Nutrient TMDL for Fordville Dam in Grand Forks County, North Dakota

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Prepared for:
US EPA Region 8
1595 Wynkoop Street
Denver, CO 80202-1129

Prepared by:
Michael J. Hargiss
Environmental Scientist
North Dakota Department of Health
Division of Water Quality
Gold Seal Center, 4th Floor
918 East Divide Avenue
Bismarck, ND 58501-1947

North Dakota Department of Health
Division of Water Quality

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Jack Dalrymple, Governor
Terry Dwelle, M.D., State Health Officer

North Dakota Department of Health
Division of Water Quality
Gold Seal Center, 4th Floor
918 East Divide Avenue
Bismarck, ND 58501-1947

701.328.5210

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1.0 INTRODUCTION AND DESCRIPTION OF THE WATERSHED

Fordville Dam is a 185 acre multipurpose reservoir built for flood protection, recreation, and wildlife habitat on the South Branch Forest River in Grand Forks County. The dam was completed in 1981 (NDDoH, 1993).

The recreational opportunities on Fordville Dam include fishing, boating, hiking, and swimming. The recreational area encompasses over 900 acres and is managed by the Grand Forks County Water Resource Board. Fordville Dam's recreational area is public friendly with a picnic area, outdoor toilets, boat ramp, and parking. Fordville Dam is a popular destination for local residents of Grand Forks, Nelson, and Walsh counties (NDDoH, 1993).

The Fordville Dam watershed lies within three level IV ecoregions. These are the Northern Glaciated Plains ecoregion (46i), which is characterized by a flat to gently rolling landscape composed of glacial drift; the Glacial Lake Agassiz Basin (48a), which is extremely flat with thick lacustrine sediments underlain by glacial till; and the Sand Deltas and Beach Ridges (48b), which consists of parallel lines of sand and gravel formed from the wave action of Lake Agassiz's varying shorelines (Figure 3). The subhumid climate fosters a grassland, transitional between the tall and shortgrass prairie. The historic tall grass prairie has been replaced by intensive agriculture (USGS, 2006). Though the soil is very fertile, agricultural success is subject to annual climatic fluctuations. Table 1 summarizes some of the geographical, hydrological, and physical characteristics of Fordville Dam and its watershed.

Table 1. General Characteristics of Fordville Dam and Fordville Dam Watershed.

Legal Name	Fordville Dam
Major Drainage Basin	Forest River Basin
Nearest Municipality	Inkster, North Dakota
Assessment Unit ID	ND-09020308-001-L_00
County Location	Grand Forks County
Physiographic Region	Glacial Lake Agassiz Basin
Latitude	48.17868
Longitude	-97.76023
Watershed Area	29,372 acres
Surface Area	185 acres
Average Depth	11 feet
Maximum Depth	30.4 feet
Volume	2,056.4 acre/feet
Tributaries	South Branch Forest River
Type of Waterbody	Reservoir
Dam Type	Earthen Dam
Fishery Type	Northern Pike, Walleye, Perch, Crappie and Bluegill

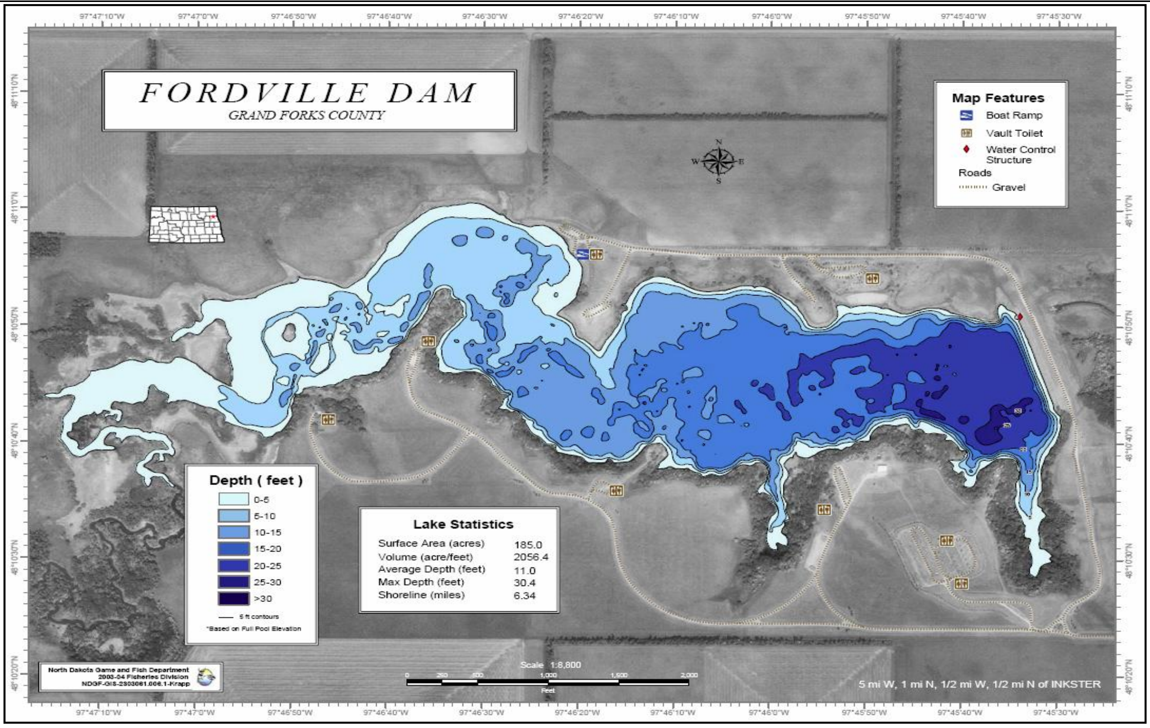

Figure 1. North Dakota Game and Fish Contour Map of Fordville Dam.

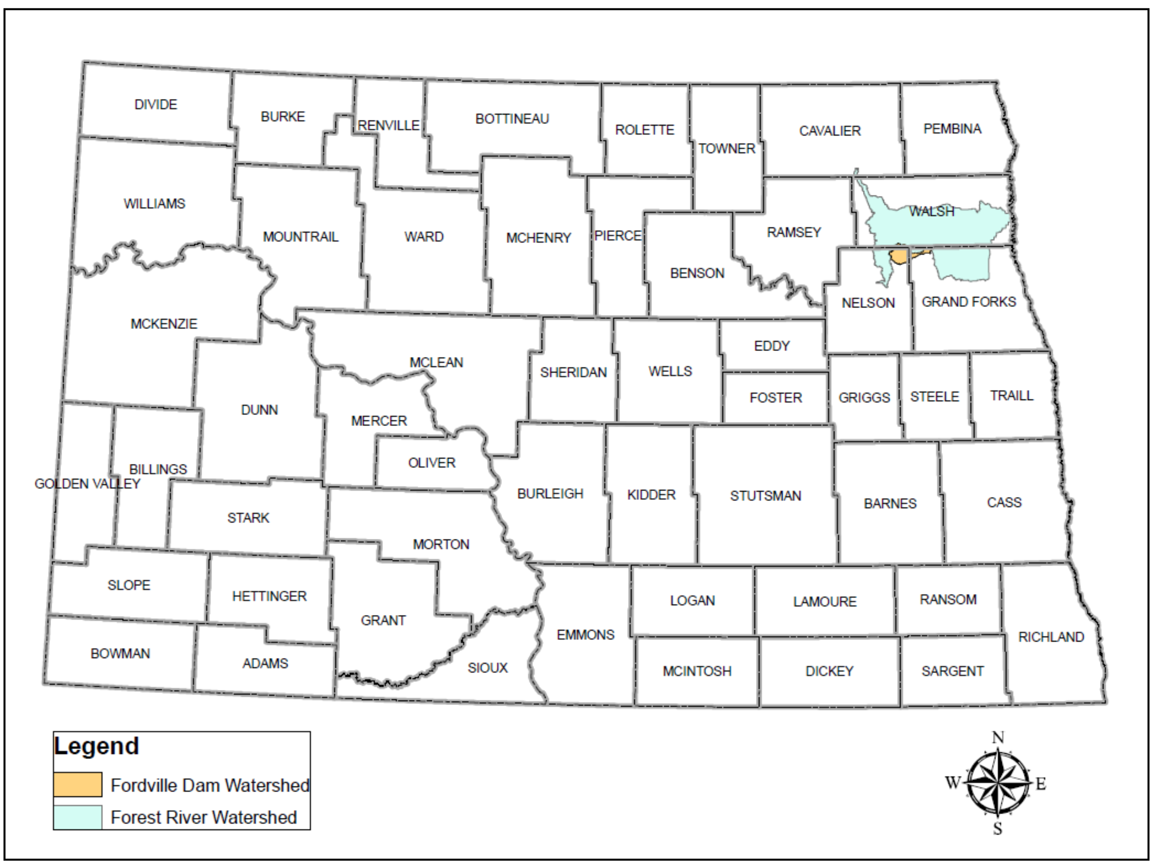

Figure 2. General Location of the Fordville Dam Watershed and Forest River Watershed.

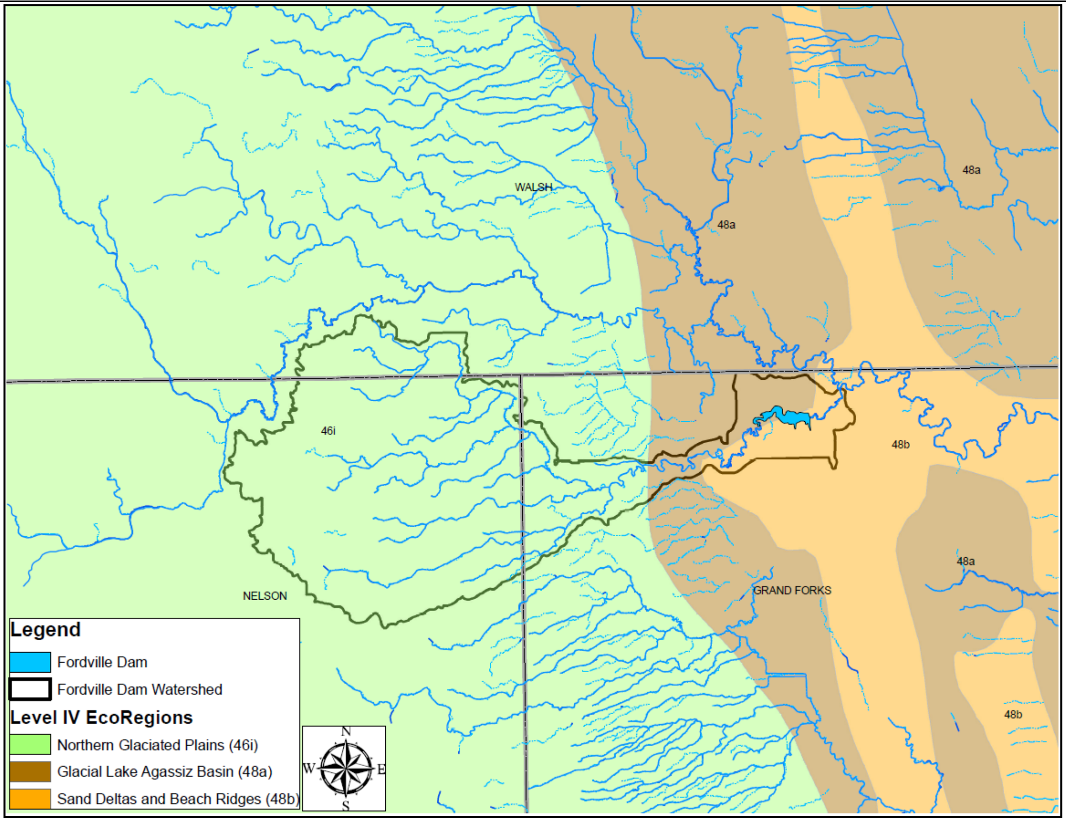

Figure 3. Level IV Ecoregions in the Fordville Dam Watershed.

1.1 Clean Water Act Section 303(d) Listing Information

As part of the 2010 Clean Water Act Section 303(d) impaired waters listing process, the North Dakota Department of Health (NDDoH) has identified Fordville Dam as an impaired waterbody (Table 2). Based on a Trophic State Index (TSI) score, recreation uses of Fordville Dam are impaired due to nutrient/eutrophication/ biological indicators. North Dakota's 2010 Section 303(d) list did not provide information on any potential sources of these impairments. This TMDL report only addresses the nutrient/eutrophication/ biological indicators impairment for recreational use.

Fordville Dam has been classified as a Class 2 cool-water fishery, "capable of supporting natural reproduction and growth of cool-water fishes (i.e. walleye and northern pike) and associated aquatic biota and marginal growth and survival of cold-water species and associated biota" (NDDoH, 2011).

The fishery that was initially established within the reservoir in 1977 consisted of northern pike, walleye, largemouth bass, crappie, and bluegill. The North Dakota Game and Fish Department conducted test netting in June 1990. The results indicated a species composition of black bullhead, yellow perch, white suckers, walleye, crappie, bluegill and northern pike. Recent fish stockings have included northern pike.

Table 2.Fordville Dam Section 303(d) Listing Information (NDDoH, 2010).

Assessment Unit ID	ND-09020308-001-L_00
Waterbody Name	Fordville Dam
Class	2 - Cool-water fishery
Impaired Uses	Recreation (fully supporting but threatened)
Causes	Nutrient/Eutrophication Biological Indicators
Priority	High
First Appeared on 303(d) list	2002

1.2 Land Use/Land Cover

Land use in the Fordville Dam watershed is primarily agricultural. According to the 2007 National Agricultural Statistical Service (NASS) land survey data, approximately 60 percent of the land is active cropland, 17 percent pasture/grassland, 12 percent wetlands, eight (8) percent in urban development, and the remaining three (3) percent in either forest, open water, barren, or fallow/idle cropland. The majority of the crops grown consist of spring wheat, dry beans, and soybeans, sunflowers, barley and corn (Figure 4).

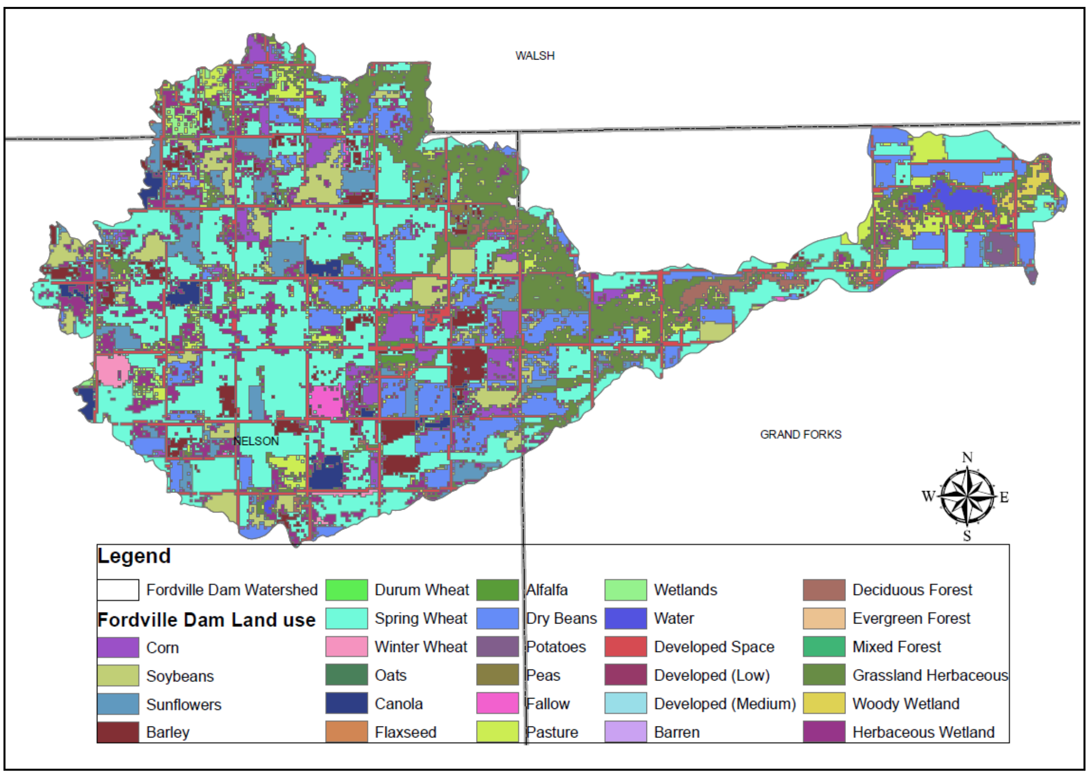

Figure 4. National Agricultural Statistical Survey 2007 Fordville Dam Watershed Land Use Map.

1.3 Climate and Precipitation

Grand Forks County has a subhumid climate characterized by warm summers with frequent hot days and occasional cool days. Winters are very cold influenced by blasts of arctic air surging over the area. Average temperatures range from 20º F in the winter to 68º F in the summer. Precipitation occurs primarily during the warm period and is normally heavy in late spring and early summer. Total average annual precipitation for Grand Forks County is about 19 inches. About 16 inches or 85 percent of rain falls between April and October. Average seasonal snowfall is approximately 41 inches. Winds prevail generally from the north at an annual average wind speed of 10 mph. Figure 4 and 5 shows the annual precipitation and temperature for Grand Forks County from 1991-2008.

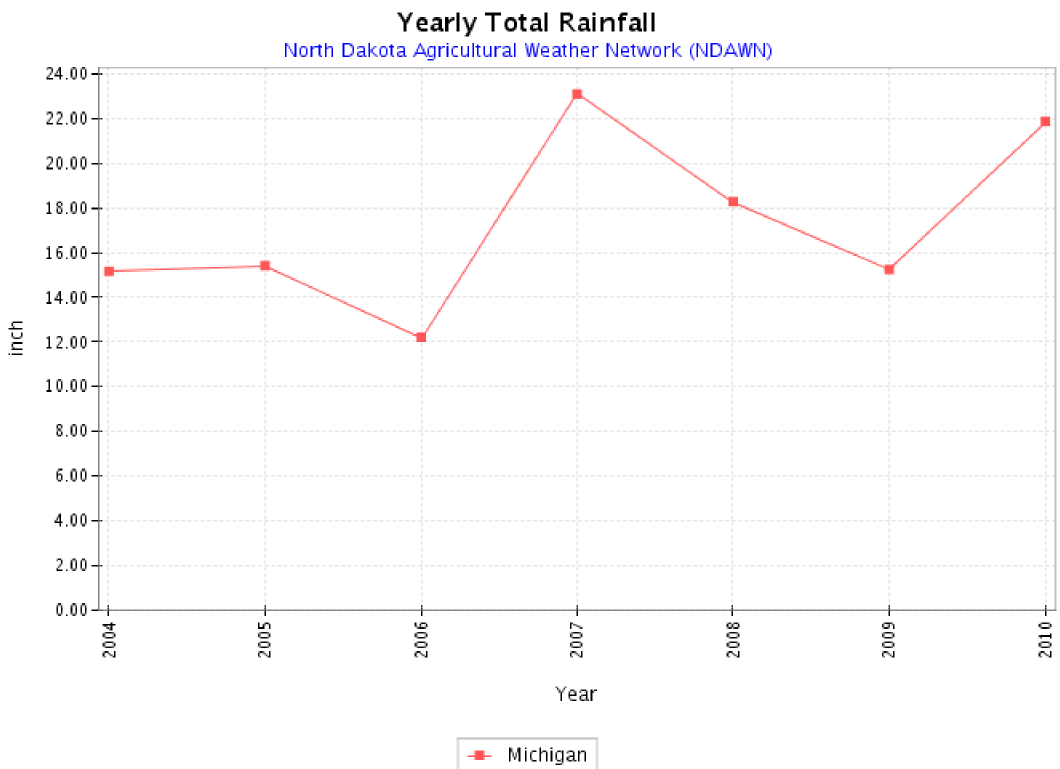

Figure 5. Total Annual Precipitation at Michigan, North Dakota from 2004-2010. North Dakota Agricultural Weather Network (NDAWN).

