Nutrient and Dissolved Oxygen TMDLs for Short Creek Dam in Burke County, North Dakota

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****Includes De-listing Justification for Sediment Impairment**

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1.0 INTRODUCTION AND DESCRIPTION OF THE WATERSHED

Short Creek Dam is located in northern Burke County in northwestern North Dakota (Figures 1 and 2). The reservoir was created for recreation in 1962 by the North Dakota Game and Fish. It has a surface area of 108.1 acres, an average depth of 11.4 feet and a maximum depth of 27.6 feet (Figure 3). The watershed flows northward and empties into the Souris River in Saskatchewan, Canada. The Burke County Soil Conservation District Board has received a great deal of public comment on the importance of Short Creek Dam as a recreation location, so there is a strong desire to maintain the fishery as well as keep the lake aesthetically pleasing for the people that use it. Table 1 summarizes some of the geographical, hydrological and physical characteristics of Short Creek Dam.

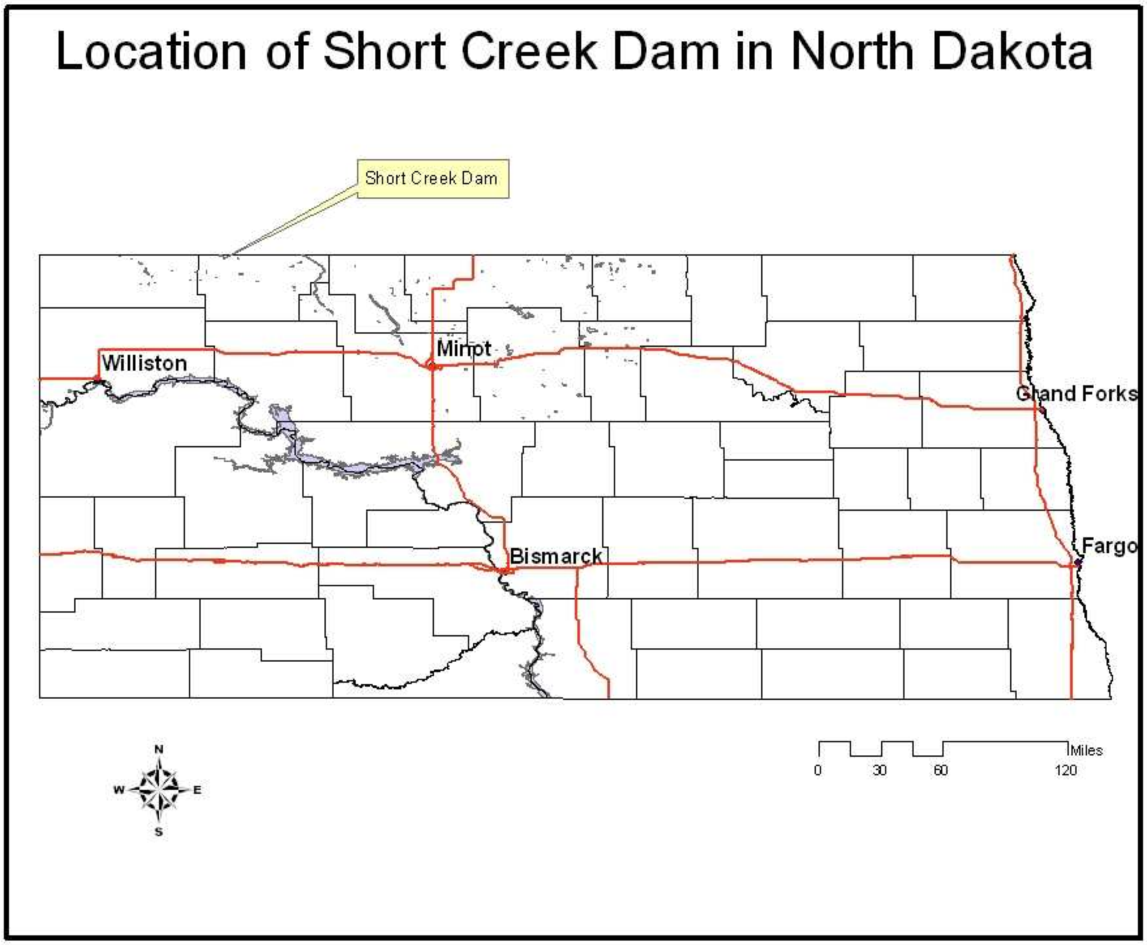

Figure 1. Location of Short Creek Dam in North Dakota.

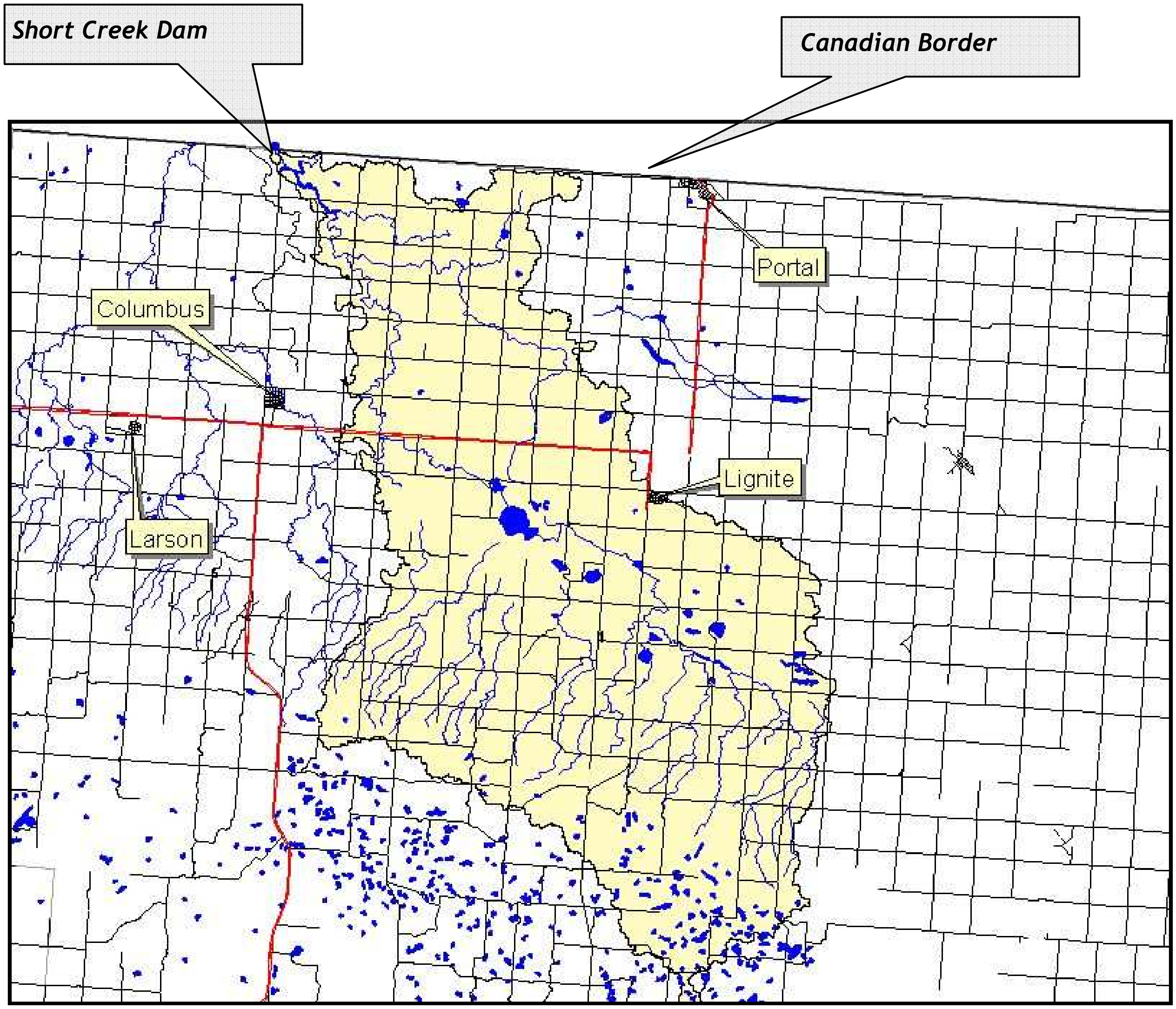

Figure 2. Location of Short Creek Dam and Watershed.

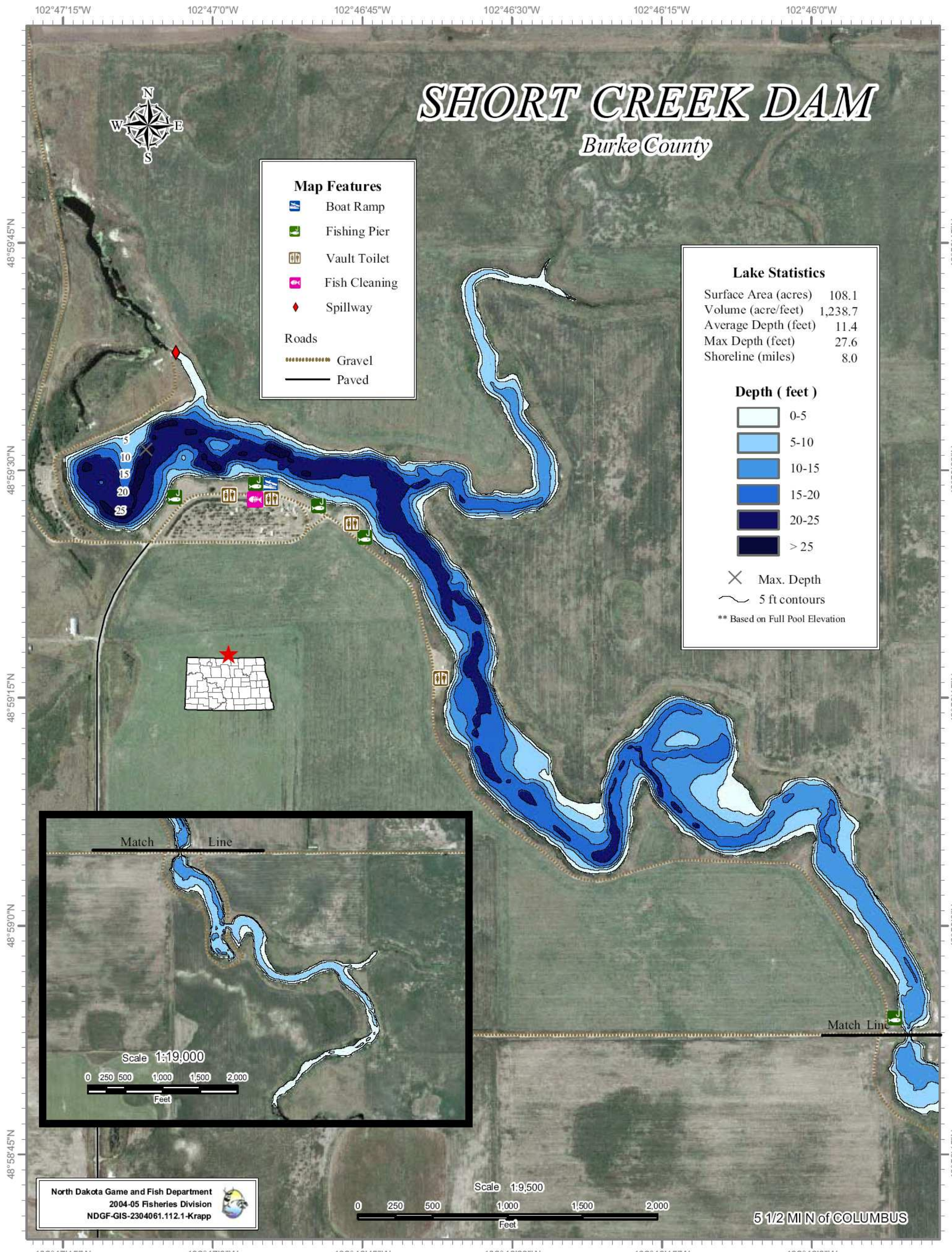

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Figure 3. Contour Map of Short Creek Dam.

Table 1. General Characteristics of Short Creek Dam and the Short Creek Dam Watershed.

Legal Name	Short Creek Dam
Major Drainage Basin	Souris River
Assessment Unit ID	ND-09010001-001-L_00
Nearest Municipality	Columbus, ND
County	Burke County, ND
Eco-region	Northern Dark Brown Prairie in the Northern Glaciated Plains
Latitude	48.99164
Longitude	-102.78601
Surface Area	108.1 acres
Watershed Area	133,600 acres (124,640 in US/ 8,960 in Canada)
Average Depth	11.4 feet
Maximum Depth	27.6 feet
Volume	1,238.7 acre-feet
Tributaries	Un-named tributaries
Outlets	Souris River (in Saskatchewan, Canada)
Type of Waterbody	Constructed Reservoir
Fishery Type	Cool water – walleye, yellow perch, northern pike

1.1 Clean Water Act Section 303(d) Listing Information

Based on the 2008 Section 303(d) list of impaired waters needing TMDLs, the North Dakota Department of Health (NDDoH) has identified Short Creek Dam as fully supporting but threatened for recreational beneficial use due to nutrient enrichment/eutrophication and biological indicators, and fully supporting, but threatened for aquatic life beneficial uses due to sediment/siltation, nutrient enrichment/eutrophication/biological indicators, and low dissolved oxygen levels (Table 2). Fish and other aquatic biota inhabiting the reservoir are threatened because accelerated eutrophication as a result of nutrient enrichment from the contributing watershed.

Table 2. 2008 Section 303(d) TMDL Listing Information for Short Creek Dam.

Waterbody Name	Short Creek Dam
Assessment Unit ID	ND-09010001-001-L_00
Class	Class 1, Capable of Supporting a Cold Water Fishery
Impaired Designated Uses	Recreation, Fish and Other Aquatic Biota (fully supporting but threatened)
Causes	Nutrients (Enrichment/Eutrophication), Dissolved Oxygen, Sedimentation/Siltation, Biological Indicators
Priority	High

1.2 Topography

Topography within this area of the Northern Glaciated Plains is generally flat with occasional "washboard" undulations. Local relief is typically less than 25 feet. It contains a high concentration of temporary and seasonal wetlands with a simple drainage pattern. Elevation ranges from 1980 to 2220 feet (MSL) and the common soils include Williams, Bowbells, Zahl, and Noonan, with Hamerly and Parnell soils in low areas and depressions. These soils are very deep, well drained or moderately well drained, and formed in glacial till. Permeability is moderate to slow. (USEPA, et al. 1998)

1.3 Land Use/Land Cover in the Watershed

Land use in the watershed is primarily agricultural (97 percent), consisting of cash crop production and livestock grazing. Forty–five percent of the agricultural land is actively cultivated, tilled mainly for durum, spring wheat, and other small grains, and 52 percent is in pasture/haylands (Figure 4). Three percent is in low density urban development. There are 14 animal feeding operations within the contributing drainage (Figure 5).

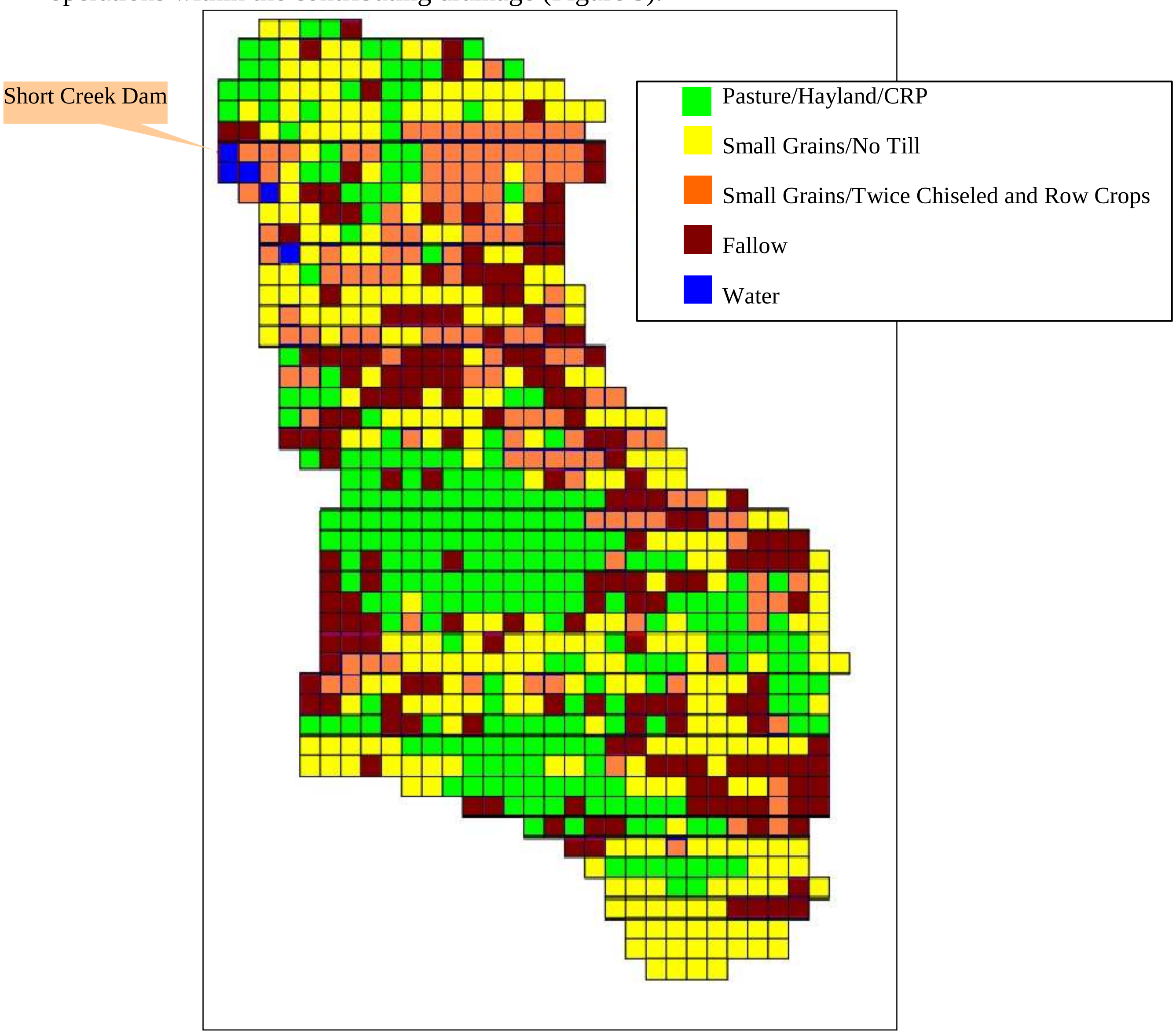


Figure 4. Land Use Map for Short Creek Watershed.

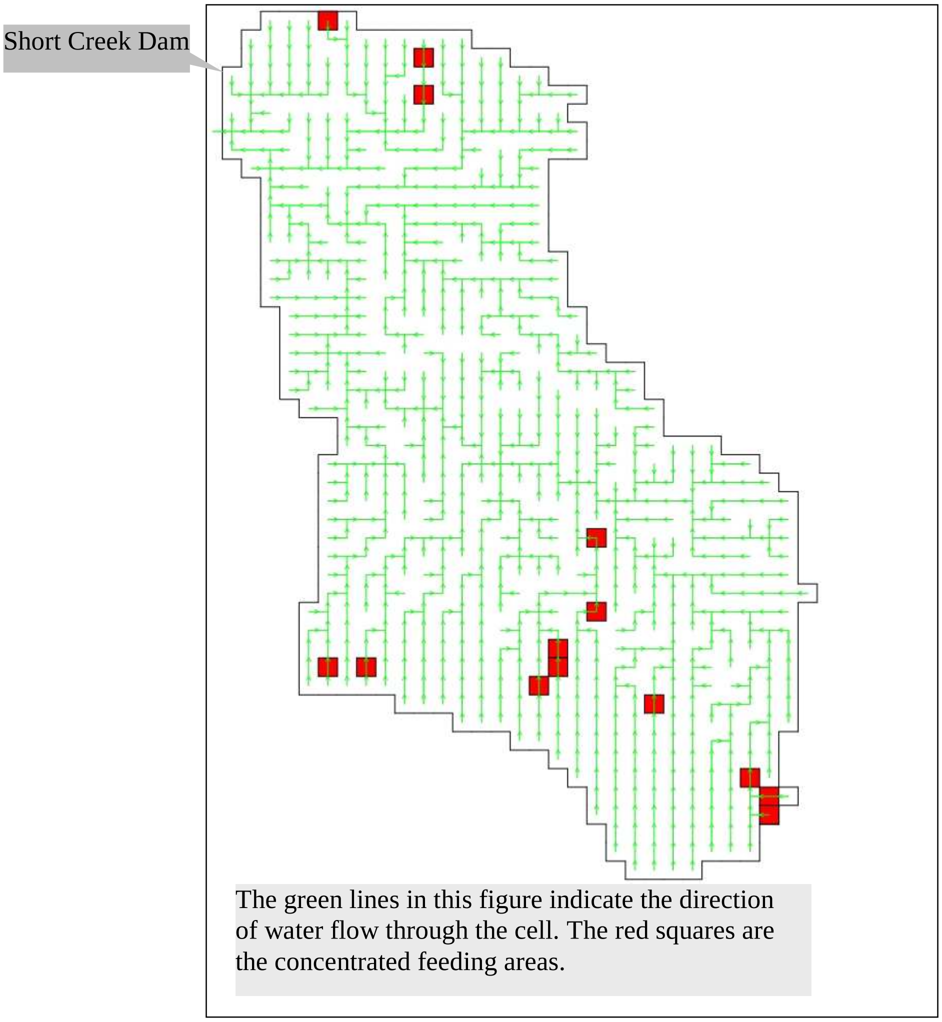


Figure 5. Location of Concentrated Feeding Operations in the Short Creek Watershed.

