Total Suspended Solids Total Maximum Daily Load Evaluation for Brule Creek, Union and Lincoln Counties, South Dakota

SOUTH DAKOTA DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES

MARCH 2022

Brule Creek Total Suspended Solids Total Maximum Daily Load Summary

Entity ID:	SD-BS-R-BRULE_01
Location:	HUC Code: 101702032304, 101702032305
Size of Watershed:	92,228 acres
Water body Type:	River/Stream
303(d) Listing Parameter:	Total Suspended Solids
Initial Listing Date:	2018 IR
TMDL Priority Ranking:	High
Listed Stream Miles:	37 miles
Designated Use of Concern:	Warmwater Marginal Fish Life Propagation
Analytical Approach:	Load Duration Curve Framework, AGNPS model, Rapid Geomorphic Assessments, Suspended Sediment Rating Curve
Target:	Meet applicable water quality standards 74:51:01:49
Indicators:	Total Suspended Solids
Threshold Value:	$\leq$ 150 mg/L 30-day average concentration from minimum 3 samples within 30-day calendar period and single sample maximum concentration of $\leq$ 263 mg/L
High Flow Zone LA:	4.17×10^{11} mg/day
High Flow Zone WLA:	0 mg/day
High Flow Zone MOS:	4.63×10^{10} mg/day
High Flow Zone TMDL:	4.63×10^{11} mg/day

Contents

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 Total Suspended Solids (TSS) impairment for segment **SD-BS-R-BRULE_01** of Brule Creek in the Big Sioux River Basin. This segment was determined to not support the designated warmwater marginal fish life propagation use and was placed on the 303(d) list of impaired waters in South Dakota's 2020 Integrated Report for Surface Water Quality Assessment. This segment has been listed as non-supporting for the Warmwater Marginal Fish Life use and has been included on the 2020 303(d) list.

1.1 Watershed Characteristics

1.1.1 General

The Brule Creek project area is presented in Figure 1. Brule Creek is a tributary of the Big Sioux River in southeastern South Dakota. The headwaters of Brule Creek are in southern Lincoln County, approximately 5 miles southeast of the community of Beresford, at the confluence of West Brule Creek and East Brule Creek. From there the stream flows south for 37 miles to its confluence with the Big Sioux River in Union County, about 4 miles northeast of the community of Elk Point, South Dakota. The total area drained by Brule Creek and its tributaries, including East Brule Creek, encompasses 214 square miles (137,004 acres). The area drained only by segment SD-BS-R-BRULE_01, which spans from the confluence of East Brule Creek and West Brule creek to where Brule Creek enters the Big Sioux River, covers 144 square miles (92,228 acres).

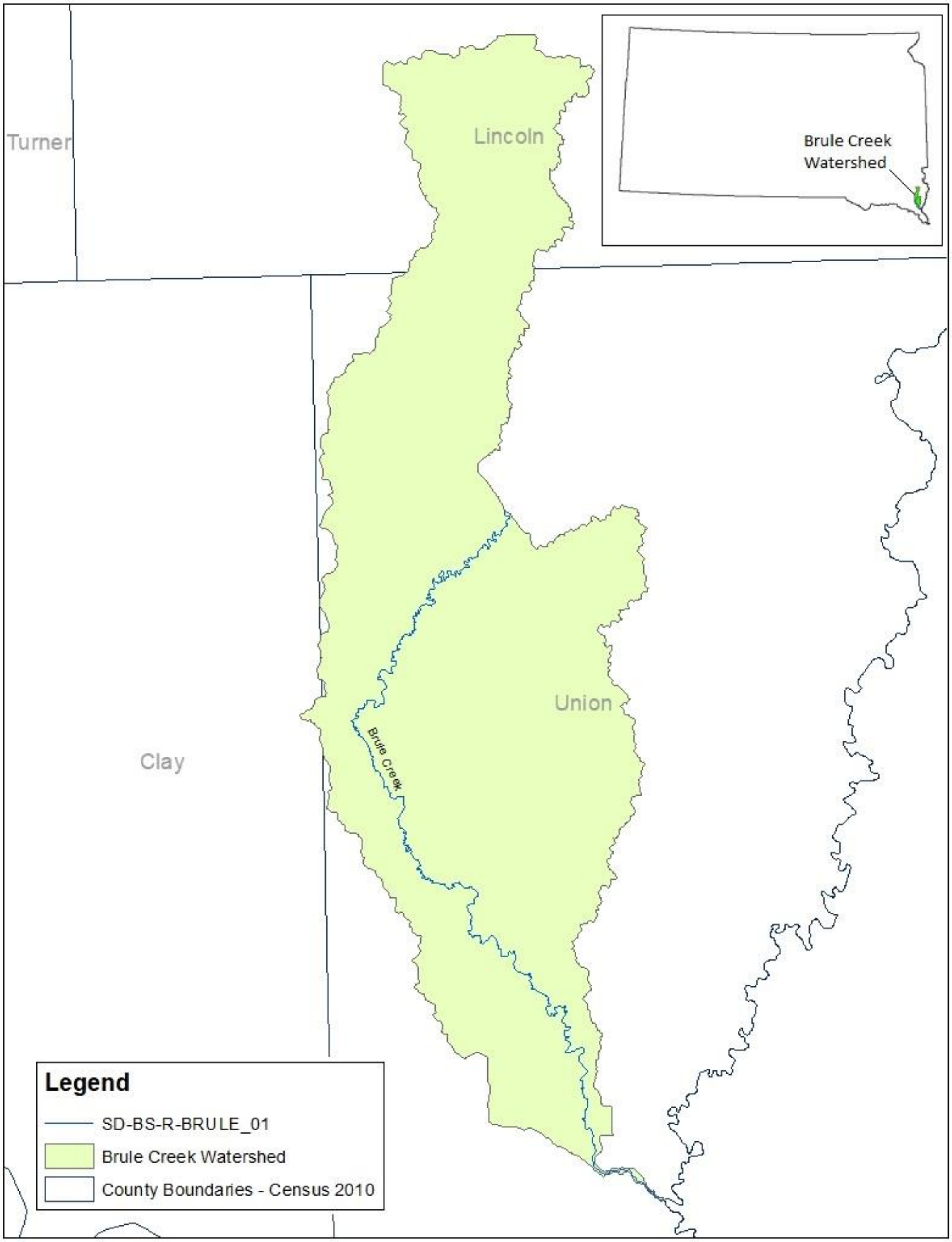

Figure 1. Brule Creek watershed map.

1.1.2 Land Use

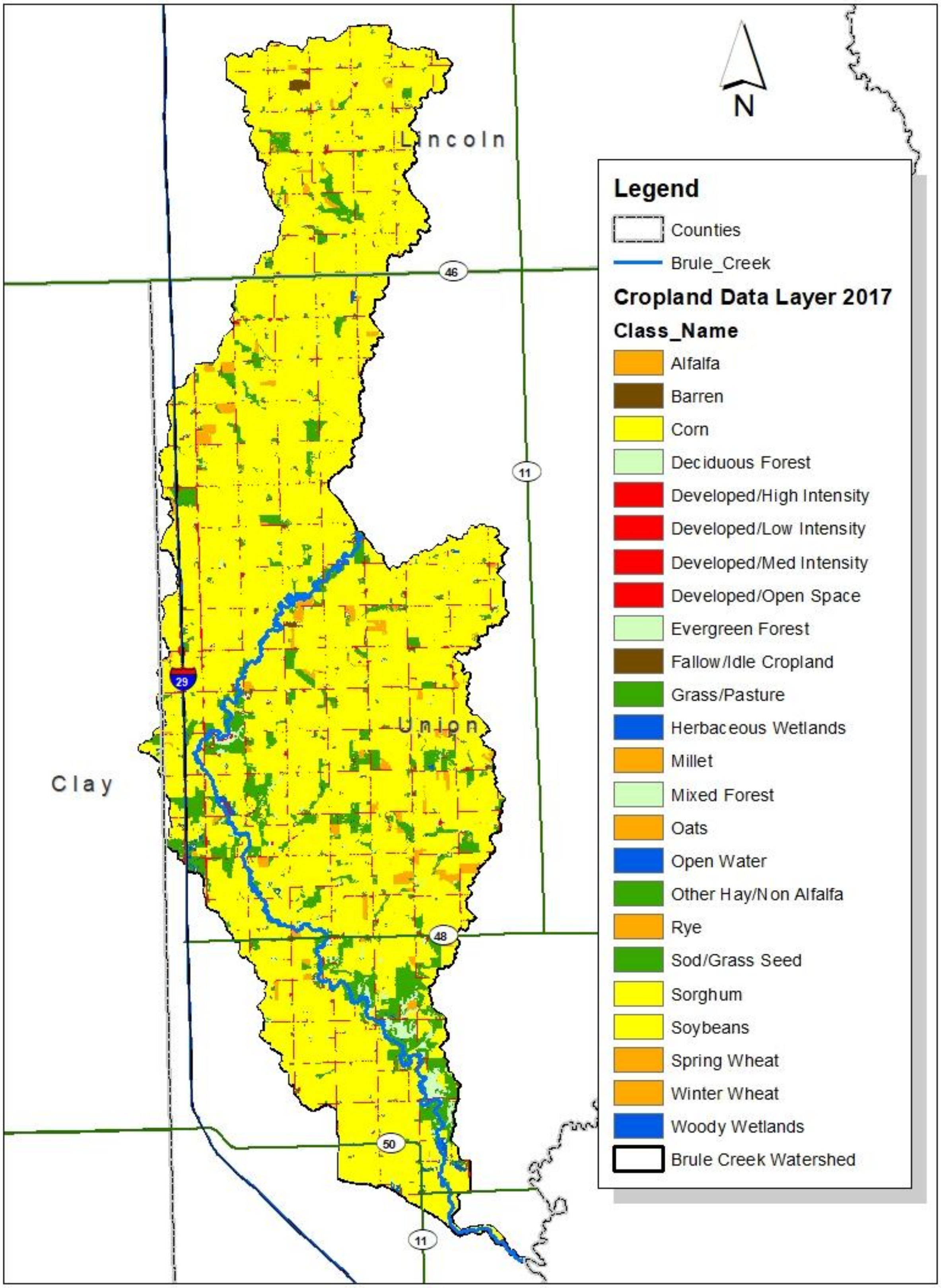

Figure 2. Map depicting land use in the Brule Creek watershed (USDA-NASS, 2017).

Table 1. Land use statistics for the Brule Creek watershed (USDA-NASS, 2017).

Land Use Type	Percent Area	Land Use Type	Percent Area
Corn	42.22%	Open Water	0.16%
Sorghum	0.00%	Developed/Open Space	3.76%
Soybeans	38.97%	Developed/Low Intensity	0.29%
Spring Wheat	0.01%	Developed/Med Intensity	0.17%
Winter Wheat	0.01%	Developed/High Intensity	0.00%
Rye	0.00%	Barren	0.01%
Oats	0.11%	Deciduous Forest	1.83%
Millet	0.00%	Evergreen Forest	0.00%
Alfalfa	2.05%	Mixed Forest	0.00%
Other Hay/Non Alfalfa	0.52%	Grass/Pasture	9.27%
Sod/Grass Seed	0.00%	Woody Wetlands	0.00%
Fallow/Idle Cropland	0.25%	Herbaceous Wetlands	0.36%

The map in Figure 2 presents land use types in the Brule Creek watershed. The percentage of the watershed area occupied by each use type is presented in Table 1. Land use is mostly agricultural in nature. Row crops such as corn and soybeans are the predominant land use type, occupying over 80% of the basin. These crops are typically grown on the more level terrain in the watershed. Grasslands and herbaceous areas are the second most common land use type in both basins and are typically used as pasture and rangeland for livestock. These land use types are typically found on steeper terrain in the watershed, usually along drainages such as Brule Creek and its tributaries. Developed land is mostly made up of roads and road ditches. Many roads in the watershed are gravel surfaced, and road ditches are typically planted in grass. The small grains, including wheat, barley, oats, and other such closely planted small grains may be found on level soils. Wooded areas are mostly concentrated in the southeastern portion of the Brule Creek watershed and Union Grove State Park.

1.1.3 Physiography

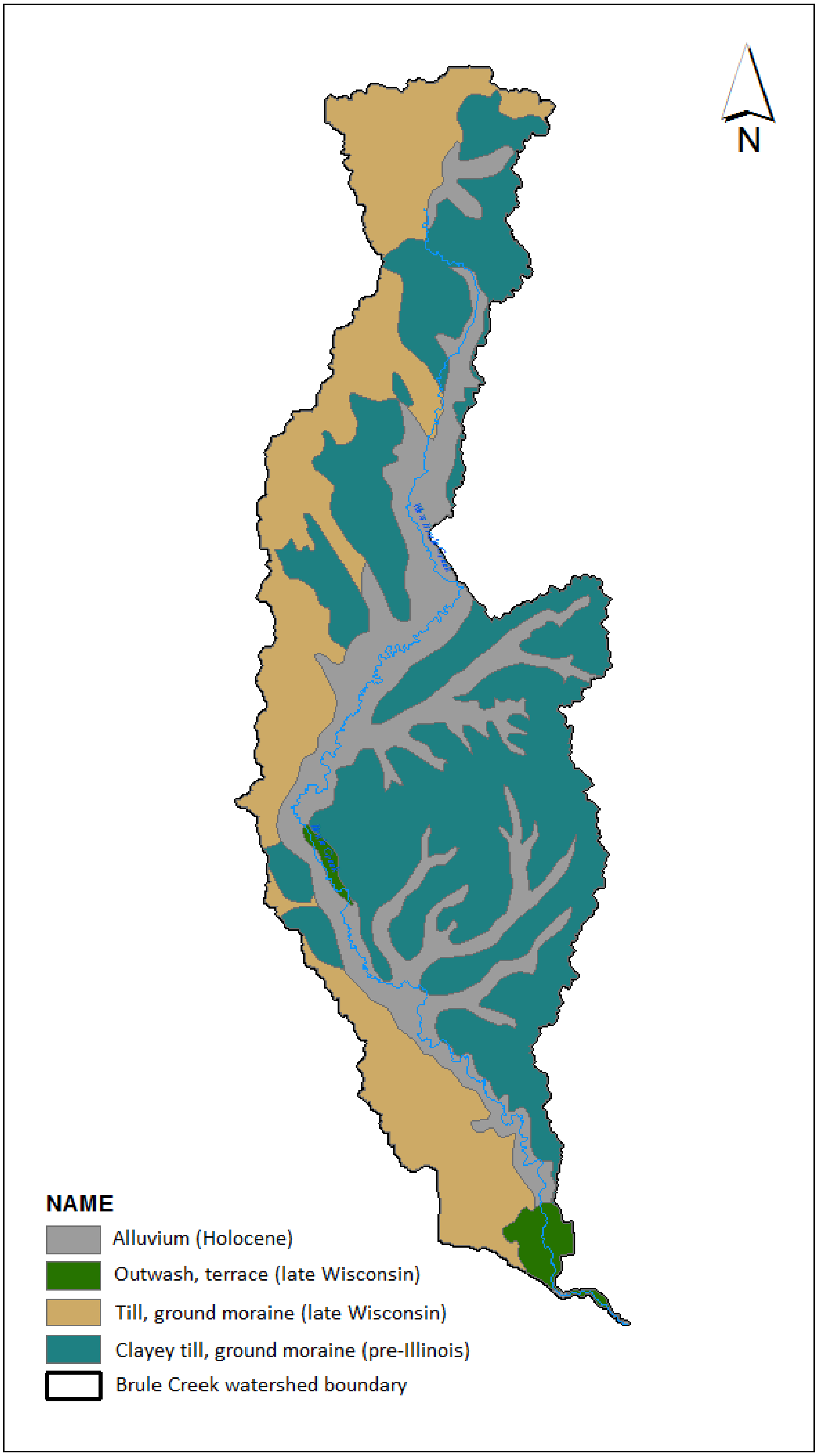

Figure 3. Map of glacial sediments in the Brule Creek and East Brule Creek watersheds (Stoeser, 2015).

The topography of South Dakota east of the Missouri River was shaped by successive periods of glaciation during the Pleistocene Epoch (10,000 – 2.5 million years ago). The most recent period of glaciation was the Late Wisconsin stage, which started about 35,000 years ago and ended 10,000 years ago. Older glacial sediments were deposited during periods of glaciation during the pre-Illinoisan stage, which ranged from 302,000 years ago to 2.5 million years ago (McCormick, 2004).

