MARAIS DES CYGNES RIVER BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody/Assessment Unit: Lake Crawford
Water Quality Impairment: Eutrophication

1. INTRODUCATION AND PROBLEM IDENTIFICATION

Subbasin: Marmaton

Counties: Crawford

HUC 8: 10290104

Ecoregion: Central Irregular Plains (40); Osage Cuestas (40b), Wooded Osage Plains (40c), and Cherokee Plains (40d)

Drainage Area: Approximately 5.8 square miles (**Figure 1**)

Conservation Pool: Area = 150 acres,
Watershed Area: Lake Surface Area = 23:1
Maximum Depth = 16 meters
Mean Depth = 4.7 meters
Retention time = 0.85 years

Designated Uses: Primary Contact Recreation, Expected Aquatic Life Support and Food Procurement Use.

2002, 2004, 303(d) Listing: Marais Des Cygnes River Basin Lakes – All lakes are impaired to a degree by eutrophication

Impaired Use: Expected Aquatic Life Support

Water Quality Standard: Nutrients – Narratives: The introduction of plant nutrients into streams, lakes or wetland 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)).

Recreational use – Narratives: 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 algae by products or nuisance growths of submersed floating, or emergent aquatic vegetation (KAR 28-16-28e(c)(7)(A)).

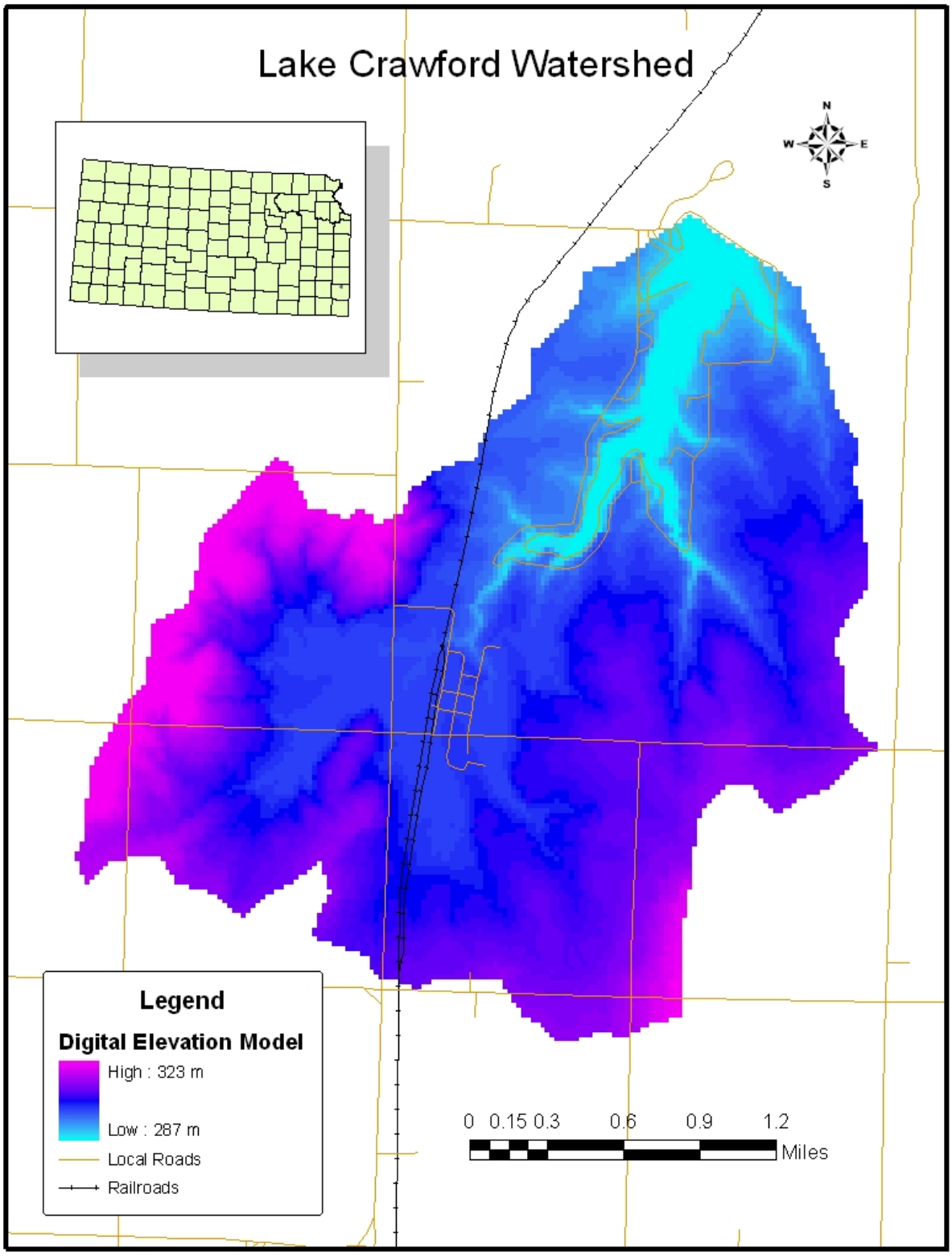

Figure 1. Digital Elevation Model (DEM) map of Lake Crawford Watershed.

CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Eutrophication: Trophic State Index = 53 (Slightly Eutrophic), ranging from 47 in 1987 to 62 in 2002.

The Trophic State Index (TSI) is derived from the chlorophyll *a* concentration (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

Monitoring Site: Station LM011101 (4-yr rotational monitoring site) in Lake Crawford.

Period of Record Used: Six Surveys during 1978 – 2002.

Stream Flow Record: Marmaton River (USGS06917380, record period from 1971 to 2005) near the City of Marmaton was used to estimate flow for West Fork Drywood Creek to Lake Crawford (Perry et al., 2004).

Long-Term Hydrologic Conditions: West Fork Drywood Creek above Lake Crawford – Median Flow = 0.7 cfs; 10% Exceedance Flow = 8.0 cfs, 90% Exceedance Flow = 0.007 cfs (**Figure 2**). The estimated mean streamflow was 5.1 cfs. Lake Crawford was built in the 1930's, with a surface area of approximately 138 acres based on a recent KDHE lake inventory data. Mean precipitation and evaporation at Lake Crawford were 1.04 m (41 in.) and 1.22 m (48 in.), respectively. The hydraulic residence (retention) time was about 10 months (0.85/yr).

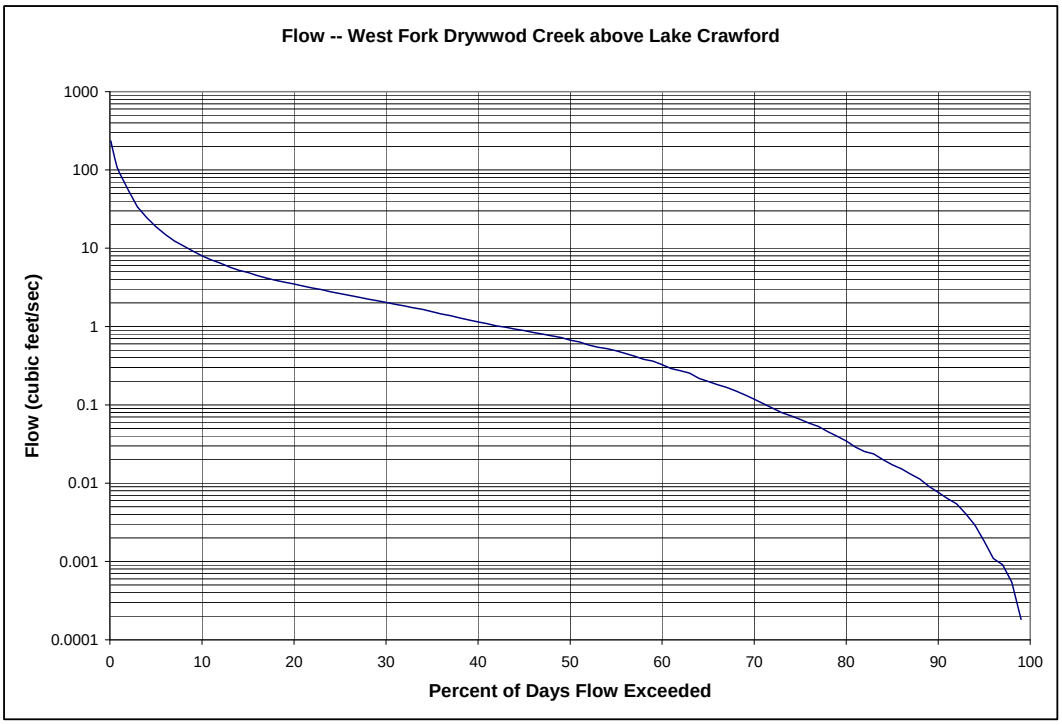

Figure 2. Flow duration for West Fork Drywood Creek above Lake Crawford.

Current Conditions: Figure 3 and 4 show turbidity and Chla for Station LM011101, respectively. The average Chla coincided with the water quality endpoint for primary contact recreation (12 µg/L). One sampling event (6/25/2002) had Chla level over the water quality endpoint for secondary contact recreation (20 µg/L). It is interesting to note that Chla concentrations consistently increased from 5.2 µg/L in 1987 to 25.0 µg/L in 2002. The average turbidity value was 3 NTU, ranging from 1 NTU in 1993 to 6 NTU 1978. Secchi depth measured in 2002 was 1.52 meters, which is double the value (0.7 meters) used for Primary Contact Recreation Use as recommended by the Bureau of Environmental Field Services KDHE, based on best professional judgment and the literature (Carney, 2003).

