Water Quality and Watershed Assessment Results for the Upper and Middle Sheyenne River- "Griggs Model" Watershed in Griggs, Foster, and Stutsman Counties 2009-2010

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1.0 INTRODUCTION

The Upper Sheyenne River sub-basin (09020202) and the Middle Sheyenne River sub-basin (09020203) collectively encompass approximately 3,913 square miles, or nearly 2.5 million acres located within twelve counties (Barnes, Benson, Eddy, Foster, Griggs, McHenry, Nelson, Pierce, Sheridan, Steele, Stutsman, and Wells Counties). This was the focus of the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project (Figure 1).

The primary goals of the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project are to assess the current water quality condition and beneficial use (e.g., aquatic life and recreation) support status of the Sheyenne River above Lake Ashtabula (Upper and Middle Sheyenne River sub-basins) and their tributaries. The project is also intended to identify possible sources or causes of any documented impairment(s) to beneficial uses. This project was funded through the North Dakota Department of Health's (NDDoH) Section 319 Nonpoint Source Pollution Management Program and Section 604(b) Watershed Planning Grant Program in partnership with the Upper Sheyenne Joint Water Resource Board, Wells County Soil Conservation District, Griggs County Soil Conservation District, State Water Commission, and Garrison Diversion Conservancy District. Data for this project was collected from May of 2009 through October of 2010.

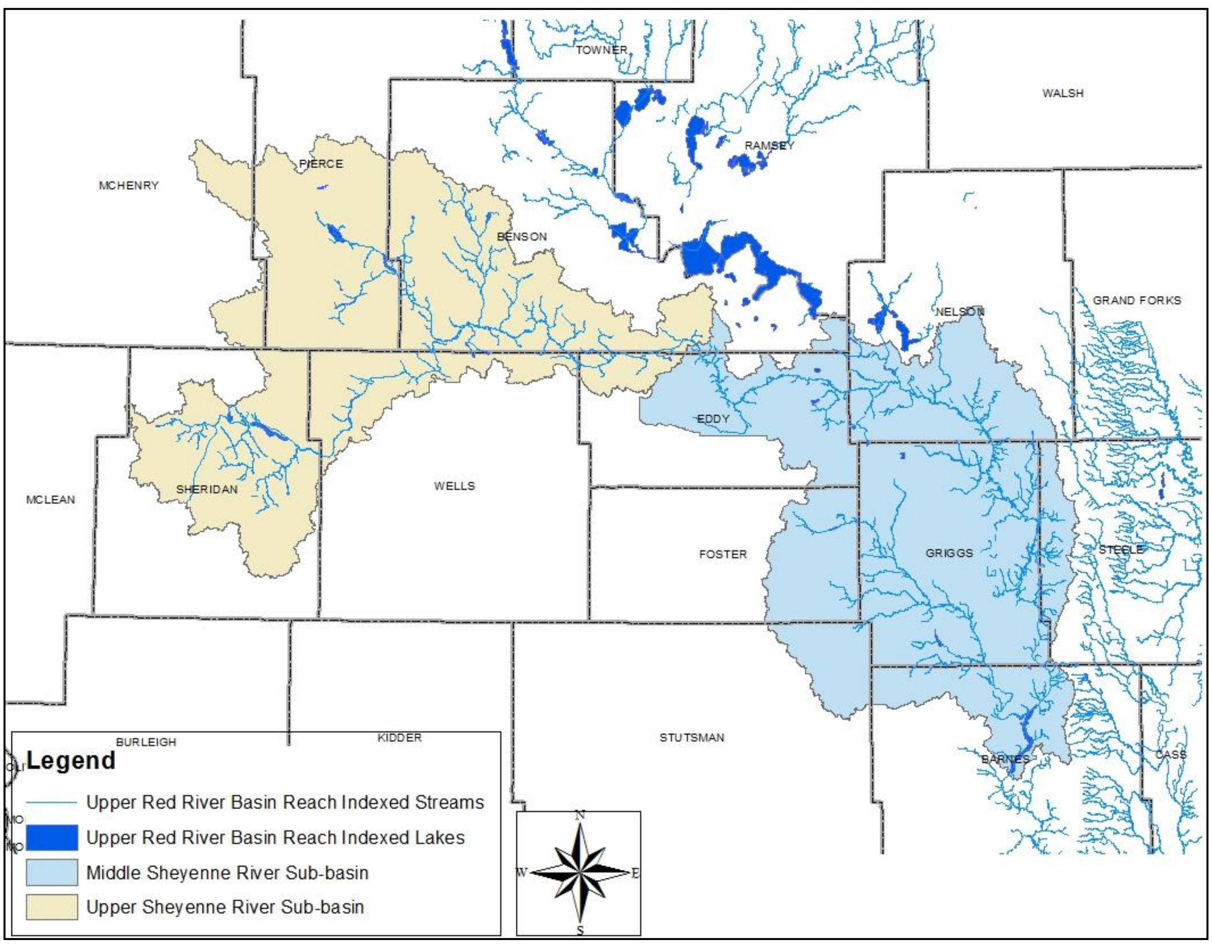

Figure 1. Upper and Middle Sheyenne River Sub-Basins.

1.1 Water Quality Assessment Report Strategy

The primary tool used to model the transport of nutrients and sediment throughout the watersheds for this assessment is the Annualized Agriculture Non Point Source (AnnAGNPS) model. Due to the large size of the Upper and Middle Sheyenne River sub-basins above Lake Ashtabula (3,913 square miles or 2,504,106 million acres in total) and the limitations of the AnnAGNPS model, seven separate watershed models had to be developed for the project (Figure 2, Table 1).

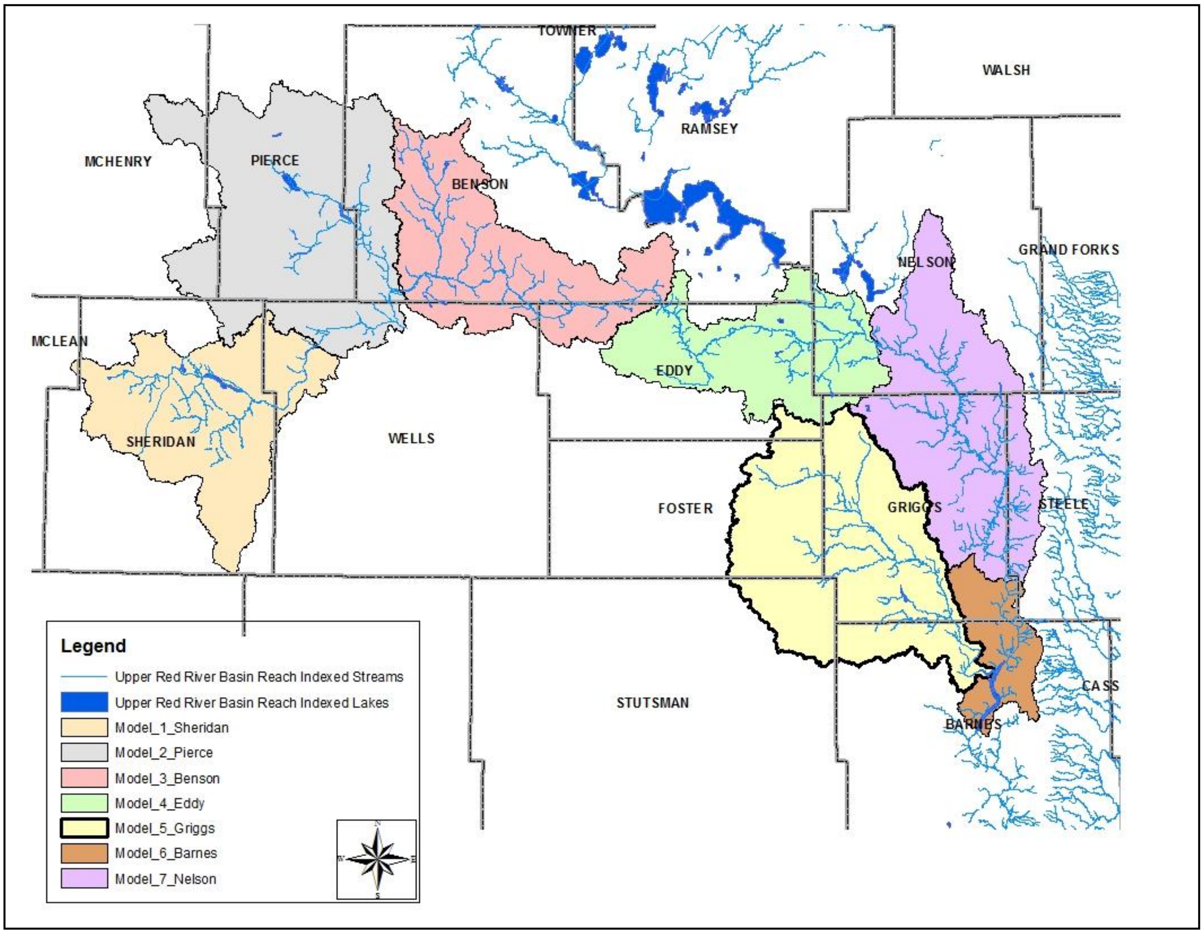

Figure 2. Upper and Middle Sheyenne River Watershed AnnAGPS Models (Highlighting the Model 5 - Griggs).

Each of the watershed models were developed based on two criteria: 1) to maintain similar watershed sizes; and 2) by placing a watershed so that a majority of the area lay with one county (Table 1).

Table 1. Description of the Seven Watershed AnnAGNPS Models.

Watershed Model	Description
Model 1 - Sheridan	Area above Harvey encompassing Sheridan and Wells Counties
Model 2 - Pierce	Area between Harvey and the junction with the North Fork Sheyenne River encompassing Pierce, Wells, Sheridan, and McHenry Counties
Model 3 - Benson	Area between the junction with the North Fork Sheyenne River and 1 mile upstream of Eddy County Hwy 1encompassing Benson, Wells, and Eddy Counties
Model 4 - Eddy	Area between 1 mile upstream of Eddy County Hwy 1 and south of Pekin encompassing Eddy, Ramsey, Griggs, and Nelson Counties
Model 5 - Griggs	**Baldhill Creek watershed encompassing Griggs, Barnes, Stutsman, Foster, and Eddy Counties**
Model 6 - Barnes	Area between upstream of the Griggs and Barnes County and Baldhill Dam (excluding Baldhill Creek) encompassing Barnes, Griggs, and Steele Counties
Model 7 - Nelson	Area south of Pekin and to upstream of the Griggs and Barnes' County lines encompassing Nelson, Griggs, and Steele Counties

In order to provide stakeholders in the Upper and Middle Sheyenne River watersheds with necessary information for making conservation management decisions, the water quality report strategy will consist of seven separate water quality reports depicting water quality and watershed assessment data for that particular modeled watershed. This approach will permit stakeholders to focus on water quality and watershed data in their specific study area. The water quality report will provide information to assist stakeholders with developing water quality targets and implementation strategies to improve water quality. This report is focused on Model 5 referred to as the "Griggs Model". It is the second furthest downstream of the seven watershed models that were developed for the Upper and Middle Sheyenne River watershed project. The watershed encompasses portions of Eddy, Foster, Griggs and Stutsman Counties.

1.2 Environmental Setting

1.2.1 Land Use

The "Griggs Model" watershed encompasses 488,125 acres in Griggs, Foster, Eddy, Stutsman and Barnes Counties, North Dakota (Table 2). According to National Agricultural Statistics Service (NASS) 2007 land cover data, the dominate land use in the subwatershed is agricultural with 68 percent used for cropland, 18 percent grassland/pasture, and the remaining 13 percent a combination of water, wetlands, or developed/open space (Figure 3). The dominant crops grown in the watershed are soybeans, spring wheat, corn, sunflowers, and barley.

Table 2. Watershed Size for the Seven AnnAGNPS Watershed Models.

Watershed Model	Area (mi^2)	Area (acres)
Model 1 - Sheridan	543.6	347,914
Model 2 - Pierce	828.1	529,982
Model 3 - Benson	535.7	342,826
Model 4 - Eddy	438.0	280,303
Model 5 - Griggs	**762.7**	**488,125**
Model 6 - Barnes	159.5	102,069
Model 7 - Nelson	645.0	412,887
Total	3912.6	2,504,005

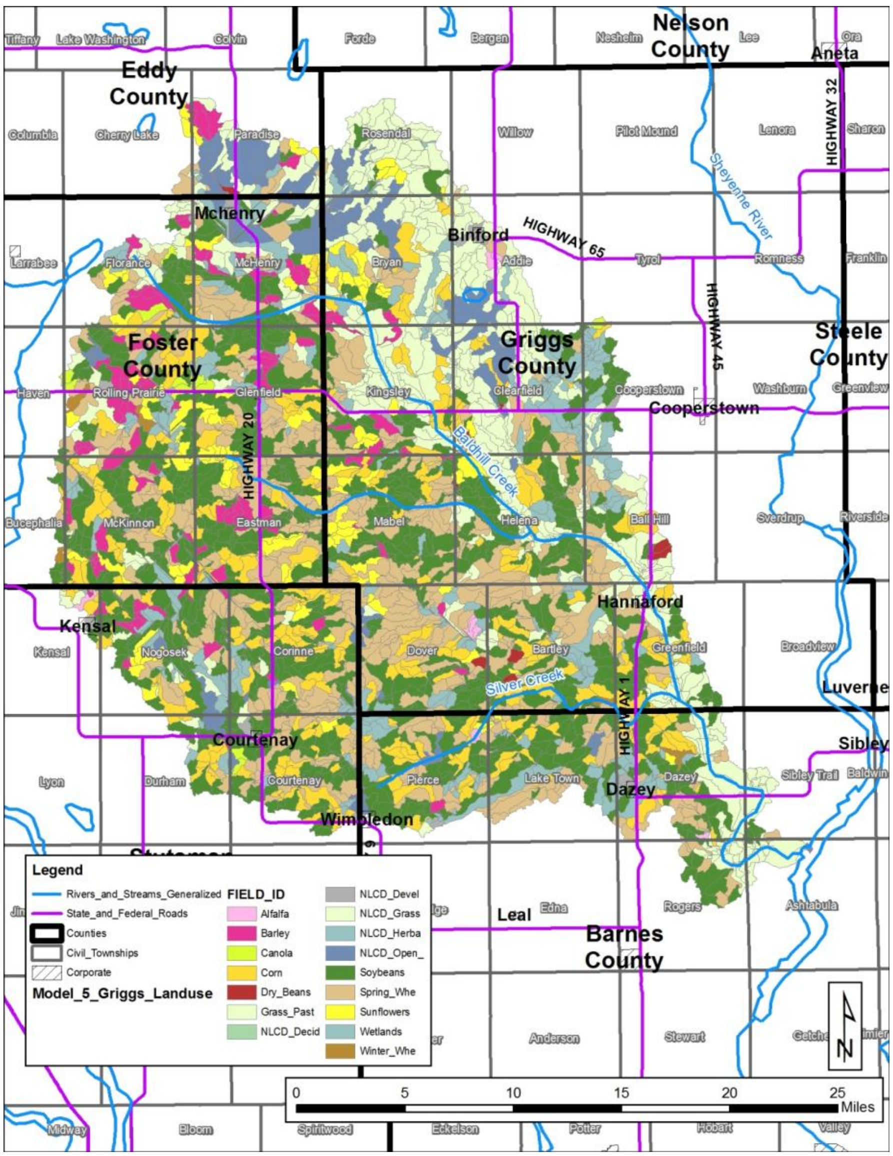

Figure 3. National Agricultural Statistical Survey Land Use Map, 2007 (Griggs Model).

1.2.2 Ecoregions

The Griggs Model watershed lies within three level IV ecoregions. These are the End Moraine Complex ecoregion (46f), Drift Plains ecoregion (46i), and Glacial Outwash ecoregion (46j) (Figure 3). The End Moraine Complex level IV ecoregion (46f) is composed of blocks of material scraped off and thrust up by the continental glacier at the south end of the Devils Lake basin. The western part of the ecoregion exhibits similar stagnate moraines similar to the Missouri Coteau while the southern moraines contain slightly higher elevations resulting in wooded lake boundaries and morainal ridges. Land use within the End Moraine Complex ecoregion consists of mixed range and cropland depending on slope and presence of rocky soil.

The Drift Plains ecoregion (46i) was created from the retreating Wisconsinan glaciers which left a subtle rolling topography and thick glacial till. A large number of temporary and seasonal wetlands are found in the Drift Plains. The Drift Plains contain productive soils and level topography which largely favors cultivation practices. Historic grasslands of transitional and mixed grass prairie have been replaced with fields of spring wheat, barley, sunflowers, and alfalfa.

The Glacial Outwash ecoregion (46j) is characterized by smoother topography and soils with high permeability and low water holding capacity. Cropland production is poor to fair with most areas being used for irrigated agriculture (USGS, 2006).

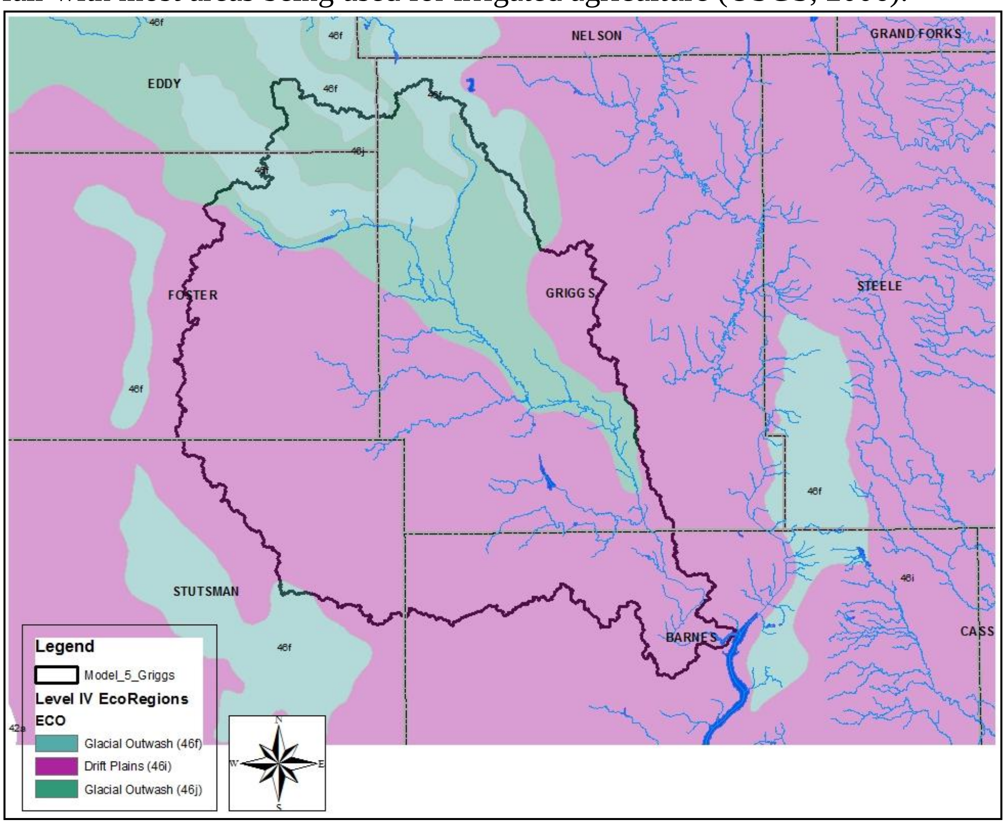

Figure 4. Level IV Ecoregions in the Griggs Model Watershed.

1.2.3 Weather Data

Precipitation data for the Upper and Middle Sheyenne River Watershed Project was obtained from the North Dakota Agricultural Weather Network (NDAWN) station located near Dazey, ND in the southeast corner of the watershed. Figure 5 shows monthly precipitation data averaged for the years of 1993-2008 compared to the precipitation totals for each month during 2009 and 2010. Snowfall data had not been converted into precipitation for the months of January through March and November through December so those months do not appear in Figure 5.

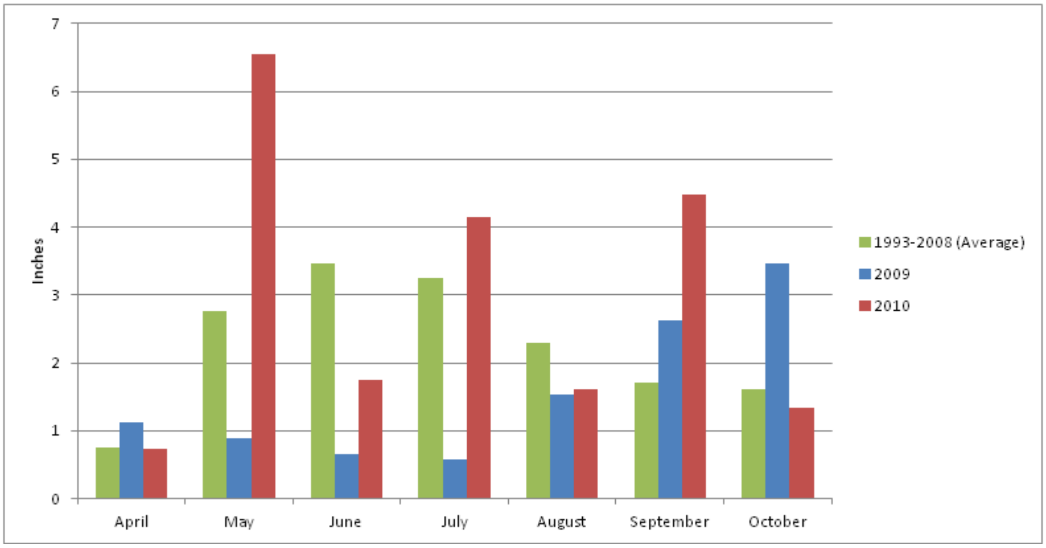

Figure 5. Monthly Precipitation for NDAWN Weather Station, Near Dazey, ND.

