CIMARRON BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody: Lake Coldwater
Water Quality Impairment: Eutrophication

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Upper Cimarron

Counties: Kiowa and Comanche

HUC 8: 11040008

HUC 10 (12): 04 (04)

Ecoregion: Southwestern Tablelands, Cimarron Breaks (26a) and Flat Tablelands and Valleys (26b)

Drainage Area: 40.5 square miles

Conservation Pool: Surface Area = 250 acres
Watershed/Lake Ratio: 104:1
Maximum Depth = 6.5 meters
Mean Depth = 2.5 meters
Storage Volume = 2,058 acre-feet
Estimated Retention Time = 1.15 years

Designated Uses: Primary Contact Recreation Class A; Expected Aquatic Life Support; Domestic Water Supply; Food Procurement; Ground Water Recharge; Industrial Water Supply; Irrigation Use; Livestock Watering Use.

303(d) Listings: Lake Coldwater Eutrophication: 2002, 2004, 2008, 2010, 2012 Kansas Cimarron River Basin Lakes.

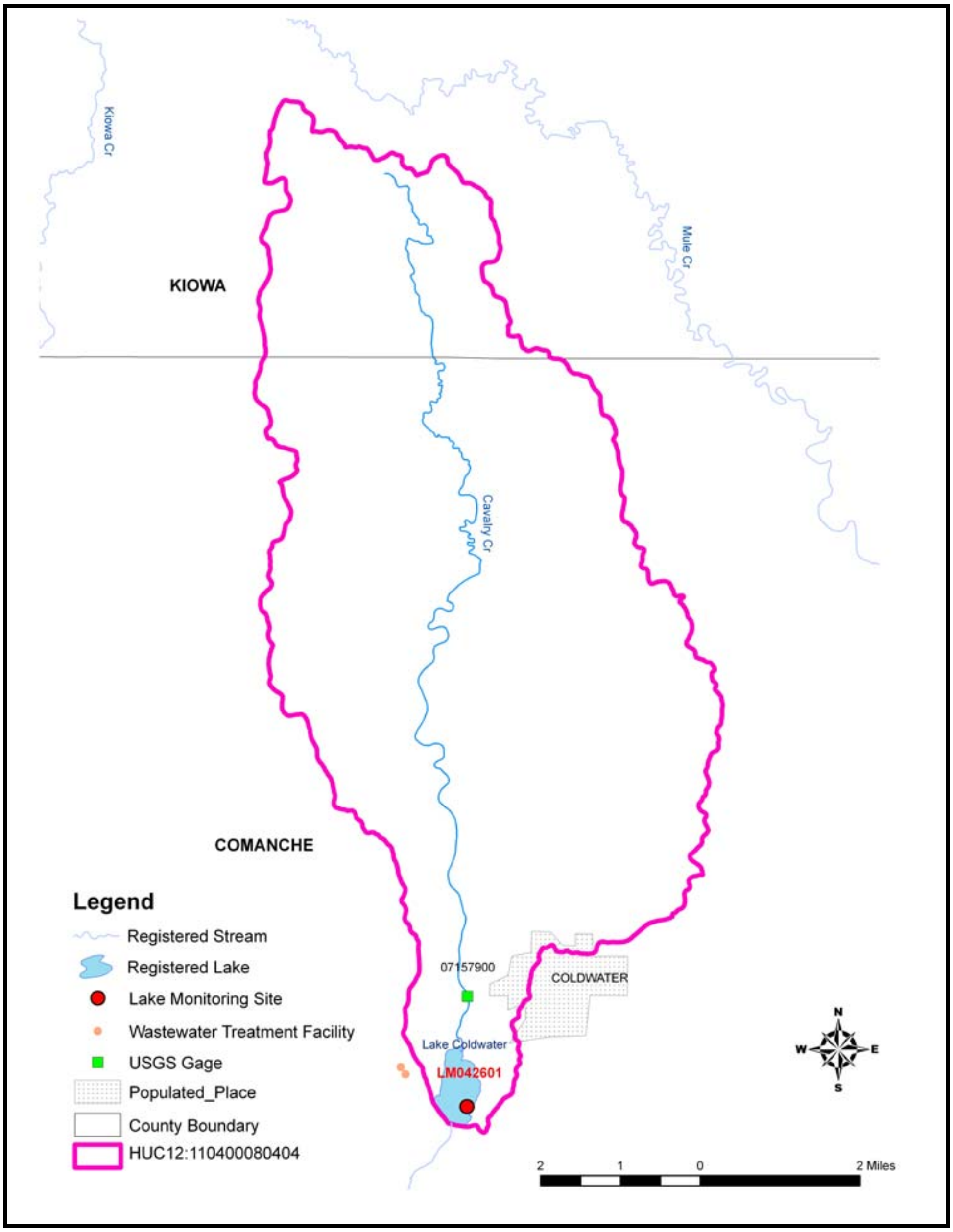
Impaired Use: All uses in Lake Coldwater are impaired to a degree by eutrophication.

Water Quality Criteria: 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)).

The introduction of plant nutrients into surface waters designated for domestic water supply use shall be controlled to prevent interference with the production of drinking water (KAR 28-16-28e(c)(3)(D)).

