Nutrient & Sediment TMDL Development for Patterson Lake, North Dakota

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1.0 INTRODUCTION AND DESCRIPTION OF THE WATERSHED

Patterson Lake is a water supply and recreational reservoir located in Stark County in southwest North Dakota (Figure 1). The reservoir was created in 1951 by damming the main stem of the Heart River west of Dickinson, North Dakota. It was constructed to create a drinking water supply, irrigation water supply, recreational facility, and also to provide flood protection. There are 634 miles of streams in the Heart River drainage system upstream of the Patterson Lake Dam. Most of the headwater streams originate in southeastern Billings County. The main stem of the Heart River flows from the northwest corner of Stark County, through Belfield and South Heart cities to Patterson Lake. The South Branch of the Heart River originates in the southeast corner of Billings County and flows northeast to the confluence with the Heart River near South Heart City. Major streams in the Patterson Lake watershed include Bull Creek, Duck Creek, Ash Creek, and Norwegian Creek. Table 1 summarizes some of the geographical, hydrological, and physical characteristics of Patterson Lake.

Table 1. General characteristics of Patterson Lake and the Patterson Lake watershed

Legal Name	**Patterson Lake**
Major Drainage Basin	Heart River
Nearest Municipality	Dickinson, North Dakota
8-Digit HUC	10130202
County Location	Stark County, North Dakota
Physiographic Region	Missouri slope upland
Latitude **Longitude**	46° 51' 36" −102° 51' 00"
Surface Area	1,194 acres
Watershed Area	272,960 acres
Average Depth	8.8 feet
Maximum Depth	27 feet
Volume	8,612 acre-feet
Tributaries	Heart River and its tributaries, Ash Creek, Duck Creek
Type of Waterbody	Constructed reservoir
Dam Type	Constructed earthen dam
Outlet	Concrete spillway
Fishery Type	Northern pike, walleye, yellow perch, bluegill, smallmouth bass, largemouth bass, channel catfish

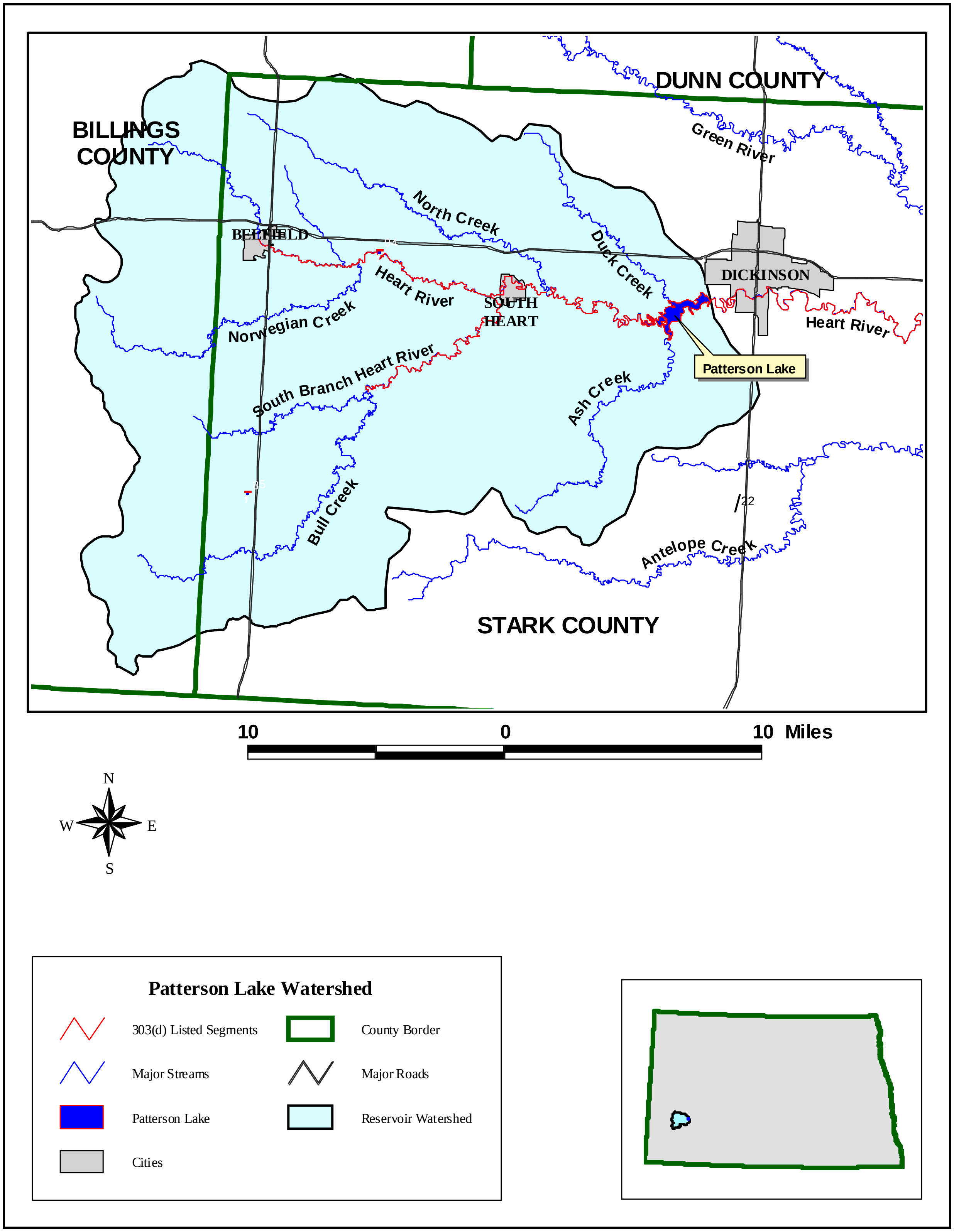

Figure 1. General location of Patterson Lake and the Patterson Lake watershed.

1.1 Clean Water Act Section 303(d) Listing Information

As part of the Clean Water Act section 303(d) listing process, the North Dakota Department of Health (NDDH) has identified Patterson Lake as an impaired waterbody (Table 2). The aquatic life and recreational uses of Patterson Lake are impaired. Aquatic life is impaired because of nutrients, sediment, and low dissolved oxygen. Recreational uses on Patterson Lake are impaired because of nutrients. The North Dakota section 303(d) list did not include any potential sources of these impairments. Patterson Lake has been classified as a Class 3 warm-water fisheries lake. A Class 3 lake is defined as capable of supporting growth and propagation of nonsalmonid fishes and associated aquatic biota (NDDH, 2001). The *Patterson Lake Diagnostic/Feasibility Study* completed by NDDH indicated that the lake is currently hypereutrophic and has nuisance algal blooms, poor fisheries production, and oxygen depletion resulting in periodic fish kills (NDDH, 2000).

Table 2. Patterson Lake section 303(d) listing information (NDDH, 1998a)

Reach Identifier	ND_L54
Waterbody Name	Patterson Lake (Dickinson Reservoir)
Class	3 – Warm-water fishery
Impaired Uses	Aquatic life (partially supporting); recreation (partially supporting)
Causes	Nutrients, sediment/turbidity, low dissolved oxygen
Priority	High (Targeted)

The Heart River from Belfield, North Dakota, to Patterson Lake has also been identified as an impaired river (Table 3). This is a 30.37-mile-long segment of the Heart River immediately upstream of Patterson Lake. This segment is not meeting the designated aquatic life and recreational uses because of nutrients, sediment, habitat, organic enrichment, and bacteria

Table 3. Heart River section 303(d) listing information (NDDH, 1998a)

Reach Identifier	ND_R52
Waterbody Name	Heart River
Waterbody Description	Heart River from Belfield, North Dakota downstream to Patterson Lake
Size	30.37 miles
Class	1A, 3
Impaired Uses	Aquatic life (partially supporting); recreation (partially supporting)
Causes	Nutrients, sediment, habitat, organic enrichment, bacteria
Priority	High (Targeted)

The South Branch Heart River was also identified as an impaired river (Table 4). According to the 1998 section 303(d) list, aquatic life in the South Branch of the Heart River is impaired because of sediment and habitat. This impaired segment extends 12.75 miles from the headwaters of the South Branch Heart River to the confluence with the main stem of the Heart River near South Heart City.

Table 4. South Branch Heart River section 303(d) listing information (NDDH, 1998a)

Reach Identifier	ND_R53
Waterbody Name	South Branch of the Heart River
Waterbody Description	South Branch Heart River downstream to its confluence with the Heart River
Size	12.75 miles
Class	1A, 3
Designated Uses	Aquatic life (partially supporting)
Causes	Sediment, habitat
Priority	High (Targeted)

1.2 Topography

The Patterson Lake Diagnostic/Feasibility Study indicated that the topography in the watershed consisted of rolling uplands with some badland regions (areas with buttes, eroded drainages, and high erosion rates) (NDDH, 2000). The entire watershed lies in the Missouri slope upland physiographic region, which is characterized by rolling hills with shale and sandstone bedrock (Greatplains.org, 2001). Coal is often strip mined from the sedimentary rocks in this region. The 1:250,000-scale digital elevation model (DEM) for the watershed indicated that there is a total elevation change of 607 feet from the headwater regions of the Heart River to Patterson Lake, and an overall slope of 0.43 percent (Figure 2). The maximum elevation was 3,002 feet and was located in the headwaters of Bull Creek. The minimum elevation of 2,395 feet was located near Patterson Lake.

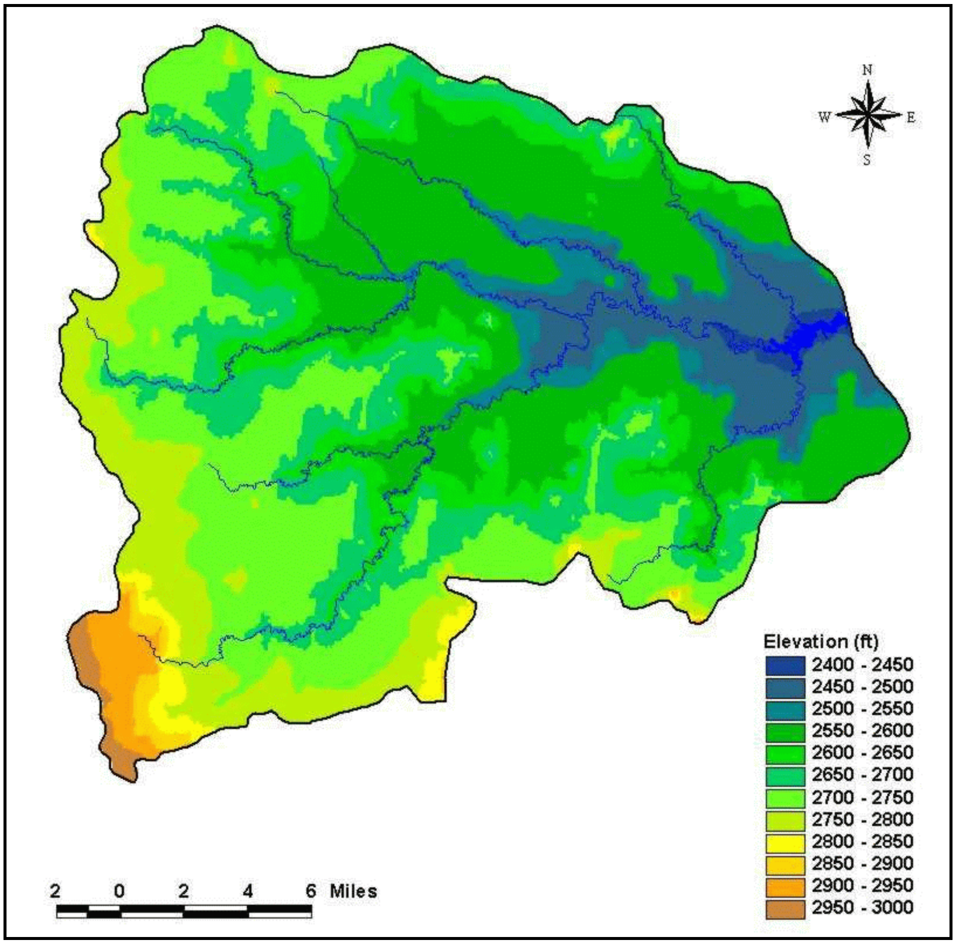

Figure 2. Topography in the Patterson Lake watershed.