Total phosphorus (TP) concentration averages 186 µg/L during 1978 – 2002 and ranges from as low as 10 µg/L in 1987 to as high as 900 µg/L in 1981 (**Figure 5**). Nutrient concentrations of Lake Crawford during 1987 – 2002 were compared to other similar lakes in the ecoregion, state and EPA Region VII levels. As indicated in **Table 1**, Lake Crawford typically has the lowest nutrient and Chla values and highest Secchi depth reading. However, TP and Chla concentrations are greater than the trophic criteria proposed by the EPA Region VII. An index (Chla/TP) was used to evaluate algal use of phosphorus supply (Carney, 2003). There is a limited response by algae to phosphorus if index are values less than 0.13, suggesting that nitrogen, light or other factors may be more important. If values are greater than 0.4, a strong algal response to changes in phosphorus prevails. The range between 0.13 and 0.4 indicates a moderate response by algal to phosphorus levels. The ratio of total nitrogen (TN) and TP was also used to determine which of these nutrients is most likely limiting plant growth in Kansas aquatic ecosystems (Dzialowski et al., 2005). Generally, lakes that were N limited had water column TN:TP ratios < 8 (mass); lakes that were co-limited by N and P had water column TN:TP ratios between 9 and 28; and lakes that were P limited had water column TN:TP ratios >

29. For Lake Crawford, Chla/TP index values average 0.35 and TN:TP ratios average 16.5, all suggesting that both nitrogen and phosphorus appear to be the primary limiting factors.

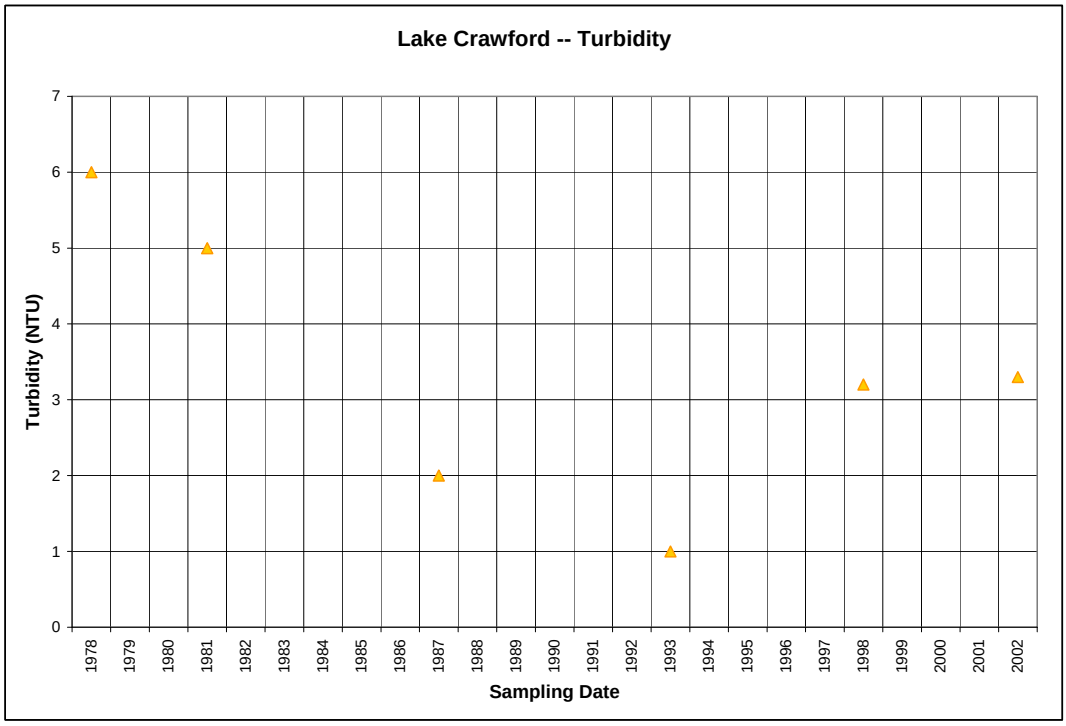

Figure 3. Turbidity concentrations at Site LM011101 during 1978 – 2002.

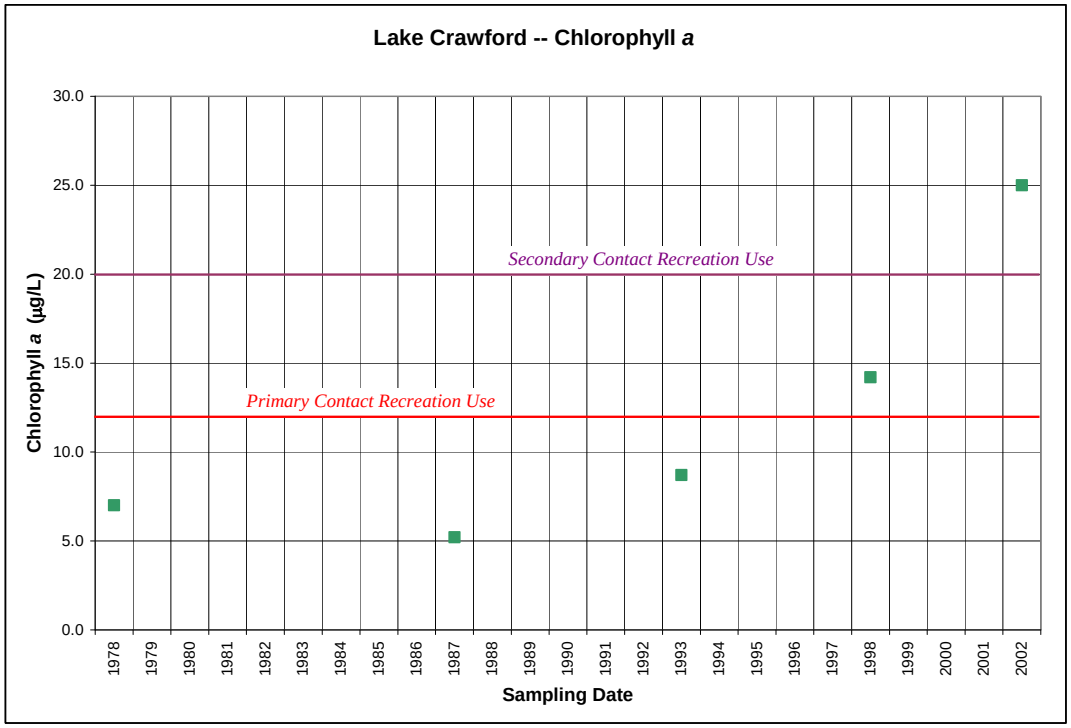

Figure 4. Chlorophyll *a* concentrations at Site LM011101 during 1978 – 2002.

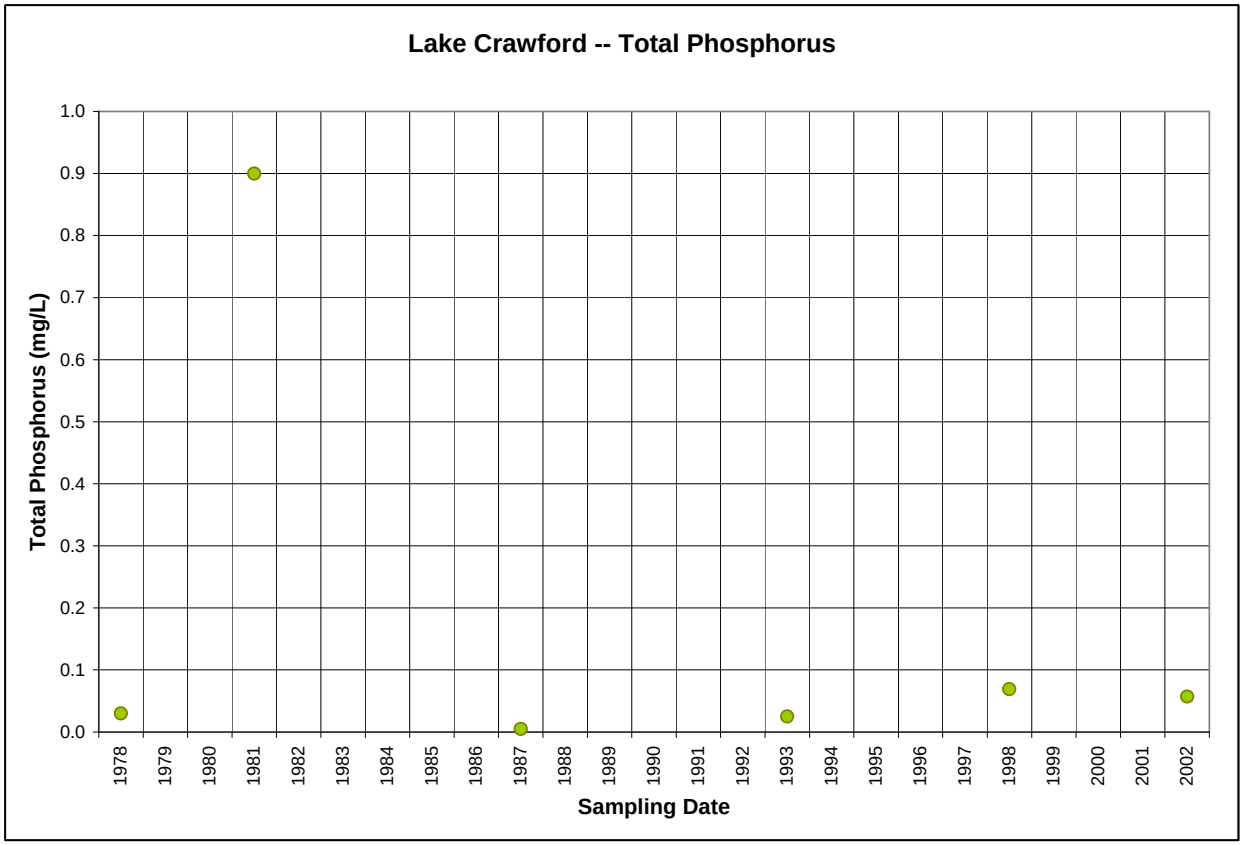

Figure 5. Total phosphorus concentrations at Site LM011101 during 1978 – 2002. (The 1987 and 1993 values were half the instrument detection limit of 10 and 50 µg/L, respectively.)