1.4 Climate and Precipitation

North Dakota's climate is characterized by large temperature variation across all time scales, light to moderate irregular precipitation, plentiful sunshine, low humidity, and nearly continuous wind. Its location at the geographic center of North America results in a strong continental climate, which is exacerbated by the mountains to the west. There are no barriers to the north or south so a combination of cold, dry air masses originating in the far north and warm humid air masses originating in the tropical regions regularly overflow the state. Movement of these air masses and their associated fronts causes near continuous wind and often results in large day to day temperature fluctuations in all seasons. The average last freeze in spring occurs in late May. In the fall, the first 32 degree or lower temperature occurs between September 10th and 25th. However, freezing temperatures have occurred as late as mid-June and as early as mid-August. About 75 percent of the annual precipitation falls during the period of April to September, with 50 to 60 percent occurring between April and July. Most of the summer rainfall is produced during thunderstorms, which occur on an average of 25 to 35 days per year. On the average, rains occur once every three or four days during the summer. Winter snowpack, although persistent from December through March, only averages around 15 inches (Enz, 2003).

Average yearly air temperature at the Bowbells, North Dakota weather station, 14 miles south and 26 miles east of Short Creek Dam, is 38 degrees and average wind speed is 10.7 mph. Average annual precipitation ranges from 7 to 14 inches. November through February averages about 0.50 inches per month, mostly as snow. Measurable precipitation (0.01 inch or more) occurs on an average of 65 to 100 days during the year; over 50 percent of these events produce less than 0.10 inch (NDAWN, 2006).

1.5 Water Quality Data

1.5.1 Background on Nutrients, Dissolved Oxygen, and Sediment

Nutrients (nitrogen and phosphorus) are necessary for plant growth. Excessive amounts can cause abundant aquatic plant growth and algal blooms to occur. When plants die, their decay will accelerate the depletion of oxygen in the water (NDDoH, 1997). The breakdown of dead organic matter can also produced un-ionized ammonia, which can adversely affect aquatic life. Fish may suffer a reduction in hatching success, reductions in growth rate and morphological development, and injury to gill tissue, liver, and kidneys (USEPA, 1999a). The appearance and odors emitted by decaying plant matter also impair aesthetic uses of the waterbody.

Dissolved oxygen is oxygen in solution that has been mixed into the water by wave action on lakes, tumbling water in rivers, and photosynthesis by algae and rooted aquatic plants. Aquatic life needs oxygen to live. Fish, invertebrates, plants, and aerobic bacteria all require oxygen for respiration. The capacity of water to hold dissolved oxygen is dependant on the temperature and salinity of the water and atmospheric pressure (NDDoH, 1997).

Sediment, like nutrients, is a vital natural component of waterbodies. However, high concentrations of suspended sediment will absorb light. Waters then become warmer, which lessens the ability of water to hold oxygen necessary for aquatic life. Because aquatic plants also receive less light, photosynthesis decreases and less oxygen is produced. Excessive suspended sediment can also clog fish gills, reduce growth rates, decrease resistance to disease and prevent egg and larval development (NDDoH, 1997).

Recognizing the need to improve water quality conditions in Short Creek Dam, a TMDL development project was initiated with sponsorship by the Burke County Soil Conservation District (SCD). Data for the TMDL development project was collected between July 2004 and September 2005. Water quality samples were collected from the reservoir and three stream sites in the watershed using the methodology described in the *Quality Assurance Project Plan (QAPP) for the Short Creek Dam TMDL Development Project* (NDDoH, 2004). These sites are identified in Table 3 and Figures 6 and 7.

Table 3. General Information on Water Sampling Sites for Short Creek Dam.

Sampling Site	Site ID	Number of Samples Taken	Latitude (approx.)	Longitude (approx.)
In-lake	380905	21	48.99164	-102.78601
Stream inlet (CAN)	385316	22	48.99546	-102.76691
Stream inlet (US)	385314	41	48.96674	-102.75647
Outlet	385315	37	48.99320	-102.78436

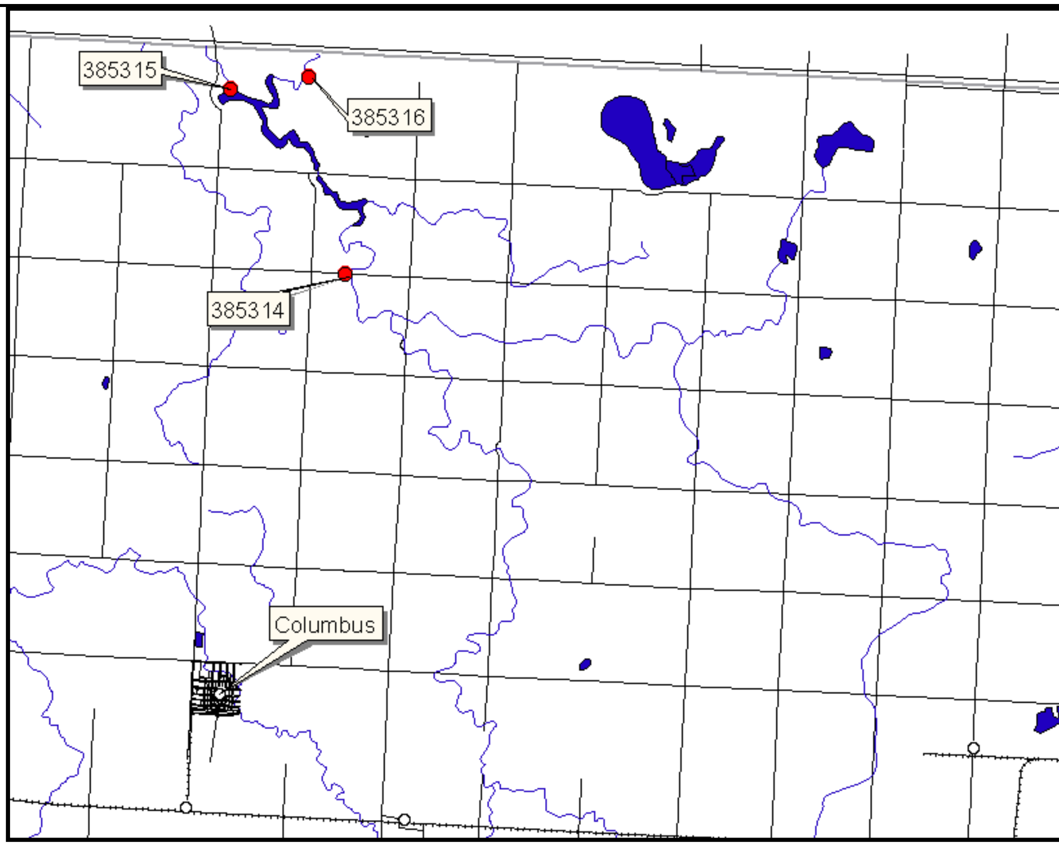


Figure 6. Short Creek Dam Stream Sampling Locations.

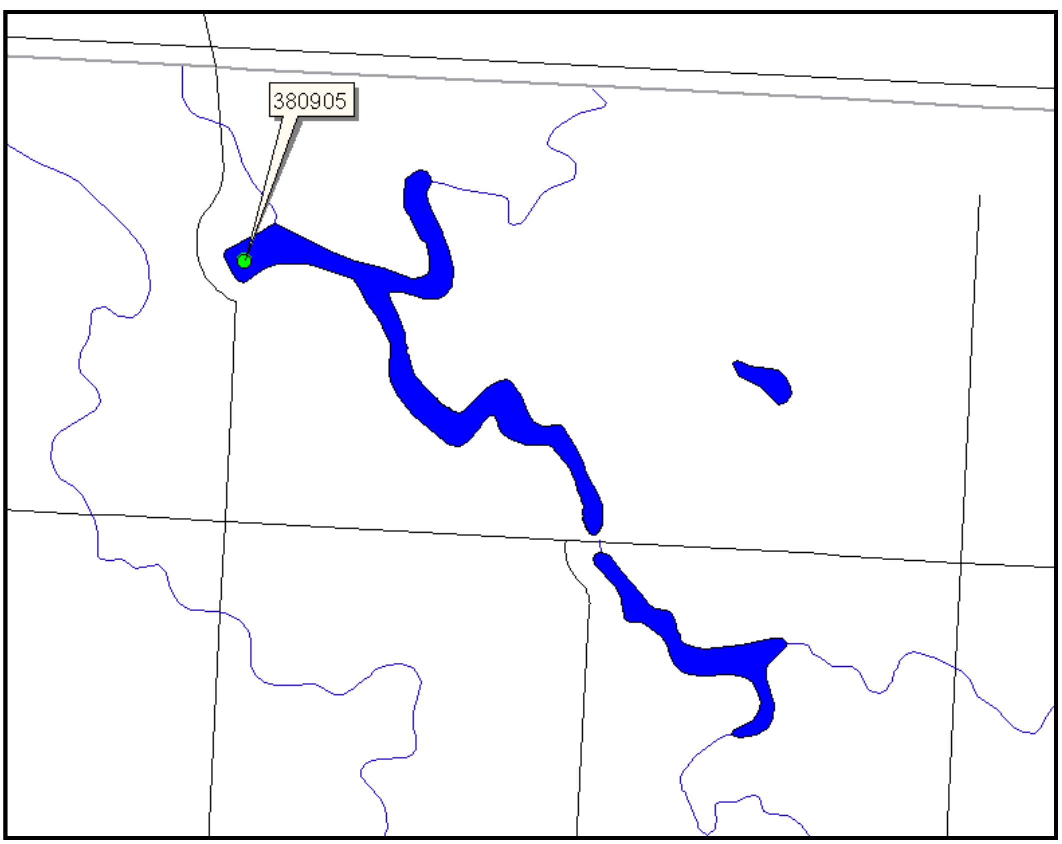


Figure 7. Short Creek Dam Sampling Location.

1.5.2 Stream Data

There were two upstream sites chosen for this project. Since a portion of the watershed is above the Canadian border, it was determined beneficial to document the load entering from this portion. The second inlet site was located approximately one mile upstream of Short Creek Dam. The outlet site was located about 50 yards downstream of the dam face, on a lake access road. An automated stage recorder and staff gage were installed at each site and discharge was measured during each water quality sampling trip. Stream parameters analyzed included total nitrogen, total Kjeldahl nitrogen, nitrate-nitrite, ammonia, total phosphorus, and total suspended solids (Tables 4, 5, and 6). Discharge and water quality parameters were used in the loading calculations (Appendix B). Stream monitoring activities occurred from July – September, 2004 and again between March and September, 2005.

Table 4. Summary of Stream Sampling Data, STORET # 385314 (Inlet Site - US).

Description	Total Nitrogen (mg/L)	TKN (mg/L)	Nitrate-Nitrite (mg/L)	Ammonia (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
Minimum	1.59	1.57	0.01	0.005	0.233	2.5*
Maximum	4.62	4.60	0.80	0.666	4.210	34.0
Median	2.75	2.60	0.01	0.016	0.816	2.5
Mean	2.882	2.786	0.09	0.100	1.102	5.866

* This value is one half of the detection limit and was used when a value of Non-Detect was returned

Table 5. Summary of Stream Sampling Data, STORET # 385316 (Inlet Site - CAN).

Description	Total Nitrogen (mg/L)	TKN (mg/L)	Nitrate-Nitrite (mg/L)	Ammonia (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
Minimum	1.57	1.53	0.01	0..005	0.311	2.5*
Maximum	3.88	3.86	0.80	0.506	1.660	11.0
Median	2.295	2.265	0.03	0.025	0.531	2.5
Mean	2.578	2.476	0.10	0.056	0.657	4.270

* This value is one half of the detection limit and was used when a value of Non-Detect was returned

Table 6. Summary of Stream Sampling Data, STORET # 385315 (Outlet Site).

Description	Total Nitrogen (mg/L)	TKN (mg/L)	Nitrate-Nitrite (mg/L)	Ammonia (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
Minimum	1.70	1.65	0.02	0.005	0.287	2.5*
Maximum	5.45	5.43	0.27	0.327	2.200	29.0
Median	2.31	2.25	0.09	0.09	0.596	5.0
Mean	2.402	2.315	0.088	0.103	0.793	6.639

* This value is one half of the detection limit and was used when a value of Non-Detect was returned

1.5.3 Reservoir Data

The in-lake site is located in the deepest part of the reservoir at the north end near the dam. Lake monitoring occurred from July through September, in 2004 and 2005 for open water sampling, and during January and February, 2005 for ice cover sampling, as outlined in the QAPP (NDDoH, 2004). A composite of parameters are listed below in Tables 7, 8, and 9, and Figures 8, 9, 10, and 11. Tables 7, 8 and 9 indicate water quality data collected at the surface, mid depth (between the surface and bottom) and bottom (just off the bottom so as not to disturb the sediment) respectively. Since phosphorus sorbs to soil particles and the lake is stratified, it is expected that the phosphorus levels near the bottom of the lake are higher. A volume weighted mean is used to determine the concentration and subsequent load for the TMDL. Through calculations using the BATHTUB model, the data extracted indicates that Short Creek Dam is very nitrogen limited. Average annual volume weighted total nitrogen concentration of 2.548 mg/L and average annual volume weighted total phosphorus concentration of 0.900 mg/L created an average total nitrogen (TN) to total phosphorus (TP) ratio of 2.83:1. (A ratio of less than 10:1 is considered nitrogen limited). The data collected characterized Short Creek Dam as a hypereutrophic, nitrogen limited lake.

Table 7. Short Creek Dam Reservoir Water Quality, Surface Samples (1 meter).

Description	Total Phosphorus (mg/L)	Nitrate/ Nitrite (mg/L)	TKN (mg/L)	Ammonia (mg/L)	Chlorophyll-*a* (µg/L)	Secchi Disk Depth (meters)
Minimum	0.442	0.01	2.00	0.005	0.75	0.55
Maximum	1.38	0.18	3.06	0.227	22.40	1.60
Median	0.806	0.07	2.44	0.141	7.60	1.35
Mean	0.882	0.075	2.449	0.121	7.753	1.264

Table 8. Short Creek Dam Reservoir Water Quality, Mid Depth (3-4 meters).

Description	Total Phosphorus (mg/L)	Nitrate/ Nitrite (mg/L)	TKN (mg/L)	Ammonia (mg/L)
Minimum	0.721	0.02	2.04	0.005
Maximum	1.28	0.12	2.82	0.476
Median	1.02	0.05	2.53	0.144
Mean	1.003	0.059	2.51	0.182

Table 9. Short Creek Dam Reservoir Water Quality, Bottom (0.5 meters from bottom).

Description	Total Phosphorus (mg/L)	Nitrate/ Nitrite (mg/L)	TKN (mg/L)	Ammonia (mg/L)
Minimum	0.481	0.01	2.07	0.005
Maximum	2.02	0.14	3.50	0.766
Median	1.05	0.06	2.54	0.179
Mean	1.042	0.063	2.623	0.201

Short Creek Dam was also compared to data from a study of similar North Dakota lakes (Table 10) (RLRSD, 2000). In general, when compared to other lakes in this region of the northwestern North Dakota glaciated plains, Short Creek Dam had lower than average TKN, ammonia, and chlorophyll-*a* concentrations, higher than average total phosphorus concentrations and nitrite/nitrate concentrations, and slightly better than average Secchi disk depth readings.

Table 10. Water Quality Data from Other Regional Lakes.

Description	Total Phosphorus (mg/L)	Nitrate/ Nitrite (mg/L)	TKN (mg/L)	Ammonia (mg/L)	Chlorophyll-*a* (μg/L)	Secchi Disk Depth (meters)
Minimum	0.031	0.006	1.09	0.025	3.5	0.15
Maximum	0.707	0.123	5.06	0.677	237.5	2.29
Mean	0.147	0.044	2.87	0.234	56.4	1.13
Median	0.056	0.029	2.57	0.191	11.0	1.01

[1]Eleven regional lakes were sampled for this study (RLRSD, 2000). Data from Short Creek Dam's TMDL Assessment (NDDoH, 2004.) was compared to data from this study.

Dissolved oxygen and temperature were monitored at the deepest site on Short Creek Dam from July 2004 through September 2005. Measurements were taken at one meter depth intervals during ice cover and open water periods each time a water quality sample was collected. Figures 8 through 11 illustrate the dissolved oxygen and temperature profiles for both years of the assessment.

During the summer of 2004 and 2005 as well as in April of 2005 the reservoir thermally stratifies. The low dissolved oxygen levels in both years in the summer as well as the winter between them were drastically low. Dissolved oxygen levels in the lowest meter for all dates were below the State water quality standard of 5.0 mg/L. In February, April and July those levels dropped to near zero. Significant portions of the water column were below water quality standards in almost all samples taken. For some samples (February and August, 2005) the entire water column was below 5.0 mg/L. The cause-and-effect relationship between nutrients, water temperature, plant growth and decomposition, and low dissolved oxygen levels in a water body is well established in the scientific arena.

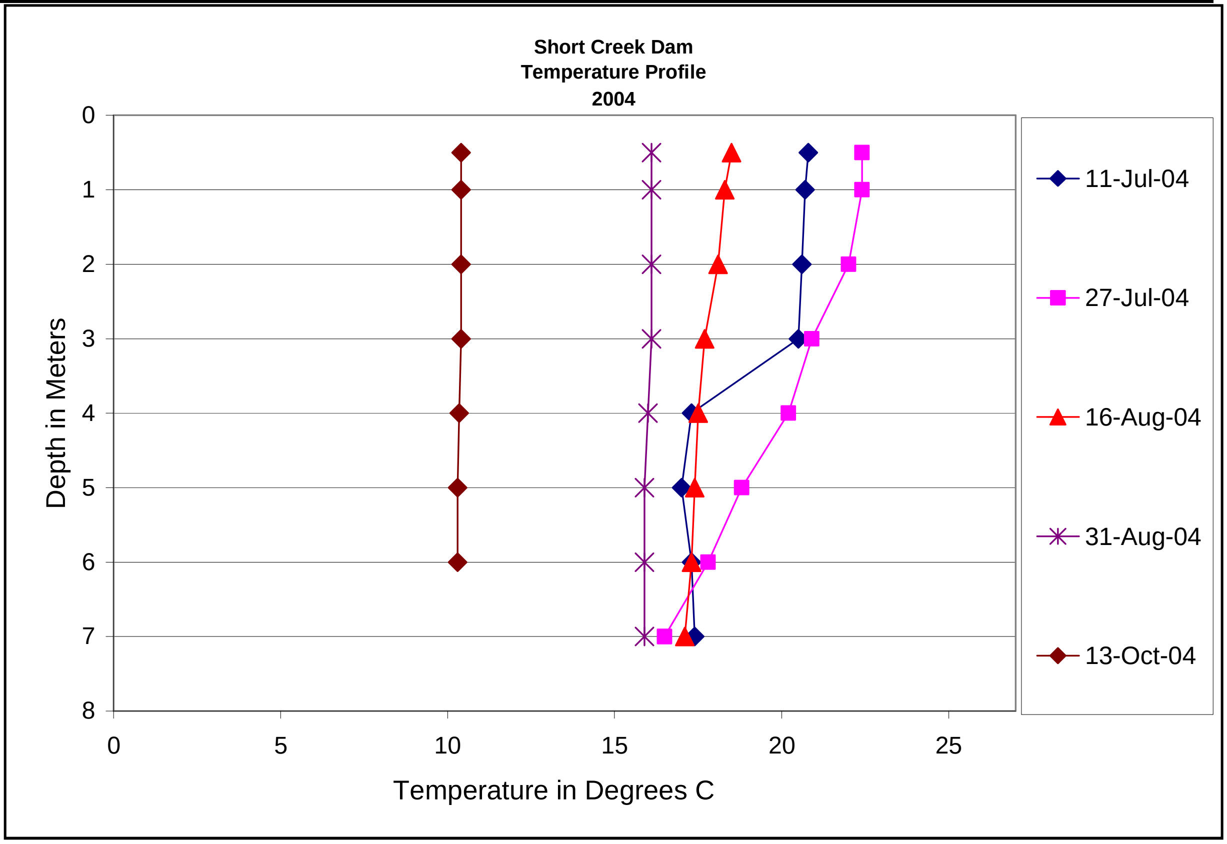


Figure 8. Temperature Profiles for Short Creek Dam (Site 380905), 2004.

