NEOSHO RIVER BASIN TOTAL MAXIMUM DAILY LOAD
Water Body: Council Grove Lake
Water Quality Impairment: Eutrophication

Revision to TMDL Originally Approved, September 30, 2002

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Neosho Headwaters **Counties:** Morris, Wabaunsee, and Geary

HUC 8: 11070201

HUC 11 (HUC14): 010 (010, 020, 030, 040, 050, 060)

Ecoregion: Flint Hills (28)

Drainage Area: Approximately 258.6 square miles (**Figure 1**)

Conservation Pool: Area = 2,589 acres
Watershed Area: Lake Surface Area = 62:1
Maximum Depth = 11 meters (36 feet)
Mean Depth = 4.4 meters (14 feet)
Retention Time = 0.49 years (5.9 months)

Designated Uses: Primary Contact Recreation; Expected Aquatic Life Support; Drinking Water; Groundwater Recharge; Industrial Water Supply Use; Food Procurement; Irrigation; Livestock Watering

Authority: Federal (U.S. Army Corps of Engineers), State (Kansas Water Office)

1998 303(d) Listing: Neosho Impaired Lakes

Impaired Use: All uses are impaired to a degree by eutrophication

Water Quality Standard: Nutrients - Narrative: The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the production of undesirable quantities or kinds of aquatic life (KAR 28-16-28e(c)(2)(A)).

The introduction of plant nutrients into surface waters designated for primary or secondary contact recreational use shall be controlled to prevent the development of objectionable concentrations of algae or algal by-products or nuisance growths of submersed, floating, or emergent aquatic vegetation (KAR 28-16-28e(c)(7)(A)).

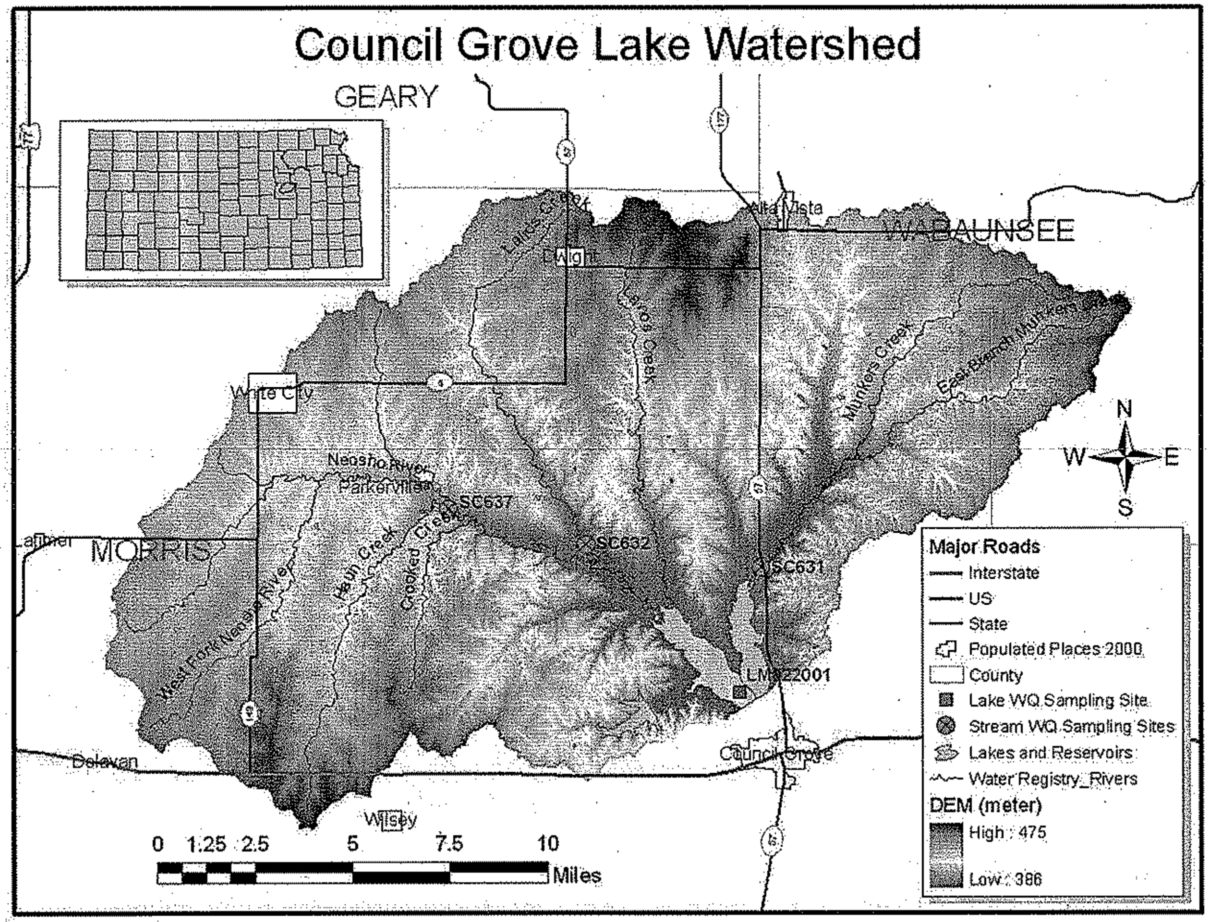

Figure 1. DEM and location of water quality sampling sites of Council Grove Lake Watershed.

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Eutrophication: Trophic State Index = 47.78 (Argillotrophic), ranging from 35 in 1993 to 53 in both 1990 and 2000. Mean chlorophyll *a* (Chla) concentration is 6.6 μg/L from 1987 – 2005. Chla = 8.3 μg/L in 2005, with its related TSI value = 51.

The Trophic State Index (TSI) is derived from the Chla. Trophic state assessments of potential algal productivity were made based on Chla, nutrient levels, and values of the Carlson Trophic State Index (TSI). Generally, some degree of eutrophic conditions is seen with Chla over 12 μg/L and hypereutrophy occurs at levels over 30 μg/L. The Carlson TSI derives from the Chla concentrations and scales the trophic state as follows:

1. Oligotrophic TSI < 40
2. Mesotrophic TSI: 40 - 49.99
3. Slightly Eutrophic TSI: 50 - 54.99
4. Fully Eutrophic TSI: 55 - 59.99

5. Very Eutrophic TSI: 60 - 63.99
6. Hypereutrophic TSI: 64
TSI score not relevant = Argillotrophic

In a number of Kansas lakes and reservoirs, high turbidity due to suspended clay particles negatively affects the development of a phytoplankton community. In such cases, nutrient availability remains high, but is not fully translated into algal productivity or biomass due to light limitation. Lakes with such high turbidity and nutrient levels, but lower than expected algal biomass, are called argillotrophic rather than oligotrophic-mesotrophic, mesotrophic, etc. In general, argillotrophic lakes tend to have very small or nonexistent, submersed macrophytes communities, and have mean Chla less than 7.2 µg/L (Carney, 2006).

Lake Monitoring Sites: Station LM022001 in Council Grove Lake; seven surveys, 1987 – 2005; U.S. Army Corps of Engineers, 1997 (USACE, 1999); Kansas Biological Survey (KBS), 2000 (Lim, 2001)

Stream Chemistry Sites: Station 631 Munkers Creek near Council Grove; 1992 – 2004
Station 632 Lairds Creek near Kelso; 1992 – 2004
Station 637 Neosho River near Parkerville; 1992 – 2004

Long-Term Hydrologic Conditions: Total inflow measured at the dam of Council Grove Lake by Tulsa District of the USACE during the period from 1995 to 2006 is shown in **Figure 2**. Median total inflow for Council Grove Lake is 20 cfs (39.74 ac-ft) while 10% and 80% exceedance total inflow are 200 cfs (397.44 ac-ft) and 5 cfs (9.94 ac-ft), respectively. During this period, annual average total inflow is 111,263 ac-ft, ranging from as low as 17,877 ac-ft in 2002 to as high as 249,583 ac-ft in 1995 (**Figure 3**). Generally, 1995 – 1999 are considered wet years while 2000 – 2003 is a dry period.

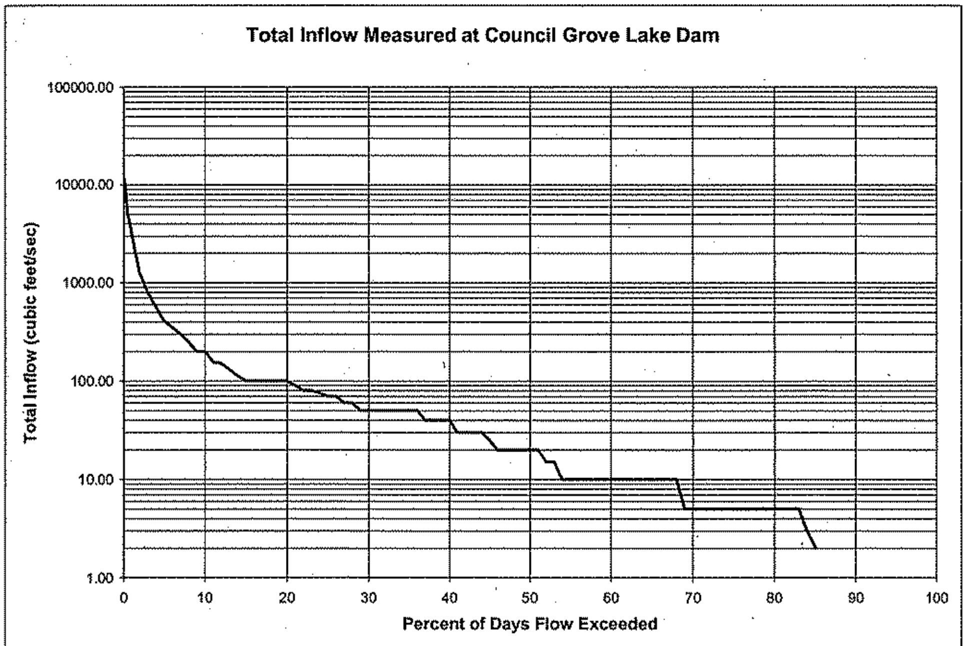

Figure 2. Flow duration of total inflow at Council Grove Lake during 1995 – 2006.

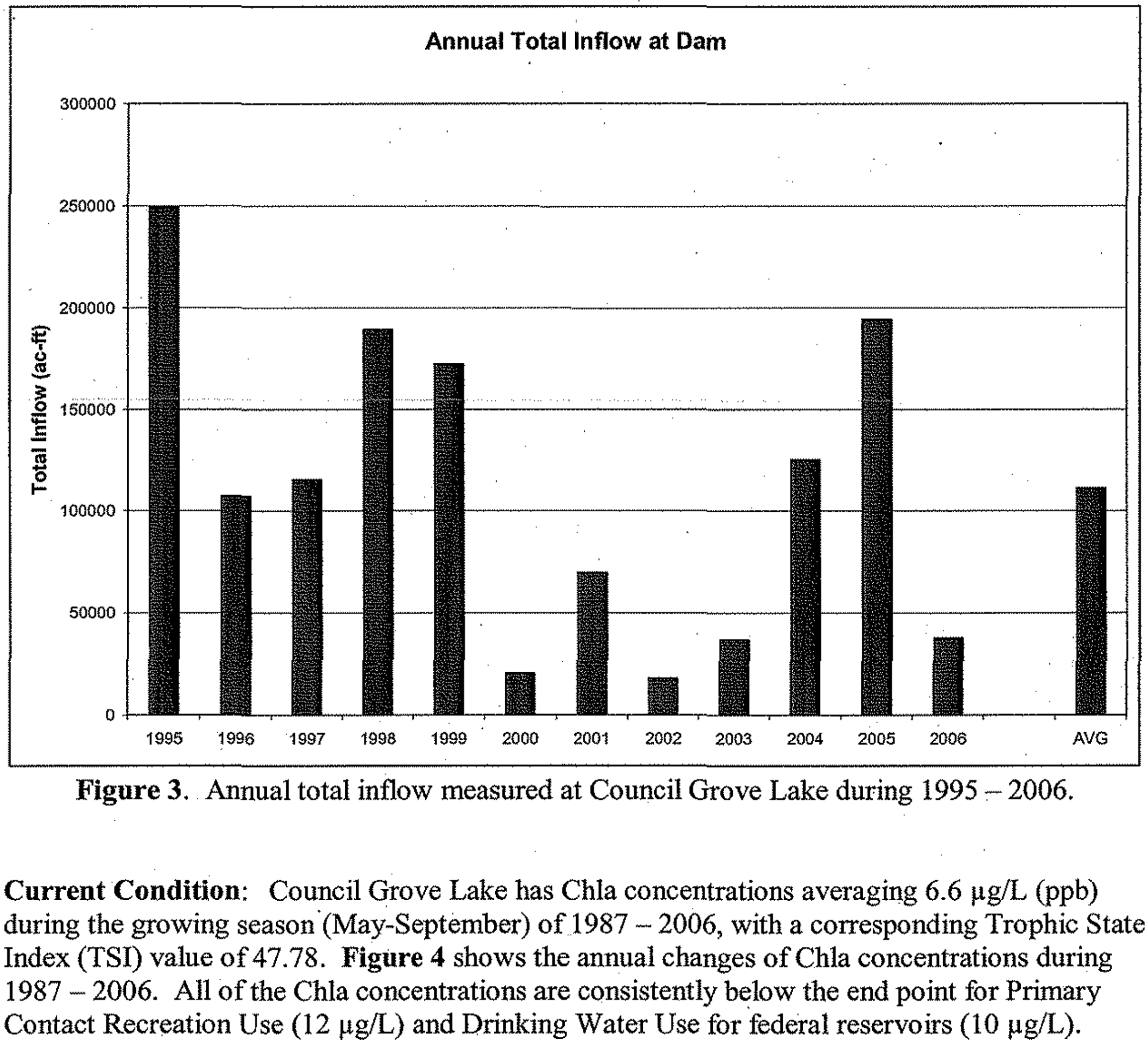

Figure 3. Annual total inflow measured at Council Grove Lake during 1995 – 2006.

Current Condition: Council Grove Lake has Chla concentrations averaging 6.6 µg/L (ppb) during the growing season (May-September) of 1987 – 2006, with a corresponding Trophic State Index (TSI) value of 47.78. **Figure 4** shows the annual changes of Chla concentrations during 1987 – 2006. All of the Chla concentrations are consistently below the end point for Primary Contact Recreation Use (12 µg/L) and Drinking Water Use for federal reservoirs (10 µg/L).

Total phosphorus (TP) concentrations average 188 µg/L, ranging from 158 µg/L in 2000 to 270 µg/L in 1993 (**Figure 5**). Total nitrogen (TN) concentrations average 941 µg/L, ranging from 270 µg/L in 2000 to 2,700 µg/L in 1993. The ratio of total nitrogen (TN) and TP has been used to determine which of these nutrients is most likely limiting plant growth in Kansas aquatic ecosystems (Dzialowski et al., 2005). Generally, lakes that are N limited have water column TN:TP ratios < 8 (mass); lakes that are co-limited by N and P have water column TN:TP ratios between 9 and 21; and lakes that are P limited have water column TN:TP ratios > 29. For Council Grove Lake, the TN:TP ratios, with the exception of TN:TP = 10 occurring in 1993, are typically less than 5, suggesting that the lake is N limited and its algal population is likely dominated by blue-green algae (cyanobacteria). A 2002 algal study conducted by the KDHE indicated that blue green algae were the most dominant species in the lake (Carney, 2003). However, a recent phytoplankton study reported that diatoms were the predominant species (Carney, 2006). This shift in species composition in 2005 is thought to be associated with a short summer residence time (0.11 yrs). In general, diatoms tend to thrive better than blue-green algae in the oxygenated flowing conditions.