Figure 1. Lake Coldwater Watershed.



2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Support for Designated Uses under 2012 303(d): Excessive nutrients are not being controlled and are thus contributing to eutrophication which is impairing aquatic life use by supporting objectionable types and quantities of algae which also leads to impairment of contact recreation within Lake Coldwater. Lake Coldwater has no municipal water rights attached to its storage, it is not being used for domestic water supply, nor is it planned as a reserve for a municipal water supply. The chlorophyll *a* endpoint of 12 μg/L is appropriate to protect the immediate uses of aquatic life support and contract recreation in Lake Coldwater. Should the lake serve as a domestic or municipal water supply in the future, as evidenced by the installation of a point of diversion within the lake, a subsequent use attainability analysis will be conducted to ascertain if the 12 μg/L endpoint adequately supports such use in the lake.

Level of Eutrophication: Very Eutrophic, Trophic State Index = 63.1

The Trophic State Index (TSI) is derived from the chlorophyll *a* concentration. Trophic state assessments of potential algal productivity were made based on chlorophyll *a*, nutrient levels, and values of the Carlson Trophic State Index (TSI). Generally, some degree of eutrophic conditions is seen with chlorophyll *a* over 12 ppb and hypereutrophy occurs at levels over 30 ppb. The Carlson TSI derives from the chlorophyll *a* 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

Lake Monitoring Sites: KDHE Station LM042601 at Lake Coldwater.
Period of Record: Seven surveys conducted by KDHE in calendar years 1979, 1986, 1990, 1995, 1999, 2002, 2005.

Flow Record: USGS Gage 07157900.
Period of Record: October 1966 to October 1981.

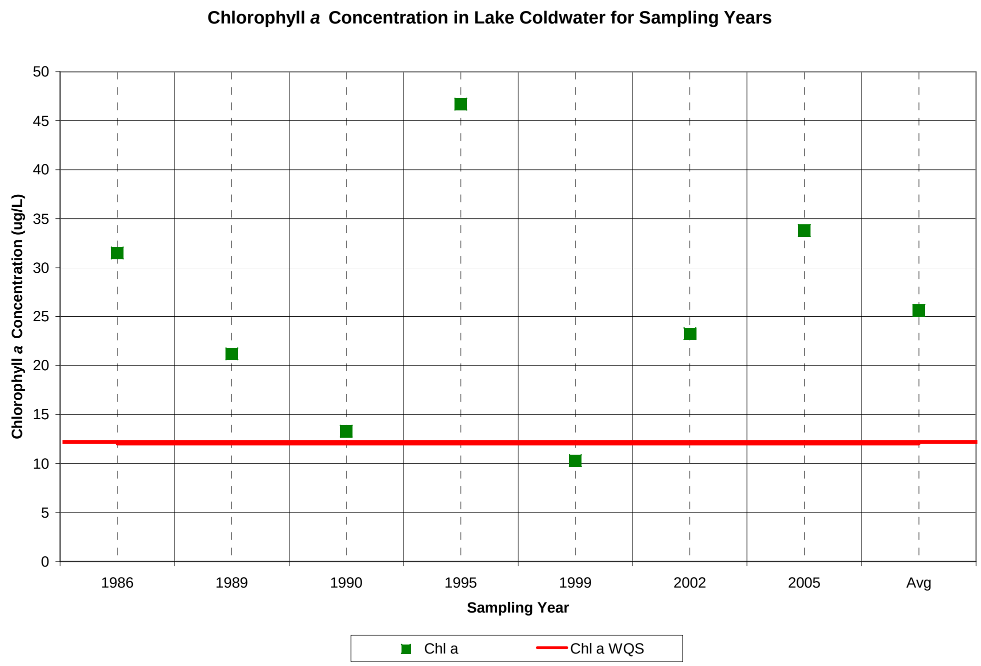
Long-Term Hydrologic Conditions: Calvary Creek (CUSEGA segment 110400083) above Lake Coldwater is the only registered stream directly feeding Lake Coldwater. The median flow of Calvary Creek above the lake is 1.50 cfs, the 10% exceedance flow is 2.90 cfs and the mean flow is 3.45 cfs (Table 1).

Table 1. Actual Long Term Flow Conditions as calculated from USGS gage information for the period of record for Calvary Creek. Flow Duration Values are in cubic feet per second (cfs) for the indicated percentage of time flow equaled or exceeded.

Location	Drainage Area (sq. mile)	Mean Flow	Median Flow	90%	75%	25%	10%
Calvary Creek at Coldwater, KS (USGS 07157900)	38.4	3.45	1.50	0.65	1.00	2.00	2.90

Current Condition: Over the period of record, Lake Coldwater had chlorophyll *a* concentrations averaging 25.6 μg/L. Chlorophyll *a* concentrations have been variable ranging from a low value of 10.3 μg/L in 1999 to a high value of 46.7 μg/L in 1995 (Figure 2).

Figure 2. Chlorophyll *a* concentrations in Lake Coldwater during 1986 – 2005 sampling years.