1.3 Water Quality Standards and Guidelines

State law (NDCC 61-28) establishes policies to protect, maintain, and improve the quality of waters of state, while the overall goal of the federal Clean Water Act (CWA) is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (NDDoH, 2012).

The national water quality standards regulation requires that states specify appropriate water uses to be achieved and protected. Appropriate uses are identified by taking into consideration the use and value of the water body for public water supply, for protection of fish, shellfish, and wildlife, and for recreational, agricultural, industrial, and navigational purposes. The protected beneficial uses of North Dakota's surface waters are defined in the *Standards of Quality for Waters of the State* (NDDoH 2011), as provided in NDAC 33-16-02.1, along with narrative and numeric criteria to protect those uses.

1.3.1 Beneficial Use and Class Description

The primary beneficial uses identified in the State's water quality standards are aquatic life and recreation. Protection for aquatic life means surface waters should be suitable for the propagation and support of fish and other aquatic biota, including aquatic macroinvertebrates, and that these waters will not adversely affect wildlife in the area. Protection of all surface waters, except wetlands, for recreation means waters should be suitable for direct body contact activities such as bathing and swimming and for secondary contact activities such as boating, fishing, and wading. Other beneficial uses identified in the State’s water quality standards are municipal and domestic water (e.g. water suitable for drinking after appropriate treatment), agriculture (e.g., stock watering and irrigation), and industrial (e.g., washing and cooling). These uses apply to all classified rivers, streams, lakes, and reservoirs.

The State’s water quality standards provide for four stream classes (I, IA, II, and III) and five lake classes (1-5). All classified lakes, reservoirs, rivers, and streams in the state are protected for aquatic life, recreation, agricultural, and industrial uses. In addition, Class I, IA, and II rivers and streams, and all classified lakes and reservoirs, are designated for use as municipal and domestic drinking water supplies, unless specifically stated otherwise.

The entire Sheyenne River is classified as Class IA. Rivers that fall into the Class IA category have the same water quality standards as Class I streams, except where natural conditions exceed Class I criteria for municipal and domestic use. In these cases the availability of softening or other treatment methods may be considered in determining whether ambient water quality meets the drinking water requirements of the NDDoH. The Sheyenne River from its headwaters to one-tenth mile downstream from Baldhill Dam is not classified for municipal or domestic use (NDDoH, 2011). Class IA rivers also have the exceptions from Class I rivers listed in Table 3 below.

Table 3. North Dakota Water Quality Standards Exceptions for Class IA Streams.

Substance or Characteristic	**Maximum Limit**
Chlorides (total)	175 mg/L (30-day arithmetic average)[1]
Sodium	60% of total cations as mEq/L[2]

[1] Milligrams per Liter or parts per million
[2] Milliequivalents per Liter

The Griggs Model portion is a tributary of the Middle Sheyenne River named Baldhill Creek is assigned aquatic life, recreation, agriculture, and industrial beneficial uses by the *Standards of Water Quality for State of North Dakota* (NDDH, 2011). However, the focus of this assessment will be on the aquatic life and recreational beneficial uses as the water quality standards applied will be protective of all other beneficial uses.

1.3.2 Narrative Water Quality Standards

For this report, the water quality standards, guidelines, and goals relevant to the Upper and Middle Sheyenne River and its beneficial uses involve both numeric and narrative standards. The NDDoH has set narrative water quality standards, which apply to all surface waters in the state as listed below:

- All waters of the state shall be free from substances attributable to municipal, industrial, or other discharges or agricultural practices in concentrations or combinations which are toxic or harmful to humans, animals, plants, or resident aquatic biota.

- No discharge of pollutants, which alone or in combination with other substances shall:
  1) Cause a public health hazard or injury to environmental resources;
  2) Impair existing or reasonable beneficial uses of the receiving waters; or
  3) Directly or indirectly cause concentrations of pollutants to exceed applicable standards of the receiving waters.

In addition to the narrative standards, the NDDoH has set a biological goal for all surface waters in the state. The goal states that "the biological condition of surface waters shall be similar to that of sites or waterbodies determined by the department to be regional reference sites." Direct measures of biological community health (i.e., indices of biological integrity), various chemical data (e.g., dissolved oxygen or metals concentrations) or best professional judgment can be used to determine if the waterbody is achieving certain narrative and numerical standards, and the narrative biological goal to fully support aquatic life uses (NDDoH, 2011).

1.3.3 Numeric Water Quality Standards

Water quality standards also identify specific numeric criteria for chemical, biological and physical parameters. The specific numeric standard assigned to each parameter ensures protection of the beneficial uses for that classification. For the purposes of this assessment report, relevant numeric standards are for E. coli bacteria and dissolved oxygen, with a site specific standard for total sulfate.

Numeric criteria for E. coli bacteria is defined as not to exceed 126 organisms per 100 mL as a geometric mean of representative samples collected during any 30-day consecutive period, nor shall more than ten percent of samples collected during any 30-day consecutive period individually exceed 409 organisms per 100 mL. For assessment purposes, the 30-day consecutive period shall follow the calendar month. This standard shall apply only during the recreation season of May 1to September 30. The waterbody is classified as fully supporting beneficial uses if both criteria are meet, fully supporting but threatened if only the first criteria is met, and not supporting if neither of the criteria are met by the waterbody (NDDH, 2012). Month-specific beneficial use attainment for the Upper and Middle Sheyenne River is determined and explained in Section 3.5.1.

Also, in addition to the Class IA exceptions for water quality standards listed in Table 3 above, the Sheyenne River from the headwaters to one tenth mile downstream of Baldhill Dam has a site specific total sulfate standard of 750 mg/L.
Currently, North Dakota is in the process of developing nutrient criteria for the State's waters. Excessive nutrients typically manifest themselves as elevated amounts of algae in lakes and reservoirs and as epiphytic algae or rooted macrophytes in streams and

rivers. The NDDoH is currently performing a pilot project to establish numeric for lentic (lake) systems, but does not yet have guidance on lotic (river) systems.

Since the department has not yet defined numeric nutrient criteria for rivers and streams, reference nitrogen and phosphorus values developed as part of the draft report entitled *An Ecological Assessment of Perennial, Wadeable Streams in the Red River Basin – North Dakota* (NDDoH 2012) will be used in this assessment report. These values which were developed for the Northern Glaciated Plains (46) ecoregion are 0.581 mg/L and 0.115 mg/L for nitrogen and phosphorus, respectively.

1.3.4 Impaired Waters Listings

Currently, the *2012 Section 303(d) List of Waters needing Total Maximum Daily Loads* recognizes portions of the Baldhill Creek as fully supporting but threatened to not supporting for recreation due to exceedences in pathogenic bacteria (formerly fecal coliform bacteria, now E. coli bacteria) (NDDH, 2012). Total Maximum Daily Loads (TMDLs) have been completed and approved for these sections of Baldhill Creek and can be found at www.ndhealth.gov/WQ and then through the TMDL/Watershed Liaison Program link.

2.0 WATER QUALITY SAMPLING METHODS

2.1 Sampling Sites

Monitoring stations were selected in the Upper and Middle Sheyenne River sub-basins to determine the current condition of water quality, potential effects of pollutant loadings, stressors and/or pollutant sources or any use impairments. Descriptions and location of sites and parameters sampled for the Griggs Model are provided in Table 4 and Figure 6.

Table 4. Description of Sampling Sites and Parameters for the Griggs Model.

Storet ID	Site Description	Parameters	Collection Year
384124	Baldhill Creek – 2 miles North of Highway 200	E. coli Bacteria	2009-2010
384129	Silver Creek a Tributary of Baldhill Creek – 1.5 miles Southeast of Walum, ND	E. coli Bacteria	2009-2010
384126[2]	Baldhill Creek – 2.5 miles North, 3.25 miles East of Dazey, ND	Water Chemistry[1] E. coli Bacteria Discharge (USGS Site 05057200) Suspended Sediment[3]	2009-2010

[1]Water chemistry includes major cations/anions, trace elements, nutrients (total nitrogen, total Kjeldahl nitrogen, nitrite-nitrate, ammonia, and total phosphorus), and total suspended solids.
[2]Collocated with USGS stream gauge station.
[3]Collected and analyzed by the USGS North Dakota Water Resource Office.

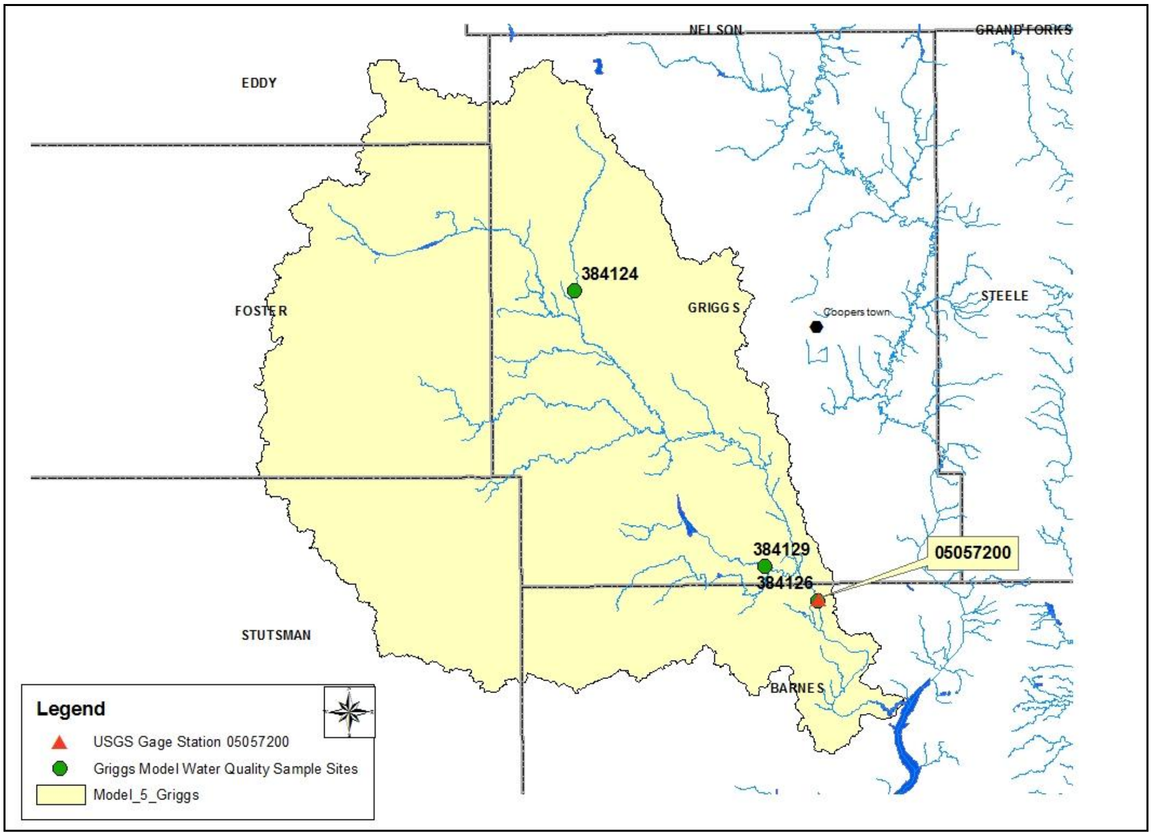

Figure 6. Stream Sampling Sites and USGS Gauge Station (05057200) for the Upper and Middle Sheyenne Water Quality and Watershed Assessment (Griggs Model).

2.2 Sampling Design

The primary goal of the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project was to assess the water quality condition and beneficial uses support status of the Upper and Middle Sheyenne River and tributaries and to identify possible sources/causes of any documented impairment to beneficial uses.

A quality assurance project plan (QAPP) was developed focusing on sample locations, frequency schedules, and methods to support the primary goal of the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project.

For a complete description the reader is referred to the Quality Assurance Project Plan for the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project (NDDoH, 2009).

2.3 Sampling Methods

Project sampling methods for the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project QAPP included water chemistry, stage, bacteria (E.coli), and macroinvertebrates.

The reader is referred to the Standard Operating Procedures for Field Samplers found at the end of the Quality Assurance Project Plan for the Upper and Middle Sheyenne River Water Quality and Watershed Assessment Project (NDDoH, 2009) for a complete description of the sampling methods used for this project.

3.0 STREAM ASSESSMENT DATA

While the Baldhill Creek and Silver Creek were sampled and analyzed for a variety of water quality constituents, only those parameters of concern are discussed in detail in this report. For a summary of all parameters sampled see Appendix A.

3.1 Hydrology

Hydrology describes the way water flows through a watershed. The water discharge measurement (volume of water) is an important complement to the concentration data collected during water quality analysis, as it allows the determination of what quantity (load) of a pollutant flows through the system over a given time. A concentration value of ten milligrams per liter (mg/L) has a very different effect on the river depending on whether there are three or three thousand liters of water that flow through a system in a day.

According to the National Oceanic and Atmospheric Administration (NOAA) National Weather Service Glossary, discharge is measured in cubic feet per second (cfs). One cubic foot per second is equal to the discharge through a rectangular cross section, one foot wide by one foot deep, flowing at an average velocity of one foot per second or approximately 7.48 gallons per second.

Daily stream discharge values were collected at one stream location within the Griggs Model watershed. This location was at the United States Geological Survey (USGS) gauging station located on Baldhill Creek near Dazey, ND (05057200). The USGS station has operated continuously since 1957 and is collocated with the North Dakota Department of Health (NDDoH) monitoring location 384126. For the purposes of this assessment, the last twenty years (1990-2010) of historical discharge records will be used to describe the hydrology of the Griggs Model watershed. This block of time should account for wet and dry cycles through the hydrological history of USGS gage station 05057200. From 1990 to 1992, the annual mean discharge of Baldhill Creek near Dazey, ND was very low most likely due to drought conditions in the late 1980's. Then in 1993-2001 the mean annual discharge fluctuated from average to above average flows most likely due to a wet cycle, then begins to drop significantly in 2002 thru 2008 (Figure 7). In 2009 and 2010, the discharge was 2.9 and 1.5 times higher than the average annual discharge of 1990-2008 which was calculated at 50 cfs. This can be attributed to record snowfalls and above average spring rains that were present all across North Dakota.

Discharge for the watershed is then used to determine the flow duration curve that will be used in the load duration curve analysis. Flow duration curve analysis looks at the cumulative frequency of historic daily flow data over a specific period of time. The flow duration curve relates flow (expressed as mean daily discharge) to the percent of time those mean daily flow values were met or exceeded. The use of "percent of time exceeded" (i.e., duration) provides a uniform scale ranging from 0 to 100 percent, thus accounting for the full range of stream flows. Low flows are exceeded most of the time, while high flows or flood flows are exceeded infrequently (USEPA, 2007). As mentioned earlier, this is a complement to the concentration data (measured in mg/L) and will help depict how often large amounts of water are flowing through the watershed

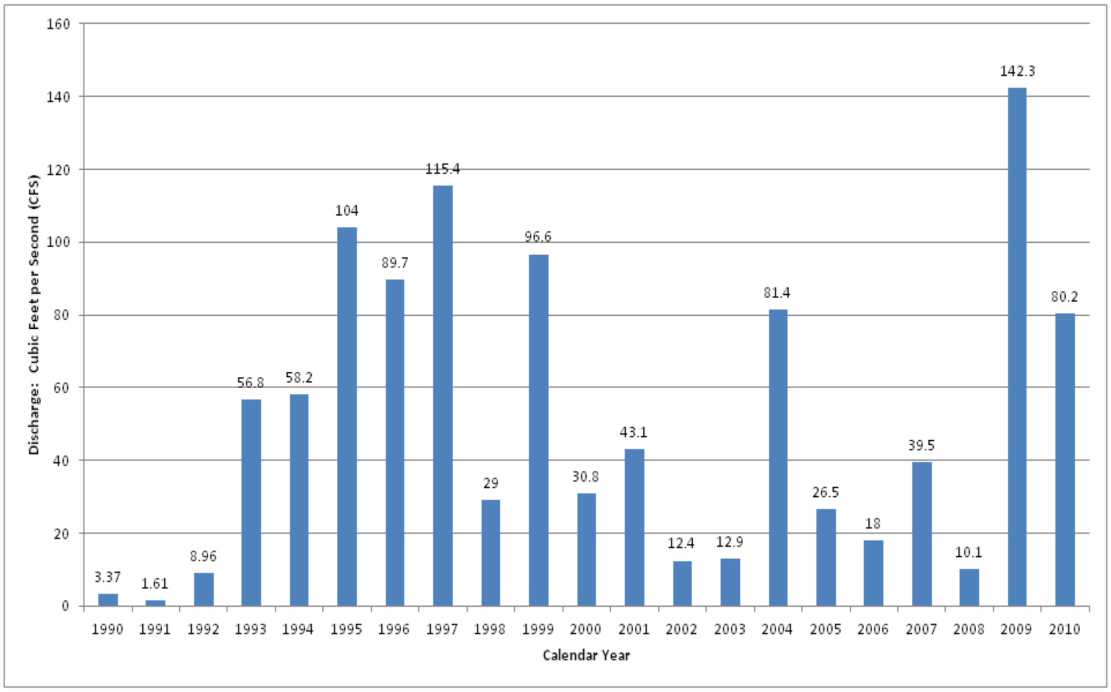

Figure 7. Mean Annual Discharge at the USGS Gauging Station (05057200) on Baldhill Creek near Dazey, ND.

A basic flow duration curve runs from high to low (0 to 100 percent) along the x-axis with the corresponding flow value on the y-axis (Figure 8). Using this approach, flow duration intensities are expressed as a percentage, with zero corresponding to the highest flows in the record (i.e., flood conditions) and 100 to the lowest flows in the record (i.e.drought). Therefore, as depicted in Figure 8, a flow duration interval of 50 percent, associated with the stream flow of 8.4 cubic feet per second (cfs), implies that 50 percent of all observed mean daily discharge values equal or exceeded 8.4 cfs.

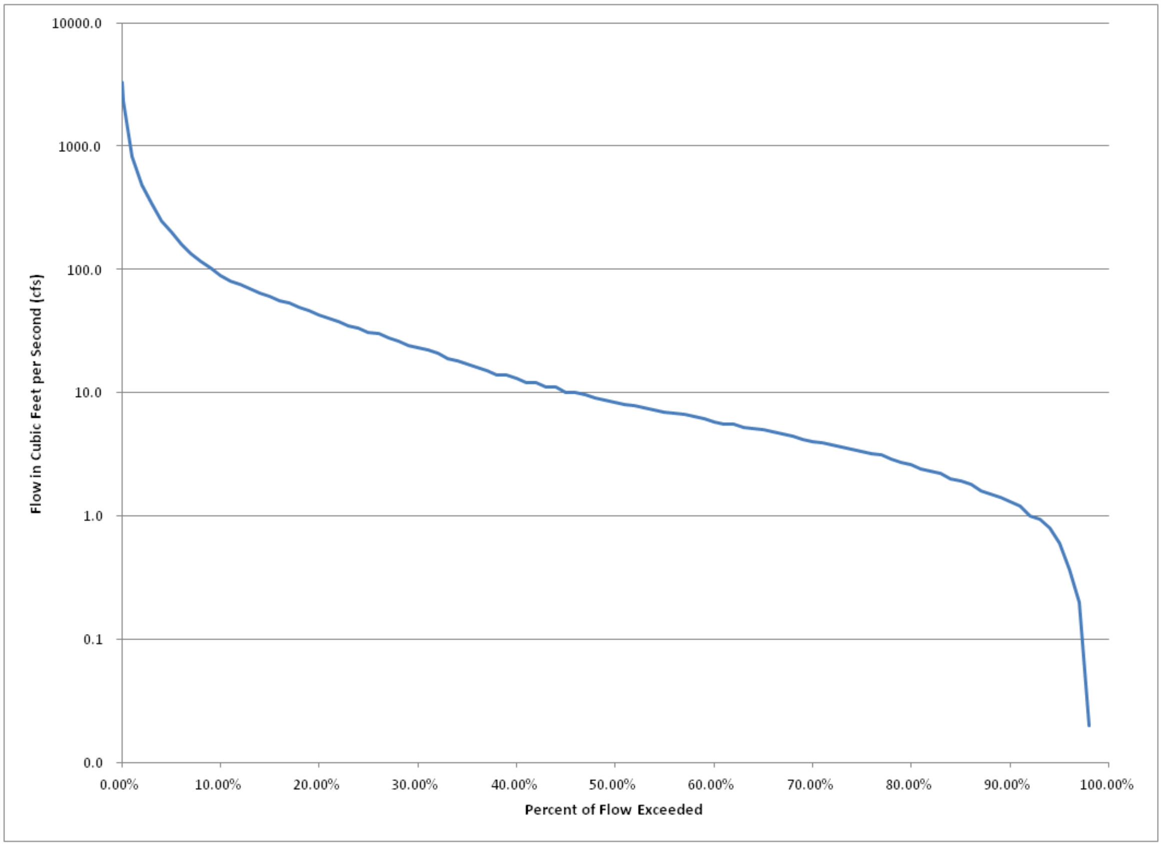

Figure 8. Flow Duration Curve for USGS Gauging Station 05057200.