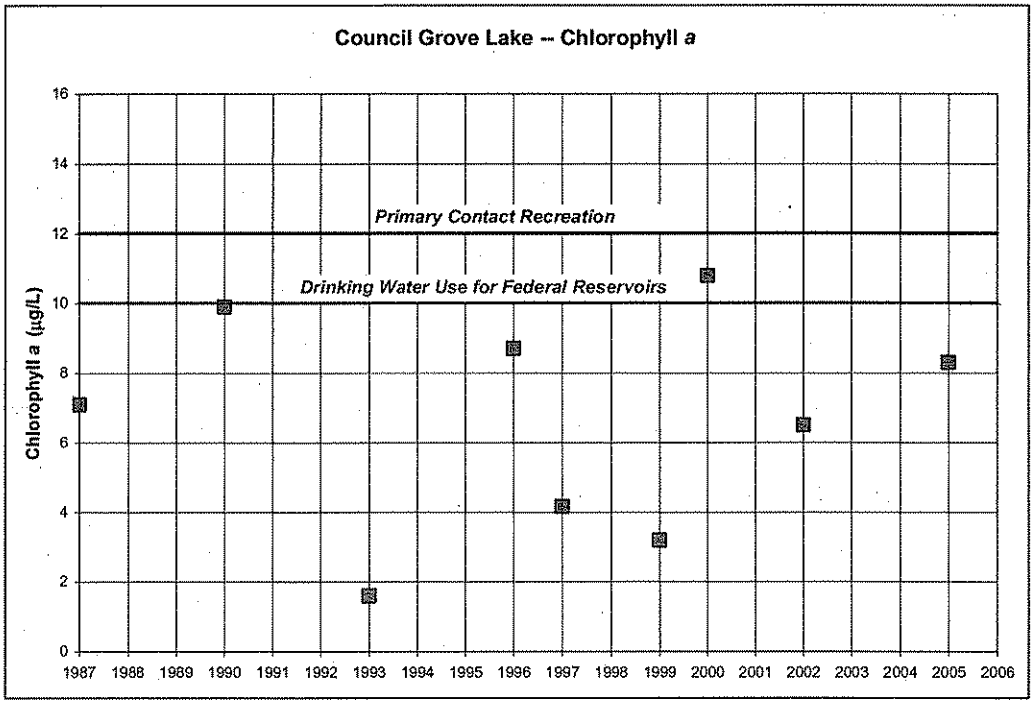

Figure 4. Chlorophyll *a* concentrations in Council Grove Lake during 1987 – 2006.

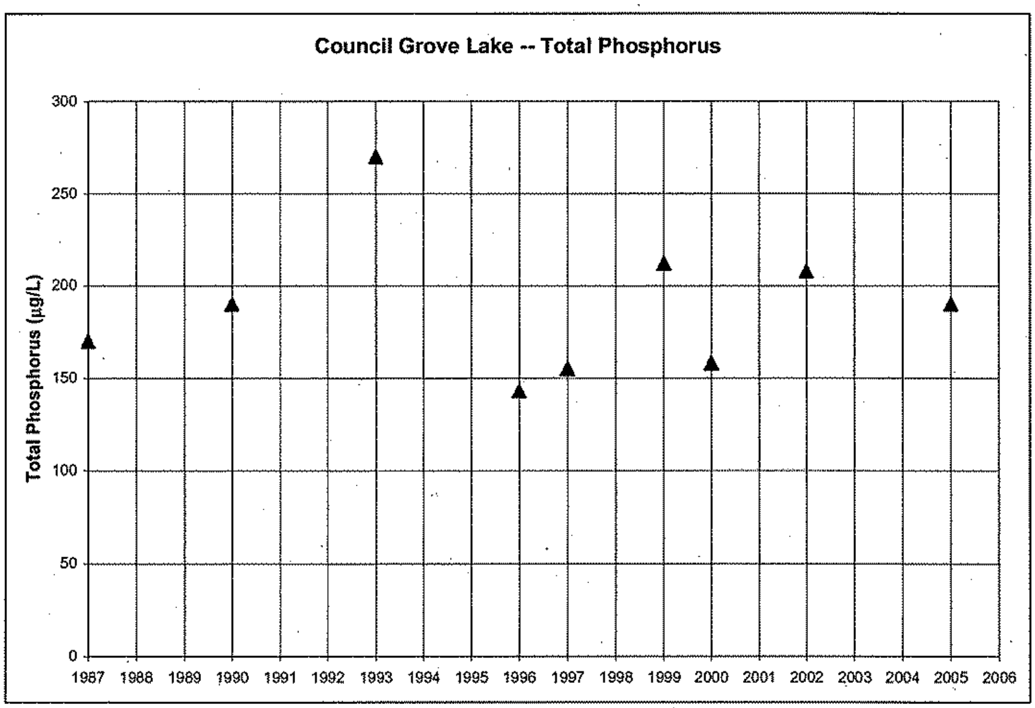

Figure 5. TP concentrations in Council Grove Lake during 1987 – 2006.

Figure 6 summarizes the current and possible future trophic conditions of Council Grove Lake using a multivariate TSI compassion chart. TSI(Chla) – TSI(TP) is plotted on the vertical axis. Points below Line TSI(Chla) – TSI(TP) = 0 indicate situations where phosphorus may not be limiting Chla whereas points above Line TSI(Chla) – TSI(TP) =0 indicate the opposite. TSI(Chla) – TSI(SD) is plotted on the horizontal axis, showing that if the Secchi depth (or SD) is greater than expected from the Chla trophic index, large particles dominate, along with zooplankton grazing. If the Secchi depth is less than expected from the Chla index, transparency is dominated by non-algal factors such as color or inorganic turbidity. Points near or on the diagonal line occur in turbid situations where phosphorus is bound to clay particles and therefore turbidity values are closely associated with phosphorus concentrations (Dip-In, 2007). The multivariate TSI plot indicates that Council Grove Lake also has ample phosphorus levels and is N-limited.

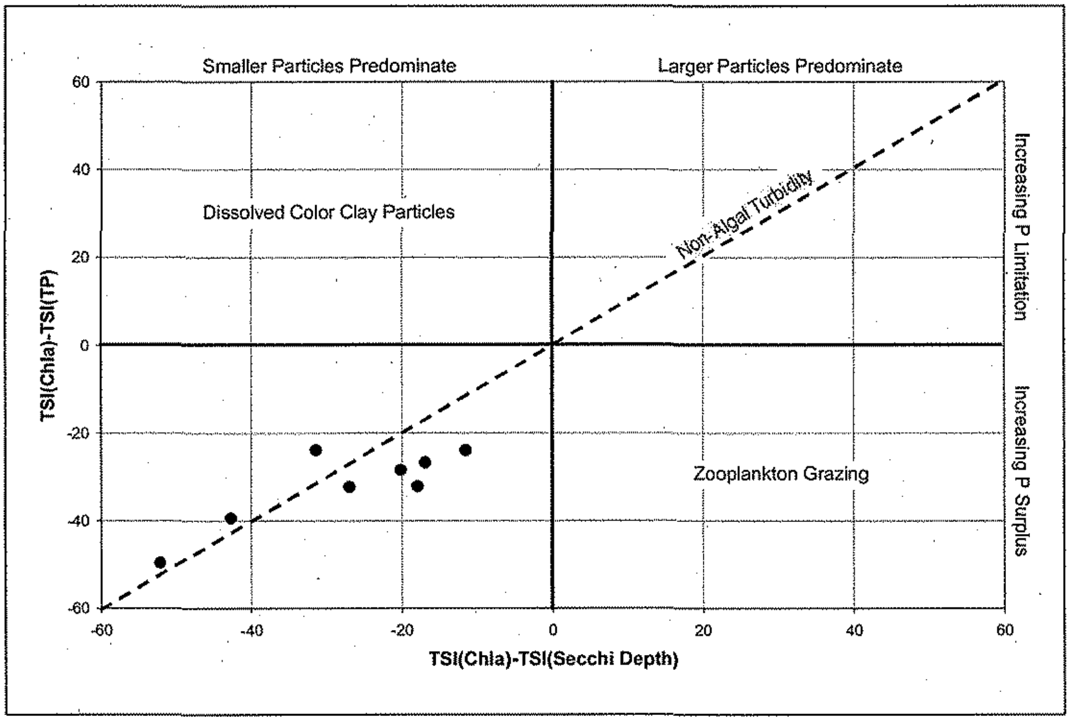

Figure 6. Multivariate TSI compassion chart of Council Grove Lake.

Changes in Chla levels are closely associated with nutrient flux from the watershed. **Figure 7** shows common water quality patterns observed in Council Grove Lake. In general, negative relationships are found between Chla and TN and TP. Council Grove Lake tends to have high Chla concentrations when TN, TP ratios and turbidity values are low. Low TN and TP concentrations tend to appear under high lake clarity (low turbidity) conditions. In addition, low Chla concentrations often appear when the total inflow of the lake is high (**Figure 8**), revealing that hydrologic regime may also play an important role in regulating Chla level.

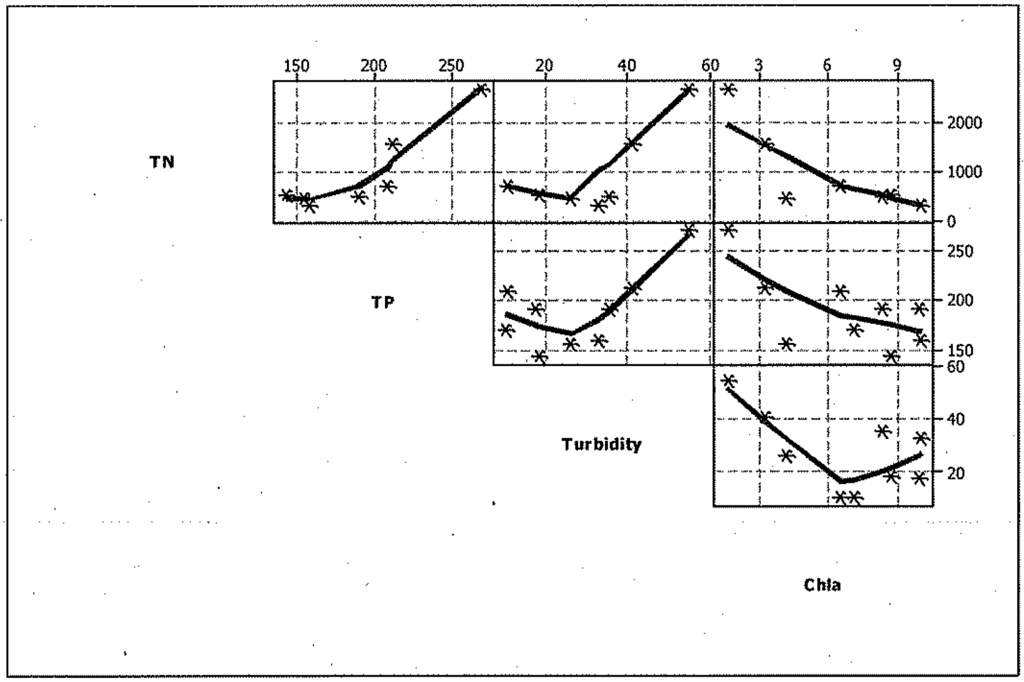

Figure 7. Common water quality patterns with lowess curves for Council Grove Lake during 1987 – 2006. Units for TN, TP, turbidity, Chla are µg/L, µg/L, NTU, and µg/L, respectively. Lowess curves are generated using localized regression analysis.

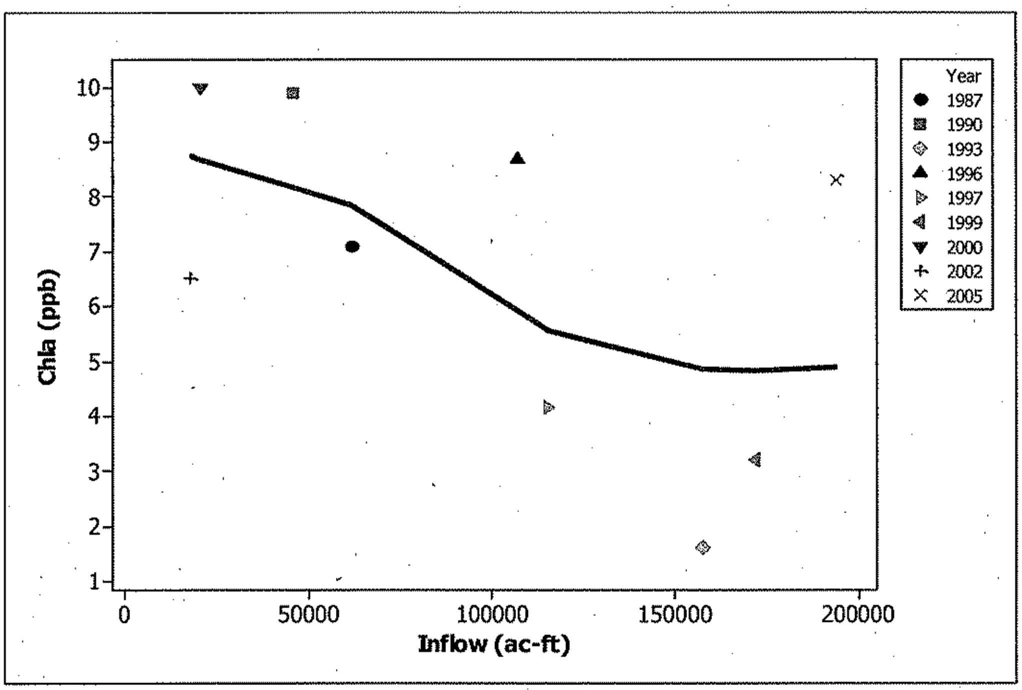

Figure 8. A scatter plot of Chla and total inflow with a lowess curve generated from localized regression analysis. Inflow values of 1987, 1990, and 1993 were estimated using USGS Gaging Station 06888500 (Mill Creek near Paxico).

Table 1 summarizes median trophic conditions of Council Grove Lake in relation to other lakes and reservoirs in the state. As indicated, Council Grove Lake's median TP values are higher than those of the federal lakes and over reference lake trophic benchmarks suggested for Kansas while median Secchi depth values are lower than the rest of the lakes and reservoirs (Dodds et al., 2006). Low Secchi depth readings measured consistently indicate Council Grove Lake is a turbid reservoir.

Table 1. Median trophic indicator values of Council Grove Lake in comparison with other federal lakes and draft lake nutrient benchmarks in Kansas. The nutrient benchmarks were derived from 47-58 lakes and reservoirs, based on the data collected between 1985 and 2002.