1.3 Land Use/Land Cover

Land use was analyzed for the Patterson Lake Diagnostic/Feasibility Study (2000), which indicated that 41.7 percent of the watershed is cropped and 51.8 percent has permanent herbaceous cover (Table 5). In contrast, satellite land use data from 1990 to 1994 indicated that 52 percent of the watershed is cropped and 45 percent has permanent herbaceous cover (Table 6; Figure 3). The difference in land use data is more likely due to the different classification schemes used than to actual land use change.

Table 5. Percent land use by subwatershed in the Patterson Lake watershed

Sub-watershed	Crop	Range	Pasture	Hay	CRP[a]	Other	Farm
South Branch Heart River below Bull Creek	40.7	24.6	12.1	7.3	9.6	3.2	2.6
South Branch Heart River near South Heart	46.5	5.0	20.2	1.2	22.0	3.8	1.8
Heart River near South Heart	43.0	8.3	24.9	10.5	7.3	4.0	2.0
North Creek	44.3	17.5	11.5	11.9	9.4	2.0	3.4
Ash Creek	39.8	17.8	13.4	14.7	3.8	6.3	4.5
Duck Creek	34.4	24.1	11.8	24.5	0.0	0.2	5.1
Entire Watershed	41.7	16.6	15.9	10.8	8.5	3.6	3.0

[a]CRP - conservation reserve program (NDDH, 2000).

Table 6. MRLC land use data for the Patterson Lake watershed.

Land Cover	Percent	Land Cover	Percent
Small Grains	51.54	Commercial/Industrial/ Transportation	0.53
Fallow	22.44	Row Crops	0.09
Grasslands/Herbaceous	17.00	Urban/Recreational Grasses	0.09
Shrubland	3.90	Low Intensity Residential	0.09
Pasture/Hay	1.92	High Intensity Residential	0.02
Bare Rock/Sand/Clay	1.40	Emergent Herbaceous Wetlands	0.02
Open Water	0.95	Quarries/Strip Mines/Gravel Pits	0.01

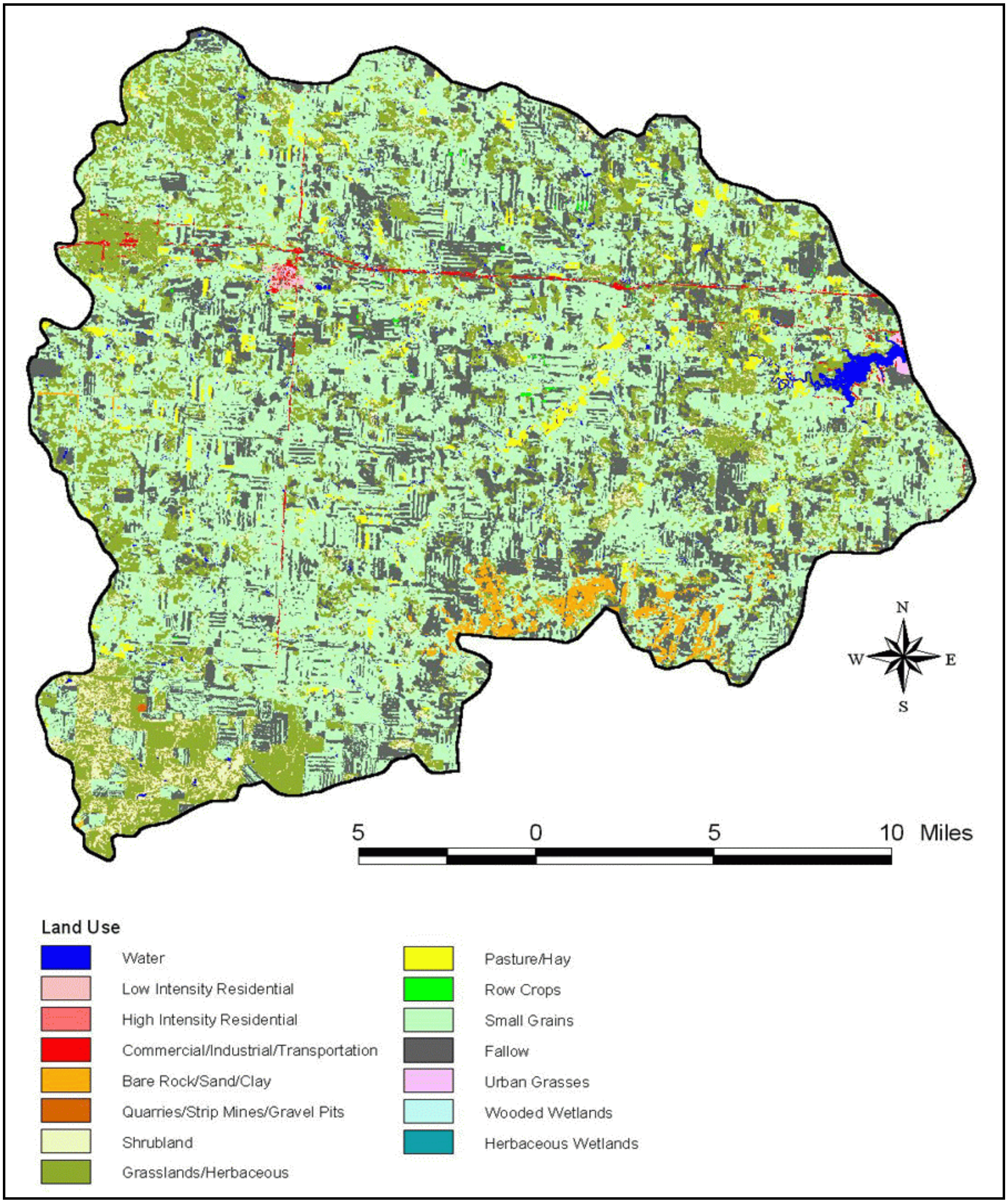

Figure 3. MRLC land use data in the Patterson Lake watershed.

1.4 Climate and Precipitation

Southwest North Dakota has a typical continental climate characterized by large annual, daily, and day-to-day temperature changes; light to moderate precipitation; low relative humidity; and nearly continuous air movement. Precipitation events tend to be brief and intense and occur primarily in the summer months. Average annual precipitation at the Dickinson Airport rain gage between 1940 and 1997 was 16.08 inches per year (Figure 4) (NCDC, 2001). June is the wettest month, with an average rainfall of 3.49 inches per year. Most of the precipitation is received during the summer months (May through August), with little precipitation from November through March. Figure 5 shows the average monthly precipitation for the Dickinson, North Dakota Airport precipitation gage.

The annual mean temperature at the Dickinson Research Extension Center between 1892 and 2000 was 40.7° Fahrenheit (DREC, 2001). The growing season in this area is from mid-April through October, and July is the warmest month (Figure 6).

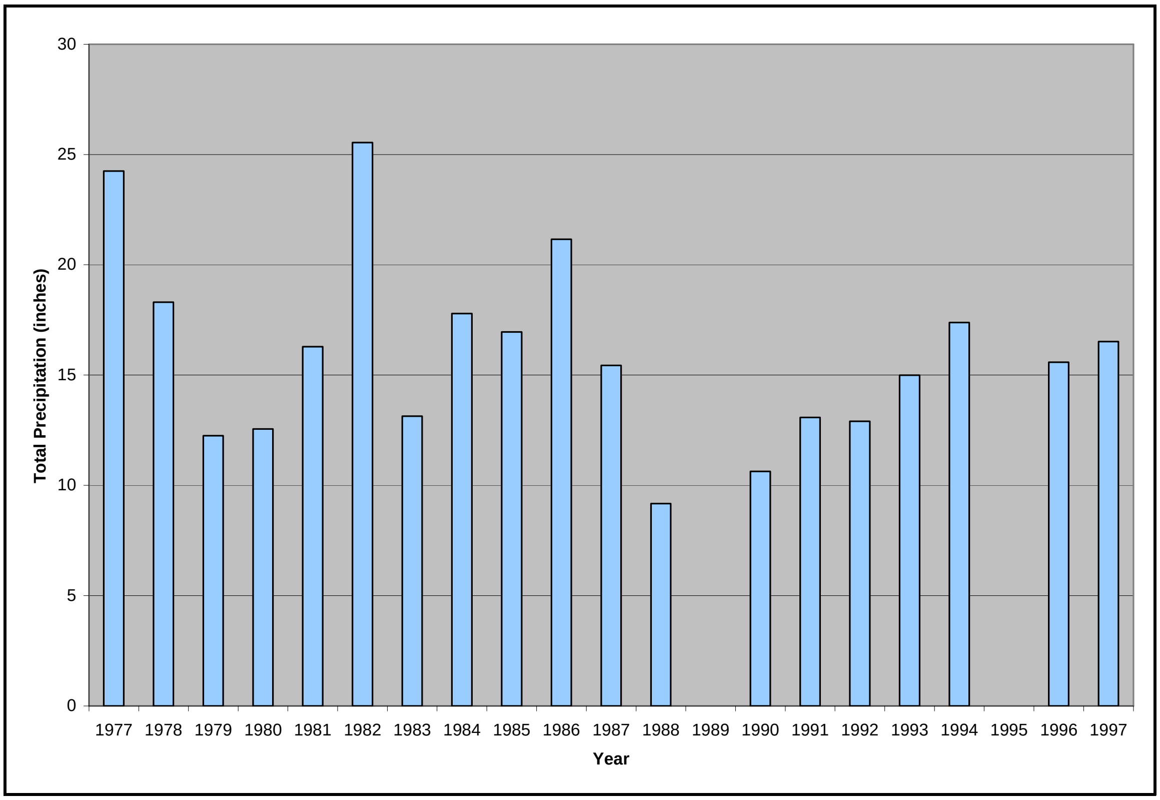

Figure 4. Total precipitation per year at the Dickinson Airport rain gage, Dickinson North Dakota, 1977-1997. Incomplete data were available for 1989 and 1995.