Variable stream flows at high and low intervals are important factors in determining NPS pollution loads. To better correlate the relationship between the pollutants of concern and the hydrology of the Sheyenne River, load duration curves were developed for total nitrogen (TN) and total phosphorus (TP). Curves were constructed by multiplying concentrations for the each parameter by the mean daily flow and a conversion factor specific to each parameter. The curve represents a reference value for TN and TP based on ecoregion criteria discussed in the draft report entitled *An Ecological Assessment of Perennial, Wadeable Streams in the Red River Basin – North Dakota* (NDDoH 2012). The points on the graphs represent the samples taken. The State does not have a water quality standard or reference value for total suspended solids (TSS), so a summary of that data is provided in Appendix A.

3.2 Nutrients

To best understand how nitrogen and phosphorus work together in a waterbody, a description of the concept of limiting nutrients is appropriate. Many studies suggest that a ratio of total nitrogen (TN) to total phosphorus (TP) of between 10 and 17 is the optimum value for growth of algae (proportions of both nitrogen and phosphorus are sufficient for growth). For example, if there was an average TN value of 30 mg/L and an average TP value of 3 mg/L, that would equal a TN:TP of 10. A nutrient in short supply, one that causes this ratio to be above or below this range of values, is called the limiting nutrient. A nutrient in short supply, one that causes this ratio to be above or below this range of values, is called the limiting nutrient. It is generally thought that a TN:TP ratio less than 10 is nitrogen limited and a TN:TP ration of greater than 17 is phosphorus limited. In most North Dakota waters, nitrogen is the limiting nutrient. This means that once the nitrogen drops to a very low amount, no matter how much phosphorus is still present, rapid uptake by plants will not occur. Calculating this relatively simple ratio can sometimes provide a useful clue as to the relative importance of nitrogen or phosphorus toward the abundance of algae in a waterbody.

3.2.1 Total Nitrogen

Nitrogen is an essential nutrient for plants and animals. However, an excess amount of nitrogen in a waterway promotes the excessive growth of algae. When the algae die and decompose, dissolved oxygen in the water essential to the health of aquatic life is consumed and can reach critically low levels resulting in mortality to aquatic plants and organisms, as well as an increase in the availability of toxic substances. Increased levels of both nitrogen and phosphorus in the water can also lead to blue-green algae blooms which can be toxic if ingested. The die-off of rooted vegetation due to lack of dissolved oxygen can lead to an increase in water temperature as well as a decrease in suitable habitat for aquatic organisms. Both of these factors can lead to stress-caused mortality of aquatic life. In addition to local effects, excessive transport of nutrients can cause eutrophication of downstream lakes and impoundments.

High levels of nitrates (a component of total nitrogen) in the water used as a livestock water supply can also harm livestock. Exceedingly high levels of nitrates in drinking water for humans, those above 10 mg/L, are considered a threat to human health. Generally, concentrations of nitrates in surface waterbodies do not reach this level because nitrates are readily taken up by plants.

Increased costs are associated with reducing high nutrient levels in drinking water supplies, including filtering of these algae toxins as well as the increase in formation of disinfection by-products used during the drinking water treatment. High nutrient levels in drinking water sources also affect water quality in other ways such as taste and odor problems, clogging of intake structures, diminished filtration effectiveness and pH fluctuations that can lead to corrosion in the distribution pipes. USEPA has calculated that for a small community water system serving 500 or fewer people, the capital cost for installing ion exchange treatment to remove excess nitrate from source water would be more than $285,000 with increased operating costs of $17,600 per year (EPA, 2009). Sources of nitrogen include: wastewater treatment plants, runoff from fertilized lawns and croplands, failing septic systems, and runoff from animal manure and feeding/storage areas (EPA, 2007). Nitrogen is also converted from one form to another through biological processes.

There are three forms of inorganic nitrogen that are commonly measured in water bodies: ammonia, nitrates and nitrites. Ammonia and nitrates are the reactive forms for plant uptake. Total nitrogen (TN) is the sum of total Kjeldahl nitrogen (organic and reduced nitrogen, not readily used by plants), ammonia, and nitrate-nitrite. It can be derived by monitoring for total Kjeldahl nitrogen (TKN), ammonia, and nitrate-nitrite

3.2.2 Total Nitrogen Load Duration Curve Analysis

According to the draft report *An Ecological Assessment of Perennial, Wadeable Streams in the Red River Basin* (Larsen, 2012), Ecoregion 46, the Northern Glaciated Plains, had a total nitrogen reference value of 0.581 mg/L. This value was derived from nutrient data collected at a set of "least disturbed" reference sites located in the Northern Glaciated Plains ecoregion of North Dakota. This value is not a water quality standard, as nutrient criteria or standards have not yet been developed, but is provided as a point of reference or goal when evaluating the data collected within the watershed.

Observed in-stream total nitrogen data obtained from monitoring site 384126 in 2009 and 2010 were converted to a pollutant load by multiplying total nitrogen concentrations by the mean daily flow and a conversion factor. These loads are plotted against the percent exceeded of the flow on the day of sample collection. Points above the criteria line of 0.581 mg/L have values that exceeded the reference concentration value for that flow, and would have also exceeded the nitrogen load of a least impaired/impacted reference stream for that given flow.

Ideally, values that are close to the line indicate a nitrogen load to the stream that is close to the least impacted streams in this ecoregion, and therefore are more healthy. The further away from the criteria line, the larger the negative impact to the stream becomes. As mentioned in the section above, the criteria line is for reference purposes only as statewide nutrient criteria have not been developed for North Dakota at this time.

In Figure 9, the load duration curve for site 384126 indicates that the total nitrogen load is highly related to flow conditions, as the symmetry of samples follow the flow curve quite closely. This indicates that sources of nitrogen are most likely from overland flow related to nonpoint source pollution runoff from high flow events like snow melt and rain storms. If there were strong sources of instream nutrients, like wastewater discharge, it would be expected to see large spikes in loads during low flow events (80% - 100% duration intervals on the graph).

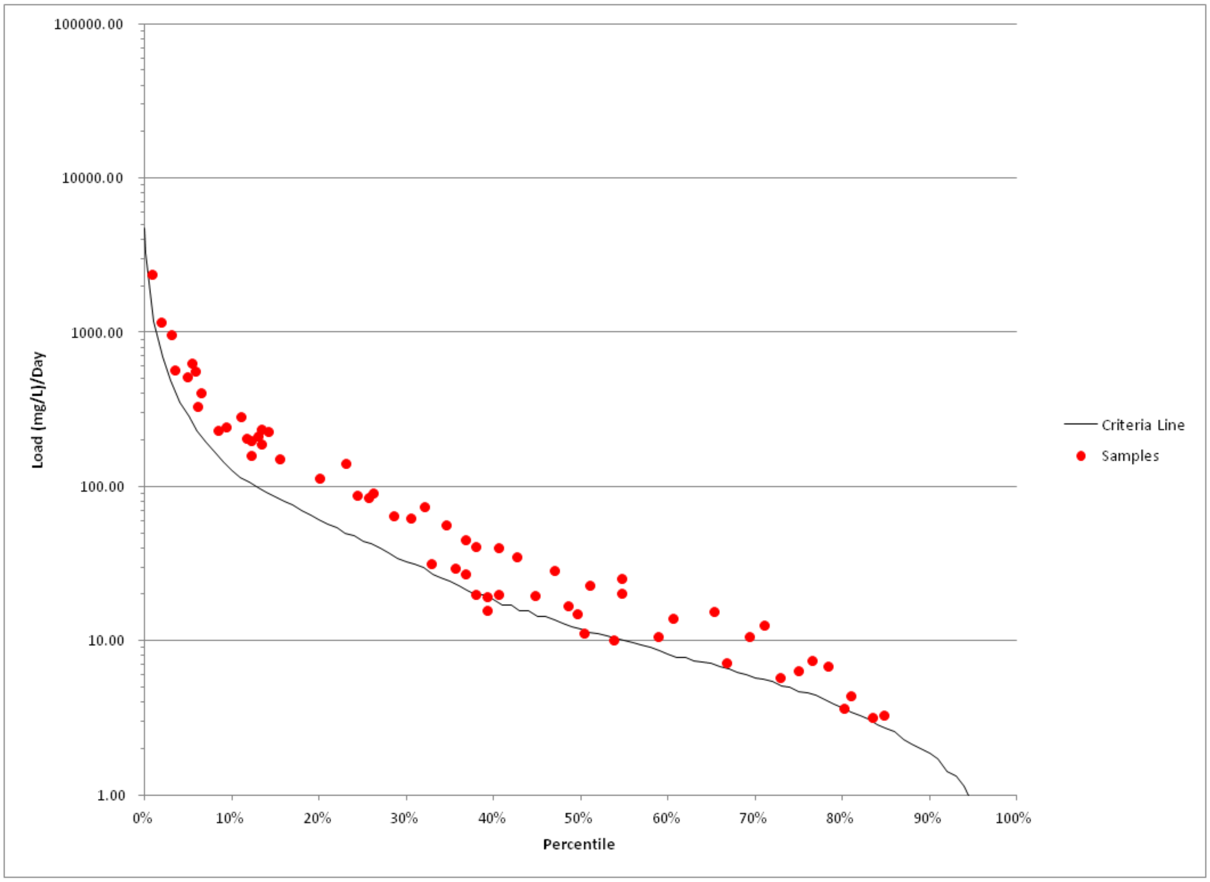

Figure 9. Total Nitrogen Load Duration Curve for the Baldhill Creek Monitoring Station 384126 (The curve reflects flow data from 1990-2010).

3.2.3 Total Phosphorus

Total Phosphorus (TP) is also an essential nutrient for plants and animals. In waterbodies, phosphorus occurs in two forms, dissolved and particulate. Dissolved phosphorus comes in both soluble reactive and soluble organic (non-reactive) forms. Particulate phosphorus is formed when phosphorus becomes incorporated into particles of soil, algae and small animals that are suspended in the water. Both dissolved and particulate phosphorus can change from one form to another very quickly (called cycling) in a waterbody. This is important because algal cells and plants can only use phosphorus in certain forms. Use is also influenced by factors such as pH, hardness of the water, the amount of dissolved oxygen in the water and the thermal stratification (layers of water having different temperatures.

While phosphorus is naturally limited in most fresh water systems because it is not as abundant as carbon and nitrogen, North Dakota sees elevated concentrations in its waters due to its abundance in most soils and the extensive agriculture that occurs across the state. Particulate phosphorus naturally bonds to soil particles and as a result can be transported over long distances with eroded soil. Because of this binding property phosphorus often settles to the bottom of streams, rivers, and lakes where is becomes unavailable for use by plants until it is both resuspended and mixed with the appropriate concentrations of nitrogen. Soluble phosphorus remains in the water column, available for plant use. Sources of phosphorus include soil and rock, wastewater treatment plants, runoff from cropland, fertilized lawns, animal manure storage areas, disturbed land areas, drained wetlands, water treatment, decomposition of organic matter, storm water runoff, and commercial cleaning preparations (USEPA, 2009).

The negative consequences of large amounts of phosphorus in a water body are similar to those of large amounts of nitrogen and have been discussed in the previous section. They are associated with algae blooms, accelerated plant growth, low dissolved oxygen from the decomposition of additional vegetation, and increased costs associated with drinking water infrastructure.

3.2.4 Total Phosphorus Load Duration Curve Analysis

Based on the draft report *An Ecological Assessment of Perennial, Wadeable Streams in the Red River Basin*, (Larsen, 2012), a total phosphorus reference value of 0.115 mg/L was estimated for the Northern Glaciated Plains Ecoregion (46). This reference value was developed based on data collected at "least disturbed" reference sites located in the Northern Glaciated Plains Ecoregion. Again, reference value of 0.115 mg/L is not a water quality standard, but is provided as a point of reference when evaluating the data.

Observed in-stream total phosphorus data obtained from monitoring site 384126 in 2009 and 2010 were converted to a phosphorus load by multiplying total phosphorus concentrations by the mean daily flow and a conversion factor. These loads are plotted against the percent exceeded of the flow on the day of sample collection. Points plotted above the criteria line of 0.115 mg/L have values that exceeded the reference concentration value for that flow.

Those concentrations also exceeded the phosphorus load of a least impaired reference stream given their flow rates at the time of collection. As in the case with the nitrogen load curve, values that are close to the line indicated a phosphorus load to the stream that is close to the least impacted streams in this ecoregion. The further away from the criteria line, the larger the negative impact to the stream becomes. If conservation practice implementation is desired at the conclusion of this report, appropriate target values for total nitrogen and phosphorus may be discussed.

In Figure 10, the load duration curve for site 384126 indicates that the total phosphorus load is also related to flow conditions. This would also suggest that sources of phosphorus could be overland flow related to nonpoint source pollution runoff during high flow events associated with snow melt and rain storms. However, the slight variation in the symmetry of the samples also indicates that in-stream processes such as plant decay or riparian grazing are significant sources as well. This is indicated by the samples at the extremely high flows (less than 20% or greater than 43 cfs) are above the criteria line, while a majority of the samples at lower flow (40% to 90%, 13 cfs to 1.3 cfs) are very close or below the criteria line.

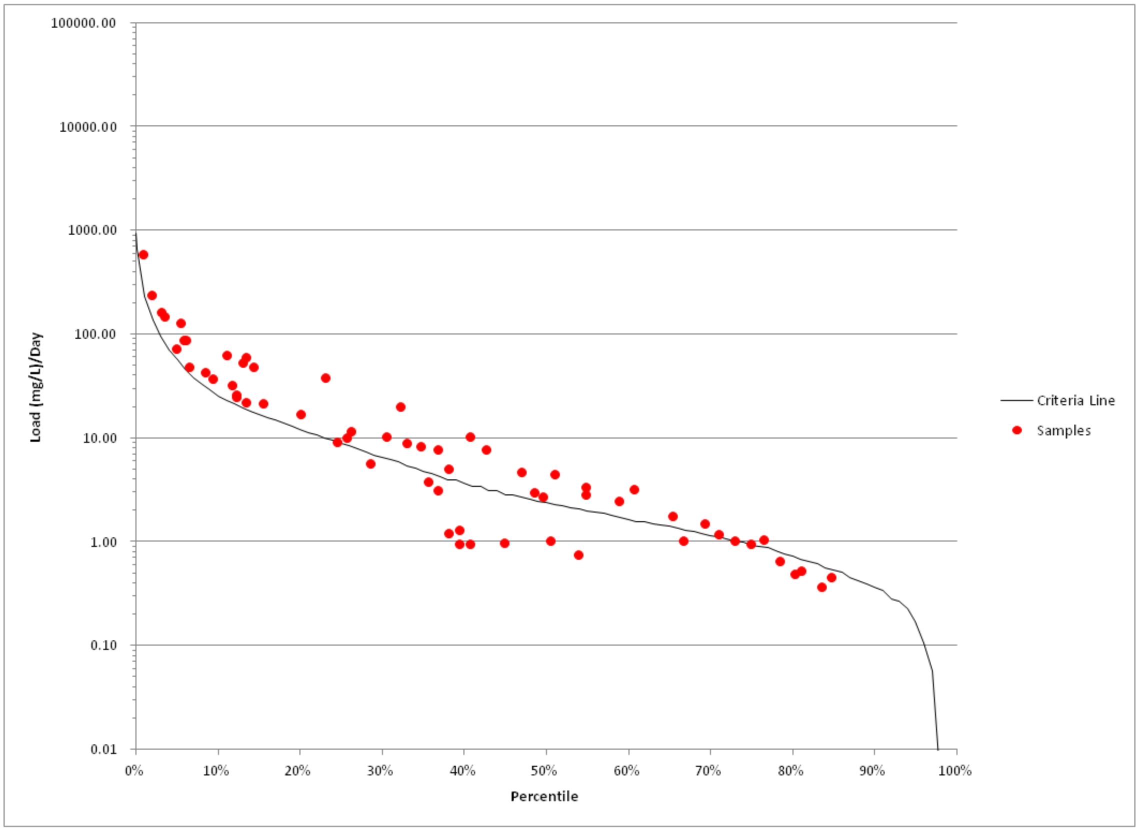

Figure 10. Total Phosphorus Load Duration Curve for the Baldhill Creek Monitoring Station 384126 (The curve reflects flow data from 1990-2010).

3.3 Total Suspended Solids

Total suspended solids (TSS) are organic and inorganic solid materials that are suspended in the water and include silt, plankton, and industrial wastes. If high concentrations of suspended solids exist in the waterbody it can lower water quality by absorbing light. The waterbody then becomes warmer and reduces the ability of the water to hold oxygen necessary for aquatic life. When aquatic plants receive less light, photosynthesis decreases and less oxygen is produced. The combination of warmer water, less light, and oxygen makes it impossible for some forms of life to exist (NDDoH, 1997).

Suspended solids can also clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. Particles that settle out can smother fish and aquatic insect eggs and suffocate newly-hatched larvae. Suspended solid material settles into microhabitats such as the spaces between rocks that aquatic insects like mayfly and stonefly nymphs and caddisfly larva inhabit (NDDoH, 1997).

Suspended solids are a result of erosion from agricultural land, bank erosion, algae growth, urban runoff, industrial waste, and wastewater discharges (NDDoH, 1997). The State of North Dakota has no numeric water quality standard or reference value for TSS. Tata is provided in Figure 13 and Table 5 to assist with later decision making.

3.4 Historic Data (1997 – 2009) from the Griggs County Section 319 Watershed Project.

A two phase implementation project was initiated in 1997 in this portion of the Upper Sheyenne River watershed including Baldhill Creek and its tributaries), and it continued until 2006. The goal of the project was to improve riparian, cropland, and livestock management in the priority areas of the Sheyenne River and Bald Hill Creek watersheds in Griggs County to ensure the beneficial uses of the water are restored and maintained for future generations.

To achieve this goal it was determined that conservation land management practices should be applied to 25 percent of the priority cropland and 35 percent of the priority pasture lands, as well as implement ten priority waste management systems and conduct information and education programs throughout the watershed.

The Griggs Section 319 Watershed Project met most of its goals within the identified priority areas by 2009. They had 53,000 of the 55,000 acres designated involved in cropland BMPs and over 40,000 acres, well over the 17,000 acre goal, in grazing and pastureland BMPs (Figure 11). Animal waste systems proved to be more difficult with only one of the projected twelve systems completed, and another two in the final development phase by 2009.

When comparing the results in Figures 12 and 13, which include current data as well as historic data, water quality improvements continued through the end of 2009 after which the nutrient concentrations started to increase again. Figure 14 shows the results of a significant decrease in total suspended solids concentrations from the initiation of the project to the present. However, those numbers had gone back up in 2010 (no samples were taken in 2011).

The increase in nutrient concentrations could be due to several factors such as increasingly wet years which (Figure 7) which resulted in greater loads entering the water with overland runoff, change in land use practices and/or types of crops planted, and the decrease in the number of Conservation Reserve Program acres within the watershed. Helping to keep the system from undergoing high eutrophication is that the Total Nitrogen to Total Phosphorus ratio remains at around five to six. The optimum ratio for aquatic plant growth, which in overabundance can lead to a depletion of dissolved oxygen and is harmful to aquatic life, is between ten and twelve.

The educational component of the 1998-2006 Griggs County Watershed Project was very successful at increasing public awareness with the completion of workshops, presentations, and displays at a wide variety of meetings held throughout the area, as well as newsletters and brochures that were made available to producers. This improved knowledge and understanding is the foundation on which all future projects can grow.

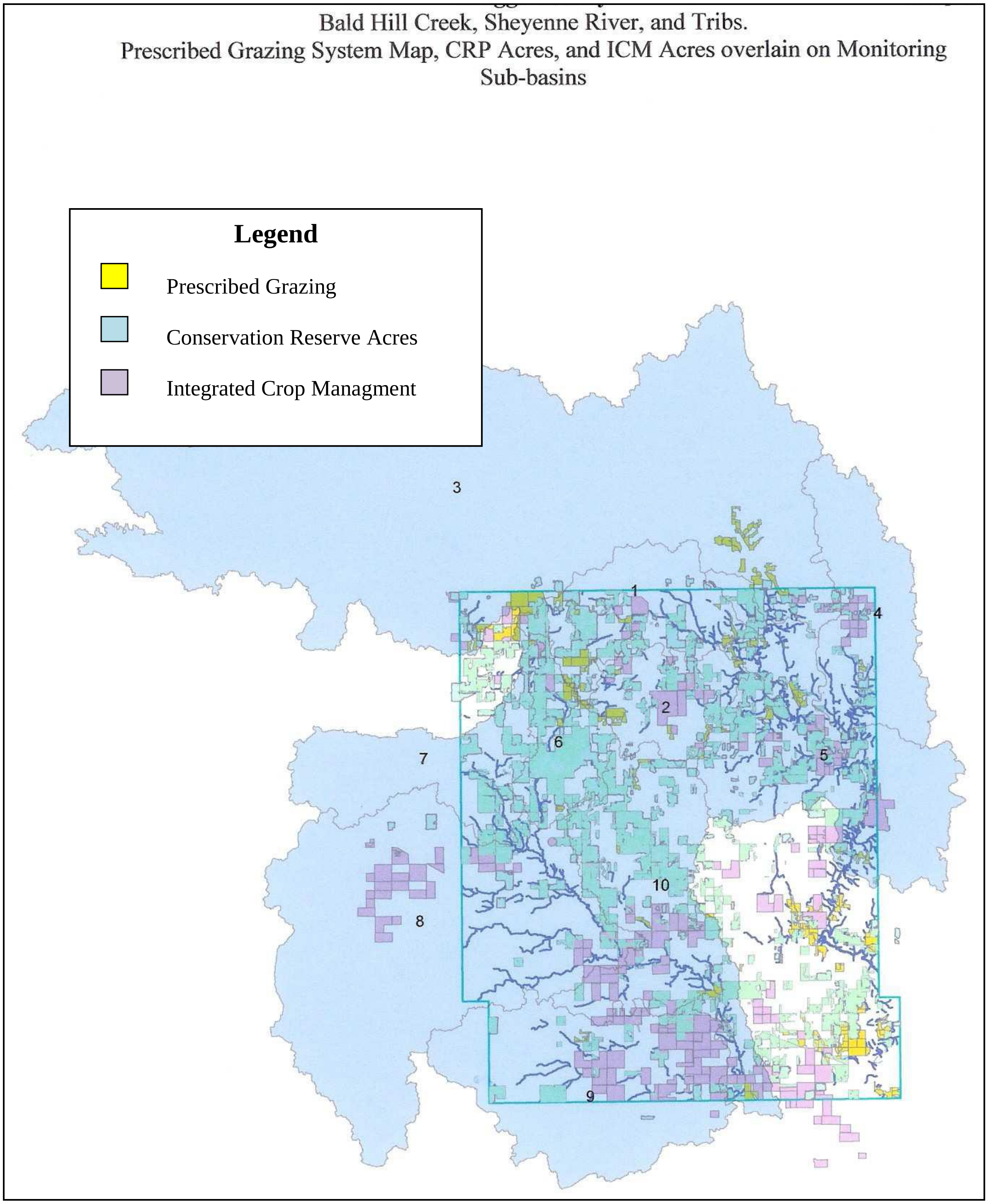

Figure 11. Map of BMPs Implemented During Griggs Section 319 Watershed Project.