Till is the most common glacial sediment in the Brule Creek watershed. Till consists of non-stratified, unsorted debris that has been transported and deposited directly by glacial ice. It is primarily composed of the rocks or sediments over which the ice traveled. In the Brule Creek basin, till is composed primarily of a silty clay matrix, a variable proportion of sand and pebbles, and few boulders. The small grain size of glacial till in the watershed is a result of the predominance of shale in the bedrock from which the till originated (McCormick, 2004).

During the Late Wisconsin, the extreme western portion of the Brule Creek watershed was covered in glacial ice. When the ice receded, a ground moraine of smooth rolling terrain was left. This terrain can be observed along the western and northern margins of the Brule Creek watershed (Figure 3). Where it is present, Late Wisconsin glacial till is usually exposed at the surface. In some areas it may be covered by loess (wind-blown sediment), particularly in the northern portion of the Brule Creek watershed adjacent to loess covered pre-Illinoisan till. The maximum thickness of Late Wisconsin till is about 150 feet in drill holes in this area (McCormick, 2004). Soils in this area are likely part of the Wentworth-Shindler-Worthing or Wakonda-Worthing-Chancellor associations. Wentworth-Shindler-Worthing soils are deep, well to poorly drained, level to steep, silty and loamy soils. Wakonda-Worthing-Chancellor soils are deep, moderately to poorly drained, nearly level to level, silty soils (USDA, 1978).

Outwash sediments from the Late Wisconsin occur where glacial melt waters deposited sand and gravel. Outwash sediments are often found at the base of the late Wisconsin till. They range from being very thin in local deposits within areas of Late Wisconsin till (<20 feet) but may be very thick in the Big Sioux River valley. In the Brule Creek watershed, the primary area of glacial outwash sediments is found near the confluence with the Big Sioux River (McCormick, 2004).

Several other periods of glaciation preceded the Late Wisconsin. Pre-Illinoisan till covers the eastern portion of the Brule Creek watershed. These features were not covered by glacial ice during the Late Wisconsin. Wind-blown loess accumulated on top of these sediments in many areas, particularly on the leeward side of hills (McCormick & Hammond, 2004). Soils in these areas are typically classified into two soil associations: The Moody-Nora-Alcester association, which is typified by deep, well to moderately well drained, nearly level to sloping, silty soils, or the Crofton-Nora-Alcester association, which is typified by deep, well to moderately well drained, gently sloping to very steep, silty soils (USDA, 1978).

Holocene alluvial sediments were deposited along drainages such as Brule Creek and its tributaries since the last glacial retreat about 10,000 years ago. Alluvium consists of clay and silt, with lesser amounts of sand and is typically black or dark-brown and rich in organic matter (McCormick, 2004). Alluvial soils in the watershed are typically classified in the Calco-Kennebec association. These are deep, poorly to moderately well drained, level to nearly level, silty soils (USDA, 1978).

1.1.4 Level 4 Ecoregions

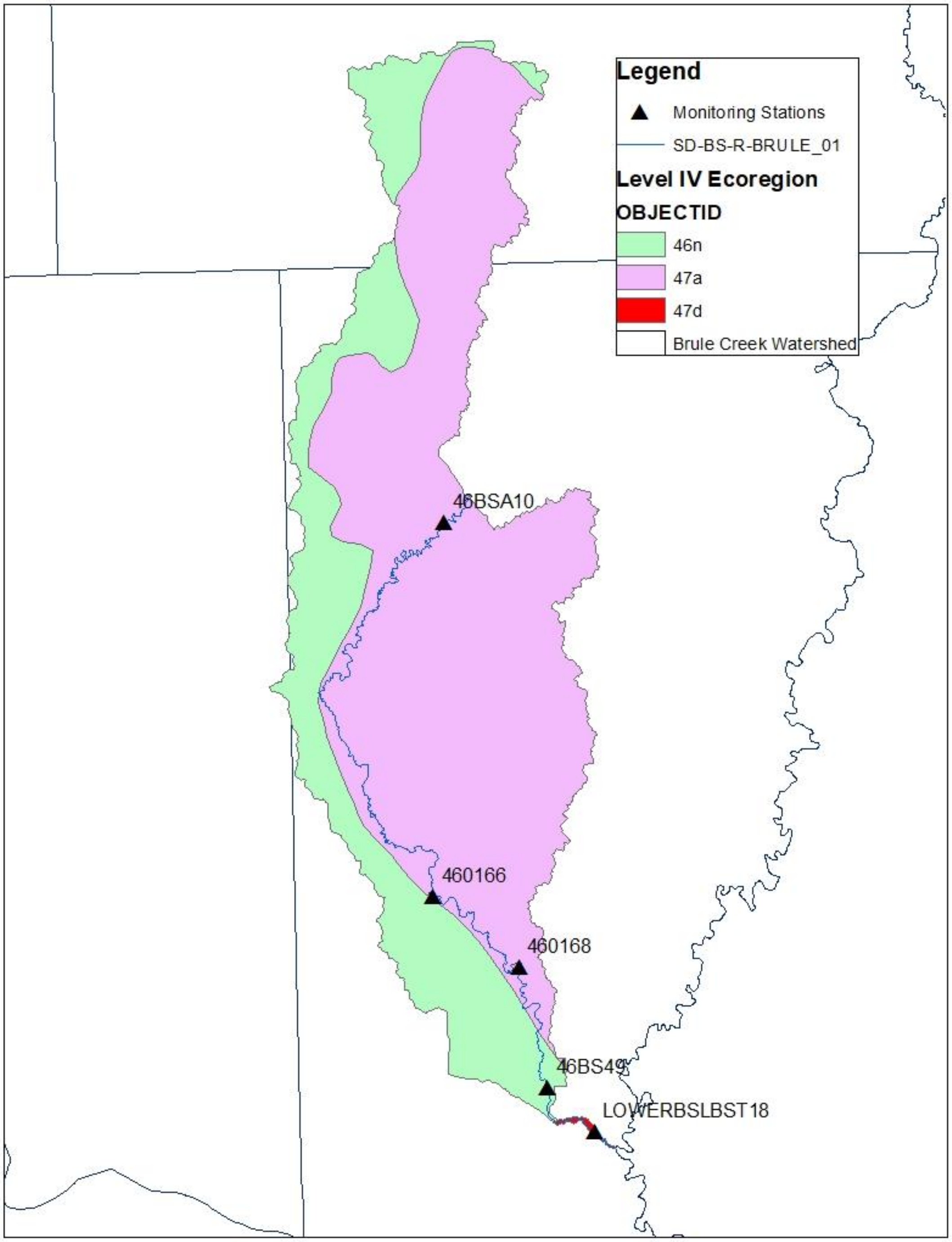

Figure 4. Map of Level 4 Ecoregions in the Brule Creek watershed.

There are three Level 4 Ecoregions in the Brule Creek watershed (Figure 4). The James River Lowlands (46n) occupy the western most edge of the watershed. The Loess Prairies (47a) occupies the majority of the watershed and covers the eastern and central areas. A small area of Missouri

Alluvial Plain (47d) is found in the extreme southern part of the watershed where Brule Creek enters the Big Sioux River.

2.0 Description of Applicable Water Quality Standards & Numeric TMDL Targets

2.1 South Dakota Water Quality Standards

Water quality standards are comprised of three main parts as defined in the Federal Clean Water Act (33 U.S.C. §1251 et seq.) and Administrative Rules of South Dakota (ARSD) Chapter 74:51:01:

- Beneficial Uses – Functions or activities that reflect waterbody management goals
- Criteria – Numeric concentrations or narrative statements that represent the level of water quality required to support beneficial uses
- Antidegradation – Additional policies that protect high quality waters

Each individual waterbody within South Dakota is designated one or more of the following beneficial uses:

(1) Domestic water supply
(2) Coldwater permanent fish life propagation
(3) Coldwater marginal fish life propagation
(4) Warmwater permanent fish life propagation
(5) Warmwater semipermanent fish life propagation
(6) Warmwater marginal fish life propagation
(7) Immersion recreation
(8) Limited contact recreation
(9) Fish and wildlife propagation, recreation, and stock watering
(10) Irrigation
(11) Commerce and industry

All waters (both lakes and streams) within South Dakota are designated the use of fish and wildlife propagation, recreation, and stock watering (9). All streams are designated the uses of (9), and (10) irrigation. Additional uses are designated by the state based on a use attainability assessment of each waterbody.

Brule Creek has been assigned the beneficial uses of: warmwater marginal fish life, limited contact recreation, irrigation waters, and fish and wildlife propagation, recreation, and stock watering. Table 2 lists the water quality standards assigned to protect the designated beneficial uses for SD-BS-R_BRULE_01. When multiple criteria exist for a particular parameter, the most stringent criterion is used.

Table 2. South Dakota water quality standards for Brule Creek.

Parameters	Criteria	Unit of Measure	Beneficial Use Requiring this Standard
Total ammonia nitrogen as N	Equal to or less than the result from Equation 3 in Appendix A of Surface Water Quality Standards	mg/L 30 average March 1 to October 31	Warmwater Marginal Fish Life Propagation
	Equal to or less than the result from Equation 4 in Appendix A of Surface Water Quality Standards	mg/L 30 average November 1 to February 29	
	Equal to or less than the result from Equation c in Appendix A of Surface Water Quality Standards	mg/L Daily Maximum	
Dissolved Oxygen	≥4.0 Oct-Apr ≥5.0 May-Sept	mg/L	Warmwater Marginal Fish Life Propagation
Total Suspended Solids	≤150 (30-day mean) ≤263 (single sample)	mg/L	Warmwater Marginal Fish Life Propagation
Temperature	≤<90	°F	Warmwater Marginal Fish Life Propagation
Escherichia coli Bacteria (May 1- Sept 30)	≤630 (geometric mean) ≤1,178 (single sample)	count/100 mL	Limited Contact Recreation
Alkalinity ($CaCO_3$)	≤750 (30-day mean) ≤1,313 (single sample)	mg/L	Fish and Wildlife Propagation, Recreation, and Stock Watering
Conductivity	≤2,500 (30-day mean) ≤4,375 (single sample)	µmhos/cm @ 25° C	Irrigation Waters
Nitrogen, nitrate as N	≤50 (30-day mean) ≤88 (single sample)	mg/L	Fish and Wildlife Propagation, Recreation, and Stock Watering
pH (standard units)	≥6.0 to ≤9.0	units	Warmwater Marginal Fish Life Propagation
Solids, total dissolved	≤2,500 (30-day mean) ≤4,375 (single sample)	mg/L	Fish and Wildlife Propagation, Recreation, and Stock Watering
Total Petroleum Hydrocarbon	≤10	mg/L	Fish and Wildlife Propagation, Recreation, and Stock Watering
Oil and Grease	≤10	mg/L	Fish and Wildlife Propagation, Recreation, and Stock Watering
Sodium Adsorption Ratio	<10	ratio	Irrigation Waters
Undissociated hydrogen sulfide	≤0.002	mg/L	Warmwater Marginal Fish Life Propagation

Additional "narrative" standards that may apply can be found in ARSD 74:51:01:05; 06; 08; and 09. These rules contain language that generally prohibits the introduction of materials into waterbodies causing pollutants to form, visible pollutants, undesirable odors and nuisance aquatic life which can all interfere with the biological integrity of a waterbody.

This TMDL document is consistent with South Dakota antidegradation policies (ARSD 74:51:01:34) because it provides recommendations and establishes pollutant limits at water quality levels necessary to meet criteria and fully support existing beneficial uses.

2.2 Total Suspended Solids Water Quality Standards

South Dakota has adopted numeric TSS criteria for the protection of coldwater permanent fish life propagation (2), coldwater marginal fish life propagation (3), warmwater permanent fish life propagation (4), warmwater semipermanent fish life propagation (5), and warmwater marginal fish life propagation (6) uses. Waters with one of the fish life propagation uses are to be maintained suitable for the propagation of fish life in order to protect aquatic life and the productivity of fisheries.

The South Dakota TSS criteria for warmwater marginal fish life propagation requires that; 1) no single sample exceed 263 mg/L and; 2) during a 30-day period, the mean of a minimum of 3 samples collected during separate weeks must not exceed 150 mg/L (ARSD 74:51:01:49). The numeric TSS criteria applicable to Brule Creek (SD-BS-R-BRULE_01) are the warmwater marginal fish life propagation values listed in Table 2.

2.3 Numeric TMDL Target

TMDLs are required to identify a numeric target to measure whether the applicable water quality standard is attained. A maximum allowable load, or TMDL, is ultimately calculated by multiplying this target with a flow value and a unit conversion factor. Generally, the pollutant causing the impairment and the parameter expressed as a numeric water quality criteria are the same. In these cases, selecting a TMDL target is as simple as applying the numeric criteria. Occasionally, an impairment is caused by narrative water quality criteria violations or by parameters that cannot be easily expressed as a load. When this occurs, the narrative criteria must be translated into a numeric TMDL target (e.g., nuisance aquatic life translated into a total phosphorus target) or a surrogate target established (e.g., a pH cause addressed through a total nitrogen target) and a demonstration should show how the chosen target is protective of water quality standards.

As seen from Table 2, there are two numeric TSS criteria for TMDL target consideration. When multiple numeric criteria exist for a single parameter, the most stringent criterion is selected as the TMDL target. The numeric TMDL target for TSS for Brule Creek is 150 mg/L, which is based on the 30-day mean threshold for TSS. This criterion is more stringent than the single sample maximum for TSS of 263 mg/L.

2.4 303(d) Assessment

Waters are assessed on a biennial basis to determine whether water quality standards are being met. SDDANR evaluates monitoring data using procedures (Table 3) outlined in the Integrated Report to determine if: 1) one or more beneficial uses are not supported, 2) the waterbody is impaired, and 3) it should be placed on the 303(d) list. Waterbodies impaired by pollutants require TMDLs. Table 3 presents South Dakota's assessment method for TSS and describes what constitutes a minimum sample size and how an impairment decision is made.

Table 3. Assessment Methods for Determining Support Status for Section 303(d) (SD DENR, 2018)

Description	Minimum Sample Size	Impairment Determination Approach
FOR CONVENTIONAL PARAMETERS (such as dissolved oxygen, TSS, E. coli bacteria, pH, water temperature, etc.)	STREAMS: a minimum of 10 samples for any one parameter are required within a waterbody reach.	STREAMS: >10% exceedance for daily maximum criteria (or 3 or more exceedances between 10 and 19 samples) or >10% exceedance for chronic criteria (or 2 or more exceedances between 2 and 19 samples)
	A minimum of two chronic (calculated) results are required for chronic criteria (30-day averages and geo means).	
	LAKES: at least two independent years of sample data and at least two sampling events per year.	LAKES: >10% exceedance when 20 or more samples were available. If < 20 samples were available, 3 exceedances were considered impaired. See lakes listing methodology section for specifics on parameters associated with a vertical profile (i.e., dissolved oxygen, water temperature, pH, and specific conductance).

The assessment method mentions chronic criteria. Although this term does not directly relate to TSS, the assessment method is organized together with other conventional parameters in the Integrated Report to show that a consistent approach is applied to many pollutants. In this limited definition, chronic refers to the 30-day mean. Different assessment methods have been established for toxic parameters and mercury in fish tissue.

Brule Creek was first included on the 2018 303(d) list of impaired waters because of multiple instances where the mean of 3 or more samples collected in a 30-day calendar period exceeded the chronic threshold of 150 mg/L, and because greater than 10% of the TSS samples exceeded the single sample maximum threshold of 263 mg/L. It remained impaired for TSS on the 2020 303(d) list.

3.0 Potential Sources

3.1 Point Sources

There is one National Point-source Discharge Elimination System (NPDES) Permitted facility located within the SD-BS-R-BRULE_01 watershed. This point source (permit #: SD0027928) is a gravel pit that is authorized to discharge to Brule Creek only under emergency conditions. This facility has discharged to Brule Creek during 13 of the last 193 months. All discharges had a maximum TSS concentration of 44.5 mg/L or less. Due to infrequent discharges and low TSS concentrations relative to the TSS standards for Brule Creek, this facility is not considered a significant source of TSS. As a result, a WLA was not given for this facility in the TMDL. The WLA for SD-BS-R-BRULE_01 is considered zero.

3.2 Non-point Sources

Typical non-point sources of TSS in agricultural watersheds such as Brule Creek are the bed and banks of streams and surface runoff from croplands, particularly row crops that are widely spaced such as corn and soybeans.

Agricultural practices may influence the degree to which these sources of TSS contribute to streams. In neighboring Minnesota, the installation of subsurface drainage, "drain tile", and the removal of upland depressions and wetlands has resulted in increased streamflow and therefore increased erosive force on river banks and beds (Schottler, 2013). The extent and location of subsurface drainage in the Brule Creek watershed is not currently known but drain tile outlet pipes running to Brule Creek and its tributaries have been observed at several locations and it is presumed that drain tile is used extensively in the watershed.

