Nutrient and Dissolved Oxygen TMDLs for Crown Butte Dam in Morton County, North Dakota

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1.0 INTRODUCTION AND DESCRIPTION OF THE WATERSHED

Crown Butte Dam is a recreational impoundment located in Morton County in south central North Dakota (Figure 1). The reservoir was created in 1963 by the damming of Crown Butte Creek during the construction of Interstate 94 west of Mandan, North Dakota. It was constructed to create a fishery and recreational facility. At full pool, Crown Butte Dam covers a surface area of 30.6 acres, has a maximum depth of 30.6 feet and an average depth of 12.5 feet (Figure 2).

Crown Butte Dam and its contributing watershed lie within Morton County and have a combined surface area of approximately 4,800 acres. Table 1 summarizes some of the geographical, hydrological, and physical characteristics of Crown Butte Dam and the Crown Butte Dam Watershed.

Table 1. General Characteristics of Crown Butte Dam and the Crown Butte Dam Watershed.

Legal Name	Crown Butte Dam
Major Drainage Basin	Missouri River Basin
Nearest Municipality	Mandan, North Dakota
Assessment Unit ID	ND-10130203-002L_00
County	Morton County, North Dakota
Latitude	46˚51'55"
Longitude	-101˚6'25"
Surface Area	30.6 acres
Watershed Area	4,760 acres
Average Depth	12.5 feet
Maximum Depth	30.6 feet
Volume	385.7 acre-feet
Tributaries	Crown Butte Creek
Outlet	Gated Structure
Type of Waterbody	Constructed Reservoir - Earthen Dam/Highway Embankment
Fishery Type	Class 3 – warm water fishery - bluegill, largemouth bass, rainbow trout
Classified Beneficial Uses	Recreation and aquatic life

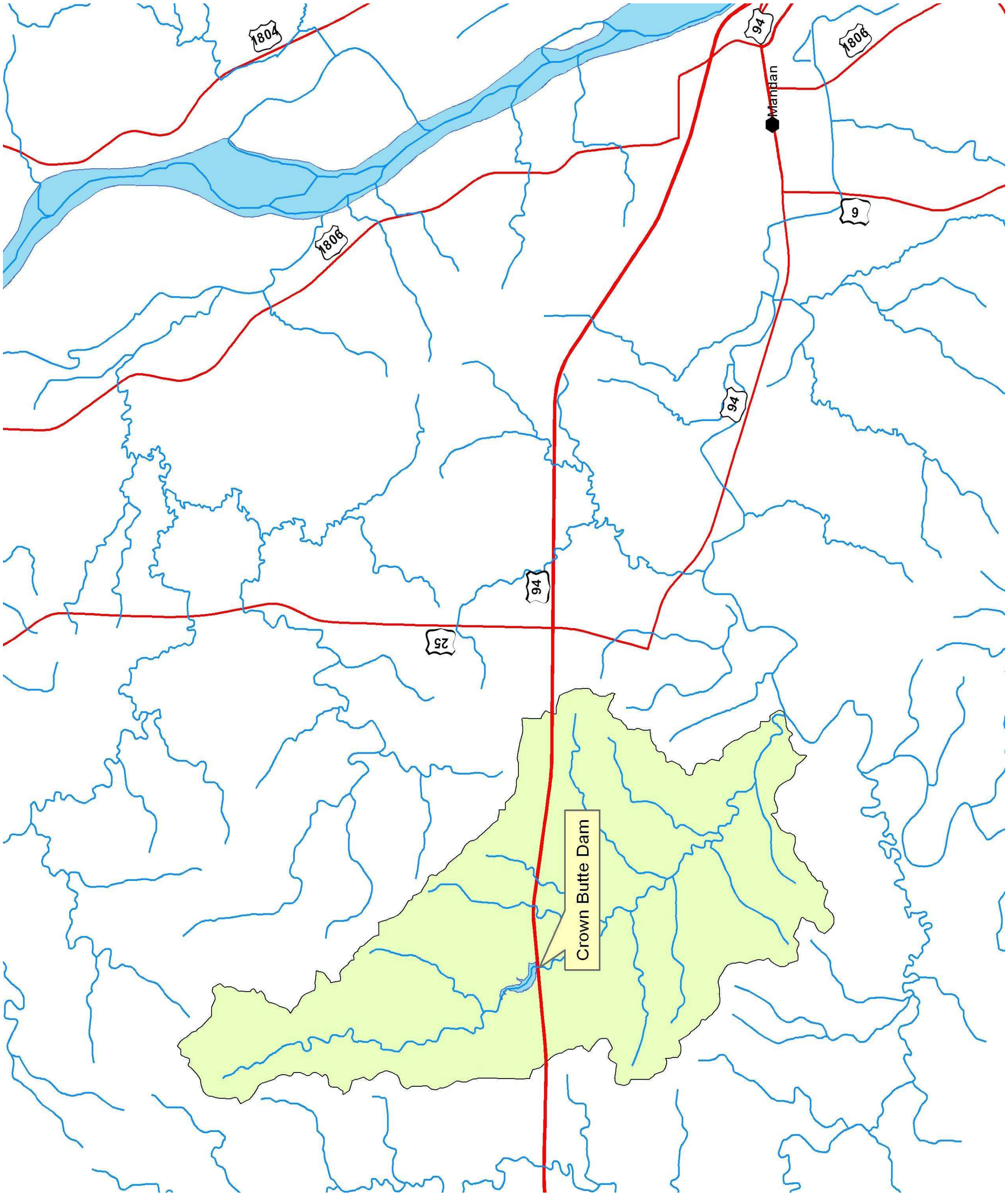


Figure 1. Location of Crown Butte Dam and the Crown Butte Dam Watershed.

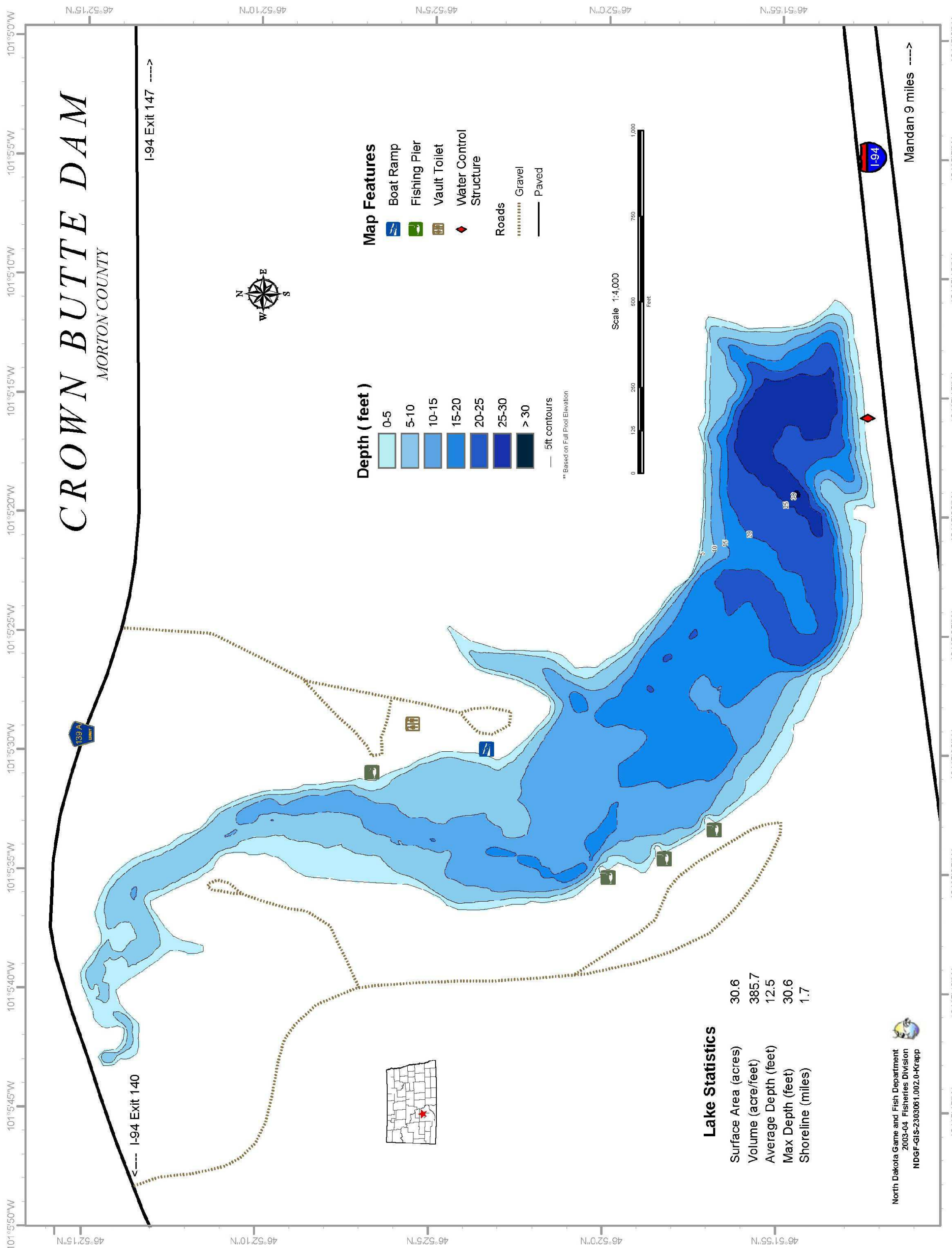


Figure 2. North Dakota Game and Fish Department Contour Map of Crown Butte Dam.

1.1 Clean Water Act Section 303(d) Listing Information

As part of the Clean Water Act Section 303(d) Total Maximum Daily Load (TMDL) listing process, the North Dakota Department of Health (NDDoH) has identified Crown Butte Dam as an impaired waterbody (Table 2). Based on its Trophic State Index (TSI) score and dissolved oxygen data, aquatic life and recreational uses of Crown Butte Dam are impaired. Aquatic life is listed as impaired due to nutrient/eutrophication and low dissolved oxygen. Recreational use is impaired due to nutrient/eutrophication. North Dakota's Section 303(d) list did not provide any potential sources of these impairments. As reflected in its title, this TMDL report only addresses the nutrient impairments for aquatic life and recreation use and the low dissolved oxygen impairment for aquatic life use. Sediment remains as a Section 303(d) TMDL listed pollutant threatening aquatic life use. Currently, there are not adequate data available to address the sediment TMDL listing. As additional monitoring data become available (e.g., through a Section 319 Watershed Implementation and Lake Restoration Project) a TMDL (or de-listing justification) will be prepared to address this pollutant.

Crown Butte Dam has been classified as a Class 3 warm-water fishery. Class 3 lakes or reservoirs "are capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present" (NDDoH 2001, revised 2006).

Table 2. Crown Butte Dam Section 303(d) Listing Information (NDDoH, 2006).

Assessment Unit ID	ND-10130203-002-L_00
Description	Crown Butte Dam
Designated Uses	Recreation and aquatic life
Use Support	Fully supporting, but threatened
Impairments	Nutrient/Eutrophication, Dissolved Oxygen, Sedimentation
Priority	1A

1.2 Topography

The watershed of Crown Butte Dam lies completely within the Northwestern Great Plains Level III ecoregion. It is characterized by a semiarid rolling plain of shale, siltstone, and sandstone punctuated by occasional buttes and badlands. The dissected topography, wooded draws, and uncultivated areas provide a haven for wildlife.

Soils in the watershed are formed from rocky, gravelly, or sandy glacial till and are moderately well drained. In general, soils in the watershed are moderately fertile, easily worked and highly susceptible to wind and water erosion. Soils in the watershed, other than river bottom soils, which can be clayey, are predominately silty or loamy and moderately well to well drained.

Slopes range from nearly level to steep with average slopes between two and nine percent (NDDoH, 1993). Elevations in the watershed range form approximately 2,133-feet (MSL) in the headwaters to approximately 1,923-feet (MSL) in the vicinity of the reservoir.

1.3 Land Use/Land Cover

Data compiled in 2005 identified land use/land cover in the Crown Butte Dam watershed as primarily agricultural (98.9 percent). Approximately 45.6 percent of the watershed is cropland, 36.8 percent pasture/hayland, and 14.7 percent enrolled in the conservation reserve program (CRP). The remainder of the land is low-density residential land or water. There are no large urban areas within the watershed, however, there are several small farmsteads spread throughout the area. Figure 3 shows land use data from the Lake Water Quality Assessment conducted by NDDoH in 1992. LWQA data identified three feedlots and twelve homesteads in the watershed. When the LWQA data were compared to the 2005 survey the percentages were very similar.

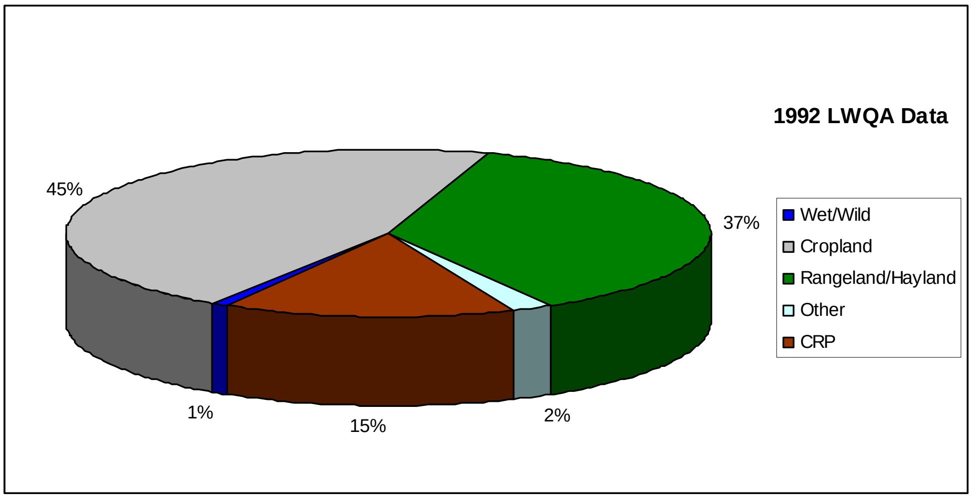


Figure 3. Land Use Data for the Crown Butte Dam Watershed in 1992.

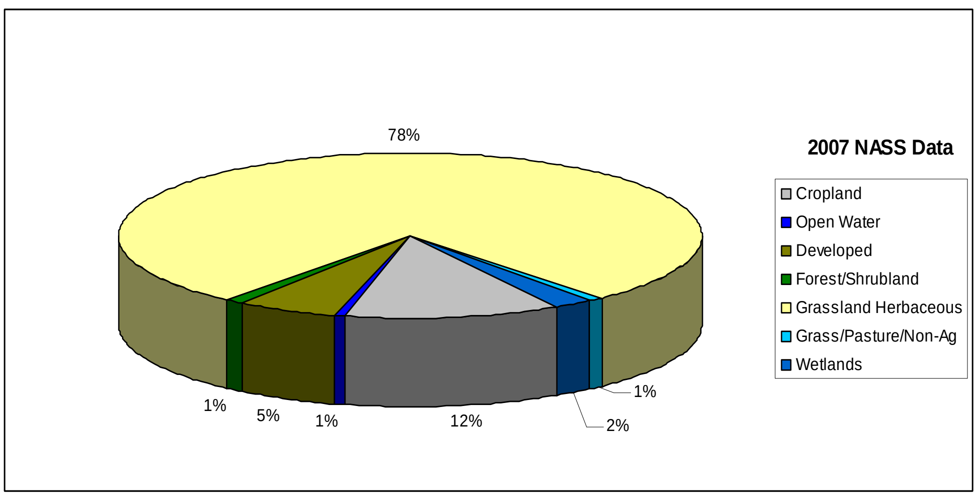


Figure 4. National Agricultural Statistics Service, Land Use Data (2007).
*** S**hows the land use data for the 12 digit Hydrologic Unit Code for Crown Butte Dam.

1.4 Climate and Precipitation

Crown Butte Dam and its watershed lie within the south central climate division of North Dakota. South central North Dakota has a typical continental climate, characterized by large annual, daily, and day-to-day temperature changes; light to moderate precipitation; and nearly continuous air movement. Mandan, North Dakota, located 11 miles to the west, has a maximum average temperature of 53.3°F and the minimum is 30.0°F (Figure 5). Average monthly precipitation in Mandan, North Dakota between 1913 and 2007 was 16.24 inches per year (HPRCC, 2007) (Figure 6).

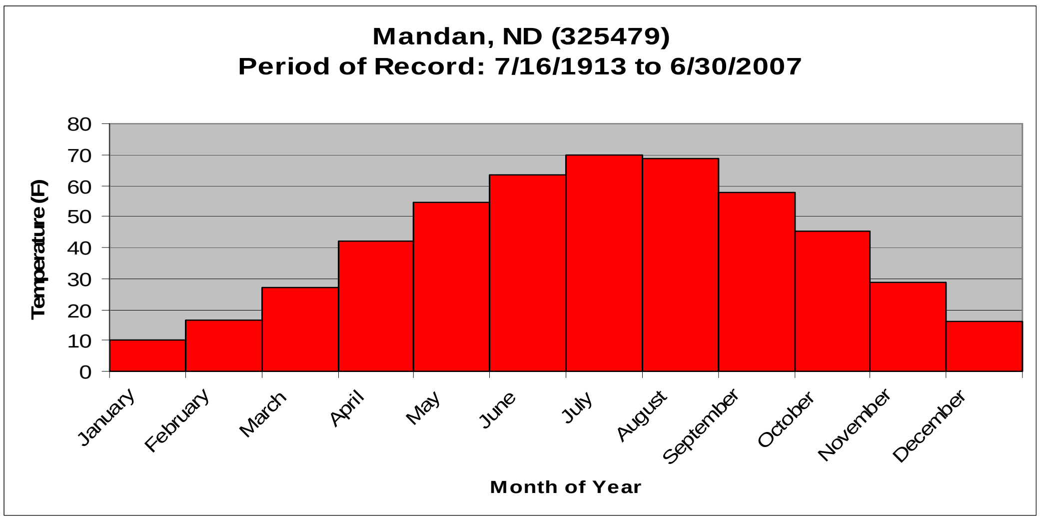


Figure 5. Average Monthly Temperature at Mandan, North Dakota (1913-2007).

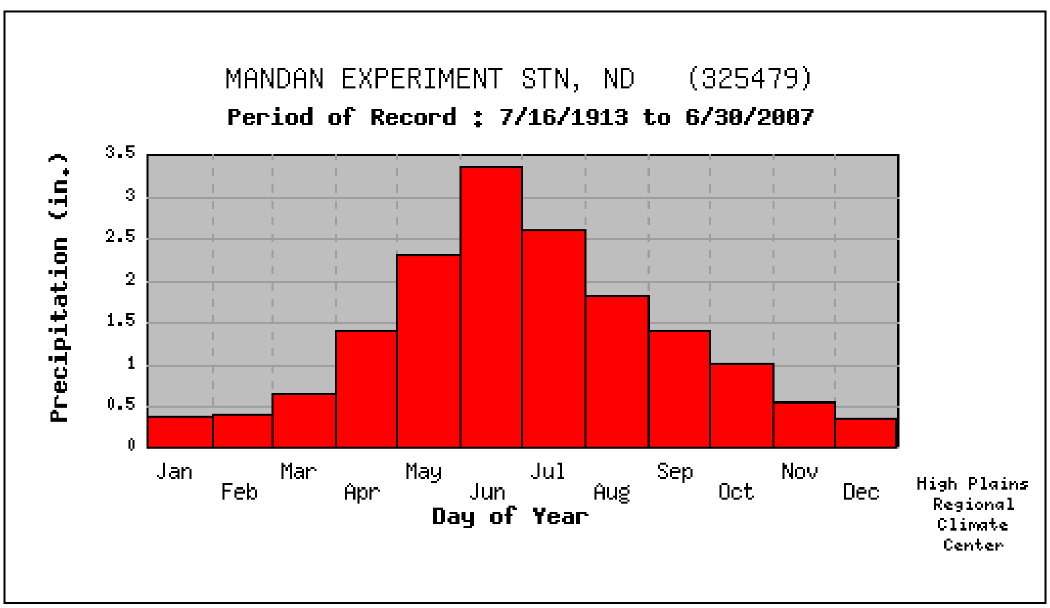


Figure 6. Average Monthly Precipitation at Mandan, North Dakota (1913-2007).

1.5 Available Water Quality Data

1.5.1 1992 – 1993 Lake Water Quality Assessment

The NDDoH conducted a Lake Water Quality Assessment (LWQA) and collected water quality samples in 1992 and 1993 from the reservoir using the methodology described in the *North Dakota Lake Assessment Atlas,* (NDDoH, 1993). Parameters analyzed included phosphorus, nitrogen, dissolved oxygen, water temperature, Secchi Disk Transparency, lake bed sediments, aquatic vegetation and phytoplankton. Data were summarized and reported in the *North Dakota Lake Assessment Atlas,* (NDDoH, 1993).

Trophic status was also determined using the water quality data collected during the LWQA project. Crown Butte Dam was identified as being hypereutrophic. This was determined based on summer total phosphate as phosphorus concentrations and Secchi Disk Transparency. Total phosphate concentrations averaged 0.965 mg/L and Secchi Disk Transparency averaged 0.75 meters

1.5.2 1995 – 2006 North Dakota Game and Fish Department Data

The North Dakota Game and Fish Department collected water quality data for Crown Butte Dam from 1995 to 2006. Data showed Secchi Disk Transparency readings of approximately 1.4-meters in the winter, and 1.1-meters in the summer. Winter temperature profiles ranged from 3.6 ºC on the top, to 5.0 °C on the bottom. Summer temperature profiles ranged from 27.5ºC to 17.1 ºC on the bottom. The dissolved oxygen profiles ranged from 16.8 mg/L to 0.9 mg/L on the bottom during the winter sampling event. The summer profile ranged from 15.0 mg/L to 0.1 mg/L.

