Nutrient, Sediment, and Dissolved Oxygen TMDLs for Armourdale Dam in Towner County, North Dakota

Final: November 2006

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1.0 INTRODUCTION AND DESCRIPTION OF THE WATERSHED

Armourdale Dam is a small reservoir on Armourdale Coulee and is located in Towner County approximately 10-miles east and 2-miles west of Rolla, North Dakota. Completed in 1961, Armourdale Dam was constructed for the purposes of water recreation and flood control. The reservior also serves as a state wildlife management area.

The Armourdale Dam watershed is a 13,680-acre watershed located in Towner County. The Armourdale Dam watershed lies completely within the Northern Glaciated Plains ecoregion (46); which is characterized by a flat to gently rolling landscape composed of glacial till. The subhumid climate fosters a grassland, transitional between the tall and shortgrass prairie. Though the till soil is very fertile, agricultural success is subject to annual climatic fluctuations. Table 1 summarizes some of the geographical, hydrological, and physical characteristics of Armourdale Dam and its watershed.

Table 1. General Characteristics of Armourdale Dam and its Watershed.

Legal Name	Armourdale Dam
Major Drainage Basin	Pembina River Basin
Nearest Municipality	Rolla, North Dakota
Assessment Unit ID	ND-09020313-011-L_00
County Location	Towner County, North Dakota
Physiographic Region	Northern Glaciated Plains
Latitude	48.88306
Longitude	-99.46639
Surface Area	79.3-acres
Watershed Area	13,680-acres
Average Depth	13.0-feet
Maximum Depth	34.8-feet
Volume	1,036.1 acre-feet
Tributaries	North and South branchs of the Armourdale Coulee
Type of Waterbody	Constructed Reservoir
Dam Type	Constructed Earthen Dam
Fishery Type	Walleye, Northern Pike, Bluegill, and Largemouth Bass

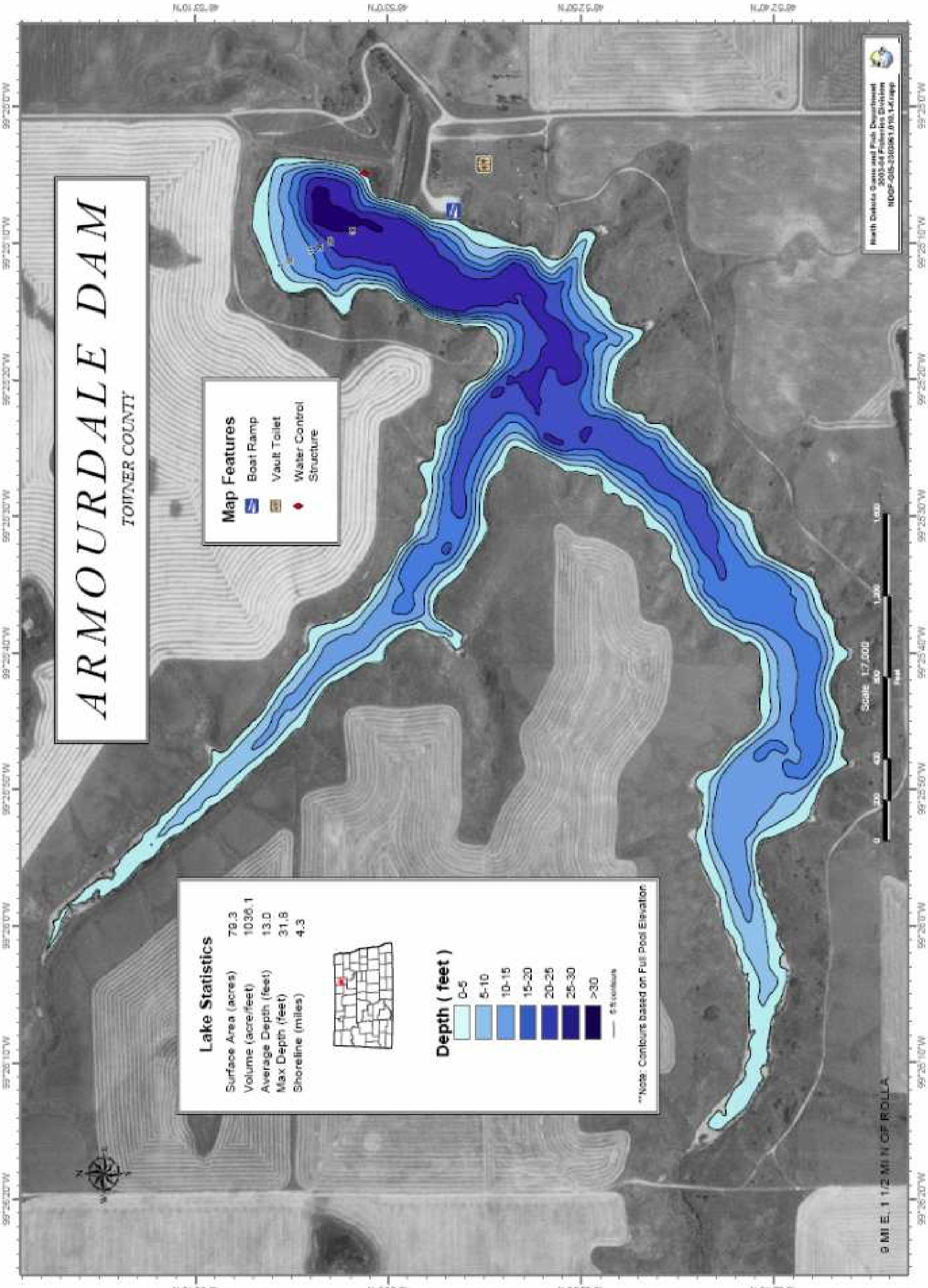

Figure 1. North Dakota Game and Fish Contour Map of Armourdale Dam.

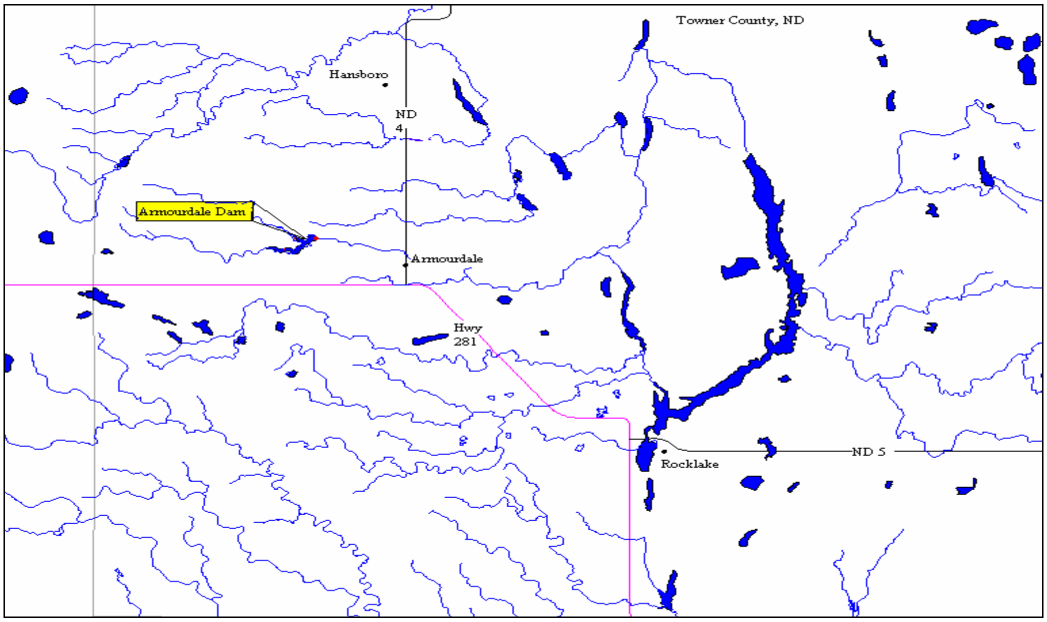

Figure 2. General Location of Armourdale Dam.

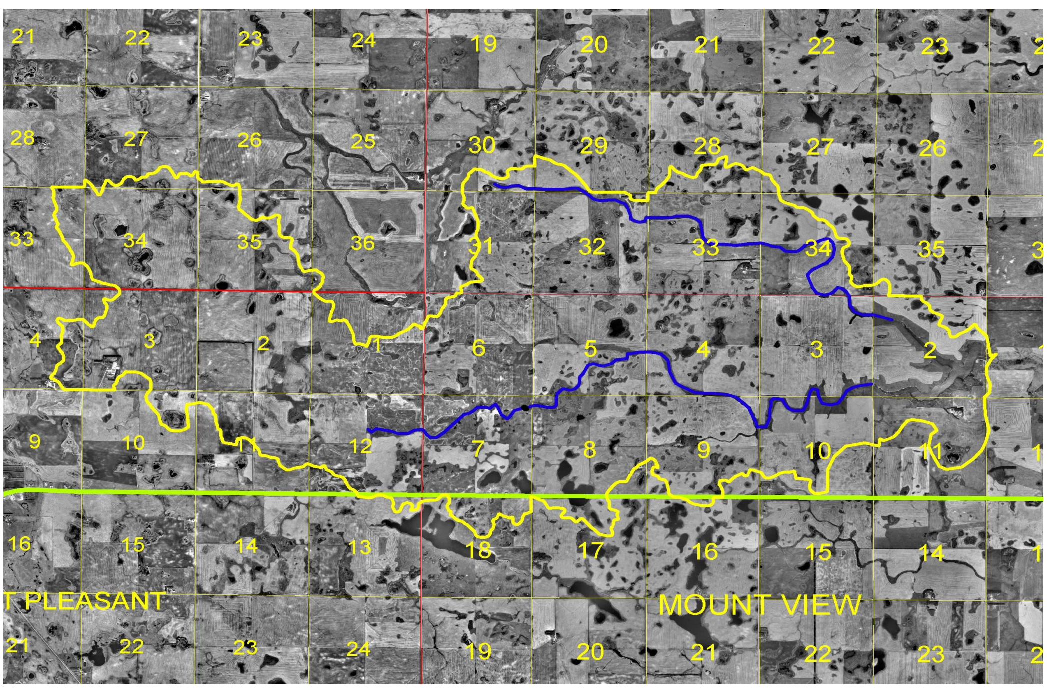

Figure 3. General Location of the Armourdale Dam Watershed.

1.1 Clean Water Act Section 303(d) Listing Information

As part of the Clean Water Act Section 303(d) listing process, the North Dakota Department of Health (NDDoH) has identified Armourdale Dam as an impaired waterbody (Table 2). Based on a Trophic State Index (TSI) score, aquatic life and recreation uses of Armourdale Dam are impaired. Aquatic life is listed as impaired due to nutrients, sedimentation, and low dissolved oxygen. Recreational use is impaired due to nutrients. North Dakota's Section

303(d) list did not provide any potential sources of these impairments. Armourdale Dam has been classified as a Class 2 cool-water fishery, "capable of supporting growth and propagation of nonsalmonid fishes and marginal growth of salmonid fishes and associated aquatic biota" (NDDoH, 1991).

Table 2. Armourdale Dam Section 303(d) Listing Information (NDDH, 2004).

Assessment Unit ID	ND-09020313-011-L_00
Waterbody Name	Armourdale Dam
Water Quality Standards Classification	2 - Cool-water fishery
Impaired Uses	Fish and Other Aquatic Biota (not supporting), Recreation (not supporting)
Causes	Nutrients, Dissolved Oxygen, Sedimentation
Priority	High
First Appeared on 303(d) list	1998

1.2 Topography

The topography of the watershed is characterized by a mixture of flats, rises, and depressions. Soils in the watershed area on land that is level to nearly level are highly calcarious and poorly to moderately drained. Ridges and knolls are moderately to well drained and depressions are poorly drained. Slopes are short and irregular ranging from 0 to 3 percent (NDDoH, 1993). The elevation in Towner County ranges from 1,775 feet MSL in the northwest to approximately 1,450 feet MSL in the southeast. Soils in Towner County are mostly very deep and well suited for cropland, except the hilly to steep soils which are utilized for pastureland or hayland. Parent material is largely glacial origin with many soils being prone to wind and water erosion

1.3 Land Use/Land Cover

Land use in the Armourdale Dam watershed is primarily agricultural (97%). Approximately 90%, 4%, and 3% of land within the watershed is used for cropland, CRP, and pasture, respectively. The remainder of the land is divided up into recreation, water, and wetlands. There are no large urban areas within the watershed. A majority of the crops grown consist of largely wheat, canola, flax, barley, corn and sunflowers. Figure 4 shows the distribution of land uses in the Armourdale Dam watershed.

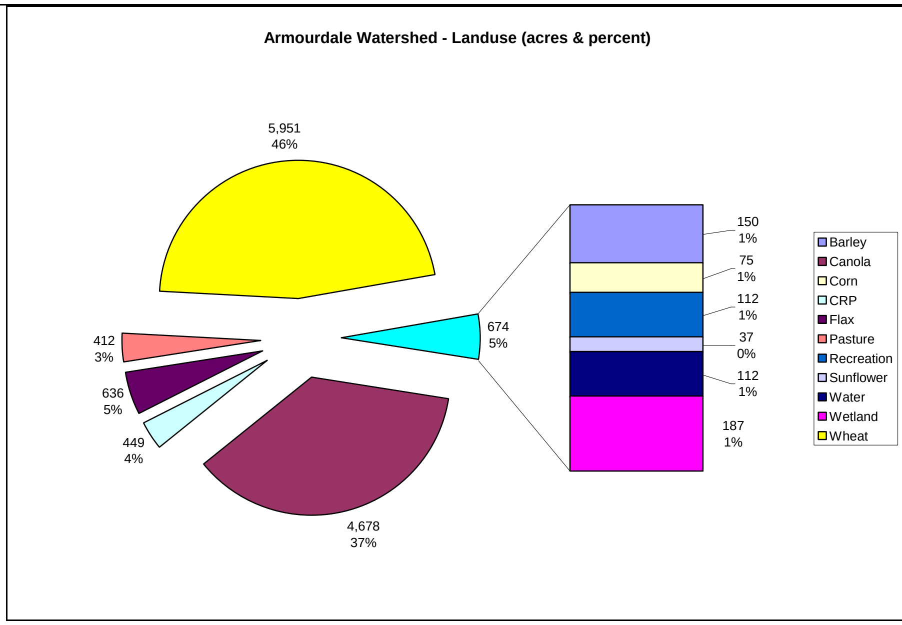

Figure 4. Armourdale Dam Watershed Landuse Data.

1.4 Climate and Precipitation

Towner County has a subhumid climate characterized by warm summers with frequent hot weather and occasional cool days. Winters are very cold influenced by arctic air surging over the area. Average temperature ranges vary from 4º F in January to 68º F in July. A majority of annual precipitation occurs in late spring to early summer with average annual rainfall of approximately 17 inches and average annual snowfall of 38 inches. Winds prevail generally from the northwest at an annual average wind speed of 12.9 mph.

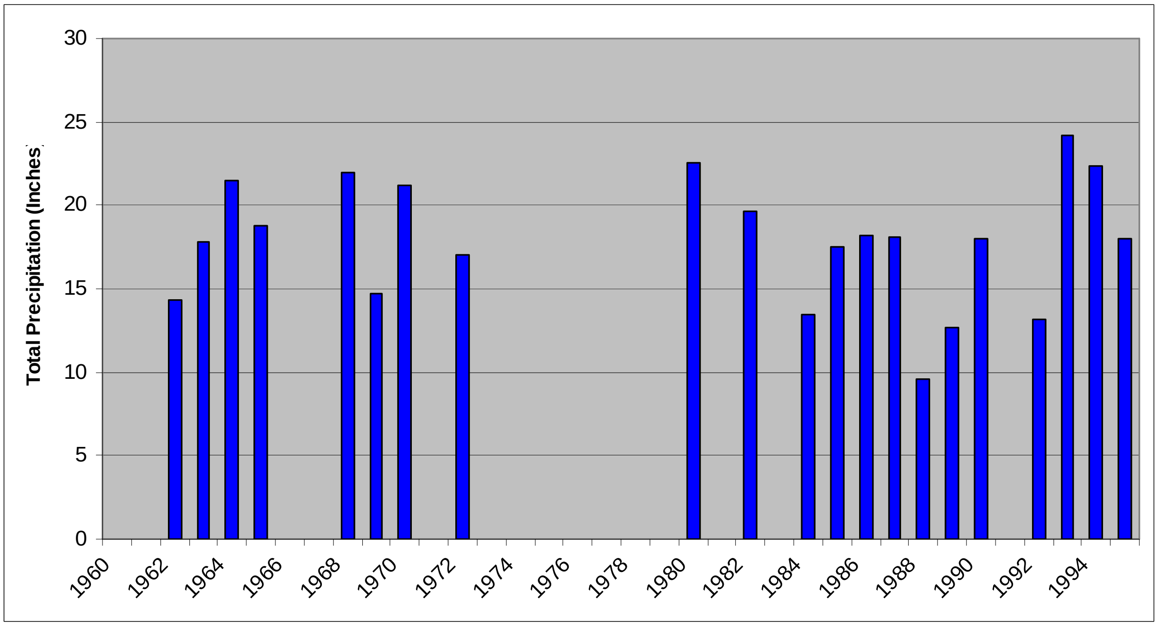

Figure 5. Total Annual Precipitation at Hansboro, North Dakota from 1960-1997. Incomplete data were available for 1960-1961, 1966-1967, 1971, 1973-1981, 1983, 1991, and 1996-1997.