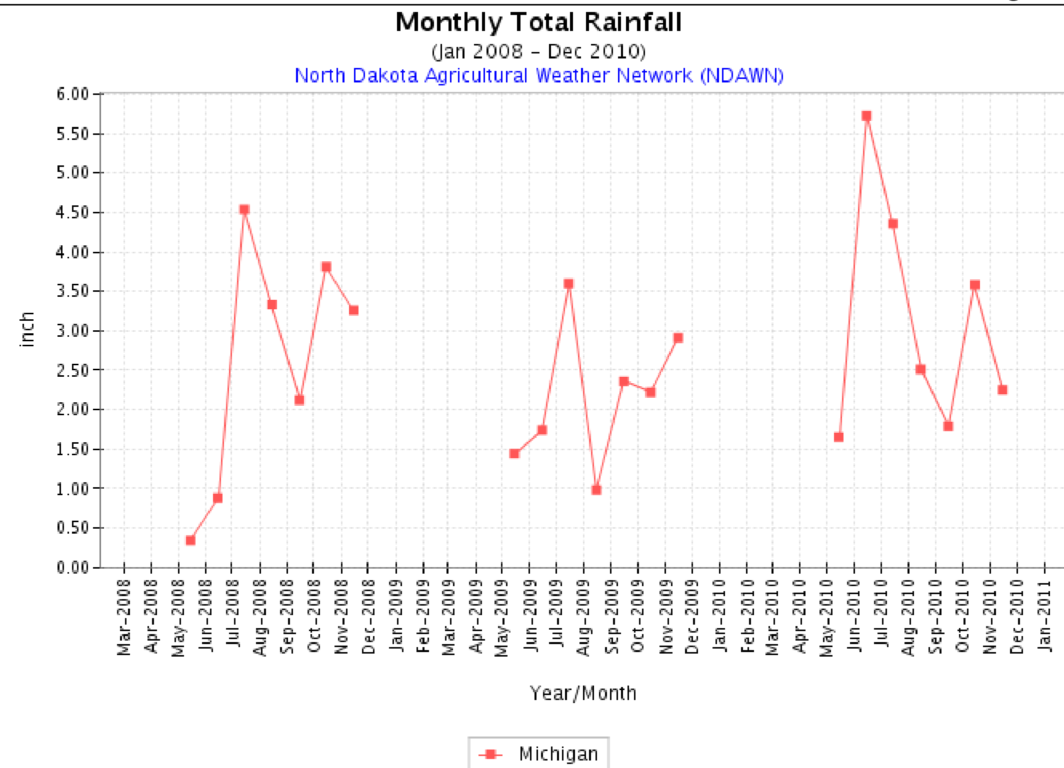

Figure 6. Monthly Total Rainfall at Michigan, North Dakota from 2008-2010. North Dakota Agricultural Weather Network (NDAWN).

1.4 Available Water Quality Data

1.4.1 1992-1993 Lake Water Quality Assessment Project

In the early 1990's through a grant from the EPA Clean Lakes Program the North Dakota Department of Health conducted a Lake Water Quality Assessment Project (LWQA) on 111 lakes and reservoirs in the state. The objective of the LWQA project was to describe the general physical and chemical condition of the state's lakes and reservoirs (NDDoH, 2002).

In cooperation with the North Dakota Game and Fish Department, lakes and reservoirs were targeted based on specific criteria. Those criteria consisted of geographic distribution, local and regional significance, fishing and recreational potential and relative trophic condition. Lakes received the highest priority if they had insufficient historical monitoring information (NDDoH, 2002).

Fordville Dam was one of the reservoirs targeted for the 1992-1993 LWQA. As such, monitoring consisted of two samples collected in the summer of 1992 and one during the winter of 1993. The samples were collected at one site located in the deepest area of the lake (381240) (Figure 6).

The 1992-1993 LWQA Project characterized Fordville Dam as having mean surface concentration of total phosphorus of 0.33 mg/L, which exceeded the State's guideline goal for lake maintenance and improvement concentration of 0.02 mg/L during all sampling occasions. Nitrate + Nitrite as N exhibited a volume weighted mean concentration of 0.11 mg/L (Table 3).

Table 3. Data Summary for Fordville Dam Lake Water Quality Assessment (1992-1993).

Parameter	Deepest Site (381240)				
	N	Avg	Max	Min	Median
Total Phosphorus (mg/L)	3	0.33	0.41	0.18	0.39
Dissolved Phosphorus (mg/L)	3	0.28	0.42	0.13	0.3
Total Nitrogen (mg/L)	3	1.6	2.41	1.17	1.21
Total Kjeldahl Nitrogen (mg/L)	3	1.14	1.95	0.62	0.85
Nitrate/Nitrite (mg/L)	3	0.11	0.29	0.01	0.02

1.4.2 2008-2010 Fordville Dam Water Quality and Watershed Assessment Project

The Grand Forks County Water Resource Board (WRB) in cooperation with the Grand Forks County Soil Conservation District (SCD) conducted a water quality and watershed assessment of Fordville Dam from November 2008 to September 2010. Sampling was conducted at one tributary inlet site (385419), at the outlet from Fordville Dam (385420), and at one reservoir site located in the deepest area of the reservoir (381240). Monitoring sites are identified in Table 4 and Figure 7.

Table 4. General Information for Water Sampling Sites for Fordville Dam.

Sample Site	Site ID	Dates Sampled		Latitude	Longitude
		Start	End		
Stream Sites					
Inlet	385419	November 2008	September 2010	48.1668934	-97.79549332
Outlet	385420	November 2008	September 2010	48.18760006	-97.74363767
Lake Sites					
Deepest	381240	January 2009	September 2010	48.17822054	-97.7601574

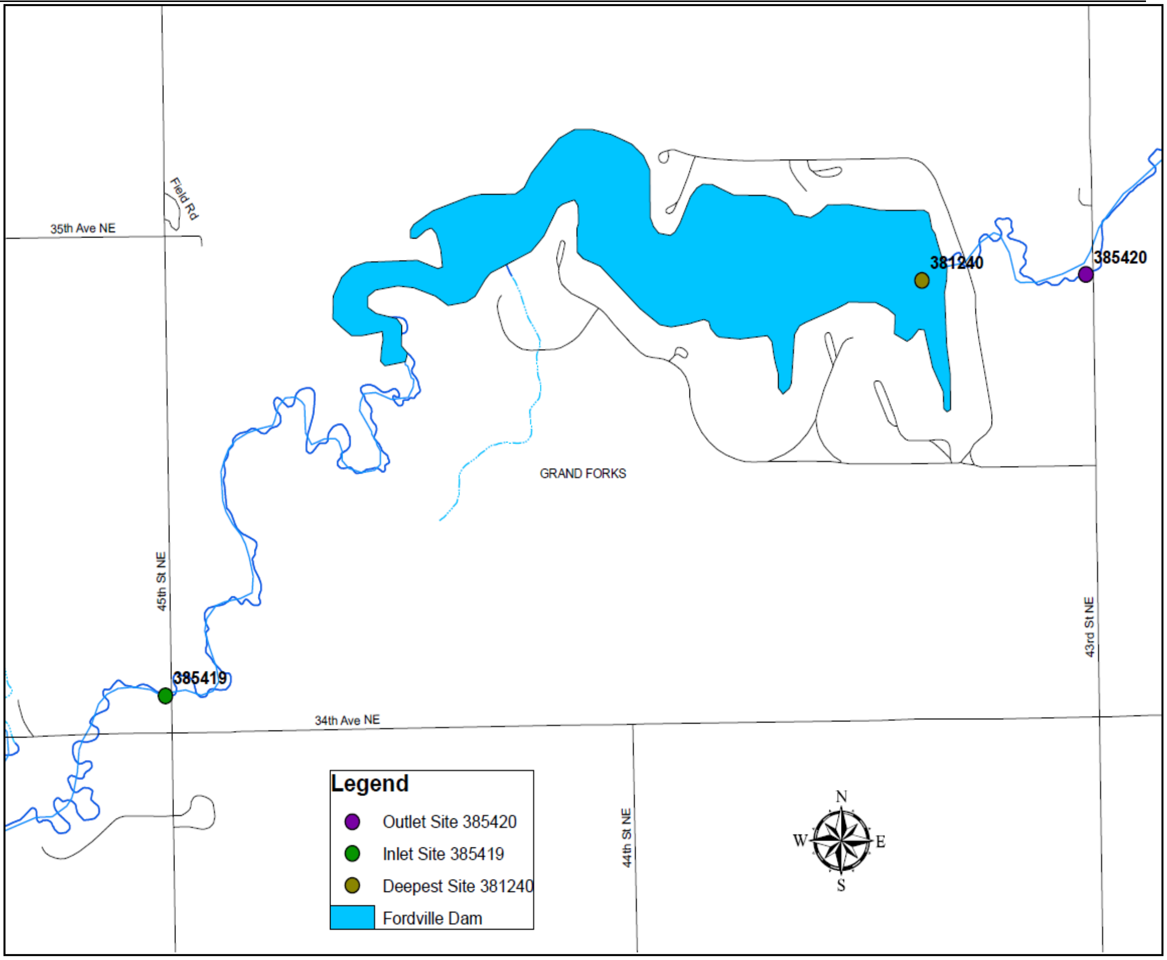

Figure 7. Stream and Lake Sampling Sites for Fordville Dam.

<u>Stream Monitoring</u>
Sampling frequency for the stream sampling sites was stratified to coincide with the typical hydrograph for the region. This sampling design resulted in more frequent samples collected during spring and early summer, typically when stream discharge is greatest and less frequent samples collected during the summer and fall. Sampling was discontinued during the winter during ice cover. Stream sampling was also terminated if the stream stopped flowing. If the stream began to flow again, water quality sampling was reinitiated.

<u>Lake Monitoring</u>
In order to accurately account for temporal variation in lake water quality, the lake was sampled twice per month during the open water season and monthly under ice cover conditions.

The Grand Forks County SCD followed the methodology for water quality sampling found in the Quality Assurance Project Plan (QAPP) for the Fordville Dam Water Quality and Watershed Assessment Project (NDDoH, 2009).

1.4.3 Nutrient Data

Water quality was monitored by the Grand Forks County SCD in Fordville Dam at the deepest site (381240) between November 2008 and September 2010. Based on the data, mean surface total phosphorus and dissolved phosphorus concentrations for Fordville Dam were 0.35 mg/L and 0.30 mg/L, respectively. Average total Kjeldahl nitrogen and nitrate/nitrite concentrations were 1.24 mg/L and 0.33 mg/L, respectively and the average total nitrogen concentration was 1.57 mg/L (Table 5).

Table 5. Data Summary for Fordville Dam Water Quality and Watershed Assessment Project 2008-2010.

	Deepest Site (381240)				
Parameter	**N**	**Avg**	**Max**	**Min**	**Median**
Total Phosphorus (mg/L)	16	0.35	0.92	0.038	0.28
Dissolved Phosphorus (mg/L)	16	0.3	0.83	0.02	0.23
Total Nitrogen (mg/L)	16	1.57	2.86	0.87	1.37
Total Kjeldahl Nitrogen (mg/L)	16	1.24	2.33	0.42	1.11
Nitrate/Nitrite (mg/L)	16	0.33	1.63	0.03	0.22
Chlorophyll-a (μg/L)	12	38.71	138	1.5	32
Secchi Disk (meters)	11	1.8	4.3	0.8	1.3

1.4.4 Secchi Disk Transparency Data

Secchi disk transparency data were collected during the open water period by the Grand Forks County SCD between May 2009 and September 2010. The average Secchi disk transparency for the sampling period was 1.79 meters. In June 2009, Fordville Dam's water level was drawn down to allow the North Dakota Game and Fish Department to install rip rap near the boat dock. The drawdown continued for several weeks complicating water quality monitoring. Due to the extensive drawdown of the dam, further water quality monitoring on the lake was discontinued for the remainder of the open water season. Lake monitoring would resume when the dam refilled with water or ice over which ever occurred first. This may explain the higher Secchi disk transparency measurements in July 2009 when compared to July 2010 (Table 6). Available data indicates a rise in trophic condition during the warmest and most productive period of the year.

Table 6. Secchi Disk Transparency Measurements in Fordville Dam Deepest Site 381240 (2009-2010).

Deepest Site 381240			
Date	**Secchi Disk Transparency (meters)**	**Date**	**Secchi Disk Transparency (meters)**
5/12/2009	1.0	6/14/2010	4.3
5/27/2009	3.2	6/29/2010	0.8
6/10/2009	2.0	7/21/2010	0.9
7/8/2009	1.3	7/28/2010	1.1
7/21/2009	2.6	8/11/2010	1.6
8/12/2009	N/A	9/17/2010	1.0

2.0 WATER QUALITY STANDARDS

The Clean Water Act requires that Total Maximum Daily Loads (TMDLs) be developed for 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 pollutant or cause of impairment (i.e., nutrients, sediment).

2.1 Narrative Water Quality Standards

The NDDoH has set narrative water quality standards, which apply to all surface waters in the state. The narrative standards pertaining to nutrient impairments are listed below (NDDoH, 2011).

- 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," (NDDoH, 2011).

2.2 Numeric Water Quality Standards

Fordville Dam is classified as a Class 2 cool water fishery. Class 2 fisheries are defined as waterbodies "capable of supporting natural reproduction and growth of cool water fishes (i.e. walleye and northern pike) and associated aquatic biota and marginal growth and survival of cold water species and associated biota" (NDDoH, 2011). All classified lakes in North Dakota are assigned aquatic life, recreation, irrigation, livestock watering, and wildlife beneficial uses. The North Dakota State Water Quality Standards (NDDoH, 2011) state that lakes shall use the same numeric criteria as Class 1 streams, including the State standard for dissolved nitrate as N, of 1.0 mg/L, where up to 10 percent of samples may exceed the 1.0 mg/L, and State guideline nutrient goals for lakes and reservoirs (Table 7).

Table 7. Numeric Standards Applicable for North Dakota Lakes and Reservoirs (NDDoH , 2011).

State Water Quality Standard	Parameter	Guidelines	Limit
Numeric Standard for Class I and Classified Lakes	Nitrates (dissolved)	1.0 mg/L	Maximum allowed[1]
Guidelines for Goals in a Lake Improvement or Maintenance Program	NO3 as N	0.25 mg/L	Goal
	PO4 as P	0.02 mg/L	Goal

[1] "Up to 10% of samples may exceed"

3.0 TMDL TARGETS

A TMDL target is the value that is measured to judge the success of the TMDL effort. TMDL targets should 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 summarize water quality targets for Fordville Dam based on its beneficial uses. If the specific target is met, it is assumed the reservoir will meet the applicable water quality standards, including its designated beneficial uses.

3.1 TSI Target

North Dakota's 2010 Integrated Section 305(b) Water Quality Assessment Report indicates that Carlson's Trophic State Index (TSI), based on Secchi Disk transparency depth, chlorophyll-a concentration, and/or total phosphorus concentration are the primary indicators used to assess beneficial uses of the State's lakes and reservoirs (NDDoH, 2010). Trophic state 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 and limited water clarity that can result in impaired aquatic life and recreational uses. Carlson's TSI attempts to measure the trophic state of a lake using nitrogen, phosphorus, chlorophyll-a, and Secchi disk depth measurements (Carlson, 1977).

The three variables (chlorophyll-*a*, Secchi disk transparency, and total phosphorus) used in Carlson's TSI independently estimate algal biomass (production as a result of excess nutrients). The three index variables are interrelated by linear regression models, and should produce the same index value for a given combination of variable values. Any of the three variables can therefore, theoretically be used to classify a waterbody. For the purpose of classification, priority is given to chlorophyll-*a*, because this variable is the most accurate of the three at predicting algal biomass (Carlson, 1980). While transparency and phosphorus may co-vary with trophic state, many times the changes in transparency are not caused by changes in algal biomass, but may be due to particulate sediment. Total phosphorus may or may not be strongly related to algal biomass due to light limitation and/or nitrogen and carbon limitation. Therefore, neither transparency nor phosphorus is an independent estimator of trophic state (Carlson and Simpson, 1996).

Based on Carlson's TSI and water quality data collected between May 2009 and September 2010, Fordville Dam was generally assessed as a eutrophic to hypereutrophic lake (Table 8). Eutrophic lakes are characterized by the growth of weeds and occasional bluegreen algal blooms. Because of the algal blooms and weed growth, these lakes are also undesirable for recreational uses such as swimming and boating.

Table 8. Carlson's Trophic State Indices for Fordville Dam.

Parameter	Relationship	Units	TSI Value	Trophic Status
Chlorophyll-a	TSI (Chl-a) = 30.6 + 9.81[ln(Chl-a)]	µg/L	66.46	Hypereutrophic
Total Phosphorus (TP)	TSI (TP) = 4.15 + 14.42[(ln(TP)]	µg/L	82.30	Hypereutrophic
Secchi Depth (SD)	TSI (SD) = 60 - 14.41[ln(SD)]	meters	51.53	Eutrophic
Total Nitrogen (TN)	TSI (TN) = 54.45 + 14.43[ln(TN)]	mg/L	59.30	Eutrophic

TSI < 30 - Oligotrophic (least productive) TSI 30-50 Mesotrophic
TSI 50-65 Eutrophic TSI > 65 - Hypereutrophic (most productive)

According to the phosphorus TSI value, Fordville Dam is a very productive lake (hypereutrophic) (Figure 8). Carlson and Simpson (1996) suggest that if the phosphorus TSI value is higher than the chlorophyll-a and Secchi disk transparency TSI value, then algae dominates light attenuation but some factor such as nitrogen limitation, zooplankton grazing, or toxics limit algal biomass as is the case with Fordville Dam (Table 9). Carlson and Simpson (1996) also state that a nitrogen index value might be a more universally applicable nutrient index than a phosphorus index, but it also means that a correspondence of the nitrogen index with the chlorophyll-a index cannot be used to indicate nitrogen limitation.

Table 9. Relationships Between TSI Variables and Conditions.

Relationship Between TSI Variables	Conditions
TSI(Chl) = TSI(TP) = TSI(SD)	Algae dominate light attenuation; TN/TP ~ 33:1
TSI(Chl) > TSI(SD)	Large particulates, such as *Aphanizomenon* flakes, dominate
TSI(TP) = TSI(SD) > TSI(CHL)	Non-algal particulates or color dominate light attenuation
TSI(SD) = TSI(CHL) > TSI(TP)	Phosphorus limits algal biomass (TN/TP >33:1)
TSI(TP) >TSI(CHL) = TSI(SD)	Algae dominate light attenuation but some factor such as nitrogen limitation, zooplankton grazing or toxics limit algal biomass.

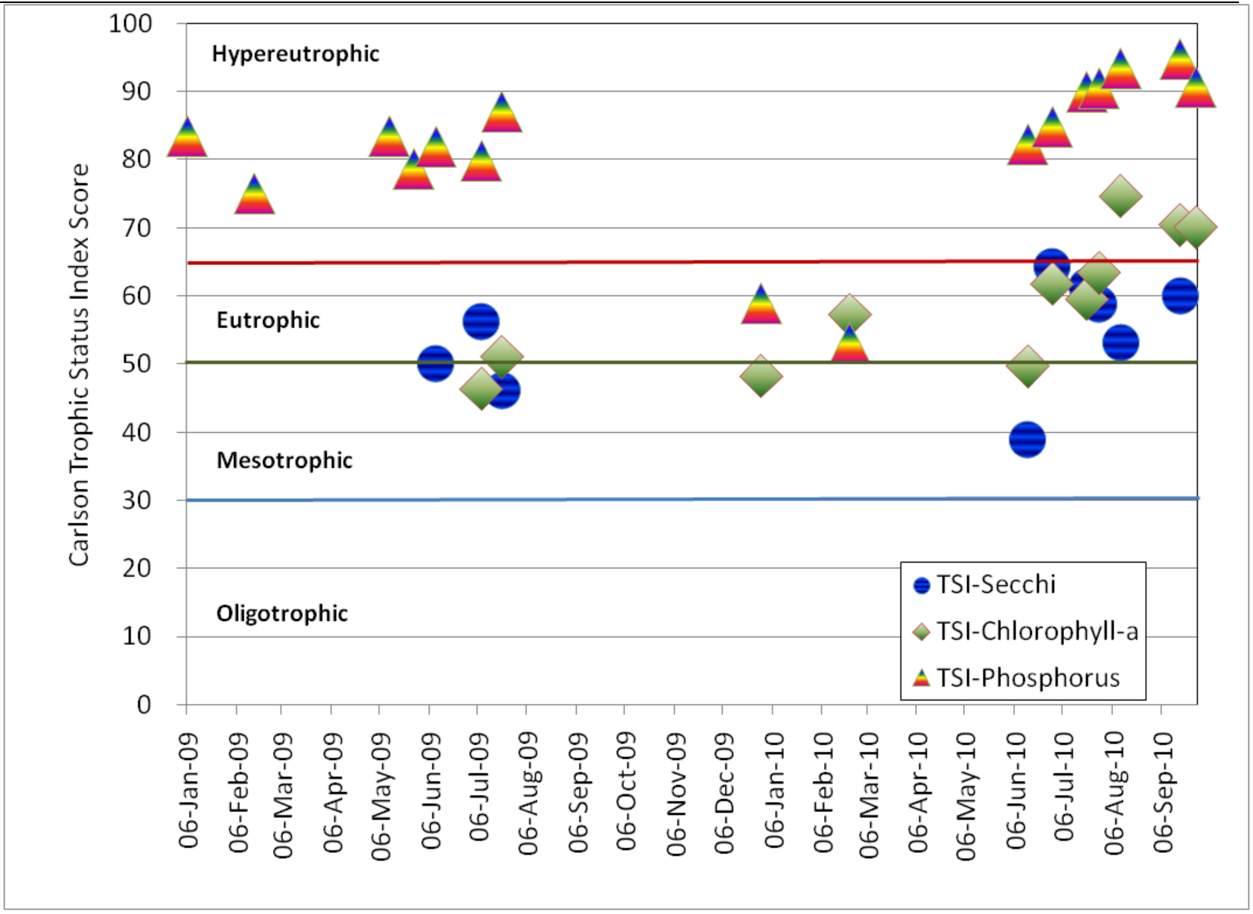

Figure 8. Temporal Distribution of Carlson's Trophic Status Index Scores for Fordville Dam.