Trophic Indicator	Council Grove Lake	Federal Lakes	Central Great Plains	Flint Hills	Statewide Benchmark
Secchi depth (cm)	45	95	117	149	129
TN (µg/L)	675	903	695	301	625
TP (µg/L)	190	76	44	19	23
Chlorophyll *a* (µg/L)	7	12	11	5	8

Desired Endpoint for Council Grove Lake 2011 – 2016:
To improve the water quality of the lake from its current argillotrophic status to non-argillotrophic and slightly eutrophic, based on 1987 – 2005 watershed/lake modeling results, the endpoint will be to maintain the growing-season's Chla concentration below 10 µg/L by 2016. The endpoint water quality and total nutrient loads for Council Grove Lake is summarized in **Table 2**.

Table 2. Desired water quality endpoints and total nutrient loads for Council Grove Lake over 2011 – 2016. Turbidity effect indicates that phytoplankton communities are negatively affected by suspended particles.

Parameter	Current Condition	Final TMDL	Final TMDL w/o Turbidity Effect	% Reduction
TN Load (lbs/yr)	1,257,384	1,116,444	1,116,444	19
TP Load (lbs/yr)	217,436	163,536	163,536	32
TN Concentration (µg/L)	941	877	877	7
TP Concentration (µg/L)	188	151	151	20
Chlorophyll *a* (µg/L)	6.6	6	9.5	9

3. SOURCE INVENTORY AND ASSESSMENT

NPDES: Three NPDES permitted municipal wastewater treatment plants (MWTP) are located within the watershed (**Figure 9**). Dwight MWTP seldom discharges effluent into Munkers Creek while Alta Vista and White City MWTPs consistently discharge below their design flow. The construction of a three-cell lagoon, though was in the consideration to remove wastewater from the septic systems around the Council Grove City Lake by the City of Council Grove, was not proceeded because of insufficient financial support. In compliance with their NPDES permits, White City samples for biochemical oxygen demand, total suspended solids, pH, and ammonia, but nitrogen and phosphorus data are not available for either of the waste treatment plants. For typical lagoon systems in Kansas, average effluent TN and TP concentrations are 7 mg/L and 2 mg/L, respectively (written communication, Mike Tate, BOW, KDHE).

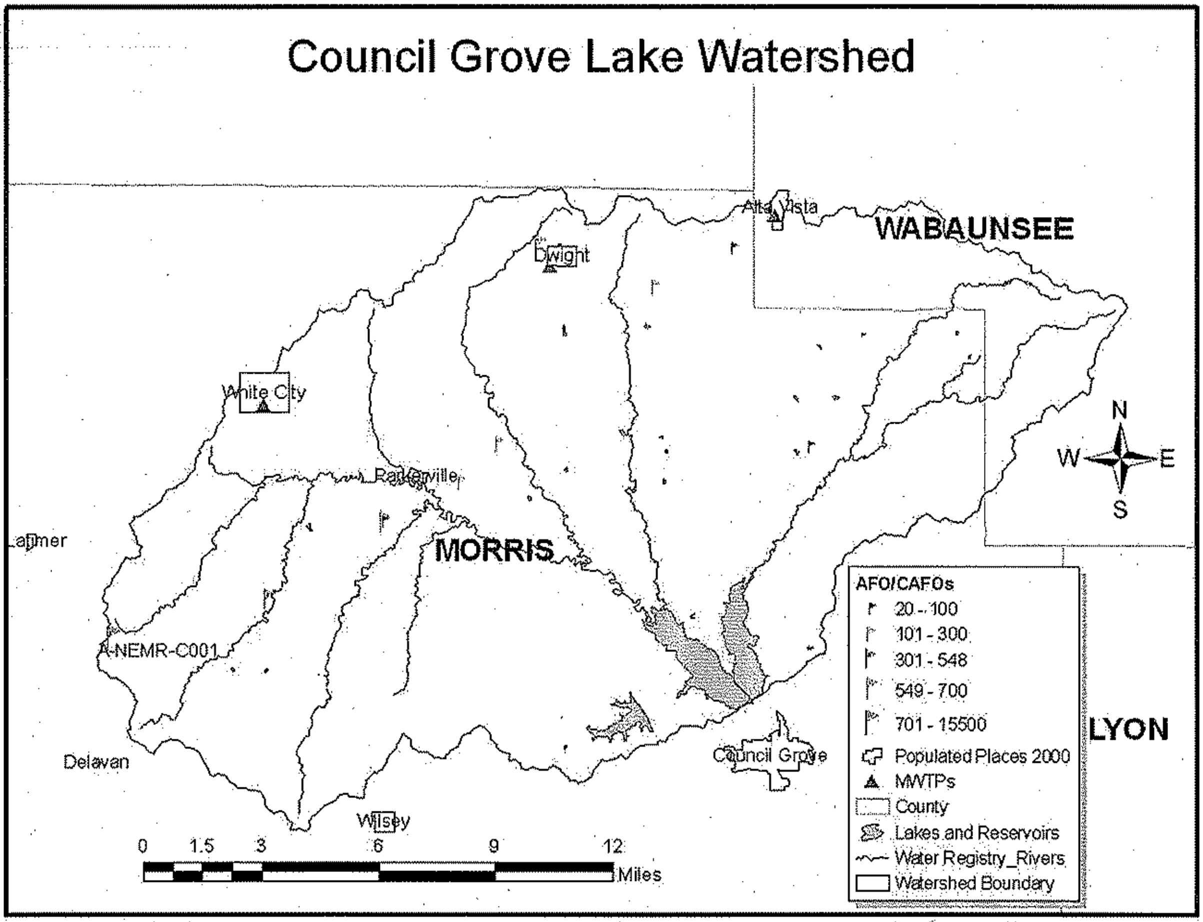

Figure 9. Location of NPDES and CAFO sites in the Council Grove Lake Watershed.

Table 3. Characteristics of NPDES permitted MWTPs located in the Council Grove Lake Watershed.

NPDES Permit	Facility Name	Type	Design Flow	Reach	Permit Expired
KS-0096733	Alta Vista MWTP	Four-Cell Lagoon	0.054 MGD	Munkers Creek	12–31–2008
KS-0051675	Dwight MWTP	Three-Cell Lagoon	0.070 MGD	Lairds Creek	12–31–2008
KS-0096873	White City MWTP	Three-Cell Lagoon	0.094 MGD	Neosho River	12–31–2008

Land Use: The most predominant land use in the Council Grove Lake Watershed is grassland (67%), according to the 2001 National Land Cover Data, of which the pasture/hay area accounts for about 11% of the total grassland area. Cultivated cropland occupies about 21% of the total area. Together, they account for 88% of the total land area in the watershed. Approximately 4% of the land is occupied by woody and deciduous forests. Urban area, such as residential, commercial and industrial uses, comprises less than 1% of the watershed (**Figure 10**).

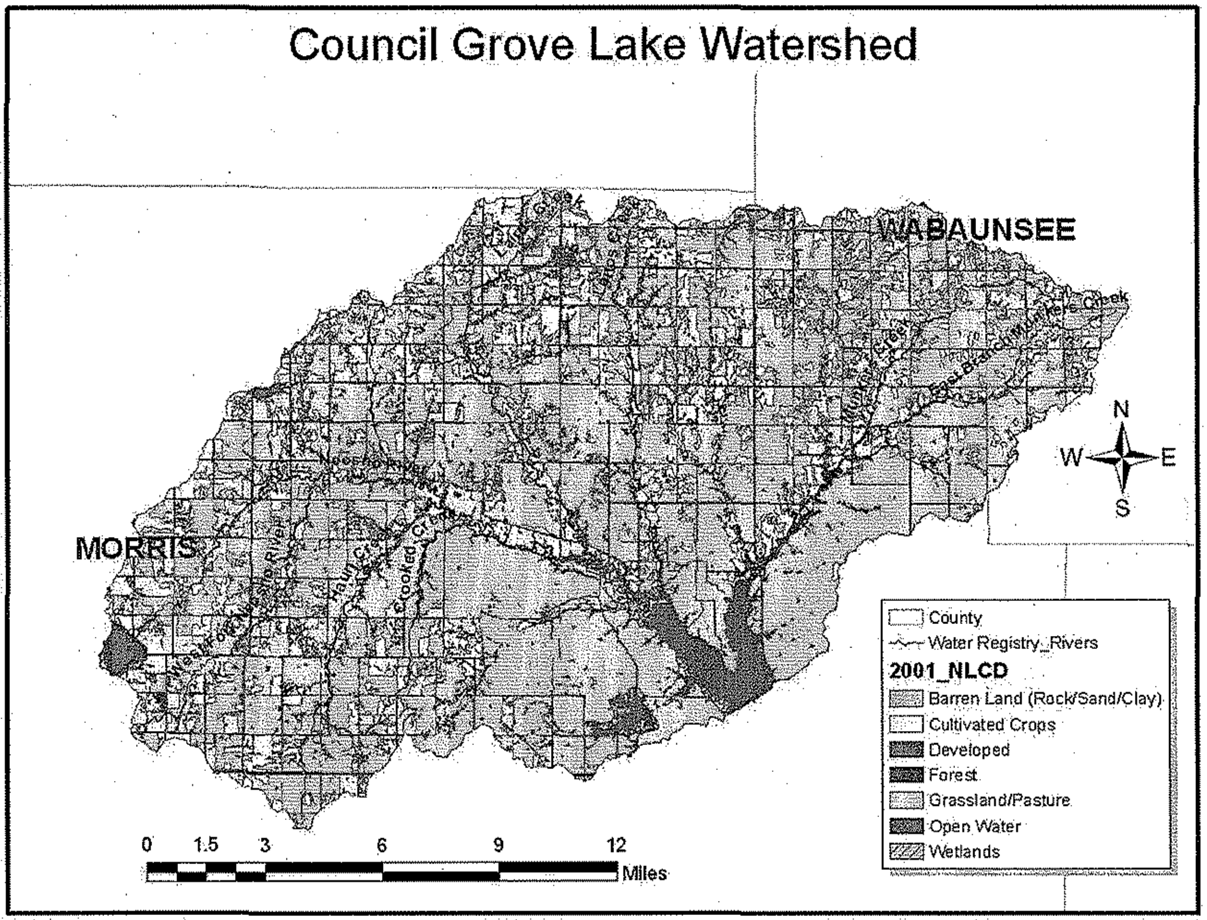

Figure 10. Land use and land cover map (2001 NLCD) of the Council Grove Lake Watershed.

Livestock Waste Management Systems: There are 10 registered confined animal feedlot operations (AFO/CAFOs) that are either certified (8) or permitted (2), which are primarily located in the central portion of the watershed (**Figure 9**). One of two permitted facilities is of sufficient size (beef, 15,500 animal units) to warrant NPDES permitting (KS0117218 or A-NEMR-C001). All the permitted and certified livestock facilities (2 dairy, 5 beef, and 3 swine) have waste management systems designed to minimize runoff entering their operation or detaining runoff emanating from their facilities. In addition, they are designed to retain a 25-year, 24-hr rainfall/runoff event as well as an anticipated two weeks of normal wastewater from their operations. Typically, this rainfall event coincides with streamflow that is less than 1-5% of the time. Though the total potential number of animals is 18,088 head in the watershed, the actual number of animals at the feedlot operations is typically less than the allowable number.

Approximately 67% of land around the lake is grassland, and the grazing density of livestock is moderate. According to the National Agricultural Statistics Service, the number of cattle surveyed for Morris and the surrounding counties are shown in **Figure 11**. On average, there are 55,247 head of cattle, ranging from 50,100 in 1992 to 62,600 in 1996.

Because of moderate grazing density of these livestock operations in the watershed, the animal waste from both confined and unconfined feeding sites is considered a major potential source of phosphorus loading going into Council Grove Lake.

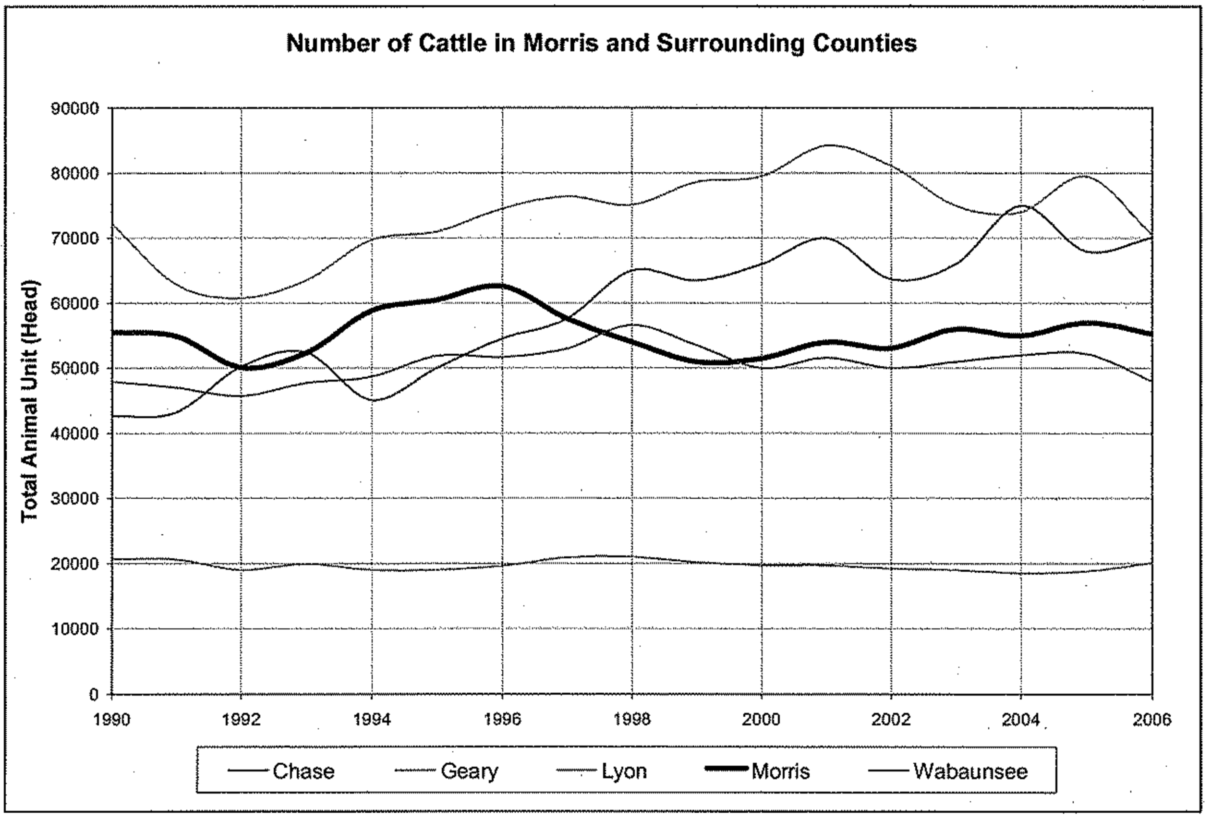

Figure 11. Cattle distribution in Morris County and surrounding counties.

On-Site Waste Systems: The population density of the watershed is 7.6 people per square mile. The estimated population changes are shown in **Table 4** for the three large cities within the watershed. Because less than one percent of the watershed is urban, stormwater runoff and urban fertilizer applications are considered a minor contributing nutrient factor. All of the urban land is located in the Neosho River/Lanos Creek subwatershed (See **Figure 10**).