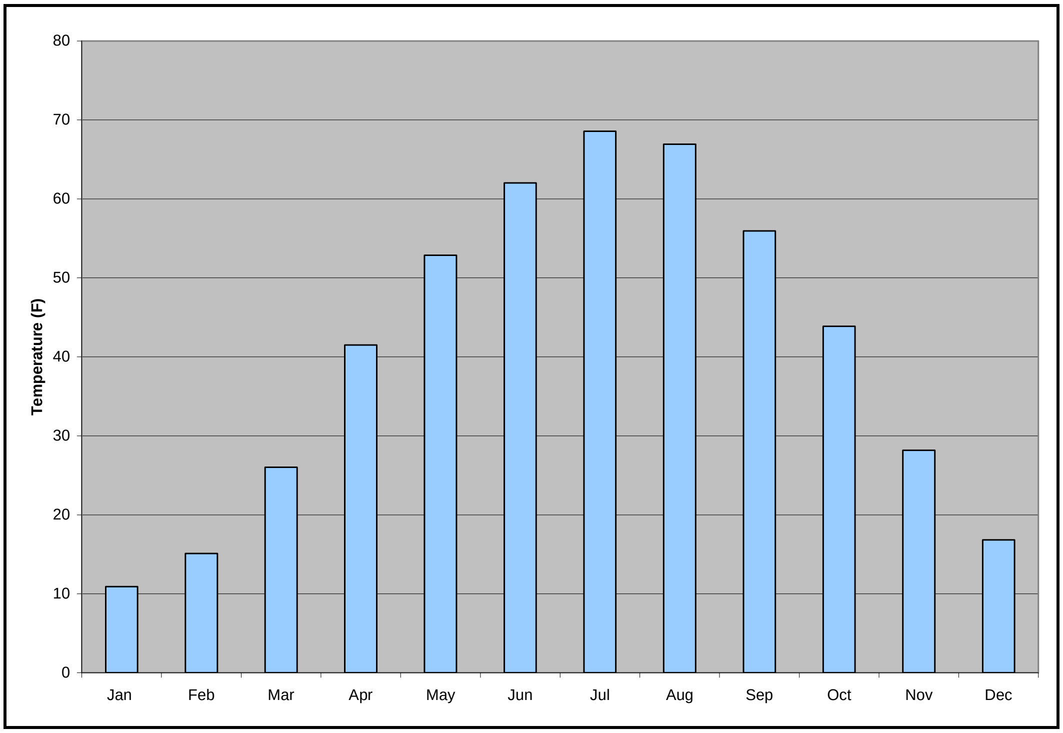

Figure 5. Average monthly temperature at the Dickinson Research Extension Center, 1892-2000.

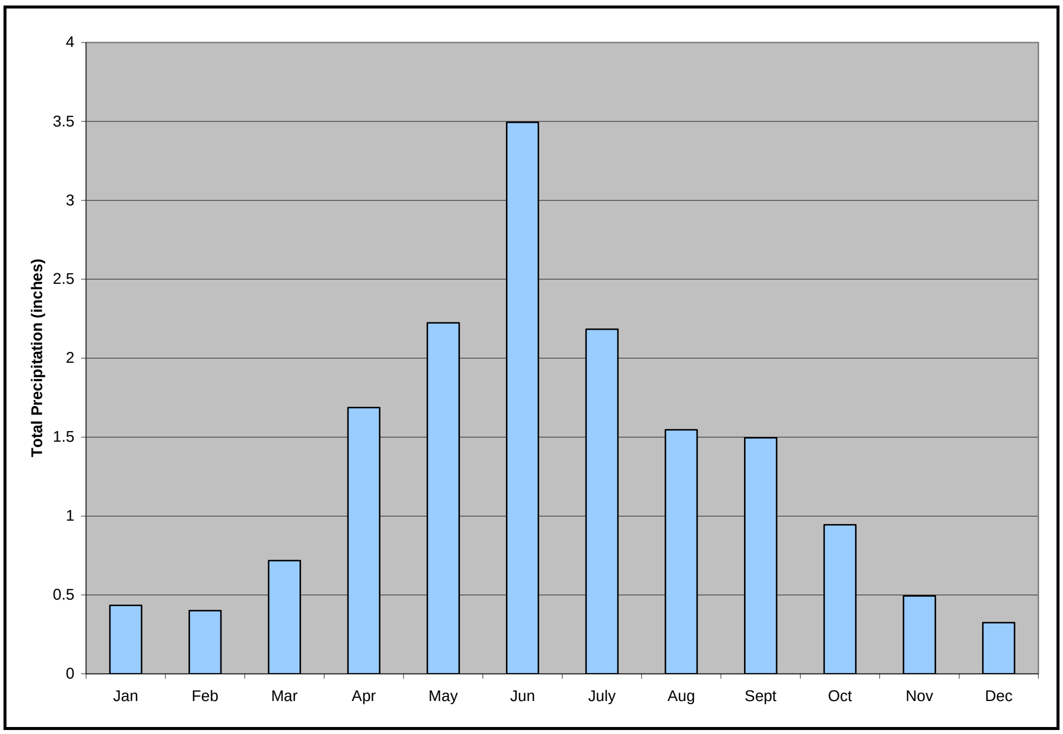

Figure 6. Average total monthly precipitation at the Dickinson Airport rain gage, 1940-1997.

1.5 Available Water Quality Data

1.5.1 Stream Data

The U.S. Geologic Survey (USGS) collected data at six sites in the Patterson Lake watershed during 1995-1996 as part of the Patterson Lake Diagnostic/Feasibility Study (Figure 7) (NDDH, 2000). Table 7 summarizes the characteristics of each station. Sampling occurred between June 3, 1995, and April 15, 1996, during multiple flow regimes. Between five and thirteen nutrient samples (total phosphorus and total nitrogen) were collected at each of these stations during the study period. Total suspended solids were sampled more often (between 33 and 66 samples at each station). Sampling also include the following:

- Estimated daily flow using stage readings and rating curves
- Estimated daily average suspended sediment
- Bed sediment particle size
- Temperature, pH, specific conductance, dissolved oxygen
- Other water chemistry

Data for the Heart River are also available at the USGS ambient sampling site (station 06343000), Heart River near South Heart. This station is located downstream of station 06342920 and includes the North Creek tributary. Data are available for multiple parameters from 1975 to 2000.

Table 7. Summary of Patterson Lake watershed monitoring stations

Station Location	Station ID	Drainage Area (square miles)	Percent of Total Watershed
South Branch Heart River below Bull Creek	6342890	113	27.6
South Branch Heart River near South Heart	6342900	20[a]	4.9
Heart River at South Heart	6342920	130[b]	31.8
North Creek near South Heart	6342970	41	10.0
Ash Creek	6343420	28	6.8
Heart River at State Avenue below Patterson Lake Dam	6344100	409	100.0

[a]Station 06342890 is located upstream of station 06342900. The drainage area reported here is the area between the two stations. The *total* drainage area at station 06342900 is 133 square miles.
[b]The total drainage area of station 06342920 is 263 square miles.

1.5.2 Lake Data

Patterson Lake was sampled at three locations between 1995 and 1996 as part of the diagnostic/feasibility study. Sampling included suspended solids, turbidity, light transparency, lakebed sediments, and water chemistry. Data were summarized and presented in the Patterson Lake Diagnostic/Feasibility Study and a USGS report titled *Water Quality in the E.A. Patterson Lake Basin, North Dakota, June 1995 through May 1996* (USGS, 1997). Monitoring stations for Patterson Lake are shown in Figure 7. Phosphorus and nitrogen data reported by the Patterson Lake Diagnostic/Feasibility Study indicated that the limiting nutrient in the lake is phosphorus. The total nitrogen to total phosphorus ratio is 8.8. Ratios above 7.2 typically indicate that phosphorus is the limiting nutrient (Chapra, 1997).

1.5.2.1 Secchi Depth Sampling

Three sets of secchi depth data were collected in Patterson Lake between 1980 and 2000 (Table 8; Figure 8). In all, 182 secchi depth samples were obtained at a total of five sites on the lake. The average long-term secchi depth for Patterson Lake was 0.55 meters (1.80 feet). However, USGS and the NDDH found lower secchi depth averages for the 1995 and 1996-study period. The USGS Patterson Lake water quality report suggested that precipitation during the study period was significantly higher than average, which may have caused more turbid conditions and lower secchi depths (USGS, 1997). In comparison, the Patterson Lake Diagnostic/Feasibility Study reported that the average secchi depth for Patterson Lake is 0.3 meters. Using a secchi depth of 0.55 meters, the Carlson trophic state index (TSI) for Patterson Lake is 68.6.

In addition to sediment, factors such as algae, total dissolved solids, and debris can affect secchi depths. Data from NDDH indicated that algae in Patterson Lake tended to be abundant or common from July through September. Algae concentrations were generally rare from April through June. Other aquatic vegetation was generally rare for most of the sampling period, except for July where several occurrences were noted.

The lowest secchi depths (most turbid conditions) in Patterson Lake on average occurred in April and May (Table 9). This is most likely because of spring precipitation events, snowmelt, and spring turnover in the lake. This also suggests that algae and plant material are not influencing turbidity as much as total suspended solids. The highest secchi depths were measured in January and February.

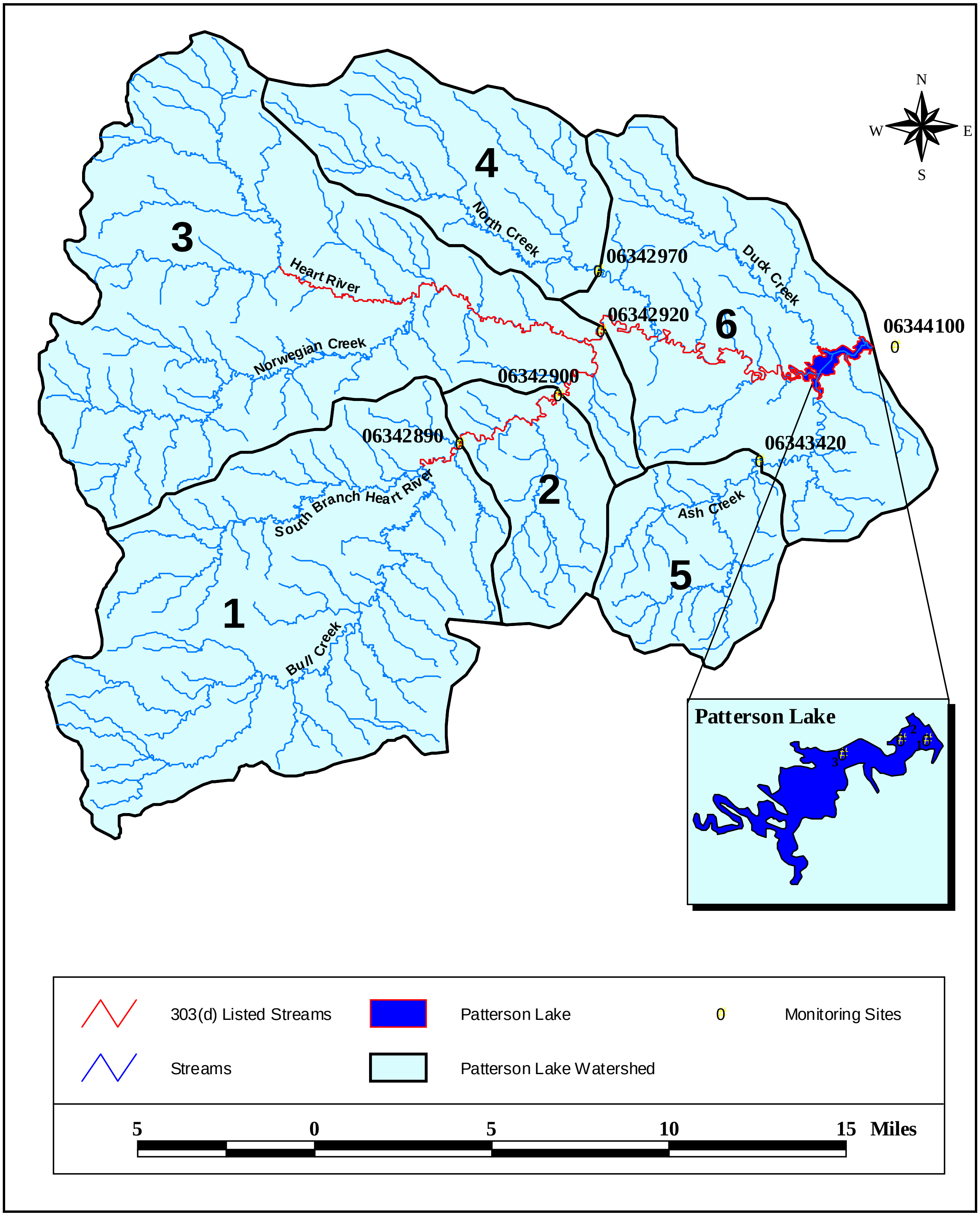

Figure 7. Location of monitoring sites in the Patterson Lake watershed.