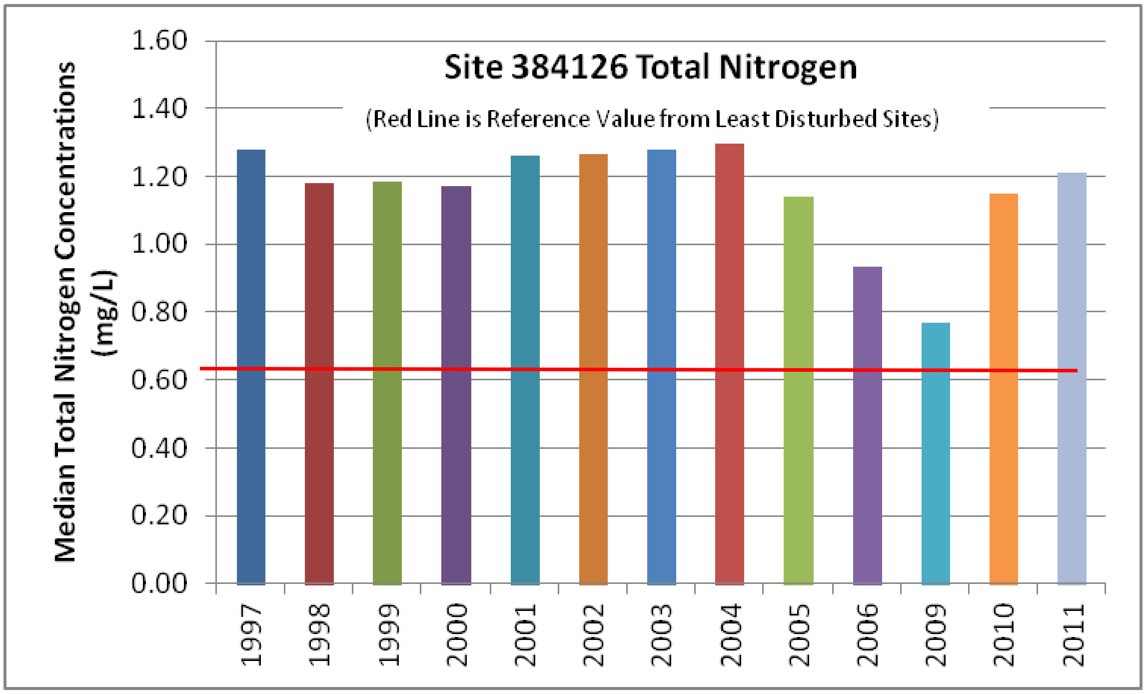

Figure 12. Annual Median Total Nitrogen Concentrations for Site 384126 (1997-2011).

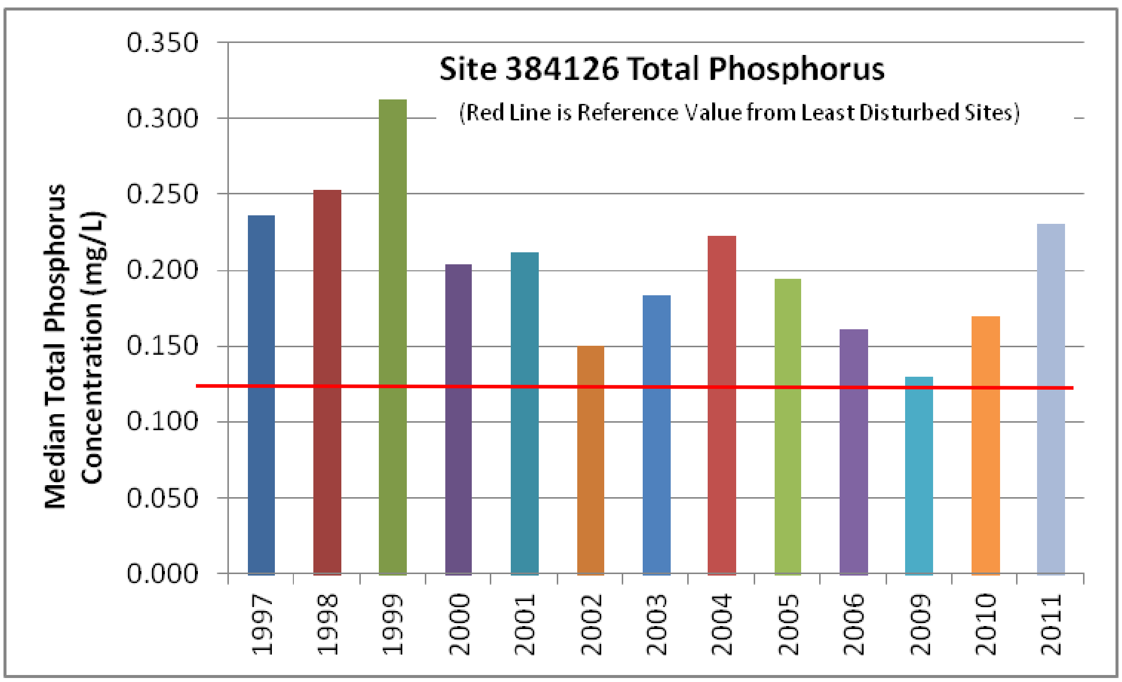

Figure 13. Annual Median Total Phosphorus Concentrations for Site 384126 (1997-2011).

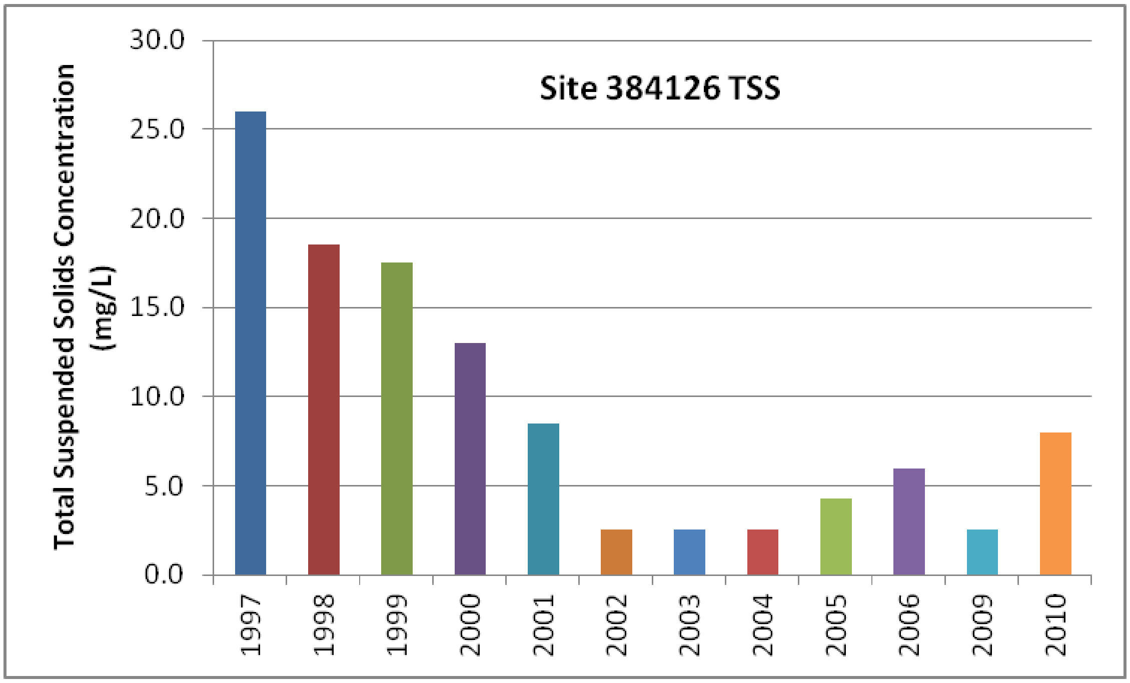

Figure 14. Annual Median Total Suspended Solids Concentrations for Site 384126 (1997 – 2010).

3.5 Total Nitrogen, Total Phosphorus and Total Suspended Solids Box and Whisker Plots for the Upper and Middle Sheyenne River Watershed.

A box and whisker plot is a convenient way of graphically depicting groups of numerical data through their five-number summaries: 1) the sample minimum; 2) lower quartile; 3) median; 4) upper quartile; 5) sample maximum. The box plot may also indicate which observations, if any might be considered outliers. For further information on box and whisker plots please refer to Appendix C.

The box and whisker plots represented in Figures 15-17 show all water quality sites that sampled for total nitrogen, total phosphorus, and total suspended solids. The box and whisker plots allow the reader to compare and contrast water quality sites upstream to downstream throughout the Upper and Middle Sheyenne sub-basins.

Total nitrogen for site 384126, located in the Griggs Model watershed, can be compared with the rest of the water quality sampling sites along the Upper and Middle Sheyenne River (Figure 15). The height of the box identifies the spread of the data, indicating the smallest and largest observations. In the case of site 384126 the height of the box is longer than most which indicates that the data had a good deal of variability in values. When comparing site 384126 to the rest of the Upper and Middle Sheyenne River, the mean value (shown by the blue diamond) is lower than upstream river reaches. This may be in part because Baldhill Creek is a tributary to the Middle Sheyenne River and has no upstream watersheds contributing to the cumulative load of nutrients. However, even though this reach has a low average value for nitrogen, all of the sites have average values that exceed the reference value of 0.581 mg/L.

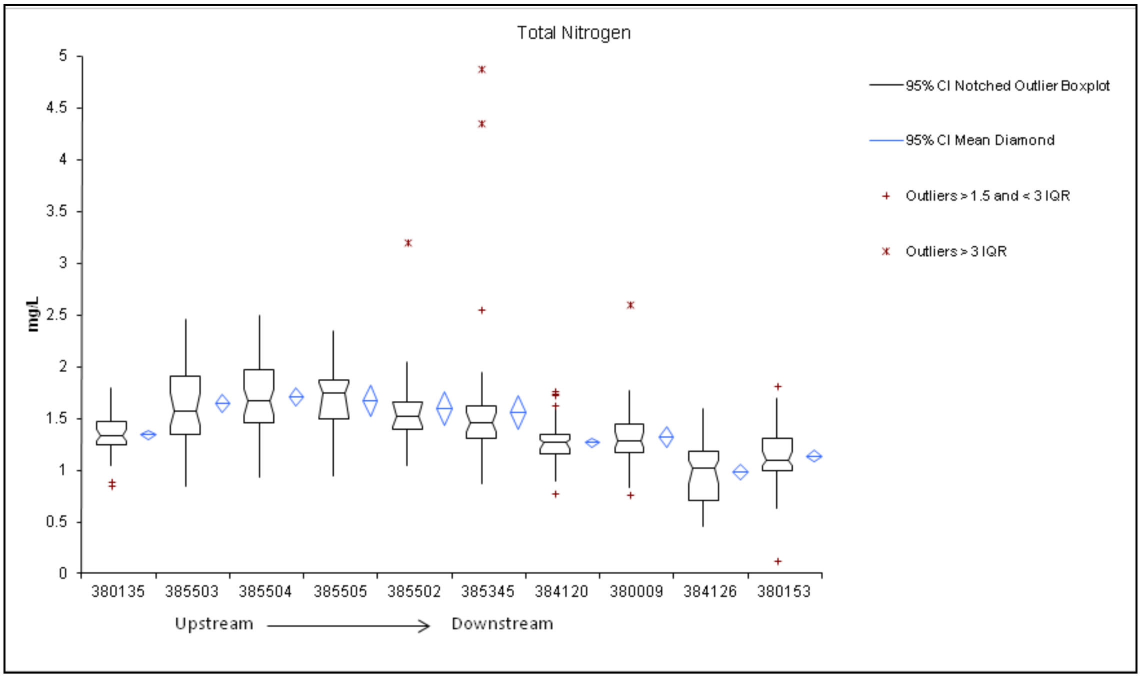

Figure 15. Box and Whisker Plot of Total Nitrogen for all the Water Quality Sampling Sites in the Upper and Middle Sheyenne River.

Phosphorus values for site 384126 are slightly lower compared to most of the downstream reaches (Figure 16), but have a great variability in values and several high outliers. As a tributary to the Sheyenne River, this data likely represents the lack of cumulative load from upstream reaches, with intermittent high values coming from overland flow during storm events.

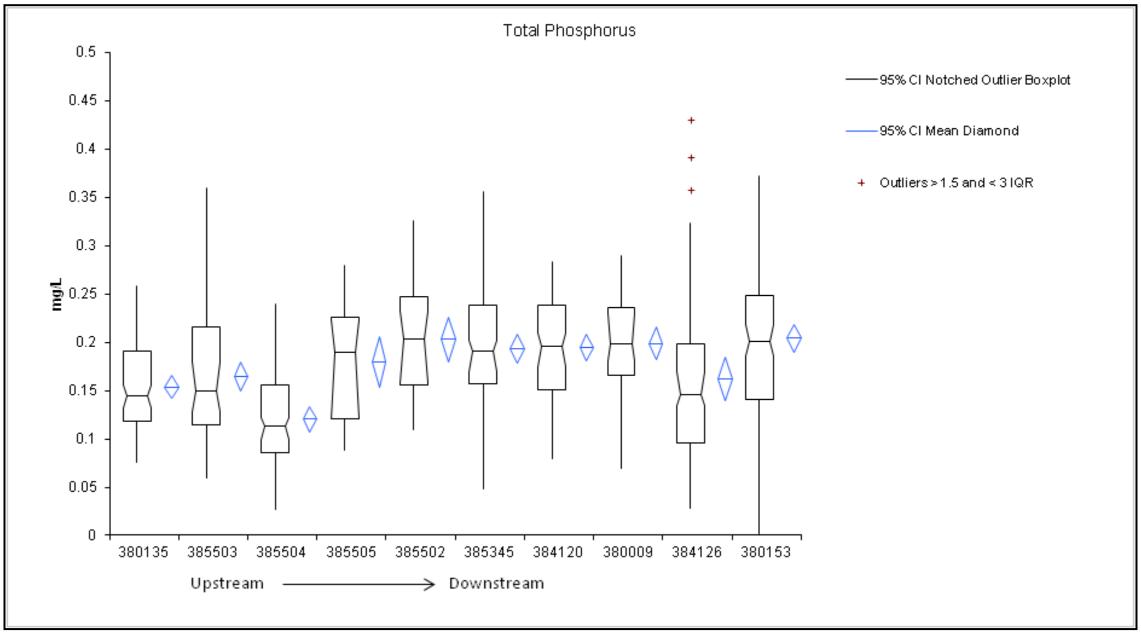

Figure 16. Box and Whisker Plot of Total Phosphorus for all the Water Quality Sampling Sites in the Upper and Middle Sheyenne River.

Suspended solids are a combination of organic matter and sediment that is suspended in the water column. It is an indication of water clarity. As shown in Figure 17, total suspended solid values for site 384126 has a very low average with little variation in values from high to low.

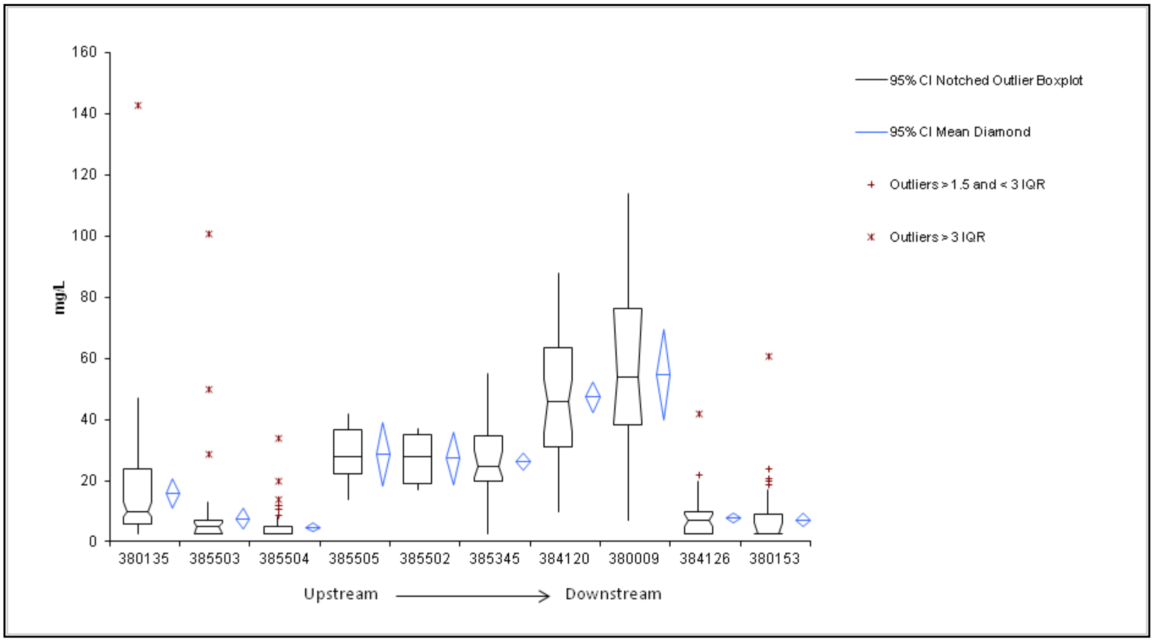

Figure 17. Box and Whisker Plot of Total Suspended Solids for all the Water Quality Sampling Sites in the Upper and Middle Sheyenne River.

3.6 Suspended Sediment

Sediment is created by the weathering of rock and is delivered to stream channels through various erosional processes including sheet, gully and rill erosion, wind, landslides, and human excavation. Sediments are also produced as a result of stream channel and bank erosion and channel disturbance. Movement of eroded sediments downslope from their point of origin into stream channels and through stream systems are influenced by multiple interacting factors including magnitude, time, location, sediment storage and transport mechanisms.

Erosion is a natural process and some sedimentation is needed to maintain healthy stream systems. However, poor land management can affect runoff in the watershed resulting in increased erosion and subsequent sediment deposition and channel degradation. Excessive sediments deposited on stream bottoms can cover fish spawning habitat, damage fish food sources, reduce prey cover, and alter habitat complexity in the stream channel. Excessive suspended sediment can make it difficult for fish to find prey and clog gills. Sediments can cause taste and odor problems, block water supply intakes, foul treatment systems, and fill reservoirs. High levels of sediment can impair swimming and boating by altering stream channel form, creating hazards due to reduced water clarity or interfere with fishing. To quantify sedimentation rates it is necessary to evaluate the degree to which sediment discharge in a particular watershed exceeds natural rates or patterns (USEPA, 1999).

Suspended sediment data for monitoring site 384126 located in the Griggs Model was compiled for 2009 and 2010 and a reference value of 25 mg/L is indicated as a red line in the graph below (Figure 18). The reference value was determined based on a paper entitled *Sediment in Streams: Sources, Biological Effects, and Control* (Waters, 1995). The paper states that suspended sediment concentrations less than 25 mg/L are not harmful to fisheries; between 25 and 80 mg/L reduces fish yield; between 80 and 400 mg/L is unlikely to display a good fishery; and suspended sediment concentration greater than 400 mg/L will exhibit a poor fishery. Suspended sediment concentrations for site 384126, when compared to the reference value, indicate that during the sampling period suspended sediment in Baldhill Creek is largely trending under the reference value range that causes stress to fish (Figure 18). Suspended sediment concentration values ranged from 0.33 to 51 mg/L. The reference value of 25 mg/L is not a State limit as suspended sediment values for water quality standards have not yet been determined. The value is provided as a point of reference in looking at the overall data.