1.5.3 2004 – 2005 Crown Butte Dam TMDL Project

In 2004, Crown Butte Dam TMDL Project was initiated. High Plains Consortium, Inc. collected samples in Crown Butte Dam and from its watershed between October 2004 and September 2005. Surface water quality parameters were monitored at three stations (Figure 7). The inlet site was located on County Road 139 where it crosses Crown Butte Creek. The in-lake site was located in the deepest part of the reservoir at the south end near the outlet structure. The outlet site was located just downstream of the reservoir.

Figure 7. Crown Butte Dam Sample Locations and Storet Numbers.

Nutrient Data

Water quality samples were collected from one inlet site, one outlet site, and one site located in the deepest area of the reservoir between October 2004 and September 2005. Tables 3 through 5 reflect a summary of the data. The data extracted from Crown Butte Dam indicates the reservoir has an in-lake total nitrogen to total phosphorus ratio of 12.82. Ratios above 7.2 generally indicate that phosphorus is the limiting nutrient (Chapra, 1997).

Table 3. Data Summary for In-lake Deepest Site* (381130), October 2004-September 2005.

Parameter	Max	Median	Avg	Min
Total Phosphorus mg/L)	0.392	0.129	0.157	0.043
Dissolved Phosphorus (mg/L)	0.329	0.083	0.106	0.034
Total Nitrogen (mg/L)	3.810	1.910	2.013	1.320
Total Kjeldahl Nitrogen (mg/L)	3.020	1.850	1.919	1.300
Nitrate/Nitrite (mg/L)	0.790	0.030	0.091	0.010
chlorophyll-a (µg/L)	150.0	28.7	44.9	2.14
Secchi Disk (meters)	2.50	1.75	1.37	0.75

***** Based only on the surface (1-meter) sample data.

Table 4. Data Summary for Crown Butte Creek - Inlet Site (384170), October 2004-September 2005.

Parameter	Max	Median	Avg	Min
Total Phosphorus mg/L)	0.489	0.207	0.238	0.136
Dissolved Phosphorus (mg/L)	0.385	0.143	0.170	0.073
Total Nitrogen (mg/L)	3.410	1.705	1.817	1.300
Total Kjeldahl Nitrogen (mg/L)	3.360	1.670	1.780	1.280
Nitrate/Nitrite (mg/L)	0.160	0.020	0.035	0.010

Table 5. Data Summary for Outlet Site (384171), October 2004-September 2005.

Parameter	Max	Median	Avg	Min
Total Phosphorus mg/L)	0.119	0.074	0.074	0.052
Dissolved Phosphorus (mg/L)	0.047	0.040	0.039	0.028
Total Nitrogen (mg/L)	1.930	1.400	1.367	0.638
Total Kjeldahl Nitrogen (mg/L)	1.870	1.380	1.313	0.453
Nitrate/Nitrite (mg/L)	0.250	0.010	0.048	0.010

Dissolved Oxygen

Dissolved oxygen was monitored from October 2004 – September 2005. Samples were collected at 1-meter intervals during ice over and open water periods. Raw data is provided in Appendix C. Figure 8 illustrates the results dissolved oxygen data for the deepest monitoring site.

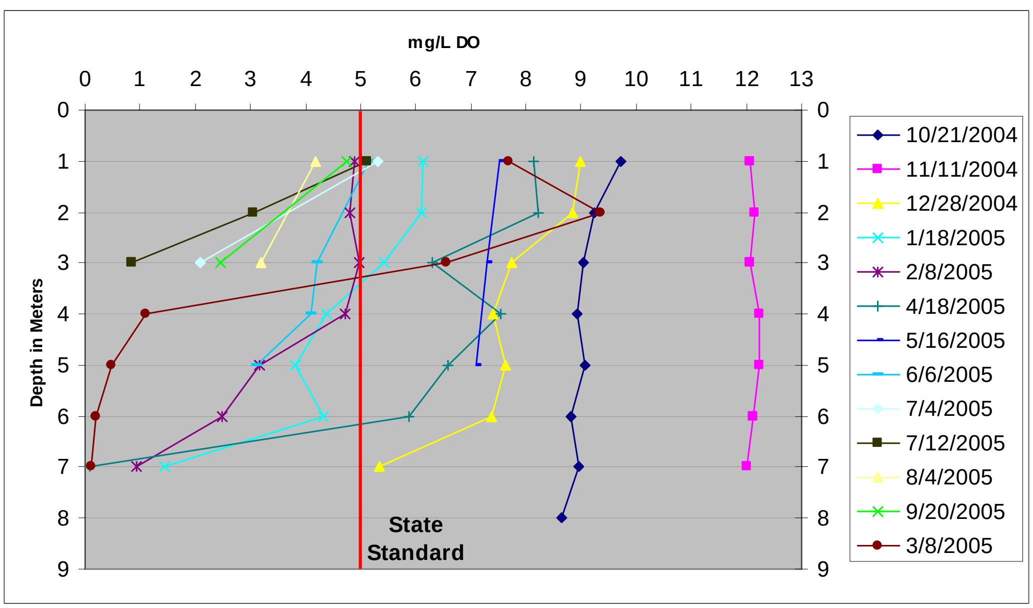


Figure 8. Summary of Dissolved Oxygen Concentration for the Crown Butte Dam Deepest Area Site (381130).

Secchi Disk Transparency

Secchi Disk Transparency data were collected 12 times during the sampling year of October 2004 to September 2005 (Figure 9). Secchi Disk Transparency readings were highest early in the growing season in May and June 2005, approximately 2.5 meters and the lowest in July, September, and November. The average Secchi Disk Transparency for the period was 1.38 meters. Based on Secchi Disk Transparency, the TSI score for this reservoir is 55.36 (well within the eutrophic range).

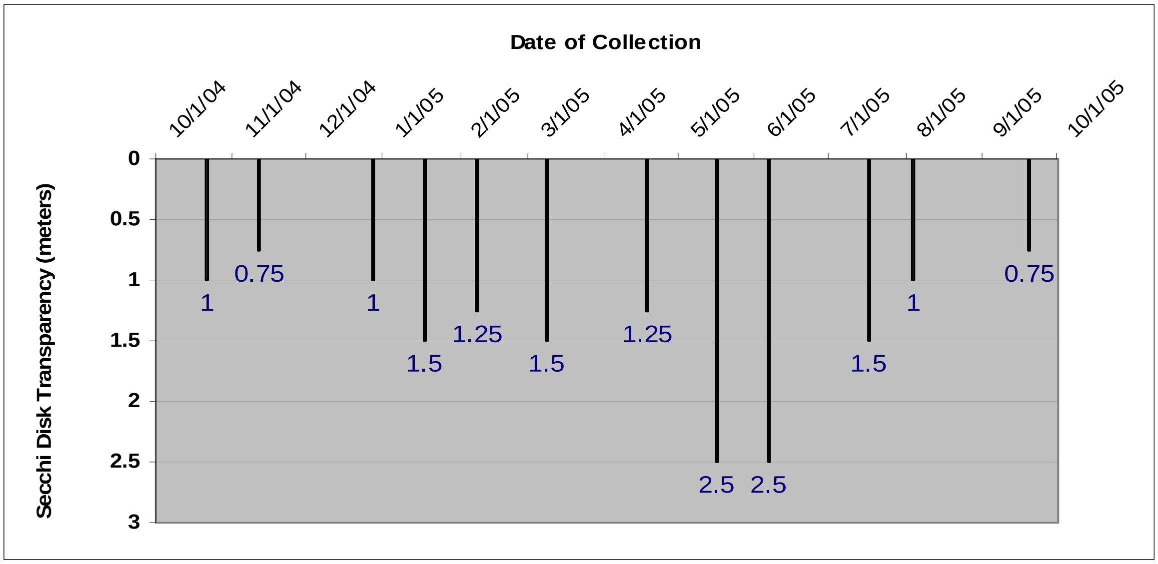


Figure 9. Secchi Disk Transparency Depths for Crown Butte Dam (October 2004 - September 2005).

Water clarity in a reservoir can be affected by many factors. Algal biomass, total suspended solids, and other debris can all affect water clarity and subsequently Secchi Disk Transparency.

Total Suspended Solids

Monthly total suspended solids (TSS) data indicate that algal biomass is the main factor limiting water clarity in Crown Butte Dam. Figure 10 shows that during the time of year when TSS loading is typically greatest (May and June), Secchi Disk Transparency was the greatest. During the late summer, when algal biomass and plant matter are typically at a maximum, Secchi disk Transparency was lowest. Due to this fact, a reduction in nutrient loading into the reservoir should decrease algal biomass and increase water clarity.

Thirty-nine total suspended solids (TSS) samples were collected between October 2004 and September 2005. For comparative analysis two outlying samples were not included. TSS samples were collected from the inlet and outlet of the reservoir. Average TSS concentrations at the inlet and outlet sites were 19.3 and 13.0 mg/L, respectively (Table 6). These data indicate that sediment is being retained within the reservoir.

Table 6. Total Suspended Solids Data Summary for the Crown Butte Dam Inlet and Outlet Sites (2004-2005).

Parameter	Max	Min	Avg
Inlet TSS (mg/L)	86.0	2.5	19.3
Outlet TSS (mg/L)	25.0	2.5	13.0

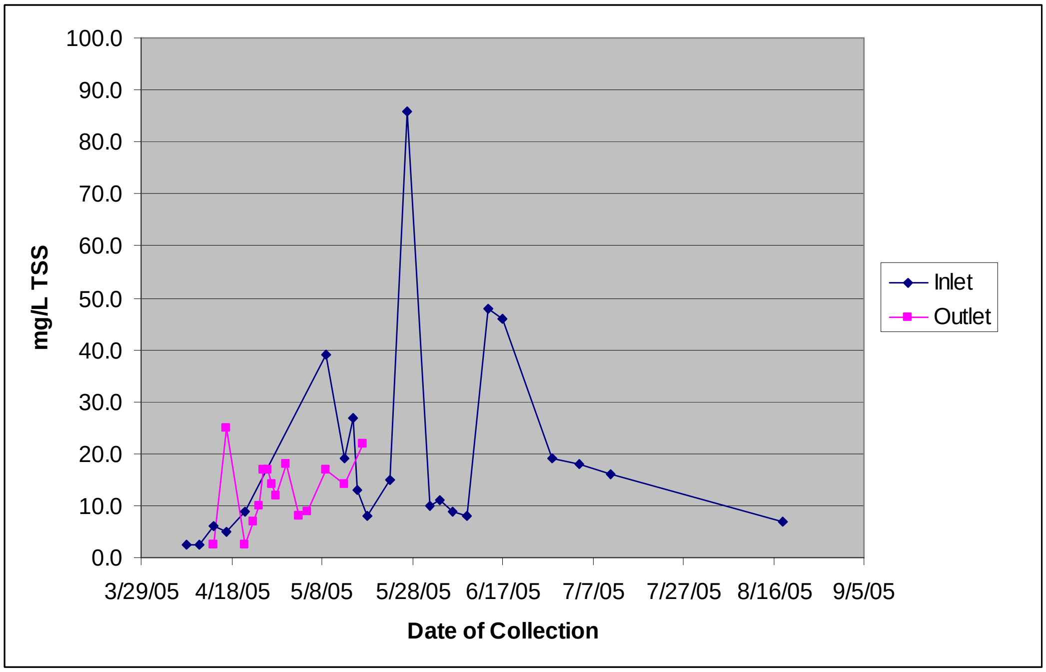


Figure 10. Total Suspended Solids Concentrations for the Crown Butte Dam Inlet and Outlet Sites (2005).

2.0 WATER QUALITY STANDARDS

The Clean Water Act requires that Total Maximum Daily Loads (TMDLs) be developed for all waters on a state's Section 303(d) list. A TMDL is defined as "the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background" such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. The purpose of a TMDL is to identify the pollutant load reductions or other actions that should be taken so that impaired waters will be able to attain water quality standards. TMDLs are required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. Separate TMDLs are required to address each cause of impairment (e.g., nutrients, organic enrichment).

2.1 Narrative Water Quality Standards

The NDDoH has set narrative water quality standards which apply to all surface waters in the state. The narrative standards pertaining to nutrient impairments are listed below (NDDoH 2001, revised 2006).

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

- No discharge of pollutants, which alone or in combination with other substances, shall:
  (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, all classified North Dakota lakes are assigned recreation, aquatic life, irrigation, livestock watering, and wildlife beneficial uses. Also, the NDDoH has set a biological goal for all surface waters in the state. The goal states “the biological condition of surface waters shall be similar to that of sites or waterbodies determined by the Department to be regional reference sites” (NDDoH, 2006).

2.2 Numeric Water Quality Standards

Crown Butte Dam is a Class 3 waterbody which carries the following definition:

- *Warm water fishery. Waters capable of supporting natural reproduction and growth of warm water fishes (e.g., largemouth bass and bluegill) and associated aquatic biota. Some cool water species may also be present.*

The State Water Quality Standards declare that lakes shall use the same numeric criteria as Class 1 streams. This includes the state standard for dissolved nitrates as 1.0 mg/L. The state standard for dissolved oxygen of 5 mg/L as a daily minimum (up to 10% of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided). In addition, guidelines for nitrates as N and phosphates as P have been established for use as goals in lake improvement and maintenance programs. The guideline for phosphates as P is 0.02 mg/L and 0.25 mg/L for nitrates as N (Table 7).

Table 7. Numeric Water Quality Standards for North Dakota Lakes and Reservoirs (NDDoH, 2006).

Parameter	Guidelines	Limit
Guidelines for Class I Streams and Classified Lakes		
Nitrates (dissolved)	1.0 mg/L	Maximum allowed[1]
Dissolved Oxygen	5 mg/L	Daily Minimum[2]
Guidelines for Goals in a lake improvement or maintenance program		
NO_3 as N	0.25 mg/L	Goal
PO_4 as P	0.02 mg/L	Goal

1 “Up to 10% of samples may exceed”
2 “Up to 10% of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided.”

3.0 TMDL TARGETS

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

3.1 Nutrient Target

The assessment methodology for lakes and reservoirs described in North Dakota's 2006 Integrated Section 305(b) and section 303(d) 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, 2006). Trophic status is the measure of productivity of a lake or reservoir and is directly related to the level of nutrients (phosphorus and nitrogen) entering the lake or reservoir from its watershed. Lakes tend to become eutrophic (more productive) with higher nitrogen and phosphorus inputs. Eutrophic lakes often have nuisance algal blooms, limited 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 Transparency measurements (Carlson, 1977).

Based on Carlson's TSI and water quality date collected between October 2004 and September 2005, Crown Butte Dam was generally assessed as a eutrophic to hypereutrophic lake (Table 8). Hypereutrophic lakes are characterized by large growths of weeds, bluegreen algal blooms, and low dissolved oxygen concentrations. These lakes experience frequent fish kills and are generally characterized as having excessive rough fish populations (carp, bullhead, sucker) and poor sport fisheries. Because of the frequent algal blooms and excessive weed growth, these lakes are also undesirable for recreational uses such as swimming and boating.

Table 8. Carlson's Trophic State Indices for Crown Butte Dam.

Parameter	Relationship	Concentration	TSI Value	Trophic Status
Chlorophyll-*a* (µg/L)	TSI (Chl-a) = 30.6 + 9.81[ln(Chl-a)]	44.9	67.92	eutrophic
Total Phosphorus (µg/L) (TP)	TSI (TP) = 4.15 + 14.42[ln(TP)]	157.0	77.06	hypereutrophic
Secchi Depth (meters) (SD)	TSI (SD) = 60 - 14.41[ln(SD)]	1.37	55.41	eutrophic
Total Nitrogen (mg/L) (TN)	TSI (TN) = 54.45 + 14.43[ln(TN)]	2.013	64.55	eutrophic

TSI < 30 - Oligotrophic (least productive) TSI 30-50 - Mesotrophic
TSI 50-70 - Eutrophic TSI > 70 - Hypereutrophic (most productive)

The reasons for the different TSI values estimated for Crown Butte Dam are varied. According to the phosphorus, chlorophyll-a, and nitrogen TSI values (Figure11), Crown Butte Dam is an extremely productive lake. Carlson and Simpson (1996) suggest that if the phosphorus and Secchi Disk Transparency TSI values are relatively similar and higher than the chlorophyll-a TSI value, then dissolved color or nonalgal particulates dominate light attenuation (Table 9). This is not the case for Crown Butte Dam, because the TSI values for phosphorus and Secchi Disk

Transparency are very different, and Secchi Disk Transparency is less than the chlorophyll-a score. The chlorophyll-a and Secchi Disk Transparency TSI scores are fairly close, indicating that 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.

Table 9. Relationships Between TSI Variables and Conditions.

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

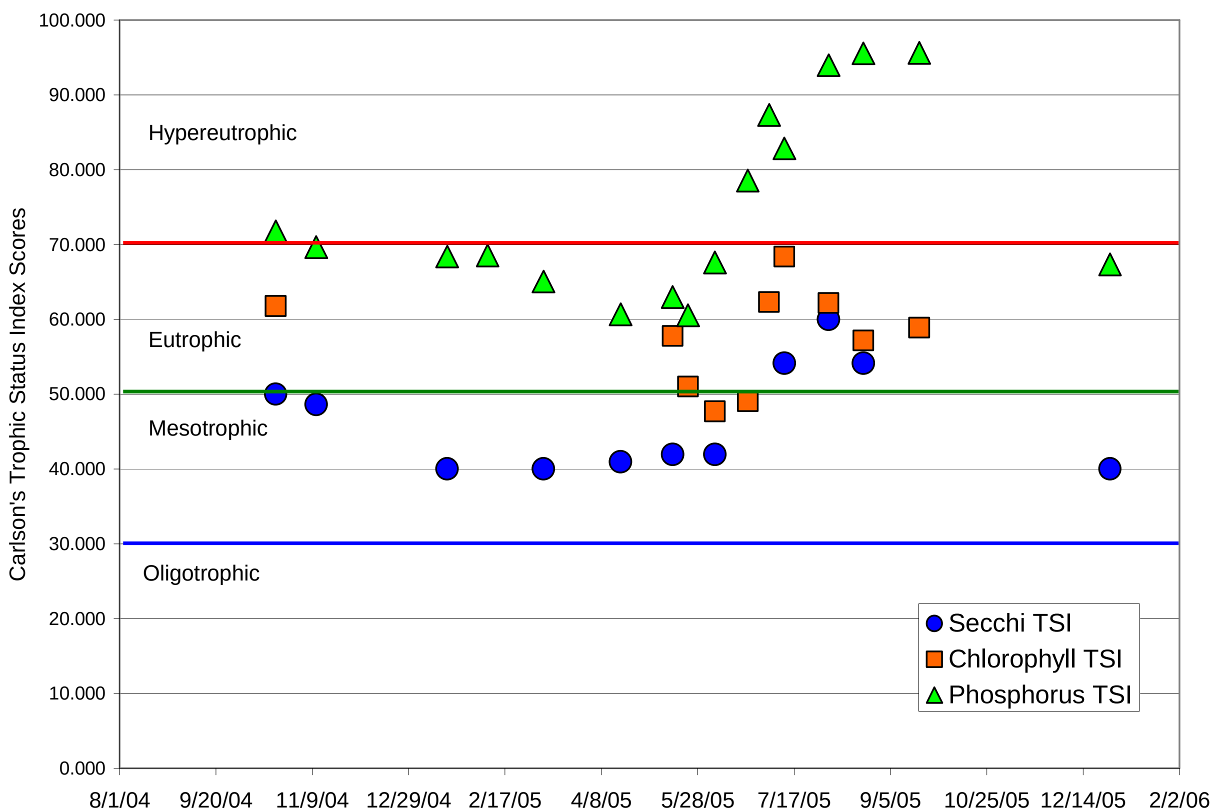
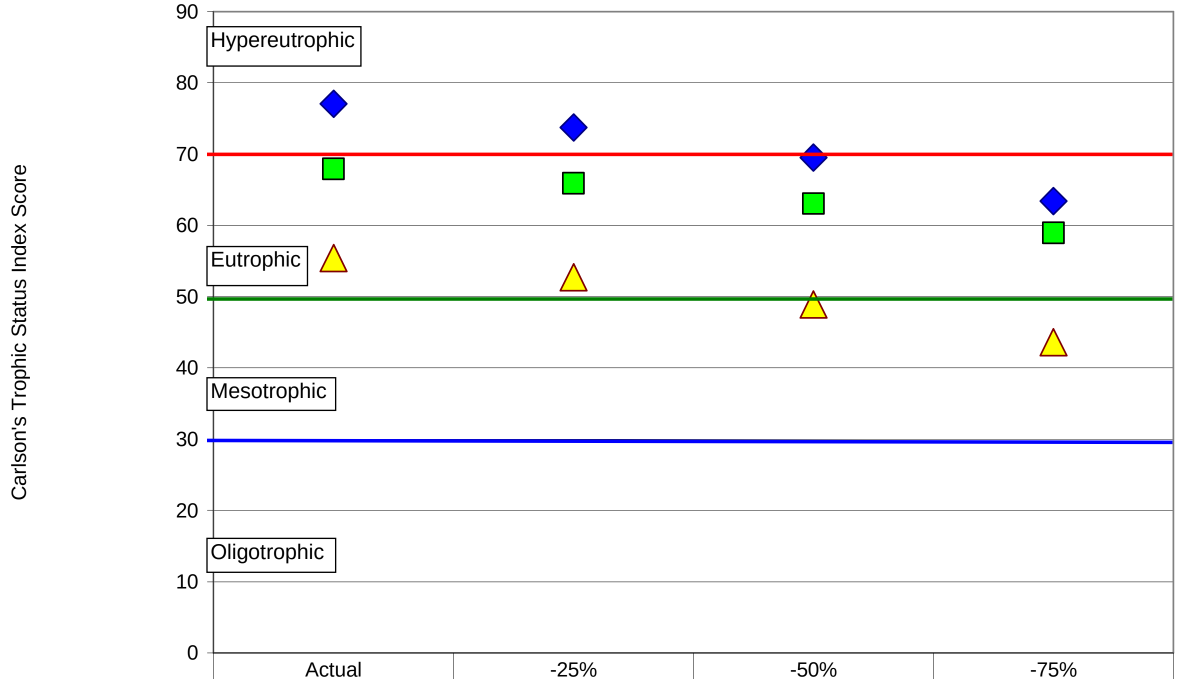


Figure 11. Temporal Distribution of TSI Scores for Crown Butte Dam.

