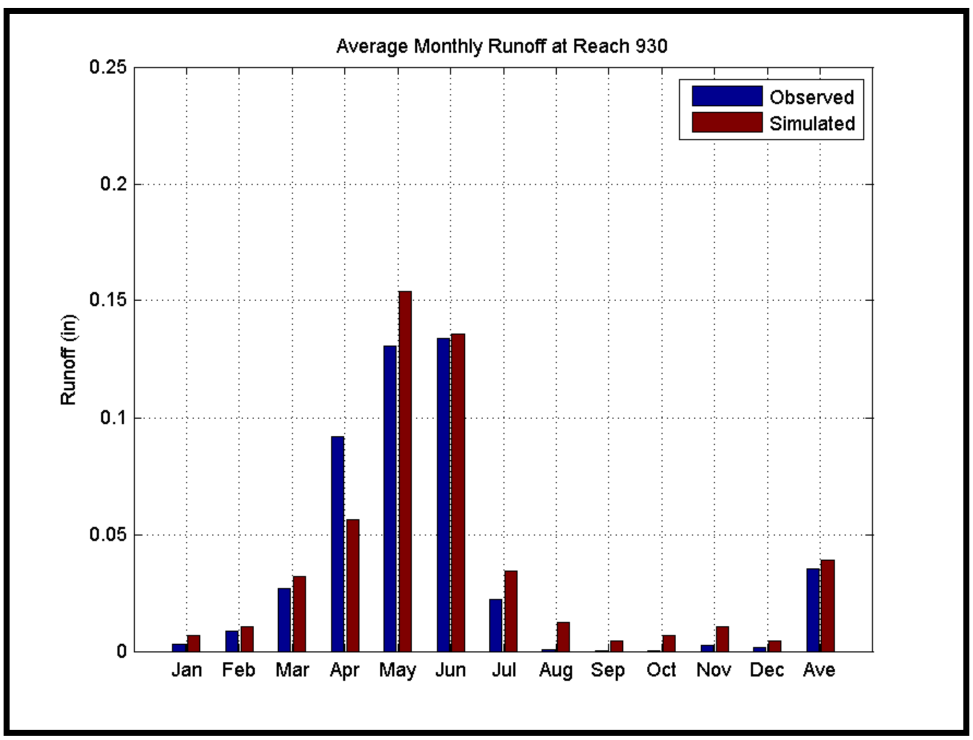

Figure 3-14. Average Monthly Runoff at Reach 930 (Horsehead Creek at Oelrichs, SD).

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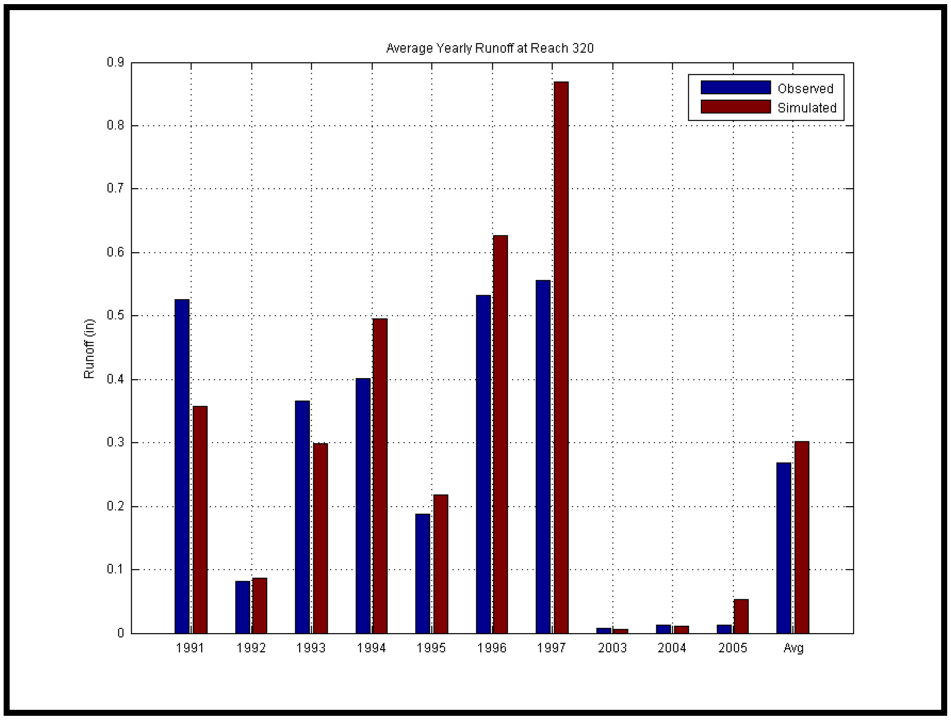

Figure 3-15. Average Yearly Runoff at Reach 320 (Beaver Creek Near Newcastle, WY).

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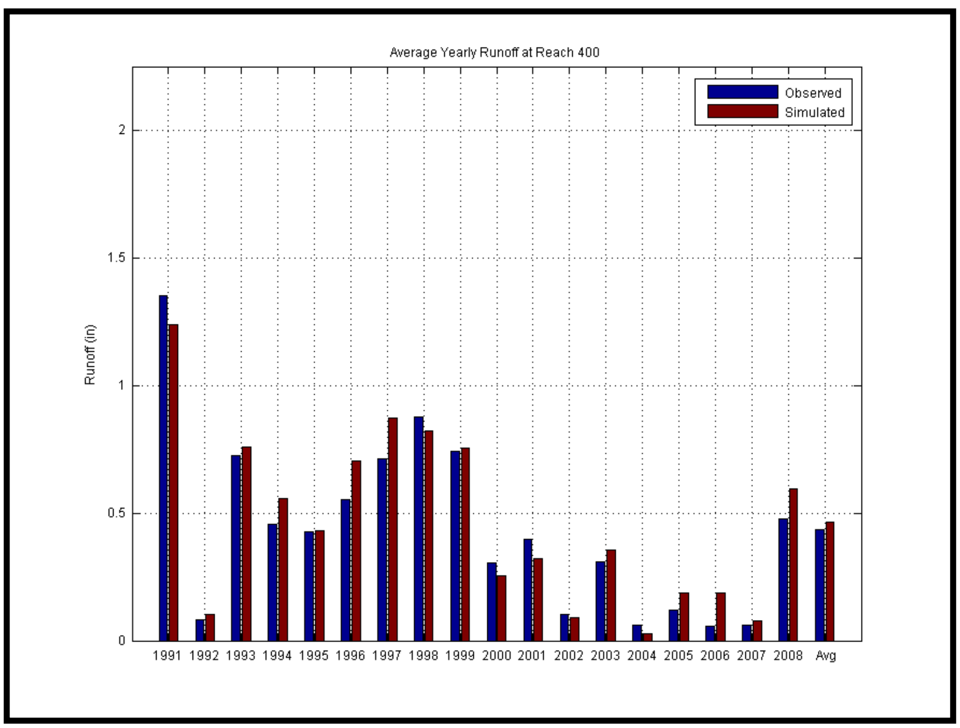

Figure 3-16. Average Monthly Runoff at Reach 400 (Cheyenne River at Edgemont, SD).

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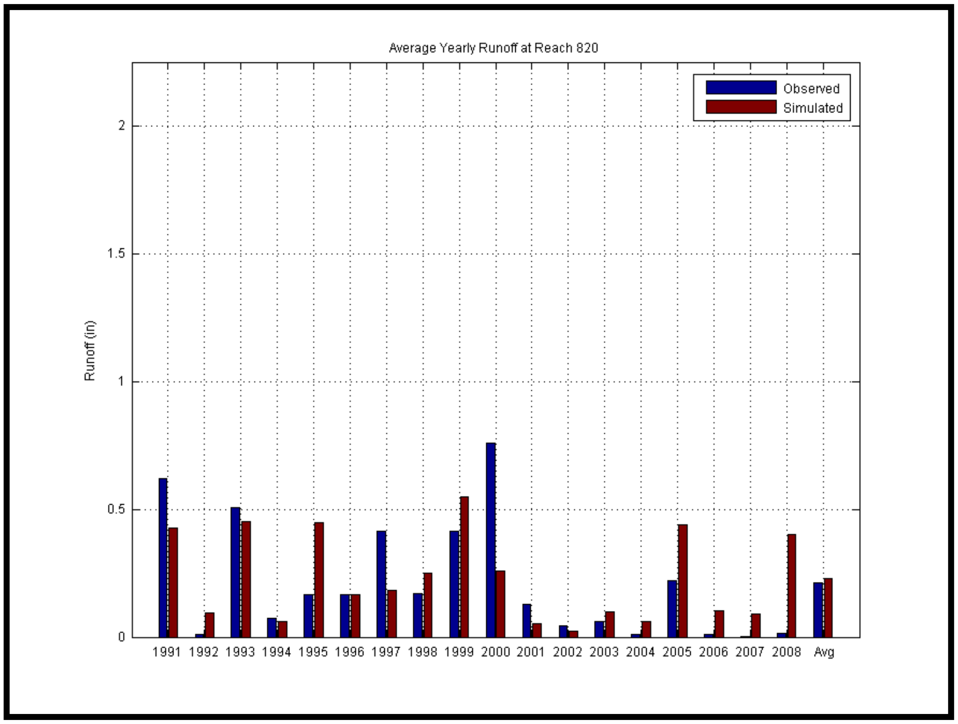

Figure 3-17. Average Yearly Runoff at Reach 820 (Hat Creek Near Edgemont, SD).

RSI-1737-09-020

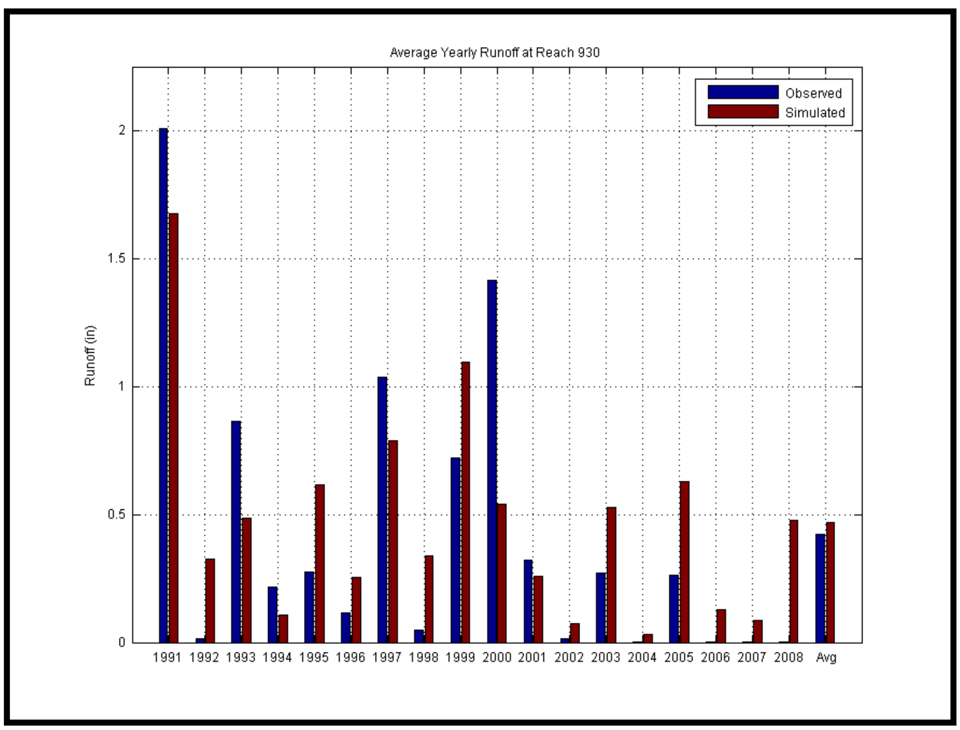

Figure 3-18. Average Yearly Runoff at Reach 930 (Horsehead Creek at Oelrichs, SD).

Table 3-4. Statistical Weight of Evidence Data Used for Evaluating the Overall Hydrologic Model Performance

Primary Calibration Gages	Obs. (in)	Sim. (in)	Residual (in)	% Vol	*R*	R^2	Years of Data
Beaver Creek (06394000)	0.27	0.30	0.03	12.44	0.84	0.71	7
Cheyenne River Near Edgemont (06395000)	0.43	0.46	0.03	6.66	0.94	0.89	18
Hat Creek (0640000)	0.21	0.23	0.02	9.53	0.68	0.47	18
Horsehead Creek (06400875)	0.42	0.47	0.05	11.14	0.84	0.71	18

Table 3-5. Statistical Weight of Evidence Data Used for Verifying Model Performance During Wet and Dry Periods

Weight of Evidence Comparison	Upper		Overall Model Performance
	Mean	Range	
Volumes			
Overall % Difference	8.7	6.66/12.4	Very Good
Wet Years % Difference	6.2	3.04/10.4	Very Good
Dry Years % Difference	15.6	10.0/17.7	Good
Monthly R^2	0.70	0.47/0.89	Fair
Flow-Duration Curve	Visual Evaluation		Good
Water Balance			Reasonable

3.3.6 Beaver Creek Fecal Calibration Results

Figures 3-19 through Figure 3-21 show the daily concentration plots for the three fecal coliform calibration reaches. The continuous red line represents the simulated fecal concentrations for the time period when observed data were collected. Blue circles represent observed data that were collected in the field and used for calibration. No continuous observed flow was available for the calibration reaches; therefore, only simulated flow is plotted on the auxiliary plot. These plots show that the model is representing the general process correctly.

Figures 3-22 through Figure 3-24 are the concentration-duration plots for the three fecal coliform calibration reaches. The plots show the paired observed and simulated data from corresponding sampling dates. The plots also show all of the concentrations within the entire

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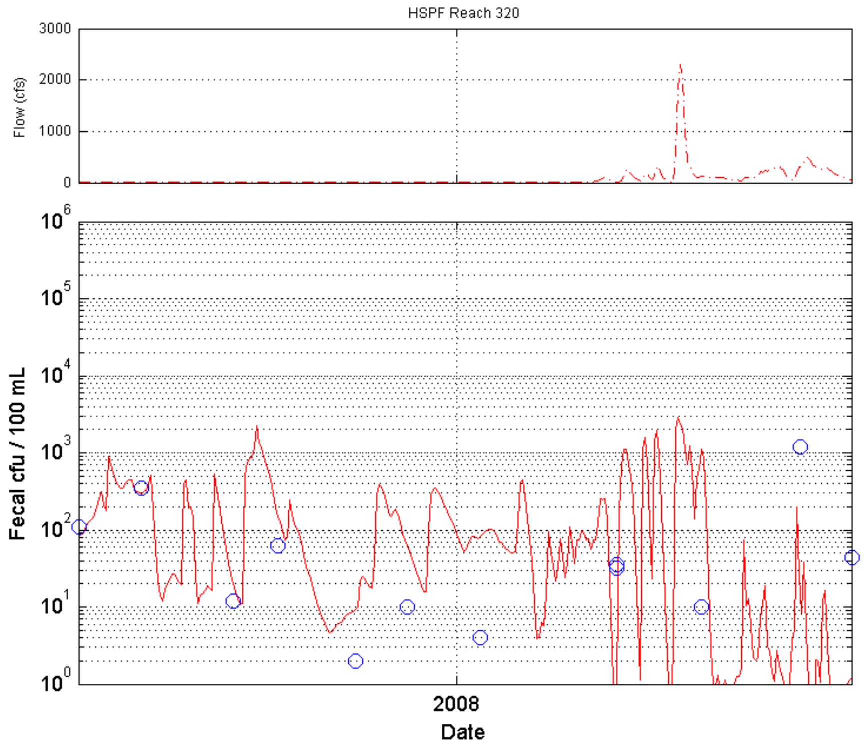

Figure 3-19. Daily Concentration Plot at Reach 320 (Beaver Creek Near Newcastle, WY).

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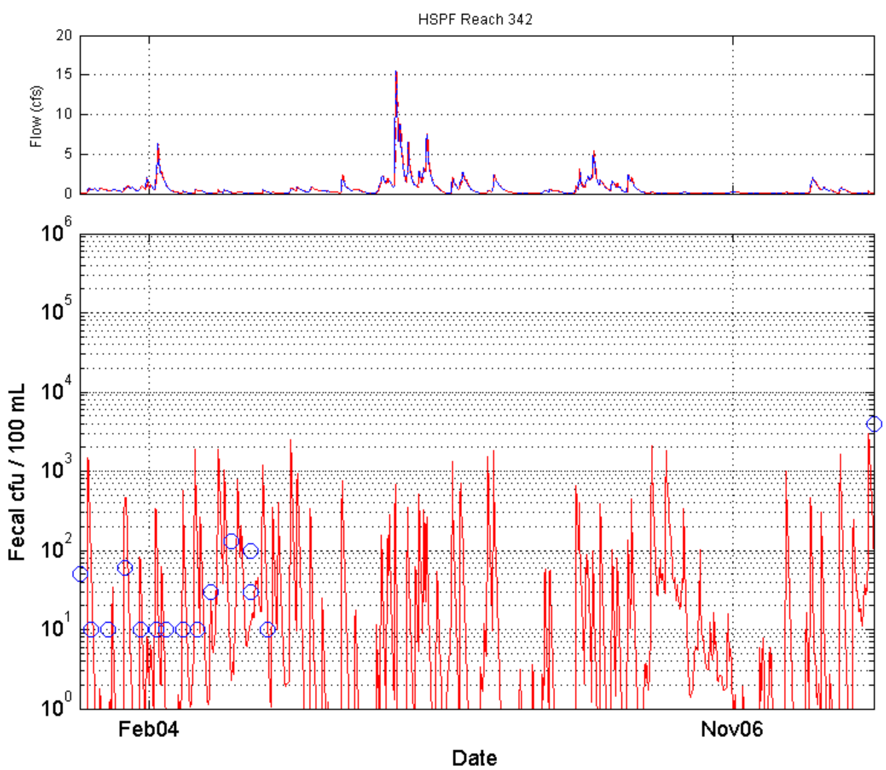

Figure 3-20. Daily Concentration Plot at Reach 342 (Pass Creek).