The management of croplands can also impact TSS concentrations in streams. Extensive tillage and farming of areas near waterways results in higher sediment contributions to streams and can undermine the structural integrity of stream banks. Agricultural practices that reduce tillage, leave crop residue in place throughout the winter months, and utilize buffer strips of native vegetation along waterways can reduce sediment contribution to streams.

Bridges, culverts, and other road crossings may also contribute sediment to streams by directing flow into stream banks where a meander occurs immediately downstream from the bridge or culvert. Areas where flow is directed into a stream bank are more likely to have failing banks, and therefore elevated sediment contributions to the stream. This is compounded when the flow regime is altered due to drain tile, which is common in the watershed.

3.3 Natural Sources

Natural sources of TSS in the Brule Creek watershed account for a proportion of TSS in the stream. Natural sources include the uplands and the bed and banks of the stream absent human influence. Three approaches to determining the natural TSS contribution to Brule Creek are presented below. The results from these analyses are provided as a reference to understand natural TSS conditions in Brule Creek. According to the estimates described below, natural sources contribute approximately 0.38% - 11.5% of the existing TSS observed in Brule Creek. Natural sources are not assigned a separate allocation in the TMDL but rather the allowable natural loading is combined with human-caused nonpoint sources and represented in the LA. Because natural loading generally cannot be reduced through the implementation of Best Management Practices (BMPs), any reductions assigned to the LA are expected to be realized through restoration activities associated with human-caused nonpoint sources.

3.3.1 South Dakota Reference Site Network

South Dakota DANR monitors a network of stream reference sites on wadable streams in Ecoregion 46 Northern Glaciated Plains. These reference sites represent a "least impacted" condition. Pristine locations that would be truly representative of natural conditions are not present in Ecoregion 46 in South Dakota. As such, TSS samples collected at these reference sites are one of the best available resources to estimate the natural TSS concentration. As shown in Figure 4, the Brule Creek Watershed is comprised of Ecoregions 46 and 47. DANR does not have an established reference network of sites in Ecoregion 47 therefore statistics from the Ecoregion 46 reference sites are compared to all Brule Creek data.

Table 4. A comparison of Total suspended solids statistics from Brule Creek to the South Dakota stream reference site network in Ecoregion 46.

TSS (mg/L)	Reference Sites	Brule Creek
n	150	75
Mean	23.2	132
25th Percentile	3	26
Median	10	47
75th Percentile	31	84

Results from reference site TSS sampling and Brule Creek are presented in Table 4. A total of 150 TSS samples have been collected within the reference site network. The 25th percentile was chosen as a representative value for a natural or background condition, which is equal to a TSS concentration of 3 mg/L. For comparison, the 25th percentile of TSS data from 2009-2018 in Brule Creek is 26 mg/L. This analysis indicates that a significant proportion of the TSS in Brule Creek comes from anthropogenic sources. If the 25% percentile value of TSS concentrations for Brule Creek is divided by the 25th percentile value of the TSS concentrations for the reference site network and one concludes the result is the proportion of the sediment in Brule Creek that is natural in origin, 11.5% of the Brule Creek sediment load comes from natural processes.

3.3.2 Mean Annual Load in Stable Ecoregion 46 Streams

Klimetz et al developed reference values for the mean annual sediment load for stable and unstable stream sites in Ecoregion 46 (Klimetz, Simon, & Schwartz, 2009). Stream sites were determined to be stable or unstable based on their rapid geomorphic assessment (RGA) score and percentile values were provided for each group. RGAs are discussed in greater detail in section 4.2.2. The results from this study provide a reference value for the sediment load that may be expected for a healthy, stable stream channel in Ecoregion 46.

The mean annual load at 46BS49 was calculated by calculating daily loads where the mean daily flow in CMS is inserted into the suspended sediment rating equation in Figure 7. Daily loads were summed for each year and the resulting annual loads averaged to provide the mean annual suspended sediment load. That result was divided by the watershed area in km^2 at 46BS49 (546 km^2) to provide a value that accounts for watershed area.

It should be noted that South Dakota DANR and its partners collect samples for total suspended solids, while the reference values from Klimetz are based on suspended sediment concentration (SSC), which is analyzed using a different laboratory method. More details on the differences between TSS and SSC and the appropriateness of substituting one for another is discussed in Section 4.2.1.

Table 5. Mean annual TSS load at 46BS49 and mean annual suspended sediment concentration (SSC) loads for streams in Ecoregion 46.

Mean Annual Sediment Load	T/Y/km^2
46BS49 TSS Load 2009-2017	**49**
Eco46 Stable Sites Median SSC Load	0.351
Eco46 All Sites Median SSC Load	0.579
Eco46 Unstable Median SSC Load	5.19
Eco46 Unstable 90th Percentile SSC Load	**10.2**

The mean annual load for Brule Creek at 46BS49 from 2009-2017 is presented in Table 5 with results for stable, unstable, and all stream sites in Ecoregion 46 from Klimetz et al's results. The mean annual load at 46BS49 is 49 T/Y/km^2. The most comparable result from Klimetz et al is the 90th percentile of unstable streams in Ecoregion 46 (10.2), indicating that Brule Creek at 46BS49 is transporting a sediment load nearly 5 times greater than some of the most unstable stream channels in Ecoregion 46. Dividing the TSS load at 46BS49 by the median sediment load from a stable stream in Ecoregion 46 provides a proportional estimate of the sediment load in Brule Creek that results from a stable, healthy stream channel in Ecoregion 46. The result of this calculation is 0.7%, indicating a very small proportion of the mean annual sediment load in Brule Creek is accounted for by natural processes.

3.3.3 Sediment load at the Q1.5 Discharge

Calculation of the sediment load at the Q1.5 discharge, or the 1.5 recurrence interval discharge value, provides another method to analyze sediment dynamics. Similar to mean annual sediment load, Klimetz et al (2009) separated stream sites in Ecoregion 46 into stable and unstable sites based on RGA score and provided percentile values for the distribution of each group. Comparing sediment load at the Q1.5 discharge provides a method of comparing sediment loads in streams that accounts for the relationship between stream flow and sediment load.

The TSS load at the Q1.5 discharge was calculated by inserting the Q1.5 discharge for Brule Creek at 46BS49 (15.8 CMS) into the suspended sediment rating equation in Figure 7, then divided by the watershed area in km^2 at 46BS49 (546 km^2).

Table 6. Sediment load at the Q1.5 flow for Brule Creek and stable Ecoregion 46 streams.

Sediment Load at Q1.5 Discharge	T/d/km^2
46BS49 TSS load	**1.037**
Eco46 Stable Median Q1.5 SSC Load	0.00393
Eco46 All Sites Median Q1.5 SSC Load	0.00831
Eco46 Unstable Median Q1.5 SSC Load	0.0768
Eco46 Unstable 90th Percentile Q1.5 SSC Load	**0.664**

The result of these calculations and results from Klimetz et al for stable, unstable, and all sites are presented in Table 6. The sediment load at 46BS49 (1.037 T/d/km$^{2)}$ is most comparable to the 90th percentile value for unstable streams in Ecoregion 46 (0.664 T/d/km^2). This indicates that at the Q1.5 discharge, Brule Creek at 46BS49 is transporting more sediment than some of the most unstable stream sites in the ecoregion. Dividing the sediment load at the Q1.5 in Brule Creek by the median sediment load for stable stream sites in Ecoregion 46 provides a proportional estimate of the sediment load in Brule Creek that results from a stable, health stream channel in Ecoregion 46. Like the analysis in Section 3.3.2 regarding mean annual sediment load, the result of this calculation indicates that very small proportion of the sediment load in Brule Creek is accounted for by natural processes (0.38%).

4.0 Data Collection and Results

4.1 Water Quality Data and Discharge Information

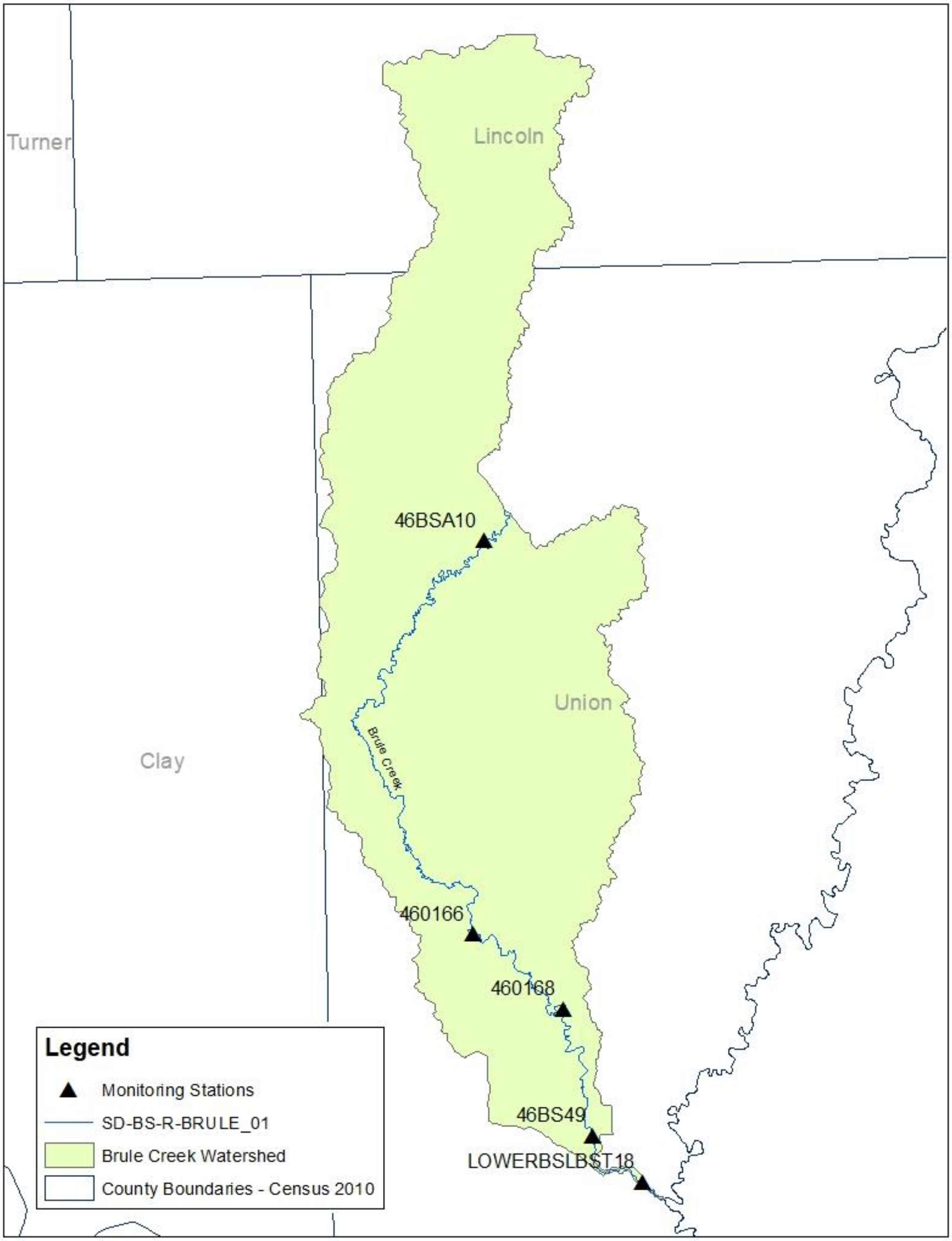

Figure 5. Map with locations of monitoring stations for Brule Creek.

Data relevant to Brule Creek TSS conditions were compiled to produce this TMDL report. Brule Creek data sources are summarized in Table 7 and are described further below.

Table 7. Summary table of water quality samples collected from Brule Creek segment SD-BS-R-BRULE_01.

Station	Project	Samples (n)	Date Range	TSS max (mg/L)	TSS min (mg/L)	TSS mean (mg/L)	TSS median (mg/L)	Percent Exceedance (30-day criterion)	Percent Exceedance (Single Sample Max)
46BSA10	WQM	8	1998-1999	10500	23	3003	2660	INSUF	13%
460166	WQM	18	2009-2013	156	14	60	60	INSUF	0%
460168	WQM	18	2009-2013	2930	5	351	47	INSUF	0%
46BS49	WQM	69	1975-2018	272	4	74	43	INSUF	13%
LOWERBSLBST18	Lower Big Sioux River Assessment	45	2002-2004	544	11	126	69	50%	38%
INSUF = Insufficient dataset at station to calculate a 30-day mean.									

The state of South Dakota operates a network of stream water quality monitoring sites throughout the state called the Water Quality Monitoring (WQM) network. There is a total of 4 WQM sites in the Brule Creek watershed (Figure 5). A total of 6 sample sets composed of at least three samples collected within 30-day periods corresponding to a calendar month across a minimum of three weeks were collected at these sites between 1975 and the end of 2018. A total of 3 of those sample sets exceeded the 30-day mean criterion of 150 mg/L for an exceedance rate of 50%.

Continuous stage and periodic discharge data was measured at sites 460166, 460168, and 46BS49 from the spring of 2010 until the present. For all three stations, a stage/discharge relationship was developed using the rating development tool in the Aquarius software package (version 3.00) and was used to generate the mean daily flow record for each site. Some TSS samples collected in late 2009 and early 2010 did not have paired flow data. Daily mean discharge data from the USGS gage on the Vermillion River at Vermillion, SD (06479010) was used as a surrogate in the empirical modeling function of the Aquarius software to create a linear regression model and generate flows for 46BS49 for 2009 and early 2010. The equation for the linear relationship between the two stations upon which the model was built is presented below.

Station 06479010 Q = 5.69(46BS49 Q) – 72.39*

The Lower Big Sioux River Assessment Project spanned from 2002-2004 and was designed to assess water quality in the southern-most basin of the Big Sioux River. Samples were collected from Brule Creek as part of this assessment project. Water quality sampling was focused on targeting flow events to determine conditions across a range of flow regimes. During this project a total of 45 TSS samples were collected from Brule Creek at station LOWERBSLBST18. Twenty-one of the samples exceeded the 30-day mean TSS criterion. Continuous stage monitoring equipment was installed at station LOWERBSLBST18 for the duration of the project and discharge measurements were collected for the purpose of developing a stage/discharge rating curve.

All sampling and discharge data collection conducted during this project was done with methods in accordance with the South Dakota Standard Operating Procedures for Field Samplers developed by the SD DANR Watershed Protection Program and approved by USEPA Region VIII (link:

https://danr.sd.gov/Conservation/WatershedProtection/ReportsPublications.aspx). TSS samples were sent to the State Health Laboratory in Pierre, SD for analysis. All sample data can be found in Appendix A.

4.2 Data Analysis

4.2.1 Water Quality Data

Figure 6 shows TSS sample concentrations from stations on Brule Creek. Sample concentrations in Brule Creek range from 4 mg/L to 10,500 mg/L. While median TSS values for Brule Creek stations aren't markedly different, Figure 6 shows substantial variability between some Brule Creek stations in regard to mean TSS concentration and the presence of outlier and extreme TSS concentrations.