A Carlson's total Phosphorus TSI target of 63.43, equating to 0.061 mg/L, was chosen for the Crown Butte Dam TMDL endpoint. This should result in a change of trophic status for the lake from hypereutrophic to eutrophic during all times of the year (Figure 12). 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. If the specified total phosphorus TMDL TSI target of 63.43 based on total phosphorus is met, the reservoir can be expected to meet the applicable water quality standards for aquatic life and recreational beneficial uses.



	Actual	-25%	-50%	-75%
Phosphorus TSI	77.06	73.73	69.51	63.43
Chlorophyll TSI	67.92	65.93	63.06	58.92
Secchi TSI	55.41	52.72	48.90	43.59

Figure 12. Predicted Trophic Response to Phosphorus Load Reductions to Crown Butte Dam of 25, 50, and 75 Percent.

3.2 Dissolved Oxygen TMDL Target

The North Dakota State Water Quality Standard for dissolved oxygen is "5 mg/L as a daily minimum (up to 10% of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided)" and will be the dissolved oxygen target for Crown Butte Dam

4.0 SIGNIFICANT SOURCES

4.1 Point Sources

There are no known point sources upstream of Crown Butte Dam.

4.2 Nonpoint Sources

Nonpoint source pollution accounts for 100 percent of the nutrient loading to Crown Butte Dam. The vast majority of nutrient loads are transported with overland runoff from agricultural areas. Existing land use and AGNPS modeling (see Section 5.3 AGNPS Modeling) within the Crown Butte Dam watershed indicates that the majority of NPS loading is coming from cropland (fifty percent of land within the watershed is cropped). Thirty-three percent of land in the watershed is used for pasture. Implementation of best management practices by producers in the watershed will be necessary in order to address loadings 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 of the receiving waterbodies. The loading capacity is the amount of a pollutant that can be assimilated by the waterbody while still attaining and maintaining water quality standards. This section discusses the technical analysis used to estimate existing loads to Crown Butte Dam and the predicted trophic response of the reservoir to reductions in loading capacity. A complete discussion of the FLUX and BATHTUB models may be found in Appendix A

5.1 FLUX 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 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 Crown Butte Dam. BATHTUB performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network. The model accounts for advective and diffusive transport and nutrient sedimentation. Eutrophication related water quality conditions are predicted using empirical relationships previously developed and tested for reservoir applications.

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

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

The reservoir data were reduced in Excel using three computational functions. These include: 1) the ability to display concentrations as a function of depth, location, or date; 2) summary statistics (mean, median, etc.); and 3) 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 along with and the associated TSI scores as a means of expressing trophic response.

As stated above, BATHTUB can compare predicted vs. actual conditions. After calibration, the model was run based on observed concentrations of phosphorus and nitrogen, to derive an estimated annual average total phosphorus load of 16 kg/yr and 107.2 kg/yr for total nitrogen. 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.

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

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

		Predicted Value		
Variable	**Observed**	**25%**	**50%**	**75%**
Total Phosphorus as P (mg/L)	0.157	0.125	0.093	0.061
Chlorophyll-a (μg/L)	44.9	36.63	27.35	17.93
Secchi Disk Transparency (meters)	1.37	1.66	2.16	3.12
Carlson's TSI for Phosphorus	77.06	83.73	69.51	63.43
Carlson's TSI for Chlorophyll-a	67.92	65.93	63.06	58.92
Carlson's TSI for Secchi Disk	55.41	52.72	48.90	43.59

To acquire a noticeable change in the trophic status, the BATHTUB model predicted that a 75 percent reduction in external total phosphorus loads (0.061 mg/L) is predicted to result in Crown Butte Dam attaining a eutrophic status.

5.3 AGNPS Watershed Model

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

The primary objectives for using the AGNPS 3.65 model were to: 1) evaluate NPS contributions within the watersheds; 2) identify critical pollutant source areas within the watershed; and 3) evaluate potential pollutant (nitrogen, phosphorus, and sediment) reduction estimates that can be achieved through the implementation of various BMP 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 were receiving cell, aspect, SCS curve, percent slope, slope shape, slope length, Manning's roughness coefficient, K-factor, C-factor, P-factor, surface conditions constant, soil texture, fertilizer inputs, point source indicators, COD factor and channel indicator.

The AGNPS 3.65 model was used in conjunction with an intensive land use survey to determine critical areas within the Crown Butte Dam Watershed. Criteria used during the land use assessment were percent cover on cropland and pasture/range conditions. These criteria were used to determine the C-factor for each cell. The initial model was run using current conditions determined during the land use assessment. A 25 yr/24 hr storm event (4.10 inches) in Morton County was applied to the model to evaluate relative pollutant yields from each 40-acre cell. Each quarter of land was given a cell number. Each cell represents 40 acres of land. A total of 4,800 acres were input into the program, representing 119 cells. Cells with sediment phosphorous levels above 0.10 lbs/ac or cells with soluble phosphorous runoff concentrations above 0.15 ppm were identified as critical. The model identified 23 cells in the watershed (440 acres of cropland and 440 acres of pasture/rangeland) as being "critical" or 18 percent of the watershed area.

The model was run a second time depicting a best-case scenario, in which all critical cropland and pasture/rangeland cells were treated with BMPs. The BMPs used during the second run were no till, nutrient management, prescribed grazing and pasture/hayland plantings. The BMPs were reflected within the model by making changes in the input parameters. Treatment of these critical cells will reduce nitrogen loading by approximately 0.04 ton (<1 percent). Because of the small watershed, nitrogen and phosphorus loads show little reduction, but with BMP implementation some reduction will be noted in the loadings. Once nutrient loadings are decreased, algal biomass will decline, dissolved oxygen will increase, and the overall trophic status of the reservoir will improve.

5.4 Dissolved Oxygen

Crown Butte Dam is listed as fully supporting but threatened for fish and aquatic biota uses because dissolved oxygen levels were observed below the North Dakota water quality standard of 5.0 mg/L as a daily minimum (up to 10% of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided). For Crown Butte 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 oxygen-demanding particles (Dodds, 2002). Dissolved oxygen gas has a strong affinity for electrons, and thus influences biogeochemical cycling and the biological availability of nutrients to primary producers such as algae. High levels of nutrients can lead to eutrophication, which is defined as the undesirable growth of algae and other aquatic plants. In turn, eutrophication can lead to increased biological oxygen demand and oxygen depletion due to the respiration of microbes that decompose the dead algae and other organic material.

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

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

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

Nürnberg (1995, 1995a, 1996, 1997), developed a model that quantified duration (days) and extent of lake oxygen depletion. AGNPS and BATHTUB models indicate that excessive nutrient loading is responsible for the low dissolved oxygen depletion, referred to as an anoxic factor (AF). This model showed that AF is positively correlated with average annual total phosphorous (TP) concentrations. The AF may also be used to quantify response to watershed restoration measures which makes it very useful for TMDL development. Nürnberg (1996), developed several regression models that show nutrients control all trophic state indicators related to oxygen and phytoplankton in lakes/reservoirs. These models were developed from water quality characteristics using a suite of North American lakes. The morphometric parameters such as surface area (A_o = 30.6 acres; 0.124 km^2), mean depth (z = 10.6 feet; 3.23 meters) were calculated, and the ratio of mean depth to the surface area is ($z/A_o^{0.5}$ = 9.18) for Crown Butte Dam. This shows that these parameters are within the range of lakes used by Nürnberg. Based on this information, the Nürnberg's empirical nutrient-oxygen relationship holds true for North Dakota lakes and reservoirs. Prescribed BMPs will reduce external loading of nutrients to the reservoir, which will reduce algae blooms and therefore increase oxygen levels over time.

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). For the purposes of this nutrient TMDL, a MOS of 10% of the loading capacity will be used as an explicit MOS.

Assuming the existing annual phosphorus load to Crown Butte Dam from tributary sources and internal cycling is 16.0 kg and the TMDL reduction goal is a 75% reduction in total annual phosphorus loading, then this would result in a TMDL target total phosphorus loading capacity of 4.0 kg of total phosphorus per year. Based on a 10 % explicit margin of safety, the MOS for the Crown Butte Dam TMDL would be 0.4 kg of phosphorus per year.

Post-implementation monitoring and adaptive management related to the effectiveness of the nutrient controls in the lake and watershed can also be used to assure attainment of the TMDL target.

6.2 Seasonality

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

7.0 TMDL

Table 11 summarizes the nutrient TMDL for Crown Butte Dam in terms of loading capacity (LC), wasteload allocations (WLA), load allocations (LA), and a margin of safety (MOS). The TMDL can be generically described by the following equation:

TMDL = LC = WLA + LA + MOS

where:

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

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

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

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

7.1 Nutrient TMDL

The BATHTUB and AGNPS computer models were used to predict the anticipated improvement in water quality with percentage reductions in the average annual total phosphorus loads from surface water runoff and internal cycling. Based on data collected in 2004 and 2005, the existing load to Crown Butte Dam is estimated at 16.0 kg/yr. Assuming a 75 percent reduction in the average annual total phosphorus concentration loading (0.061 mg/L), as determined by BATHTUB and AGNPS modeling, the Loading Capacity would be 4.00 kg/yr. Assuming 10 percent (0.40 kg/yr) is assigned to the MOS and there are no point sources in the watershed, all of the remaining Loading Capacity (3.60 kg/yr) is assigned to the Load Allocation (Table 11).

Table 11. Summary of the Nutrient TMDL for Crown Butte Dam.

Category	Total Phosphorus (kg/yr)	Explanation
Existing Load	16.00	From observed data
Loading Capacity	4.00	75 percent total reduction based on BATHTUB and AGNPS modeling
Wasteload Allocation	0.00	No point sources
Load Allocation	3.60	Entire loading capacity minus MOS is allocated to non-point sources
MOS	0.40	10 percent of the Loading Capacity is reserved as an explicit margin of safety.

In November 2006 EPA issued a memorandum “Establishing TMDL “Daily” Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et. al., No. 05-5015 (April 25, 2006) and Implications for NPDES Permits,” which recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increment in conjunction with other appropriate temporal expressions that may be necessary to implement the relevant water quality standard. While the Department believes that the appropriate temporal expression for phosphorus loading to lakes and reservoirs is as an annual load, the phosphorus TMDL has also been expressed as a daily load. In order to express this phosphorus TMDL as a daily load the annual loading capacity of 4.00 kg/yr was divided by 365 days. Based on this analysis, the phosphorus TMDL, expressed as an average daily load, is 0.011 kg/day with the load allocation equal to 0.010 kg/day and the MOS equal to 0.001 kg/day.

7.2 Dissolved Oxygen TMDL

As a result of the direct influence of eutrophication on increased biological oxygen demand and microbial respiration, it is anticipated that meeting the phosphorus load reduction target in Crown Butte Dam will address the dissolved oxygen impairment. A reduction in total phosphorus load to Crown Butte 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

Phosphorus loads into the reservoir could be reduced by 75 percent by treating of the AGNPS identified critical areas. There are 22 cells within the Crown Butte Dam watershed identified as “critical” by AGNPS modeling. These cells represent a total area of 440 (cropland) and 440 (pasture/rangeland) acres, or 18.3 percent of the watershed. If 18.3 percent of the critical watershed areas can be treated with appropriate best management practices (BMPs), then the specified reduction is possible. Further, internally derived phosphorus reductions may also be achieved through hypolimnetic withdrawal from the reservoir.

Restoration alternatives for reservoirs and lakes can generally be classified as:

- Source controls;
- In-lake controls; and
- Problem treatment.

Source controls are used to modify the quality of water entering a lake or reservoir. Examples of source controls are management within the watershed to reduce erosion (i.e., BMPs), chemical treatment to reduce inflow nutrient concentrations, and point source treatment or diversion. Implementation of BMPs will be on volunteer basis for the Crown Butte Dam TMDL. BMPs will primarily consist of altering the current tillage practices for cultivated land within the watershed to reduce the nutrient load reaching the reservoir. Potential conservation management practices are tillage, residue and grazing management options. These options include the use of no-till, ridge till, mulch tillage, grazing management and manure management. The application of alum, a chemical used to remove phosphorus from the water column, and dredging are examples of in-lake controls. Problem treatment includes weed harvesting, aeration, and chemical treatment to reduce plant growth and the release of nutrients from lake sediments.

9.0 PUBLIC PARTICIPATION

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

- Morton County Soil Conservation District

- Morton County Water Resource Board
- North Dakota Game and Fish Department
- USDA-NRCS State and Morton County Field Offices
- U.S. Fish and Wildlife Service, Ecological Services Field Office, Bismarck ND
- US Environmental Protection Agency - Region VIII

In addition to mailing copies of this TMDL for Crown Butte Dam to interested parties, the draft TMDL report was been 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 from interested parties was also printed in the following newspapers:

- The Bismarck Tribune
- Mandan News

In response to the Department's public notice, comments were received from the US EPA Region 8, in the form of an email from Vern Berry, and from Scott Elstad with the North Dakota Game and Fish Department. A letter in support of the Crown Butte Dam TMDL report was also received from Ted Becker representing the Morton County Soil Conservation District. A copy of the US EPA's comments and the Morton County SCD's letter are provided in Appendices E and F, respectively. The Department's response to comments is provided in Appendix G.

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) for Crown Butte Dam.

Specifically, monitoring will be conducted for all variables that are currently causing impairments to the beneficial uses of the waterbody. These include, but are not limited to nutrients (i.e., nitrogen and phosphorus) and dissolved oxygen. Once a watershed restoration plan (e.g. 319 PIP) is implemented, monitoring will be conducted in the lake/reservoir beginning two years after implementation and extending five years after the implementation project is complete.

11.0 TMDL IMPLEMENTATION STRATEGY

Implementation of TMDLs is dependent upon the availability of Section 319 Nonpoint Source Pollution Watershed Restoration funds or other watershed restoration programs (e.g. USDA EQIP, ND Game and Fish Department Save Our Lakes Program), 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.

It is recognized that significant land use changes may have or will have taken place in the watershed by the time a Watershed Restoration Project is undertaken. Therefore, it is recommended that as the first step in a Watershed Restoration Project the original AGNPS watershed model (or AnnAGNPS model) be updated and re-run with current land use conditions. Results of this model output should then be used to direct BMP implementation in the watershed.

In the event a Watershed Restoration Project is undertaken, monitoring will also be a required component of the project. As a part of the watershed project, data are collected to monitor and track the effects of BMP implementation as well as to judge overall project success. A Quality Assurance Project Plan will be developed as part of the project that details the strategy of how, when and where monitoring will be conducted to gather the data needed to document success in meeting the TMDL implementation goal(s). As data are gathered and analyzed, watershed restoration tasks will be adapted, if necessary, to place BMPs where they will have the greatest benefit to water quality and in meeting the TMDL goal(s).

12.0 ENDANGERED SPECIES ACT COMPLIANCE

The North Dakota Department of Health has reviewed the list of Threatened and Endangered Species in Morton County as provided by the US Fish and Wildlife Service (Appendix D). Although there are listed species present in the county they do not utilize the waterbody that is targeted by this TMDL. It is, therefore, the Department's best professional judgment that the Crown Butte Dam TMDL poses "No Adverse Effect" to those Threatened and Endangered species listed for Morton County.

As mentioned in Section 9.0, the US Fish and Wildlife Service was sent a copy of this document for their review during the public comment period. No comments were received.

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Appendix A
A Calibrated Trophic Response Model (BATHTUB) for Crown Butte Dam

A Calibrated Trophic Response Model (Bathtub) for Crown Butte Dam
As a Tool to Evaluate Various Nutrient Reduction Alternatives
Based on Data Collected by the High Plains Consortium Inc. from
October 21, 2004 through September 20, 2005
Prepared by
Jerry D. Reinisch
February, 2007
Revised September 12, 2007
By Peter Wax
North Dakota Department of Health
Second Revision October 10, 2008

Introduction

In order to meet the project goals, as set forth by the project sponsors of improving the trophic condition of Crown Butte 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 Crown Butte Dam. The model enables investigations into various nutrient reduction alternatives relative to the project goal of improving Crown Butte 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

Crown Butte Dam 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 evaluating the effects of various nutrient reduction alternatives on the predicted trophic status of Crown Butte 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, Crown Butte 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 Crown Butte Dam Bathtub Model.

Model Option	Model Selection	Calibration Factor
Conservative Substance	1 Computed	1.00
Phosphorus Balance	7 Settling Velocity	0.56
Phosphorus – Ortho P	7	1.32
Nitrogen Balance	5 Bachman Flushing	0.57
Organic Nitrogen	5	1.58
Chlorophyll-a	4 P, Linear	1.05
Secchi Depth	1 Vs. Chla & Turbidity	1.65
Phosphorus Calibration	1 Decay Rates	NA
Nitrogen Calibration	1 Decay Rates	NA
Availability Factors	0 Ignore	NA
Mass-Balance Tables	0 Use Observed Concentrations	NA

Results

The trophic response model, BATHTUB, has been calibrated to match Crown Butte Dam's trophic response for the project period October 21, 2004 through September 20, 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 Crown Butte Dam are nitrogen and phosphorus. After calibration, the observed annual mean concentration of total nitrogen and total phosphorus in the first meter of reservoir depth compared well with those of the BATHTUB model. The calibrated model predicted Crown Butte Dam's average annual total phosphorus concentration in the first meter of depth to be 156 mg L^{-1} compared to the observed concentration of 0.157 mg L^{-1} and it's total nitrogen concentration to be 2004 mg L^{-1} compared to the observed concentration of 2.013 mg L^{-1} (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 as good a job of predicting average chlorophyll-a concentration and secchi disk transparency within the reservoir as total phosphorus and total nitrogen (Table 2).

Once predictions of total phosphorus, chlorophyll-a, and secchi disk transparency are made, the model calculates Carlson's Trophic Status Index (TSI) (Carlson 1977) as a means of expressing predicted trophic response (Table 2). Carlson's TSI is an index that can be used to measure the relative trophic state of a lake or reservoir. Simply stated, trophic state is how much production (i.e., algal and weed growth) occurs in the waterbody. The lower the nutrient concentrations are within the waterbody the lower the production and the lower the trophic state or level.

In contrast, increased nutrient concentrations in a lake or reservoir increase the production of algae and weeds which make the lake or reservoir more eutrophic or of a higher trophic state. Oligotrophic is the term which describes the least productive lakes and hypereutrophic is the term used to describe lakes and reservoirs with excessive nutrients and primary production.

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

Variable	Observed	Predicted
Total Phosphorus as P (mg/L)	0.157	0.156
Total Dissolved Phosphorus as P (mg/L)	0.106	0.105
Total Nitrogen as N (mg/L)	2.013	2.004
Organic Nitrogen as N (mg/L)	1.919	1.911
Chlorophyll-a (mg/L)	44.90	45.92
Secchi Disk Transparency (meters)	1.37	1.34
Carlson's TSI for Phosphorus	77.06	76.99
Carlson's TSI for Chlorophyll-a	67.92	68.14
Carlson's TSI for Secchi Disk	55.41	55.74

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 suggest Crown Butte Dam is hypereutrophic, while the TSI values for chlorophyll-a and secchi disk indicated the reservoir is eutrophic. Figure 2 is a graphic that shows the annual temporal distribution of Crown Butte 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 Crown Butte 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).

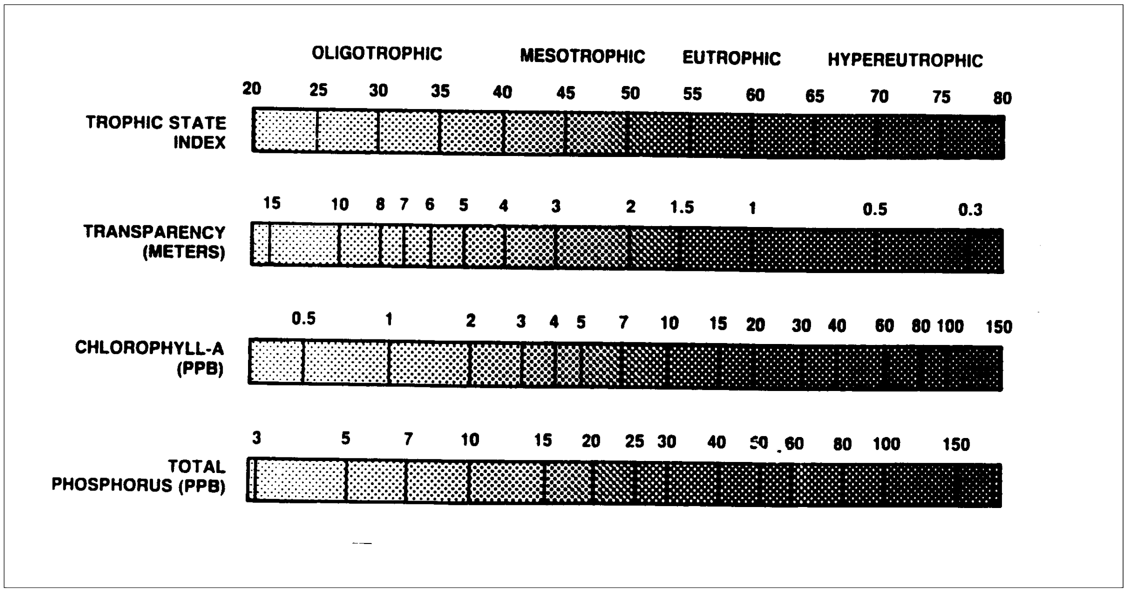


Figure 1. Graphic depiction of Carlson's Trophic Status Index

Predicted changes in trophic response to Crown Butte Dam were evaluated by reducing externally derived nutrient loads by 25, 50, and 75 percent. These reductions were simulated in the model by reducing the total phosphorus and nitrogen concentrations in the contributing tributary and other external delivery sources by 25, 50, and 75 percent, while flow was held constant.