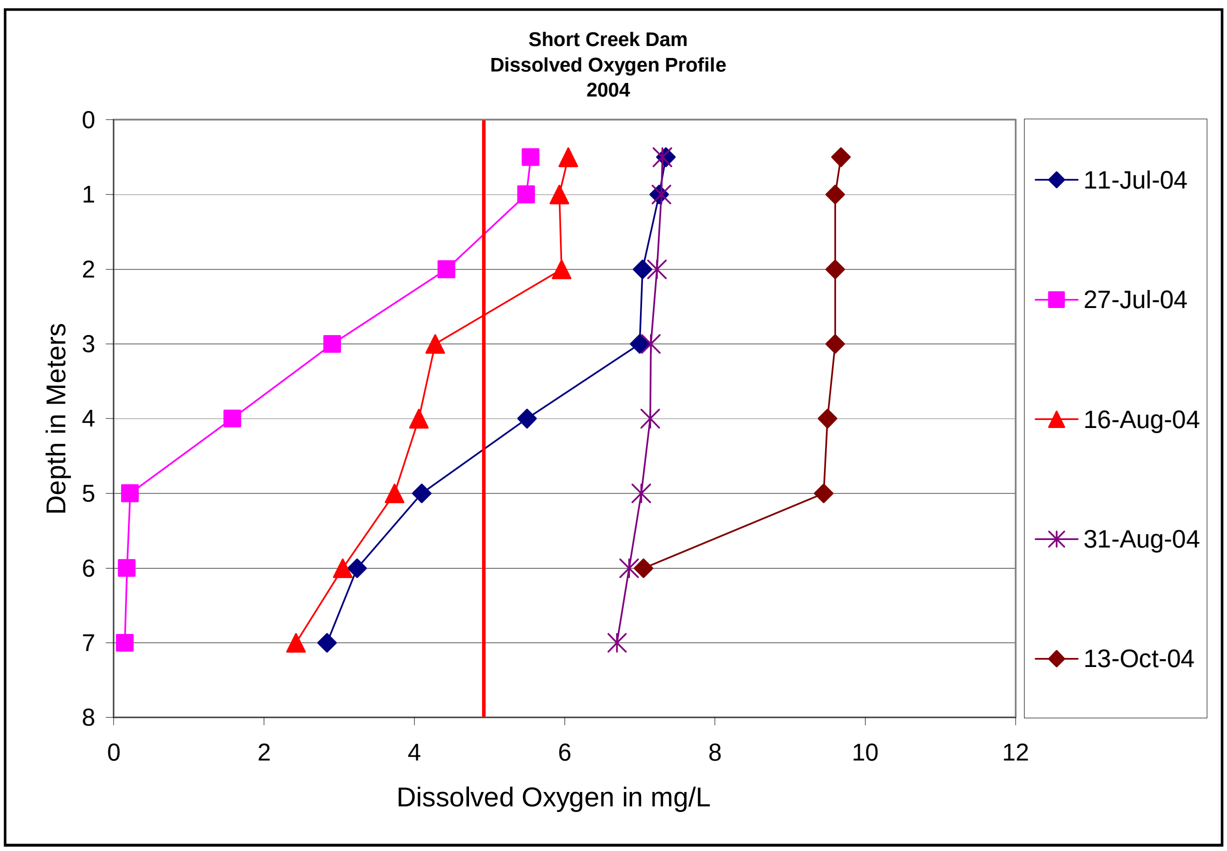


Figure 9. Dissolved Oxygen Profiles for Short Creek Dam (Site 380905), 2004.

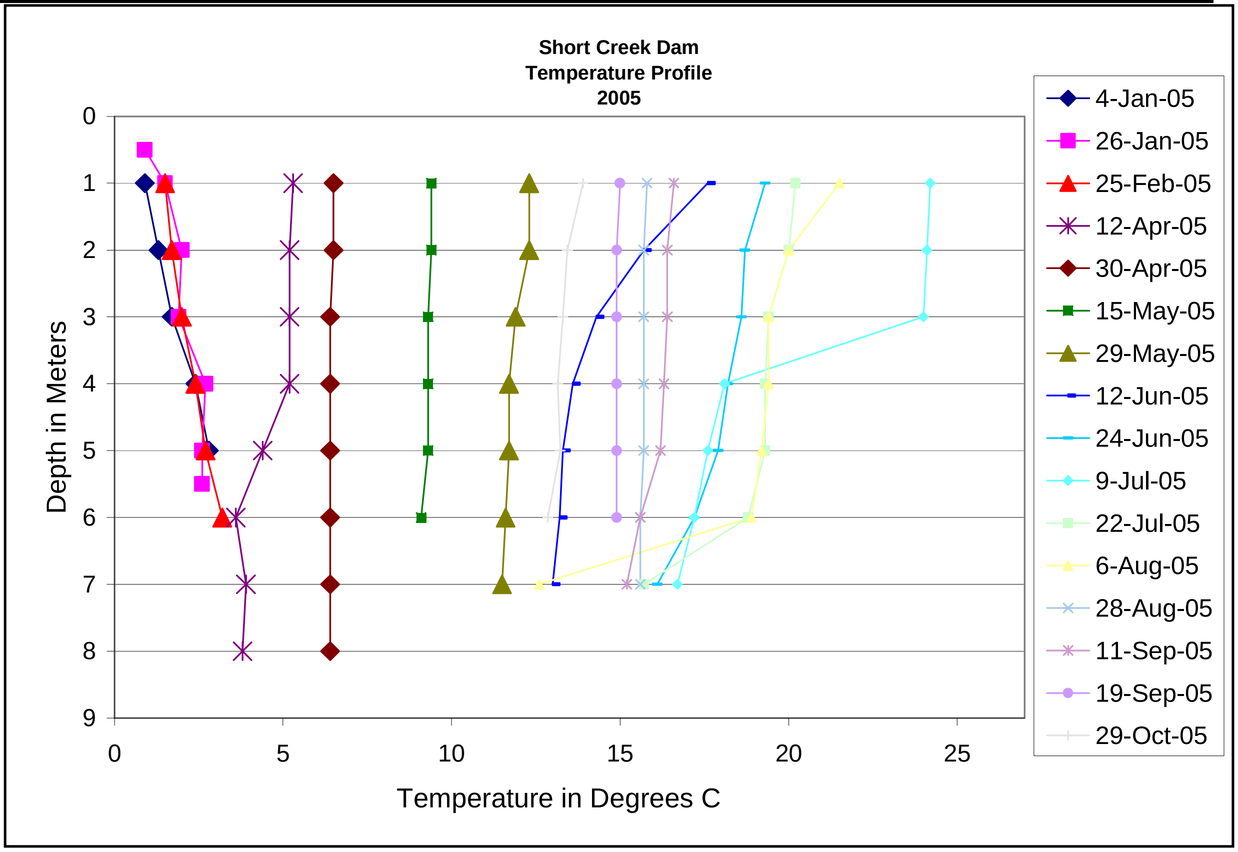


Figure 10. Temperature Profiles for Short Creek Dam (Site 380905), 2005.

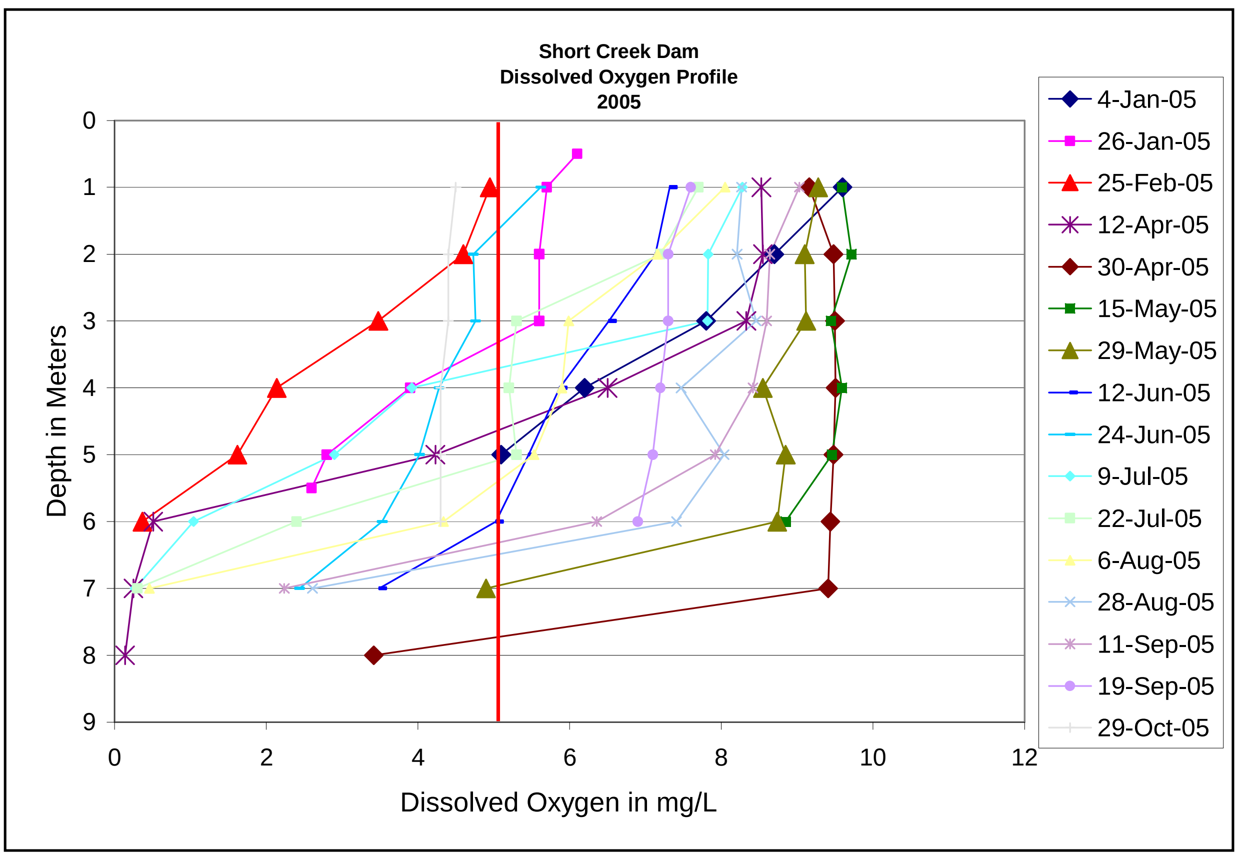


Figure 11. Dissolved Oxygen Profiles for Short Creek Dam (Site 380905), 2005.

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 waste load allocations for point sources and load allocations for non point sources and natural background” such that the capacity of the water body to assimilate pollutant loading 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, dissolved oxygen).

2.1 Narrative Water Quality Standards

The North Dakota Department of Health has set narrative water quality standards which apply to all surface waters in the state. The narrative standards pertaining to nutrient and sediment impairments are listed below (NDDoH, 2006).

- 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:
  - Cause a public health hazard or injury to environmental resources;
  - Impair existing or reasonable beneficial uses of the receiving waters; or
  - 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, 2006).

2.2 Numeric Water Quality Standards

Short Creek Dam is classified as a Class 2 cool water fishery. Class 2 fisheries are “waters capable of supporting natural reproduction and growth of cool water fishes (e.g. northern pike and walleye) and associated aquatic biota. These waters are also capable of supporting the growth and marginal survival of cold water species and associated biota.” The tributaries flowing into and out of Short Creek Dam are classified as Class 3 streams where “the quality of the waters in this class shall be suitable for agricultural and industrial uses such as livestock watering, irrigation, washing, and cooling. These streams have low average flows and generally prolonged periods of no flow. The quality of these waters must be maintained to protect recreation, fish, and aquatic biota (NDDoH, 2006).

All classified North Dakota lakes are assigned recreation, aquatic life, irrigation, livestock watering, and wildlife beneficial uses. Those beneficial uses threatened in Short Creek Dam include recreation and fish and other aquatic biota. Short Creek Dam’s beneficial uses have been assessed as fully supporting, but threatened as a result of nutrient enrichment, low dissolved oxygen, and sedimentation. The State’s water quality standards state that lakes shall use the same numeric criteria as Class 1 streams. This includes the State standard for dissolved oxygen set at no less than 5.0 mg/L as a daily minimum (with up to 10 percent of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided), and nitrate as N at 1.0 mg/L. The State water quality standards also specify guidelines for lake or reservoir improvement programs as well (Table 11). Lake use attainment determinations are often made using Carlson's Trophic State Index (TSI), which is further discussed in Section 3.1 (Carlson, 1977). No numeric criteria have been developed for sediment.

Table 11. Numeric Standards and Guidelines for Classified Lakes and Reservoirs (NDDoH, 2006).

Parameter	Parameter Limitation	Limit
Standards for Class I Streams and Classified Lakes:		
Nitrates (dissolved)	1.0 mg/l	Maximum allowed[1]
Dissolved Oxygen	5.0 mg/l	Daily Minimum[2]
Guidelines for Goals in a Lake Improvement or Maintenance Program:		
NO_3 as N	0.25 mg/l	Goal
PO_4 as P	0.02 mg/l	Goal

[1] ""Up to 10 percent of samples may exceed."
[2] "Up to 10 percent of representative samples collected during any three year period may be less than this value provided lethal conditions are avoided

3.0 TMDL TARGETS

A TMDL target is the value that is measured to judge the success of the TMDL effort. TMDL targets must be based on state water quality standards, but can also include site-specific values when no numeric criteria are specified in the standard. The following sections summarize water quality targets for Short Creek Dam based on its beneficial uses. If the specific target is met, it is assumed the reservoir will meet applicable water quality standards, including its designated beneficial uses.

3.1 Nutrient Target

North Dakota's 2008 Integrated Section 305(b) Water Quality Assessment Report indicates that Carlson's Trophic State Indices (TSIs), based on Secchi disk depth (transparency), chlorophyll-*a* concentration, and total phosphorus concentration, are the primary indicators used to assess beneficial uses of the State's lakes and reservoirs, (NDDoH, 2008). 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, limited water clarity, and low dissolved oxygen concentrations that can result in impaired aquatic life and recreational uses. Carlson's TSI attempts to measure the trophic state of a lake using the above variables (Carlson, 1977).

The three variables (chlorophyll-*a*, Secchi disk depth, and total phosphorus) 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, 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 1996).

Based on the water quality data collected between July 2004 and September 2005 and the resulting Carlson TSI scores, Short Creek Dam was generally assessed as a eutrophic lake (Table 12, Figure 12). While the total phosphorus TSI was exceedingly high suggesting a hypereutrophic reservoir, the nitrogen limited nature of the reservoir keeps the other two TSI values, and the actual aesthetic visual condition of the reservoir, in the eutrophic range. The short residence time (0.436 years) is another factor that may account for this difference in TSI values. Nitrogen and particulate phosphorus would be flushed from the system while dissolved phosphorus would continue to persist due to internal nutrient cycling. Also, as stated above, phosphorus TSI is not an independent estimator of trophic state. With the high amounts of total phosphorus available, should more nitrogen enter the system, it would immediately be used in plant and algal production, thus increasing both chlorophyll-*a* and Secchi disk depth TSI values. A phosphorus target was chosen as a TMDL endpoint for nutrients as it is important that available phosphorus in the system be reduced to keep the reservoir from moving to a higher eutrophic state. As an added margin of safety, to address the causes of nutrient enrichment in this watershed which are related to agriculture, it is assumed that any best management practice(s) implemented to reduce phosphorus loading will also reduce the amount of nitrogen entering the system.

Table 12. Carlson's Trophic State Indices for Short Creek Dam.

Parameter	**Relationship**	**Units**	**TSI Value**[1]
Chlorophyll-*a*	TSI (Chl-a) = 30.6 + 9.81[ln(Chl-a)]	µg/L	51.00
Total Phosphorus (TP)	TSI (TP) = 4.15 + 14.42[ln(TP)]	µg/L	102.24
Secchi Disk Depth (SD)	TSI (SD) = 60 - 14.41[ln(SD)]	meters	56.78

[1]TSI values were calculated using mean surface values from the Short Creek Dam in-lake monitoring station.
TSI < 25 = Oligotrophic (least productive) TSI 50-75 = Eutrophic
TSI 25-50 = Mesotrophic TSI > 75 = Hypereutrophic (most productive)

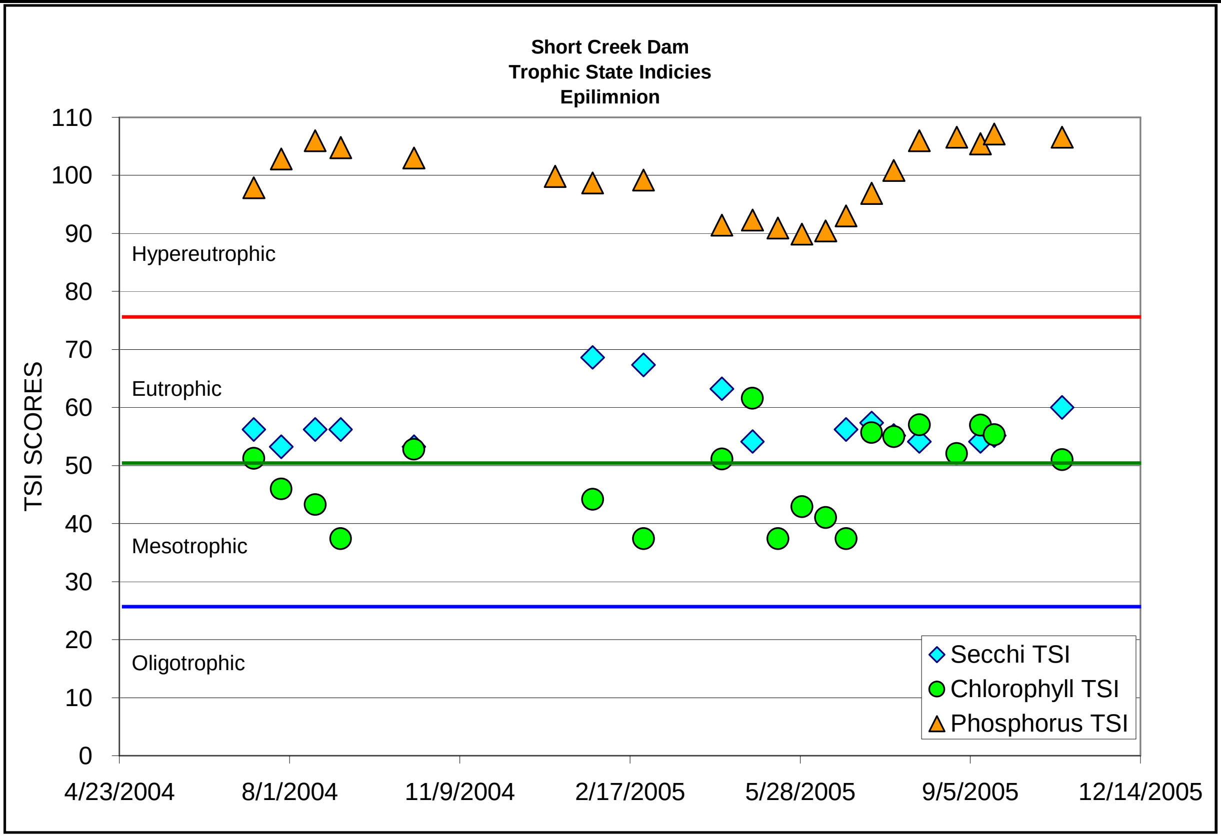


Figure 12. Temporal Distribution of Carlson's Trophic Status Index Scores for Short Creek Dam.