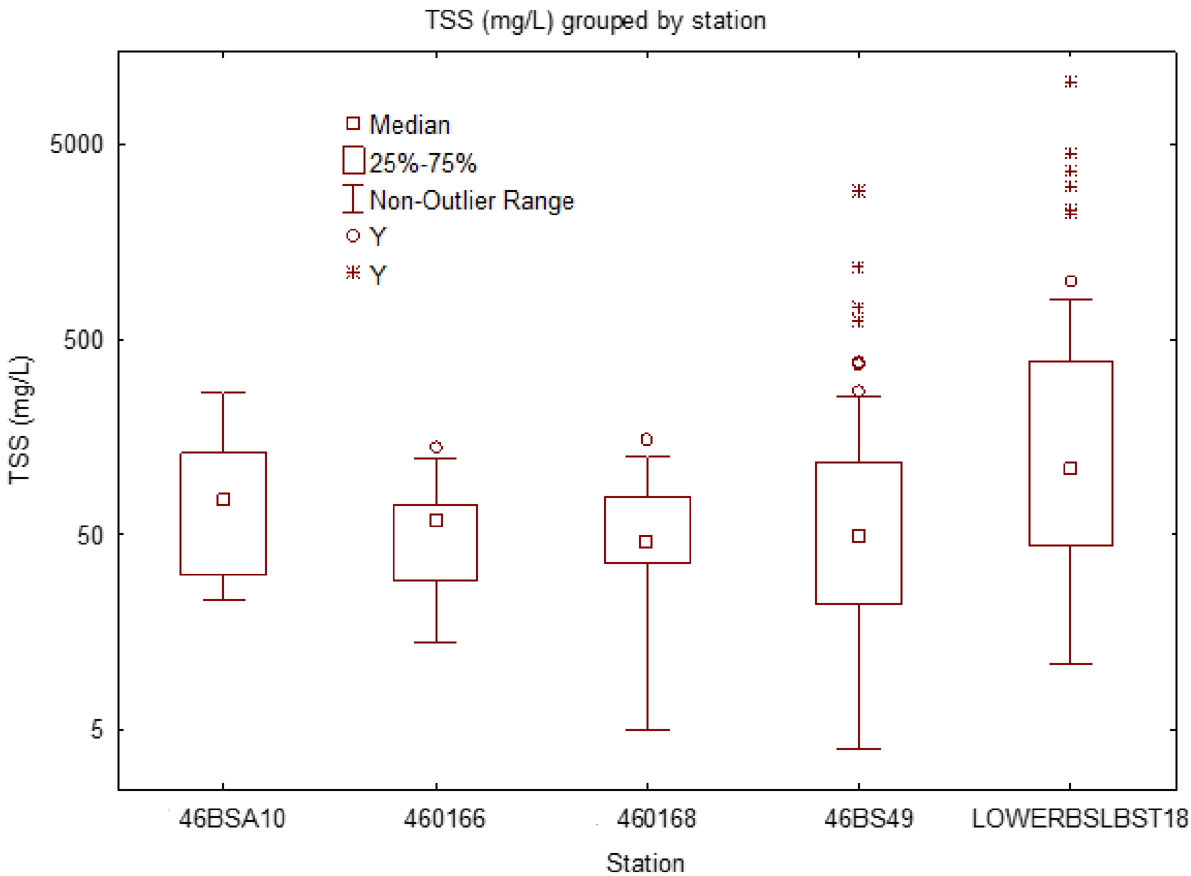

Figure 6. Box plot of Brule Creek TSS concentration grouped by station in left-right order upstream to downstream.

The most extreme concentrations in Brule Creek were measured at station LOWERBSLBST18, which is located approximately 1 river mile upstream from the confluence with the Big Sioux River. Extreme TSS concentrations relative to upstream stations were also observed at station 46BS49, located approximately 2.6 river miles upstream of LOWERBSLBST18. These two stations are the most downstream on Brule Creek.

TSS concentrations appear to be higher in the lower reaches of Brule Creek. Stream channel instability is likely the most important factor driving TSS concentration. Both 46BS49 and LOWERBSLBST18 had higher Rapid Geomorphic Assessment scores, indicating greater channel instability, than upstream stations 460166 and 460168.

The TSS sampling results from LOWERBSLBST18 are likely influenced by the sampling design for the Lower Big Sioux River Assessment Project, which targeted high flow events. Load duration curve analysis (Section 5.1) and the TSS rating curve analysis below (Figure 7) indicate that high flows are associated with high TSS concentrations in Brule Creek. A routine sampling approach would likely have resulted in TSS concentration data more similar to 46BS49.

Stations 460168 and 460166 are located 5.3 and 11.5 miles upstream of 46BS49, respectively. These two stations have similar TSS data distributions. Most notably, while the median value for these stations is similar to 46BS49, the extreme TSS concentrations observed at 46BS49 were not observed at 460168 and 460166.

Data from station 46BSA10 is of limited use in analysis due to the limited number of samples (n=8), the lack of flow data at this station, and the age of the data (collected 1998-1999). Data from this station was not used for analysis for these reasons.

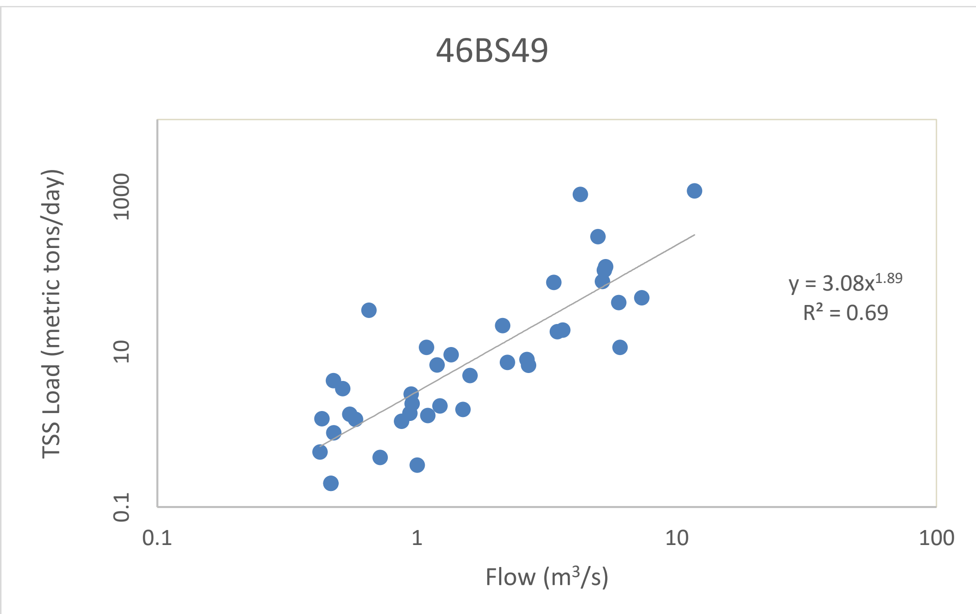

Figure 7. Total suspended solids rating curve for station 46BS49 on Brule Creek.

To investigate the relationship between TSS and flow on Brule Creek, a suspended sediment rating curve was developed for station 46BS49, where suspended sediment load is plotted against flow. Flow is plotted on the x-axis in cubic meters per second, and TSS load (TSS concentration times flow) is plotted on the y-axis in metric tonnes. A best fit line was applied, and the resulting rating equation was used to examine channel stability and sediment loading dynamics. Suspended sediment concentration (SSC) data, rather than TSS, is typically used to develop a suspended sediment rating curve. The laboratory protocol for analyzing TSS is known to bias against sand sized particles (>63 μm) during sub-sampling (Gray, 2000), resulting in underestimates of the sediment load. A general equation is available to convert TSS data to SSC, but it is not recommended for data from individual stations if paired TSS and SSC are not available (Glysson, 2000). No SSC data is available for Brule Creek, so it was not possible to develop an equation representing the relationship between the two methods. TSS data was used in place of SSC data for the following analysis to aid in characterization of the sediment dynamics of Brule Creek. Because caution should be used when using TSS in place of SSC with these methods, they will not be used for calculating the TMDL but rather to provide supporting information regarding sediment conditions in Brule Creek.

The coefficient and exponent of the rating equation can be used to determine how the stream is transporting sediment at various flow conditions. Klimetz (2009) developed SSC rating relationships for streams in Level III Ecoregion 46 and reported median values for rating equation coefficients and exponents. They then separated stream segments into stable and unstable groups based on Rapid Geomorphic Assessment (RGA) scores and calculated median coefficient and exponent values for the two groups. The difference between the median of the two groups was shown to be statistically significant at $p = 0.01$ for coefficient values and at $p < 0.05$ for exponent values. The median values of the coefficient and exponent for stable streams may be considered "reference" conditions for streams in Ecoregion 46. This analysis was performed only for station 46BS49 because it is the only station on Brule Creek located in Level III Ecoregion 46. Other Brule Creek stations are in Level III Ecoregion 47 (Figure 4).

The coefficient of the rating equation reflects how the river transports sediment at low flows, where lower coefficient values mean lower sediment transport rates at low flows. Streams of the Great Plains ecoregions, where the channel boundary is typically composed of fine sediments that are easily entrained and transported at low flows, typically have higher coefficient values than mountain streams, where the channel boundary is composed of coarser materials that are not easily mobilized. For comparison, the median coefficient value for all streams in Ecoregion 46 was 3.51, while the median coefficient for Ecoregion 17 – Rocky Mountains was 0.17. The coefficient value for Brule Creek is 3.08. This value is similar to the median value for stable Ecoregion 46 streams of 2.71. According to this analysis, Brule Creek at 46BS49 transports sediment during low flow conditions similarly to a reference quality stream in Ecoregion 46.

The exponent of the rating equation provides insight into the response of channels during periods of high flow. Higher exponents tend to be found in streams of mountainous regions (2.07 for Ecoregion 17 – Rocky Mountains), where large suspended sediment loads are common at high flows due to high channel slopes and flow velocities. Lower exponent values are associated with regions of less physical relief, for example 1.07 for all Ecoregion 46 streams. The exponent value for Brule Creek at 46BS49 is 1.89. This value is well above the median value for stable streams in Ecoregion 46 of 1.02 and exceeds the median value for unstable Ecoregion 46 streams of 1.16. The exponent value for 46BS49 exceeds even the 90^{th} percentile value for unstable streams in Ecoregion 46 of 1.46. These figures indicate an unstable stream channel that transports large sediment loads during high flow conditions relative to other Ecoregion 46 streams.

4.2.2 Rapid Geomorphic Assessments

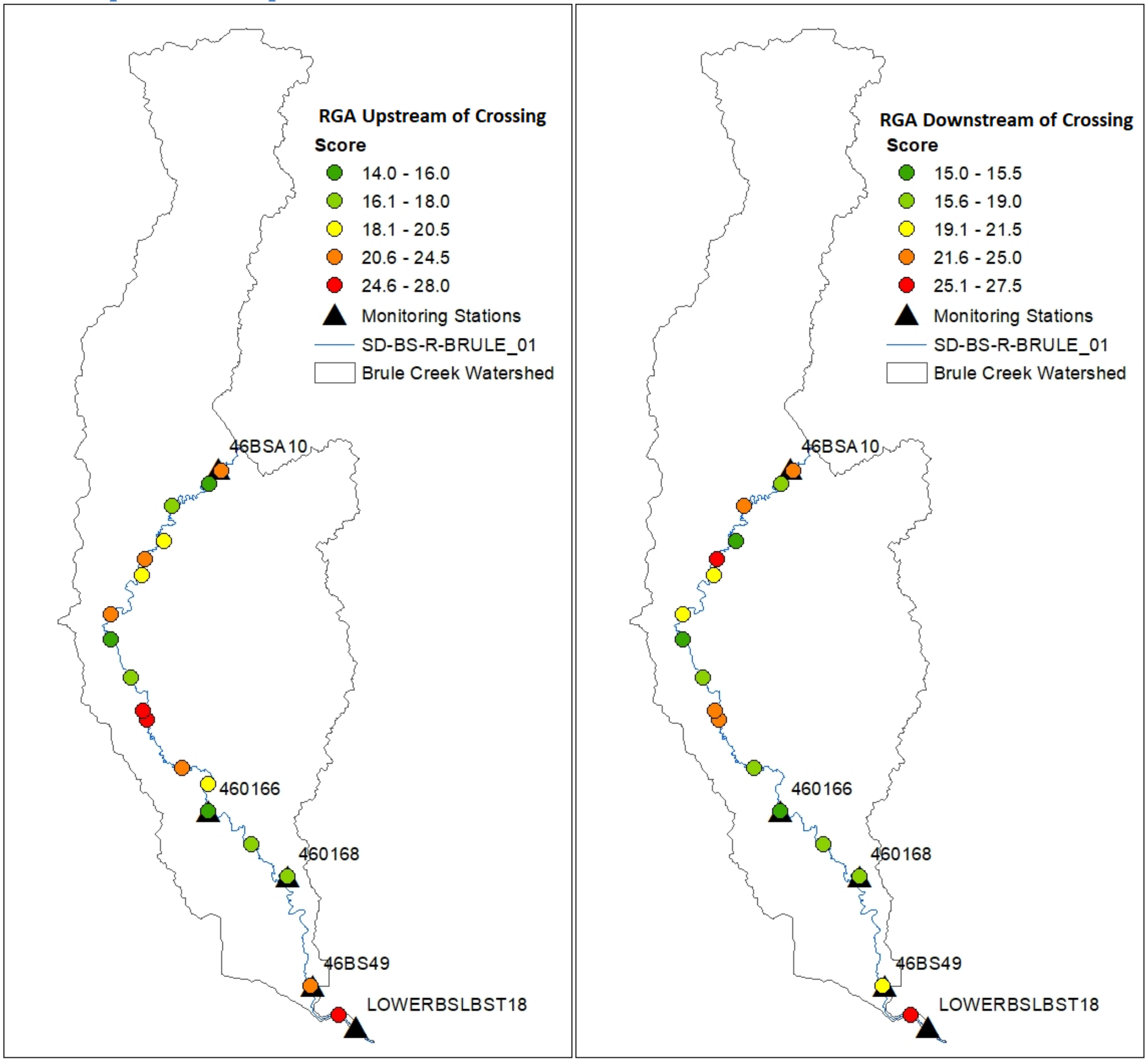

Figure 8. Map depicting rapid geomorphic assessments (RGAs) conducted in the Brule Creek watershed.

A total of 35 Rapid Geomorphic Assessments (RGAs) were performed on Brule Creek (Figure 8, Appendix A). Separate RGAs were performed on the upstream and downstream side of road crossings. An RGA is an assessment of the stability of stream bed and banks that considers stream bed composition, bank vegetation, existence of failing stream banks, presence of erosional and depositional areas, and stage of channel evolution. The RGA results in an overall score between zero and 30. A score below 10 represents a stable site while a score greater than 20 indicates an extremely unstable site. Scores between 10 and 20 indicate some degree of instability (Klimetz, 2009).

Table 8. RGA results from Brule Creek.

Watershed	N	Median	Mean	Max	Min
Brule Creek	35	20.5	20.74	28	14

RGA scores from Brule Creek ranged from 14 to 28, indicating that no locations assessed on Brule Creek could be considered stable. Of the 35 RGAs conducted on Brule Creek, 18 (51%) scored higher than 20, indicating extreme instability. Furthermore, both the mean and median values for Brule Creek RGA scores exceeded 20 (Table 8).

RGAs were performed at several of the monitoring locations on Brule Creek, including 460166, 460168, and 46BS49. Sites 460166 and 460168, which did not have extreme TSS sample concentrations, scored much lower on RGAs (scores of 16 upstream, 15.5 downstream and 18 upstream, 18.5 downstream, respectively) than 46BS49 (score of 23.5 upstream, 20.5 downstream), which does have extreme TSS concentrations. These results indicate that localized unstable channel conditions may be associated with extreme TSS concentrations at 46BS49 and the bed and banks of the stream are likely to be a significant TSS source.

Table 9. Basic statistics for Rapid Geomorphic Assessment scores conducted on the upstream and downstream sides of road crossings in Brule Creek.

	N	Median	Mean	Max	Min
Upstream	17	20.5	21.0	28.0	14.0
Downstream	17	20.0	20.5	27.5	15.0

Separate RGAs were performed for the upstream and downstream sides of bridges and culverts in order to assess the potential impact of road crossings. Median and mean RGA scores for the upstream and downstream sides of road crossings on Brule Creek were similar (Table 9). This analysis indicates that road crossings may cause some stream bank instability in Brule Creek in situations where road crossing structures are not properly aligned perpendicular to the flow direction as discussed in Section 3.2, but in general the upstream and downstream sides of road crossing structures exhibit similar stability.

4.2.3 Annual Agricultural Nonpoint Source Modeling

The Annualized Agricultural Nonpoint Source model (AnnAGNPS) is used to estimate the water quality impacts for different land use and best management implementation scenarios. The model divides the watershed into cells and utilizes data on climate, topography, predominant soil, and majority land management to estimate sheet and rill erosion according to the RUSLE2 Universal Soil Loss Equation. Additionally, data is inputted for landscape features in the watershed that impact water quality such as animal feeding operations and wetlands.

The AnnAGNPS model is used to simulate sheet and rill erosion throughout the watershed so that the erosional distribution can be estimated. Rates of erosion are proportional to rates of rainfall, so the water is calibrated to USGS stream gage data, and then the sediment is calibrated to match the average annual values for measured TSS. Initially it is assumed that agriculture in the watershed is employing the use of field cultivators, conventional planters, and chisel plowing.

Tillage practices influence the rate of sheet and rill erosion estimated by the AnnAGNPS model so a second simulation is employed to illustrate the differences in erosional rates when conservation tillage practices are employed. The difference between the conservation tillage simulation and the calibrated simulation estimates either the impact on the distribution of sheet and rill erosion due to conservation tillage implementation, or the error in the initial estimate made by assuming traditional tillage practices. Tillage practices are modified in cells with predominate agricultural land use, which are selected using a pseudo random number generator in order to prevent bias in the cell selection process.