A Carlson's chlorophyll-a TSI target of 58.7, equivalent to a 50 percent reduction in total phosphorus loading as modeled by BATHTUB, was chosen for the Fordville Dam TMDL endpoint. This will reduce average growing season concentrations of chlorophyll-a , total phosphorus and total nitrogen to 17.5 µg/L, 0.113 mg/L and 0.733 mg/L, respectively, which is predicted to result in a change of trophic status for the lake from hypereutrophic to eutrophic.

4.0 SIGNIFICANT SOURCES

There are no known point sources upstream of Fordville Dam. The pollutants of concern originate from non-point sources.

5.0 TECHNICAL ANALYSIS

Establishing a relationship between in-stream water quality targets and pollutant 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 waterbody. The loading capacity is the amount of a pollutant that can be assimilated by the waterbody while still attaining and maintaining water quality standards. This section discusses the technical analysis used to estimate existing loads to Fordville Dam and the predicted trophic response of the reservoir to reductions in loading capacity.

5.1 Tributary Load Analysis

To facilitate the analysis and reduction of tributary inflow and outflow water quality and flow data the FLUX program was employed. The FLUX program, developed by the US Army Corps of Engineers Waterways Experiment Station (Walker, 1996), uses six calculation techniques to estimate the average mass discharge or loading that passes through a given river or stream site. FLUX estimates loadings based on grab sample chemical concentrations and the continuous daily flow record. Load is therefore defined as the mass of a pollutant during a given time period (e.g., hour, day, month, season, year). The FLUX program allows the user, through various iterations, to select the most appropriate load calculation technique and data stratification scheme, either by flow or date, which will give a load estimate with the smallest statistical error, as represented by the coefficient of variation. Output from the FLUX program (Appendix A) is then provided as an input file to calibrate the BATHTUB eutrophication response model. For a complete description of the FLUX program the reader is referred to Walker (1996).

5.2 BATHTUB Trophic Response Model

The BATHTUB model (Walker, 1996) was used to predict and evaluate the effects of various nutrient load reduction scenarios on Fordville Dam. BATHTUB performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network. The model 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 BATHTUB model is developed in three phases. The first two phases involve the analysis and reduction of the tributary and in-lake water quality data. The third phase involves model calibration. In the data reduction phase, the in-lake and tributary monitoring data collected as part of the project were summarized in a format which can serve as inputs to the model.

The tributary data were analyzed and reduced by the FLUX program. FLUX uses tributary inflow and outflow water quality and flow data to estimate average mass discharge or loading that passes a river or stream site using six calculation techniques. Load is therefore defined as the mass of a pollutant during a given unit of time. The FLUX model then allows the user to pick the most appropriate load calculation technique with the smallest statistical error. Output for the FLUX program is then used to calibrate the BATHTUB model.

The reservoir data were reduced in Excel using three computational functions. These include: 1) the ability to display concentrations as a function of depth, location, or date; 2) summary statistics (mean, median, etc.); and 3) evaluation of trophic status. The output data from the Excel program were then used to calibrate the BATHTUB model.

When the input data from FLUX and Excel programs are entered into the BATHTUB model the user has the ability to compare predicted conditions (model output) to actual conditions using general rates and factors. The BATHTUB model is then calibrated by combining tributary load estimates for the project period with in-lake water quality estimates. The model is termed calibrated when the predicted estimates for the trophic response variables are similar to observed estimates from the project monitoring data. BATHTUB then has the ability to predict total phosphorus concentration, chlorophyll-a concentration, and Secchi disk depth along with and the associated TSI scores as a means of expressing trophic response.

As stated above, BATHTUB can compare predicted vs. actual conditions. After calibration, the model was run based on observed concentrations of phosphorus and nitrogen, to derive an estimated annual average total phosphorus load of 6,610.3 kg and annual average nitrogen load of 37,927.5 kg. The model was then run to evaluate the effectiveness of a number of nutrient reduction alternatives including; (1) reducing externally derived nutrient loads; (2) reducing internally available nutrients; and (3) reducing both external and internal nutrient loads (See Appendix C for more detail).

BATHTUB modeled the trophic response of Fordville Dam by reducing externally derived nutrient loads. Phosphorus was used in the initial set of simulation models based on its known relationship to eutrophication and that it is controllable with the implementation of watershed Best Management Practices (BMPs) or lake restoration methods. Simulated reductions were achieved by reducing concentrations of phosphorus and nitrogen in the contributing tributaries by 10, 25, 50, and 75 percent while keeping the hydraulic discharge constant (Table 10).

Table 10. Observed and Predicted Values for Selected Trophic Response Variables Assuming a 10, 25, 50, and 75 Percent Reduction in External Phosphorus and Nitrogen Loading.

Variable	Observed Value	Predicted Value			
		10%	25%	50%	75%
Total Phosphorus (mg/L)	0.256	0.203	0.169	0.113	0.057
Total Nitrogen (mg/L)	1.436	1.297	1.085	0.733	0.381
Chlorophyll-a (µg/L)	38.7	34.31	27.94	17.46	6.54
Secchi Disk Transparency (meters)	1.8	1.88	2.06	2.44	3.01
Carlson's TSI for Phosphorus	82.3	80.77	78.15	72.34	62.44
Carlson's TSI for Chlorophyll-a	66.46	65.28	63.27	58.66	49.03
Carlson's TSI for Secchi Disk	51.53	50.87	49.58	47.17	44.13

To acquire a noticeable change in the tropic status of Fordville Dam, the BATHTUB model predicted that a 50 percent reduction in external total phosphorus (and nitrogen) loads would achieve the phorphorus TSI target of 0.113 mg/L. This reduction in phosphorus loading is predicted to result in a reservoir in the eutrophic status range (Figure 9).

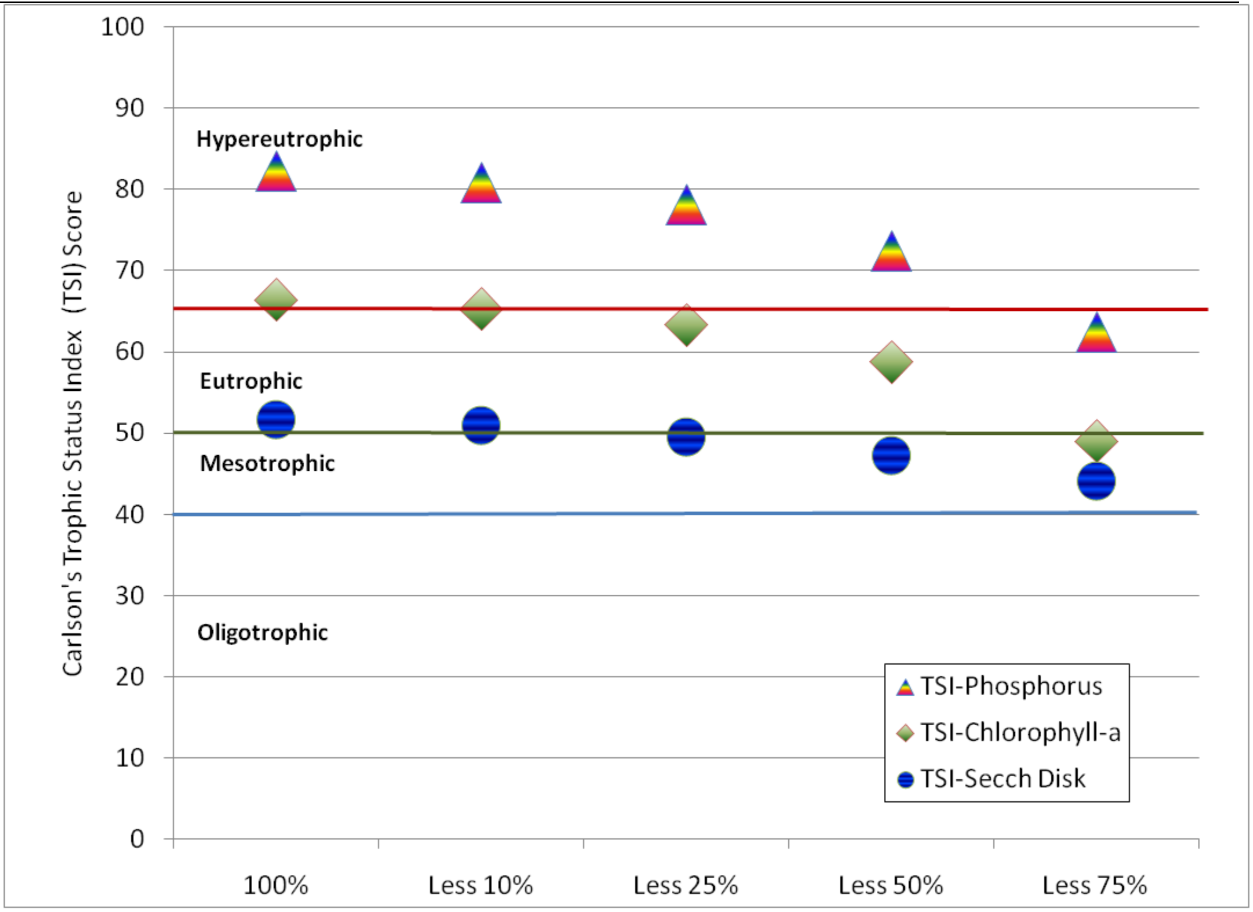

Figure 9. Predicted Trophic Response Measured by Carlson's TSI Scores to Phosphorus Load Reductions to Fordville Dam of 10, 25, 50, and 75 Percent.

5.3 AnnAGNPS Watershed Model

The Annualized Agricultural NonPoint Source Pollution (AnnAGNPS) model was developed by the USDA Agricultural Research Service and Natural Resource Conservation Service (NRCS). 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).

A daily mass balance 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 input data categories can be split into five major classifications: climatic data, land characterization, field operations, chemical characteristics, and feedlot operations. Climatic data includes precipitation, maximum and minimum air temperature, relative humidity, sky cover, and wind speed. Land characterization consists of soil characterization, curve number, RUSLE parameters, and watershed drainage characterization. Field operations contain tillage, planting, harvest, rotation, chemical operations, and irrigation schedules. Finally, feedlot operations require daily manure rates, times of manure removal, and residue amount from previous operations.

Input parameters are used to verify the model. Some input parameters may be repeated for each cell, soil type, landuse, feedlot, and channel reach. Default values are available for some input parameters, others can be simplified because of duplication. Daily climatic input data can be obtained through weather generators, local data, and/or both.

Geographical input data including cell boundaries, land slope, slope direction, and landuse can be generated by GIS or DEM (Digital Elevation Models).
Output data is expressed through an event based report for stream reaches and a source accounting report for land or reach components. Output parameters are selected by the user for the desired watershed source locations (specific cells, reaches, feedlots, point sources, or gullies) for any simulation period. Source accounting for land or reach components are calculated as a fraction of a pollutant load passing through any reach in the stream network that came from the user identified watershed source locations. Event based output data is defined as event quantities for user selected parameters at desired stream reach locations.

AnnAGNPS was utilized for the Fordville Dam Water Quality and Watershed Assessment project. The Fordville Dam watershed delineation began with downloading a 30-meter digital elevation model (DEM) of Grand Forks County. Delineation is defined as drawing a boundary and dividing the land within the boundary into subwatersheds in such a matter that each subwatershed has uniformed hydrological parameters (land slope, elevation, etc.). One drawback of using a 30-meter DEM in a relatively flat area such as the Red River Valley, is it inability to identify slight changes in elevation. Due to this drawback the AnnAGNPS model can delineate a boundary that does not match the true shape of the watershed. Usually these areas are non-contributing in nature to the watershed, as is the case with Fordville Dam (Figure 10).

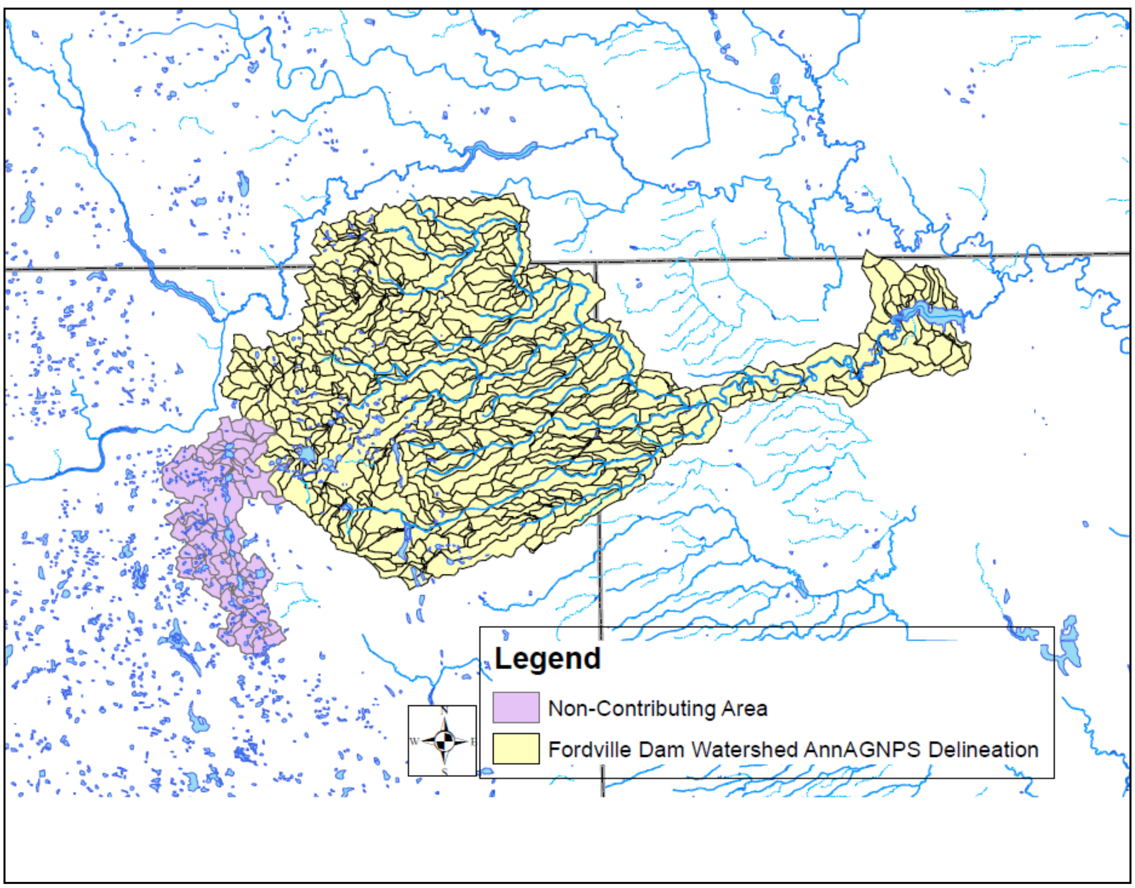

Figure 10. Fordville Dam AnnAGNPS Delineated Watershed and Non-Contributing Area.

Land use and soil digital images were then used to extract the dominate identification of landuse and soil for each subwatershed. This process is achieved by overlaying Landsat and soil images over the subwatershed file. Each dominate soil is then further identified by its physical and chemical soil properties found in a database called National Soils Information System (NASIS) developed by the NRCS. Dominate landuse identification input parameters were obtained using Revised Universal Soil Loss Equation (RUSLE).

A three year simulation period was run on the Fordville Dam watershed at its present condition to provide a best estimation of the current land use practices applied to the soils and slopes of the watershed to obtain nutrient loads from the individual cells as well as the watershed as a whole. Major land use in the Fordville Dam watershed was identified as wheat, winter wheat, barley, corn, canola, peas, soybeans, dry beans, sunflowers, pasture, rangeland, residential/urban, riparian woodlands, and potato. Air seeders, double disk planters, and potato planter were used in the cropland field operations. Crop rotations were determined from three years of land survey data from the National Agricultural Statistical Service (NASS). Typical planting of the fields was done in late April early May with fertilizer being applied at planting in specific amounts determined by crop type, harvest occurred in late September to mid October, spring tillage was done in early May with a chisel. Fertilizer application rates of metaphosphate, 16-52-0 (mono-ammonium phosphate), and multiple forms of anhydrous ammonia (i.e. 80-21-0, 80-26-0, etc.) were determined by the crop rotation and entered into the model (Table 11).

Table 11. Fertilizer Type and Application Rate for the Fordville Dam AnnAGNPS Model.

Crop Rotation	Fertilizer Type	Application Rate (lb/acre)
N/A	Metaphosphate	0.29
Corn Follow Wheat	80-27-0	175.5
Wheat Follow Soybean	80-26-0	112.3
Sunflower Follow Corn	80-24-0	85.2
Wheat Follow Corn	80-21-0	140.0
Canola Follow Wheat	80-32-0	105.3
Potato Follow Wheat	80-31-0	203.5
Flax Follow Wheat	16-52-0	34.6
Canola Follow Barley	80-23-0	203.5
Wheat Follow Peas	80-30-0	98.3
Small Grain Follow Small Grain	80-22-0	125.0
Corn Follow Beans	80-28-0	115.0

Climate data was derived from the North Dakota Agricultural Weather Network (NDAWN) weather station located in Michigan, ND from January 2007 thru December 2009.

The compiled data was used to assess the watershed to identify “critical cells” located in the watershed for potential best management practice (BMP) implementation (Figure 11). Critical cells were determined to be cells in the watershed providing an estimated annual phosphorus yield of 0.128 lbs/acre/year or greater.

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 that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." The margin of safety (MOS) can either be incorporated into conservative assumptions used to develop the TMDL (implicit) or added as a separate component of the TMDL (explicit). For the purposes of this nutrient TMDL, a MOS of 10 percent of the loading capacity will be used as an explicit MOS.

Assuming the existing annual phosphorus load to Fordville Dam from tributary sources and internal cycling is 6610.3 kg and the TMDL reduction goal is a 50 percent reduction in total annual phosphorus loading, then this would result in a TMDL target total phosphorus loading capacity of 3,305.15 kg of total phosphorus per year. Based on a 10 percent explicit margin of safety, the MOS for the Fordville Dam TMDL would be 330.52 kg of phosphorus per year.

Monitoring and adaptive management during the implementation phase, along with post-implementation monitoring related to the effectiveness of the TMDL controls, will be used to ensure the attainment of the targets.

6.2 Seasonality

Section 303(d)(1)(C) of the Clean Water Act and the EPA's regulations require that a TMDL be established with seasonal variations. The Fordville Dam TMDL addresses seasonality because the BATHTUB and AnnAGNPS models incorporate seasonal differences in their prediction of annual total phosphorus and nitrogen loadings.

7.0 TMDL

Table 10 summarizes the nutrient TMDL for Fordville Dam 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 non-point sources;

MOS margin of safety, or an accounting of the 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 the loading capacity.

7.1 Nutrient TMDL

Table 12. Summary of the Phosphorus TMDL for Fordville Dam.

Category	Total Phosphorus (kg/yr)	Explanation
Existing Load	6,610.3	From observed data
Loading Capacity	3,305.15	50 percent total reduction based on BATHTUB modeling
Wasteload Allocation	0	No point sources
Load Allocation	2,974.64	Entire loading capacity minus MOS is allocated to non-point sources
MOS	330.51	10% of the loading capacity (kg/yr) is reserved as an explicit margin of safety

Based on data collected in 2008 thru 2010, the existing annual total phosphorus load to Fordville Dam is estimated at 6,610.30 kg. Assuming a 50 percent reduction in phosphorus loading will result in Fordville Dam reaching a total phosphorus concentration of 0.113 mg/L, resulting in an average growing season TMDL target chlorophyll-a concentration of 17.5 µg/L, the phosphorus TMDL or Loading Capacity is 3,305.15 kg per year. Assuming 10 percent of the loading capacity (330.52 kg/yr) is explicitly assigned to the MOS and there are no point sources in the watershed all of the remaining loading capacity (2,974.64 kg/yr) is assigned to the load allocation.