A major strength of TSI is that the interrelationships between variables can be used to identify certain conditions in the lake or reservoir that are related to the factors that limit algal biomass or affect the measured variables. When more than one of the three variables is measured, it is possible that different index values will be obtained. Because the relationships between the variables were originally derived from regression relationships and the correlations were not perfect, some variability between the index values is to be expected. (Carlson 1996). These deviations in the total phosphorus or the Secchi disk depth index from the chlorophyll index can be used to identify conditions and causes relating to the lake or reservoir's trophic state. Some possible interpretations of deviations of the index values are given in Table 13 below (updated from Carlson 1983).

Table 13. Relationships Between TSI Variables and Conditions (updated from Carlson 1983).

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

As reflected in relationship 5 (Table 13), it is therefore possible that the chlorophyll-*a* and Secchi disk depth indices may be close together, but both significantly less than the total phosphorus TSI score. This suggests that the algae are nitrogen-limited, as in the case for Short Creek Dam or that intense zooplankton grazing may be suppressing algal growth and therefore chlorophyll-*a* concentrations (Carlson 1996). Carlson and Simpson(1996) suggest that if the phosphorus and Secchi disk depth values are relatively similar and higher than the chlorophyll-*a* TSI value, then dissolved color or non-algal particulates dominate light attenuation. It follows that, if the Secchi disk depth and chlorophyll-*a* TSI values are similar (as is the case for Short Creek Dam), then chlorophyll-*a* is dominating light attenuation. These statements support the data analysis and modeling that was done to indicate that Short Creek Dam is a nitrogen-limited water body.

A Carlson's TSI target of 69.59 based on total phosphorus was chosen for the Short Creek Dam endpoint. This corresponds to a 90 percent reduction (Table 14) in phosphorus loading from the watershed (see Section 5.0 for technical analysis). While this reduced TSI value will correspond to a higher total phosphorus concentration (0.09 mg/L) than the concentration of total phosphorus in the State water quality standard guideline for in-lake improvement (0.02 mg/L), it will result in a lowering of the trophic state for the reservoir for all times of the year. It should also be noted that the related total nitrogen concentration will be reduced from 2.55 mg/L to 0.35 mg/L, which is very near the lake improvement guideline of 0.25 mg/L total nitrogen. As discussed previously, all three TSI values are used in determining the trophic status of the reservoir and thus whether beneficial uses are being met. If the specified TMDL phosphorus TSI target of 69.59 is met, the reservoir can be expected to meet the applicable water quality standards for aquatic life and recreational beneficial uses.

3.2 Dissolved Oxygen Target

The North Dakota State Water Quality Standard for dissolved oxygen is "5.0 mg/L as a daily minimum (up to 10 percent of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided)" and will be the dissolved oxygen target for Short Creek Dam

4.0 SIGNIFICANT SOURCES

There are no known point sources in the Short Creek Dam watershed. Nutrients impairing the reservoir's beneficial uses are from non point sources. There are fourteen animal feeding operations in the watershed which is considered part of the nonpoint source load.

5.0 TECHNICAL ANALYSIS

Establishing a relationship between in-lake water quality targets and source loading is a critical component of TMDL development. Identifying the cause-and-effect relationship between pollutant loads and the water quality response is necessary to evaluate the loading capacity of the receiving 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 Short Creek 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, 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 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 B) 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 Short Creek 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 serves as an input 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 suing six calculation techniques. Load is therefore defined as the mass of 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 Microsoft Excel using three computational functions. These include: 1) the ability to display concentrations as a function of depth, location, and date; 2) summary statistics (e.g., mean, median, etc.); and 3) evaluation of the trophic status. The output data from the Excel program were then used as input to calibrate the BATHTUB model.

When the input data from FLUX and Excel programs are entered in to 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 the observed estimates from assessment project monitoring data. BATHTUB then has the ability to predict total phosphorus concentration, chlorophyll-*a* concentration, and Secchi disk depth 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 and estimated annual average total phosphorus load of 5,073.3 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 A for more detail).

In the case of Short Creek Dam, BATHTUB was used to model the trophic status response of total phosphorus reductions in externally derived phosphorus loading. Phosphorus was used in the simulation model based on its known relationship to eutrophication and also that it is controllable with the implementation of watershed Best Management Practices (BMPs). Changes in trophic response were evaluated by reducing externally derived phosphorus loading by 25, 50, 75, and 90 percent (Table 14). Simulated reductions in chlorophyll-*a*, Secchi disk depth, and total phosphorus-based TSI scores were achieved by reducing phosphorus concentrations in contributing tributaries and other externally delivered sources. Flow was held constant due to uncertainty in estimating changes in hydraulic discharge with the implementation of BMPs.

Table 14. Observed and Model Predicted Values for Selected Trophic Response Variables Assuming a 25, 50, 75, and 90 Percent Reduction in External Phosphorus Loading.

Variable	Observed	Predicted			
		25% Reduction	50% Reduction	75% Reduction	90% Reduction
Total Phosphorus as P (mg/L)[1]	0.900	0.678	0.453	0.228	0.094
Total Nitrogen as N (mg/L)[1]	2.548	1.926	1.321	0.716	0.353
Chlorophyll-*a* (µg/L)[1]	8.00	7.07	5.75	3.35	1.14
Secchi Disk Depth (meters)[2]	1.25	1.29	1.34	1.46	1.59
Carlson's TSI for Phosphorus	102.24	98.15	92.34	82.47	69.59
Carlson's TSI for Chlorophyll-*a*	51.00	49.79	47.75	42.45	31.86
Carlson's TSI for Secchi Disk	56.78	56.36	55.73	54.52	53.31
Metalimnetic Oxygen Demand (mg/L per day)[3]	0.076	0.072	0.065	0.050	0.029
Hypolimnetic Oxygen Demand (mg/L per day)[3]	0.088	0.084	0.075	0.058	0.034

[1] Volume weighted mean
[2] Average
[3] Based on the calibrated BATHTUB model predicted rate

5.3 AGNPS Watershed Model

In order to identify significant NPS pollutant sources in the Short Creek Dam watershed and to assess the relative reductions in nutrient (nitrogen and phosphorus) and sediment loading that can be expected from the implementation of BMPs in the watershed, an AGNPS 3.65 model analysis was employed.

The primary objectives for using the AGNPS 3.65 model were to 1) evaluate NPS contributions within the watershed; 2) identify critical pollutant source areas within the watershed; and 3) evaluate potential pollutant (nitrogen, phosphorus, and sediment) reduction estimates that can be achieved through the implementation of various BMP scenarios.

The AGNPS 3.65 model is a single event model that has twenty input parameters. Sixteen parameters were used to calculate nutrient/sediment output, surface runoff and erosion. The parameters used were receiving cell, aspect, SCS curve, percent slope, slope shape, slope length, Manning's roughness coefficient, K-factor, C-factor, P-factor, surface conditions constant, soil texture, fertilizer inputs, point source indicators, COD factor, and channel indicator.

The AGNPS 3.65 model was used in conjunction with an intensive land use survey to determine critical areas within the Short Creek Dam watershed. Criteria used during the land use assessment were percent cover on cropland and pasture/range condition. These criteria were used to determine the C factor for each cell. The initial model was run using current conditions determined during the land use assessment. A 25yr/24hr storm event (4.10 inches) in Burke County was applied to the model to evaluate relative pollutant yields from each 160-acre cell. Each quarter of land was given a cell number and each cell represents 160 acres of land. A total of 840 cells were input into the program, representing 134,720 acres. Since this model cannot follow curved lines, but only square cell blocks, this watershed area used in this model is slightly larger than the actual watershed area listed in Table 1.

To identify critical cells for nutrient (phosphorus) loading, knowing that there had to be a 90 percent reduction in phosphorus load in order to affect the needed change, the final output cell of the watershed was identified. Then beginning with cells that had greater than 5 lbs of sediment phosphorus, BMPs were applied through manipulation of the AGNPS model to those cells. The phosphorus loading in the final cell was noted and since it did not meet the 90 percent load reduction, the AGNPS model was re-run with BMP manipulations to cells that had greater than 4 lbs of sediment phosphorus. The final output cell was then again reviewed and this process continued with 3.5 lbs, 3.0 lbs, etc until 0.5 lbs sediment phosphorus cells, manipulated with BMPs, reached the targeted reduction. BMPs applied to cells with greater than 0.5 lbs sediment phosphorus achieved a slightly greater than 90 percent reduction in phosphorus loading. The BMPs used were no till, nutrient management, prescribed grazing, native grass seeding, and pasture/hayland forage plantings. Cells that had greater than 0.5 lbs sediment phosphorus were identified as critical cells (Figure 13). These 579 cells represent 69 percent of the watershed. Once nutrient loadings are decreased, algal biomass will decline, dissolved oxygen will increase, and the overall trophic status of the reservoir will improve.

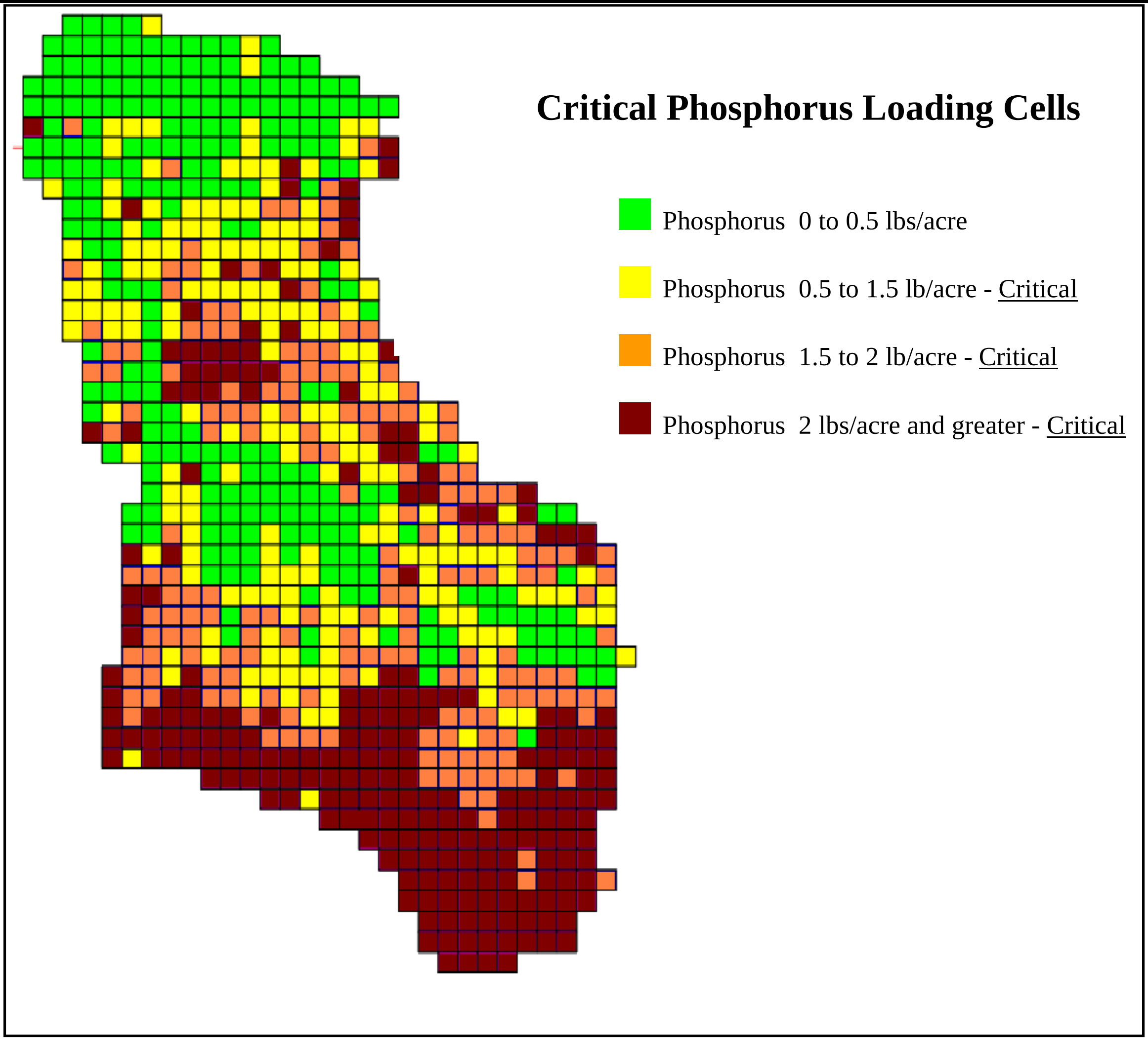


Figure 13. AGNPS Identified High Phosphorus Loading Areas.

5.4 Dissolved Oxygen

Short Creek Dam is considered impaired due to dissolved oxygen levels observed below the North Dakota water quality standard of 5.0 mg/L as a daily minimum. This assessment is based on the dissolved oxygen profile data collected in the 2004- 2005 TMDL assessment. For Short Creek Dam, low dissolved oxygen levels, sometime reaching throughout the entire water column, appear to be related to excessive nutrient loading.

The cycling of nutrients in aquatic ecosystems is largely determined by oxidation-reduction (redox) potential and the distribution of dissolved oxygen and oxygen-demanding particles (Dodds, 2002). Dissolved oxygen gas has a strong affinity for electrons, and thus influences biogeochemical cycling and the biological availability of nutrients to primary producers such as algae. High levels of nutrients can lead to eutrophication, which is defined as the undesirable growth of algae and other aquatic plants. In turn, eutrophication can lead to increased biological oxygen demand and oxygen depletion due to the respiration of microbes that decompose the dead algae and other organic material.

AGNPS and BATHTUB models indicate that excessive nutrient loading is responsible for the low dissolved oxygen levels in Short Creek Dam. Wetzel (1983) summarized, “The loading of organic matter to the hypolimnion and sediments of productive eutrophic lakes increases the consumption of dissolved oxygen. As a result, the oxygen content of the hypolimnion is reduced progressively during the period of summer stratification."

Carpenter et al. (1998), has shown that non point sources of phosphorous has lead to eutrophic conditions for many lake/reservoirs across the U.S. One consequence of eutrophication is oxygen depletions caused by decomposition of algae and aquatic plants. They also document that a reduction in nutrients will eventually lead to the reversal of eutrophication and attainment of designated beneficial uses. However, the rates of recovery are variable among lakes/reservoirs. This supports the Department of Health's viewpoint that decreased nutrient loads at the watershed level will result in improved oxygen levels, the concern is that this process takes a significant amount of time (5-15 years).

In Lake Erie, heavy loadings of phosphorous have impacted the lake severely. Monitoring and research from the 1960's has shown that depressed hypolimnetic dissolved oxygen levels were responsible for large fish kills and large mats of decaying algae. Bi-national programs to reduce nutrients into the lake have resulted in a downward trend of the oxygen depletion rate since monitoring began in the 1970's. The trend of oxygen depletion has lagged behind that of phosphorous reduction, but this was expected (See: http://www.epa.gov/glnpo/lakeerie/dostory.html).

Nürnberg (1995, 1995a, 1996, 1997), developed a model that quantified duration (days) and extent of lake oxygen depletion, referred to as an anoxic factor (AF). This model showed that AF is positively correlated with average annual total phosphorous (TP) concentrations. The AF may also be used to quantify response to watershed restoration measures which makes it very useful for TMDL development. Nürnberg (1996) developed several regression models that show nutrients control all trophic state indicators related to oxygen and phytoplankton in lakes and reservoirs. These models were developed from water quality characteristics using a suite of North American lakes. NDDoH has calculated the morphometric parameters such as surface area (A_o = 108.1 acres; 0.548 km^2), mean depth (z = 11.4 feet; 3.51 meters), and the ratio of mean depth to the surface area ($z/A_o^{0.5}$ = 4.7) for Short Creek Dam which show that these parameters are within the range of lakes used by Nürnberg. Based on this information, NDDoH is confident that Nürnberg's empirical nutrient-oxygen relationship holds true for North Dakota lakes and reservoirs. The NDDoH is also confident that prescribed BMPs will reduce external loading of nutrients to Short Creek Dam which will reduce algae blooms, thereby reducing hypolimnetic oxygen depletions rates resulting in increase oxygen levels over time.

Best professional judgment concludes that as levels of phosphorus are reduced by the implementation of best management practices, dissolved oxygen levels will improve. This is supported by the research of Thornton, et al (1990). They state that, "…as organic deposits were exhausted, oxygen conditions improved."

This conclusion is also supported by BATHTUB model predictions of both metalimnetic and hypolimnetic oxygen demand. The calibrated model predicts that metalimnetic and hypolimnetic oxygen demand in Short Creek Dam is currently 0.076 and 0.088 mg/L per day, respectively (Table 14). With a 90 percent reduction in total phosphorus loading, the metalimnetic and hypolimnetic oxygen demand rate is predicted to decrease by 38 percent to 0.029 and 0.034 mg/L per day, respectively (Table 14).

5.5 Sediment

A sediment balance was calculated for Short Creek Dam (Table 15). The time period over which this amount of storage occurred was .999 years.

Table 15. Sediment Balance for Short Creek Dam.

Parameter	Inflow (kg)	Outflow (kg)	Storage (kg)
Total Suspended Solids	25,433.0	25,380.1	52.9

Based on the Mulholland and Elwood (1982) average accumulation rate of 2 cm/yr within reservoirs, a conversion from mass of sediment storage to depth of sediment storage is needed to determine a comparison.

In order to perform the conversion from mass to depth, the particle density of soil is needed. In most mineral soils the average density of particles is in the range of 2.6 to 2.7 g/cm^3. This narrow range reflects the predominance of quartz and clay minerals in the soil matrix. Since soils in the Short Creek Dam watershed are mineral soils, the particle density of silicate minerals can be used to calculate a depth of sediment accumulation within the reservoir. However, for the sake of providing an implicit margin of safety, the low end of the range (2.6 g/cm^3) will be used to calculate the equivalent depth of 52.9 kg of sediment in Short Creek Dam.

Based on a sediment loading rate of 52,900 g/yr divided by a sediment density of 2.60 g/cm^3, the sediment volume deposited in Short Creek Dam is 20,346.15 cm^3 each year.

$$52{,}900 \text{ g/yr} * (2.60 \text{ g/cm}^3)^{-1} = 20{,}346.15 \text{ cm}^3\text{/yr}$$

Based on a surface area of 108.1 acres (4,374,651,792.61 cm^2), the annual sedimentation rate is 8.90073 x 10^{13} cm per year.

$$(20{,}346.15 \text{ cm}^3\text{/yr}) / (4{,}374{,}651{,}792.61 \text{ cm}^2) = 8.90073 \times 10^{13} \text{ cm/yr}$$

This estimated annual sediment accumulation rate is well below the average sedimentation rate of typical reservoirs.

Further support for the removal of sediment as a pollutant of concern can also be found in literature. As Waters (1995) states, suspended sediment concentration less than 25 mg/L is not harmful to fisheries; between 25 and 80 mg/L reduces fish yield; between 80 and 400 mg/L is unlikely to display a good fishery; and suspended sediment concentration greater than 400 mg/L will exhibit a poor fishery. Therefore, research by Waters (1995) supports the view that the mean TSS concentration entering Short Creek Dam of 10.136 mg/L (US + Canada) is not considered harmful to fisheries. No samples exceeded the 25 mg/L concentration stated by Waters (1995) as reducing fish yield. Therefore, it is the recommendation of this TMDL report that in the next North Dakota Section 303(d) list cycle, Short Creek Dam should be de-listed for sediment impairments.

Justification for delisting is also based on the Natural Resources Conservation Service (NRCS) Sedimentation Rate Standard for reservoirs. This standard is set at 1/8 inch of sediment eroded from the watershed drainage areas delivered and detained in the sediment pool over the 50-year expected life of the project. Therefore:

Assuming Watershed Area = 133,600 acres = 208.75 mi^2 = 5.82×10^{9} ft^2
and,

NRCS Sedimentation Rate equals 1/8 inch = 0.125 inch = 0.01041667 ft over 50 years
then,

NRCS Sediment Standard Volume =

$$5.82 \times 10^{9}\ ft^2 * 0.01041667\ ft = 6.06 \times 10^{7}\ ft^3$$

$$\text{where : } 6.06 \times 10^{7}\ ft^3 = \mathbf{1.72 \times 10^{12}\ cm^3}$$

Compare this to the calculated annual sedimentation rate from observed data entering Short Creek Dam over 50 years:

Calculated Sediment Volume from data = 20,346.15 cm^3/yr * 50 yr = $\mathbf{1.02 \times 10^{6}\ cm^3}$**.**

Using the NRCS Sedimentation Rate Standard of 1/8 inch over 50 years, Short Creek Dam's predicted sediment accumulation rate would be 1.72×10^{12} cm^3. When compared to the current sedimentation rate over 50 years entering the reservoir, 1.02×10^{6} cm^3 appears to be well under the predicted sedimentation rate standard.