1.5 Available Water Quality Data

1.5.1 1991-1992 Lake Water Quality Assessment Project

A Lake Water Quality Assessment (LWQA) was conducted on Armourdale Dam in 1991-1992. Two samples were collected in the summer 1991 and once during the winter of 1991. Samples were collected at one site located in the deepest area of the lake (381225). During summer sampling in 1991, Armourdale Dam thermally stratified in July and August between five and seven meters. Dissolved oxygen concentrations during this period were between 7.0 and 11.0 mg L^{-1} above the thermocline and declining to below 2.0 mg L^{-1} near the bottom. Winter sampling in February observed thermal stratification occurring at a depth between one and three meters. Dissolved oxygen concentrations were between 1.0 and 3.0 mg L^{-1} above the thermocline and near 1.0 mg L^{-1} below the thermocline.

The 1991-1992 LWQA project characterized Armourdale Dam as having relatively high concentrations of total phosphate as P (0.676 mg L^{-1}), total Kjeldahl nitrogen (2.93 mg L^{-1}), and ammonia (0.789 mg L^{-1}). Other sample parameters and average volume weighted mean concentrations are provided in Table 3. The volume-weighted means are calculated by weighting the parameter analyzed by the percentage of water volume represented at each depth interval.

Trophic status was also determined using the water quality data collected during the LWQA project. Armourdale Dam was identified as being hypereutrophic with total phosphorus at 0.676 mg L^{-1}, chlorophyll-a concentrations ranged from between 23 and 43 $\mu g\ L^{-1}$, and secchi disk transparency was less than 1.0-meters. Other evidence for a hypereutrophic assessment included a macrophyte community occupying nearly 100 percent of the surface area to a depth of 3-meters, a phytoplankton population dominated by blue-green algae species, and a low dissolved oxygen concentration during ice cover and below the hypoliminion during ice free periods of the year.

Table 3. Data Summary for Armourdale Dam Lake Water Quality Assessment (1991-1992).

Parameter	Units	Lake Water Quality Assessment (1991-1992)				Volume Weighted Mean
		Max	Median	Avg	Min	
Total Phosphorus	mg L^{-1}	1.94	0.572	0.863	0.486	0.676
Dissolved Phosphorus	mg L^{-1}	1.82	0.46	0.879	0.43	0.642
Total Nitrogen	mg L^{-1}	5.82	0.43	1.46	0.017	0.789
Total Kjeldahl Nitrogen	mg L^{-1}	8	2.44	3.23	1.5	2.93
Nitrate/Nitrite	mg L^{-1}	0.155	0.018	0.031	0	0.028

1.5.2 2002-2003 Armourdale TMDL Project

The Towner County Soil Conservation District (SCD) conducted a water quality assessment of Armourdale Dam and its watershed from December 2002 to September 2004. Sampling was done on two inlet sites (384045 and 384046), one outlet site (385215), and three reservoir sites (381225, 385216, and 385217) on the Armourdale Dam and its accompanying watershed. Sites are identified in Tables 3 and 4, and Figures 6 and 7.

Stream Monitoring

Sampling frequency for the stream sampling sites was stratified to coincide with the typical hydrograph for the region. This sampling design results in more frequent samples during spring and early summer, typically when stream discharge is greatest and less frequent samples during the summer and fall. Sampling was discontinued during the winter during ice cover. Sampling was terminated when the stream stopped flowing.

Lake Monitoring

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

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

Sample Site	Site ID	Dates Sampled Start	End	Latitude	Longitude
Stream Sites					
South Inlet	384045	3/25/03	6/15/04	48.87272	-99.46048
North Inlet	384046	3/25/03	6/15/04	48.89177	-99.44347
Dam Outlet	385215	3/17/04	6/15/04	48.88357	-99.41659
Lake Sites					
South Arm	385217	1/30/03	9/11/04	48.87833	-99.43194
North Arm	385216	1/30/03	9/11/04	48.88375	-99.41874
Deepest	381225	12/19/02	9/11/04	48.88337	-99.4271

The Towner County SCD followed the methodology for water quality sampling found in the QAPP Quality Assurance Project Plan for the Armourdale Dam TMDL Project. (NDDoH, 2002) Sampling and analysis variables are shown in Table 4.

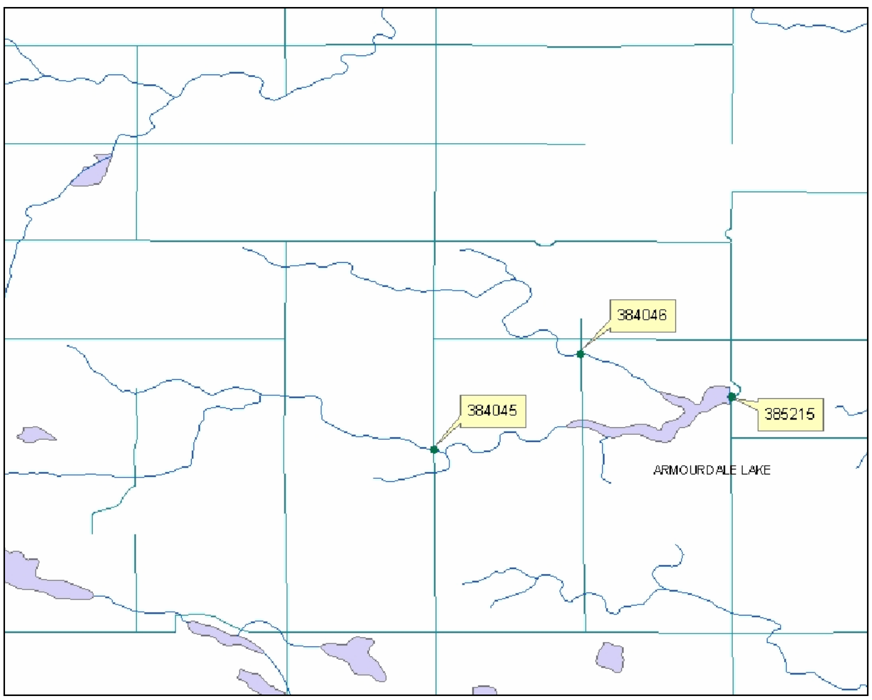

Figure 6. Stream Sampling Sites for the Armourdale Dam.

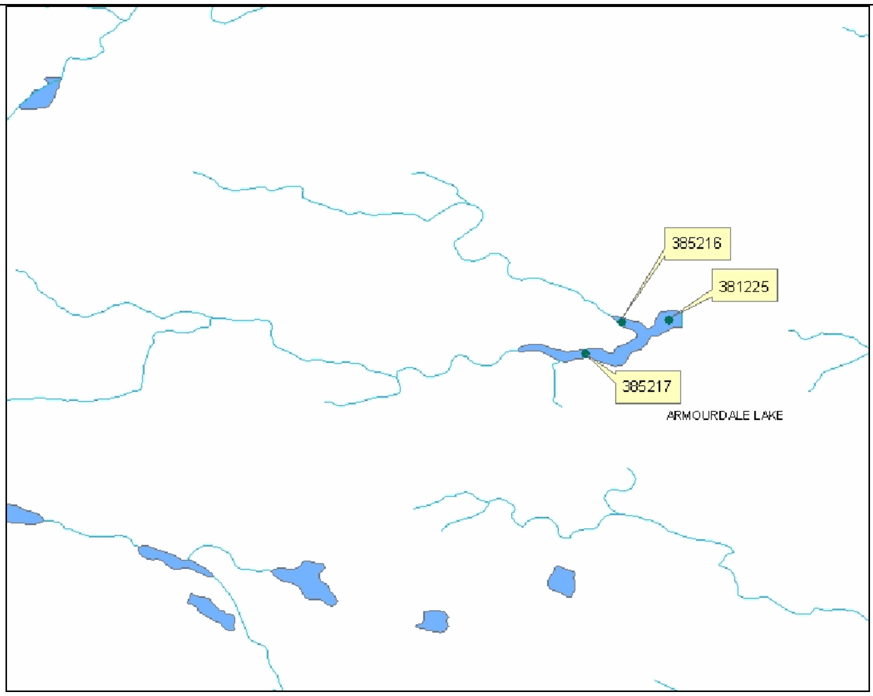

Figure 7. Lake Sampling Sites for Armourdale Dam.

Table 5. Armourdale Dam Sampling and Analysis Parameters.

Field Measurements	General Chemical Variables	Nutrient Variables	Biological Variables
Secchi Disk Transparency	pH	Total Phosphorus	Chlorophyll-a
Temperature	Specific Conductance	Dissolved Phosphorus	Phytoplankton
Dissolved Oxygen	Major Anions & Cations	Total Nitrogen	
	Total Suspended Solids	Total Kjeldahl Nitrogen	
		Nitrate plus Nitrite Nitrogen	
		Ammonia Nitrogen	

1.5.3 Nutrient Data

Surface water quality parameters were monitored in Armourdale Dam at three sites between December 2002 and September 2004. Data for the three sites in the lake are summarized in Table 6. The data show that of average total phosphorus and dissolved phosphorus concentrations were comparable at all three sites with values ranging from 0.209-0.214 mg L^{-1} and 0.172-0.179 mg L^{-1}, respectively. Total Kjeldahl nitrogen and nitrate/nitrite displayed a similar pattern with ranging values from 1.83-1.86 mg L^{-1} and 0.14-0.16 mg L^{-1}, respectively. Total nitrogen was also similar with average concentrations ranging from 1.99-2.06 mg L^{-1}. Armourdale has a total nitrogen to total phosphorus ratio of 10.04. Ratios above 7.2 generally indicate that phosphorus is the limiting nutrient (Chapra, 1997).

Table 6. Data Summary for Armourdale Dam TMDL Project 2002-2004.

Parameter	North Arm Site (385216)					South Arm Site (385217)					Deepest Site (381225)				
	N	Max	Median	Avg	Min	N	Max	Median	Avg	Min	N	Max	Median	Avg	Min
Total Phosphorus (mg/L)	10	0.329	0.214	0.210	0.114	10	0.373	0.209	0.218	0.113	33	0.595	0.214	0.219	0.061
Dissolved Phosphorus (mg/L)	10	0.312	0.163	0.172	0.085	10	0.323	0.167	0.175	0.086	33	0.475	0.183	0.179	0.024
Total Nitrogen (mg/L)	10	2.4	2.035	1.998	1.47	10	2.43	2.065	2.023	1.47	33	2.56	2.05	1.996	1.49
Total Kjeldahl Nitrogen (mg/L)	10	2.15	1.94	1.835	1.33	10	2.21	1.97	1.867	1.34	33	2.36	1.98	1.852	1.26
Nitrate/Nitrite (mg/L)	10	0.36	0.13	0.163	0.05	10	0.36	0.12	0.155	0.01	33	0.35	0.1	0.144	0.02
Chlorophyll-a (μg/L)	0	0	0	0	0	2	45.4	23.2	23.2	1	5	60.9	1	13.58	1
Secchi Disk (meters)	2	1.25	0.925	0.925	0.6	2	1	0.9	0.9	0.8	5	1	1	1	1

Nutrient concentrations from Armourdale Dam in 2002-2004 can be compared to data collected from the 1991-1992 Lake Water Quality Assessment. Nutrient concentrations reported for 1991-1992 LWQA were higher for total phosphorus and dissolved phosphorus but lower for nitrate/nitrite, total Kjeldahl nitrogen, and slightly lower for total nitrogen when compared to 2002-2004 data (Table 3 and 6).

1.5.4 Dissolved Oxygen and Temperature

Dissolved oxygen and temperature were monitored at the deepest, north arm, and south arm sites of Armourdale Dam from February 2002-September 2004. Samples were collected at 1-meter intervals during ice over and open water periods. During summer sampling in 2004, Armourdale Dam thermally stratified at the deepest site on August 29, 2004 between five and six meters of depth. Dissolved oxygen concentrations ranged from 8.2 mg L^{-1} at the surface, and 7.5 mg L^{-1} at the bottom. Based on 2003 and 2004 data there appears to be a periods during winter ice over and open water when dissolved oxygen concentrations are below the 5 mg L^{-1} state was standard in the hypolimnion. This was particular evident from measurements taken in February and March of 2004. This trend is very similar to the previous LWQA conducted in 1991-1992. The north and south arm sites appeared to show the same trends towards dissolved oxygen concentration levels as the deepest site, with concentrations falling below the state standard during the months of February and March 2004 (Figures 8-13).

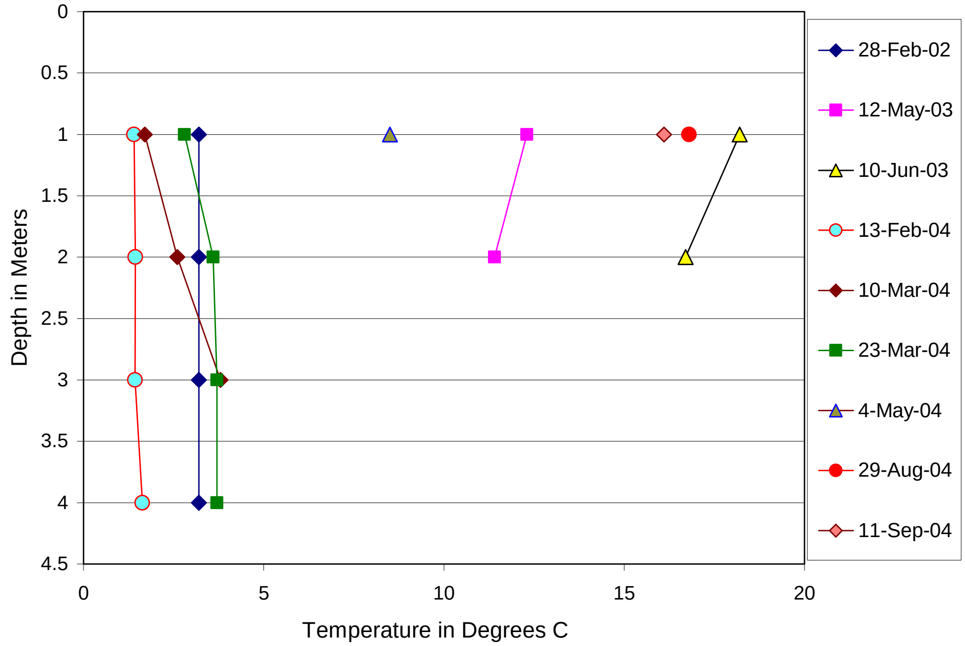

Figure 8. Summary of Temperature Data for the Armourdale Dam North Arm Site (385216).

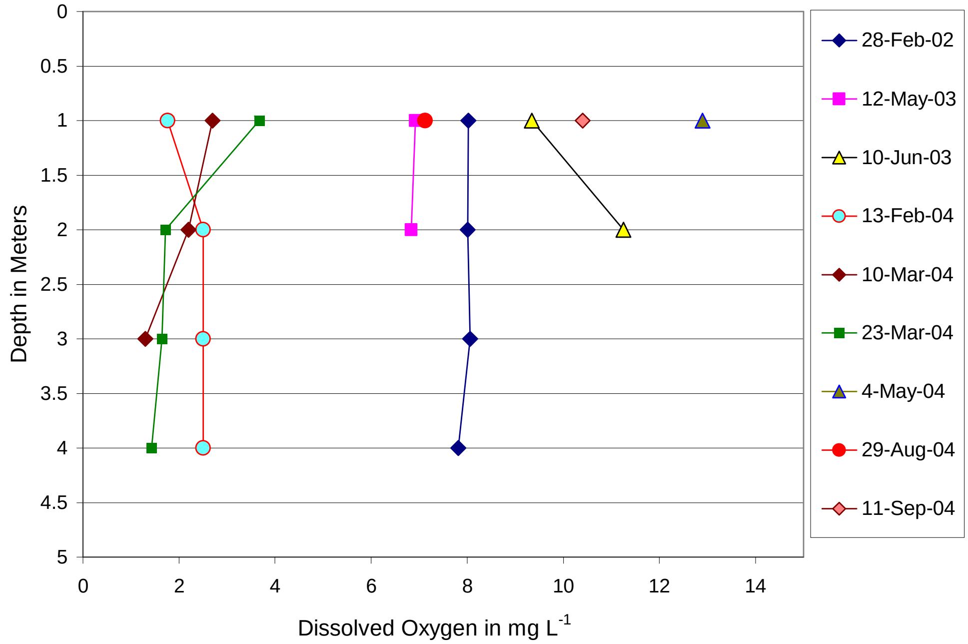

Figure 9. Summary of Dissolved Oxygen Concentrations for the Armourdale Dam North Arm Site (385216).

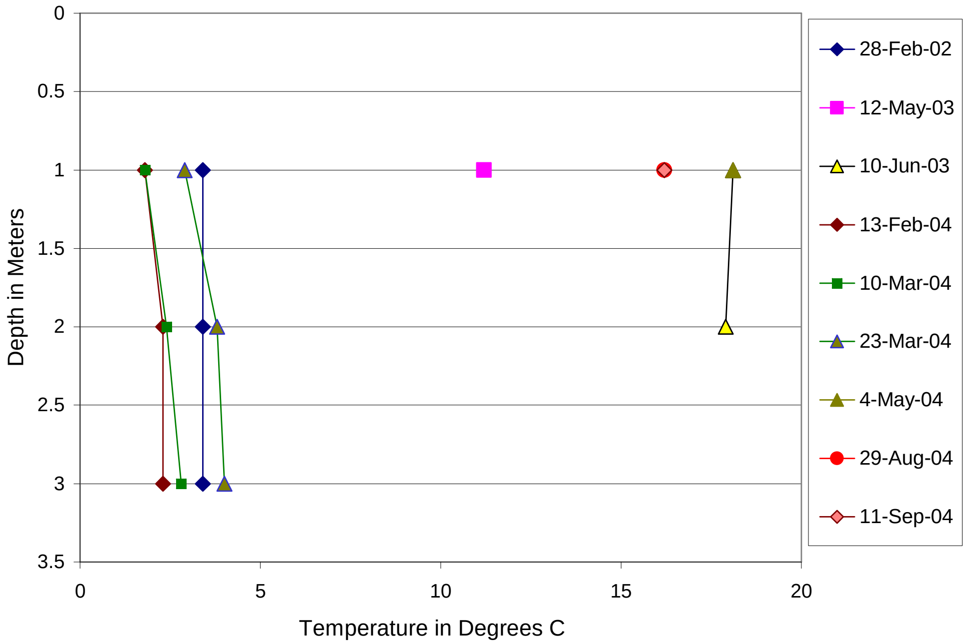

Figure 10. Summary of Temperature Data for the Armourdale Dam South Arm Site (385217).