In November 2006 EPA issued a memorandum “Establishing TMDL “Daily” Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et. al., No. 05-5015 (April 25, 2006) and Implications for NPDES Permits,” which recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increment in conjunction with other appropriate temporal expressions that may be necessary to implement the relevant water quality standard. While the North Dakota Department of Health believes that the appropriate temporal expression for phosphorus loading to lakes and reservoirs is as an annual load, the phosphorus TMDL has also been expressed as a daily load. In order to express this phosphorus TMDL as a daily load the annual loading capacity of 3,305.15 kg/yr was divided by 365 days. Based on this analysis, the phosphorus TMDL, expressed as an average daily load, is 9.06 kg/day with the load allocation equal to 8.15 kg/day and the MOS equal to 0.91 kg/day.

8.0 ALLOCATION

A 50 percent nutrient load reduction target was established for the entire Fordville Dam watershed. This reduction was set based on the BATHTUB model, which predicted that under similar hydraulic conditions, an external nutrient load reduction of 50 percent would lower Carlson's phosphorus TSI from 82 to 72.

Using the AnnAGNPS model, it was determined that cells with a phosphorus yield of 0.128 lbs/acre/yr or greater as priority areas in the watershed (Figure 11). These priority areas account for approximately 8,618 acres of the watershed and are agriculturally based. These cells are the critical cells which should be examined by an implementation project to determine the necessity and types of BMP's to be implemented. Based on the AnnAGNPS model, if BMP's are implemented on these critical areas, it is estimated that the phosphorus load would be reduced by 50 percent, thereby meeting the TMDL goal.

The TMDL in this report is a plan to improve water quality by implementing BMPs through a volunteer, incentive-based approach. This TMDL plan is put forth as a recommendation to what needs to be accomplished for Fordville Dam and its watershed to meet and protect its beneficial uses. Water quality monitoring should continue to assess the effects of recommendations made in this TMDL. Monitoring may indicate that loading capacity recommendations be adjusted.

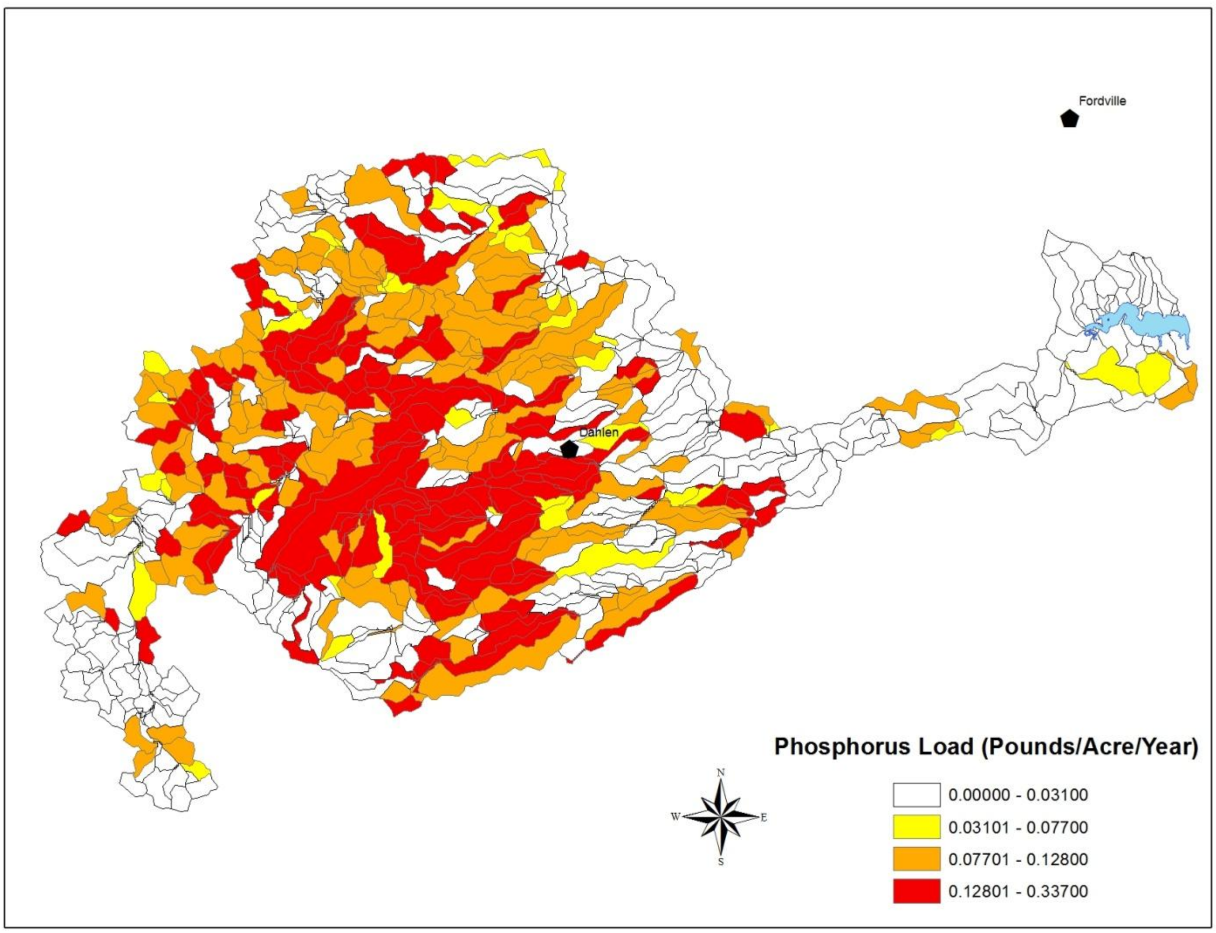

Figure 11. AnnAGNPS Model Identification of Critical Areas for BMP Implementation.

9.0 PUBLIC PARTICIPATION

To satisfy the public participation requirement of this TMDL, a hard copy of the TMDL for Fordville Dam and a request for comment was mailed to participating agencies, partners, and to those who requested a copy. Those included in the mailing of a hard copy were as follows:

- Grand Forks County Water Resource Board;
- Grand Forks County Soil Conservation District
- Nelson County Soil Conservation District;
- Nelson County Water Resource Board;
- Natural Resource Conservation Service (State Office); and
- U.S. Environmental Protection Agency, Region VIII.

In addition to mailing copies of this TMDL for Fordville Dam to interested parties, the TMDL was posted on the North Dakota Department of Health, Division of Water Quality web site at http://www.ndhealth.gov/WQ/SW/Z2_TMDL/TMDLs_Under_PublicComment/B_Under_Public_Comment.htm . A 30 day public notice soliciting comment and participation was also be published in the Grand Forks Herald and the Lakota American.

10.0 MONITORING

To insure that the BMPs implemented as a part of any watershed restoration plan will reduce phosphorus levels, water quality monitoring will be conducted in accordance with an approved Quality Assurance Project Plan (QAPP).

Specifically, monitoring will be conducted for all variables that are currently causing impairments to the beneficial uses of the waterbody. Once a watershed restoration plan (e.g. 319 PIP) is implemented, monitoring will be conducted in the lake/reservoir beginning two years after implementation and extending five years after the implementation project is complete.

11.0 TMDL IMPLEMENTATION STRATEGY

Implementation of TMDLs is dependent upon the availability of Section 319 NPS funds or other watershed restoration programs (e.g. USDA EQIP), as well as securing a local project sponsor and the required matching funds. Provided these three requirements are in place, a project implementation plan (PIP) is developed in accordance with the TMDL and submitted to the North Dakota Nonpoint Source Pollution Task Force and US EPA for approval. The implementation of the best management practices contained in the NPS PIP is voluntary. Therefore, success of any TMDL implementation project is ultimately dependent on the ability of the local project sponsor to find cooperating producers.

Monitoring is an important and required component of any PIP. As a part of the PIP, data are collected to monitor and track the effects of BMP implementation as well as to judge overall project success. Quality Assurance Project Plans (QAPPs) detail the strategy of how, when and where monitoring will be conducted to gather the data needed to document the TMDL implementation goal(s). As data are gathered and analyzed, watershed restoration tasks are adapted to place BMPs where they will have the greatest benefit to water quality.

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Appendix A
Flux Analysis

Fordville Dam Inlet 385419 VAR=NH3-4 METHOD= 4 REG-1

TABULATION OF MISSING DAILY FLOWS:

Flow File =385419_Q.wk1 , Station =CFS
Daily Flows from 20081101 to 20101031

Summary:
Reported Flows = 730
Missing Flows = 0
Zero Flows = 194
Positive Flows = 536

Fordville Dam Inlet 385419 VAR=NH3-4 METHOD= 4 REG-1

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	9.07
2			0	0	9.07	36.27
3			0	0	36.27	987.80

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	28	28	454	5.97
2	11	11	155	22.06
3	6	6	121	71.96
EXCLUDED	0	0	0	.00
TOTAL	45	45	730	100.00

Fordville Dam Inlet 385419 VAR=NH3-4 METHOD= 4 REG-1
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	454	28	28	6.0	1.742	2.488	.027	.677
2	155	11	11	22.1	18.844	15.281	-.377	.400
3	121	6	6	72.0	78.741	138.391	.655	.199
***	730	45	45	100.0	18.136	23.736		

FLOW STATISTICS
FLOW DURATION = 730.0 DAYS = 1.999 YEARS
MEAN FLOW RATE = 18.136 HM3/YR
TOTAL FLOW VOLUME = 36.25 HM3
FLOW DATE RANGE = 20081101 TO 20101031
SAMPLE DATE RANGE = 20081114 TO 20100913

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	5415.0	2709.3	.1909E+07	149.39	.510
2 Q WTD C	3287.7	1645.0	.3932E+06	90.70	.381
3 IJC	3414.9	1708.6	.4622E+06	94.21	.398
4 REG-1	2390.3	1196.0	.8634E+05	65.94	.246
5 REG-2	3259.7	1630.9	.3227E+06	89.93	.348
6 REG-3	2381.8	1191.7	.8689E+05	65.71	.247

Fordville Dam Inlet 385419 VAR=NO2-3 METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =385419_Q.wk1 , Station =CFS
Daily Flows from 20081101 to 20101031

Summary:
Reported Flows = 730
Missing Flows = 0
Zero Flows = 194
Positive Flows = 536

Fordville Dam Inlet 385419 VAR=NO2-3 METHOD= 3 IJC

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	9.07
2			0	0	9.07	36.27
3			0	0	36.27	987.80

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	28	28	454	5.97
2	11	11	155	22.06
3	6	6	121	71.96
EXCLUDED	0	0	0	.00
TOTAL	45	45	730	100.00

Fordville Dam Inlet 385419 VAR=NO2-3 METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	454	28	28	6.0	1.742	2.488	.067	.544
2	155	11	11	22.1	18.844	15.281	.430	.631
3	121	6	6	72.0	78.741	138.391	.319	.642
***	730	45	45	100.0	18.136	23.736		

FLOW STATISTICS
FLOW DURATION = 730.0 DAYS = 1.999 YEARS
MEAN FLOW RATE = 18.136 HM3/YR
TOTAL FLOW VOLUME = 36.25 HM3
FLOW DATE RANGE = 20081101 TO 20101031
SAMPLE DATE RANGE = 20081114 TO 20100913

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	43306.1	21667.9	.4046E+08	1194.73	.294
2 Q WTD C	26296.8	13157.4	.1256E+08	725.48	.269
3 IJC	25748.7	12883.2	.1166E+08	710.36	.265
4 REG-1	22789.4	11402.5	.4005E+08	628.72	.555
5 REG-2	26411.7	13214.9	.2280E+08	728.65	.361
6 REG-3	31698.8	15860.3	.5826E+08	874.51	.481

Fordville Dam Inlet 385419 VAR=TN METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =385419_Q.wk1 , Station =CFS
Daily Flows from 20081101 to 20101031

Summary:
Reported Flows = 730
Missing Flows = 0
Zero Flows = 194
Positive Flows = 536

Fordville Dam Inlet 385419 VAR=TN METHOD= 3 IJC

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	9.07
2			0	0	9.07	36.27
3			0	0	36.27	987.80

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	28	28	454	5.97
2	11	11	155	22.06
3	6	6	121	71.96
EXCLUDED	0	0	0	.00
TOTAL	45	45	730	100.00

Fordville Dam Inlet 385419 VAR=TN METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	454	28	28	6.0	1.742	2.488	.035	.154
2	155	11	11	22.1	18.844	15.281	-.045	.874
3	121	6	6	72.0	78.741	138.391	.257	.427
***	730	45	45	100.0	18.136	23.736		

FLOW STATISTICS
FLOW DURATION = 730.0 DAYS = 1.999 YEARS
MEAN FLOW RATE = 18.136 HM3/YR
TOTAL FLOW VOLUME = 36.25 HM3
FLOW DATE RANGE = 20081101 TO 20101031
SAMPLE DATE RANGE = 20081114 TO 20100913

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	105814.1	52943.3	.1451E+09	2919.21	.228
2 Q WTD C	66715.3	33380.5	.1018E+08	1840.55	.096
3 IJC	66434.8	33240.1	.8634E+07	1832.81	.088
4 REG-1	59456.0	29748.4	.2615E+08	1640.28	.172
5 REG-2	66382.8	33214.1	.1877E+08	1831.38	.130
6 REG-3	64483.6	32263.9	.4751E+08	1778.98	.214

ordville Dam Inlet 385419 VAR=TDP METHOD= 5 REG-2

TABULATION OF MISSING DAILY FLOWS:

Flow File =385419_Q.wk1 , Station =CFS
Daily Flows from 20081101 to 20101031

Summary:
Reported Flows = 730
Missing Flows = 0
Zero Flows = 194
Positive Flows = 536

Fordville Dam Inlet 385419 VAR=TDP METHOD= 5 REG-2

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	9.07
2			0	0	9.07	36.27
3			0	0	36.27	987.80

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	28	28	454	5.97
2	11	11	155	22.06
3	6	6	121	71.96
EXCLUDED	0	0	0	.00
TOTAL	45	45	730	100.00

Fordville Dam Inlet 385419 VAR=TDP METHOD= 5 REG-2
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	454	28	28	6.0	1.742	2.488	.200	.005
2	155	11	11	22.1	18.844	15.281	.105	.770
3	121	6	6	72.0	78.741	138.391	.536	.239
***	730	45	45	100.0	18.136	23.736		

FLOW STATISTICS
FLOW DURATION = 730.0 DAYS = 1.999 YEARS
MEAN FLOW RATE = 18.136 HM3/YR
TOTAL FLOW VOLUME = 36.25 HM3
FLOW DATE RANGE = 20081101 TO 20101031
SAMPLE DATE RANGE = 20081114 TO 20100913

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	11016.8	5512.2	.2257E+07	303.93	.273
2 Q WTD C	6976.1	3490.5	.7109E+05	192.46	.076
3 IJC	7050.6	3527.7	.6551E+05	194.51	.073
4 REG-1	5561.5	2782.7	.6483E+06	153.43	.289
5 REG-2	7000.0	3502.4	.6028E+05	193.12	.070
6 REG-3	6543.0	3273.7	.3084E+06	180.51	.170

```
Fordville Dam Inlet 385419        VAR=TP        METHOD= 5 REG-2

 TABULATION OF MISSING DAILY FLOWS:

 Flow File =385419_Q.wkl                    ,   Station =CFS
 Daily Flows from 20081101 to 20101031

 Summary:
 Reported Flows =  730
 Missing Flows =     0
 Zero Flows =      194
 Positive Flows =  536

 Fordville Dam Inlet 385419        VAR=TP        METHOD= 5 REG-2

 STRATIFICATION SCHEME:
       ---- DATE ----   -- SEASON --  -------- FLOW --------
 STR    >=MIN    < MAX  >=MIN  < MAX       >=MIN       < MAX
   1                       0      0          .00        9.07
   2                       0      0         9.07       36.27
   3                       0      0        36.27      987.80

 STR   SAMPLES    EVENTS     FLOWS  VOLUME %
   1        28        28       454      5.97
   2        11        11       155     22.06
   3         6         6       121     71.96
 EXCLUDED    0         0         0       .00
    TOTAL   45        45       730    100.00


 Fordville Dam Inlet 385419        VAR=TP        METHOD= 5 REG-2
 COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
 STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
  1       454  28  28   6.0        1.742        2.488        .195   .005
  2       155  11  11  22.1       18.844       15.281        .124   .721
  3       121   6   6  72.0       78.741      138.391        .714   .150
***       730  45  45 100.0       18.136       23.736

 FLOW STATISTICS
 FLOW DURATION =     730.0 DAYS  =  1.999 YEARS
 MEAN FLOW RATE =    18.136 HM3/YR
 TOTAL FLOW VOLUME =      36.25 HM3
 FLOW DATE RANGE   = 20081101 TO 20101031
 SAMPLE DATE RANGE = 20081114 TO 20100913

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD        18933.1        9473.0      .1005E+08     522.33    .335
 2 Q WTD C        11760.5        5884.3      .7841E+06     324.45    .150
 3 IJC            11994.9        6001.6      .8418E+06     330.92    .153
 4 REG-1           8583.7        4294.8      .1653E+07     236.81    .299
 5 REG-2          11771.3        5889.7      .3631E+06     324.75    .102
 6 REG-3          10319.0        5163.0      .7235E+06     284.68    .165
```

Fordville Dam Inlet 385419 VAR=TDS METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385419_Q.wk1 , Station =CFS
Daily Flows from 20081101 to 20101031

Summary:
Reported Flows = 730
Missing Flows = 0
Zero Flows = 194
Positive Flows = 536

Fordville Dam Inlet 385419 VAR=TDS METHOD= 2 Q WTD C

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	9.07
2			0	0	9.07	36.27
3			0	0	36.27	987.80

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	28	28	454	5.97
2	11	11	155	22.06
3	6	6	121	71.96
EXCLUDED	0	0	0	.00
TOTAL	45	45	730	100.00

Fordville Dam Inlet 385419 VAR=TDS METHOD= 2 Q WTD C
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	454	28	28	6.0	1.742	2.488	-.040	.069
2	155	11	11	22.1	18.844	15.281	-.438	.090
3	121	6	6	72.0	78.741	138.391	-.569	.106
***	730	45	45	100.0	18.136	23.736		

FLOW STATISTICS
FLOW DURATION = 730.0 DAYS = 1.999 YEARS
MEAN FLOW RATE = 18.136 HM3/YR
TOTAL FLOW VOLUME = 36.25 HM3
FLOW DATE RANGE = 20081101 TO 20101031
SAMPLE DATE RANGE = 20081114 TO 20100913

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	31232250.0	15626820.0	.4634E+13	861638.90	.138
2 Q WTD C	22503520.0	11259470.0	.2810E+13	620829.80	.149
3 IJC	21941390.0	10978210.0	.2862E+13	605321.50	.154
4 REG-1	26393800.0	13205940.0	.5711E+13	728155.20	.181
5 REG-2	24315480.0	12166070.0	.6061E+13	670818.10	.202
6 REG-3	27320880.0	13669790.0	.5651E+13	753731.40	.174

Fordville Dam Inlet 385419 VAR=TSS METHOD= 5 REG-2

TABULATION OF MISSING DAILY FLOWS:

Flow File =385419_Q.wk1 , Station =CFS
Daily Flows from 20081101 to 20101031

Summary:
Reported Flows = 730
Missing Flows = 0
Zero Flows = 194
Positive Flows = 536

Fordville Dam Inlet 385419 VAR=TSS METHOD= 5 REG-2

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	9.07
2			0	0	9.07	36.27
3			0	0	36.27	987.80

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	27	27	454	5.97
2	11	11	155	22.06
3	6	6	121	71.96
EXCLUDED	0	0	0	.00
TOTAL	44	44	730	100.00

Fordville Dam Inlet 385419 VAR=TSS METHOD= 5 REG-2
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	454	27	27	6.0	1.742	2.580	.152	.028
2	155	11	11	22.1	18.844	15.281	1.047	.016
3	121	6	6	72.0	78.741	138.391	1.523	.046
***	730	44	44	100.0	18.136	24.275		

FLOW STATISTICS
FLOW DURATION = 730.0 DAYS = 1.999 YEARS
MEAN FLOW RATE = 18.136 HM3/YR
TOTAL FLOW VOLUME = 36.25 HM3
FLOW DATE RANGE = 20081101 TO 20101031
SAMPLE DATE RANGE = 20081114 TO 20100913