The average Secchi depth in Lake Coldwater is 0.58 meters with the lowest reading occurring in 1989 at 0.36 meters (Figure 3). Total phosphorus (TP) concentrations are available for the period of record (with the exception of 1989) and averaged 42.0 μg/L, ranging from 16.0 μg/L in 2005 to 70.0 μg/L in 1995 (Figure 4). Total nitrogen concentrations are available for the sampling years 1995, 1999, 2002 and 2005 and ranged from 485 μg/L in 1999 to 892 μg/L in 2002 with an average of 696 μg/L. Turbidity in Lake Coldwater, for the period of record, averaged 11.6 NTU with a range of 7.05 to 19.1 NTU while total suspended solids ranged from 14.0 to 32.5 mg/L (Table 2).

Figure 3. Secchi Depth at Lake Coldwater for the period of record.

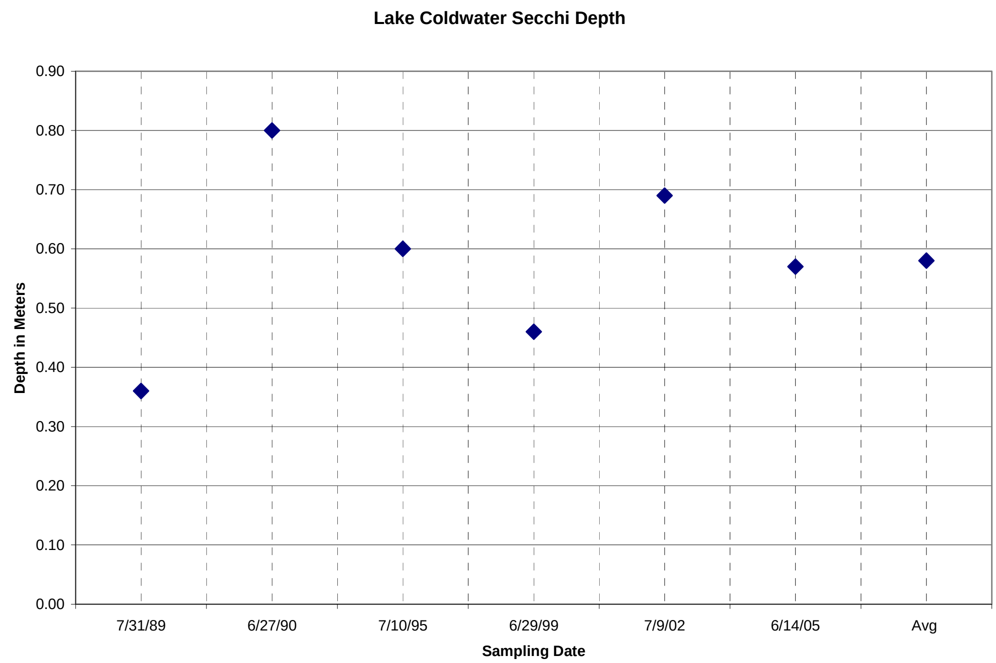
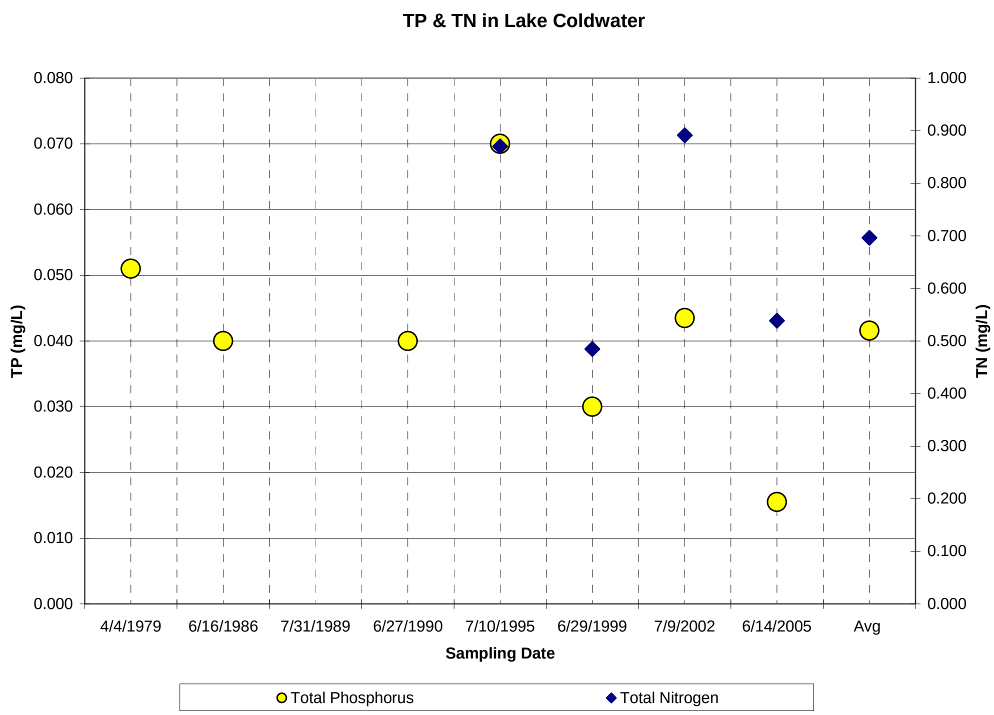


Figure 4. Average Total Phosphorus and Total Nitrogen concentration by sampling date.