Table 8. Secchi depth sampling in Patterson Lake

Agency	Purpose	Number of Sites	Number of Samples	Period of Record	Average Secchi Depth (meters)
USGS	Ambient sampling program	1	72	1980-2000	0.95
USGS	Patterson Lake water quality report	3	15	1995-1996	0.17
NDDH	NDDH water quality analysis	5	95	1996	0.3
Total	All sampling	5	182	1980-2000	0.55

Table 9. Average monthly Secchi depths in Patterson Lake

Month	Average Secchi Depth (meters)	Month	Average Secchi Depth (meters)
January	2.52	July	0.48
February	1.47	August	0.43
March	NA	September	0.41
April	0.35	October	0.55
May	0.21	November	0.56
June	0.36	December	NA

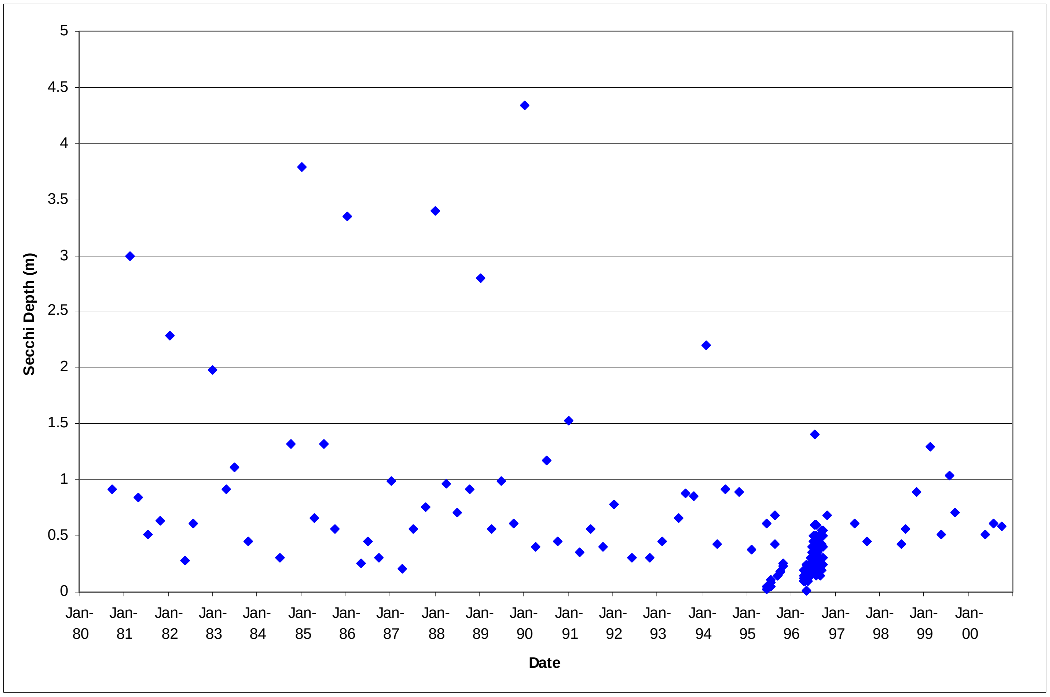

Figure 8. Secchi depth data for Patterson Lake, 1980-2000.

1.5.2.2 Total Suspended Solids

The only available total suspended solids (TSS) data for Patterson Lake were collected by NDDH in 1996. Fifty samples were collected at five sites on 10 different days between May 15 and September 24, 1996. The average TSS concentration for this time period was 20.1 mg/L (Table 10). Higher TSS concentrations were found at the shoreline station, which suggests that shoreline erosion is contributing to sediment concentrations. The lowest average TSS concentrations were found in the middle of the reservoir.

Table 10. TSS sampling in Patterson Lake

Site ID	Site Description	Average TSS (mg/L)
1	Deepest part of the reservoir	21.7
2	Littoral/shoreline	36.3
3	Inlet	18.4
4	Widest/middle part of the reservoir	10.9
5	Upper reservoir	13.4
All data		20.1

Meteorological data, such as precipitation, wind speed, and temperature, are also available for Patterson Lake. Figure 9 shows the TSS concentrations plotted with the daily precipitation data. The highest TSS concentrations for each site occurred in mid-May. The reason for this is unclear but may be due to sediment resuspension, wind, spring turnover, and effects from regulation of water in the dam. High TSS concentrations in May also coincide with the low secchi depths (more turbid conditions) found in April and May.

Average daily wind speed is plotted with TSS concentrations in Figure 10. While there was no direct correlation between daily wind speed and TSS, Figure 11 shows that higher TSS concentrations tended to be present after periods of higher winds.

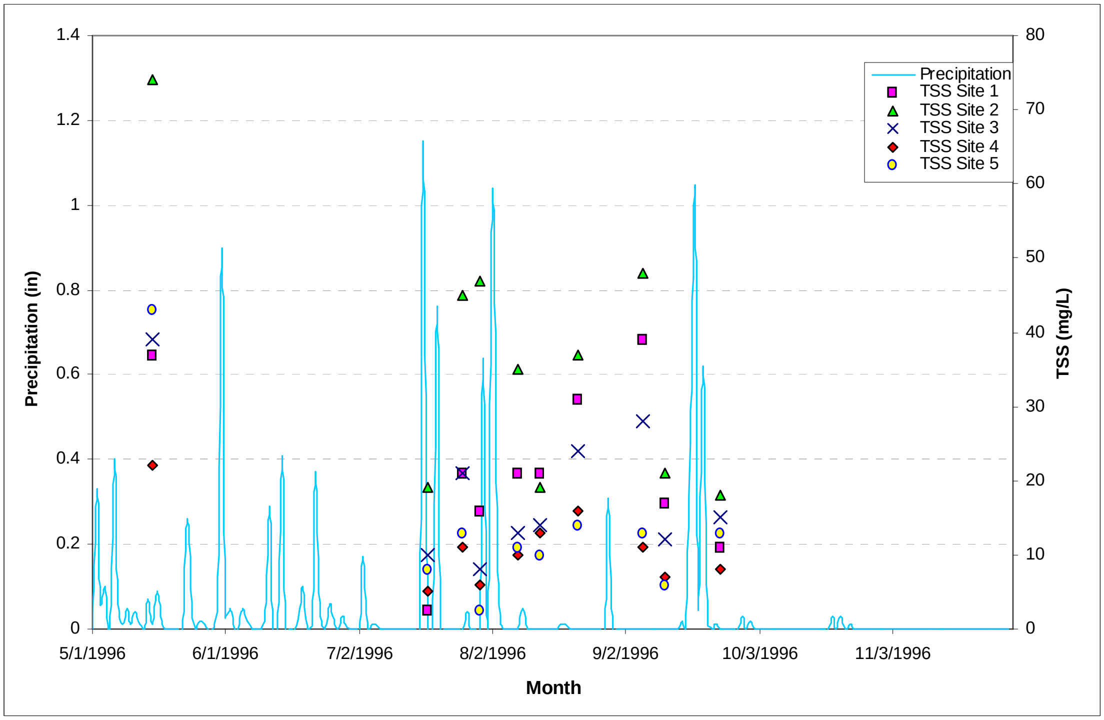

Figure 9. TSS and precipitation in Patterson Lake.

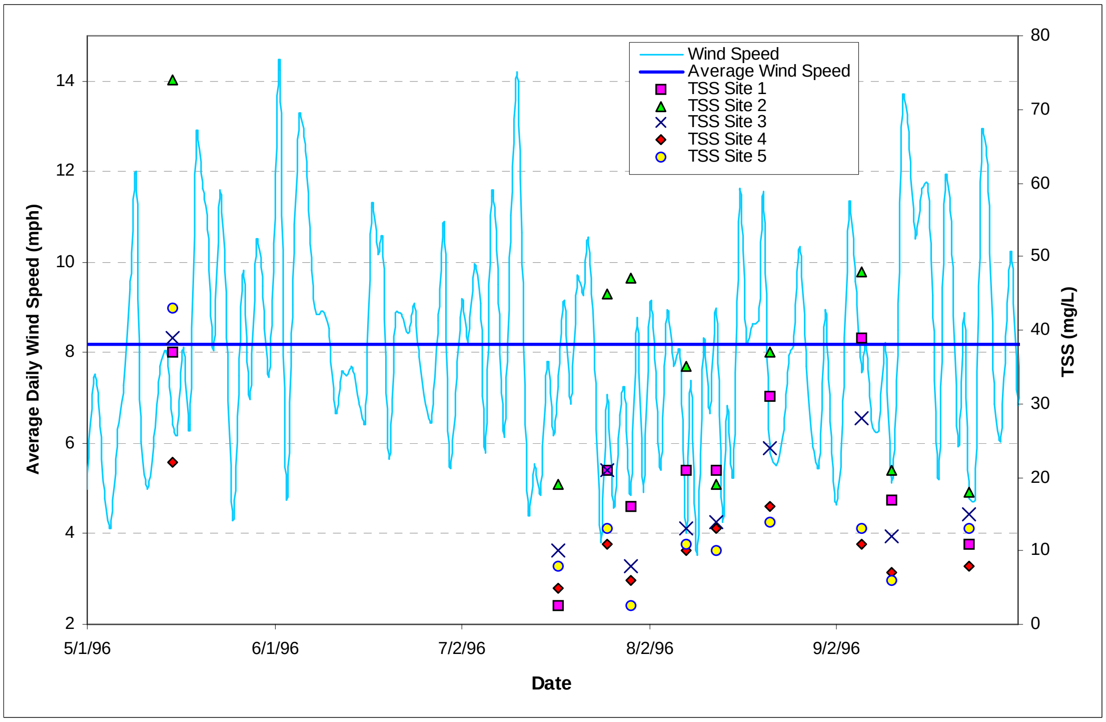

Figure 10. Wind speed and TSS in Patterson Lake, 1996.