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	5658017.0	2830946.0	.2128E+13	156094.00	.515
2 Q WTD C	3285190.0	1643720.0	.3681E+12	90632.18	.369
3 IJC	3439030.0	1720693.0	.4219E+12	94876.34	.377
4 REG-1	1499640.0	750333.5	.1221E+12	41372.24	.466
5 REG-2	2953652.0	1477838.0	.1597E+12	81485.70	.270
6 REG-3	2499551.0	1250631.0	.1450E+12	68957.88	.305

Fordville Dam Outlet 385420 VAR=NH3-4 METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =385420_Q.wk1 , Station =CFS
Daily Flows from 20081101 to 20101031

Summary:
Reported Flows = 730
Missing Flows = 0
Zero Flows = 202
Positive Flows = 528

Fordville Dam Outlet 385420 VAR=NH3-4 METHOD= 3 IJC

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	9.11
2			0	0	9.11	36.43
3			0	0	36.43	355.84

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	8	8	402	6.44
2	25	25	209	29.35
3	15	15	119	64.21
EXCLUDED	0	0	0	.00
TOTAL	48	48	730	100.00

Fordville Dam Outlet 385420 VAR=NH3-4 METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	402	8	8	6.4	2.131	6.713	1.097	.435
2	209	25	25	29.3	18.671	19.571	-.553	.112
3	119	15	15	64.2	71.741	76.894	.753	.073
***	730	48	48	100.0	18.214	35.342		

FLOW STATISTICS
FLOW DURATION = 730.0 DAYS = 1.999 YEARS
MEAN FLOW RATE = 18.214 HM3/YR
TOTAL FLOW VOLUME = 36.40 HM3
FLOW DATE RANGE = 20081101 TO 20101031
SAMPLE DATE RANGE = 20081113 TO 20100913

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	4840.3	2421.8	.2319E+06	132.97	.199
2 Q WTD C	4129.9	2066.4	.5428E+05	113.45	.113
3 IJC	4170.1	2086.5	.5457E+05	114.56	.112
4 REG-1	3919.6	1961.2	.5521E+05	107.68	.120
5 REG-2	3843.2	1922.9	.9384E+05	105.58	.159
6 REG-3	4511.8	2257.4	.1530E+06	123.94	.173

```
Fordville Dam Outlet 385420       VAR=NO2-3     METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =385420_Q.wk1                    ,   Station =CFS
Daily Flows from 20081101 to 20101031

Summary:
Reported Flows =  730
Missing Flows =     0
Zero Flows =      202
Positive Flows =  528

Fordville Dam Outlet 385420       VAR=NO2-3     METHOD= 3 IJC

STRATIFICATION SCHEME:
       ---- DATE ----   -- SEASON --  -------- FLOW --------
STR    >=MIN    < MAX  >=MIN  < MAX       >=MIN       < MAX
  1                        0      0         .00        9.11
  2                        0      0        9.11       36.43
  3                        0      0       36.43      355.84

STR   SAMPLES    EVENTS     FLOWS  VOLUME %
  1         8         8       402      6.44
  2        25        25       209     29.35
  3        15        15       119     64.21
EXCLUDED    0         0         0       .00
   TOTAL   48        48       730    100.00


Fordville Dam Outlet 385420       VAR=NO2-3     METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS
STR       NQ  NC  NE  VOL%   TOTAL FLOW SAMPLED FLOW   C/Q SLOPE SIGNIF
 1       402   8   8   6.4        2.131        6.713       -.772   .582
 2       209  25  25  29.3       18.671       19.571       -.184   .795
 3       119  15  15  64.2       71.741       76.894        .959   .197
***      730  48  48 100.0       18.214       35.342

FLOW STATISTICS
FLOW DURATION =     730.0 DAYS  =  1.999 YEARS
MEAN FLOW RATE =    18.214 HM3/YR
TOTAL FLOW VOLUME =      36.40 HM3
FLOW DATE RANGE   = 20081101 TO 20101031
SAMPLE DATE RANGE = 20081113 TO 20100913

METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
1 AV LOAD        23976.6       11996.5      .7216E+07     658.66    .224
2 Q WTD C        21617.1       10815.9      .4578E+07     593.84    .198
3 IJC            21585.5       10800.2      .4449E+07     592.97    .195
4 REG-1          20809.8       10412.0      .8103E+07     571.66    .273
5 REG-2          19946.1        9979.9      .1270E+08     547.94    .357
6 REG-3          34237.2       17130.3      .6496E+08     940.53    .470
```

Fordville Dam Outlet 385420 VAR=TN METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =385420_Q.wk1 , Station =CFS
Daily Flows from 20081101 to 20101031

Summary:
Reported Flows = 730
Missing Flows = 0
Zero Flows = 202
Positive Flows = 528

Fordville Dam Outlet 385420 VAR=TN METHOD= 3 IJC

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	9.11
2			0	0	9.11	36.43
3			0	0	36.43	355.84

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	8	8	402	6.44
2	25	25	209	29.35
3	15	15	119	64.21
EXCLUDED	0	0	0	.00
TOTAL	48	48	730	100.00

Fordville Dam Outlet 385420 VAR=TN METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	402	8	8	6.4	2.131	6.713	-.016	.968
2	209	25	25	29.3	18.671	19.571	-.060	.750
3	119	15	15	64.2	71.741	76.894	.237	.330
***	730	48	48	100.0	18.214	35.342		

FLOW STATISTICS
FLOW DURATION = 730.0 DAYS = 1.999 YEARS
MEAN FLOW RATE = 18.214 HM3/YR
TOTAL FLOW VOLUME = 36.40 HM3
FLOW DATE RANGE = 20081101 TO 20101031
SAMPLE DATE RANGE = 20081113 TO 20100913

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	65139.7	32592.2	.2099E+08	1789.45	.141
2 Q WTD C	55471.9	27754.9	.4536E+07	1523.86	.077
3 IJC	55575.6	27806.8	.4316E+07	1526.71	.075
4 REG-1	54935.7	27486.7	.5247E+07	1509.13	.083
5 REG-2	54485.4	27261.4	.6157E+07	1496.76	.091
6 REG-3	55903.3	27970.8	.7004E+07	1535.71	.095

Fordville Dam Outlet 385420 VAR=TDP METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =385420_Q.wk1 , Station =CFS
Daily Flows from 20081101 to 20101031

Summary:
Reported Flows = 730
Missing Flows = 0
Zero Flows = 202
Positive Flows = 528

Fordville Dam Outlet 385420 VAR=TDP METHOD= 3 IJC

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	9.11
2			0	0	9.11	36.43
3			0	0	36.43	355.84

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	8	8	402	6.44
2	25	25	209	29.35
3	15	15	119	64.21
EXCLUDED	0	0	0	.00
TOTAL	48	48	730	100.00

Fordville Dam Outlet 385420 VAR=TDP METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	402	8	8	6.4	2.131	6.713	-.553	.678
2	209	25	25	29.3	18.671	19.571	.668	.014
3	119	15	15	64.2	71.741	76.894	.200	.090
***	730	48	48	100.0	18.214	35.342		

FLOW STATISTICS
FLOW DURATION = 730.0 DAYS = 1.999 YEARS
MEAN FLOW RATE = 18.214 HM3/YR
TOTAL FLOW VOLUME = 36.40 HM3
FLOW DATE RANGE = 20081101 TO 20101031
SAMPLE DATE RANGE = 20081113 TO 20100913

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	7903.8	3954.6	.3498E+06	217.13	.150
2 Q WTD C	6658.5	3331.5	.2218E+05	182.91	.045
3 IJC	6693.8	3349.2	.2286E+05	183.89	.045
4 REG-1	6640.7	3322.6	.2274E+05	182.43	.045
5 REG-2	6578.9	3291.7	.3853E+05	180.73	.060
6 REG-3	6694.6	3349.6	.1410E+05	183.91	.035

Fordville Dam Outlet 385420 VAR=TP METHOD= 6 REG-3

TABULATION OF MISSING DAILY FLOWS:

Flow File =385420_Q.wk1 , Station =CFS
Daily Flows from 20081101 to 20101031

Summary:
Reported Flows = 730
Missing Flows = 0
Zero Flows = 202
Positive Flows = 528

Fordville Dam Outlet 385420 VAR=TP METHOD= 6 REG-3

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	9.11
2			0	0	9.11	36.43
3			0	0	36.43	355.84

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	8	8	402	6.44
2	25	25	209	29.35
3	15	15	119	64.21
EXCLUDED	0	0	0	.00
TOTAL	48	48	730	100.00

Fordville Dam Outlet 385420 VAR=TP METHOD= 6 REG-3

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	402	8	8	6.4	2.131	6.713	-.553	.679
2	209	25	25	29.3	18.671	19.571	.639	.016
3	119	15	15	64.2	71.741	76.894	.318	.017
***	730	48	48	100.0	18.214	35.342		

FLOW STATISTICS
FLOW DURATION = 730.0 DAYS = 1.999 YEARS
MEAN FLOW RATE = 18.214 HM3/YR
TOTAL FLOW VOLUME = 36.40 HM3
FLOW DATE RANGE = 20081101 TO 20101031
SAMPLE DATE RANGE = 20081113 TO 20100913

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	11179.7	5593.7	.9570E+06	307.12	.175
2 Q WTD C	9475.7	4741.1	.1064E+06	260.31	.069
3 IJC	9565.5	4786.0	.1127E+06	262.77	.070
4 REG-1	9391.9	4699.2	.5482E+05	258.00	.050
5 REG-2	9257.1	4631.7	.7079E+05	254.30	.057
6 REG-3	9379.9	4693.1	.3188E+05	257.67	.038

Fordville Dam Outlet 385420 VAR=TDS METHOD= 5 REG-2

TABULATION OF MISSING DAILY FLOWS:

Flow File =385420_Q.wk1 , Station =CFS
Daily Flows from 20081101 to 20101031

Summary:
Reported Flows = 730
Missing Flows = 0
Zero Flows = 202
Positive Flows = 528

Fordville Dam Outlet 385420 VAR=TDS METHOD= 5 REG-2

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	9.11
2			0	0	9.11	36.43
3			0	0	36.43	355.84

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	8	8	402	6.44
2	25	25	209	29.35
3	15	15	119	64.21
EXCLUDED	0	0	0	.00
TOTAL	48	48	730	100.00

Fordville Dam Outlet 385420 VAR=TDS METHOD= 5 REG-2
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	402	8	8	6.4	2.131	6.713	.500	.034
2	209	25	25	29.3	18.671	19.571	-.124	.136
3	119	15	15	64.2	71.741	76.894	-.572	.003
***	730	48	48	100.0	18.214	35.342		

FLOW STATISTICS
FLOW DURATION = 730.0 DAYS = 1.999 YEARS
MEAN FLOW RATE = 18.214 HM3/YR
TOTAL FLOW VOLUME = 36.40 HM3
FLOW DATE RANGE = 20081101 TO 20101031
SAMPLE DATE RANGE = 20081113 TO 20100913

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	23397950.0	11706990.0	.4073E+12	642763.00	.055
2 Q WTD C	18500540.0	9256605.0	.4246E+12	508226.70	.070
3 IJC	18324570.0	9168562.0	.4355E+12	503392.70	.072
4 REG-1	18575800.0	9294261.0	.1295E+12	510294.10	.039
5 REG-2	18879790.0	9446360.0	.1298E+12	518645.00	.038
6 REG-3	19026230.0	9519629.0	.1382E+12	522667.80	.039

Fordville Dam Outlet 385420 VAR=TSS METHOD= 6 REG-3

TABULATION OF MISSING DAILY FLOWS:

Flow File =385420_Q.wk1 , Station =CFS
Daily Flows from 20081101 to 20101031

Summary:
Reported Flows = 730
Missing Flows = 0
Zero Flows = 202
Positive Flows = 528

Fordville Dam Outlet 385420 VAR=TSS METHOD= 6 REG-3

STRATIFICATION SCHEME:

	---- DATE ----		-- SEASON --		-------- FLOW --------	
STR	>=MIN	< MAX	>=MIN	< MAX	>=MIN	< MAX
1			0	0	.00	9.11
2			0	0	9.11	36.43
3			0	0	36.43	355.84

STR	SAMPLES	EVENTS	FLOWS	VOLUME %
1	8	8	402	6.44
2	24	24	209	29.35
3	15	15	119	64.21
EXCLUDED	0	0	0	.00
TOTAL	47	47	730	100.00

Fordville Dam Outlet 385420 VAR=TSS METHOD= 6 REG-3
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	402	8	8	6.4	2.131	6.713	-1.382	.204
2	209	24	24	29.3	18.671	19.692	-.598	.053
3	119	15	15	64.2	71.741	76.894	1.411	.000
***	730	47	47	100.0	18.214	35.739		

FLOW STATISTICS
FLOW DURATION = 730.0 DAYS = 1.999 YEARS
MEAN FLOW RATE = 18.214 HM3/YR
TOTAL FLOW VOLUME = 36.40 HM3
FLOW DATE RANGE = 20081101 TO 20101031
SAMPLE DATE RANGE = 20081113 TO 20100913

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1326682.0	663795.3	.7649E+11	36445.16	.417
2 Q WTD C	1185612.0	593211.9	.3662E+11	32569.83	.323
3 IJC	1238753.0	619800.8	.4125E+11	34029.68	.328
4 REG-1	1113165.0	556963.9	.1088E+11	30579.67	.187
5 REG-2	1040609.0	520660.8	.3528E+10	28586.47	.114
6 REG-3	1004854.0	502771.2	.2045E+10	27604.26	.090

Appendix B
BATHTUB Results for Fordville Dam

CASE: Calibrated Fordville

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	SBrForest Inlet	118.786	18.136	.000E+00	.000	.153
2	4	SBrForest Outlet	129.423	18.214	.000E+00	.000	.141
3	1	ungaged shed	9.890	2.150	.000E+00	.000	.217
		PRECIPITATION	.747	.280	.314E-02	.200	.375
		TRIBUTARY INFLOW	128.676	20.286	.000E+00	.000	.158
		***TOTAL INFLOW	129.423	20.566	.314E-02	.003	.159
		GAUGED OUTFLOW	129.423	18.214	.000E+00	.000	.141
		ADVECTIVE OUTFLOW	.000	2.169	.616E-02	.036	-20150.510
		***TOTAL OUTFLOW	129.423	20.383	.616E-02	.004	.157
		***EVAPORATION	.000	.183	.302E-02	.300	.000

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	SBrForest Inlet	5889.7	89.1	.361E+06	100.0	.102	324.8	49.6
2	4	SBrForest Outlet	4693.2	71.0	.105E+06	29.0	.069	257.7	36.3
3	1	ungaged shed	698.2	10.6	.000E+00	.0	.000	324.8	70.6
		PRECIPITATION	22.4	.3	.126E+03	.0	.500	80.0	30.0
		TRIBUTARY INFLOW	6587.9	99.7	.361E+06	100.0	.091	324.8	51.2
		***TOTAL INFLOW	6610.3	100.0	.361E+06	100.0	.091	321.4	51.1
		GAUGED OUTFLOW	4112.7	62.2	.351E+06	97.2	.144	225.8	31.8
		ADVECTIVE OUTFLOW	489.8	7.4	.529E+04	1.5	.148	225.8	********
		***TOTAL OUTFLOW	4602.5	69.6	.440E+06	121.8	.144	225.8	35.6
		***RETENTION	2007.8	30.4	.801E+06	221.8	.446	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
27.28	.1228	225.8	.0855	23.3939	.3037

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	SBrForest Inlet	33239.8	87.6	.856E+07	98.4	.088	1832.8	279.8
2	4	SBrForest Outlet	27807.5	73.3	.458E+07	52.7	.077	1526.7	214.9
3	1	ungaged shed	3940.5	10.4	.000E+00	.0	.000	1832.8	398.4
		PRECIPITATION	747.1	2.0	.140E+06	1.6	.500	2666.7	1000.0
		TRIBUTARY INFLOW	37180.4	98.0	.856E+07	98.4	.079	1832.8	288.9
		***TOTAL INFLOW	37927.5	100.0	.870E+07	100.0	.078	1844.2	293.1
		GAUGED OUTFLOW	26158.9	69.0	.684E+09	7869.3	1.000	1436.2	202.1
		ADVECTIVE OUTFLOW	3115.3	8.2	.972E+07	111.8	1.001	1436.2	********
		***TOTAL OUTFLOW	29274.2	77.2	.857E+09	9855.4	1.000	1436.2	226.2
		***RETENTION	8653.3	22.8	.866E+09	9955.4	3.400	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
27.28	.1228	1436.2	.0948	21.1031	.2282

CASE: Calibrated Fordville

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Ford's Deepest

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	225.8	.14	225.5	.16	1.00	.01	.00	.01
TOTAL N	MG/M3	1436.2	1.00	1438.0	.15	1.00	.00	-.01	.00
C.NUTRIENT	MG/M3	96.8	.72	96.9	.14	1.00	.00	.00	.00
CHL-A	MG/M3	38.7	.32	38.6	.56	1.00	.01	.01	.00
SECCHI	M	1.8	.19	1.8	.32	1.01	.06	.04	.03
ORGANIC N	MG/M3	908.4	.09	906.7	.46	1.00	.02	.01	.00
TP-ORTHO-P	MG/M3	207.7	.17	207.5	.46	1.00	.00	.00	.00
HOD-V	MG/M3-DAY	.0	.00	542.3	.32	.00	.00	.00	.00
MOD-V	MG/M3-DAY	.0	.00	318.6	.39	.00	.00	.00	.00

CASE: Calibrated Fordville

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 1 Ford's Deepest

	----- VALUES -----		--- RANKS (%) ----	
VARIABLE	OBSERVED	ESTIMATED	OBSERVED	ESTIMATED
TOTAL P MG/M3	225.80	225.52	95.8	95.7
TOTAL N MG/M3	1436.20	1438.02	71.3	71.4
C.NUTRIENT MG/M3	96.83	96.92	89.4	89.4
CHL-A MG/M3	38.70	38.61	96.7	96.7
SECCHI M	1.80	1.78	74.9	74.5
ORGANIC N MG/M3	908.40	906.69	89.9	89.8
TP-ORTHO-P MG/M3	207.70	207.55	97.9	97.9
HOD-V MG/M3-DAY	.00	542.25	.0	99.6
MOD-V MG/M3-DAY	.00	318.57	.0	98.5
ANTILOG PC-1	951.60	954.96	85.0	85.0
ANTILOG PC-2	21.81	21.60	99.0	98.9
(N - 150) / P	5.70	5.71	5.4	5.5
INORGANIC N / P	29.16	29.56	49.3	49.8
TURBIDITY 1/M	1.00	1.00	71.4	71.4
ZMIX * TURBIDITY	1.83	1.83	24.2	24.2
ZMIX / SECCHI	1.02	1.03	.4	.4
CHL-A * SECCHI	69.66	68.76	99.7	99.6
CHL-A / TOTAL P	.17	.17	41.6	41.6
FREQ(CHL-a>10) %	96.94	96.92	.0	.0
FREQ(CHL-a>20) %	77.48	77.36	.0	.0
FREQ(CHL-a>30) %	54.02	53.86	.0	.0
FREQ(CHL-a>40) %	35.81	35.67	.0	.0
FREQ(CHL-a>50) %	23.47	23.35	.0	.0
FREQ(CHL-a>60) %	15.45	15.35	.0	.0
CARLSON TSI-P	82.30	82.28	.0	.0
CARLSON TSI-CHLA	66.46	66.44	.0	.0
CARLSON TSI-SEC	51.53	51.68	.0	.0

CASE: Calibrated Fordville 90%

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	SBrForest Inlet	118.786	18.136	.000E+00	.000	.153
2	4	SBrForest Outlet	129.423	18.214	.000E+00	.000	.141
3	1	ungaged shed	9.890	2.150	.000E+00	.000	.217
		PRECIPITATION	.747	.280	.314E-02	.200	.375
		TRIBUTARY INFLOW	128.676	20.286	.000E+00	.000	.158
		***TOTAL INFLOW	129.423	20.566	.314E-02	.003	.159
		GAUGED OUTFLOW	129.423	18.214	.000E+00	.000	.141
		ADVECTIVE OUTFLOW	.000	2.169	.616E-02	.036	-20150.510
		***TOTAL OUTFLOW	129.423	20.383	.616E-02	.004	.157
		***EVAPORATION	.000	.183	.302E-02	.300	.000