Table 1. Trophic state of Lake Crawford and its comparisons with other ecoregional, state and regional lakes and reservoirs.

Lake	TN	TP	TN:TP	Chl *a*	Secchi depth	Non-algal turbidity	Chla/TP
	µg/L	µg/L		µg/L	m	1/m	
Lake Crawford	588	50	16.5	12	1.52	0.04	0.35
Central Irregular Plains[1]	873	66	17.9	17	1.03	0.55	0.46
TMDL lake survey[2]	1,530	146	15.2	33	0.55	0.99	0.32
Kansas[1]	875	72	16.0	19	0.97	0.56	0.45
EPA Region VII area[1]	1,685	129	27.8	29	0.88	0.41	0.36
Trophic Criteria[1] (EPA Region VII)	700	35	20.0	8	--	--	0.23

[1]RTAG – EPA Region VII database (100 - 1000 acres) obtained from the Kansas Biological Survey.
[2]Small – medium size of TMDL lakes surveyed in 2002 and 2003.

Non-algal turbidity values, derived from both Secchi depth and Chla values, if greater than 1, indicate inorganic particles are important in creating turbidity while values less than 0.4 tend to indicate very low levels of suspended silts and/or clay (Carney, 2003). In 2002, non-algal turbidity value was 0.04 m^{-1}, suggesting that Lake Crawford does not experience any major inorganic turbidity influence that can greatly affect the biological activities in the water column.

Figure 6 shows dissolved oxygen (DO) patterns observed in Lake Crawford. In general, DO concentrations stratified with depth at 5-6 meters. Average DO concentrations for the top 5-m water column were 8.9 mg/L in 1987, 7.35 mg/L in 1993, 4.7 mg/L in 1998, and 6.9 mg/L in 2002. The lower DO concentrations in 1998 were likely the combined result of higher temperature (e.g., 28.5˚C compared to 27.5˚C in 1993 and 2002) and nutrients (e.g., TP) that enhanced the biological consumption of DO in the lake. As one would expect, the changes in pH values positively correlated with DO during 1987 – 2002 (**Figure 7**), with the lowest pH value (7.3) noted in 1998.

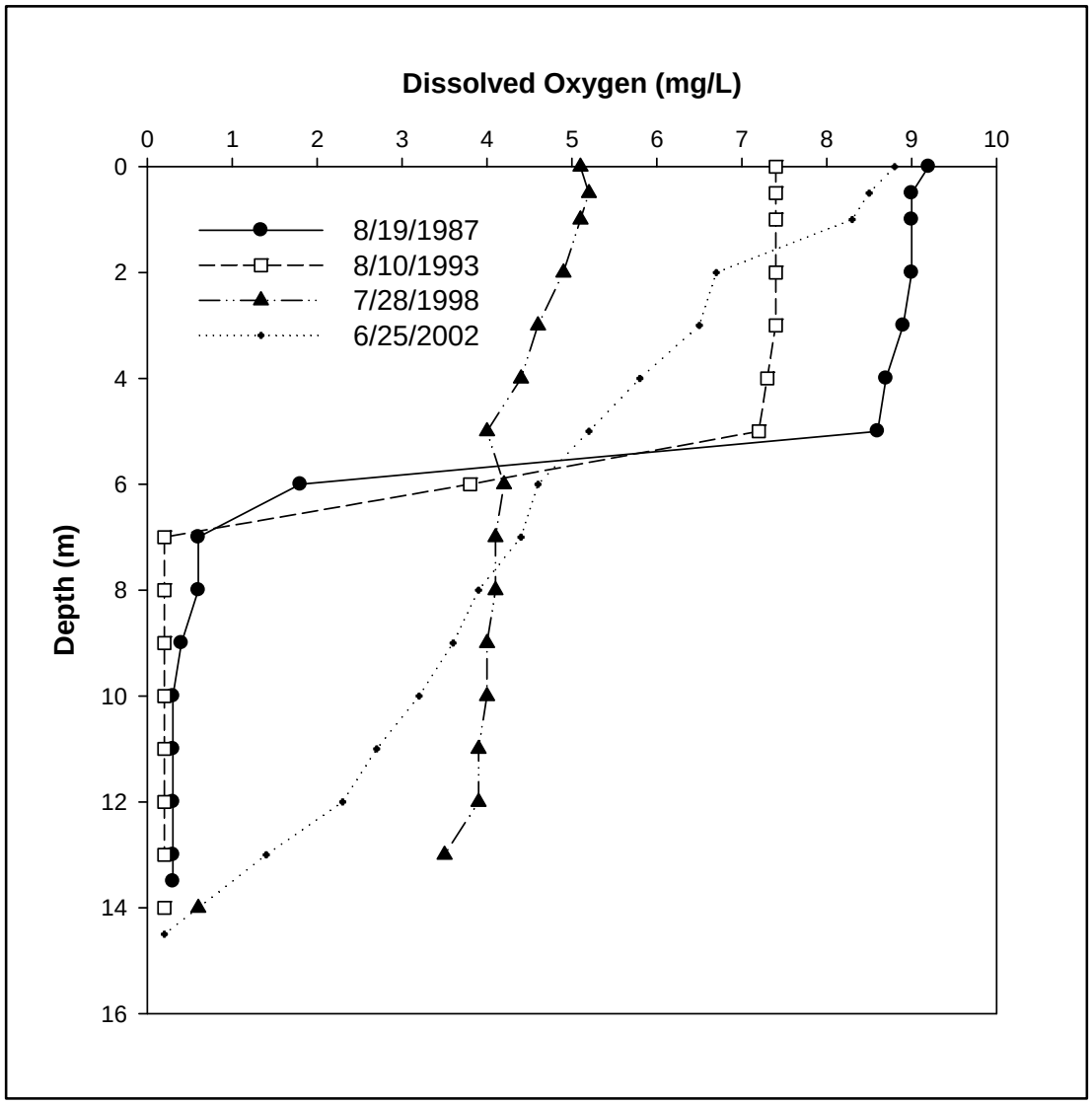

Figure 6. Dissolved oxygen patterns in Lake Crawford during 1987 – 2002.

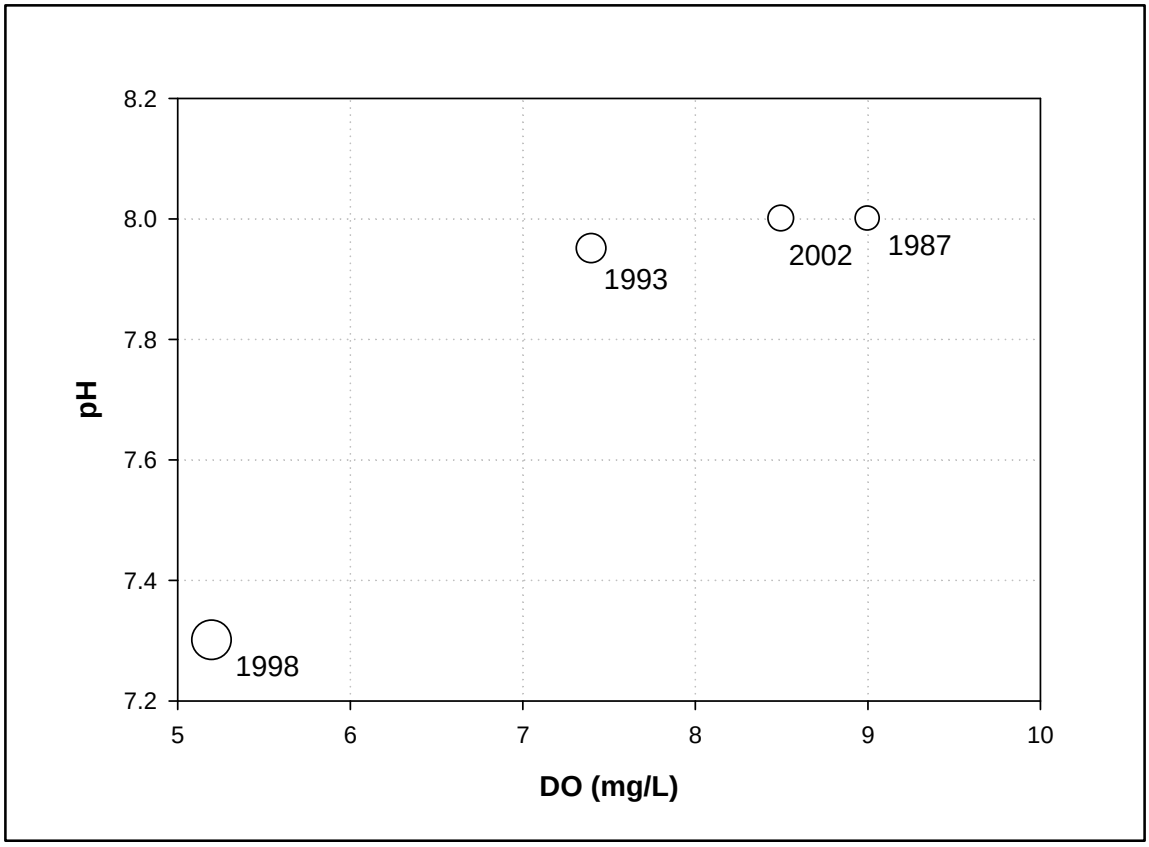

Figure 7. Bubble plot of pH-DO relationship at Site LM011101.
(Note: A bubble plot is a scatter plot (DO-pH) with additional data (pH/DO) shown by the size of a symbol.)