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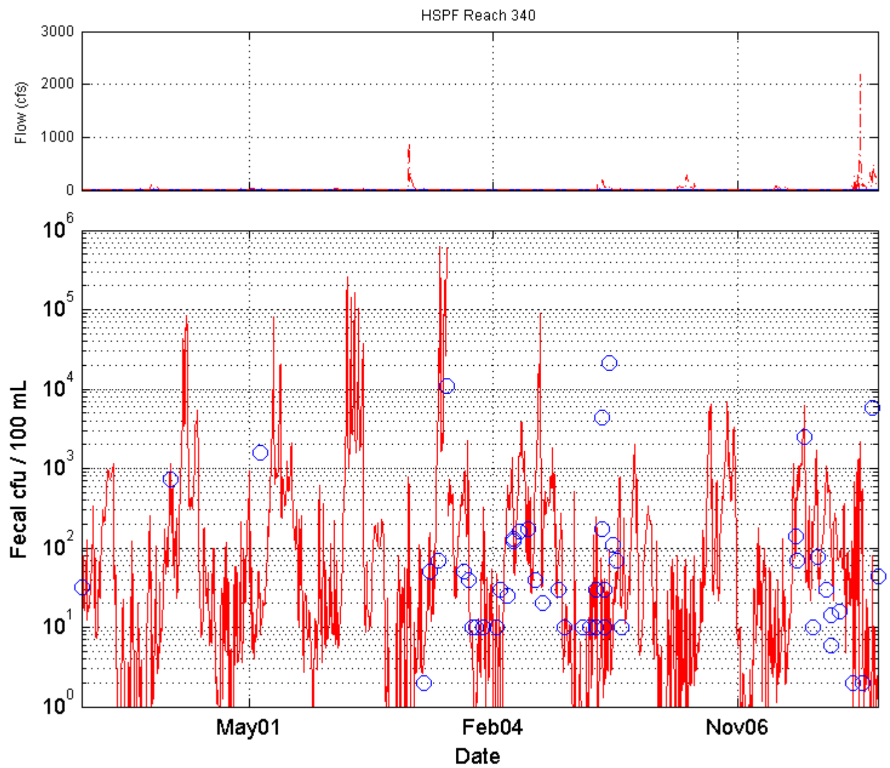

Figure 3-21. Daily Concentration Plot at Reach 340 (Beaver Creek Near Burdock).

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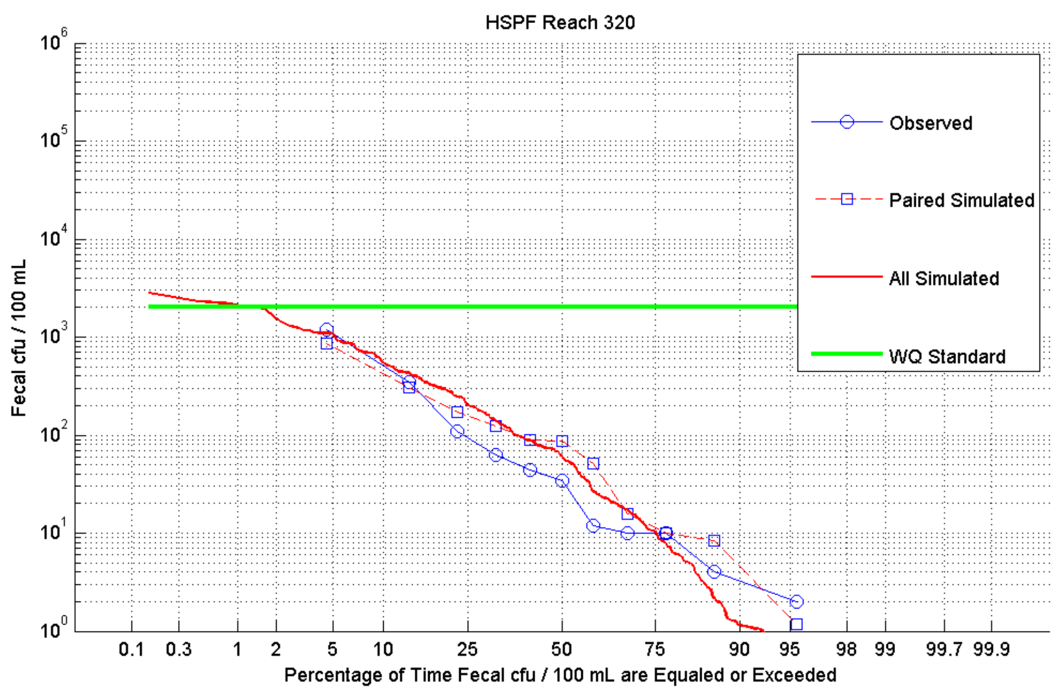

Figure 3-22. Concentration Duration Curve at Reach 320 (Beaver Creek Near Newcastle, WY).

RSI-1737-09-025

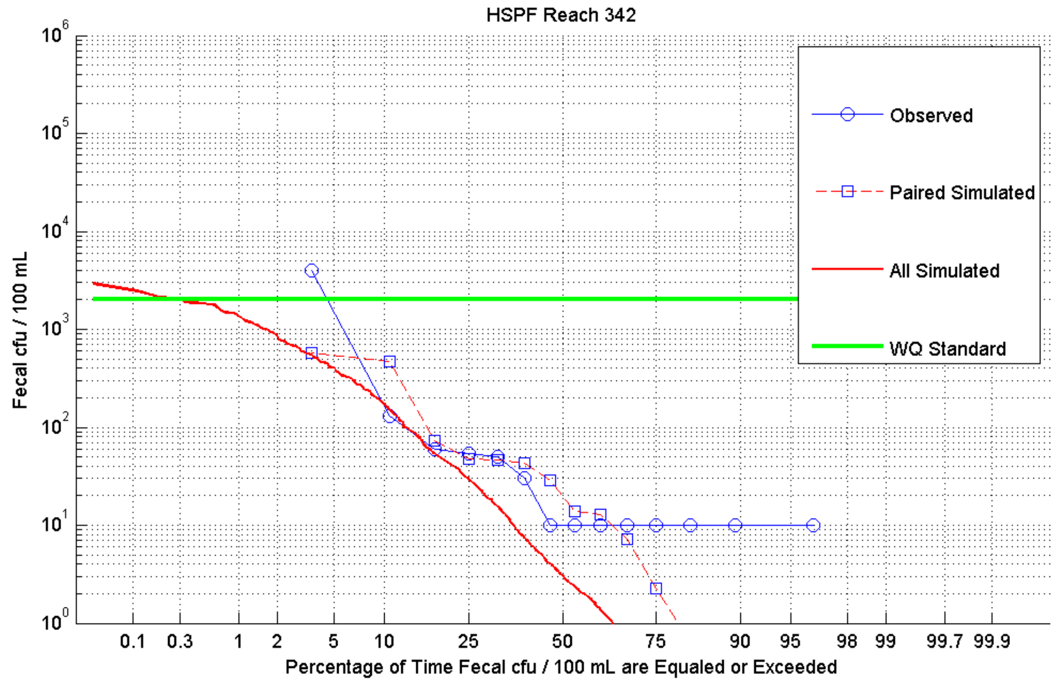

Figure 3-23. Concentration Duration Curve at Reach 342 (Pass Creek).

RSI-1737-09-026

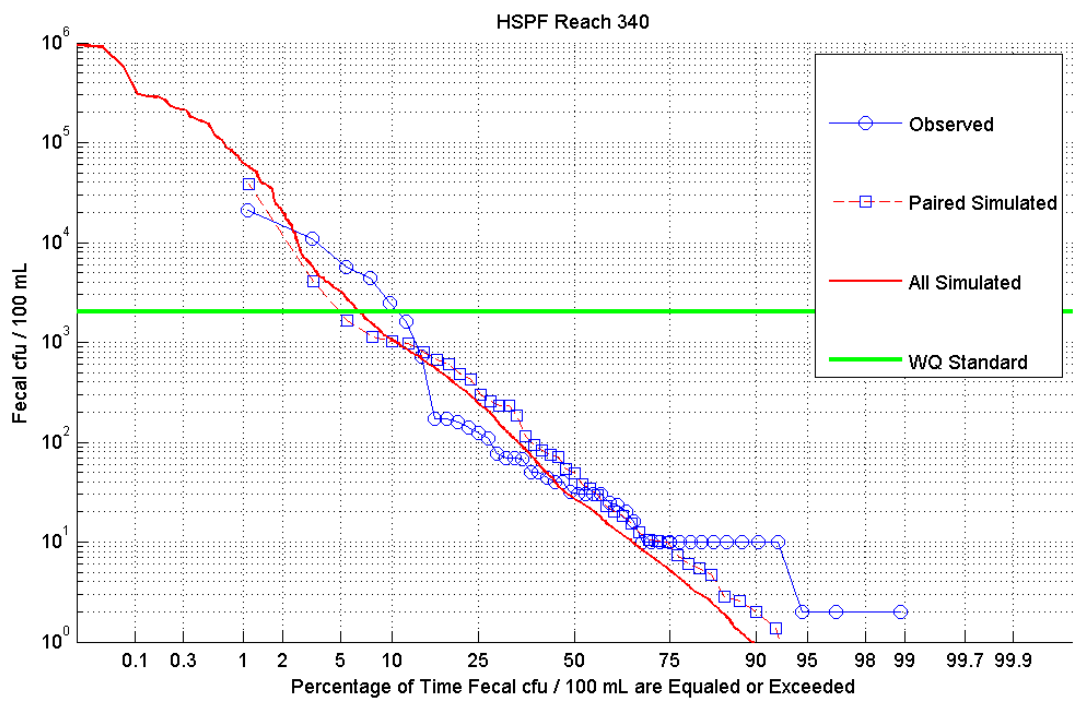

Figure 3-24. Concentration Duration Curve at Reach 340 (Beaver Creek Near Burdock).

time frame of the observed data and are represented with a solid red line. Because fecal coliform is highly variable on a daily basis, these plots are used to visually examine the overall trends in fecal concentrations during the calibration time period. The results show a very good model representation of the fecal coliform concentration trends that were observed in the field. Very little weight was placed on the lower limb of the curve because concentrations at or below the detection limit of 10 fecal colony-forming units (cfu)/100 milliliters (ml) are not considered reliable data points. Overall, the model performance of fecal coliform simulation was considered satisfactory and fully capable of modeling the fecal coliform trends in the Beaver Creek Watershed.

4.0 BEST MANAGEMENT PRACTICE APPROACH AND RESULTS

4.1 BEAVER CREEK FECAL COLIFORM

The following section reviews the approach and results of fecal coliform best management practices (BMPs) that were modeled for the Beaver Creek Watershed.

4.1.1 Overview

A suite of BMPs were chosen to assess the potential of reducing fecal coliform loadings to Beaver Creek. Four BMP scenarios were simulated to represent improved rangeland practices and reduction in direct source loadings based on discussions with SD DENR personnel. BMPs were applied only within the South Dakota areas of the multistate watershed. The BMP scenarios were applied to the existing baseline hydrology and fecal coliform model application that was calibrated previously. The four scenarios are cumulative scenarios allowing each scenario to build on each other to show the cumulative effects of implementing the BMPs. Impacts from individual BMPs can be found by subtracting previous BMP loading from the current cumulative BMP loading. The following sections will describe the four different scenarios simulated and the model application results and conclusions.

4.1.2 BMP Scenario Descriptions

Scenario 1: Wyoming Compliance with South Dakota Water-Quality Standard. Scenario 1 simulates the loadings at the Wyoming/South Dakota state line to be at or below the South Dakota single sample water-quality standard (2,000 org/100 ml). This scenario does not implement any specific BMPs for the land within Wyoming or South Dakota but, rather, compares the baseline water-quality concentration to the water-quality standard at the state line and uses the minimum of the two values. The minimum value is then entered as a time series into the reach downstream (Reach 335) of the Wyoming/South Dakota state line.

Scenario 2: Fix Failing Septic Systems. Scenario 2 builds on Scenario 1 and adds the effects of fixing failing septic systems within the South Dakota portions of the watershed that are considered direct source loadings into the reach. This was simulated by taking out the septic loads for reaches contained in the South Dakota portion of the Beaver Creek Watershed (Figure 4-1).

Scenario 3: Eliminate Direct Defecation by Cattle. Scenario 3 builds on Scenario 2 and also eliminates direct source loadings because of direct defecation by cattle in the South Dakota reaches. This scenario represents a combination of rangeland practices that limit access to the streams (e.g., fencing of riparian areas or offstream watering). To simulate this BMP, the direct source loadings of direct defecation were removed from South Dakota reaches in the Beaver Creek Watershed (Figure 4-1).

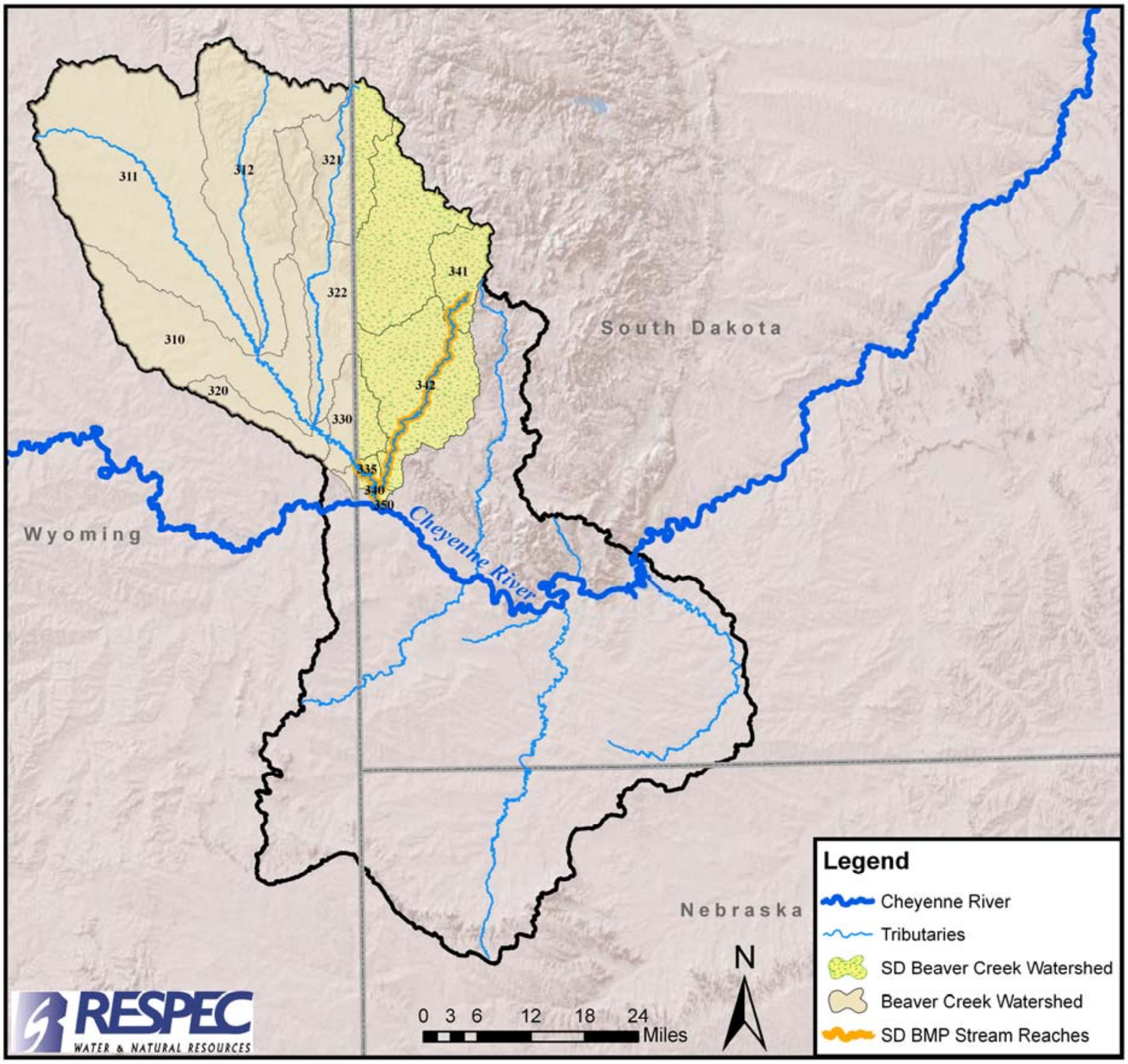

Figure 4-1. South Dakota Reaches With Direct Source BMPs Implemented.

Scenario 4: Rangeland Management. The last scenario simulated was rangeland management that builds upon the previous three scenarios. The objective of Scenario 4 is to reduce the indirect source loadings from rangeland by improving the overall pasture condition and thereby increasing infiltration and reducing runoff that carries bacteria to the stream. Scenario 3 reduces the direct loadings into the stream; whereas, Scenario 4 implements practices to reduce indirect source loadings caused by overland flow. Although the sources of the loadings from these two scenarios are different, the BMPs used can coincide, including riparian fencing and offstream watering. Riparian fencing keeps cattle out of the stream and riparian zones which reduces the direct source loadings and also improves the vegetative buffer which can then filter out bacteria coming from overland flow. A more defined BMP, often called controlled (managed) grazing, rotates cattle to and from different areas or pastures to reduce overgrazing. Managed grazing promotes healthy soil structure by reducing soil erosion and increasing infiltration rates which, in turn, increases forage quality and quantity available to livestock in both upland and riparian areas. This reduces bacteria (and sediment) transport because of overland flow and erosion. Controlled grazing can be practiced by using fencing, herding, and strategic placement of supplement blocks and water sources.

Although research has been done on the effectiveness of rangeland management BMPs, very few researchers have provided statistics on the percent reduction in bacteria because of these various practices. Effectiveness monitoring was primarily done through visual inspection and indirect measurements rather than direct concentration or load measurements. Scrimgeour and Kendall [2003] found that benthic organism monitoring signaled the onset of recovery after riparian fencing/buffers were practiced. Sheffield et al. [1997] found reductions of fecal coliform of 99 percent, 87 percent, and 57 percent between three different pastures studied. These reductions were attributed to controlled grazing practices which used strategic supplement block movement throughout the pasture and offstream watering. These practices reduced the amount of time cattle tended to be in or near the riparian zones and allowed recovery of root systems and vegetative cover within the riparian and upland areas.

