Nutrient, Sediment and Dissolved Oxygen TMDLs for Carbury Dam in Bottineau County, North Dakota

Final: October 2006

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*This document also contains justification for de-listing Carbury Dam for sediment impairments

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1.0 INTRODUCTION AND DESCRIPTION OF THE WATERSHED

Carbury Dam is located in the Lower Souris sub-basin of the Souris River basin in northeastern Bottineau County, North Dakota (Figures 1 and 2). Specifically, it is located five miles west and four miles north of the city of Bottineau, North Dakota (T162N, R76W, Sec.5,6,7,8). Carbury Dam is a small, multipurpose structure designed to provide flood water storage, recreation, and wildlife enhancement. It was built as a part of the boundary creek watershed project, on August 31, 1966 under the authority of the Watershed Protection and Flood Prevention Act. Construction began in June 1981 and was completed in 1982.

Carbury Dam is a narrow impoundment covering 130 acres with a maximum depth of 25 feet and an average depth of nine feet. Table 1 summarizes some of the geographical, hydrological, and physical characteristics of Carbury Dam.

Approximately 30 percent of Carbury Dam's shoreline is publicly owned. Public facilities include camping platforms, picnic shelters, vault toilets, and a boat ramp. Public use varies depending on the productivity of the fishery, but is fairly considerable year-round.

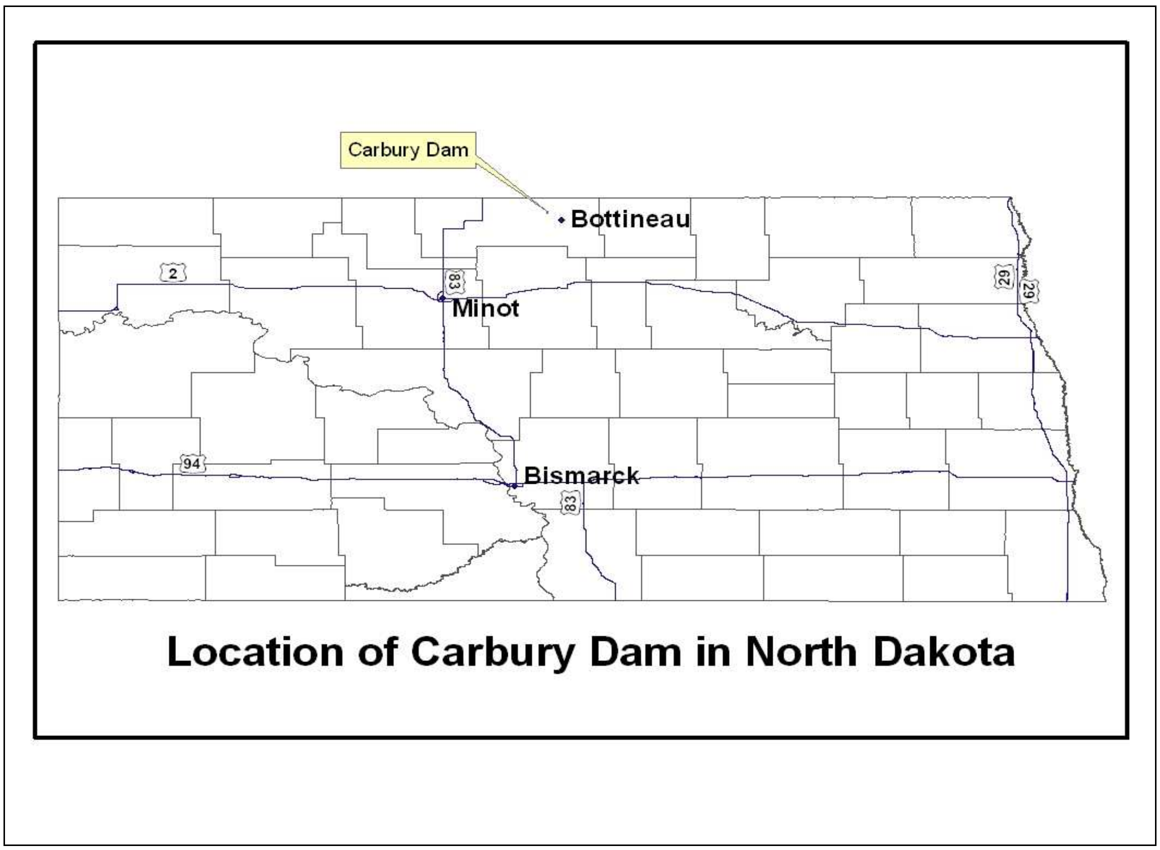

Figure 1. Location of Carbury Dam in North Dakota.

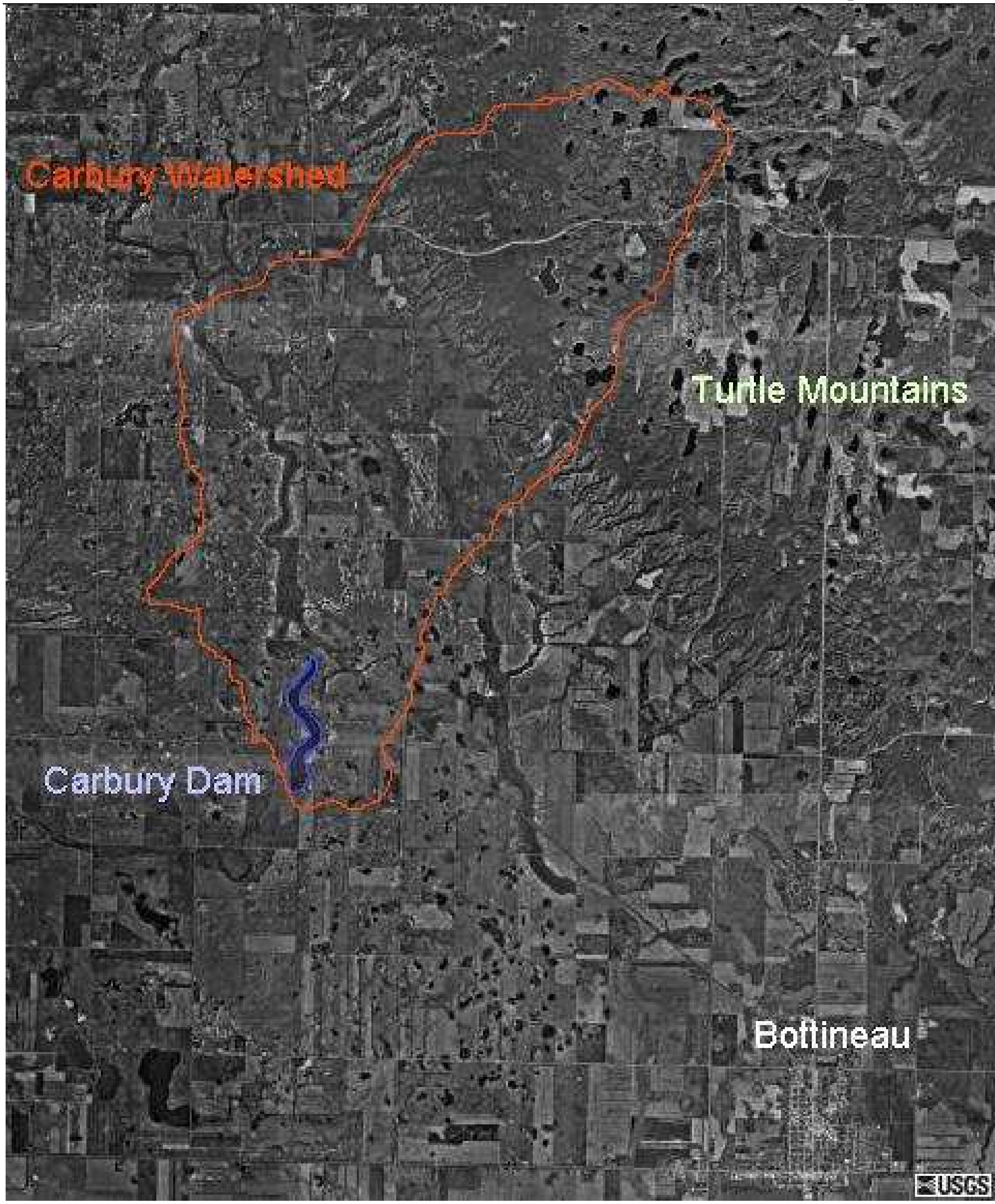

Figure 2. Location of Carbury Dam and Watershed.

Table 1. General Characteristics of Carbury Dam and the Watershed.

Legal Name	Carbury Dam
Major Drainage Basin	Souris River
8-Digit HUC	09010003
Nearest Municipality	Bottineau, ND
County	Bottineau County, ND
Eco-region	Northern Black Prairie in the Northern Glaciated Plains
Latitude	48.87861
Longitude	-100.551944
Surface Area	111 acres
Watershed Area	11,520 acres
Average Depth	10.5 feet
Maximum Depth	25.2 Feet
Volume	1170.6 acre-feet
Tributaries	Un-named tributaries
Outlets	Boundary Creek to Souris River
Type of Waterbody	Constructed Reservoir
Fishery Type	Cool water – rainbow trout, yellow perch, small mouth bass, bluegill
Classified Beneficial Uses	Municipal and domestic water supply, recreation, aquatic life, agricultural uses, and industrial water supply

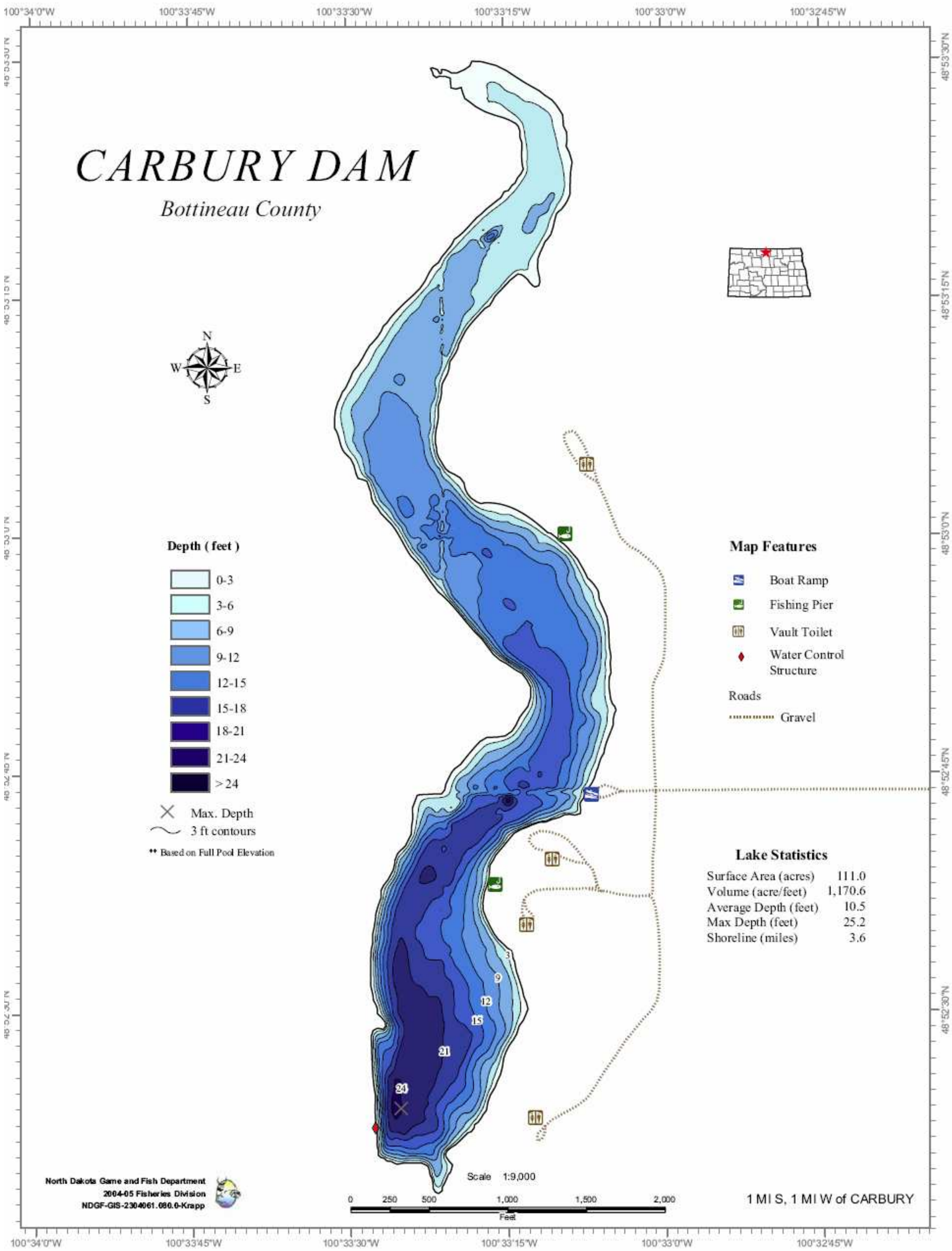

Figure 3. Contour Map of Carbury Dam

1.1 Clean Water Act Section 303(d) Listing Information

Based on the 2004 Section 303(d) List of Impaired Waters Needing TMDLs (NDDoH, 2004), the North Dakota Department of Health (NDDoH) has identified Carbury dam as fully supporting but threatened for recreation and aquatic life beneficial uses due to nutrients, sedimentation, and low dissolved oxygen. Table 2 details the TMDL listing information for Carbury Dam.

Table 2. 2004 Section 303(d) TMDL Listing Information for Carbury Dam.

Assessment Unit ID	ND-09010003-001-L_00
Description	Carbury Dam
Size	111 surface acres
Impaired Designated Uses	Fish and Other Aquatic Biota; Recreation
Use Support	Fully Supporting but Threatened
Impairment	Nutrients, Sediment, and Dissolved Oxygen
Priority	1 (High)

1.2 Topography

Approximately 85 percent of the Carbury Dam watershed lies within the Northern Black Prairie region of the Glaciated Plains physiographic region, with the remaining 15 percent extending into the Turtle Mountains. Elevation ranges from 1655 to 2541 feet msl. The Northern Black Prairie represents a broad phonological transition zone marking the introduction from the north of a boreal influence in climate. Aspen and birch appear in wooded areas, willows grow on wetland perimeters, and rough fescue becomes evident in grassland associations. This ecoregion has the shortest growing season and the lowest January temperatures of any level IV ecoregion in the Dakotas. The majority of the watershed is nearly level to gently rolling, interspersed by well-defined drainages and forested areas. The portion of the watershed located in the Turtle Mountains has very irregular topography with 600 to 800 feet of relief and steep gradients. The predominant soil types are loams and silt loams, and are very high in fines. Common soil types include Barnes, Hamerly, Parnell and Svea.

1.3 Landuse/Land Cover in Watershed

In 1992, primary landuse was agriculture with 4,205 acres, or 36.5 percent in cultivation, which is extensively tilled to durum, barley, spring wheat and other small grains. The remaining landuses included 1,924 acres Range/Hayland, 2,949 acres of woodlands, and 1,947 acres in CRP/Wetlands/Wildlife. The remaining 495 acres are comprised of farmsteads, feedlots, or town (Figure 3).

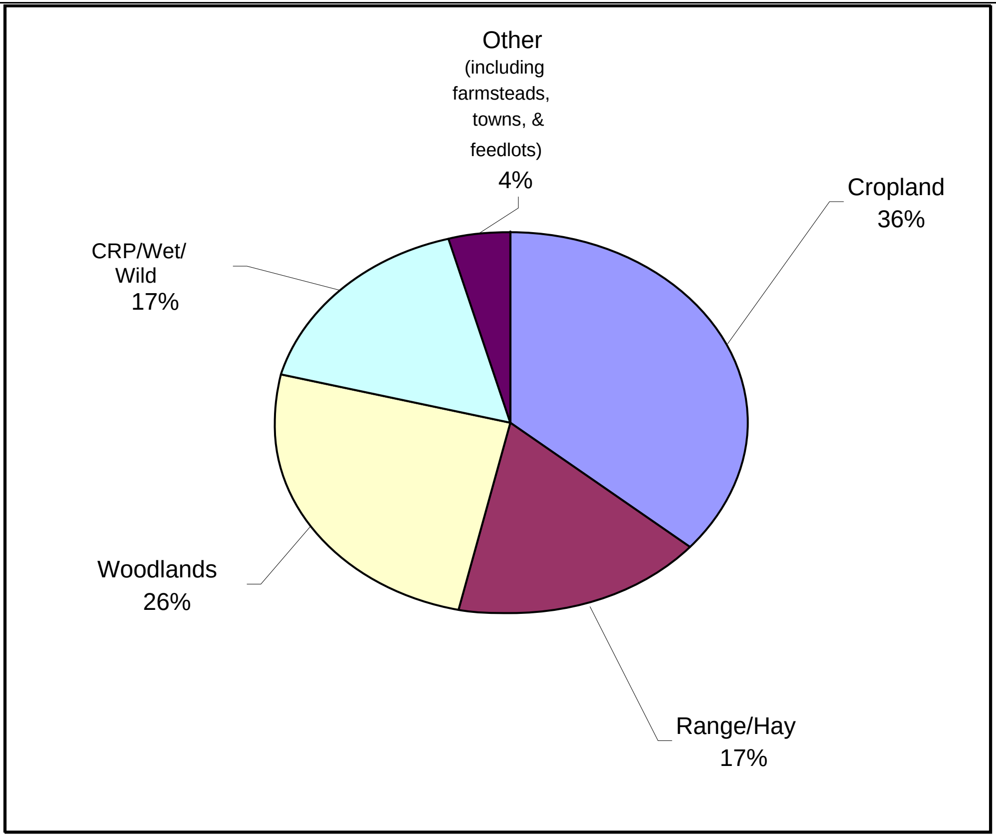

Figure 4. Landuse in Carbury Watershed, 1992.

Information from the landuse assessment completed as a part of the Carbury Dam TMDL project in 2004 showed that the percent of crop residue after fall tillage was relatively high, ranging from 50 percent to 20 percent. Average crop residue after fall tillage for the entire watershed was 40 percent. Following spring tillage and spring planting, estimates of crop residue dropped to 25 percent on average.

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 Bottineau weather station, five miles east and four miles south of Carbury Dam, is 38 degrees Fahrenheit. The average wind speed is 8.9 mph. Average annual precipitation is 18.8 inches (NDAWN. 2004).

1.5 Available Water Quality Data

The Turtle Mountain Soil Conservation District (SCD) conducted a water quality assessment of Carbury Dam and its watershed from March of 2003 through February of 2004. 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 Carbury Dam TMDL Development Project* (NDDoH, 2002). The sites are identified in Table 3 and Figures 4 and 5. The data were analyzed and summarized by Mr. Peter Wax, Environmental Scientist, NDDoH and provided in this report.