The ratio of total nitrogen and total phosphorus has been used to determine which of these nutrients is most likely limiting plant growth in Kansas aquatic ecosystems. Generally, lakes that are nitrogen limited have water column TN:TP ratios < 8 (mass); lakes that are co-limited by nitrogen and phosphorus have water column TN:TP ratios between 9 and 21; and lakes that are phosphorus limited have water column TN:TP ratios > 29 (Dzialowski et al., 2005). Figure 5 shows movement from nitrogen/phosphorus co-limitation to phosphorus limitation, for the period of record. The TN:TP ratio peaks in 2005 with a TN:TP ratio of 34.7.

Figure 5. TN:TP ratio for period of record at Lake Coldwater.

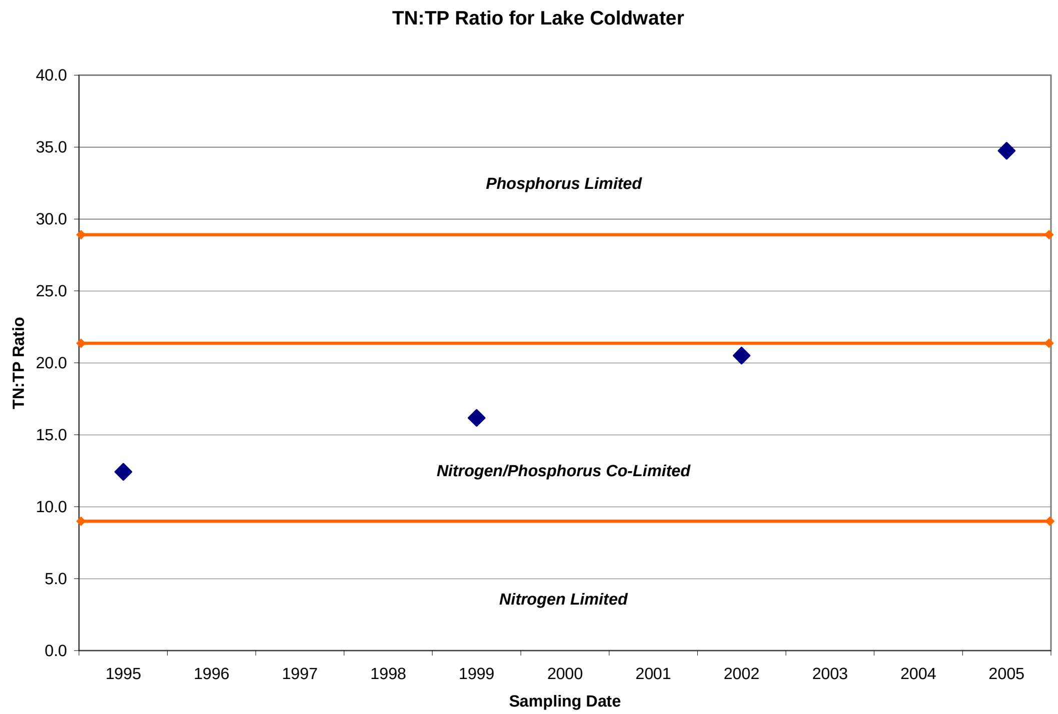


Table 2. Concentration averages for Lake Coldwater for the period of record.

Sample Year	Chl-a (µg/L)	TN (mg/L)	TP (mg/L)	TN:TP ratio	Secchi Depth (m)	Turbidity (NTU)	TSS (mg/L)
1979	*	*	0.051	*	*	11.0	18.5
1986	31.5	*	0.040	*	*	15.0	*
1989	21.2	*	*	*	0.360	*	*
1990	13.3	*	0.040	*	0.800	7.05	14.0
1995	46.7	0.870	0.070	12.4	0.600	9.00	25.0
1999	10.3	0.485	0.030	16.2	0.460	14.5	32.5
2002	23.3	0.892	0.044	20.5	0.690	6.6	14.5
2005	33.8	0.539	0.016	34.7	0.570	19.1	32.0
Average	*25.6*	*0.696*	*0.042*	*16.7*	*0.580*	*11.6*	*22.8*

* Data not available.

Table 3 lists the six metrics measuring the roles of light and nutrients in Lake Coldwater. Non-algal turbidity (NAT) values < $0.4m^{-1}$ indicates there are very low levels of suspended silt and/or clay. The values between 0.4 and $1.0m^{-1}$ indicate inorganic turbidity assumes greater influence on water clarity but would not assume a significant limiting role until values exceed $1.0m^{-1}$.

Table 3. Lake Coldwater limiting factor metrics.