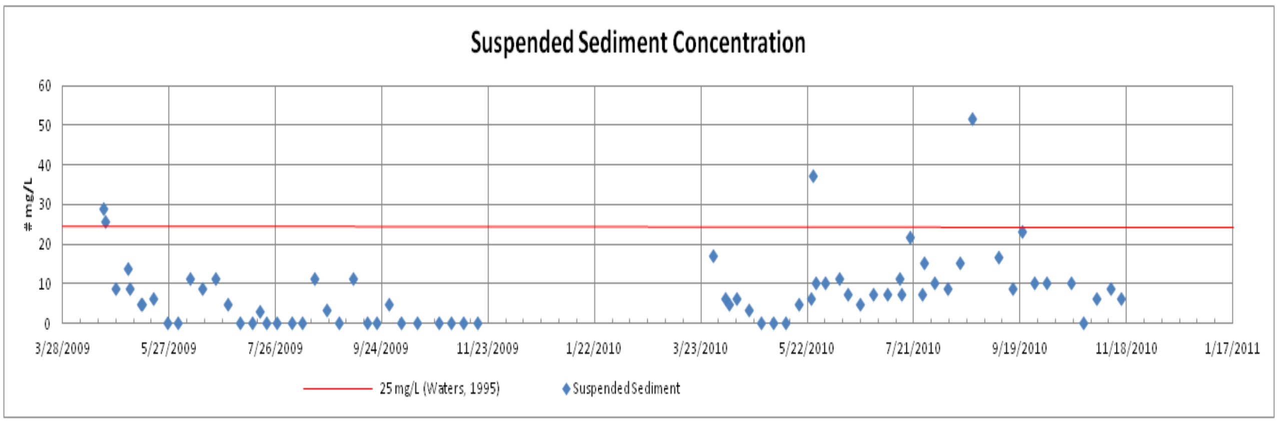

Figure 18. Suspended Sediment Concentration for Baldhill Creek Monitoring Station 384126.

3.7 Pathogens

Excessive amounts of fecal bacteria in surface water used for recreation have been known to indicate an increased risk of pathogen-induced illness to humans. Infections due to pathogen contaminated waters include: gastrointestinal, respiratory, eye, ear, nose, throat, and skin disease (EPA, 1986). The fecal bacteria known to cause the most harm to humans is E. coli bacteria and is the parameter now used in NDDoH water quality standards (refer to Section 1.3.3).

3.7.1 Recreational Use Support Assessment Methodology

Recreation use is any activity that relies on water for sport and enjoyment. Recreation use includes primary contact activities such as swimming and wading and secondary contact activities such as boating, fishing, and wading. Recreation use in rivers and streams is considered fully supporting where there is little or no risk of illness through either primary or secondary contact with the water. The State's recreation use support assessment methodology for rivers and streams is based on the State's numeric water quality standards for E. coli bacteria (Section 1.3.3).

For each assessment based solely on E. coli data, the following criteria are used:

- Assessment Criteria 1: For each assessment unit, the geometric mean of samples collected during any month for May 1 through September 30 does not exceed a density of 126 colony forming units (CFUs) per 100 millimeters (mL). A minimum of five monthly samples is required to compute the geometric mean. If necessary, samples may be pooled by month across years.

- Assessment Criteria 2: For each assessment unit, less than 10 percent of samples collected during any month from May 1 through September 30 may exceed a density of 409 CFUs per 100 mL. A minimum of five monthly samples is required to compute the percent of samples exceeding the criteria. If necessary, samples may be pooled by month across years.

The two criteria are then applied using the following use support decision criteria:

- Fully Supporting: Both criteria 1 and 2 are met

- Fully Supporting but Threatened: Criterion 1 not met, while is 2 met

- Not Supporting: Criterion 1and 2 are not met.

3.7.2 Recreational Use Assessments for Sites 384124, 384126, and 384129

Within the Griggs Model watershed, E. coli data was collected at three sites: monitoring site 384126 along with the nutrient and TSS data, monitoring site 384124 and monitoring site 384129 (Figure 6). Data was collected during the recreation season of May 1 through September 30 in 2009 and 2010. Recreational beneficial use attainment was determined for each site and is summarized in Table 5 and the complete set of data is available in Appendix B.

Analysis of E. coli data collected at site 384124 in 2009 and 2010 demonstrated that the months of May and June were fully supporting the beneficial uses. The geometric mean and percent exceed calculations for beneficial use in the month of July was fully supporting but threatened. A recreational use assessment could not be calculated for the months of August and September due to an insufficient amount of samples taken in 2009 and 2010.

The recreational use support assessment for site 384129 concluded that during the months of July and August recreational beneficial uses were not supporting. May and June were calculated as fully supporting recreational beneficial uses. A recreational use assessment could not be calculated for the month of September due to an insufficient amount of samples taken in 2009 and 2010.

Analysis of the data collected in 2009 and 2010 for site 384126 concluded that the geometric mean and percent exceeded calculations indicate that for May and September beneficial uses were fully supporting but threatened because of E. coli. For the months of June, July, and August site 384126 was fully supporting the recreational beneficial use.

Table 5. Summary of E. coli Data for Sites 384124, 384129, and 384126 Data Collected in 2009 to 2010.

384124					
Recreational Season	**May**	**June**	**July**	**August**	**September**
Number of Samples	7	10	5	0	0
Geometric Mean	16	84	125	N/A	N/A
% Exceeded 409 CFU/100 mL	0%	10%	40%	N/A	N/A
Recreational Use Assessment	FS	FS	FSBT	INSFD	INSFD
384129					
Recreational Season	**May**	**June**	**July**	**August**	**September**
Number of Samples	8	10	8	9	4
Geometric Mean	16	93	193	149	108
% Exceeded 409 CFU/100 mL	0%	10%	38%	22%	25%
Recreational Use Assessment	FS	FS	NS	NS	INSFD
384126					
Recreational Season	**May**	**June**	**July**	**August**	**September**
Number of Samples	8	10	8	10	8
Geometric Mean	22	105	68	44	43
% Exceeded 409 CFU/100 mL	13%	0%	0%	10%	13%
Recreational Use Assessment	FSBT	FS	FS	FS	FSBT

FS – Fully Supporting; FSBT- Fully Supporting but Threatened; NS – Not Supporting; INSFD – Insufficient Data

4.0 WATERSHED ASSESSMENT

4.1 Riparian Vegetation and Streambank Stability

Riparian areas are the vegetative buffers adjacent to a river or stream. The riparian area includes the stream, streambanks, and wetlands adjacent to the streams. Riparian areas protect water quality by capturing, storing and treating water through their soils before it gets to streams. A thick growth of diverse vegetation, plant residues covering the soil surface, and non-compacted soils facilitate water capture and storage. Healthy growing plants take up nutrients transported into the riparian areas. Soil organic matter captures or facilitates degradation of contaminants. Healthy riparian vegetation captures water and filters the water through the soil. Riparian areas with a high diversity of plant species are most effective in slowing the flow of water and storing it for future use (Bellows, 2003).

Riparian vegetation has an important effect in stabilizing stream banks. In general, all root systems reinforce the soil and increase stability. Fine roots are more effective than thick roots, but the diversity of plants works together to hold streambank soils in place and protect them from erosion and undercutting by floodwaters, transported woody debris, or ice jams. The deep, penetrating roots of sedges, rushes, willow, grasses, and other herbaceous plants provide structural support for stream banks, while the thicker, harder roots of woody plants protect streambanks against bank scouring by floods and ice jams (Winward, 2000). Banks devoid of vegetation and saturated with water are more likely to collapse; however riparian vegetation improves the drainage of bank soils through plant uptake of water results in increased stability. Riparian vegetation such as grasses can decrease water flow velocity and the erosive action of water. The weight of the vegetation usually does not have an effect on bank stability unless it is located on steep banks that are not capable of supporting themselves (USACOE, 2001).

Bank erosion and failure are natural stream channel process. Bank erosion is the particle-by-particle loss of the bank material due to the shear stress exerted by the water on the banks. The particle-by-particle loss can be observed along exposed banks that are devoid of vegetation. Bank failure is the sudden collapse of a portion of the bank material into the river. Bank failures are most easily observed along cutbanks in meander bends and occur due to the removal of the bank material along the toe. Although bank erosion and failure are natural processes, the rates of bank erosion or failure can be accelerated by anthropogenic (human impact) changes in the hydraulic and geomorphic variables (e.g. dams, drainage, and channelization) (USACOE, 2001).

4.1.1 Rapid Geomorphic Assessment (RGA)

The Rapid Geomorphic Assessment (RGA) method was used to evaluate the channel-stability conditions and stage of evolution of the mainstem Upper and Middle Sheyenne River using the Channel-Stability Ranking Scheme. The RGA uses diagnostic criteria of channel form to infer dominant channel processes and the magnitude of channel instabilities through a series of nine criteria. Evaluations of this sort do not include an evaluation of the watershed or upland conditions; however, stream channels act as conduits for energy, flow and materials as they move through the watershed and will reflect a balance or imbalance in the delivery of sediment. The RGA provides a rapid characterization of stream stability conditions.

The RGA procedure for the Upper and Middle Sheyenne River consisted of three steps completed at each site:

1. Determine the "reach". The "reach" is described as the length of channel covering 6-20 channel widths, thus is scale dependent and covers at least two pool-riffle sequences.

2. Take photographs looking upstream, downstream and across the reach; for quality assurance and quality control purposes. Photographs are used with the RGA forms to review the field evaluations
3. Make observations of channel conditions and diagnostic criteria listed on the channel-stability ranking scheme.

A field form containing nine criteria (Appendix D) was used to record observations of field conditions during the RGAs. Each criterion was ranked from zero to four and all values summed to provide an index of relative channel stability. The higher the number the greater the instability: sites with values greater than 20 exhibit considerable instability; stable sites generally rank 10 or less. Intermediate values denote reaches of moderate instability. However, values are not weighted, thus a site with a value of 20 is not twice as unstable as a site with a value of 10. The process of filling out the form enables the final decision of "Stage of Channel Evolution." For purposes of the Upper and Middle Sheyenne River assessment, sites with total scores of 0 to 10 are considered stable and sites with scores of 20 to 30 as unstable, recognizing that scores which fall in the range of 10 to 20 have moderate instability and will rely on specific assessment values to determine the trend toward improvement or greater instability.

Sixty sites were randomly selected throughout the entire Upper and Middle Sheyenne River watershed, thirty in the Upper Sheyenne River sub-basin (09020202) and thirty in the Middle Sheyenne River sub-basin (09020203). While some sites occurred in the Griggs Model subwatershed (Figure 19), there were not enough sites located in each of the sub watersheds to determine geomorphic assessments at that level. Therefore, for the purposes of this assessment, the results apply to the entire mainstem of the Upper and Middle Sheyenne River. At each site numeric values were assigned to each of the nine RGA criteria and then summed to calculate an overall RGA score for each site. By analyzing the scores for the 60 randomly selected sites, an overall assessment of stream stability can be made for the Upper and Middle Sheyenne River.

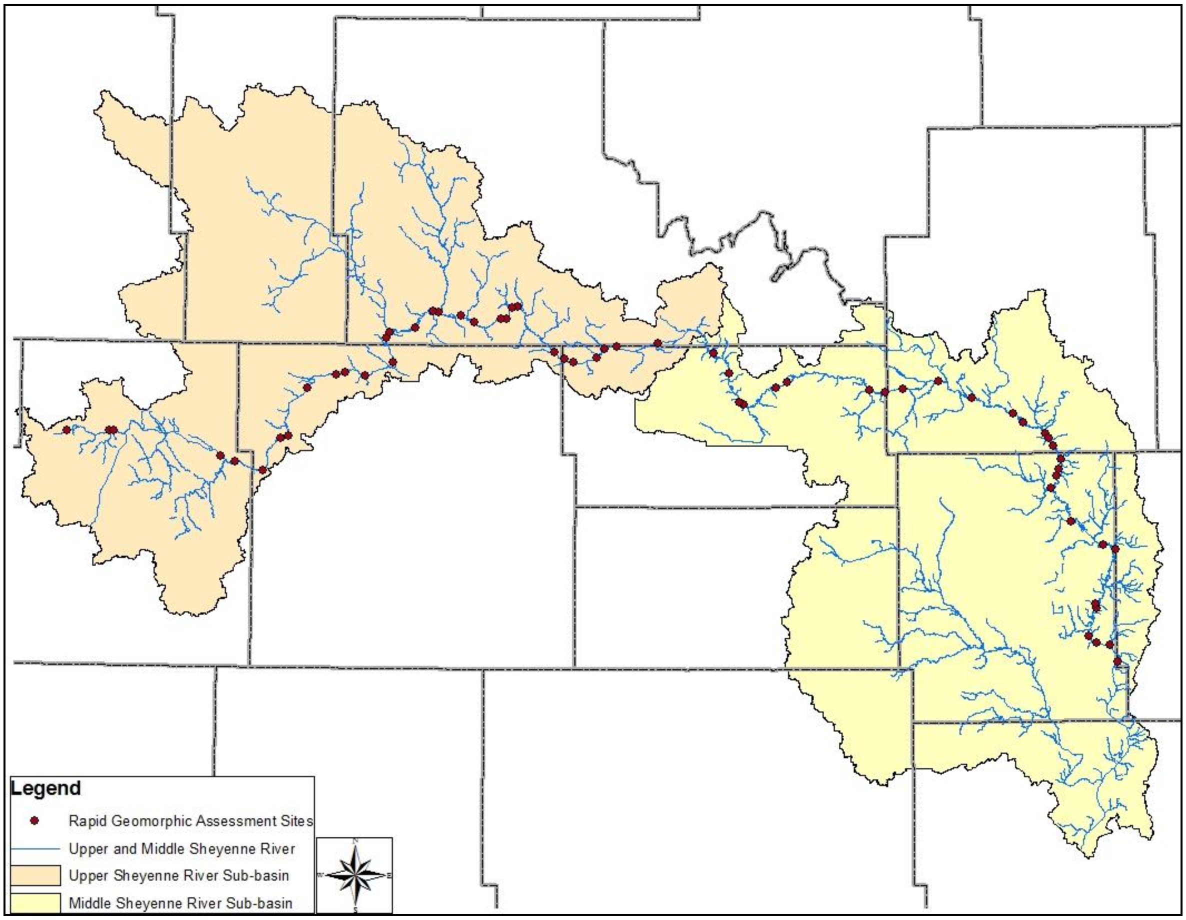

Figure 19. RGA Assessment Sites on the Upper and Middle Sheyenne River Mainstem.

Table 6. Rapid Geomorphic Assessment Scoring Ranges and Percentages of the Upper and Middle Sheyenne River.

RGA Scoring Range	0-10	10-20	20-30
Classification	Stable	Moderate Instability	Unstable
Percentage of Stream Sites	10	55	35

The RGA scores indicate that 35 percent of the sites sampled were unstable, with only 10 percent stable, with the remaining 55 percent were assessed as moderately unstable (Table 6). The unstable sites are located throughout the mainstem which indicates active channel processes occurring throughout the Upper and Middle Sheyenne River and not just in isolated areas. These active channel processes include deepening of the channel bed and widening of the channel, this was evident in the unstable sites. While the moderately unstable sites usually exhibited some channel widening with some aggradation as the sediments deposited out raising the channel bed.

4.2 Macroinvertebrate Index of Biotic Integrity (IBI)

Aquatic macroinvertebrates are the most common organisms used in water quality assessments because: 1) they are extremely common; 2) they exhibit high diversity rates; 3) they are fairly sedentary in any given waterbody; 4) they are rapid colonizers; 5) they exhibit variability in tolerance values; and 6) they are extremely vital links in the transfer of energy through the food web. Human disturbance of streams and watersheds alter key attributes of the aquatic environment, (i.e., water quality, flow regime, habitat structure) which elicits a response from the macroinvertebrate community and can ultimately result in decreased biotic integrity. For example, if pollutants enter a waterway, sensitive species will suffer while tolerant species will continue to thrive. Changes in species composition such as this can easily be detected through biological monitoring using macroinvertebrates as indicators of water quality.

In order to develop biological indicators capable of assessing the biological condition of the state's rivers and streams, the North Dakota Department of Health (NDDoH) is developing an index of biotic integrity (IBI) based on aquatic macroinvertebrate data for each ecoregion. A previous monitoring effort in the Northern Glaciated Plains Ecoregion has produced a preliminary IBI for the region (Larsen 2012). Final metrics for this region and values used to standardize these metrics are shown in Tables 7 and 8.

Once the final metrics were determined, raw metric values were transformed into standardized metric scores using the following equations developed by Minns et al. (1994) that standardized metrics on a scale of 0 to 100.

Metrics that decrease with impairment:

$$Ms = (M_R/M_{MAX}) \times 100$$

Metrics that increase with impairment:

$$Ms = (M_{MAX} - M_R) / (M_{MAX} - M_{MIN}) \times 100;$$

Where Ms = standardized metric value;

M_R = the raw metric value;

M_{MAX} = the maximum metric value; and

M_{MIN} = the minimum metric value.

Once an IBI has been developed, it becomes a valuable assessment tool. An IBI produces a "multi-metric" index, which assumes that multiple measures of the biological community, also known as metrics (e.g., species richness, species composition, tolerance levels, trophic structure), will respond to increased pollution or habitat alterations. Metric development reduces the number of biological community attributes that need evaluation to only those that are sensitive to impairment or habitat degradation. Metrics selected for the IBI are given a standardized score based on their response to disturbance. Individual metric scores are then combined into an overall IBI score (Table 8). These overall IBI scores can be matched with a qualitative rating such as those associated with a biological condition gradient (e.g., excellent, good, fair, poor) or with aquatic life use support (e.g., least disturbed, moderately disturbed, and most disturbed) (Table 9).

There were not enough sites in each Model watershed to determine specific IBIs for that watershed, so they are combined for the entire Upper and Middle Sheyenne River. A summary of IBI scores is given in Table 8. Threshold values for the Northern Glaciated Plains (46) Ecoregion were determined based on the statistical distribution of reference, or best available, site IBI scores in the region and are provided in Table 9.

Table 7. Northern Glaciated Plains Ecoregion (46) of the Red River Basin Maximum and Minimum Values Used to Standardize Metrics.

Final Metric	Category	Reaction to Perturbation	Minimum Value	Maximum Value
Percent EPT	Composition	Decrease	2.37	75.59
Percent Non-Insect	Composition	Increase	0.97	78.23
Percent Univoltine	Life Cycle/Composition	Decrease	3.48	76.69
Tolerant Taxa	Tolerance	Increase	1	12
Hilsenhoff Biotic Index (HBI)	Tolerance	Increase	4.52	7.31
Swimmer Taxa	Habit	Increase	0	8

Table 8. Standardized Metric Scores and Final IBI Scores for the Upper and Middle Sheyenne River.

Site	Date	Percent EPT	Percent Non-Insect	Percent Univoltine	Tolerant Taxa	HBI	Swimmer Taxa	IBI Score
551443	9/21/2009	0	28.72171	5.680578	9.090909	9.32257	25	13
551444	9/21/2009	2.705371	81.13911	2.39991	72.72727	36.9682	75	45
551445	9/21/2009	8.801727	72.02868	2.628933	27.27273	33.7483	37.5	30
551446	9/21/2009	0	0	0.773093	54.54545	12.1012	50	20
551447	9/22/2009	0.515756	0	0.762544	63.63636	0	75	23
551448	9/22/2009	69.58745	68.71019	70.85052	54.54545	57.5075	75	66
551449	9/22/2009	1.054125	0	2.857263	54.54545	21.0433	75	26
551450	9/22/2009	10.1165	0	8.948683	36.36364	0	37.5	15
551451	9/22/2009	11.53871	8.840805	20.89495	9.090909	5.02387	37.5	15
551452	9/22/2009	25.1986	64.27462	24.31972	45.45455	37.5099	62.5	43
551532	9/28/2010	25.98132	98.14288	100	36.36364	63.086	0	54
551533	9/28/2010	68.22149	100	100	63.63636	85.2329	0	70
551534	9/28/2010	23.17142	95.45606	97.46436	36.36364	46.4424	0	50
551535	9/28/2010	31.26917	96.54884	100	36.36364	30.6069	0	49
551536	9/29/2010	32.02322	93.55115	100	36.36364	47.3861	0	52
551537	9/29/2010	66.67549	97.11364	100	27.27273	61.1891	0	59
551538	9/29/2010	41.34145	91.0783	100	9.090909	47.7596	0	48
551539	9/29/2010	26.93862	99.68978	100	45.45455	11.7627	0	47
551540	9/29/2010	17.81901	98.08571	100	54.54545	20.8323	0	49
551541	9/30/2010	47.47598	94.99261	100	72.72727	31.9373	0	58

Table 9. Threshold Index of Biotic Integrity Values for the Northern Glaciated Plains Ecoregion 46.