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	SBrForest Inlet	5300.8	89.1	.292E+06	100.0	.102	292.3	44.6
2	4	SBrForest Outlet	4693.2	78.9	.105E+06	35.9	.069	257.7	36.3
3	1	ungaged shed	628.4	10.6	.000E+00	.0	.000	292.3	63.5
		PRECIPITATION	22.4	.4	.126E+03	.0	.500	80.0	30.0
		TRIBUTARY INFLOW	5929.2	99.6	.292E+06	100.0	.091	292.3	46.1
		***TOTAL INFLOW	5951.6	100.0	.292E+06	100.0	.091	289.4	46.0
		GAUGED OUTFLOW	4112.7	69.1	.351E+06	119.9	.144	225.8	31.8
		ADVECTIVE OUTFLOW	489.8	8.2	.529E+04	1.8	.148	225.8	********
		***TOTAL OUTFLOW	4602.5	77.3	.440E+06	150.3	.144	225.8	35.6
		***RETENTION	1349.1	22.7	.732E+06	250.3	.634	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
27.28	.1228	225.8	.0950	21.0628	.2267

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	SBrForest Inlet	29915.9	87.4	.693E+07	98.0	.088	1649.5	251.8
2	4	SBrForest Outlet	27807.5	81.3	.458E+07	64.8	.077	1526.7	214.9
3	1	ungaged shed	3546.5	10.4	.000E+00	.0	.000	1649.5	358.6
		PRECIPITATION	747.1	2.2	.140E+06	2.0	.500	2666.7	1000.0
		TRIBUTARY INFLOW	33462.4	97.8	.693E+07	98.0	.079	1649.5	260.1
		***TOTAL INFLOW	34209.5	100.0	.707E+07	100.0	.078	1663.4	264.3
		GAUGED OUTFLOW	26158.9	76.5	.684E+09	9678.8	1.000	1436.2	202.1
		ADVECTIVE OUTFLOW	3115.3	9.1	.972E+07	137.5	1.001	1436.2	********
		***TOTAL OUTFLOW	29274.2	85.6	.857E+09	12121.5	1.000	1436.2	226.2
		***RETENTION	4935.2	14.4	.864E+09	12221.5	5.956	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
27.28	.1228	1436.2	.1051	19.0343	.1443

CASE: Calibrated Fordville 90%

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Ford's Deepest

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	225.8	.14	203.0	.16	1.11	.74	.39	.49
TOTAL N	MG/M3	1436.2	1.00	1297.1	.15	1.11	.10	.46	.10
C.NUTRIENT	MG/M3	96.8	.72	86.5	.14	1.12	.16	.56	.15
CHL-A	MG/M3	38.7	.32	34.3	.53	1.13	.37	.35	.19
SECCHI	M	1.8	.19	1.9	.29	.96	-.24	-.16	-.13
ORGANIC N	MG/M3	908.4	.09	826.8	.43	1.10	1.07	.38	.22
TP-ORTHO-P	MG/M3	207.7	.17	189.6	.43	1.10	.55	.25	.20
HOD-V	MG/M3-DAY	.0	.00	511.2	.30	.00	.00	.00	.00
MOD-V	MG/M3-DAY	.0	.00	300.3	.37	.00	.00	.00	.00

CASE: Calibrated Fordville 90%

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 1 Ford's Deepest

VARIABLE		VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P	MG/M3	225.80	203.05	95.8	94.6
TOTAL N	MG/M3	1436.20	1297.05	71.3	65.7
C.NUTRIENT	MG/M3	96.83	86.48	89.4	86.6
CHL-A	MG/M3	38.70	34.31	96.7	95.4
SECCHI	M	1.80	1.88	74.9	76.8
ORGANIC N	MG/M3	908.40	826.78	89.9	86.2
TP-ORTHO-P	MG/M3	207.70	189.56	97.9	97.4
HOD-V	MG/M3-DAY	.00	511.16	.0	99.4
MOD-V	MG/M3-DAY	.00	300.31	.0	98.2
ANTILOG PC-1		951.60	788.43	85.0	81.4
ANTILOG PC-2		21.81	20.86	99.0	98.7
(N - 150) / P		5.70	5.65	5.4	5.3
INORGANIC N / P		29.16	34.86	49.3	56.4
TURBIDITY	1/M	1.00	1.00	71.4	71.4
ZMIX * TURBIDITY		1.83	1.83	24.2	24.2
ZMIX / SECCHI		1.02	.97	.4	.3
CHL-A * SECCHI		69.66	64.64	99.7	99.5
CHL-A / TOTAL P		.17	.17	41.6	40.8
FREQ(CHL-a>10) %		96.94	95.34	.0	.0
FREQ(CHL-a>20) %		77.48	71.24	.0	.0
FREQ(CHL-a>30) %		54.02	46.26	.0	.0
FREQ(CHL-a>40) %		35.81	28.85	.0	.0
FREQ(CHL-a>50) %		23.47	17.94	.0	.0
FREQ(CHL-a>60) %		15.45	11.28	.0	.0
CARLSON TSI-P		82.30	80.77	.0	.0
CARLSON TSI-CHLA		66.46	65.28	.0	.0
CARLSON TSI-SEC		51.53	50.87	.0	.0

CASE: Calibrated Fordville 75%

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	SBrForest Inlet	118.786	18.136	.000E+00	.000	.153
2	4	SBrForest Outlet	129.423	18.214	.000E+00	.000	.141
3	1	ungaged shed	9.890	2.150	.000E+00	.000	.217
PRECIPITATION			.747	.280	.314E-02	.200	.375
TRIBUTARY INFLOW			128.676	20.286	.000E+00	.000	.158
***TOTAL INFLOW			129.423	20.566	.314E-02	.003	.159
GAUGED OUTFLOW			129.423	18.214	.000E+00	.000	.141
ADVECTIVE OUTFLOW			.000	2.169	.616E-02	.036	-20150.510
***TOTAL OUTFLOW			129.423	20.383	.616E-02	.004	.157
***EVAPORATION			.000	.183	.302E-02	.300	.000

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	SBrForest Inlet	4417.2	89.0	.203E+06	99.9	.102	243.6	37.2
2	4	SBrForest Outlet	4693.2	94.6	.105E+06	51.6	.069	257.7	36.3
3	1	ungaged shed	523.7	10.6	.000E+00	.0	.000	243.6	52.9
PRECIPITATION			22.4	.5	.126E+03	.1	.500	80.0	30.0
TRIBUTARY INFLOW			4940.9	99.5	.203E+06	99.9	.091	243.6	38.4
***TOTAL INFLOW			4963.3	100.0	.203E+06	100.0	.091	241.3	38.3
GAUGED OUTFLOW			4112.7	82.9	.351E+06	172.7	.144	225.8	31.8
ADVECTIVE OUTFLOW			489.8	9.9	.529E+04	2.6	.148	225.8	********
***TOTAL OUTFLOW			4602.5	92.7	.440E+06	216.4	.144	225.8	35.6
***RETENTION			360.8	7.3	.643E+06	316.4	2.222	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
27.28	.1228	225.8	.1139	17.5651	.0727

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	SBrForest Inlet	24929.9	87.1	.481E+07	97.2	.088	1374.6	209.9
2	4	SBrForest Outlet	27807.5	97.1	.458E+07	92.6	.077	1526.7	214.9
3	1	ungaged shed	2955.4	10.3	.000E+00	.0	.000	1374.6	298.8
PRECIPITATION			747.1	2.6	.140E+06	2.8	.500	2666.7	1000.0
TRIBUTARY INFLOW			27885.3	97.4	.481E+07	97.2	.079	1374.6	216.7
***TOTAL INFLOW			28632.4	100.0	.495E+07	100.0	.078	1392.2	221.2
GAUGED OUTFLOW			26158.9	91.4	.684E+09	13817.2	1.000	1436.2	202.1
ADVECTIVE OUTFLOW			3115.3	10.9	.972E+07	196.2	1.001	1436.2	********
***TOTAL OUTFLOW			29274.2	102.2	.857E+09	17304.4	1.000	1436.2	226.2
***RETENTION			-641.8	-2.2	.862E+09	17404.4	9.999	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
27.28	.1228	1436.2	.1255	15.9313	-.0224

CASE: Calibrated Fordville 75%

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Ford's Deepest

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	225.8	.14	169.3	.16	1.33	2.00	1.07	1.32
TOTAL N	MG/M3	1436.2	1.00	1085.6	.15	1.32	.28	1.27	.28
C.NUTRIENT	MG/M3	96.8	.72	70.8	.14	1.37	.43	1.56	.42
CHL-A	MG/M3	38.7	.32	27.9	.49	1.39	1.01	.94	.56
SECCHI	M	1.8	.19	2.1	.25	.87	-.72	-.48	-.43
ORGANIC N	MG/M3	908.4	.09	708.5	.38	1.28	2.82	.99	.64
TP-ORTHO-P	MG/M3	207.7	.17	162.9	.38	1.27	1.47	.66	.59
HOD-V	MG/M3-DAY	.0	.00	461.3	.28	.00	.00	.00	.00
MOD-V	MG/M3-DAY	.0	.00	271.0	.36	.00	.00	.00	.00

CASE: Calibrated Fordville 75%

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 1 Ford's Deepest

VARIABLE		VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P	MG/M3	225.80	169.33	95.8	92.0
TOTAL N	MG/M3	1436.20	1085.60	71.3	55.0
C.NUTRIENT	MG/M3	96.83	70.82	89.4	80.4
CHL-A	MG/M3	38.70	27.94	96.7	92.2
SECCHI	M	1.80	2.06	74.9	80.2
ORGANIC N	MG/M3	908.40	708.54	89.9	78.5
TP-ORTHO-P	MG/M3	207.70	162.94	97.9	96.3
HOD-V	MG/M3-DAY	.00	461.33	.0	99.2
MOD-V	MG/M3-DAY	.00	271.03	.0	97.4
ANTILOG PC-1		951.60	567.96	85.0	74.0
ANTILOG PC-2		21.81	19.55	99.0	98.3
(N - 150) / P		5.70	5.53	5.4	4.9
INORGANIC N / P		29.16	59.02	49.3	75.5
TURBIDITY	1/M	1.00	1.00	71.4	71.4
ZMIX * TURBIDITY		1.83	1.83	24.2	24.2
ZMIX / SECCHI		1.02	.89	.4	.2
CHL-A * SECCHI		69.66	57.58	99.7	99.3
CHL-A / TOTAL P		.17	.17	41.6	39.3
FREQ(CHL-a>10)	%	96.94	91.11	.0	.0
FREQ(CHL-a>20)	%	77.48	59.08	.0	.0
FREQ(CHL-a>30)	%	54.02	33.55	.0	.0
FREQ(CHL-a>40)	%	35.81	18.71	.0	.0
FREQ(CHL-a>50)	%	23.47	10.59	.0	.0
FREQ(CHL-a>60)	%	15.45	6.15	.0	.0
CARLSON TSI-P		82.30	78.15	.0	.0
CARLSON TSI-CHLA		66.46	63.27	.0	.0
CARLSON TSI-SEC		51.53	49.58	.0	.0

CASE: Calibrated Fordville 50%

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	SBrForest Inlet	118.786	18.136	.000E+00	.000	.153
2	4	SBrForest Outlet	129.423	18.214	.000E+00	.000	.141
3	1	ungaged shed	9.890	2.150	.000E+00	.000	.217
		PRECIPITATION	.747	.280	.314E-02	.200	.375
		TRIBUTARY INFLOW	128.676	20.286	.000E+00	.000	.158
		***TOTAL INFLOW	129.423	20.566	.314E-02	.003	.159
		GAUGED OUTFLOW	129.423	18.214	.000E+00	.000	.141
		ADVECTIVE OUTFLOW	.000	2.169	.616E-02	.036	-20150.510
		***TOTAL OUTFLOW	129.423	20.383	.616E-02	.004	.157
		***EVAPORATION	.000	.183	.302E-02	.300	.000

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	SBrForest Inlet	2944.9	88.8	.902E+05	99.9	.102	162.4	24.8
2	4	SBrForest Outlet	4693.2	141.5	.105E+06	116.1	.069	257.7	36.3
3	1	ungaged shed	349.1	10.5	.000E+00	.0	.000	162.4	35.3
		PRECIPITATION	22.4	.7	.126E+03	.1	.500	80.0	30.0
		TRIBUTARY INFLOW	3294.0	99.3	.902E+05	99.9	.091	162.4	25.6
		***TOTAL INFLOW	3316.5	100.0	.904E+05	100.0	.091	161.3	25.6
		GAUGED OUTFLOW	4112.7	124.0	.351E+06	388.2	.144	225.8	31.8
		ADVECTIVE OUTFLOW	489.8	14.8	.529E+04	5.9	.148	225.8	********
		***TOTAL OUTFLOW	4602.5	138.8	.440E+06	486.5	.144	225.8	35.6
		***RETENTION	-1286.1	-38.8	.530E+06	586.5	.566	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P: POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
27.28	.1228	225.8	.1704	11.7370	-.3878

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL N

ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	SBrForest Inlet	16620.0	85.9	.214E+07	93.9	.088	916.4	139.9
2	4	SBrForest Outlet	27807.5	143.8	.458E+07	201.2	.077	1526.7	214.9
3	1	ungaged shed	1970.3	10.2	.000E+00	.0	.000	916.4	199.2
		PRECIPITATION	747.1	3.9	.140E+06	6.1	.500	2666.7	1000.0
		TRIBUTARY INFLOW	18590.3	96.1	.214E+07	93.9	.079	916.4	144.5
		***TOTAL INFLOW	19337.4	100.0	.228E+07	100.0	.078	940.3	149.4
		GAUGED OUTFLOW	26158.9	135.3	.684E+09	30030.7	1.000	1436.2	202.1
		ADVECTIVE OUTFLOW	3115.3	16.1	.972E+07	426.5	1.001	1436.2	********
		***TOTAL OUTFLOW	29274.2	151.4	.857E+09	37610.0	1.000	1436.2	226.2
		***RETENTION	-9936.8	-51.4	.859E+09	37710.0	2.950	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N: POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
27.28	.1228	1436.2	.1859	10.7594	-.5139

CASE: Calibrated Fordville 50%

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Ford's Deepest

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	225.8	.14	113.1	.16	2.00	4.80	2.57	3.17
TOTAL N	MG/M3	1436.2	1.00	733.2	.15	1.96	.67	3.06	.67
C.NUTRIENT	MG/M3	96.8	.72	44.7	.16	2.17	1.07	3.85	1.04
CHL-A	MG/M3	38.7	.32	17.5	.41	2.22	2.46	2.30	1.51
SECCHI	M	1.8	.19	2.4	.18	.74	-1.60	-1.08	-1.15
ORGANIC N	MG/M3	908.4	.09	513.7	.29	1.77	6.48	2.28	1.89
TP-ORTHO-P	MG/M3	207.7	.17	119.1	.30	1.74	3.37	1.52	1.64
HOD-V	MG/M3-DAY	.0	.00	364.7	.25	.00	.00	.00	.00
MOD-V	MG/M3-DAY	.0	.00	214.2	.34	.00	.00	.00	.00

CASE: Calibrated Fordville 50%

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 1 Ford's Deepest

VARIABLE		VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P	MG/M3	225.80	113.15	95.8	83.0
TOTAL N	MG/M3	1436.20	733.18	71.3	31.3
C.NUTRIENT	MG/M3	96.83	44.65	89.4	61.0
CHL-A	MG/M3	38.70	17.46	96.7	79.0
SECCHI	M	1.80	2.44	74.9	85.8
ORGANIC N	MG/M3	908.40	513.75	89.9	56.3
TP-ORTHO-P	MG/M3	207.70	119.09	97.9	92.7
HOD-V	MG/M3-DAY	.00	364.66	.0	98.2
MOD-V	MG/M3-DAY	.00	214.24	.0	94.7
ANTILOG PC-1		951.60	275.28	85.0	53.5
ANTILOG PC-2		21.81	16.52	99.0	96.4
(N - 150) / P		5.70	5.15	5.4	4.0
INORGANIC N / P		29.16	219.43	49.3	97.8
TURBIDITY	1/M	1.00	1.00	71.4	71.4
ZMIX * TURBIDITY		1.83	1.83	24.2	24.2
ZMIX / SECCHI		1.02	.75	.4	.1
CHL-A * SECCHI		69.66	42.54	99.7	97.8
CHL-A / TOTAL P		.17	.15	41.6	35.3
FREQ(CHL-a>10) %		96.94	72.20	.0	.0
FREQ(CHL-a>20) %		77.48	29.83	.0	.0
FREQ(CHL-a>30) %		54.02	11.83	.0	.0
FREQ(CHL-a>40) %		35.81	4.98	.0	.0
FREQ(CHL-a>50) %		23.47	2.24	.0	.0
FREQ(CHL-a>60) %		15.45	1.07	.0	.0
CARLSON TSI-P		82.30	72.34	.0	.0
CARLSON TSI-CHLA		66.46	58.66	.0	.0
CARLSON TSI-SEC		51.53	47.17	.0	.0

CASE: Calibrated Fordville 25%

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	SBrForest Inlet	118.786	18.136	.000E+00	.000	.153
2	4	SBrForest Outlet	129.423	18.214	.000E+00	.000	.141
3	1	ungaged shed	9.890	2.150	.000E+00	.000	.217
PRECIPITATION			.747	.280	.314E-02	.200	.375
TRIBUTARY INFLOW			128.676	20.286	.000E+00	.000	.158
***TOTAL INFLOW			129.423	20.566	.314E-02	.003	.159
GAUGED OUTFLOW			129.423	18.214	.000E+00	.000	.141
ADVECTIVE OUTFLOW			.000	2.169	.616E-02	.036	-20150.510
***TOTAL OUTFLOW			129.423	20.383	.616E-02	.004	.157
***EVAPORATION			.000	.183	.302E-02	.300	.000

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	SBrForest Inlet	1472.5	88.2	.226E+05	99.4	.102	81.2	12.4
2	4	SBrForest Outlet	4693.2	281.1	.105E+06	462.3	.069	257.7	36.3
3	1	ungaged shed	174.6	10.5	.000E+00	.0	.000	81.2	17.7
PRECIPITATION			22.4	1.3	.126E+03	.6	.500	80.0	30.0
TRIBUTARY INFLOW			1647.0	98.7	.226E+05	99.4	.091	81.2	12.8
***TOTAL INFLOW			1669.4	100.0	.227E+05	100.0	.090	81.2	12.9
GAUGED OUTFLOW			4112.7	246.4	.351E+06	1546.3	.144	225.8	31.8
ADVECTIVE OUTFLOW			489.8	29.3	.529E+04	23.3	.148	225.8	********
***TOTAL OUTFLOW			4602.5	275.7	.440E+06	1937.9	.144	225.8	35.6
***RETENTION			-2933.1	-175.7	.462E+06	2037.9	.232	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
27.28	.1228	225.8	.3385	5.9082	-1.7569

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	SBrForest Inlet	8309.9	82.8	.535E+06	79.3	.088	458.2	70.0
2	4	SBrForest Outlet	27807.5	276.9	.458E+07	679.9	.077	1526.7	214.9
3	1	ungaged shed	985.1	9.8	.000E+00	.0	.000	458.2	99.6
PRECIPITATION			747.1	7.4	.140E+06	20.7	.500	2666.7	1000.0
TRIBUTARY INFLOW			9295.0	92.6	.535E+06	79.3	.079	458.2	72.2
***TOTAL INFLOW			10042.1	100.0	.674E+06	100.0	.082	488.3	77.6
GAUGED OUTFLOW			26158.9	260.5	.684E+09	*******	1.000	1436.2	202.1
ADVECTIVE OUTFLOW			3115.3	31.0	.972E+07	1441.2	1.001	1436.2	********
***TOTAL OUTFLOW			29274.2	291.5	.857E+09	*******	1.000	1436.2	226.2
***RETENTION			-19232.1	-191.5	.858E+09	*******	1.523	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
27.28	.1228	1436.2	.3579	5.5875	-1.9151

CASE: Calibrated Fordville 25%

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Ford's Deepest

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	225.8	.14	57.0	.16	3.96	9.57	5.12	6.33
TOTAL N	MG/M3	1436.2	1.00	380.7	.15	3.77	1.33	6.03	1.31
C.NUTRIENT	MG/M3	96.8	.72	18.2	.22	5.31	2.31	8.31	2.21
CHL-A	MG/M3	38.7	.32	6.5	.34	5.92	5.49	5.14	3.77
SECCHI	M	1.8	.19	3.0	.12	.60	-2.72	-1.83	-2.29
ORGANIC N	MG/M3	908.4	.09	310.9	.18	2.92	12.18	4.29	5.35
TP-ORTHO-P	MG/M3	207.7	.17	73.4	.20	2.83	6.30	2.84	4.05
HOD-V	MG/M3-DAY	.0	.00	223.2	.23	.00	.00	.00	.00
MOD-V	MG/M3-DAY	.0	.00	131.1	.32	.00	.00	.00	.00

CASE: Calibrated Fordville 25%

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 1 Ford's Deepest

		----- VALUES -----		--- RANKS (%) ----	
VARIABLE		OBSERVED	ESTIMATED	OBSERVED	ESTIMATED
TOTAL P	MG/M3	225.80	56.96	95.8	57.6
TOTAL N	MG/M3	1436.20	380.75	71.3	6.5
C.NUTRIENT	MG/M3	96.83	18.22	89.4	20.0
CHL-A	MG/M3	38.70	6.54	96.7	31.9
SECCHI	M	1.80	3.01	74.9	91.1
ORGANIC N	MG/M3	908.40	310.89	89.9	20.4
TP-ORTHO-P	MG/M3	207.70	73.42	97.9	82.7
HOD-V	MG/M3-DAY	.00	223.22	.0	92.3
MOD-V	MG/M3-DAY	.00	131.14	.0	82.3
ANTILOG PC-1		951.60	71.60	85.0	17.4
ANTILOG PC-2		21.81	10.73	99.0	83.5
(N - 150) / P		5.70	4.05	5.4	1.8
INORGANIC N / P		29.16	69.86	49.3	80.5
TURBIDITY	1/M	1.00	1.00	71.4	71.4
ZMIX * TURBIDITY		1.83	1.83	24.2	24.2
ZMIX / SECCHI		1.02	.61	.4	.0
CHL-A * SECCHI		69.66	19.68	99.7	82.3
CHL-A / TOTAL P		.17	.11	41.6	20.0
FREQ(CHL-a>10) %		96.94	16.00	.0	.0
FREQ(CHL-a>20) %		77.48	1.73	.0	.0
FREQ(CHL-a>30) %		54.02	.28	.0	.0
FREQ(CHL-a>40) %		35.81	.06	.0	.0
FREQ(CHL-a>50) %		23.47	.02	.0	.0
FREQ(CHL-a>60) %		15.45	.01	.0	.0
CARLSON TSI-P		82.30	62.44	.0	.0
CARLSON TSI-CHLA		66.46	49.03	.0	.0
CARLSON TSI-SEC		51.53	44.13	.0	.0

Appendix C
A Calibrated Trophic Response Model (Bathtub) for Fordville Dam

A Calibrated Trophic Response Model (Bathtub) for Fordville Dam As a Tool to Evaluate Various Nutrient Reduction Alternatives Based on Data Collected by the Grand Forks County Soil Conservation District from November, 2008 through October, 2010

Prepared by
Peter Wax
May, 2011

Introduction

The objective of monitoring Fordville Dam and Fordville Dam's hydraulic and nutrient load is to: (1) develop a water and nutrient budget for the reservoir; (2) identify the primary sources and causes of nutrients and sediments to the reservoir; and (3) examine and make recommendations for reservoir preservation measures that reduce documented nutrient and sediment loadings to the reservoir, and (4) develop a calibrated trophic response model for Fordville Dam.