Table 3. General Information for Water Sampling Sites for Carbury Dam.

Sampling Site	Site ID	Number of Samples Taken	Latitude (approx.)	Longitude (approx.)
In-lake	381200	15	48^o 52’ 43”	-100^o 33’ 07”
Outlet	385228	0	48^o 52’ 40”	-100^o 33’ 21”
East Tributary	385229	6	48^o 53’ 22”	-100^o 32’ 35”
West Tributary	385230	8	48^o 53’ 35”	-100^o 33’ 38”

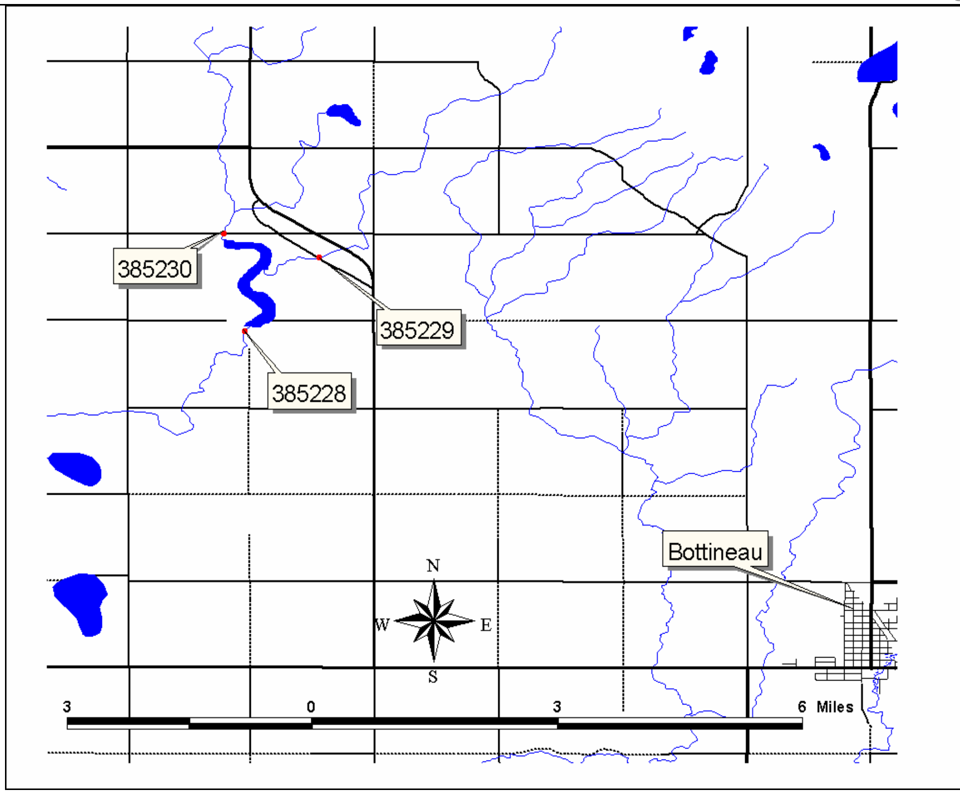

Figure 5. Carbury Dam Stream Sampling Locations

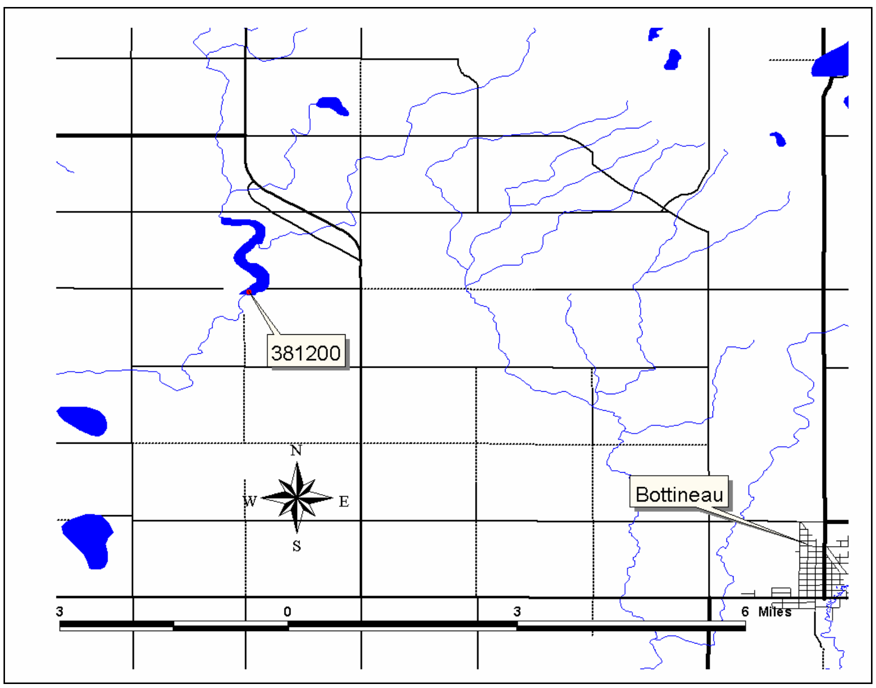

Figure 6. Carbury Dam Sampling Location.

1.5.1 Stream Data

Three stream sites were monitored during the 2003-2004 assessment: two inlet sites and one outlet site. Due to very dry conditions during the 2003 sampling season, the outlet site never had flow and therefore no data was collected. The two inlet sites were monitored from spring thaw through May 20, for the West Tributary site (385230) and May 9, for the East Tributary site (385229), at which time flow in the streams stopped.

Manual stream gauging stations were installed at the stream monitoring sites and used to collect stage/discharge data. Note the difference in flow in Figures 12 and 13. Stream parameters analyzed included ammonia, total Kjeldahl nitrogen, nitrate-nitrite, total nitrogen, dissolved phosphorus, total phosphorus, and total suspended solids (Tables 4 and 5, and Figures 6 through 11). Total suspended solids were all below the detection limits of 5 mg/L

Table 4. Summary of Stream Sampling Data, STORET # 385229 (East Tributary).

Description	Total Nitrogen (mg/L)	TKN (mg/L)	Nitrate-Nitrite (mg/L)	Ammonia (mg/L)	Total Dissolved P (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
Minimum	1.44	1.09	0.04	0.015	0.150	0.185	ND[1]
Maximum	4.15	2.78	1.37	0.177	0.652	0.740	ND[1]
Median	1.82	1.38	0.45	0.049	0.212	0.276	ND[1]
Mean	2.15	1.60	0.55	0.048	0.275	0.331	ND[1]

[1] Non-detect, < 5mg/L

Table 5. Summary of Stream Sampling Data, STORET # 385230 (West Tributary).

Description	Total Nitrogen (mg/L)	TKN (mg/L)	Nitrate-Nitrite (mg/L)	Ammonia (mg/L)	Total Dissolved P (mg/L)	Total Phosphorus (mg/L)	TSS (mg/L)
Minimum	1.63	1.51	ND[a]	ND[b]	0.022	0.052	ND[e]
Maximum	4.84	2.87	2.10	0.103	0.518	0.681	ND[e]
Median	2.20	2.07	0.025[d]	0.028[e]	0.076	0.125	N/A
Mean	2.51	2.17	0.340[d]	0.037[e]	0.137	0.195	N/A

[a] ND = Non-Detect: <0.02 mg/L
[b] ND = Non-Detect: <0.01 mg/L
[c] ND = Non-Detect: <5 mg/L
[d] For samples with Non-Detect, 0.02 mg/L was used to calculate Median/Mean
[e] For samples with Non-Detect, 0.01 mg/L was used to calculate Median/Mean

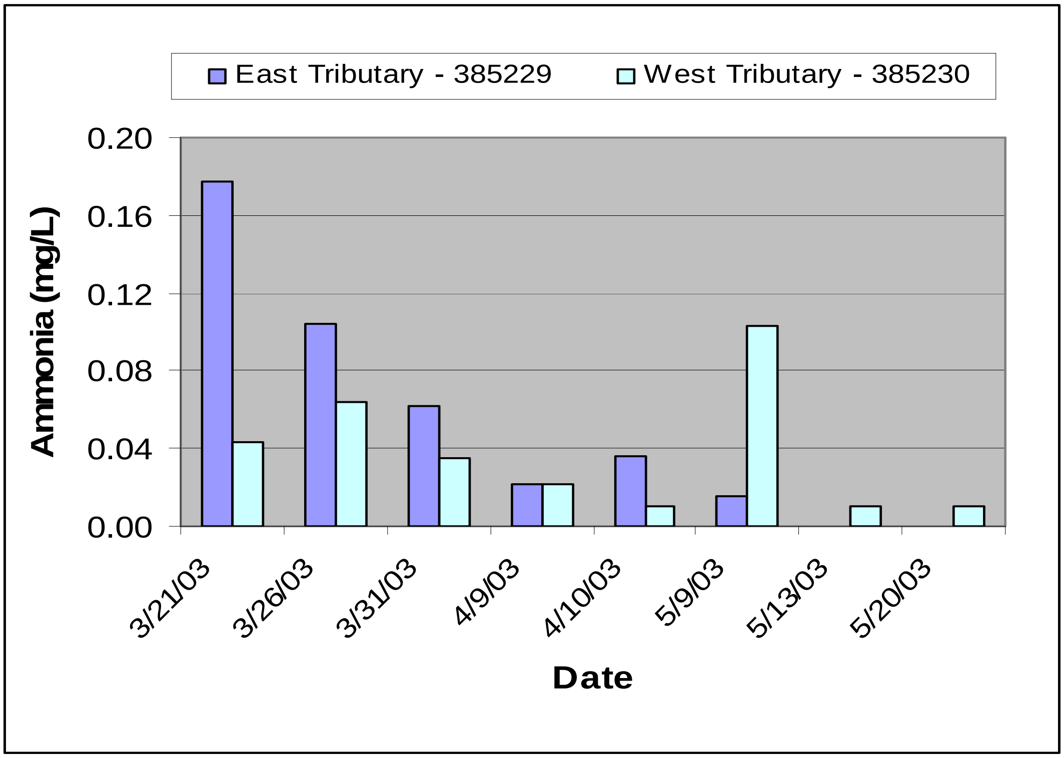

Figure 7. Ammonia at Inlets.

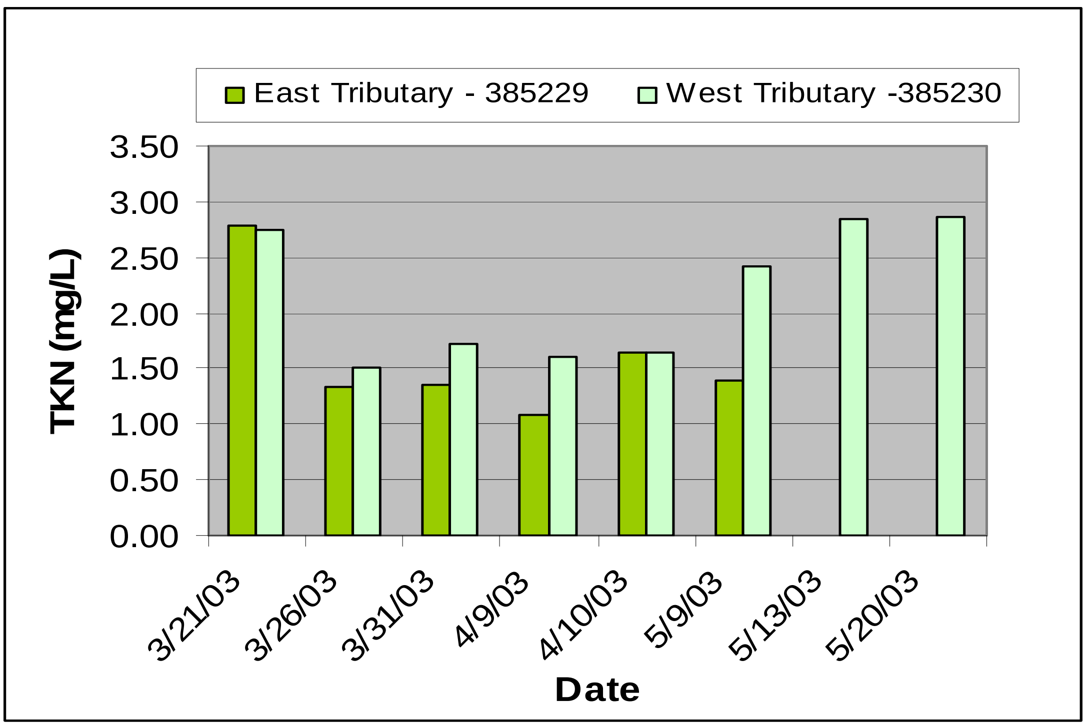

Figure 8. TKN at Inlets.

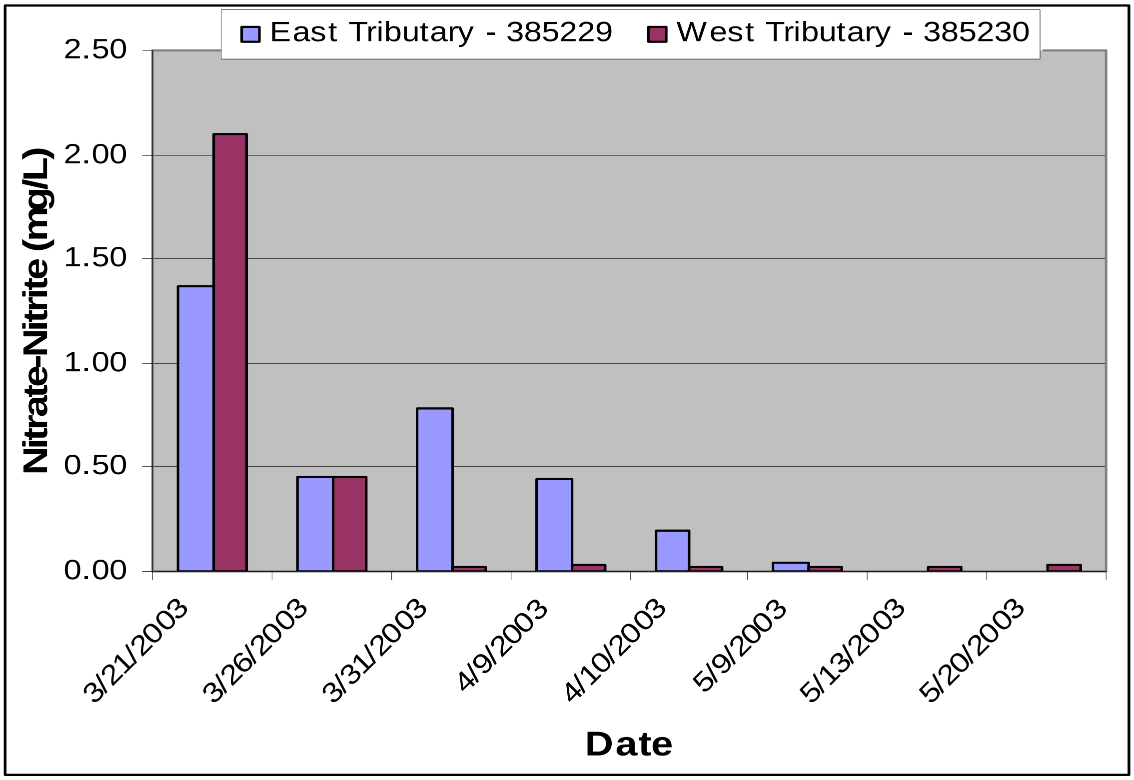

Figure 9. Nitrate-Nitrite for Inlets.

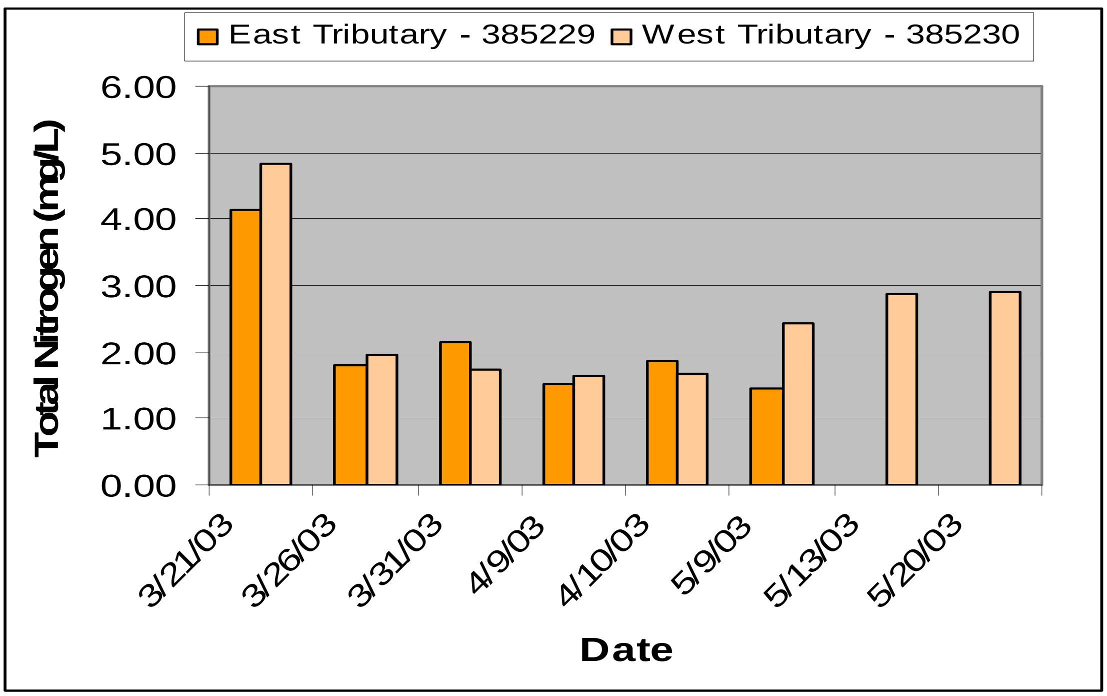

Figure 10. Total Nitrogen at Inlets

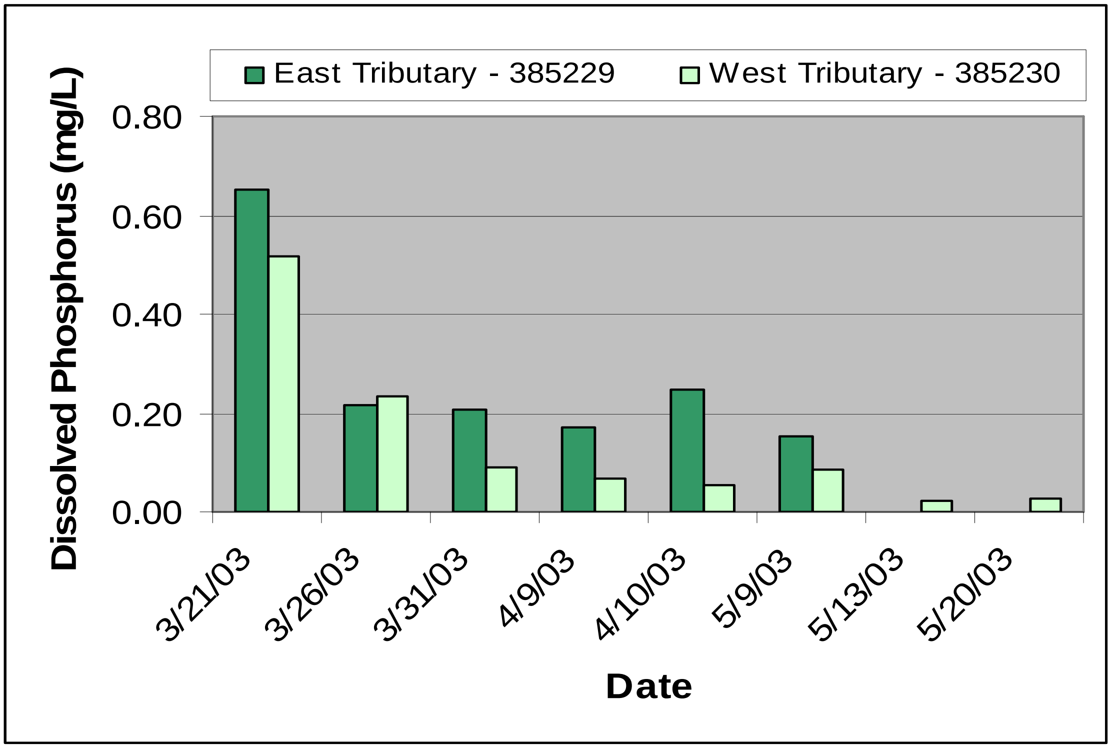

Figure 11. Dissolved Phosphorus at Inlets.