6.0 MARGIN OF SAFETY AND SEASONALITY

6.1 Margin of Safety

Section 303(d) of the Clean Water Act and EPA's regulations require that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." The margin of safety (MOS) can either be incorporated into conservative assumptions used to develop the TMDL (implicit) or added as a separate component of the TMDL (explicit). For purposes of this nutrient TMDL, a MOS of ten percent of the loading capacity will be used as an explicit MOS.

Assuming the combined "normal" year load of total phosphorus to Short Creek Dam is 5,073.3 kg/yr, and the TMDL reduction goal is a 90 percent reduction in total phosphorus loading, then this would result in a TMDL target total phosphorus loading capacity of 324.5 kg/yr total phosphorus. Based on a 10 percent explicit margin of safety, the MOS for Short Creek Dam TMDL would be 32.45 kg of total phosphorus per year. Additionally, conservative assumptions were used within the calculations and models, thus adding implicitly to the margin of safety.

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 U.S. Environmental Protection Agency (EPA's) regulations require that a TMDL be established with seasonal variations. The Short Creek Dam TMDLs address seasonality because the FLUX analysis and BATHTUB model incorporates seasonal differences in the prediction of annual total phosphorus loadings.

7.0 TMDL

Table 16 summarizes the nutrient TMDL (which will also address the dissolved oxygen TMDL) for Short Creek Dam in terms of loading capacity (LC), wasteload allocations (WLA), load allocations (LA), and a margin of safety(MOS). 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 uncertainty about the relationship between pollutant loads and receiving water quality. The margin of safety can be provided implicitly through analytical assumptions or explicitly by reserving a portion of loading capacity.

7.1 Nutrient TMDL

Based on data collected between July 2004 and September 2005 the existing annual load to Short Creek Dam is estimated at 5,073.3 kg. Assuming the 90 percent reduction in the existing total phosphorus loading based on BATHTUB and AGNPS modeling results reaching a total phosphorus concentration of 0.09 mg/L, the Loading Capacity is 324.5 kg/yr. Assuming that 10 percent of the loading capacity is explicitly assigned to the MOS (32.45 kg/yr) and there are no point sources in the watershed, then all of the remaining LC is assigned to the load allocation (292.05 kg/yr).

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 Department 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 324.5 kg/yr was divided by 365 days. Based on this analysis, the phosphorus TMDL, expressed as an average daily load, is 0.889 kg/day with the load allocation equal to 0.800 kg/day and the MOS equal to 0.089 kg/day.

Table 16. Summary of the Nutrient TMDL for Short Creek Dam.

Category	Total Phosphorus (kg/yr)	Explanation
Existing Load	5,073.3	From observed data
Loading Capacity	324.5	90% reduction based on BATHTUB model simulations
Wasteload Allocation	0	No point sources
Load Allocation	292.05	Entire loading capacity minus MOS is allocated to non point sources
MOS	32.45	Explicit ten percent (10%) MOS.

7.2 Dissolved Oxygen TMDL

As a result of the direct influence of eutrophication on increased biological oxygen demand and microbial respiration, it is expected that by attaining the phosphorus load reduction target established for Short Creek Dam, the dissolved oxygen impairment will be addressed. A reduction in total phosphorus loading to Short Creek Dam is expected to lower algal biomass levels in the water column, thereby reducing both metalimnetic and hypolimnetic oxygen demand exerted by the decomposition of these primary producers, (see Section 5.4 for additional justification). The predicted reduction in metalimnetic and hypolimnetic oxygen demand is therefore assumed to result in attainment of the dissolved oxygen standard.

7.3 De-List for Sediment TMDL

No reduction necessary. This report provides justification for de-listing for sediment (see Section 5.5).

8.0 ALLOCATION

Short Creek Dam's watershed supports extensive agriculture where cropland and range/pasture constitute the majority of the land use. Sub-dividing it into smaller units, based on hydrology or type of conservation practice implemented, would not be practical. This TMDL will be implemented by several parties on a volunteer basis. Phosphorus loads into the reservoir will be reduced by 90 percent by treating the AGNPS identified critical cells (Figure 13). There are 579 cells within the Short Creek Dam watershed identified as "critical" by AGNPS modeling. These cells represent a total area of 69 percent of the watershed. If the critical areas in the watershed can be treated with BMPs (no till, nutrient management, grazing systems, native/tame grass seeding on steep slopes, etc.), then the specified reduction is possible.

While it is believed that instituting BMPs will result in the needed water quality improvements, the history of sediment and nutrient deposition may strongly effect internal nutrient cycling. The correct use of the hypolimnetic draw down may aid in improving water quality, as well as providing an additional margin of safety for the phosphorus TMDL. Additionally, public willingness towards accepting conservation practices will be necessary to facilitate the implementation of the additional BMPs that are needed in the reservoir's watershed.

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 must be accomplished for Short Creek 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 should be adjusted.

9.0 PUBLIC PARTICIPATION

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

- Burke County Soil Conservation District;
- Burke County Water Resource Board;
- Natural Resources Conservation Service (Burke County Field and State Offices);
- North Dakota Game and Fish Department (Save Our Lakes Program, District Fisheries Biologist); and
- U.S. Environmental Protection Agency, Region 8.

In addition to the mailed copies, the TMDL for Short Creek Dam was posted on the North Dakota Department of Health, Division of Water Quality web site at: http://www.health.state.nd.us/WQ/sw/Z2_TMDL/TMDLs_Under_PublicComment/B_Under_Public_Comment.htm. A 30 day public notice soliciting comment and participation was published in the Burke County Tribune, The Bismarck Tribune, and the Minot Daily News.

The only comments received were from the EPA Region 8. These were their normal public notice review comments. There were no comments received which required a response by the NDDoH..

10.0 MONITORING

To insure that the BMPs implemented as part of any watershed restoration plan will reduce phosphorus levels and result in a corresponding increase in dissolved oxygen, 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. These include, but are not limited to nutrients (i.e. nitrogen and phosphorus) and dissolved oxygen. Once a watershed restoration plan (e.g. Section 319 Project Implementation Plan) is implemented, monitoring will be conducted in the 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 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 ND Non point 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 dependant 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.

12.0 REFERENCES

Carlson, R.E. 1977. *A Trophic State Index for Lakes.* Limnology and Oceanography. 22:361-369.

Carlson, R.E. 1980. *More complications in the chlorophyll-Secchi disk relationship.* Oceanography. 25:375-382.

Carlson, R.E. and J. Simpson. 1996. *A Coordinator's Guide to Volunteer Lake Monitoring Methods*. North American Lake Management Society. 96 pp.

Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N., Smith, V.H.,1998. Non point Pollution of Surface Waters with Phosphorus and Nitrogen. *Ecological Applications* 8: 559-568.

Chapra, S., 1997. Surface Water-Quality Monitoring. The McGraw Hill Companies, Inc.

Cooke, G. Dennis, et. al., 1986. *Restoration and Management of Lakes and Reservoirs.* 2nd ed. Boca Raton: Lewis, 1993.

Dodds, W. K. 2002. Freshwater Ecology: Concepts and Environmental Applications. Academic Press, San Diego, California.

Enz, John W. 2003. *North Dakota Topographic, Climate, and Agricultural Overview*. North Dakota State University. Available at http://www.soilsci.ndus.nodak.edu?Enz/enz/reports/ndclimate.htm

Forester, Deborah L., 2000. *Water Quality in the Credit River: 1964 to 1998*. M.A. Department of Geography/Institute for Environmental Studies, University of Toronto, Canada.

Hutchinson, G.E. 1973. *Eutrophication. The Scientific Background of a Contemporary Practical Problem.* American Science. 61:269-279.

MacDonald, L.H., A. Smart, and R.C. Wissmar. 1991. *Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska*. EPA Publication.

Middlebrooks, E.J. Falkenborg, D.H. Maloney, T.E. 1997. *Modeling the Eutrophication Process.* Ann Arbor Science Publishers, Inc. Ann Arbor, MI

Mulholland, P.J. and Elwood, J.W. 1982. *The role of lake and reservoir sediments as sinks in the perturbed global carbon cycle.* Tellus, v. 34, pp. 490-499.

NDASS. 2004. *North Dakota Landcover Classification 2003.* North Dakota Agricultural Statistics Service & North Dakota State University Extension Service, Fargo, North Dakota. CD-ROM.

NDAWN. 2004. *Bowbells, North Dakota Weather Station.* North Dakota Agricultural Weather Network. North Dakota State University, Fargo, North Dakota. Available at: http://ndawn.ndsu.nodak.edu/index.html

NDDoH. 1996. *North Dakota Lake Assessment Atlas, Volume II.* North Dakota Department of Health, Division of Water Quality, Bismarck, North Dakota.

NDDoH. 1997. North Dakota Non Point Source Pollution Program Fact Sheets: *Nitrates, Phosphorus*, and *TSS.* North Dakota Department of Health, Division of Water Quality, Bismarck, North Dakota. Available at: http://www.health.state.nd.us/wq/sw/Z1_NPS/A_Main.htm

NDDoH. 1998. *North Dakota Water Quality Assessment 1996-1997.* North Dakota Department of Health, Division of Water Quality, Bismarck, North Dakota.

NDDoH. 2000. *North Dakota Water Quality Assessment 1998-1999.* North Dakota Department of Health, Division of Water Quality, Bismarck, North Dakota.

NDDoH. 2006. *Standards of Water Quality for the State of North Dakota.* Chapter 33-16-02 of the North Dakota Century Code. North Dakota Department of Health, Division of Water Quality, Bismarck, North Dakota.

NDDoH. 2003. *Quality Assurance Project Plan for the Short Creek Dam TMDL Development Project.* North Dakota Department of Health, Division of Water Quality, Bismarck, North Dakota.

NDDoH. 2008. *North Dakota 2008 Integrated Section 305(b) Water Quality Assessment Report and Section 305(d) List of Waters Needing Total Maximum Daily Loads.* North Dakota Department of Health, Division of Water Quality, Bismarck, North Dakota.

Nürnberg, Gertrud K., 1995. Quantifying Anoxia in Lakes. *Limnology and Oceanography* 40:1100-1111.

Nürnberg, Gertrud K., 1995. The anoxic Factor, a Quantitative Measure of Anoxia and Fish Species Richness in Central Ontario Lakes. *Transactions of the American Fisheries Society* 124: 677-686.

Nürnberg, Gertrud K., 1997. Coping with Water Quality Problems due to Hypolimnetic Anoxia in Central Ontario Lakes. *Water Qual. Res. J. Canada* 32:391-405.

Nürnberg, Gertrud K., 1998. Trophic State of Clear and Colored, Soft and Hardwater Lakes with Special Consideration of Nutrients, Anoxia, Phytoplankton and Fish. *Journal of Lake and Reservoir Management* 12:432-447.

Thorton, Kent W. Kimmel, B. Payne, Forrest E. 1990. *Reservoir Limnology: Ecological Perspectives*. Wiley-Interscience Publication. New York, NY.

Tunney, H. Carton O.T. 1997. *Phosphorus Loss from Soil to Water*. Cab International. New York, NY.

USEPA, NDDoH, et. al. 1998. *Ecoregions of North Dakota and South Dakota.* Poster.

USEPA, 1999a. *Protocol for Developing Nutrient TMDLs.* EPA 841-B-99-007. U.S. Environmental Protection Agency. Office of Water, Washington, DC.

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

Vollenweider, R.A. 1968. *Scientific Fundamentals of the Eutrophication of Lakes and lowing Waters, with Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication.* Technical Report DAS/CSI/68.27, Organization for Economic Cooperation and Development, Paris.
Walker, W.W. 1996. *Simplified Procedures for Eutrophication Assessment and Prediction: User Manual.* Instruction Report W-96-2. U.S. Army Corps of Engineer Waterways Experiment Station, Vicksburg, MS.

Waters, T.F. 1995. *Sediment in streams – Sources, biological effects, and control*. American Fisheries Society, Monograph 7. Bethesda, Maryland.

Wax, Peter . 2005. Environmental Scientist. North Dakota Department of Health, Bismarck, ND. Telephone conversations over the period of January 2004 to May 2005.

Wetzel, R.G. 1983. *Limnology*. 2nd ed. Saunders College Publishing. Fort Worth, TX

Appendix A

A Calibrated Trophic Response Model (BATHTUB) for Short Creek Dam and Model Output

A Calibrated Trophic Response Model (Bathtub) for Short Creek Dam
As a Tool to Evaluate Various Nutrient Reduction Alternatives
Based on Data Collected by the Burke County Soil Conservation District from
July 11, 2004 through October 29, 2005
Prepared by
Peter Wax
July 7, 2006 Revised June, 2009

Introduction

In order to meet the project goals, as set forth by the project sponsors of identifying possible options to improve the trophic condition of Short Creek Dam to levels capable of maintaining the reservoirs beneficial uses (e.g., fishing, recreation, and drinking water supply), and the objectives of this project, which are to: (1) develop a nutrient and sediment 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 restoration measures which will reduce documented nutrient and sediment loadings to the reservoir, a calibrated trophic response model was developed for Short Creek Dam. The model enables investigations into various nutrient reduction alternatives relative to the project goal of improving Short Creek Dam's trophic status. The model will allow resource managers and the public to relate changes in nutrient loadings to the trophic condition of the reservoir and to set realistic lake restoration goals that are scientifically defensible, achievable and socially acceptable.

Methods

For purposes of this project, the BATHTUB program was use 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, in 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 grab sample chemical 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

Short Creek Dam's in-lake water quality data was reduced using Microsoft Excel. The data was reduced in excel to provide three computational functions, including: (1) the ability to display constitute concentrations 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 Excel 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 of evaluating the effects of various nutrient reduction alternatives on the predicted trophic status of Short Creek Dam. BATHTUB performs water and nutrient balance calculations in a steady-state. The BATHTUB model also allows the user to spatially segment the reservoir. Eutrophication related water quality variables (e.g., total phosphorus, total nitrogen, chlorophyll-*a*, Secchi disk 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, Short Creek Dam was modeled as a single, spatially averaged, reservoir.

Once input is provided to the model from FLUX and Excel 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 Short Creek Dam Bathtub Model.

Model Option	Model Selection	Calibration Factor
Conservative Substance	0 Not Computed	1.00
Phosphorus Balance	7 Settling Velocity	1.13
Phosphorus – Ortho P	7	3.50
Nitrogen Balance	7 Settling Velocity	1.00
Organic Nitrogen	7	6.00
Chlorophyll-a	2 P, Light, Turbidity	0.17
Secchi Depth	1 vs. Chla & Turbidity	1.00
Phosphorus Calibration	2 Concentrations	NA
Nitrogen Calibration	2 Concentrations	NA
Availability Factors	2 All Models Except 2	NA
Mass-Balance Tables	0 Use Observed Concentrations	NA

Results

The trophic response model, BATHTUB, has been calibrated to match Short Creek Dam's trophic response for the project period between June 11, 2004 to October 29 2005. This is accomplished by combining tributary loading for the hydrologic year October 31, 2004 through October 31, 2005 with in-lake water quality collected between October 31, 2004 and October 31, 2005. Tributary flow and concentration data for the project period are reduced by the FLUX program and the corresponding in-lake water quality data are reduced utilizing Excel. The output from these two programs is then provided as input to the BATHTUB model. The 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 model 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 Short Creek 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. The model predicts that the reservoir has an annual volume weighted average total phosphorus concentration of 0.901 mg L^{-1} and an annual average volume weighted total nitrogen concentration of 2.531 mg L^{-1} compared to observed values for total phosphorus and total nitrogen of 0.900 mg L^{-1} and 2.548 mg L^{-1}, respectively (Table 2).

Other measures of trophic response predicted by the model are average annual chlorophyll-a concentration and average Secchi disk transparency. The calibrated 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 predicted 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)	0.900	0.901
Total Dissolved Phosphorus as P (µg/L)	0.815	0.817
Total Nitrogen as N (µg/L)	2.584	2.531
Organic Nitrogen as N (µg/L)	2.337	2.289
Chlorophyll-a (µg/L)	8.00	7.87
Secchi Disk Transparency (meters)	1.25	1.26
Carlson's TSI for Phosphorus	102.24	102.26
Carlson's TSI for Chlorophyll-a	51.00	50.84
Carlson's TSI for Secchi Disk	56.78	56.72

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). Over all the predicted and observed TSI values for phosphorus, chlorophyll and Secchi disk depth suggest Short Creek Dam is eutrophic. Figure 2 is a graphic that shows the annual temporal distribution of Short Creek Dam's trophic state based on the three parameters total phosphorus as phosphate, and chlorophyll-*a* concentrations and Secchi disk depth.

<u>Model Predictions</u>

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 comparing 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 Short Creek 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).