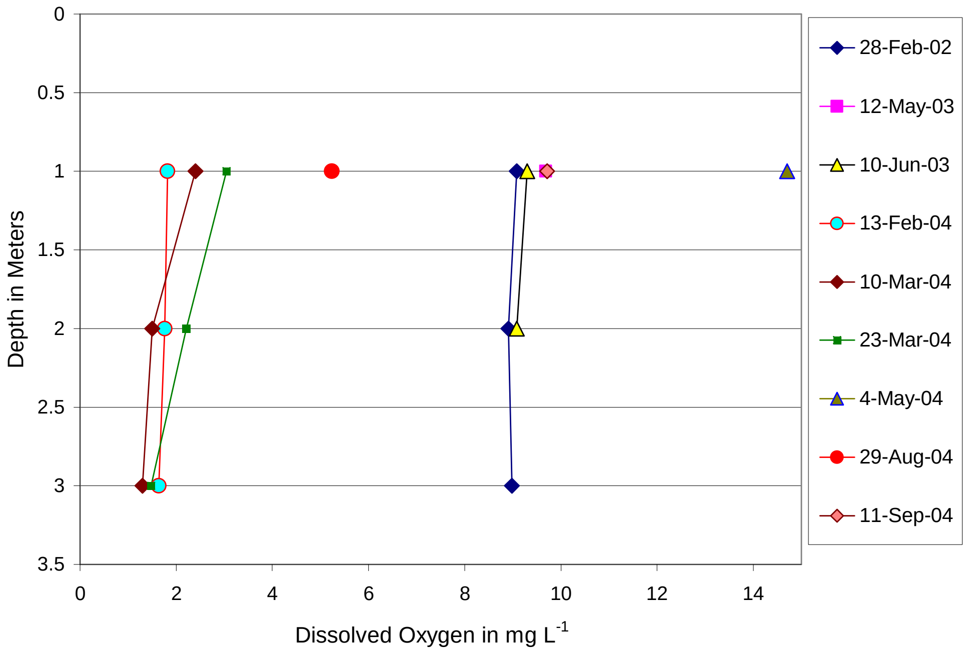

Figure 11. Summary of Dissolved Oxygen Concentrations for the Armourdale Dam South Arm Site (385217).

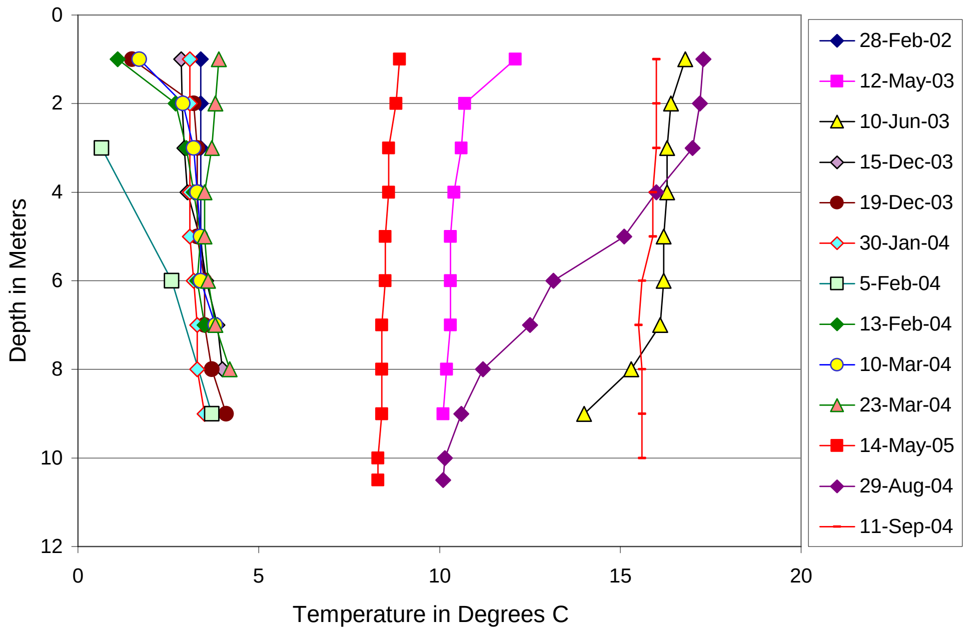

Figure 12. Summary of Temperature Data for the Armourdale Dam Deepest Area Site (381225).

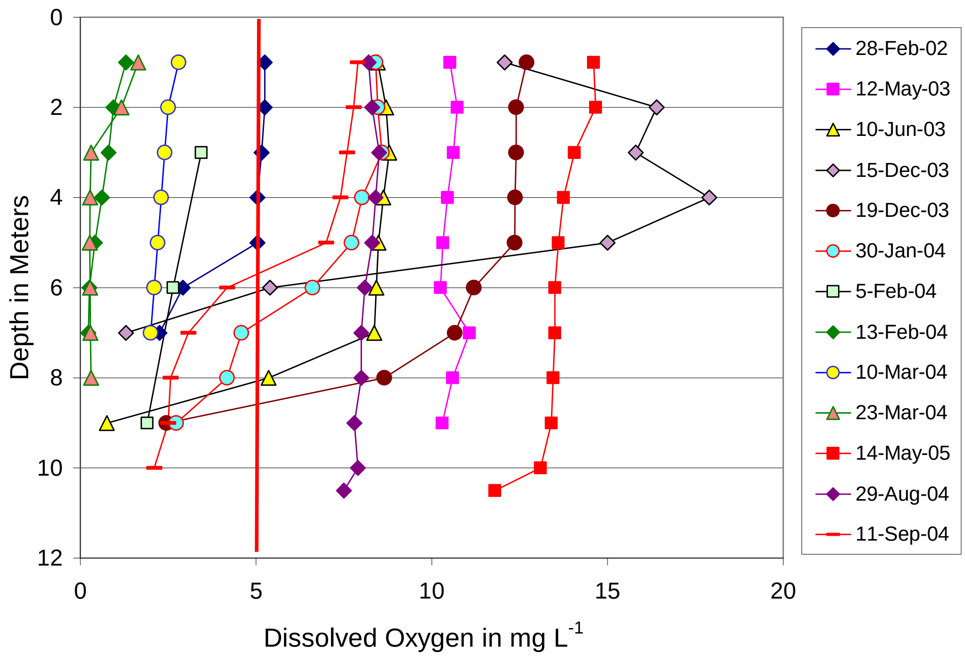

Figure 13. Summary of Dissolved Oxygen Concentrations for the Armourdale Dam Deepest Area Site (381225).

1.5.5 Secchi Disk Transparency and Chlorophyll-a

Secchi disk transparency measurements were collected by the Towner County SCD staff between December 2002 and September 2004. As shown in Table 7 Secchi transparency measurements were only taken three times at the deepest sites and only two times each at the north and south arm sites. Based on there limited data an accurate assessment of the trophic status of Armourdale Dam based on secchi disk transparency is inconclusive.

Table 7. Summary of Secchi Depths in Armourdale Dam (2002-2004).

North Arm Site (385216)		South Arm Site (385217)		Deepest Site (381225)	
Date	Average Secchi Depth (M)	Date	Average Secchi Depth (M)	Date	Average Secchi Depth (M)
5/4/2004	0.6	5/4/2004	0.8	2/28/2003	3.5
8/29/2004	1.25	8/29/2004	1	5/4/2004	0.6
				9/11/2004	2

Since there is very little data available for secchi disk transparency, the chlorophyll TSI (Table 10) will be used as an indicator of trophic status for the reservoir. Justification for using the chlorophyll TSI is given in Carlson and Simpson (1996). According to Carlson and Simpson, Secchi disk and chlorophyll TSI's are usually in close agreement in a shallow and nutrient enriched reservoir because most of the light limitation is related to algae in the water.

1.5.6 Tributary Total Suspended Solids

Sixteen total suspended solids (TSS) samples were collected by the Towner County SCD staff between March 2003 and June 2004. TSS samples were collected from the north and south inlet and from the outlet to the reservoir. Average TSS concentrations at the north inlet were 12.7 mg L^{-1}, 7.4 mg L^{-1} at the south inlet site, and 14.2 mg L^{-1} from the outlet (Table 8). These data suggest that very little sediment is being retained within the reservoir. As shown in Table 8, TSS concentrations in samples taken from the outlet are more than half of that of the combined average of the two inlets.

Table 8. Average Total Suspended Solids Concentrations for the Armourdale Dam North and South Inlet and Outlet Sites (2003-2004).

Site ID	Site Description	Average TSS (mg L^{-1})
384046	North Inlet	12.7
384045	South Inlet	7.4
385216	Outlet	14.2
Storage		5.9

2.0 WATER QUALITY STANDARDS

The Clean Water Act requires that Total Maximum Daily Loads (TMDLs) be developed for waters on a state's Section 303(d) list. A TMDL is defined as "the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background" such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. The purpose of a TMDL is to identify the pollutant load reductions or other actions that should be taken so that impaired waters will be able to attain water quality standards.

TMDLs are required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. Separate TMDLs are required to address each pollutant or cause of impairment (i.e., nutrients, sediment).

2.1 Narrative Water Quality Standards

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

2.2 Numeric Water Quality Standards

Armourdale Dam is classified as a Class 2, cool water fishery. Class 2 fisheries are defined as waterbodies "capable of supporting growth and propagation of nonsalmonid fishes and marginal growth of salmonid fishes and associated aquatic biota" (NDDoH, 1991). All classified lakes in North Dakota are assigned aquatic life, recreation, irrigation, livestock watering, and wildlife beneficial uses. The North Dakota State Water Quality Standards state that lakes shall use the same numeric criteria as Class 1 streams. This includes the state standard for dissolved oxygen set at no less than 5 mg L^{-1}. State standards for lakes and reservoirs also specify guidelines for nitrogen (1.0 mg L^{-1} as nitrate) and phosphorus (0.1 mg L^{-1} as total phosphorus) (Table 9).

Table 9. Numeric Standards Applicable for North Dakota Lakes and Reservoirs (NDDoH , 2001).

Parameter		Guidelines	Limit
Guidelines or Standards for Classified Lakes			
	Nitrates (dissolved)	1.0 mg L^{-1}	Maximum allowed[1]
	Phosphorus (total)	0.1 mg L^{-1}	Maximum allowed[1]
	Dissolved Oxygen	5 mg L^{-1}	Not less than
Guidelines for goals in a lake improvement or maintenance program			
	NO_3 as N	0.25 mg L^{-1}	Goal
	PO_4 as P	0.02 mg L^{-1}	Goal

[1] **"Interim guideline limits"**

3.0 TMDL TARGETS

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

3.1 Nutrient Target

North Dakota's 2004 Integrated Section 305(b) Water Quality Assessment Report indicates that Carlson's Trophic State Index (TSI) is the primary indicator used to assess beneficial uses of the state's lakes and reservoirs (NDDoH, 2004). Trophic status is the measure of productivity of a lake or reservoir and is directly related to the level of nutrients (i.e., phosphorus and nitrogen) entering the lake or reservoir from its watershed. Lakes tend to become eutrophic (more productive) with higher nitrogen and phosphorus inputs. Eutrophic lakes often have nuisance algal blooms, limited water clarity, and low dissolved oxygen concentrations that can result in impaired aquatic life and recreational uses. Carlson's TSI attempts to measure the trophic state of a lake using nitrogen, phosphorus, chlorophyll-a, and Secchi disk depth measurements (Carlson, 1977).

Based on Carlson's TSI and water quality data collected between December 2002 and September 2004, Armourdale Dam was generally assessed as a eutrophic to hypereutrophic lake (Table 10). Hypereutrophic lakes are characterized by large growths of weeds, blue-green algal blooms, and low dissolved oxygen concentrations. These lakes experience frequent fish kills and are generally characterized as having excessive rough fish populations (e.g., carp, bullhead and

sucker) and poor sport fisheries. Because of the frequent algal blooms and excessive weed growth, these lakes are also undesirable for recreational uses such as swimming and boating.
A Carlson's TSI target of 73.15 based on total phosphorus was chosen for the Armourdale Dam endpoint. While this will not bring concentrations of total phosphorus to the NDDoH State Water Quality Standard guideline for lakes (i.e., 0.02 mg/L), it should result in a change of trophic status for the lake from hypereutrophic down to eutrophic during all times of the year. Given the size of the lake, the probable amount of phosphorus in bottom sediments, nearly constant wind in North Dakota causing a mixing effect, and few cost efficient ways to reduce in-lake nutrient cycling, this was determined to be the best possible outcome for the reservoir.

Table 10. Carlson's Trophic State Indices for Armourdale Dam.

Parameter	Relationship	Units	TSI Value	Trophic Status
Chlorophyll-a	TSI (Chl-a) = 30.6 + 9.81[ln(Chl-a)]	μg/L	56.89	Eutrophic
Total Phosphorus (TP)	TSI (TP) = 4.15 + 14.42[(ln(TP)]	μg/L	81.93	Hypereutrophic
Secchi Depth (SD)	TSI (SD) = 60 - 14.41[ln(SD)]	meters	50.01	Eutrophic
Total Nitrogen (TN)	TSI (TN) = 54.45 + 14.43[ln(TN)]	mg/L	64.45	Hypereutrophic

TSI < 25 - Oligotrophic (least productive) TSI 25-50 Mesotrophic
TSI 50-75 Eutrophic TSI > 75 - Hypereutrophic (most productive)

The reasons for the different TSI values estimated for Armourdale Dam are varied. According to phosphorus TSI value (Figure 14), Armourdale Dam is an extremely productive lake (hypereutrophic). Carlson and Simpson (1996) suggest that if the phosphorus and secchi depth TSI values are relatively similar and higher than chlorophyll-a TSI values, then dissolved color or nonalgal particulates dominate light attenuation. It follows that, as is the case with Armourdale Dam, if the secchi depth and chlorophyll-a TSI values are similar, then chlorophyll-a is dominating light attenuation. Carlson and Simpson (1996) also state that a nitrogen index value might be a more universally applicable nutrient index than a phosphorus index, but it also means that a correspondence of the nitrogen index with the chlorophyll-a index cannot be used to indicate nitrogen limitation.

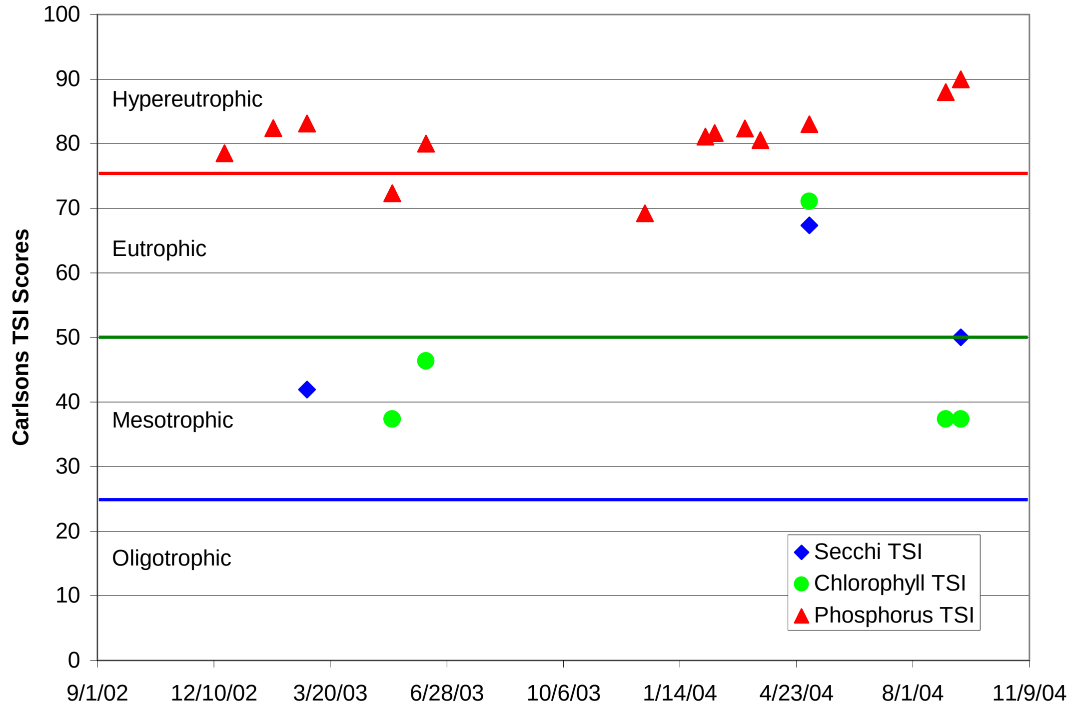

Figure 14. Temporal distribution of Carlosn's Trophic Status Index scores for Armourdale Dam

If the specified TMDL TSI target of 73.15 based on total P is met, the reservoir can be expected to meet the applicable water quality standards for aquatic life and recreational beneficial uses.

3.2 Dissolved Oxygen Target

The North Dakota State Water Quality Standard for dissolved oxygen is "no less than 5.0 mg/L^{-1}" and will be the dissolved oxygen target for Armourdale Dam.

4.0 SIGNIFICANT SOURCES

There are no known point sources upstream of Armourdale Dam. It has been determined that all the pollutants of concern originated from non-point sources. Most of the land upstream from Armourdale Dam is farmed. The remainder is used for pasture or enrolled in the Conservation Reserve Program (CRP). There are no urban areas within the watershed. There are also no lake homes around the reservoir. However, there are many small farmsteads spread throughout the area.