Although there are many septic systems scattered around the lake, failing septic systems may be a minor source of nutrients transported to the lake. The following number of septic systems is present within the counties: Geary (1202), Morris (1589), and Wabaunsee (1424). There are 350 septic tanks in the Council Grove City Lake community and 90 full-time homes.

Table 4. Expected population change for the cities of Alta Vista, Dwight, and White City from 2000 – 2020.

City	Changes (%)
Alta Vista	8.3
Dwight	2.1
White City	8.4

Contributing Runoff: **Figure 12** shows soil permeability values across the watershed, based on NRCS STATSGO database. The watershed-wide soil permeability averages 0.29"/hr. According to an USGS open-file report (Juracek, 2000), the threshold soil-permeability values that represent very high, high, moderate, low, very low, and extremely low rainfall intensity, were set at 3.43, 2.86, 2.29, 1.71, 1.14, and 0.57"/hr, respectively. The lower rainfall intensities generally occur more frequently than the higher rainfall intensities. The higher soil-permeability thresholds imply a more intense storm during which areas with higher soil permeability potentially may contribute runoff. Runoff is chiefly generated as infiltration excess with rainfall intensities greater than soil permeabilities. As soil profiles become saturated, excess overland flow is produced.

For the Council Grove Lake Watershed, about 97% of the total area has a soil permeability value either less than or equal to 1.14"/hr. **Figure 13** displays runoff potential calculated, based on 1.14"/hr (1 = contributing areas; 0 = non-contributing areas). Under the extreme low (0.57"/hr) rainfall intensity (or runoff) condition, the potential contributing area is about 83%. Storms that produce 0.29"/hr of rain will generate runoff from 68% of the watershed area. Eighty-one percent of cultivated cropland has a soil permeability value either less than or equal to 0.29"/hr.

Background Levels: Approximately 4% of land in the watershed is forest. Nutrients released from leaf decomposition may be contributing to the nutrient loading. The atmospheric nutrient input and geological formations (i.e., soil and bedrock) may also contribute to the nutrient load. Rapid flow conditions generated due to short hydrologic residence time may cause certain sediment resuspension and thereof lead to elevation of nutrient concentrations and increases of phytoplankton production in the water column.

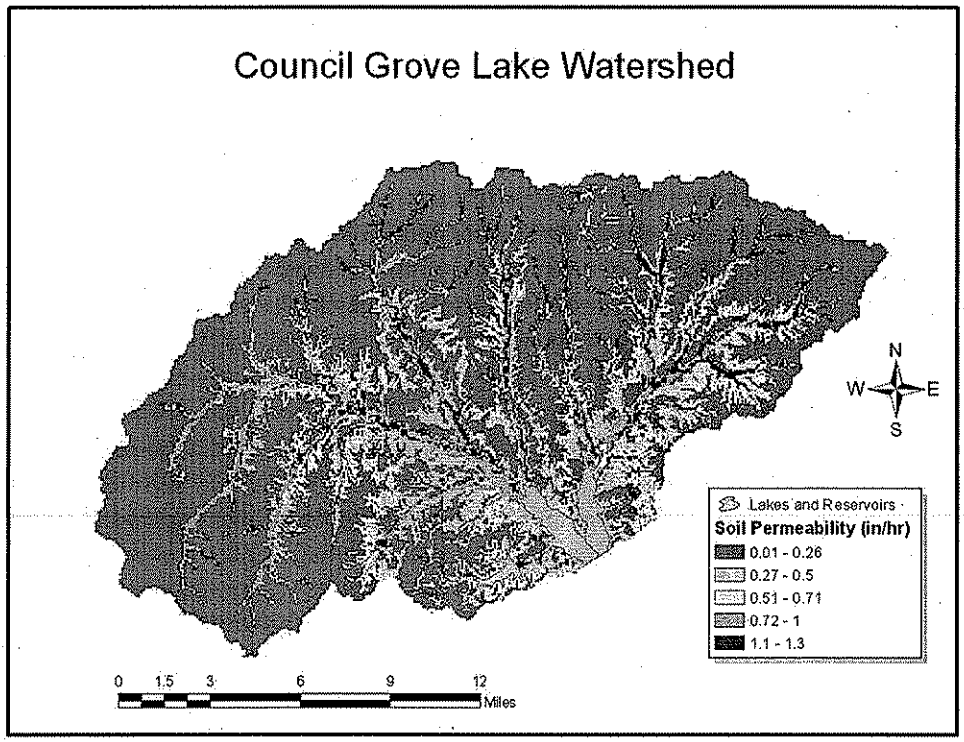

Figure 12. Soil permeability of Council Grove Lake Watershed.

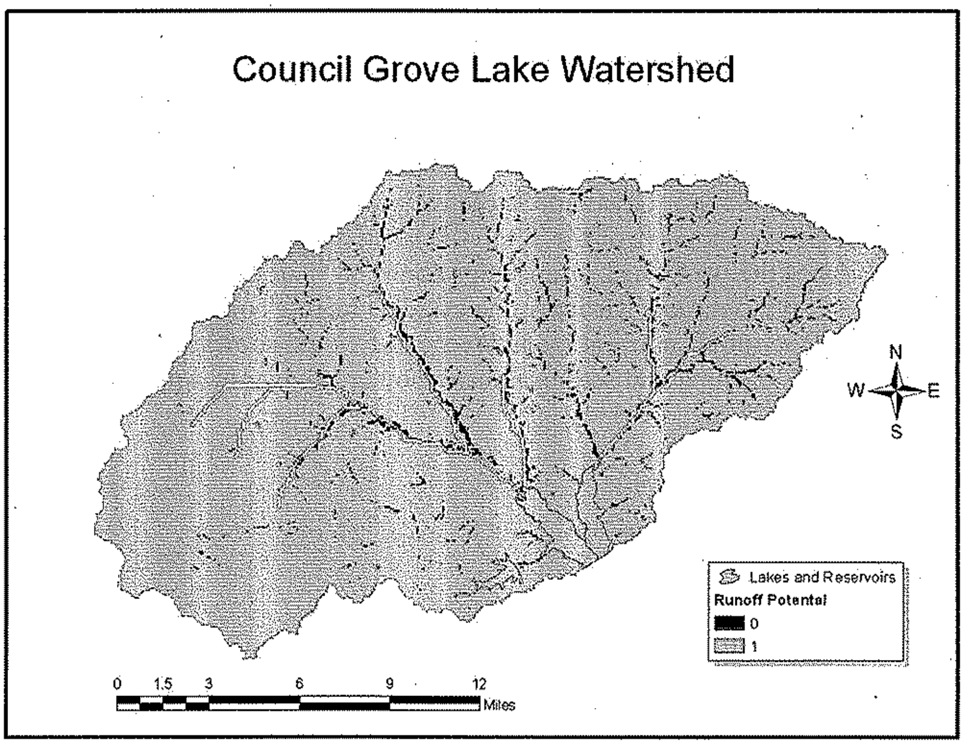

Figure 13. Runoff potential of Council Grove Lake Watershed (1 = runoff contributing areas).

4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

The watershed and lake models used for this TMDL analysis were Spreadsheet Tool for Estimating Pollutant Load (STEPL) and BATHTUB, respectively. STEPL is a simple watershed model that provides both agricultural and urban annual average sediment and nutrient simulations as well as implementation evaluation of various best management practices. This simple watershed model has been widely used in many states including EPA Region V. BATHTUB is an empirical receiving water quality model, that was developed by U.S. Army Corps of Engineers (Walker, 1996), and has been commonly applied in the nation to address many TMDLs relating to issues associated with morphometrically complex lakes and reservoirs (Mankin et al., 2003; Wang et al., 2005).

The Council Grove Lake Watershed was divided into six small subwatersheds (**Figure 14**). While the Neosho River Branch receives flow (and sediment and nutrients) from Subwatersheds 11070201010010 11070201010020, 11070201010030, and 11070201010060, the Munkers Creek Branch obtains its flow and nutrients from the other two subwatersheds (11070201010040 and 11070201010050). The 2001 National Land Cover Data (NLCD) was used in the STEPL model. Rainfall data (e.g., average and rain days) for each sub-watersheds was calculated based on the rainfall stations located within or nearby the individual subwatersheds. Septic system data (i.e., number of septic systems, population per system, and failure rate) was obtained from county health department and Twin Lake's Watershed Restoration and Protection Strategy (WRAPS) group. Though the STEPL can calculated groundwater nutrient load, this function was not used in this modeling study. Because Council Grove Lake has a large watershed-to-lake ratio value (62) and a high sedimentation rate according to the Kansas Water Office, the sediment delivery ratio that accounts for an instream process was not activated in the model. In addition, the determination of curve number and soil hydrologic group in the STEPL model were based on both land use and soil characteristics.

The results of the STEPL model simulation indicate that annual total watershed TN load to Council Grove for the current runoff condition is 594.31 tons (1,189,020 lbs) while annual TP load is 105.29 tons (210,584 lb). Grassland is the major nutrient source that contributes approximately 48% of TN and 37% of the TP to the lake (**Figure 15**). Cropland, although occupying only 21% of the watershed, contributes about 36 % of the TN and 52% of the TP to Council Grove Lake. Nutrient loads from septic systems merely contribute less than 0.1% of the total nutrient loads. The runoff nutrient loads for the individual subwatersheds are shown in **Table 5.** Detailed STEPL input and setting information are shown in **Appendix A**

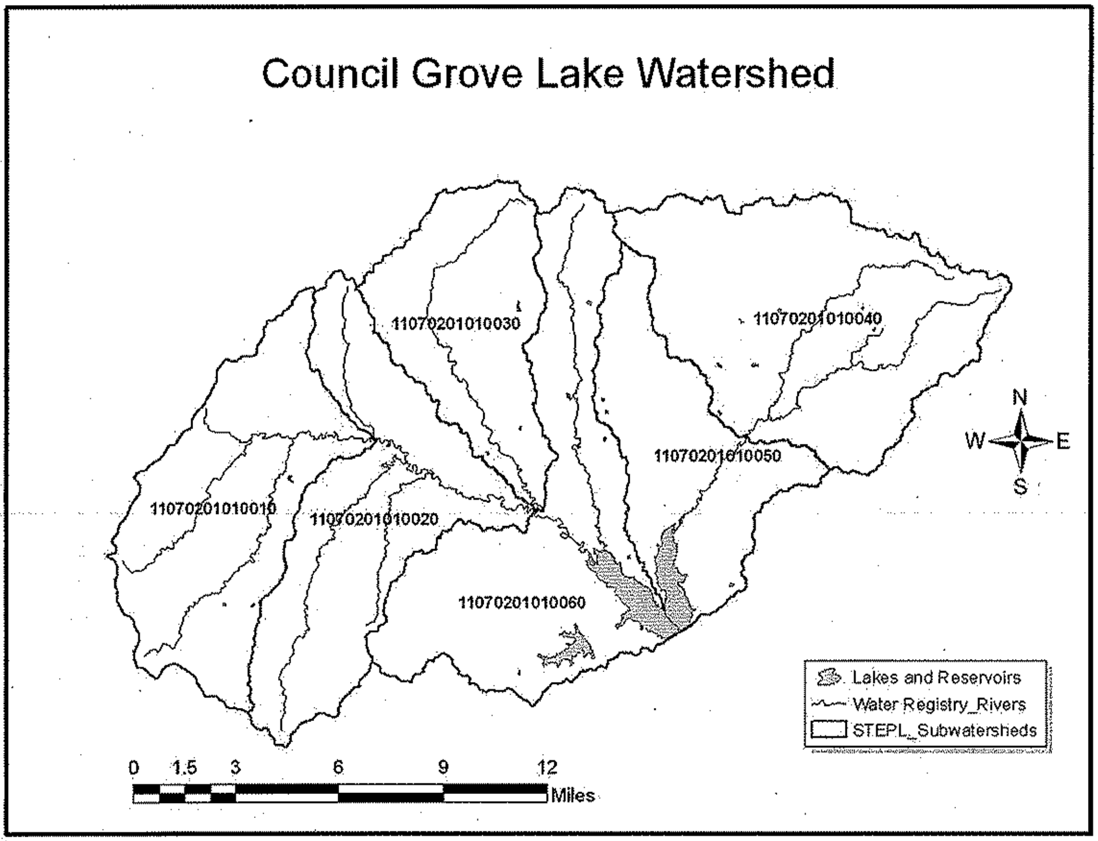

Figure 14. Subwatersheds used in STEPL modeling.

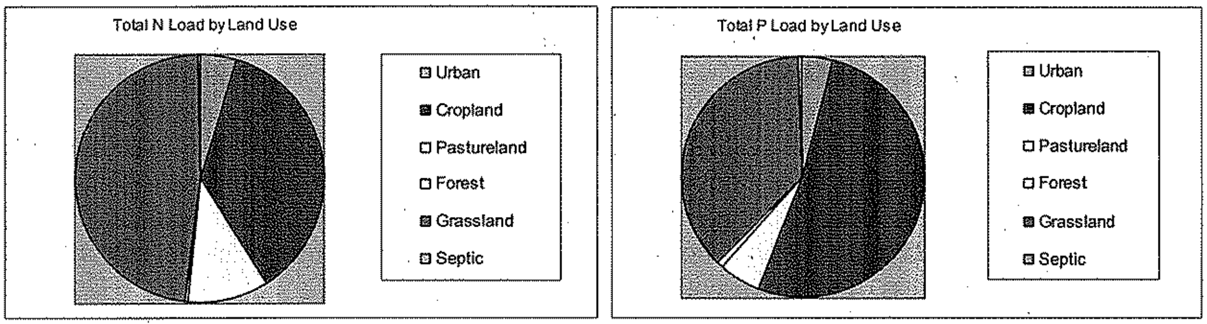

Figure 15. Runoff TN and TP loads by land use categories in STEPL modeling.

Table 5. STEPL-simulated annual average watershed and subwatershed runoff nutrient loads.

Subwatershed (HUC14)	Area (ac)	TN (ton)	TP (ton)
Basin 11070201010010	27,931	118.06	22.61
Basin 11070201010020	27,521	83.58	15.41
Basin 11070201010030	19,555	83.55	15.64
Basin 11070201010040	36,578	158.22	25.72
Basin 11070201010050	19,348	61.21	11.02
Basin 11070201010060	30,834	89.89	14.89
Total	***161,768***	***594.31***	***105.29***

Table 6 lists the ranking of the per-unit-area runoff nutrient loads for the six subwatersheds on an annual basis. According to STEPL modeling results, the top three subwatersheds that export more N loading are Basins 11070201010040, 11070201010030, and 11070201010010 whereas Basins 11070201010010, 11070201010030, and 11070201010040 are the subwatersheds contributing more TP loading. Unit nutrient loading maps are shown in **Appendix B.**

Table 6. Watershed ranking of annual runoff TN and TP loads per unit of area.