The model results indicate that if it were possible to reduce external phosphorus loading to Crown Butte 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 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 Crown Butte Dam that would be noticeable to the average lake users as the reduction in the amount of green in the lake and overall clarity would increase to, or nearly to the mesotrophic range.

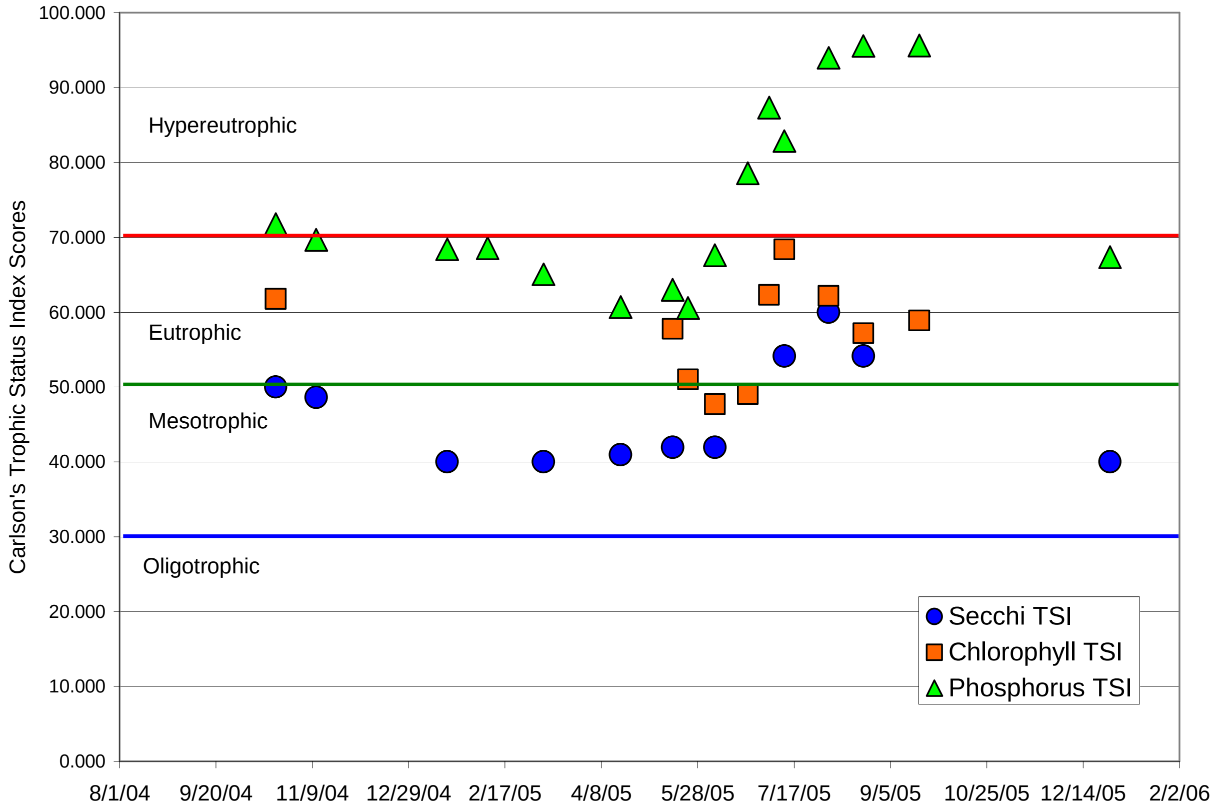
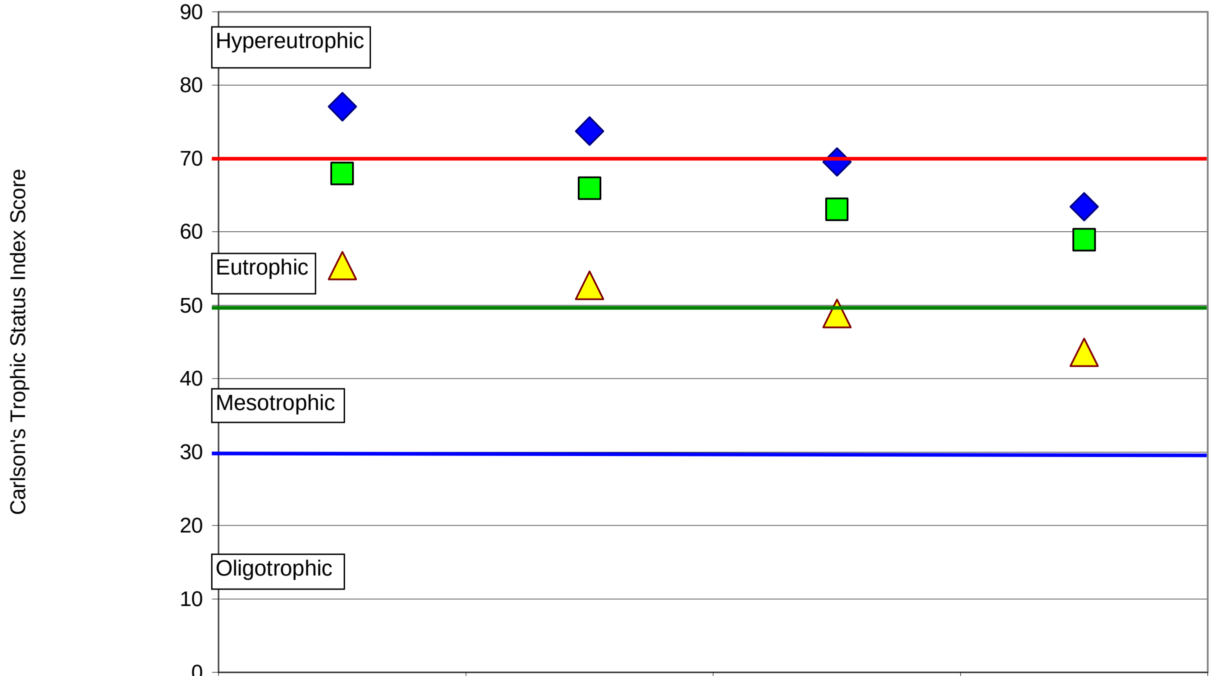


Figure 2. Temporal distribution of Carlson's Trophic Status Index scores for Crown Butte Dam (October 21, 2004 and September 20, 2005)

With a 75 percent reduction in external phosphorus and nitrogen load, the model predicts a reduction in Carlson's TSI score from 67.92 to 58.92 for chlorophyll-a from 55.41 to 43.59 for secchi disk transparency, corresponding to a trophic state of eutrophic and mesotrophic, respectively.

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.

Variable	Observed	-25%	-50%	-75%
Total Phosphorus as P (µg/L)	0.157	0.125	0.093	0.061
Total Nitrogen as N (µg/L)	2.013	1.771	1.539	1.306
Chlorophyll-a (µg/L)	44.9	36.63	27.35	17.93
Secchi Disk Transparency (meters)	1.37	1.66	2.16	3.12
Carlson's TSI for Phosphorus	77.06	73.73	69.51	63.43
Carlson's TSI for Chlorophyll-a	67.92	65.93	63.06	58.92
Carlson's TSI for Secchi Disk	55.41	52.72	48.90	43.59



	Actual	-25%	-50%	-75%
Phosphorus TSI	77.06	73.73	69.51	63.43
Chlorophyll TSI	67.92	65.93	63.06	58.92
Secchi TSI	55.41	52.72	48.90	43.59

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

Appendix B
BATHTUB Model Results

CASE: Crownbutte 2006 - Calibrated Model

HYDRAULIC AND DISPERSION PARAMETERS:

SEG	OUT	NET INFLOW HM3/YR	RESIDENCE TIME YRS	OVERFLOW RATE M/YR	MEAN VELOCITY KM/YR	DISPERSION ESTIMATED KM2/YR	DISPERSION NUMERIC KM2/YR	EXCHANGE RATE HM3/YR
1	0	.06	8.27505	.5	1.0	1.	0.	0.

CASE: crownbutte 2006

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	FLOW (HM3/YR) VARIANCE	FLOW (HM3/YR) CV	RUNOFF M/YR
1	1	inlet	19.260	.057	.000E+00	.000	.003
2	4	Outlet	19.387	.057	.000E+00	.000	.003
		TRIBUTARY INFLOW	19.260	.057	.000E+00	.000	.003
		***TOTAL INFLOW	19.384	.057	.000E+00	.000	.003
		GAUGED OUTFLOW	19.387	.057	.000E+00	.000	.003
		***TOTAL OUTFLOW	19.384	.057	.000E+00	.000	.003

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: CONSERV

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

HYDRAULIC OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	CONSERV POOL CONC MG/M3	CONSERV RESIDENCE TIME YRS	CONSERV TURNOVER RATIO -	CONSERV RETENTION COEF -
.46	8.2751	.0	.0000	.0000	.0000

CASE: Crownbutte 2006 - Calibrated Model

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	inlet	16.0	81.2	.000E+00	.0	.000	281.0	.8
2	4	Outlet	16.7	84.6	.000E+00	.0	.000	293.0	.9
		PRECIPITATION	3.7	18.8	.345E+01	100.0	.500	.0	30.0
		TRIBUTARY INFLOW	16.0	81.2	.000E+00	.0	.000	281.0	.8
		***TOTAL INFLOW	19.7	100.0	.345E+01	100.0	.094	346.2	1.0
		GAUGED OUTFLOW	8.9	45.4	.000E+00	.0	.000	157.0	.5
		***TOTAL OUTFLOW	8.9	45.4	.000E+00	.0	.000	157.0	.5
		***RETENTION	10.8	54.6	.345E+01	100.0	.172	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
.46	8.2751	157.0	3.7532	.2664	.5464

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	inlet	107.2	46.4	.000E+00	.0	.000	1880.0	5.6
2	4	Outlet	109.9	47.6	.000E+00	.0	.000	1928.0	5.7
		PRECIPITATION	123.8	53.6	.383E+04	100.0	.500	.0	1000.0
		TRIBUTARY INFLOW	107.2	46.4	.000E+00	.0	.000	1880.0	5.6
		***TOTAL INFLOW	231.0	100.0	.383E+04	100.0	.268	4051.9	11.9
		GAUGED OUTFLOW	114.7	49.7	.000E+00	.0	.000	2013.0	5.9
		***TOTAL OUTFLOW	114.7	49.7	.000E+00	.0	.000	2013.0	5.9
		***RETENTION	116.2	50.3	.383E+04	100.0	.533	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
.46	8.2751	2013.0	4.1110	.2432	.5032

CASE: Crownbutte 2006 - Calibrated Model

CASE: crownbutte 2006

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

SEGMENT: 1 Deepest

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	157.0	.00	156.2	.26	1.01	.00	.02	.02
TOTAL N	MG/M3	2013.0	.00	2003.6	.38	1.00	.00	.02	.01
C.NUTRIENT	MG/M3	110.4	.00	109.8	.25	1.01	.00	.03	.02
CHL-A	MG/M3	44.9	.00	45.9	.37	.98	.00	-.06	-.06
SECCHI	M	1.4	.00	1.3	.36	1.02	.00	.08	.06
ORGANIC N	MG/M3	1919.0	.00	1911.8	.34	1.00	.00	.02	.01
TP-ORTHO-P	MG/M3	106.0	.00	105.0	.41	1.01	.00	.03	.02
HOD-V	MG/M3-DAY	.0	.00	162.6	.24	.00	.00	.00	.00
MOD-V	MG/M3-DAY	.0	.00	156.1	.32	.00	.00	.00	.00

CASE: crownbutte 2006

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

SEGMENT: 1 Deepest

VARIABLE		VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P	MG/M3	157.00	156.19	90.6	90.5
TOTAL N	MG/M3	2013.00	2003.56	86.2	86.1
C.NUTRIENT	MG/M3	110.39	109.83	92.1	92.0
CHL-A	MG/M3	44.90	45.92	97.9	98.0
SECCHI	M	1.38	1.34	62.5	61.3
ORGANIC N	MG/M3	1919.00	1911.78	99.7	99.7
TP-ORTHO-P	MG/M3	106.00	104.98	90.8	90.6
HOD-V	MG/M3-DAY	.00	162.63	.0	84.2
MOD-V	MG/M3-DAY	.00	156.05	.0	87.9
ANTILOG PC-1		1657.47	1689.30	92.8	93.0
ANTILOG PC-2		22.13	22.14	99.1	99.1
(N - 150) / P		11.87	11.87	29.9	29.9
INORGANIC N / P		1.84	1.79	.3	.2
TURBIDITY	1/M	.08	.08	1.1	1.1
ZMIX * TURBIDITY		.64	.64	2.0	2.0
ZMIX / SECCHI		5.82	5.95	63.4	64.8
CHL-A * SECCHI		61.74	61.70	99.5	99.4
CHL-A / TOTAL P		.29	.29	72.4	73.8
CARLSON TSI-P		77.06	76.99	.0	.0
CARLSON TSI-CHLA		67.92	68.14	.0	.0
CARLSON TSI-SEC		55.41	55.74	.0	.0

CASE: **Crownbutte 2006 – Calibrated Model Less 25% N and P loads**

HYDRAULIC AND DISPERSION PARAMETERS:

SEG	OUT	NET INFLOW HM3/YR	RESIDENCE TIME YRS	OVERFLOW RATE M/YR	MEAN VELOCITY KM/YR	DISPERSION ESTIMATED KM2/YR	DISPERSION NUMERIC KM2/YR	EXCHANGE RATE HM3/YR
1	0	.06	8.27505	.5	1.0	1.	0.	0.

CASE: crownbutte 2006

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	FLOW (HM3/YR) VARIANCE	CV	RUNOFF M/YR
1	1	inlet	19.260	.057	.000E+00	.000	.003
2	4	Outlet	19.387	.057	.000E+00	.000	.003
TRIBUTARY INFLOW			19.260	.057	.000E+00	.000	.003
***TOTAL INFLOW			19.384	.057	.000E+00	.000	.003
GAUGED OUTFLOW			19.387	.057	.000E+00	.000	.003
***TOTAL OUTFLOW			19.384	.057	.000E+00	.000	.003

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: CONSERV

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

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	CONSERV POOL CONC MG/M3	CONSERV RESIDENCE TIME YRS	CONSERV TURNOVER RATIO -	CONSERV RETENTION COEF -
.46	8.2751	.0	.0000	.0000	.0000

Crownbutte 2006 – Calibrated Model Less 25% N and P loads

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL P

ID T LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1 1 inlet	12.0	76.4	.000E+00	.0	.000	211.0	.6
2 4 Outlet	16.7	106.1	.000E+00	.0	.000	293.0	.9
PRECIPITATION	3.7	23.6	.345E+01	100.0	.500	.0	30.0
TRIBUTARY INFLOW	12.0	76.4	.000E+00	.0	.000	211.0	.6
***TOTAL INFLOW	15.7	100.0	.345E+01	100.0	.118	276.2	.8
GAUGED OUTFLOW	8.9	56.9	.000E+00	.0	.000	157.0	.5
***TOTAL OUTFLOW	8.9	56.9	.000E+00	.0	.000	157.0	.5
***RETENTION	6.8	43.1	.345E+01	100.0	.273	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
.46	8.2751	157.0	4.7045	.2126	.4315

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL N

ID T LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1 1 inlet	80.4	39.4	.000E+00	.0	.000	1410.0	4.2
2 4 Outlet	109.9	53.8	.000E+00	.0	.000	1928.0	5.7
PRECIPITATION	123.8	60.6	.383E+04	100.0	.500	.0	1000.0
TRIBUTARY INFLOW	80.4	39.4	.000E+00	.0	.000	1410.0	4.2
***TOTAL INFLOW	204.2	100.0	.383E+04	100.0	.303	3581.9	10.5
GAUGED OUTFLOW	114.7	56.2	.000E+00	.0	.000	2013.0	5.9
***TOTAL OUTFLOW	114.7	56.2	.000E+00	.0	.000	2013.0	5.9
***RETENTION	89.4	43.8	.383E+04	100.0	.692	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
.46	8.2751	2013.0	4.6505	.2150	.4380

CASE: **Crownbutte 2006 – Calibrated Model Less 25% N and P loads**

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

SEGMENT: 1 Deepest

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	157.0	.00	124.6	.27	1.26	.00	.86	.86
TOTAL N	MG/M3	2013.0	.00	1771.2	.41	1.14	.00	.58	.31
C.NUTRIENT	MG/M3	110.4	.00	91.6	.25	1.21	.00	.93	.74
CHL-A	MG/M3	44.9	.00	36.6	.37	1.23	.00	.59	.54
SECCHI	M	1.4	.00	1.7	.36	.83	.00	-.67	-.52
ORGANIC N	MG/M3	1919.0	.00	1577.3	.34	1.22	.00	.78	.58
TP-ORTHO-P	MG/M3	106.0	.00	83.2	.42	1.27	.00	.66	.58
HOD-V	MG/M3-DAY	.0	.00	145.3	.24	.00	.00	.00	.00
MOD-V	MG/M3-DAY	.0	.00	139.4	.33	.00	.00	.00	.00

CASE: crownbutte 2006

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

SEGMENT: 1 Deepest

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	157.00	124.60	90.6	85.6
TOTAL N MG/M3	2013.00	1771.16	86.2	81.3
C.NUTRIENT MG/M3	110.39	91.59	92.1	88.1
CHL-A MG/M3	44.90	36.63	97.9	96.1
SECCHI M	1.38	1.66	62.5	71.3
ORGANIC N MG/M3	1919.00	1577.27	99.7	99.1
TP-ORTHO-P MG/M3	106.00	83.17	90.8	85.8
HOD-V MG/M3-DAY	.00	145.26	.0	80.3
MOD-V MG/M3-DAY	.00	139.38	.0	84.4
ANTILOG PC-1	1657.47	1133.08	92.8	87.9
ANTILOG PC-2	22.13	21.96	99.1	99.0
(N - 150) / P	11.87	13.01	29.9	34.7
INORGANIC N / P	1.84	4.68	.3	3.1
TURBIDITY 1/M	.08	.08	1.1	1.1
ZMIX * TURBIDITY	.64	.64	2.0	2.0
ZMIX / SECCHI	5.82	4.83	63.4	50.8
CHL-A * SECCHI	61.74	60.70	99.5	99.4
CHL-A / TOTAL P	.29	.29	72.4	73.8
CARLSON TSI-P	77.06	73.73	.0	.0
CARLSON TSI-CHLA	67.92	65.93	.0	.0
CARLSON TSI-SEC	55.41	52.72	.0	.0

CASE: **Crownbutte 2006 – Calibrated Model Less 50% N and P Loads**

HYDRAULIC AND DISPERSION PARAMETERS:

SEG	OUT	NET INFLOW HM3/YR	RESIDENCE TIME YRS	OVERFLOW RATE M/YR	MEAN VELOCITY KM/YR	DISPERSION ESTIMATED KM2/YR	DISPERSION NUMERIC KM2/YR	EXCHANGE RATE HM3/YR
1	0	.06	8.27505	.5	1.0	1.	0.	0.