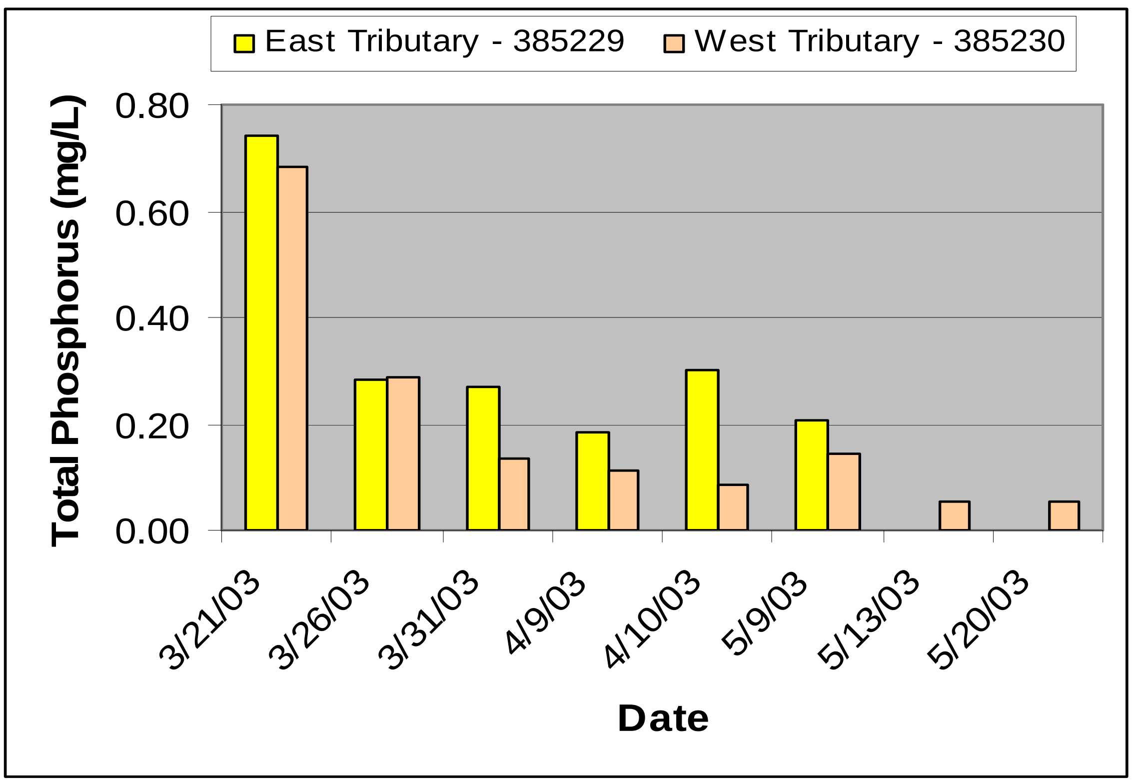

Figure 12. Total Phosphorus at Inlets.

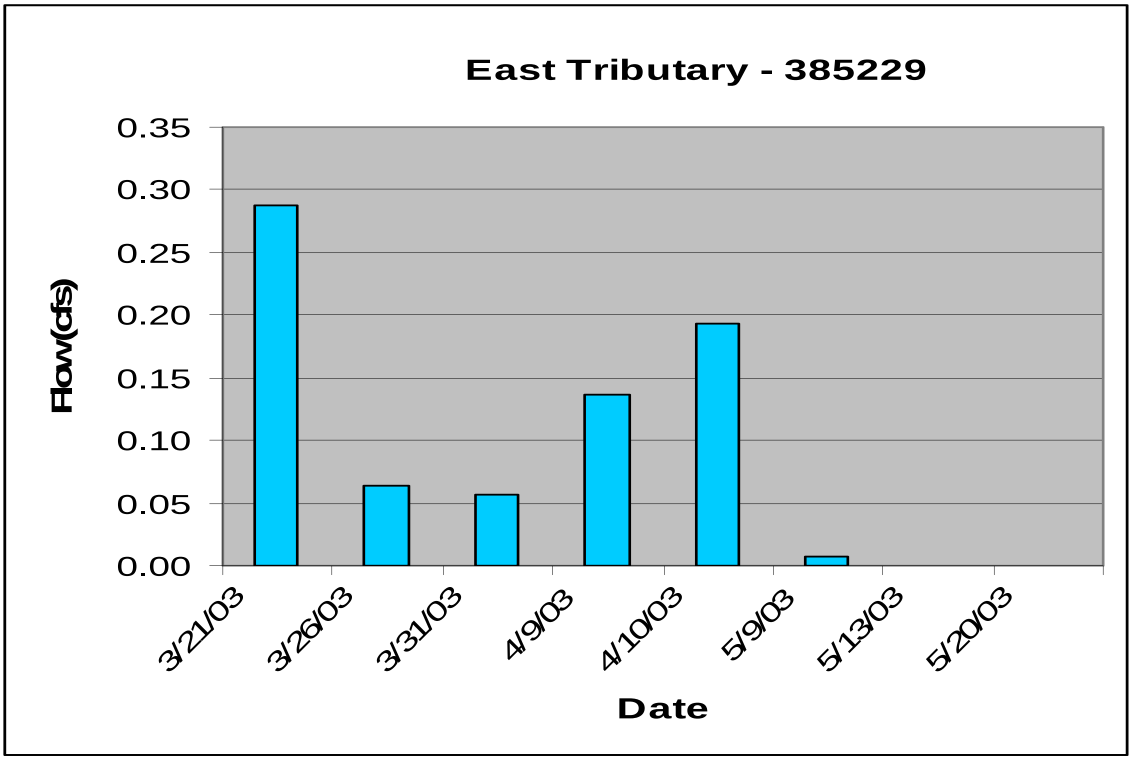

Figure 13. Flow at East Tributary, STORET # 385229.

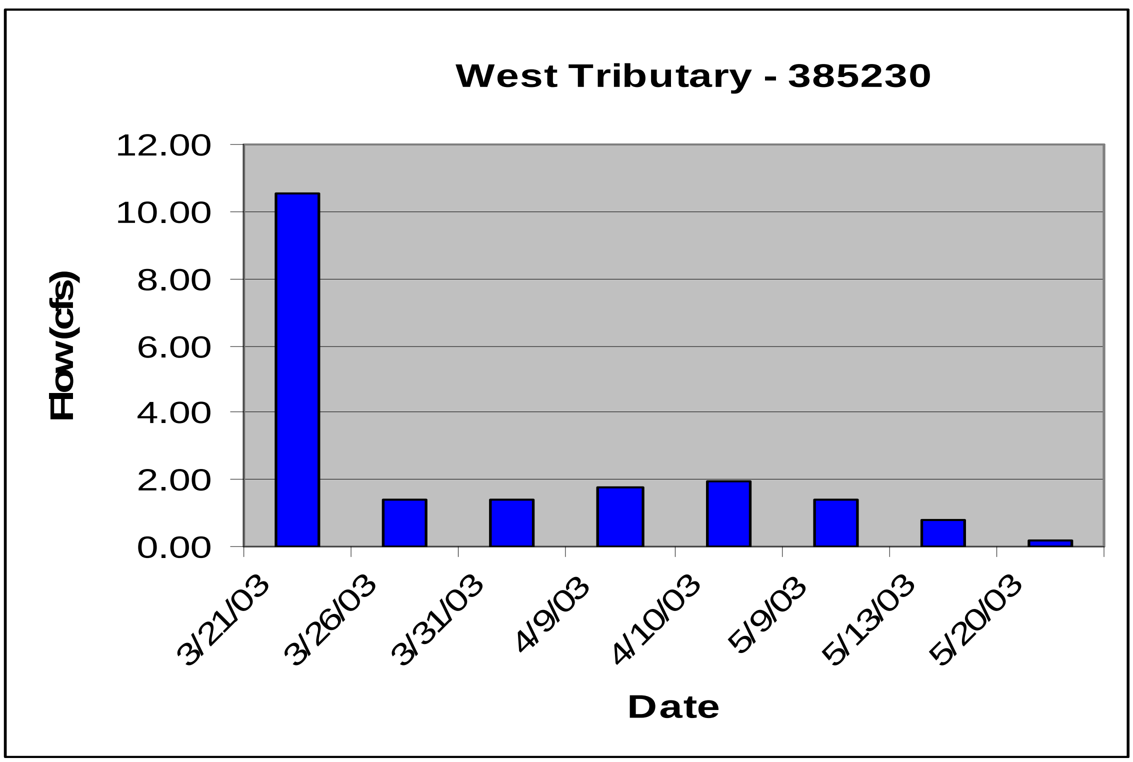

Figure 14. Flow at West Tributary, STORET # 385230.

1.5.2 Reservoir Data

The in-lake site is located in the deepest part of the reservoir at the south end near the dam. Lake monitoring occurred from January 20, 2003 until October 6, 2003, as outlined in the QAPP (NDDoH, 2002). Reservoir parameters included phytoplankton, chlorophyll-a, pH, specific conductance, major cations and anions, total nitrogen, total Kjeldahl nitrogen, nitrate-nitrite, ammonia, phosphorus (total and dissolved), Secchi disk transparency, and temperature and dissolved oxygen profiles (Figures 14 through 16). The data collected characterized Carbury Dam as a hyper-eutrophic, nitrogen limited lake, as depicted in Figures 17 and 18.

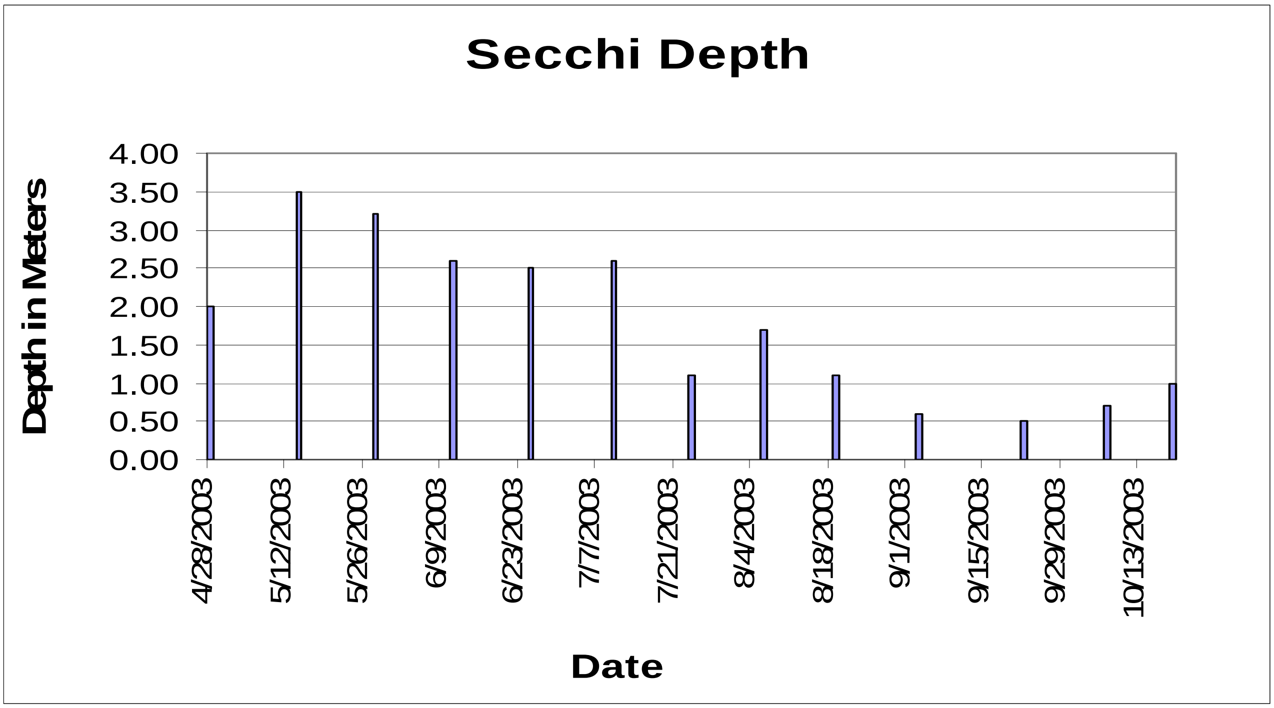

Figure 15. Carbury Dam Secchi Depth Data.

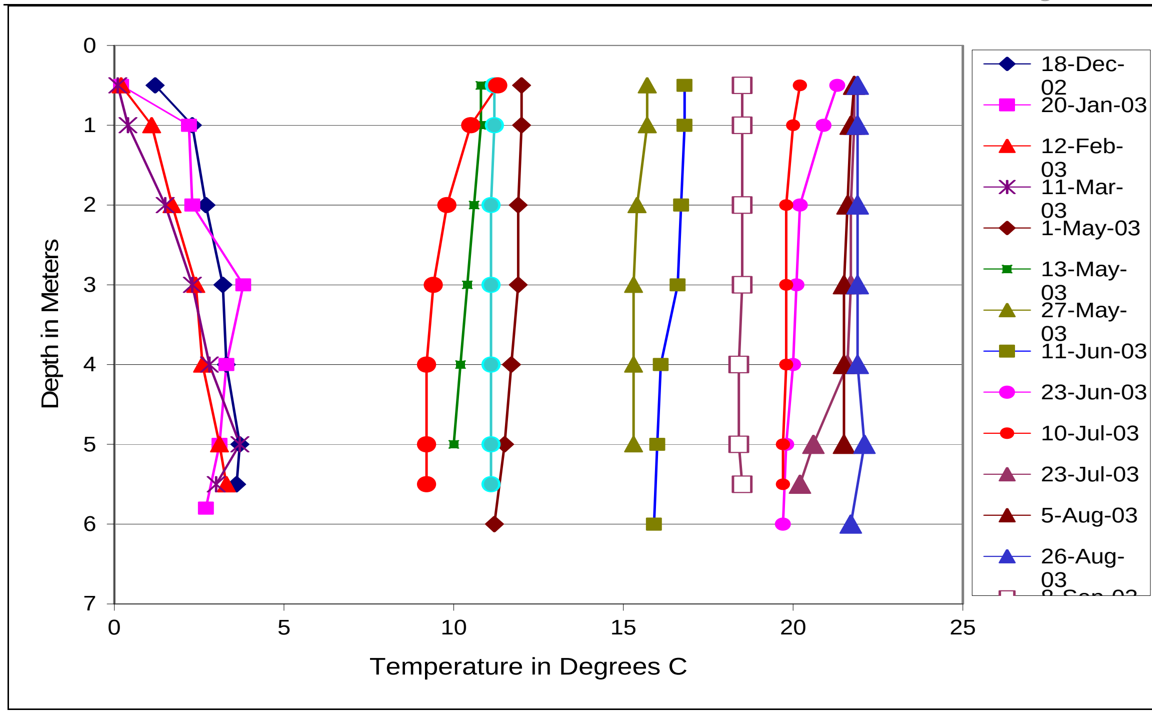

Figure 16. Carbury Dam Temperature Profile.

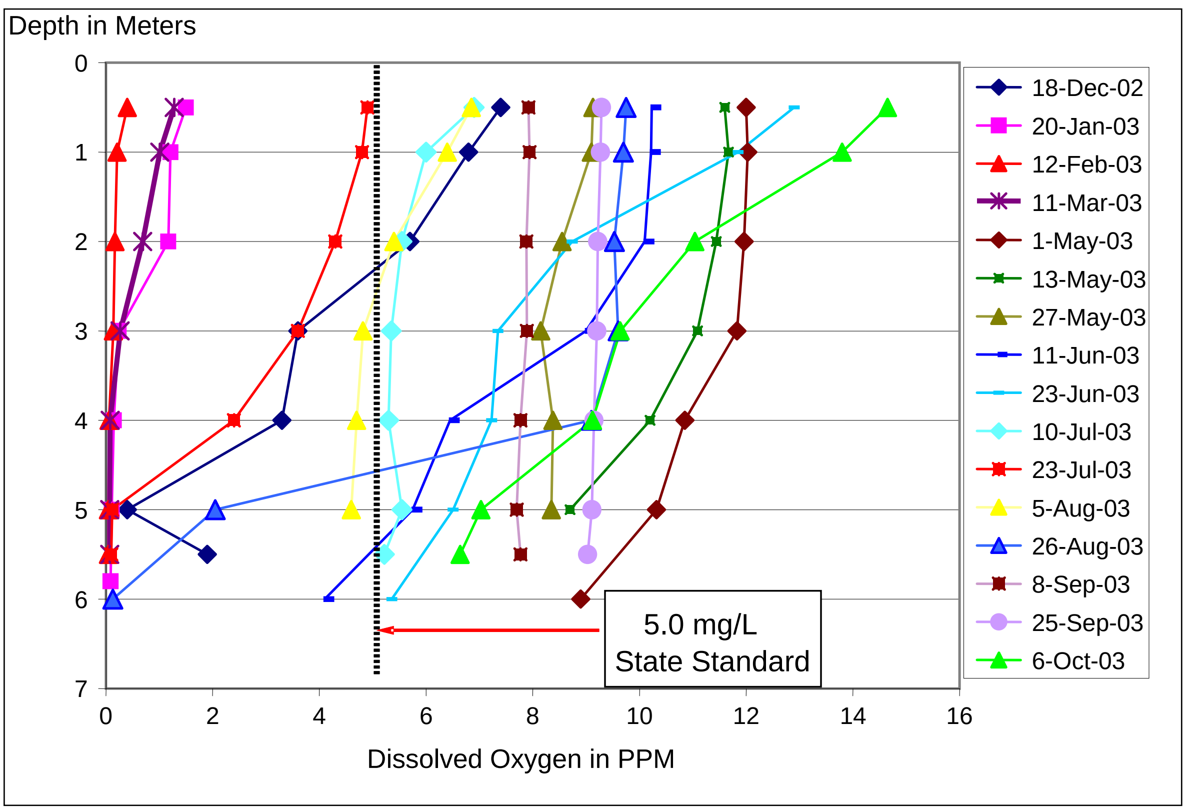

Figure 17. Carbury Dam Dissolved Oxygen Profile.