Figure 8 summarizes the current and possible future trophic conditions of Lake Crawford using a multivariate TSI comparison chart. TSI(Chla) – TSI(TP) is plotted on the vertical axis. Points below TSI(Chla) < TSI(TP) indicate situations where phosphorus may not be limiting Chla where points above TSI(Chla) > TSI(TP) 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 organic materials dominate by 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, 2005). As indicated in **Figure 8**, Lake Crawford is a clear and N+P-limiting Lake. According to the most recent KDHE's lake survey, algal communities in Lake Crawford, based on cell count, were dominated by green algae (62%, Carney, 2003).

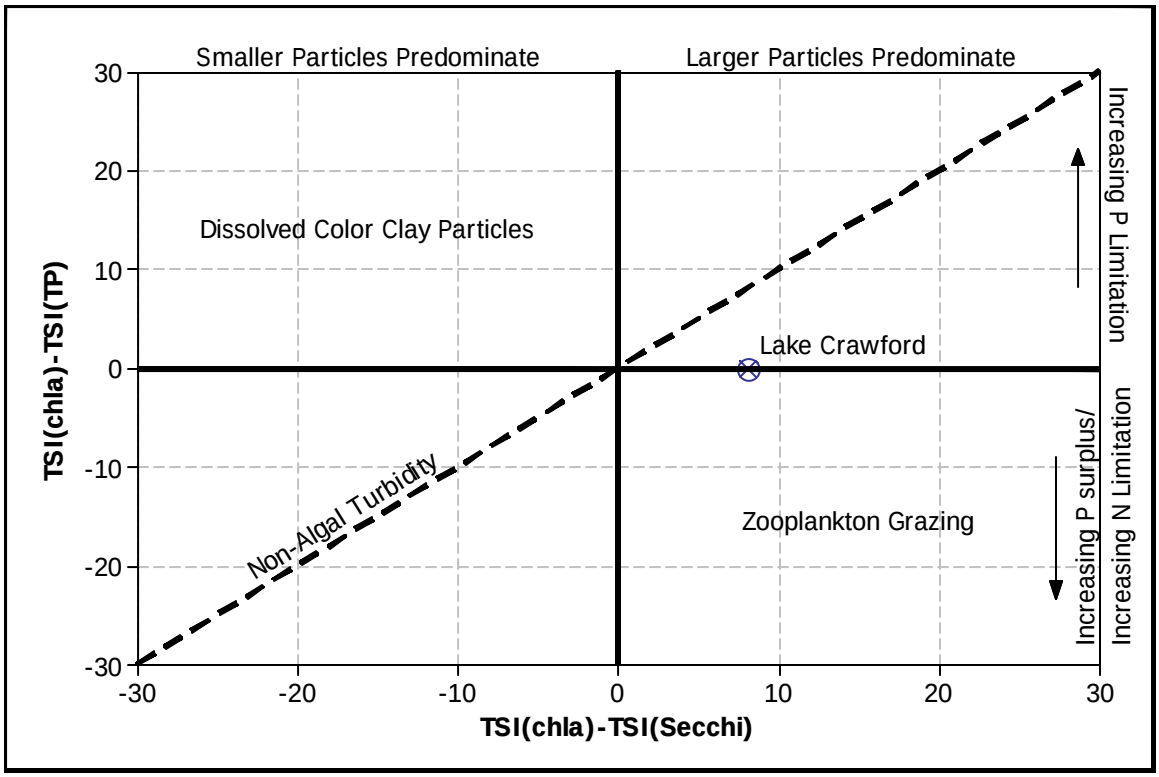

Figure 8. Multivariate TSI compassion chart of Lake Crawford.

Coontail (*Ceratophyllum demersum*), submersed aquatic plant, occupies as little as 5% of lake area near the shoreline (Carney, 2003), and along with algae, it provides fair sport fishing opportunities for Lake Crawford. According to the Kansas Department of Wildlife and Parks' (KDWP) fish survey, the number Stock or adult fish Captured Per Unit time Effort (Stock CPUE) shows that sight-feeding bass and crappie increase in their populations from 1991 to 2005, with the exception of in the recent years (**Figure 9**). Bluegill population averages 17 CPUE and similarly has fairly low number in the last five year (9 CPUE). The population of walleye, however, shows a steady diminishing trend since 1995. From 1991 to 2005, bottom-feeding fish like gizzard shad and channel catfish shows an increasing pattern in their populations (**Figure 10**).

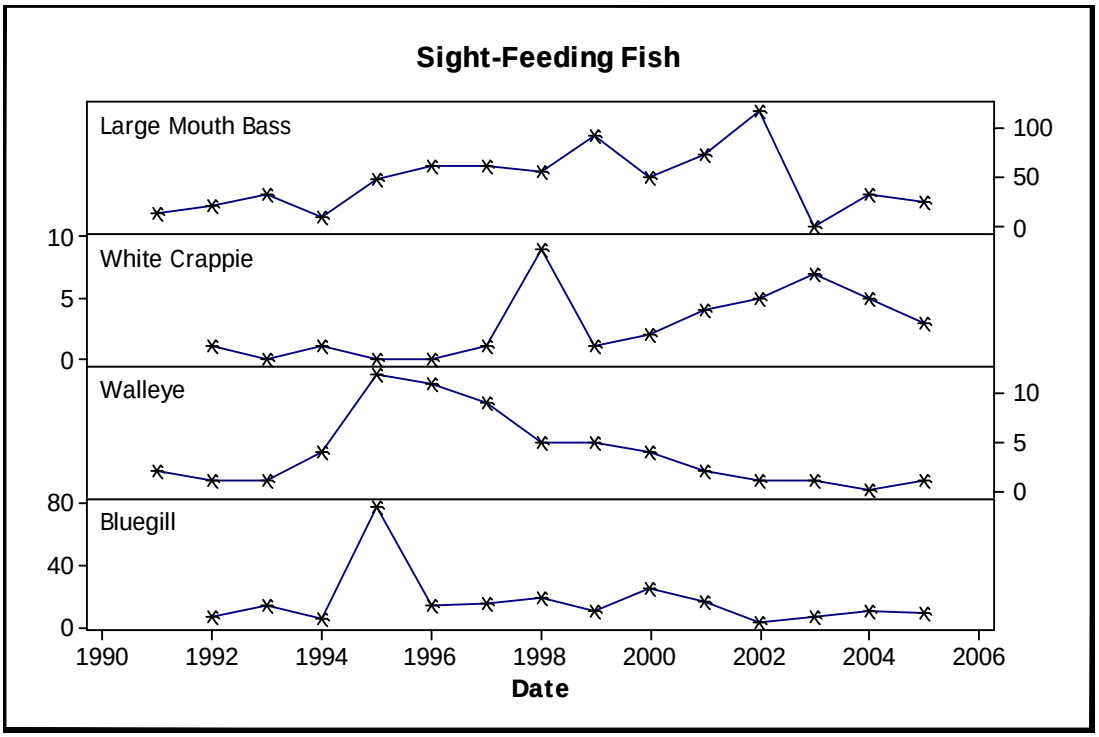

Figure 9. Stock CPUE for sight-feeding fish. [Sight-feeding fish are represented by large mouth bass (>8" in length), white crappie (>5"), walleye (>10"), and bluegill (>3").]