CASE: crownbutte 2006

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	FLOW (HM3/YR) VARIANCE	FLOW (HM3/YR) CV	RUNOFF M/YR
1	1	inlet	19.260	.057	.000E+00	.000	.003
2	4	Outlet	19.387	.057	.000E+00	.000	.003
TRIBUTARY INFLOW			19.260	.057	.000E+00	.000	.003
***TOTAL INFLOW			19.384	.057	.000E+00	.000	.003
GAUGED OUTFLOW			19.387	.057	.000E+00	.000	.003
***TOTAL OUTFLOW			19.384	.057	.000E+00	.000	.003

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: CONSERV

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

HYDRAULIC OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	CONSERV POOL CONC MG/M3	CONSERV RESIDENCE TIME YRS	CONSERV TURNOVER RATIO -	CONSERV RETENTION COEF -
.46	8.2751	.0	.0000	.0000	.0000

Crownbutte 2006 – Calibrated Model Less 50% N and P Loads

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	inlet	8.0	68.4	.000E+00	.0	.000	141.0	.4
2	4	Outlet	16.7	142.1	.000E+00	.0	.000	293.0	.9
		PRECIPITATION	3.7	31.6	.345E+01	100.0	.500	.0	30.0
		TRIBUTARY INFLOW	8.0	68.4	.000E+00	.0	.000	141.0	.4
		***TOTAL INFLOW	11.8	100.0	.345E+01	100.0	.158	206.2	.6
		GAUGED OUTFLOW	8.9	76.2	.000E+00	.0	.000	157.0	.5
		***TOTAL OUTFLOW	8.9	76.2	.000E+00	.0	.000	157.0	.5
		***RETENTION	2.8	23.8	.345E+01	100.0	.663	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
.46	8.2751	157.0	6.3019	.1587	.2384

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL N

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	inlet	53.6	30.2	.000E+00	.0	.000	940.0	2.8
2	4	Outlet	109.9	62.0	.000E+00	.0	.000	1928.0	5.7
		PRECIPITATION	123.8	69.8	.383E+04	100.0	.500	.0	1000.0
		TRIBUTARY INFLOW	53.6	30.2	.000E+00	.0	.000	940.0	2.8
		***TOTAL INFLOW	177.4	100.0	.383E+04	100.0	.349	3111.9	9.2
		GAUGED OUTFLOW	114.7	64.7	.000E+00	.0	.000	2013.0	5.9
		***TOTAL OUTFLOW	114.7	64.7	.000E+00	.0	.000	2013.0	5.9
		***RETENTION	62.6	35.3	.383E+04	100.0	.988	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
.46	8.2751	2013.0	5.3528	.1868	.3531

CASE: **Crownbutte 2006 – Calibrated Model Less 50% N and P Loads**

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

SEGMENT: 1 Deepest

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	157.0	.00	93.0	.29	1.69	.00	1.95	1.81
TOTAL N	MG/M3	2013.0	.00	1538.8	.44	1.31	.00	1.22	.61
C.NUTRIENT	MG/M3	110.4	.00	72.5	.26	1.52	.00	2.09	1.61
CHL-A	MG/M3	44.9	.00	27.3	.39	1.64	.00	1.43	1.27
SECCHI	M	1.4	.00	2.2	.36	.64	.00	-1.61	-1.25
ORGANIC N	MG/M3	1919.0	.00	1242.8	.33	1.54	.00	1.74	1.31
TP-ORTHO-P	MG/M3	106.0	.00	61.3	.43	1.73	.00	1.49	1.26
HOD-V	MG/M3-DAY	.0	.00	125.5	.25	.00	.00	.00	.00
MOD-V	MG/M3-DAY	.0	.00	120.4	.33	.00	.00	.00	.00

CASE: crownbutte 2006

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

SEGMENT: 1 Deepest

	----- VALUES -----		--- RANKS (%) ----	
VARIABLE	OBSERVED	ESTIMATED	OBSERVED	ESTIMATED
TOTAL P MG/M3	157.00	93.02	90.6	77.0
TOTAL N MG/M3	2013.00	1538.76	86.2	74.9
C.NUTRIENT MG/M3	110.39	72.50	92.1	81.2
CHL-A MG/M3	44.90	27.35	97.9	91.7
SECCHI M	1.38	2.16	62.5	81.9
ORGANIC N MG/M3	1919.00	1242.76	99.7	97.1
TP-ORTHO-P MG/M3	106.00	61.35	90.8	77.4
HOD-V MG/M3-DAY	.00	125.51	.0	74.4
MOD-V MG/M3-DAY	.00	120.43	.0	79.0
ANTILOG PC-1	1657.47	680.68	92.8	78.2
ANTILOG PC-2	22.13	21.68	99.1	99.0
(N - 150) / P	11.87	14.93	29.9	42.4
INORGANIC N / P	1.84	9.35	.3	12.2
TURBIDITY 1/M	.08	.08	1.1	1.1
ZMIX * TURBIDITY	.64	.64	2.0	2.0
ZMIX / SECCHI	5.82	3.70	63.4	33.2
CHL-A * SECCHI	61.74	59.09	99.5	99.3
CHL-A / TOTAL P	.29	.29	72.4	73.8
CARLSON TSI-P	77.06	69.51	.0	.0
CARLSON TSI-CHLA	67.92	63.06	.0	.0
CARLSON TSI-SEC	55.41	48.90	.0	.0

CASE: **Crownbutte 2006 – Calibrated Model Less 75% N and P Loads**

HYDRAULIC AND DISPERSION PARAMETERS:

SEG	OUT	NET INFLOW HM3/YR	RESIDENCE TIME YRS	OVERFLOW RATE M/YR	MEAN VELOCITY KM/YR	DISPERSION ESTIMATED KM2/YR	DISPERSION NUMERIC KM2/YR	EXCHANGE RATE HM3/YR
1	0	.06	8.27505	.5	1.0	1.	0.	0.

CASE: crownbutte 2006

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	FLOW (HM3/YR) VARIANCE	FLOW (HM3/YR) CV	RUNOFF M/YR
1	1	inlet	19.260	.057	.000E+00	.000	.003
2	4	Outlet	19.387	.057	.000E+00	.000	.003
TRIBUTARY INFLOW			19.260	.057	.000E+00	.000	.003
***TOTAL INFLOW			19.384	.057	.000E+00	.000	.003
GAUGED OUTFLOW			19.387	.057	.000E+00	.000	.003
***TOTAL OUTFLOW			19.384	.057	.000E+00	.000	.003

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS

COMPONENT: CONSERV

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

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	CONSERV POOL CONC MG/M3	CONSERV RESIDENCE TIME YRS	CONSERV TURNOVER RATIO -	CONSERV RETENTION COEF -
.46	8.2751	.0	.0000	.0000	.0000

Crownbutte 2006 – Calibrated Model Less 75% N and P Loads

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL P

ID T LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1 1 inlet	4.0	51.8	.000E+00	.0	.000	70.0	.2
2 4 Outlet	16.7	216.8	.000E+00	.0	.000	293.0	.9
PRECIPITATION	3.7	48.2	.345E+01	100.0	.500	.0	30.0
TRIBUTARY INFLOW	4.0	51.8	.000E+00	.0	.000	70.0	.2
***TOTAL INFLOW	7.7	100.0	.345E+01	100.0	.241	135.2	.4
GAUGED OUTFLOW	8.9	116.2	.000E+00	.0	.000	157.0	.5
***TOTAL OUTFLOW	8.9	116.2	.000E+00	.0	.000	157.0	.5
***RETENTION	-1.2	-16.2	.345E+01	100.0	1.492	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
.46	8.2751	157.0	9.6123	.1040	-.1616

GROSS MASS BALANCE BASED UPON OBSERVED CONCENTRATIONS
COMPONENT: TOTAL N

ID T LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1 1 inlet	26.8	17.8	.000E+00	.0	.000	470.0	1.4
2 4 Outlet	109.9	73.0	.000E+00	.0	.000	1928.0	5.7
PRECIPITATION	123.8	82.2	.383E+04	100.0	.500	.0	1000.0
TRIBUTARY INFLOW	26.8	17.8	.000E+00	.0	.000	470.0	1.4
***TOTAL INFLOW	150.6	100.0	.383E+04	100.0	.411	2641.9	7.8
GAUGED OUTFLOW	114.7	76.2	.000E+00	.0	.000	2013.0	5.9
***TOTAL OUTFLOW	114.7	76.2	.000E+00	.0	.000	2013.0	5.9
***RETENTION	35.8	23.8	.383E+04	100.0	1.727	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL N POOL CONC MG/M3	TOTAL N RESIDENCE TIME YRS	TOTAL N TURNOVER RATIO -	TOTAL N RETENTION COEF -
.46	8.2751	2013.0	6.3051	.1586	.2381

CASE: **Crownbutte 2006 – Calibrated Model Less 75% N and P Loads**

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

SEGMENT: 1 Deepest

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	157.0	.00	61.0	.34	2.57	.00	3.52	2.76
TOTAL N	MG/M3	2013.0	.00	1306.4	.49	1.54	.00	1.97	.88
C.NUTRIENT	MG/M3	110.4	.00	51.5	.29	2.14	.00	3.79	2.62
CHL-A	MG/M3	44.9	.00	17.9	.43	2.50	.00	2.65	2.14
SECCHI	M	1.4	.00	3.1	.38	.44	.00	-2.93	-2.19
ORGANIC N	MG/M3	1919.0	.00	903.5	.33	2.12	.00	3.01	2.28
TP-ORTHO-P	MG/M3	106.0	.00	39.2	.49	2.70	.00	2.72	2.05
HOD-V	MG/M3-DAY	.0	.00	101.6	.26	.00	.00	.00	.00
MOD-V	MG/M3-DAY	.0	.00	97.5	.34	.00	.00	.00	.00

CASE: crownbutte 2006

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

SEGMENT: 1 Deepest

VARIABLE		VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P	MG/M3	157.00	60.98	90.6	60.6
TOTAL N	MG/M3	2013.00	1306.36	86.2	66.1
C.NUTRIENT	MG/M3	110.39	51.53	92.1	67.7
CHL-A	MG/M3	44.90	17.93	97.9	80.0
SECCHI	M	1.38	3.12	62.5	91.9
ORGANIC N	MG/M3	1919.00	903.46	99.7	89.7
TP-ORTHO-P	MG/M3	106.00	39.22	90.8	61.1
HOD-V	MG/M3-DAY	.00	101.62	.0	64.5
MOD-V	MG/M3-DAY	.00	97.51	.0	69.4
ANTILOG PC-1		1657.47	330.61	92.8	59.1
ANTILOG PC-2		22.13	21.18	99.1	98.8
(N - 150) / P		11.87	18.96	29.9	56.4
INORGANIC N / P		1.84	18.51	.3	31.7
TURBIDITY	1/M	.08	.08	1.1	1.1
ZMIX * TURBIDITY		.64	.64	2.0	2.0
ZMIX / SECCHI		5.82	2.56	63.4	14.3
CHL-A * SECCHI		61.74	56.00	99.5	99.2
CHL-A / TOTAL P		.29	.29	72.4	73.8
CARLSON TSI-P		77.06	63.43	.0	.0
CARLSON TSI-CHLA		67.92	58.92	.0	.0
CARLSON TSI-SEC		55.41	43.59	.0	.0

Appendix C
Water Quality Data Collected in Support of the Crown Butte Dam TMDL Development Project (2004-2005)

Crown Butte Dam (Deepest Area) Water Quality Data for 2004-2005

SITE ID	LOCATION	DEPTH	DATE COLLECT	TIME COLLECT	ANALYTE NAME	RESULT	DETECT LIMIT	UNITS
381130	Crown Butte Dam - Deepest	0.923	10/21/2004	10:30	Chlor A	17.6		ug/L
381130	Crown Butte Dam - Deepest	0.923	5/16/2005	16:40	Chlor A	*Non-detect	6	ug/L
381130	Crown Butte Dam - Deepest	0.923	5/23/2005	20:30	Chlor A	15		ug/L
381130	Crown Butte Dam - Deepest	0.923	6/6/2005	9:10	Chlor A	*Non-detect	4.28	ug/L
381130	Crown Butte Dam - Deepest	0.923	6/23/2005	12:15	Chlor A	76.1		ug/L
381130	Crown Butte Dam - Deepest	0.923	7/4/2005	8:20	Chlor A	18.7		ug/L
381130	Crown Butte Dam - Deepest	0.923	7/12/2005	15:40	Chlor A	38.7		ug/L
381130	Crown Butte Dam - Deepest	0.923	8/5/2005	10:15	Chlor A	150		ug/L
381130	Crown Butte Dam - Deepest	0.923	8/22/2005	11:00	Chlor A	55		ug/L
381130	Crown Butte Dam - Deepest	0.923	9/20/2005	13:20	Chlor A	72.6		ug/L
381130	Crown Butte Dam - Deepest	1	10/21/2004	10:30	Diss P	0.089		mg/L
381130	Crown Butte Dam - Deepest	1	11/11/2004	14:30	Diss P	0.052		mg/L
381130	Crown Butte Dam - Deepest	1	12/28/2004	10:00	Diss P	0.091		mg/L
381130	Crown Butte Dam - Deepest	1	1/18/2005	11:00	Diss P	0.078		mg/L
381130	Crown Butte Dam - Deepest	1	2/8/2005	10:30	Diss P	0.101		mg/L
381130	Crown Butte Dam - Deepest	1	3/9/2005	12:15	Diss P	0.057		mg/L
381130	Crown Butte Dam - Deepest	1	4/18/2005	13:45	Diss P	0.087		mg/L
381130	Crown Butte Dam - Deepest	1	5/16/2005	16:00	Diss P	0.042		mg/L
381130	Crown Butte Dam - Deepest	1	5/23/2005	20:10	Diss P	0.034		mg/L
381130	Crown Butte Dam - Deepest	1	6/6/2005	9:10	Diss P	0.035		mg/L
381130	Crown Butte Dam - Deepest	1	7/4/2005	8:00	Diss P	0.068		mg/L
381130	Crown Butte Dam - Deepest	1	8/4/2005	10:15	Diss P	0.16		mg/L
381130	Crown Butte Dam - Deepest	1	8/22/2005	11:00	Diss P	0.267		mg/L
381130	Crown Butte Dam - Deepest	1	9/20/2005	13:00	Diss P	0.329		mg/L
381130	Crown Butte Dam - Deepest	1	10/21/2004	10:30	N (Total)	1.67		mg/L
381130	Crown Butte Dam - Deepest	1	11/11/2004	14:30	N (Total)	1.6		mg/L
381130	Crown Butte Dam - Deepest	1	12/28/2004	10:00	N (Total)	1.76		mg/L
381130	Crown Butte Dam - Deepest	1	1/18/2005	11:00	N (Total)	1.95		mg/L
381130	Crown Butte Dam - Deepest	1	2/8/2005	10:30	N (Total)	1.91		mg/L
381130	Crown Butte Dam - Deepest	1	3/9/2005	12:15	N (Total)	1.61		mg/L
381130	Crown Butte Dam - Deepest	1	4/18/2005	13:45	N (Total)	1.32		mg/L
381130	Crown Butte Dam - Deepest	1	5/16/2005	16:00	N (Total)	2.18		mg/L
381130	Crown Butte Dam - Deepest	1	5/23/2005	20:10	N (Total)	1.52		mg/L
381130	Crown Butte Dam - Deepest	1	6/6/2005	9:10	N (Total)	1.64		mg/L
381130	Crown Butte Dam - Deepest	1	7/4/2005	8:00	N (Total)	3.81		mg/L
381130	Crown Butte Dam - Deepest	1	7/12/2005	15:50	N (Total)	2.41		mg/L
381130	Crown Butte Dam - Deepest	1	8/4/2005	10:15	N (Total)	2.21		mg/L
381130	Crown Butte Dam - Deepest	1	8/22/2005	11:00	N (Total)	2.13		mg/L
381130	Crown Butte Dam - Deepest	1	9/20/2005	13:00	N (Total)	2.47		mg/L
381130	Crown Butte Dam - Deepest	1	10/21/2004	10:30	NH3-N	0.012		mg/L
381130	Crown Butte Dam - Deepest	1	11/11/2004	14:30	NH3-N	0.031		mg/L
381130	Crown Butte Dam - Deepest	1	12/28/2004	10:00	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	1	1/18/2005	11:00	NH3-N	0.13		mg/L
381130	Crown Butte Dam - Deepest	1	2/8/2005	10:30	NH3-N	0.08		mg/L
381130	Crown Butte Dam - Deepest	1	3/9/2005	12:15	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	1	4/18/2005	13:45	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	1	5/16/2005	16:00	NH3-N	0.271		mg/L
381130	Crown Butte Dam - Deepest	1	5/23/2005	20:10	NH3-N	0.068		mg/L
381130	Crown Butte Dam - Deepest	1	6/6/2005	9:10	NH3-N	0.027		mg/L
381130	Crown Butte Dam - Deepest	1	7/4/2005	8:00	NH3-N	2.44		mg/L
381130	Crown Butte Dam - Deepest	1	7/12/2005	15:50	NH3-N	0.103		mg/L

SITE ID	LOCATION	DEPTH	DATE COLLECT	TIME COLLECT	ANALYTE NAME	RESULT	DETECT LIMIT	UNITS
381130	Crown Butte Dam - Deepest	1	8/4/2005	10:15	NH3-N	0.01		mg/L
381130	Crown Butte Dam - Deepest	1	8/22/2005	11:00	NH3-N	0.017		mg/L
381130	Crown Butte Dam - Deepest	1	9/20/2005	13:00	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	1	10/21/2004	10:30	NO3+NO2	0.03		mg/L
381130	Crown Butte Dam - Deepest	1	11/11/2004	14:30	NO3+NO2	*Non-detect	0.02	mg/L
381130	Crown Butte Dam - Deepest	1	12/28/2004	10:00	NO3+NO2	0.05		mg/L
381130	Crown Butte Dam - Deepest	1	1/18/2005	11:00	NO3+NO2	0.06		mg/L
381130	Crown Butte Dam - Deepest	1	2/8/2005	10:30	NO3+NO2	0.06		mg/L
381130	Crown Butte Dam - Deepest	1	3/9/2005	12:15	NO3+NO2	0.02		mg/L
381130	Crown Butte Dam - Deepest	1	4/18/2005	13:45	NO3+NO2	0.02		mg/L
381130	Crown Butte Dam - Deepest	1	5/16/2005	16:00	NO3+NO2	0.08		mg/L
381130	Crown Butte Dam - Deepest	1	5/23/2005	20:10	NO3+NO2	0.09		mg/L
381130	Crown Butte Dam - Deepest	1	6/6/2005	9:10	NO3+NO2	0.1		mg/L
381130	Crown Butte Dam - Deepest	1	7/4/2005	8:00	NO3+NO2	0.79		mg/L
381130	Crown Butte Dam - Deepest	1	7/12/2005	15:50	NO3+NO2	*Non-detect	0.02	mg/L
381130	Crown Butte Dam - Deepest	1	8/4/2005	10:15	NO3+NO2	0.02		mg/L
381130	Crown Butte Dam - Deepest	1	8/22/2005	11:00	NO3+NO2	0.02		mg/L
381130	Crown Butte Dam - Deepest	1	9/20/2005	13:00	NO3+NO2	*Non-detect	0.02	mg/L
381130	Crown Butte Dam - Deepest	1	10/21/2004	10:30	P (Total)	0.129		mg/L
381130	Crown Butte Dam - Deepest	1	11/11/2004	14:30	P (Total)	0.101		mg/L
381130	Crown Butte Dam - Deepest	1	12/28/2004	10:00	P (Total)	0.118		mg/L
381130	Crown Butte Dam - Deepest	1	1/18/2005	11:00	P (Total)	0.126		mg/L
381130	Crown Butte Dam - Deepest	1	2/8/2005	10:30	P (Total)	0.138		mg/L
381130	Crown Butte Dam - Deepest	1	3/9/2005	12:15	P (Total)	0.105		mg/L
381130	Crown Butte Dam - Deepest	1	4/18/2005	13:45	P (Total)	0.082		mg/L
381130	Crown Butte Dam - Deepest	1	5/16/2005	16:00	P (Total)	0.141		mg/L
381130	Crown Butte Dam - Deepest	1	5/23/2005	20:10	P (Total)	0.043		mg/L
381130	Crown Butte Dam - Deepest	1	6/6/2005	9:10	P (Total)	0.062		mg/L
381130	Crown Butte Dam - Deepest	1	7/4/2005	8:00	P (Total)	0.226		mg/L
381130	Crown Butte Dam - Deepest	1	7/12/2005	15:50	P (Total)	0.137		mg/L
381130	Crown Butte Dam - Deepest	1	8/4/2005	10:15	P (Total)	0.256		mg/L
381130	Crown Butte Dam - Deepest	1	8/22/2005	11:00	P (Total)	0.295		mg/L
381130	Crown Butte Dam - Deepest	1	9/20/2005	13:00	P (Total)	0.392		mg/L
381130	Crown Butte Dam - Deepest	1	10/21/2004	10:30	TKN	1.64		mg/L
381130	Crown Butte Dam - Deepest	1	11/11/2004	14:30	TKN	1.58		mg/L
381130	Crown Butte Dam - Deepest	1	12/28/2004	10:00	TKN	1.71		mg/L
381130	Crown Butte Dam - Deepest	1	1/18/2005	11:00	TKN	1.89		mg/L
381130	Crown Butte Dam - Deepest	1	2/8/2005	10:30	TKN	1.85		mg/L
381130	Crown Butte Dam - Deepest	1	3/9/2005	12:15	TKN	1.59		mg/L
381130	Crown Butte Dam - Deepest	1	4/18/2005	13:45	TKN	1.3		mg/L
381130	Crown Butte Dam - Deepest	1	5/16/2005	16:00	TKN	2.1		mg/L
381130	Crown Butte Dam - Deepest	1	5/23/2005	20:10	TKN	1.43		mg/L
381130	Crown Butte Dam - Deepest	1	6/6/2005	9:10	TKN	1.54		mg/L
381130	Crown Butte Dam - Deepest	1	7/4/2005	8:00	TKN	3.02		mg/L
381130	Crown Butte Dam - Deepest	1	7/12/2005	15:50	TKN	2.39		mg/L
381130	Crown Butte Dam - Deepest	1	8/4/2005	10:15	TKN	2.19		mg/L
381130	Crown Butte Dam - Deepest	1	8/22/2005	11:00	TKN	2.11		mg/L
381130	Crown Butte Dam - Deepest	1	9/20/2005	13:00	TKN	2.45		mg/L
381130	Crown Butte Dam - Deepest	2	6/23/2005	12:15	Diss P	0.037		mg/L
381130	Crown Butte Dam - Deepest	2	6/23/2005	12:15	N (Total)	1.89		mg/L
381130	Crown Butte Dam - Deepest	2	6/23/2005	12:15	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	2	6/23/2005	12:15	NO3+NO2	0.02		mg/L
381130	Crown Butte Dam - Deepest	2	6/23/2005	12:15	P (Total)	0.071		mg/L