Based on the literature review, an efficiency (reduction) factor of 87 percent was applied to fecal loadings originating in 131 square miles of rangeland located within the South Dakota portions of the Beaver Creek Watershed to simulate rangeland management practices being implemented (Figure 4-2). An efficiency factor within the model simply decreases the load by the specified factor. This type of application does not explicitly alter the vegetative cover or hydrologic properties. Rather, it assumes only a fraction of the total baseline fecal load will be transported by overland flow because of improved rangeland vegetative qualities. Properties pertaining to in-stream transport within the reaches will stay the same for the remaining load that is washed off the land surface. Altering individual model parameters to simulate BMP effects is possible but can be very challenging and subjective as there is currently very little to no literature or published research that estimates how individual model parameters are actually affected by implementing these BMPs. Therefore, using an efficiency factor was chosen to simplify and reduce the amount of assumptions and uncertainty in the model application.

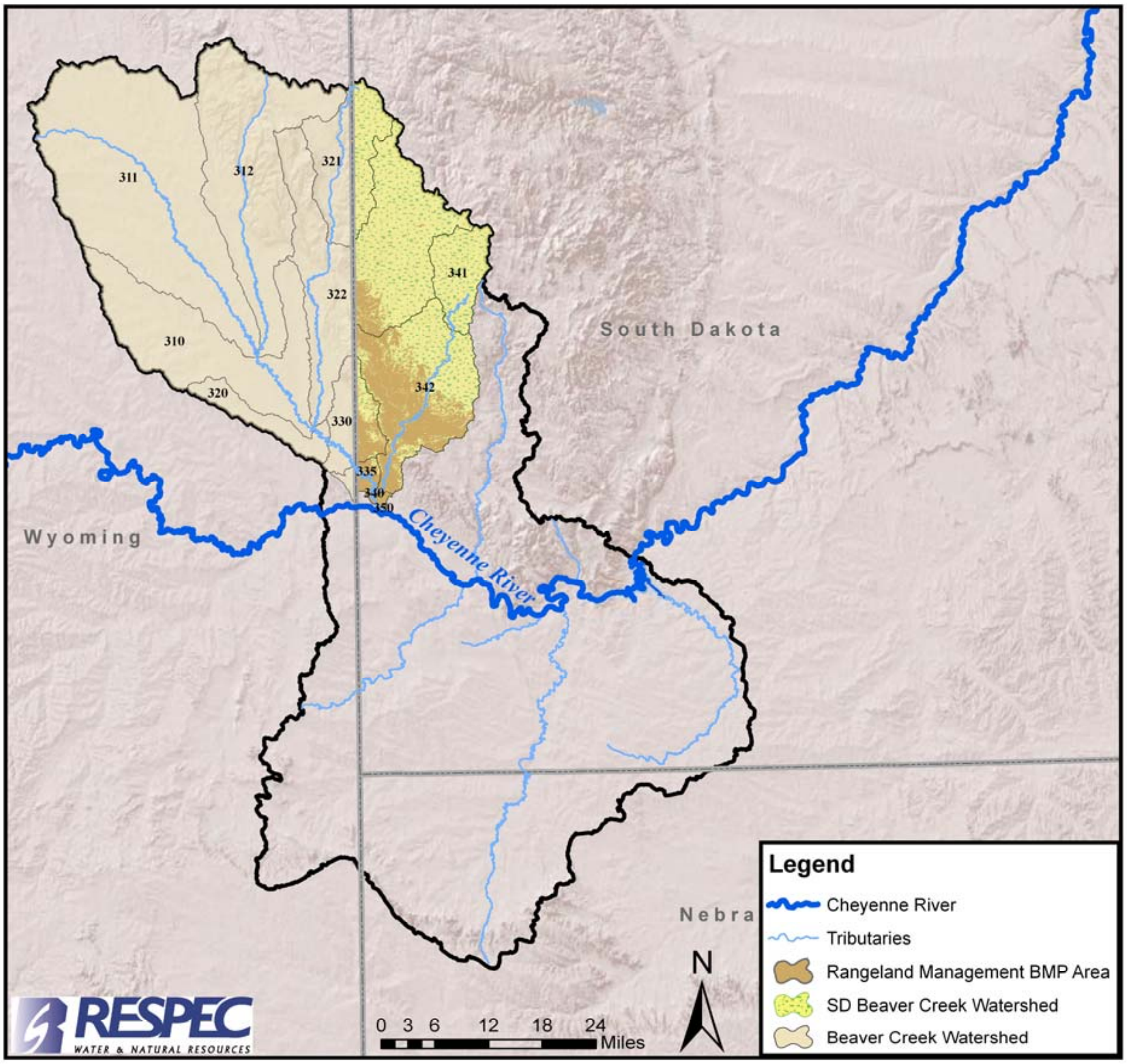

Figure 4-2. Area Where Rangeland Management BMPs Were Applied Within the South Dakota Portion of the Beaver Creek Watershed.

4.1.3 Model Application Results and Conclusions

The model results give an idea of how much the baseline fecal loadings can be reduced by implementing the previously described BMPs (Table 4-1). The results for each BMP scenario contain the cumulative results of the previously modeled scenarios. Therefore, to obtain the individual totals, the previous scenario's loading must be subtracted from the current cumulative loading.

The average recreation season reduction needed based on the current load and the TMDL load is approximately 50 percent. The model results support that this amount of reduction is possible through implementation of the four BMP scenarios. On average, the model predicted a 46 percent reduction in the annual average recreation season loads because of the cumulative effects of the BMP scenarios (Figure 4-3). Over the 18 years of simulation, the annual recreation season percent reduction ranged from a minimum of 31 percent to a maximum reduction of 68 percent. This trend was very similar when comparing between the wet years (1991–1998) and the dry years (1999–2008). The trend in the average annual recreation season loads attributed to the cumulative BMP effects is shown in Figure 4-4.

BMP scenarios varied in the extent of load reductions due to the individual BMP effects. Based on the model results, Scenario 2 had nearly no effect on the amount of load in the watershed. With this said, fixing failing septic systems (Scenario 2) may be beneficial to the environment, but it may not be the BMP with the highest cost-benefit ratio with regard to the amount of loading that it will reduce. This was expected as the septic system density is not very high in the area of study. Based on the model results, BMP scenarios that are most influential in reducing the fecal load are Scenario 3, which resulted in a 26 percent reduction in load, and Scenario 4, which resulted in a 15 percent reduction in load. It is important to acknowledge the similarities and differences between these two scenarios. Both scenarios deal with rangeland management, but the sources of loadings being addressed can vary. The individual effects of Scenario 3 only remove direct defecation loads from in-stream cattle defecation. Reducing these loads will have the most impact on the low flow regimes and will only affect the quality of the riparian zones. Individual effects of Scenario 4 improve the quality and cover of the overall vegetation in both riparian and upland areas by addressing positive rangeland management practices. This will result in reducing loadings from overland flow transport as well as direct defecation loads. Scenario 4 tends to have a greater effect on the high flow regime loads but can also reduce low flow loadings, depending on the degree of management that is implemented. In summary, Scenario 4 tends to be the BMP of choice as it can reduce both low and high flow loadings and will increase the overall vegetative qualities and cover of both upland and riparian areas.

Table 4-1. Summary of Load and Exceedance Reductions for BMP Scenarios

	Baseline	Scenario 1 (WY Compliance)	Scenario 2 (Remove Septic Loads)	Scenario 3 (Remove Direct Defecation)	Scenario 4 (Rangeland Management)
Beaver Creek- Reach 335					
Modeled % Exceedance (single sample)	10%	9%	9%	7%	7%
Cumulative Avg. Annual Rec. Season Load (10^6 cfu/yr)	1,961,295	1,888,288	1,888,287	1,287,812	1,233,507
Individual BMP Load Reduction (10^6 cfu/yr)	--	73,007	0.5	600,476	54,304
Individual BMP Percent Reduction	--	4%	0%	31%	3%
Cumulative BMP Percent Reduction	--	4%	4%	34%	37%
Beaver Creek- Reach 340					
Modeled % Exceedance (single sample)	9%	9%	9%	4%	4%
Cumulative Avg. Annual Rec. Season Load (10^6 cfu/yr)	2,278,851	2,205,871	2,205,870	1,612,022	1,251,629
Individual BMP Load Reduction (10^6 cfu/yr)	--	72,980	1	593,848	360,393
Individual BMP Percent Reduction	--	3%	0%	30%	16%
Cumulative BMP Percent Reduction	--	3%	3%	33%	49%
Pass Creek- Reach 341					
Modeled % Exceedance (single sample)	0%	0%	0%	0%	0%
Cumulative Avg. Annual Rec. Season Load (10^6 cfu/yr)	378	378	378	285	285
Individual BMP Load Reduction (10^6 cfu/yr)	--	0	0	92	0
Individual BMP Percent Reduction	--	0%	0%	24%	0%
Cumulative BMP Percent Reduction	--	0%	0%	24%	24%
Pass Creek- Reach 342					
Modeled % Exceedance (single sample)	0%	0%	0%	0%	0%
Cumulative Avg. Annual Rec. Season Load (10^6 cfu/yr)	369,920	369,920	369,920	369,653	51,475
Individual BMP Load Reduction (10^6 cfu/yr)	--	0	0	267	318,178
Individual BMP Percent Reduction	--	0%	0%	0%	86%
Cumulative BMP Percent Reduction	--	0%	0%	0%	86%
Beaver Creek - Reach 350 (TMDL Endpoint)					
Modeled % Exceedance (single sample)	9%	9%	9%	4%	4%
Cumulative Avg. Annual Rec. Season Load (10^6 cfu/yr)	1,903,042	1,830,348	1,830,347	1,314,866	1,030,358
Individual BMP Load Reduction (10^6 cfu/yr)	--	72,694	0.5	515,482	284,508
Individual BMP Percent Reduction	--	4%	0%	28%	15%
Cumulative BMP Percent Reduction	--	4%	4%	31%	46%

* Modeled Percent Exceedance represents the percent of samples that exceeded the single sample concentration of 2,000 cfu/100 ml based on the results of the HSPF model application.

**Individual Load Reduction is the reduction in average annual load from 1991-2008 that corresponds to a single BMP (not cumulative BMP effects).

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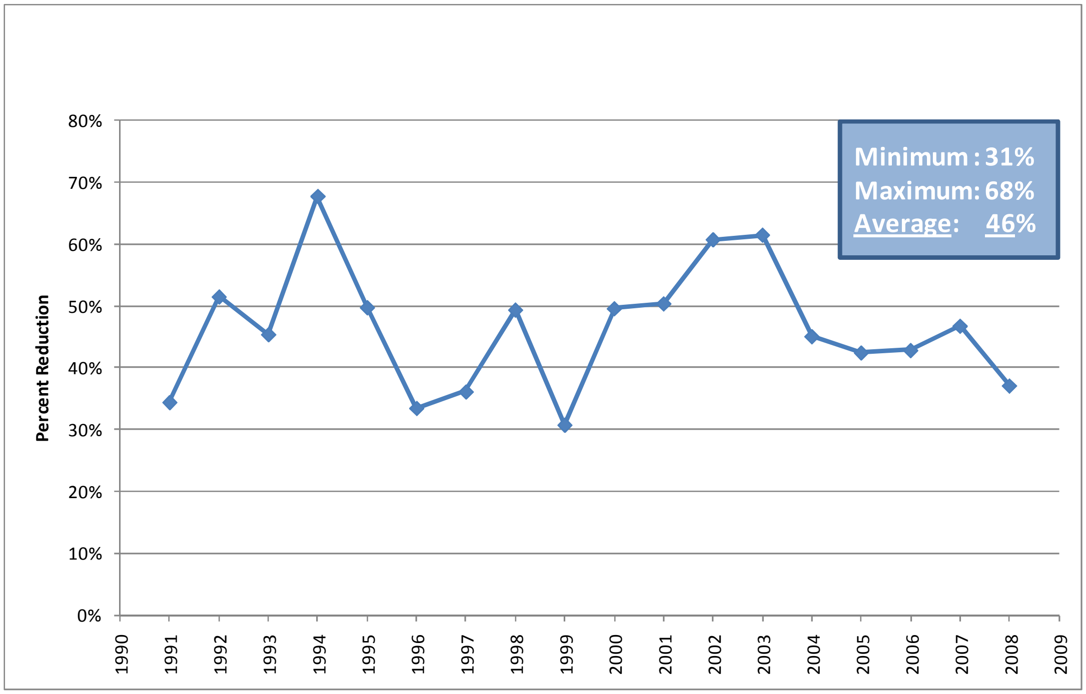

Figure 4-3. Percent Reductions of Annual Recreation Season Loads Because of Cumulative Effects of Implementing all Four Best Management Practices.

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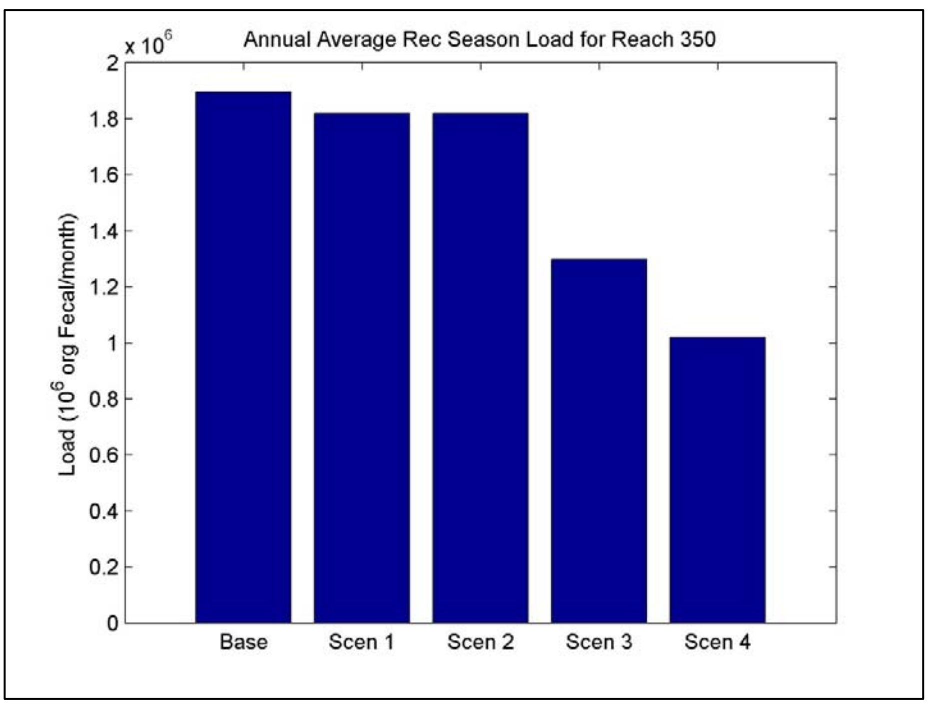

Figure 4-4. Average Annual Recreation Season Loads Attributed to the Cumulative BMP Effects at the Beaver Creek TMDL Endpoint.

5.0 DELIVERABLE DOCUMENTS

5.1 HYDROLOGY AND BASELINE FECAL COLIFORM

The deliverables for the project are described below. The current deliverable products include the model results from the existing conditions without best management practice (BMP) scenarios applied. All deliverable documents are referenced to Appendix A located on the Cheyenne River TMDL Sharepoint site and found on a cd in Appendix A of this report.

1. ***Upper Cheyenne River Watershed Model.*** The watershed model application developed during the model development, calibration, and verification phase is provided. All files necessary to run the model using the DOS or Windows executables (i.e., **WinHSPF** or **WinHSPF Lite**) are included. The application files include:

    - UCI. The **HSPF** Users Control Input (UCI) file contains all of the input to **HSPF** except the time-series data contained in the WDM file. The UCI file contains the options, parameters, watershed characterization data, and information to control the interaction with the WDM file (i.e., the datasets for input and output time-series data).

    - WDM. This is the repository for **HSPF**'s time-series data and includes all data used to run the model and used in performing the calibration/validation (i.e., data and model results).

2. ***BIT Spreadsheet.*** The **BIT** spreadsheet used to identify initial estimates of source loadings is provided. In addition to the original **BIT** spreadsheet, a worksheet called "Percent Reductions" was added to describe the percent reduction from the original **BIT** load estimates that were made to the direct source loadings as well as the MFACT or multiplication factor that was entered into the **HSPF** model application. The MFACT takes into account the percent of area of each subwatershed within the BIT spreadsheet categories. Reduction factors were only specified for the Beaver Creek subwatersheds since they were the only subwatersheds in the Upper Cheyenne River Watershed that were calibrated for fecal coliform.

3. ***Geodatabase.*** A geodatabase has been provided in Appendix A that contains a variety of spatial and tabular data that has been linked through relationship classes. Metadata is provided for all attributes within the geodatabase.

    - Spatial Data. There are four spatial layers included: the subwatershed endpoints, streams/reaches, subwatersheds for the entire Upper Cheyenne River Watershed and the landuse categories used for the model application. The attribute called "ReachID" identifies the reach number assigned within the **HSPF** model. Attributes of the spatial data are further described within the metadata of each file.