Riparian vegetation also influences the rate of sheet and rill erosion estimated by the AnnAGNPS model, so a third simulation is employed to illustrate the differences in erosional rates when riparian vegetation is present. The difference between the riparian vegetation filter strips simulation and the calibrated simulation illustrates either the effectiveness of riparian vegetation filter strips to impact on the distribution of sheet and rill erosion through implementation or the error in the initial estimate made by omitting riparian vegetation.

Land use makes a significant impact on sheet and rill erosion, so a pre-settlement simulation was employed to gage the impact of land development on sheet and rill erosion. Land use is modified to native grassland and forest to estimate the anthropogenic impact of land development on sheet and rill erosion.

Table 10. AnnAGNPS results for Brule Creek, East Brule Creek, and West Brule Creek.

Results Table	All	Brule Creek	East Brule	West Brule
Cells	1875	866	646	363
Acres	129357	60567	44651	24140
Tons per year	21294	12610	6999	2543
Average Tons/Acre/Year	0.15	0.16	0.14	0.13
Median Tons/Acre/Year	0.13	0.11	0.15	0.12
Tons/ac/yr Average 25% no till	0.12	0.13	0.12	0.11
Tons/ac/year Average 100% no till	0.08	0.09	0.07	0.07
Tons/ac/yr Average 20 foot filter	0.04	0.04	0.04	0.04
Tons/ac/year Average 50 foot filter	0.03	0.04	0.03	0.03
Tons/ac/year Average Presettlement	0.0005	0.0007	0.0002	0.0002
Tons/ac/yr Median 25% no till	0.1	0.09	0.11	0.09
Tons/ac/year Median 100% no till	0.07	0.06	0.08	0.06
Tons/ac/yr Median 20 foot filter	0.04	0.03	0.04	0.04
Tons/ac/year Median 50 foot filter	0.03	0.02	0.03	0.03
Tons/ac/year Median Presettlement	0.0002	0.0002	0.0002	0.0001
Differences in tons/ac/year				
Average 25% no till	0.02	0.03	0.02	0.02
Average 100% no till	0.07	0.1	0.06	0.07
Average 20 foot filter	0.1	0.11	0.1	0.09
Average 50 foot filter	0.11	0.12	0.1	0.1
Average Presettlement	0.15	0.16	0.14	0.13
Median 25% no till	0.03	0.02	0.03	0.02
Median 100% no till	0.06	0.05	0.07	0.05
Median 20 foot filter	0.09	0.08	0.1	0.08
Median 50 foot filter	0.1	0.08	0.11	0.09
Median Presettlement	0.13	0.11	0.15	0.12
Percent Reduction				
Average 25% no till	15.5%	16.8%	13.9%	14.5%
Average 100% no till	46.2%	46.7%	45.9%	45.5%
Average 20 foot filter	71.2%	71.8%	70.6%	70.8%
Average 50 foot filter	76.7%	76.4%	77.0%	76.9%
Average Presettlement	99.7%	99.5%	99.8%	99.8%

The results of the simulations (Table 10) quantify the differences in predicted erosional rates in tons per acre per year for the entire watershed. Due to the assumptions made in the different simulation scenarios the results are not obtainable reductions in the real world, but the results are useful in identifying areas where best management practice implementation would be the most effective.

The spatial distribution of values can be characterized through spatial autocorrelation which is a measure of spatial dependency determined by the Moran I statistic. Calculating the Moran I statistic at different distances allows the calculation of the critical distance at which the values for each cell are most like the values in neighboring cells. The critical distance is used as an input for a hot spot analysis on the sediment loading values from the AnnAGNPS results. Cluster analysis using the Getis-Ord Gi* statistic identifies regions that have statistically significant clusters of high or low values for each of the simulations. Each simulation contains regions of high and low values. The cluster analysis of the different metrics agree there exists a statistically significant cluster of high values in areas where the hot spots intersect, thus these regions are delineated as the priority zones for implementation efforts in Brule Creek. The results of the intersection of the hot spots indicate that there exists a large region where implementation of best management practices would produce the best results (Figure 9).

Analysis was also run for East Brule Creek and West Brule Creek watersheds for potential future TMDL development in these segments. In East Brule Creek the regions where the largest reductions would be expected are more localized. Reducing TSS concentrations in East Brule Creek would likely reduce TSS concentrations in Brule Creek.

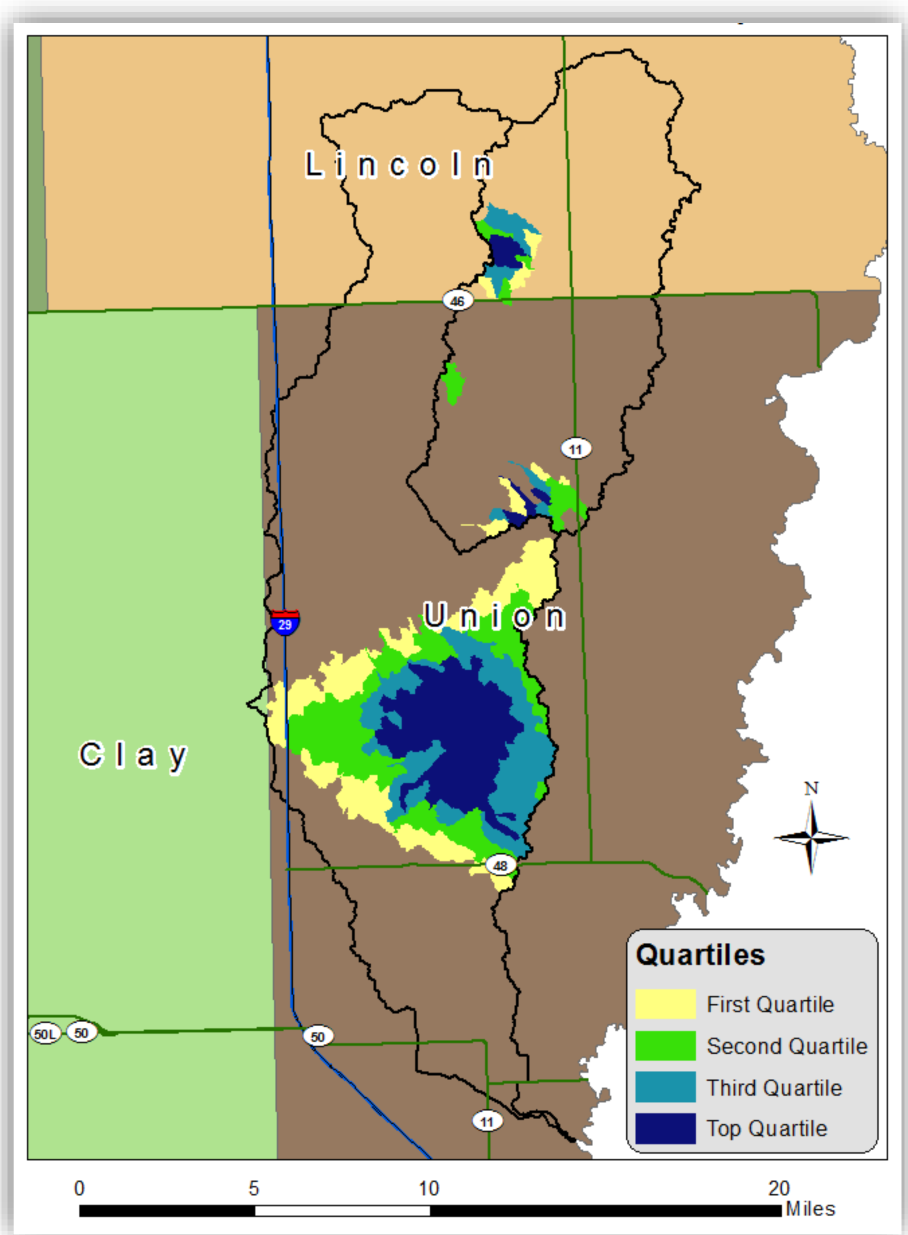

Figure 9. Priority zones determined by AnnAGNPS modeling for TSS in the Brule Creek and East Brule Creek basins.

5.0 TMDL Loading Analysis

5.1 TMDL Load Duration Curve

For the purpose of TMDL development, a load duration curve framework was used to display TSS concentration at different flow frequencies across the entire flow regime. Flows were divided into 5 zones based on the flow frequency percentile, where daily mean flow values are assigned a percentile based on their frequency of occurrence. For example, 1^{st} percentile flows are of such great magnitude that they are only exceeded 1% of the time, while flows at the 99^{th} percentile are so common that they are exceeded 99% of the time.

The load duration curve for station 46BS49 was used for calculating TMDL loading and reductions because it had the most robust and recent continuous flow record and TSS concentration data. TSS samples collected from 2009-2018 were paired with mean daily flow measurements from the gage at 46BS49. Sample data from 2009-2018 was used to represent the most current conditions for Brule Creek (Figure 10).

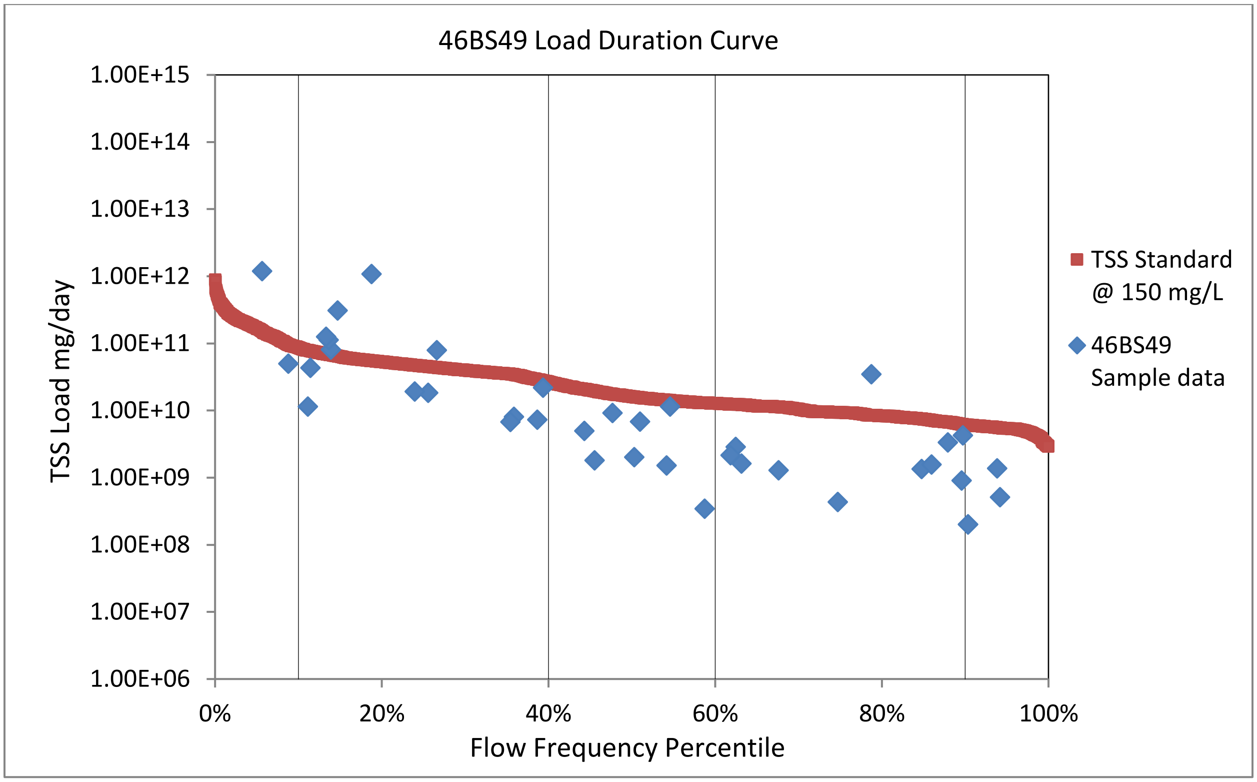

Figure 10. Load duration curve for station 46BS49 on Brule Creek.

All TSS samples that exceeded the target of 150 mg/L, except for one, occurred less than 26.61% of the flow frequency period of record. Of the 2 samples collected in the high flow zone (0-10%), one sample exceeded the TMDL target. A total of 14 samples were collected in the 2nd flow zone (10-40%), of which 6 exceeded the TMDL target. A total of 8 samples were collected in the 3rd flow zone (40-60%) and none of those samples exceeded the TMDL target. A total of 11 samples were collected in the 4th flow zone (60-90%), and one sample exceeded the TMDL target. A total of 4 samples were collected in the low flow zone (90-100%) with none of those samples exceeding the TMDL target.

5.2 TMDL Allocations

The LDC in Figure 10 represents the dynamic expression of the TSS TMDL for Brule Creek. The LDC results in a unique maximum daily load in milligrams of TSS per day that corresponds to a measured average daily flow in liters per day multiplied by the target concentration (i.e. 150 mg/L). To aid in the implementation of the TMDL and estimation of needed TSS load reductions, Table 11 presents a combination of allocations for each of five flow zones. Methods used to calculate the TMDL components are discussed below. Sample and flow data from station 46BS49 was used to calculate the TMDL.

Table 11. Brule Creek TMDL and load allocations.

TMDL Component	Flow Zone				
	0-10%	10-40%	40-60%	60-90%	90-100%
LA (mg/day)	4.17E+11	5.52E+10	1.35E+10	7.98E+09	1.98E+09
WLA(mg/day)	0	0	0	0	0
MOS(mg/day)	4.63E+10	6.13E+09	1.50E+09	8.86E+08	2.20E+08
TMDL @ 150 mg/L (mg/day)	4.63E+11	6.13E+10	1.50E+10	8.86E+09	2.20E+09
*Current Load (mg/day)	2.44E+11	2.94E+11	7.92E+09	6.15E+09	2.06E+08
Load Reduction	0%	79%	0%	0%	0%
Flow Range (CFS)	< 188	43-188	25-43	6-25	< 6
95^{th} Percentile Flow (CFS)	1262	167	41	24	6

*** Current load is the 95th percentile of all samples in the flow zone times the 95th percentile flow in each flow zone**

5.2.1 Load Allocation

To develop the TSS allocations the TMDL was first calculated. The TMDL for each flow zone was calculated by multiplying the 30-day average TSS criterion of 150 mg/L by the 95^{th} percentile flow value.

The monthly criterion of 150 mg/L was used to develop the TMDL to ensure compliance with both TSS thresholds. For each of the five flow zones, the 95^{th} percentile of the range of TSS concentrations within a flow zone was set as the current load. TSS loads experienced during the largest stream flows (e.g. top 5 percent) cannot be feasibly controlled by practical management practices. Setting the flow zone goal at the 95^{th} percentile of the range of TSS concentrations will allow for the natural variability of the system.

Portions of the TMDL were allocated to point sources as a waste-load allocation (WLA) and nonpoint sources as a load allocation (LA). A fraction of the TMDL was also reserved as a margin of safety (MOS) to account for uncertainty in the calculations of these load allocations. The method used to calculate the MOS is discussed below. The LA was determined by subtracting the WLA and MOS from the TMDL and represents the allowable loading from human-caused nonpoint sources and natural background. Thus, the TMDL is the sum of WLA, LA, and MOS.

5.2.2 Wasteload Allocation

The WLA for Brule Creek is zero. There is one NPDES permitted facility in the watershed, a gravel mining operation that discharges infrequently and at low TSS concentration. In many cases, effluent from this facility would dilute TSS in Brule Creek, lowering the concentration in the creek. As a result, the WLA for this TMDL was assigned a zero value.

5.2.3 Margin of Safety

A margin of safety (MOS) was established to account for uncertainty in the data analyses. A margin of safety may be provided (1) by using conservative assumptions in the calculation of the loading capacity of the waterbody and (2) by establishing allocations that in total are lower than the defined loading capacity. In the case of Brule Creek the latter approach was used to establish a safety margin.

A 10% explicit MOS was calculated within the load duration curve framework to account for uncertainty (e.g., loads from tributary streams, effectiveness of controls, etc.). This 10% explicit MOS was calculated from the TMDL within each flow zone and reserved as unallocated assimilative capacity. The remaining assimilative capacity was attributed to nonpoint sources (LA).