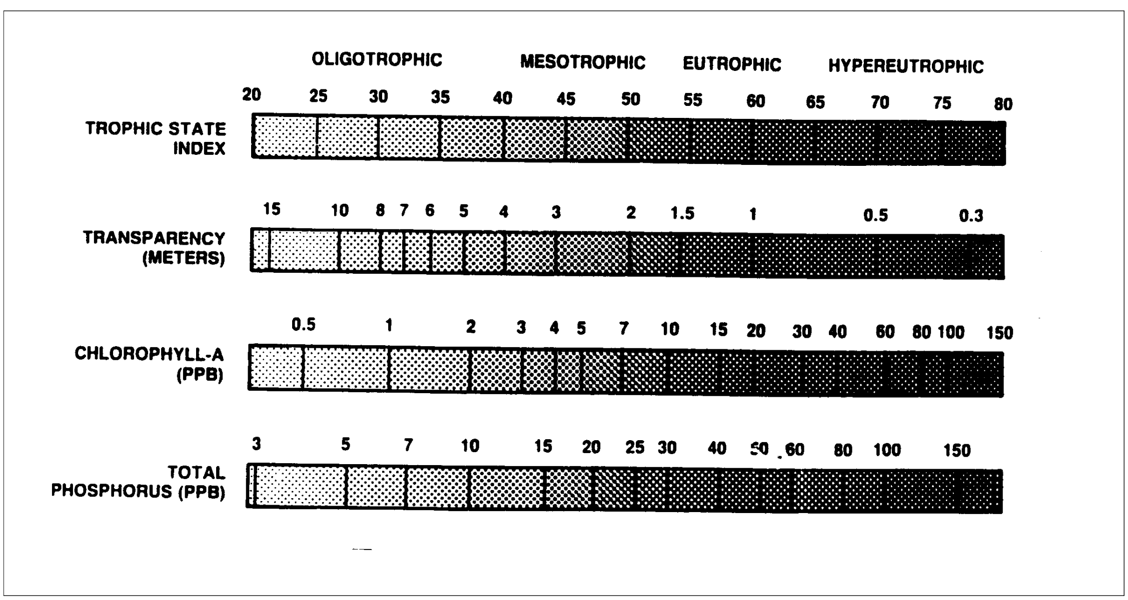


Figure 1. Graphic depiction of Carlson's Trophic Status Index

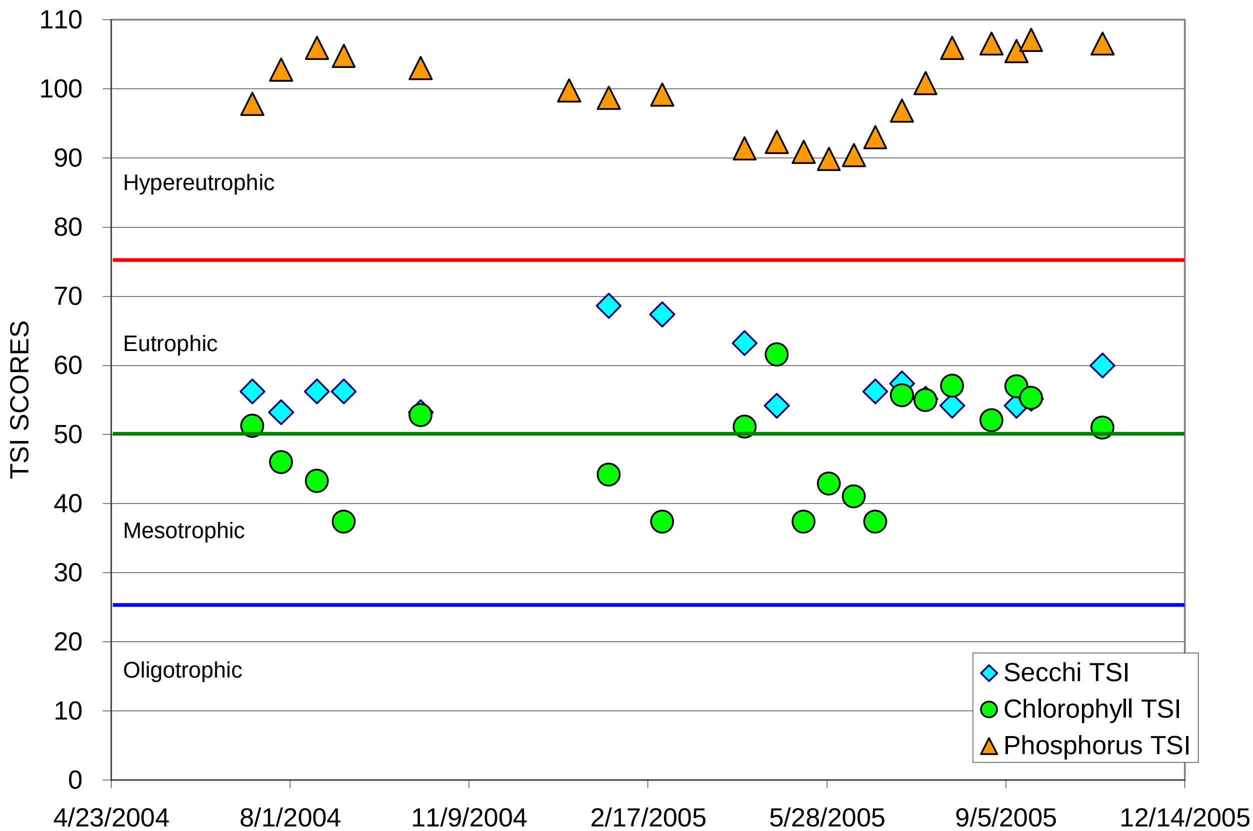


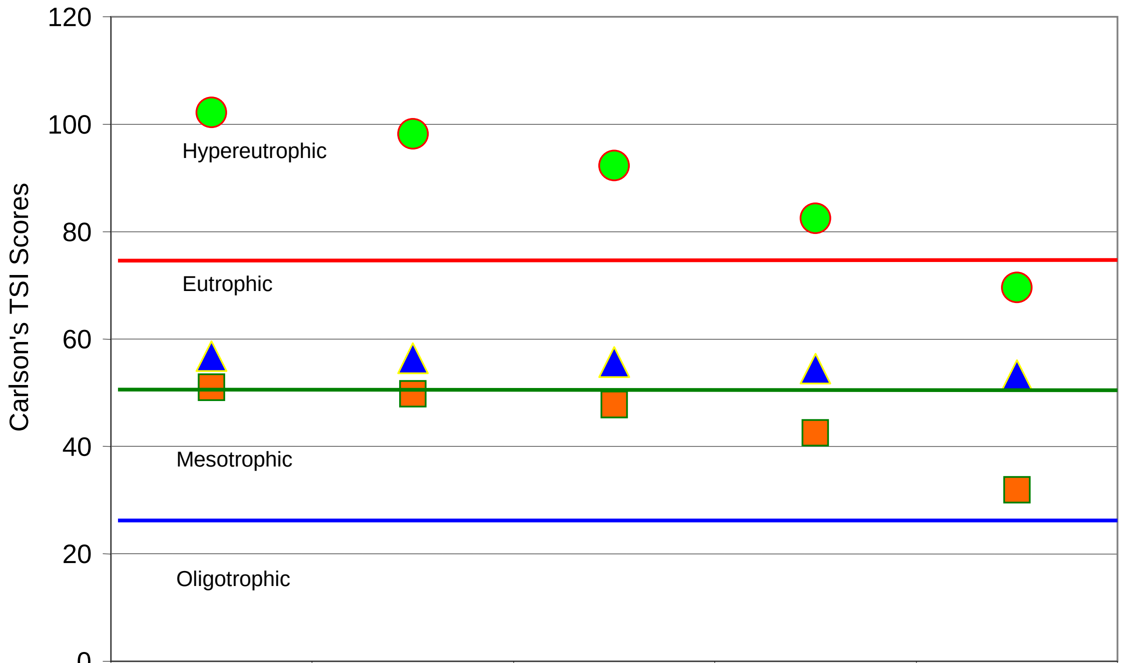
Figure 2. Temporal distribution of Carlosn's Trophic Status Index scores for Short Creek Dam (7/11/2004-10/31/2005)

Predicted changes in trophic response to Short Creek Dam were evaluated by reducing externally derived phosphorus loads by 25, 50, 75, and 90 percent. These reductions were simulated in the model by reducing the phosphorus and nitrogen concentrations in the contributing tributary and other external delivery sources by 25, 50, 75, and 90 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 phosphorus loading to Short Creek Dam by 90 percent the average annual total phosphorus concentrations in the lake would decrease significantly (Table 3, Figure 3). With a 90 percent reduction in external phosphorus and nitrogen load, the model predicts a reduction in Carlson's TSI score from 51.00 to 31.86 for chlorophyll-*a* and from 56.78 to 53.31 for Secchi disk transparency

Table 3. Calibrated model, Observed, and Predicted Values for Selected Trophic Response Variables Assuming a 25, 50, 75, 90 Percent Reduction in External Phosphorus and Nitrogen Loading.

Variable	Observed	-25%	-50%	-75%	-90%
Total Phosphorus as P (mg/L)	0.900	0.678	0.453	0.228	0.094
Total Dissolved Phosphorus (mg/L)	0.815	0.599	0.382	0.172	0.051
Total Nitrogen as N (mg/L)	2.584	1.926	1.321	0.716	0.353
Chlorophyll-*a* (µg/L)	8.00	7.07	5.75	3.35	1.14
Secchi Disk Transparency (meters)	1.25	1.29	1.34	1.46	1.59
Carlson's TSI for Phosphorus	102.24	98.15	92.34	82.47	69.59
Carlson's TSI for Chlorophyll-a	51.00	49.79	47.75	42.45	31.86
Carlson's TSI for Secchi Disk	56.78	56.36	55.73	54.52	53.31



	Observed	Less 25%	Less 50 %	Less 75 %	Less 90 %
TSI-Phosphorus	102.2	98.2	92.3	82.5	69.6
TSI-Chlorophyll-a	50.8	49.8	47.8	42.5	31.9
TSI-Secchi Disk	56.7	56.4	55.7	54.5	53.3

Figure 3. Predicted trophic response to phosphorus load reductions to Short Creek Dam of 25, 50, 75, and 90 percent

Model Output:

Gross Water Balance/Model Calibration

CASE: Short Creek 2005

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	FLOW (HM3/YR) VARIANCE	FLOW (HM3/YR) CV	RUNOFF M/YR
1	1	NE_INLET	36.260	.700	.000E+00	.000	.019
2	1	S_Inlet	504.400	2.868	.000E+00	.000	.006
3	1	UnGauged	.437	.090	.000E+00	.000	.206
4	4	Outlet	541.090	3.505	.000E+00	.000	.006
PRECIPITATION			.437	.262	.275E-02	.200	.600
TRIBUTARY INFLOW			541.097	3.658	.000E+00	.000	.007
***TOTAL INFLOW			541.534	3.920	.275E-02	.013	.007
GAUGED OUTFLOW			541.090	3.505	.000E+00	.000	.006
ADVECTIVE OUTFLOW			.444	-.022	.199E-01	6.477	-.049
***TOTAL OUTFLOW			541.534	3.483	.199E-01	.041	.006
***EVAPORATION			.000	.437	.172E-01	.300	.000

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: CONSERV

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	NE_INLET	.0	.0	.000E+00	.0	.000	.0	.0
2	1	S_Inlet	.0	.0	.000E+00	.0	.000	.0	.0
3	1	UnGauged	.0	.0	.000E+00	.0	.000	.0	.0
4	4	Outlet	.0	.0	.000E+00	.0	.000	.0	.0

	HYDRAULIC	CONSERV			
OVERFLOW RATE	RESIDENCE TIME	POOL CONC	RESIDENCE TIME	TURNOVER RATIO	RETENTION COEF
M/YR	YRS	MG/M3	YRS	-	-
7.97	.4360	.0	.0000	.0000	.0000

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	NE_INLET	637.8	12.6	.000E+00	.0	.000	911.2	17.6
2	1	S_Inlet	4284.4	84.4	.000E+00	.0	.000	1493.9	8.5
3	1	UnGauged	131.5	2.6	.000E+00	.0	.000	1461.0	300.9
4	4	Outlet	2327.3	45.9	.000E+00	.0	.000	664.0	4.3
		PRECIPITATION	19.6	.4	.960E+02	100.0	.500	74.7	44.9
		TRIBUTARY INFLOW	5053.7	99.6	.000E+00	.0	.000	1381.6	9.3
		***TOTAL INFLOW	5073.3	100.0	.960E+02	100.0	.002	1294.1	9.4
		GAUGED OUTFLOW	3154.5	62.2	.000E+00	.0	.000	900.0	5.8
		ADVECTIVE OUTFLOW	-19.6	-.4	.161E+0516821.1		6.477	900.0	-44.2
		***TOTAL OUTFLOW	3134.9	61.8	.161E+0516820.9		.041	900.0	5.8
		***RETENTION	1938.4	38.2	.162E+0516920.9		.066	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.97	.4360	900.0	.2694	3.7120	.3821

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	NE_INLET	1028.1	15.7	.000E+00	.0	.000	1468.7	28.4
2	1	S_Inlet	4951.7	75.4	.000E+00	.0	.000	1726.5	9.8
3	1	UnGauged	155.8	2.4	.000E+00	.0	.000	1731.2	356.6
4	4	Outlet	8068.5	122.9	.000E+00	.0	.000	2302.0	14.9
		PRECIPITATION	430.4	6.6	.463E+05	100.0	.500	1641.7	985.0
		TRIBUTARY INFLOW	6135.6	93.4	.000E+00	.0	.000	1677.3	11.3
		***TOTAL INFLOW	6566.0	100.0	.463E+05	100.0	.033	1674.9	12.1
		GAUGED OUTFLOW	8930.7	136.0	.000E+00	.0	.000	2548.0	16.5
		ADVECTIVE OUTFLOW	-55.5	-.8	.129E+06	279.4	6.477	2548.0	-125.1
		***TOTAL OUTFLOW	8875.2	135.2	.129E+06	279.4	.041	2548.0	16.4
		***RETENTION	-2309.2	-35.2	.176E+06	379.4	.182	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
7.97	.4360	2548.0	.5893	1.6969	-.3517

Short Creek Dam at 25% Reduction in Nutrient Load

CASE: Short Creek 2005 - 25%

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	NE_INLET	36.260	.700	.000E+00	.000	.019
2	1	S_Inlet	504.400	2.868	.000E+00	.000	.006
3	1	UnGauged	.437	.090	.000E+00	.000	.206
4	4	Outlet	541.090	3.505	.000E+00	.000	.006
		PRECIPITATION	.437	.262	.275E-02	.200	.600
		TRIBUTARY INFLOW	541.097	3.658	.000E+00	.000	.007
		***TOTAL INFLOW	541.534	3.920	.275E-02	.013	.007
		GAUGED OUTFLOW	541.090	3.505	.000E+00	.000	.006
		ADVECTIVE OUTFLOW	.444	-.022	.199E-01	6.477	-.049
		***TOTAL OUTFLOW	541.534	3.483	.199E-01	.041	.006
		***EVAPORATION	.000	.437	.172E-01	.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	NE_INLET	298.2	12.7	.000E+00	.0	.000	426.0	8.2
2	1	S_Inlet	1978.9	84.2	.000E+00	.0	.000	690.0	3.9
3	1	UnGauged	60.8	2.6	.000E+00	.0	.000	675.0	139.0
4	4	Outlet	2327.3	99.0	.000E+00	.0	.000	664.0	4.3
		PRECIPITATION	13.1	.6	.430E+02	100.0	.500	50.0	30.0
		TRIBUTARY INFLOW	2337.9	99.4	.000E+00	.0	.000	639.1	4.3
		***TOTAL INFLOW	2351.0	100.0	.430E+02	100.0	.003	599.7	4.3
		GAUGED OUTFLOW	3154.5	134.2	.000E+00	.0	.000	900.0	5.8
		ADVECTIVE OUTFLOW	-19.6	-.8	.161E+05	37581.8	6.477	900.0	-44.2
		***TOTAL OUTFLOW	3134.9	133.3	.161E+05	37581.3	.041	900.0	5.8
		***RETENTION	-783.9	-33.3	.162E+05	37681.3	.162	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P: POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
7.97	.4360	900.0	.5813	1.7202	-.3334

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	NE_INLET	1142.4	15.1	.000E+00	.0	.000	1632.0	31.5
2	1	S_Inlet	5790.5	76.7	.000E+00	.0	.000	2019.0	11.5
3	1	UnGauged	182.3	2.4	.000E+00	.0	.000	2025.0	417.0
4	4	Outlet	8068.5	106.8	.000E+00	.0	.000	2302.0	14.9
		PRECIPITATION	437.0	5.8	.477E+05	100.0	.500	1666.7	1000.0
		TRIBUTARY INFLOW	7115.1	94.2	.000E+00	.0	.000	1945.1	13.1
		***TOTAL INFLOW	7552.1	100.0	.477E+05	100.0	.029	1926.5	13.9
		GAUGED OUTFLOW	8930.7	118.3	.000E+00	.0	.000	2548.0	16.5
		ADVECTIVE OUTFLOW	-55.5	-.7	.129E+06	271.1	6.477	2548.0	-125.1
		***TOTAL OUTFLOW	8875.2	117.5	.129E+06	271.1	.041	2548.0	16.4
		***RETENTION	-1323.1	-17.5	.177E+06	371.1	.318	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
7.97	.4360	2548.0	.5123	1.9518	-.1752

CASE: Short Creek 2005 - 25%

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET
SEGMENT: 1 Short Crk Dam

VARIABLE		VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P	MG/M3	900.00	677.67	99.9	99.8
TOTAL N	MG/M3	2548.00	1926.47	92.8	84.6
C.NUTRIENT	MG/M3	195.08	144.63	98.3	96.0
CHL-A	MG/M3	8.00	7.07	41.8	35.6
SECCHI	M	1.25	1.29	57.6	59.1
ORGANIC N	MG/M3	2337.00	2180.74	99.9	99.9
TP-ORTHO-P	MG/M3	85.00	79.49	86.4	84.8
HOD-V	MG/M3-DAY	.00	83.77	.0	54.5
MOD-V	MG/M3-DAY	.00	72.49	.0	53.6
ANTILOG PC-1		997.52	752.84	85.8	80.4
ANTILOG PC-2		5.81	5.72	42.3	41.2
(N - 150) / P		2.66	2.62	.3	.3
INORGANIC N / P		.26	.00	.0	.0
TURBIDITY	1/M	.60	.60	49.3	49.3
ZMIX * TURBIDITY		2.04	2.04	28.8	28.8
ZMIX / SECCHI		2.72	2.64	16.7	15.5
CHL-A * SECCHI		10.00	9.11	48.9	43.6
CHL-A / TOTAL P		.01	.01	.0	.0
FREQ(CHL-a>10) %		25.14	19.25	.0	.0
FREQ(CHL-a>20) %		3.69	2.35	.0	.0
FREQ(CHL-a>30) %		.73	.41	.0	.0
FREQ(CHL-a>40) %		.18	.10	.0	.0
FREQ(CHL-a>50) %		.05	.03	.0	.0
FREQ(CHL-a>60) %		.02	.01	.0	.0
CARLSON TSI-P		102.24	98.15	.0	.0
CARLSON TSI-CHLA		51.00	49.79	.0	.0
CARLSON TSI-SEC		56.78	56.36	.0	.0

Short Creek Dam at 50% Reduction in Nutrient Load

CASE: Short Creek 2005 - 50%

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	NE_INLET	36.260	.700	.000E+00	.000	.019
2	1	S_Inlet	504.400	2.868	.000E+00	.000	.006
3	1	UnGauged	.437	.090	.000E+00	.000	.206
4	4	Outlet	541.090	3.505	.000E+00	.000	.006
		PRECIPITATION	.437	.262	.275E-02	.200	.600
		TRIBUTARY INFLOW	541.097	3.658	.000E+00	.000	.007
		***TOTAL INFLOW	541.534	3.920	.275E-02	.013	.007
		GAUGED OUTFLOW	541.090	3.505	.000E+00	.000	.006
		ADVECTIVE OUTFLOW	.444	-.022	.199E-01	6.477	-.049
		***TOTAL OUTFLOW	541.534	3.483	.199E-01	.041	.006
		***EVAPORATION	.000	.437	.172E-01	.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	NE_INLET	198.8	12.6	.000E+00	.0	.000	284.0	5.5
2	1	S_Inlet	1319.3	83.9	.000E+00	.0	.000	460.0	2.6
3	1	UnGauged	40.5	2.6	.000E+00	.0	.000	450.0	92.7
4	4	Outlet	2327.3	148.1	.000E+00	.0	.000	664.0	4.3
		PRECIPITATION	13.1	.8	.430E+02	100.0	.500	50.0	30.0
		TRIBUTARY INFLOW	1558.6	99.2	.000E+00	.0	.000	426.1	2.9
		***TOTAL INFLOW	1571.7	100.0	.430E+02	100.0	.004	400.9	2.9
		GAUGED OUTFLOW	3154.5	200.7	.000E+00	.0	.000	900.0	5.8
		ADVECTIVE OUTFLOW	-19.6	-1.2	.161E+05	37581.8	6.477	900.0	-44.2
		***TOTAL OUTFLOW	3134.9	199.5	.161E+05	37581.3	.041	900.0	5.8
		***RETENTION	-1563.2	-99.5	.162E+05	37681.3	.081	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	------------- TOTAL P ------------- POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
7.97	.4360	900.0	.8696	1.1500	-.9946

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	NE_INLET	761.6	14.7	.000E+00	.0	.000	1088.0	21.0
2	1	S_Inlet	3860.3	74.5	.000E+00	.0	.000	1346.0	7.7
3	1	UnGauged	121.5	2.3	.000E+00	.0	.000	1350.0	278.0
4	4	Outlet	8068.5	155.7	.000E+00	.0	.000	2302.0	14.9
		PRECIPITATION	437.0	8.4	.477E+05	100.0	.500	1666.7	1000.0
		TRIBUTARY INFLOW	4743.4	91.6	.000E+00	.0	.000	1296.7	8.8
		***TOTAL INFLOW	5180.4	100.0	.477E+05	100.0	.042	1321.5	9.6
		GAUGED OUTFLOW	8930.7	172.4	.000E+00	.0	.000	2548.0	16.5
		ADVECTIVE OUTFLOW	-55.5	-1.1	.129E+06	271.1	6.477	2548.0	-125.1
		***TOTAL OUTFLOW	8875.2	171.3	.129E+06	271.1	.041	2548.0	16.4
		***RETENTION	-3694.8	-71.3	.177E+06	371.1	.114	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
7.97	.4360	2548.0	.7469	1.3388	-.7132

CASE: Short Creek 2005 - 50%

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

SEGMENT: 1 Short Crk Dam

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	900.00	453.04	99.9	99.4
TOTAL N MG/M3	2548.00	1321.47	92.8	66.7
C.NUTRIENT MG/M3	195.08	95.43	98.3	89.0
CHL-A MG/M3	8.00	5.75	41.8	26.2
SECCHI M	1.25	1.34	57.6	61.4
ORGANIC N MG/M3	2337.00	1999.01	99.9	99.8
TP-ORTHO-P MG/M3	85.00	71.21	86.4	81.9
HOD-V MG/M3-DAY	.00	75.49	.0	48.9
MOD-V MG/M3-DAY	.00	65.33	.0	47.7
ANTILOG PC-1	997.52	499.84	85.8	70.7
ANTILOG PC-2	5.81	5.48	42.3	38.1
(N - 150) / P	2.66	2.59	.3	.3
INORGANIC N / P	.26	.00	.0	.0
TURBIDITY 1/M	.60	.60	49.3	49.3
ZMIX * TURBIDITY	2.04	2.04	28.8	28.8
ZMIX / SECCHI	2.72	2.53	16.7	13.8
CHL-A * SECCHI	10.00	7.73	48.9	34.7
CHL-A / TOTAL P	.01	.01	.0	.0
FREQ(CHL-a>10) %	25.14	11.43	.0	.0
FREQ(CHL-a>20) %	3.69	1.01	.0	.0
FREQ(CHL-a>30) %	.73	.15	.0	.0
FREQ(CHL-a>40) %	.18	.03	.0	.0
FREQ(CHL-a>50) %	.05	.01	.0	.0
FREQ(CHL-a>60) %	.02	.00	.0	.0
CARLSON TSI-P	102.24	92.34	.0	.0
CARLSON TSI-CHLA	51.00	47.75	.0	.0
CARLSON TSI-SEC	56.78	55.73	.0	.0