	Least Disturbed	Moderately Disturbed	Most Disturbed
IBI Score	>70	≤ 70 and ≥ 59	< 59

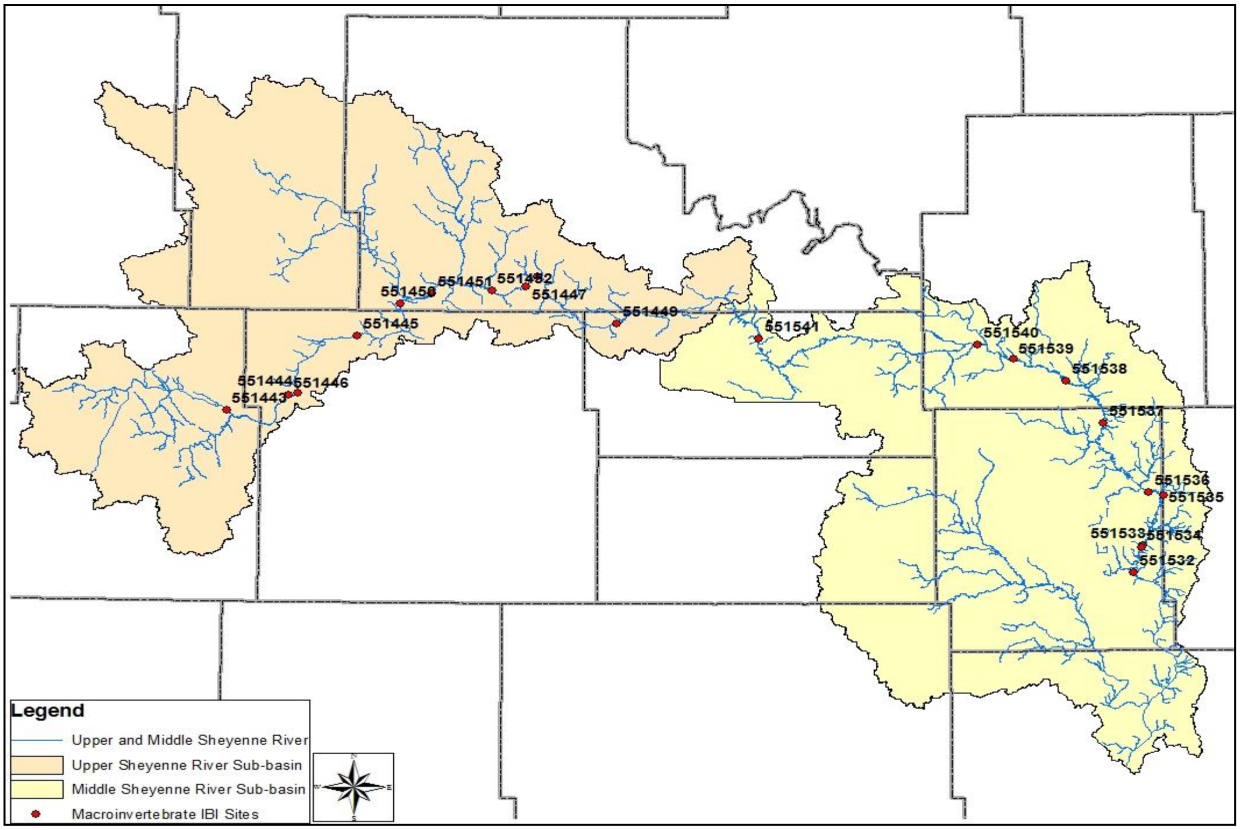

Figure 20. Macroinvertebrate Index of Biological Integrity Sites on the Upper and Middle Sheyenne River.

4.3 Annualized Agricultural Non-Point Source Pollution (AnnAGNPS) Model

The Annualized Agricultural Non-Point Source Pollution (AnnAGNPS) model Version 5.1, developed by the USDA's Agricultural Research Service and Natural Resource Conservation Service (NRCS) was used in the Upper and Middle Sheyenne River watershed assessment (Moore Engineering, 2011). The AnnAGNPS model consists of a system of computer models used to predict nonpoint source pollution (NPS) loadings within agricultural watersheds. The Continuous Simulation Surface Runoff Model contains programs for: 1) input generation and editing; 2) "annualized" pollutant loading model; and 3) output reformatting and analysis.

The AnnAGNPS model uses batch processing, continual-simulation, and surface runoff pollutant loading to generate amounts of water, sediment, and nutrients moving from land areas (cells) and flowing into the watershed stream network at user specified locations (reaches) on a daily basis. The water, sediment, and chemicals travel throughout the specified watershed outlets. Feedlots, gullies, point sources, and impoundments are special components that can be included in the cells and reaches. Each component adds water, sediment, or nutrients to the reaches.

The AnnAGNPS model is able to partition soluble nutrients between surface runoff and infiltration. Sediment-attached nutrients are also calculated in the stream system.

Sediment is divided into five particle size classes (clay, silt, sand, small aggregate, and large aggregate) and are moved separately through the stream reaches.

AnnAGNPS uses various models to develop an annualized load in the watershed. These models account for surface runoff, soil moisture, erosion, nutrients, and reach routing. Each model serves a particular purpose and function in simulating the NPS processes occurring in the watershed.

To generate surface runoff and soil moisture, the soil profile is divided into two layers. The top layer is used as the tillage layer and has properties that change (bulk density etc.). While the remaining soil profile makes up the second layer with properties that remain static. A daily soil moisture budget is calculated based on rainfall, irrigation, and snow melt runoff, evapotranspiration, and percolation. Runoff is calculated using the NRCS Runoff Curve Number equation. These curve numbers can be modified based on tillage operations, soil moisture, and crop stage.

Overland sediment erosion was determined using a modified watershed-scale version of (Revised Universal Soil Loss Equation) RUSLE (Geter and Theurer, 1998).

Daily mass balances for nitrogen (N), phosphorus (P), and organic carbon (OC) are calculated for each cell. Major components of N and P considered include plant uptake N and P, fertilization, residue decomposition, and N and P transport. Soluble and sediment absorbed N and P are also calculated. Nitrogen and phosphorus are then separated into organic and mineral phases. Plant uptake N and P are modeled through a crop growth stage index (Bosch et. al. 1998)

The reach routing model moves sediment and nutrients through the watershed. Sediment routing is calculated based upon transport capacity relationships using the Bagnold Stream Power Equation (Bagnold, 1966). Routing of nutrients through the watershed is accomplished by subdividing them into soluble and sediment attached components and are based on reach travel time, water temperature, and decay constant. Infiltration is also used to further reduce soluble nutrients. Both the upstream and downstream points of the reach are calculated for equilibrium concentrations by using a first order equilibrium model.

AnnAGNPS uses 34 different categories of input data and over 400 separate input parameters to execute the model. The necessary datasets used for the AnnAGNPS model include topography, soil layers, land cover layers, crop management, and climate (weather) data. These are a collection of geographical information systems (GIS) layers, publications, and management routines from other agricultural sources. All input datasets were developed using metric units, a process which is consistent with the work being conducted by the North Dakota Department of Health for their AnnAGNPS models. Therefore, all the input parameters for the AnnAGNPS input data are in metric units. The datasets generated from the AnnAGNPS program are also in metric units. However, the tables and figures shown in this report are presented in English units.

4.3.1 AnnAGNPS Results for the Griggs Model Watershed

Results from the AnnAGNPS model for the Sheyenne River watershed above Baldhill Dam were determined using five years of data from January 205 through December 2009.

The results of the AnnAGNPS model will be discussed separately for each of the seven watershed water quality reports. For each of these seven models, the average annual load for a parameter (water, nitrogen, phosphorus, and sediment) was determined for an individual cell.

The Griggs Model contains 3,162 cells (488,125 acres) (Figure 21 and Table 10). For each one of the cells, the annual average parameter load divided by the cell’s area was determined resulting in average annual yield, or amount of each parameter expected to be produced by the entire sub-watershed. The following summarizes how these parameters are presented:

- Water as Runoff – inches per year (in/yr)
- Nitrogen – pounds per acre per year (lb/acre/yr)
- Phosphorus – pounds per acre per year (lb/acre/yr)
- Sediment – pounds per acre per year (lb/acre/yr)

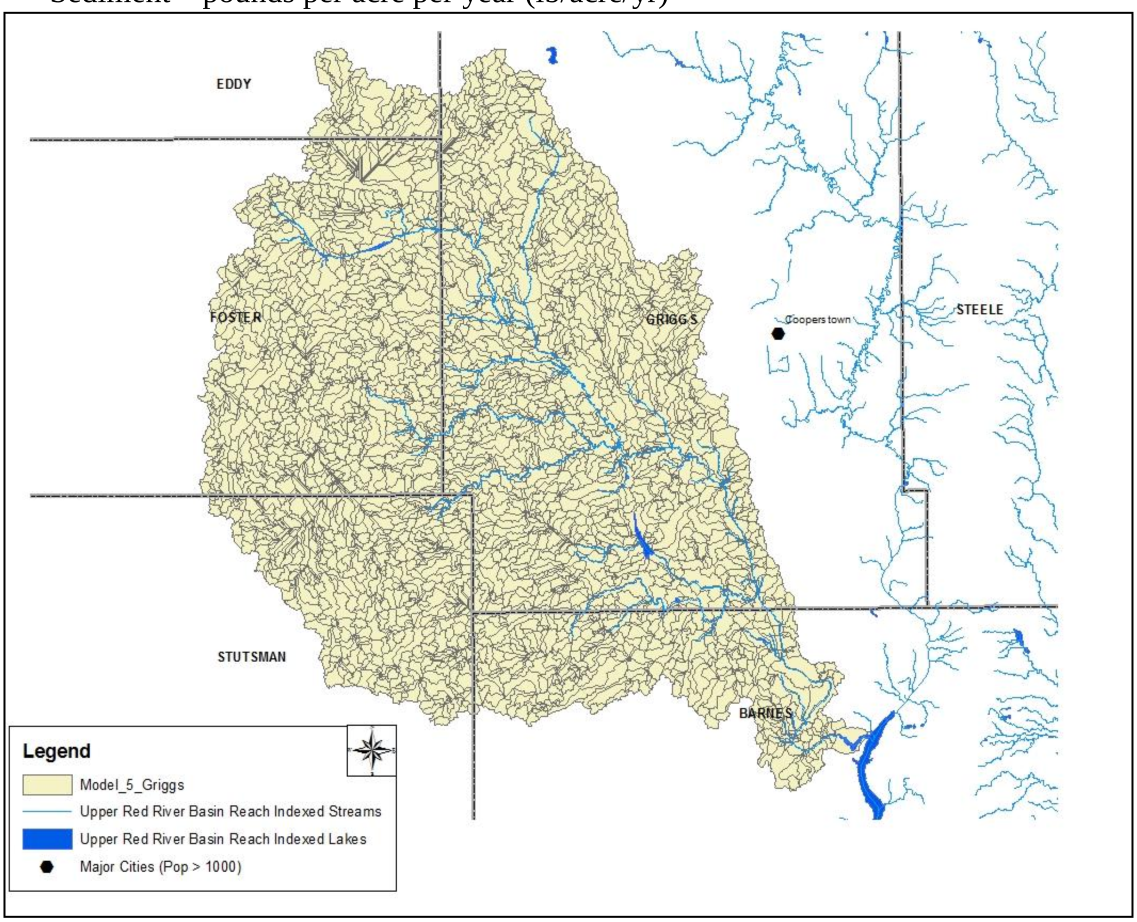

Figure 21. AnnAGNPS Model Watershed Delineation for Griggs Model.

Table 10. Watershed Area and Number of AnnAGNPS Cells.

Watershed Model	Area (mi^2)	Area (acres)	AnnAGNPS Cells
Model_1_Sheridan	543.6	347,914	2,260
Model_2_Pierce	828.1	529,982	3,510
Model_3_Benson	535.7	342,826	2,227
Model 4 - Eddy	438.0	280,303	1,833
Model_5_Griggs	**762.7**	**488,125**	**3,162**
Model_6_Barnes	159.5	102,069	648
Model_7_Nelson	645.0	412,887	2,517
Total	3912.6	2,504,005	16,157

Table 11 provides a summary of the average annual yields for the Griggs Model and each subwatershed as an annual average yield for runoff, nitrogen, phosphorus, and sediment yields, along with how each subwatershed ranks compared to the others.

Table 11. Average Annual Yields and Watershed Comparisons for all Watershed Models.

	Area		Runoff		Nitrogen		Phosphorus		Sediment	
Watershed Model	Acres	Rank	in/yr	Rank	lb/acre/yr	Rank	lb/acre/yr	Rank	lb/acre/yr	Rank
Model 1 - Sheridan	347,914	4	0.14	7	6.76	7	1.5	5	70	6
Model 2 - Pierce	529,982	1	0.15	6	6.89	6	1.46	7	81	5
Model 3 - Benson	342,826	5	0.17	3	10.05	3	2.22	2	119	1
Model 4 - Eddy	280,303	6	0.16	5	7.23	5	1.5	5	119	1
Model 5 - Griggs	**488,125**	**2**	**0.31**	**1**	**10.55**	**2**	**2.21**	**3**	**64**	**7**
Model 6 - Barnes	102,069	7	0.17	3	9.62	4	2.1	4	99	3
Model 7 - Nelson	412,887	3	0.18	2	10.68	1	2.28	1	98	4

The Griggs Watershed Model was compared with the other six watershed models to evaluate watershed size, average annual runoff and average annual contributions of nitrogen, phosphorus, and sediment to the watershed (Table 11). The Griggs Watershed Model ranked second in watershed size (488,125 acres) among all the other watershed models. Annual runoff from the watershed was ranked first, total nitrogen contributions ranked second, annual phosphorus contributions ranked third, and annual sediment contributions ranked seventh.

These results indicate that land use has a specific correlation to annual contributions of nutrients and sediment in the watershed. In this case the Griggs Watershed Model is almost entirely in crop production, with only a small area in the northeast in pasture and grassland (Figure 3). Since very few areas are buffered with established continuous vegetation, there is little in the way of buffers to keep nutrients from entering the river during runoff events.

Figures 22 through 25 show the distribution of water, nitrogen, phosphorus, and sediment yields for each of the cells in the model’s watershed grouped into six categories. Green and light green colors indicate a lower yield, light orange a middle level of yield, while the dark orange and red colors indicate the highest yields of water (runoff), nitrogen, phosphorus, and sediment. White indicates a zero value and is either water or solid rock. These figures also indicate how the average values listed in Table 11 above don’t adequately explain what is occurring in the watershed. The majority of the watershed (the southwest region) has values significantly higher than the average, but the very low values in the northeast portion of the watershed are bringing the averages down.

In Figure 22 annual runoff yields for the Griggs Model indicate that a majority of the watersheds cells contribute yields ranging from 0.51-1.00 inches per year. Figure 23 shows annual contributions of nitrogen into the Griggs Model watershed which identified a majority of the watershed cells in the category of 5.01 to 15.00 lb/acre/yr, with many cells in the category of 15.01 to 30.0 lbs/acre/yr. Figure 24 which shows a majority of watershed cells contributing phosphorus yields ranging from 2.51-5.00 lb/acre/yr. Figure 25 indicates very little sediment from runoff into the Griggs Model watershed, with a majority of the watershed cells in the lowest category of 1 – 100 lbs/acre/yr.

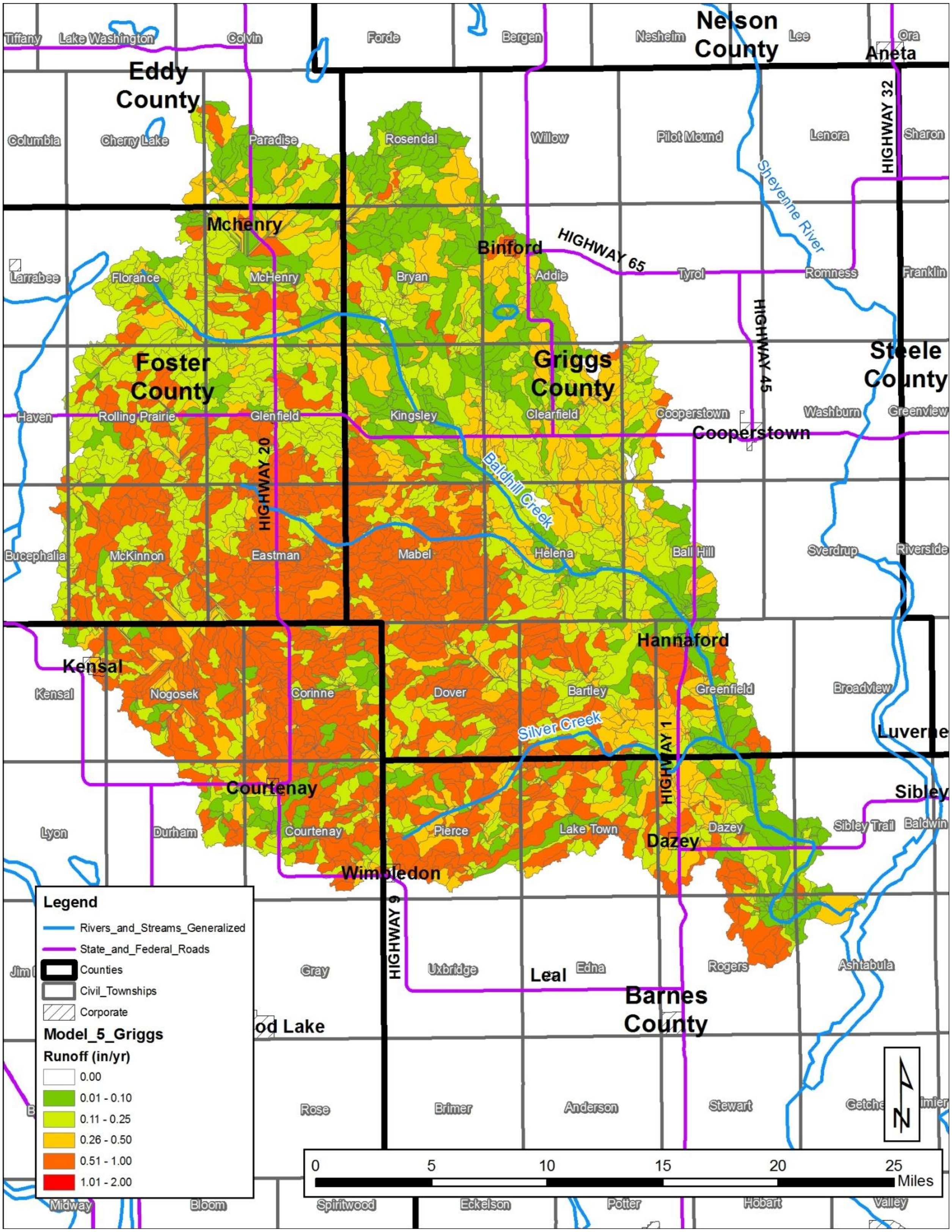

Figure 22. AnnAGNPS Predicted Water Runoff for the Griggs Model (Moore Engineering, 2010).

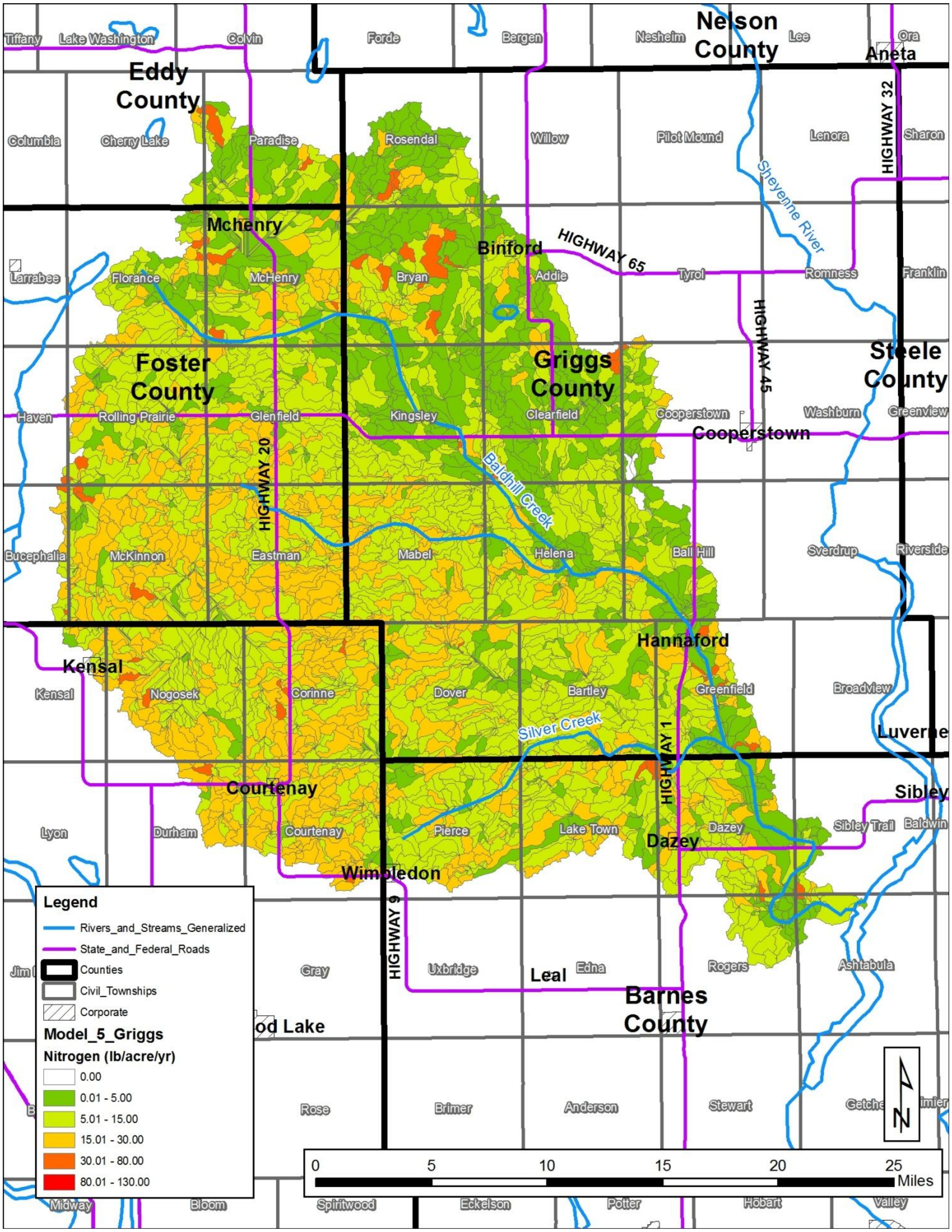

Figure 23. AnnAGNPS Model Predicted Nitrogen Yield for the Griggs Model (Moore Engineering, 2010).