Sampling Year	Non-algal Turbidity	Light Availability in the Mixed Layer	Partitioning of Light Extinction between Algae & Non-algal Turbidity	Algal use of Phosphorus Supply	Light Availability in the Mixed Layer for a Given Surface Light	Shading in Water Column due to Algae and Inorganic Turbidity	Chl-*a* (µg/L)
	NAT	**Zmix*NAT**	**Chl-a*SD**	**Chl-a/TP**	**Zmix/SD**	**Shading**	
1990	2.24	No Data Available	10.6	0.333	No Data Available	No Data Available	13.3
1995	0.499	No Data Available	28.0	0.667	No Data Available	No Data Available	46.7
1999	1.92	5.19	4.74	0.343	5.89	5.25	10.3
2002	0.868	1.94	16.0	0.534	3.24	4.06	23.3
2005	0.909	2.19	19.3	2.18	4.22	5.08	33.8

The depth of the mixed layer in meters (Z) multiplied by the NAT value assesses light availability in the mixed layer. There is abundant light within the mixed layer of the lake and potentially a high response by algae to nutrient inputs when this value is less than 3. Values greater than 6 would indicate the opposite.

The partitioning of light extinction between algae and non-algal turbidity is expressed as Chl-a*SD (Chlorophyll *a* * Secchi Depth). Inorganic turbidity is not responsible for light extinction in the water column and there is a strong algal response to changes in nutrient levels when this value is greater than 16. Values less than 6 indicate that inorganic turbidity is primarily responsible for light extinction in the water column and there is a weak algal response to changes in nutrient levels.

Values of algal use of phosphorus supply (Chl-a/TP) that are greater than 0.4 indicate a strong algal response to changes in phosphorus levels, where values less than 0.13 indicate a limited response by algae to phosphorus.

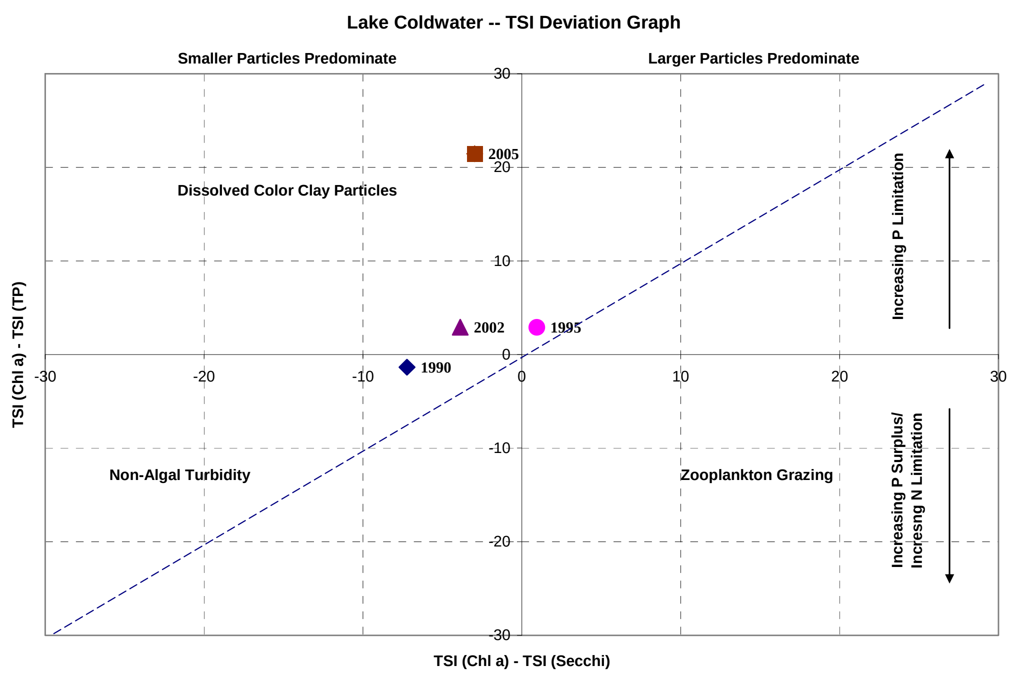
The light availability in the mixed layer for a given surface light is represented as Zmix/SD. Values less than 3 indicate that light availability is high in the mixed zone and there is a high probability of strong algal responses to changes in nutrient levels.

Shading values less than 16 indicate that self-shading of algae does not significantly impede productivity. This metric is most applicable to lakes with maximum depths of less than 5 meters (Carney, 2004).

The above metrics indicate inorganic turbidity and limited light availability in the mixed layer led to weak response to nutrient inputs in 1990 and 1999. However, in 1995, 2002 and 2005 there was abundant light in the water column leading to strong responses to changes in nutrient levels as evidenced by the Chlorophyll *a* levels for the respective years. Self shading of algae in Lake Coldwater does not appear to be impeding algal productivity.

Another method for evaluating limiting factors is the TSI deviation metrics. Figure 6 (Multivariate Deviation Graph) summarizes the current trophic conditions at Lake Coldwater using a multivariate TSI comparison chart for the period of record. Where TSI(Chl-a) is greater than TSI(TP), the situation indicates phosphorus is limiting chlorophyll *a*, whereas negative values indicate turbidity limits chlorophyll *a*. Where TSI(Chl-a)-TSI(SD) is plotted on the horizontal axis, if the Secchi depth (SD) trophic index is less than the chlorophyll *a* trophic index, then there is dominant zooplankton grazing. Transparency would be dominated by non-algal factors such as color or inorganic turbidity if the Secchi depth index were more than the chlorophyll *a* index. Points near the diagonal line occur in turbid situations where phosphorus is bound to clay particles and therefore turbidity values are closely associated with phosphorus concentrations.