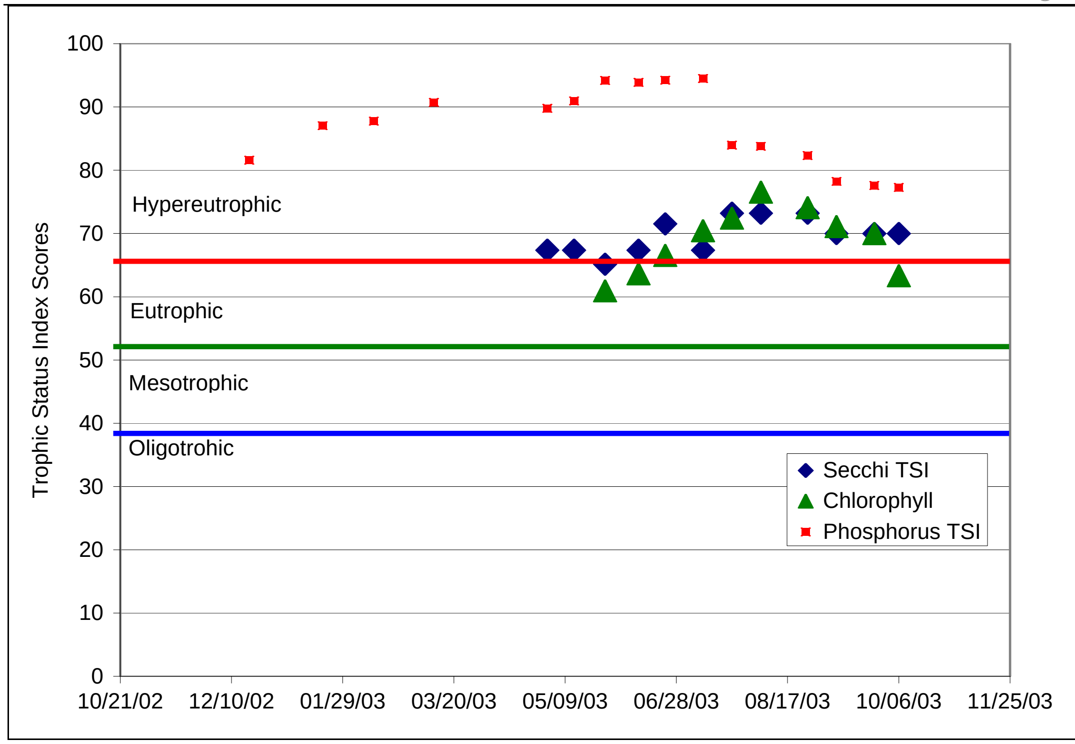

Figure 18. Carbury Dam's Trophic Status.

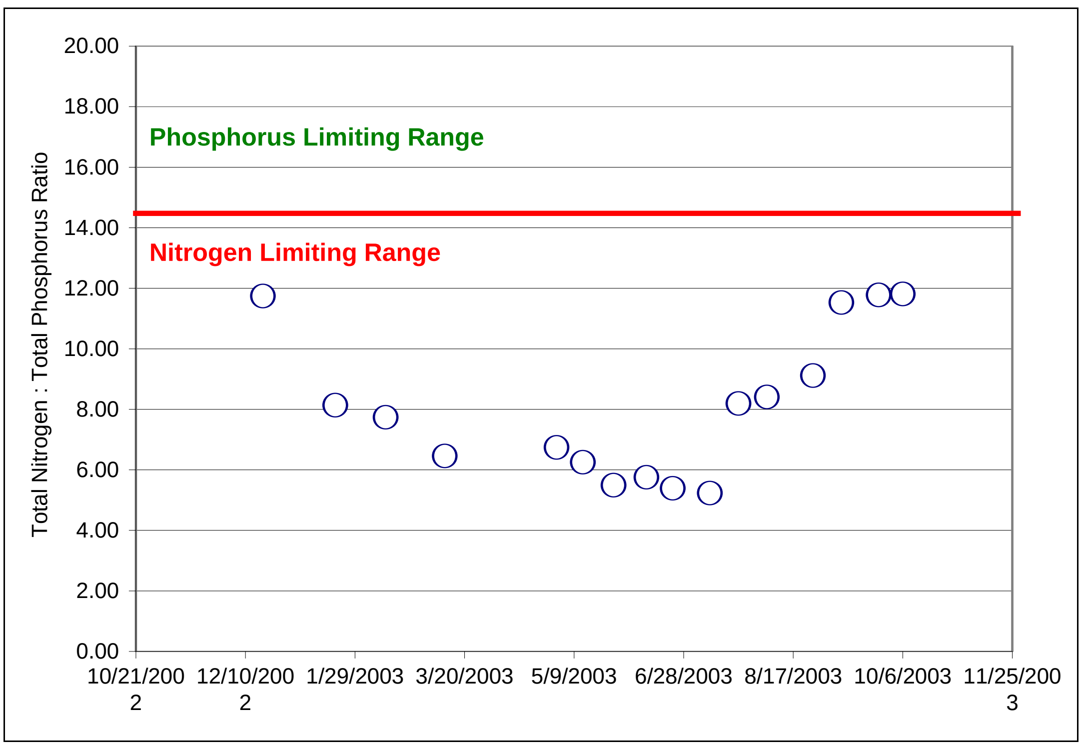

Figure 19. Carbury Dam's Ratio of Total N to Total P.

Carbury Dam was also compared to data from a study of similar North Dakota lakes (RLRSD, 2000). When compared to other lakes in this region, the North Dakota glaciated plains, Carbury Dam had higher total phosphorus concentrations, lower nitrate/nitrite concentrations and chlorophyll-a concentrations, and about the same TKN and ammonia concentrations. Secchi Disk depths were also shallower than the average readings for other lakes (Table 6).

Table 6. Regional Lake Water Quality Compared to Carbury Dam Water Quality.

	Total Phosphorus	Nitrate/ Nitrite	TKN	Ammonia	Chlorophyll-*a*[2]	Secchi Disk Depth
Units	mg/L	mg/L	mg/L	mg/L	µg/L	meters
Carbury Dam	0.268	0.024	2.22	0.212	49.69	0.52
Other North Dakota Lakes[1]						
Max	0.707	0.123	5.06	0.677	237.5	2.29
Min	0.031	0.006	1.09	0.025	3.5	0.15
Average	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 the RLRSD study (RLRSD, 2000). Data from Carbury Dam's TMDL Assessment (NDDoH, 2002.) was compared to data from this study. Carbury values are depth averaged except for nitrate/nitrite and chlorophyll-*a*.

2.0 WATER QUALITY STANDARDS

The Carbury Dam is a Class 2 lake with the following definition:

- *Cool water fishery. Waters capable of supporting growth and propagation of non-salmonid fishes and marginal growth of salmonid fishes and associated aquatic biota.*

It is also defined in the State Water Quality Standards that:

- *The beneficial uses and parameter limitations designated for Class I streams shall apply to all classified lakes.*

The tributaries flowing in to and out of Carbury Dam are Class III streams.

- *The quality of the waters in this class shall be suitable for agricultural and industrial uses such as stock watering, irrigation, washing, and cooling. These streams have low average flows and generally prolonged periods of no flow. The quality of these waters must be maintained to protect recreation, fish, and aquatic biota*. (NDDoH, 2001).

2.1 Narrative Water Quality Standard

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 impairments are listed below (NDDoH, 2001).

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

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

In addition to the narrative standards, the NDDH has set a biological goal for all surface waters in the state. The goal states that "the biological condition of surface waters shall be similar to that of sites or waterbodies determined by the department to be regional reference sites," (NDDoH, 2001).

2.2 Numeric Water Quality Standards

Standards of Quality for Waters of the State (North Dakota Century Code 33-16) establishes numeric standards for dissolved oxygen, total phosphorus, and nitrates (dissolved) (Table 7). The numeric standards for Class I Streams include all classified lakes. In addition, nutrient guidelines that have been established for use as goals in lake improvement and maintenance programs are also listed in Table 7. 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 7. Numeric Standards from *Standards of Quality for Waters of the State* (North Dakota Century code 33-16).

Parameter	Parameter Limitation	Condition
Standards for Class I Streams and Classified Lakes:		
Nitrates (dissolved)	1.0 mg/l	Maximum allowed[1]
Phosphorus (total)	0.1 mg/l	Maximum allowed[1]
Dissolved Oxygen	5.0 mg/l	Not less than
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] The standards for nitrates(N) and phosphorus (P) are intended as interim guideline limits. Since each stream or lake has unique characteristics which determine the levels of these constituents that will cause excessive plant growth (eutrophication), the department reserves the right to review these standards after additional study and to set specific limitations on any waters of the state. However, in no case shall the standard for nitrates (N) exceed 10 mg/L for waters used as municipal or domestic drinking water supply.

3.0 TMDL TARGETS

TMDL targets are the values that are 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.

Carlson's Trophic State Index (TSI) has consistently been used by NDDoH to assess beneficial uses in the State's lake and reservoirs (NDDoH, 1998; NDDoH, 2000; NDDoH, 2004). 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, and/or from internal cycling. Lakes tend to become eutrophic (more productive) with higher nitrogen and phosphorus inputs. Eutrophic lakes often have nuisance algal blooms, limited clarity, and low dissolved oxygen concentrations that can result in impaired aquatic life and recreational uses. Carlson’s TSI attempts to measure the trophic state of a lake using nitrogen, phosphorus, chlorophyll-a, and Secchi disk depth measurements. (Carlson, 1977). The various TSI values were calculated for Carbury Dam using the data obtained from the assessment study. Table 8 shows that Carbury Dam is classified as a hypereutrophic lake.

Table 8. Carlson's Trophic State Indexes for Carbury Dam.

Parameter	Relationship	Units	TSI Value[1]
Chlorophyll-*a*	TSI (Chl-a) = 30.6 + 9.81[ln(Chl-a)]	µg/L	63
Total Phosphorus (TP)	TSI (TP) = 4.15 + 14.42[ln(TP)]	µg/L	88
Secchi Depth (SD)	TSI (SD) = 60 - 14.41[ln(SD)]	meters	69

[1]TSI values were calculated using average surface values from the Carbury Dam in-lake monitoring station.
TSI < 40 = Oligotrophic (least productive)
TSI 40-50 = Mesotrophic
TSI 50-60 = Eutrophic
TSI > 60 = Hypereutrophic (most productive)

3.1 Nutrient Target

Nitrogen and phosphorus are necessary for plant growth. Excessive amounts can cause over 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). Breakdown of dead organic matter can also produce 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 impair aesthetic uses of the waterbody.

Through analysis of assessment data, Carbury Dam was determined to be nitrogen limited. In order to decrease the trophic state from hypereutrophic down to mesotrophic, a reduction in phosphorus loading will have to occur. According to BATHTUB modeling results (see Appendix A), the average annual total phosphorus concentrations in the lake would decrease from 0.343 mg/L to 0.127 mg/L with a 75 percent reduction in external phosphorus loading. This would correspond to a chlorophyll-a TSI score of 58 (Table 9). The nutrient target has therefore been set to the chlorophyll-a TSI score of 58. Monitoring will take place during the implementation phase of the project to ensure that the phosphorus reduction determined by the model is adequate. It is likely that the average lake user will see a noticeable change in the lake resulting from the improved trophic state achieved when this TSI score is reached. If this target is met, narrative standards will also be met (NDDoH, 2001) and the beneficial uses of aquatic life and recreation will be fully supported.

Table 9. Observed and Predicted TSI Scores Assuming a 75 Percent Reduction in External Phosphorus Loading

Variable	TSI Score Observed	TSI Score Modeled with a 75% Reduction in External P Loading
Carlson's TSI for Phosphorus	88	74
Carlson's TSI for Chlorophyll-a	63	58
Carlson's TSI for Secchi Disk	69	65

TSI < 40 = Oligotrophic (least productive)
TSI 40-50 = Mesotrophic
TSI 50-60 = Eutrophic
TSI > 60 = Hypereutrophic (most productive)

The three variables, chlorophyll pigments, Secchi 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). Although transparency and phosphorus may co-vary with trophic state, the changes in transparency are caused by changes in algal biomass and total phosphorus may or may not be strongly related to algal biomass. Neither transparency nor phosphorus is an independent estimator of trophic state. (Carlson 1996).

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 of the total phosphorus or the Secchi 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 10 below (updated from Carlson 1983).

Table 10. Relationship Between TSI Variables and Conditions.

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

It is possible that therefore, that the chlorophyll and transparency indices may be close together, but both will fall below the phosphorus curve. This suggests that the algae are nitrogen-limited. Intense zooplankton grazing, for example, may cause the chlorophyll and Secchi depth indices to fall below the phosphorus index as the zooplankton remove algal cells from the water or Secchi depth may fall below chlorophyll if the grazers selectively eliminate the smaller cells (Carlson 1996). This statement supports the data analysis and modeling that was done to indicate that Carbury Dam is a shallow nitrogen limited waterbody (Figure 18). Based on the above information and in order to easily and effectively measure the effects of reduction in external phosphorus loading, which directly equates to algal biomass, a TSI score of 58 for chlorophyll-a was chosen as a target.

Studies have also shown that in shallow lakes, the percent reduction in total phosphorus was not as great as the reduction in loading. (Cooke, et. al., 1986). This causes most total phosphorus TSI scores to be elevated above the other two TSI scores, therefore estimating a slightly higher trophic state for the lake than may actually be observed. Also the improvement in Secchi disk depth of the water is not linearly related with a reduction in total phosphorus concentrations (Carlson, 1977). The degree of improvement in Secchi disk depth, for an equal amount of phosphorus diverted, will become greater as a mesotrophic state is approached. (Cooke, et.al., 1986).

The reason the TSI for total phosphorus was not chosen is two-fold. First, there is a great deal of interest in the watershed to improve lake water quality. In order for an implementation phase to go forward, it will have to be spearheaded by a local interest group. In order to make this document easily usable for a non-scientist, the TSI target of the most publicly identifiable component was chosen. A chlorophyll-a TSI score of 58 will provide results slightly greater than the 75 percent load reduction in phosphorus required, thus adding to the Margin of Safety for the TMDL, while bringing the lake into the lower trophic state of eutrophic. Second, studies have shown that in shallow lakes the percent reduction in total phosphorus concentrations was not as great as the reduction in loading. (Cooke, et. al., 1986). This causes most total phosphorus TSI scores to be elevated above the other two TSI scores, therefore estimating a slightly higher trophic state for the lake than may actually be observed. Also the improvement in Secchi depth of the water is not linearly related with a reduction in TP concentrations (Carlson, 1977). The degree of improvement in Secchi depth, for an equal amount of phosphorus diverted, will become greater as a eutrophic state is approached. (Cooke, et.al., 1986).

While the target TSI score resulting from the 75 percent phosphorus load reduction will not bring the concentration of total phosphorus to the NDDoH State Water Quality Standard guideline for lakes (0.02 mg/L)(Table 11), it should be recognized that these are just guidelines. Lakes vary a great deal in North Dakota. Shallow lakes are especially hard to improve without addressing the internal phosphorus cycling, which comes at high expense. This reduction in phosphorus load should result in a change of trophic status for the lake from hypereutrophic down to eutrophic. Given the size of the lake (130 acres), the likely amount of phosphorus in the bottom sediments available for internal cycling, the nearly constant wind in north central North Dakota causing a mixing effect, and few cost effective ways to reduce in-lake nutrient cycling, this was determined to be the best possible outcome for Carbury Dam.

3.2 Dissolved Oxygen Target

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 limited by the temperature and salinity of the water and atmospheric pressure (NDDoH, 1997).

Carbury Dam is listed as fully supporting but threatened for fish and aquatic biota uses because of dissolved oxygen levels falling below the North Dakota water quality standard. The North Dakota water quality standard for dissolved oxygen is "not less than 5.0 mg/L". For lakes and reservoirs this is based on an instantaneous reading throughout the water column.

AgNPS and BATHTUB models indicate that excessive nutrient loading is responsible for the low dissolved oxygen levels in Carbury 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 nonpoint 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 DO levels were responsible for large fish kills and large mats of decaying algae. Binational 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/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 = 130.0 acres; 0.53 km^2), mean depth (z = 9 feet; 2.74 meters), and the ratio of mean depth to the surface area ($z/A_o^{0.5} = 3.76$) for Carbury 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. NDDoH is also confident that prescribed BMPs will reduce external loading of nutrients to the Dam which will reduce algae blooms and therefore 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." By reducing phosphorous to a level where the desired trophic state of the reservoir is met, it has been determined that the designated beneficial uses for Carbury Dam will be met.

To insure that the implementation of BMPs 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.

To meet the dissolved oxygen target of 5.0 mg/L, a 75 percent load reduction in phosphorus as determined by the BATHTUB model to bring the trophic state and corresponding TSI scores into the mesotrophic range, has been selected as a surrogate target for dissolved oxygen in this TMDL for the reasons stated above.

4.0 SIGNIFICANT SOURCES

4.1 Point Sources

The town of Carbury is the only nearby population center. It has a population of 12 and no wastewater lagoons. This is the only known point source in the watershed.