- Tabular Data. Four tables were included within the geodatabase. The table named "Average Daily Baseline Conditions" contains the average daily observed and simulated flow (cfs), average daily total fecal concentrations (cfu/100 ml), and total daily loads (10^6 cfu/day) on a daily basis at each subwatershed for the entire calibration period. Observed flow was very limited within the Beaver Creek Watershed. When observed flow was not available, a value of –9999 was placed in the attribute field. Within the fecal coliform concentration attributes, an empty cell represents times when the model simulated no flow and, therefore, a fecal coliform concentration was undefined. Four more attributes were added to describe estimates of the loads and concentrations contributed from Wyoming and South Dakota. Obtaining model results directly for each state is nearly impossible since this is a very complex system which relies on flow and loadings from both states. Each state's contribution of flow affects the hydrology and hydraulics of the system. For this reason, a combination of modeled results and calculated ratios was used to divide the total loading into estimated individual state loadings. Wyoming loads (10^6 cfu/day) were obtained by running the model application without any loadings from South Dakota. South Dakota loadings were calculated by subtracting the Wyoming loads from the total loads on a daily basis. To obtain estimates of the respective states daily concentrations, the total concentration was multiplied by the ratio of the individual state loads to the total loads on a daily basis (Equation 4-1).

$$C_{State} = \frac{L_{State}}{L_{Total}} \times C_{Total} \qquad (4\text{-}1)$$

where:

C_{State} = Calculated concentration contributed from the respective state (cfu/100 ml)

L_{State} = Load contributed from the respective state (10^6 cfu/day)

C_{Total} = Concentration contributed from South Dakota and Wyoming (cfu/100 ml)

L_{Total} = Load contributed from South Dakota and Wyoming (10^6 cfu/day).

The table named "Baseline Summary Table" contains the median daily observed and simulated flow (cfs), the median daily fecal concentrations (cfu/100 ml), and the median daily fecal loads (cfu/100 ml) on a yearly basis at each subwatershed for the entire calibration period. The data are provided for the entire contributing watershed (total) and are further separated Wyoming and South Dakota estimates based on the calculated loads and concentrations. When observed flow was not available, a value of

–9999 was placed in the attribute field. Within the fecal coliform concentration attributes, an empty cell represents times when the model simulated no flow and, therefore, a fecal coliform concentration was undefined.

The table named "Load Contribution Table" contains the cumulative average monthly loads (10^6 cfu/month) derived from all upstream subwatersheds. Loads provided in the table are divided into loadings coming from the Wyoming contributing area, loads coming from the South Dakota contributing area, as well as the total load from both Wyoming and South Dakota. The loads are divided into nine different sources of direct and indirect runoff. Indirect sources include washoff from urban, forest, cropland, rangeland, barren, recharge, and effective impervious area (EIA). Direct sources include septic loads and direct defecation by cattle loads. Each source is labeled with a unique "SourceID" which corresponds to a particular source. Note that this is a cumulative loading from all of the upstream subwatersheds and does not take into account decay that can occur during in-stream transport.

The final table named "Percent Contribution Table" contains the percent contribution represented by the loading from the "Load Contributions Table." This table also breaks the percent loads by source and location (South Dakota, Wyoming, and total). Values were calculated by taking the average monthly load from a particular source and dividing it by the total average monthly load contributed by all of the sources.

4. ***Source Contributions Spreadsheet.*** A spreadsheet containing the average monthly loadings by source is provided. This spreadsheet contains the same data as the geodatabase with addition of two pie charts for each reach showing the total percent contribution from South Dakota and Wyoming during the recreation season (defined as May 1 through September 30) and the percent contribution by source during the recreation season.

6.0 REFERENCES

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APPENDIX A

DELIVERABLE DOCUMENTS

LOCATED ON THE ATTACHED CD AND ON THE WORLD WIDE WEB AT HTTPS://CONNECT.PODASSOC.COM/CHEYENNE RIVER TMDL

BIT Spreadsheet
Fecal Results
Fecal_Source_Contributions
UCHMET
UCRWM_Base_Fecal

EPA REGION VIII TMDL REVIEW

TMDL Document Info:

Document Name:	**Fecal Coliform Bacteria Total Maximum Daily Load (TMDL) for Beaver Creek, Fall River County, South Dakota**
Submitted by:	**Cheryl Saunders, SD DENR**
Date Received:	**October 6, 2009**
Review Date:	**November 3, 2009**
Reviewer:	**Vern Berry, EPA**
Rough Draft / Public Notice / Final?	**Public Notice Draft**
Notes:	

Reviewers Final Recommendation(s) to EPA Administrator (used for final review only):

- ☐ Approve
- ☐ Partial Approval
- ☐ Disapprove
- ☐ Insufficient Information

Approval Notes to Administrator:

This document provides a standard format for EPA Region 8 to provide comments to state TMDL programs on TMDL documents submitted to EPA for either formal or informal review. All TMDL documents are evaluated against the minimum submission requirements and TMDL elements identified in the following 8 sections:

1. Problem Description
   1.1. .TMDL Document Submittal Letter
   1.2. Identification of the Waterbody, Impairments, and Study Boundaries
   1.3. Water Quality Standards
2. Water Quality Target
3. Pollutant Source Analysis
4. TMDL Technical Analysis
   4.1. Data Set Description
   4.2. Waste Load Allocations (WLA)
   4.3. Load Allocations (LA)
   4.4. Margin of Safety (MOS)
   4.5. Seasonality and variations in assimilative capacity
5. Public Participation
6. Monitoring Strategy
7. Restoration Strategy
8. Daily Loading Expression

Under Section 303(d) of the Clean Water Act, waterbodies that are not attaining one or more water quality standard (WQS) are considered "impaired." When the cause of the impairment is determined to be a pollutant, a TMDL analysis is required to assess the appropriate maximum allowable pollutant loading rate. A TMDL document consists of a technical analysis conducted to: (1) assess the maximum pollutant loading rate that a waterbody is able to assimilate while maintaining water quality standards; and (2) allocate that assimilative capacity among the known sources of that pollutant**.** A well written TMDL document will describe a path forward that may be used by those who implement the TMDL recommendations to attain and maintain WQS.

Each of the following eight sections describes the factors that EPA Region 8 staff considers when reviewing TMDL documents. Also included in each section is a list of EPA's minimum submission requirements relative to that section, a brief summary of the EPA reviewer's findings, and the reviewer's comments and/or suggestions. Use of the verb "must" in the minimum submission requirements denotes information that is required to be submitted because it relates to elements of the TMDL required by the CWA and by regulation. Use of the term "should" below denotes information that is generally necessary for EPA to determine if a submitted TMDL is approvable.

This review template is intended to ensure compliance with the Clean Water Act and that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Problem Description

A TMDL document needs to provide a clear explanation of the problem it is intended to address. Included in that description should be a definitive portrayal of the physical boundaries to which the TMDL applies, as well as a clear description of the impairments that the TMDL intends to address and the associated pollutant(s) causing those impairments. While the existence of one or more impairment and stressor may be known, it is important that a comprehensive evaluation of the water quality be conducted prior to development of the TMDL to ensure that all water quality problems and associated stressors are identified. Typically, this step is conducted prior to the 303(d) listing of a waterbody through the monitoring and assessment program. The designated uses and water quality criteria for the waterbody should be examined against available data to provide an evaluation of the water quality relative to all applicable water quality standards. If, as part of this exercise, additional WQS problems are discovered and additional stressor pollutants are identified, consideration should be given to concurrently evaluating TMDLs for those additional pollutants. If it is determined that insufficient data is available to make such an evaluation, this should be noted in the TMDL document.

1.1 TMDL Document Submittal Letter

When a TMDL document is submitted to EPA requesting formal comments or a final review and approval, the submittal package should include a letter identifying the document being submitted and the purpose of the submission.

Minimum Submission Requirements.

☒ A TMDL submittal letter should be included with each TMDL document submitted to EPA requesting a formal review.

☒ The submittal letter should specify whether the TMDL document is being submitted for initial review and comments, public review and comments, or final review and approval.

☐ Each TMDL document submitted to EPA for final review and approval should be accompanied by a submittal letter that explicitly states that the submittal is a final TMDL submitted under Section 303(d) of the Clean Water Act for EPA review and approval. This clearly establishes the State's/Tribe's intent to submit, and EPA's duty to review, the TMDL under the statute**.** The submittal letter should contain such identifying information as the name and location of the waterbody and the pollutant(s) of concern, which matches similar identifying information in the TMDL document for which a review is being requested.

Recommendation:

☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The public notice draft Beaver Creek fecal coliform TMDL was submitted to EPA for review during the public notice period via an email from Cheryl Saunders, SD DENR on 10/06/2009. The email included the draft TMDL document and a public notice announcement requesting review and comment.

COMMENTS: None

1.2 Identification of the Waterbody, Impairments, and Study Boundaries

The TMDL document should provide an unambiguous description of the waterbody to which the TMDL is intended to apply and the impairments the TMDL is intended to address. The document should also clearly delineate the physical boundaries of the waterbody and the geographical extent of the watershed area studied. Any additional information needed to tie the TMDL document back to a current 303(d) listing should also be included.

Minimum Submission Requirements:

☒ The TMDL document should clearly identify the pollutant and waterbody segment(s) for which the TMDL is being established. If the TMDL document is submitted to fulfill a TMDL development requirement for a waterbody on the state's current EPA approved 303(d) list, the TMDL document submittal should clearly identify the waterbody and associated impairment(s) as they appear on the State's/Tribe's current EPA approved 303(d) list, including a full waterbody description, assessment unit/waterbody ID, and the priority ranking of the waterbody. This information is necessary to ensure that the administrative record and the national TMDL tracking database properly link the TMDL document to the 303(d) listed waterbody and impairment(s).

☒ One or more maps should be included in the TMDL document showing the general location of the waterbody and, to the maximum extent practical, any other features necessary and/or relevant to the understanding of the TMDL analysis, including but not limited to: watershed boundaries, locations of major pollutant sources, major tributaries included in the analysis, location of sampling points, location of discharge gauges, land use patterns, and the location of nearby waterbodies used to provide surrogate information or reference conditions. Clear and concise descriptions of all key features and their relationship to the waterbody and water quality data should be provided for all key and/or relevant features not represented on the map

☐ If information is available, the waterbody segment to which the TMDL applies should be identified/geo-referenced using the National Hydrography Dataset (NHD). If the boundaries of the TMDL do not correspond to the Waterbody ID(s) (WBID), Entity_ID information or reach code (RCH_Code) information should be provided. If NHD data is not available for the waterbody, an alternative geographical referencing system that unambiguously identifies the physical boundaries to which the TMDL applies may be substituted.

Recommendation:
☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: Beaver Creek is a medium sized stream located in Fall River County, South Dakota and is a tributary of the Cheyenne River in the Beaver sub-basin (HUC 10120107). Beaver Creek has a total drainage area of 1670 square miles (4,325 square km). The SD 303(d) listed segment of Beaver Creek includes 15.5 miles (25 km) of the creek from the Wyoming border to the mouth (i.e., confluence with Cheyenne River; SD-CH-R-BEAVER_01). It is listed as a lower priority for TMDL development.

South Dakota's designated uses for Beaver Creek include warmwater semi-permanent fish life propagation waters, limited-contract recreation waters, fish and wildlife propagation, recreation, and stock watering, and irrigation. South Dakota DENR's 2008 303(d) list shows Beaver Creek as impaired for fecal coliform bacteria which is impairing the limited contact recreation uses, for specific conductance and total dissolved solids (TDS) which are impairing the fish and wildlife propagation, recreation and stock watering uses, and for specific conductance and salinity which are impairing the irrigation uses. The specific conductance, TDS and salinity impairments in this segment will be addressed by SD DENR in a separate TMDL document.

COMMENTS: Because this is a trans-boundary or multijurisdictional TMDL, we recommend that the Problem Identification section include a brief description of the list status of Beaver Creek in WY – at least for the segment immediately upstream of the WY/SD border.

SD DENR RESPONSE: The following language was added to Section 1.2 of the TMDL on pg. 4: "Beaver Creek is not a listed as an impaired waterbody in Wyoming's most current 303(d) list."

1.3 Water Quality Standards

TMDL documents should provide a complete description of the water quality standards for the waterbodies addressed, including a listing of the designated uses and an indication of whether the uses are being met, not being met, or not assessed. If a designated use was not assessed as part of the TMDL analysis (or not otherwise recently assessed), the documents should provide a reason for the lack of assessment (e.g., sufficient data was not available at this time to assess whether or not this designated use was being met).

Water quality criteria (WQC) are established as a component of water quality standard at levels considered necessary to protect the designated uses assigned to that waterbody. WQC identify quantifiable targets and/or qualitative water quality goals which, if attained and maintained, are intended to ensure that the designated uses for the waterbody are protected. TMDLs result in maintaining and attaining water quality standards by determining the appropriate maximum pollutant loading rate to meet water quality criteria, either directly, or through a surrogate measurable target. The TMDL document should include a description of all applicable water quality criteria for the impaired designated uses and address whether or not the criteria are being attained, not attained, or not evaluated as part of the analysis. If the criteria were not evaluated as part of the analysis, a reason should be cited (e.g. insufficient data were available to determine if this water quality criterion is being attained).

Minimum Submission Requirements:

☒ The TMDL must include a description of the applicable State/Tribal water quality standard, including the designated use(s) of the waterbody, the applicable numeric or narrative water quality criterion, and the anti-degradation policy. (40 C.F.R. §130.7(c)(1)).

☒ The purpose of a TMDL analysis is to determine the assimilative capacity of the waterbody that corresponds to the existing water quality standards for that waterbody, and to allocate that assimilative capacity between the significant sources. Therefore, <u>all TMDL documents must be written to meet the existing water quality standards</u> for that waterbody (CWA §303(d)(1)(C)).

Note: In some circumstances, the load reductions determined to be necessary by the TMDL analysis may prove to be infeasible and may possibly indicate that the existing water quality standards and/or assessment methodologies may be erroneous. However, the TMDL must still be determined based on existing water quality standards. Adjustments to water quality standards and/or assessment methodologies may be evaluated separately, from the TMDL.

☒ The TMDL document should describe the relationship between the pollutant of concern and the water quality standard the pollutant load is intended to meet. This information is necessary for EPA to evaluate whether or not attainment of the prescribed pollutant loadings will result in attainment of the water quality standard in question.

☒ If a standard includes multiple criteria for the pollutant of concern, the document should demonstrate that the TMDL value will result in attainment of all related criteria for the pollutant. For example, both acute and chronic values (if present in the WQS) should be addressed in the document, including consideration of magnitude, frequency and duration requirements.

Recommendation:
☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Beaver Creek segment addressed by this TMDL is impaired based on fecal coliform concentrations for limited contact recreation. South Dakota has applicable numeric standards for fecal coliform that may be applied to this stream segment. The numeric standards being implemented in this TMDL are: a daily maximum value of fecal coliform of 2000 CFU/100 mL in any one sample, or a maximum geometric mean of 1000 CFU/100 mL based on a minimum of 5 samples obtained during separate 24-hour periods for any 30-day period from May through September. Discussion of additional applicable water quality standards for Beaver Creek can be found on pages 5 - 7 of the TMDL document.

COMMENTS: As a multijurisdictional TMDL that addresses pollutant loadings from two states (SD and WY), there should be recognition and discussion of the WQS on both sides of the border. The Water Quality Standards section of the TMDL should include a listing or discussion of the applicable WY standards including any numeric or narrative standards that relate to bacteria.

Also, the document (i.e., TMDL Allocations section) seems to imply that the chronic, 30-day average standard is not applicable to the impaired stream segment because too few samples were collected. The applicability of the chronic criterion is independent of the specific number of field samples taken prior to development of the TMDL. If too few samples were collected, then DENR may not be able to make a valid determination of whether the criterion was met during those periods, but the chronic criterion would still apply. In this case, both the chronic and acute criteria are applicable to the impaired segment of Beaver Creek, independent of whether sufficient sampling occurred to make a determination as to whether the chronic criterion was met.

SD DENR RESPONSE: To address the comment regarding the need for a discussion of the water quality standards on both sides of the state border, the following language was added to Water Quality Standards and Numeric Water Quality Targets section of the TMDL document on pg 6: "In Wyoming, Beaver Creek is classified as a "2ABww" water, which indicates that the stream is a primary recreation water that supports warm water game fish. During the designated summer recreation season (May 1 through September 30), all Wyoming waters designated for primary contact recreation shall not exceed a geometric mean of 126 organisms per 100 milliliters of *E. coli* bacteria based on a minimum of not less than 5 samples obtained during separate 24 hour periods for any 30-day period. Sufficient data were not available to determine compliance with this criterion. Wyoming surface water quality standards also include a single-sample maxima *E. coli* criterion for primary recreation waters; however, the standards state that "an exceedence of the single-sample maxima shall not be cause for listing a water body on the State 303(d) list or development of a TMDL or watershed plan." (http://soswy.state.wy.us/Rules/RULES/6547.pdf)

SD DENR recognizes that both the acute and the chronic criteria within SD Surface Water Quality Standards are applicable to the impaired reach of Beaver Creek. However, SD DENR was not able to determine compliance with the chronic criterion based on sample data alone. However, the following statement was added to Section 2.0 of the TMDL document on pg. 13, "Since only one or two water samples were collected during any 30-day period, compliance with the geometric mean criterion was evaluated using the HSPF model-predicted, daily concentrations." To address EPA's concern regarding compliance with all applicable criteria, the TMDL was revised and is now based on both the acute and chronic criteria to ensure that all applicable criteria are met. This change was determined to be warranted when comparing the monthly average model-predicted daily concentrations to the chronic criterion, as the monthly geometric mean concentrations were occasionally higher than the chronic criterion, particularly during low flow periods. Results of the load duration curve analysis indicate that the low flow zone (i.e. 0 – 0.5 cfs) requires a greater load reduction based on the chronic criterion compared to the acute criterion. Conversely, the remaining flow zones (i.e. 0.5 – 834 cfs) require greater load reductions based on the daily maximum criteria compared to the chronic criterion.

2. Water Quality Targets

TMDL analyses establish numeric targets that are used to determine whether water quality standards are being achieved. Quantified water quality targets or endpoints should be provided to evaluate each listed pollutant/water body combination addressed by the TMDL, and should represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the water quality target. For pollutants with narrative standards, the narrative standard should be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include a variety of targets representing water column sediment such as TSS, embeddeness, stream morphology, up-slope conditions and a measure of biota).

Minimum Submission Requirements:

☒ The TMDL should identify a numeric water quality target(s) for each waterbody pollutant combination. The TMDL target is a quantitative value used to measure whether or not the applicable water quality standard is attained.