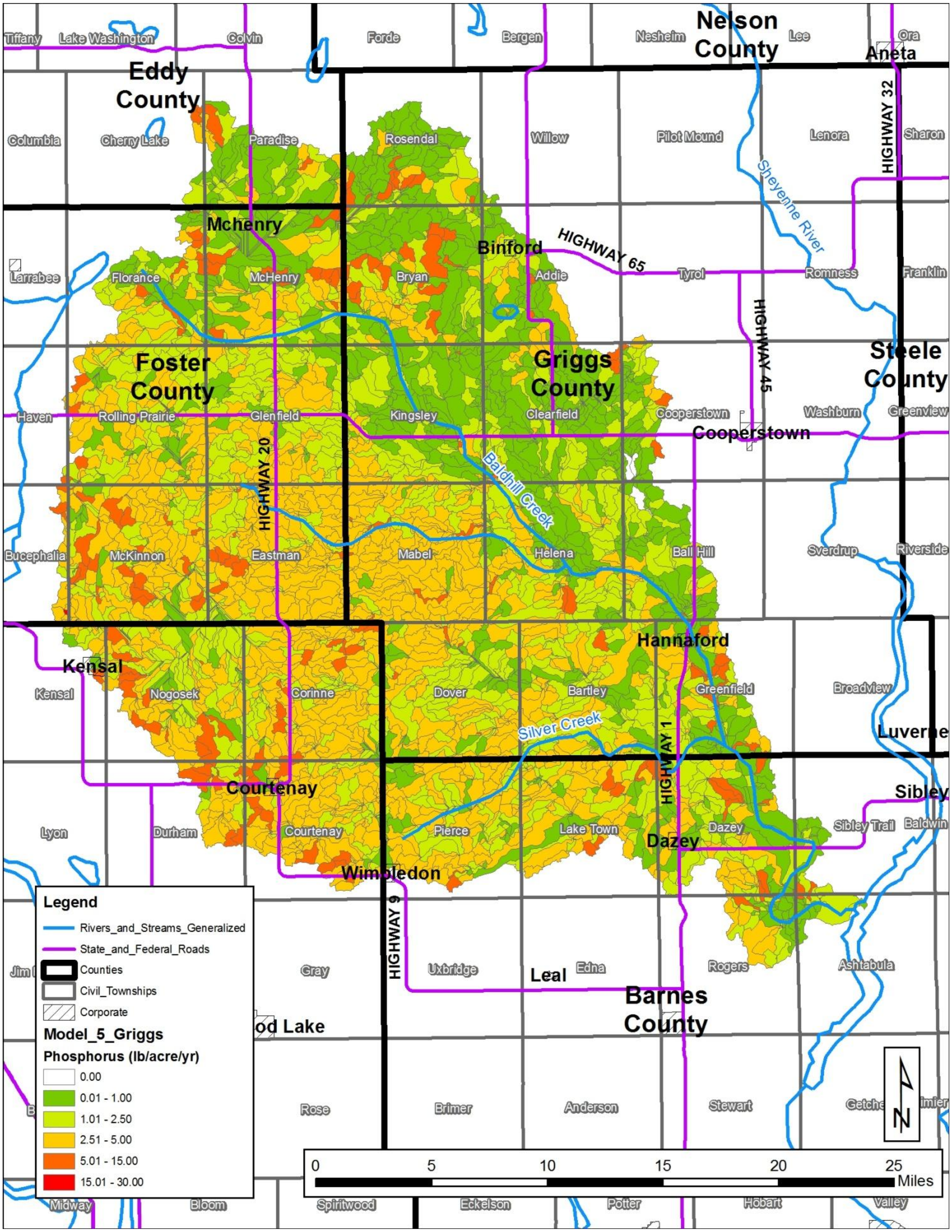

Figure 24. AnnAGNPS Model Predicted Phosphorus Yield for the Griggs Model (Moore Engineering, 2010).

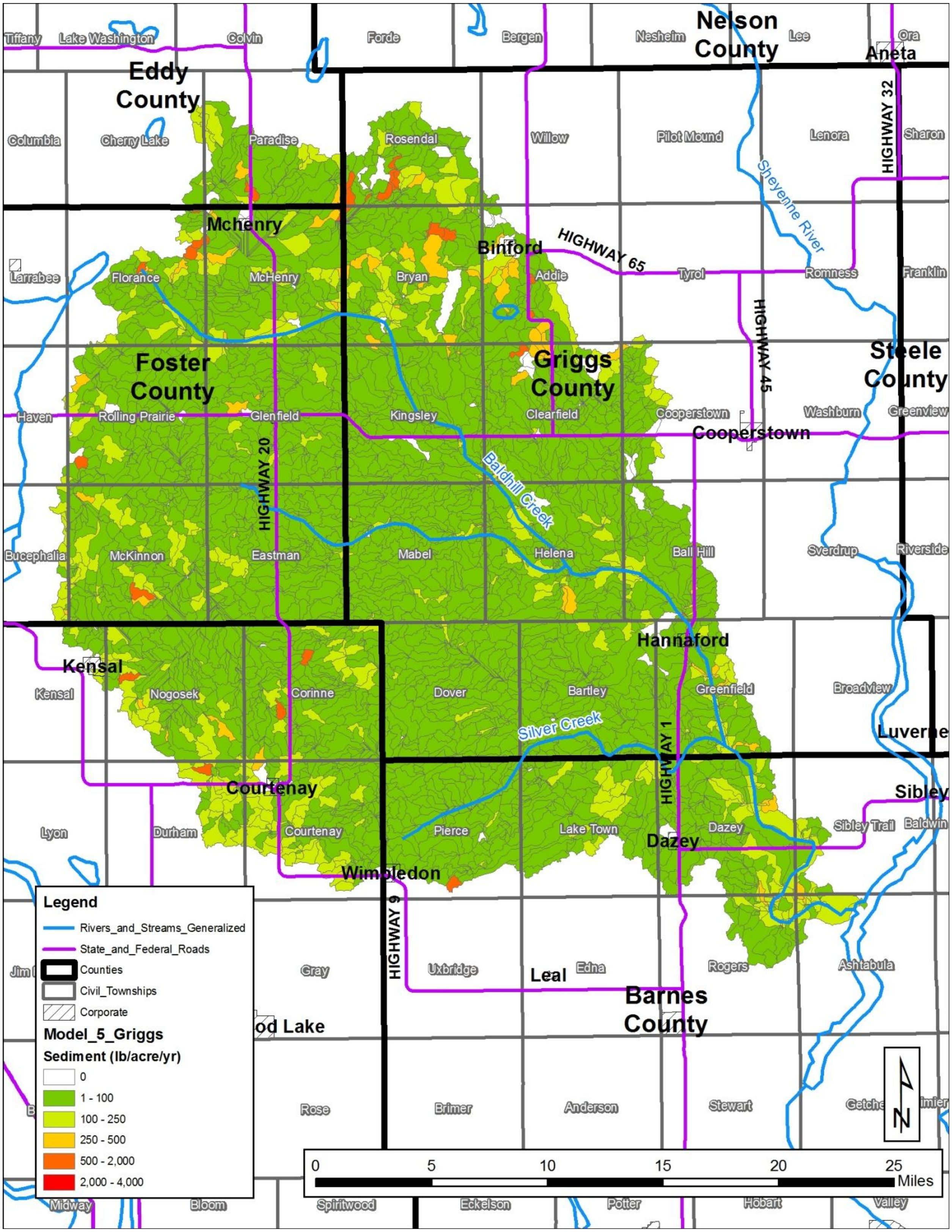

Figure 25. AnnAGNPS Model Predicted Sediment Yield for the Griggs Model (Moore Engineering, 2010).

5.0 CONCLUSION

5.1 Nutrients (Total Phosphorus and Nitrogen)

Water moving through soils will leave most nutrients attached soil particles. However, nitrate is especially soluble in water, and will transport through soils via water flow. Coarse textured soils have lower water-holding capacity and will have a higher potential to lose nitrate via leaching, when compared with fine-textured soils. Some sandy soils, for instance, may retain only one half inch of water per foot of soil, where as some silty loam or clay loam soils may retain up to two inches of water per foot. However, nitrate can be leached from any soil if excess rainfall or irrigation saturates the soil and causes water to move through the root zone (NDSU, 2005).

Particulate phosphorus tends to stay attached to soil particles and settle to the bottom of a waterbody unless mixing occurs. Soluble phosphorus will produce excessive algae when in the presence of sufficient amounts of inorganic (reactive) nitrogen compounds.

The nutrient loads for Griggs Model watershed are directly proportional to flow and suggest the pollution transport is flow dominated (Figures 9 and 10), with possible secondary sources from instream processes such as algae blooms, riparian grazing, or septic systems. The highest TN and TP yields occur in areas of high runoff (Figures 22 through 25) which also suggests a transport by overland runoff during high precipitation events. These areas coincide with the most actively cropped acres in the watershed (Figure 3) indicating that best management practices for cropped land and addition of buffer strips and riparian condition improvement would benefit water quality. The Griggs Model watershed is nitrogen limited with TN:TP ratios of 6.8 in 2009 and 5.7 in 2010, these values are below the optimum range of 10 – 17.

Land use data indicates a watershed dominated by cropland, with some pasture land adjacent to the river which would transport nutrients into the water with large storm events and runoff (Figure 3). Since particulate phosphorus lasts longer in the erosion process by attaching to soil particles, where reactive nitrogen changes form including into that of a gas, the slightly higher total nitrogen numbers suggest that by addressing sources near the riparian zone, improvement will be more effective. No long term trends in nitrogen or phosphorus yields were noted, suggesting that agriculture production activities and runoff are variable from year to year.

5.2 Pathogens (E.coli Bacteria)

Escherichia coli, commonly known as E. coli, is one of the most common species of coliform bacteria. It is a normal component of the large intestines in humans and other warm blooded animals. E. coli is used as an indicator species because it is not feasible to test water for each possible type of disease-causing pathogen. Fecal indicator bacteria such as E. coli are used to indicate on a statistical basis, the likelihood of contracting a disease by ingesting or recreating in such waters.

Pathogens such as E. coli undergo a poorly defined process of dispersion, transport, and inactivation. The transport of pathogens overland in surface runoff is clearly responsible for high flow/precipitation event related increases in the concentrations of in-stream waterborne pathogens in many watersheds. However, there are significant knowledge gaps concerning life cycle and propagation in soils and surface water. This is part of the reason for the two-part values of the State water quality standards. The monthly means help address chronic E. coli concentrations over time to account for reproduction within the waterbody, and the acute high limit addresses spikes that may dissipate, but present health concerns in their initial values.

For the Griggs Model watershed, three sites were sampled for E. coli bacteria. As this entire model represents a tributary (Baldhill Creek) to the Upper and Middle Sheyenne river, it is expected that flow will decrease in the summer months. This is why there was insufficient data at the upstream site (384124) in August and September. In May and June, with flows sufficient to dilute the concentrations, water quality standards were met. As the flow decreased in July and more livestock had access to the river, E. coli concentrations exceeded both of the water quality standards.

Monitoring station 384129 located on a tributary to Baldhill Creek exhibits some of the same characteristics as the upstream site 384124 with decreasing flows in the summer months resulting in insufficient data in September. May and June indicated that E. coli bacteria water quality standards were being met, most likely due to increased flows and dilution. As the summer progressed flows decreased and livestock had access to the river, which is indicated by E. coli concentrations exceeding state water quality standards.

Site 384126 is located near the confluence of Baldhill Creek with the Sheyenne River. Since it is the furthest downstream site flows remained consistent to obtain sufficient amounts of E. coli bacteria data for the months of May through September. E. coli bacteria concentrations met water quality standards throughout the recreational season of May through September.

5.3 Suspended Sediment

Suspended sediment concentrations values at monitoring station 384126 were largely trending below the reference value of 25 mg/L. Although a handful of values were above the reference value, they were also below the 80 mg/L suspended sediment value that was indicated to reduce fish yield (Waters, 1995). These suspended sediment exceedences largely occurred during no flow, which could indicate an instream disturbances. The land use map in Figure 3 indicates an extensive amount of range land along riparian areas of the mainstem of Baldhill Creek. Cattle accessing the river bottoms to graze likely increase sediment erosion potential in these areas.

5.4 Other Watershed Data

Other watershed-wide data indicate possible negative impacts to water quality. A majority of the rapid geomorphic assessments (RGAs) scored in the moderately unstable and unstable categories (Table 6). These changes to the physical condition of the stream often represent the first cues that negative impacts are occurring. Riparian areas with healthy slopes and a variety of vegetation may provide buffers that can trap nonpoint source pollution runoff and prevent much of it from entering the waterway. In addition, most of the IBI scores fell into the ranges associated with most disturbed threshold values (Table 9). Aquatic insects also serve as one of the first indicators to show stress from disturbed habitat and water pollution, and can be an indicator that overall riparian health is beginning to fail. Both of these indicators should be acknowledged when developing a water quality improvement plan.

6.0 IMPLEMENTATION STRATEGY

When beginning a water quality improvement project the implementation of conservation practices, most often called Best Management Practices (BMPs), is one step in a plan towards achieving a healthy watershed. It is first important to identify the problems and possible sources of impairment. This report is designed to provide that tool. Then it is necessary to identify critical areas, which are areas where BMPs will have the greatest impact. Examples are riparian areas adjacent to the river, areas of high erosion or nutrient loads, etc. After that it is just a matter of finding the right tool for the job. In order to initiate discussion and provide a starting point for ideas that could lead towards water quality improvement, several BMPs and their effects are described below. This list is not comprehensive and NRCS also has several BMPs for use throughout the watershed. As always, it is up to a project sponsor, like a water board or soil conservation district, to decide which tools they wish to use.

6.1 Livestock Management

Livestock management BMPs are designed to promote healthy water quality and riparian areas through management of livestock and associated grazing land. Fecal matter and nutrient wastes from livestock, erosion from poorly managed grazing land and riparian areas can be significant sources of E. coli bacteria and nutrient loading to surface water. Precipitation, plant cover, number of animals, and soils are factors that affect the amount of nonpoint source pollution delivered to a waterbody because of livestock. Several BMPs are known to reduce nonpoint source pollution from livestock. These BMPs include:

<u>Livestock exclusion from riparian areas:</u> This practice is established to remove livestock from grazing riparian areas and watering in the stream. Livestock exclusion is accomplished through fencing. A reduction in stream bank erosion can be expected by minimizing or eliminating hoof trampling. A stable stream bank will support vegetation that will hold banks in place and serve a secondary function as a filter from nonpoint source runoff. Added vegetation will create aquatic habitat and shading for macroinvertebrates and fish. Direct deposit of fecal matter into the stream and stream

banks will be eliminated as a result of livestock exclusion by fencing, reducing bacteria and nutrient loads.

Water well and tank development: Fencing animals from stream access requires an alternative water source. Installing water wells and tanks satisfies this need. Installing water tanks provides a quality water source and keeps animals from wading and defecating in streams. This will reduce the probability of pathogenic infections to livestock and the public, as well as reduce the amount of nutrients and sediment entering the waterbody.

Prescribed grazing: This practice is used to increase ground cover and ground stability by rotating livestock throughout multiple fields. Grazing with a specified rotation minimizes overgrazing and resulting erosion. The Natural Resource Conservation Service (NRCS) recommends grazing systems to improve and maintain water quality and quantity. Duration, intensity, frequency, and season of grazing can be managed to enhance vegetation cover and litter, resulting in reduced runoff, improved infiltration, increased quantity of soil water for plant growth, and better manure distribution and increased rate of decomposition (NRCS, 1998). In a study by Tiedemann et al. (1988), as presented by USEPA (1993), the effects of four grazing strategies on bacteria levels in thirteen watersheds in Oregon were studied during the summer of 1984. Results of the study (Table 12) showed that when livestock are managed at a stocking rate of 19 acres per animal unit month, with water developments and fencing, bacteria levels were reduced significantly.

Table 12. Bacterial Water Quality Response to Four Grazing Strategies (Tiedemann et al., 1988).

Grazing Strategy		Geometric Mean Bacteria Count
Strategy A:	Ungrazed	40/L
Strategy B:	Grazing without management for livestock distribution; 20.3 ac/AUM.	150/L
Strategy C:	Grazing with management for livestock distribution: fencing and water developments; 19.0 ac/AUM	90/L
Strategy D:	Intensive grazing management, including practices to attain uniform livestock distribution and improve forage production with cultural practices such as seeding, fertilizing, and forest thinning; 6.9 ac/AUM	950/L

Vegetative filter strip- Vegetated filter strips are used to reduce the amount of sediment, particulate organics, dissolved contaminants, nutrients, and E. coli bacteria to streams. The effectiveness of filter strips and other BMPs in removing pollutants is quite successful. Results from a study by Pennsylvania State University (1992a) as presented by USEPA (1993), suggest that vegetative filter strips are capable of removing up to 55 percent of bacteria, 65 percent of sediment, and 85 percent of total phosphorus loading to rivers and streams (Table 13). The ability of the filter strip to remove contaminants is dependent on field slope, filter strip slope, erosion rate, amount and particulate size distribution of sediment delivered to the filter strip, density and height of vegetation, and runoff volume associated with erosion producing events (NRCS, 2001).

Waste management system- Waste management systems can be effective in controlling up to 90 percent of bacteria loading originating from confined animal feeding areas (Table 13). A waste management system is made up of various components designed to control nonpoint source pollution from concentrated animal feeding operations (CAFOs) and animal feeding operations (AFOs). Diverting clean water from the feeding area and containing dirty water from the feeding area in a pond are typical practices of a waste management system. Manure handling and application of manure is designed to be adaptive to environmental, soil, and plant conditions to minimize the probability of contamination of surface water.

Table 13. Relative Gross Effectiveness[a] of Confined Livestock Control Measures (Pennsylvania State University, 1992a).

Practice[b] Category	Runoff[c] Volume	Total[d] Phosphorus (%)	Total[d] Nitrogen (%)	Sediment (%)	Fecal Bacteria (%)
Animal Waste System[e]	-	90	80	60	85
Diversion System[f]	-	70	45	NA	NA
Filter Strips[g]	-	85	NA	60	55
Terrace System	-	85	55	80	NA
Containment Structures[h]	-	60	65	70	90

NA Not Available.
a Actual effectiveness depends on site-specific conditions. Values are not cumulative between practice categories.
b Each category includes several specific types of practices.
c - = reduction; + = increase; 0 = no change in surface runoff.
d Total phosphorus includes total and dissolved phosphorus; total nitrogen includes organic-N, ammonia-N, and nitrate-N.
e Includes methods for collecting, storing, and disposing of runoff and process-generated wastewater.
f Specific practices include diversion of uncontaminated water from confinement facilities.
g Includes all practices that reduce contaminant losses using vegetative control measures.
h Includes such practices as waste storage ponds, waste storage structures, waste treatment lagoons.

Septic System: Septic systems provide an economically feasible way of disposing of household wastes where other means of waste treatment are unavailable (e.g., public or private treatment facilities). The basis for most septic systems involves the treatment and distribution of household wastes through a series of steps involving the following:

1. A sewer line connecting the house to a septic tank
2. A septic tank that allows solids to settle out of the effluent
3. A distribution system that dispenses the effluent to a leach field
4. A leaching system that allows the effluent to enter the soil

Septic system failures are caused when one or more components of the septic system do not work properly and untreated waste or wastewater leaves the system. Wastes may pond in the leach field and ultimately run off directly into nearby streams or percolate into groundwater. Untreated septic system waste is a potential source of nutrients (nitrogen and phosphorus), organic matter, suspended solids, and E. coli bacteria. Land application of septic system sludge, although unlikely, may also be a source of contamination.

Septic system failure can occur for several reasons, although the most common reason is improper maintenance (e.g., age, inadequate pumping). Other reasons for failure include improper installation, location, and choice of system. Harmful household chemicals can also cause failure by killing the bacteria that digest the waste. While the number of systems that are not functioning properly is unknown, it is estimated that 28 percent of the systems in North Dakota are failing (USEPA, 2002).

6.2 Farmland Management

No-Till Farming: This crop residue management technique increases the amount of water and organic matter (nutrients) in the soil and decreases erosion, by growing crops from year to year without disturbing the soil through tillage. Excessive tillage can lead to soil compaction, loss of organic matter, degradation of soil aggregates, harm to soil microbes and other organisms, and soil erosion where topsoil is blown or washed away, often carrying with it nutrients and bacteria that end up in the river. Less tillage reduces labor, fuel and machinery costs while increasing the water content of the soil. No-till also has carbon sequestration potential through storage of soil organic matter

Nutrient Management: A nutrient management is defined by the NRCS as a plan to manage the amount, source, placement, form and timing of the application of nutrients and soil amendments. The purpose is to meet the nutrient needs of the crops being grown while minimizing the loss of nutrients to surface and ground water. It helps to manage commercial fertilizer and animal manure input costs while protecting water quality.

Buffer Strips/Grassed Waterways: Buffer strips are strips of land designed to intercept storm water and minimize runoff and soil erosion from crop fields. Buffers reduce the amount of sediment and pollutants carried by runoff to nearby rivers and lakes. Grassed waterways are generally broad, shallow, grassed channels, designed to prevent soil erosion while draining runoff water from adjacent cropland. As water travels down the waterway the grass vegetation prevents erosion that would otherwise result from concentrated flows. The soil microbes and grass in these practices also facilitate the transformation and uptake of nutrients to protect surface waters.

Cover Crops: - Cover crops are planted primarily to manage soil fertility and quality, water, weeds, pests, diseases, and biodiversity. By reducing soil erosion, cover crops reduce both the rate and quantity of water that drains off the field. The increased soil organic matter enhances the soil structure, as well as the water and nutrient hold and buffering capacity of soil.

Critical Area Planting: Critical area planting is the planting of grass, legumes or other vegetation to protect small, badly eroding areas. The permanent vegetation stabilizes areas such as gullies, over-grazed hillsides or terrace backslopes. By stabilizing the soil, it reduces damage from sediment and nutrient runoff to downstream waterbodies.