4.2 Nonpoint Sources

Non-point source pollution accounts for almost 100 percent of the nutrient and sediment loading to Carbury Dam. According to the 2003 landuse assessment, approximately 89 percent of the landuse is agricultural, with 36.5 percent actively cultivated. The remaining 63.5 percent of the watershed is used for pasture or has permanent cover. The remaining four percent consists of farmsteads or feedlots. There are two Animal Feeding Operations (AFOs) located within the watershed. Currently there are few developed areas in the watershed.

According to the Turtle Mountain Soil Conservation District (SCD), 72 percent of the cultivated lands and 50 to 65 percent of the remaining lands were adequately treated to prevent soil loss in 1992 (NDDoH, 1996). "Adequately treated" is defined as the amount of land treatment necessary to achieve the soil loss tolerance (T). The average T value for Carbury watershed is between 3-5 tons per acre. Assuming a conservative delivery rate of 10 to 15 percent, between 2,129 and 3,194 tons of soil potentially reaches Carbury Dam annually.

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 waterbodies. The loading capacity is the amount of pollutant that can be assimilated by the waterbody while still attaining and maintaining the beneficial uses listed in the State's water quality standards. This section discusses the technical analysis used to estimate existing loads to Carbury 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 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, developed by the US Army Corps of Engineers Waterways Experiment Station (Walker, 1996), was used to predict and evaluate the effects of various nutrient load reduction scenarios on Carbury 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 are summarized, or reduced, into 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. In the case of Carbury Dam, the FLUX program came up with an annual phosphorus load of 220.1 kg/yr. 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 water quality data was reduced in Microsoft Excel using three computational functions. These are 1) the ability to display concentrations as a function of depth, location, and/or date; 2) summary statistics (e.g., mean, median, etc.); and 3) an 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. After calibration, the observed average annual concentration of total nitrogen and total phosphorus compared well with those of the BATHTUB model. The model's predictions and observed data are summarized in Table 11.

Table 11. Observed and Predicted Values for Selected Trophic Response Variables for the Calibrated BATHTUB Model.

Variable	Value	
	Observed	Predicted
Total Phosphorus as P (mg/L)	0.343[1]	0.343[1]
Total Nitrogen as N (mg/L)	2.419[1]	2.420
Organic Nitrogen as N (mg/L)	0.458[1]	0.457[1]
Chlorophyll-a (*u*g/L)	28.0[1]	28.38[1]
Secchi Disk Transparency (m)	0.50[2]	0.58[2]
Carlson's TSI for Phosphorus	88.33	88.34
Carlson's TSI for Chlorophyll-a	63.29	63.42
Carlson's TSI for Secchi Disk	69.42	67.73

1-Annual volume weighted averages

2-Average

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 220.1 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. For Carbury Dam, only external nutrient loads were addressed. Internal loadings are variable from year to year and are not controllable without taking special and often expensive measures (e.g. dredging, addition of chemical flocculants, etc.) 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).

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

The model results indicate that if it were possible to reduce external phosphorus loading to Carbury Dam by 75 percent, the average annual total phosphorus and chlorophyll-a concentrations in the lake would decrease and Secchi disk transparency depth would increase. Observed and predicted values are shown for comparison in Table 12. Table 13 shows the observed and predicted 75 percent load reduction values used in the TSI calculations, and later for constructing the TMDL (Section 7.0).

Table 12. Observed and Predicted Values for Selected Trophic Response Variables Assuming a 25, 50, and 75 Percent Reduction in External Phosphorus Loading.

	Observed	**Predicted**		
Variable		**25% Reduction**	**50% Reduction**	**75% Reduction**
Total Phosphorus as P (mg/L) [1]	0.343	0.265	0.185	0.127
Total Nitrogen as N (mg/L) [1]	2.420	1.994	1.564	1.147
Organic Nitrogen as N (mg/L) [1]	0.458	0.425	0.379	0.320
Chlorophyll-a (*u*g/L) [1]	28.00	25.64	21.75	16.88
Secchi Disk Transparency (m) [2]	0.50	0.61	0.65	0.70
Carlson's TSI for Phosphorus	88.33	84.58	79.44	74.0
Carlson's TSI for Chlorophyll-a	66.29	62.43	60.81	58.33
Carlson's TSI for Secchi Disk	69.42	67.14	66.26	65.07

1- Depth-weighted average
2-Average

Table 13. Observed Load and Predicted Load Reduction Values from BATHTUB Model.

TMDL	**Observed Phosphorus Load (kg/yr)**	**Observed Total Suspended Sediment Load (kg/yr)**	**Predicted 75 Percent Reduction (kg/yr)**
Nutrient	220.1		55.05
Sediment		1403.1	N/A
Dissolved Oxygen	220.1		55.05

5.3 Sediment Loading Analysis

A sediment balance was calculated for Carbury Dam (Table 14). The time period over which this amount of storage occurred was 1.005 years, therefore sediment accumulated within the reservoir at a rate of 2,005.285 kg/yr. Let it be noted that this number is expected to be elevated due to the fact that drought conditions meant no outflow from the dam.

Table 14. Sediment Balance for Carbury Dam (2003).

	Inflow East Trib. (kg)	Inflow West Trib. (kg)	Outflow (kg)	Storage (kg)
TSS	47.2	1,948.1	0.0	1,995.3

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 Carbury 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 2,005.285 kg/yr of sediment in Carbury Dam.

Based on a sediment loading rage of 2,005,000. g/yr times a sediment density of 2.60 g/cm^3, the sediment volume deposited in Carbury Dam is 771,153.8 cm^3 each year.

$$2{,}005{,}000.\ \text{g/yr} * (2.60\ \text{g/cm}^3)^{-1} = 771{,}153.8\ \text{cm}^3/\text{yr}$$

Based on a surface area of 130 acres (5,260,913,349.12 cm^2), the annual sedimentation rate is 0.000147 cm per year [(771,153.8 cm^3/yr)/ (5,260,913,349.12 cm^2)]. This estimated annual sediment accumulation rate is well below the average sedimentation rate of typical reservoirs. Therefore, it is the recommendation of the TMDL that, in the next North Dakota 303(d) list cycle, Carbury 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. As mentioned in Section 3.3, 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 = 11,520 acres = 18 mi^2 = 5.01811200 x 10^8 ft^2

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

NRCS Sediment Standard Volume =

$$5.01811200 \times 10^{8}\ ft^{2} * 0.01041667\ ft = 5{,}227{,}201.67\ ft^{3}$$

$$\text{where :}\quad 5{,}227{,}201.67\ ft^{3} = \mathbf{1.48017868420471 \times 10^{11} cm^{3}}$$

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

Calculated Sediment Volume from data = 771,153.8 cm^3/yr * 50 yr = **3.855769 x 10^7 cm^3.**

Using the NRCS Sedimentation Rate Standard of 1/8 inch over 50 years, Carbury Dam's predicted sediment accumulation rate would be 1.48017868420471 x 10^{11} cm^3. When compared to the current sedimentation rate over 50 years using assessment data, 3.855769 x 10^7 cm^3, Carbury Dam appears to be well under the predicted sedimentation rate standard.

Further support for the removal of TSS as a pollutant of concern can also be found in literature. As Waters (1995) states suspended sediment concentration less than 25 mg L^{-1} is not harmful to fisheries; between 25 and 80 mg L^{-1} reduces fish yield; between 80 and 400 mg L^{-1} is unlikely to display a good fishery; and suspended sediment concentration greater than 400 mg L^{-1} will exhibit a poor fishery. For both of the inlet streams to Carbury Dam, TSS scores were below detectable limits. Therefore, research by Waters (1995) supports the view that TSS concentration in Carbury Dam is not considered harmful to aquatic life threshold. Therefore it is the recommendation of the TMDL that, in the next North Dakota 303 (d) list cycle Carbury Dam should be delisted for sediment impairments.

5.4 AGNPS Watershed Model

In order to identify significant NPS pollutant sources in the Carbury 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, the Agricultural Nonpoint Source Model (AGNPS) 3.65 developed by the United States Department of Agriculture, Agricultural Research Service, was employed. This model analyzes and predicts the effect single storm events can be expected to have on water quality in a watershed. AGNPS identified critical areas that might yield high sediment and nutrient loads.

The primary objectives for using the AGNPS model were to 1) evaluate NPS contributions within the watersheds; 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 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 model was used in conjunction with an intensive landuse survey to determine critical areas within the Carbury Dam watershed. Criteria used during the landuse 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 landuse assessment. A 25yr/24hr storm event (4.10 inches) in Bottineau County was applied to the model to evaluate relative pollutant yields from each 40-acre cell. Each quarter,quarter of land was given a cell number and each cell represents 40 acres of land. A total of 288 cells were input into the program, representing 11,520 acres.

The NRCS has determined the soil loss tolerance (T) average value for the Carbury Dam watershed is 3 to 5 tons per acre. This is the rate that will result when the land is adequately treated for erosion. It should be noted that “adequately treated” still allows for soil loss to occur. At the rate of 4 tons per acre, there is the potential for greater than 46,000 tons of soil to be lost annually from these moderate soil loss cells alone. The high soil loss cells, though fewer in number, account for roughly the same amount of annual soil loss as the moderate soil loss cells. These high loss cells were determined to be the critical cells for sediment loading reduction (Figure 19).

To identify critical cells for nutrient loading, knowing that there had to be a 75 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 5lbs 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 75 percent load reduction, the AGNPS model was re-run with BMP manipulations to cells that had greater than 4lbs of sediment phosphorus. The final output cell was then again reviewed and this process continued with 3.0 lbs, 2.0 lbs, and finally 1.0 lbs sediment phosphorus cells being manipulated with BMPs until the targeted reduction was met. At 1.0 lbs sediment phosphorus level, greater than the needed reduction was met, so analysis went into determining what percentage of these cells needed BMPs applied to achieve the necessary phosphorus load reduction for the watershed. This will allow the stakeholder some decision on where the BMPs are placed during the implementation phase of the TMDL. Cells that had greater than 1.0 lbs sediment phosphorus were identified as critical cells (Figure 20).

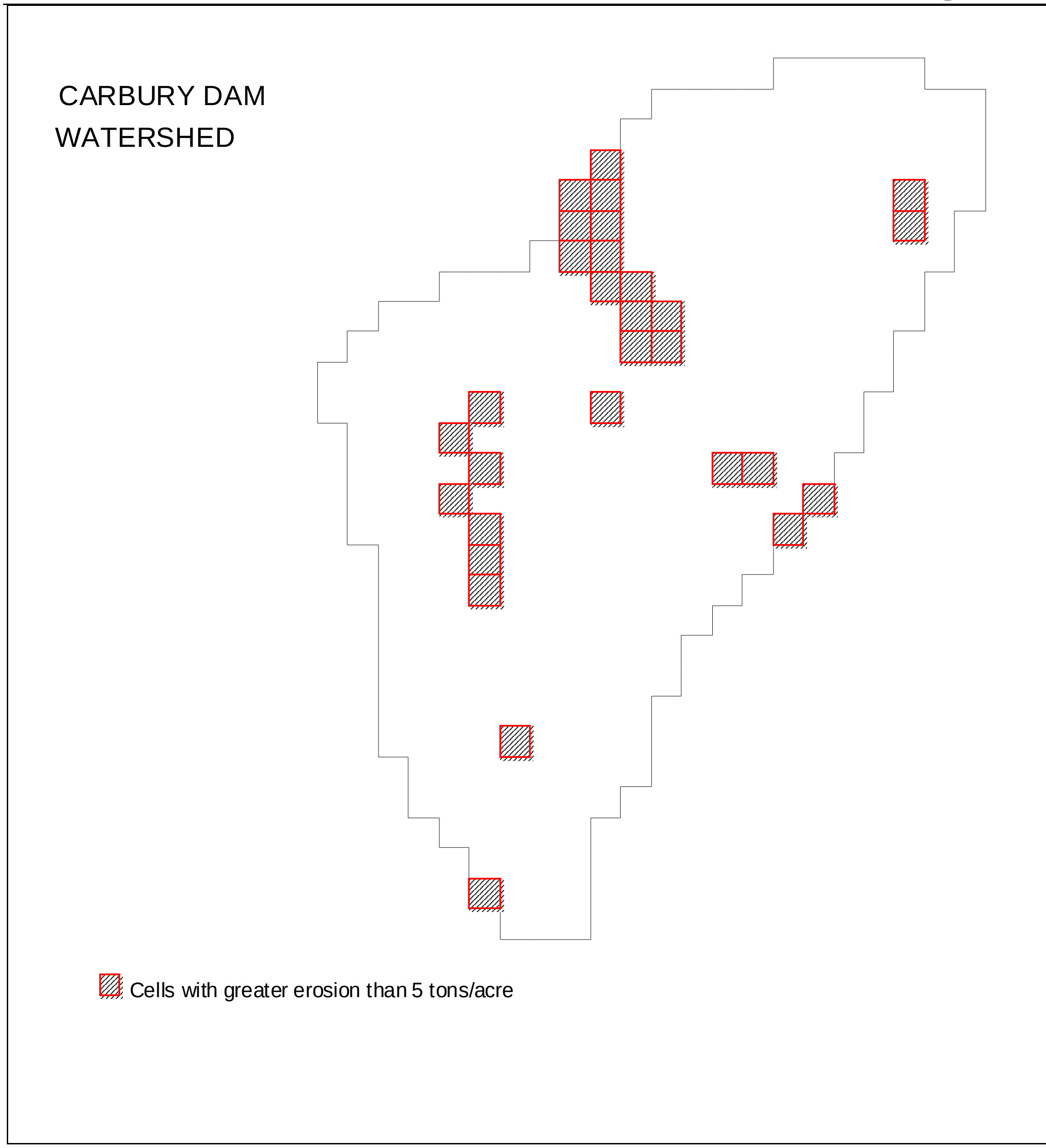

Figure 20. Cells within Carbury Dam Watershed with Soil Erosion > 5 tons/ac.

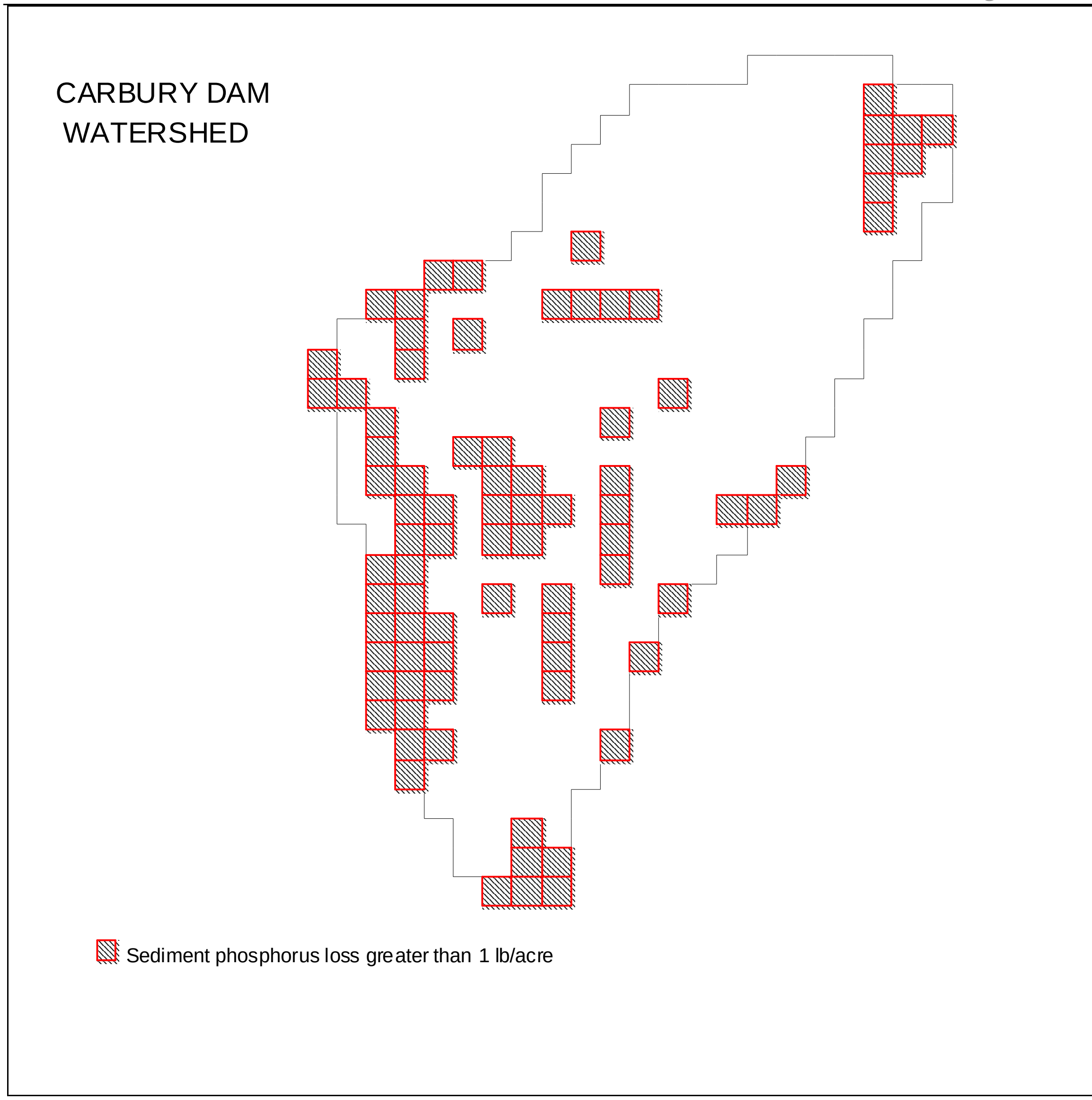

Figure 21. Cells Within Carbury Dam Watershed with Sediment Attached Phosphorus > 1 lb/ac.

It was determined in earlier sections that Carbury Dam should be de-listed for sediment, so no further analysis was done for sediment using the AGNPS model.

For phosphorus loading it was determined that if 86 percent of the sediment phosphorus cells were addressed through BMPs, the phosphorus load would decrease by just over 75 percent, thus meeting the target reduction.

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).

Assuming an annual total phosphorus load of 220.1 kg/yr, reductions of 165 kg/yr in total phosphorus loads will be achieved through the implementation of best management practices affecting agricultural land in the watershed. Since the watershed and the phosphorus load are so small, an implicit margin of safety is being used. This occurs through conservative assumptions made with data entered into the models and with analyzing the model outputs. Additionally, the two animal feeding operations were not allocated in this formula because their small size makes them non-permitted. By addressing these animal feeding operations in the implementation phase, significant additional nutrient and sediment reduction will be achieved.

Also, due to the impairments being nonpoint source in nature and mostly derived from agricultural sources, all TMDLs are inherently linked to each other (see descriptions of each in Section 3.0). Phosphorus, because of its tendency to sorb to soil particles and organic matter, is primarily transported in surface runoff with eroded sediments (USEPA, 1999a). Dissolved oxygen can decline if nutrient and sediment loads are high. A reduction focused on phosphorus will improve the water quality in regards to sediment and dissolved oxygen as well.