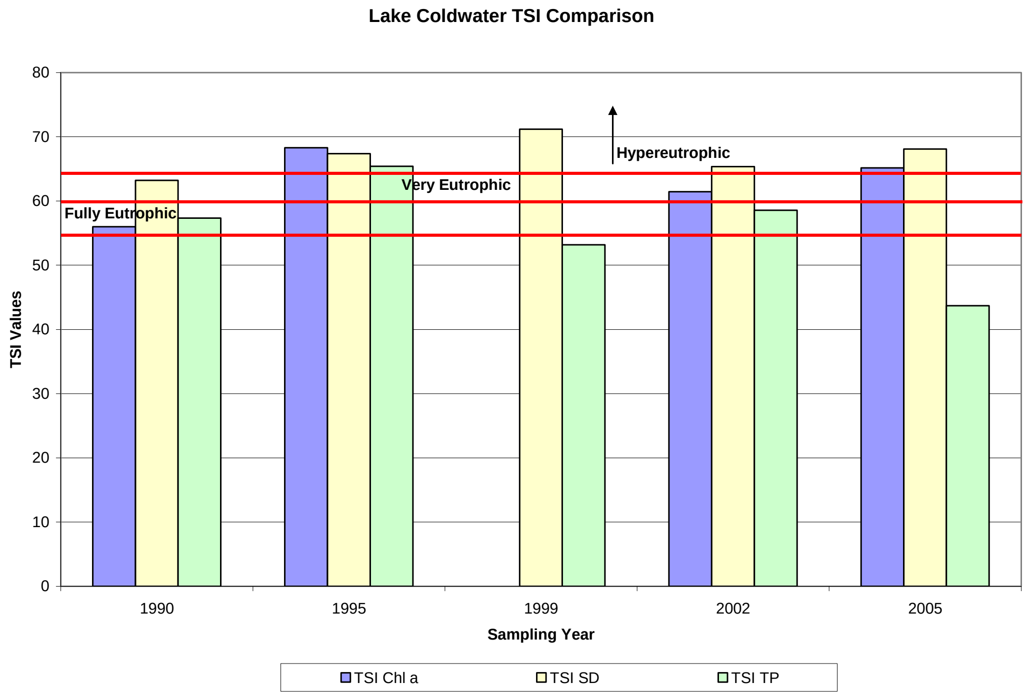
Figure 6. Multivariate TSI comparison chart for Lake Coldwater.



The multivariate TSI comparison chart in Figure 6 shows that phosphorus and inorganic turbidity are limiting chlorophyll *a* concentrations in Lake Coldwater.

The Carlson Trophic State Indices for Chlorophyll *a*, Secchi depth and total phosphorus in Lake Coldwater (Figure 7) shows the lake has been fully eutrophic state since at least 1990 with all three TSI values reaching hypereutrophic status in 1995. An improvement in the total phosphorus TSI is seen in the last year for the period of record (2005) but the reduction in the phosphorus TSI is not reflected in the chlorophyll *a* and secchi depth TSI values.

Figure 7. Lake Coldwater Trophic State Indices (Chl *a* TSI not available for 1999).



The median trophic conditions within Lake Coldwater compared to Federal lakes in the state are summarized in Table 4. Trophic Indicators in Lake Coldwater meet the Federal Lake benchmarks for total phosphorus and total nitrogen while missing the mark for secchi depth and chlorophyll *a*. The tropic indicator values within Lake Coldwater do not meet any of the Kansas statewide benchmarks, however.

Table 4. Median trophic indicator values of Lake Coldwater in comparison with federal lakes and draft nutrient benchmarks in Kansas. The nutrient benchmarks were derived from 47-58 lakes and reservoirs, based on the data collected between 1985-2002 (Dodds et al., 2006).

Trophic Indicator	Lake Coldwater	Federal Lake	Statewide Benchmark
Secchi Depth (cm)	58.5	95	129
TN (µg/L)	724	903	625
TP (µg/L)	40.0	76	23
Chlorophyll *a* (µg/L)	23.3	12	8