6.0 Seasonal Variation

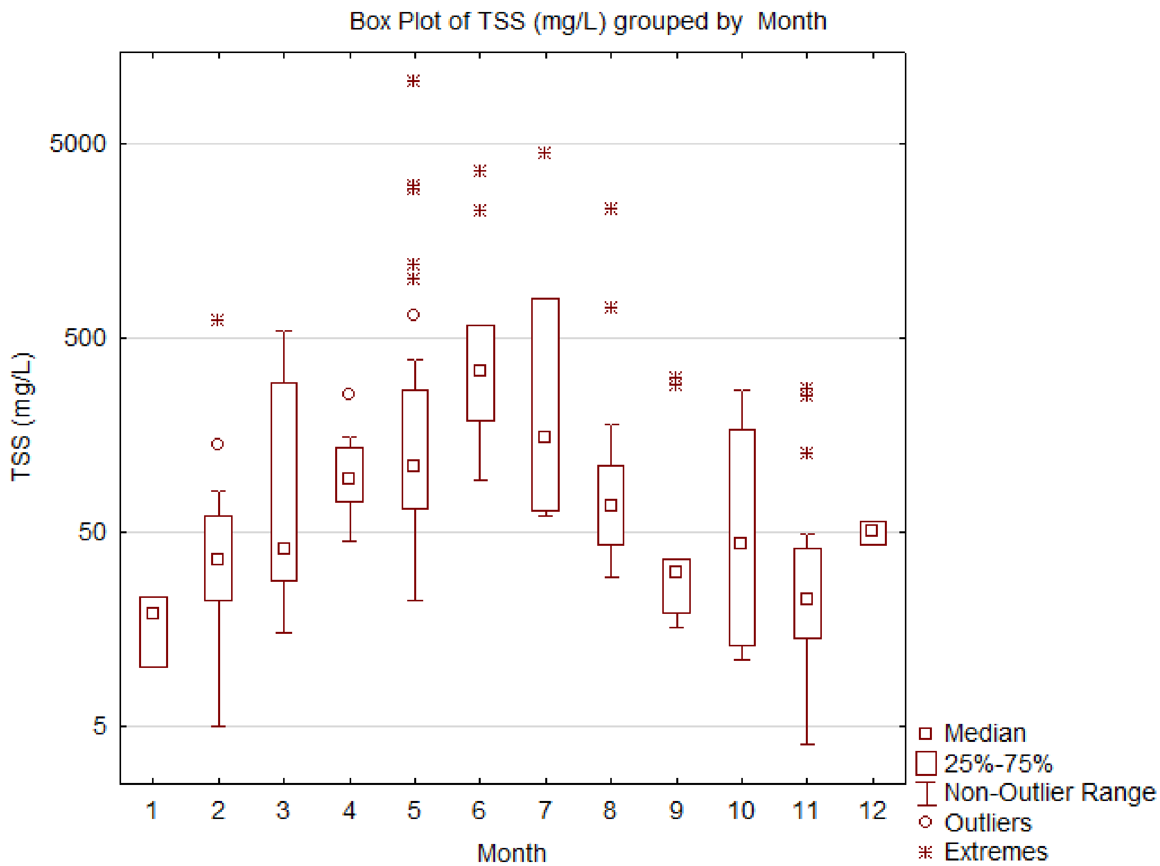

Figure 11. Box plot of Brule Creek TSS samples from all stations grouped by month of sample collection.

Brule Creek exhibited a strong seasonal component. TSS samples collected in June had a higher median value than all other months (Figure 11). The maximum concentration was observed in May, with June, July, and August also showing extreme concentrations. South Dakota streams typically experience their highest rate of flow in spring and early summer months. Previous analyses in this report have concluded that high flow conditions in Brule Creek are associated with high TSS concentrations and loads, so it is expected that the months with greater precipitation and stream flow will have higher TSS concentrations than months with lower precipitation and stream flow.

7.0 Public Participation

STATE AGENCIES

South Dakota Department of Agriculture and Natural Resources was the primary state agency involved in the completion of this assessment. Ambient water quality monitoring data was used to develop the TMDL and calculate pollutant loadings.

A 30-day public comment period was issued for the draft TMDL. A public notice letter was published in the following local newspapers: Sioux Falls Argus Leader, Vermillion Plain Talk, and Southern Union County Leader-Courier. The draft TMDL document and ability to comment was made available on DENRs One-Stop Public Notice Page at: https://danr.sd.gov/public/default.aspx. The public comment period began January 13th and ended February 18th, 2022. No public comments were received during the 30-day comment period.

FEDERAL AGENCIES

Environmental Protection Agency (EPA) provided the primary source of funds for data analysis used in this report as well as for the completion of the Lower Big Sioux River Assessment Project. Data from the United States Geological Survey (USGS) was used for modeling some portions of the flow data used in this report.

LOCAL GOVERNMENT, INDUSTRY, ENVIRONMENTAL, AND OTHER GROUPS AND PUBLIC AT LARGE

The primary local sponsor for the Lower Big Sioux River Assessment Project was the South Dakota Association of Conservation Districts. During the summer sampling seasons, project personnel frequently met with landowners in the field. These meetings were most often facilitated through the landowners stopping to ask questions while data collection was occurring. Although informal in nature, these meetings provide and important medium for obtaining local landowner views and opinions.

8.0 Adaptive Management and Monitoring Strategy

The Department may adjust the load and/or waste load allocations in this TMDL to account for new information or circumstances that are developed or come to light during the implementation of the TMDL and a review of the new information or circumstances indicate that such adjustments are appropriate. Adjustment of the load and waste load allocation will only be made following an opportunity for public participation. New information generated during TMDL implementation may include, among other things, monitoring data, BMP effectiveness information and land use information. The Department will propose adjustments only in the event that any adjusted LA or WLA will not result in a change to the loading capacity; the adjusted TMDL, including its WLAs and LAs, will be set at a level necessary to implement the applicable water quality standards; and any adjusted WLA will be supported by a demonstration that load allocations are practicable.
The Department will follow EPA guidance for revising or withdrawing TMDLs in accordance with considerations documented in EPA's 2012 draft memo before taking action (http://www.epa.gov/sites/production/files/2015-10/documents/drafttmdl_32212.pdf).

Long-term TSS monitoring will continue in the Brule Creek watershed. WQM site 46BS49 will be monitored monthly as part of the ambient water monitoring program. In addition, the Rotating Basin water quality assessment project conducted TSS monitoring at station 46BS49 on a bimonthly basis from 2019-2021. DANR continues to maintain a long-term stream gage at 46BS49. Data collected as part of these monitoring efforts will be used to determine beneficial use support in accordance with 303(d) listing methods, evaluate TMDL effectiveness following BMP implementation and to make potential future adjustments to the TMDLs, if necessary.

9.0 Restoration Strategy

The TMDL for Brule Creek (SD-BS-BRULE_01) corresponds exclusively to the 303(d) listed segment identified in South Dakota's 2020 Integrated Report for Surface Water Quality.

Future implementation efforts will be directed at the Brule Creek watershed. The Central Big Sioux River Implementation Project is currently underway in the Brule Creek watershed. The Lower Big Sioux Implementation Project merged with the Central Big Sioux River Implementation Project and all activities in the watershed are now controlled by the Central Big Sioux River Implementation Project.

The Central Big Sioux River Implementation Project is focusing on riparian area protection and cropland management BMPs. Both of these efforts have the potential to reduce TSS concentrations in Brule Creek. Stream bank stabilization and restoration efforts as well the installation of riparian buffer strips should focus on areas with the worst RGA scores, particularly the lower reaches of Brule Creek. Conversion to conservation tillage will be beneficial in any area of the Brule Creek watershed, but resources would be most efficiently allocated to hot spot areas identified in the AnnAGNPS modeling section of this document. The project coordinator has established relationships with federal, state and local entities as well as stakeholders in the watershed to increase project awareness and seek additional sources of funding to assure long-term project success. The long-term goal of this implementation effort is to achieve the TMDL reduction derived in this document and ultimately reduce TSS inputs to Brule Creek to protect the upstream and downstream uses.

Bibliography

Flint, R. F. (1955). *Pleistocene Geology of Eastern South Dakota.* United States Geological Survey, Washington, D.C.

Glysson, D. G., Gray, J. R., & Conge, L. M. (2000). *Adjustment of Total Suspended Solids Data for Use in Sediment Studies.* U.S. Geological Survey.

Gray, J. R., Glysson, G. D., Turcois, L. M., & Schwarz, G. E. (2000). *Comparability of suspended-sediment concentration and total suspended solids data.* U.S. Dept. of the Interior, U.S. Geological Survey.

Hogan, E. P. (1995). *The Geography of South Dakota.* Sioux Falls: The Center for Western Studies, Augustana College.

Klimetz, L., Simon, A., & Schwartz, J. (2009). *Characterization of Suspended-Sediment Transport Conditions for Stable, "Reference" Streams in Selected Ecoregions of EPA Region 8.* Oxford: USDA Agricultural Research Service National Sedimentation Laboratory.

McCormick, K. A., & Hammond, R. H. (2004). *Bulletin 39: Geology of Lincoln and Union Counties, South Dakota.* South Dakota Department of the Environment and Natural Resources, South Dakota Geological Survey, Vermillion, SD.

Schottler, S. P., Ulrich, J., Belmont, P., Moore, R., Lauer, J. W., Engstrom, D. R., & Almendinger, J. E. (2013). Twentieth century agriculture drainage creates more erosive rivers. *Hydrological Processes*.

SD DENR. (2020). *2020 Integrated Report for Surface Water Quality.* Pierre: SD DENR.

SD DENR. (2019). *Standard Operating Procedures for Field Samplers Volume 1.* Pierre: SD DENR.

Stoeser, D. B., Green, G. N., Morath, L. C., Heran, W. D., Wilson, A. B., Moore, D. W., & Van Gosen, B. S. (2005). *Preliminary integrated geologic map databases for the United States: Central states: Montana, Wyoming, Colorado, New Mexico, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, Iowa, Missouri, Arkansas, and Louisiana.* United States Geological Survey. Retrieved from Preliminary integrated geologic map databases for the United States: Central states: Montana, Wyoming, Colorado, New Mexico, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, Iowa, Missouri, Arkansas, and Louisiana.

USDA. (1978). *Soil Survey of Union County, South Dakota.* Washington, DC: National Cooperative Soil Survey.

USDA National Agricultural Statistics Service. (2017). *2017 Census of Agriculture.* USDA.

Appendix A: Data

Table 12. Total suspended solids sample data collected from Brule Creek.

Sample Date	Sample Time	StationID	TSS (mg/L)	Flow (cfs)
02/19/2009	13:00	460166	61	
05/28/2009	16:00	460166	30	
08/18/2009	18:00	460166	71	
11/23/2009	17:00	460166	49	143
02/23/2010	13:40	460166	18	374
05/25/2010	16:10	460166	124	82
08/24/2010	11:00	460166	121	0
11/08/2010	16:20	460166	26	232
02/24/2011	15:50	460166	141	232
05/18/2011	16:10	460166	71	160
08/10/2011	15:05	460166	29	64
11/16/2011	14:40	460166	16	38
02/27/2012	14:15	460166	58	120
05/16/2012	13:50	460166	72	25
08/22/2012	13:50	460166	64	3
11/20/2012	13:20	460166	14	5
02/14/2013	13:40	460166	36	219
05/22/2013	14:00	460166	80	19
02/19/2009	11:20	460168	41	
05/28/2009	13:30	460168	37	
08/18/2009	15:30	460168	108	
11/23/2009	14:40	460168	47	
02/23/2010	11:50	460168	22	
05/25/2010	13:30	460168	126	69
08/23/2010	14:20	460168	156	83
11/08/2010	13:40	460168	36	94
02/24/2011	13:30	460168	78	956
05/18/2011	13:45	460168	99	148
08/10/2011	13:50	460168	43	56
11/16/2011	13:30	460168	13	38
02/27/2012	12:45	460168	35	35
05/16/2012	12:30	460168	53	33
08/22/2012	12:30	460168	46	0
11/20/2012	12:05	460168	5	10
02/14/2013	11:50	460168	52	14
05/22/2013	12:30	460168	60	23
09/09/1975	11:00	46BS49	42	
09/10/1975	10:50	46BS49	42	

Sample Date	Sample Time	StationID	TSS (mg/L)	Flow (cfs)
09/11/1975	12:15	46BS49	42	
01/20/1976	08:00	46BS49	377	
01/21/1976	11:10	46BS49	63	
01/22/1976	12:20	46BS49	108	
03/02/1976	11:35	46BS49	22	
03/03/1976	12:15	46BS49	79	
03/04/1976	11:45	46BS49	45	
10/22/1997	08:00	46BS49	57	
11/05/1997	08:00	46BS49	29	
12/17/1997	08:00	46BS49	10	
01/29/1998	08:00	46BS49	10	
02/26/1998	08:00	46BS49	48	
03/19/1998	08:00	46BS49	15	
04/29/1998	08:00	46BS49	88	
05/27/1998	08:00	46BS49	136	
06/10/1998	08:00	46BS49	382	
07/15/1998	08:00	46BS49	138	
08/19/1998	08:00	46BS49	36	
10/28/1998	08:00	46BS49	72	
11/19/1998	08:00	46BS49	248	
12/15/1998	08:00	46BS49	57	
01/27/1999	08:00	46BS49	19	
02/23/1999	08:00	46BS49	81	
04/12/1999	08:00	46BS49	256	
05/17/1999	08:00	46BS49	272	
06/14/1999	08:00	46BS49	242	
08/23/1999	08:00	46BS49	49	
09/29/1999	08:00	46BS49	16	
02/19/2009	09:40	46BS49	35	94
05/28/2009	11:50	46BS49	35	33
08/18/2009	13:05	46BS49	122	38
11/23/2009	12:40	46BS49	36	57
05/25/2010	12:10	46BS49	118	75
08/23/2010	13:00	46BS49	181	183
11/08/2010	12:20	46BS49	29	95
02/24/2011	12:10	46BS49	79	259
05/18/2011	12:30	46BS49	84	211
08/10/2011	12:10	46BS49	38	79
11/16/2011	11:50	46BS49	26	34

Sample Date	Sample Time	StationID	TSS (mg/L)	Flow (cfs)
07/02/2002	14:30	LOWERBSLBST18	152	14
07/10/2002	13:00	LOWERBSLBST18	4460	11
07/17/2002	09:00	LOWERBSLBST18	60	12
07/24/2002		LOWERBSLBST18	64	9
08/20/2002	09:30	LOWERBSLBST18	72	25
08/22/2002	17:00	LOWERBSLBST18	2300	18
09/23/2002	08:30	LOWERBSLBST18	20	9
09/23/2002	08:30	LOWERBSLBST18	17	9
10/15/2002	10:45	LOWERBSLBST18	11	16
03/25/2003	15:00	LOWERBSLBST18	41	5
03/25/2003	15:00	LOWERBSLBST18	41	5
03/28/2003	14:00	LOWERBSLBST18	544	40
04/02/2003		LOWERBSLBST18	72	38
04/09/2003	16:00	LOWERBSLBST18	45	21
04/15/2003	13:00	LOWERBSLBST18	156	55
05/01/2003	10:00	LOWERBSLBST18	384	63
05/13/2003	13:00	LOWERBSLBST18	656	192
05/20/2003	13:00	LOWERBSLBST18	272	82
06/11/2003	10:00	LOWERBSLBST18	186	49
06/18/2003	11:00	LOWERBSLBST18	110	26
06/24/2003	14:30	LOWERBSLBST18	3660	31
06/26/2003	16:00	LOWERBSLBST18	2240	93
07/09/2003	17:00	LOWERBSLBST18	810	114
07/22/2003	11:00	LOWERBSLBST18	162	51
08/18/2003	11:00	LOWERBSLBST18	29	12
09/01/2003	15:00	LOWERBSLBST18	36	5
09/01/2003	15:15	LOWERBSLBST18	33	5
09/10/2003	08:00	LOWERBSLBST18	312	6
09/10/2003	08:00	LOWERBSLBST18	284	6
09/24/2003	11:30	LOWERBSLBST18	19	15
10/23/2003	13:00	LOWERBSLBST18	15	16
04/06/2004		LOWERBSLBST18	93	0
04/19/2004	17:00	LOWERBSLBST18	68	0
05/10/2004	14:00	LOWERBSLBST18	3020	49
05/25/2004	14:00	LOWERBSLBST18	996	440
06/02/2004	11:00	LOWERBSLBST18	375	404
06/16/2004	15:00	LOWERBSLBST18	304	89
06/29/2004	10:30	LOWERBSLBST18	93	73
08/17/2004	16:45	LOWERBSLBST18	44	25
08/17/2004	16:30	LOWERBSLBST18	44	25

Table 13. Rapid geomorphic assessment (RGA) results from Brule Creek.