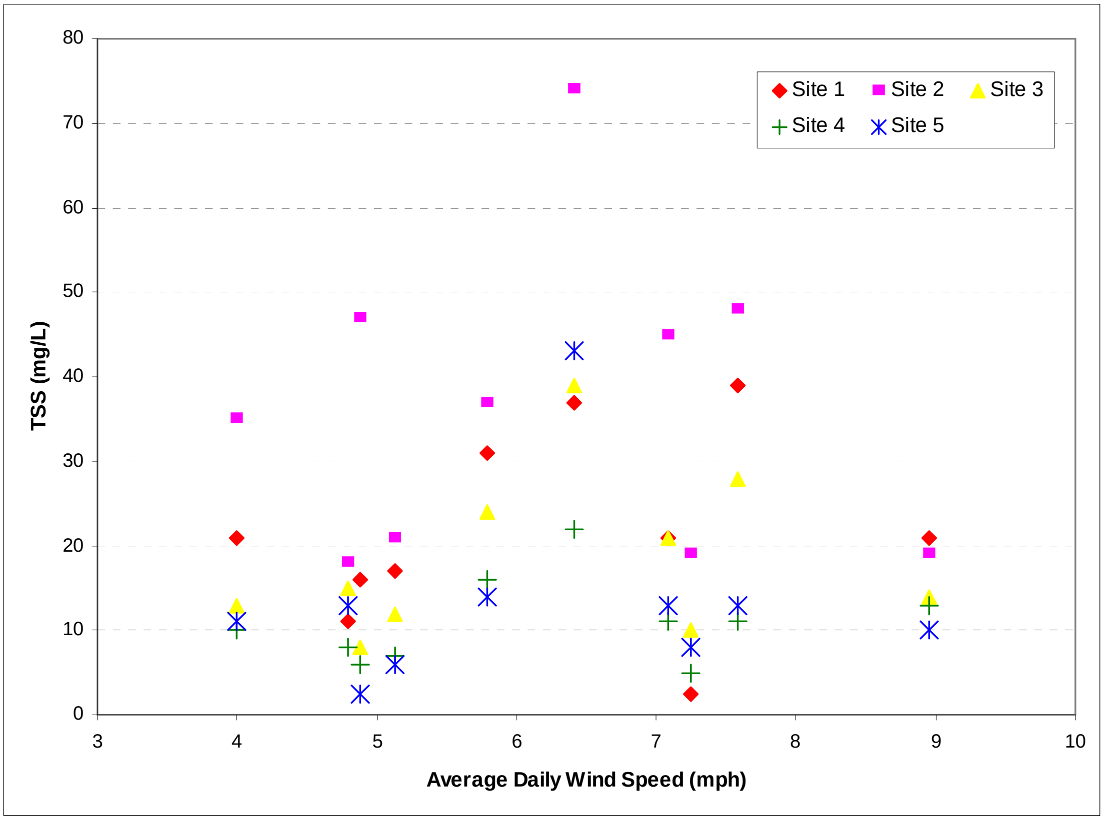

Figure 11. Average daily wind speed versus TSS in Patterson Lake, 1996.

2.0 WATER QUALITY STANDARDS

The Clean Water Act requires that Total Maximum Daily Loads (TMDLs) be developed for all waters on a state's section 303(d) list. A TMDL is defined as "the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background" such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. The purpose of a TMDL is to identify the pollutant load reductions or other actions that should be taken so that impaired waters will be able to attain water quality standards. TMDLs are required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. Separate TMDLs are required to address each cause of impairment (i.e., nutrients, sediment, bacteria). USEPA Region 8 has contracted with Tetra Tech, Inc., to develop TMDLs for nutrient and sediment impairments in Patterson Lake and impaired rivers in the Patterson Lake watershed, including the Heart River from Belfield, North Dakota, downstream to Patterson Lake and the South Branch Heart River downstream to its confluence with the Heart River. This report will not directly address other causes of impairment (habitat, organic enrichment, bacteria, and low dissolved oxygen). It is believed that these impairments might be eliminated by implementing the nutrient and sediment TMDLs. Monitoring will be continued to determine the impairment status of the lake and rivers.

2.1 Narrative Water Quality Standards

The North Dakota Department of Health has set narrative water quality standards that apply to all surface waters in the state. The narrative standards pertaining to nutrient and sediment impairments are listed below (NDDH, 2001).

- All waters of the state shall be free from substances attributable to municipal, industrial, or other discharges or agricultural practices in concentrations or combinations that 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:
    a. Cause a public health hazard or injury to environmental resources;
    b. Impair existing or reasonable beneficial uses of the receiving waters; or
    c. Directly or indirectly cause concentrations of pollutants to exceed applicable standards of the receiving waters.

In addition to the narrative standards, the NDDH 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" (NDDH, 2001).

2.2 Numeric Water Quality Standards

2.2.1 Stream Water Quality Standards

Both the Heart River and the South Branch Heart River are Class 1A and Class 3 streams The NDDH definition of Class 1A and Class 3 streams is shown below (NDDH, 2001).

> **Class 1A -** The quality of the waters in this class shall be suitable for the propagation and/or protection of resident fish species and other aquatic biota and for swimming, boating, and other water recreation. The quality of the waters shall be for irrigation, stock watering, and wildlife without injurious effects. After treatment consisting of coagulation, settling, filtration, and chlorination, or equivalent treatment processes, the

water quality shall meet the bacteriological, physical, and chemical requirements of the department for municipal or domestic use. Treatment for municipal use may also require softening to meet the requirements of the department.

Class 3 - The quality of the waters in this class shall be suitable for agricultural and industrial uses such as stock watering, irrigation, washing, and cooling. These streams have low average flows and, generally, prolonged periods of no flow. They are of limited seasonal value for immersion recreation, fish life, and aquatic biota. The quality of these waters must be maintained to protect recreation, fish, and aquatic biota.

Numeric criteria have been developed for Class 1A and Class 3 streams for some pollutants; however, there are no criteria for nitrogen, phosphorus, or sediment. Nitrate and total phosphorus guidelines have been established (maximum allowable limit) and are shown in Table 11. Comparable guidelines from the Ohio Environmental Protection Agency (OEPA) are shown in Table 11. The OEPA guidelines are based on relationships between nutrient concentrations and corresponding healthy populations of fish and macroinvertebrates.

Table 11. North Dakota nitrate and total phosphorus guidelines for Class 3 and Class 1A streams

Parameter	Guidelines (max)	OEPA Guidelines (average)
Nitrates (Dissolved)	1.0 mg/L	1.5 mg/L (small rivers)
Total Phosphorus	0.1 mg/L	0.17 mg/L (small rivers)

2.2.2 Lake Water Quality Standards

Patterson Lake has been classified as a Class 3 warm-water fishery. Class 3 lakes are “waters capable of supporting growth and propagation of nonsalmonid fishes and associated aquatic biota” (NDDH, 2001). All classified lakes in North Dakota are assigned aquatic life, recreation, irrigation, livestock watering, and wildlife beneficial uses. Lake use attainment determinations are often made using Carlson’s Trophic State Index (TSI), which is further discussed in section 3.1 (Carlson, 1977). The North Dakota State Code states that lakes shall use the same numeric criteria as Class 1 streams. However, different nitrogen and phosphorus guidelines have been established for lakes (Table 12).

Table 12. North Dakota guidelines for all classified lakes

Parameter	Criteria/Guidelines	Limit
NO_3 as N	0.25 mg/L	Maximum allowable limit
PO_4 as P	0.02 mg/L	Maximum allowable limit

3.0 TMDL TARGETS

A TMDL target is the value that is measured to judge the success of the TMDL effort. TMDL targets must be based on state water quality standards, but can also include site-specific values when no numeric criteria are specified in the standard. The following sections are broken down into two parts that cover stream and lake targets applicable to the Heart River, South Branch Heart River, and Patterson Lake.

3.1 Patterson Lake Targets

North Dakota's 1998 Clean Water Act section 305(b) report indicates that Carlson's TSI is the primary indicator used to assess beneficial uses in the state's lakes and reservoirs (NDDH, 1998b). Trophic status is the measure of productivity of a lake or reservoir and is directly related to the level of nutrients (phosphorus and nitrogen) entering the lake or reservoir from its watershed. Lakes tend to become eutrophic (more productive) with higher nitrogen and phosphorus inputs. Eutrophic lakes often have nuisance algal blooms, limited clarity, and low dissolved oxygen concentrations that can result in impaired aquatic life and recreational uses. Carlson's Trophic State Index (TSI) attempts to measure the trophic state of a lake using nitrogen, phosphorus, chlorophyll *a*, and Secchi disk depth measurements (Carlson, 1977).

According to Carlson's TSI and water quality data collected between June 3, 1995, and April 15, 1996, Patterson Lake was a hypereutrophic lake (Table 13). Hypereutrophic lakes are characterized by large growths of weeds, bluegreen algal blooms, and low dissolved oxygen concentrations. These lakes experience frequent fish kills and are generally characterized as having excessive rough fish populations (carp, bullhead, sucker) and poor sport fisheries. Because of the frequent algal blooms and excessive weed growth, these lakes are also undesirable for recreational uses such as swimming and boating.

Table 13. Carlson's trophic state indexes and Patterson Lake values

Parameter	Relationship	Units	TSI Value
Chlorophyll *a*	TSI (Chl-a) = 30.6 + 9.81[ln(Chl-a)]	µg/L	57.2
Total Phosphorus (TP)	TSI (TP) = 4.15 + 14.42[ln(TP)]	µg/L	77.2
Secchi Depth (SD)	TSI (SD) = 60−14.41[ln(SD)]	meters	77.4

TSI < 40 = Oligotrophic (least productive). TSI > 60 = Hypereutrophic (most productive)

The reason for the large difference in TSI values is unknown. According to the phosphorus and secchi depth TSI values, Patterson Lake is an extremely productive lake (hypereutrophic). Carlson and Simpson (1996) suggest that when the phosphorus and secchi depth TSI values are relatively similar and higher than the chlorophyll *a* TSI value, then dissolved color or nonalgal particulates dominate light attenuation. This is supported by the fact that Patterson Lake has a known sediment problem and is listed on the North Dakota section 303(d) list for a sediment impairment.

A Carlson's TSI target of 65 was chosen for the Patterson Lake TMDL endpoint. Carlson's TSI directly addresses the total phosphorus impairment and indirectly addresses sediment impairments by measuring water clarity (Secchi depth). The TSI target was chosen based on the knowledge that (a) phosphorus is likely the limiting nutrient in Patterson Lake, (b) sediment is affecting water clarity in Patterson Lake, and (c) best professional judgment indicates this is representative of natural conditions in lakes in southwest

North Dakota. A total phosphorus TSI target of 65 corresponds to a total phosphorus concentration target of 0.068 mg/L and a Secchi depth target of 0.71 meters (2.33 feet).

3.2 Heart River Targets

3.2.1 Nutrients

Both the Heart River and the South Branch Heart River are impaired because of nutrients, but the specific nutrient is not identified on the section 303(d) list. An analysis of USGS data at station 06343000 (Heart River near South Heart) indicated that the Heart River is phosphorus limited, with a total nitrogen to total phosphorus ratio of 9.1. A target for total phosphorus will therefore be used for the TMDL because the river is phosphorus limited.

North Dakota guidelines suggest using a water quality target of 0.1 mg/L total phosphorus and 1.0 mg/L dissolved nitrates for all streams in North Dakota (NDDH, 2001). However, the basis for these values is unknown, and they do not take into account important site-specific factors such as drainage area and background conditions. OEPA recently conducted a comprehensive study of nutrient water quality standards for streams of various watershed sizes and habitats. The results from the study indicated that small, warm-water habitat rivers (drainage areas between 200 and 1,000 square miles) should have a total phosphorus target of 0.17 mg/L (OEPA, 1999). This value is less stringent than the North Dakota standard because it considers the watershed size and habitat designation. A TMDL target of 0.17 mg/L total phosphorus concentration has therefore been chosen for the Heart River.

3.2.2 Sediment

Both the Heart River from Belfield downstream to Patterson Lake and the South Branch Heart River downstream to its confluence with the Heart River are impaired because of sediments. North Dakota standards do not specify sediment criteria for streams. However, South Dakota has a total suspended solids (TSS) standard for streams of 90 mg/L for the protection of warmwater permanent aquatic life. The sediment target of 90 mg/L TSS will be used for the South Branch Heart River and Heart River.

4.0 SIGNIFICANT SOURCES

As there are no known point sources upstream of Patterson Lake, the pollutants of concern are originating from nonpoint sources. Most of the land upstream of Patterson Lake is farmed. The remainder is used for pasture or is kept as permanent herbaceous cover. There are few urban areas. Some areas in the southern part of the watershed have been disturbed because of coal strip mining and oil exploration. These areas could be contributing sediment loads to the watershed. Nutrients are most likely being transported with overland runoff and sediment from the agricultural areas. The badland areas near South Heart are very susceptible to erosion due to geology and soils, and may be contributing major amounts of sediment to the Heart River system. The small towns of South Heart, Belfield, and Fryburg also may be contributing some nutrient loads from failing septic systems, but there are currently no data to support this.