The vast majority of nutrient loads are transported with overland runoff from agricultural areas. Precipitation directly to the lake's surface is another possible source of nutrients. Existing land use and AGNPS modeling (see Section 5.3 AGNPS Watershed Model) within the Armourdale Dam watershed indicates that the majority of NPS loading is likely coming from cropland, (90.0 percent of land within the watershed is cropped). A small percentage (3.0%) of land in the watershed is used for pasture. It is possible that a small amount of nutrient loading also originates from land used for pasture. Best management practices will also be implemented on land used for pasture in order to address loading from these lands.

5.0 TECHNICAL ANALYSIS

Establishing a relationship between in-stream water quality targets and pollutant source loading is a critical component of TMDL development. Identifying the cause-and-effect relationship between pollutant loads and the water quality response is necessary to evaluate the loading capacity and trophic response of the receiving waterbody. The loading capacity is the amount of a pollutant that can be assimilated by the waterbody while still attaining and maintaining water quality standards. This section discusses the technical analysis to estimate existing loads to Armourdale Dam and the predicted trophic response of the reservoir to reductions in loading capacity.

5.1 Tributary Load Analysis

To facilitate the analysis and reduction of tributary inflow and outflow water quality and flow data the FLUX program was employed. The FLUX program, developed by the US 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 (Walker, 1996) was used to predict and evaluate the effects of various nutrient load reduction scenarios on Armourdale Dam. BATHTUB performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network. The model accounts for advective and diffusive transport and nutrient sedimentation. Eutrophication related water quality conditions are predicted using empirical relationships previously developed and tested for reservoir applications.

The BATHTUB model is developed in three phases. The first two phases involve the analysis and reduction of the tributary and in-lake water quality data. The third phase involves model calibration. In the data reduction phase, the in-lake and tributary monitoring data collected as part of the project were summarized in a format which can serve as inputs to the model

The tributary data were analyzed and reduced by the FLUX program. FLUX uses tributary inflow and outflow water quality and flow data to estimate average mass discharge or loading that passes a river or stream site using six calculation techniques. The FLUX model then allows the user to pick the most appropriate load calculation technique with the smallest statistical error. Load is therefore defined as the mass of pollutant during a given unit of time. Output for the FLUX program is then used to calibrate the BATHTUB model. In the case of Armourdale Dam the FLUX program estimated annual phosphorus loading as 4,004.2 kg/yr.

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

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

As state above, BATHTUB can compare predicted vs. actual conditions. After calibration, the model was run based on observed concentrations of phosphorus and nitrogen, to derive an estimated annual average total phosphorus load of 4,004.2 kg and annual average nitrogen load of 41,777.3 kg. The model was then run to evaluate the effectiveness of a number of nutrient reduction alternatives including: (1) reducing externally derived nutrient loads; (2) reducing internally available nutrients; and (3) reducing both external and internal nutrient loads.

In the case of Armourdale Dam, BATHTUB modeled externally derived phosphorus. Phosphorus was used in the simulation model based on its known relationship to eutrophication and that it is controllable with the implementation of watershed Best Management Practices (BMPs). Changes in trophic response were evaluated by reducing external derived phosphorus loading by 25, 50, and 75 percent. Simulated reductions were achieved by reducing phosphorus concentrations in contributing tributaries and other external delivery sources. Flow was held constant due to uncertainty in estimating changes in hydraulic discharge with the implementation of BMPs.

The model results indicated that if external phosphorus loading was reduced by 75 percent entering into Armourdale Dam, the average annual total phosphorus and chlorophyll-a concentration in the lake would decrease and secchi disk transparency depth would increase, but only phosphorus would be measurable. The large reduction in nutrient load would result in an improvement to the trophic status of Armourdale Dam that would be noticeable to the average lake user as the reduction in the amount of algal blooms per year and overall clarity improvement would approach the mesotrophic range.

A 75 percent reduction in external phosphorus load, the model predicts a reduction in Carlson's TSI score from 56.89 to 54.93 for chlorophyll-a and 50.01 to 49.69 for secchi disk transparency, corresponding to a trophic state of borderline eutrophic and mesotrophic. More importantly, and for the long term health of the lake, a 75 percent reduction in phosphorus loading would reduce the total phosphorus TSI score from 81.93 to 73.15 which is a change from hypereutrophic to eutrophic. A 75 percent reduction in total phosphorus loads would achieve the target of 0.12 mg L^{-1} (Table 11 and Figure 15). This reduction in phosphorus is predicted to result in a reservoir in the eutrophic range.

Table 11. Observed and Predicted Values for Selected Trophic Response Variables Assuming a 25, 50, and 75 Percent Reduction in External Phosphorus and Nitrogen Loading.

Variable	Observed Value	Predicted Value		
		25%	50%	75%
Total Phosphorus (mg/L)	0.22	0.184	0.14	0.12
Total Dissolved Phosphorus (mg/L)	0.042	0.042	0.041	0.039
Total Nitrogen (mg/L)	2.00	1.883	1.76	1.637
Organic Nitrogen (mg/L)	1.537	1.497	1.446	1.386
Chlorophyll-a (µg/L)	14.58	13.98	13.04	11.94
Secchi Disk Transparency (meters)	2.00	2.00	2.02	2.04
Carlson's TSI for Phosphorus	81.93	79.35	76.29	73.15
Carlson's TSI for Chlorophyll-a	56.89	56.48	55.79	54.93
Carlson's TSI for Secchi Disk	50.01	50.01	49.86	49.69

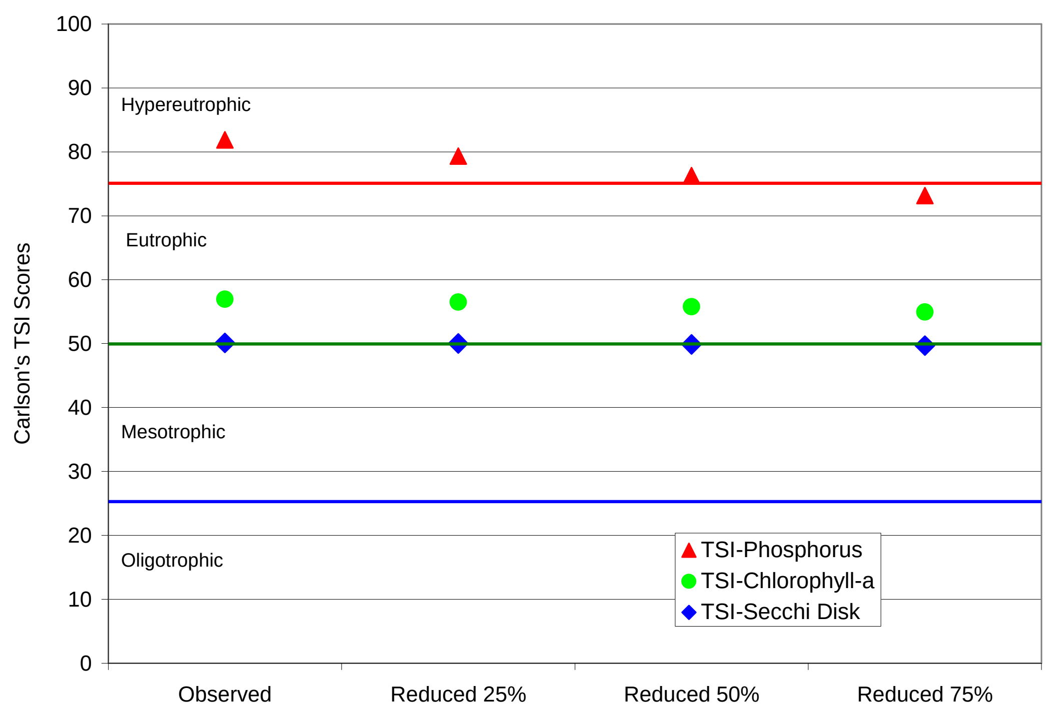

Figure 15. Predicted Trophic Response to Phosphorus Load Reductions to Armourdale Dam of 25, 50, and 75 Percent.

5.3 AGNPS Watershed Model

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

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

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

The AGNPS 3.65 model was used in conjunction with an intensive land use survey to determine critical areas within the Armourdale Dam watershed. Criteria used during the landuse assessment where percent cover on cropland and pasture/range conditions. These criteria were used to determine the C factor for each cell. The model was run using current conditions determined during the land use assessment.

Annual run-off and annual nutrient yields were calculated for the watershed using the AgNPS model (Table 12).

The initial Armourdale Dam watershed summary data is listed in Table 13. Additional modeling comparisons were made by changing crop rotations on selected portions of the watershed. The watershed was divided into 342, 40-acre cells for evaluation. Each cell was evaluated for soil and characteristics, terrain, and land-use characteristics.

Table 12. Runoff and Annual Yields Summary for the Armourdale Dam Watershed.

Watershed Name	Armourdale Dam
Watershed Area	13,680.00 acres
Cell Area	40.00 acres
Characteristic Storm Precipitation	4.00 inches
Storm Energy-Intensity Value	98.49
Values at the Watershed Outlet	
Number of Cells	197
Runoff Volume (rainfall equivalent)	1.86 inches
Peak Runoff Rate	2,514.85 cfs
Total Nitrogen in Sediment	0.71 lbs/acre
Total Soluble Nitrogen in Runoff	0.36 lbs/acre
Soluble Nitrogen Concentration in Runoff	0.86 ppm
Total Phosphorus in Sediment	0.35 lbs/acre
Soluble Phosphorus Concentration in Runoff	0.02 lbs/acre
Total Soluble Chemical Oxygen Demand in Runoff	32.71 lbs/acre
Soluble Chemical Oxygen Demand Concentration in Runoff	77.59 ppm
Total Sediment	1761.92 tons
Mean Concentration	611.10 ppm
Area Weighed Erosion (Upland)	3.00 +/acre

Table 13. Armourdale Dam Watershed AGNPS Summary.

Watershed Studied			
Watershed Area	13,680 acres		
Cell Area	40 acres		
Characteristic Storm Precipitation	4.0 inches		
Storm Energy-Intensity Value	98.49 inches		
Values at the Watershed Outlet			
Original		**C-factor >.3 to CRP**	**C-factor >.3 and >5%slope to CRP**
Number of Cells	342		
Runoff Volume (rainfall equivalent)	1.86 inches		
Peak Run-off Rate	2,514.85 cfs		
Total Nitrogen in Sediment	0.71 lbs/acre		.14
Total Soluble Nitrogen in Runoff	0.36 lbs/acre		
Soluble Nitrogen Concentration Runoff	0.86 ppm		
Total Phosphorus in Sediment	0.35 lbs/acre	0.20	0.07
Total Soluble Phosphorus in Runoff	0.02 lbs/acre		
Soluble Phosphorus Concentration in Runoff	0.05 ppm		
Total Soluble Chemical Oxygen Demand in Runoff	32.71 lbs/acre		
Soluble Chemical Oxygen Demand Concentration in Runoff	77.59 ppm		

The AGNPS model predicted that with the 2002-03 farming practices being utilized in the Armourdale Dam watershed, a mixture of cropland, CRP and rangeland, the total nitrogen in sediment value would be 0.71 pounds per acre and the total phosphorus in sediment value would be 0.35 pounds per acre. Cover-management factors (C-factors) were determined for each cell within the Armourdale Dam watershed. The C-factor is used to reflect the cropping and management practices on erosion rates. This factor indicates how the cropping management practices will affect the annual soil loss and how that soil-loss potential will be distributed. By changing the land management practices in cells with slopes of greater than 5% and a cropland C-factor greater than 0.3, the total nitrogen (TN) and total phosphorus (TP) in sediment levels would be reduced for the watershed. By converting there C-factors to numbers for grass-like vegetation in the AGNPS model, a reduction was noted of 0.14 lbs/acre for total nitrogen and 0.07 lbs/acre for total phosphorus, an 80% reduction.

5.4 Dissolved Oxygen

Armourdale Dam is listed as not supporting, fish and aquatic biota uses because dissolved oxygen concentrations have been observed below the North Dakota water quality standard. The North Dakota water quality standard for dissolved oxygen is "not less than 5.0 mg L^{-1}". For Armourdale Dam, low dissolved oxygen levels appear to be related to excessive nutrient loadings.

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

AGNPS and BATHTUB models indicate that excessive nutrient loading is responsible for the low dissolved oxygen levels in Armourdale 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 phosphorus 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 phosphorus 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 phosphorus (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 = 13,680 acres; 55.36 km^2), mean depth (z = 13.0 feet; 3.96 meters), and the ratio of mean depth to the surface area ($z/A_o^{0.5}$ = 0.53) for Armourdale 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.

5.5 Sediment

A sediment balance was calculated for Armourdale 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 29,239.7 kg/yr.

Table 14. Sediment Balance for Armourdale Dam (2002-2003).

	Inflow (kg)	Outflow (kg)	Storage (kg)
Total Suspended Solids	68741.4	39355.5	29385.9

Mulholland and Elwood (1982) state that the average accumulation of sediment within reservoirs is 2 cm/yr. Based on a conversion from mass of sediment storage to depth of sediment storage, it can be assumed that Armourdale Dam is accumulating sediment at a current rate that considered acceptable for reservoirs. In order to perform the conversion from mass to depth, the particle density of soil is needed. For most mineral soils the average density of particles is in the range of 2.6 to 2.7 g/cm^3. An average particle density of 2.65 g/cm^3 (the density of quartz) is often applied to soils comprised principally of silicate materials. Since soils in the Armourdale 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, the low end of the range (2.6 g/cm^3) will be used to calculate the equivalent depth of 29,239.7 kg of sediment in Armourdale Dam.

Based on a sediment loading rate of 29,239,700 g/yr times a sediment density of 2.60 g/cm, the sediment volume deposited in Armourdale Dam is 76,023,220 cm^3 each year.

$$29{,}239{,}700 \text{ g/yr} * (2.60 \text{ g/cm}^3)^{-1} = 76{,}023{,}220 \text{ cm}^3\text{/yr}$$

Based on a surface area of 85.5-acres (3,460,062,241.15 cm^2), the annual sedimentation rate is 0.0219 cm per year [(76,023,220 cm^3/yr)/ (3,460,062,241.15 cm^2)].

This estimated annual sediment accumulation rate is well below the 2 cm/yr average sedimentation rate of typical reservoirs.

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. Therefore, research by Waters (1995) supports the view that average TSS concentrations in Armourdale Dam of 5.9 mg L^{-1} is not considered harmful to aquatic life threshold (Table 8). In fact, only one sample out of sixteen exceeded the 25 mg L^{-1} concentration stated by Waters (1995) as harmful. Therefore it is the recommendation of the TMDL that, in the next North Dakota 303 (d) list cycle Armourdale Dam should be delisted for sediment impairments.

Justification for delisting is also based on the Natural Resource Conservation Service (NRCS) Sedimentation Rate Standard for reservoirs. The NRCS Sedimentation Standard is estimated as 1/4 of an inch of sediment eroded from the watershed drainage area delivered and detained in the sediment pool over the 50-year expected life of project.

This is a conservative estimate used primarily in northeastern North Dakota. Detailed surveys conducted on Renwick Dam in the Tongue River Watershed have discovered a sedimentation rate of approximately 1/8 of an inch. In the case of the Renwick Dam survey, delivery of the sediments was tied to severe storm events in the spring when soil had been recently tilled and had no cover. To calculate the allowable sedimentation rate for Armourdale Dam based on the NRCS standard the approximate rate of 1/8 of an inch will be used.

Assuming,
Watershed Area = 21.4 mi^2
and
NRCS Sedimentation Rate Standard equals 1/8 inch over 50 yrs
Then,
Watershed Area = 21.4 mi^2 = (112,992 ft* 112,992 ft) = 12,767,192,064 ft^2;

Sediment Volume =
(12,767,192,064 ft^2 * 1/8 inch)/12 inches = 132,991,584 ft^3;

Predicted amount of sediment in Armourdale Dam at 1/8 inch over 50 years =
(132,991,584 ft^3 * 28,316.8467117 cm^3) = 3.76590229807 x 10^{12} cm^3;

Compare this too,
The calculated annual sedimentation rate from observed data entering Armourdale Dam =
29,239,700 g/yr * $(2.60\ g/cm^3)^{-1}$ = 76,023,220 cm^3/yr

Calculated amount of sediment accumulation rate from observed data entering Armourdale Dam over 50 years
(76,023,220 cm^3/yr * 50 yrs) = 3.801161 x 10^9 cm^3

Using a sedimentation rate standard of 1/8 inch over 50 years, Armourdale Dam's predicted sediment accumulation rate could be 3.76590229807 x 10^{12} cm^3. When compared with the current sedimentation accumulation rate into the reservoir over 50 years of 3.801161 x 10^9 cm^3. Armourdale Dam appears to be under the predicted sedimentation rate standard.

6.0 MARGIN OF SAFETY AND SEASONALITY

6.1 Margin of Safety

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

6.2 Seasonality

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

7.0 TMDL

Table 15 summarizes the nutrient TMDL for Armourdale Dam in terms of loading capacity, wasteload allocations, load allocations, and a margin of safety. The TMDL can be generically described by the following equation.

TMDL = LC = WLA + LA + MOS

where

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

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

LA = load allocation, or the portion of the TMDL allocated to existing or future non-point sources;

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

7.1 Nutrient TMDL

Table 15. Summary of the Phosphorus TMDL for Armourdale Dam.

Category	Total Phosphorus (kg/yr)	Explanation
Existing Load	4,004.2	From observed data
Loading Capacity	1,001.05	75 percent total reduction based on BATHTUB modeling
Wasteload Allocation	0.0	No point sources
Load Allocation	900.95	Entire loading capacity minus MOS is allocated to non-point sources
MOS	100.10	10% of the loading capacity (1,001.5kg/yr) is reserved as an explicit margin of safety

Based on data collected in 2002 and 2003, the existing annual total phosphorus load to Armourdale Dam is estimated at 4,004.2 kg. Assuming a 75% reduction in phosphorus loading will result in Armourdale Dam reaching a TMDL target total phosphorus concentration of 0.12 mg L^{-1}, the TMDL or Loading Capacity is 1,001.05 kg per year. Assuming 10% of the loading capacity (100.10 kg/yr) is explicitly assigned to the MOS and there are no point sources in the watershed all of the remaining loading capacity (900.95 kg/yr) is assigned to the load allocation

7.2 Sediment TMDL

No reduction necessary, delist for sediment.