Ranking	TN (lbs/ac)	Ranking	TP (lbs/ac)
Basin 11070201010040	8.65	Basin 11070201010010	1.62
Basin 11070201010030	8.54	Basin 11070201010030	1.60
Basin 11070201010010	8.45	Basin 11070201010040	1.41
Basin 11070201010050	6.33	Basin 11070201010050	1.14
Basin 11070201010020	6.07	Basin 11070201010020	1.12
Basin 11070201010060	5.83	Basin 11070201010060	0.97

Council Grove Lake was segmented into five sections (2 riverine, 2 transitional, main basin), according to lake morphological characteristics, and then modeled using BATHTUB (**Figure 16**). Atmospheric N input data was obtained from National Atmospheric Deposition Program/National Trend Network while P deposition rate data was estimated using the 1983 study of Rast and Lee. Water quality data for the main basin segment was averaged using the 1987 – 2005 data from the KDHE and U.S. Corps of Engineers, Tulsa District Office and Kansas Biological Survey. Runoff total nutrient loading data (TN and TP) was provided from the STEPL model whereas the dissolved runoff nutrient loads were estimated based on water quality data collected at the KDHE's Monitoring stations (SC631 and SC632). Nutrient loading from the Council Grove City Lake Watershed to Council Grove Lake (Neosho Transitional Segment) was estimated based on its proportional area to the Subwatershed 11070201010060. Because the lake data is limited, annual loading estimation was therefore used to model chlorophyll and other water quality parameters, which is suggested to be more robust than the seasonal estimation (Pers. Comm., W. Walker, Jr.). The detailed BATHTUB setting and nutrient model selections as well as model's goodness of fit are provided in **Appendix C**.

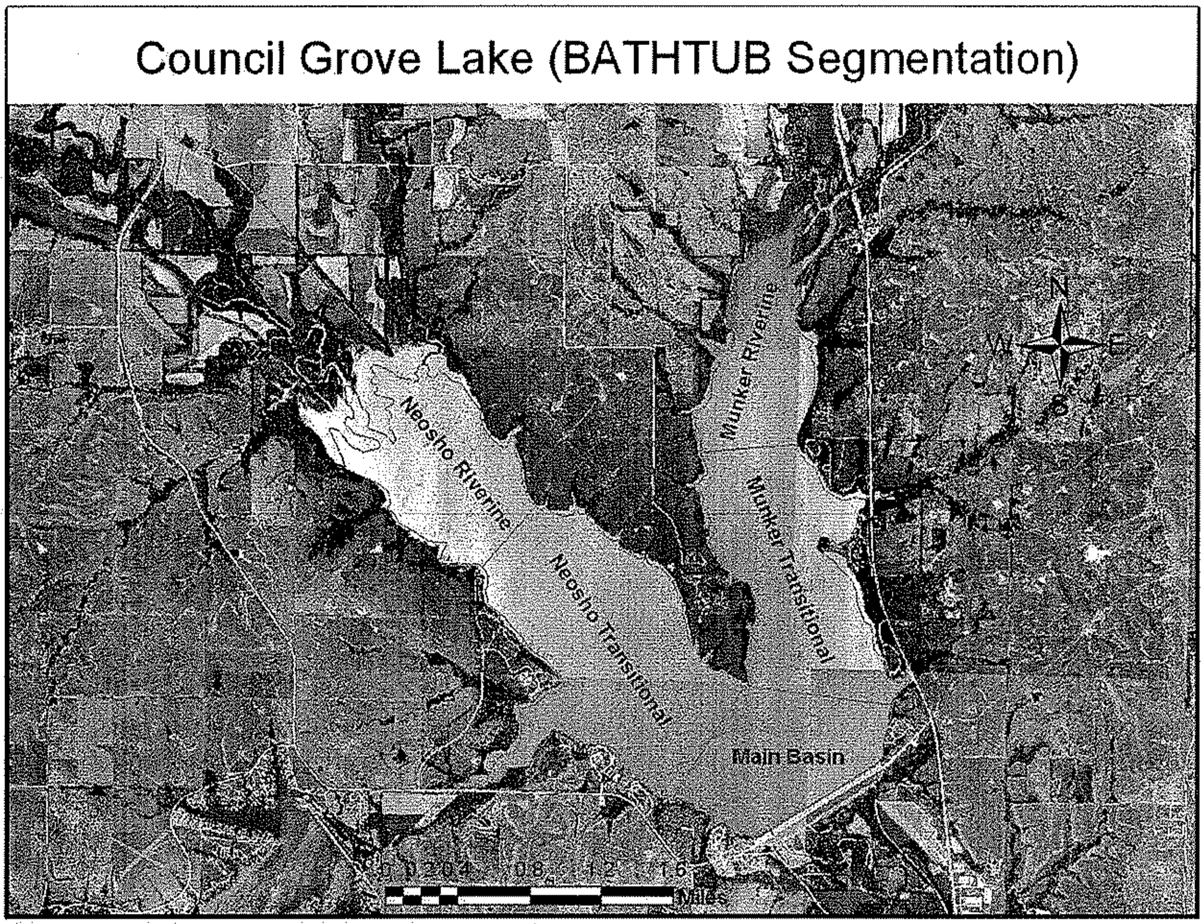

Figure 16. BATHTUB segments (riverine, transitional, and main basin areas).

Figure 17 shows the modeling results of the calibrated BATHTUB model for various watershed conditions; Current (**Figure 17a**), BMPs on All Cropland (**Figure 17b**), Tallgrass with Existing Forests (**Figure 17c**), and Tallgrass with No Turbidity Effect seen in the lake (**Figure 17d**). As expected, the current Chla concentration (6.4 μg/L) decrease as the watershed is implemented with BMPs on all cropland (6.0 μg/L) and converted to the tallgrass or prairie condition (5.3 μg/L). If turbidity effect is removed, then the Chla concentration would be elevated to 8.5 μg/L for the tallgrass/prairie condition. According to Watershed Management Section, KDHE, there is about 2% of the cropland that has been implemented with BMPs since 2001 (Written Comm., Daniel Zerr, KDHE)

BATHTUB estimated that approximately 77% of TN and 75% of TP were retained annually by the lake while 23% of TN and 25% of TP exited the reservoir through outflow, in particular seepage and groundwater. For Council Grove Lake, annual atmospheric deposition contributed about 8.52 tons and 0.12 tons of TN and TP, respectively.

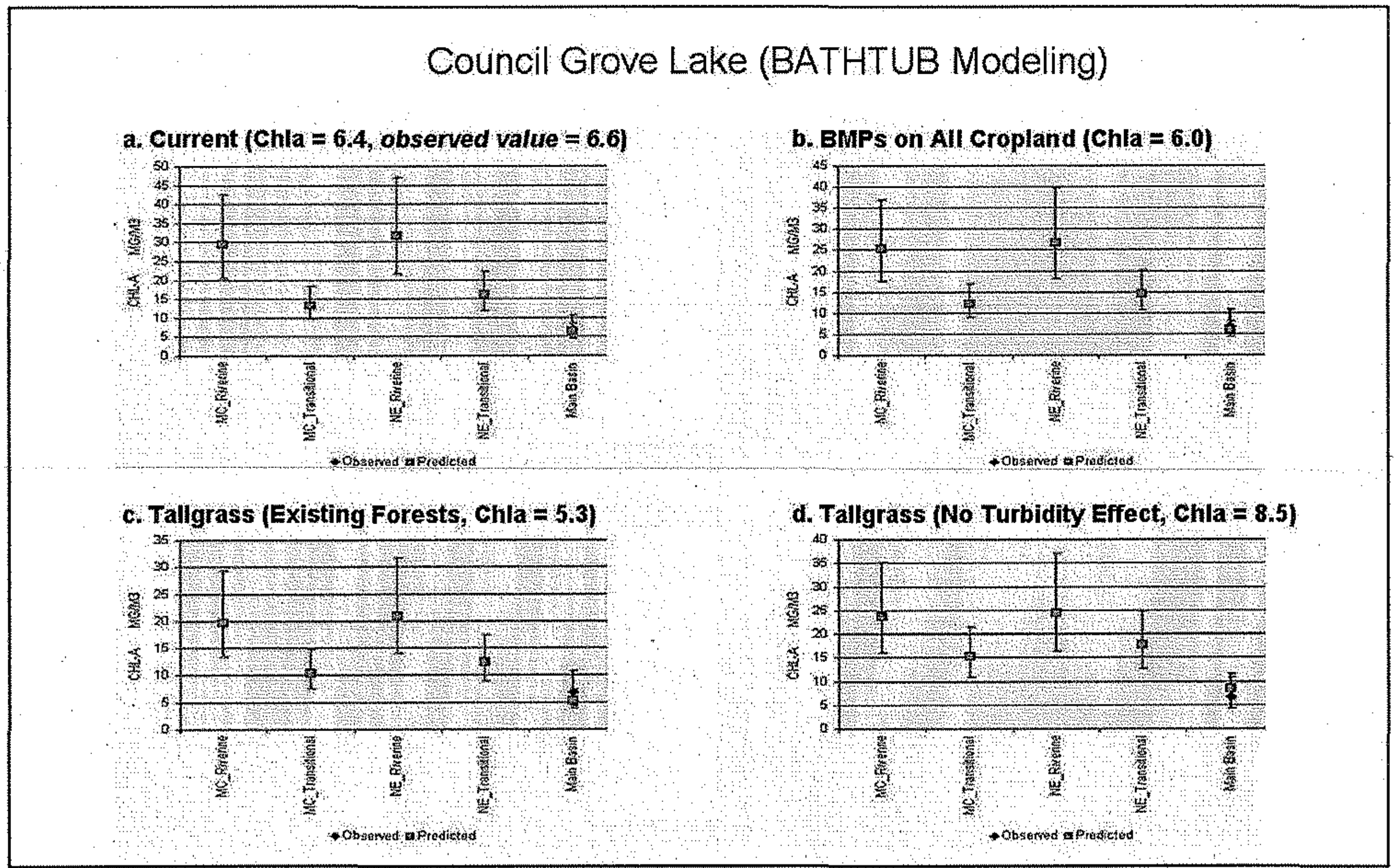

Figure 17. Error bar plots (mean ± standard deviation) of Chla, estimated by BATHTUB model, for the various watershed management conditions.

Council Grove Lake is designated as a Class A Primary Contact Recreational Lake. According to the state eutrophication TMDLs (http://www.kdheks.gov/tmdl/eutro.htm), 12 μg/L of Chla has been historically targeted for primary contact recreational lakes (i.e., swimming) whereas the 20 μg/L of Chla is implemented for secondary contact recreation lakes (i.e., fishing). The statewide goal for federal lakes and lakes serving as water supplies is a Chla endpoint of 10 μg/L. Thus, the ultimate target of an average Chla concentration of 10 μg/L should be attained.

Phytoplankton communities in Council Grove Lake are greatly controlled by the high levels of turbidity generated from short hydrologic residence times as a result of a large watershed to lake surface area ratio (62). Based on the STEPL modeling results, nearly all of the nutrient loads come from the watershed. Because the lake is in excess of TP concentrations and the cropland is identified as the most important phosphorus source, implementing BMPs for all the cropland within the watershed is highly recommended. If there is no turbidity effect (i.e., suspended particles do not affect phytoplankton communities) imposed for the lake, Chla would be 9.5 μg/L, which is just below the target level of 10 μg/L.

Therefore, a 19% of TN and a 32% of TP reduction from the cropland by BMP implementation are required for the final TMDL development. Thus, without considering atmospheric deposition to the lake, the overall watershed load to achieve 10 µg/L of Chla will be 498.95 tons/yr (997,910 lbs/yr) for TN and 74.22 tons/yr (148,436 lbs/yr) for TP. For this TMDL development, baseflow is calculated from the lake's total inflow using Web-based Hydrograph Analysis Tool (Purdue University, 2008) while its associated nutrient concentrations were derived from the KDHE monitoring stations. With the consideration of the wet (or rainfall) deposition, the current total nutrient loading to Council Grove Lake and TMDL's targets are summarized in **Table 2**.

Point Sources: The Waste Load Allocation is associated with the Waste Treatment Plants. Ongoing inspections and monitoring of these NPDES sites will be made to ascertain the contributions that have been made by the source. These Waste Treatment Plants should comply with any future permit conditions. The Wasteload Allocation should be at 2,112 kg (4,647 lbs) of TN and 604 kg (1,328 lbs) of TP per year, based on expected average nutrient concentrations in wastewater lagoon effluent (7 mg/L of TN and 2 mg/L of TP). Wasteload allocations for these facilities are listed in **Appendix D**.

Nonpoint Sources: Degraded water quality is closely associated with excess nutrient loading that comes predominantly from nonpoint pollution sources. The source assessment suggests that cropland and grassland contribute to elevated Chla concentrations seen in the lake. To manage Chla levels to the desirable endpoint, a 19% of TN reduction, along with a 32% reduction of TP, from the watershed is necessary. Annual atmospheric deposition was 8.52 ton/yr (17,039 lbs/yr) for TN and 0.12 tons/yr (233 lb/yr) for TP. The estimated watershed nonpoint source (NPS) load, based on BATHTUB, to achieve 10 µg/L of Chla are 496.63 tons/yr (993,263 lbs/yr) for TN and 73.55 tons/yr (147,108 lbs/yr) for TP. Therefore, Load Allocations for Council Grove Lake are set to 505.15 tons (1,010,302 lbs) of TN and 73.67 tons (147,341 lbs) of TP per year. Daily loads of TN and TP, required by EPA Region VII, are calculated in **Appendix E** (USEPA, 1991).

Defined Margin of Safety: The margin of safety is explicit and provides some hedge against the uncertainty of annual allocated nutrient loads in reaching the chlorophyll *a* endpoint. Therefore, the margin of safety, 10% of the total nutrient loads from the watershed, will be 101,495 lbs of TN and 14,867 lbs per year of TP for the final TMDL goals.

Table 9. TMDL Waste Load and Load Allocations for the Council Grove Lake Watershed.

	WLA	LA	MOS	TMDL
TN (lbs/yr)	4,647	1,010,302	101,495	1,116,444
TP (lbs/yr)	1,328	147,341	14,867	163,536

State Water Plan Implementation Priority: Because Council Grove Lake is a federal reservoir, with a relatively small lake surface area, and a large regional benefit for recreation and state invested water supply, this TMDL will be a High Priority for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Neosho Headwaters (HUC 8: 11070201) with a priority ranking of 38 (Medium Priority for restoration).

Priority HUC 14s: Best management practice implementation should concentrate on the watersheds of 11070201010010 (Upper Neosho River Subwatershed), 11070201010030 (Lairds Creek Subwatershed), and 11070201010040 (Upper Munkers Creek Subwatershed).

5. IMPLEMENTATION

Desired Implementation Activities

There is a good potential that agricultural best management practices will improve the water quality in Council Grove Lake. Some of the recommended agricultural practices are as follows:

1. Perform soil tests and apply nutrient best management practices to reduce nutrient additions to the lake from excess fertilization,
2. Maintain conservation tillage and contour farming to minimize cropland erosion,
3. Promote and adopt continuous no-till cultivation to increase the amount of water infiltration and minimize cropland soil erosion and nutrient transports,
4. Install grass buffer strips along streams,
5. Reduce activities within riparian areas,
6. Reduce both confined and non-confined animal feeding operation sites,
7. Evaluate a lake application of chelating agents to bond phosphorus to sediments,
8. Construct ponds/detention basins, erosion control structures and/or wetlands to reduce soil erosion and to trap sediment and lower peak runoff rates.