Generally, the pollutant of concern and the numeric water quality target are, respectively, the chemical causing the impairment and the numeric criteria for that chemical (e.g., chromium) contained in the water quality standard. Occasionally, the pollutant of concern is different from the parameter that is the subject of the numeric water quality target (e.g., when the pollutant of concern is phosphorus and the numeric water quality target is expressed as a numerical dissolved oxygen criterion). In such cases, the TMDL should explain the linkage between the pollutant(s) of concern, and express the quantitative relationship between the TMDL target and pollutant of concern. In all cases, TMDL targets must represent the attainment of current water quality standards.

☐ When a numeric TMDL target is established to ensure the attainment of a narrative water quality criterion, the numeric target, the methodology used to determine the numeric target, and the link between the pollutant of concern and the narrative water quality criterion should all be described in the TMDL document. Any additional information supporting the numeric target and linkage should also be included in the document.

Recommendation:
☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The water quality targets for this TMDL are based on SD's numeric water quality standards for fecal coliform bacteria based on the limited contact recreational beneficial use for Beaver Creek. The fecal coliform daily maximum value is ≤ 2000 CFU/100 mL in any one sample, and the maximum geometric mean is ≤ 1000 CFU/100 mL for 5 samples over a 30 day period. Both criteria are applicable from May 1st through September 30th.

COMMENTS: The TMDL water quality target from page 6 of the TMDL document is based on the daily maximum fecal coliform criterion for limited contact recreational use (i.e., ≤ 2000 cfu/100mL). However, the TMDL summary on page 1 of the document also lists the 30-day geometric mean of ≤ 1000 cfu/100mL as the target for the TMDL. The TMDL must address both the acute and chronic WQS if they exist for a given pollutant. Typically, both values are used as targets in the TMDL, but you may choose to use one criterion in the load duration curve analysis (or modeling) to derive the applicable loading capacities and reductions needed to meet the standards. This should be accompanied by a demonstration that the other criterion will also be protected by this approach.

Page 12 mentions that the daily maximum fecal coliform standard was used as the target for this TMDL because the observed fecal coliform loads do not appear to exceed the geometric mean criterion as demonstrated in Table 5 of the document. This reasoning seems appropriate; however, the values shown in Table 5 do not appear to match the data collected as part of the watershed assessment. First, the title of Table

5 cites a geometric mean criterion of 200 cfu/100 mL, whereas for Beaver Creek the chronic criterion is 1000 cfu/100 mL. Second, the number of samples in each flow zone and the corresponding geometric mean values do not appear to reflect the data points plotted on the LDC in Figure 3. Therefore, it is not clear if the use of the daily maximum standard as the TMDL target will ensure that the 30-day average standard will be met.

Also, for multijurisdictional TMDLs the standards on both sides of the border should be compared to one another, and the most stringent WQSs should be used as the targets for the TMDL. This type of comparison should be included in the Beaver Creek TMDL document.

SD DENR RESPONSE: As described above, the TMDL is now based on both the chronic and acute criteria to ensure compliance with all applicable bacteria standards. Table 5 from the previous draft TMDL document, listing the geometric mean concentrations by flow zone, was removed from the TMDL document.

The impaired segment of Beaver Creek is located downstream of the Wyoming portion of the stream. Water quality data collected in South Dakota was compared to the South Dakota water quality standards to identify the stream impairment. Thus, the TMDL is based on the most stringent South Dakota water quality standards. SD DENR recognizes that Wyoming has more stringent bacteria criteria; the geometric mean criterion for *E. coli* are 126 cfu/100ml and 630 cfu/100ml in Wyoming and South Dakota, respectively. However, once Beaver Creek crosses the SD/WY border, the applicable South Dakota standards must be met, regardless of whether Wyoming criteria or more or less stringent.

3. Pollutant Source Analysis

A TMDL analysis is conducted when a pollutant load is known or suspected to be exceeding the loading capacity of the waterbody. Logically then, a TMDL analysis should consider all sources of the pollutant of concern in some manner. The detail provided in the source assessment step drives the rigor of the pollutant load allocation. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each significant source (or source category) when the relative load contribution from each source has been estimated. Therefore, the pollutant load from each significant source (or source category) should be identified and quantified to the maximum practical extent. This may be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach may be appropriate. The approach should be clearly defined in the document.

Minimum Submission Requirements:

☒ The TMDL should include an identification of all potentially significant point and nonpoint sources of the pollutant of concern, including the geographical location of the source(s) and the quantity of the loading, e.g., lbs/per day. This information is necessary for EPA to evaluate the WLA, LA and MOS components of the TMDL.

☒ The level of detail provided in the source assessment should be commensurate with the nature of the watershed and the nature of the pollutant being studied. Where it is possible to separate natural background from nonpoint sources, the TMDL should include a description of both the natural background loads and the nonpoint source loads.

☒ Natural background loads should not be assumed to be the difference between the sum of known and quantified anthropogenic sources and the existing *in situ* loads (e.g. measured in stream) unless it can be demonstrated that all significant anthropogenic sources of the pollutant of concern have been identified, characterized, and properly quantified.

☒ The sampling data relied upon to discover, characterize, and quantify the pollutant sources should be included in the document (e.g. a data appendix) along with a description of how the data were analyzed to characterize and quantify the pollutant sources. A discussion of the known deficiencies and/or gaps in the data set and their potential implications should also be included.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The TMDL document identifies the fecal coliform loading sources in the watershed based on the HSPF model results as shown in Table 3 excerpted below from the TMDL. Also, data from the bacterial source tracking results indicate that agricultural livestock are a significant source of fecal coliform loading in the watershed, and domestic animals and humans contribute much smaller percentages of the total load.

Table 3. Fecal coliform bacteria loading sources based on HSPF model results.

Land Use / Source	Load Contribution (%)
Nonpoint Sources	
Rangeland	96.57%
Impervious Urban	2.94%
Groundwater Recharge Zone	0.17%
Barren	0.14%
Forest	0.13%
Pervious Urban	0.01%
Cropland	0.01%
Direct Sources*	
Livestock Direct Defecation	0.03%
Septic Tank Failures	0.00%

COMMENTS: None.

4. TMDL Technical Analysis

TMDL determinations should be supported by a robust data set and an appropriate level of technical analysis**.** This applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader.

A TMDL analysis determines the maximum pollutant loading rate that may be allowed to a waterbody without violating water quality standards. The TMDL analysis should demonstrate an understanding of the relationship between the rate of pollutant loading into the waterbody and the resultant water quality impacts. This stressor → response relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and load allocations needs to be clearly articulated and supported by an appropriate level of technical analysis. Every effort should be made to be as detailed as possible, and to base all conclusions on the best available scientific principles.

The pollutant loading allocation is at the heart of the TMDL analysis. TMDLs apportion responsibility for taking actions by allocating the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways, such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or division of responsibility.

The pollutant loading allocation that will result in achievement of the water quality target is expressed in the form of the standard TMDL equation:

$$TMDL = \sum LAs + \sum WLAs + MOS$$

Where:

TMDL = Total Pollutant Loading Capacity of the waterbody

LAs = Pollutant Load Allocations

WLAs = Pollutant Wasteload Allocations

MOS = The portion of the Load Capacity allocated to the Margin of safety.

Minimum Submission Requirements:

☒ A TMDL must identify the loading capacity of a waterbody for the applicable pollutant, taking into consideration temporal variations in that capacity. EPA regulations define loading capacity as the greatest amount of a pollutant that a water can receive without violating water quality standards (40 C.F.R. §130.2(f)).

☒ The total loading capacity of the waterbody should be clearly demonstrated to equate back to the pollutant load allocations through a balanced TMDL equation. In instances where numerous LA, WLA and seasonal TMDL capacities make expression in the form of an equation cumbersome, a table may be substituted as long as it is clear that the total TMDL capacity equates to the sum of the allocations.

☒ The TMDL document should describe the methodology and technical analysis used to establish and quantify the cause-and-effect relationship between the numeric target and the identified pollutant sources. In many instances, this method will be a water quality model.

☒ It is necessary for EPA staff to be aware of any assumptions used in the technical analysis to understand and evaluate the methodology used to derive the TMDL value and associated loading allocations. Therefore, the TMDL document should contain a description of any important assumptions (including the basis for those assumptions) made in developing the TMDL, including but not limited to:

(1) the spatial extent of the watershed in which the impaired waterbody is located and the spatial extent of the TMDL technical analysis;
(2) the distribution of land use in the watershed (e.g., urban, forested, agriculture);
(3) a presentation of relevant information affecting the characterization of the pollutant of concern and its allocation to sources such as population characteristics, wildlife resources, industrial activities etc…;
(4) present and future growth trends, if taken into consideration in determining the TMDL and preparing the TMDL document (e.g., the TMDL could include the design capacity of an existing or planned wastewater treatment facility);
(5) an explanation and analytical basis for expressing the TMDL through surrogate measures, if applicable. Surrogate measures are parameters such as percent fines and turbidity for sediment impairments; chlorophyll *a* and phosphorus loadings for excess algae; length of riparian buffer; or number of acres of best management practices.

☒ The TMDL document should contain documentation supporting the TMDL analysis, including an inventory of the data set used, a description of the methodology used to analyze the data, a discussion of strengths and weaknesses in the analytical process, and the results from any water quality modeling used. This information is necessary for EPA to review the loading capacity determination, and the associated load, wasteload, and margin of safety allocations.

☒ TMDLs must take critical conditions (e.g., steam flow, loading, and water quality parameters, seasonality, etc…) into account as part of the analysis of loading capacity (40 C.F.R. §130.7(c)(1)). TMDLs should define applicable critical conditions and describe the approach used to determine both point and nonpoint source loadings under such critical conditions. In particular, the document should discuss the approach used to compute and allocate nonpoint source loadings, e.g., meteorological conditions and land use distribution.

☐ Where both nonpoint sources and NPDES permitted point sources are included in the TMDL loading allocation, and attainment of the TMDL target depends on reductions in the nonpoint source loads, the TMDL document must include a demonstration that nonpoint source loading reductions needed to implement the load allocations are actually practicable [40 CFR 130.2(i) and 122.44(d)].

Recommendation:
☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The technical analysis should describe the cause and effect relationship between the identified pollutant sources, the numeric targets, and achievement of water quality standards. It should also include a description of the analytical processes used, results from water quality modeling, assumptions and other pertinent information. The technical analysis for the Beaver Creek TMDL describes how the fecal coliform loads were derived in order to meet the applicable water quality standards for the 303(d) impaired stream segment.

Data on Beaver Creek was collected during the Upper Cheyenne River watershed assessment project from September 2003 – August 2005. Data has also been collected at the DENR ambient monitoring station near the mouth of the creek since 1999 and by RESPEC Consulting and Services from July 2007 – June 2008. Most of the data was collected from the sampling point near the mouth of the creek.

The Hydrologic Simulation Program Fortran (HSPF) model was used to determine the contribution of fecal coliform bacteria from identified sources in the Beaver Creek watershed and evaluate the implementation of Best Management Practices (BMPs) to control these sources.

The TMDL loads and loading capacities were derived using the load duration curve (LDC) approach resulting in a flow-variable target that considers the entire flow regime within the recreational season (May 1 - September 30) as shown in Figure 3 of the TMDL document. The LDC is a dynamic expression of the allowable load for any given day within the recreation season. To aid in interpretation and implementation of the TMDL, the LDC flow intervals were grouped into five flow zones: high flows (0–10%), moist conditions (10–40%), mid-range flows (40–60%), dry conditions (60–90%), and low flows (90–100%) according to EPA's *An Approach for Using Load Duration Curves in the Development of TMDLs.* The LDC is a dynamic expression of the allowable load for any given daily flow. Loading capacities were derived from this approach for each flow regime: high flow = 2.54 E+13 cfu/day; moist flow = 3.38 E+12 cfu/day; mid-range flow = 5.89 E+11 cfu/day; dry flow = 2.29 E+11 cfu/day and low flow = 2.55 E+10 cfu/day.

COMMENTS: Is it possible, based on the data collected from the monitoring sites in WY and the HSPF model, to breakout the approximate fecal coliform loads from WY and SD separately? It would be helpful for both states to know their approximate "Current load" and their "TMDL load" contribution (i.e., either in cfu/day or as a percent of the total load). Then each state could understand their role in implementing controls to achieve the level of reduction necessary to fully restore the water quality in South Dakota.

SD DENR RESPONSE: A load allocation (LA) for each state was added to Tables 4 and 5 on page 15 of the TMDL document of the TMDL document and an explanation of the LA derivation was included in Section 5.1 on page 13.

4.1 Data Set Description

TMDL documents should include a thorough description and summary of all available water quality data that are relevant to the water quality assessment and TMDL analysis. An inventory of the data used for the TMDL analysis should be provided to document, for the record, the data used in decision making. This also provides the reader with the opportunity to independently review the data. The TMDL analysis should make use of all readily available data for the waterbody under analysis unless the TMDL writer determines that the data are not relevant or appropriate. For relevant data that were known but rejected, an explanation of why the data were not utilized should be provided (e.g., samples exceeded holding times, data collected prior to a specific date were not considered timely, etc…).

Minimum Submission Requirements:

- ☒ TMDL documents should include a thorough description and summary of all available water quality data that are relevant to the water quality assessment and TMDL analysis such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and appropriate water quality criteria.
- ☒ The TMDL document submitted should be accompanied by the data set utilized during the TMDL analysis. If possible, it is preferred that the data set be provided in an electronic format and referenced in the document. If electronic submission of the data is not possible, the data set may be included as an appendix to the document.

Recommendation:
☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Beaver Creek TMDL data description and summary are included mostly in the Problem Identification section of the document, and the full data set is included in Appendix A. The recent water quality monitoring was conducted over the period from July 2007 to June 2008. A total of 26 fecal coliform samples were collected during the recreation season from May 1 to September 30. The data set also includes approximately 18 years of flow record on Beaver Creek that was used by the HSPF program to simulate stream flow for the recreation season.

COMMENTS: We are confused by the number of samples available for the TMDL analysis. Page 4 mentions that 4 of 26 samples (May 1 – September 30) exceeded the daily maximum criterion. Yet the load duration curve (Figure 3) shows 24 data points, and Appendix A seems to include 30 data points at BVR030 between May 1 and September 30. Also, the Table 5 summary used to calculate the geometric mean seems to indicate that 40 samples were used. The numbers should be revised to be consistent, or include more details on why the numbers are different in each context.

SD DENR RESPONSE: The number of samples (n=26) listed in Section 1.3 on page 4 of the TMDL document is correct. The duration curve was revised and includes 26 instantaneous load estimates; however, some of the data points overlap and cannot be distinguished as individual points. The data set listed in Appendix A includes four QA/QC samples (i.e. duplicates), and these samples were not used in the TMDL analyses. Table 5 from the previous draft was removed from the TMDL document.

4.2 Waste Load Allocations (WLA):

Waste Load Allocations represent point source pollutant loads to the waterbody. Point source loads are typically better understood and more easily monitored and quantified than nonpoint source loads. Whenever practical, each point source should be given a separate waste load allocation. All NPDES permitted dischargers that discharge the pollutant under analysis directly to the waterbody should be identified and given separate waste load allocations. The finalized WLAs are required to be incorporated into future NPDES permit renewals.

Minimum Submission Requirements:

☒ EPA regulations require that a TMDL include WLAs for all significant and/or NPDES permitted point sources of the pollutant. TMDLs must identify the portion of the loading capacity allocated to individual existing and/or future point source(s) (40 C.F.R. §130.2(h), 40 C.F.R. §130.2(i)). In some cases, WLAs may cover more than one discharger, e.g., if the source is contained within a general permit. If no allocations are to be made to point sources, then the TMDL should include a value of zero for the WLA.

☒ All NPDES permitted dischargers given WLA as part of the TMDL should be identified in the TMDL, including the specific NPDES permit numbers, their geographical locations, and their associated waste load allocations.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Wasteload Allocation section of the Beaver Creek TMDL document says that there are no municipal or other point sources that discharge directly to the impaired segment of Beaver Creek. Therefore, the WLA for this TMDL is zero. The only point source located in the watershed is over 50 miles upstream of the impaired segment in Upton, WY.

COMMENTS: None.

4.3 Load Allocations (LA):

Load allocations include the nonpoint source, natural, and background loads. These types of loads are typically more difficult to quantify than point source loads, and may include a significant degree of uncertainty. Often it is necessary to group these loads into larger categories and estimate the loading rates based on limited monitoring data and/or modeling results. The background load represents a composite of all upstream pollutant loads into the waterbody. In addition to the upstream nonpoint and upstream natural load, the background load often includes upstream point source loads that are not given specific waste load allocations in this particular TMDL analysis. In instances where nonpoint source loading rates are particularly difficult to quantify, a performance-based allocation approach, in which a detailed monitoring plan and adaptive management strategy are employed for the application of BMPs, may be appropriate.

Minimum Submission Requirements:

☒ EPA regulations require that TMDL expressions include LAs which identify the portion of the loading capacity attributed to nonpoint sources and to natural background. Load allocations may range from reasonably accurate estimates to gross allotments (40 C.F.R. §130.2(g)). Load allocations may be included for both existing and future nonpoint source loads. Where possible, load allocations should be described separately for natural background and nonpoint sources.

☒ Load allocations assigned to natural background loads should not be assumed to be the difference between the sum of known and quantified anthropogenic sources and the existing *in situ* loads (e.g., measured in stream) unless it can be demonstrated that all significant anthropogenic sources of the pollutant of concern have been identified and given proper load or waste load allocations.

Recommendation:
☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Pollutant Source Assessment section of the TMDL explains that nonpoint sources contribute nearly all of the fecal loading in the watershed. Approximately 97-98 percent of the bacteria load to the impaired segment of Beaver Creek is attributed to livestock from rangeland. Therefore, most of the loading capacity has been allocated to the nonpoint sources in the form of load allocations. Table 4, excerpted from the TMDL document below, includes the load allocations at each of the five flow regimes.

Table 4. Beaver Creek fecal coliform bacteria Total Maximum Daily Load (TMDL) allocations by flow zone, including load allocations for both South Dakota and Wyoming portions of the watershed.