7.3 Dissolved Oxygen TMDL

As a result of this direct influence it is anticipated that meeting the phosphorus load reduction target in Armourdale Dam will address the dissolved oxygen impairment. A reduction in total phosphorus load to Armourdale Dam would be expected to lower algal biomass levels in the water column thereby reducing the biological oxygen demand exerted by the decomposition of these primary producers. The reduction in biological oxygen demand is therefore assumed to result in attainment of the dissolved oxygen standard.

8.0 ALLOCATION

Armourdale Dam's watershed is small and supports extensive agriculture where cropland constitutes a majority of the landuse. Sub-dividing it into smaller units, based on hydrology or type of conservation practice implemented, would not be practical. Using the AGNPS model, it was determined that if 69 percent of the cells (9,480 acres) in the watershed containing greater than 5% slopes and with C-factors greater than 0.3 were addressed through BMPs (Figure 16), then the sediment load would decrease by 87 percent and total nitrogen and total phosphorus would decrease by 80 percent. These values are within the reduction required by the above TMDL. Also, by effectively using the hypolimnetic draw-down according to the 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 is it believed that instituting BMPs will result in the needed water quality improvements, the history of sediment and nutrient deposition may strongly effect internal nutrient cycling. The correct use of the hypolimnetic draw down may aid in improving water quality, as well as providing an additional margin of safety for the phosphorus TMDL. Also, public willingness towards conservation practices will facilitate the implementation of the additional needed BMPs.

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

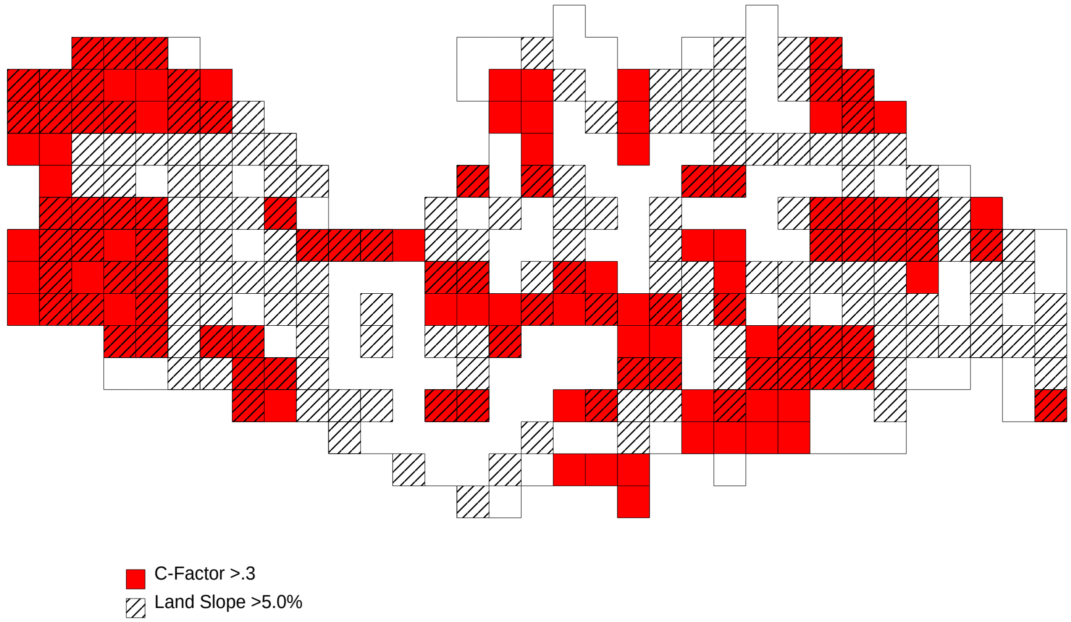

Figure 16. AGNPS Model Identification of Areas Needing BMP Implementation

9.0 PUBLIC PARTICIPATION

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

- Towner County Soil Conservation District
- Towner County Water Resource Board
- Natural Resource Conservation Service (Towner County Field Office)
- Environmental Protection Agency
- U.S. Fish & Wildlife Service

In addition to mailing copies of this TMDL for Armourdale Dam to interested parties, the TMDL 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 following newspapers:

- Towner County Record-Herald, published September 2, 2006
- Devils Lake Journal, published September 1, 2006
- The Bismarck Tribune, published September 1, 2006

The public comment period concluded November 3, 2006. Comments were received from the U.S. Environmental Protection Agency (EPA) and the U. S. Fish and Wildlife Service (USFWS). Formal written comments submitted to the NDDoH can be found in Appendices C and D. The Department's responses to all comments received are in Appendix E.

10.0 MONITORING

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 (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 5 years after the implementation project is complete.

11.0 TMDL IMPLEMENTATION STRATEGY

Implementation of TMDLs is dependent upon the availability of Section 319 NPS funds or other watershed restoration programs (e.g. USDA EQIP), as well as securing a local project sponsor and the required matching funds. Provided these three requirements are in place, a project implementation plan (PIP) is developed in accordance with the TMDL and submitted to the 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 dependent on the ability of the local project sponsor to find cooperating producers.

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

12.0 ENDANGERED SPECIES ACT COMPLIANCE

States are encouraged to participate with the USFWS and the EPA in documenting threatened and endangered species on the Endangered Species List. In an effort to assist in Endangered Species Act compliance, a request for a list of endangered and/or threatened species was made to the USFWS (Figure 17 and 18). A hard copy of the draft TMDL report was sent to the USFWS Bismarck, North Dakota office for review. The following is a list of threatened or endangered species specific to Towner County. While potentially present in Towner County, these species may or may not use habitats directly associated with Armourdale Dam and its watershed.

- Whooping Crane (Grus Americana), Endangered
- Gray wolf (Canis lupus), Endangered
- Bald Eagle (Haliaeetus leucocephalus), Threatened

On October 25, 2006 the NDDoH received comments from the USFWS which included an assessment stating that the proposed TMDL will have “no effect” on federally listed threatened or endangered species and “no adverse modification” to proposed or designated critical habitat. The department concurs with this "no effect" determination regarding this proposed TMDL.

U.S. FISH & WILDLIFE SERVICE

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

OFFICE TRANSMITTAL

To: Michael Hargiss
ND Department of Health
Fargo, ND

☐ Action
■ Information

From: Kevin Johnson Division: Ecological Services Date: 8-29-05

Attached is a list of threatened and endangered species for Towner County. If you need any more information, please let me know.

Figure 17. Office Transmittal Received from U.S. Fish & Wildlife Service.

FEDERAL THREATENED AND ENDANGERED SPECIES
FOUND IN TOWNER COUNTY
NORTH DAKOTA
August 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.

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.

Figure 18. Threatened and Endangered Species List and Designated Critical Habitat.

13.0 REFERENCES

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Appendix A

A Calibrated Trophic Response Model (Bathtub) for Armourdale Dam
As a Tool to Evaluate Various Nutrient Reduction Alternatives
Based on Data Collected by the Towner County Soil Conservation District from
December 19, 2002 through September 11, 2004
Prepared by
Peter Wax
October 5, 2005

Introduction

In order to meet the project goals, as set forth by the project sponsors of improving the trophic condition of Armourdale Dam to levels capable of maintaining the reservoirs beneficial uses (e.g., fishing, recreation, and drinking water supply), and the objectives of this project, which are to: (1) develop a nutrient and sediment budget for the reservoir; (2) identify the primary sources and causes of nutrients and sediments to the reservoir; and (3) examine and make recommendations for reservoir restoration measures which will reduce documented nutrient and sediment loadings to the reservoir, a calibrated trophic response model was developed for Armourdale Dam. The model enables investigations into various nutrient reduction alternatives relative to the project goal of improving Armourdale Dam's trophic status. The model will allow resource managers and the public to relate changes in nutrient loadings to the trophic condition of the reservoir and to set realistic lake restoration goals that are scientifically defensible, achievable and socially acceptable.

Methods

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

Tributary Data

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

Lake Data

Armourdale Dam's in-lake water quality data was reduced using Microsoft Excel. The data was reduced in excel to provide three computational functions, including: (1) the ability to display constitutes as a function of depth, location, and/or date; (2) calculate summary statistics (e.g., mean, median and standard error in the mixed layer of the lake or reservoir); and (3) track the temporal trophic status. As is the case with FLUX, output from the Excel program is used as input to calibrate the BATHTUB model.

Bathtub Model Calibration

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

Within the BATHTUB program the user can select from six schemes based on reservoir morphometry and the needs of the resource manager. Using BATHTUB the user can view the reservoir as a single spatially averaged reservoir or as single segmented reservoir. The user can also model parts of the reservoir, such as an embayment, or model a collection of reservoirs. For purposes of this project, Armourdale Dam was modeled as a single, spatially averaged, reservoir. Once input is provided to the model from FLUX and Excel the user can compare predicted conditions (i.e., model output) to actual conditions. Since BATHTUB uses a set of generalized rates and factors, predicted vs. actual conditions may differ by a factor of 2 or more using the initial, un-calibrated, model. These differences reflect a combination of measurement errors in the inflow and outflow data, as well as unique features of the reservoir being modeled.

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

Table 1. Selected model parameters, number and name of model, and where appropriate the calibration factor used for Armourdale Dam Bathtub Model.

Model Option	Model Selection	Calibration Factor
Conservative Substance	1 Computed	1.00
Phosphorus Balance	5 Vollenweider	1.08
Phosphorus – Ortho P	5	0.61
Nitrogen Balance	7 Settling Velocity	1.65
Organic Nitrogen	7	2.39
Chlorophyll-a	2 P, Light, T	0.80
Secchi Depth	1 Vs. Chla & Turbidity	4.70
Phosphorus Calibration	2 Concentrations	NA
Nitrogen Calibration	2 Concentrations	NA
Availability Factors	2 All Models Except 2	NA
Mass-Balance Table	0 Use Observed Concentrations	NA

Results

The trophic response model, BATHTUB, has been calibrated to match Armourdale Dam's trophic response for the project period from October 1, 2004 through October 1, 2005. This is accomplished by combining tributary loading estimates for the project period with in-lake water quality estimates. Tributary flow and concentration data for the project period are reduced by the FLUX program and the corresponding in-lake water quality data are reduced utilizing Excel. The output from these two programs is then provided as input to the BATHTUB model. The model is calibrated through several iterations, first by selecting appropriate empirical relationships for model coefficients (e.g., nitrogen and phosphorus sedimentation, nitrogen and phosphorus decay, oxygen depletion, and algal/chlorophyll growth), and second by adjusting model calibration factors for those coefficients (Table 1). The model is termed calibrated when the predicted estimates for the trophic response variables are similar to observed estimates made from project monitoring data.

The two most important nutrients controlling trophic response in Armourdale Dam are nitrogen and phosphorus. After calibration the observed average annual concentration of total nitrogen and total phosphorus compare well with those of the BATHTUB model. The model predicts that the dam has an annual volume weighted mean total phosphorus concentration of 0.219 mg L^{-1} and an annual average volume weighted total nitrogen concentration of 2.006 mg L^{-1} compared to observed values for total phosphorus and total nitrogen of 0.220 mg L^{-1} and 2.000 mg L^{-1}, respectively (Table 2).

Other measures of trophic response predicted by the model are average annual chlorophyll-a concentration and average secchi disk transparency. The calibrated model did just as good a job of predicting average chlorophyll-a concentration and secchi disk transparency within the reservoir as total phosphorus and total nitrogen (Table 2).
Once predictions of total phosphorus, chlorophyll-a, and secchi disk transparency are made, the model calculates Carlson's Trophic Status Index (TSI) (Carlson 1977) as a means of expressing predicted trophic response (Table 2). Carlson's TSI is an index that can be used to measure the relative trophic state of a lake or reservoir. Simply stated, trophic state is how much production (i.e., algal and weed growth) occurs in the waterbody. The lower the nutrient concentrations are within the waterbody the lower the production and the lower the trophic state or level. In contrast, increased nutrient concentrations in a lake or reservoir increase the production of algae and weeds which make the lake or reservoir more eutrophic or of a higher trophic state.

Oligotrophic is the term which describes the least productive lakes and hypereutrophic is the term used to describe lakes and reservoirs with excessive nutrients and primary production.

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

Variable	Value: Observed	Value: Predicted
Total Phosphorus as P (mg/L)	0.220	0.219
Total Nitrogen as N (mg/L)	2.000	2.006
Organic Nitrogen as N (mg/L)	1.537	1.534
Chlorophyll-a (μg/L)	14.58	14.67
Secchi Disk Transparency (meters)	2.00	1.99
Carlson's TSI for Phosphorus	81.93	81.87
Carlson's TSI for Chlorophyll-a	56.89	56.94
Carlson's TSI for Secchi Disk	50.01	50.11

Figure 1 provides a graphic summary of the TSI range for each trophic level compared to values for each of the trophic response variables. The calibrated model provided predictions of trophic status which are similar to the observed TSI values for the project period (Table 2). Predicted and observed TSI values for phosphorus and secchi disk suggest Armourdale Dam is hypereutrophic, while the TSI value chlorophyll-a indicate the reservoir is eutrophic. Figure 2 is a graphic that shows the annual temporal distribution of Armourdale Dam's trophic state based on the three parameters total phosphorus as phosphate, and chlorophyll-a concentrations and secchi disk depth transparency.

Model Predictions

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

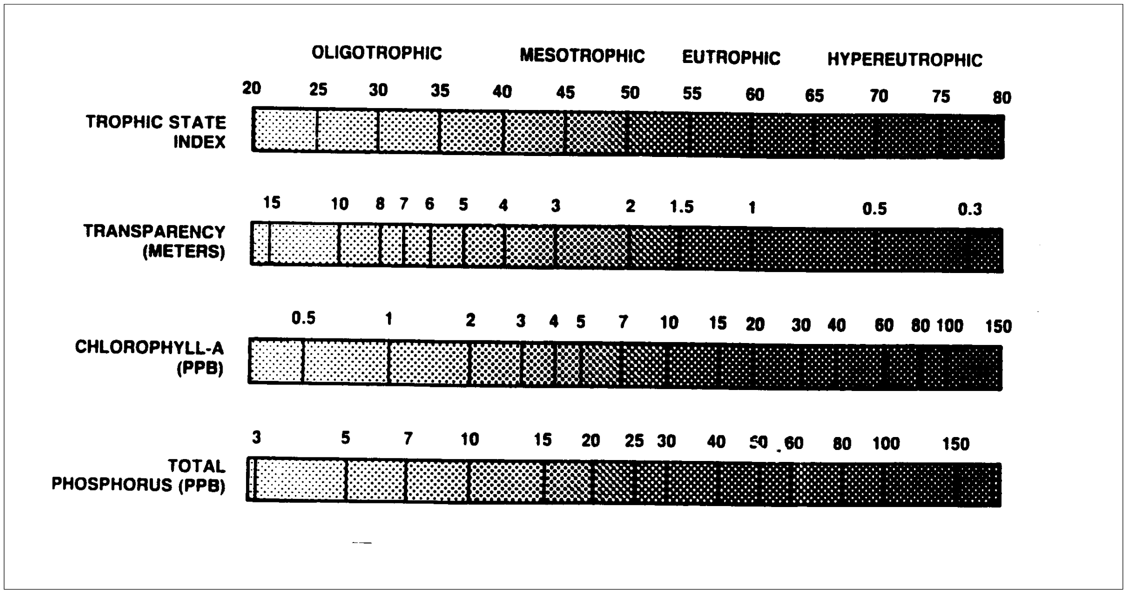

Figure 1. Graphic depiction of Carlson's Trophic Status Index

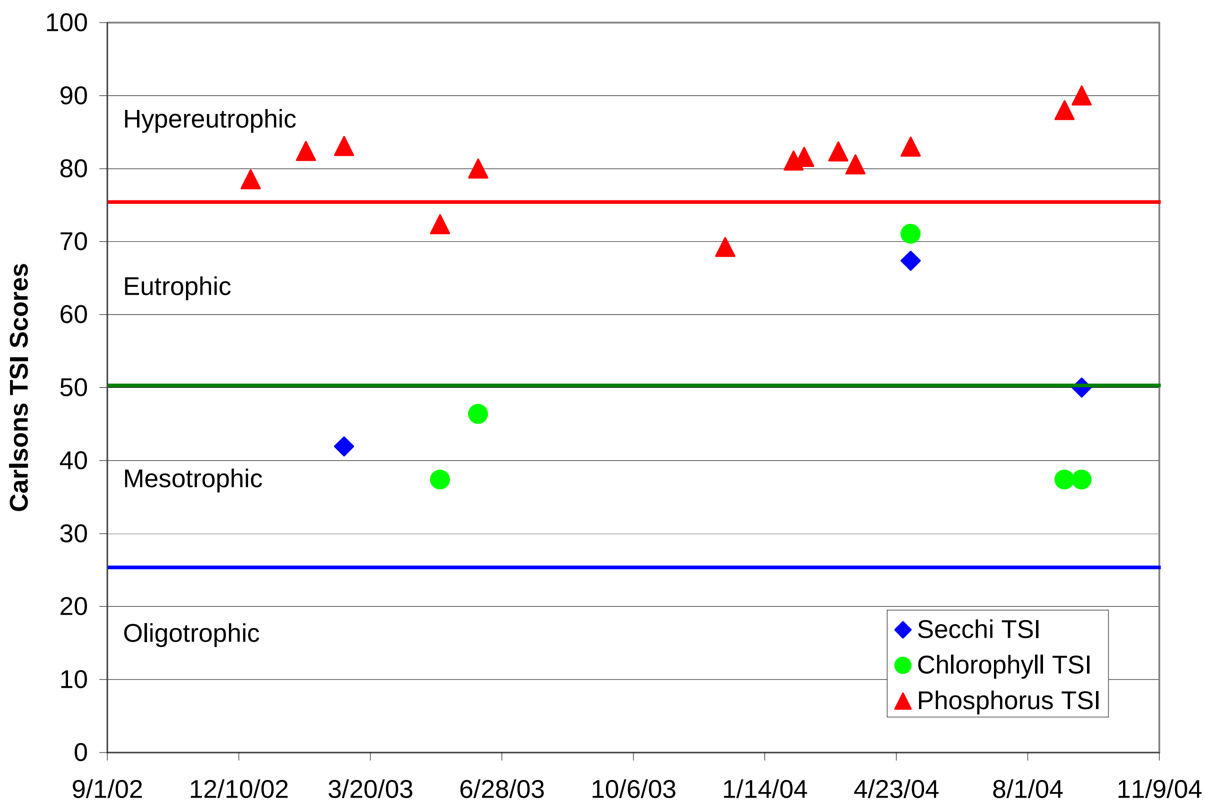

Figure 2. Temporal distribution of Carlosn's Trophic Status Index scores for Armourdale Dam (12-19-02 though 9-11-04)

Predicted changes in trophic response to Armourdale Dam 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 Armourdale 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, but only phosphorus would be measurably (Table 3, Figure 3). It is also likely, that this large a reduction in nutrient load would result in an improvement to the trophic status of Armourdale Dam that would be noticeable to the average lake as the reduction in the amount of algal blooms per year and overall clarity improvement would approach the mesotrophic range.