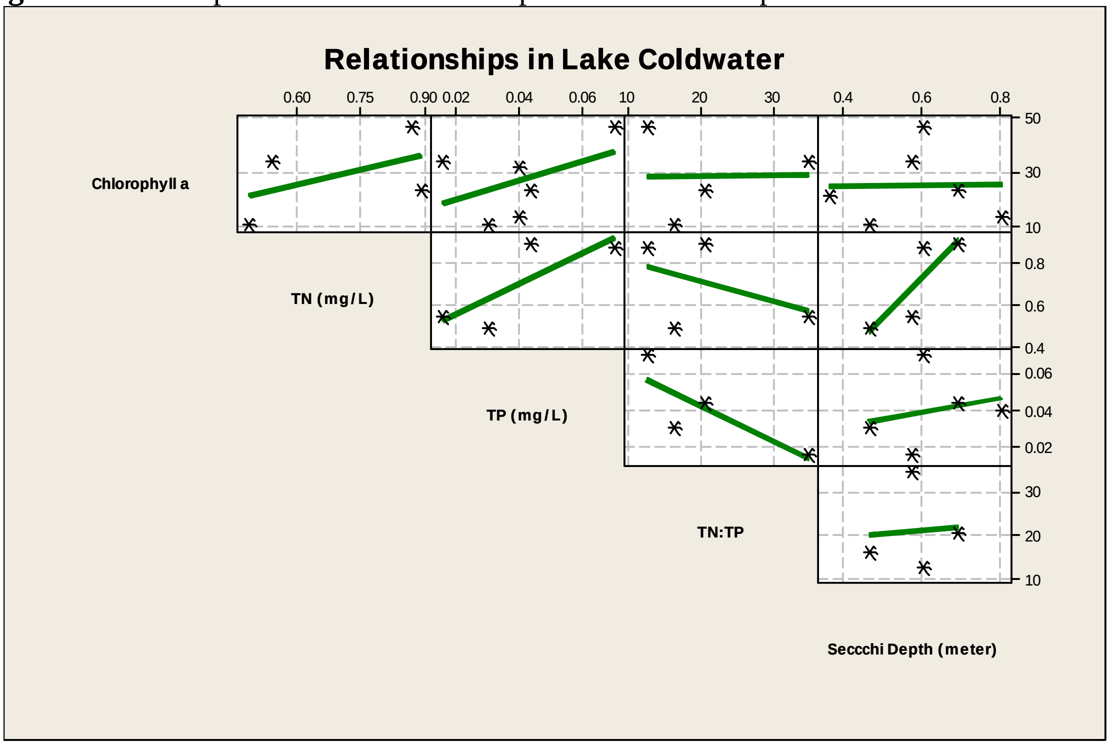
Algal Communities: As expected and seen in Table 5, chlorophyll *a* concentrations increase with an increase in total cell count in Lake Coldwater. Although 75% of the communities observed in 1995 were classified as blue-green algae or cyanobacteria, the percentage of blue-green algae observed in Lake Coldwater has steadily decreased over the period of record and there were no blue-green algae communities observed in the 2005 sampling.

Table 5. Algal communities observed in Lake Coldwater during KDHE sampling years.

Sampling Date	Total Cell Count cells/mL	Percent Composition				Chl-*a* µg/L
		Green	Blue-Green	Diatom	Other	
1995	56950	10	75	14	1	46.7
1999	3623	65	24	10	1	10.3
2002	5607	15	11	17	57	23.3
2005	65520	6	0	94	0	33.8

Relationships: Within Lake Coldwater there are poor relationships between: chlorophyll *a* and the TN:TP ratio; chlorophyll *a* and secchi depth; secchi depth and total phosphorus and secchi depth and the TN:TP ratio. There are moderate relationships between: chlorophyll *a* and total nitrogen; chlorophyll *a* and total phosphorus and total nitrogen and total phosphorus (Figure 8).

Figure 8. Matrix plot of Lake Coldwater parameters for the period of record.



Stream Data: There is not a KDHE monitoring station associated with Calvary Creek, above Lake Coldwater. There is flow data for Calvary Creek for the period of 10/1/1966 through 10/31/1981 for USGS gage 07157900 that was located above Lake Coldwater (Figure 9). Flow data for the creek reveals a median flow of 1.50 cfs and a 10% exceedance of 2.90 cfs (Table 1). Average monthly flows in Calvary Creek (Figure 10) show seasonal variability of the monthly average flows and is typical for seasonal fluctuations in rainfall amounts. The high average flows in May, June and September reflect seasonal high intensity rainfall events while the low median flows during July, August and September point to favorable conditions for algal growth in Lake Coldwater.

Figure 9. Flow Duration Curve for Calvary Creek at USGS 07157900.