Implementation Programs Guidance

NPDES-KDHE

a. Evaluate nutrient loading from all permitted dischargers in the watershed,
b. Work with dischargers to reducing individual loadings.

Nonpoint Source Pollution Technical Assistance - KDHE

a. Support Section 319 demonstration projects for reduction of sediment runoff from agricultural activities as well as nutrient management,
b. Provide technical assistance on practices geared to establishment of vegetative buffer strips,
c. Provide technical assistance on nutrient management in vicinity of streams,
d. Support Watershed Restoration and Protection Strategy (WRAPS) efforts for Council Grove Lake,
e. Incorporate the provisions of this TMDL into any Twin Lakes WRAPS documents.

Water Resource Cost Share Nonpoint Source Pollution Control Program - SCC

a. Apply conservation farming practices, including terraces and waterways, sediment control basins, and constructed wetlands,
b. Provide sediment control practices to minimize erosion and sediment and nutrient transport.

Riparian Protection Program - SCC

a. Establish or re-establish natural riparian systems, including vegetative filter strips and streambank vegetation,
b. Develop riparian restoration projects,
c. Promote wetland construction to assimilate nutrient loadings.

Buffer Initiative Program - SCC

a. Install grass buffer strips near streams,
b. Leverage Conservation Reserve Enhancement Program to hold riparian land out of production.

Extension Outreach and Technical Assistance - Kansas State University

a. Educate agricultural producers on sediment, nutrient, and pasture management,
b. Educate livestock producers on livestock waste management and manure applications and nutrient management planning,
c. Provide technical assistance on livestock waste management systems and nutrient management plans,
d. Provide technical assistance on buffer strip design and minimizing cropland runoff,
e. Encourage annual soil testing to determine capacity of field to hold nutrients.
f. Support outreach efforts by Twin Lakes WRAPS.

Time Frame for Implementation: Pollutant reduction practices should be installed within the priority subwatersheds before 2012, with follow-up implementation, including other subwatersheds over 2012 – 2016. Achievement of the 10 µg/L of Chla goal is set for 2016.

Targeted Participants: Primary participants for implementation will be agricultural producers within the drainage of the lake. Initial work before 2011 should include local assessments by conservation district personnel and county extension agents to locate within the lake drainage:

1. Total row crop acreage and fertilizer application rate,
2. Cultivation alongside lake,
3. Drainage alongside or through animal feeding lots,
4. Livestock use of riparian areas,
5. Fields with manure applications.

Milestone for 2012: The year 2012 marks the midpoint of the ten-year implementation window for the watershed. At that point in time, sampled data from Council Grove Lake should indicate evidence of reduced phosphorus levels in the conservation pool elevations relative to the conditions seen over 1987-2004.

Delivery Agents: The primary delivery agents for program participation will be conservation districts for programs of the State Conservation Commission and the Natural Resources Conservation Service. Producer outreach and awareness will be delivered by Kansas State Extension and Twin Lakes WRAPS. Implementation decisions and scheduling will be guided by planning documents prepared through Twin Lakes WRAPS.

Reasonable Assurances:

Authorities: The following authorities may be used to direct activities in the watershed to reduce pollution.

1. K.S.A. 65-164 and 165 empowers the Secretary of KDHE to regulate the discharge of sewage into the waters of the state.

2. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

3. K.A.R. 28-16-69 to -71 implements water quality protection by KDHE through the establishment and administration of critical water quality management areas on a watershed basis.

4. K.S.A. 2-1915 empowers the State Conservation Commission to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.

5. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control non-point source pollution.

6. K.S.A. 82a-901, *et seq*. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.

7. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan*.

8. The *Kansas Water Plan* and the Neosho River Basin Plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

9. K.S.A. 32-807 authorizes Kansas Department of Wildlife and Parks to manage lake resources.

Funding: The State Water Plan Fund annually generates $16-18 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the *Kansas Water Plan*. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watersheds and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection through the WRAPS program. This watershed and its TMDL are a High Priority consideration.

Effectiveness: Nutrient control has been proven effective through conservation tillage, contour farming and use of grass waterways and buffer strips. The key to success will be widespread utilization of conservation farming within the watersheds cited in this TMDL.

6. MONITORING

Future lake sampling should occur at least 3 times between 2008 and 2015. Monitoring of tributary levels of nutrients during runoff events will help direct abatement efforts toward major contributors. Additionally, tracking of nutrient loads from the existing municipal lagoons should be done to confirm their small contribution to the lake.

7. FEEDBACK

Public Meetings: Public meetings to discuss TMDLs in the Neosho Basin were held on December 8, 2006 in Columbus, September 27, 2007 in Schermerhorn Nature Center (Galena), February 28 in Burlington at the Coffey County Courthouse and May 15, 2008 in Emporia City Library. An active Internet Web site was established at http://www.kdhe.state.ks.us/tmdl/ to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Neosho Basin.

Public Hearing: Public Hearings on the TMDL of the Neosho Basin were held in Burlington at the Coffey County Courthouse on July 24, 2008.

Discussion with Interest Groups: The staff of Watershed Management Section of KDHE was briefed on the implications of this TMDL on January 31, 2008, and Twin Lakes Fact Sheet that summarized the TMDL was sent to Watershed Management Section and Twin Lakes WRAPS on June 18, 2008.

Basin Advisory Committee: The Neosho Basin Advisory Committee met to discuss the TMDLs in the basin on September 27, 2007 in Schermerhorn Nature Center (Galena), February 28 in Burlington at the Coffey County Courthouse and May 15, 2008 in Emporia City Library.

Milestone Evaluation: In 2012, evaluation will be made as to the degree of implementation which has occurred within the watershed and current condition of Council Grove Lake. Subsequent decisions will be made through the Council Grove Lake WRAPS, regarding the implementation approach and follow up of additional implementation in the watershed.

Consideration for 303(d) Delisting: The lake will be evaluated for delisting under Section 303(d), based on the monitoring data over the period 2008 – 2015. Therefore, the decision for delisting will come about in the preparation of the 2016 303(d) list. Should modifications be made to the applicable water quality criteria during the ten-year implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities may be adjusted accordingly.

Incorporation into Continuing Planning Process, Water Quality Management Plan and the Kansas Water Planning Process: Under the current version of the Continuing Planning Process (CPP), the next anticipated revision will come in 2008 which will emphasize implementation of WRAPS activities. At that time, incorporation of this TMDL will be made into the WRAPS. Recommendations of this TMDL will be considered in *Kansas Water Plan* implementation decisions under the State Water Planning Process after Fiscal Years 2008 – 2015.

Developed, April 6, 2009

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Appendix A. STEPL Input and Setting

1. Input watershed land use area (ac) and precipitation (in)

Watershed	Urban	Cropland	Pastureland	Forest	User Defined	Feedlots	Feedlot Percent Paved	Total	Annual Rainfall (Rain correction factors 0.887)	Rain Days (0.423)	Avg. Rain/Event
11070201010010	1731.6	9152.9	1057.9	916.1	15073.0	0	0-24%	27931.45811	34	81.9	0.871
11070201010020	936.9	5248.4	1068.8	1572.2	18694.8	0	0-24%	27521.13962	34	81.9	0.871
11070201010030	858.0	5669.4	1593.1	1042.8	10391.4	0	0-24%	19554.73389	34.5	81.9	0.883
11070201010040	1584.8	7624.7	5703.2	1048.1	20617.4	0	0-24%	36578.16966	35.5	81.5	0.913
11070201010050	659.6	3077.2	1066.8	1023.6	13520.6	0	0-24%	19347.90689	35	81.9	0.896
11070201010060	1202.9	3467.8	1717.3	1646.1	22798.2	0	0-24%	30834.42792	34.75	81.9	0.890

User defined = grassland plus shrubland used in 2001 NLCD.

2. Input agricultural animals

Watershed	Beef Cattle	Dairy Cattle	Swine (Hog)	Sheep	Horse	Chicken	Turkey	Duck	# of months manure applied
11070201010010	1685	17	0	20	41	23	0	0	3
11070201010020	1675	17	0	20	41	23	0	0	3
11070201010030	1185	12	0	14	29	17	0	0	3
11070201010040	2464	23	0	14	58	35	0	0	3
11070201010050	1240	12	0	15	30	17	0	0	3
11070201010060	2006	20	0	23	49	28	0	0	3

3. Input septic system and illegal direct wastewater discharge data

Watershed	No. of Septic Systems	Population per Septic System	Septic Failure Rate, %	Wastewater Direct Discharge, # of People	Direct Discharge Reduction, %
11070201010010	83	1.97	20	0	0
11070201010020	83	1.97	20	0	0
11070201010030	83	1.97	20	0	0
11070201010040	110	2.1	20	0	0
11070201010050	83	1.97	20	0	0
11070201010060	83	1.97	20	0	0

4. Modify the Universal Soil Loss Equation (USLE) parameters

Watershed	Cropland					Pastureland					Forest	
	R	K	LS	C	P	R	K	LS	C	P	R	K
11070201010010	200.000	0.335	0.266	0.200	0.934	200.000	0.330	0.266	0.050	1.000	200.000	
11070201010020	200.000	0.335	0.268	0.200	0.934	200.000	0.330	0.268	0.050	1.000	200.000	
11070201010030	200.000	0.335	0.266	0.200	0.934	200.000	0.330	0.266	0.050	1.000	200.000	
11070201010040	200.000	0.335	0.298	0.200	0.959	200.000	0.350	0.227	0.030	1.000	200.000	
11070201010050	200.000	0.335	0.266	0.200	0.934	200.000	0.330	0.266	0.050	1.000	200.000	
11070201010060	200.000	0.335	0.266	0.200	0.934	200.000	0.330	0.266	0.050	1.000	200.000	

5. Select average soil hydrologic group (SHG), SHG A = highest infiltration and SHG D = lowest infiltration

Watershed	SHG A	SHG B	SHG C	SHG D	SHG Selected	Soil N conc.%	Soil P conc.%	Soil BOD conc.%
11070201010010	○	○	○	◉	D	0.145	0.064	0.290
11070201010020	○	○	◉	○	C	0.145	0.064	0.290
11070201010030	○	○	○	◉	D	0.145	0.064	0.290
11070201010040	○	○	○	◉	D	0.145	0.064	0.290
11070201010050	○	○	◉	○	C	0.145	0.064	0.290
11070201010060	○	○	◉	○	C	0.145	0.064	0.290

6. Reference runoff curve number (may be modified)

SHG	A	B	C	D
Urban	83	89	92	93
Cropland	67	78	85	89
Pastureland	49	69	79	84
Forest	39	60	73	79
User Defined	40	64	75	81

6a. Detailed urban reference runoff curve number (may be modified)

Urban\SHG	A	B	C	D
Commercial	89	92	94	95
Industrial	81	88	91	93
Institutional	81	88	91	93
Transportatior	98	98	98	98
Multi-Family	77	85	90	92
Single-Family	57	72	81	86
Urban-Cultivat	67	78	85	89
Vacant-Devel	77	85	90	92
Open Space	49	69	79	84

7. Nutrient concentration in runoff (mg/l)

Land use	N	P	BOD
1. L-Cropland	**1.9**	**0.3**	**4**
1a. w/ manure	8.1	2	12.3
2. M-Cropland	**2.9**	**0.4**	**6.1**
2a. w/ manure	12.2	3	18.5
3. H-Cropland	**4.4**	**0.5**	**9.2**
3a. w/ manure	18.3	4	24.6
4. Pastureland	**4**	**0.3**	**13**
5. Forest	**0.2**	**0.1**	**0.5**
6. User Defined	2.3	0.15	6.7

8. Input or modify urban land use distribution

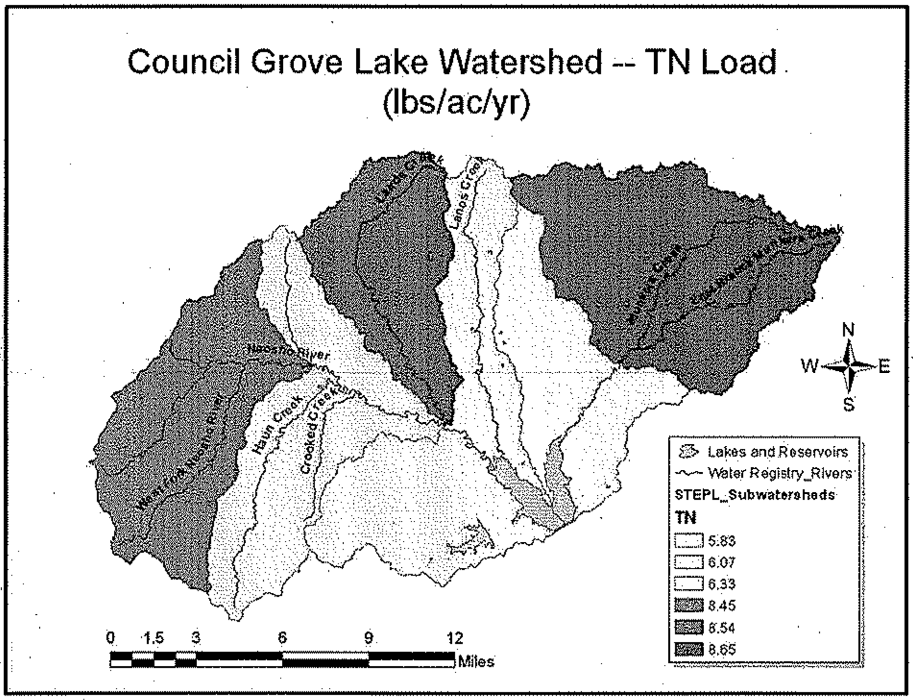
Watershed	Urban Area (ac.)	Commercial %	Industrial %	Institutional %	Transportation %	Multi-Family %	Single-Family %	Urban-Cultivated	Vacant (developed)	Open Space %	Total % Area
11070201010010	1731.56626	15	10	10	10	10	30	5	5	5	100
11070201010020	936.9494801	15	10	10	10	10	30	5	5	5	100
11070201010030	857.9993103	15	10	10	10	10	30	5	5	5	100
11070201010040	1584.785662	15	10	10	10	10	30	5	5	5	100
11070201010050	659.6231089	15	10	10	10	10	30	5	5	5	100
11070201010060	1202.933714	15	10	10	10	10	30	5	5	5	100

9. Input irrigation area (ac) and irrigation amount (in)

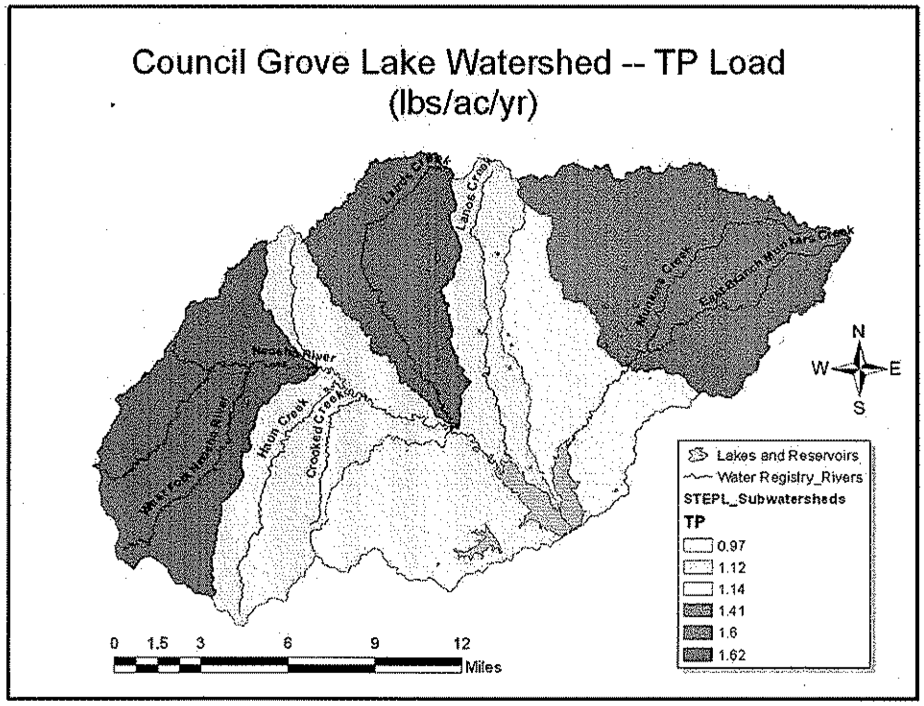
Watershed	Total Cropland (ac)	Cropland: Acres Irrigated	Water Depth (in) per Irrigation - Before BMP	Water Depth (in) per Irrigation - After BMP	Irrigation Frequency (#/Year)
11070201010010	9152.925193	0	0	0	0
11070201010020	5248.436028	0	0	0	0
11070201010030	5669.436962	0	0	0	0
11070201010040	7624.714064	0	0	0	0
11070201010050	3077.205226	0	0	0	0
11070201010060	3467.768942	0	0	0	0

Appendix B. Unit Nutrient Loading Maps

Total Nitrogen Load (lbs/ac/yr).