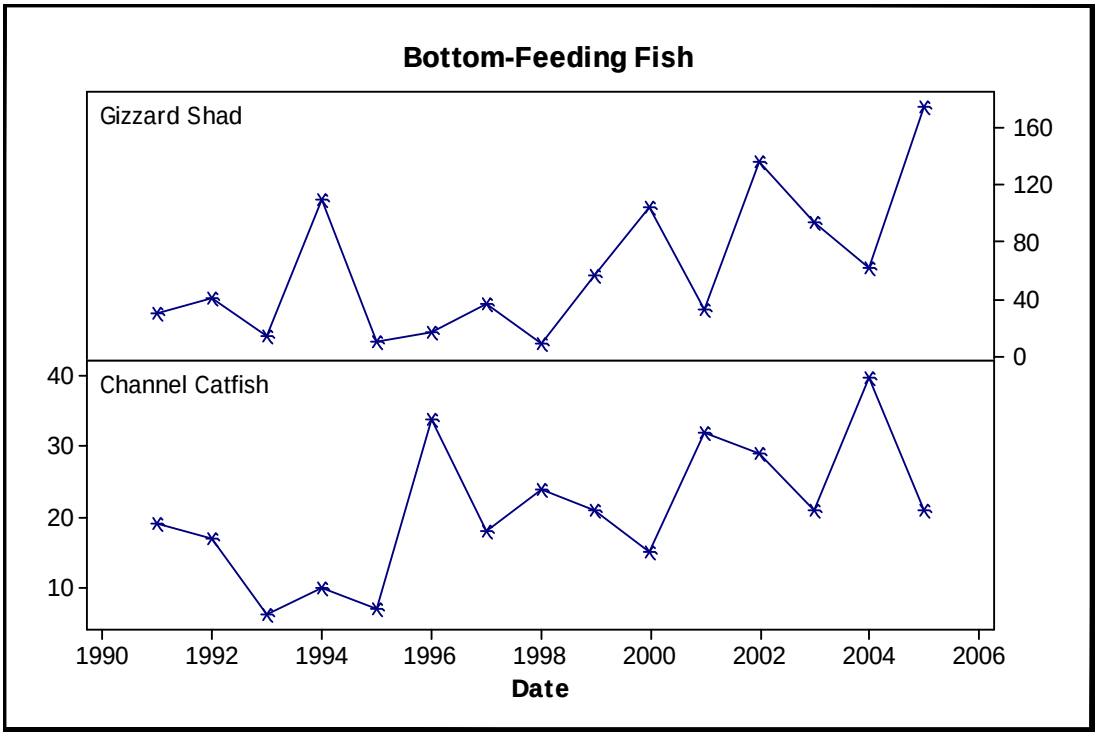

Figure 10. Stock CPUE for sight-feeding fish. [Bottom-feeding fish are represented gizzard shad (>5"), and channel catfish (>11").]

2. SOURCE INVENTORY AND ASSESSMENT

NPDES: There is only one NPDES discharger within the Lake Crawford watershed (**Table 2**). The Crawford County Sewer District #4 facility serves homes surrounding Lake Crawford and has just recently been completed in 2006. The demand put on this facility will vary seasonally as the majority of the lake residences are only occupied during the warmer months. There has not been any discharge from this facility to date and discharge from the lagoon system is not expected to occur in the next couple of years. When this facility does discharge there are permit limits for biochemical oxygen demand, total suspended solids, pH, ammonia, and fecal coliform bacteria. Though this NPDES site is located in the watershed, it is not designed to discharge any effluent into Lake Crawford.

Table 2. NPDES Permitted facilities within the Drywood Creek Watershed.

Facility	NPDES#	KS Permit #	Type	Rec Stream	Design Q	Expires
Crawford County Sewer District #4	KS0096741	M-MC52-OO01	3-Cell Lagoon	WF Drywood Cr via unnamed Trib via drainage ditch	0.03 MGD	3/31/2009

Land Use: The predominant land use is cultivated cropland, which accounts for 23% of the total land area in the watershed (**Figure 11**). Urban area, such as residential, commercial and industrial uses, only comprises less than 1% of the watershed. Approximately 29% of the land is occupied either by Ash-Elm Hackberry or mixed Oak floodplain forest, whereas 23% is tall grass prairie. The area under the Conservation Reserve Program (CRP) only accounts for about 0.2% (7 acres) of the entire watershed. There are about 1,968 acres of riparian area (30-meter buffer along the stream system) in the watershed and the tall grass prairie occupies 44% of the total riparian buffer area. Ash-Elm Hackberry and mixed Oak floodplain forest account for about 55%. The riparian-related land use information was derived from KDHE watershed data.

Livestock Waste Management Systems: There are no confined animal feedlot operations located within the watershed. According to the National Agricultural Statistics Service, the number of cattle averaged in the pasture (e.g., non-native and tall grass prairies) from 1994 – 2006, based on the watershed area in Crawford County, is 706 head.

On-Site Waste Systems: Using 2000 census data from the U.S Census Bureau, the population of the entire watershed was estimated at 221 people (some census blocks fell both within and outside of the watershed, so the true population is likely somewhat lower), and therefore the watershed population density is relatively low (10 people/sq. mile) when compared to the density of Crawford County (64 people/sq. mile). County-wise estimation indicates that the population in 2000 (38,242) has increased by approximately 8% since 1990 (35,568). Because this watershed is a rural, agricultural area, all of the farm houses are not connected in a public sewer system, failing on-site systems may contribute significant nutrient loadings and aggravate eutrophication problems under the low flow conditions. Many of the houses in the watershed are located on the lake shore, and should failing or improperly maintained septic systems be present, they are likely to contribute through groundwater flow to the nutrient concentrations observed in the lake.

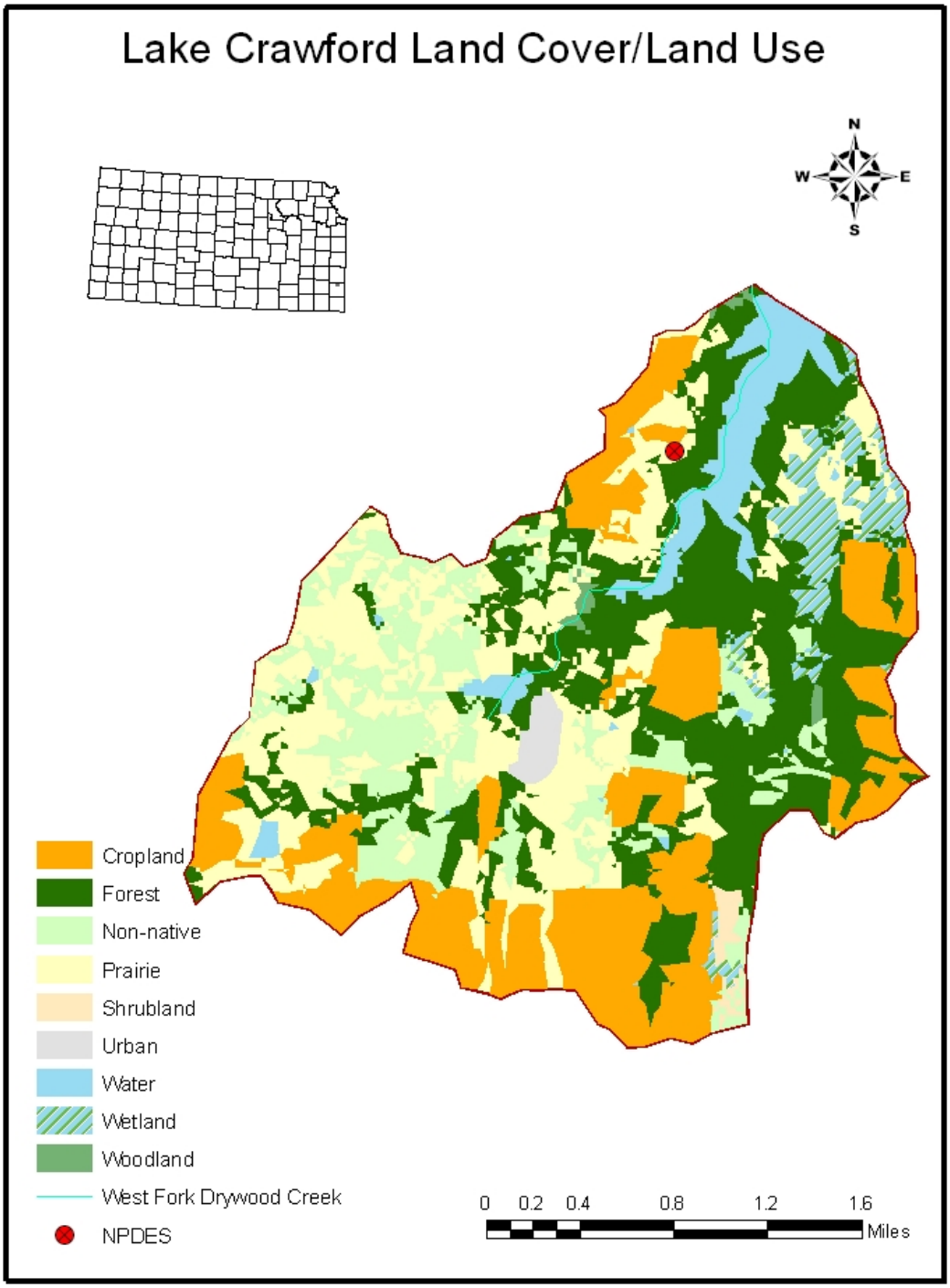

Figure 11. NPDES site and land use/land cover of Lake Crawford Watershed.

Contributing Runoff: The Lake Crawford watershed's average soil permeability is 0.59 inches/hour according to the Mean Soil Permeability database from Kansas Geological Survey. Only about 10% of the watershed area has a mean soil permeability value of 1.29"/hr. Runoff is chiefly generated as infiltration excess with rainfall intensities greater than soil permeabilities. As the watersheds' soil profiles become saturated, excess overland flow is produced. Generally, storms producing less than 0.5"/hr of rain will generate runoff from 53% of this watershed. **Figure 12** shows potential runoff-contributing areas, based on the threshold soil permeability value of 1.14"/hr, from very low rainfall intensity events.