Date	Latitude	Longitude	Length (m)	Width (m)	Structure	Reach Assessed	Stream Pattern	Bed Material	Bed/ Bank	Incision	Constriction	L/I Erosion	R/O Erosion	L/I Instability	R/O Instability	L/I Vegetated	R/O Vegetated	L/I Accretion	R/O Accretion	Channel Stage	Score
05/16/2012	42.9825	-96.7192	50	5	Bridge	Above	Straight	4	3	3	1	1	1	0.5	0.5	1	2	1.5	1.5	4	24
05/16/2012	42.9772	-96.7266	80	7	Bridge	Above	Straight	4	1	2	1	1	1	0	0	0	0	1.5	1.5	3	16
05/17/2012	42.87723	-96.7664			Bridge	Above		4	2	3	1	2	2	1.5	2	1	2	0.5	2	4	28
05/17/2012	42.9679	-96.748			Bridge	Above		4	1	3	0	1	2	0.5	2	0.5	0.5	0	0.5	4	17
05/17/2012	42.74874	-96.65979		8	Bridge	Above		4	3	4	2	1	1	1.5	1	2	1.5	2	1	4	27
05/17/2012	42.76153	-96.67534	80	8	Bridge	Above	Straight	4	2	4	1	2	0	2	0.5	0.5	0.5	2	1	4	23.5
05/17/2012	42.80868	-96.68706	150	6	Bridge	Above		4	3	1	1	0	0	0.5	0	2	1.5	1.5	0.5	3	18
05/17/2012	42.82259	-96.70733	80	8	Bridge	Above	Straight	4	1	3	0	1	1	0.5	0.5	1.5	0.5	1	0	3	17
05/17/2012	42.83726	-96.73195		9	Bridge	Above	leanderir	4	2	4	1	0	0	0	0	1	1	0	0	3	16
05/17/2012	42.91171	-96.7857	100	10	Bridge	Above		4	2	0	0	0	2	0	1	0.5	0.5	0	1.5	3	14
05/17/2012	42.88078	-96.76848	100	8	Bridge	Above	Straight	4	3	4	1	2	2	1.5	1.5	0.5	1	1.5	2	4	26
05/17/2012	42.94578	-96.76512	35	8	Bridge	Above	leanderir	4	2	4	1	1	2	0.5	2	0.5	1	0	2	4	24
05/17/2012	42.93898	-96.76679	35		Bridge	Above	leanderir	4	1	4	0	1	1	1	1.5	1	2	0.5	0.5	3	20.5
05/17/2012	42.92239	-96.78557	45	12	Bridge	Above	Straight	4	2	3	1	2	1	1	2	1	0.5	2	1	4	24.5
05/17/2012	42.89533	-96.77493	100	10	Bridge	Above	Straight	4	2	1	0	0	2	0.5	1.5	0.5	1.5	0.5	1	3	17.8
05/17/2012	42.9533	-96.7534	50	6	Bridge	Above	Straight	4	2	3	0	1	2	1	2	0	0.5	1.5	0.5	4	19
05/17/2012	42.85607	-96.7467	100	6	Bridge	Above	Straight	4	2	4	1	1	2	0.5	1.5	0.5	1.5	1	1.5	4	24.5
05/16/2012	42.9825	-96.7192	50	5	Bridge	Below	Straight	4	1	3	0	2	2	1.5	2	1	1	1.5	0.5	4	23.5
05/16/2012	42.9772	-96.7266	60	8	Bridge	Below	Straight	4	1	2	1	2	2	1	0.5	0	0	1	1.5	3	19
05/17/2012	42.89533	-96.77493	100	10	Bridge	Below		4	2	1	0	2	0	2	0.5	1	0	1.5	1.5	3	18.5
05/17/2012	42.9679	-96.748			Bridge	Below		4	1	3	1	2	2	1.5	2	1.5	1.5	1	1.5	4	25
05/17/2012	42.74874	-96.65979		8	Bridge	Below	Straight	4	3	4	1	0	2	0.5	1.5	2	1.5	0.5	2	4	26
05/17/2012	42.76153	-96.67534			Bridge	Below		4	3	4	0	0	1	0.5	0.5	1	1	1	0.5	4	20.5
05/17/2012	42.80868	-96.68706		6	Bridge	Below		4	3	4	0	2	0	0.5	0	0	0.5	1.5	0	3	18.5
05/17/2012	42.82259	-96.70733	80	8	Bridge	Below	Straight	4	1	4	0	2	0	1.5	0	0	0	0	1.5	3	17
05/17/2012	42.83728	-96.73195	115	9	Bridge	Below	Straight	4	1	0	3	0	0	0.5	0	2	1.5	0.5	0	3	15.5
05/17/2012	42.85607	-96.7467		6	Bridge	Below	Braided	4	1	3	0	1	2	0.5	1	1	0.5	0.5	0	3	17.5
05/17/2012	42.91171	-96.7857	120	10	Bridge	Below	Braided	4	3	0	0	0	0	1	1	1	1.5	0.5	0.5	3	15.5
05/17/2012	42.87723	-96.7664			Bridge	Below	Straight	4	1	3	1	2	2	1.5	1.5	1	0.5	1.5	1	4	24
05/17/2012	42.88078	-96.76848	100	8	Bridge	Below	Straight	4	3	4	0	1	2	0.5	1.5	0.5	0.5	1	1.5	4	23.5
05/17/2012	42.9533	-96.7534	40	6	Bridge	Below	Straight	4	1	3	0	1	1	0	0	0	0	0.5	0.5	4	15
05/17/2012	42.94578	-96.76512	35	8	Bridge	Below	Straight	4	2	4	3	0	2	0	2	2	2	2	0.5	4	27.5
05/17/2012	42.93898	-96.76679	40		Bridge	Below	leanderir	4	1	4	0	1	2	0	1.5	0.5	1	1	1.5	4	21.5
05/17/2012	42.92239	-96.78557	35	10	Bridge	Below	Straight	4	1	4	0	1	1	0.5	2	1.5	0.5	0.5	1.5	4	21.5
05/16/2012	42.8487	-96.73142	70	9	None	lo structur	Braided	4	2	3	0	2	0	1.5	0	1	1.5	1.5	0	3	19.5

Appendix B: EPA Approval Letter and Decision Document

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
1595 Wynkoop Street
Denver, CO 80202-1129
Phone 800-227-8917
www.epa.gov/region08

March 18, 2022

Ref: 8WD-CWS

SENT VIA EMAIL

Hunter Roberts, Secretary
South Dakota Department of Agriculture and Natural Resources
Hunter.Roberts@state.sd.us

Re: Approval of Total Suspended Solids Total Maximum Daily Load Evaluation for Brule Creek, Union and Lincoln Counties, South Dakota

Dear Mr. Roberts,

The U.S. Environmental Protection Agency (EPA) has completed review of the total maximum daily load (TMDL) submitted by your office on February 22nd, 2022. In accordance with the Clean Water Act (33 U.S.C. §1251 *et. seq*.) and the EPA's implementing regulations at 40 C.F.R. Part 130, the EPA hereby approves South Dakota's TMDL for Brule Creek. The EPA has determined that the separate elements of the TMDL listed in the enclosure adequately address the pollutant of concern, are designed to attain and maintain applicable water quality standards, consider seasonal variation and include a margin of safety. The EPA's rationale for this action is contained in the enclosure.

Thank you for submitting this TMDL for our review and approval. If you have any questions, please contact Peter Brumm on my staff at (406) 457-5029.

Sincerely,

Judy Bloom, Manager
Clean Water Branch

Enclosure:
EPA Decision Rationale - Brule Creek TSS TMDL

Cc: Barry McLaury, Administrator, SD Department of Environment and Natural Resources
Paul Lorenzen, Environmental Scientist III, SD Department of Environment & Natural Resources

EPA TOTAL MAXIMUM DAILY LOAD (TMDL) DECISION RATIONALE

TMDL: Total Suspended Solids Total Maximum Daily Load Evaluation for Brule Creek, Union and Lincoln Counties, South Dakota

ATTAINS TMDL ID: R8-SD-2022-01

LOCATION: Union and Lincoln counties, South Dakota

IMPAIRMENTS/POLLUTANTS: The TMDL submittal addresses one river segment with a warmwater marginal fish life propagation use that is impaired due to high concentrations of Total Suspended Solids (TSS).

Waterbody/Pollutant Addressed in this TMDL Action

Assessment Unit ID	Waterbody Description	Pollutant Addressed
SD-BS-R-BRULE_01	Brule Creek (Big Sioux River to the confluence of its east and west forks)	TSS

BACKGROUND: The South Dakota Department of Agriculture and Natural Resources (DANR) submitted to EPA the final TSS TMDL for Brule Creek with a letter requesting review and approval dated February 22, 2022. EPA previously reviewed and provided staff comments on a draft version of the report in 2021 but did not submit comments during the subsequent public comment period (January 13, 2022 to February 18, 2022).

The submittal included:

- Letter requesting EPA's review and approval of the TMDL
- Final TMDL report
- Data appendices

APPROVAL RECOMMENDATIONS: Based on the review presented below, the reviewer recommends approval of the final Brule Creek TSS TMDL. All the required elements of an approvable TMDL have been met.

TMDL Approval Summary	
Number of TMDLs Approved:	1
Number of Causes Addressed by TMDLs:	1

REVIEWERS: Peter Brumm, EPA

The following review summary explains how the TMDL submission meets the statutory and regulatory requirements of TMDLs in accordance with Section 303(d) of the Clean Water Act (CWA), and EPA's implementing regulations in 40 C.F.R. Part 130.

EPA REVIEW OF THE BRULE CREEK TSS TMDL

This TMDL review document includes EPA's guidelines that summarize the currently effective statutory and regulatory requirements relating to TMDLs (CWA Section 303(d) and 40 C.F.R. Part 130). These TMDL review guidelines are not themselves regulations. Any differences between these guidelines and EPA's regulations should be resolved in favor of the regulations themselves. The italicized sections of this document describe the information generally necessary for EPA to determine if a TMDL submittal fulfills the legal requirements for approval. The sections in regular type reflect EPA's analysis of the state's compliance with these requirements. Use of the verb "must" below denotes information that is required to be submitted because it relates to elements of the TMDL required by the CWA and by regulation.

1. Identification of Waterbody, Pollutant of Concern, Pollutant Sources, and Priority Ranking

The TMDL submittal must clearly identify (40 C.F.R. §130.7(c)(1)):

- *the waterbody as it appears on the State's/Tribe's 303(d) list;*
- *the pollutant for which the TMDL is being established; and*
- *the priority ranking of the waterbody.*

The TMDL submittal must include (40 C.F.R. §130.7(c)(1); 40 C.F.R. §130.2):

- *an identification of the point and nonpoint sources of the pollutant of concern, including location of the source(s) and the quantity of the loading (e.g., lbs. per day);*
- *facility names and NPDES permit numbers for point sources within the watershed; and*
- *a description of the natural background sources, and the magnitude and location of the sources, where it is possible to separate natural background from nonpoint sources.*

This information is necessary for EPA's review of the load and wasteload allocations, which are required by regulation.

The TMDL submittal should also contain a description of any important assumptions made in developing the TMDL, such as:

- *the spatial extent of the watershed in which the impaired waterbody is located;*
- *the assumed distribution of land use in the watershed (e.g., urban, forested, agriculture);*
- *population characteristics, wildlife resources, and other relevant information affecting the characterization of the pollutant of concern and its allocation to sources;*
- *present and future growth trends, if taken into consideration in preparing the TMDL (e.g., the TMDL could include the design capacity of a wastewater treatment facility); and*
- *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.*

Brule Creek is located in southeastern South Dakota and is part of the larger Big Sioux River Basin. The impaired waterbody segment subject to this TMDL extends 37 miles upstream from Brule Creek's confluence with the Big Sioux River to the confluence of East and West Brule Creeks and is identified as SD-BS-R-BRULE_01. The watershed draining into this segment is described as 144 miles^2. Figure 1 displays the general location of the Brule Creek Watershed with the impaired segment shown in blue. Figure 2 shows land use and Figure 4 shows the monitoring locations where data was collected to support TMDL development.

This segment was first listed as impaired by TSS on South Dakota's 2018 303(d) List and remained an impairment on subsequent list cycles. It was assigned a high priority for TMDL development on the most recent EPA-approved 303(d) list in 2020 and the South Dakota's draft 2022 303(d) List. This priority ranking information is contained on Page 2. Brule Creek is subject to a 2011 fecal coliform TMDL and a 2020 *E. coli* TMDL, both of which address the creek's impaired limited contract recreation use. Once this TSS TMDL is finalized, all known Brule Creek impairments will be addressed by TMDLs.

Section 1.1.1 (Land Use) and Table 1 summarize the land use distribution draining into the impaired segment which is predominantly corn (42.22%) and soybeans (38.97%) with portions of grass/pasture (9.27%) and developed open space (3.76%). Section 3.2 (Non-point Sources) discusses nonpoint sources as streambed and bank erosion, and surface runoff. Local activities that affect these loading pathways include agricultural practices, such as subsurface drainage (i.e., "tiling") and tillage, and transportation infrastructure, such as bridges, culverts and road crossings. The natural TSS load was quantified using South Dakota's reference site network and various literature reference values from Klimetz et al. (2009) as summarized in Section 3.3 (Natural Sources). The Klimetz et al. (2009) report was supported by, and developed for, EPA Region 8.

Point sources are reviewed and described in Section 3.1 (Point Sources). A single permit (SD0027928), held by L.G. Everist, Inc., allows a gravel pit to discharge into Brule Creek. Over the last 16 years, discharges from this facility have been rare and all observed effluent concentrations were well below the numeric TSS criterion. Existing permit effluent limits for TSS include a 30-day mean limit of 25 mg/L and a daily maximum limit of 45 mg/L. Due to infrequent discharges and low TSS concentrations, the L.G. Everist facility is not considered a significant source of TSS.

Assessment: EPA concludes that DANR adequately identified the impaired waterbody, the pollutant of concern, the priority ranking, the identification, location and magnitude of the pollutant sources, and the important assumptions and information used to develop the TMDL.

2. Description of the Applicable Water Quality Standards and Numeric Water Quality Target

The TMDL submittal 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 antidegradation policy (40 C.F.R. §130.7(c)(1)); and*
- *a numeric water quality target for each TMDL. If the TMDL is based on a target other than a numeric water quality criterion, then a numeric expression must be developed from a narrative criterion and a description of the process used to derive the target must be included in the submittal (40 C.F.R. §130.2(i)).*

EPA needs this information to review the loading capacity determination, and load and wasteload allocations, which are required by regulation.

Section 2.1 (South Dakota Water Quality Standards) describes the water quality standards applicable to the impaired segment with citations to relevant South Dakota regulations. SD-BR-R-BRULE_01 is designated the following beneficial uses:

- warmwater marginal fish life propagation,

- limited contact recreation,
- fish and wildlife propagation, recreation, and stock watering,
- irrigation waters.

All numeric criteria applicable to these uses are presented in Table 2. DANR determined that TSS is preventing the creek's warmwater marginal fish life propagation use from being fully supported. Numeric TSS criteria for this use are comprised of a 30-day mean criterion (≤ 150 mg/L) and a single sample maximum criterion (≤ 263 mg/L). These criteria apply year-round. DANR selected the 30-day mean criterion (≤ 150 mg/L) as the TMDL target and expects that meeting this target will lead to conditions necessary to support the single sample maximum criterion (≤ 263 mg/L) as well as the relevant narrative criteria cited in the TMDL report.

The TMDL is consistent with South Dakota antidegradation policies because it provides recommendations and establishes pollutant limits at water quality levels necessary to meet criteria and fully support existing beneficial uses.

Assessment: EPA concludes that DANR adequately described the applicable water quality standards and numeric water quality target for this TMDL.

3. Loading Capacity - Linking Water Quality and Pollutant Sources

The TMDL submittal must include the loading capacity for each waterbody and pollutant of concern. 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 TMDL submittal must:

- *describe the method used to establish 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;*
- *contain documentation supporting the TMDL analysis, including the basis for any assumptions; a discussion of strengths and weaknesses in the analytical process; and results from any water quality modeling; and*
- *include a description and summary of the water quality data used for the TMDL analysis.*

EPA needs this information to review the loading capacity determination, and load and wasteload allocations, which are required by regulation (40 C.F.R. §130.2).

The full water quality dataset should be made available as an appendix to the TMDL or as a separate electronic file. Other datasets used (e.g., land use, flow), if not included within the TMDL submittal, should be referenced by source and year. The TMDL analysis should make use of all readily available data for the waterbody unless the TMDL writer determines that the data are not relevant or appropriate.

The pollutant loadings may be expressed as either mass-per-time, toxicity or other appropriate measure (40 C.F.R. §130.2(i)). Most TMDLs should be expressed as daily loads (USEPA. 2006a). If the TMDL is expressed in terms other than a daily load (e.g., annual load), the submittal should explain why it is appropriate to express the TMDL in the unit of measurement chosen.