SITE ID	LOCATION	DEPTH	DATE COLLECT	TIME COLLECT	ANALYTE NAME	RESULT	DETECT LIMIT	UNITS
381130	Crown Butte Dam - Deepest	2	6/23/2005	12:15	TKN	1.87		mg/L
381130	Crown Butte Dam - Deepest	2.5	9/20/2005	13:15	Diss P	0.323		mg/L
381130	Crown Butte Dam - Deepest	2.5	9/20/2005	13:15	N (Total)	2.39		mg/L
381130	Crown Butte Dam - Deepest	2.5	9/20/2005	13:15	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	2.5	9/20/2005	13:15	NO3+NO2	*Non-detect	0.02	mg/L
381130	Crown Butte Dam - Deepest	2.5	9/20/2005	13:15	P (Total)	0.379		mg/L
381130	Crown Butte Dam - Deepest	2.5	9/20/2005	13:15	TKN	2.37		mg/L
381130	Crown Butte Dam - Deepest	3	5/16/2005	16:15	Diss P	0.025		mg/L
381130	Crown Butte Dam - Deepest	3	5/23/2005	20:15	Diss P	0.026		mg/L
381130	Crown Butte Dam - Deepest	3	6/6/2005	9:20	Diss P	0.03		mg/L
381130	Crown Butte Dam - Deepest	3	7/4/2005	8:15	Diss P	0.124		mg/L
381130	Crown Butte Dam - Deepest	3	8/4/2005	10:30	Diss P	0.179		mg/L
381130	Crown Butte Dam - Deepest	3	8/22/2005	11:15	Diss P	0.279		mg/L
381130	Crown Butte Dam - Deepest	3	5/16/2005	16:15	N (Total)	1.9		mg/L
381130	Crown Butte Dam - Deepest	3	5/23/2005	20:15	N (Total)	1.54		mg/L
381130	Crown Butte Dam - Deepest	3	6/6/2005	9:20	N (Total)	1.86		mg/L
381130	Crown Butte Dam - Deepest	3	7/4/2005	8:15	N (Total)	3.46		mg/L
381130	Crown Butte Dam - Deepest	3	7/12/2005	16:00	N (Total)	2.62		mg/L
381130	Crown Butte Dam - Deepest	3	8/4/2005	10:30	N (Total)	2.58		mg/L
381130	Crown Butte Dam - Deepest	3	8/22/2005	11:15	N (Total)	1.98		mg/L
381130	Crown Butte Dam - Deepest	3	5/16/2005	16:15	NH3-N	0.278		mg/L
381130	Crown Butte Dam - Deepest	3	5/23/2005	20:15	NH3-N	0.088		mg/L
381130	Crown Butte Dam - Deepest	3	6/6/2005	9:20	NH3-N	0.036		mg/L
381130	Crown Butte Dam - Deepest	3	7/4/2005	8:15	NH3-N	0.027		mg/L
381130	Crown Butte Dam - Deepest	3	7/12/2005	16:00	NH3-N	0.032		mg/L
381130	Crown Butte Dam - Deepest	3	8/4/2005	10:30	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	3	8/22/2005	11:15	NH3-N	0.01		mg/L
381130	Crown Butte Dam - Deepest	3	5/16/2005	16:15	NO3+NO2	0.07		mg/L
381130	Crown Butte Dam - Deepest	3	5/23/2005	20:15	NO3+NO2	0.08		mg/L
381130	Crown Butte Dam - Deepest	3	6/6/2005	9:20	NO3+NO2	0.08		mg/L
381130	Crown Butte Dam - Deepest	3	7/4/2005	8:15	NO3+NO2	0.02		mg/L
381130	Crown Butte Dam - Deepest	3	7/12/2005	16:00	NO3+NO2	*Non-detect	0.02	mg/L
381130	Crown Butte Dam - Deepest	3	8/4/2005	10:30	NO3+NO2	*Non-detect	0.02	mg/L
381130	Crown Butte Dam - Deepest	3	8/22/2005	11:15	NO3+NO2	*Non-detect	0.02	mg/L
381130	Crown Butte Dam - Deepest	3	5/16/2005	16:15	P (Total)	0.086		mg/L
381130	Crown Butte Dam - Deepest	3	5/23/2005	20:15	P (Total)	0.045		mg/L
381130	Crown Butte Dam - Deepest	3	6/6/2005	9:20	P (Total)	0.066		mg/L
381130	Crown Butte Dam - Deepest	3	7/4/2005	8:15	P (Total)	0.251		mg/L
381130	Crown Butte Dam - Deepest	3	7/12/2005	16:00	P (Total)	0.139		mg/L
381130	Crown Butte Dam - Deepest	3	8/4/2005	10:30	P (Total)	0.309		mg/L
381130	Crown Butte Dam - Deepest	3	8/22/2005	11:15	P (Total)	0.282		mg/L
381130	Crown Butte Dam - Deepest	3	5/16/2005	16:15	TKN	1.83		mg/L
381130	Crown Butte Dam - Deepest	3	5/23/2005	20:15	TKN	1.46		mg/L
381130	Crown Butte Dam - Deepest	3	6/6/2005	9:20	TKN	1.78		mg/L
381130	Crown Butte Dam - Deepest	3	7/4/2005	8:15	TKN	3.44		mg/L
381130	Crown Butte Dam - Deepest	3	7/12/2005	16:00	TKN	2.6		mg/L
381130	Crown Butte Dam - Deepest	3	8/4/2005	10:30	TKN	2.56		mg/L
381130	Crown Butte Dam - Deepest	3	8/22/2005	11:15	TKN	1.96		mg/L
381130	Crown Butte Dam - Deepest	4	10/21/2004	10:30	Diss P	0.087		mg/L
381130	Crown Butte Dam - Deepest	4	11/11/2004	14:30	Diss P	0.054		mg/L
381130	Crown Butte Dam - Deepest	4	12/28/2004	10:00	Diss P	0.061		mg/L
381130	Crown Butte Dam - Deepest	4	1/18/2005	11:00	Diss P	0.09		mg/L
381130	Crown Butte Dam - Deepest	4	2/8/2005	10:45	Diss P	0.103		mg/L

SITE ID	LOCATION	DEPTH	DATE COLLECT	TIME COLLECT	ANALYTE NAME	RESULT	DETECT LIMIT	UNITS
381130	Crown Butte Dam - Deepest	4	3/9/2005	12:15	Diss P	0.053		mg/L
381130	Crown Butte Dam - Deepest	4	4/18/2005	14:00	Diss P	0.046		mg/L
381130	Crown Butte Dam - Deepest	4	6/23/2005	12:15	Diss P	0.122		mg/L
381130	Crown Butte Dam - Deepest	4	10/21/2004	10:30	N (Total)	1.64		mg/L
381130	Crown Butte Dam - Deepest	4	11/11/2004	14:30	N (Total)	1.42		mg/L
381130	Crown Butte Dam - Deepest	4	12/28/2004	10:00	N (Total)	1.77		mg/L
381130	Crown Butte Dam - Deepest	4	1/18/2005	11:00	N (Total)	2.01		mg/L
381130	Crown Butte Dam - Deepest	4	2/8/2005	10:45	N (Total)	1.88		mg/L
381130	Crown Butte Dam - Deepest	4	3/9/2005	12:15	N (Total)	1.69		mg/L
381130	Crown Butte Dam - Deepest	4	4/18/2005	14:00	N (Total)	1.35		mg/L
381130	Crown Butte Dam - Deepest	4	6/23/2005	12:15	N (Total)	1.93		mg/L
381130	Crown Butte Dam - Deepest	4	10/21/2004	10:30	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	4	11/11/2004	14:30	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	4	12/28/2004	10:00	NH3-N	0.042		mg/L
381130	Crown Butte Dam - Deepest	4	1/18/2005	11:00	NH3-N	0.233		mg/L
381130	Crown Butte Dam - Deepest	4	2/8/2005	10:45	NH3-N	0.056		mg/L
381130	Crown Butte Dam - Deepest	4	3/9/2005	12:15	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	4	4/18/2005	14:00	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	4	6/23/2005	12:15	NH3-N	0.164		mg/L
381130	Crown Butte Dam - Deepest	4	10/21/2004	10:30	NO3+NO2	0.04		mg/L
381130	Crown Butte Dam - Deepest	4	11/11/2004	14:30	NO3+NO2	0.02		mg/L
381130	Crown Butte Dam - Deepest	4	12/28/2004	10:00	NO3+NO2	0.06		mg/L
381130	Crown Butte Dam - Deepest	4	1/18/2005	11:00	NO3+NO2	0.06		mg/L
381130	Crown Butte Dam - Deepest	4	2/8/2005	10:45	NO3+NO2	0.06		mg/L
381130	Crown Butte Dam - Deepest	4	3/9/2005	12:15	NO3+NO2	*Non-detect	0.02	mg/L
381130	Crown Butte Dam - Deepest	4	4/18/2005	14:00	NO3+NO2	*Non-detect	0.02	mg/L
381130	Crown Butte Dam - Deepest	4	6/23/2005	12:15	NO3+NO2	0.02		mg/L
381130	Crown Butte Dam - Deepest	4	10/21/2004	10:30	P (Total)	0.122		mg/L
381130	Crown Butte Dam - Deepest	4	11/11/2004	14:30	P (Total)	0.081		mg/L
381130	Crown Butte Dam - Deepest	4	12/28/2004	10:00	P (Total)	0.111		mg/L
381130	Crown Butte Dam - Deepest	4	1/18/2005	11:00	P (Total)	0.143		mg/L
381130	Crown Butte Dam - Deepest	4	2/8/2005	10:45	P (Total)	0.128		mg/L
381130	Crown Butte Dam - Deepest	4	3/9/2005	12:15	P (Total)	0.093		mg/L
381130	Crown Butte Dam - Deepest	4	4/18/2005	14:00	P (Total)	0.081		mg/L
381130	Crown Butte Dam - Deepest	4	6/23/2005	12:15	P (Total)	0.164		mg/L
381130	Crown Butte Dam - Deepest	4	10/21/2004	10:30	TKN	1.6		mg/L
381130	Crown Butte Dam - Deepest	4	11/11/2004	14:30	TKN	1.4		mg/L
381130	Crown Butte Dam - Deepest	4	12/28/2004	10:00	TKN	1.71		mg/L
381130	Crown Butte Dam - Deepest	4	1/18/2005	11:00	TKN	1.95		mg/L
381130	Crown Butte Dam - Deepest	4	2/8/2005	10:45	TKN	1.82		mg/L
381130	Crown Butte Dam - Deepest	4	3/9/2005	12:15	TKN	1.67		mg/L
381130	Crown Butte Dam - Deepest	4	4/18/2005	14:00	TKN	1.33		mg/L
381130	Crown Butte Dam - Deepest	4	6/23/2005	12:15	TKN	1.91		mg/L
381130	Crown Butte Dam - Deepest	4.5	5/16/2005	16:30	Diss P	0.031		mg/L
381130	Crown Butte Dam - Deepest	4.5	5/16/2005	16:30	N (Total)	1.73		mg/L
381130	Crown Butte Dam - Deepest	4.5	5/16/2005	16:30	NH3-N	0.273		mg/L
381130	Crown Butte Dam - Deepest	4.5	5/16/2005	16:30	NO3+NO2	0.07		mg/L
381130	Crown Butte Dam - Deepest	4.5	5/16/2005	16:30	P (Total)	0.056		mg/L
381130	Crown Butte Dam - Deepest	4.5	5/16/2005	16:30	TKN	1.66		mg/L
381130	Crown Butte Dam - Deepest	5	5/23/2005	20:20	Diss P	0.021		mg/L
381130	Crown Butte Dam - Deepest	5	6/6/2005	9:30	Diss P	0.128		mg/L
381130	Crown Butte Dam - Deepest	5	6/23/2005	12:15	Diss P	0.051		mg/L
381130	Crown Butte Dam - Deepest	5	5/23/2005	20:20	N (Total)	1.5		mg/L

SITE ID	LOCATION	DEPTH	DATE COLLECT	TIME COLLECT	ANALYTE NAME	RESULT	DETECT LIMIT	UNITS
381130	Crown Butte Dam - Deepest	5	6/6/2005	9:30	N (Total)	2.32		mg/L
381130	Crown Butte Dam - Deepest	5	6/23/2005	12:15	N (Total)	1.65		mg/L
381130	Crown Butte Dam - Deepest	5	5/23/2005	20:20	NH3-N	0.1		mg/L
381130	Crown Butte Dam - Deepest	5	6/6/2005	9:30	NH3-N	0.283		mg/L
381130	Crown Butte Dam - Deepest	5	6/23/2005	12:15	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	5	5/23/2005	20:20	NO3+NO2	0.09		mg/L
381130	Crown Butte Dam - Deepest	5	6/6/2005	9:30	NO3+NO2	0.06		mg/L
381130	Crown Butte Dam - Deepest	5	6/23/2005	12:15	NO3+NO2	*Non-detect	0.02	mg/L
381130	Crown Butte Dam - Deepest	5	5/23/2005	20:20	P (Total)	0.061		mg/L
381130	Crown Butte Dam - Deepest	5	6/6/2005	9:30	P (Total)	0.22		mg/L
381130	Crown Butte Dam - Deepest	5	6/23/2005	12:15	P (Total)	0.067		mg/L
381130	Crown Butte Dam - Deepest	5	5/23/2005	20:20	TKN	1.41		mg/L
381130	Crown Butte Dam - Deepest	5	6/6/2005	9:30	TKN	2.26		mg/L
381130	Crown Butte Dam - Deepest	5	6/23/2005	12:15	TKN	1.63		mg/L
381130	Crown Butte Dam - Deepest	6	4/18/2005	14:15	Diss P	0.038		mg/L
381130	Crown Butte Dam - Deepest	6	4/18/2005	14:15	N (Total)	1.33		mg/L
381130	Crown Butte Dam - Deepest	6	4/18/2005	14:15	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	6	4/18/2005	14:15	NO3+NO2	0.02		mg/L
381130	Crown Butte Dam - Deepest	6	4/18/2005	14:15	P (Total)	0.079		mg/L
381130	Crown Butte Dam - Deepest	6	4/18/2005	14:15	TKN	1.31		mg/L
381130	Crown Butte Dam - Deepest	7	10/21/2004	10:30	Diss P	0.09		mg/L
381130	Crown Butte Dam - Deepest	7	11/11/2004	14:30	Diss P	0.046		mg/L
381130	Crown Butte Dam - Deepest	7	12/28/2004	10:00	Diss P	0.087		mg/L
381130	Crown Butte Dam - Deepest	7	1/18/2005	11:00	Diss P	0.095		mg/L
381130	Crown Butte Dam - Deepest	7	2/8/2005	11:00	Diss P	0.104		mg/L
381130	Crown Butte Dam - Deepest	7	3/9/2005	12:15	Diss P	0.262		mg/L
381130	Crown Butte Dam - Deepest	7	10/21/2004	10:30	N (Total)	1.61		mg/L
381130	Crown Butte Dam - Deepest	7	11/11/2004	14:30	N (Total)	1.41		mg/L
381130	Crown Butte Dam - Deepest	7	12/28/2004	10:00	N (Total)	1.85		mg/L
381130	Crown Butte Dam - Deepest	7	1/18/2005	11:00	N (Total)	2.1		mg/L
381130	Crown Butte Dam - Deepest	7	2/8/2005	11:00	N (Total)	1.89		mg/L
381130	Crown Butte Dam - Deepest	7	3/9/2005	12:15	N (Total)	2.76		mg/L
381130	Crown Butte Dam - Deepest	7	10/21/2004	10:30	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	7	11/11/2004	14:30	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	7	12/28/2004	10:00	NH3-N	*Non-detect	0.01	mg/L
381130	Crown Butte Dam - Deepest	7	1/18/2005	11:00	NH3-N	0.265		mg/L
381130	Crown Butte Dam - Deepest	7	2/8/2005	11:00	NH3-N	0.133		mg/L
381130	Crown Butte Dam - Deepest	7	3/9/2005	12:15	NH3-N	0.92		mg/L
381130	Crown Butte Dam - Deepest	7	10/21/2004	10:30	NO3+NO2	0.04		mg/L
381130	Crown Butte Dam - Deepest	7	11/11/2004	14:30	NO3+NO2	0.02		mg/L
381130	Crown Butte Dam - Deepest	7	12/28/2004	10:00	NO3+NO2	0.07		mg/L
381130	Crown Butte Dam - Deepest	7	1/18/2005	11:00	NO3+NO2	0.07		mg/L
381130	Crown Butte Dam - Deepest	7	2/8/2005	11:00	NO3+NO2	0.07		mg/L
381130	Crown Butte Dam - Deepest	7	3/9/2005	12:15	NO3+NO2	*Non-detect	0.02	mg/L
381130	Crown Butte Dam - Deepest	7	10/21/2004	10:30	P (Total)	0.12		mg/L
381130	Crown Butte Dam - Deepest	7	11/11/2004	14:30	P (Total)	0.076		mg/L
381130	Crown Butte Dam - Deepest	7	12/28/2004	10:00	P (Total)	0.115		mg/L
381130	Crown Butte Dam - Deepest	7	1/18/2005	11:00	P (Total)	0.151		mg/L
381130	Crown Butte Dam - Deepest	7	2/8/2005	11:00	P (Total)	0.132		mg/L
381130	Crown Butte Dam - Deepest	7	3/9/2005	12:15	P (Total)	0.4		mg/L
381130	Crown Butte Dam - Deepest	7	10/21/2004	10:30	TKN	1.57		mg/L
381130	Crown Butte Dam - Deepest	7	11/11/2004	14:30	TKN	1.39		mg/L
381130	Crown Butte Dam - Deepest	7	12/28/2004	10:00	TKN	1.78		mg/L

SITE ID	LOCATION	DEPTH	DATE COLLECT	TIME COLLECT	ANALYTE NAME	RESULT	DETECT LIMIT	UNITS
381130	Crown Butte Dam - Deepest	7	1/18/2005	11:00	TKN	2.03		mg/L
381130	Crown Butte Dam - Deepest	7	2/8/2005	11:00	TKN	1.82		mg/L
381130	Crown Butte Dam - Deepest	7	3/9/2005	12:15	TKN	2.74		mg/L

Crown Butte Dam (Deepest Area) Secchi Disk Transparency Depth Data for 2004-2005

Date	Secchi Depth (meter)s
10/21/2004	1
11/11/2004	0.75
12/28/2004	1
1/18/2005	1.5
2/8/2005	1.25
3/8/2005	1.5
4/18/2005	1.25
5/16/2005	2.5
6/6/2005	2.5
7/17/2005	1.5
8/4/2005	1
9/20/2005	0.75

Crown Butte Dam (Deepest Area) Dissolved Oxygen/Temperature Profile Data for 2004-2005

Date	Depth	Temp.	Units	DO	Units
10/21/04	1	7.3	Celsius	9.73	mg/L
	2	7.3	Celsius	9.24	mg/L
	3	7.3	Celsius	9.03	mg/L
	4	7.3	Celsius	8.92	mg/L
	5	7.3	Celsius	9.08	mg/L
	6	7.3	Celsius	8.83	mg/L
	7	7.3	Celsius	8.97	mg/L
	8	7.3	Celsius	8.64	mg/L
11/11/04	1	5.1	Celsius	12.06	mg/L
	2	5.1	Celsius	12.16	mg/L
	3	4.9	Celsius	12.06	mg/L
	4	4.8	Celsius	12.25	mg/L
	5	4.8	Celsius	12.25	mg/L
	6	4.8	Celsius	12.12	mg/L
	7	4.7	Celsius	12	mg/L
12/28/04	1	1.2	Celsius	9	mg/L
	2	1.2	Celsius	8.85	mg/L
	3	1.6	Celsius	7.74	mg/L
	4	1.6	Celsius	7.4	mg/L
	5	1.6	Celsius	7.64	mg/L
	6	1.7	Celsius	7.37	mg/L
	7	2.3	Celsius	5.35	mg/L
01/18/05	1	1.2	Celsius	6.12	mg/L
	2	1.2	Celsius	6.1	mg/L
	3	1.8	Celsius	5.44	mg/L
	4	2.1	Celsius	4.38	mg/L
	5	2.2	Celsius	3.82	mg/L
	6	2.1	Celsius	4.31	mg/L
	7	3	Celsius	1.43	mg/L
02/08/05	1	3.3	Celsius	4.89	mg/L
	2	3.2	Celsius	4.8	mg/L
	3	3.1	Celsius	4.97	mg/L
	4	3	Celsius	4.72	mg/L
	5	2.7	Celsius	3.16	mg/L
	6	2.6	Celsius	2.48	mg/L
	7	3.1	Celsius	0.92	mg/L
03/08/05	1	7.5	Celsius	7.69	mg/L
	2	7.3	Celsius	9.35	mg/L
	3	5.5	Celsius	6.55	mg/L
	4	3.9	Celsius	1.1	mg/L
	5	3.6	Celsius	0.48	mg/L
	6	3.6	Celsius	0.21	mg/L
	7	3.9	Celsius	0.12	mg/L
04/18/05	1	13.6	Celsius	8.13	mg/L
	2	12.8	Celsius	8.23	mg/L
	3	12.2	Celsius	6.31	mg/L
	4	11.7	Celsius	7.54	mg/L
	5	11.5	Celsius	6.58	mg/L
	6	11.1	Celsius	5.89	mg/L
	7	10.4	Celsius	0.08	mg/L

Date	Depth	Temp.	Units	DO	Units
05/16/05	1	11.8	Celsius	7.51	mg/L
	3	11.5	Celsius	7.29	mg/L
	5	10.2	Celsius	7.1	mg/L
06/06/05	1	18.4	Celsius	5.14	mg/L
	3	18.6	Celsius	4.22	mg/L
	4	16.9	Celsius	4.1	mg/L
	5	15.8	Celsius	3.12	mg/L
07/04/05	1	20.8	Celsius	5.3	mg/L
	3	20.7	Celsius	2.1	mg/L
07/12/05	1	27.5	Celsius	5.12	mg/L
	2	26.6	Celsius	3.05	mg/L
	3	26.3	Celsius	0.86	mg/L
08/04/05	1	21.9	Celsius	4.17	mg/L
	3	20.8	Celsius	3.19	mg/L
09/20/05	1	17.3	Celsius	4.75	mg/L
	3	17.5	Celsius	2.45	mg/L