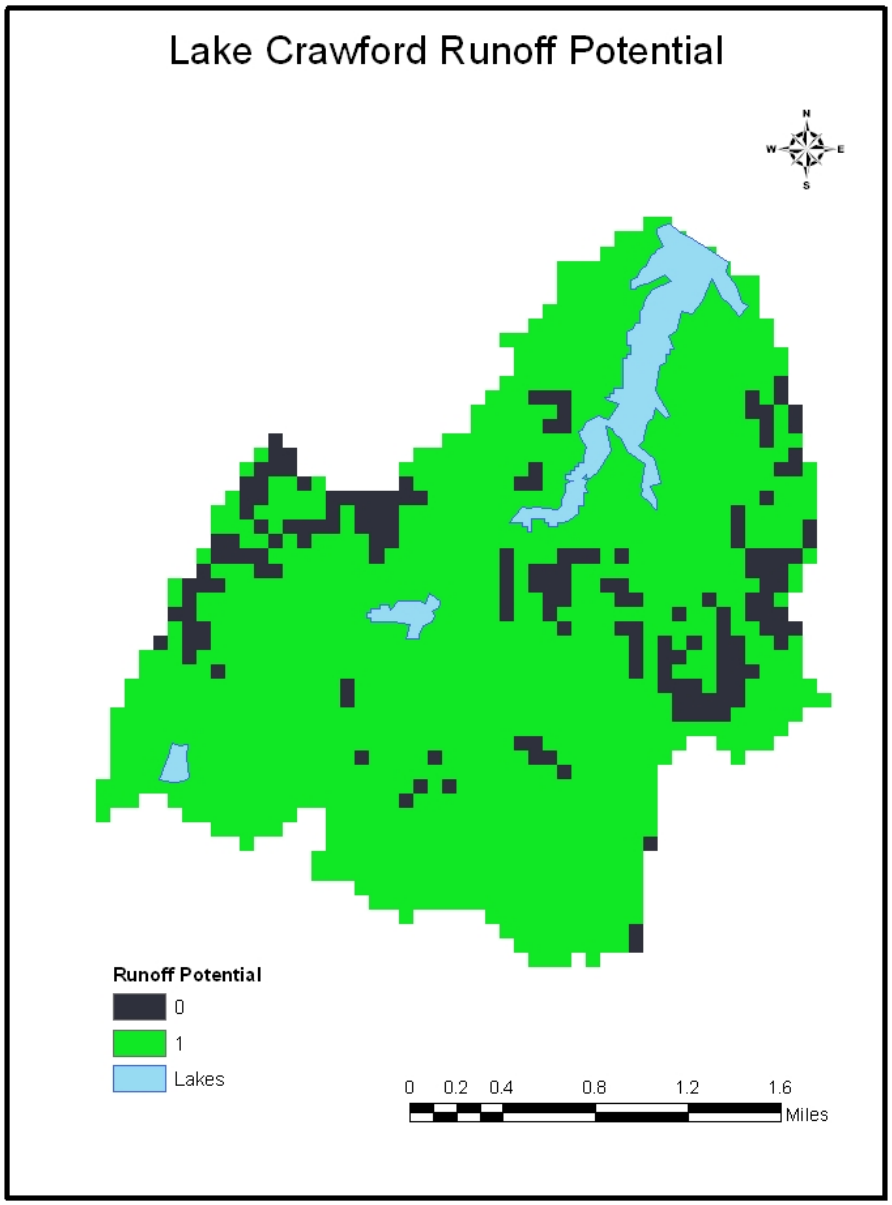

Figure 12. Potential runoff-contributing areas (indicated by 1) in Lake Crawford Watershed.

Internal nutrient loading: Lake Crawford was targeted for a pilot project to determine if breaking lake stratification would improve water quality. In 1996 a bubbling system located on the lake bottom went online and has been operated from April to October of each year thereafter. Dissolved oxygen profiles (**Figure 6**) suggest that while the stratification may have been broken, the depth of water available meeting the aquatic life (5 mg/l, KAR 28-16-28e(c)(2)(A)) standard has not changed, and that the average dissolved oxygen concentrations in the epilimnion (top 5 m) have been lower since this system went online. Other apparent effects include higher total phosphorus, turbidity and Chla in the epilimnion after the system went online than before (**Table 3**). This bubble unit likely contributes to the observed conditions in the epilimnion of Lake Crawford, and appears to have a deleterious effect. While hypolimnetic oxygenation has been widely promoted to alleviate water quality problems in lentic systems, research since this system went online suggests that benthic phosphorus loading is not addressed with this method (Gachter and Wehrli, 1998; Gachter and Muller, 2003). Our sample sizes are small (2 before and 3 after the unit went online) so further research is warranted to determine of the magnitude of change attributable to this source.

All lakes naturally load some nutrients from their bottoms, but stratified lakes are limited to the rate of diffusion for nutrients originating below the thermocline most of the year. During mixing, typically in fall and spring for dimictic lakes, nutrients from the hypolimnion become available for a period of time, typically resulting in short duration increases in Chla. These changes are typically outside of the primary contact recreation season, and pose little cause for concern.

Table 3. Epilimnetic conditions before and after the installation of the destratification unit.

Destratification	TP (mg/L)	Chlorophyll *a* (μg/L)	DO (mg/L)	Turbidity (NTU)
Before (1981 – 1995)	below detection limits	6.5	8.13	2
After (1996 – 2006)	0.06	20.0	6.09	6

Background Levels: Fifty-five percent of the 30-m riparian buffer areas are covered by forests and about 44% of the riparian areas are occupied by tall grass prairie. Leaf and grass litter from these riparian areas may contribute to the nutrient loading. The atmospheric nutrients and geological formations (i.e., soil and bedrock) may also contribute to nutrient loads. Because Lake Crawford is a small lake, nutrient cycling of the sediment (from wind mixing and bottom feeding fish) is likely contributing available nutrients to the lake for algal uptake. Likewise, bottom feeding fish may also re-suspend the sediment and thus contribute some available nutrients to algal communities in the water column (**Figure 10**).

3. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

Point Sources: A current Wasteload Allocation of zero is established by this TMDL because of the lack of discharging point sources in the watershed (**Appendix B)**. Though there is a NPDES site located in the watershed, it does not discharge any effluent into Lake Crawford. Should future point sources be proposed in the watershed and discharge into the impaired lake, the current wasteload allocation will be revised by adjusting current load allocations to account for the presence and impact of these new point source dischargers.

Non-Point Sources: Given the land use characteristics of the watershed, nutrient loading comes predominantly from nonpoint source pollution, which overland runoff can easily carry nutrients along with sediment to the stream segments and eventually to the lake. Because eutrophication is the main water quality concern and Lake Crawford is designated as a Class A Primary Contact Recreation, 12 µg/L of chlorophyll *a* is therefore targeted in this TMDL to achieve full support status – the waterbody being fully supportive for all of its designated uses (KDHE, 2007).

For eutrophication assessment, the BATHTUB model was used. BATHTUB is an empirical receiving water quality model, that was developed by U.S. Army Corps of Engineers (Walker, 1996), and has been widely used 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).

BATHTUB was calibrated based on existing data of 1993 – 2002. For Lake Crawford, the loads were estimated from Vollenweider 1982 Combined OECD (Wisconsin DNR, 2003) and USGS lake data. The BATHTUB setting and nutrient model selections are provided in Appendix A. Based on BATHTUB modeling results, the estimated current N and P loads were 5,004 kg/yr (11,008 lb/yr) and 480 kg/yr (1,055 lb/yr), respectively. Annual atmospheric deposition was 607 kg/yr for TN and 18 kg/yr for TP. To reach the desired Chla endpoint, a 30% nutrient (TN and TP) reduction is required (**Figure 13**). Load Allocations are therefore set to 4,110 kg/yr for TN and 354 kg/yr for TP, with 3,503 kg N/yr and 336 kg P/yr exported from the watershed. Thus, the maximum daily loads of TN and TP, based on a 1991 water quality – based toxics control technical support document (USEPA, 1991), are 23.0 kg/day (50.6 lbs/day) and 2.0 kg/day (4.4 lbs/day), respectively (**Appendix C**).

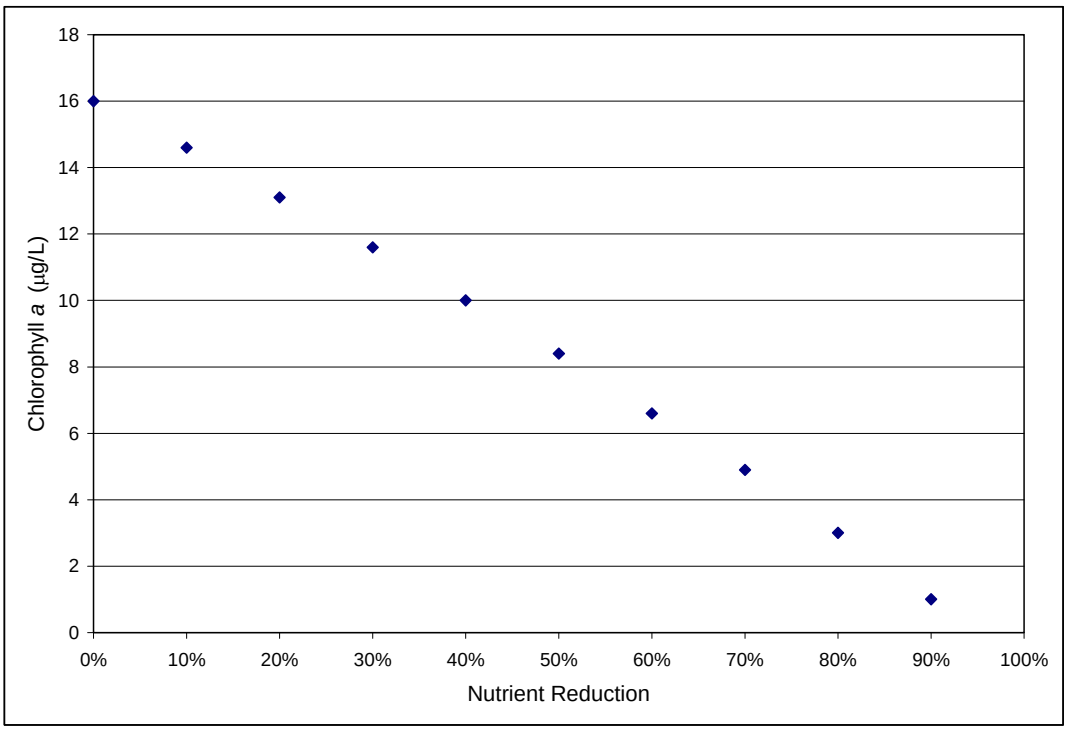

Figure 13. Changes in Chla levels in relation to nutrient (TN and TP) loading reduction.