TMDL Component	Flow Zone (expressed as CFU*10^9/day)				
	High	Moist	Mid-range	Dry	Low
	77-834 cfs	13-76 cfs	5.0-12 cfs	0.6-5.0 cfs	0-0.5 cfs
LA	21,990.56	2,604.43	449.48	151.46	19.08
WLA	0	0	0	0	0
MOS	3,366.13	773.20	139.72	77.57	6.36
TMDL	25,356.69	3,377.63	589.20	229.02	25.45
Current Load*	42,389.12	31,524.99	0.77	60.35	99.04
Load Reduction	40%	89%	0%	0%	74%

COMMENTS: As mentioned in comments above, we disagree with the statement in the Load Allocation section that implies that the 30-day, geometric mean fecal coliform criterion is not applicable to this TMDL. The approach to demonstrate that the geometric mean criterion has not been exceeded is reasonable, but the data summary to support it (Table 5), seems to include some errors. Please, include further explanation or revise as needed.

As mentioned in the comments above, it would be helpful to include separate "Current loads" and "TMDL loads" for SD and WY. If these loads could be broken out to show the relative contribution from WY and SD, then the information could be used by each state to assist in implementation efforts to restore the water quality in South Dakota.

SD DENR RESPONSE: As mentioned above, Table 5 was removed from the TMDL document, and the TMDL is now based on the chronic and acute criterion. An explanation of the LA derivation was included in the Load Allocation Section of the TMDL document on page 13. Current or baseline loads for the 30-day averaging period were calculated differently than the daily averaging period, and the methods used are described on page 14 of the TMDL document. Current loads are reported for each flow zone in Tables 4 and 5 on page 15 and was defined as the 95th percentile load in each flow zone.

A load allocation (LA) for both South Dakota and Wyoming was added to Tables 4 and 5 on page 15 and the Section 5.1 on page 13. The individual state LAs were based on the modeled, relative load contributions of each state to the impaired segment of Beaver Creek.

4.4 Margin of Safety (MOS):

Natural systems are inherently complex. Any mathematical relationship used to quantify the stressor → response relationship between pollutant loading rates and the resultant water quality impacts, no matter how rigorous, will include some level of uncertainty and error. To compensate for this uncertainty and ensure water quality standards will be attained, a margin of safety is required as a component of each TMDL. The MOS may take the form of a explicit load allocation (e.g., 10 lbs/day), or may be implicitly built into the TMDL analysis through the use of conservative assumptions and values for the various factors that determine the TMDL pollutant load → water quality effect relationship. Whether explicit or implicit, the MOS should be supported by an appropriate level of discussion that addresses the level of uncertainty in the various components of the TMDL technical analysis, the assumptions used in that analysis, and the relative effect of those assumptions on the final TMDL. The discussion should demonstrate that the MOS used is sufficient to ensure that the water quality standards would be attained if the TMDL pollutant loading rates are met. In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).

Minimum Submission Requirements:

☒ TMDLs must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)). EPA's 1991 TMDL Guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS).

- ☐ If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS should be identified and described. The document should discuss why the assumptions are considered conservative and the effect of the assumption on the final TMDL value determined.
- ☒ If the MOS is explicit, the loading set aside for the MOS should be identified. The document should discuss how the explicit MOS chosen is related to the uncertainty and/or potential error in the linkage analysis between the WQS, the TMDL target, and the TMDL loading rate.
- ☐ If, rather than an explicit or implicit MOS, the TMDL relies upon a phased approach to deal with large and/or unquantifiable uncertainties in the linkage analysis, the document should include a description of the planned phases for the TMDL as well as a monitoring plan and adaptive management strategy.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Beaver Creek TMDL includes an explicit MOS derived by calculating 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. The explicit MOS values are included in Table 4 of the TMDL document.

COMMENTS: None.

4.5 Seasonality and variations in assimilative capacity:

The TMDL relationship is a factor of both the loading rate of the pollutant to the waterbody and the amount of pollutant the waterbody can assimilate and still attain water quality standards. Water quality standards often vary based on seasonal considerations. Therefore, it is appropriate that the TMDL analysis consider seasonal variations, such as critical flow periods (high flow, low flow), when establishing TMDLs, targets, and allocations.

Minimum Submission Requirements:

☒ The statute and regulations require that a TMDL be established with consideration of seasonal variations. The TMDL must describe the method chosen for including seasonal variability as a factor. (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)).

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: By using the load duration curve approach to develop the TMDL allocations seasonal variability in fecal coliform loads are taken into account. Highest steam flows typically occur during late spring, and the lowest stream flows occur during the winter months. Also, the TMDL is seasonal since the fecal coliform criteria are in effect from May 1 to September 30, therefore the TMDL is only applicable during that period.

COMMENTS: None.

5. Public Participation

EPA regulations require that the establishment of TMDLs be conducted in a process open to the public, and that the public be afforded an opportunity to participate. To meaningfully participate in the TMDL process it is necessary that stakeholders, including members of the general public, be able to understand the problem and the proposed solution. TMDL documents should include language that explains the issues to the general public in understandable terms, as well as provides additional detailed technical information for the scientific community. Notifications or solicitations for comments regarding the TMDL should be made available to the general public, widely circulated, and clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for approval, a copy of the comments received by the state and the state responses to those comments should be included with the document.

Minimum Submission Requirements:
☒ The TMDL must include a description of the public participation process used during the development of the TMDL (40 C.F.R. §130.7(c)(1)(ii)).

☐ TMDLs submitted to EPA for review and approval should include a summary of significant comments and the State's/Tribe's responses to those comments.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The State's submittal includes a summary of the public participation process that has occurred. It describes the opportunities that the public has been given to be involved in the TMDL development process to date. In particular, the State has encouraged participation through presentations to local groups in the watershed, and making the TMDL available for a 30-day public notice period prior to finalization.

COMMENTS: None.

6. Monitoring Strategy

TMDLs may have significant uncertainty associated with the selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL document to articulate the means by which the TMDL will be evaluated in the field, and to provide for future supplemental data that will address any uncertainties that may exist when the document is prepared.

Minimum Submission Requirements:

☐ When a TMDL involves both NPDES permitted point source(s) and nonpoint source(s) allocations, and attainment of the TMDL target depends on reductions in the nonpoint source loads, the TMDL document should include a monitoring plan that describes the additional data to be collected to determine if the load reductions provided for in the TMDL are occurring.

☐ Under certain circumstances, a phased TMDL approach may be utilized when limited existing data are relied upon to develop a TMDL, and the State believes that the use of additional data or data based on better analytical techniques would likely increase the accuracy of the TMDL load calculation and merit development of a second phase TMDL. EPA recommends that a phased TMDL document or its implementation plan include a monitoring plan and a scheduled timeframe for revision of the TMDL. These elements would not be an intrinsic part of the TMDL and would not be approved by EPA, but may be necessary to support a rationale for approving the TMDL. http://www.epa.gov/owow/tmdl/tmdl_clarification_letter.pdf

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: Beaver Creek should continue to be monitored as part SD DENR's ambient water quality monitoring program at the Beaver Creek site near the confluence with the Cheyenne River (STORET ID: 460654). Additional data may be needed to fully assess compliance with the chronic criterion for fecal coliform. Post-implementation monitoring will be necessary to assure the TMDL targets have been reached and maintenance of the beneficial use occurs.

COMMENTS: None.

7. Restoration Strategy

The overall purpose of the TMDL analysis is to determine what actions are necessary to ensure that the pollutant load in a waterbody does not result in water quality impairment. Adding additional detail regarding the proposed approach for the restoration of water quality is not currently a regulatory requirement, but is considered a value added component of a TMDL document. During the TMDL analytical process, information is often gained that may serve to point restoration efforts in the right direction and help ensure that resources are spent in the most efficient manner possible. For example, watershed models used to analyze the linkage between the pollutant loading rates and resultant water quality impacts might also be used to conduct "what if" scenarios to help direct BMP installations to locations that provide the greatest pollutant reductions. Once a TMDL has been written and approved, it is often the responsibility of other water quality programs to see that it is implemented. The level of quality and detail provided in the restoration strategy will greatly influence the future success in achieving the needed pollutant load reductions.

Minimum Submission Requirements:

☒ EPA is not required to and does not approve TMDL implementation plans. However, in cases where a WLA is dependent upon the achievement of a LA, "reasonable assurance" is required to demonstrate the necessary LA called for in the document is practicable). A discussion of the BMPs (or other load reduction measures) that are to be relied upon to achieve the LA(s), and programs and funding sources that will be relied upon to implement the load reductions called for in the document, may be included in the implementation/restoration section of the TMDL document to support a demonstration of "reasonable assurance".

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Implementation section of the TMDL document describes the best management practices (BMPs) recommended for implementation in order to reduce the fecal coliform loads. Four management scenarios were simulated using the HSPF model: 1) reduced Wyoming bacteria loads to comply with South Dakota water quality criteria, 2) removal of septic system bacteria loads, 3) exclusion of cattle from streams, and 4) general rangeland management. According to the model, the first two scenarios would not significantly reduce the fecal coliform loads in the impaired segment of Beaver Creek. Therefore, implementation of scenarios 3 and 4 are recommended because they are most likely to reduce the fecal coliform loads to levels that would meet the TMDL targets.

Since there are no point sources that discharge directly to the impaired segment of Beaver Creek, there is no need to include a discussion of reasonable assurance in this TMDL document.

COMMENTS: None.

8. Daily Loading Expression

The goal of a TMDL analysis is to determine what actions are necessary to attain and maintain WQS. The appropriate averaging period that corresponds to this goal will vary depending on the pollutant and the nature of the waterbody under analysis. When selecting an appropriate averaging period for a TMDL analysis, primary concern should be given to the nature of the pollutant in question and the achievement of the underlying WQS. However, recent federal appeals court decisions have pointed out that the title TMDL implies a "daily" loading rate. While the most appropriate averaging period to be used for developing a TMDL analysis may vary according to the pollutant, a daily loading rate can provide a more practical indication of whether or not the overall needed load reductions are being achieved. When limited monitoring resources are available, a daily loading target that takes into account the natural variability of the system can serve as a useful indicator for whether or not the overall load reductions are likely to be met. Therefore, a daily expression of the required pollutant loading rate is a required element in all TMDLs, in addition to any other load averaging periods that may have been used to conduct the TMDL analysis. The level of effort spent to develop the daily load indicator should be based on the overall utility it can provide as an indicator for the total load reductions needed.

Minimum Submission Requirements:

☒ The document should include an expression of the TMDL in terms of a daily load. However, the TMDL may also be expressed in temporal terms other than daily (e.g., an annual or monthly load). If the document expresses the TMDL in additional "non-daily" terms the document should explain why it is appropriate or advantageous to express the TMDL in the additional unit of measurement chosen.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Beaver Creek fecal coliform TMDL includes daily loads expressed as colonies per day. The daily TMDL loads are included in the TMDL Allocations section of the TMDL document (Table 4).

COMMENTS: None.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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DENVER, CO 80202-1129
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http://www.epa.gov/region08

MAR 12 2010

Ref: 8EPR-EP

Steven M. Pirner
Secretary
South Dakota Department of Environment & Natural Resources
Joe Foss Building
523 East Capitol
Pierre, SD 57501-3181

Re: TMDL Approvals
Beaver Creek; Fecal Coliform; SD-CH-R-BEAVER_01

Dear Mr. Pirner:

We have completed our review of the total maximum daily loads (TMDLs) as submitted by your office for the waterbodies listed in the enclosure to this letter. In accordance with the Clean Water Act (33 U.S.C. 1251 *et. seq.*), we approve all aspects of the TMDLs as developed for the water quality limited waterbodies as described in Section 303(d)(1). Based on our review, we feel the separate elements of the TMDLs listed in the enclosed table adequately address the pollutants of concern as given in the table, taking into consideration seasonal variation and a margin of safety.

Thank you for submitting these TMDLs for our review and approval. If you have any questions, the most knowledgeable person on my staff is Vern Berry and he may be reached at 303-312-6234.

Sincerely,

Martin Hestmark
for Eddie A. Sierra
Acting Assistant Regional Administrator
Office of Ecosystems Protection
and Remediation

Enclosure

ENCLOSURE 1: APPROVED TMDLs

Fecal Coliform Bacteria Total Maximum Daily Load (TMDL) for Beaver Creek, Fall River County, South Dakota (January 2010).

Submitted: 2/25/2010

1	Pollutant TMDLs completed.
1	Causes addressed from the 2008 303(d) list.
0	Determinations that no pollutant TMDL needed.

Segment: Beaver Creek - from the Wyoming border to the mouth (confluence with Cheyenne River)

303(d) ID: SD-CH-R-BEAVER 01

Parameter/Pollutant (303(d) list cause): FECAL COLIFORM - 259

Water Quality Targets: daily maximum of < = 2000 CFU/100 mL in any one sample; geometric mean of < = 1000 CFU/100 mL over a 30-day period. Criteria are applicable from May 1 - Sept. 30.

Allocation*	Value	Units	Permits
WLA	0	CFU/DAY	
MOS	0.77E+12	CFU/DAY	
LA	2.6E+12	CFU/DAY	
TMDL	3.37E+12	CFU/DAY	

Notes: Loads shown represent the loads during the moist flow regime as defined by the load duration curve for Beaver Creek (see Table 4 in the TMDL document). The moist range flows are when significant differences occur between the existing loads and the target loads, and represent the flow regime that is most likely to be targeted for BMP implementation. The Beaver Creek fecal coliform TMDL covers portions of Wyoming and South Dakota. Separate load allocations were calculated for Wyoming (1.6E+12 cfu/day) and South Dakota (1.0E+12 cfu/day).

* LA = Load Allocation, WLA = Wasteload Allocation, MOS = Margin of Safety, TMDL = sum(WLAs) + sum(LAs) + MOS

ENCLOSURE 2

EPA REGION VIII TMDL REVIEW

TMDL Document Info:

Document Name:	**Fecal Coliform Bacteria Total Maximum Daily Load (TMDL) for Beaver Creek, Fall River County, South Dakota**
Submitted by:	**Cheryl Saunders, SD DENR**
Date Received:	**February 25, 2010**
Review Date:	**March 8, 2010**
Reviewer:	**Vern Berry, EPA**
Rough Draft / Public Notice / Final?	**Final**
Notes:	

Reviewers Final Recommendation(s) to EPA Administrator (used for final review only):

☒ Approve
☐ Partial Approval
☐ Disapprove
☐ Insufficient Information

Approval Notes to Administrator:

This document provides a standard format for EPA Region 8 to provide comments to state TMDL programs on TMDL documents submitted to EPA for either formal or informal review. All TMDL documents are evaluated against the minimum submission requirements and TMDL elements identified in the following 8 sections:

1. Problem Description
   1.1. TMDL Document Submittal Letter
   1.2. Identification of the Waterbody, Impairments, and Study Boundaries
   1.3. Water Quality Standards
2. Water Quality Target
3. Pollutant Source Analysis
4. TMDL Technical Analysis
   4.1. Data Set Description
   4.2. Waste Load Allocations (WLA)
   4.3. Load Allocations (LA)
   4.4. Margin of Safety (MOS)
   4.5. Seasonality and variations in assimilative capacity
5. Public Participation
6. Monitoring Strategy
7. Restoration Strategy
8. Daily Loading Expression

Under Section 303(d) of the Clean Water Act, waterbodies that are not attaining one or more water quality standard (WQS) are considered "impaired." When the cause of the impairment is determined to be a pollutant, a TMDL analysis is required to assess the appropriate maximum allowable pollutant loading rate.

A TMDL document consists of a technical analysis conducted to: (1) assess the maximum pollutant loading rate that a waterbody is able to assimilate while maintaining water quality standards; and (2) allocate that assimilative capacity among the known sources of that pollutant. A well written TMDL document will describe a path forward that may be used by those who implement the TMDL recommendations to attain and maintain WQS.

Each of the following eight sections describes the factors that EPA Region 8 staff considers when reviewing TMDL documents. Also included in each section is a list of EPA's minimum submission requirements relative to that section, a brief summary of the EPA reviewer's findings, and the reviewer's comments and/or suggestions. Use of the verb "must" in the minimum submission requirements denotes information that is required to be submitted because it relates to elements of the TMDL required by the CWA and by regulation. Use of the term "should" below denotes information that is generally necessary for EPA to determine if a submitted TMDL is approvable.

This review template is intended to ensure compliance with the Clean Water Act and that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Problem Description

A TMDL document needs to provide a clear explanation of the problem it is intended to address. Included in that description should be a definitive portrayal of the physical boundaries to which the TMDL applies, as well as a clear description of the impairments that the TMDL intends to address and the associated pollutant(s) causing those impairments. While the existence of one or more impairment and stressor may be known, it is important that a comprehensive evaluation of the water quality be conducted prior to development of the TMDL to ensure that all water quality problems and associated stressors are identified. Typically, this step is conducted prior to the 303(d) listing of a waterbody through the monitoring and assessment program. The designated uses and water quality criteria for the waterbody should be examined against available data to provide an evaluation of the water quality relative to all applicable water quality standards. If, as part of this exercise, additional WQS problems are discovered and additional stressor pollutants are identified, consideration should be given to concurrently evaluating TMDLs for those additional pollutants. If it is determined that insufficient data is available to make such an evaluation, this should be noted in the TMDL document.

1.1 TMDL Document Submittal Letter

When a TMDL document is submitted to EPA requesting formal comments or a final review and approval, the submittal package should include a letter identifying the document being submitted and the purpose of the submission.

Minimum Submission Requirements.

- ☒ A TMDL submittal letter should be included with each TMDL document submitted to EPA requesting a formal review.
- ☒ The submittal letter should specify whether the TMDL document is being submitted for initial review and comments, public review and comments, or final review and approval.
- ☒ Each TMDL document submitted to EPA for final review and approval should be accompanied by a submittal letter that explicitly states that the submittal is a final TMDL submitted under Section 303(d) of the Clean Water Act for EPA review and approval. This clearly establishes the State's/Tribe's intent to submit, and EPA's duty to review, the TMDL under the statute. The submittal letter should contain such identifying information as the name and location of the waterbody and the pollutant(s) of concern, which matches similar identifying information in the TMDL document for which a review is being requested.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The final Beaver Creek fecal coliform TMDL was submitted to EPA for and approval via an email from Cheryl Saunders, SD DENR on February 25, 2010. The email included the final TMDL document and a letter requesting approval of the TMDL.