Crown Butte Dam Inlet Data for 2004-2004

SITE ID	LOCATION	DATE COLLECT	TIME COLLECT	ANALYTE	RESULT	DETECT LIMIT	UNITS
384170	Crown Butte Dam-Inlet	4/8/2005	13:45	Diss P	0.118		mg/L
384170	Crown Butte Dam-Inlet	4/8/2005	13:45	N (Total)	1.97		mg/L
384170	Crown Butte Dam-Inlet	4/8/2005	13:45	NH3-N	*Non-detect	0.010	mg/L
384170	Crown Butte Dam-Inlet	4/8/2005	13:45	NO3+NO2	*Non-detect	0.02	mg/L
384170	Crown Butte Dam-Inlet	4/8/2005	13:45	P (Total)	0.165		mg/L
384170	Crown Butte Dam-Inlet	4/8/2005	13:45	TKN	1.95		mg/L
384170	Crown Butte Dam-Inlet	4/8/2005	13:45	TSS	*Non-detect	5.	mg/L
384170	Crown Butte Dam-Inlet	4/11/2005	15:30	Diss P	0.143		mg/L
384170	Crown Butte Dam-Inlet	4/11/2005	15:30	N (Total)	1.76		mg/L
384170	Crown Butte Dam-Inlet	4/11/2005	15:30	NH3-N	*Non-detect	0.010	mg/L
384170	Crown Butte Dam-Inlet	4/11/2005	15:30	NO3+NO2	0.02		mg/L
384170	Crown Butte Dam-Inlet	4/11/2005	15:30	P (Total)	0.151		mg/L
384170	Crown Butte Dam-Inlet	4/11/2005	15:30	TKN	1.74		mg/L
384170	Crown Butte Dam-Inlet	4/11/2005	15:30	TSS	*Non-detect	5.	mg/L
384170	Crown Butte Dam-Inlet	4/14/2005	8:15	Diss P	0.139		mg/L
384170	Crown Butte Dam-Inlet	4/14/2005	8:15	N (Total)	2.19		mg/L
384170	Crown Butte Dam-Inlet	4/14/2005	8:15	NH3-N	0.095		mg/L
384170	Crown Butte Dam-Inlet	4/14/2005	8:15	NO3+NO2	0.05		mg/L
384170	Crown Butte Dam-Inlet	4/14/2005	8:15	P (Total)	0.195		mg/L
384170	Crown Butte Dam-Inlet	4/14/2005	8:15	TKN	2.14		mg/L
384170	Crown Butte Dam-Inlet	4/14/2005	8:15	TSS	6.		mg/L
384170	Crown Butte Dam-Inlet	4/17/2005	10:30	Diss P	0.096		mg/L
384170	Crown Butte Dam-Inlet	4/17/2005	10:30	N (Total)	1.96		mg/L
384170	Crown Butte Dam-Inlet	4/17/2005	10:30	NH3-N	0.027		mg/L
384170	Crown Butte Dam-Inlet	4/17/2005	10:30	NO3+NO2	0.06		mg/L
384170	Crown Butte Dam-Inlet	4/17/2005	10:30	P (Total)	0.162		mg/L
384170	Crown Butte Dam-Inlet	4/17/2005	10:30	TKN	1.90		mg/L
384170	Crown Butte Dam-Inlet	4/17/2005	10:30	TSS	5.		mg/L
384170	Crown Butte Dam-Inlet	4/21/2005	12:15	Diss P	0.096		mg/L
384170	Crown Butte Dam-Inlet	4/21/2005	12:15	N (Total)	1.68		mg/L
384170	Crown Butte Dam-Inlet	4/21/2005	12:15	NH3-N	*Non-detect	0.010	mg/L
384170	Crown Butte Dam-Inlet	4/21/2005	12:15	NO3+NO2	0.04		mg/L
384170	Crown Butte Dam-Inlet	4/21/2005	12:15	P (Total)	0.143		mg/L
384170	Crown Butte Dam-Inlet	4/21/2005	12:15	TKN	1.64		mg/L
384170	Crown Butte Dam-Inlet	4/21/2005	12:15	TSS	9.		mg/L
384170	Crown Butte Dam-Inlet	5/9/2005	10:45	Diss P	0.287		mg/L
384170	Crown Butte Dam-Inlet	5/9/2005	10:45	N (Total)	3.41		mg/L
384170	Crown Butte Dam-Inlet	5/9/2005	10:45	NH3-N	0.071		mg/L
384170	Crown Butte Dam-Inlet	5/9/2005	10:45	NO3+NO2	0.05		mg/L
384170	Crown Butte Dam-Inlet	5/9/2005	10:45	P (Total)	0.352		mg/L
384170	Crown Butte Dam-Inlet	5/9/2005	10:45	TKN	3.36		mg/L
384170	Crown Butte Dam-Inlet	5/9/2005	10:45	TSS	39.		mg/L
384170	Crown Butte Dam-Inlet	5/13/2005	14:35	Diss P	0.157		mg/L
384170	Crown Butte Dam-Inlet	5/13/2005	14:35	N (Total)	2.23		mg/L
384170	Crown Butte Dam-Inlet	5/13/2005	14:35	NH3-N	0.061		mg/L
384170	Crown Butte Dam-Inlet	5/13/2005	14:35	NO3+NO2	0.02		mg/L
384170	Crown Butte Dam-Inlet	5/13/2005	14:35	P (Total)	0.224		mg/L
384170	Crown Butte Dam-Inlet	5/13/2005	14:35	TKN	2.21		mg/L
384170	Crown Butte Dam-Inlet	5/13/2005	14:35	TSS	19.		mg/L

SITE ID	LOCATION	DATE COLLECT	TIME COLLECT	ANALYTE	RESULT	DETECT LIMIT	UNITS
384170	Crown Butte Dam-Inlet	5/15/2005	15:40	Diss P	0.080		mg/L
384170	Crown Butte Dam-Inlet	5/15/2005	15:40	N (Total)	1.49		mg/L
384170	Crown Butte Dam-Inlet	5/15/2005	15:40	NH3-N	0.065		mg/L
384170	Crown Butte Dam-Inlet	5/15/2005	15:40	NO3+NO2	0.02		mg/L
384170	Crown Butte Dam-Inlet	5/15/2005	15:40	P (Total)	0.154		mg/L
384170	Crown Butte Dam-Inlet	5/15/2005	15:40	TKN	1.47		mg/L
384170	Crown Butte Dam-Inlet	5/15/2005	15:40	TSS	27.		mg/L
384170	Crown Butte Dam-Inlet	5/16/2005	12:30	Diss P	0.073		mg/L
384170	Crown Butte Dam-Inlet	5/16/2005	12:30	N (Total)	1.57		mg/L
384170	Crown Butte Dam-Inlet	5/16/2005	12:30	NH3-N	0.072		mg/L
384170	Crown Butte Dam-Inlet	5/16/2005	12:30	NO3+NO2	0.05		mg/L
384170	Crown Butte Dam-Inlet	5/16/2005	12:30	P (Total)	0.136		mg/L
384170	Crown Butte Dam-Inlet	5/16/2005	12:30	TKN	1.52		mg/L
384170	Crown Butte Dam-Inlet	5/16/2005	12:30	TSS	13.		mg/L
384170	Crown Butte Dam-Inlet	5/18/2005	17:00	Diss P	0.122		mg/L
384170	Crown Butte Dam-Inlet	5/18/2005	17:00	N (Total)	1.52		mg/L
384170	Crown Butte Dam-Inlet	5/18/2005	17:00	NH3-N	0.019		mg/L
384170	Crown Butte Dam-Inlet	5/18/2005	17:00	NO3+NO2	0.06		mg/L
384170	Crown Butte Dam-Inlet	5/18/2005	17:00	P (Total)	0.160		mg/L
384170	Crown Butte Dam-Inlet	5/18/2005	17:00	TKN	1.46		mg/L
384170	Crown Butte Dam-Inlet	5/18/2005	17:00	TSS	8.		mg/L
384170	Crown Butte Dam-Inlet	5/23/2005	14:15	Diss P	0.132		mg/L
384170	Crown Butte Dam-Inlet	5/23/2005	14:15	N (Total)	1.54		mg/L
384170	Crown Butte Dam-Inlet	5/23/2005	14:15	NH3-N	0.043		mg/L
384170	Crown Butte Dam-Inlet	5/23/2005	14:15	NO3+NO2	0.02		mg/L
384170	Crown Butte Dam-Inlet	5/23/2005	14:15	P (Total)	0.182		mg/L
384170	Crown Butte Dam-Inlet	5/23/2005	14:15	TKN	1.52		mg/L
384170	Crown Butte Dam-Inlet	5/23/2005	14:15	TSS	15.		mg/L
384170	Crown Butte Dam-Inlet	5/27/2005	13:20	Diss P	0.096		mg/L
384170	Crown Butte Dam-Inlet	5/27/2005	13:20	N (Total)	1.30		mg/L
384170	Crown Butte Dam-Inlet	5/27/2005	13:20	NH3-N	0.047		mg/L
384170	Crown Butte Dam-Inlet	5/27/2005	13:20	NO3+NO2	0.02		mg/L
384170	Crown Butte Dam-Inlet	5/27/2005	13:20	P (Total)	0.189		mg/L
384170	Crown Butte Dam-Inlet	5/27/2005	13:20	TKN	1.28		mg/L
384170	Crown Butte Dam-Inlet	5/27/2005	13:20	TSS	86.		mg/L
384170	Crown Butte Dam-Inlet	6/1/2005	13:45	Diss P	0.137		mg/L
384170	Crown Butte Dam-Inlet	6/1/2005	13:45	N (Total)	1.45		mg/L
384170	Crown Butte Dam-Inlet	6/1/2005	13:45	NH3-N	*Non-detect	0.010	mg/L
384170	Crown Butte Dam-Inlet	6/1/2005	13:45	NO3+NO2	*Non-detect	0.02	mg/L
384170	Crown Butte Dam-Inlet	6/1/2005	13:45	P (Total)	0.197		mg/L
384170	Crown Butte Dam-Inlet	6/1/2005	13:45	TKN	1.43		mg/L
384170	Crown Butte Dam-Inlet	6/1/2005	13:45	TSS	10.		mg/L
384170	Crown Butte Dam-Inlet	6/3/2005	10:45	Diss P	0.259		mg/L
384170	Crown Butte Dam-Inlet	6/3/2005	10:45	N (Total)	1.97		mg/L
384170	Crown Butte Dam-Inlet	6/3/2005	10:45	NH3-N	0.040		mg/L
384170	Crown Butte Dam-Inlet	6/3/2005	10:45	NO3+NO2	0.02		mg/L
384170	Crown Butte Dam-Inlet	6/3/2005	10:45	P (Total)	0.299		mg/L
384170	Crown Butte Dam-Inlet	6/3/2005	10:45	TKN	1.95		mg/L
384170	Crown Butte Dam-Inlet	6/3/2005	10:45	TSS	11.		mg/L
384170	Crown Butte Dam-Inlet	6/6/2005	13:10	Diss P	0.167		mg/L
384170	Crown Butte Dam-Inlet	6/6/2005	13:10	N (Total)	1.70		mg/L
384170	Crown Butte Dam-Inlet	6/6/2005	13:10	NH3-N	0.064		mg/L
384170	Crown Butte Dam-Inlet	6/6/2005	13:10	NO3+NO2	*Non-detect	0.02	mg/L

SITE ID	LOCATION	DATE COLLECT	TIME COLLECT	ANALYTE	RESULT	DETECT LIMIT	UNITS
384170	Crown Butte Dam-Inlet	6/6/2005	13:10	P (Total)	0.231		mg/L
384170	Crown Butte Dam-Inlet	6/6/2005	13:10	TKN	1.68		mg/L
384170	Crown Butte Dam-Inlet	6/6/2005	13:10	TSS	9.		mg/L
384170	Crown Butte Dam-Inlet	6/9/2005	13:50	Diss P	0.385		mg/L
384170	Crown Butte Dam-Inlet	6/9/2005	13:50	N (Total)	1.82		mg/L
384170	Crown Butte Dam-Inlet	6/9/2005	13:50	NH3-N	0.022		mg/L
384170	Crown Butte Dam-Inlet	6/9/2005	13:50	NO3+NO2	0.02		mg/L
384170	Crown Butte Dam-Inlet	6/9/2005	13:50	P (Total)	0.403		mg/L
384170	Crown Butte Dam-Inlet	6/9/2005	13:50	TKN	1.80		mg/L
384170	Crown Butte Dam-Inlet	6/9/2005	13:50	TSS	8.		mg/L
384170	Crown Butte Dam-Inlet	6/14/2005	13:45	Diss P	0.208		mg/L
384170	Crown Butte Dam-Inlet	6/14/2005	13:45	N (Total)	1.49		mg/L
384170	Crown Butte Dam-Inlet	6/14/2005	13:45	NH3-N	0.076		mg/L
384170	Crown Butte Dam-Inlet	6/14/2005	13:45	NO3+NO2	0.02		mg/L
384170	Crown Butte Dam-Inlet	6/14/2005	13:45	P (Total)	0.314		mg/L
384170	Crown Butte Dam-Inlet	6/14/2005	13:45	TKN	1.47		mg/L
384170	Crown Butte Dam-Inlet	6/14/2005	13:45	TSS	48.		mg/L
384170	Crown Butte Dam-Inlet	6/17/2005	11:45	Diss P	0.208		mg/L
384170	Crown Butte Dam-Inlet	6/17/2005	11:45	N (Total)	1.52		mg/L
384170	Crown Butte Dam-Inlet	6/17/2005	11:45	NH3-N	0.113		mg/L
384170	Crown Butte Dam-Inlet	6/17/2005	11:45	NO3+NO2	0.03		mg/L
384170	Crown Butte Dam-Inlet	6/17/2005	11:45	P (Total)	0.298		mg/L
384170	Crown Butte Dam-Inlet	6/17/2005	11:45	TKN	1.49		mg/L
384170	Crown Butte Dam-Inlet	6/17/2005	11:45	TSS	46.		mg/L
384170	Crown Butte Dam-Inlet	6/28/2005	17:35	Diss P	0.298		mg/L
384170	Crown Butte Dam-Inlet	6/28/2005	17:35	N (Total)	1.81		mg/L
384170	Crown Butte Dam-Inlet	6/28/2005	17:35	NH3-N	0.062		mg/L
384170	Crown Butte Dam-Inlet	6/28/2005	17:35	NO3+NO2	0.03		mg/L
384170	Crown Butte Dam-Inlet	6/28/2005	17:35	P (Total)	0.347		mg/L
384170	Crown Butte Dam-Inlet	6/28/2005	17:35	TKN	1.78		mg/L
384170	Crown Butte Dam-Inlet	6/28/2005	17:35	TSS	19.		mg/L
384170	Crown Butte Dam-Inlet	7/4/2005	7:45	Diss P	0.163		mg/L
384170	Crown Butte Dam-Inlet	7/4/2005	7:45	N (Total)	1.43		mg/L
384170	Crown Butte Dam-Inlet	7/4/2005	7:45	NH3-N	0.083		mg/L
384170	Crown Butte Dam-Inlet	7/4/2005	7:45	NO3+NO2	*Non-detect	0.02	mg/L
384170	Crown Butte Dam-Inlet	7/4/2005	7:45	P (Total)	0.217		mg/L
384170	Crown Butte Dam-Inlet	7/4/2005	7:45	TKN	1.41		mg/L
384170	Crown Butte Dam-Inlet	7/4/2005	7:45	TSS	18.		mg/L
384170	Crown Butte Dam-Inlet	7/11/2005	10:00	N (Total)	2.45		mg/L
384170	Crown Butte Dam-Inlet	7/11/2005	10:00	NH3-N	0.378		mg/L
384170	Crown Butte Dam-Inlet	7/11/2005	10:00	NO3+NO2	0.16		mg/L
384170	Crown Butte Dam-Inlet	7/11/2005	10:00	P (Total)	0.489		mg/L
384170	Crown Butte Dam-Inlet	7/11/2005	10:00	TKN	2.29		mg/L
384170	Crown Butte Dam-Inlet	7/11/2005	10:00	TSS	16.		mg/L
384170	Crown Butte Dam-Inlet	8/18/2005	12:15	Diss P	0.197		mg/L
384170	Crown Butte Dam-Inlet	8/18/2005	12:15	N (Total)	1.71		mg/L
384170	Crown Butte Dam-Inlet	8/18/2005	12:15	NH3-N	0.042		mg/L
384170	Crown Butte Dam-Inlet	8/18/2005	12:15	NO3+NO2	0.05		mg/L
384170	Crown Butte Dam-Inlet	8/18/2005	12:15	P (Total)	0.227		mg/L
384170	Crown Butte Dam-Inlet	8/18/2005	12:15	TKN	1.66		mg/L
384170	Crown Butte Dam-Inlet	8/18/2005	12:15	TSS	7.		mg/L

Crown Butte Dam Outlet Data for 2004-2005

SITE ID	LOCATION	DATE COLLECT	TIME COLLECT	ANALYTE NAME	RESULT	DETECT LIMIT	UNITS
384171	Crown Butte Dam - Outlet	10/21/2004	10:30	Diss P	0.032		mg/L
384171	Crown Butte Dam - Outlet	10/21/2004	10:30	N (Total)	0.638		mg/L
384171	Crown Butte Dam - Outlet	10/21/2004	10:30	NH3-N	*Non-detect	0.010	mg/L
384171	Crown Butte Dam - Outlet	10/21/2004	10:30	NO3+NO2	0.08		mg/L
384171	Crown Butte Dam - Outlet	10/21/2004	10:30	P (Total)	0.075		mg/L
384171	Crown Butte Dam - Outlet	10/21/2004	10:30	TKN	0.558		mg/L
384171	Crown Butte Dam - Outlet	10/21/2004	10:30	TSS	7.		mg/L
384171	Crown Butte Dam - Outlet	11/11/2004	10:30	Diss P	0.047		mg/L
384171	Crown Butte Dam - Outlet	11/11/2004	10:30	N (Total)	0.673		mg/L
384171	Crown Butte Dam - Outlet	11/11/2004	10:30	NH3-N	*Non-detect	0.010	mg/L
384171	Crown Butte Dam - Outlet	11/11/2004	10:30	NO3+NO2	0.22		mg/L
384171	Crown Butte Dam - Outlet	11/11/2004	10:30	P (Total)	0.079		mg/L
384171	Crown Butte Dam - Outlet	11/11/2004	10:30	TKN	0.453		mg/L
384171	Crown Butte Dam - Outlet	11/11/2004	10:30	TSS	38.		mg/L
384171	Crown Butte Dam - Outlet	4/14/2005	9:40	Diss P	0.045		mg/L
384171	Crown Butte Dam - Outlet	4/14/2005	9:40	N (Total)	1.47		mg/L
384171	Crown Butte Dam - Outlet	4/14/2005	9:40	NH3-N	*Non-detect	0.010	mg/L
384171	Crown Butte Dam - Outlet	4/14/2005	9:40	NO3+NO2	0.03		mg/L
384171	Crown Butte Dam - Outlet	4/14/2005	9:40	P (Total)	0.074		mg/L
384171	Crown Butte Dam - Outlet	4/14/2005	9:40	TKN	1.44		mg/L
384171	Crown Butte Dam - Outlet	4/14/2005	9:40	TSS	*Non-detect	5.	mg/L
384171	Crown Butte Dam - Outlet	4/17/2005	13:50	Diss P	0.045		mg/L
384171	Crown Butte Dam - Outlet	4/17/2005	13:50	N (Total)	1.35		mg/L
384171	Crown Butte Dam - Outlet	4/17/2005	13:50	NH3-N	0.054		mg/L
384171	Crown Butte Dam - Outlet	4/17/2005	13:50	NO3+NO2	0.25		mg/L
384171	Crown Butte Dam - Outlet	4/17/2005	13:50	P (Total)	0.105		mg/L
384171	Crown Butte Dam - Outlet	4/17/2005	13:50	TKN	1.10		mg/L
384171	Crown Butte Dam - Outlet	4/17/2005	13:50	TSS	25.		mg/L
384171	Crown Butte Dam - Outlet	4/21/2005	13:45	Diss P	0.047		mg/L
384171	Crown Butte Dam - Outlet	4/21/2005	13:45	N (Total)	1.24		mg/L
384171	Crown Butte Dam - Outlet	4/21/2005	13:45	NH3-N	*Non-detect	0.010	mg/L
384171	Crown Butte Dam - Outlet	4/21/2005	13:45	NO3+NO2	*Non-detect	0.02	mg/L
384171	Crown Butte Dam - Outlet	4/21/2005	13:45	P (Total)	0.058		mg/L
384171	Crown Butte Dam - Outlet	4/21/2005	13:45	TKN	1.22		mg/L
384171	Crown Butte Dam - Outlet	4/21/2005	13:45	TSS	*Non-detect	5.	mg/L
384171	Crown Butte Dam - Outlet	4/23/2005	11:40	Diss P	0.036		mg/L
384171	Crown Butte Dam - Outlet	4/23/2005	11:40	N (Total)	1.39		mg/L
384171	Crown Butte Dam - Outlet	4/23/2005	11:40	NH3-N	*Non-detect	0.010	mg/L
384171	Crown Butte Dam - Outlet	4/23/2005	11:40	NO3+NO2	*Non-detect	0.02	mg/L
384171	Crown Butte Dam - Outlet	4/23/2005	11:40	P (Total)	0.066		mg/L
384171	Crown Butte Dam - Outlet	4/23/2005	11:40	TKN	1.37		mg/L
384171	Crown Butte Dam - Outlet	4/23/2005	11:40	TSS	7.		mg/L
384171	Crown Butte Dam - Outlet	4/24/2005	15:00	Diss P	0.035		mg/L
384171	Crown Butte Dam - Outlet	4/24/2005	15:00	N (Total)	1.41		mg/L
384171	Crown Butte Dam - Outlet	4/24/2005	15:00	NH3-N	*Non-detect	0.010	mg/L
384171	Crown Butte Dam - Outlet	4/24/2005	15:00	NO3+NO2	*Non-detect	0.02	mg/L
384171	Crown Butte Dam - Outlet	4/24/2005	15:00	P (Total)	0.061		mg/L
384171	Crown Butte Dam - Outlet	4/24/2005	15:00	TKN	1.39		mg/L
384171	Crown Butte Dam - Outlet	4/24/2005	15:00	TSS	10.		mg/L
384171	Crown Butte Dam - Outlet	4/25/2005	12:45	Diss P	0.034		mg/L