Short Creek Dam at 75% Reduction in Nutrient Load

CASE: Short Creek 2005 - 75%

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	NE_INLET	36.260	.700	.000E+00	.000	.019
2	1	S_Inlet	504.400	2.868	.000E+00	.000	.006
3	1	UnGauged	.437	.090	.000E+00	.000	.206
4	4	Outlet	541.090	3.505	.000E+00	.000	.006
		PRECIPITATION	.437	.262	.275E-02	.200	.600
		TRIBUTARY INFLOW	541.097	3.658	.000E+00	.000	.007
		***TOTAL INFLOW	541.534	3.920	.275E-02	.013	.007
		GAUGED OUTFLOW	541.090	3.505	.000E+00	.000	.006
		ADVECTIVE OUTFLOW	.444	-.022	.199E-01	6.477	-.049
		***TOTAL OUTFLOW	541.534	3.483	.199E-01	.041	.006
		***EVAPORATION	.000	.437	.172E-01	.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	NE_INLET	99.4	12.5	.000E+00	.0	.000	142.0	2.7
2	1	S_Inlet	659.6	83.2	.000E+00	.0	.000	230.0	1.3
3	1	UnGauged	20.3	2.6	.000E+00	.0	.000	225.0	46.3
4	4	Outlet	2327.3	293.7	.000E+00	.0	.000	664.0	4.3
		PRECIPITATION	13.1	1.7	.430E+02	100.0	.500	50.0	30.0
		TRIBUTARY INFLOW	779.3	98.3	.000E+00	.0	.000	213.0	1.4
		***TOTAL INFLOW	792.4	100.0	.430E+02	100.0	.008	202.1	1.5
		GAUGED OUTFLOW	3154.5	398.1	.000E+00	.0	.000	900.0	5.8
		ADVECTIVE OUTFLOW	-19.6	-2.5	.161E+05	37581.8	6.477	900.0	-44.2
		***TOTAL OUTFLOW	3134.9	395.6	.161E+05	37581.3	.041	900.0	5.8
		***RETENTION	-2342.5	-295.6	.162E+05	37681.2	.054	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
7.97	.4360	900.0	1.7248	.5798	-2.9562

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	NE_INLET	380.8	13.6	.000E+00	.0	.000	544.0	10.5
2	1	S_Inlet	1930.2	68.7	.000E+00	.0	.000	673.0	3.8
3	1	UnGauged	60.8	2.2	.000E+00	.0	.000	675.0	139.0
4	4	Outlet	8068.5	287.3	.000E+00	.0	.000	2302.0	14.9
		PRECIPITATION	437.0	15.6	.477E+05	100.0	.500	1666.7	1000.0
		TRIBUTARY INFLOW	2371.7	84.4	.000E+00	.0	.000	648.4	4.4
		***TOTAL INFLOW	2808.7	100.0	.477E+05	100.0	.078	716.5	5.2
		GAUGED OUTFLOW	8930.7	318.0	.000E+00	.0	.000	2548.0	16.5
		ADVECTIVE OUTFLOW	-55.5	-2.0	.129E+06	271.1	6.477	2548.0	-125.1
		***TOTAL OUTFLOW	8875.2	316.0	.129E+06	271.1	.041	2548.0	16.4
		***RETENTION	-6066.5	-216.0	.177E+06	371.1	.069	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
7.97	.4360	2548.0	1.3776	.7259	-2.1599

CASE: Short Creek 2005 - 75%
OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 1 Short Crk Dam

VARIABLE		VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P	MG/M3	900.00	228.41	99.9	95.9
TOTAL N	MG/M3	2548.00	716.47	92.8	30.0
C.NUTRIENT	MG/M3	195.08	46.23	98.3	62.7
CHL-A	MG/M3	8.00	3.35	41.8	9.0
SECCHI	M	1.25	1.46	57.6	65.5
ORGANIC N	MG/M3	2337.00	1670.76	99.9	99.3
TP-ORTHO-P	MG/M3	85.00	56.26	86.4	74.6
HOD-V	MG/M3-DAY	.00	57.61	.0	34.8
MOD-V	MG/M3-DAY	.00	49.85	.0	33.1
ANTILOG PC-1		997.52	218.74	85.8	46.5
ANTILOG PC-2		5.81	4.51	42.3	25.0
(N - 150) / P		2.66	2.48	.3	.2
INORGANIC N / P		.26	.01	.0	.0
TURBIDITY	1/M	.60	.60	49.3	49.3
ZMIX * TURBIDITY		2.04	2.04	28.8	28.8
ZMIX / SECCHI		2.72	2.32	16.7	10.8
CHL-A * SECCHI		10.00	4.89	48.9	15.0
CHL-A / TOTAL P		.01	.01	.0	.0
FREQ(CHL-a>10) %		25.14	1.90	.0	.0
FREQ(CHL-a>20) %		3.69	.07	.0	.0
FREQ(CHL-a>30) %		.73	.01	.0	.0
FREQ(CHL-a>40) %		.18	.00	.0	.0
FREQ(CHL-a>50) %		.05	.00	.0	.0
FREQ(CHL-a>60) %		.02	.00	.0	.0
CARLSON TSI-P		102.24	82.47	.0	.0
CARLSON TSI-CHLA		51.00	42.45	.0	.0
CARLSON TSI-SEC		56.78	54.52	.0	.0

Short Creek Dam at 90% Reduction in Nutrient Load

CASE: Short Creek 2005 (90 percent reduction in nutrient loads)

CASE: Short Creek 2005

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	NE_INLET	36.260	.700	.000E+00	.000	.019
2	1	S_Inlet	504.400	2.868	.000E+00	.000	.006
3	1	UnGauged	.437	.090	.000E+00	.000	.206
4	4	Outlet	541.090	3.505	.000E+00	.000	.006
		PRECIPITATION	.437	.262	.275E-02	.200	.600
		TRIBUTARY INFLOW	541.097	3.658	.000E+00	.000	.007
		***TOTAL INFLOW	541.534	3.920	.275E-02	.013	.007
		GAUGED OUTFLOW	541.090	3.505	.000E+00	.000	.006
		ADVECTIVE OUTFLOW	.444	-.022	.199E-01	6.477	-.049
		***TOTAL OUTFLOW	541.534	3.483	.199E-01	.041	.006
		***EVAPORATION	.000	.437	.172E-01	.300	.000

GROSS MASS BALANCE BASED UPON 90% REDUCTION IN OBSERVED INFLOW CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	NE_INLET	39.7	12.2	.000E+00	.0	.000	56.7	1.1
2	1	S_Inlet	263.6	81.2	.000E+00	.0	.000	91.9	.5
3	1	UnGauged	8.1	2.5	.000E+00	.0	.000	90.0	18.5
4	4	Outlet	2327.3	717.3	.000E+00	.0	.000	664.0	4.3
		PRECIPITATION	13.1	4.0	.430E+02	100.0	.500	50.0	30.0
		TRIBUTARY INFLOW	311.4	96.0	.000E+00	.0	.000	85.1	.6
		***TOTAL INFLOW	324.5	100.0	.430E+02	100.0	.020	82.8	.6
		GAUGED OUTFLOW	3154.5	972.2	.000E+00	.0	.000	900.0	5.8
		ADVECTIVE OUTFLOW	-19.6	-6.0	.161E+05	37587.7	6.477	900.0	-44.2
		***TOTAL OUTFLOW	3134.9	966.2	.161E+05	37587.2	.041	900.0	5.8
		***RETENTION	-2810.4	-866.2	.162E+05	37687.2	.045	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.97	.4360	900.0	4.2122	.2374	-8.6616

GROSS MASS BALANCE BASED UPON 90% REDUCTION IN OBSERVED INFLOW CONCENTRATIONS
COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	NE_INLET	152.3	11.0	.000E+00	.0	.000	217.6	4.2
2	1	S_Inlet	772.1	55.7	.000E+00	.0	.000	269.2	1.5
3	1	UnGauged	24.3	1.8	.000E+00	.0	.000	270.0	55.6
4	4	Outlet	8068.5	582.3	.000E+00	.0	.000	2302.0	14.9
		PRECIPITATION	437.0	31.5	.477E+05	100.0	.500	1666.7	1000.0
		TRIBUTARY INFLOW	948.7	68.5	.000E+00	.0	.000	259.3	1.8
		***TOTAL INFLOW	1385.7	100.0	.477E+05	100.0	.158	353.5	2.6
		GAUGED OUTFLOW	8930.7	644.5	.000E+00	.0	.000	2548.0	16.5
		ADVECTIVE OUTFLOW	-55.5	-4.0	.129E+06	271.1	6.477	2548.0	-125.1
		***TOTAL OUTFLOW	8875.2	640.5	.129E+06	271.1	.041	2548.0	16.4
		***RETENTION	-7489.5	-540.5	.177E+06	371.1	.056	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
7.97	.4360	2548.0	2.7924	.3581	-5.4049

CASE: Short Creek 2005 – 90%

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET
SEGMENT: 1 Short Crk Dam

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED(-90%)	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	900.00	93.53	99.9	77.1
TOTAL N MG/M3	2548.00	353.47	92.8	5.2
C.NUTRIENT MG/M3	195.08	16.68	98.3	17.1
CHL-A MG/M3	8.00	1.14	41.8	.3
SECCHI M	1.25	1.59	57.6	69.5
ORGANIC N MG/M3	2337.00	1368.57	99.9	98.1
TP-ORTHO-P MG/M3	85.00	42.50	86.4	64.3
HOD-V MG/M3-DAY	.00	33.58	.0	13.3
MOD-V MG/M3-DAY	.00	29.06	.0	11.6
ANTILOG PC-1	997.52	59.39	85.8	14.0
ANTILOG PC-2	5.81	2.71	42.3	5.0
(N - 150) / P	2.66	2.18	.3	.1
INORGANIC N / P	.26	.02	.0	.0
TURBIDITY 1/M	.60	.60	49.3	49.3
ZMIX * TURBIDITY	2.04	2.04	28.8	28.8
ZMIX / SECCHI	2.72	2.14	16.7	8.4
CHL-A * SECCHI	10.00	1.81	48.9	.7
CHL-A / TOTAL P	.01	.01	.0	.0
FREQ(CHL-a>10) %	25.14	.01	.0	.0
FREQ(CHL-a>20) %	3.69	.00	.0	.0
FREQ(CHL-a>30) %	.73	.00	.0	.0
FREQ(CHL-a>40) %	.18	.00	.0	.0
FREQ(CHL-a>50) %	.05	.00	.0	.0
FREQ(CHL-a>60) %	.02	.00	.0	.0
CARLSON TSI-P	102.24	69.59	.0	.0
CARLSON TSI-CHLA	51.00	31.86	.0	.0
CARLSON TSI-SEC	56.78	53.31	.0	.0

Appendix B
Flux Data and Analysis

Short Creek NE Inlet Site #385316 (Canadian portion of watershed)

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Short Creek 2005 NE Inlet

 TABULATION OF MISSING DAILY FLOWS:

 Flow File =385316_Q.wk1
 Daily Flows from 20041231 to 20051230

 Summary:
 Reported Flows =  365

 Missing Flows =     0
 Zero Flows =      117
 Positive Flows =  248

 Short Creek 2005 NE Inlet         VAR=nh3-4     METHOD= 6 REG-3
 Comparison of Sampled & Total Flow Distributions
        ------ SAMPLED -----     ------- TOTAL ------
 STRAT   N     MEAN  STD DEV      N     MEAN  STD DEV     DIFF    T PROB(>T)
  1     21     1.95     2.58    365      .70     1.74     1.25  -2.20   .037
***     21     1.95     2.58    365      .70     1.74     1.25  -2.20   .037

 Average Sample Interval =   5.8 Days, Date Range = 20050305 to 20050704
 Maximum Sample Interval =    28 Days, Date Range = 20050416 to 20050515
 Percent of Total Flow Volume Occuring In This Interval =  20.3%

 Total Flow Volume on Sampled Days =         41.0 hm3
 Total Flow Volume on All Days     =        254.7 hm3
 Percent of Total Flow Volume Sampled =    16.1%