COMMENTS: None.

1.2 Identification of the Waterbody, Impairments, and Study Boundaries

The TMDL document should provide an unambiguous description of the waterbody to which the TMDL is intended to apply and the impairments the TMDL is intended to address. The document should also clearly delineate the physical boundaries of the waterbody and the geographical extent of the watershed area studied. Any additional information needed to tie the TMDL document back to a current 303(d) listing should also be included.

Minimum Submission Requirements:

☒ The TMDL document should clearly identify the pollutant and waterbody segment(s) for which the TMDL is being established. If the TMDL document is submitted to fulfill a TMDL development requirement for a waterbody on the state's current EPA approved 303(d) list, the TMDL document submittal should clearly identify the waterbody and associated impairment(s) as they appear on the State's/Tribe's current EPA approved 303(d) list, including a full waterbody description, assessment unit/waterbody ID, and the priority ranking of the waterbody. This information is necessary to ensure that the administrative record and the national TMDL tracking database properly link the TMDL document to the 303(d) listed waterbody and impairment(s).

☒ One or more maps should be included in the TMDL document showing the general location of the waterbody and, to the maximum extent practical, any other features necessary and/or relevant to the understanding of the TMDL analysis, including but not limited to: watershed boundaries, locations of major pollutant sources, major tributaries included in the analysis, location of sampling points, location of discharge gauges, land use patterns, and the location of nearby waterbodies used to provide surrogate information or reference conditions. Clear and concise descriptions of all key features and their relationship to the waterbody and water quality data should be provided for all key and/or relevant features not represented on the map

☐ If information is available, the waterbody segment to which the TMDL applies should be identified/geo-referenced using the National Hydrography Dataset (NHD). If the boundaries of the TMDL do not correspond to the Waterbody ID(s) (WBID), Entity_ID information or reach code (RCH_Code) information should be provided. If NHD data is not available for the waterbody, an alternative geographical referencing system that unambiguously identifies the physical boundaries to which the TMDL applies may be substituted.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: Beaver Creek is a medium sized stream located in Fall River County, South Dakota and is a tributary of the Cheyenne River in the Beaver sub-basin (HUC 10120107). Beaver Creek has a total drainage area of 1670 square miles (4,325 square km). Approximately 71% of the watershed drainage area is in Wyoming and 29% is in South Dakota (see Figure 1 in the TMDL document). The South Dakota 303(d) listed segment of Beaver Creek includes 15.5 miles (25 km) of the creek from the Wyoming border to the mouth (i.e., confluence with Cheyenne River; SD-CH-R-BEAVER_01). It is listed as a lower priority for TMDL development.

South Dakota's designated uses for Beaver Creek include warmwater semi-permanent fish life propagation waters, limited-contract recreation waters, fish and wildlife propagation, recreation, and stock watering, and irrigation. South Dakota DENR's 2008 303(d) list shows Beaver Creek as impaired for fecal coliform bacteria which is impairing the limited contact recreation uses, for specific conductance and total dissolved solids (TDS) which are impairing the fish and wildlife propagation, recreation and stock watering uses, and for specific conductance and salinity which are impairing the irrigation uses. The specific conductance, TDS and salinity impairments in this segment will be addressed by SD DENR in a separate TMDL document.

In Wyoming, Beaver Creek is classified as a 2ABww water, which indicates that the stream is designated as a primary recreation water that supports warm water game fish. Beaver Creek is not listed as an impaired waterbody on Wyoming's most recent (2008) 303(d) list.

COMMENTS: None.

1.3 Water Quality Standards

TMDL documents should provide a complete description of the water quality standards for the waterbodies addressed, including a listing of the designated uses and an indication of whether the uses are being met, not being met, or not assessed. If a designated use was not assessed as part of the TMDL analysis (or not otherwise recently assessed), the documents should provide a reason for the lack of assessment (e.g., sufficient data was not available at this time to assess whether or not this designated use was being met).

Water quality criteria (WQC) are established as a component of water quality standard at levels considered necessary to protect the designated uses assigned to that waterbody. WQC identify quantifiable targets and/or qualitative water quality goals which, if attained and maintained, are intended to ensure that the designated uses for the waterbody are protected. TMDLs result in maintaining and attaining water quality standards by determining the appropriate maximum pollutant loading rate to meet water quality criteria, either directly, or through a surrogate measurable target. The TMDL document should include a description of all applicable water quality criteria for the impaired designated uses and address whether or not the criteria are being attained, not attained, or not evaluated as part of the analysis. If the criteria were not evaluated as part of the analysis, a reason should be cited (e.g. insufficient data were available to determine if this water quality criterion is being attained).

Minimum Submission Requirements:

☒ The TMDL must include a description of the applicable State/Tribal water quality standard, including the designated use(s) of the waterbody, the applicable numeric or narrative water quality criterion, and the anti-degradation policy. (40 C.F.R. §130.7(c)(1)).

☒ The purpose of a TMDL analysis is to determine the assimilative capacity of the waterbody that corresponds to the existing water quality standards for that waterbody, and to allocate that assimilative capacity between the significant sources. Therefore, <u>all TMDL documents must be written to meet the existing water quality standards</u> for that waterbody (CWA §303(d)(1)(C)).

Note: In some circumstances, the load reductions determined to be necessary by the TMDL analysis may prove to be infeasible and may possibly indicate that the existing water quality standards and/or assessment methodologies may be erroneous. However, the TMDL must still be determined based on existing water quality standards. Adjustments to water quality standards and/or assessment methodologies may be evaluated separately, from the TMDL.

☒ The TMDL document should describe the relationship between the pollutant of concern and the water quality standard the pollutant load is intended to meet. This information is necessary for EPA to evaluate whether or not attainment of the prescribed pollutant loadings will result in attainment of the water quality standard in question.

☒ If a standard includes multiple criteria for the pollutant of concern, the document should demonstrate that the TMDL value will result in attainment of all related criteria for the pollutant. For example, both acute and chronic values (if present in the WQS) should be addressed in the document, including consideration of magnitude, frequency and duration requirements.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Beaver Creek segment addressed by this TMDL is impaired based on South Dakota's fecal coliform water quality standards for limited contact recreation. South Dakota has applicable numeric standards for fecal coliform that may be applied to this stream segment. The numeric standards being implemented in this TMDL are: a daily maximum value of fecal coliform of 2000 CFU/100 mL in any one sample, or a maximum geometric mean of 1000 CFU/100 mL based on a minimum of 5 samples obtained during separate 24-hour periods for any 30-day period from May through September.

South Dakota has recently adopted *Escherichia coli* criteria for the protection of the limited contact and immersion recreation uses. The E. coli criteria for limited contact recreation are: a daily maximum value of 630 CFU/100 mL in any one sample, or a maximum geometric mean of 1,178 CFU/100 mL based on a minimum of 5 samples obtained during separate 24-hour periods for any 30-day period from May through September. Only one of the 25 (4%) E. coli samples collected from Beaver Creek exceeded the acute E. coli criterion (1,178 CFU/100ml). Greater than 10% of samples must exceed water quality criteria for that parameter to be included as a cause of impairment on the 303(d) impaired waters list. Therefore, Beaver Creek does not require an E. coli TMDL because the parameter is not currently listed as a cause of impairment to this stream. Bacteria sample data collected to date in Beaver Creek show a statistically significant correlation between fecal coliform bacteria and E. coli concentrations. Because the two indicators are closely related, the fecal coliform bacteria TMDL and associated implementation strategy described in the TMDL document are expected to address both the fecal coliform bacteria and possible future E. coli impairments to the designated uses of Beaver Creek.

Wyoming also has water quality standards for E. coli. All Wyoming waters designated for primary contact recreation shall not exceed a geometric mean of 126 organisms per 100 milliliters of E. coli bacteria based on a minimum of not less than 5 samples obtained during separate 24 hour periods for any 30-day period. Sufficient data were not available to determine compliance with this criterion. However, Beaver Creek is not listed as an impaired waterbody on Wyoming's most recent (2008) 303(d) list.

Discussion of additional applicable water quality standards for Beaver Creek can be found on pages 4 - 7 of the TMDL document.

COMMENTS: None.

2. Water Quality Targets

TMDL analyses establish numeric targets that are used to determine whether water quality standards are being achieved. Quantified water quality targets or endpoints should be provided to evaluate each listed pollutant/water body combination addressed by the TMDL, and should represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the water quality target. For pollutants with narrative standards, the narrative standard should be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include a variety of targets representing water column sediment such as TSS, embeddeness, stream morphology, up-slope conditions and a measure of biota).

Minimum Submission Requirements:

☒ The TMDL should identify a numeric water quality target(s) for each waterbody pollutant combination. The TMDL target is a quantitative value used to measure whether or not the applicable water quality standard is attained.

Generally, the pollutant of concern and the numeric water quality target are, respectively, the chemical causing the impairment and the numeric criteria for that chemical (e.g., chromium) contained in the water quality standard. Occasionally, the pollutant of concern is different from the parameter that is the subject of the numeric water quality target (e.g., when the pollutant of concern is phosphorus and the numeric water quality target is expressed as a numerical dissolved oxygen criterion). In such cases, the TMDL should explain the linkage between the pollutant(s) of concern, and express the quantitative relationship between the TMDL target and pollutant of concern. In all cases, TMDL targets must represent the attainment of current water quality standards.

☐ When a numeric TMDL target is established to ensure the attainment of a narrative water quality criterion, the numeric target, the methodology used to determine the numeric target, and the link between the pollutant of concern and the narrative water quality criterion should all be described in the TMDL document. Any additional information supporting the numeric target and linkage should also be included in the document.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The water quality targets for this TMDL are based on South Dakota's numeric water quality standards for fecal coliform bacteria based on the limited contact recreational beneficial use for Beaver Creek. The numeric TMDL targets established for Beaver Creek were determined for each of five flow conditions or zones, and are based on either the acute (2,000 CFU/100ml) or chronic (1,000 CFU/100ml) fecal coliform bacteria criterion, depending on which criterion required the greatest load reduction. The approach explained in the TMDL Technical Analysis section ensures that both the acute and chronic fecal coliform water quality standards will be met.

COMMENTS: None.

3. Pollutant Source Analysis

A TMDL analysis is conducted when a pollutant load is known or suspected to be exceeding the loading capacity of the waterbody. Logically then, a TMDL analysis should consider all sources of the pollutant of concern in some manner. The detail provided in the source assessment step drives the rigor of the pollutant load allocation. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each significant source (or source category) when the relative load contribution from each source has been estimated. Therefore, the pollutant load from each significant source (or source category) should be identified and quantified to the maximum practical extent. This may be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach may be appropriate. The approach should be clearly defined in the document.

Minimum Submission Requirements:

☒ The TMDL should include an identification of all potentially significant point and nonpoint sources of the pollutant of concern, including the geographical location of the source(s) and the quantity of the loading, e.g., lbs/per day. This information is necessary for EPA to evaluate the WLA, LA and MOS components of the TMDL.

☒ The level of detail provided in the source assessment should be commensurate with the nature of the watershed and the nature of the pollutant being studied. Where it is possible to separate natural background from nonpoint sources, the TMDL should include a description of both the natural background loads and the nonpoint source loads.

☒ Natural background loads should not be assumed to be the difference between the sum of known and quantified anthropogenic sources and the existing *in situ* loads (e.g. measured in stream) unless it can be demonstrated that all significant anthropogenic sources of the pollutant of concern have been identified, characterized, and properly quantified.

☒ The sampling data relied upon to discover, characterize, and quantify the pollutant sources should be included in the document (e.g. a data appendix) along with a description of how the data were analyzed to characterize and quantify the pollutant sources. A discussion of the known deficiencies and/or gaps in the data set and their potential implications should also be included.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The TMDL document identifies the fecal coliform loading sources in the watershed as all nonpoint source, based on the HSPF model results as shown in Table 3, excerpted below from the TMDL. Also, data from the bacterial source tracking results indicate that agricultural livestock are a significant source of fecal coliform loading in the watershed. There are no municipal or other point sources that discharge directly to the impaired segment of Beaver Creek. The only point source located in the watershed is over 50 miles upstream of the impaired segment in Upton, WY.

Table 3. Fecal coliform bacteria loading sources based on HSPF model results.

Land Use / Source	Load Contribution (%)
Nonpoint Sources	
Rangeland	96.57%
Impervious Urban	2.94%
Groundwater Recharge Zone	0.17%
Barren	0.14%
Forest	0.13%
Pervious Urban	0.01%
Cropland	0.01%
Direct Sources*	
Livestock Direct Defecation	0.03%
Septic Tank Failures	0.00%

* Livestock direct defecation and septic tank failures were modeled as direct sources of bacteria loads; however, these sources are considered nonpoint source discharges under the Clean Water Act and are not regulated as point sources of pollution.

COMMENTS: None.

4. TMDL Technical Analysis

TMDL determinations should be supported by a robust data set and an appropriate level of technical analysis. This applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader.

A TMDL analysis determines the maximum pollutant loading rate that may be allowed to a waterbody without violating water quality standards. The TMDL analysis should demonstrate an understanding of the relationship between the rate of pollutant loading into the waterbody and the resultant water quality impacts. This stressor → response relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and load allocations needs to be clearly articulated and supported by an appropriate level of technical analysis. Every effort should be made to be as detailed as possible, and to base all conclusions on the best available scientific principles.

The pollutant loading allocation is at the heart of the TMDL analysis. TMDLs apportion responsibility for taking actions by allocating the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways, such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or division of responsibility.

The pollutant loading allocation that will result in achievement of the water quality target is expressed in the form of the standard TMDL equation:

$$TMDL = \sum LAs + \sum WLAs + MOS$$

Where:

TMDL = Total Pollutant Loading Capacity of the waterbody

LAs = Pollutant Load Allocations

WLAs = Pollutant Wasteload Allocations

MOS = The portion of the Load Capacity allocated to the Margin of safety.

Minimum Submission Requirements:

☒ A TMDL must identify the loading capacity of a waterbody for the applicable pollutant, taking into consideration temporal variations in that capacity. EPA regulations define loading capacity as the greatest amount of a pollutant that a water can receive without violating water quality standards (40 C.F.R. §130.2(f)).

☒ The total loading capacity of the waterbody should be clearly demonstrated to equate back to the pollutant load allocations through a balanced TMDL equation. In instances where numerous LA, WLA and seasonal TMDL capacities make expression in the form of an equation cumbersome, a table may be substituted as long as it is clear that the total TMDL capacity equates to the sum of the allocations.

☒ The TMDL document should describe the methodology and technical analysis used to establish and quantify the cause-and-effect relationship between the numeric target and the identified pollutant sources. In many instances, this method will be a water quality model.

☒ It is necessary for EPA staff to be aware of any assumptions used in the technical analysis to understand and evaluate the methodology used to derive the TMDL value and associated loading allocations. Therefore, the TMDL document should contain a description of any important assumptions (including the basis for those assumptions) made in developing the TMDL, including but not limited to:

(1) the spatial extent of the watershed in which the impaired waterbody is located and the spatial extent of the TMDL technical analysis;
(2) the distribution of land use in the watershed (e.g., urban, forested, agriculture);
(3) a presentation of relevant information affecting the characterization of the pollutant of concern and its allocation to sources such as population characteristics, wildlife resources, industrial activities etc…;
(4) present and future growth trends, if taken into consideration in determining the TMDL and preparing the TMDL document (e.g., the TMDL could include the design capacity of an existing or planned wastewater treatment facility);

(5) an explanation and analytical basis for expressing the TMDL through surrogate measures, if applicable. Surrogate measures are parameters such as percent fines and turbidity for sediment impairments; chlorophyll *a* and phosphorus loadings for excess algae; length of riparian buffer; or number of acres of best management practices.

☒ The TMDL document should contain documentation supporting the TMDL analysis, including an inventory of the data set used, a description of the methodology used to analyze the data, a discussion of strengths and weaknesses in the analytical process, and the results from any water quality modeling used. This information is necessary for EPA to review the loading capacity determination, and the associated load, wasteload, and margin of safety allocations.

☒ TMDLs must take critical conditions (e.g., steam flow, loading, and water quality parameters, seasonality, etc…) into account as part of the analysis of loading capacity (40 C.F.R. §130.7(c)(1)). TMDLs should define applicable critical conditions and describe the approach used to determine both point and nonpoint source loadings under such critical conditions. In particular, the document should discuss the approach used to compute and allocate nonpoint source loadings, e.g., meteorological conditions and land use distribution.

☐ Where both nonpoint sources and NPDES permitted point sources are included in the TMDL loading allocation, and attainment of the TMDL target depends on reductions in the nonpoint source loads, the TMDL document must include a demonstration that nonpoint source loading reductions needed to implement the load allocations are actually practicable [40 CFR 130.2(i) and 122.44(d)].

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The technical analysis should describe the cause and effect relationship between the identified pollutant sources, the numeric targets, and achievement of water quality standards. It should also include a description of the analytical processes used, results from water quality modeling, assumptions and other pertinent information. The technical analysis for the Beaver Creek TMDL describes how the fecal coliform loads were derived in order to meet the applicable water quality standards for the 303(d) impaired stream segment.

Data on Beaver Creek was collected during the Upper Cheyenne River watershed assessment project from September 2003 – August 2005. Data has also been collected at the DENR ambient monitoring station near the mouth of the creek since 1999 and by RESPEC Consulting and Services from July 2007 – June 2008. Most of the data was collected from the sampling point near the mouth of the creek.

The Hydrologic Simulation Program Fortran (HSPF) model was used to determine the contribution of fecal coliform bacteria from identified sources in the Beaver Creek watershed and evaluate the implementation of Best Management Practices (BMPs) to control these sources.