With a 75 percent reduction in external phosphorus and nitrogen load, the model predicts a reduction in Carlson's TSI score from 56.89 to 54.93 for chlorophyll-a and from 50.01 to 49.69 for secchi disk transparency, corresponding to a trophic state of borderline eutrophic and mesotrophic, respectively. More importantly for the long term health of the lake would be the reductions in total phosphorus TSI score of 81.93 to 73.15 which is a change from hypereutrophic to eutrophic.

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

		Predicted		
Variable	Observed	25 %	50 %	75 %
Total Phosphorus as P (mg/L)	0.220	0.184	0.140	0.120
Total Diss. Phosphorus as P (mg/L)	0.042	0.042	0.041	0.039
Total Nitrogen as N (mg/L)	2.000	1.883	1.760	1.637
Organic Nitrogen as N (mg/L)	1.537	1.497	1.446	1.386
Chlorophyll-a (μg/L)	14.58	13.98	13.04	11.94
Secchi Disk Transparency (meters)	2.00	2.00	2.02	2.04
Carlson's TSI for Phosphorus	81.93	79.35	76.29	73.15
Carlson's TSI for Chlorophyll-a	56.89	56.48	55.79	54.93
Carlson's TSI for Secchi Disk	50.01	50.01	49.86	49.69

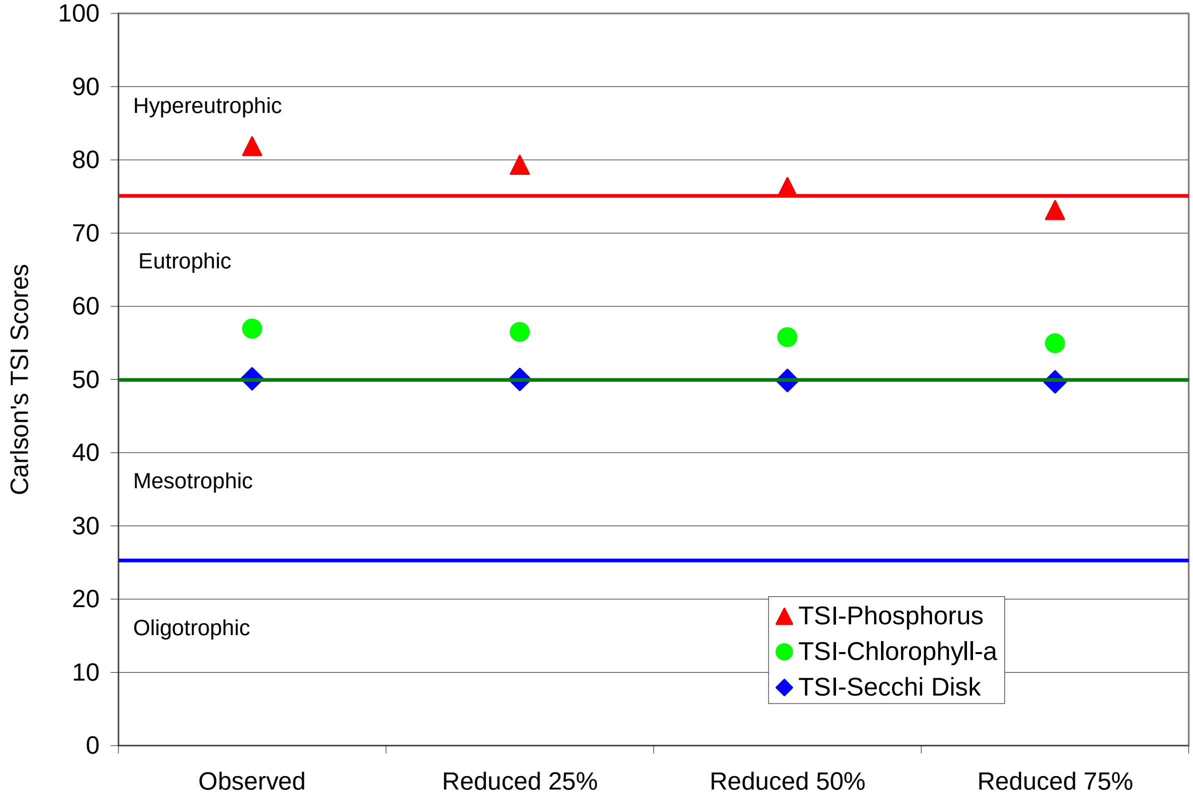

Figure 3. Predicted trophic response to phosphorus load reductions to Armourdale Dam of 25, 50, and 75 percent

Appendix B

Flux Model Analysis

```
384046 Armourdale N.Inlet 2004    VAR=nh3-3     METHOD= 2 Q WTD C

 TABULATION OF MISSING DAILY FLOWS:

 Flow File =384046_Q.wkl                    ,   Station =Flow
 Daily Flows from 20031031 to 20041031


Average Sample Interval =   9.8 Days, Date Range = 20040329 to 20040615
 Maximum Sample Interval =    38 Days, Date Range = 20040406 to 20040515
 Percent of Total Flow Volume Occuring In This Interval =    .2%

 Total Flow Volume on Sampled Days =         15.9 hm3
 Total Flow Volume on All Days     =        323.5 hm3
 Percent of Total Flow Volume Sampled =     4.9%

 Maximum Sampled Flow Rate =       10.81 hm3/yr
 Maximum Total Flow Rate   =       14.39 hm3/yr
 Number of Days when Flow Exceeded Maximum Sampled Flow = 19 out of  367
 Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
       Maximum Sampled Flow Rate =    84.0%

384046 Armourdale N.Inlet 2004    VAR=nh3-3     METHOD= 2 Q WTD C

 TABULATION OF MISSING DAILY FLOWS:

 Flow File =384046_Q.wkl                    ,   Station =Flow
 Daily Flows from 20031031 to 20041031

 Summary:
 Reported Flows =  367

 Missing Flows =     0
 Zero Flows =      290
 Positive Flows =   77

 384046 Armourdale N.Inlet 2004    VAR=nh3-3     METHOD= 3 IJC
 Comparison of Sampled & Total Flow Distributions
        ------ SAMPLED -----     ------- TOTAL ------
 STRAT   N     MEAN  STD DEV      N     MEAN  STD DEV     DIFF    T PROB(>T)
  1      8     1.98     3.73    367      .88     3.25     1.10   -.83   .439
***      8     1.98     3.73    367      .88     3.25     1.10   -.83   .439
```

384046 Armourdale N.Inlet 2004 VAR=nh3-3 METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	367	8	8	100.0	.881	1.984	.382	.071
***	367	8	8	100.0	.881	1.984		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = .881 HM3/YR
TOTAL FLOW VOLUME = .89 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	490.4	488.0	.1795E+06	553.65	.868
2 Q WTD C	217.9	216.8	.1576E+05	245.98	.579
3 IJC	236.7	235.6	.1783E+05	267.27	.567
4 REG-1	159.7	159.0	.4985E+04	180.37	.444
5 REG-2	379.7	377.9	.3298E+05	428.66	.481
6 REG-3	191.2	190.3	.2086E+05	215.89	.759

384046 Armourdale N.Inlet 2004 VAR=no2+no3 METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384046_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 290
Positive Flows = 77

384046 Armourdale N.Inlet 2004 VAR=no2+no3 METHOD= 3 IJC

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	.881	1.984	.491	.064
***	367	8	8	100.0	.881	1.984		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = .881 HM3/YR
TOTAL FLOW VOLUME = .89 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	4253.8	4233.5	.8417E+07	4802.85	.685
2 Q WTD C	1889.9	1880.9	.7136E+05	2133.82	.142
3 IJC	1896.1	1887.1	.5101E+05	2140.85	.120
4 REG-1	1269.1	1263.0	.6962E+06	1432.85	.661
5 REG-2	3308.9	3293.2	.1169E+08	3736.01	1.038
6 REG-3	7015.5	6982.0	.4428E+08	7920.96	.953

384046 Armourdale N.Inlet 2004 VAR=inorg-n METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384046_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 290
Positive Flows = 77

384046 Armourdale N.Inlet 2004 VAR=inorg-n METHOD= 3 IJC
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	.881	1.984	.478	.063
***	367	8	8	100.0	.881	1.984		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = .881 HM3/YR
TOTAL FLOW VOLUME = .89 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	4744.2	4721.6	.1096E+08	5356.50	.701
2 Q WTD C	2107.8	2097.7	.7639E+05	2379.80	.132
3 IJC	2132.8	2122.7	.2813E+05	2408.12	.079
4 REG-1	1430.4	1423.6	.5893E+06	1615.07	.539
5 REG-2	3693.7	3676.1	.1003E+08	4170.49	.862
6 REG-3	6913.6	6880.7	.3427E+08	7805.96	.851

384046 Armourdale N.Inlet 2004 VAR=tkn METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384046_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 290
Positive Flows = 77

384046 Armourdale N.Inlet 2004 VAR=tkn METHOD= 3 IJC

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	.881	1.984	-.030	.048
***	367	8	8	100.0	.881	1.984		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = .881 HM3/YR
TOTAL FLOW VOLUME = .89 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	2729.5	2716.5	.3221E+07	3081.80	.661
2 Q WTD C	1212.7	1206.9	.3287E+03	1369.19	.015
3 IJC	1210.4	1204.7	.3885E+03	1366.66	.016
4 REG-1	1242.9	1237.0	.6551E+03	1403.32	.021
5 REG-2	1048.6	1043.6	.7823E+04	1183.91	.085
6 REG-3	1176.7	1171.1	.1694E+04	1328.62	.035

384046 Armourdale N.Inlet 2004 VAR=tn METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384046_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 290
Positive Flows = 77

384046 Armourdale N.Inlet 2004 VAR=tn METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	367	8	8	100.0	.881	1.984	.105	.172
***	367	8	8	100.0	.881	1.984		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = .881 HM3/YR
TOTAL FLOW VOLUME = .89 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	6983.3	6950.0	.2187E+08	7884.65	.673
2 Q WTD C	3102.6	3087.8	.7751E+05	3503.01	.090
3 IJC	3106.6	3091.7	.5899E+05	3507.51	.079
4 REG-1	2850.2	2836.6	.1560E+06	3218.05	.139
5 REG-2	4227.4	4207.2	.1500E+07	4773.00	.291
6 REG-3	3599.5	3582.4	.8803E+06	4064.10	.262

384046 Armourdale N.Inlet 2004 VAR=t-d-p METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384046_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 290
Positive Flows = 77

384046 Armourdale N.Inlet 2004 VAR=t-d-p METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	367	8	8	100.0	.881	1.984	-.044	.672
***	367	8	8	100.0	.881	1.984		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = .881 HM3/YR
TOTAL FLOW VOLUME = .89 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	660.2	657.1	.1244E+06	745.43	.537
2 Q WTD C	293.3	291.9	.1160E+06	331.18	1.167
3 IJC	247.9	246.7	.1534E+06	279.88	1.588
4 REG-1	303.9	302.4	.1169E+06	343.08	1.130
5 REG-2	235.1	234.0	.6198E+06	265.44	3.365
6 REG-3	383.4	381.5	.1343E+06	432.83	.961

384046 Armourdale N.Inlet 2004 VAR=tp METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384046_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 290
Positive Flows = 77

```
384046 Armourdale N.Inlet 2004    VAR=tp        METHOD= 3 IJC
 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         .881        1.984        .101   .064
***       367   8   8 100.0         .881        1.984

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .881 HM3/YR
 TOTAL FLOW VOLUME =        .89 HM3
 FLOW DATE RANGE   = 20031031 TO 20041031
 SAMPLE DATE RANGE = 20040329 TO 20040615

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD         1508.0         1500.8      .1007E+07    1702.67    .669
 2 Q WTD C          670.0          666.8      .1913E+04     756.47    .066
 3 IJC              670.4          667.2      .1869E+04     756.91    .065
 4 REG-1            617.5          614.5      .6646E+04     697.17    .133
 5 REG-2            905.5          901.2      .5345E+05    1022.38    .257
 6 REG-3            727.2          723.7      .1465E+05     821.08    .167


384046 Armourdale N.Inlet 2004    VAR=tp        METHOD= 3 IJC

 TABULATION OF MISSING DAILY FLOWS:

 Flow File =384046_Q.wk1                    ,   Station =Flow
 Daily Flows from 20031031 to 20041031

 Summary:
 Reported Flows =  367
 Missing Flows =     0
 Zero Flows =      290
 Positive Flows =   77

 384046 Armourdale N.Inlet 2004    VAR=tp        METHOD= 3 IJC
 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         .881        1.984        .101   .064
***       367   8   8 100.0         .881        1.984

 FLOW STATISTICS
 FLOW DURATION =     367.0 DAYS  =  1.005 YEARS
 MEAN FLOW RATE =      .881 HM3/YR
 TOTAL FLOW VOLUME =        .89 HM3
 FLOW DATE RANGE   = 20031031 TO 20041031
 SAMPLE DATE RANGE = 20040329 TO 20040615

 METHOD         MASS (KG)   FLUX (KG/YR)  FLUX VARIANCE CONC (PPB)      CV
 1 AV LOAD         1508.0         1500.8      .1007E+07    1702.67    .669
 2 Q WTD C          670.0          666.8      .1913E+04     756.47    .066
 3 IJC              670.4          667.2      .1869E+04     756.91    .065
 4 REG-1            617.5          614.5      .6646E+04     697.17    .133
 5 REG-2            905.5          901.2      .5345E+05    1022.38    .257
 6 REG-3            727.2          723.7      .1465E+05     821.08    .167
```

384046 Armourdale N.Inlet 2004   VAR=tss   METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384046_Q.wk1   ,   Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows =   0
Zero Flows =   290
Positive Flows =   77

384046 Armourdale N.Inlet 2004   VAR=tss   METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	367	8	8	100.0	.881	1.984	.214	.188
***	367	8	8	100.0	.881	1.984		

FLOW STATISTICS
FLOW DURATION =   367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE =   .881 HM3/YR
TOTAL FLOW VOLUME =   .89 HM3
FLOW DATE RANGE   = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	115929.5	115376.7	.1249E+11	130892.20	.969
2 Q WTD C	51505.5	51259.9	.1958E+10	58153.16	.863
3 IJC	57835.6	57559.8	.2412E+10	65300.28	.853
4 REG-1	43280.2	43073.8	.1223E+10	48866.27	.812
5 REG-2	82161.9	81770.1	.5510E+10	92766.35	.908
6 REG-3	22505.9	22398.6	.4826E+09	25410.66	.981

384045 Armourdale S.Inlet 2004

TABULATION OF MISSING DAILY FLOWS:

Flow File =384045_Q.wk1   ,   Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367

Missing Flows =   0
Zero Flows =   271
Positive Flows =   96

384045 Armourdale S.Inlet 2004 VAR=nh3-4 METHOD= 3 IJC

Comparison of Sampled & Total Flow Distributions

STRAT	SAMPLED N	SAMPLED MEAN	SAMPLED STD DEV	TOTAL N	TOTAL MEAN	TOTAL STD DEV	DIFF	T	PROB(>T)
1	11	3.03	3.81	367	1.39	4.61	1.64	-1.40	.188
***	11	3.03	3.81	367	1.39	4.61	1.64	-1.40	.188

Average Sample Interval = 7.1 Days, Date Range = 20040329 to 20040615
Maximum Sample Interval = 21 Days, Date Range = 20040423 to 20040515
Percent of Total Flow Volume Occuring In This Interval = 1.9%

Total Flow Volume on Sampled Days = 30.0 hm3
Total Flow Volume on All Days = 510.8 hm3
Percent of Total Flow Volume Sampled = 5.9%

Maximum Sampled Flow Rate = 11.47 hm3/yr
Maximum Total Flow Rate = 21.30 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 19 out of 367
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate = 75.0%

384045 Armourdale S.Inlet 2004 VAR=nh3-4 METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	367	11	11	100.0	1.392	3.030	.579	.014
***	367	11	11	100.0	1.392	3.030		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 1.392 HM3/YR
TOTAL FLOW VOLUME = 1.40 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1023.0	1018.1	.4649E+06	731.53	.670
2 Q WTD C	469.8	467.5	.4423E+05	335.95	.450
3 IJC	508.0	505.6	.4617E+05	363.26	.425
4 REG-1	299.3	297.9	.2775E+05	214.03	.559
5 REG-2	1044.2	1039.2	.1610E+06	746.72	.386
6 REG-3	285.4	284.0	.7384E+05	204.09	.957