As an added margin of safety during the implementation phase, a project implementation plan will be developed to include concurrent and post-implementation monitoring to investigate the effectiveness of the TMDL controls and to determine attainment of the targets. The project implementation plan is not a static document, but an adaptive management tool to be used and modified as the situation necessitates throughout the implementation phase.

6.2 Seasonality

Section 303(d)(1)(C) of the Clean Water Act and the U.S. Environmental Protection Agency (EPA's) regulations require that a TMDL be established with seasonal variations. The Carbury Dam TMDLs address seasonality because the BATHTUB model incorporates season differences in its prediction of annual average total phosphorus concentrations.

7.0 TMDL

The tables below summarizes the nutrient, sediment, and dissolved oxygen TMDLs for Carbury Dam in terms of loading capacity, wasteload allocations, load allocations, and a margin of safety. The TMDL can be generically described by the following equation:

TMDL = LC = WLA + LA + MOS
Where:

LC loading capacity, or the greatest loading a waterbody can receive without violating water quality standards;

WLA wasteload allocation, or the portion of the TMDL allocated to existing or future point sources;

LA load allocation, or the portion of the TMDL allocated to existing or future nonpoint sources;

MOS margin of safety, or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. The margin of safety can be provided implicitly through analytical assumptions or explicitly by reserving a portion of loading capacity.

7.1 Nutrient TMDL

Table 15. Summary of the Nutrient TMDL for Carbury Dam.

Category	Total Phosphorus (kg/yr)	Explanation
Existing Load	220.1	From observed data
Loading Capacity	55.05	75% reduction based on BATHTUB model simulations
Wasteload Allocation	0	No point sources
Load Allocation	55.05	Entire loading capacity minus MOS is allocated to nonpoint sources
MOS	n/a	Implicit through conservative assumptions made during the model computations and in data analysis.

This TMDL is a "measured load" calculated by a computer model representing a long term average load; actual loads may be higher or lower in a given year. Likewise the actual loads to the lake post-implementation (i.e. as expressed by the loading capacity), may be higher or lower in a given year.

7.2 Sediment TMDL

No reduction necessary. De-list for sediment.

7.3 Dissolved Oxygen TMDL

The Water Quality Standard for the Carbury Dam is a dissolved oxygen level of “not less than 5mg/l” (*Standards of Quality for Waters of the State*, North Dakota Century Code 33-16). This TMDL shall be achieved through using phosphorus as a surrogate, as described in Section 3.3

Table 16. Summary of the Dissolved Oxygen TMDL for Carbury Dam, Using Phosphorus as a Surrogate.

Category	Total Phosphorus (kg/yr)	Explanation
Existing Load	220.1	From observed data
Loading Capacity	55.05	50% reduction based on BATHTUB model simulations
Wasteload Allocation	0	No point sources
Load Allocation	55.05	Entire loading capacity minus MOS is allocated to nonpoint sources.
MOS	n/a	Implicit through conservative assumptions made during the model computations and in data analysis.

8.0 ALLOCATION

The Carbury Dam watershed is very small and supports extensive agriculture where cropland constitutes a majority of the landuse. The West Tributary contributes 99% of the loading volume, so it would be practical to concentrate implementation efforts there. While is it believed that instituting BMPs will result in the needed water quality improvements, the history of sediment and nutrient deposition may strongly affect in-lake cycling. Also, by effectively using the hypolimnetic draw-down according to recommendations from the NDDoH and the North Dakota Game and Fish, there will be an additional phosphorus load decrease and possible additional improvement in winter dissolved oxygen levels.

While it is believed that instituting BMPs will result in the needed water quality improvements, the history of sediment and nutrient deposition may strongly affect 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. Conversation with the Bottineau County NRCS office has indicated a growing trend towards improved conservation practices resulting in better land cover. This knowledge base and public willingness towards conservation practices will facilitate the implementation of the additional needed BMPs.

9.0 PUBLIC PARTICIPATION

To satisfy the public participation requirement of this TMDL, a hard copy of the TMDL for Carbury Dam and request for comment was mailed to the following entities:

Turtle Mountain Soil Conservation District (chairman)

Mouse River Soil Conservation District (chairman)

Boundary Creek Water Resource Board

Bottineau County Water Resource Board

Natural Resources Conservation Service (Bottineau County Field Offices)

North Dakota Game and Fish Department (Save Our Lakes Program)

U.S. Fish and Wildlife Service

U.S. Environmental Protection Agency, Region 8

Other interested parties who request a copy

In addition to the mailed copies, the TMDL for Carbury Dam was posted on the North Dakota Department of Health, Division of Water Quality web site at http://www.health.state.nd.us/wq/. A 30 day public notice soliciting comment and participation was also published in the Bottineau Courant, Minot Daily Herald and the Bismarck Tribune. Both formal and informal comments are addressed in this final report (Appendix C.)

10.0 MONITORING

To insure that the implementation of BMPs will reduce phosphorus levels and resulting 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. 319 PIP) is implemented, monitoring will be conducted in the lake/reservoir beginning two years after implementation and extending five years after the implementation project is complete

11.0 TMDL IMPLEMENTATION STRATEGY

Implementation of TMDLs is dependent upon the availability of Section 319 NPS funds or other watershed restoration programs (e.g. USDA EQIP), as well as securing a local project sponsor and 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 Nonpoint Source Pollution Task Force and US EPA for approval. The implementation of the best management practices contained in the NPS pollution management project 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 ENDANGERED SPECIES ACT COMPLIANCE

States are encouraged to participate with the U.S. Fish and Wildlife Service and EPA in the Endangered Species Act consultation process to document, adversely or beneficially, the potential effects the TMDL may have on threatened or endangered species. In an effort to assist with this process, a request for a list of endangered and/or threatened species was made to the US Fish and Wildlife Service (Figure 21). A hard copy of the draft TMDL report will also be sent to the U.S. Fish and Wildlife Service's Endangered Species Office in Bismarck, ND for review. The following is a list of threatened or endangered species specific to the Carbury Dam watershed and Bottineau County.

U.S. Fish & Wildlife Service
3425 Miriam Avenue
Bismarck, North Dakota 58501

OFFICE TRANSMITTAL

To: Heather Duchscherer
ND Department of Health
Towner, ND

☐ Action
■ Information

From: Kevin Johnson Division: Ecological Services Date: 6-21-05

Attached is the information you requested in you April 12, 2005, letter on TMDL for several watersheds in northwestern North Dakota.

If you need any other information, please let us know.

Figure 22. Notification Received From the U.S. Fish and Wildlife Service.

The following items were enclosed with the above memo:

FEDERAL THREATENED AND ENDANGERED SPECIES
FOUND IN BOTTINEAU COUNTY
NORTH DAKOTA
June 2005

ENDANGERED SPECIES

Birds

Whooping crane (Grus Americana): Migrates through west and central counties during spring and fall. Prefers to roost on wetlands and stockdams with good visibility. Young adult summered in North Dakota in 1989, 1990, and 1993. Total population 140-150 birds.

Fish

Pallid sturgeon (Scaphirhynchus albus): Known only from the Missouri and Yellowstone Rivers. No reproduction has been documented in 15 years.

Mammals

Gray wolf (Canis lupus): Occasional visitor in North Dakota. Most frequently observed in the Turtle Mountains area.

THREATENED SPECIES

Birds

Bald eagle (Haliaeetus leucocephalus): Migrates spring and fall statewide but primarily along the major river courses. It concentrates along the Missouri River during winter and is known to nest in the floodplain forest.

DESIGNATED CRITICAL HABITAT

Birds

Piping Plover - Alkali Lakes and Wetlands - Critical habitat includes: (1) shallow, seasonally to permanently flooded, mixosaline to hypersaline wetlands with sandy to gravelly, sparsely vegetated beaches, salt-encrusted mud flats, and/or gravelly salt flats; (2) springs and fens along edges of alkali lakes and wetlands; and (3) adjacent uplands 200 feet (61 meters) above the high water mark of the alkali lake or wetland.

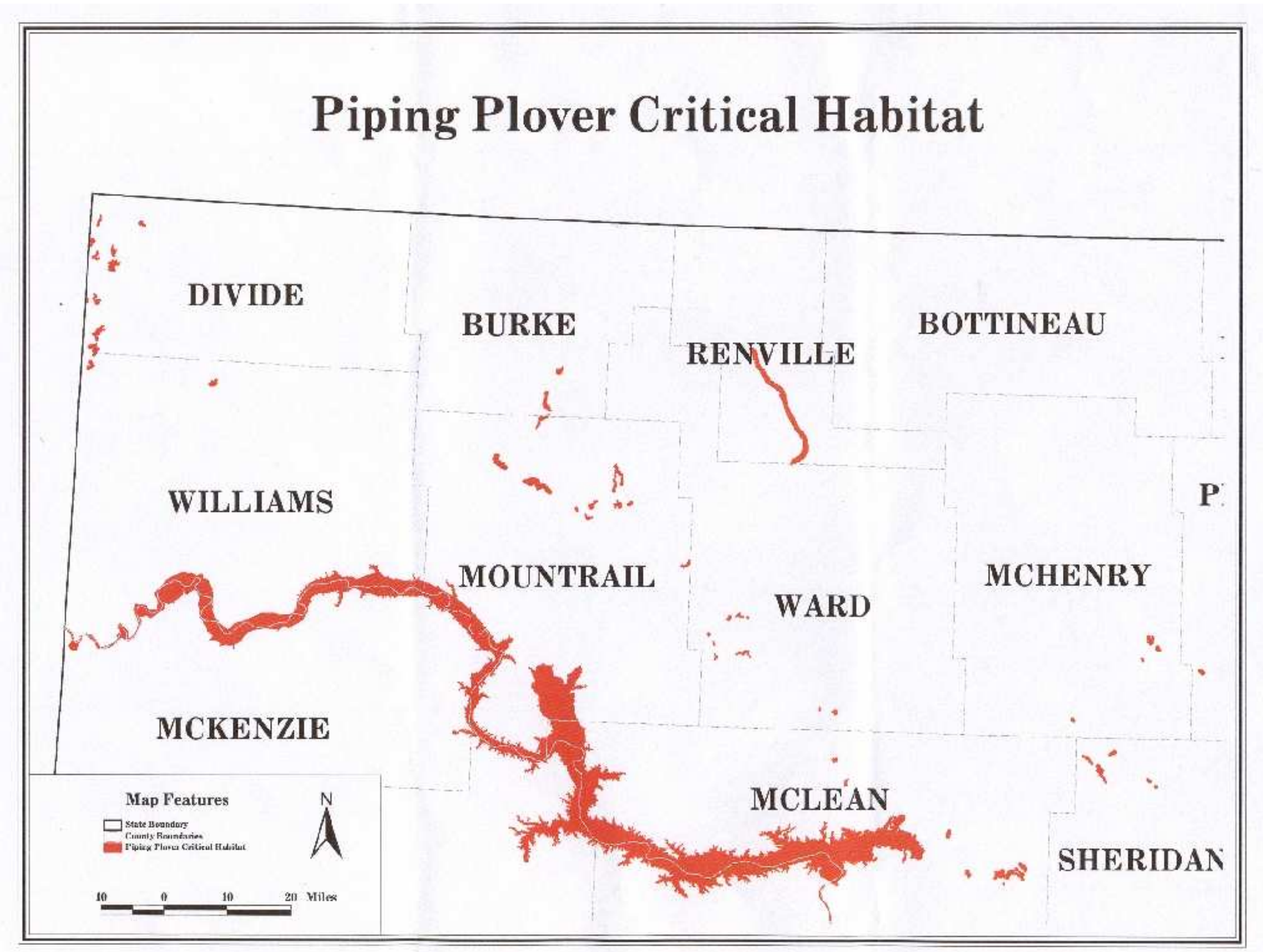

Figure 23. Map of Piping Plover Critical Habitat.

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Appendix A
Stream Modeling Results

East inlet 385229 VAR=NH3-4 METHOD= 2 Q WTD C

Comparison of Sampled & Total Flow Distributions

	------ SAMPLED -----		------- TOTAL ------					
STRAT	N	MEAN	STD DEV	N	MEAN	STD DEV	DIFF	T	PROB(>T)
1	6	.11	.09	364	.01	.03	.10	-2.69	.043
***	6	.11	.09	364	.01	.03	.10	-2.69	.043

Average Sample Interval = 8.2 Days, Date Range = 20030321 to 20030509
Maximum Sample Interval = 28 Days, Date Range = 20030410 to 20030509
Percent of Total Flow Volume Occuring In This Interval = 41.2%

Total Flow Volume on Sampled Days = .7 hm3
Total Flow Volume on All Days = 3.4 hm3
Percent of Total Flow Volume Sampled = 19.3%

Maximum Sampled Flow Rate = .26 hm3/yr
Maximum Total Flow Rate = .26 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 0 out of 364
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate = .0%

East inlet 385229 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	364	6	6	100.0	.009	.111	.413	.233
***	364	6	6	100.0	.009	.111		

FLOW STATISTICS
FLOW DURATION = 364.0 DAYS = .997 YEARS
MEAN FLOW RATE = .009 HM3/YR
TOTAL FLOW VOLUME = .01 HM3
FLOW DATE RANGE = 20030101 TO 20031231
SAMPLE DATE RANGE = 20030321 TO 20030509

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	10.5	10.6	.4946E+02	1117.69	.664
2 Q WTD C	.9	.9	.2479E+00	95.49	.550
3 IJC	1.0	1.0	.3331E+00	101.48	.600
4 REG-1	.3	.3	.1097E+00	34.56	1.012
5 REG-2	1.1	1.1	.1922E+00	111.26	.416
6 REG-3	.7	.8	.9267E-01	79.22	.406

East inlet 385229 VAR=Diss-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	364	6	6	100.0	.009	.111	.263	.152
***	364	6	6	100.0	.009	.111		

FLOW STATISTICS

FLOW DURATION = 364.0 DAYS = .997 YEARS

MEAN FLOW RATE = .009 HM3/YR

TOTAL FLOW VOLUME = .01 HM3

FLOW DATE RANGE = 20030101 TO 20031231

SAMPLE DATE RANGE = 20030321 TO 20030509

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	42.3	42.4	.6574E+03	4480.28	.604
2 Q WTD C	3.6	3.6	.2491E+01	382.79	.435
3 IJC	3.8	3.8	.3255E+01	406.08	.469
4 REG-1	1.9	1.9	.7161E+00	200.66	.445
5 REG-2	4.5	4.5	.3747E+01	473.32	.432
6 REG-3	2.7	2.7	.5320E+00	281.26	.274

```
East inlet 385229                 VAR=NO2+NO3   METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385229_Q.wk1                    ,   Station =cfs
Daily Flows from 20030101 to 20031231
Flow Dates Missing   : 20030708 - 20030708
Flow Dates Missing   : 20030818 - 20030818
Dates Out of Sequence: 20030914 - 20030914

Summary:
Reported Flows =  364
Missing Flows =     2
Zero Flows =      312
Positive Flows =   52

East inlet 385229                 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       364   6   6 100.0         .009         .111        .730   .073
***      364   6   6 100.0         .009         .111

FLOW STATISTICS
FLOW DURATION =     364.0 DAYS  =   .997 YEARS
MEAN FLOW RATE =      .009 HM3/YR
TOTAL FLOW VOLUME =        .01 HM3
FLOW DATE RANGE   = 20030101 TO 20031231
SAMPLE DATE RANGE = 20030321 TO 20030509

METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
1 AV LOAD           83.9           84.2      .2915E+04    8892.52    .641
2 Q WTD C            7.2            7.2      .1423E+02     759.77    .524
3 IJC                7.6            7.6      .1933E+02     803.37    .578
4 REG-1              1.2            1.2      .1595E+02     126.26   3.340
5 REG-2              6.0            6.0      .7390E+01     633.02    .453
6 REG-3              6.2            6.2      .4372E+01     654.79    .337
```

East inlet 385229 VAR=Tot-N METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385229_Q.wk1 , Station =cfs
Daily Flows from 20030101 to 20031231
Flow Dates Missing : 20030708 - 20030708
Flow Dates Missing : 20030818 - 20030818
Dates Out of Sequence: 20030914 - 20030914

Summary:
Reported Flows = 364
Missing Flows = 2
Zero Flows = 312
Positive Flows = 52

East inlet 385229 VAR=Tot-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	364	6	6	100.0	.009	.111	.177	.205
***	364	6	6	100.0	.009	.111		

FLOW STATISTICS
FLOW DURATION = 364.0 DAYS = .997 YEARS
MEAN FLOW RATE = .009 HM3/YR
TOTAL FLOW VOLUME = .01 HM3
FLOW DATE RANGE = 20030101 TO 20031231
SAMPLE DATE RANGE = 20030321 TO 20030509