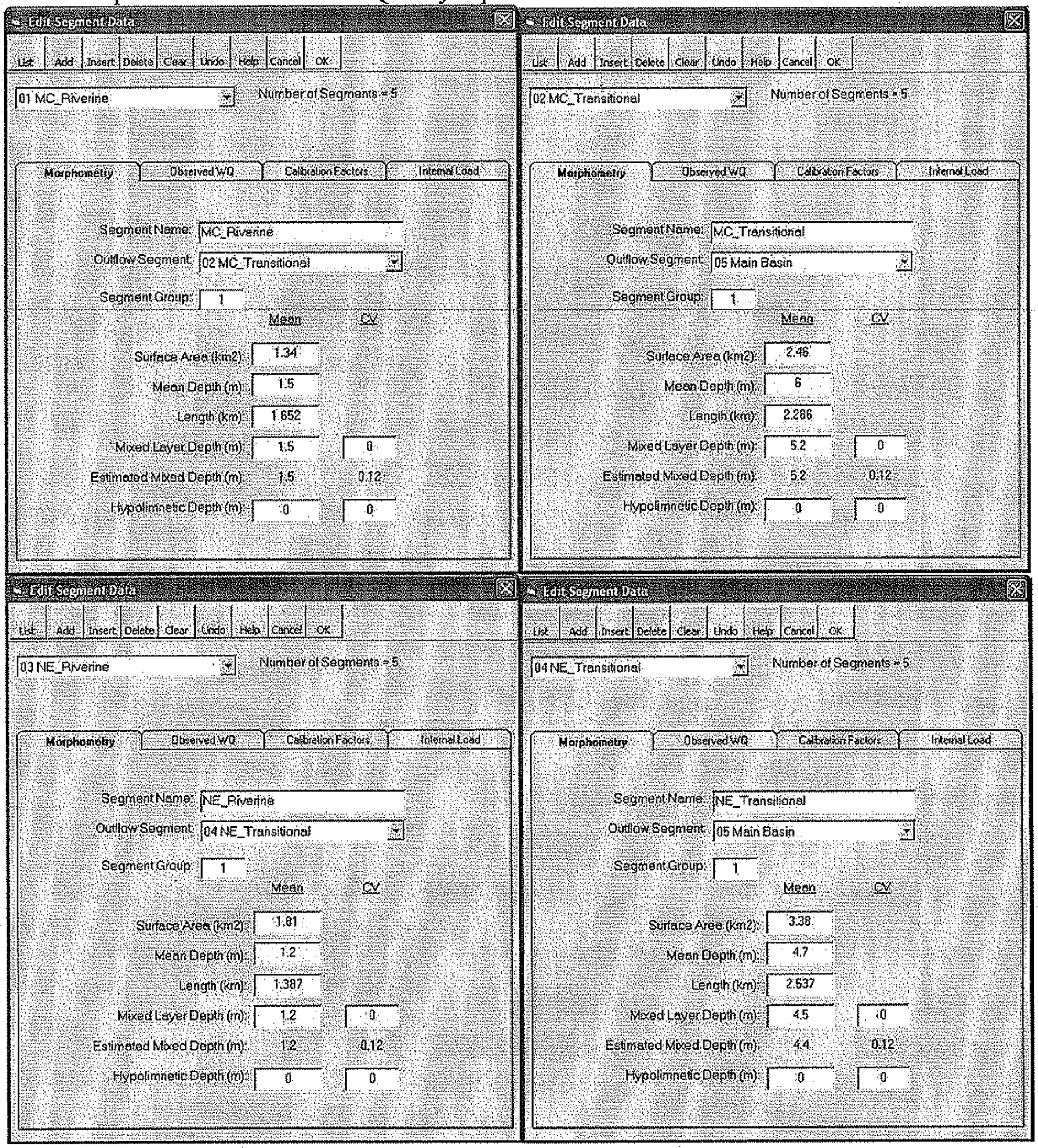


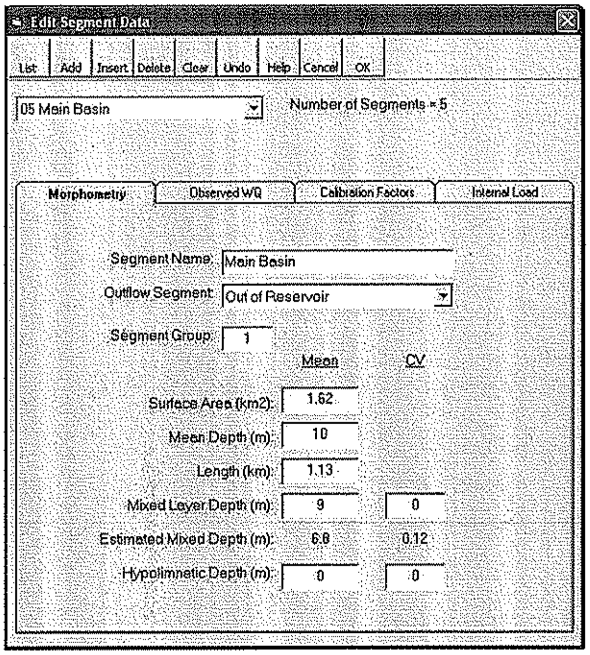
Total Phosphorus Load (lbs/ac/yr).



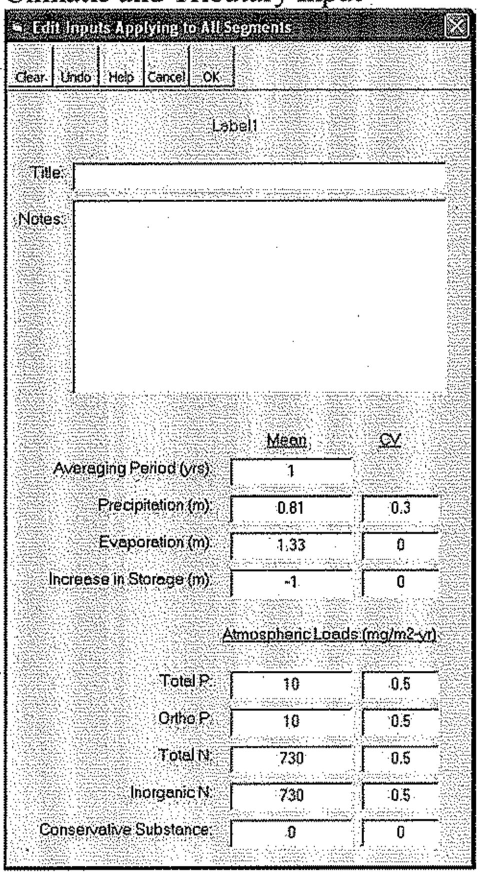
Appendix C. BATHTUB Input and Output Files

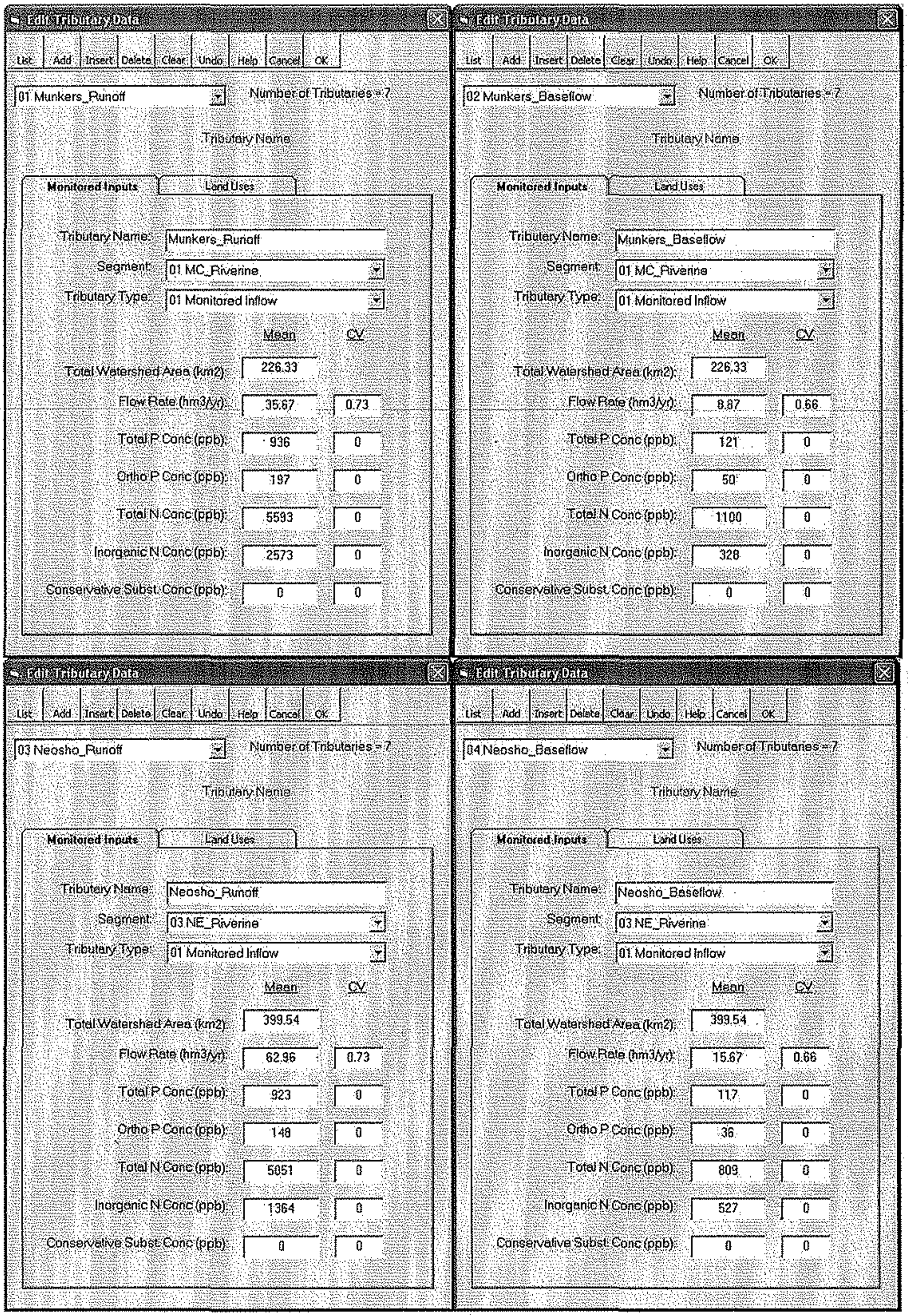
Lake Morphometrical and Water Quality Input