Defined Margin of Safety: The margin of safety provides some hedge against the uncertainty of variable annual total nitrogen and phosphorus loads. Therefore, the margin of safety is explicit and will be 411 kg/yr (904 lbs/yr) and 35 kg/yr (78 lbs/yr) for TN and TP, respectively. And the daily margins of safety are set to 2.3 kg/day (5.1 lbs/day) for TN and 0.2 kg/day (0.4 lbs/day) for TP.

State Water Plan Implementation Priority: Because this lake has slightly elevated Chla concentrations, it may be restored without extensive watershed management efforts. Therefore, this TMDL will be a **High Priority** for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Marmaton River Basin (HUC 8: 10290104) with a priority ranking of 17 (High Priority for restoration work).

4. IMPLEMENTATION

Desired Implementation Activities

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

1. Promote and adopt continuous no-till cultivation to increase the amount of water infiltration and minimize cropland soil erosion and nutrient transports,
2. Perform soil tests and apply nutrient best management practices (BMPs) to reduce nutrient additions to the lake from excess fertilization,
3. Maintain and improve grass buffers and filterstrips along streams and channels in the watershed,
4. Maintain and expand the areas of CRP in the watershed,
5. Reduce activities within riparian areas,
6. Test septic systems in the watershed for proper maintenance and function,
7. Repair failing septic systems and promote proper maintenance,
8. Conduct a pilot study of lake conditions while suspending operation of destratification unit

Implementation Programs Guidance

Septic System Programs – LEPP

a. Promote proper maintenance of on-site wastewater treatment systems

b. Locate failing on-site systems and provide technical assistance on appropriate replacements.

Lake Stratification Field Study – KDWP & KDHE

a. Develop appropriate protocols for conducting a field study of lake conditions while operation of the destratification unit is suspended.

b. Implement field study of lake conditions while destratification unit operation is suspended, including testing water quality during summer stratification.

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, and

b. Provide technical assistance on practices geared to the establishment of vegetative buffer strips.

Water Resource Cost Share and Nonpoint Source Pollution Control Program - SCC

a. Apply conservation farming practices, including no-till, terraces and contours, sediment control basins, and constructed wetlands,

b. Provide sediment control practices to minimize erosion and sediment and nutrient transport.

c. Incorporate implementation activities under Marais des Cygnes Basin's WRAPS planning.

Riparian Protection Program - SCC

a. Establish or reestablish natural riparian systems, including vegetative filter strips and streambank vegetation, and

b. Develop riparian restoration projects.

Buffer Initiative Program - SCC

a. Install grass buffer strips near streams, and

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. Provide technical assistance on buffer strip design and minimize cropland runoff, and

c. Continue to educate residents and landowners about nonpoint source pollution.

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 Marais Des Cygnes 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. This watershed and its TMDL are a **High Priority** consideration.

Effectiveness: Improvements in sediment and nutrient loads to the lake can be accomplished through appropriate management and control systems, including buffer strips and riparian restoration projects. Improvement of failing septic systems has been proven to improve water quality.

6. MONITORING

KDHE will continue its 4-yr sampling schedule in order to assess the impairment that drives this TMDL. Based on that sampling, the priority status of 303(d) listing will be evaluated in 2012. Should impaired status be verified, the desired endpoints under this TMDL will be refined and direct more intensive sampling will need to be conducted during the growing season over the period 2012 – 2014 to assess progress in this TMDL's implementation. If a project to evaluate lake response, once the destratification unit is not operated during the growing season, proceeds, a targeted sampling effort will need to be made by KDHE and KDWP to assess trophic conditions.

7. FEEDBACK

Public Meetings: Public meetings to discuss this TMDL in the Marais des Cygnes Basin have been held since 2001. An active Internet Web site was established at www.kdheks.gov/tmdl/ to convey information to the public on the general establishment of TMDLs in the Marais des Cygnes Basin and this specific TMDL.

Public Hearing: A Public Hearing on this TMDL was held in Ft. Scott on May 31, 2007.

Basin Advisory Committee: The Marais des Cygnes Basin Advisory Committee met to discuss this TMDL on June 22, 2006 in Pomona, November 29, 2006 in Williamsburg, December 18, 2006 in Ft. Scott, January 30, 2007 in Ottawa, March 13, 2007 in Ft. Scott and May 17, 2007 in Ottawa.

Milestone Evaluation: In 2012, evaluation will be made as to implementation of management practices to minimize the non-point source runoff contributing to this impairment. Subsequent decisions will be made regarding the implementation approach, priority of allotting resources for implementation and the need for additional or follow up implementation in this watershed at the next TMDL cycle for this basin in 2012.

Consideration for 303(d) Delisting: The lake will be evaluated for delisting under Section 303d, based on the monitoring data over the period 2008 – 2015. Therefore, the decision for delisting will come about in the preparation of the 2016 303d list. Should modifications be made to the applicable water quality criteria during the 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 2007, which will emphasize revision of the Water Quality Management Plan (WQMP). At that time, incorporation of this TMDL will be made into both of the CPP and WQMP documents. Recommendations of this TMDL will be considered in *Kansas Water Plan* implementation decisions under the State Water Planning Process during Fiscal Years 2008 – 2015.

Revised, October 23, 2007

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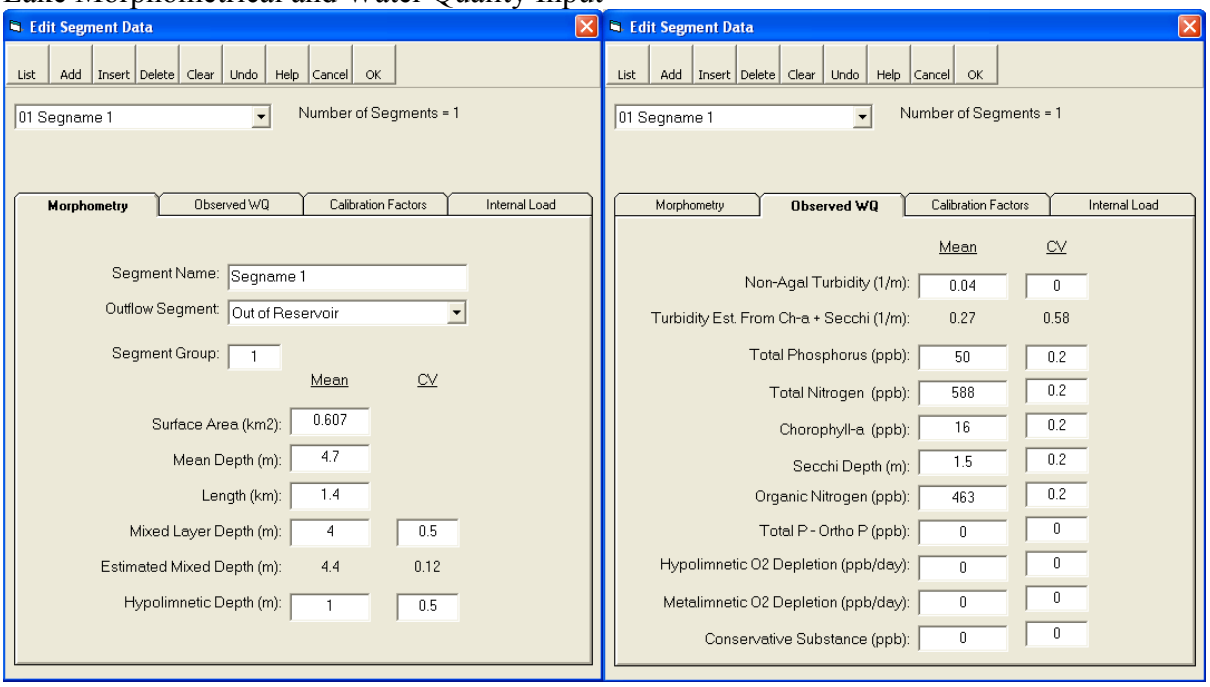
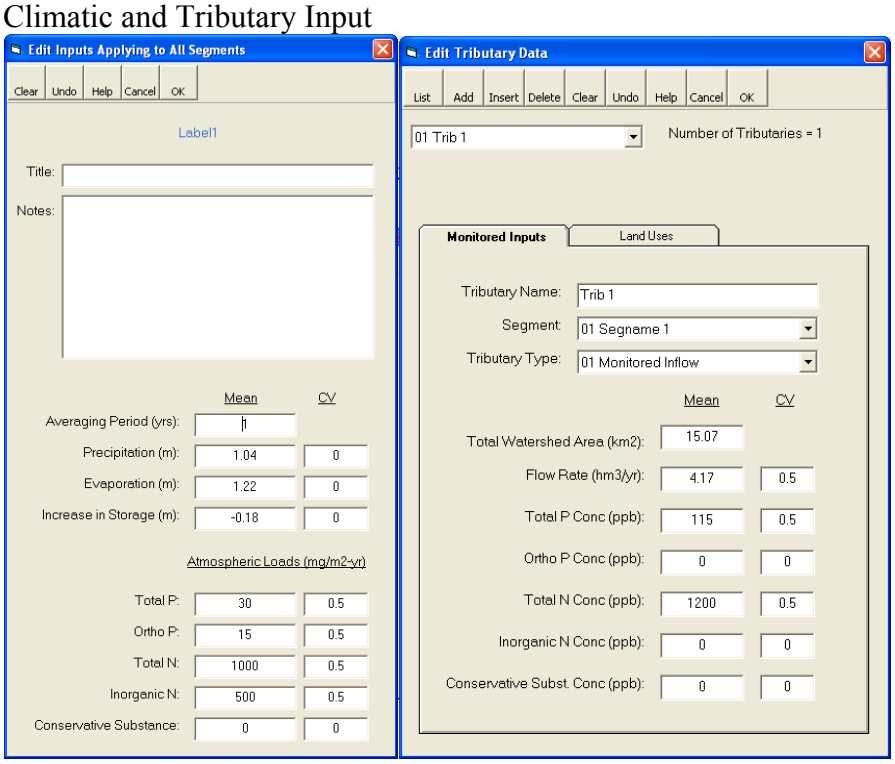
Appendix A