The TMDL loads and loading capacities were derived using the load duration curve (LDC) approach resulting in a flow-variable target that considers the entire flow regime within the recreational season (May 1 - September 30) as shown in Figure 2 of the TMDL document. The LDC is a dynamic expression of the allowable load for any given day within the recreation season. To aid in interpretation and implementation of the TMDL, the LDC flow intervals were grouped into five flow zones: high flows (0–10%), moist conditions (10–40%), mid-range flows (40–60%), dry conditions (60–90%), and low flows (90–100%) according to EPA's *An Approach for Using Load Duration Curves in the Development of TMDLs.*

The loading capacity (LC) for Beaver Creek, based on the acute criterion, was calculated by multiplying the acute fecal coliform bacteria criterion by the simulated daily average flow at the Beaver Creek outlet as predicted by the HSPF model. The LC based on the chronic criterion was calculated by multiplying the chronic criterion by the monthly average model-predicted flows.

Measured sample concentrations and flow data were used to estimate current daily loads. The product of fecal coliform sample concentrations (CFU/100 ml) from SD DENR monitoring site number 460128, the measured flow (cfs) at the time the water sample was collected, and a unit conversion factor (0.0245). When measured flow data were not available for a sample date, simulated daily average flow data were used for the daily load calculation. A total of 26 observed (instantaneous) load estimates were calculated. The 95% percentile of the range of these estimates within each flow zone was defined as the baseline daily load. Baseline conditions for the 30-day averaging period were calculated differently than the daily averaging period. To estimate current monthly geometric mean loads, the product of the monthly geometric mean concentrations (CFU/100ml) and monthly average stream flows (cfs), calculated from the model's daily time series data, was multiplied by a conversion factor (0.7339). A total of 90 monthly geometric mean load estimates were calculated. The 95% percentile of the range of these estimates within each flow zone was defined as the baseline monthly geometric mean load.

Calculated loads using both the acute and chronic fecal coliform criteria are shown in Tables 4 and 5 of the TMDL document. These tables provide separate estimated load allocations for Wyoming and South Dakota.

COMMENTS: None.

4.1 Data Set Description

TMDL documents should include a thorough description and summary of all available water quality data that are relevant to the water quality assessment and TMDL analysis. An inventory of the data used for the TMDL analysis should be provided to document, for the record, the data used in decision making. This also provides the reader with the opportunity to independently review the data. The TMDL analysis should make use of all readily available data for the waterbody under analysis unless the TMDL writer determines that the data are not relevant or appropriate. For relevant data that were known but rejected, an explanation of why the data were not utilized should be provided (e.g., samples exceeded holding times, data collected prior to a specific date were not considered timely, etc…).

Minimum Submission Requirements:

☒ TMDL documents should include a thorough description and summary of all available water quality data that are relevant to the water quality assessment and TMDL analysis such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and appropriate water quality criteria.

☒ The TMDL document submitted should be accompanied by the data set utilized during the TMDL analysis. If possible, it is preferred that the data set be provided in an electronic format and referenced in the document. If electronic submission of the data is not possible, the data set may be included as an appendix to the document.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Beaver Creek TMDL data description and summary are included mostly in the Water Quality Data section (see Section 1.3) of the document, and the full data set is included in Appendix A. The recent water quality monitoring was conducted over the period from July 2007 to June 2008. A total of 26 fecal coliform samples were collected during the recreation season from May 1 to September 30. The data set also includes approximately 18 years of flow record on Beaver Creek that was used by the HSPF program to simulate stream flow for the recreation season.

COMMENTS: None.

4.2 Waste Load Allocations (WLA):

Waste Load Allocations represent point source pollutant loads to the waterbody. Point source loads are typically better understood and more easily monitored and quantified than nonpoint source loads. Whenever practical, each point source should be given a separate waste load allocation. All NPDES permitted dischargers that discharge the pollutant under analysis directly to the waterbody should be identified and given separate waste load allocations. The finalized WLAs are required to be incorporated into future NPDES permit renewals.

Minimum Submission Requirements:

☒ EPA regulations require that a TMDL include WLAs for all significant and/or NPDES permitted point sources of the pollutant. TMDLs must identify the portion of the loading capacity allocated to individual existing and/or future point source(s) (40 C.F.R. §130.2(h), 40 C.F.R. §130.2(i)). In some cases, WLAs may cover more than one discharger, e.g., if the source is contained within a general permit. If no allocations are to be made to point sources, then the TMDL should include a value of zero for the WLA.

☒ All NPDES permitted dischargers given WLA as part of the TMDL should be identified in the TMDL, including the specific NPDES permit numbers, their geographical locations, and their associated waste load allocations.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Wasteload Allocation section of the Beaver Creek TMDL document says that there are no municipal or other point sources that discharge directly to the impaired segment of Beaver Creek. Therefore, the WLA for this TMDL is zero. The only point source located in the watershed is over 50 miles upstream of the impaired segment in Upton, WY.

COMMENTS: None.

4.3 Load Allocations (LA):

Load allocations include the nonpoint source, natural, and background loads. These types of loads are typically more difficult to quantify than point source loads, and may include a significant degree of uncertainty. Often it is necessary to group these loads into larger categories and estimate the loading rates based on limited monitoring data and/or modeling results. The background load represents a composite of all upstream pollutant loads into the waterbody. In addition to the upstream nonpoint and upstream natural load, the background load often includes upstream point source loads that are not given specific waste load allocations in this particular TMDL analysis. In instances where nonpoint source loading rates are particularly difficult to quantify, a performance-based allocation approach, in which a detailed monitoring plan and adaptive management strategy are employed for the application of BMPs, may be appropriate.

Minimum Submission Requirements:

☒ EPA regulations require that TMDL expressions include LAs which identify the portion of the loading capacity attributed to nonpoint sources and to natural background. Load allocations may range from reasonably accurate estimates to gross allotments (40 C.F.R. §130.2(g)). Load allocations may be included for both existing and future nonpoint source loads. Where possible, load allocations should be described separately for natural background and nonpoint sources.

☒ Load allocations assigned to natural background loads should not be assumed to be the difference between the sum of known and quantified anthropogenic sources and the existing *in situ* loads (e.g., measured in stream) unless it can be demonstrated that all significant anthropogenic sources of the pollutant of concern have been identified and given proper load or waste load allocations.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Pollutant Source Assessment section of the TMDL explains that nonpoint sources contribute all of the fecal loading to the watershed. Approximately 97 percent of the bacteria load to the impaired segment of Beaver Creek is attributed to livestock from rangeland. Therefore, most of the loading capacity has been allocated to nonpoint sources in the form of load allocations, with the remainder allocated to the margin of safety to account for uncertainty. Tables 4, 5 and 6 excerpted from the TMDL document below, include the load allocations at each of the five flow regimes using the daily maximum criterion and the geometric mean criterion. The allocations listed for the high, moist, mid-range, and dry flow zones in Table 4 (using the acute criterion) and the low flow zone in Table 5 (using the chronic criterion) represent the TMDL goals to attain compliance with all applicable water quality standards. To arrive at a daily expression of the low flow zone goal, the monthly geometric mean TMDL allocations were simply divided by 30 (Table 6).

Table 4. Beaver Creek fecal coliform bacteria TMDL based on the daily maximum criterion. The table lists daily allocations by flow zone, including load allocations for both South Dakota and Wyoming portions of the watershed.

TMDL Component	Flow Zone (expressed as CFU*10^9/day)				
	High 77-834 cfs	Moist 13-76 cfs	Mid-range 5.0-12 cfs	Dry 0.6-5.0 cfs	Low 0-0.5 cfs
LA_{SD}*	10,345	1,564	300	76	9
LA_{WY}*	11,646	1,040	150	75	10
WLA	0	0	0	0	0
MOS	3,366	773	140	78	6
TMDL	25,357	3,378	589	229	25
Current Load**	42,389	31,525	1	60	99
Load Reduction	40%	89%	0%	0%	74%

* Load allocations are provided for both South Dakota (LA_{SD}) and Wyoming (LA_{WY}).
** Current load is the 95th percentile of observed fecal coliform bacteria load for each flow zone.

Table 5. Beaver Creek fecal coliform bacteria TMDL based on the geometric mean criterion. The table lists monthly allocations by flow zone, including load allocations for both South Dakota and Wyoming portions of the watershed.

TMDL Component	Flow Zone (expressed as CFU*10^9/month)				
	High 77-834 cfs	Moist 13-76 cfs	Mid-range 5.0-12 cfs	Dry 0.6-5.0 cfs	Low 0-0.5 cfs
LA_{SD}*	96,120	23,928	10,076	2,112	118
LA_{WY}*	108,214	15,912	5,035	2,090	129
WLA	0	0	0	0	0
MOS	58,579	20,462	3,978	1,691	255
TMDL	262,913	60,301	19,089	5,894	503
Current Load**	817	671	980	1,373	2,633
Load Reduction	0%	0%	0%	0%	81%

* Load allocations are provided for both South Dakota (LA_{SD}) and Wyoming (LA_{WY}).
** Current load is the 95th percentile of model-predicted monthly geometric mean loads for each flow zone.

Table 6. Daily expression of low flow zone monthly allocations, calculated by dividing the monthly allocations in Table 5 by 30.

TMDL Component	Flow Zone (expressed as CFU*10^9/day) Low 0-0.5 cfs
LA_{SD}*	4
LA_{WY}*	4
WLA	0
MOS	9
TMDL	17
Current Load**	88
Load Reduction	81%

COMMENTS: None.

4.4 Margin of Safety (MOS):

Natural systems are inherently complex. Any mathematical relationship used to quantify the stressor → response relationship between pollutant loading rates and the resultant water quality impacts, no matter how rigorous, will include some level of uncertainty and error. To compensate for this uncertainty and ensure water quality standards will be attained, a margin of safety is required as a component of each TMDL. The MOS may take the form of a explicit load allocation (e.g., 10 lbs/day), or may be implicitly built into the TMDL analysis through the use of conservative assumptions and values for the various factors that determine the TMDL pollutant load → water quality effect relationship. Whether explicit or implicit, the MOS should be supported by an appropriate level of discussion that addresses the level of uncertainty in the various components of the TMDL technical analysis, the assumptions used in that analysis, and the relative effect of those assumptions on the final TMDL. The discussion should demonstrate that the MOS used is sufficient to ensure that the water quality standards would be attained if the TMDL pollutant loading rates are met. In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).

Minimum Submission Requirements:

☒ TMDLs must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)). EPA's 1991 TMDL Guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS).

- ☐ If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS should be identified and described. The document should discuss why the assumptions are considered conservative and the effect of the assumption on the final TMDL value determined.
- ☒ If the MOS is explicit, the loading set aside for the MOS should be identified. The document should discuss how the explicit MOS chosen is related to the uncertainty and/or potential error in the linkage analysis between the WQS, the TMDL target, and the TMDL loading rate.
- ☐ If, rather than an explicit or implicit MOS, the TMDL relies upon a phased approach to deal with large and/or unquantifiable uncertainties in the linkage analysis, the document should include a description of the planned phases for the TMDL as well as a monitoring plan and adaptive management strategy.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Beaver Creek TMDL includes an explicit MOS derived by calculating 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. The explicit MOS values are included in Tables 4, 5 and 6 of the TMDL document.

COMMENTS: None.

4.5 Seasonality and variations in assimilative capacity:

The TMDL relationship is a factor of both the loading rate of the pollutant to the waterbody and the amount of pollutant the waterbody can assimilate and still attain water quality standards. Water quality standards often vary based on seasonal considerations. Therefore, it is appropriate that the TMDL analysis consider seasonal variations, such as critical flow periods (high flow, low flow), when establishing TMDLs, targets, and allocations.

Minimum Submission Requirements:

☒ The statute and regulations require that a TMDL be established with consideration of seasonal variations. The TMDL must describe the method chosen for including seasonal variability as a factor. (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)).

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: By using the load duration curve approach to develop the TMDL allocations seasonal variability in fecal coliform loads are taken into account. Highest steam flows typically occur during late spring, and the lowest stream flows occur during the winter months. Also, the TMDL is seasonal since the fecal coliform criteria are in effect from May 1 to September 30, therefore the TMDL is only applicable during that period.

COMMENTS: None.

5. Public Participation

EPA regulations require that the establishment of TMDLs be conducted in a process open to the public, and that the public be afforded an opportunity to participate. To meaningfully participate in the TMDL process it is necessary that stakeholders, including members of the general public, be able to understand the problem and the proposed solution. TMDL documents should include language that explains the issues to the general public in understandable terms, as well as provides additional detailed technical information for the scientific community. Notifications or solicitations for comments regarding the TMDL should be made available to the general public, widely circulated, and clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for approval, a copy of the comments received by the state and the state responses to those comments should be included with the document.

Minimum Submission Requirements:

☒ The TMDL must include a description of the public participation process used during the development of the TMDL (40 C.F.R. §130.7(c)(1)(ii)).

☐ TMDLs submitted to EPA for review and approval should include a summary of significant comments and the State's/Tribe's responses to those comments.

Recommendation:

☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The State's submittal includes a summary of the public participation process that has occurred. It describes the opportunities that the public has been given to be involved in the TMDL development process to date. In particular, the State has encouraged participation through presentations to local groups in the watershed, and making the TMDL available for a 30-day public notice period prior to finalization.

COMMENTS: None.

6. Monitoring Strategy

TMDLs may have significant uncertainty associated with the selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL document to articulate the means by which the TMDL will be evaluated in the field, and to provide for future supplemental data that will address any uncertainties that may exist when the document is prepared.

Minimum Submission Requirements:

☐ When a TMDL involves both NPDES permitted point source(s) and nonpoint source(s) allocations, and attainment of the TMDL target depends on reductions in the nonpoint source loads, the TMDL document should include a monitoring plan that describes the additional data to be collected to determine if the load reductions provided for in the TMDL are occurring.

☐ Under certain circumstances, a phased TMDL approach may be utilized when limited existing data are relied upon to develop a TMDL, and the State believes that the use of additional data or data based on better analytical techniques would likely increase the accuracy of the TMDL load calculation and merit development of a second phase TMDL. EPA recommends that a phased TMDL document or its implementation plan include a monitoring plan and a scheduled timeframe for revision of the TMDL. These elements would not be an intrinsic part of the TMDL and would not be approved by EPA, but may be necessary to support a rationale for approving the TMDL. http://www.epa.gov/owow/tmdl/tmdl_clarification_letter.pdf

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: Beaver Creek should continue to be monitored as part SD DENR's ambient water quality monitoring program at the Beaver Creek site near the confluence with the Cheyenne River (STORET ID: 460654). Additional data may be needed to fully assess compliance with the chronic criterion for fecal coliform. Post-implementation monitoring will be necessary to assure the TMDL targets have been reached and maintenance of the beneficial use occurs.

COMMENTS: None.

7. Restoration Strategy

The overall purpose of the TMDL analysis is to determine what actions are necessary to ensure that the pollutant load in a waterbody does not result in water quality impairment. Adding additional detail regarding the proposed approach for the restoration of water quality is not currently a regulatory requirement, but is considered a value added component of a TMDL document. During the TMDL analytical process, information is often gained that may serve to point restoration efforts in the right direction and help ensure that resources are spent in the most efficient manner possible. For example, watershed models used to analyze the linkage between the pollutant loading rates and resultant water quality impacts might also be used to conduct "what if" scenarios to help direct BMP installations to locations that provide the greatest pollutant reductions. Once a TMDL has been written and approved, it is often the responsibility of other water quality programs to see that it is implemented. The level of quality and detail provided in the restoration strategy will greatly influence the future success in achieving the needed pollutant load reductions.

Minimum Submission Requirements:

☒ EPA is not required to and does not approve TMDL implementation plans. However, in cases where a WLA is dependent upon the achievement of a LA, "reasonable assurance" is required to demonstrate the necessary LA called for in the document is practicable). A discussion of the BMPs (or other load reduction measures) that are to be relied upon to achieve the LA(s), and programs and funding sources that will be relied upon to implement the load reductions called for in the document, may be included in the implementation/restoration section of the TMDL document to support a demonstration of "reasonable assurance".

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Implementation section of the TMDL document describes the best management practices (BMPs) recommended for implementation in order to reduce the fecal coliform loads. Four management scenarios were simulated using the HSPF model: 1) reduced Wyoming bacteria loads to comply with South Dakota water quality criteria, 2) removal of septic system bacteria loads, 3) exclusion of cattle from streams, and 4) general rangeland management. According to the model, the first two scenarios would not significantly reduce the fecal coliform loads in the impaired segment of Beaver Creek. Therefore, implementation of scenarios 3 and 4 are recommended because they are most likely to reduce the fecal coliform loads to levels that would meet the TMDL targets.

Since there are no point sources that discharge directly to the impaired segment of Beaver Creek, there is no need to include a discussion of reasonable assurance in this TMDL document.

COMMENTS: None.

8. Daily Loading Expression

The goal of a TMDL analysis is to determine what actions are necessary to attain and maintain WQS. The appropriate averaging period that corresponds to this goal will vary depending on the pollutant and the nature of the waterbody under analysis. When selecting an appropriate averaging period for a TMDL analysis, primary concern should be given to the nature of the pollutant in question and the achievement of the underlying WQS. However, recent federal appeals court decisions have pointed out that the title TMDL implies a "daily" loading rate. While the most appropriate averaging period to be used for developing a TMDL analysis may vary according to the pollutant, a daily loading rate can provide a more practical indication of whether or not the overall needed load reductions are being achieved. When limited monitoring resources are available, a daily loading target that takes into account the natural variability of the system can serve as a useful indicator for whether or not the overall load reductions are likely to be met. Therefore, a daily expression of the required pollutant loading rate is a required element in all TMDLs, in addition to any other load averaging periods that may have been used to conduct the TMDL analysis. The level of effort spent to develop the daily load indicator should be based on the overall utility it can provide as an indicator for the total load reductions needed.

Minimum Submission Requirements:

☒ The document should include an expression of the TMDL in terms of a daily load. However, the TMDL may also be expressed in temporal terms other than daily (e.g., an annual or monthly load). If the document expresses the TMDL in additional "non-daily" terms the document should explain why it is appropriate or advantageous to express the TMDL in the additional unit of measurement chosen.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Beaver Creek fecal coliform TMDL includes daily loads expressed as colonies per day. The daily TMDL loads are included in the TMDL and Allocations section of the TMDL document (Tables 4 and 6).

COMMENTS: None.