Mean daily discharge, annual runoff, and annual yields were calculated at each of the six tributary monitoring stations in the Patterson Lake watershed (Table 14). USGS estimated that 18,510 acre-feet of water flowed into Patterson Lake between June 3, 1995, and April 15, 1996. Runoff yield for the entire Patterson Lake watershed was 45.3 acre-feet/square mile. The hydraulic residence time of the lake was 0.49 years during the study period.

Using the hydrology estimates and water quality data at each of the six monitoring stations, USGS estimated phosphorus, nitrogen, and sediment loadings and yields for each subwatershed (Tables 15 and 16). As shown in Table 17, Patterson Lake is very efficient at retaining sediment and phosphorus loadings (65 and 53 percent retention, respectively), while most of the nitrogen loadings leave the lake (4 percent retention). The South Branch Heart River has the highest sediment yield. Ash Creek and the South Branch Heart River had the highest nutrient yields.

Table 14. Summary of hydrologic characteristics for subwatersheds in the Patterson Lake watershed from June 1995 through May 1996 (NDDH, 2000)

ID	Subwatershed	Drainage Area (square miles)	Runoff (acre-feet)	Percent of Total Runoff	Runoff Yield (acre-feet/mi^2)
1	South Branch Heart River below Bull Creek	113	5280	28.5	46.7
2	South Branch Heart River near South Heart	20	2100	11.3	105.0
3	Heart River at South Heart	130	5920	32.0	45.5
4	North Creek near South Heart	41	1980	10.7	48.3
5	Ash Creek	28	1650	8.9	58.9
6	Ungaged	77	1570	8.5	20.4
	Heart River at State Avenue below Patterson Lake Dam	409	18500	99.9	—

Table 15. Phosphorus, nitrogen, and sediment loads at the Patterson Lake tributary monitoring stations from June 1995 through May 1996 (NDDH, 2000)

ID	Subwatershed	Drainage Area (square miles)	Phosphorus Load (tons)	Nitrogen Load (tons)	Sediment Load (tons)
1	South Branch Heart River below Bull Creek	113	2.79	10.08	12100
2	South Branch Heart River near South Heart	20	4.17	7.18	3300
3	Heart River at South Heart	130	2.36	15.22	2100
4	North Creek near South Heart	41	1.02	4.1	1130
5	Ash Creek	28	1.51	4.44	1490
6	Ungaged	77	NA	NA	NA
	Heart River at State Avenue below Patterson Lake Dam	409	5.57	39.46	7120

Table 16. Phosphorus, nitrogen, and sediment yields at the Patterson Lake tributary monitoring stations from June 1995 through May 1996 (NDDH, 2000)

ID	Subwatershed	Drainage Area (square miles)	Phosphorus Yield (tons/mi^2)	Nitrogen Yield (tons/mi^2)	Sediment Yield (tons/mi^2)
1	South Branch Heart River below Bull Creek	113	0.025	0.089	107.0
2	South Branch Heart River near South Heart	20	0.208	0.359	165.0
3	Heart River at South Heart	130	0.018	0.117	16.0
4	North Creek near South Heart	41	0.025	0.1	28.0
5	Ash Creek	28	0.054	0.159	53.0
6	Ungaged	77	NA	NA	NA
	Heart River at State Avenue below Patterson Lake Dam	409	0.014	0.096	17.4

Table 17. Estimate of total loads entering and leaving Patterson Lake between June 1995 through May 1996 (NDDH, 2000)

Parameter	Load Entering Lake (tons)	Load Leaving Lake[a] (tons)	Net Gain or Loss (tons)	Percent Gain or Loss
Suspended Sediment	20120	7120	13000	65
Nitrogen	41.02	39.46	1.56	4
Phosphorus	11.85	5.57	6.28	53

[a]Loads leaving Patterson Lake were measured by the Heart River at State Avenue below the Patterson Lake Dam monitoring site.

5.0 TECHNICAL ANALYSIS

Establishing a relationship between in-stream or in-lake water quality targets and source loading is a critical component of TMDL development. Identifying the cause-and-effect relationship between pollutant loads and the water quality response is necessary to evaluate the loading capacity of the receiving waterbodies. The loading capacity is the amount of pollutant that can be assimilated by the waterbody while still attaining and maintaining water quality standards. This section discusses the estimation of the loading capacity and existing loadings in Patterson Lake, the Heart River, and the South Branch Heart River.

5.1 Patterson Lake

5.1.1 Phosphorus

NDDH used the 1995 to 1996 data collection efforts in Patterson Lake and the Patterson Lake watershed to run a BATHTUB model (Walker, 1996) to predict changes in the trophic status of the lake based on changes or reductions in nutrient loadings. BATHTUB performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network, which accounts for advective and diffusive transport, and nutrient sedimentation. Eutrophication related water quality conditions are predicted using empirical relationships previously developed and tested for reservoir applications. The FLUX and PROFILE programs were used to analyze the collected water quality data and then prepare the data to calibrate the BATHTUB model. After calibrating the model, NDDH determined that predicted concentrations were similar to actual values in Patterson Lake (Table 18) (USGS, 1997).

Table 18. Observed and predicted average annual values for Patterson Lake

Variable	Units	Observed Value	Predicted Value
Total Phosphorus as P	mg/L	0.158	0.159
Total Nitrogen as N	mg/L	1.386	1.386
Organic Nitrogen as N	mg/L	0.808	0.808
Chlorophyll *a*	*u*g/L	15	15
Secchi Disk Transparency	meters	0.03	0.3

After the BATHTUB model was calibrated, several different alternatives were evaluated to predict the trophic response in Patterson Lake. Phosphorus reductions can be obtained through internal and external BMPs or restoration practices. The BATHTUB model predicted that a 75 percent reduction in internal phosphorus loadings and a 50 percent reduction in external phosphorus loadings would achieve a total phosphorus TSI of 62.87, which is below the TMDL target of 65. The loads associated with these reductions are summarized in Section 7.0.

5.1.2 Sediment

The overall target for Patterson Lake is to achieve a Carlson's TSI of 65. Because there are no sediment or total suspended solids (TSS) criteria for lakes in North Dakota, the Carlson's TSI target was used to calculate the allowable sediment loads into the lake. A TSI of 65 is equivalent to a Secchi depth of 0.71 meters. To convert this into a load, a relationship was developed between TSS and Secchi depth in Patterson Lake (Figure 12). The best fit relationship is shown below.

$$Secchi\ Depth = 1.6261\ (TSS)^{-0.5736}$$
$$R^2 = 0.7456$$

Using this relationship, a Secchi depth target of 0.71 meters is equivalent to a total suspended solids (TSS) target concentration of 4.25 mg/L. It should be noted that this relationship shows that Secchi depths and water clarity are more sensitive to TSS changes when a small concentration of TSS is initially present.

For the past 20 years, Secchi depth has been measured in Patterson Lake at the USGS ambient sampling station, and the average depth is 0.55 meters. This equates to a long-term TSS concentration of 6.5 mg/L using the relationship above. Assuming there is a direct relationship between sediment loads and resulting TSS concentrations, a 35 percent reduction in loads will be needed to meet the TMDL target.

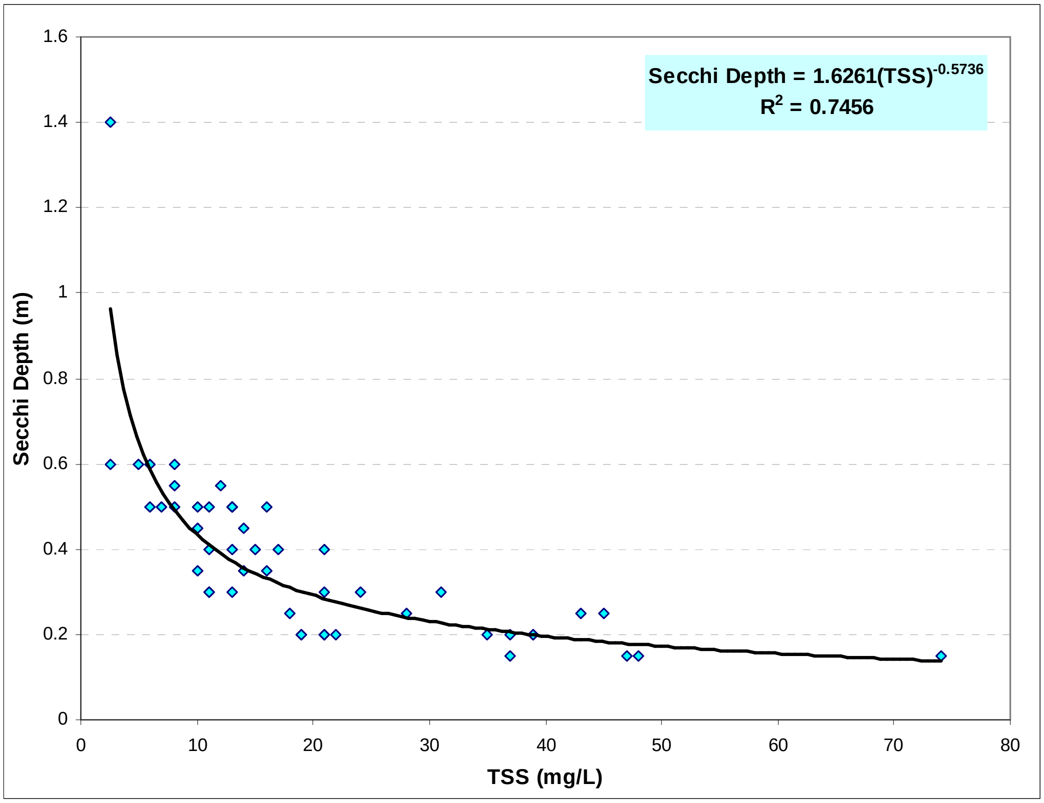

Figure 12. Secchi depth versus TSS in Patterson Lake, 1996.

5.2 Heart River and South Branch Heart River

5.2.1 Total Phosphorus

A statistical model based on flow can be used to establish existing and allowable TP loads in the Heart River if the flow record is of sufficient length and representative of long-term conditions. The available flow record at the Heart River near South Heart USGS gage (station 06343000) is 55 years. The observed daily USGS flows were arranged in order of magnitude, and each flow was assigned a percent that reflects the chance of a flow less than or equal to it. To evaluate the allowable TP loading for the watershed, each flow was then multiplied by the 0.17 mg/L target (see section 3.2.1) to calculate a corresponding maximum loading limit for each flow. The individual lines were plotted to present a loading capacity line by flow percentile, as shown in Figure 13.

Existing TP loads for the Heart River watershed were calculated using observed in-stream TP concentrations and associated flows downloaded from the USGS National Water Information System (NWIS) database for station 06343000. Daily TP loads for the Heart River were calculated for the days with both flow and TP measurements by multiplying the flow by the associated TP concentration (Figure 14). The calculated existing loads were then grouped based on 10 flow percentile groupings. Median individual loads were used to establish a line representing existing loading for all flows for the Heart River. Figure 14 presents all individual existing loadings for the Heart River and the representative loading line arranged by flow percentile.