BATHTUB Input and Output Files

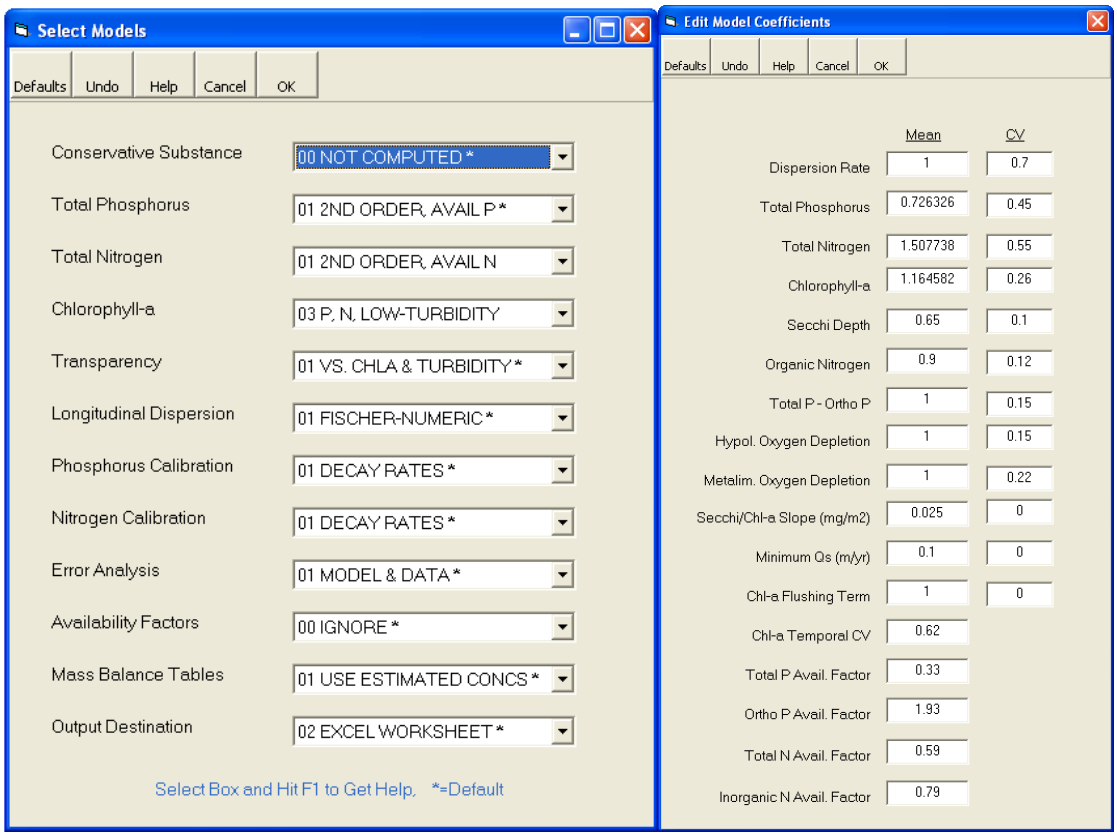
Lake Morphometrical and Water Quality Input



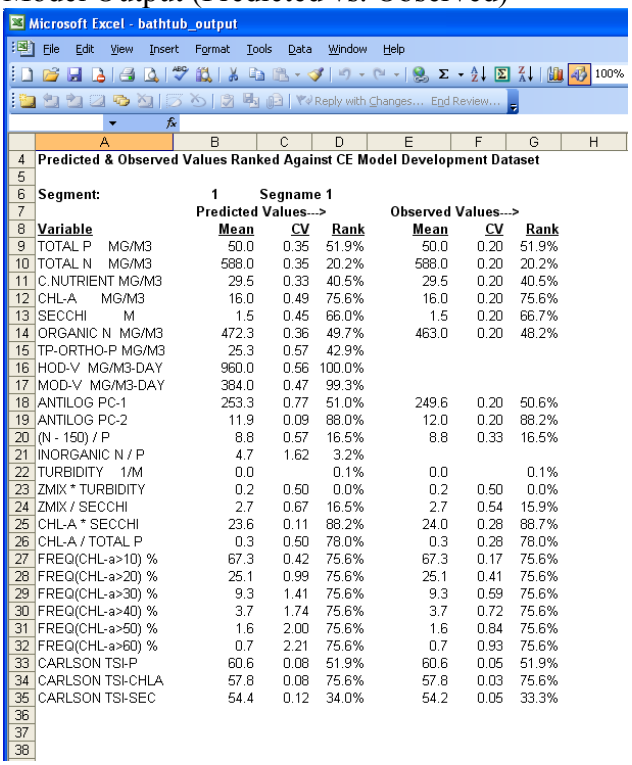
Climatic and Tributary Input



Model Selection and Coefficient Input



Model Output (Predicted vs. Observed)



Microsoft Excel - bathtub_output

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 **Segname** 1

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	50.0	0.35	51.9%	50.0	0.20	51.9%
TOTAL N MG/M3	588.0	0.35	20.2%	588.0	0.20	20.2%
C.NUTRIENT MG/M3	29.5	0.33	40.5%	29.5	0.20	40.5%
CHL-A MG/M3	16.0	0.49	75.6%	16.0	0.20	75.6%
SECCHI M	1.5	0.45	66.0%	1.5	0.20	66.7%
ORGANIC N MG/M3	472.3	0.36	49.7%	463.0	0.20	48.2%
TP-ORTHO-P MG/M3	25.3	0.57	42.9%			
HOD-V MG/M3-DAY	960.0	0.56	100.0%			
MOD-V MG/M3-DAY	384.0	0.47	99.3%			
ANTILOG PC-1	253.3	0.77	51.0%	249.6	0.20	50.6%
ANTILOG PC-2	11.9	0.09	88.0%	12.0	0.20	88.2%
(N - 150) / P	8.8	0.57	16.5%	8.8	0.33	16.5%
INORGANIC N / P	4.7	1.62	3.2%			
TURBIDITY 1/M	0.0		0.1%	0.0		0.1%
ZMIX * TURBIDITY	0.2	0.50	0.0%	0.2	0.50	0.0%
ZMIX / SECCHI	2.7	0.67	16.5%	2.7	0.54	15.9%
CHL-A * SECCHI	23.6	0.11	88.2%	24.0	0.28	88.7%
CHL-A / TOTAL P	0.3	0.50	78.0%	0.3	0.28	78.0%
FREQ(CHL-a>10) %	67.3	0.42	75.6%	67.3	0.17	75.6%
FREQ(CHL-a>20) %	25.1	0.99	75.6%	25.1	0.41	75.6%
FREQ(CHL-a>30) %	9.3	1.41	75.6%	9.3	0.59	75.6%
FREQ(CHL-a>40) %	3.7	1.74	75.6%	3.7	0.72	75.6%
FREQ(CHL-a>50) %	1.6	2.00	75.6%	1.6	0.84	75.6%
FREQ(CHL-a>60) %	0.7	2.21	75.6%	0.7	0.93	75.6%
CARLSON TSI-P	60.6	0.08	51.9%	60.6	0.05	51.9%
CARLSON TSI-CHLA	57.8	0.08	75.6%	57.8	0.03	75.6%
CARLSON TSI-SEC	54.4	0.12	34.0%	54.2	0.05	33.3%

Appendix B. Wasteload allocation for an active NPDES facility. The wasteloads are calculated based on average TN (7 mg/L) and TP (2 mg/L) values for Kansas lagoon systems. This facility, although located in the watershed, does not discharge any effluent to Lake Crawford.

Facility	Permit #	Wasteload Allocation
NPDES		
Crawford County	M-MC52-OO01	1.75 lbs N/day
Sewer District #4	(KS0096741)	0.50 lbs P/day

Appendix C.

Conversion to Daily Loads as Regulated by EPA Region VII

The TMDL has estimated an annual average loads for TN, TP, and TSS 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	CV	$e^{[Z\sigma - 0.5\sigma^2]}$	MDL	LA	MOS (10%)
TN	9,042 lbs/yr	0.34	2.04	50.62 lbs/day	45.56 lbs/day	5.06 lbs/day
TP	779 lbs/yr	0.35	2.08	4.44 lbs/day	4.00 lbs/day	0.44 lbs/day