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	297.4	298.4	.2531E+05	31511.41	.533
2 Q WTD C	25.4	25.5	.7442E+02	2692.31	.338
3 IJC	26.5	26.6	.9840E+02	2812.78	.372
4 REG-1	16.4	16.5	.1768E+02	1740.95	.255
5 REG-2	31.0	31.1	.1384E+03	3288.85	.378
6 REG-3	20.9	20.9	.1753E+02	2211.50	.200

```
 East inlet 385229                VAR=Tot-P     METHOD= 2 Q WTD C

 TABULATION OF MISSING DAILY FLOWS:

 Flow File =385229_Q.wkl                    ,    Station =cfs
 Daily Flows from 20030101 to 20031231
 Flow Dates Missing   : 20030708 - 20030708
 Flow Dates Missing   : 20030818 - 20030818
 Dates Out of Sequence: 20030914 - 20030914

 Summary:
 Reported Flows =  364
 Missing Flows =     2
 Zero Flows =      312
 Positive Flows =   52

 East inlet 385229                VAR=Tot-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       364   6   6 100.0         .009         .111        .213   .239
***       364   6   6 100.0         .009         .111

 FLOW STATISTICS
 FLOW DURATION =     364.0 DAYS  =   .997 YEARS
 MEAN FLOW RATE =      .009 HM3/YR
 TOTAL FLOW VOLUME =        .01 HM3
 FLOW DATE RANGE   = 20030101 TO 20031231
 SAMPLE DATE RANGE = 20030321 TO 20030509

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD           49.0           49.2      .8393E+03    5195.64    .589
 2 Q WTD C            4.2            4.2      .3040E+01     443.91    .415
 3 IJC                4.4            4.4      .3969E+01     469.24    .448
 4 REG-1              2.5            2.5      .9694E+00     262.85    .396
 5 REG-2              5.2            5.2      .5308E+01     547.73    .444
 6 REG-3              3.2            3.2      .7225E+00     342.29    .262
```

```
East inlet 385229                VAR=TSS       METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385229_Q.wk1                    ,   Station =cfs
Daily Flows from 20030101 to 20031231
Flow Dates Missing   : 20030708 - 20030708
Flow Dates Missing   : 20030818 - 20030818
Dates Out of Sequence: 20030914 - 20030914

Summary:
Reported Flows =  364
Missing Flows =     2
Zero Flows =      312
Positive Flows =   52

East inlet 385229                VAR=TSS       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       364   6   6 100.0         .009         .111        .000   .995
***      364   6   6 100.0         .009         .111

FLOW STATISTICS
FLOW DURATION =     364.0 DAYS  =   .997 YEARS
MEAN FLOW RATE =      .009 HM3/YR
TOTAL FLOW VOLUME =        .01 HM3
FLOW DATE RANGE   = 20030101 TO 20031231
SAMPLE DATE RANGE = 20030321 TO 20030509

METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
1 AV LOAD          552.4          554.3      .3542E+05   58521.09    .340
2 Q WTD C           47.2           47.4     -.2110E-04    5000.00    .000
3 IJC               47.2           47.4     -.2110E-04    5000.00    .000
4 REG-1             47.2           47.4      .3925E-04    5000.00    .000
5 REG-2             47.2           47.4     -.6965E-04    5000.00    .000
6 REG-3             47.2           47.4      .3507E-04    5000.00    .000




West inlet 385230                VAR=NH3-4     METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385230_Q.wk1                    ,   Station =cfs
Daily Flows from 20030101 to 20031231
Dates Out of Sequence: 20030417 - 20030417
Dates Out of Sequence: 20030504 - 20030504

Summary:
Reported Flows =  367
Missing Flows =     0
Zero Flows =      257
Positive Flows =  110

West inlet 385230                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       367   8   8 100.0         .388        2.157        .349   .273
```

```
***       367   8   8 100.0         .388        2.157

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .388 HM3/YR
 TOTAL FLOW VOLUME =        .39 HM3
 FLOW DATE RANGE   = 20030101 TO 20031231
 SAMPLE DATE RANGE = 20030321 TO 20030520
```

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	89.6	89.1	.2249E+04	229.91	.532
2 Q WTD C	16.1	16.0	.6247E+01	41.33	.156
3 IJC	16.2	16.2	.4003E+01	41.66	.124
4 REG-1	8.9	8.8	.5356E+01	22.72	.263
5 REG-2	12.0	11.9	.6326E+02	30.68	.669
6 REG-3	16.7	16.6	.4278E+02	42.86	.394

West inlet 385230 VAR=DISS-P METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385230_Q.wk1 , Station =cfs
Daily Flows from 20030101 to 20031231
Dates Out of Sequence: 20030417 - 20030417
Dates Out of Sequence: 20030504 - 20030504

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 257
Positive Flows = 110

West inlet 385230 VAR=DISS-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	367	8	8	100.0	.388	2.157	.736	.017
***	367	8	8	100.0	.388	2.157		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = .388 HM3/YR
TOTAL FLOW VOLUME = .39 HM3
FLOW DATE RANGE = 20030101 TO 20031231
SAMPLE DATE RANGE = 20030321 TO 20030520

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	703.2	699.9	.3573E+06	1804.91	.854
2 Q WTD C	126.4	125.8	.7213E+04	324.46	.675
3 IJC	144.2	143.5	.1020E+05	370.03	.704
4 REG-1	35.7	35.6	.3482E+03	91.75	.525
5 REG-2	58.0	57.7	.3021E+03	148.79	.301
6 REG-3	53.4	53.2	.2489E+03	137.15	.297

West inlet 385230 VAR=NO2+NO3 METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385230_Q.wk1 , Station =cfs
Daily Flows from 20030101 to 20031231
Dates Out of Sequence: 20030417 - 20030417
Dates Out of Sequence: 20030504 - 20030504

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 257
Positive Flows = 110

West inlet 385230 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	367	8	8	100.0	.388	2.157	.943	.108
***	367	8	8	100.0	.388	2.157		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = .388 HM3/YR
TOTAL FLOW VOLUME = .39 HM3
FLOW DATE RANGE = 20030101 TO 20031231
SAMPLE DATE RANGE = 20030321 TO 20030520

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	2572.3	2560.0	.6055E+07	6601.95	.961
2 Q WTD C	462.4	460.2	.1602E+06	1186.80	.870
3 IJC	546.2	543.6	.2269E+06	1401.79	.876
4 REG-1	91.7	91.3	.5951E+04	235.33	.845
5 REG-2	157.7	157.0	.1801E+05	404.76	.855
6 REG-3	114.6	114.1	.1327E+05	294.18	1.010

West inlet 385230 VAR=TKN METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385230_Q.wk1 , Station =cfs
Daily Flows from 20030101 to 20031231
Dates Out of Sequence: 20030417 - 20030417
Dates Out of Sequence: 20030504 - 20030504

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 257
Positive Flows = 110

West inlet 385230 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	367	8	8	100.0	.388	2.157	-.049	.635
***	367	8	8	100.0	.388	2.157		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = .388 HM3/YR
TOTAL FLOW VOLUME = .39 HM3
FLOW DATE RANGE = 20030101 TO 20031231
SAMPLE DATE RANGE = 20030321 TO 20030520

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	5088.2	5063.9	.8861E+07	13059.41	.588
2 Q WTD C	914.7	910.3	.3080E+05	2347.63	.193
3 IJC	949.7	945.1	.4442E+05	2437.39	.223
4 REG-1	995.5	990.7	.3662E+05	2554.98	.193
5 REG-2	942.8	938.3	.9502E+05	2419.70	.329
6 REG-3	844.4	840.4	.1957E+05	2167.19	.166

West inlet 385230 VAR=TOT-N METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385230_Q.wk1 , Station =cfs
Daily Flows from 20030101 to 20031231
Dates Out of Sequence: 20030417 - 20030417
Dates Out of Sequence: 20030504 - 20030504

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 257
Positive Flows = 110

West inlet 385230 VAR=TOT-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	367	8	8	100.0	.388	2.157	.074	.590
***	367	8	8	100.0	.388	2.157		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = .388 HM3/YR
TOTAL FLOW VOLUME = .39 HM3
FLOW DATE RANGE = 20030101 TO 20031231
SAMPLE DATE RANGE = 20030321 TO 20030520

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	7660.5	7623.9	.2949E+08	19661.37	.712
2 Q WTD C	1377.1	1370.5	.3296E+06	3534.44	.419
3 IJC	1495.8	1488.7	.4711E+06	3839.19	.461
4 REG-1	1212.8	1207.0	.1781E+06	3112.85	.350
5 REG-2	1309.5	1303.3	.3821E+06	3361.01	.474
6 REG-3	1004.3	999.5	.6799E+05	2577.53	.261

West inlet 385230 VAR=TOT-P METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385230_Q.wk1 , Station =cfs
Daily Flows from 20030101 to 20031231
Dates Out of Sequence: 20030417 - 20030417
Dates Out of Sequence: 20030504 - 20030504

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 257
Positive Flows = 110

West inlet 385230 VAR=TOT-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	367	8	8	100.0	.388	2.157	.598	.016
***	367	8	8	100.0	.388	2.157		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = .388 HM3/YR
TOTAL FLOW VOLUME = .39 HM3
FLOW DATE RANGE = 20030101 TO 20031231
SAMPLE DATE RANGE = 20030321 TO 20030520

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	940.5	936.0	.6138E+06	2413.84	.837
2 Q WTD C	169.1	168.3	.1175E+05	433.93	.644
3 IJC	191.7	190.8	.1662E+05	492.10	.676
4 REG-1	60.6	60.3	.8870E+03	155.59	.494
5 REG-2	93.3	92.9	.8726E+03	239.52	.318
6 REG-3	75.8	75.5	.3692E+03	194.59	.255

West inlet 385230 VAR=TSS METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385230_Q.wk1 , Station =cfs
Daily Flows from 20030101 to 20031231
Dates Out of Sequence: 20030417 - 20030417
Dates Out of Sequence: 20030504 - 20030504

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 257
Positive Flows = 110

West inlet 385230 VAR=TSS 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	367	8	8	100.0	.388	2.157	.000	1.000
***	367	8	8	100.0	.388	2.157		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = .388 HM3/YR
TOTAL FLOW VOLUME = .39 HM3
FLOW DATE RANGE = 20030101 TO 20031231
SAMPLE DATE RANGE = 20030321 TO 20030520

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	10836.9	10785.2	.2770E+08	27813.99	.488
2 Q WTD C	1948.1	1938.8	.1191E-01	5000.00	.000
3 IJC	1948.1	1938.8	.1191E-01	5000.00	.000
4 REG-1	1948.1	1938.8	.3002E-01	5000.00	.000
5 REG-2	1948.1	1938.8	-.2237E-01	5000.00	.000
6 REG-3	1948.1	1938.8	-.7134E-02	5000.01	.000

Appendix B
Lake Modeling Results

CASE: Carbury Calibration

HYDRAULIC AND DISPERSION PARAMETERS:

SEG	OUT	NET INFLOW HM3/YR	RESIDENCE TIME YRS	OVERFLOW RATE M/YR	MEAN VELOCITY KM/YR	----DISPERSION----- ESTIMATED KM2/YR	NUMERIC KM2/YR	EXCHANGE RATE HM3/YR
1	0	.25	6.46635	.5	1.0	0.	0.	0.

CASE: Carbury Calibration

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	East 385229	14.570	.009	.000E+00	.000	.001
2	1	West 385230	38.040	.388	.000E+00	.000	.010
3	1	Ungaugedshed	2.430	.014	.000E+00	.000	.006
4	4	Outlet 385228	55.578	.000	.000E+00	.000	.000
		PRECIPITATION	.538	.323	.417E-02	.200	.600
		TRIBUTARY INFLOW	55.040	.411	.000E+00	.000	.007
		***TOTAL INFLOW	55.578	.734	.417E-02	.088	.013
		ADVECTIVE OUTFLOW	.000	.250	.253E-01	.637	139586.500
		***TOTAL OUTFLOW	55.578	.250	.253E-01	.637	.004
		***EVAPORATION	.000	.484	.211E-01	.300	.000

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: CONSERV

ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	East 385229	.0	.0	.000E+00	.0	.000	.0	.0
2	1	West 385230	.0	.0	.000E+00	.0	.000	.0	.0
3	1	Ungaugedshed	.0	.0	.000E+00	.0	.000	.0	.0
4	4	Outlet 385228	.0	.0	.000E+00	.0	.000	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	-------------- CONSERV -------------- POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
.46	6.4663	.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	East 385229	6.5	2.1	.000E+00	.0	.000	716.9	.4
2	1	West 385230	265.4	86.8	.000E+00	.0	.000	684.1	7.0
3	1	Ungaugedshed	9.7	3.2	.000E+00	.0	.000	694.0	4.0
4	4	Outlet 385228	.0	.0	.000E+00	.0	.000	343.0	.0
		PRECIPITATION	24.1	7.9	.146E+03	100.0	.500	74.8	44.9
		TRIBUTARY INFLOW	281.6	92.1	.000E+00	.0	.000	685.2	5.1
		***TOTAL INFLOW	305.7	100.0	.146E+03	100.0	.039	416.7	5.5
		ADVECTIVE OUTFLOW	85.6	28.0	.297E+04	2042.4	.637	343.0********	
		***TOTAL OUTFLOW	85.6	28.0	.297E+04	2042.4	.637	343.0	1.5
		***RETENTION	220.1	72.0	.312E+04	2142.4	.254	.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 -
.46	6.4663	343.0	1.8107	.5523	.7200

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	East 385229	20.4	1.1	.000E+00	.0	.000	2263.7	1.4
2	1	West 385230	1185.4	66.9	.000E+00	.0	.000	3055.2	31.2
3	1	Ungaugedshed	37.2	2.1	.000E+00	.0	.000	2659.1	15.3
4	4	Outlet 385228	.0	.0	.000E+00	.0	.000	2419.0	.0
		PRECIPITATION	529.9	29.9	.702E+05	100.0	.500	1641.7	985.0
		TRIBUTARY INFLOW	1243.0	70.1	.000E+00	.0	.000	3024.4	22.6
		***TOTAL INFLOW	1772.9	100.0	.702E+05	100.0	.149	2416.1	31.9
		ADVECTIVE OUTFLOW	603.8	34.1	.148E+06	210.6	.637	2419.0	********
		***TOTAL OUTFLOW	603.8	34.1	.148E+06	210.6	.637	2419.0	10.9
		***RETENTION	1169.2	65.9	.218E+06	310.6	.399	.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 -
.46	6.4663	2419.0	2.2021	.4541	.6594

CASE: Carbury Calibration

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

SEGMENT: 1 deepest

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	343.0	.00	343.3	.53	1.00	.00	.00	.00
TOTAL N	MG/M3	2419.0	.00	2419.7	.44	1.00	.00	.00	.00
C.NUTRIENT	MG/M3	165.6	.00	165.7	.43	1.00	.00	.00	.00
CHL-A	MG/M3	28.0	.00	28.4	.32	.99	.00	-.04	-.04
SECCHI	M	.5	.00	.6	.16	.89	.00	-.42	-.72
ORGANIC N	MG/M3	458.0	.00	457.3	.26	1.00	.00	.01	.01
TP-ORTHO-P	MG/M3	89.0	.00	89.1	.27	1.00	.00	.00	.00
HOD-V	MG/M3-DAY	.0	.00	426.2	.22	.00	.00	.00	.00
MOD-V	MG/M3-DAY	.0	.00	258.8	.31	.00	.00	.00	.00

CASE: Carbury Calibration

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

SEGMENT: 1 deepest

VARIABLE		VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P	MG/M3	343.00	343.28	98.6	98.6
TOTAL N	MG/M3	2419.00	2419.66	91.6	91.6
C.NUTRIENT	MG/M3	165.59	165.66	97.2	97.2
CHL-A	MG/M3	28.00	28.38	92.2	92.5
SECCHI	M	.52	.58	16.8	21.0
ORGANIC N	MG/M3	458.00	457.30	47.3	47.2
TP-ORTHO-P	MG/M3	89.00	89.05	87.4	87.4
HOD-V	MG/M3-DAY	.00	426.20	.0	98.9
MOD-V	MG/M3-DAY	.00	258.81	.0	97.0
ANTILOG PC-1		1532.10	1459.45	91.9	91.3
ANTILOG PC-2		6.04	6.60	45.3	52.0
(N - 150) / P		6.62	6.61	8.3	8.3
INORGANIC N / P		7.72	7.72	8.8	8.8
TURBIDITY	1/M	1.00	1.00	71.4	71.4
ZMIX * TURBIDITY		3.00	3.00	47.5	47.5
ZMIX / SECCHI		5.77	5.13	62.8	55.0
CHL-A * SECCHI		14.56	16.60	69.2	75.4
CHL-A / TOTAL P		.08	.08	8.4	8.7
CARLSON TSI-P		88.33	88.34	.0	.0
CARLSON TSI-CHLA		63.29	63.42	.0	.0
CARLSON TSI-SEC		69.42	67.73	.0	.0