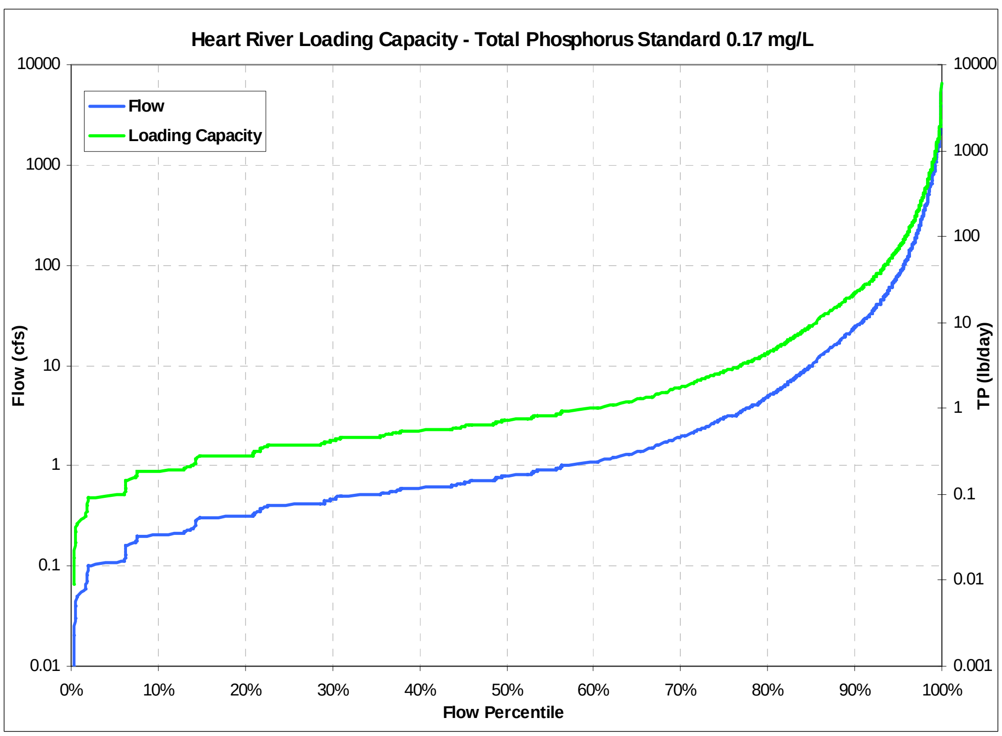

Figure 13. Loading capacity for all observed flows in the Heart River.

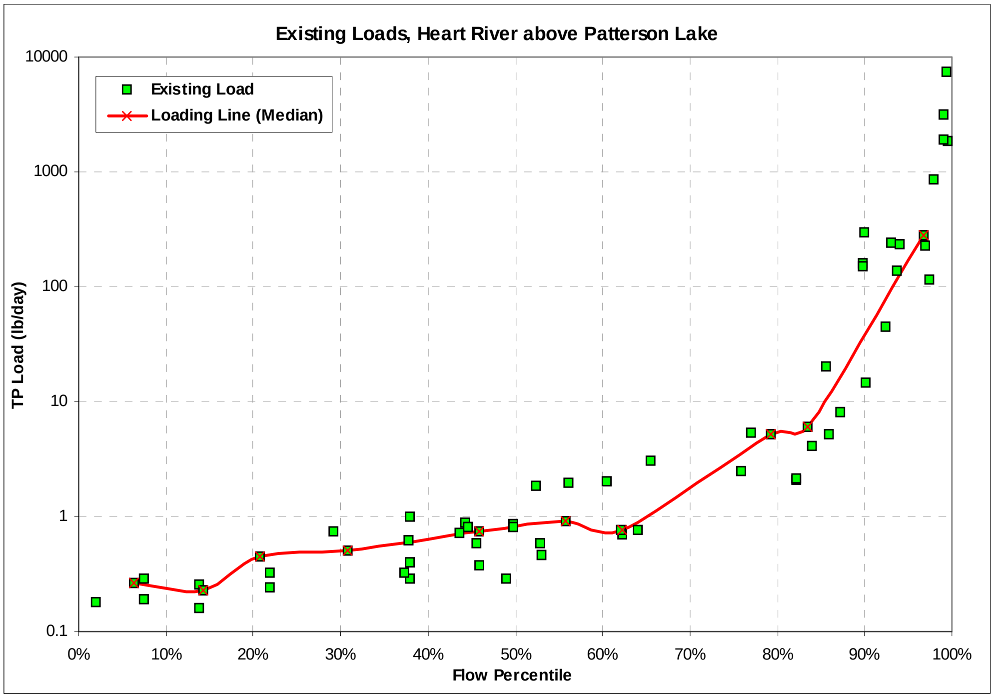

Figure 14. Existing loads and loading line for all flows in the Heart River.

To evaluate the load reductions and controls necessary to attain the TMDL target in the Heart River, the existing TP loadings were compared to the loading capacity. Figure 15 presents the estimated loading capacity curve and existing loadings based on monitoring data, arranged by flow percentile, for the Heart River. In general, most percentile groups have a median load above the loading capacity limit, indicating the need for reductions of TP loads at most flows. By plotting the loading capacities and individual existing loads by flow percentile, the specific dates of flows and loads are removed and the curve can be applied to different time periods. The estimated current and allowable TP loads for the Heart River are shown in Section 7.0. They indicate that loads must be reduced approximately 42 percent.

No long-term flow record is available for the South Branch Heart River. Therefore, the flow data for the Heart River were used to conduct a similar analysis for the South Branch. Results are summarized in Section 7.0.

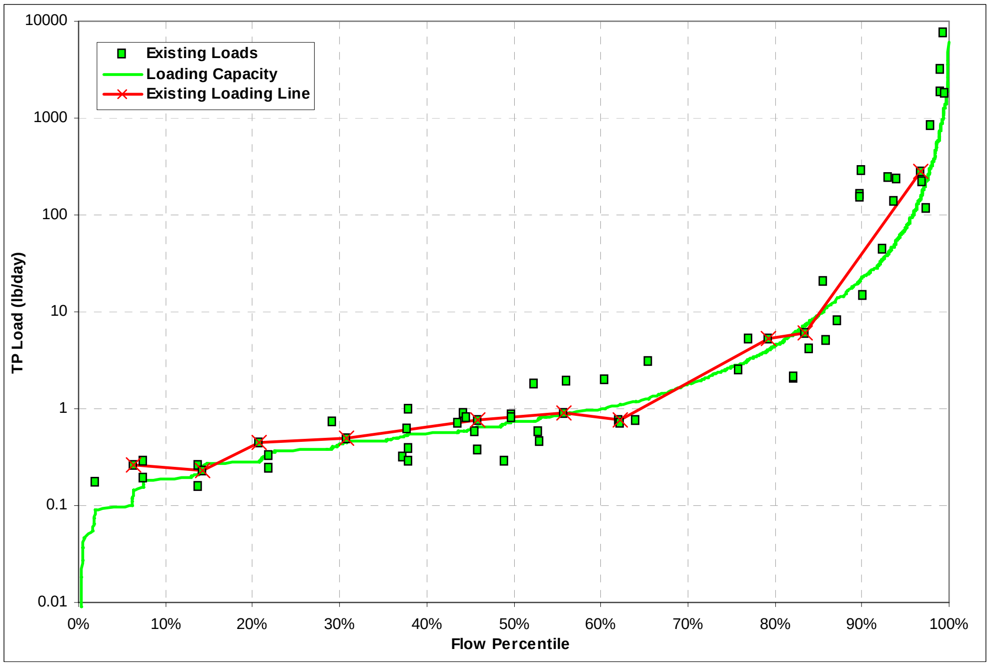

Figure 15. Estimated existing TP loading and loading capacity for the Heart River.

5.2.2 Sediment

A total suspended solids target of 90 mg/L was chosen to address the sediment impairment in the Heart River and South Branch Heart River. However, the only available data for the streams are suspended sediment concentration (SSC). USGS states that the two measurements (TSS and SSC) are relatively similar and differ only in the method of measuring the sample (USGS, 2000). Furthermore, TSS and SSC measurements are more similar when there are few sand particles suspended in solution, as is the case in the Heart River. *For the purpose of this report, it is assumed that TSS and SSC concentrations in the Heart River and South Branch Heart River are equivalent*.

A statistical loading model, similar to the total phosphorus analysis, was used to establish TSS loads at the Heart River. The available flow record at the Heart River near South Heart USGS gage (station 06343000) is 55 years. The observed daily USGS flows were arranged in order of magnitude, and each flow was assigned a percent that reflects the chance of a flow less than or equal to it. To evaluate the allowable TSS loading for the watershed, each flow was then multiplied by the 90 mg/L target to calculate a corresponding maximum loading limit for each flow. The upper 10 percent of flows were excluded from the calculation of allowable loads because of the extremity of these events and the corresponding near impossibility of meeting the target. The individual lines were plotted to present a loading capacity line by flow percentile, as shown in Figure 16.

Existing TSS loadings for the Heart River watershed were calculated using observed in-stream TSS concentrations and associated flows downloaded from the USGS NWIS database for stations 06343000 and 06342920. Daily TSS loads for the Heart River were calculated for the days with both flow and TSS measurements by multiplying the flow by the associated TSS concentration (Figure17)[1]. The calculated existing loads were then grouped based on 10 flow percentile groupings. Median individual loads per percentile group were used to establish a line representing existing loading for all flows for the Heart River. Figure 17 presents all individual existing loadings for the Heart River and the representative loading line arranged by flow percentile.

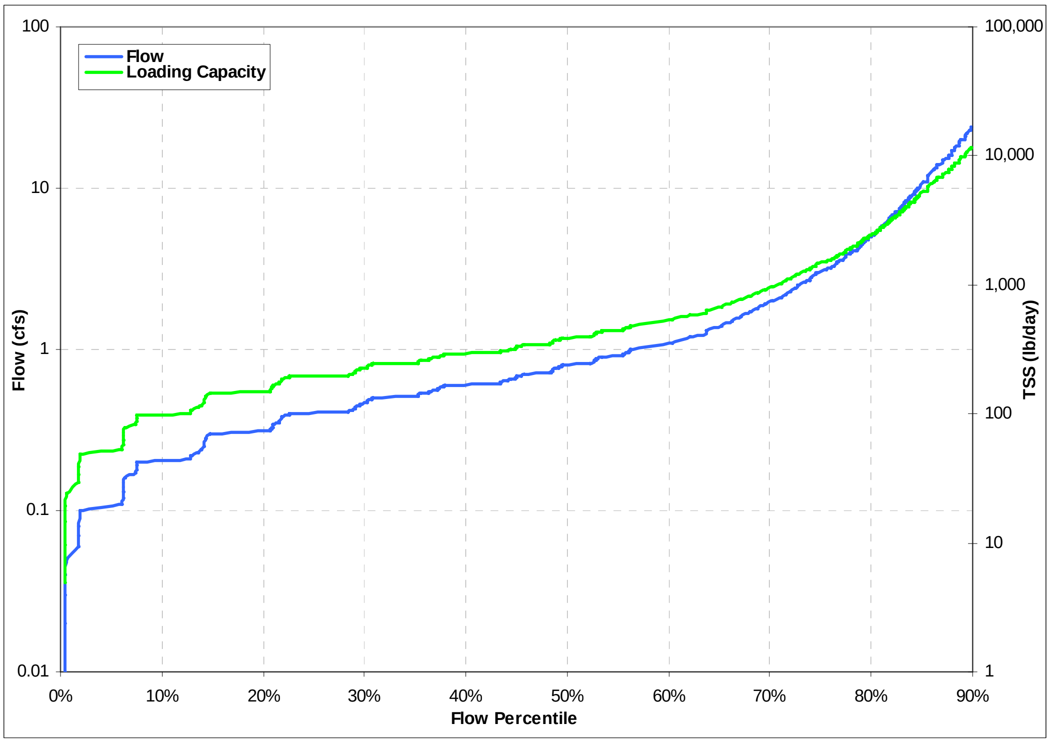

Figure 16. TSS loading capacity for all 90 percent of flows in the Heart River.

[1]Samples from July 12-15, 1995, were not included in this analysis because of possible erroneous TSS loads during that time period. The source and cause of the loads at that time are not known.