Climatic and Tributary Input

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List Add Insert Delete Clear Undo Help Cancel OK
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Tributary Name
Monitored Inputs
Land Uses
Tributary Name: Munkers_Runoff
Segment: 01 MC_Riverine
Tributary Type: 01 Monitored Inflow
Mean CV
Total Watershed Area (km2): 226.33
Flow Rate (hm3/yr): 35.67 0.73
Total P Conc (ppb): 936 0
Ortho P Conc (ppb): 197 0
Total N Conc (ppb): 5593 0
Inorganic N Conc (ppb): 2573 0
Conservative Subst. Conc (ppb): 0 0
Edit Tributary Data
List Add Insert Delete Clear Undo Help Cancel OK
02 Munkers_Baseflow
Number of Tributaries = 7
Tributary Name
Monitored Inputs
Land Uses
Tributary Name: Munkers_Baseflow
Segment: 01 MC_Riverine
Tributary Type: 01 Monitored Inflow
Mean CV
Total Watershed Area (km2): 226.33
Flow Rate (hm3/yr): 8.87 0.66
Total P Conc (ppb): 121 0
Ortho P Conc (ppb): 50 0
Total N Conc (ppb): 1100 0
Inorganic N Conc (ppb): 328 0
Conservative Subst. Conc (ppb): 0 0
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Number of Tributaries = 7
Tributary Name
Monitored Inputs
Land Uses
Tributary Name: Neosho_Runoff
Segment: 03 NE_Riverine
Tributary Type: 01 Monitored Inflow
Mean CV
Total Watershed Area (km2): 399.54
Flow Rate (hm3/yr): 62.96 0.73
Total P Conc (ppb): 923 0
Ortho P Conc (ppb): 148 0
Total N Conc (ppb): 5051 0
Inorganic N Conc (ppb): 1364 0
Conservative Subst. Conc (ppb): 0 0
Edit Tributary Data
List Add Insert Delete Clear Undo Help Cancel OK
04 Neosho_Baseflow
Number of Tributaries = 7
Tributary Name
Monitored Inputs
Land Uses
Tributary Name: Neosho_Baseflow
Segment: 03 NE_Riverine
Tributary Type: 01 Monitored Inflow
Mean CV
Total Watershed Area (km2): 399.54
Flow Rate (hm3/yr): 15.67 0.66
Total P Conc (ppb): 117 0
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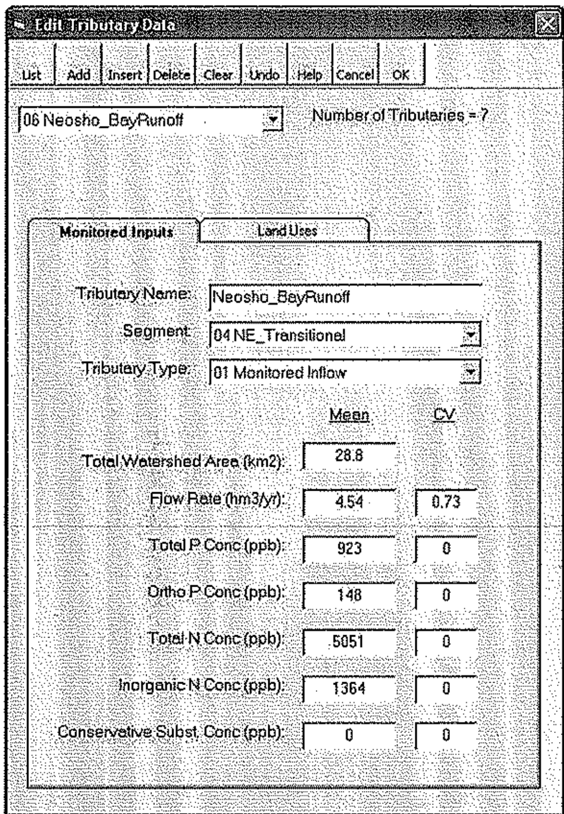
Total N Conc (ppb): 809 0
Inorganic N Conc (ppb): 527 0
Conservative Subst. Conc (ppb): 0 0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Monitored Inputs
Land Uses
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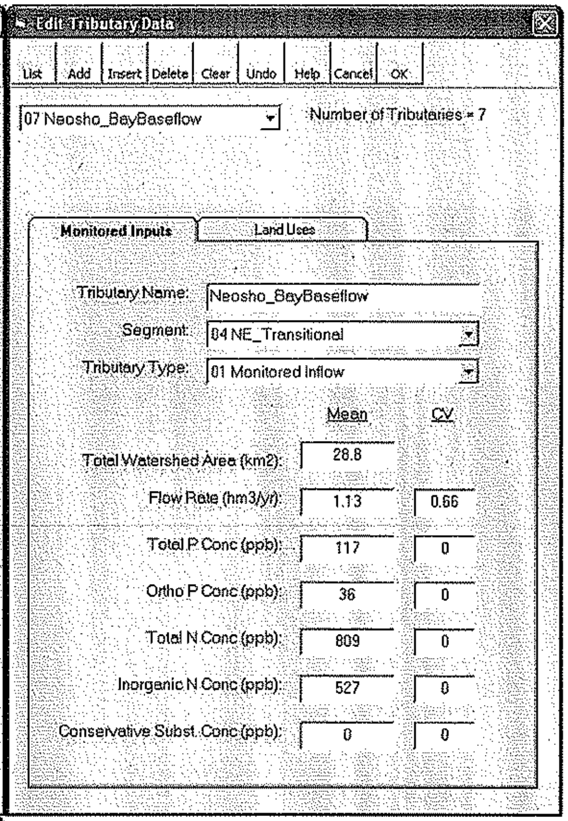
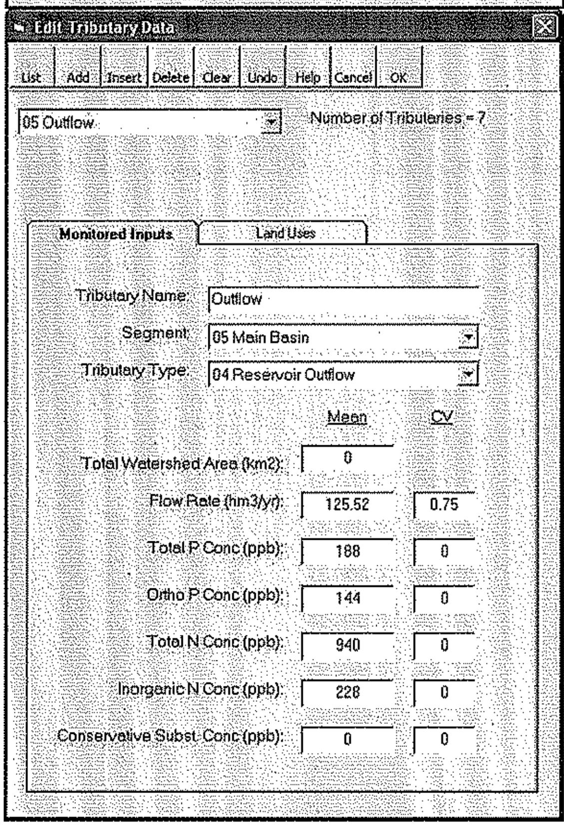
Segment: 04 NE_Transitional
Tributary Type: 01 Monitored Inflow
Mean CV
Total Watershed Area (km2): 28.8
Flow Rate (hm3/yr): 4.54 0.73
Total P Conc (ppb): 923 0
Ortho P Conc (ppb): 148 0
Total N Conc (ppb): 5051 0
Inorganic N Conc (ppb): 1364 0
Conservative Subst. Conc (ppb): 0 0


Edit Tributary Data
List Add Insert Delete Clear Undo Help Cancel OK
07 Neosho_BayBaseflow
Number of Tributaries = 7
Monitored Inputs
Land Uses
Tributary Name: Neosho_BayBaseflow
Segment: 04 NE_Transitional
Tributary Type: 01 Monitored Inflow
Mean CV
Total Watershed Area (km2): 28.8
Flow Rate (hm3/yr): 1.13 0.66
Total P Conc (ppb): 117 0
Ortho P Conc (ppb): 36 0
Total N Conc (ppb): 809 0
Inorganic N Conc (ppb): 527 0
Conservative Subst. Conc (ppb): 0 0


Edit Tributary Data
List Add Insert Delete Clear Undo Help Cancel OK
05 Outflow
Number of Tributaries = 7
Monitored Inputs
Land Uses
Tributary Name: Outflow
Segment: 05 Main Basin
Tributary Type: 04 Reservoir Outflow
Mean CV
Total Watershed Area (km2): 0
Flow Rate (hm3/yr): 125.52 0.75
Total P Conc (ppb): 188 0
Ortho P Conc (ppb): 144 0
Total N Conc (ppb): 940 0
Inorganic N Conc (ppb): 228 0
Conservative Subst. Conc (ppb): 0 0

Model Selection and Coefficient Input

Select Models

Defaults | Undo | Help | Cancel | OK

Model	Selection
Conservative Substance	00 NOT COMPUTED *
Total Phosphorus	01 2ND ORDER, AVAIL P *
Total Nitrogen	01 2ND ORDER, AVAIL N
Chlorophyll-a	01 P, N, LIGHT, T
Transparency	01 VS. CHLA & TURBIDITY *
Longitudinal Dispersion	01 FISCHER-NUMERIC *
Phosphorus Calibration	01 DECAY RATES *
Nitrogen Calibration	01 DECAY RATES *
Error Analysis	01 MODEL & DATA *
Availability Factors	00 IGNORE *
Mass Balance Tables	01 USE ESTIMATED CONCS *
Output Destination	02 EXCEL WORKSHEET *

Select Box and Hit F1 to Get Help, *=Default

Edit Model Coefficients

Defaults | Undo | Help | Cancel | OK

	Mean	CV
Dispersion Rate	1	0.7
Total Phosphorus	0.5	0.45
Total Nitrogen	3	0.55
Chlorophyll-a	1.3	0.26
Secchi Depth	1	0.1
Organic Nitrogen	1.5	0.12
Total P - Ortho P	0.7	0.15
Hypol. Oxygen Depletion	1	0.15
Metalim. Oxygen Depletion	1	0.22
Secchi/Chl-a Slope (m2/mg)	0.025	0
Minimum Qs (m/yr)	0.1	0
Chl-a Flushing Term	1	0
Chl-a Temporal CV	0.62	
Total P Avail. Factor	0.33	
Ortho P Avail. Factor	1.93	
Total N Avail. Factor	0.59	
Inorganic N Avail. Factor	0.79	

Model Output (Predicted vs. Observed)

	A	B	C	D	E	F	G	H
150								
151	**Segment:**	**5**	**Main Basin**					
152		**Predicted Values--->**			**Observed Values--->**			
153	**Variable**	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**	
154	TOTAL P MG/M3	187.1	0.24	93.5%	188.0	0.21	93.6%	
155	TOTAL N MG/M3	986.7	0.29	49.0%	940.1	0.94	46.0%	
156	C.NUTRIENT MG/M3	65.3	0.32	77.5%	62.1	0.75	75.6%	
157	CHL-A MG/M3	6.4	0.29	30.8%	6.6	0.46	32.4%	
158	SECCHI M	0.4	0.10	10.2%	0.4	0.52	10.1%	
159	ORGANIC N MG/M3	710.3	0.15	78.6%	712.0	0.82	78.8%	
160	TP-ORTHO-P MG/M3	42.7	0.16	64.5%	44.0	0.25	65.7%	
161	ANTILOG PC-1	513.7	0.33	71.4%	509.5	0.63	71.2%	
162	ANTILOG PC-2	2.4	0.20	3.2%	2.5	0.51	3.6%	
163	(N - 150) / P	4.5	0.36	2.5%	4.2	1.14	2.0%	
164	INORGANIC N / P	1.9	0.99	0.3%	1.6	4.65	0.2%	
165	TURBIDITY 1/M	2.3		93.3%	2.3		93.3%	
166	ZMIX * TURBIDITY	20.4		99.2%	20.4		99.2%	
167	ZMIX / SECCHI	21.9	0.10	99.6%	22.0	0.50	99.6%	
168	CHL-A * SECCHI	2.6	0.29	2.8%	2.7	0.69	3.0%	
169	CHL-A / TOTAL P	0.0	0.36	0.3%	0.0	0.50	0.3%	
170	FREQ(CHL-a>10) %	15.1	0.73	30.8%	16.3	1.12	32.4%	
171	FREQ(CHL-a>20) %	1.6	1.20	30.8%	1.8	1.87	32.4%	
172	FREQ(CHL-a>30) %	0.3	1.50	30.8%	0.3	2.36	32.4%	
173	FREQ(CHL-a>40) %	0.1	1.72	30.8%	0.1	2.72	32.4%	
174	FREQ(CHL-a>50) %	0.0	1.90	30.8%	0.0	3.01	32.4%	
175	FREQ(CHL-a>60) %	0.0	2.05	30.8%	0.0	3.25	32.4%	
176	CARLSON TSI-P	79.6	0.04	93.5%	79.7	0.04	93.6%	
177	CARLSON TSI-CHLA	48.8	0.06	30.8%	49.1	0.09	32.4%	
178	CARLSON TSI-SEC	72.8	0.02	89.8%	72.8	0.10	89.9%	

Goodness of Fit (calibration/validation)

T = Student's t-Statistic testing for significant difference between Observed & Predicted Means using three alternative measures of error: observed error only, T(1); error typical of model development data set, T(2); and observed and predicted error, T(3). Tests of model applicability are normally based upon T(2) and T(3). However, if an appropriate sedimentation model is selected, T(1) can be then used as a basis for deciding whether calibration is appropriate.

Microsoft Excel - bathtub_output.xls

Segment:	5	Main Basin						
	Observed		Predicted		Obs/Pred	T-Statistics --->		
Variable	**Mean**	**CV**	**Mean**	**CV**	**Ratio**	**T1**	**T2**	**T3**
TOTAL P MG/M3	188.0	0.21	187.1	0.24	1.01	0.02	0.02	0.02
TOTAL N MG/M3	940.1	0.94	986.7	0.29	0.95	-0.05	-0.22	-0.05
C.NUTRIENT MG/M3	62.1	0.75	65.3	0.32	0.95	-0.07	-0.25	-0.06
CHL-A MG/M3	6.6	0.46	6.4	0.29	1.03	0.07	0.10	0.06
SECCHI M	0.4	0.52	0.4	0.10	1.00	-0.01	-0.01	-0.01
ORGANIC N MG/M3	712.0	0.82	710.3	0.15	1.00	0.00	0.01	0.00
TP-ORTHO-P MG/M3	44.0	0.25	42.7	0.16	1.03	0.12	0.08	0.10
ANTILOG PC-1	509.5	0.63	513.7	0.33	0.99	-0.01	-0.02	-0.01
ANTILOG PC-2	2.5	0.51	2.4	0.20	1.03	0.06	0.10	0.06
(N - 150) / P	4.2	1.14	4.5	0.36	0.94	-0.05	-0.19	-0.05

Appendix D. Wasteload allocation for NPDES and CAFO facilities.

Facility	Permit #	Wasteload Allocation (lbs N/day)	Wasteload Allocation (lbs P/day)
NPDES			
Alta Vista	KS-0096733 (M-NE05-OO01)	3.15	0.90
Dwight	KS-0051675 (M-NE20-OO01)	4.09	1.17
White City	KS-0096873 (M-NE68-OO02)	5.49	1.57
Daily Total		***12.73***	***3.64***
Annual Total (lbs/yr)		***4,647***	***1,328***
CAFO			
Swine (Total head: 700)	A-NEMR-SA03	0	0
Beef (260)	A-NEMR-BA16	0	0
Beef (400)	A-NEMR-BA01	0	0
Beef (200)	A-NEMR-BA02	0	0
Beef (300)	A-NEMR-BA14	0	0
Dairy (20)	A-NEMR-MA04	0	0
Swine (100)	A-NEMR-SA04	0	0
Beef (15500)	A-NEMR-C001	0	0
Swine (548)	A-NEMR-S015	0	0
Dairy (60)	A-NEMR-M003	0	0

Appendix E.

Conversion to Daily Loads as Regulated by EPA Region VII

The TMDL has estimated an annual average loads for TN and TP that if achieves should meet the water quality targets. A recent court decision often referred to as Anacostia decision have dictated that TMDL include a "daily" load (Friends of the Earth, Inc v. EPA, et al.).

Expressing this TMDL in daily time steps could be misled to imply a daily response to a daily load. It is important to recognize that the growing season mean chlorophyll *a* is affected by many factors such as: internal lake nutrient loading, water residence time, wind action and the interaction between light penetration, nutrients, sediment load and algal response.

To translate long term averages to maximum daily load values, EPA Region 7 has suggested the approach described in the Technical Support Document for Water Quality Based Toxics Control (EPA/505/2-90-001) (TSD).

Maximum Daily Load (MDL) = (Long-Term Average Load) * $e^{[Z\sigma - 0.5\sigma^2]}$

where $\sigma^2 = \ln(CV^2 + 1)$

CV = Coefficient of Variation = Standard Deviation/Mean
Z = 2.326 for 99th percentile probability basis

Parameter	LTA (LA)	CV	$e^{[Z\sigma-0.5\sigma^2]}$	MDL (LA)
TN	1,010,302 lbs/yr	0.94	4.64	12,837.63 lbs/day
TP	147,341 lbs/yr	0.21	1.59	640.49 lbs/day

Parameter	LTA (NPS)	CV	$e^{[Z\sigma-0.5\sigma^2]}$	MDL (NPS)
TN	993,263 lbs/yr	0.94	4.64	12,621.12 lbs/day
TP	147,108 lbs/yr	0.21	1.59	639.47 lbs/day

Parameter	LTA (MOS)	CV	$E^{[Z\sigma-0.5\sigma^2]}$	MOS (TMDL)
TN	101,495 Lbs/yr	0.94	4.64	1289.67 lbs/day
TP	14,867 lbs/yr	0.21	1.59	64.63 lbs/day