CASE: Carbury (-25%) Nutrient Conc
HYDRAULIC AND DISPERSION PARAMETERS:

```
               NET RESIDENCE  OVERFLOW      MEAN ----DISPERSION-----
EXCHANGE
            INFLOW      TIME      RATE  VELOCITY ESTIMATED   NUMERIC
RATE
 SEG OUT    HM3/YR       YRS      M/YR     KM/YR    KM2/YR    KM2/YR
HM3/YR
   1   0       .25   6.46635        .5       1.0        0.        0.
0.
 CASE: Carbury (-25%) Nutrient Conc
 GROSS WATER BALANCE:
                       DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
 ID  T LOCATION                  KM2          MEAN  VARIANCE    CV        M/YR
 ----------------------------------------------------------------------------
  1  1 East 385229            14.570          .009  .000E+00  .000        .001
  2  1 West 385230            38.040          .388  .000E+00  .000        .010
  3  1 Ungaugedshed            2.430          .014  .000E+00  .000        .006
  4  4 Outlet 385228          55.578          .000  .000E+00  .000        .000
 ----------------------------------------------------------------------------
 PRECIPITATION                  .538          .323  .000E+00  .000        .600
 TRIBUTARY INFLOW             55.040          .411  .000E+00  .000        .007
 ***TOTAL INFLOW              55.578          .734  .000E+00  .000        .013
 ADVECTIVE OUTFLOW              .000          .250  .000E+00  .000  139586.500
 ***TOTAL OUTFLOW             55.578          .250  .000E+00  .000        .004
 ***EVAPORATION                 .000          .484  .000E+00  .000        .000
 ----------------------------------------------------------------------------

 GROSS MASS BALANCE BASED UPON  OBSERVED CONCENTRATIONS
 COMPONENT: CONSERV
                       ----- LOADING ---- --- VARIANCE ---         CONC
EXPORT
 ID T LOCATION               KG/YR   %(I)  KG/YR**2   %(I)    CV   MG/M3
KG/KM2
 ----------------------------------------------------------------------------
---
  1 1 East 385229               .0     .0  .000E+00     .0  .000      .0
.0
  2 1 West 385230               .0     .0  .000E+00     .0  .000      .0
.0
  3 1 Ungaugedshed              .0     .0  .000E+00     .0  .000      .0
.0
  4 4 Outlet 385228             .0     .0  .000E+00     .0  .000      .0
.0
 ----------------------------------------------------------------------------
---
 ----------------------------------------------------------------------------
---

           HYDRAULIC    -------------- CONSERV  --------------
  OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
      RATE      TIME      CONC      TIME     RATIO      COEF
      M/YR       YRS     MG/M3       YRS         -         -
       .46    6.4663        .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	East 385229	4.8	2.1	.000E+00	.0	.000	537.6	.3
2	1	West 385230	199.3	84.6	.000E+00	.0	.000	513.8	5.2
3	1	Ungaugedshed	7.3	3.1	.000E+00	.0	.000	521.4	3.0
4	4	Outlet 385228	.0	.0	.000E+00	.0	.000	343.0	.0
		PRECIPITATION	24.1	10.2	.000E+00	.0	.000	74.8	44.9
		TRIBUTARY INFLOW	211.5	89.8	.000E+00	.0	.000	514.6	3.8
		***TOTAL INFLOW	235.6	100.0	.000E+00	.0	.000	321.1	4.2
		ADVECTIVE OUTFLOW	85.6	36.3	.000E+00	.0	.000		343.0********
		***TOTAL OUTFLOW	85.6	36.3	.000E+00	.0	.000	343.0	1.5
		***RETENTION	150.0	63.7	.000E+00	.0	.000	.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 -
.46	6.4663	343.0	2.3497	.4256	.6366

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	East 385229	15.3	1.0	.000E+00	.0	.000	1697.6	1.0
2	1	West 385230	889.2	60.9	.000E+00	.0	.000	2291.7	23.4
3	1	Ungaugedshed	26.6	1.8	.000E+00	.0	.000	1902.6	11.0
4	4	Outlet 385228	.0	.0	.000E+00	.0	.000	2419.0	.0
		PRECIPITATION	529.9	36.3	.000E+00	.0	.000	1641.7	985.0
		TRIBUTARY INFLOW	931.1	63.7	.000E+00	.0	.000	2265.4	16.9
		***TOTAL INFLOW	1461.0	100.0	.000E+00	.0	.000	1991.0	26.3
		ADVECTIVE OUTFLOW	603.8	41.3	.000E+00	.0	.000		2419.0********
		***TOTAL OUTFLOW	603.8	41.3	.000E+00	.0	.000	2419.0	10.9
		***RETENTION	857.2	58.7	.000E+00	.0	.000	.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 -
.46	6.4663	2419.0	2.6723	.3742	.5867

CASE: Carbury (-25%) Nutrient Conc

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

SEGMENT: 1 deepest

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	343.0	.00	264.5	.00	1.30	.00	.97	.00
TOTAL N	MG/M3	2419.0	.00	1994.0	.00	1.21	.00	.88	.00
C.NUTRIENT	MG/M3	165.6	.00	132.9	.00	1.25	.00	1.10	.00
CHL-A	MG/M3	28.0	.00	25.6	.00	1.09	.00	.25	.00
SECCHI	M	.5	.00	.6	.00	.85	.00	-.57	.00
ORGANIC N	MG/M3	458.0	.00	424.8	.00	1.08	.00	.30	.00
TP-ORTHO-P	MG/M3	89.0	.00	82.9	.00	1.07	.00	.20	.00
HOD-V	MG/M3-DAY	.0	.00	405.1	.00	.00	.00	.00	.00
MOD-V	MG/M3-DAY	.0	.00	246.0	.00	.00	.00	.00	.00

CASE: Carbury (-25%) Nutrient Conc

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

SEGMENT: 1 deepest

VARIABLE		VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P	MG/M3	343.00	264.54	98.6	97.1
TOTAL N	MG/M3	2419.00	1993.95	91.6	85.9
C.NUTRIENT	MG/M3	165.59	132.87	97.2	95.0
CHL-A	MG/M3	28.00	25.64	92.2	90.4
SECCHI	M	.52	.61	16.8	22.6
ORGANIC N	MG/M3	458.00	424.80	47.3	41.5
TP-ORTHO-P	MG/M3	89.00	82.86	87.4	85.8
HOD-V	MG/M3-DAY	.00	405.10	.0	98.7
MOD-V	MG/M3-DAY	.00	245.99	.0	96.5
ANTILOG PC-1		1532.10	1158.77	91.9	88.2
ANTILOG PC-2		6.04	6.54	45.3	51.3
(N - 150) / P		6.62	6.97	8.3	9.5
INORGANIC N / P		7.72	8.64	8.8	10.7
TURBIDITY	1/M	1.00	1.00	71.4	71.4
ZMIX * TURBIDITY		3.00	3.00	47.5	47.5
ZMIX / SECCHI		5.77	4.92	62.8	52.2
CHL-A * SECCHI		14.56	15.63	69.2	72.7
CHL-A / TOTAL P		.08	.10	8.4	13.4
CARLSON TSI-P		88.33	84.58	.0	.0
CARLSON TSI-CHLA		63.29	62.43	.0	.0
CARLSON TSI-SEC		69.42	67.14	.0	.0

CASE: Carbury (-50%) Nutrient Conc
HYDRAULIC AND DISPERSION PARAMETERS:

SEG	OUT	NET INFLOW HM3/YR	RESIDENCE TIME YRS	OVERFLOW RATE M/YR	MEAN VELOCITY KM/YR	----DISPERSION----- ESTIMATED KM2/YR	NUMERIC KM2/YR	EXCHANGE RATE HM3/YR
1	0	.25	6.46635	.5	1.0	0.	0.	0.

CASE: Carbury (-50%) Nutrient Conc

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	East 385229	14.570	.009	.000E+00	.000	.001
2	1	West 385230	38.040	.388	.000E+00	.000	.010
3	1	Ungaugedshed	2.430	.014	.000E+00	.000	.006
4	4	Outlet 385228	55.578	.000	.000E+00	.000	.000
		PRECIPITATION	.538	.323	.417E-02	.200	.600
		TRIBUTARY INFLOW	55.040	.411	.000E+00	.000	.007
		***TOTAL INFLOW	55.578	.734	.417E-02	.088	.013
		ADVECTIVE OUTFLOW	.000	.250	.253E-01	.637	139586.500
		***TOTAL OUTFLOW	55.578	.250	.253E-01	.637	.004
		***EVAPORATION	.000	.484	.211E-01	.300	.000

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: CONSERV

ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	East 385229	.0	.0	.000E+00	.0	.000	.0	.0
2	1	West 385230	.0	.0	.000E+00	.0	.000	.0	.0
3	1	Ungaugedshed	.0	.0	.000E+00	.0	.000	.0	.0
4	4	Outlet 385228	.0	.0	.000E+00	.0	.000	.0	.0

HYDRAULIC OVERFLOW RATE M/YR	RESIDENCE TIME YRS	-------------- CONSERV -------------- POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
.46	6.4663	.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	East 385229	3.2	2.0	.000E+00	.0	.000	358.6	.2
2	1	West 385230	132.7	80.5	.000E+00	.0	.000	342.1	3.5
3	1	Ungaugedshed	4.9	2.9	.000E+00	.0	.000	347.0	2.0
4	4	Outlet 385228	.0	.0	.000E+00	.0	.000	343.0	.0
		PRECIPITATION	24.1	14.6	.146E+03	100.0	.500	74.8	44.9
		TRIBUTARY INFLOW	140.8	85.4	.000E+00	.0	.000	342.6	2.6
		***TOTAL INFLOW	164.9	100.0	.146E+03	100.0	.073	224.8	3.0
		ADVECTIVE OUTFLOW	85.6	51.9	.297E+04	2042.4	.637	343.0********	
		***TOTAL OUTFLOW	85.6	51.9	.297E+04	2042.4	.637	343.0	1.5
		***RETENTION	79.3	48.1	.312E+04	2142.4	.704	.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 -
.46	6.4663	343.0	3.3564	.2979	.4809

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	East 385229	10.2	.9	.000E+00	.0	.000	1132.3	.7
2	1	West 385230	592.7	51.7	.000E+00	.0	.000	1527.6	15.6
3	1	Ungaugedshed	12.9	1.1	.000E+00	.0	.000	924.4	5.3
4	4	Outlet 385228	.0	.0	.000E+00	.0	.000	2419.0	.0
		PRECIPITATION	529.9	46.3	.702E+05	100.0	.500	1641.7	985.0
		TRIBUTARY INFLOW	615.8	53.7	.000E+00	.0	.000	1498.4	11.2
		***TOTAL INFLOW	1145.8	100.0	.702E+05	100.0	.231	1561.4	20.6
		ADVECTIVE OUTFLOW	603.8	52.7	.148E+06	210.6	.637		2419.0********
		***TOTAL OUTFLOW	603.8	52.7	.148E+06	210.6	.637	2419.0	10.9
		***RETENTION	542.0	47.3	.218E+06	310.6	.862	.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 -
.46	6.4663	2419.0	3.4076	.2935	.4730

CASE: Carbury (-50%) Nutrient Conc

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

SEGMENT: 1 deepest

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	343.0	.00	185.2	.53	1.85	.00	2.29	1.16
TOTAL N	MG/M3	2419.0	.00	1563.7	.48	1.55	.00	1.98	.91
C.NUTRIENT	MG/M3	165.6	.00	99.4	.46	1.67	.00	2.54	1.12
CHL-A	MG/M3	28.0	.00	21.7	.39	1.29	.00	.73	.65
SECCHI	M	.5	.00	.6	.17	.80	.00	-.78	-1.30
ORGANIC N	MG/M3	458.0	.00	378.6	.29	1.21	.00	.76	.65
TP-ORTHO-P	MG/M3	89.0	.00	74.1	.30	1.20	.00	.50	.62
HOD-V	MG/M3-DAY	.0	.00	373.1	.24	.00	.00	.00	.00
MOD-V	MG/M3-DAY	.0	.00	226.6	.33	.00	.00	.00	.00

CASE: Carbury (-50%) Nutrient Conc

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

SEGMENT: 1 deepest

VARIABLE		VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P	MG/M3	343.00	185.19	98.6	93.4
TOTAL N	MG/M3	2419.00	1563.71	91.6	75.7
C.NUTRIENT	MG/M3	165.59	99.40	97.2	90.0
CHL-A	MG/M3	28.00	21.75	92.2	86.2
SECCHI	M	.52	.65	16.8	25.1
ORGANIC N	MG/M3	458.00	378.65	47.3	33.0
TP-ORTHO-P	MG/M3	89.00	74.06	87.4	82.9
HOD-V	MG/M3-DAY	.00	373.08	.0	98.3
MOD-V	MG/M3-DAY	.00	226.55	.0	95.5
ANTILOG PC-1		1532.10	832.49	91.9	82.5
ANTILOG PC-2		6.04	6.34	45.3	49.0
(N - 150) / P		6.62	7.63	8.3	12.0
INORGANIC N / P		7.72	10.66	8.8	15.1
TURBIDITY	1/M	1.00	1.00	71.4	71.4
ZMIX * TURBIDITY		3.00	3.00	47.5	47.5
ZMIX / SECCHI		5.77	4.63	62.8	48.0
CHL-A * SECCHI		14.56	14.09	69.2	67.6
CHL-A / TOTAL P		.08	.12	8.4	21.0
CARLSON TSI-P		88.33	79.44	.0	.0
CARLSON TSI-CHLA		63.29	60.81	.0	.0
CARLSON TSI-SEC		69.42	66.26	.0	.0

CASE: Carbury (-75%) Nutrient Conc
HYDRAULIC AND DISPERSION PARAMETERS:

		NET INFLOW	RESIDENCE TIME	OVERFLOW RATE	MEAN VELOCITY	----DISPERSION----- ESTIMATED	NUMERIC	EXCHANGE RATE
SEG	OUT	HM3/YR	YRS	M/YR	KM/YR	KM2/YR	KM2/YR	HM3/YR
1	0	.25	6.46635	.5	1.0	0.	0.	0.

CASE: Carbury (-75%) Nutrient Conc

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	East 385229	14.570	.009	.000E+00	.000	.001
2	1	West 385230	38.040	.388	.000E+00	.000	.010
3	1	Ungaugedshed	2.430	.014	.000E+00	.000	.006
4	4	Outlet 385228	55.578	.000	.000E+00	.000	.000
		PRECIPITATION	.538	.323	.000E+00	.000	.600
		TRIBUTARY INFLOW	55.040	.411	.000E+00	.000	.007
		***TOTAL INFLOW	55.578	.734	.000E+00	.000	.013
		ADVECTIVE OUTFLOW	.000	.250	.000E+00	.000	139586.500
		***TOTAL OUTFLOW	55.578	.250	.000E+00	.000	.004
		***EVAPORATION	.000	.484	.000E+00	.000	.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	East 385229	.0	.0	.000E+00	.0	.000	.0	.0
2	1	West 385230	.0	.0	.000E+00	.0	.000	.0	.0
3	1	Ungaugedshed	.0	.0	.000E+00	.0	.000	.0	.0
4	4	Outlet 385228	.0	.0	.000E+00	.0	.000	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	CONSERV POOL CONC MG/M3	CONSERV RESIDENCE TIME YRS	CONSERV TURNOVER RATIO -	CONSERV RETENTION COEF -
.46	6.4663	.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	East 385229	1.6	1.4	.000E+00	.0	.000	179.3	.1
2	1	West 385230	66.6	58.9	.000E+00	.0	.000	171.7	1.8
3	1	Ungaugedshed	20.7	18.3	.000E+00	.0	.000	1479.1	8.5
4	4	Outlet 385228	.0	.0	.000E+00	.0	.000	343.0	.0
		PRECIPITATION	24.1	21.3	.000E+00	.0	.000	74.8	44.9
		TRIBUTARY INFLOW	88.9	78.7	.000E+00	.0	.000	216.4	1.6
		***TOTAL INFLOW	113.1	100.0	.000E+00	.0	.000	154.1	2.0
		ADVECTIVE OUTFLOW	85.6	75.7	.000E+00	.0	.000		343.0********
		***TOTAL OUTFLOW	85.6	75.7	.000E+00	.0	.000	343.0	1.5
		***RETENTION	27.5	24.3	.000E+00	.0	.000	.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 -
.46	6.4663	343.0	4.8961	.2042	.2428

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	East 385229	5.1	.6	.000E+00	.0	.000	566.1	.3
2	1	West 385230	296.5	35.3	.000E+00	.0	.000	764.1	7.8
3	1	Ungaugedshed	9.3	1.1	.000E+00	.0	.000	664.4	3.8
4	4	Outlet 385228	.0	.0	.000E+00	.0	.000	2419.0	.0
		PRECIPITATION	529.9	63.0	.000E+00	.0	.000	1641.7	985.0
		TRIBUTARY INFLOW	310.9	37.0	.000E+00	.0	.000	756.4	5.6
		***TOTAL INFLOW	840.8	100.0	.000E+00	.0	.000	1145.8	15.1
		ADVECTIVE OUTFLOW	603.8	71.8	.000E+00	.0	.000		2419.0********
		***TOTAL OUTFLOW	603.8	71.8	.000E+00	.0	.000	2419.0	10.9
		***RETENTION	237.0	28.2	.000E+00	.0	.000	.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 -
.46	6.4663	2419.0	4.6435	.2154	.2819

CASE: Carbury (-75%) Nutrient Conc

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

SEGMENT: 1 deepest

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	343.0	.00	127.0	.00	2.70	.00	3.69	.00
TOTAL N	MG/M3	2419.0	.00	1147.5	.00	2.11	.00	3.39	.00
C.NUTRIENT	MG/M3	165.6	.00	69.5	.00	2.38	.00	4.32	.00
CHL-A	MG/M3	28.0	.00	16.9	.00	1.66	.00	1.46	.00
SECCHI	M	.5	.00	.7	.00	.74	.00	-1.08	.00
ORGANIC N	MG/M3	458.0	.00	320.9	.00	1.43	.00	1.42	.00
TP-ORTHO-P	MG/M3	89.0	.00	63.1	.00	1.41	.00	.94	.00
HOD-V	MG/M3-DAY	.0	.00	328.7	.00	.00	.00	.00	.00
MOD-V	MG/M3-DAY	.0	.00	199.6	.00	.00	.00	.00	.00

CASE: Carbury (-75%) Nutrient Conc

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

SEGMENT: 1 deepest

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	343.00	126.95	98.6	86.1
TOTAL N MG/M3	2419.00	1147.49	91.6	58.4
C.NUTRIENT MG/M3	165.59	69.54	97.2	79.8
CHL-A MG/M3	28.00	16.88	92.2	77.7
SECCHI M	.52	.70	16.8	28.6
ORGANIC N MG/M3	458.00	320.94	47.3	22.2
TP-ORTHO-P MG/M3	89.00	63.05	87.4	78.3
HOD-V MG/M3-DAY	.00	328.70	.0	97.4
MOD-V MG/M3-DAY	.00	199.60	.0	93.5
ANTILOG PC-1	1532.10	532.49	91.9	72.3
ANTILOG PC-2	6.04	5.90	45.3	43.5
(N - 150) / P	6.62	7.86	8.3	12.9
INORGANIC N / P	7.72	12.94	8.8	20.2
TURBIDITY 1/M	1.00	1.00	71.4	71.4
ZMIX * TURBIDITY	3.00	3.00	47.5	47.5
ZMIX / SECCHI	5.77	4.27	62.8	42.4
CHL-A * SECCHI	14.56	11.87	69.2	58.5
CHL-A / TOTAL P	.08	.13	8.4	27.1
CARLSON TSI-P	88.33	74.00	.0	.0
CARLSON TSI-CHLA	63.29	58.33	.0	.0
CARLSON TSI-SEC	69.42	65.07	.0	.0

Appendix C

Formal/Informal Comments Received
During 30 Day Public Notice Period
and the NDDoH's Response to Comments

During the 30 day public notice soliciting comment and participation for the Carbury Dam

Nutrient and Dissolved Oxygen TMDLs, the NDDoH received informal comments from the North Dakota Game and Fish office, as well as from Mr. Vern Berry of US EPA, Region 8. Below are the comments made, the sections they address, and the Department's response.

NDG&F:

Section 1.0 Page 2, Figure 2: The NDG&F felt that the area adjacent to the northwest edge of the displayed Carbury Dam watershed was also a contributing area and should be included within the boundary.

NDDoH Response: The current boundary was verified and will remain as originally indicated.

Page 3, Tables 1 and 2: The NDG&F provided updated lake statistics for Carbury Dam.

NDDoH Response: The tables were changed accordingly.

US EPA, Region 8:

Section 4.1: This section lists two feedlots under the point source category. These appear to be below the threshold for needing NPDES permit coverage, therefore we recommend moving them to the nonpoint source section. The potential nutrient loads from failing septic systems and from animal feeding areas should be considered during the BMP implementation as possible sources that can help achieve the desired phosphorus load reduction.

NDDOH Response: The mention of the two animal feeding operations (AFOs) was taken out of Section 4.1 (Point Sources) and added to Section 4.2 (Nonpoint Sources). There are no dwellings around Carbury Dam, but all potential sources of nutrient loads (failing septic systems and animal feeding areas included) are investigated during the implementation phase of any TMDL project.

Section 7.1 , Page 34: A statement needs to be added to the TMDL section that explains that the TMDL load is a "measured load" and may not represent the actual long term average load (actual loads may be higher or lower in any given year**)** Likewise the actual loads to the lake post-implementation (i.e. as expressed by the loading capacity), may be higher or lower in a given year.

NDDOH Response: The wording on "measured load" was added to Section 7.1.

Monitoring Strategy: We recommend expanding the monitoring language in Section 8.0. Monitoring is necessary to address margin of safety and seasonality needs, as well as provide additional data to ensure that the goals of the TMDL are met. Monitoring should continue until it can be demonstrated that water quality goals are achieved. We recommend that the monitoring period continue for at least 10 years after the BMLs are implemented (perhaps conducting monitoring every 3-5 years until the TMDL target is met).

NDDOH Response: Section 8.0 was not changed but Section 10.0 Monitoring and Section 11.0 TMDL Implementation Strategy were added to address the concerns brought up by EPA.