 Maximum Sampled Flow Rate =        8.82 hm3/yr
 Maximum Total Flow Rate   =       16.99 hm3/yr
 Number of Days when Flow Exceeded Maximum Sampled Flow =  2 out of  365
 Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
       Maximum Sampled Flow Rate =    10.3%
```

Short Creek 2005 NE Inlet VAR=nh3-4 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	266	8	8	4.8	.046	.146	-.208	.709
2	48	4	4	14.2	.754	.781	4.955	.186
3	51	9	9	81.0	4.046	4.077	-.362	.525
***	365	21	21	100.0	.698	1.952		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = .698 HM3/YR
TOTAL FLOW VOLUME = .70 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050704

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	50.4	50.4	.5109E+03	72.23	.448
2 Q WTD C	47.2	47.3	.4549E+03	67.71	.451
3 IJC	49.0	49.0	.5623E+03	70.21	.484
4 REG-1	44.6	44.7	.4470E+03	63.98	.473
5 REG-2	49.6	49.7	.4473E+03	71.16	.426
6 REG-3	59.3	59.3	.1648E+04	85.03	.684

Short Creek 2005 NE Inlet VAR=no2+no3 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	266	8	8	4.8	.046	.146	-.410	.217
2	48	4	4	14.2	.754	.781	4.036	.158
3	51	9	9	81.0	4.046	4.077	.707	.337
***	365	21	21	100.0	.698	1.952		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = .698 HM3/YR
TOTAL FLOW VOLUME = .70 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050704

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	119.0	119.1	.2259E+04	170.64	.399
2 Q WTD C	115.8	115.9	.2035E+04	166.04	.389
3 IJC	115.9	115.9	.2064E+04	166.12	.392
4 REG-1	113.8	113.9	.3612E+04	163.16	.528
5 REG-2	119.7	119.7	.4716E+04	171.59	.574
6 REG-3	147.9	148.0	.1064E+05	212.08	.697

Short Creek 2005 NE Inlet VAR=inorg-n 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	266	8	8	4.8	.046	.146	-.278	.494
2	48	4	4	14.2	.754	.781	4.442	.160
3	51	9	9	81.0	4.046	4.077	.314	.608
***	365	21	21	100.0	.698	1.952		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = .698 HM3/YR
TOTAL FLOW VOLUME = .70 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050704

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	169.4	169.5	.4003E+04	242.88	.373
2 Q WTD C	163.0	163.1	.3519E+04	233.75	.364
3 IJC	164.8	164.9	.3905E+04	236.33	.379
4 REG-1	158.6	158.7	.4903E+04	227.39	.441
5 REG-2	168.3	168.4	.5875E+04	241.37	.455
6 REG-3	190.3	190.4	.1078E+05	272.90	.545

Short Creek 2005 NE Inlet VAR=tkn 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	266	8	8	4.8	.046	.146	-.036	.784
2	48	4	4	14.2	.754	.781	-.310	.624
3	51	9	9	81.0	4.046	4.077	-.367	.005
***	365	21	21	100.0	.698	1.952		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = .698 HM3/YR
TOTAL FLOW VOLUME = .70 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050704

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1600.7	1601.8	.3010E+05	2295.35	.108
2 Q WTD C	1406.0	1407.0	.8587E+04	2016.16	.066
3 IJC	1388.1	1389.0	.7257E+04	1990.43	.061
4 REG-1	1415.5	1416.5	.4173E+04	2029.77	.046
5 REG-2	1403.0	1404.0	.3824E+04	2011.80	.044
6 REG-3	1435.0	1435.9	.4298E+04	2057.62	.046

Short Creek 2005 NE Inlet VAR=t-n 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	266	8	8	4.8	.046	.146	-.046	.726
2	48	4	4	14.2	.754	.781	-.150	.818
3	51	9	9	81.0	4.046	4.077	-.318	.025
***	365	21	21	100.0	.698	1.952		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = .698 HM3/YR
TOTAL FLOW VOLUME = .70 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050704

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1719.8	1720.9	.4009E+05	2466.00	.116
2 Q WTD C	1521.8	1522.9	.1317E+05	2182.20	.075
3 IJC	1503.9	1505.0	.1210E+05	2156.55	.073
4 REG-1	1530.7	1531.7	.8266E+04	2194.89	.059
5 REG-2	1517.4	1518.5	.6860E+04	2175.88	.055
6 REG-3	1556.9	1557.9	.8394E+04	2232.42	.059

Short Creek 2005 NE Inlet VAR=t-d-p 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	266	8	8	4.8	.046	.146	.177	.606
2	48	4	4	14.2	.754	.781	-.138	.879
3	51	9	9	81.0	4.046	4.077	-.555	.042
***	365	21	21	100.0	.698	1.952		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = .698 HM3/YR
TOTAL FLOW VOLUME = .70 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050704

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	360.4	360.6	.1390E+04	516.76	.103
2 Q WTD C	312.7	313.0	.1719E+04	448.45	.132
3 IJC	305.6	305.8	.1499E+04	438.21	.127
4 REG-1	310.3	310.5	.7521E+03	444.99	.088
5 REG-2	313.0	313.2	.7297E+03	448.83	.086
6 REG-3	331.9	332.1	.6611E+03	475.93	.077

Short Creek 2005 NE Inlet VAR=t-p 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	266	8	8	4.8	.046	.146	.161	.625
2	48	4	4	14.2	.754	.781	.082	.914
3	51	9	9	81.0	4.046	4.077	-.442	.075
***	365	21	21	100.0	.698	1.952		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = .698 HM3/YR
TOTAL FLOW VOLUME = .70 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050704

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	428.8	429.1	.2357E+04	614.82	.113
2 Q WTD C	375.9	376.1	.1561E+04	538.95	.105
3 IJC	369.6	369.8	.1339E+04	529.96	.099
4 REG-1	372.9	373.1	.8557E+03	534.66	.078
5 REG-2	375.6	375.9	.7962E+03	538.57	.075
6 REG-3	395.5	395.8	.8359E+03	567.13	.073

Short Creek 2005 NE Inlet 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	266	8	8	4.8	.046	.146	-.269	.044
2	48	4	4	14.2	.754	.781	.375	.344
3	51	9	9	81.0	4.046	4.077	-.144	.312
***	365	21	21	100.0	.698	1.952		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = .698 HM3/YR
TOTAL FLOW VOLUME = .70 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050704

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	4346.5	4349.5	.4087E+06	6232.62	.147
2 Q WTD C	3916.8	3919.5	.3837E+05	5616.40	.050
3 IJC	3897.0	3899.7	.3562E+05	5588.02	.048
4 REG-1	3976.9	3979.6	.4182E+05	5702.55	.051
5 REG-2	3907.1	3909.7	.2690E+05	5602.45	.042
6 REG-3	3999.2	4001.9	.4533E+05	5734.51	.053

Short Creek South Inlet Site #385314

Short Creek 2005 South Inlet

Comparison of Sampled & Total Flow Distributions

	------ SAMPLED -----			------- TOTAL ------					
STRAT	N	MEAN	STD DEV	N	MEAN	STD DEV	DIFF	T	PROB(>T)
1	37	5.45	6.84	365	2.87	5.47	2.59	-2.23	.030
***	37	5.45	6.84	365	2.87	5.47	2.59	-2.23	.030

Average Sample Interval = 4.9 Days, Date Range = 20050305 to 20050904
Maximum Sample Interval = 12 Days, Date Range = 20050315 to 20050328
Percent of Total Flow Volume Occuring In This Interval = 10.6%

Total Flow Volume on Sampled Days = 201.8 hm3
Total Flow Volume on All Days = 1046.9 hm3
Percent of Total Flow Volume Sampled = 19.3%

Maximum Sampled Flow Rate = 22.69 hm3/yr
Maximum Total Flow Rate = 22.69 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 0 out of 365
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate = .0%

Short Creek 2005 South Inlet VAR=nh3-4 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	268	17	17	6.3	.245	.611	-1.165	.004
2	33	8	8	8.8	2.801	2.518	1.733	.610
3	64	12	12	84.9	13.889	14.275	.186	.839
***	365	37	37	100.0	2.868	5.455		

FLOW STATISTICS

FLOW DURATION = 365.0 DAYS = .999 YEARS

MEAN FLOW RATE = 2.868 HM3/YR

TOTAL FLOW VOLUME = 2.87 HM3

FLOW DATE RANGE = 20041231 TO 20051230

SAMPLE DATE RANGE = 20050305 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	219.0	219.2	.5167E+04	76.41	.328
2 Q WTD C	206.1	206.3	.4800E+04	71.91	.336
3 IJC	206.6	206.7	.4939E+04	72.07	.340
4 REG-1	237.9	238.1	.9165E+04	82.99	.402
5 REG-2	256.5	256.7	.1908E+05	89.49	.538
6 REG-3	374.4	374.6	.3344E+06	130.60	1.544

Short Creek 2005 South Inlet VAR=no2+no3 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	268	17	17	6.3	.245	.611	-.098	.707
2	33	8	8	8.8	2.801	2.518	1.664	.585
3	64	12	12	84.9	13.889	14.275	-.202	.814
***	365	37	37	100.0	2.868	5.455		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 2.868 HM3/YR
TOTAL FLOW VOLUME = 2.87 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	304.4	304.6	.2093E+05	106.20	.475
2 Q WTD C	295.3	295.5	.2007E+05	103.02	.479
3 IJC	296.2	296.4	.2072E+05	103.34	.486
4 REG-1	311.2	311.4	.2503E+05	108.58	.508
5 REG-2	326.2	326.4	.3536E+05	113.81	.576
6 REG-3	380.3	380.6	.1981E+06	132.68	1.169

Short Creek 2005 South Inlet VAR=inorg-n 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	268	17	17	6.3	.245	.611	-.764	.018
2	33	8	8	8.8	2.801	2.518	1.702	.594
3	64	12	12	84.9	13.889	14.275	.052	.949
***	365	37	37	100.0	2.868	5.455		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 2.868 HM3/YR
TOTAL FLOW VOLUME = 2.87 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	523.4	523.8	.4564E+05	182.61	.408
2 Q WTD C	501.4	501.8	.4336E+05	174.93	.415
3 IJC	502.8	503.1	.4472E+05	175.40	.420
4 REG-1	545.4	545.8	.6140E+05	190.27	.454
5 REG-2	568.5	568.9	.1009E+06	198.34	.558
6 REG-3	737.9	738.4	.9601E+06	257.43	1.327

Short Creek 2005 South Inlet VAR=tkn 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	268	17	17	6.3	.245	.611	-.265	.027
2	33	8	8	8.8	2.801	2.518	.080	.874
3	64	12	12	84.9	13.889	14.275	.282	.051
***	365	37	37	100.0	2.868	5.455		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 2.868 HM3/YR
TOTAL FLOW VOLUME = 2.87 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	8238.7	8244.4	.6957E+06	2874.25	.101
2 Q WTD C	7419.9	7425.0	.8094E+05	2588.61	.038
3 IJC	7428.3	7433.4	.8009E+05	2591.54	.038
4 REG-1	7506.2	7511.4	.9763E+05	2618.71	.042
5 REG-2	7369.5	7374.5	.1009E+06	2570.99	.043
6 REG-3	7448.4	7453.5	.1012E+06	2598.54	.043

Short Creek 2005 South Inlet VAR=t-n 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	268	17	17	6.3	.245	.611	-.263	.030
2	33	8	8	8.8	2.801	2.518	.146	.820
3	64	12	12	84.9	13.889	14.275	.290	.043
***	365	37	37	100.0	2.868	5.455		

FLOW STATISTICS

FLOW DURATION = 365.0 DAYS = .999 YEARS

MEAN FLOW RATE = 2.868 HM3/YR

TOTAL FLOW VOLUME = 2.87 HM3

FLOW DATE RANGE = 20041231 TO 20051230

SAMPLE DATE RANGE = 20050305 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	8543.1	8549.0	.7424E+06	2980.45	.101
2 Q WTD C	7715.2	7720.5	.8279E+05	2691.62	.037
3 IJC	7724.6	7729.8	.8180E+05	2694.87	.037
4 REG-1	7805.1	7810.5	.1119E+06	2722.98	.043
5 REG-2	7668.2	7673.5	.1214E+06	2675.22	.045
6 REG-3	7758.5	7763.8	.1178E+06	2706.72	.044

Short Creek 2005 South Inlet VAR=t-d-p 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	268	17	17	6.3	.245	.611	-.733	.030
2	33	8	8	8.8	2.801	2.518	.123	.899
3	64	12	12	84.9	13.889	14.275	.731	.110
***	365	37	37	100.0	2.868	5.455		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 2.868 HM3/YR
TOTAL FLOW VOLUME = 2.87 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	2613.4	2615.2	.1487E+06	911.75	.147
2 Q WTD C	2358.0	2359.6	.7361E+05	822.63	.115
3 IJC	2360.5	2362.1	.7191E+05	823.51	.114
4 REG-1	2458.8	2460.5	.9126E+05	857.81	.123
5 REG-2	2377.6	2379.2	.9657E+05	829.47	.131
6 REG-3	2498.4	2500.1	.1292E+06	871.62	.144

Short Creek 2005 South Inlet VAR=t-p METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	268	17	17	6.3	.245	.611	-.718	.035
2	33	8	8	8.8	2.801	2.518	.195	.835
3	64	12	12	84.9	13.889	14.275	.600	.144
***	365	37	37	100.0	2.868	5.455		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 2.868 HM3/YR
TOTAL FLOW VOLUME = 2.87 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	2928.2	2930.2	.1646E+06	1021.55	.138
2 Q WTD C	2632.4	2634.2	.7805E+05	918.36	.106
3 IJC	2633.9	2635.7	.7624E+05	918.91	.105
4 REG-1	2757.0	2758.9	.1038E+06	961.86	.117
5 REG-2	2670.8	2672.6	.1118E+06	931.75	.125
6 REG-3	2775.8	2777.7	.1335E+06	968.41	.132

Short Creek 2005 South Inlet VAR=tss METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	268	17	17	6.3	.245	.611	-.499	.006
2	33	8	8	8.8	2.801	2.518	.036	.949
3	64	11	11	84.9	13.889	14.333	.106	.766
***	365	36	36	100.0	2.868	5.227		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 2.868 HM3/YR
TOTAL FLOW VOLUME = 2.87 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050305 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	21380.9	21395.5	.1887E+08	7459.18	.203
2 Q WTD C	19182.8	19195.9	.1560E+08	6692.32	.206
3 IJC	19134.8	19147.9	.1540E+08	6675.59	.205
4 REG-1	19846.9	19860.5	.1578E+08	6924.02	.200
5 REG-2	19348.4	19361.6	.1535E+08	6750.08	.202
6 REG-3	19014.7	19027.7	.1333E+08	6633.68	.192

Short Creek South Outlet Site #385315

Short Creek 2005 Outlet

TABULATION OF MISSING DAILY FLOWS:

Flow File =385315_Q.wk1
Daily Flows from 20041231 to 20051230

Summary:
Reported Flows = 365
Missing Flows = 0
Zero Flows = 176
Positive Flows = 189

Short Creek 2005 Outlet VAR=inorg-n METHOD= 6 REG-3
Comparison of Sampled & Total Flow Distributions

	------ SAMPLED -----			------- TOTAL ------				
STRAT	N	MEAN	STD DEV	N	MEAN	STD DEV	DIFF	T	PROB(>T)
1	32	7.90	3.21	365	3.50	4.22	4.39	-7.22	.000
***	32	7.90	3.21	365	3.50	4.22	4.39	-7.22	.000

Average Sample Interval = 5.0 Days, Date Range = 20050328 to 20050904
Maximum Sample Interval = 14 Days, Date Range = 20050430 to 20050515
Percent of Total Flow Volume Occuring In This Interval = 6.0%

Total Flow Volume on Sampled Days = 252.8 hm3
Total Flow Volume on All Days = 1279.3 hm3
Percent of Total Flow Volume Sampled = 19.8%

Maximum Sampled Flow Rate = 13.70 hm3/yr
Maximum Total Flow Rate = 14.57 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 2 out of 365
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate = 2.2%

Short Creek 2005 Outlet VAR=inorg-n

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	365	32	32	100.0	3.505	7.899	.293	.304
***	365	32	32	100.0	3.505	7.899		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 3.505 HM3/YR
TOTAL FLOW VOLUME = 3.50 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050328 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1594.7	1595.8	.5900E+05	455.30	.152
2 Q WTD C	707.6	708.1	.6633E+04	202.03	.115
3 IJC	709.4	709.9	.6725E+04	202.54	.116
4 REG-1	557.6	558.0	.1126E+05	159.21	.190
5 REG-2	689.1	689.6	.5479E+04	196.76	.107
6 REG-3	712.6	713.1	.6819E+04	203.46	.116

Short Creek 2005 Outlet VAR=tkn

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	365	32	32	100.0	3.505	7.899	-.152	.057
***	365	32	32	100.0	3.505	7.899		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 3.505 HM3/YR
TOTAL FLOW VOLUME = 3.50 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050328 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	17421.5	17433.4	.1466E+07	4973.97	.069
2 Q WTD C	7730.2	7735.5	.1116E+06	2207.03	.043
3 IJC	7721.8	7727.0	.1100E+06	2204.62	.043
4 REG-1	8747.7	8753.7	.3393E+06	2497.54	.067
5 REG-2	8015.7	8021.2	.1423E+06	2288.56	.047
6 REG-3	7858.5	7863.9	.1175E+06	2243.67	.044

Short Creek 2005 Outlet VAR=t-n

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	365	32	32	100.0	3.505	7.899	-.128	.081
***	365	32	32	100.0	3.505	7.899		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 3.505 HM3/YR
TOTAL FLOW VOLUME = 3.50 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050328 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	18188.3	18200.8	.1619E+07	5192.91	.070
2 Q WTD C	8070.5	8076.0	.9805E+05	2304.18	.039
3 IJC	8063.3	8068.9	.9641E+05	2302.15	.038
4 REG-1	8954.8	8960.9	.2752E+06	2556.65	.059
5 REG-2	8307.6	8313.3	.1229E+06	2371.90	.042
6 REG-3	8180.7	8186.3	.1092E+06	2335.67	.040

Short Creek 2005 Outlet VAR=t-d-p

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	365	32	32	100.0	3.505	7.899	-.522	.011
***	365	32	32	100.0	3.505	7.899		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 3.505 HM3/YR
TOTAL FLOW VOLUME = 3.50 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050328 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	4526.9	4530.0	.1890E+06	1292.47	.096
2 Q WTD C	2008.7	2010.0	.3776E+05	573.49	.097
3 IJC	2003.4	2004.8	.3728E+05	571.98	.096
4 REG-1	3070.1	3072.2	.3749E+06	876.52	.199
5 REG-2	2568.3	2570.0	.3035E+06	733.26	.214
6 REG-3	2136.9	2138.4	.4357E+05	610.11	.098

Short Creek 2005 Outlet VAR=t-p

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	365	32	32	100.0	3.505	7.899	-.476	.010
***	365	32	32	100.0	3.505	7.899		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 3.505 HM3/YR
TOTAL FLOW VOLUME = 3.50 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050328 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	5253.0	5256.6	.2195E+06	1499.78	.089
2 Q WTD C	2330.8	2332.4	.4229E+05	665.48	.088
3 IJC	2325.1	2326.7	.4169E+05	663.82	.088
4 REG-1	3431.7	3434.1	.3566E+06	979.79	.174
5 REG-2	2871.0	2873.0	.2479E+06	819.69	.173
6 REG-3	2460.8	2462.5	.4729E+05	702.58	.088

Short Creek 2005 Outlet VAR=tss

TABULATION OF MISSING DAILY FLOWS:

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	365	31	31	100.0	3.505	7.845	-.315	.087
***	365	31	31	100.0	3.505	7.845		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 3.505 HM3/YR
TOTAL FLOW VOLUME = 3.50 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050328 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	56885.0	56924.0	.3051E+08	16241.12	.097
2 Q WTD C	25414.2	25431.6	.5125E+07	7255.96	.089
3 IJC	25362.7	25380.1	.5026E+07	7241.25	.088
4 REG-1	32747.5	32769.9	.5691E+08	9349.67	.230
5 REG-2	28153.8	28173.1	.1970E+08	8038.13	.158
6 REG-3	26371.8	26389.9	.7508E+07	7529.37	.104

Short Creek 2005 Outlet VAR=nh3-4

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	365	32	32	100.0	3.505	7.899	-.099	.797
***	365	32	32	100.0	3.505	7.899		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 3.505 HM3/YR
TOTAL FLOW VOLUME = 3.50 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050328 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	827.9	828.4	.2069E+05	236.36	.174
2 Q WTD C	367.3	367.6	.3105E+04	104.88	.152
3 IJC	367.8	368.1	.3162E+04	105.01	.153
4 REG-1	398.1	398.4	.8227E+04	113.67	.228
5 REG-2	375.2	375.4	.1934E+04	107.11	.117
6 REG-3	408.1	408.4	.3622E+04	116.53	.147

Short Creek 2005 Outlet VAR=no2+no3

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	365	32	32	100.0	3.505	7.899	.521	.071
***	365	32	32	100.0	3.505	7.899		

FLOW STATISTICS
FLOW DURATION = 365.0 DAYS = .999 YEARS
MEAN FLOW RATE = 3.505 HM3/YR
TOTAL FLOW VOLUME = 3.50 HM3
FLOW DATE RANGE = 20041231 TO 20051230
SAMPLE DATE RANGE = 20050328 TO 20050904

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	766.9	767.4	.1928E+05	218.94	.181
2 Q WTD C	340.3	340.5	.2376E+04	97.15	.143
3 IJC	341.6	341.8	.2430E+04	97.52	.144
4 REG-1	222.8	223.0	.2387E+04	63.62	.219
5 REG-2	329.2	329.4	.1876E+04	93.98	.131
6 REG-3	330.8	331.1	.1952E+04	94.45	.133

Appendix C
US EPA Region 8 Public Notice Review

EPA REGION VIII TMDL REVIEW

TMDL Document Info:

Document Name:	**Nutrient and Dissolved Oxygen TMDLs for Short Creek Dam in Burke County, North Dakota**
Submitted by:	**Mike Ell, North Dakota Department of Health**
Date Received:	**July 29, 2009**
Review Date:	**August 25, 2009**
Reviewer:	**Vern Berry, EPA**
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
   1.1. TMDL Document Submittal Letter
   1.2. Identification of the Waterbody, Impairments, and Study Boundaries
   1.3. Water Quality Standards
2. Water Quality Target
3. Pollutant Source Analysis
4. TMDL Technical Analysis
   4.1. Data Set Description
   4.2. Waste Load Allocations (WLA)
   4.3. Load Allocations (LA)
   4.4. Margin of Safety (MOS)
   4.5. Seasonality and variations in assimilative capacity
5. Public Participation
6. Monitoring Strategy
7. Restoration Strategy
8. Daily Loading Expression

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

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

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

1. Problem Description

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

1.1 TMDL Document Submittal Letter

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

Minimum Submission Requirements.

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

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

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

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

SUMMARY: A draft version of the Short Creek Dam TMDL document was submitted to EPA for review and comment via an email from Mike Ell, NDDoH on July 29, 2009. The email included a public notice letter inviting comments 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: Short Creek Dam (reservoir) is located in Burke County in northwestern North Dakota (approximately 6 miles north of the city of Columbus, North Dakota). It is an 108.1 acre man-made impoundment in the Upper Souris sub-basin of the Souris River basin of North Dakota (HUC 09010001). It was created by damming Short Creek and was completed in 1962. Short Creek Dam is listed on the State's 2008 303(d) list (ND-09010001-001-L_00) as impaired for aquatic life use by nutrients/eutrophication/biological indicators, dissolved oxygen and sedimentation/siltation, and recreational use by nutrients/eutrophication/biological indicators. Approximately 133,600 acres of land drain to the reservoir from the watershed. It is classified as a Class 1 cold water fishery, and is listed as a high priority (i.e., 1A) for TMDL development. The majority of the land use in this watershed is agricultural (approximately 97 percent). Forty-five percent of the land in the watershed cropland and 52 percent is pasture/haylands. The remaining landuse in the watershed is low density 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, all TMDL documents must be written to meet the existing water quality standards 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: Short Creek Dam is impaired for nutrients/eutrophication/biological indicators and dissolved oxygen. 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: NO_3 as N = 0.25 mg/L; PO_4 as P = 0.02 mg/L; and total phosphorus = 0.1 mg/L.

The numeric standard for dissolved oxygen is $\geq$ 5.0 mg/L (single sample minimum).

Other applicable water quality standards are included on pages 14 - 15 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 Short Creek Dam during the period of the assessment was 102.24. Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that a 90% reduction in phosphorus loading to the reservoir will achieve a total phosphorus TSI of 69.59, which corresponds to a phosphorus concentration of 0.094 mg/L. This should result in a change of trophic status for the reservoir from hypereutrophic to eutrophic during all times of the year. This target is based on best professional judgement and will fully support its beneficial uses.

The TMDL does not contain a target for sediment because the assessment concludes that the reservoir is not impaired for sediment. The report recommends removing Short Creek Dam sediment as a cause of impairment from the next Section 303(d) list.

The water quality targets used in this TMDL are: **maintain a mean annual total phosphorus TSI at or below 69.59 (TP concentration $\leq$ 0.094 mg/L); and maintain a dissolved oxygen level of greater than or equal to 5 mg/L.**

COMMENTS: None.

3. Pollutant Source Analysis

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

Minimum Submission Requirements:

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

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

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

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

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

SUMMARY: The TMDL identifies the major sources of phosphorus as coming from nonpoint source agricultural landuses within the watershed. There are no known point source contributions in this watershed. A nutrients loading analysis was performed using the ANGPS model which looked at various agricultural land use and land management factors. Cropland and range/pasture/haylands are the primary sources identified.

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: 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 Short Creek 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 Short Creek Dam reservoir.

The BATHTUB model was used to predict the trophic response of Short Creek 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 75 and 90 percent while keeping the hydraulic discharge constant. The BATHTUB model predicted that a 90% reduction in external total phosphorus loads would result in attaining a eutrophic status in the reservoir. As a result of this modeling, the loading capacity for the reservoir was determined to be 324.5 kg/yr of phosphorus.

The Agricultural Non-Point Source Model (AGNPS) model was used to simulate alterations in land use practices and the resulting nutrient reduction response. The primary objective for using the AGNPS 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 identified 579 critical cells (i.e., those with greater than 0.5 lbs of sediment phosphorus – see

Figure 13 in the TMDL document) where BMPs should be applied to achieve a 90 percent reduction in phosphorus loading from the watershed.

The technical analysis also addresses the Short Creek Dam sediment listing. The analysis concludes that the reservoir is not impaired by sediment, and that it should be delisted from the state's Section 303(d) list. Justification for this action is based on: 1) the conclusion that the average total suspended solids (TSS) concentration in the tributary entering into Short Creek Dam of 10.14 mg/L is not considered harmful to fisheries; and 2) the conclusion that the sediment accumulation rate in the reservoir is well below the average sedimentation rate of typical reservoirs - based on calculations of sediment balance and accumulation rates in the reservoir compared to NRCS and literature values.

Improvements in the dissolved oxygen concentration of the lake can be achieved through reduction of organic loading to the lake as a result of proposed BMP implementation. The TMDL contains a linkage analysis between phosphorous loading and low dissolved oxygen in lakes and reservoirs. It is anticipated that meeting the phosphorous load reduction target in Short Creek Dam will address the dissolved oxygen impairment.

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.

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 Short Creek Dam TMDL includes data summary tables in Sections throughout the document. The recent water quality monitoring was conducted over the period from July 2004 to September 2005.

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 Short Creek Dam watershed. Therefore the WLA for this TMDL is zero (see Table 16 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 (292.05 kg/yr). Ten percent of the loading capacity was allocated as an explicit margin of safety (32.45 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).

- ☐ <u>If the MOS is implicit</u>, 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.
- ☒ <u>If the MOS is explicit</u>, 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.
- ☐ <u>If</u>, rather than an explicit or implicit MOS, the <u>TMDL relies upon a phased approach</u> 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 Short Creek Dam TMDL includes an explicit MOS derived by calculating 10 percent of the loading capacity. The explicit MOS for the Short Creek Dam TMDL is 32.45 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: Short Creek 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 <u>is not</u> 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 list of BMPs that are recommended to meet the TMDL loads. 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 Short Creek Dam nutrient TMDL includes a daily phosphorus load expressed as 0.889 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, and 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 Short Creek 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.