A calibrated trophic response model enables managers to investigate various nutrient reduction alternatives relative to preserving and improving Fordville Dam's trophic status for future generations. The model allows water and land resource managers to relate changes in nutrient loadings to the lake's trophic response and to set realistic goals that are scientifically defensible, physically achievable, and socially acceptable.

Methods

For purposes of this project, the BATHTUB model was used to predict changes in trophic status based on changes in nutrient loading. The BATHTUB program, developed by the US Army Corps of Engineers Waterways Experiment Station (Walker 1996), applies an empirically derived eutrophication model to reservoirs. The model is developed in three phases. The first two phases involve the analysis and reduction of the tributary and in-lake water quality data. The third phase involves model calibration. In the data reduction phase, the in-lake and tributary monitoring data collected as part of the project are summarized, or reduced, into a format which can serve as inputs to the model. The following is a brief explanation of the computer software, methods, and procedures used to complete each of these phases.

Tributary Data

To facilitate the analysis and reduction of tributary inflow and outflow water quality and flow data the FLUX program was employed. The FLUX program, also developed by the US Corps of Engineers Waterways Experiment Station (Walker 1996), uses six calculation techniques to estimate the average mass discharge or loading that passes a given river or stream site. FLUX estimates loadings based on chemical grab sample concentrations and continuous daily flow record. Load is therefore defined as the mass of a pollutant during a given time period (e.g., hour, day, month, season, year). The FLUX program allows the user, through various iterations, to select the most appropriate load calculation technique and data stratification scheme, either by flow or date, which will give a load estimate with the smallest statistical error, as represented by the coefficient of variation. Output from the FLUX program is then provided as an input file to calibrate the BATHTUB eutrophication response model. For a complete description of the FLUX program the reader is referred to Walker (1996).

Lake Data

Fordville Dam's water quality data was reduced using the PROFILE program, also developed by the US Corps of Engineers Waterways Experiment Station (Walker 1996). PROFILE weights the concentrations by the layers represented at each sampling depth. The program provides the results as a volume-weighted concentration per visit and then an open water annual volume-weighted mean. The Profile program is very robust and is able to provide three computational functions, including: (1) the ability to display constitutes as a function of depth, location, and/or date; (2) calculate summary statistics (e.g., mean, median and standard error in the mixed layer of the lake or reservoir); and (3) track the temporal trophic status. As is the case with FLUX, output from the Profile program is used as input to calibrate the BATHTUB model.

Bathtub Model Calibration

As stated previously, the BATHTUB eutrophication model was selected for this project as a means evaluating the effects of various nutrient reduction alternatives on the predicted trophic status of Fordville Dam. BATHTUB performs water and nutrient balance calculations in a steady state. Eutrophication related water quality variables (e.g., total phosphorus, total nitrogen, chlorophyll-*a*, secchi depth, organic nitrogen, orthophosphorous, and hypolimnetic oxygen depletion rate) are predicted using empirical relationships previously developed and tested for reservoir systems (Walker 1985).

Within the BATHTUB program the user can select from six schemes based on reservoir morphometry and the needs of the resource manager. Using BATHTUB the user can view the reservoir as a single spatially averaged reservoir or as single segmented reservoir. The user can also model parts of the reservoir, such as an embayment, or model a collection of reservoirs. For purposes of this project, Fordville Dam was modeled as a single, spatially averaged, reservoir.

Once input is provided to the model from FLUX and Profile the user can compare predicted conditions (i.e., model output) to actual conditions. Since BATHTUB uses a set of generalized rates and factors, predicted vs. actual conditions may differ by a factor of 2 or more using the initial, un-calibrated, model. These differences reflect a combination of measurement errors in the inflow and outflow data, as well as unique features of the reservoir being modeled.

In order to closely match an actual in-lake condition with the predicted condition, BATHTUB allows the user to modify a set of calibration factors (Table 1). For a complete description of the BATHTUB model the reader is referred to Walker (1996).

Table 1. Selected Model Parameters, Number and Name of Model, and Where Appropriate the Calibration Factor Used for Fordville Dam's Bathtub Model

Model Option	Model Selection	Calibration Factor
Conservative Substance	0 Not Computed	1.00
Phosphorus Balance	5 Vollenweider	1.25
Phosphorus – Ortho P	5	2.35
Nitrogen Balance	5 Bachman Flushing	1.09
Organic Nitrogen	6	0.82
Chlorophyll-a	1 P, N, Light, T	1.55
Secchi Depth	1 vs. Chla & Turbidity	3.5
Phosphorus Calibration	1 Decay Rates	NA
Nitrogen Calibration	1 Decay Rates	NA
Availability Factors	0 Ignore	NA
Mass-Balance Tables	0 Use Observed Concentrations	NA

Results

The trophic response model, BATHTUB, has been calibrated to match Fordville Dam's trophic condition for the period between January 6, 2009 and September 6, 2010. Calibration was accomplished by combining tributary loading estimates for the project period (November 2008 through October 2010) with in-lake water quality estimates. Tributary flow and concentration data for the project period are reduced by the FLUX program and the corresponding in-lake water quality data were reduced utilizing the Profile Program and the output from these two programs are then provided as input to the BATHTUB model.

The BATHTUB model is calibrated through several iterations, first by selecting appropriate empirical relationships for model coefficients (e.g., nitrogen and phosphorus sedimentation, nitrogen and phosphorus decay, oxygen depletion, and algal/chlorophyll growth), and second by adjusting the models calibration factors for those coefficients (Table 1). The model is termed calibrated when the predicted estimates for the trophic response variables are similar to observed estimates made from project monitoring data.

The two most important nutrients controlling trophic response in Fordville Dam are nitrogen and phosphorus. After calibration the observed average annual concentration of total nitrogen and total phosphorus compare well with those of the BATHTUB model. Once calibrated, the model predicted the reservoirs annual volume weighted mean total nitrogen concentration at 1437.01 µg L^{-1} and total phosphorus at 225.68 µg L^{-1}compared to observed values for total nitrogen and total phosphorus of 1438.02 µg L^{-1} and 225.5 µg L^{-1}, respectively (Table 2).

Other measures of trophic response predicted by the model are mean annual chlorophyll-a concentration and average secchi disk transparency. After calibration the model did just as good a job of predicting average chlorophyll-a concentration and secchi disk transparency within the reservoir as total phosphorus and total nitrogen (Table 2).

Once predictions of total phosphorus, chlorophyll-a, and secchi disk transparency are made, the model calculates Carlson's Trophic Status Index (TSI) (Carlson 1977) as a means of expressing trophic response (Table 2). Carlson's TSI is an index that can be used to measure the relative trophic state of a lake or reservoir. Simply stated, trophic state is how much production (i.e., algal and weed growth) occurs in the waterbody. The lower the nutrient concentrations are within the waterbody the lower the production and the lower the trophic state or level. In contrast, increased nutrient concentrations in a lake or reservoir increase the production of algae and weeds which make the lake or reservoir more eutrophic or of a higher trophic state. Oligotrophic is the term which describes the least productive lakes and hypereutrophic is the term used to describe lakes and reservoirs with excessive nutrients and primary production.

Table 2. Observed and Predicted Values for Selected Trophic Response Variables for the Calibrated "BATHTUB" Model

Variable	Observed	Predicted
Total Phosphorus as P (µg/L)	225.8	225.52
Total Dissolved Phosphorus as P (µg/L)	207.7	207.55
Total Nitrogen as N (µg/L)	1436.2	1438.20
Organic Nitrogen as N (µg/L)	908.4	906.69
Chlorophyll-a (µg/L)	38.7	38.61
Secchi Disk Transparency (meters)	1.80	1.78
Carlson's TSI for Phosphorus	82.30	82.28
Carlson's TSI for Chlorophyll-a	66.46	66.44
Carlson's TSI for Secchi Disk	51.53	51.68

Figure 1 provides a graphic summary of the TSI range for each trophic level compared to values for each of the trophic response variables. The calibrated model provided predictions of trophic status which are similar to the observed TSI values for the project period (Table 2). Predicted and observed TSI values for phosphorus and chlorophyll-a suggest Fordville Dam is beginning life as hypereutrophic, while the TSI value of secchi disk depth indicated the reservoir is eutrophic.

Model Predictions

Once the model is calibrated to existing conditions, the model can be used to evaluate the effectiveness of any number of nutrient reduction or lake restoration alternatives. This evaluation is accomplished by comparing the predicted trophic state, as reflected by Carlson's TSI, with currently observed TSI values. Modeled nutrient reduction alternatives are presented in three basic categories: (1) reducing externally derived nutrient loads; (2) reducing internally available nutrients; and (3) reducing both external and internal nutrient loads. For Fordville Dam only external nutrient loads were addressed. External nutrient loads were addressed because they are known to cause eutrophication and because they are controllable through the implementation of watershed Best Management Practices (BMPs).

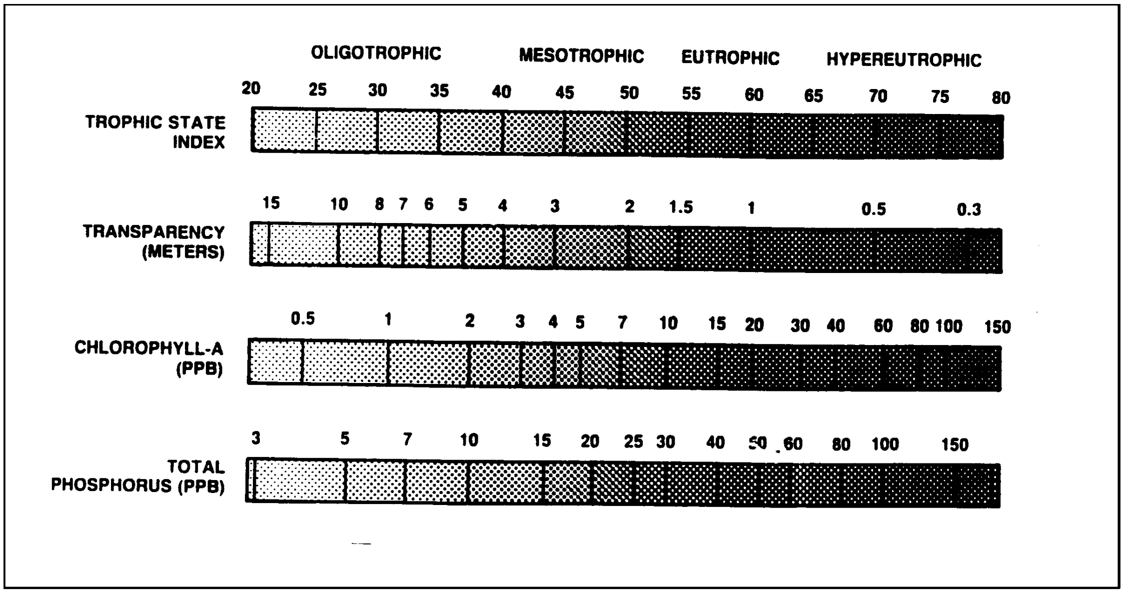

Figure 1. Graphic Depiction of Carlson's Trophic Status Index.

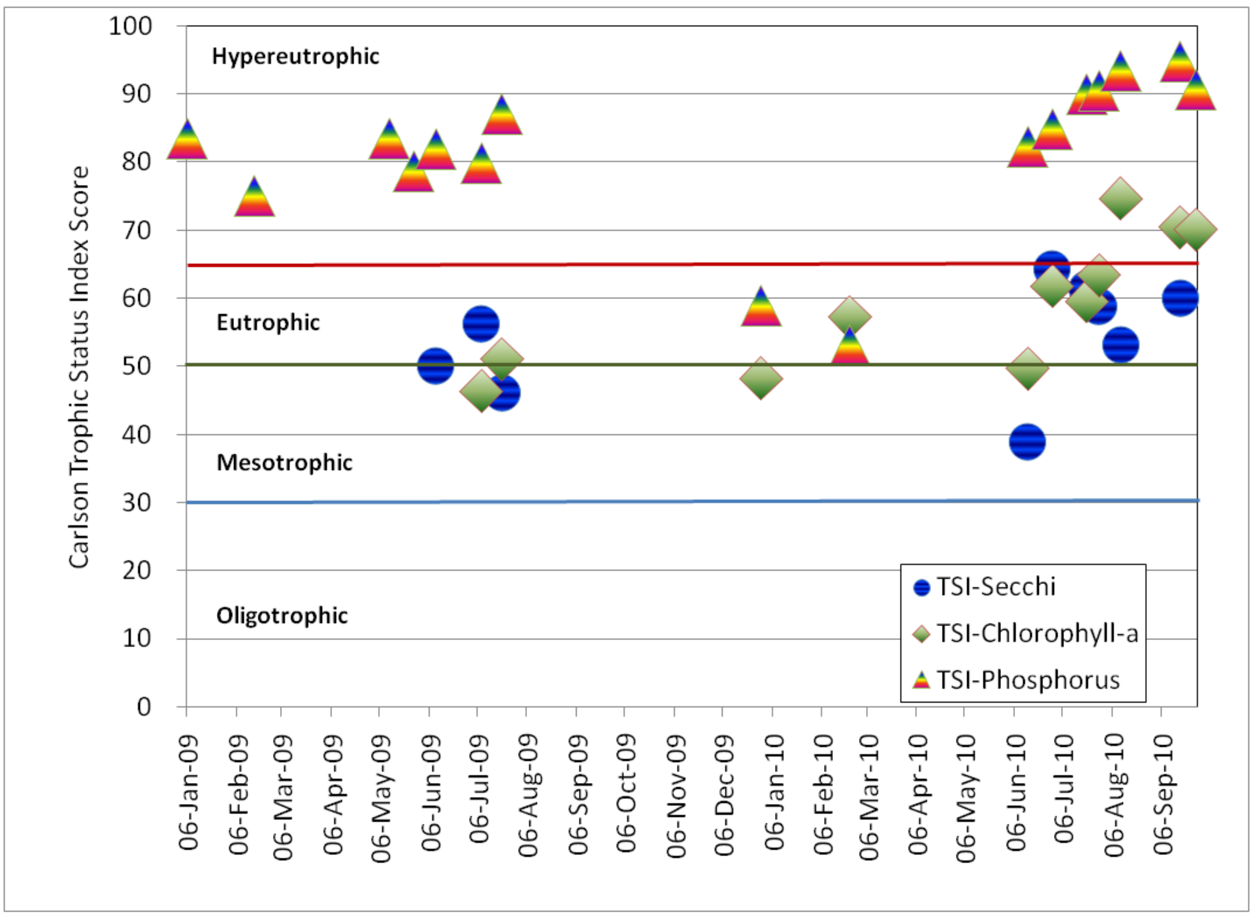

Figure 2. Temporal Distribution of Carlson's Trophic Status Index Scores for Fordville Dam (5/29/2009 though 10/22/2009)

Predicted changes in Fordville Dam’s trophic response were evaluated by reducing externally derived nutrient loads by 10, 25, 50, and 75 percent. These reductions were simulated in the model by reducing all species of phosphorus and nitrogen concentrations in the contributing tributary and other external delivery sources by 10, 25, 50, and 75 percent. Since there is no reliable means of estimating how much hydraulic discharge would be reduced through the implementation of BMPs, flow was held constant.

The model results indicate that if it were possible to reduce external nutrient loading to Fordville Dam by 50 percent, the lake would experience a measurable reductions of in-lake total phosphorus and result in a noticeable decrease in chlorophyll-a concentrations and water clarity (Table 3, Figure 3). On the extreme end, a 75 percent reduction in external nutrient load would results in a model predicted reduction in Carlson's TSI score from 66.46 to 49.03 for chlorophyll-a and from 51.53 to 44.13 for secchi disk transparency, corresponding to a trophic state of mesotrophic and oligotrophic, respectively.