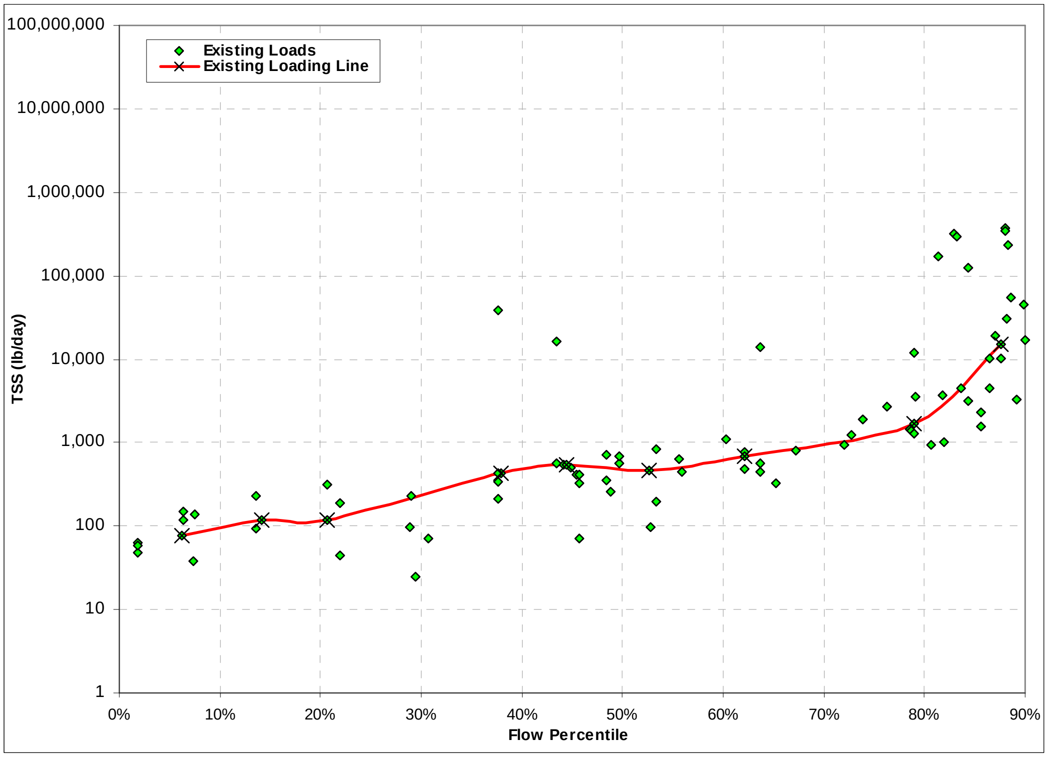

Figure 17. Existing loads and representative loading line for Heart River arranged by flow percentile.

To evaluate the load reductions and controls necessary to achieve the TMDL target in the Heart River, the existing TSS loadings were compared to the loading capacity. Figure 18 presents the estimated loading capacity curve and existing loadings based on monitoring data, arranged by flow percentile, for the Heart River. In general, the existing loading line is equal to or lower than the allowable loading capacity until higher flows occur. At high flow, the existing loading data and loading line regularly exceed the allowable loading capacity. By plotting the loading capacities and individual existing loads by flow percentile, the specific dates of flows and loads are removed and the curve can be applied to different time periods. The analysis indicates the need to reduce the loads from 265 tons/yr to 173 tons/yr (approximately a 35 percent reduction).

No long-term flow data are available for the South Branch Heart River. Also, many of the sediment samples obtained for the South Branch Heart River were obtained during wet weather events and few samples were obtained during average or low flows. A separate sediment loading analysis for the South Branch Heart River could not be conducted because of this. Therefore the TMDL for the Heart River (which includes the South Branch drainage area) encompasses the load reductions needed for the South Branch Heart River.

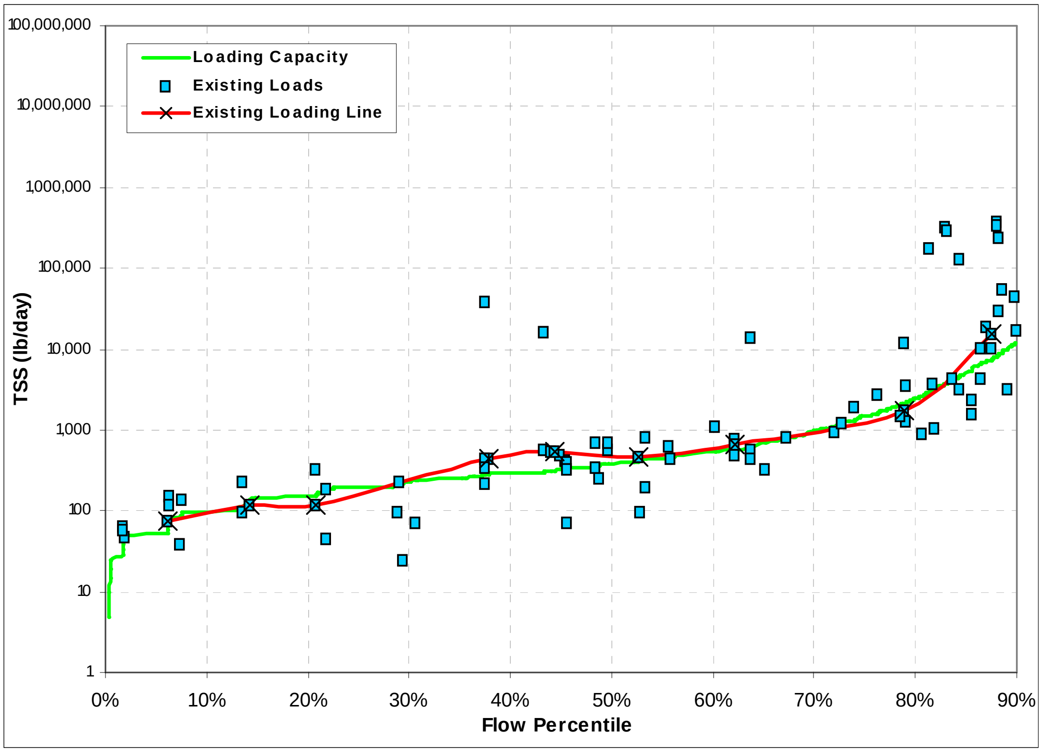

Figure 18. Estimated existing TSS loading and loading capacity for the Heart River.

6.0 MARGIN OF SAFETY AND SEASONALITY

6.1 Margin of Safety

Section 303(d) of the Clean Water Act and EPA's regulations require that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." The margin of safety (MOS) can be either incorporated into conservative assumptions used to develop the TMDL (implicit) or added as a separate component of the TMDL (explicit). The MOS has been incorporated into these TMDLs in several ways:

Patterson Lake

- The 50 percent reduction in external TP loads and 75 percent reduction in internal TP loads are predicted to result in a TSI of 62.87, which is below the target of 65.
- An explicit five percent margin of safety will be incorporated into the sediment TMDL (i.e., a 40 percent reduction in sediment loading is specified even though the analysis indicates that only a 35 percent reduction is needed).

Heart River and South Branch Heart River

- A 50 percent reduction in TP loadings is included in the TMDL (to meet the lake TMDL) even though the technical analysis indicates that only a 42 percent reduction is needed to achieve the river TMDL targets.
- An explicit five percent margin of safety will be incorporated into the sediment TMDL (i.e., a 40 percent reduction in sediment loading is specified even though the analysis indicates that only a 35 percent reduction is needed).

Post-implementation monitoring related to the effectiveness of the TMDL controls can also be used to ensure attainment of the targets, using adaptive management during the implementation phase.

6.2 Seasonality

Section 303(d)(1)(C) of the Clean Water Act and the U.S. Environmental Protection Agency (EPA's) regulations require that a TMDL be established with seasonal variations. The Patterson Lake TMDLs address seasonality because the BATHTUB model incorporates season differences in its prediction of annual average total phosphorus concentrations. The Heart River TMDLs address seasonality by evaluating existing and allowable loads over the full range of flows that in turn reflect seasonal differences.

7.0 TMDL

Tables 19 through 21 summarize the TMDLs for Patterson Lake, the Heart River, and the South Branch Heart River in terms of loading capacity, wasteload allocations, load allocations, and a margin of safety. The TMDL can be generically described by the following equation:

TMDL = LC = WLA + LA + MOS

where

LC loading capacity, or the greatest loading a waterbody can receive without violating water quality standards;
WLA wasteload allocation, or the portion of the TMDL allocated to existing or future point sources;
LA load allocation, or the portion of the TMDL allocated to existing or future nonpoint sources;
MOS margin of safety, or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. The margin of safety can be provided implicitly through analytical assumptions or explicitly by reserving a portion of loading capacity.

Table 19. Summary of TMDLs for Patterson Lake

Category	Total Phosphorus (tons/year)	Explanation	Total Suspended Solids (tons/year)	Explanation
Existing Load	11.850	From observed data	20,120	From observed data
Loading Capacity	5.925	50 percent reduction based on BATHTUB modeling	13,080	Estimate of 35 percent reduction needed to meet TSS and Secchi targets
Wasteload Allocation	0	No point sources	0	No point sources
Load Allocation	5.925	Entire loading capacity is allocated to nonpoint sources	12,425	Entire loading capacity minus MOS is allocated to nonpoint sources
MOS	Implicit	Reductions will result in TSI below target	655	Five percent of the loading capacity

Table 20. Summary of TMDLs for the Heart River[a]

Category	Total Phosphorus (tons/year)	Explanation	Total Suspended Solids (tons/yr)[b]	Explanation
Existing Load	4.751	From observed data	264.9	From observed data
Loading Capacity	2.747	Results of load duration curve analysis (see section 5.2)	173.2	Results of load duration curve analysis (see section 5.2)
Wasteload Allocation	0	No point sources	0	No point sources
Load Allocation	2.3755	A 50 percent reduction is needed to meet the Patterson Lake TMDL	164.5	Entire loading capacity minus MOS is allocated to nonpoint sources
MOS	0.3715	MOS includes the extra reductions necessary to meet Patterson Lake TMDL	8.7	Five percent of the loading capacity

[a] Note that the assessment point for the Heart River TMDLs is the USGS gage at South Heart.
[b]The upper 10 percent of flows were excluded from the calculation of allowable TSS loads in the Heart River because of the extremity of these events. Loads shown in this table are for 90 percent of flows only.

8.0 ALLOCATION

These TMDLs will be implemented by a number of parties on a volunteer basis. A draft Project Implementation Plan, included as an appendix, describes major source categories and how they might be controlled.

9.0 PUBLIC PARTICIPATION

To satisfy the public participation requirement of this TMDL, a request for comment and hard copies of the Nutrient and Sediment TMDL for Patterson Lake were mailed parcel post to participating agencies, partners, and those who requested a copy. Those included in the mailing of a hard copy are as follows:

- Natural Resource Conservation Service
- City of Dickinson, North Dakota
- North Dakota Game and Fish Department
- Western Stark Soil Conservation District
- Central Stark Soil Conservation District
- Stark County Water Resource Board

In addition to mailing copies of the Nutrient and Sediment TMDL for Patterson Lake, a public notice soliciting comment and participation was printed in the following newspapers covering the Patterson Lake and its watershed:

- The Dickinson Press, printed, December 8, 2002
- Billings County Pioneer, printed, December 12, 2002
- Golden Valley News, printed, December 12, 2002

No comments were received during the comment period regarding the Nutrient and Sediment TMDL for Patterson Lake. Questions regarding this TMDL were answered to the satisfaction of those who inquired.

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