The TMDL submittal must describe the critical conditions and related physical conditions in the waterbody as part of the analysis of loading capacity (40 C.F.R. §130.7(c)(1)). The critical condition can be thought of as the "worst case" scenario of environmental conditions (e.g., stream flow, temperature, loads) in the waterbody in *which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. TMDLs should define the applicable critical conditions and describe the approach used to estimate both point and nonpoint source loads under such critical conditions.*

Loading sources were characterized and quantified using multiple approaches. Rapid Geomorphic Assessments were performed at 35 Brule Creek locations upstream and downstream of road crossings to assess the potential impact of the transportation network. Results indicate that road crossings may cause some stream bank instability, but sites upstream and downstream of crossings generally exhibited similar stability suggesting the overall impact from road crossings is minimal for Brule Creek (Table 9). AnnAGNPS, a model that estimates sheet and rill erosion rates, was used to run various land use and agricultural best management practice (BMP) scenarios. Model results were further reviewed using spatial autocorrelation to delineate priority zones for TMDL implementation activities. The results of these efforts are displayed in Table 10 and Figure 9.

DANR relied on the load duration curve approach to define the TSS loading capacity for Brule Creek. A load duration curve is a graphical representation of pollutant loads across various flows. The approach correlates water quality conditions to stream flow and provides insight into the variability of source contributions. EPA has published guidance on the use of load duration curves for TMDL development (USEPA, 2007) and the practice is well established. Using this approach, DANR set the TMDL equivalent to the loading capacity and expressed the TMDL in units of milligrams (mg) per day at five different flow zones, as listed in Table 11. The load duration curve, and TMDL based on the curve, is shown visually in Figure 10 with instantaneous loads calculated from the monitoring dataset.

Water quality monitoring data used in the analysis is summarized in Section 4.1 (Water Quality Data and Discharge Information) and provided fully in Appendix A (Data).

While the loading capacity is defined for multiple stream flow conditions, DANR described critical conditions in Brule Creek occurring during periods of greater precipitation. Monitoring data indicated that TSS concentrations were commonly highest in June, which DANR attributed to periods of greater precipitation. The existing loads in Figure 10 demonstrate that most exceedances occur during the top 30 percent of flows.

Assessment: EPA concludes that the loading capacity was calculated using an acceptable approach, used a water quality target consistent with water quality criteria, and has been appropriately set at a level necessary to attain and maintain the applicable water quality standards. The pollutant load has been expressed as a daily load. The critical conditions were described and factored into the calculations and were based on a reasonable approach to establish the relationship between the target and pollutant sources.

4. Load Allocation

The TMDL submittal must include load allocations (LAs). EPA regulations define LAs as the portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution and to natural background sources. Load allocations may range from reasonably accurate estimates to gross allotments (40 C.F.R. §130.2(g)). Where possible, separate LAs should be provided for natural background and for nonpoint sources.

In the rare instance that a TMDL concludes that there are no nonpoint sources or natural background for a pollutant, the load allocation must be expressed as zero and the TMDL should include a discussion of the reasoning behind this decision.

As described in Section 5.2.1 (Load Allocation), DANR established a single LA as the allowable load remaining after accounting for the WLA and explicit MOS (i.e., LA = TMDL – WLA – MOS). Because the Brule Creek WLA equals zero, the calculation can be simplified as LA = TMDL – MOS. Table 11 presents the LA across the TMDL's five flow zones. This composite LA represents all nonpoint source contributions, both human and natural, as one allocation, however, individual nonpoint source categories were characterized in greater depth in Section 3.2 (Non-point Sources), Section 3.3 (Natural Sources) and Section 4.2 (Data Analysis).

Assessment: EPA concludes that the LA provided in the TMDL is reasonable and will result in attainment of the water quality standards.

5. Wasteload Allocations

The TMDL submittal must include wasteload allocations (WLAs). EPA regulations define WLAs as the portion of a receiving water's loading capacity that is allocated to existing and future point sources (40 C.F.R. §130.2(h)). If no point sources are present or if the TMDL recommends a zero WLA for point sources, the WLA must be expressed as zero. If the TMDL recommends a zero WLA after considering all pollutant sources, there must be a discussion of the reasoning behind this decision, since a zero WLA implies an allocation only to nonpoint sources and natural background will result in attainment of the applicable water quality standards, and all point sources have no measurable contribution.

The individual WLAs may take the form of uniform percentage reductions or individual mass based limitations for dischargers where it can be shown that this solution meets WQSs and does not result in localized impairments. In some cases, WLAs may cover more than one discharger (e.g., if the source is contained within a general permit).

DANR established a WLA equal to zero in the Brule Creek TSS TMDL. There is one permitted point source facility that discharges to Brule Creek: the L.G. Everist, Inc. Spink Gravel Pit (SD0027928). DANR cited the facility's infrequent and insignificant discharge when making the determination to set a zero WLA. The rationale for this decision is further outlined in Section 3.1 (Point Sources) and Section 5.2.2 (Wasteload Allocation).

Assessment: EPA concludes that the TMDL considered all point sources contributing loads to the impaired segment, upstream segments and tributaries in the watershed and the recommendation of zero WLA was justified and reasonable.

6. Margin of Safety

*The TMDL submittal must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load allocations, wasteload allocations and water quality (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)). The MOS may be **implicit** or **explicit**.*

*If the MOS is **implicit**, the conservative assumptions in the analysis that account for the MOS must be described. If the MOS is **explicit**, the loading set aside for the MOS must be identified.*

The Brule Creek TSS TMDL includes an explicit MOS derived as 10% of the TMDL. The explicit MOS is included in Table 11 and varies by flow zone.

Assessment: EPA concludes that the TMDL incorporates an adequate explicit margin of safety.

7. Seasonal Variation

The TMDL submittal must be established with consideration of seasonal variations. The method chosen for including seasonal variations in the TMDL must be described (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)).

The load duration curve method used to establish the TMDL incorporates variations in stream flow, which in turn, is influenced by other climatic and human factors that change throughout the year. To account for these variations, DANR developed the TMDL at five different flow zones as listed in Table 11. The monthly variability of monitored TSS concentrations is summarized in Section 6.0 (Seasonal Variation). June exhibited the highest median TSS concentration, however, exceedances of the TMDL target were observed across multiple months. DANR associated periods of greater precipitation and stream flow to conditions with greater TSS loads and concentrations.

Assessment: EPA concludes that seasonal variations were adequately described and considered to ensure the TMDL allocations will be protective of the applicable water quality standards throughout any given year.

8. Reasonable Assurances

When a TMDL is developed for waters impaired by both point and nonpoint sources, EPA guidance (USEPA. 1991) and court decisions say that the TMDL must provide reasonable assurances that nonpoint source control measures will achieve expected load reductions in order for the TMDL to be approvable. This information is necessary for EPA to determine that the TMDL, including the load and wasteload allocations, has been established at a level necessary to implement the applicable water quality standards (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)).

EPA guidance (USEPA. 1997) also directs Regions to work with States to achieve TMDL load allocations in waters impaired only by nonpoint sources. However, EPA cannot disapprove a TMDL for nonpoint source-only impaired waters, which do not have a demonstration of reasonable assurance that LAs will be achieved, because such a showing is not required by current regulations.

The TMDL contained in this submittal is for a nonpoint source-only impaired water. Still, nonregulatory, voluntary-based reasonable assurances are provided for the LA where the submittal discusses DANR's adaptive management approach to the TMDL process, the monitoring commitment that will be used to gage TMDL effectiveness in the future (Section 8.0, Adaptive Management and Monitoring Strategy), and implementation projects already underway. These assurances include the recommendation of specific activities and geographic areas to focus implementation, which are discussed in Section 9.0 (Restoration Strategy).

Assessment: EPA considered the reasonable assurances contained in the TMDL submittal and concludes that they are adequate to meet the load reductions.

9. Monitoring Plan

The TMDL submittal should include a monitoring plan for all:

- *Phased TMDLs; and*
- *TMDLs with both WLA(s) and LA(s) where reasonable assurances are provided.*

Under certain circumstances, a phased TMDL should be developed when there is significant uncertainty associated with the selection of appropriate numeric targets, estimates of source loadings, assimilative capacity, allocations or when limited existing data are relied upon to develop a TMDL. EPA guidance (USEPA. 2006b) recommends that a phased TMDL submittal, or a separate document (e.g., implementation plan), include a monitoring plan, an explanation of how the supplemental data will be used to address any uncertainties that may exist when the phased TMDL is prepared and a scheduled timeframe for revision of the TMDL.

For TMDLs that need to provide reasonable assurances, the monitoring plan should describe the additional data to be collected to determine if the load reductions included in the TMDL are occurring and leading to attainment of water quality standards.

EPA guidance (USEPA. 1991) recommends post-implementation monitoring for all TMDLs to determine the success of the implementation efforts. Monitoring plans are not a required part of the TMDL and are not approved by EPA but may be necessary to support the decision rationale for approval of the TMDL.

In Section 8.0 (Adaptive Management and Monitoring Strategy) DANR commits to supporting future water quality monitoring activities and stream flow recording at site 46BS49 to judge progress towards achieving the goals outlined in the TMDL. This submittal is not considered a phased TMDL, however, DANR maintains the ability to modify the TMDL and allocations as new data becomes available using an adaptive management approach in accordance with the TMDL revision process previously recommended by EPA.

Assessment: Monitoring plans are not a required element of EPA's TMDL review and decision-making process. The TMDL submitted by DANR includes a commitment to monitor progress toward attainment of water quality standards. EPA is taking no action on the monitoring strategy included in the TMDL submittal.

10. Implementation

EPA policy (USEPA. 1997) encourages Regions to work in partnership with States/Tribes to achieve nonpoint source load allocations established for 303(d)-listed waters impaired by nonpoint sources. Regions may assist States/Tribes in developing implementation plans that include reasonable assurances that nonpoint source LAs established in TMDLs for waters impaired solely or primarily by nonpoint sources will in fact be achieved. The policy recognizes that other relevant watershed management processes may be used in the TMDL process. EPA is not required to and does not approve TMDL implementation plans.

EPA encourages States/Tribes to include restoration recommendations (e.g., framework) in all TMDLs for stakeholder and public use to guide future implementation planning. This could include identification of a *range of potential management measures and practices that might be feasible for addressing the main loading sources in the watershed (see USEPA. 2008b, Chapter 10). Implementation plans are not a required part of the TMDL and are not approved by EPA but may be necessary to support the decision rationale for approval of the TMDL.*

In Section 9.0 (Restoration Strategy), DANR describes work already underway focusing on riparian protection and cropland management BMPs as part of the Central Big Sioux Implementation Project. The TMDL report also encourages future stream bank stabilization and riparian restoration efforts focus on areas with the highest RGA scores, and suggests that agricultural BMPs (e.g., conservation tillage) would be most efficiently applied to priority zones identified by the AnnAGNPS model.

Assessment: Although not a required element of the TMDL approval, DANR discussed how information derived from the TMDL analysis process can be used to support implementation of the TMDL. EPA is taking no action on the implementation portion of the TMDL submittal.

11. Public Participation

EPA policy is that there must be full and meaningful public participation in the TMDL development process. Each State/Tribe must, therefore, provide for public participation consistent with its own continuing planning process and public participation requirements (40 C.F.R. §25.3 and §130.7(c)(1)(ii)).

The final TMDL submittal must describe the State/Tribe's public participation process, including a summary of significant comments and the State/Tribe's responses to those comments (40 C.F.R. §25.3 and §25.8). Inadequate public participation could be a basis for disapproving a TMDL; however, where EPA determines that a State/Tribe has not provided adequate public participation, EPA may defer its approval action until adequate public participation has been provided for, either by the State/Tribe or by EPA.

Section 7.0 (Public Participation) explains the public engagement process DANR followed during development of the TMDL. A draft TMDL report was released for public comment from January 13, 2022 to February 18, 2022. The opportunity for public review and comment was posted on DANR's website and announced in three area newspapers: the Sioux Falls Argus Leader, Vermillion Plain Talk, and Southern Union County Leader-Courier. No public comments were submitted.

Assessment: EPA has reviewed DANR's public participation process and concludes that DANR involved the public during the development of the TMDL and provided adequate opportunities for the public to comment on the draft report.

12. Submittal Letter

The final TMDL submittal must 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 (40 C.F.R. §130.7(d)(1)). The final submittal letter should contain such identifying information as the waterbody name, location, assessment unit number and the pollutant(s) of concern.

A transmittal letter with the appropriate information was included with the final TMDL report submission from DANR, dated February 22, 2022 and signed by Paul Lorenzen, Environmental Scientist Manager-TMDL Team Leader, Water Protection Program.

Assessment: EPA concludes that the state's submittal package clearly and unambiguously requested EPA to act on the TMDL in accordance with the Clean Water Act and the submittal contained all necessary supporting information.

References

DANR (previously DENR). 2011. *Fecal Coliform Bacteria Total Maximum Daily Load Evaluation for Brule Creek, Union County, South Dakota*. South Dakota Department of Agriculture and Natural Resources. Pierre, South Dakota.

DANR (previously DENR). 2018a. *The 2018 South Dakota Integrated Report for Surface Water Quality Assessment*. South Dakota Department of Agriculture and Natural Resources. Pierre, South Dakota.

DANR (previously DENR). 2018b. *Surface Water Discharge Permit L.G. Everist, Inc. – NWIA Permit No.: SD0027928*. South Dakota Department of Agriculture and Natural Resources. Pierre, South Dakota.

DANR (previously DENR). 2020a. *The 2020 South Dakota Integrated Report for Surface Water Quality Assessment*. South Dakota Department of Agriculture and Natural Resources. Pierre, South Dakota.

DANR (previously DENR). 2020b. *Escherichia Coli Total Maximum Daily Loads (TMDLs) Conversion with Existing Fecal Coliform TMDLs for Impaired Streams Designated Recreation Uses in South Dakota*. South Dakota Department of Agriculture and Natural Resources. Pierre, South Dakota.

DANR. 2022. *Draft – The 2022 South Dakota Integrated Report for Surface Water Quality Assessment*. South Dakota Department of Agriculture and Natural Resources. Pierre, South Dakota.

Klimetz, L., Simon, A., & Schwartz, J. 2009. *Characterization of Suspended-Sediment Transport Conditions for Stable, "Reference" Streams in Selected Ecoregions of EPA Region 8*. Agricultural Research Service National Sedimentation Laboratory, U.S. Department of Agriculture, Oxford, MS.

USEPA. 1991. *Guidance for water quality-based decisions: The TMDL process.* EPA 440-4-91-001. Office of Water, Assessment and Watershed Protection Division and Office of Wetlands, Oceans, and Watersheds, U.S. Environmental Protection Agency, Washington, DC.

USEPA. 1997. *New policies for establishing and implementing Total Maximum Daily Loads (TMDLs)*. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

USEPA. 1999. *Protocol for Developing Sediment TMDLs*. EPA 841-B-99-004. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

USEPA. 2000. *Bacterial Indicator Tool User's Guide*. EPA-823-B-01-003. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

USEPA. 2006a. *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit.* Office of Water, Office of Wetlands, Oceans, and Watersheds, U.S. Environmental Protection Agency, Washington, DC.

USEPA. 2006b. *Clarification Regarding "Phased" Total Maximum Daily Loads.* Office of Water, Office of Wetlands, Oceans, and Watersheds, U.S. Environmental Protection Agency, Washington, DC.

USEPA. 2007. *An Approach for Using Load Duration Curves in the Development of TMDLs.* EPA-841-B-07-006. Office of Water, Office of Wetlands, Oceans and Watersheds, U.S. Environmental Protection Agency, Washington, DC.

USEPA. 2008. *Handbook for Developing Watershed Plans to Restore and Protect our Waters.* EPA-841-B-08-002. Office of Water, Environmental Protection Agency, Washington, DC.

USEPA. 2010. *National Pollutant Discharge Elimination System (NPDES) Permit Writers' Manual, Chapter 6, Water Quality-Based Effluent Limitations.* EPA-833-K-10-001. Office of Water, Office of Wastewater Management, Water Permits Division, Washington, DC.

USEPA. 2014. *Water Quality Standards Handbook: Chapter 1: General Provisions.* EPA-820-B-14-008. EPA Office of Water, Office of Science and Technology, Washington, DC.

USEPA. 2017. *Water Quality Standards Handbook: Chapter 3: Water Quality Criteria.* EPA-823-B-17-001. EPA Office of Water, Office of Science and Technology, Washington, DC.