384045 Armourdale S.Inlet 2004 VAR=no2+no3 METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384045_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 271
Positive Flows = 96

384045 Armourdale S.Inlet 2004 VAR=no2+no3 METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	367	11	11	100.0	1.392	3.030	.734	.012
***	367	11	11	100.0	1.392	3.030		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 1.392 HM3/YR
TOTAL FLOW VOLUME = 1.40 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	7048.0	7014.4	.1218E+08	5040.11	.498
2 Q WTD C	3236.7	3221.3	.3507E+06	2314.63	.184
3 IJC	3351.8	3335.8	.3303E+06	2396.91	.172
4 REG-1	1828.8	1820.0	.6442E+06	1307.77	.441
5 REG-2	7264.9	7230.3	.1944E+07	5195.24	.193
6 REG-3	5833.3	5805.5	.2547E+08	4171.47	.869

384045 Armourdale S.Inlet 2004 VAR=inorg-n METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384045_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 271
Positive Flows = 96

384045 Armourdale S.Inlet 2004 VAR=inorg-n METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	367	11	11	100.0	1.392	3.030	.710	.010
***	367	11	11	100.0	1.392	3.030		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 1.392 HM3/YR
TOTAL FLOW VOLUME = 1.40 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	8070.9	8032.5	.1708E+08	5771.64	.515
2 Q WTD C	3706.5	3688.8	.5812E+06	2650.58	.207
3 IJC	3859.8	3841.4	.5716E+06	2760.16	.197
4 REG-1	2133.5	2123.3	.8344E+06	1525.70	.430
5 REG-2	8327.0	8287.3	.1807E+07	5954.77	.162
6 REG-3	5595.8	5569.1	.2167E+08	4001.65	.836

384045 Armourdale S.Inlet 2004   VAR=tkn   METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384045_Q.wk1   ,   Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows =   0
Zero Flows =   271
Positive Flows =   96

384045 Armourdale S.Inlet 2004   VAR=tkn   METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	367	11	11	100.0	1.392	3.030	.011	.753
***	367	11	11	100.0	1.392	3.030		

FLOW STATISTICS
FLOW DURATION =   367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE =   1.392 HM3/YR
TOTAL FLOW VOLUME =   1.40 HM3
FLOW DATE RANGE   = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	5039.2	5015.2	.4753E+07	3603.61	.435
2 Q WTD C	2314.2	2303.2	.6130E+05	1654.93	.107
3 IJC	2353.0	2341.8	.7049E+05	1682.69	.113
4 REG-1	2295.2	2284.3	.8134E+05	1641.33	.125
5 REG-2	2409.6	2398.1	.8800E+06	1723.16	.391
6 REG-3	2090.8	2080.8	.1106E+06	1495.15	.160

384045 Armourdale S.Inlet 2004   VAR=tn   METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384045_Q.wk1   ,   Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows =   0
Zero Flows =   271
Positive Flows =   96

384045 Armourdale S.Inlet 2004 VAR=tn METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	367	11	11	100.0	1.392	3.030	.175	.027
***	367	11	11	100.0	1.392	3.030		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 1.392 HM3/YR
TOTAL FLOW VOLUME = 1.40 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	12087.2	12029.6	.3179E+08	8643.72	.469
2 Q WTD C	5551.0	5524.5	.6286E+06	3969.56	.144
3 IJC	5704.8	5677.6	.6469E+06	4079.59	.142
4 REG-1	4845.9	4822.8	.1117E+07	3465.35	.219
5 REG-2	8855.5	8813.3	.9882E+07	6332.67	.357
6 REG-3	4830.4	4807.4	.3117E+07	3454.27	.367

384045 Armourdale S.Inlet 2004 VAR=t-d-p METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384045_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 271
Positive Flows = 96

384045 Armourdale S.Inlet 2004 VAR=t-d-p METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	367	11	11	100.0	1.392	3.030	-.095	.526
***	367	11	11	100.0	1.392	3.030		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 1.392 HM3/YR
TOTAL FLOW VOLUME = 1.40 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	1176.4	1170.8	.3622E+06	841.24	.514
2 Q WTD C	540.2	537.7	.9074E+05	386.33	.560
3 IJC	525.8	523.3	.1240E+06	376.00	.673
4 REG-1	581.6	578.9	.7626E+05	415.94	.477
5 REG-2	330.2	328.7	.4726E+06	236.15	2.092
6 REG-3	470.2	468.0	.6523E+05	336.28	.546

384045 Armourdale S.Inlet 2004   VAR=tp   METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384045_Q.wk1   ,   Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows =   0
Zero Flows =   271
Positive Flows =   96

384045 Armourdale S.Inlet 2004   VAR=tp   METHOD= 3 IJC
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	367	11	11	100.0	1.392	3.030	.078	.470
***	367	11	11	100.0	1.392	3.030		

FLOW STATISTICS
FLOW DURATION =   367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE =   1.392 HM3/YR
TOTAL FLOW VOLUME =   1.40 HM3
FLOW DATE RANGE   = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	2124.6	2114.5	.1034E+07	1519.32	.481
2 Q WTD C	975.7	971.0	.2048E+05	697.74	.147
3 IJC	1007.1	1002.3	.1668E+05	720.16	.129
4 REG-1	918.0	913.6	.7329E+05	656.48	.296
5 REG-2	1258.9	1252.9	.7856E+06	900.23	.707
6 REG-3	791.4	787.6	.1619E+06	565.91	.511

384045 Armourdale S.Inlet 2004   VAR=tss   METHOD= 3 IJC

TABULATION OF MISSING DAILY FLOWS:

Flow File =384045_Q.wk1   ,   Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows =   0
Zero Flows =   271
Positive Flows =   96

384045 Armourdale S.Inlet 2004   VAR=tss   METHOD= 3 IJC

COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	367	11	11	100.0	1.392	3.030	-.033	.564
***	367	11	11	100.0	1.392	3.030		

FLOW STATISTICS
FLOW DURATION =   367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE =   1.392 HM3/YR
TOTAL FLOW VOLUME =   1.40 HM3
FLOW DATE RANGE   = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040329 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	23213.7	23103.0	.1201E+09	16600.38	.474
2 Q WTD C	10660.7	10609.8	.3262E+07	7623.59	.170
3 IJC	10958.1	10905.8	.3538E+07	7836.27	.172
4 REG-1	10940.4	10888.2	.4684E+07	7823.59	.199
5 REG-2	9246.3	9202.2	.4715E+08	6612.18	.746
6 REG-3	8726.2	8684.6	.5347E+07	6240.25	.266

385216 Armoredale Outlet 2004   VAR=nh3-4   METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385216_Q.wk1   ,   Station =Flow
Daily Flows from 20031031 to 20041031

Average Sample Interval =   6.4 Days, Date Range = 20040317 to 20040615
Maximum Sample Interval =   12 Days, Date Range = 20040423 to 20040506
Percent of Total Flow Volume Occuring In This Interval = 14.7%

Total Flow Volume on Sampled Days =   125.7 hm3
Total Flow Volume on All Days   =   864.7 hm3
Percent of Total Flow Volume Sampled =   14.5%

Maximum Sampled Flow Rate =   20.64 hm3/yr
Maximum Total Flow Rate   =   23.33 hm3/yr
Number of Days when Flow Exceeded Maximum Sampled Flow = 1 out of 367
Percent of Total Flow Volume Occurring at Flow Rates Exceeding the
Maximum Sampled Flow Rate =   2.7%

385216 Armoredale Outlet 2004   VAR=nh3-4   METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385216_Q.wk1   ,   Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367

Missing Flows =   0
Zero Flows =   273
Positive Flows =   94

385216 Armoredale Outlet 2004 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	14	14	100.0	2.356	8.978	-.674	.023
***	367	14	14	100.0	2.356	8.978		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.356 HM3/YR
TOTAL FLOW VOLUME = 2.37 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040317 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	938.9	934.5	.9696E+05	396.62	.333
2 Q WTD C	246.4	245.2	.5002E+04	104.08	.288
3 IJC	246.5	245.3	.5202E+04	104.11	.294
4 REG-1	606.7	603.8	.2448E+05	256.29	.259
5 REG-2	343.3	341.7	.1659E+05	145.03	.377
6 REG-3	283.7	282.3	.1508E+05	119.82	.435

385216 Armoredale Outlet 2004 VAR=no2+no3 METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385216_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 273
Positive Flows = 94

385216 Armoredale Outlet 2004 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	14	14	100.0	2.356	8.978	.815	.021
***	367	14	14	100.0	2.356	8.978		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.356 HM3/YR
TOTAL FLOW VOLUME = 2.37 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040317 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	9560.8	9515.2	.1332E+08	4038.62	.384
2 Q WTD C	2508.9	2496.9	.4777E+06	1059.78	.277
3 IJC	2562.6	2550.3	.4941E+06	1082.46	.276
4 REG-1	842.9	838.9	.1833E+06	356.04	.510
5 REG-2	2562.3	2550.1	.5119E+06	1082.37	.281
6 REG-3	2788.4	2775.1	.1483E+07	1177.87	.439

385216 Armoredale Outlet 2004 VAR=inorg-n METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385216_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 273
Positive Flows = 94

385216 Armoredale Outlet 2004 VAR=inorg-n METHOD= 2 Q WTD C
COMPARISON OF SAMPLED AND TOTAL FLOW DISTRIBUTIONS

STR	NQ	NC	NE	VOL%	TOTAL FLOW	SAMPLED FLOW	C/Q SLOPE	SIGNIF
1	367	14	14	100.0	2.356	8.978	.053	.852
***	367	14	14	100.0	2.356	8.978		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.356 HM3/YR
TOTAL FLOW VOLUME = 2.37 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040317 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	10499.7	10449.7	.1535E+08	4435.24	.375
2 Q WTD C	2755.2	2742.1	.5533E+06	1163.86	.271
3 IJC	2809.0	2795.6	.5747E+06	1186.58	.271
4 REG-1	2566.7	2554.5	.1312E+07	1084.23	.448
5 REG-2	2830.9	2817.4	.8970E+06	1195.81	.336
6 REG-3	3056.8	3042.2	.1536E+07	1291.24	.407

385216 Armoredale Outlet 2004 VAR=tkn METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385216_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 273
Positive Flows = 94

385216 Armoredale Outlet 2004 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	14	14	100.0	2.356	8.978	-.168	.000
***	367	14	14	100.0	2.356	8.978		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.356 HM3/YR
TOTAL FLOW VOLUME = 2.37 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040317 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	13191.1	13128.2	.5680E+07	5572.12	.182
2 Q WTD C	3461.5	3445.0	.1774E+05	1462.19	.039
3 IJC	3456.8	3440.3	.1879E+05	1460.21	.040
4 REG-1	4331.6	4311.0	.2156E+05	1829.75	.034
5 REG-2	3162.3	3147.2	.2327E+05	1335.79	.048
6 REG-3	3445.0	3428.6	.1751E+05	1455.22	.039

385216 Armoredale Outlet 2004 VAR=tn METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385216_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 273
Positive Flows = 94

385216 Armoredale Outlet 2004 VAR=tn 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	14	14	100.0	2.356	8.978	-.009	.897
***	367	14	14	100.0	2.356	8.978		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.356 HM3/YR
TOTAL FLOW VOLUME = 2.37 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040317 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	22751.9	22643.4	.3210E+08	9610.74	.250
2 Q WTD C	5970.4	5941.9	.4392E+06	2521.97	.112
3 IJC	6019.4	5990.7	.4507E+06	2542.68	.112
4 REG-1	6045.2	6016.3	.6545E+06	2553.56	.134
5 REG-2	5940.7	5912.4	.6966E+06	2509.44	.141
6 REG-3	5580.3	5553.7	.4440E+06	2357.20	.120

385216 Armoredale Outlet 2004 VAR=tdp METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385216_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 273
Positive Flows = 94

385216 Armoredale Outlet 2004 VAR=tdp 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	14	14	100.0	2.356	8.978	-.169	.070
***	367	14	14	100.0	2.356	8.978		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.356 HM3/YR
TOTAL FLOW VOLUME = 2.37 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040317 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	2348.7	2337.5	.2719E+06	992.11	.223
2 Q WTD C	616.3	613.4	.6637E+04	260.34	.133
3 IJC	616.0	613.1	.6795E+04	260.23	.134
4 REG-1	772.4	768.7	.9838E+04	326.25	.129
5 REG-2	562.7	560.1	.7157E+04	237.71	.151
6 REG-3	601.1	598.2	.6626E+04	253.91	.136

385216 Armoredale Outlet 2004 VAR=tp METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385216_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 273
Positive Flows = 94

385216 Armoredale Outlet 2004 VAR=tp 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	14	14	100.0	2.356	8.978	-.139	.179
***	367	14	14	100.0	2.356	8.978		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.356 HM3/YR
TOTAL FLOW VOLUME = 2.37 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040317 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	3100.3	3085.5	.6369E+06	1309.60	.259
2 Q WTD C	813.5	809.7	.1009E+05	343.65	.124
3 IJC	820.9	817.0	.1043E+05	346.76	.125
4 REG-1	979.2	974.6	.2581E+05	413.64	.165
5 REG-2	754.2	750.6	.1722E+05	318.59	.175
6 REG-3	764.4	760.7	.1263E+05	322.89	.148

385216 Armoredale Outlet 2004 VAR=tss METHOD= 2 Q WTD C

TABULATION OF MISSING DAILY FLOWS:

Flow File =385216_Q.wk1 , Station =Flow
Daily Flows from 20031031 to 20041031

Summary:
Reported Flows = 367
Missing Flows = 0
Zero Flows = 273
Positive Flows = 94

385216 Armoredale Outlet 2004 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	14	14	100.0	2.356	8.978	.050	.776
***	367	14	14	100.0	2.356	8.978		

FLOW STATISTICS
FLOW DURATION = 367.0 DAYS = 1.005 YEARS
MEAN FLOW RATE = 2.356 HM3/YR
TOTAL FLOW VOLUME = 2.37 HM3
FLOW DATE RANGE = 20031031 TO 20041031
SAMPLE DATE RANGE = 20040317 TO 20040615

METHOD	MASS (KG)	FLUX (KG/YR)	FLUX VARIANCE	CONC (PPB)	CV
1 AV LOAD	149976.5	149261.3	.4933E+10	63352.19	.471
2 Q WTD C	39355.5	39167.8	.2608E+09	16624.31	.412
3 IJC	40204.3	40012.6	.2945E+09	16982.87	.429
4 REG-1	36787.5	36612.0	.2663E+09	15539.54	.446
5 REG-2	40386.0	40193.4	.3482E+09	17059.62	.464
6 REG-3	35008.6	34841.7	.1482E+09	14788.15	.349

Appendix C
EPA Formal Comments

EPA REGION VIII TMDL REVIEW FORM

Document Name:	**Armourdale Dam Nutrient and Dissolved Oxygen TMDLs**
Submitted by:	**Mike Ell, NDDoH**
Date Received:	**October 4, 2006**
Review Date:	**October 26, 2006**
Reviewer:	**Vern Berry, EPA**
Formal or Informal Review?	**Informal - Public Notice**

This document provides a standard format for EPA Region 8 to provide comments to the North Dakota Department of Health (NDDoH) on TMDL documents provided to the EPA for either official formal or informal review. All TMDL documents are measured against the following 12 review criteria:

1. Water Quality Impairment Status
2. Water Quality Standards
3. Water Quality Targets
4. Significant Sources
5. Technical Analysis
6. Margin of Safety and Seasonality
7. Total Maximum Daily Load
8. Allocation
9. Public Participation
10. Monitoring Strategy
11. Restoration Strategy
12. Endangered Species Act Compliance

Each of the 12 review criteria are described below to provide the rational for the review, followed by EPA's comments. This review is intended to ensure compliance with the Clean Water Act and also to ensure that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Water Quality Impairment Status

> ***Criterion Description – Water Quality Impairment Status***
>
> *TMDL documents must include a description of the listed water quality impairments. While the 303(d) list identifies probable causes and sources of water quality impairments, the information contained in the 303(d) list is generally not sufficiently detailed to provide the reader with an adequate understanding of the impairments. TMDL documents should include a thorough description/summary of all available water quality data such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and/or appropriate water quality standards.*

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Armourdale Dam (reservoir) is located near the town of Rolla in Towner County, North Dakota. It is a 79.3 acre man-made impoundment on Armourdale Coulee in the Pembina River subbasin, within the larger Red River basin. The North and South branches of Armourdale Coulee drain into the reservoir. Armourdale Dam is listed on the State's 2004 303(d) list as impaired for aquatic life and recreational uses by nutrients/eutrophication, and for aquatic life for low dissolved oxygen and sedimentation/siltation. Approximately 13,680 acres of land drain to the reservoir from the watershed. Armourdale Dam is classified as a Class 2 cool water fishery, and is listed as a high priority (i.e., 1A) for TMDL development. The majority of the land use in this watershed is agricultural (approximately 93 percent). Cropland acreage is approximately 90% and pastureland is approximately 3%.

2. Water Quality Standards

> ***Criterion Description – Water Quality Standards***
>
> *The TMDL document must include a description of all applicable water quality standards for all affected jurisdictions. TMDLs result in maintaining and attaining water quality standards. Water quality standards are the basis from which TMDLs are established and the TMDL targets are derived, including the numeric, narrative, use classification, and antidegradation components of the standards.*

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Armourdale Dam is impaired for dissolved oxygen and nutrients/eutrophication and sedimentation/siltation. The North Dakota Department of Health has set narrative water quality standards that apply to all surface waters of the state. The NDDoH narrative standards that apply to nutrients and sedimentation include:

> *"All waters of the state shall be free from substances attributable to municipal, industrial, or other discharges or agricultural practices in concentrations or combinations which are toxic or harmful to humans, animals, plants, or resident aquatic biota." (See NDAC 33-16-02-08.1.a.(4))*
>
> *"No discharge of pollutants, which alone or in combination with other substances, shall:*
> *1. Cause a public health hazard or injury to environmental resources;*

2. Impair existing or reasonable beneficial uses of the receiving waters; or
3. Directly or indirectly cause concentrations of pollutants to exceed applicable standards of the receiving waters." (See NDAC 33-16-02-08.1.e.)