SITE ID	LOCATION	DATE COLLECT	TIME COLLECT	ANALYTE NAME	RESULT	DETECT LIMIT	UNITS
384171	Crown Butte Dam - Outlet	4/25/2005	12:45	N (Total)	1.40		mg/L
384171	Crown Butte Dam - Outlet	4/25/2005	12:45	NH3-N	*Non-detect	0.010	mg/L
384171	Crown Butte Dam - Outlet	4/25/2005	12:45	NO3+NO2	*Non-detect	0.02	mg/L
384171	Crown Butte Dam - Outlet	4/25/2005	12:45	P (Total)	0.068		mg/L
384171	Crown Butte Dam - Outlet	4/25/2005	12:45	TKN	1.38		mg/L
384171	Crown Butte Dam - Outlet	4/25/2005	12:45	TSS	17.		mg/L
384171	Crown Butte Dam - Outlet	4/26/2005	16:10	Diss P	0.042		mg/L
384171	Crown Butte Dam - Outlet	4/26/2005	16:10	N (Total)	1.48		mg/L
384171	Crown Butte Dam - Outlet	4/26/2005	16:10	NH3-N	*Non-detect	0.010	mg/L
384171	Crown Butte Dam - Outlet	4/26/2005	16:10	NO3+NO2	*Non-detect	0.02	mg/L
384171	Crown Butte Dam - Outlet	4/26/2005	16:10	P (Total)	0.077		mg/L
384171	Crown Butte Dam - Outlet	4/26/2005	16:10	TKN	1.46		mg/L
384171	Crown Butte Dam - Outlet	4/26/2005	16:10	TSS	17.		mg/L
384171	Crown Butte Dam - Outlet	4/27/2005	16:00	Diss P	0.039		mg/L
384171	Crown Butte Dam - Outlet	4/27/2005	16:00	N (Total)	1.51		mg/L
384171	Crown Butte Dam - Outlet	4/27/2005	16:00	NH3-N	*Non-detect	0.010	mg/L
384171	Crown Butte Dam - Outlet	4/27/2005	16:00	NO3+NO2	*Non-detect	0.02	mg/L
384171	Crown Butte Dam - Outlet	4/27/2005	16:00	P (Total)	0.081		mg/L
384171	Crown Butte Dam - Outlet	4/27/2005	16:00	TKN	1.49		mg/L
384171	Crown Butte Dam - Outlet	4/27/2005	16:00	TSS	14.		mg/L
384171	Crown Butte Dam - Outlet	4/28/2005	17:00	Diss P	0.045		mg/L
384171	Crown Butte Dam - Outlet	4/28/2005	17:00	N (Total)	1.49		mg/L
384171	Crown Butte Dam - Outlet	4/28/2005	17:00	NH3-N	*Non-detect	0.010	mg/L
384171	Crown Butte Dam - Outlet	4/28/2005	17:00	NO3+NO2	*Non-detect	0.02	mg/L
384171	Crown Butte Dam - Outlet	4/28/2005	17:00	P (Total)	0.076		mg/L
384171	Crown Butte Dam - Outlet	4/28/2005	17:00	TKN	1.47		mg/L
384171	Crown Butte Dam - Outlet	4/28/2005	17:00	TSS	12.		mg/L
384171	Crown Butte Dam - Outlet	4/30/2005	15:00	Diss P	0.040		mg/L
384171	Crown Butte Dam - Outlet	4/30/2005	15:00	N (Total)	1.54		mg/L
384171	Crown Butte Dam - Outlet	4/30/2005	15:00	NH3-N	*Non-detect	0.010	mg/L
384171	Crown Butte Dam - Outlet	4/30/2005	15:00	NO3+NO2	*Non-detect	0.02	mg/L
384171	Crown Butte Dam - Outlet	4/30/2005	15:00	P (Total)	0.085		mg/L
384171	Crown Butte Dam - Outlet	4/30/2005	15:00	TKN	1.52		mg/L
384171	Crown Butte Dam - Outlet	4/30/2005	15:00	TSS	18.		mg/L
384171	Crown Butte Dam - Outlet	5/3/2005	12:10	Diss P	0.030		mg/L
384171	Crown Butte Dam - Outlet	5/3/2005	12:10	N (Total)	1.34		mg/L
384171	Crown Butte Dam - Outlet	5/3/2005	12:10	NH3-N	*Non-detect	0.010	mg/L
384171	Crown Butte Dam - Outlet	5/3/2005	12:10	NO3+NO2	*Non-detect	0.02	mg/L
384171	Crown Butte Dam - Outlet	5/3/2005	12:10	P (Total)	0.055		mg/L
384171	Crown Butte Dam - Outlet	5/3/2005	12:10	TKN	1.32		mg/L
384171	Crown Butte Dam - Outlet	5/3/2005	12:10	TSS	8.		mg/L
384171	Crown Butte Dam - Outlet	5/5/2005	17:45	Diss P	0.028		mg/L
384171	Crown Butte Dam - Outlet	5/5/2005	17:45	N (Total)	1.38		mg/L
384171	Crown Butte Dam - Outlet	5/5/2005	17:45	NH3-N	*Non-detect	0.010	mg/L
384171	Crown Butte Dam - Outlet	5/5/2005	17:45	NO3+NO2	*Non-detect	0.02	mg/L
384171	Crown Butte Dam - Outlet	5/5/2005	17:45	P (Total)	0.062		mg/L
384171	Crown Butte Dam - Outlet	5/5/2005	17:45	TKN	1.36		mg/L
384171	Crown Butte Dam - Outlet	5/5/2005	17:45	TSS	9.		mg/L
384171	Crown Butte Dam - Outlet	5/9/2005	12:25	Diss P	0.038		mg/L
384171	Crown Butte Dam - Outlet	5/9/2005	12:25	N (Total)	1.39		mg/L
384171	Crown Butte Dam - Outlet	5/9/2005	12:25	NH3-N	0.059		mg/L
384171	Crown Butte Dam - Outlet	5/9/2005	12:25	NO3+NO2	0.02		mg/L
384171	Crown Butte Dam - Outlet	5/9/2005	12:25	P (Total)	0.052		mg/L

SITE ID	LOCATION	DATE COLLECT	TIME COLLECT	ANALYTE NAME	RESULT	DETECT LIMIT	UNITS
384171	Crown Butte Dam - Outlet	5/9/2005	12:25	TKN	1.37		mg/L
384171	Crown Butte Dam - Outlet	5/9/2005	12:25	TSS	17.		mg/L
384171	Crown Butte Dam - Outlet	5/13/2005	16:05	Diss P	0.042		mg/L
384171	Crown Butte Dam - Outlet	5/13/2005	16:05	N (Total)	1.61		mg/L
384171	Crown Butte Dam - Outlet	5/13/2005	16:05	NH3-N	0.225		mg/L
384171	Crown Butte Dam - Outlet	5/13/2005	16:05	NO3+NO2	0.06		mg/L
384171	Crown Butte Dam - Outlet	5/13/2005	16:05	P (Total)	0.066		mg/L
384171	Crown Butte Dam - Outlet	5/13/2005	16:05	TKN	1.55		mg/L
384171	Crown Butte Dam - Outlet	5/13/2005	16:05	TSS	14.		mg/L
384171	Crown Butte Dam - Outlet	5/17/2005	13:00	Diss P	0.045		mg/L
384171	Crown Butte Dam - Outlet	5/17/2005	13:00	N (Total)	1.93		mg/L
384171	Crown Butte Dam - Outlet	5/17/2005	13:00	NH3-N	0.264		mg/L
384171	Crown Butte Dam - Outlet	5/17/2005	13:00	NO3+NO2	0.06		mg/L
384171	Crown Butte Dam - Outlet	5/17/2005	13:00	P (Total)	0.119		mg/L
384171	Crown Butte Dam - Outlet	5/17/2005	13:00	TKN	1.87		mg/L
384171	Crown Butte Dam - Outlet	5/17/2005	13:00	TSS	22.		mg/L

Appendix D
County Occurrence of Endangered, Threatened and Candidate Species and Designated Critical Habitat in North Dakota (March 2006)

County Occurrence of Endangered, Threatened and Candidate Species and Designated Critical Habitat in North Dakota (March 2006)

Species E – Endangered T – Threatened C – Candidate	Adams	Barnes	Benson	Billings	Bottineau	Bowman	Burke	Burleigh	Cass	Cavalier	Dickey	Divide	Dunn	Eddy	Emmons	Foster	Go. Valley	Gr. Forks	Grant	Griggs	Hettinger	Kidder	Lamoure	Logan	McHenry	McIntosh	McKenzie
Interior Least Tern – E								X					X		X												X
Whooping Crane – E	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Black Footed Ferret - E	X			X		X							X				X		X		X						X
Pallid Sturgeon – E								X					X		X												X
Gray Wolf – T					X		X		X	X	X	X	X					X							X	X	X
Bald Eagle – T	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Piping Plover – T			X				X	X				X	X	X	X	X						X		X	X	X	X
Western Prairie Fringed Orchid – T																											
Dakota Skipper – C							X							X											X		X
Designated Critical Habitat																											
Piping Plover			X				X	X				X	X	X	X							X		X	X	X	X

County Occurrence of Endangered, Threatened and Candidate Species and Designated Critical Habitat in North Dakota (March 2006)

Species E – Endangered T – Threatened C – Candidate	McLean	Mercer	Morton	Mountrail	Nelson	Oliver	Pembina	Pierce	Ramsey	Ransom	Renville	Richland	Rolette	Sargent	Sheridan	Sioux	Slope	Stark	Steele	Stutsman	Towner	Traill	Walsh	Ward	Wells	Williams
Interior Least Tern – E	X	X	X	X		X										X										X
Whooping Crane – E	X	X	X	X		X		X			X		X		X	X	X	X		X	X			X	X	X
Black Footed Ferret - E		X	X			X										X	X	X								
Pallid Sturgeon – E	X	X	X	X		X										X										X
Gray Wolf – T	X		X	X	X		X	X	X		X	X	X	X	X						X		X	X		X
Bald Eagle – T	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Piping Plover – T	X	X	X	X		X		X			X				X	X				X				X	X	X
Western Prairie Fringed Orchid – T										X		X														
Dakota Skipper – C										X		X	X	X						X				X	X	
Designated Critical Habitat																										
Piping Plover																										X

Appendix E
Review Comments Provided by the US EPA Region 8

-----Original Message-----
From: Berry.Vern@epamail.epa.gov [mailto:Berry.Vern@epamail.epa.gov]
Sent: Thursday, October 16, 2008 3:20 PM
To: Ell, Mike J.
Subject: EPA Comments on Sweetbriar Dam and Crown Butte Dam TMDLs

Mike,

Thanks for the couple of extra days to review these TMDLs. They look pretty good - just a few comments to make them ready for final approval.

Thanks,
Vern

===

Crown Butte Dam Nutrient and Dissolved Oxygen TMDLs

Section 3.1, Page 13: It is not clear which data was used to derive the TSI values for chlorophyll-a, total phosphorus and total nitrogen, shown in Table 8. The Secchi disk data and TSI summary on page 10 seems to indicate that the Secchi depth values were taken at the in-lake deepest site, and the SD TSI value was derived from that data. We could assume that the TSI values for chl-a, TP and TN were derived by using the average values taken from the in-lake deepest site (reservoir site) from Oct 2004-Sept 2005 for each parameter, and using the TSI equations to calculate the average TSI values. However, it also seems possible that the TSI values in Table 8 came from the BATHTUB modeling (Appendix A). Note: the "observed" TSI values in Appendix A, Table 2, and those in Appendix C do not match those shown in Table 8, page 13.

Our new TMDL review form says that the TMDL document should be accompanied by the data set utilized during the TMDL analysis.
Currently, the Crown Butte Dam TMDL only includes a partial data set (i.e., Appendix C). We assume that data from all of the sites were used to run the FLUX and BATHTUB programs. Please provide the complete data set in one of the appendices.

Section 5.2, Table 10: The Observed TSI values for phosphorus, chlorophyll-a and Secchi disk in Table 10 do not match the values in the BATHTUB model results in Appendix A, Table 2. Please revise as necessary to make them consistent, or explain why they are different.

Section 6.1, MOS: We suggest stating the MOS used in this TMDL in the MOS section rather than just providing the definition of a MOS.

Sediment Impairment: The sediment impairment is shown in Table 2, but is not included in the text of Section 1.1 - please include it in the text.
There is a short TSS section on page 10, but it does not provide enough information to say whether or not the reservoir is still considered impaired for sediment, or if the sediment impairment will be addressed at a later time. We suggest adding a couple of sentences to say that the sediment impairment will be addressed in a separate action (TMDL or delisting), or provide additional information to justify delisting in this document.

Appendix F
Letter of Support Provided by the Morton County Soil Conservation District

MORTON COUNTY SOIL
CONSERVATION DISTRICT
2540 OVERLOOK LANE
MANDAN, ND 58554
701-667-1163 - Ext. 3

September 23, 2008

Mr. Mike Ell
ND Dept. of Health
Division of Water Quality
Gold Seal Center
918 E Divide Ave., 4th Floor
Bismarck, ND 58501-1947

Dear Mike:

We congratulate the Department of Health on a well written Nutrient and Dissolved Oxygen TMDL for Crown Butte Dam, which succinctly defines the problem. Further, improving water quality to maintain a warm water fishery is important, reasonable and obtainable. A good recreation site near an urban population will continue to be heavily used.

Most of the surplus nutrients in the water come from the surrounding land upstream in the watershed. These watersheds are primarily agricultural, although there is considerable land use change due to urban sprawl including "equine slums." We are concerned with haphazard changes in land use.

The Morton County SCD currently has a watershed coordinator assigned to help keep concentrated animal feeding operation (feedlots) from discharging surplus nutrients into the watershed. We are trying to get agricultural producers to use improved methods such as no-till farming and riparian barriers. We believe achieving the goals of improving water quality will require cooperation of many county, state and federal agencies.

Sincerely,

Ted Becker
sb

Ted Becker
Supervisor

Appendix G
Department Response to Public Comments

Department Response to Comments

During the 30 day public notice soliciting comment and participation for the Crown Butte Dam Nutrient and Dissolved Oxygen TMDL, the North Dakota Department of Health received comments from the US EPA (see Appendix E) and from Scott Elstad with the North Dakota Game and Fish Department. Below is a summary of the comments provided by Mr. Elstad and the US EPA and the departments' response.

Comments from Mr. Elstad: Several comments were made regarding changes in the Crown Butte Dam watershed since the sampling and watershed analysis were completed for this TMDL. These comments include:

"[Section] 1.3 New data is now available, most notably the elimination of CRP acreage from the FSA. Although using 2005 data meshes better with the WQ data that was taken."

"From the time that the Crown Butte data were collected to the time the report was written [3 years], significant changes occurred in the Crown Butte watershed. Should these be identified, possibly followed up on (WQ samples taken [and] analyzed) before someone realizes the BMPs are already in place and maybe the goals are already reached?"

"There is also an 8,000 head CAFO (which the NDDoH is contemplating approving) being proposed to be built in the Crown Butte watershed – should this at least be mentioned as a possible detriment to future WQ? You mention (1.3) farmsteads & feedlots in the watershed…what about CAFO's…..?"

NDDoH Response: In most cases, there is a 1-2 year lag between when the monitoring and watershed assessment data are collected and when the TMDL report is completed. The Department recognizes that this lag may result in some land use changes by the time the final TMDL report is completed. Unless the data can be analyzed and the report written in less that 1 year this potential problem is unavoidable. The TMDL report is written to reflect conditions when the data are collected. This also includes appropriate technical analysis and modeling. If it is recognized, prior to the development and implementation of a watershed restoration project, that water quality and/or land use have changed significantly then the Department recommends that additional water quality data be collected and that the watershed model be updated to reflect current conditions. See the Department's response to the following comment as well.

Comment from Mr. Elstad: "A question, mostly. At what point will critical cells and/or BMPs be identified (3.1)? These reports are very lengthy to simply say 'the lake is impaired, and a reduction of 75% will bring it down to a eutrophic state' (3.1). But these reports would be much more useful if they identified, or at least suggested, what the next step should be. You mention that you found x-number of critical cells in the Sweet Briar watershed – where are they located? What makes them critical? What is the recommended BMP to treat them? Which sub-watershed should efforts be concentrated – above which sampling site, etc? Can an individual/organization request these identified areas – have a jpg produced? The same questions for the Crown Butte TMDL (all TMDLs) in Section 8.0 (among others) where are these cells so that efforts & obligations can be made to correct these problem areas.

NDDoH Response: The Crown Butte Dam, as well as the Sweet Briar Dam TMDLs (both located in Morton County), were unique in that a private contractor (HPC, Inc.) was hired by the Morton County SCD to conduct the sampling, modeling, analysis and report writing for these TMDLs. Typically, the results of the AGNPS or AnnAGPS modeling includes a map depicting critical cells that when treated will result in the nutrient reduction necessary to meet the TMDL target. In the case of the Sweet Briar Dam TMDL, a map depicting the critical cells was not made available by the contractor. A narrative description of the AGNPS model results was, however, provided. This narrative description, including the definition of critical cells is provided in Sectiom 5.3, AGNPS Watershed Model. In general, critical cells were based on percent cover on cropland and pasture/range conditions determined through the landuse assessment. These criteria were used to determine the C-factor for each cell in the model. The initial model was run using current conditions determined during the land use assessment. A 25 yr/24 hr storm event (4.10 inches) in Morton County was applied to the model to evaluate relative pollutant yields from each 40-acre cell. Each quarter of land was given a cell number. Each cell represents 40 acres of land. A total of 4,800 acres were input into the program, representing 119 cells. Cells with sediment phosphorous levels above 0.10 lbs/ac or cells with soluble phosphorous runoff concentrations above 0.15 ppm were identified as critical. The model identified 23 cells in the watershed (440 acres of cropland and 440 acres of pasture/rangeland) as being "critical" or 18 percent of the watershed area.

The Department also recognizes that a map depicting critical cells will be necessary in order to carry out any Watershed Restoration Project. In order to address this need additional language has been added to Section 11.0, TMDL Implementation Strategy, which reads:

> "It is recognized that significant land use changes may have or will have taken place in the watershed by the time a Watershed Restoration Project is undertaken. Therefore, it is recommended that as the first step in a Watershed Restoration Project the original AGNPS watershed model (or AnnAGNPS model) be updated and re-run with current land use conditions. Results of this model output should then be used to direct BMP implementation in the watershed."

Comment from Mr. Elstad: "[Section] 3.1 page 14 last para….Doesn't Crown Butte set up (stratify)? Thus it would have complete mixing, even with an almost constant wind…?"

NDDoH Response: During the course of the TMDL study, Crown Butte Dam was drawn down for dam repairs/dredging. As a result the temperature/DO profile data show complete mixing during the summer months. At full pool elevation it is likely that the reservoir will thermally stratify. However, given the maximum depth of the reservoir, its size and the intensity of wind event in North Dakota, stratification is only expected to occur for short periods of time. It therefore seems reasonable to assume the lake completely mixes.

Comment from US EPA: "Section 3.1, Page 13: It is not clear which data was used to derive the TSI values for chlorophyll-a, total phosphorus and total nitrogen, shown in Table 8. The Secchi disk data and TSI summary on page 10 seems to indicate that the Secchi depth values were taken at the in-lake deepest site, and the SD TSI value was derived from that data. We could assume that the TSI values for chl-a, TP and TN were derived by using the average values taken from the in-lake deepest site (reservoir site) from Oct 2004-Sept 2005 for each parameter, and using the TSI equations to calculate the average TSI values. However, it also seems possible that the TSI values in Table 8 came from the BATHTUB modeling (Appendix A). Note: the "observed" TSI values in Appendix A, Table 2, and those in Appendix C do not match those shown in Table 8, page 13."

NDDoH Response: The Secchi Disk Transparency TSI of 55.41 reported in Section 3.1 was derived from the mean of the 12 individual Secchi Disk Transparency measurements taken from the deepest area of the reservoir and reported in Figure 9. The chlorophyll-a, total phosphorus and total nitrogen TSI values of 67.92, 77.06 and 64.55, respectively, were based on the mean concentrations calculated from samples collected between October 2004 and September 2005 at the 1-meter depth interval. These concentrations are reported in Table 3 and were used as input into the BATHTUB model.

Comment from US EPA: "Our new TMDL review form says that the TMDL document should be accompanied by the data set utilized during the TMDL analysis. Currently, the Crown Butte Dam TMDL only includes a partial data set (i.e., Appendix C). We assume that data from all of the sites were used to run the FLUX and BATHTUB programs. Please provide the complete data set in one of the appendices."

NDDoH Response: All of the in-lake, inlet and outlet data collected during 2004 and 2005 for the Crown Butte Dam TMDL development project has now been included in Appendix C.

Comment from US EPA: "Section 5.2, Table 10: The Observed TSI values for phosphorus, chlorophyll-a and Secchi disk in Table 10 do not match the values in the BATHTUB model results in Appendix A, Table 2. Please revise as necessary to make them consistent, or explain why they are different."

NDDoH Response: Table 10 has been revised to accurately reflect the BATHTUB model output provided in Appendices A and B.

Comment from US EPA: "Section 6.1, MOS: We suggest stating the MOS used in this TMDL in the MOS section rather than just providing the definition of a MOS.."

NDDoH Response: Additional language has been added to Section 6.1 describing how the 10 percent explicit margin of safety that has been used for this TMDL was calculated and the values used.

Comment from US EPA: "Sediment Impairment: The sediment impairment is shown in Table 2, but is not included in the text of Section 1.1 - please include it in the text. There is a short TSS section on page 10, but it does not provide enough information to say whether or not the reservoir is still considered impaired for sediment, or if the sediment impairment will be addressed at a later time. We suggest adding a couple of sentences to say that the sediment impairment will be addressed in a separate action (TMDL or delisting), or provide additional information to justify delisting in this document."

NDDoH Response: Additional language has been added to Section 1.1, Clean Water Act Section 303(d) Listing Information, stating that the purpose of this TMDL report is for the pollutants nutrients and low dissolved oxygen and that the sediment listing will be addressed as additional data become available.