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Appendix A
Summary for General Chemistry and Trace Metals for Site 384126

Parameter	Units	Samples	Mean	Min	Max	Median
Total Phosphorus (TP)	mg/L	63	0.16	0.03	0.43	0.15
Total Nitrogen (TN)	mg/L	63	0.98	0.46	1.60	1.02
Total Kjeldahl Nitrogen (TKN)	mg/L	63	0.95	0.43	1.55	0.99
Nitrate + Nitrite (N+N)	mg/L	63	0.02	0.02	0.19	0.02
Ammonia (NH_3)	mg/L	63	0.08	0.02	0.78	0.03
Total Suspended Solids (TSS)	mg/L	63	7.68	2.50	42.00	7.00
Calcium (Ca)	mg/L	17	82.56	36.70	116.00	83.90
Chloride (Cl)	mg/L	17	13.49	4.27	35.90	12.30
Potassium (K)	mg/L	17	10.24	6.90	15.90	10.10
Sodium (Na)	mg/L	17	52.91	13.60	132.00	48.30
Aluminum (Al)	ug/L	17	137.65	25.00	385.00	123.00
Antimony (Sb)[1]	ug/L	17	2.50	2.50	2.50	2.50
Arsenic (As)	ug/L	17	3.24	2.50	7.24	2.50
Barium (Ba)	ug/L	17	49.40	33.70	59.50	51.60
Beryllium (Be)[1]	ug/L	17	2.50	2.50	2.50	2.50
Boron (B)	ug/L	17	186.71	79.00	373.00	179.00
Cadmium (Cd)[1]	ug/L	17	2.50	2.50	2.50	2.50
Chromium (Cr)[1]	ug/L	17	2.50	2.50	2.50	2.50
Copper (Cu)	ug/L	17	2.91	2.50	9.48	2.50
Iron (Fe)	mg/L	17	0.24	0.07	0.56	0.22
Lead (Pb)	ug/L	17	4.83	2.50	10.30	2.50
Magnesium (Mg)	mg/L	17	45.01	17.80	67.20	45.90
Manganese (Mn)	mg/L	17	0.26	0.10	0.85	0.16
Nickel (Ni)	ug/L	17	2.91	2.50	6.09	2.50
Selenium (Se)[1]	ug/L	17	2.50	2.50	2.50	2.50
Silver (Ag)[1]	ug/L	17	2.50	2.50	2.50	2.50
Thallium (Tl)[1]	ug/L	17	2.50	2.50	2.50	2.50
Zinc (Zn)	ug/L	17	8.98	2.50	23.40	9.34
pH	N/A	17	8.21	7.96	8.43	8.20
Sulfate as (SO4)	mg/L	17	197.70	67.90	319.00	202.00

[1]Antimony, Beryllium, Cadmium, Chromium, Selenium, Silver, and Thallium were all under the lower dection limit of 5.0 ug/L.

Appendix B
E. coli Sample Results and Recreational Use Attainment for Sites 384124, 384129, and 384126

384124

	May		June		July		August		September	
	04-May-09	10	01-Jun-09	20	06-Jul-09	10				
	11-May-09	20	08-Jun-09	110	13-Jul-09	20				
	18-May-09	20	15-Jun-09	280	06-Jul-10	900				
	03-May-10	10	22-Jun-09	220	13-Jul-10	1900				
	10-May-10	10	29-Jun-09	500	19-Jul-10	90				
	17-May-10	10	01-Jun-10	10						
	24-May-10	70	09-Jun-10	70						
			14-Jun-10	30						
			21-Jun-10	50						
			28-Jun-10	250						
Number of Samples		7		10		5	N/A		N/A	
Geometric Mean		16		84		125	N/A		N/A	
% Exceed 409 CFU/100 mL		0%		10%		40%	N/A		N/A	
Recreational Use Assessment	Fully Supporting		Fully Supporting		FSBT		Insufficiant Data		Insufficiant Data	

384129

	May		June		July		August		September	
	04-May-09	10	01-Jun-09	20	06-Jul-09	130	04-Aug-09	70	07-Sep-10	620
	11-May-09	10	08-Jun-09	350	13-Jul-09	10	10-Aug-09	140	15-Sep-10	80
	18-May-09	10	15-Jun-09	110	21-Jul-09	130	17-Aug-09	130	20-Sep-10	90
	26-May-09	40	22-Jun-09	60	27-Jul-09	100	24-Aug-09	600	27-Sep-10	30
	03-May-10	10	29-Jun-09	150	06-Jul-10	1000	02-Aug-10	1000		
	10-May-10	30	01-Jun-10	50	13-Jul-10	4000	09-Aug-10	150		
	17-May-10	10	09-Jun-10	80	19-Jul-10	700	16-Aug-10	50		
	24-May-10	30	14-Jun-10	70	26-Jul-10	40	23-Aug-10	80		
			21-Jun-10	50			30-Aug-10	80		
			28-Jun-10	500						
Number of Samples		8		10		8		9		4
Geometric Mean		16		93		193		149		108
% Exceed 409 CFU/100 mL		0%		10%		38%		22%		25%
Recreational Use Assessment	Fully Supporting		Fully Supporting		Not Supporting		Not Supporting		Insufficiant Data	

384126

	May		June		July		August		September	
	04-May-09	10	01-Jun-09	40	06-Jul-09	20	04-Aug-09	60	08-Sep-09	70
	11-May-09	10	08-Jun-09	180	13-Jul-09	30	10-Aug-09	110	16-Sep-09	30
	18-May-09	40	15-Jun-09	290	21-Jul-09	120	17-Aug-09	500	21-Sep-09	10
	26-May-09	20	22-Jun-09	80	27-Jul-09	180	24-Aug-09	180	28-Sep-09	20
	03-May-10	10	29-Jun-09	100	06-Jul-10	280	31-Aug-09	30	07-Sep-10	20
	10-May-10	10	01-Jun-10	60	13-Jul-10	100	02-Aug-10	10	15-Sep-10	70
	17-May-10	10	09-Jun-10	70	19-Jul-10	30	09-Aug-10	70	20-Sep-10	420
	24-May-10	600	14-Jun-10	60	26-Jul-10	40	16-Aug-10	20	27-Sep-10	50
			21-Jun-10	100			23-Aug-10	10		
			28-Jun-10	400			30-Aug-10	10		
Number of Samples		8		10		8		10		8
Geometric Mean		22		105		68		44		43
% Exceed 409 CFU/100 mL		13%		0%		0%		10%		13%
Recreational Use Assessment	Fully Supporting but Threatened		Fully Supporting		Fully Supporting		Fully Supporting		Fully Supporting but Threatened	

Appendix C
Further Information on Box and Whisker Plots

The Technical Definition

In descriptive statistics, a box plot or boxplot (also known as a box-and-whisker diagram or plot) is a convenient way of graphically depicting groups of numerical data through their five-number summaries: the smallest observation (sample minimum), lower quartile (Q1), median (Q2), upper quartile (Q3), and largest observation (sample maximum). A boxplot may also indicate which observations, if any, might be considered outliers.

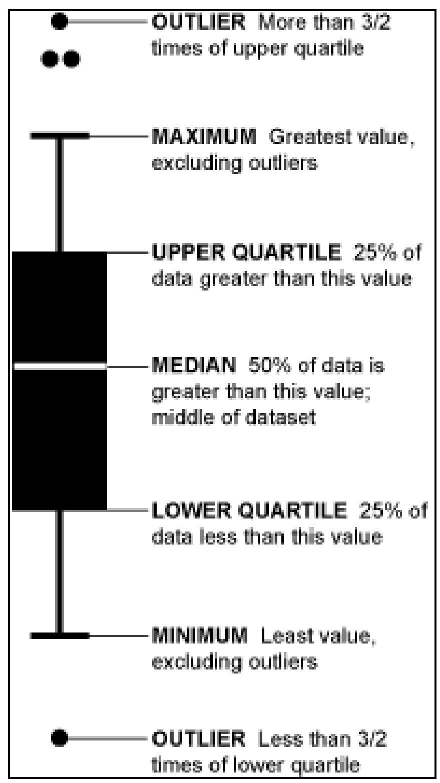
Box plots display differences between populations without making any assumptions of the underlying statistical distribution: they are non-parametric. The spacings between the different parts of the box help indicate the degree of dispersion (spread) and skewness in the data, and identify outliers. Boxplots can be drawn either horizontally or vertically.

Box and whisker plots are uniform in their use of the box: the bottom and top of the box are always the 25th and 75th percentile (the lower and upper quartiles, respectively), and the band near the middle of the box is always the 50th percentile (the median).

Any data not included between the whiskers should be plotted as an outlier with a dot, small circle, or star, but occasionally this is not done.Some box plots include an additional character to represent the mean of the data.On some box plots a crosshatch is placed on each whisker, before the end of the whisker.

How to Read (and Use) a Box-and-Whisker Plot

February 15, 2008 to Statistical Visualization by Nathan Yau



The box-and-whisker plot is an exploratory graphic, created by John W. Tukey, used to show the distribution of a dataset (at a glance). Think of the type of data you might use a histogram with, and the box-and-whisker (or box plot, for short) could probably be useful.

Reading a Box-and-Whisker Plot

Let's say we ask 2,852 people (and they miraculously all respond) how many hamburgers they've consumed in the past week. We'll sort those responses from least to greatest and then graph them with our box-and-whisker.

Take the top 50% of the group (1,426) who ate more hamburgers; they are represented by everything above the median (the white line). Those in the top 25% of hamburger eating (713) are shown by the top "whisker" and dots. Dots represent those who ate a lot more than normal or a lot less than normal (outliers). If more than one outlier ate the same number of hamburgers, dots are placed side by side.

Find Skews in the Data

The box-and-whisker of course shows you more than just four split groups. You can also see which way the data sways. For example, if there are more people who eat a lot of burgers than eat a few, the median is going to be higher or the top whisker could be longer than the bottom one. Basically, it gives you a good overview of the data's distribution.

For more information you can also visit:
www.worsleyschool.net/science/files/box/plot.html

Appendix D
Rapid Geomorphic Assessment (RGA) Methodology

Rapid Geomorphic Assessments: RGA's

To evaluate channel-stability conditions and stage of channel evolution of a particular reach, a Rapid Geomorphic Assessment (RGA) will be carried out using the Channel-Stability Ranking Scheme. RGAs utilize diagnostic criteria of channel form to infer dominant channel processes and the magnitude of channel instabilities through a series of nine questions. Granted, evaluations of this sort do not include an evaluation of watershed or upland conditions; however, stream channels act as conduits for energy, flow and materials as they move through the watershed and will reflect a balance or imbalance in the delivery of sediment. RGA's provide a rapid characterization of stability conditions.

The RGA procedure consists of four steps to be completed on site:

1. Determine the 'reach'. The 'reach' is described as the length of channel covering 6-20 channel widths, thus is scale dependent and covers at least two pool-riffle sequences.
2. Take photographs looking upstream, downstream and across the reach; for quality assurance and quality control purposes. Photographs are used with RGA forms to review the field evaluation
3. Make observations of channel conditions and diagnostic criteria listed on the channel-stability ranking scheme.
4. Sample bed material.

Channel-Stability Index

A field form containing nine criteria (Figure J.1) will be used to record observations of field conditions during RGAs. Each criterion was ranked from zero to four and all values summed to provide an index of relative channel stability. The higher the number the greater the instability: sites with values greater than 20 exhibit considerable instability; stable sites generally rank 10 or less. Intermediate values denote reaches of moderate instability. However, rankings are not weighted, thus a site ranked 20 is not twice as unstable as a site ranked 10. The process of filling out the form enables the final decision of 'Stage of Channel Evolution'.

CHANNEL-STABILITY RANKING SCHEME

River__________________________ Site Identifier_____________________________________

Date _____________ Time_______ Crew _______________ Samples Taken__________________________

Pictures (circle) U/S D/S X-section Slope__________ Pattern: Meandering / Straight / Braided

1. Primary bed material

	Bedrock	Boulder/Cobble	Gravel	Sand	Silt Clay	
	0	1	2	3	4	_____

2. Bed/bank protection

	Yes	No	(with)	1 bank protected	2 banks	
	0	1		2	3	_____

3. Degree of incision (Relative elevation of "normal" low water; floodplain/terrace @ 100%)

	0-10%	11-25%	26-50%	51-75%	76-100%	
	4	3	2	1	0	_____

4. Degree of constriction (Relative decrease in top-bank width from up to downstream)

	0-10%	11-25%	26-50%	51-75%	76-100%	
	0	1	2	3	4	_____

5. Stream bank erosion (Each bank)

	None	Fluvial	Mass wasting (failures)	
Left	0	1	2	_____
Right	0	1	2	_____

6. Stream bank instability (Percent of each bank failing)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	0	0.5	1	1.5	2	_____
Right	0	0.5	1	1.5	2	_____

7. Established riparian woody-vegetative cover (Each bank)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	2	1.5	1	0.5	0	_____
Right	2	1.5	1	0.5	0	_____

8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)

	0-10%	11-25%	26-50%	51-75%	76-100%	
Left	2	1.5	1	0.5	0	_____
Right	2	1.5	1	0.5	0	_____

9. Stage of channel evolution

	I	II	III	IV	V	VI	
	0	1	2	4	3	1.5	_____

Figure J.1 - Channel stability ranking scheme used to conduct rapid geomorphic assessments (RGA's). The channel stability index is the sum of the values obtained for the nine criteria.

1. Primary bed material

Bedrock	The parent material that underlies all other material. In some cases this becomes exposed at the surface. Bedrock can be recognized by appearing as large slabs of rock, parts of which may be covered by other surficial material.
Boulder/Cobble	All rocks greater than 64 mm median diameter.
Gravel	All particles with a median diameter between 64.0 – 2.00 mm
Sand	All Particles with a median diameter between 2.00 – 0.63 mm
Silt Clay	All fine particles with a median diameter of less than 0.63 mm

2. Bed/bank protection

Yes	Mark if the channel bed is artificially protected, such as with rip rap or concrete.
No	Mark if the channel bed is not artificially protected and is composed of natural material.
1 bank protected	Mark if one bank is artificially protected, such as with rip rap or concrete.
2 banks	Mark if two banks are artificially protected.

3. Degree of incision (Relative elevation Of "normal" low water; floodplain/terrace @ 100%)

Calculated by measuring water depth at deepest point across channel, divided by bank height from bank top to bank base (where slope breaks to become channel bed). This ratio is given as a percentage and the appropriate category marked.

4. Degree of constriction (Relative decrease in top-bank width from up to downstream)

Often only found where obstructions or artificial protection are present within the channel. Taking the reach length into consideration, channel width at the upstream and downstream parts of the reach are measured and the relative difference calculated.

5. Stream bank erosion (Each bank)

The dominant form of bank erosion is marked separately for each bank, left and right, facing in a downstream direction.

If the reach is a meandering reach, the banks are viewed in terms of ‘Inside, Outside’ as opposed to ‘Left, Right’ (appropriate for questions 5-8). Inside bank, being the inner bank of the meander, if the stream bends to the left as you face downstream, this would be the left bank. Outside bank, being the outer bank, on your right as you face downstream in a stream meandering left.

None	No erosion
Fluvial	Fluvial processes, such as undercutting of the bank toe, cause erosion.
Mass Wasting	Mass movement of large amounts of material from the bank is the method of bank erosion. Often characterized by high, steep banks with shear bank faces. Debris at the bank toe appears to have

fallen from higher up in the bank face. Includes, rotational slip failures and block failures.

6. Stream bank instability (Percent of each bank failing)
   If the bank exhibits mass wasting, mark percentage of bank with failures over the length of the reach. If more than 50% failures are marked, the dominant process is mass wasting (see question 5).

7. Established riparian woody-vegetative cover (Each bank)
   Riparian woody-vegetative cover is the more permanent vegetation that grows on the stream banks, distinguished by its woody stem, this includes trees and bushes but does not include grasses. Grasses grow and die annually with the summer and thus do not provide any form of bank protection during winter months whilst permanent vegetation does.

8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)
   The percentage of the reach length with fluvial deposition of material (often sand, also includes fines and gravels) is marked.

9. Stage of channel evolution
   Stage of channel evolution are given by Simon and Hupp, 1986 (see diagram below). All of the above questions help lead to an answer to this question. Refer bank to previously answered questions for guidance. See Table 2 for guidelines of what features are often found with each stage of channel evolution.

Total Score Total up the responses to the 9 questions.

Stages of Channel Evolution

The channel evolution framework set out by Simon and Hupp (1986) is used to assess the stability of a channel reach (Figure J.2; Table J.1). With stages of channel evolution tied to discrete channel processes and not strictly to specific channel shapes, they have been successfully used to describe systematic channel-adjustment processes over time and space in diverse environments, subject to various disturbances such as stream response to: channelization in the Southeast US Coastal Plain (Simon, 1994); volcanic eruptions in the Cascade Mountains (Simon, 1999); and dams in Tuscany, Italy (Rinaldi and Simon, 1998). Because the stages of channel evolution represent shifts in dominant channel processes, they are systematically related to suspended-sediment and bed-material discharge (Simon, 1989a; Kuhnle and Simon, 2000), fish-community structure, rates of channel widening (Simon and Hupp, 1992), and the density and distribution of woody-riparian vegetation (Hupp, 1992).

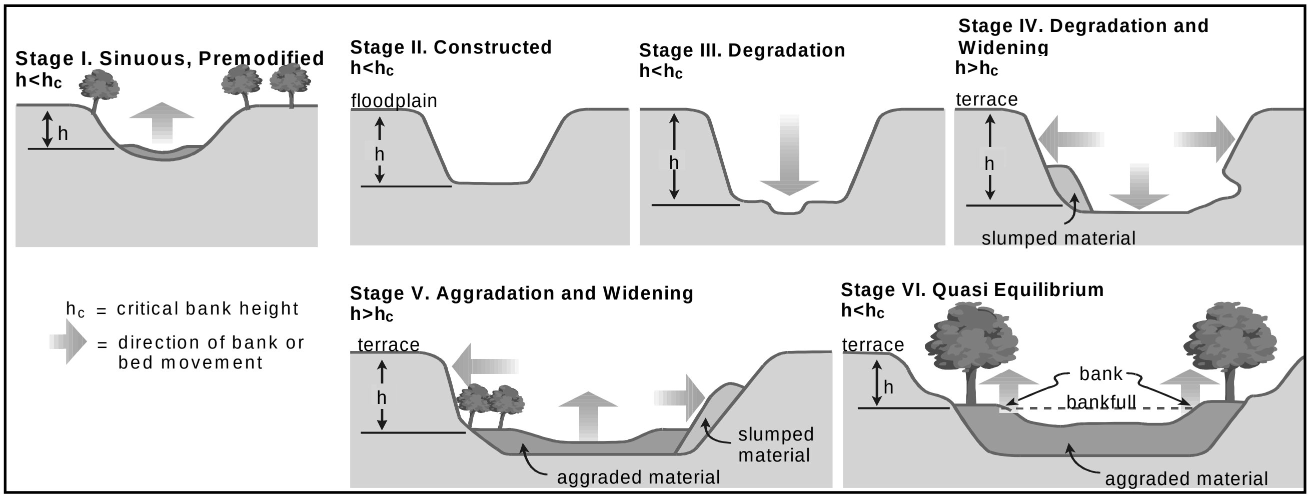


Figure J.2 - Six stages of channel evolution from Simon and Hupp (1986) and Simon (1989b) identifying Stages I and VI as "reference" conditions for given Ecoregions

Table J.1 – Summary of conditions to be expected at each stage of channel evolution.

Stage	Descriptive Summary
I	*Pre-modified* – Stable bank conditions, no mass wasting, small, low angle bank slopes. Established woody vegetation, convex upper bank, and concave lower bank.
II	*Constructed* – Artificial reshaping of existing banks. Vegetation often removed, banks steepened, heightened and made linear.
III	*Degradation* – Lowering of channel bed and consequent increase of bank heights. Incision without widening. Bank toe material removed causing an increase in bank angle.
IV	*Threshold* – Degradation and basal erosion. Incision and active channel widening. Mass wasting from banks and excessive undercutting. Leaning and fallen vegetation. Vertical face may be present.
V	*Aggradation* – Deposition of material on bed, often sand. Widening of channel through bank retreat; no incision. Concave bank profile. Filed material re-worked and deposited. May see floodplain terraces. Channel follows a meandering course.
VI	*Restabilization* – Reduction in bank heights, aggradation of the channel bed. Deposition on the upper bank therefore visibly buried vegetation. Convex shape. May see floodplain terraces.

An advantage of a process-based channel-evolution scheme is that Stages I and VI represent true "reference" conditions. In some cases, such as in the Midwestern United States where land clearing activities near the turn of the 20th Century caused massive changes in rainfall-runoff relations and land use, channels are unlikely to recover to Stage I, pre-modified conditions. Stage VI, a re-stabilized condition, is a much more likely target under present regional land use and altered hydrologic regimes (Simon and Rinaldi, 2000) and can be used as a "reference" condition. Stage VI streams can be characterized as a 'channel-within-a-channel', where the previous floodplain surface is less frequently inundated and can be described as a terrace. This morphology is typical of recovering and re-stabilized stream systems following incision. In pristine areas, where disturbances have not occurred or where they are far less severe, Stage I conditions can be appropriate as a reference.

Unfortunately it is not uncommon that suspended-sediment sampling was carried out over twenty years ago. It may also be the case that the stage of channel evolution relevant to a given site now, was not relevant at the time of suspended-sediment sampling. As we cannot readily create a rating equation to fit the current stability of a given site, plotting certain stream morphology characteristics against a range of discharges over time can help us to establish the stability of the channel at the time of suspended-sediment sampling.