Table 3. Observed and Predicted Values for Selected Trophic Response Variables from a 10, 25, 50, and 75 Percent Reduction in External Phosphorus and Nitrogen Loading

Variable	Observed	-10%	-25%	-50%	-75%
Total Phosphorus as P (µg/L)	225.80	203.05	169.33	113.15	56.96
Total Nitrogen as N (µg/L)	1436.20	1297.05	1085.60	733.18	380.75
Chlorophyll-a (µg/L)	38.70	34.31	27.94	17.46	6.54
Secchi Disk Transparency (meters)	1.80	1.88	2.06	2.44	3.01
Carlson's TSI for Phosphorus	82.30	80.77	78.15	72.34	62.44
Carlson's TSI for Chlorophyll-a	66.46	65.28	63.27	58.66	49.03
Carlson's TSI for Secchi Disk	51.53	50.87	49.58	47.17	44.13

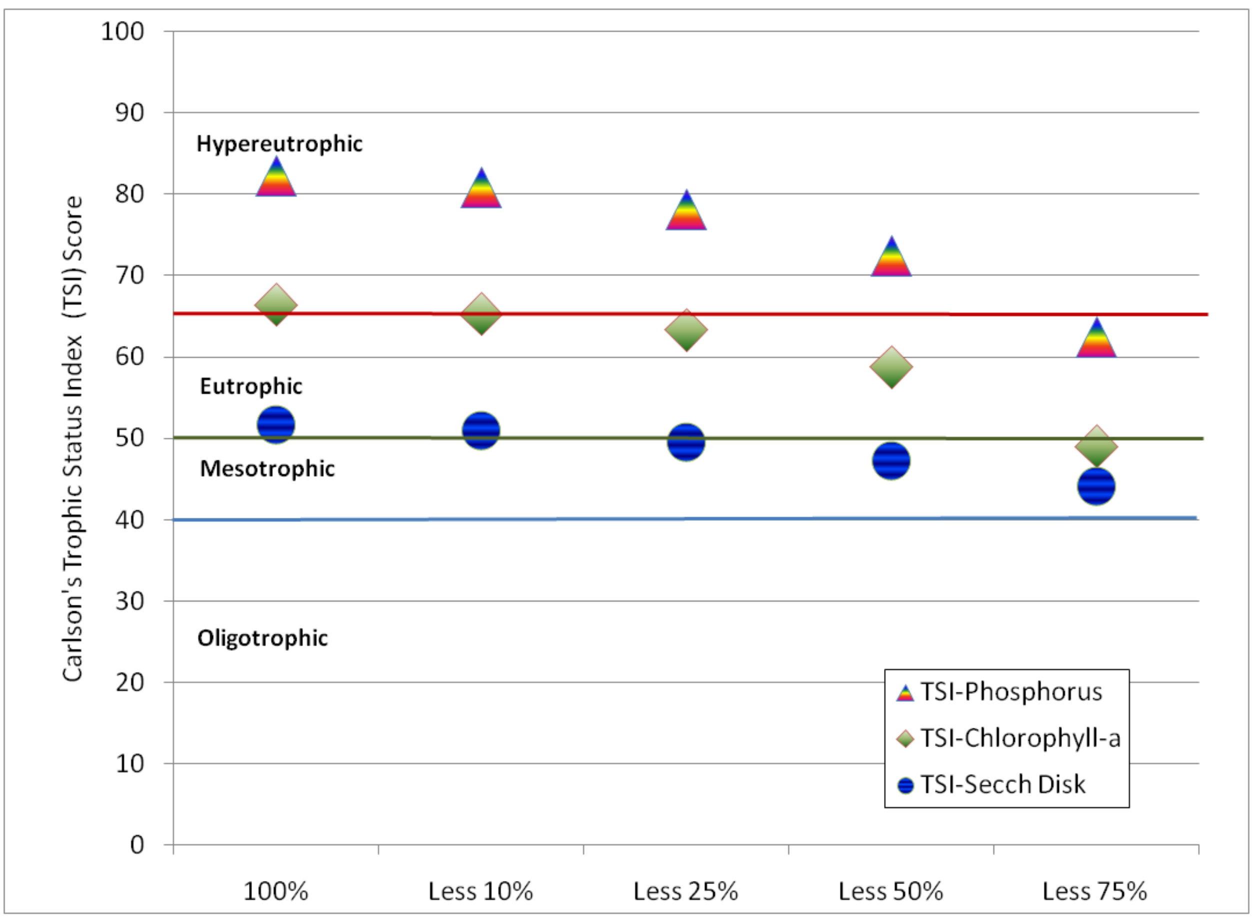

Figure 3. Predicted Change in Fordville Dam's Trophic Condition to Nutrient Load Reductions of 10, 25, 50, and 75 Percent.

Appendix D
US EPA Region 8 Public Notice Review and Comments

EPA REGION VIII TMDL REVIEW

TMDL Document Info:

Document Name:	**Nutrient TMDL for Fordville Dam in Grand Forks County, North Dakota**
Submitted by:	**Mike Ell, North Dakota Department of Health**
Date Received:	**August 3, 2011**
Review Date:	**August 31, 2011**
Reviewer:	**Vern Berry, Environmental Protection Agency**
Rough Draft / Public Notice / Final Draft?	**Public Notice Draft**
Notes:	

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

☐ Approve
☐ Partial Approval
☐ Disapprove
☐ Insufficient Information

Approval Notes to Administrator:

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

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

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

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

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

1. Problem Description

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

1.1 TMDL Document Submittal Letter

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

Minimum Submission Requirements.

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

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

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

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

SUMMARY: A draft version of the Fordville Dam TMDL document was submitted to EPA for review during the public notice period via an email from Mike Ell, NDDoH on August 3, 2011. The email included the draft TMDL document and a public notice announcement requesting review and comment on the draft TMDL.

COMMENTS: None.

1.2 Identification of the Waterbody, Impairments, and Study Boundaries

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

Minimum Submission Requirements:

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

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

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

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

SUMMARY: Fordville Dam (reservoir) is located in Grand Forks County in northeastern North Dakota (approximately 50 miles northwest of the city of Grand Forks, North Dakota). It is an 185 acre man-made impoundment in the Forest sub-basin of the Red River basin of North Dakota (HUC 09020308). It was created by damming the South Branch Forest River and was completed in 1981. Fordville Dam is listed on the State's 2010 303(d) list (ND-09020308-001-L_00) as having an impaired recreational use from nutrients/eutrophication/biological indicators. Approximately 29,382 acres of land drain to the reservoir from the watershed. It is classified as a Class 2 cool-water fishery capable of supporting natural reproduction and growth of cool-water fishes (i.e. walleye and northern pike) and associated aquatic biota and marginal growth and survival of cold-water species and associated biota. It is listed as a high priority for TMDL development.

COMMENTS: None.

1.3 Water Quality Standards

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

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

Minimum Submission Requirements:

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

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

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

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

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

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

SUMMARY: Fordville Dam is impaired for nutrients/eutrophication/biological indicators. The North Dakota Department of Health has set narrative water quality standards that apply to all surface waters of the state. The NDDoH narrative standards that apply to nutrients include:

> *"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." (See NDAC 33-16-02-08.1.a.(4))*
>
> *"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." (See NDAC 33-16-02-08.1.e.)*

In addition to the narrative standards, the NDDH has set a biological goal for all surface waters of the state:

> *"The biological condition of surface waters shall be similar to that of sites or waterbodies determined by the department to be regional reference sites." (See NDAC 33-16-02-08.2.a.)*

Currently, North Dakota does not have a numeric standard for nutrients, however nutrient guidelines for lakes have been established. The nutrient guidelines for lakes are: NO3 as N = 0.25 mg/L; PO4 as P = 0.02 mg/L; and total phosphorus = 0.1 mg/L.

Other applicable water quality standards are included on pages 10 - 11 of the TMDL report.

COMMENTS: None.

2. Water Quality Targets

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

Minimum Submission Requirements:

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

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

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

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

SUMMARY: The main water quality target for this TMDL is based on interpretation of narrative provisions found in State water quality standards. In North Dakota, algal blooms can limit contact and immersion recreation beneficial uses. Also algal blooms can deplete oxygen levels which can affect aquatic life uses. Several algal species are considered to be nuisance aquatic species. TSI measurements can be used to estimate how much algal production may occur in lakes. Therefore, TSI is used as a measure of the narrative standard in order to determine whether beneficial uses are being met.

The mean total phosphorus TSI for Fordville Dam during the period of the assessment was 82.3. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that a 50% reduction in phosphorus loading to the reservoir will achieve an in-lake total phosphorus TSI of 72, which corresponds to a phosphorus concentration of 0.113 mg/L. This should result in a change of trophic status for the reservoir from hypereutrophic to top end of the eutrophic range during all times of the year. This target is based on best professional judgement.

The water quality targets used in this TMDL are: **maintain a mean annual total phosphorus TSI at or below 72 (TP concentration $\leq$ 0.113 mg/L).**

COMMENTS: We recommend using a different target than the TP TSI value currently written into the TMDL document. Given the work done by Houston Engineering for ND nutrient criteria it seems that the TP concentrations are often high in ND lakes/reservoirs, and are not well correlated with the chlorophyll-a algal response. That work, as well as the references in the TMDL document (see the last paragraph on page 11 of the Fordville Dam TMDL), suggest that using a chlorophyll-a TSI target would be a better indicator of lake productivity and expected fishery type. A chl-a TSI of 50 would be more likely to protect the cool water fishery classification for Fordville Dam (see Carlson's TSI chart: http://www.secchidipin.org/tsi.htm that indicates a cool water fishery that supports walleye should achieve a TSI of 50 or below). However, we have been working with SD to set lake/reservoir TMDL targets for chl-a TSI at or below 60 or a chl-a concentration at or below 20 ug/L (as a growing season average) for more recent TMDLs until such time that state specific nutrient criteria are developed. For the Fordville Dam TMDL a chl-a TSI less than 60 can be met with the same 50% reduction in TP that is currently written into the document, and only minor changes would need to be made to the overall document. Therefore, we recommend that the target be changed to chlorophyll-a TSI = 58.7 (corresponding to a 50% reduction in TP loading as modeled by BATHTUB) and/or a chlorophyll-a concentration of 17.5 ug/L growing season average.

3. Pollutant Source Analysis

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

Minimum Submission Requirements:

- ☒ The TMDL should include an identification of all potentially significant point and nonpoint sources of the pollutant of concern, including the geographical location of the source(s) and the quantity of the loading, e.g., lbs/per day. This information is necessary for EPA to evaluate the WLA, LA and MOS components of the TMDL.
- ☒ The level of detail provided in the source assessment should be commensurate with the nature of the watershed and the nature of the pollutant being studied. Where it is possible to separate natural background from nonpoint sources, the TMDL should include a description of both the natural background loads and the nonpoint source loads.
- ☒ Natural background loads should not be assumed to be the difference between the sum of known and quantified anthropogenic sources and the existing *in situ* loads (e.g. measured in stream) unless it can be demonstrated that all significant anthropogenic sources of the pollutant of concern have been identified, characterized, and properly quantified.
- ☒ The sampling data relied upon to discover, characterize, and quantify the pollutant sources should be included in the document (e.g. a data appendix) along with a description of how the data were analyzed to characterize and quantify the pollutant sources. A discussion of the known deficiencies and/or gaps in the data set and their potential implications should also be included.

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

SUMMARY: The TMDL document includes the landuse breakdown for the watershed based on the 2007 National Agricultural Statistics Service (NASS) data. In 2007, the dominant land use in the Fordville Dam watershed was agriculture consisting of crop production. Approximately 60 percent of the landuse in the watershed was cropland, 17 percent was grassland/pastureland, 12 percent was wetlands, and the remaining 11 percent was developed space, barren forest or fallow/idle cropland. The majority of the crops grown consist of spring wheat, dry beans, and soybeans, sunflowers, barley and corn.

TMDL identifies the major sources of phosphorus as coming from nonpoint source agricultural landuses within the watershed. There are no known point sources upstream of Fordville Dam. A nutrient loading analysis was performed using the annualized agricultural nonpoint source (AnnAGNPS) model which looked at various agricultural land uses and land management practices in the watershed. Cropland used to grow wheat, winter wheat, barley, corn, canola, peas, soybeans, dry beans, sunflowers as well as pasture and rangeland were the primary landuse sources identified. The compiled data was used to assess the watershed to identify "critical cells" located in the watershed for potential best management practice (BMP) implementation. Critical cells were determined to be cells in the watershed providing an estimated annual phosphorus yield of 0.128 lbs/acre/year or greater.
COMMENTS: None.

4. TMDL Technical Analysis

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

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

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

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

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

Where:

TMDL = Total Pollutant Loading Capacity of the waterbody

LAs = Pollutant Load Allocations

WLAs = Pollutant Wasteload Allocations

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

Minimum Submission Requirements:

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

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

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

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

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

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

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

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

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

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

In order to determine the cause and effect relationship between the water quality target and the identified sources, various models and loading analysis were utilized. The FLUX model was used to facilitate the analysis and reduction of the tributary inflow and the reservoir outflow water quality data for nutrients and sediment, as well as flow data into and out of Fordville Dam. Output from the FLUX program was then used as an input file to calibrate the BATHTUB eutrophication response model. The BATHTUB model was used to evaluate and predict the effects of various nutrient reduction scenarios, and the subsequent eutrophication response in Fordville Dam reservoir.

The BATHTUB model was used to predict the trophic response of Fordville Dam by reducing exteranlly derived nutrient loads. Once the BATHTUB model is calibrated using the tributary load estimates and the in-lake water quality estimates, the model can predict the total phosphorus concentrations, chlorophyll-a concentrations, and the Secchi disk transparency, and the associated TSI scores, as a means of expressing trophic response. Phosphorus was used in the initial set of simulation models based on its known relationship to eutrophication, and because it is controable with the implementation of watershed best management practices (BMPs). Simulated reductions were achieved by reducing concentrations of phosphorus and nitrogen in the contributing tributaries by 25, 50 and 75 percent while keeping the hydraulic discharge constant. The BATHTUB model predicted that a 50% reduction in external total phosphorus loads is predicted to result in attaining a total phosphorus TSI in the eutrophic range in the reservoir. As a result of this modeling, the loading capacity for the reservoir was determined to be 3,305.15 kg/yr of phosphorus.

Table 10. Observed and Predicted Values for Selected Trophic Response Variables Assuming a 10, 25, 50, and 75 Percent Reduction in External Phosphorus and Nitrogen Loading.

Variable	Observed Value	Predicted Value			
		10%	25%	50%	75%
Total Phosphorus (mg/L)	0.256	0.203	0.169	0.113	0.057
Total Nitrogen (mg/L)	1.436	1.297	1.085	0.733	0.381
Chlorophyll-a (µg/L)	38.7	34.31	27.94	17.46	6.54
Secchi Disk Transparency (meters)	1.8	1.88	2.06	2.44	3.01
Carlson's TSI for Phosphorus	82.3	80.77	78.15	72.34	62.44
Carlson's TSI for Chlorophyll-a	66.46	65.28	63.27	58.66	49.03
Carlson's TSI for Secchi Disk	51.53	50.87	49.58	47.17	44.13

The Annualized Agricultural Non-Point Source Model (AnnAGNPS) model was used to simulate alterations in land use practices and the resulting nutrient loading reduction. The primary objectives for using the AnnAGNPS model were to: 1) evaluate nonpoint source contributions within the watershed; 2) identify critical pollutant source areas within the watershed; and 3) evaluate potential pollutant reduction estimates achievable from implementation of various BMP scenarios. The results from the nutrient loading source analysis was used to assess the watershed to identify “critical cells” (i.e., those with greater than or equal to 0.128 lbs/acre/yr of phosphorus loading – see Figure 11 in the TMDL document). Based on the AnnAGNPS model, if BMP’s are implemented on these critical areas, it is estimated that the phosphorus load would be reduced by 50 percent, thereby meeting the TMDL goal.

There are no permitted point sources in the watershed so it’s not necessary to fully document reasonable assurance demostrating that the nonpoint source loadings are practicable.

COMMENTS: To be consistent with the recommended revision to the TMDL target we recommend the following additional revisions: 1) change the dividing line between eutrophic and hypereutrophic to 65 (mostly we've seen from Carlson and others that the line separating those trophic states is at 60 or 65, but NDDoH has used 65 in the past); 2) change the current Trophic Status for chl-a in Table 8 from eutrophic to hypereutrophic; 3) change the TSI ranges below Table 8 to TSI 50-65 Eutrophic; TSI > 65 Hypereutrophic; 4) move the line between hypereutrophic and eutrophic to 65 in Figures 8 and 9; and 5) delete the last sentence in Section 3.1 (page 13) that implies that the target is based on what is achievable ("...best possible outcome for the reservoir") rather than what is necessary to meet the water quality standards and protect the beneficial uses.

4.1 Data Set Description

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

Minimum Submission Requirements:

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

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

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

SUMMARY: The Fordville Dam TMDL includes data summary tables in primarily in Section 1.4, Available Water Quality Data, and in other sections throughout the document. The recent water quality monitoring was conducted over the period from November 2008 to September 2010.

COMMENTS: None.

4.2 Waste Load Allocations (WLA):

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

Minimum Submission Requirements:

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

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

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

SUMMARY: There are no permitted point sources in the Fordville Dam watershed. Therefore the WLA for this TMDL is zero (see Table 12 in the TMDL document).

COMMENTS: None.

4.3 Load Allocations (LA):

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

Minimum Submission Requirements:

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

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

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

SUMMARY: The Technical Analysis section of the TMDL describes how the phosphorus loading capacity for the reservoir was derived. The loading capacity was derived from the current loading, the TSI target and the reduction response from the BATHTUB model. Most of the loading capacity was allocated to nonpoint sources in the watershed which is expressed as the LA (2,974.64 kg/yr). Ten percent of the loading capacity was allocated as an explicit margin of safety (330.51 kg/yr).

COMMENTS: None.

4.4 Margin of Safety (MOS):

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

Minimum Submission Requirements:

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

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

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

SUMMARY: The Fordville Dam TMDL includes an explicit MOS derived by calculating 10 percent of the loading capacity. The explicit MOS for the Fordville Dam TMDL is 303.51 kg/yr.

COMMENTS: None.

4.5 Seasonality and variations in assimilative capacity:

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

Minimum Submission Requirements:

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

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

SUMMARY: Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing BMPs that can be tailored to seasonal needs.

COMMENTS: None.

5. Public Participation

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

Minimum Submission Requirements:

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

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

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

SUMMARY: The TMDL includes a summary of the public participation process that has occurred. It describes the opportunities the public had to be involved in the TMDL development process. Copies of the draft TMDL were mailed to stakeholders in the watershed during public comment. Also, the draft TMDL was posted on NDoDH's Water Quality Division website, and a public notice for comment was published in state and local newspapers.

COMMENTS: None.

6. Monitoring Strategy

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

Minimum Submission Requirements:

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

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

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

SUMMARY: Fordville Dam will be monitored once a watershed restoration plan is implemented and will be conducted beginning two years after implementation and extend until five years after the implementation project is complete (i.e., for a three year period).

COMMENTS: None.

7. Restoration Strategy

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

Minimum Submission Requirements:

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

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

SUMMARY: The TMDL Allocation section of the TMDL document includes a map (Figure 11) of priority areas where implementation of BMPs is recommended in order to meet the TMDL loading goals. NDDoH typically works with local conservation districts or other cooperators to develop and implement a project implementation plan after the TMDL has been developed and approved.

There are no permitted point sources in the watershed so it's not necessary to fully document reasonable assurance demostrating that the nonpoint source loadings are practicable.

COMMENTS: None.

8. Daily Loading Expression

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

Minimum Submission Requirements:

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

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

SUMMARY: The Fordville Dam nutrient TMDL includes a daily phosphorus load expressed as 9.06 kg per day. The NDDoH believes that describing the phosphorus load as an annual load is more realistic and protective of the waterbody. Most phosphorus based eutrophication models use annual phosphorus loads, because seasonality and unpredictable precipitation patterns make a daily load unrealistic. EPA recognizes that, under the specific circumstances, the state may deem the annual load the most appropriate timeframe (i.e., the TSI water quality target is based on an interpretation of narrative water quality standards which naturally does not include an averaging period). EPA notes that the Fordville Dam TMDL calculations for phosphorus include an approximated daily load derived through simple division of the annual load by the number of days in a year**.** This should be considered an "average" daily load that typically will not match the actual phosphorus load reaching the reservoir on a given day.

COMMENTS: None.

Appendix E
NDDoH’s Response to Comments Received from US EPA Region 8

EPA Region 8 Comment: We recommend using a different target than the TP TSI value currently written into the TMDL document. Given the work done by Houston Engineering for ND nutrient criteria it seems that the TP concentrations are often high in ND lakes/reservoirs, and are not well correlated with the chlorophyll-a algal response. That work, as well as the references in the TMDL document (see the last paragraph on page 11 of the Fordville Dam TMDL), suggest that using a chlorophyll-a TSI target would be a better indicator of lake productivity and expected fishery type. A chl-a TSI of 50 would be more likely to protect the cool water fishery classification for Fordville Dam (see Carlson's TSI chart: http://www.secchidipin.org/tsi.htm that indicates a cool water fishery that supports walleye should achieve a TSI of 50 or below). However, we have been working with SD to set lake/reservoir TMDL targets for chl-a TSI at or below 60 or a chl-a concentration at or below 20 ug/L (as a growing season average) for more recent TMDLs until such time that state specific nutrient criteria are developed. For the Fordville Dam TMDL a chl-a TSI less than 60 can be met with the same 50% reduction in TP that is currently written into the document, and only minor changes would need to be made to the overall document. Therefore, we recommend that the target be changed to chlorophyll-a TSI = 58.7 (corresponding to a 50% reduction in TP loading as modeled by BATHTUB) and/or a chlorophyll-a concentration of 17.5 ug/L growing season average.

NDDoH Response: The last paragraph of Section 3.1 was reworded to accommodate the change in the TMDL target from a TSI score based on total phosphorus concentration to one based on a growing season average chlorophyll-a concentration of 17.5 µg/L.

EPA Region 8 Comment: To be consistent with the recommended revision to the TMDL target we recommend the following additional revisions: 1) change the dividing line between eutrophic and hypereutrophic to 65 (mostly we've seen from Carlson and others that the line separating those trophic states is at 60 or 65, but NDDoH has used 65 in the past); 2) change the current Trophic Status for chl-a in Table 8 from eutrophic to hypereutrophic; 3) change the TSI ranges below Table 8 to TSI 50-65 Eutrophic; TSI > 65 Hypereutrophic; 4) move the line between hypereutrophic and eutrophic to 65 in Figures 8 and 9; and 5) delete the last sentence in Section 3.1 (page 13) that implies that the target is based on what is achievable ("...best possible outcome for the reservoir") rather than what is necessary to meet the water quality standards and protect the beneficial uses.

NDDoH Response: All suggested revisions we made.