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

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

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

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

Other applicable water quality standards are included on pages 14 - 16 of the TMDL report.

3. Water Quality Targets

Criterion Description – Water Quality Targets

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

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☒ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

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

Nutrient reduction response modeling was conducted with BATHTUB, an Army Corps of Engineers eutrophication response model. The results of the modeling show that a 75% reduction in external phosphorous loading to the reservoir will achieve a total phosphorous TSI of 73.15, which corresponds to a phosphorous concentration of 0.12 mg/L. This target is based on best professional judgement and will fully support its beneficial uses.

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

The water quality targets used in this TMDL are: **maintain a mean annual total phosphorous TSI at or below 73.15; maintain a dissolved oxygen level of not less than 5 mg/L.**

COMMENTS – We recommend that the nutrient target be clearly stated in the first or second paragraph of Section 3.1 rather than the last paragraph. Further, we recommend that Section 3.1 be renamed "Nutrient Target" to correspond to the TMDL (i.e., "3.1 Nutrient Target" - matches the "Nutrient TMDL" in Section 7.1).

Section 3.0, TMDL Targets, do not mention a target for dissolved oxygen. Typically, when a pollutant has a numeric water quality standard, the TMDL target is equal to the numeric standard (e.g., DO $\geq$ 5.0 mg/L. We recommend that a brief section (e.g., "Section 3.2 – Dissolved Oxygen Target") be added to include a target for dissolved oxygen.

4. Significant Sources

Criterion Description – Significant Sources

TMDLs must consider all significant sources of the stressor of concern. All sources or causes of the stressor must be identified or accounted for in some manner. The detail provided in the source assessment step drives the rigor of the allocation step. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each significant source when the relative load contribution from each source has been estimated. Ideally, therefore, the pollutant load from each significant source should be quantified. This can be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach can be employed so long as the approach is clearly defined in the document.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The TMDL identifies the major sources of phosphorous as coming from nonpoint source agricultural landuses within the watershed. In particular, a loading analysis was done for nutrients and sediment considering various agricultural land use and land management factors. Cropland and pastureland are the primary sources identified. Approximately 90% of the landuse is cropland and 3% is pastureland in the watershed.

5. Technical Analysis

Criterion Description – Technical Analysis

*TMDLs must be supported by an appropriate level of technical analysis. It applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader. Of particular importance, the cause and effect relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and allocations needs to be supported by an appropriate level of technical analysis.*

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☒ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The technical analysis addresses the needed phosphorous reduction to achieve the desired water quality. The TMDL recommends a 75% reduction in external average annual total phosphorous loads to Armourdale Dam. Based on the loads measured during the period of the assessment the total phosphorous load should be 1,001.1 kg/yr to achieve the proposed TP TSI target. This reduction is based in large part on the BATHTUB mathematical modeling of the reservoir and its predicted response to nutrient load reductions. The FLUX model was used to facilitate the analysis and reduction of tributary inflow and outflow nutrient and sediment loadings for Armourdale Dam. Output from the FLUX program is then provided as an input file to calibrate the BATHTUB eutrophication response model.

The Agricultural Non-Point Source Model (AGNPS) model was used to simulate alterations in land use practices and the resulting nutrient reduction response. The nutrient loading source analysis, that was used to identify necessary controls in the watershed, was based on the identification of critical cells and highly critical cells (i.e., those with higher phosphorous loading rates). The initial load reductions specified by this TMDL will be achieved through controls on the critical cells within the watershed to improve: pasture conditions, tillage practices or fertilizer management.

The technical analysis also addresses the Armourdale Dam sediment listing. The analysis concludes that the reservoir is not impaired by sediment, and that it should be delisted from the state's Section 303(d) list. Justification for this action is based on the conclusion that the sediment accumulation rate in the Dam is well below the average sedimentation rate of typical reservoirs - based on calculations of sediment balance and accumulation rates in the reservoir compared to NRCS and literature values.

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

COMMENTS – The dissolved oxygen linkage analysis should be moved from Section 7.3 and added to the DO technical analysis Section 5.4. We suggest that the third paragraph of Section 5.4 be moved, and modified as necessary, to Section 7.3.

Also, because the original sediment impairment listing, in part, was related to the aquatic life beneficial use, there needs to be some discussion in Section 5.5 of the results from the TSS sampling and how the concentrations are below the level found in research studies to be harmful to aquatic life. This is a critical component of the sediment delisting justification (see language in the Carbury Dam TMDL or the Dead Colt Creek Dam TMDL for reference).

6. Margin of Safety and Seasonality

Criterion Description – Margin of Safety and Seasonality

A margin of safety (MOS) is a required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (303(d)(1)(c)). The MOS can be implicitly expressed by incorporating a margin of safety into conservative assumptions used to develop the TMDL. In other cases, the MOS can be built in as a separate component of the TMDL (in this case, quantitatively, a TMDL = WLA + LA + MOS). In all cases, specific documentation describing the rational for the MOS is required. Seasonal considerations, such as critical flow periods (high flow, low flow), also need to be considered when establishing TMDLs , targets, and allocations.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – A 10% explicit margin of safety is specified in the nutrient TMDL of 100.1 kg/yr of phosphorous. Seasonality was adequately considered by evaluating the cumulative impacts of the various seasons on water quality and by proposing BMPs that can be tailored to seasonal needs.

7. TMDL

Criterion Description – Total Maximum Daily Load
TMDLs include a quantified pollutant reduction target. According to EPA regulations (see 40 CFR 130.2(i)). TMDLs can be expressed as mass per unit of time, toxicity, % load reduction, or other measure. TMDLs must address, either singly or in combination, each listed pollutant/water body combination.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The TMDL established for Armourdale Dam is a 1,001.1 kg/yr total phosphorus load to the reservoir (75% reduction in external annual total phosphorus load). This is the "measured load" which derived from the BATHTUB model using the flow and concentration data collected during the period of the assessment. The annual loading will vary from year-to-year; therefore, this TMDL is considered a long term average percent reduction in phosphorous loading. The TMDL contains a linkage analysis between phosphorous loading and low dissolved oxygen in lakes and reservoirs. It is anticipated that meeting the phosphorous load reduction target in Armourdale Dam will address the dissolved oxygen impairment.

8. Allocation

Criterion Description – Allocation
TMDLs apportion responsibility for taking actions or allocate the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or dividing of responsibility. A performance based allocation approach, where a detailed strategy is articulated for the application of BMPs, may also be appropriate for nonpoint sources. Every effort should be made to be as detailed as possible and also, to base all conclusions on the best available scientific principles. In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – This TMDL addresses the need to achieve further reductions in nutrients to attain water quality goals in Armourdale Dam. The allocations in the TMDL include a "load allocation" attributed agricultural to nonpoint sources, and an explicit margin of safety. There are no known point source contributions in this watershed. The source allocations for phosphorous are assigned to the critical loading cells in the watershed that were identified by the AGNPS model. The subwatershed areas with critical phosphorous loading are shown in Figure 16 of the TMDL. There is a desire to move forward with controls in the areas of the basin where there is confidence that phosphorous reductions can be achieved through modifications to critical cells within the watershed.

9. Public Participation

Criterion Description – Public Participation

The fundamental requirement for public participation is that all stakeholders have an opportunity to be part of the process. Notifications or solicitations for comments regarding the TMDL should clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for review, a copy of the comments received by the state should be also submitted to EPA.

☒ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☐ Not a required element in this case. Comments or questions provided for informational purposes.

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

10. Monitoring Strategy

Criterion Description – Monitoring Strategy

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

☐ Satisfies Criterion
☒ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.

☐ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – Future monitoring is recommended in Section 10.0 of the TMDL to address margin of safety and seasonality needs, as well as provide additional data to ensure that the goals of the TMDL are met.

COMMENTS – 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 BMPs are implemented (perhaps conducting monitoring every 3-5 years until the TMDL target is met).

11. Restoration Strategy

Criterion Description – Restoration Strategy

At a minimum, sufficient information should be provided in the TMDL document to demonstrate that if the TMDL were implemented, water quality standards would be attained or maintained. Adding additional detail regarding the proposed approach for the restoration of water quality *<u>is not</u>* *currently a regulatory requirement, but is considered a value added component of a TMDL document.*

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – The North Dakota Department of Health will work with the local soil conservation district, local volunteer groups and landowners to initiate restoration projects in the watershed.

12. Endangered Species Act Compliance

Criterion Description – Endangered Species Act Compliance

EPA's approval of a TMDL may constitute an action subject to the provisions of Section 7 of the Endangered Species Act (ESA). EPA will consult, as appropriate, with the US Fish and Wildlife Service (USFWS) to determine if there is an effect on listed endangered and threatened species pertaining to EPA's approval of the TMDL. The responsibility to consult with the USFWS lies with EPA and is not a requirement under the Clean Water Act for approving TMDLs. States are encouraged, however, to participate with USFWS and EPA in the consultation process and, most importantly, to document in its TMDLs the potential effects (adverse or beneficial) the TMDL may have on listed as well as candidate and proposed species under the ESA.

☐ Satisfies Criterion
☐ Satisfies Criterion. Questions or comments provided below should be considered.
☐ Partially satisfies criterion. Questions or comments provided below need to be addressed.
☐ Criterion not satisfied. Questions or comments provided below need to be addressed.
☒ Not a required element in this case. Comments or questions provided for informational purposes.

SUMMARY – EPA will request ESA Section 7 concurrence from the USFWS for this TMDL.

Appendix D
USFWS Formal Comments

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Ecological Services
3425 Miriam Avenue
Bismarck, North Dakota 58501

OCT 25 2006
DIV. OF WATER QUALITY

OCT 23 2006

Mr. Mike Ell
Environmental Administrator
Division of Water Quality
North Dakota Department of Health
918 East Divide Avenue
Bismarck, North Dakota 58501-1947

Dear Mr. Ell:

The U.S. Fish and Wildlife Service (Service) has reviewed draft Total Maximum Daily Loads for Indian Creek Dam in Hettinger County, and for Armourdale Dam in Towner County, and offers the following comments.

The North Dakota Department of Health (Department) has identified both Indian Creek and Armourdale Dams as being water quality limited and needing Total Maximum Daily Loads (TMDL). Both reservoirs are on the Department's Section 303(d) List of Impaired Waters. Aquatic life in the reservoirs is listed as impaired due to nutrients, sedimentation, and low dissolved oxygen. Recreational uses are impaired due to nutrients. The draft TMDL indicates there are no waste allocations from point sources in either watershed. Pollutant loads are attributed to nonpoint sources.

The draft documents provide a good discussion on identifying the pollutant reductions needed and actions that should be taken to achieve water quality standards for the two reservoirs. The Service supports the Department's efforts to restore the aquatic life and recreational uses of these two waterbodies.

Section 12.0 "Endangered Species Act compliance" within both drafts lists threatened and endangered species "*specific to*" the water body and respective county. The list of species in both documents is correct for the respective county; however, the species listed are not, as the documents say, "*specific to*" the waterbodies. Although listed species could use habitats associated with the waterbodies, we do not have any records of listed species occurring specifically at Indian Creek Dam or Armourdale Dam.

Section 12.0 could benefit from a discussion on how the proposed TMDL would affect threatened or endangered species. If a Federal agency authorizes, funds, or carries out a proposed action, the responsible Federal agency, or its designated agent, is required to evaluate whether the action "may affect" listed species or may adversely modify proposed or designated critical habitat. If the Federal agency determines the action "may affect" listed species or may adversely modify proposed or designated critical habitat, then the responsible Federal agency shall request formal section 7 consultation with this office. If the evaluation shows a "no effect" determination for listed species and no adverse modification of proposed or designated critical habitat, further consultation is not necessary. If a private entity or state or local agency receives Federal funding for a project or action, or if any Federal permit is required, the responsible Federal agency may designate the fund recipient or permittee as its agent for purposes of section 7 consultation.

The U.S. Environmental Protection Agency (EPA) is the Federal agency that must approve or disapprove the Department's proposed TMDL's for Indian Creek and Armourdale Dam. Expanding Section 12.0 to include a discussion on affects to federally listed species and any adverse modification of proposed or designated critical habitat would assist EPA in their determination of "may affect" or "no affect." A yet more efficient approach would be to have the Department designated as EPA's agent for purposes of ESA determinations. If the determination is "No Effect", there is no further need for coordination with or concurrence by the Service. Additionally, an expanded discussion on the proposed TMDL's affect, if any, on listed species would provide the Service with an opportunity during the draft comment period to review the Department's endangered species assessment. The Department could then submit to EPA the final TMDL along with the Service's comments and the Department's determination relative to affects to federally-listed species. This would expedite EPA's review and approval/disapproval of the final TMDL and eliminate the administrative step of EPA's requesting Service concurrence on EPA's affects determination.

In light of the absence of discussions on affects to threatened or endangered species within the current draft TMDL documents, the Service is providing the Department with our assessment that the TMDL's for Indian Creek Dam and Armourdale Dam will have "no effect" on federally listed threatened or endangered species and "no adverse modification" to proposed or designated critical habitat. If you concur with this determination, no further concurrence is needed from the Service.

Thank you for the opportunity to comment on the draft documents. If you have any questions or need further assistance please do not hesitate to contact Kevin Johnson of my staff, or contact me directly, at 701-250-4481, or at the letterhead address.

Sincerely,

Jeffrey K. Towner

Jeffrey K. Towner
Field Supervisor
North Dakota Field Office

cc: Director, ND Game & Fish Department, Bismarck
(Attn: S. Ellstad)

Appendix E
Department Response to All Comments

A 30 day public notice soliciting comment and participation for the Armourdale Dam Nutrient, Sediment, and Dissolved Oxygen TMDLs was held from October 3 to November 3, 2006. The North Dakota Department of Health received a formal letter from Vern Berry of the Environmental Protection Agency (EPA) dated October 26, 2006, and Jeffrey K.Towner Field Supervisor of the United States Fish and Wildlife Service (USFWS) dated October 23, 2006. Below are the comments made, ~~and~~ the section(s) they address, and the Department's response.

Environmental Protection Agency (EPA) Comments

<u>Section 3.0 TMDL Targets</u>

Comment from EPA: "We recommend that the nutrient target be clearly stated in the first or second paragraph of Section 3.1 rather than the last paragraph. Further, we recommend that Section 3.1 be renamed "Nutrient Target" to correspond to the TMDL (i.e., "3.1 Nutrient Target" - matches the "Nutrient TMDL" in Section 7.1)."

"Section 3.0, TMDL Targets, do not mention a target for dissolved oxygen. Typically, when a pollutant has a numeric water quality standard, the TMDL target is equal to the numeric standard (e.g., DO $\geq$ 5.0 mg/L. We recommend that a brief section (e.g., "Section 3.2 – Dissolved Oxygen Target") be added to include a target for dissolved oxygen."

NDDOH Response: Corrections were made to the TMDL document pertaining to the renaming of Section 3.1, the nutrient target was addressed, and language was added to Section 3.2 concerning the dissolved oxygen target per EPA request.

<u>Section 5.4 Dissolved Oxygen and Section 7.3 Dissolved Oxygen TMDL</u>

Comments from EPA: "The dissolved oxygen linkage analysis should be moved from Section 7.3 and added to the DO technical analysis Section 5.4. We suggest that the third paragraph of Section 5.4 be moved, and modified as necessary, to Section 7.3."

NDDOH Response: Changes have been made to the TMDL document concerning the dissolved oxygen linkage analysis in Section 7.3 and dissolved oxygen technical analysis Section 5.4 per EPA request.

<u>Section 5.5 Sediment</u>

Comments from EPA: "Also, because the original sediment impairment listing, in part, was related to the aquatic life beneficial use, there needs to be some discussion in Section 5.5 of the results from the TSS sampling and how the concentrations are below the level found in research studies to be harmful to aquatic life. This is a critical component of the sediment delisting justification (see language in the Carbury Dam TMDL or the Dead Colt Creek Dam TMDL for reference)."

NDDOH Response: Language has been added to Section 5.5 of the TMDL document addressing TSS sampling and concentrations along with their effect on aquatic life.

United States Fish and Wildlife Service Comments

<u>Section 12.0 Endangered Species Act Compliance</u>

Comment from USFWS: "Section 12.0 "Endangered Species Act Compliance" within both drafts lists threatened and endangered species "specific to" the water body and respective county. The list of species in both documents is correct for the respective county; however, the species listed are not, as the documents say, "specific to" the waterbodies. Although listed species could use habitats associated with the waterbodies, we do not have any records of listed species occurring specifically at Indian Creek Dam or Armourdale Dam."

NDDOH Response: Section 12.0 has been changed to reflect the USFWS comments regarding endangered or threatened species and their presence in the waterbody or associated habitats.

Comments from USFWS: "…In light of the absence of discussions on affects to threatened or endangered species within the current draft TMDL documents, the Service is providing the Department with our assessment that the TMDL's for Indian Creek Dam and Armourdale Dam will have "no effect" on federally listed threatened or endangered species and "no adverse modification" to proposed or designated critical habitat. If you concur with this determination, no further concurrence is needed from the Service."

NDDOH Response: The North Dakota Department of Health concurs with the United States Fish and Wildlife Service's determination of a "no effect" on federally listed threatened or endangered species and "no adverse modification" to proposed or designated critical habitat relating to the Armourdale Dam TMDL. Language has been added to Section 12.0 of the TMDL document concurring with the USFWS's determination.