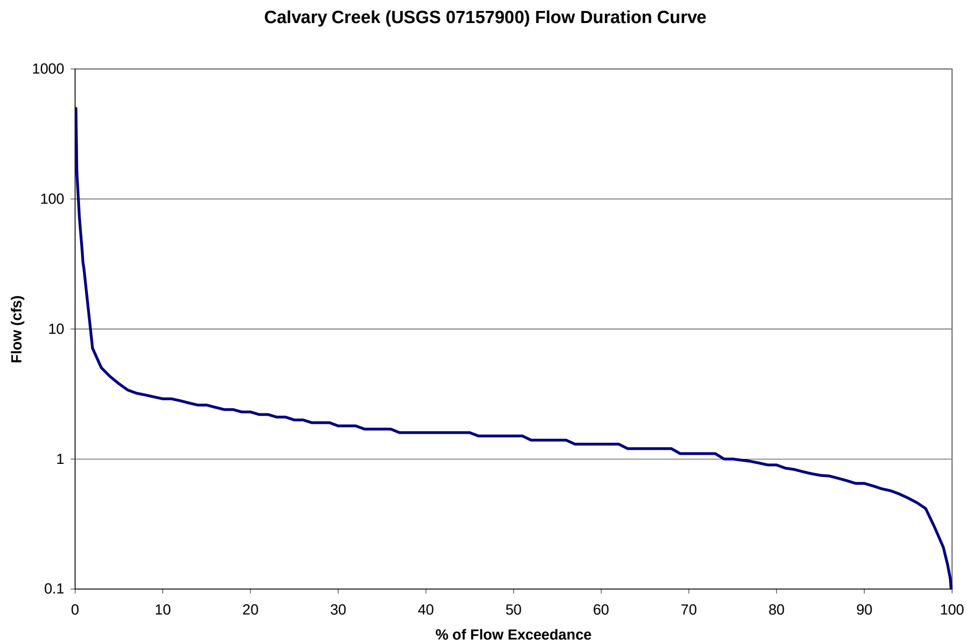
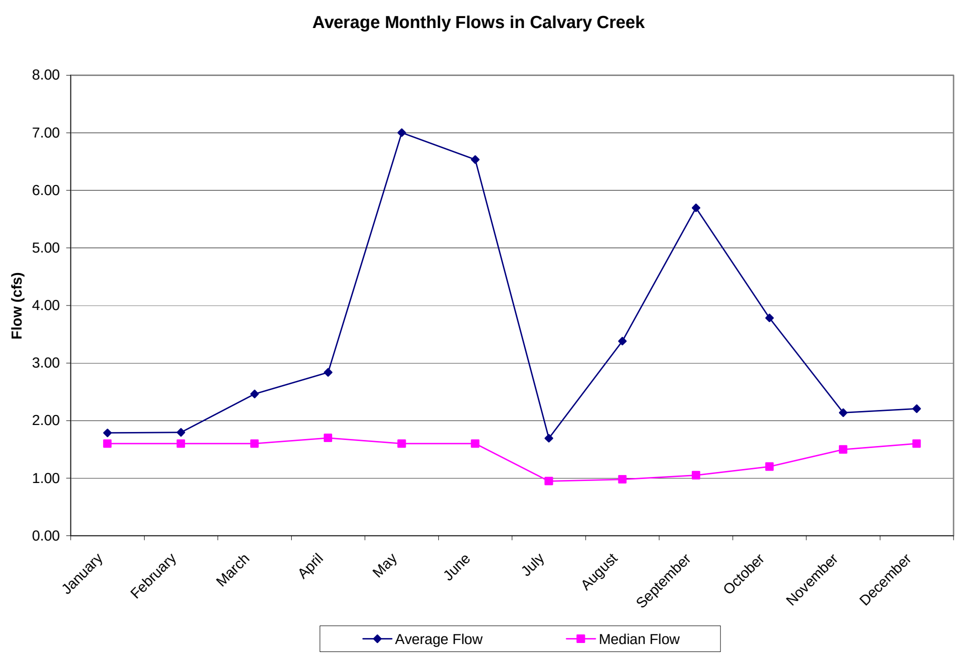


Figure 10. Average monthly flows in Calvary Creek for the period of record.



Desired Endpoints of Water Quality (Implied Load Capacity) in Lake Coldwater:

In order to improve the trophic condition of Lake Coldwater from its current Very Eutrophic status, the desired endpoint will be to maintain summer chlorophyll *a* average concentrations below 12 μg/L with a corresponding TSI of 55, with the reductions focused on phosphorus and nitrogen loading in the lake. Reductions in phosphorus and nitrogen loading will address the accelerated succession of aquatic biota and the development of objectionable concentrations of algae and algae by-products as determined by the chlorophyll *a* concentrations in the lake. The chlorophyll *a* endpoint of 12 μg/L will ensure long-term protection to fully support Primary Contact Recreation and Aquatic Life Use within the lake. Should Lake Coldwater become an active or reserve municipal water supply, as determined by the addition of a point of diversion for municipal use, a use attainability analysis will be conducted to ascertain if the12 μg/L endpoint adequately supports such use in the lake.

Based on the BATHTUB reservoir eutrophication model (Appendix A); total phosphorus and total nitrogen concentrations entering the lake must be reduced by 65% by way of Calvary Creek. With this reduction, the endpoint for Lake Coldwater will be met. This reduction at the inflow to Lake Coldwater will result in a 48% reduction in total phosphorus concentration, a 36% reduction in total nitrogen concentration and a 53% reduction in Chlorophyll *a* concentration in Lake Coldwater (Table 6). Achievement of the endpoint indicates loads are within the loading capacity of the lake, the water quality standards are attained, and full support of the designated uses of the lake has been achieved. Seasonal variation has been incorporated in this TMDL since the peaks of algal growth occur in the summer months. The current average condition for Lake Coldwater utilized in the model input was based on data from 1979-2005 from KDHE station LM042601 for the main basin of the lake. Water quality data for Calvary Creek was estimated based on data from 1993-2009 from KDHE sampling station SC624 located below Lake Coldwater on Calvary Creek. Flow data for Calvary Creek was based on USGS gage 07157900 data for the period of 1966 through 1981.

Table 6. Lake Coldwater Current average condition and TMDL based on BATHTUB.

	Current Avg. Condition	TMDL	Percent Reduction
Total Phosphorus – Annual Load (lbs/year)	466.35	177.76	62%
Total Phosphorus – Daily Load* (lbs/day)	3.06	1.166	62%
Total Phosphorus – Lake Concentration (mg/L)	0.042	0.022	48%
Total Nitrogen – Annual Load (lbs/year)	5,524	2,957	46%
Total Nitrogen – Daily Load* (lbs/day)	29.2	15.65	46%
Total Nitrogen – Lake Concentration (mg/L)	0.696	0.444	36%
Chlorophyll *a* Concentration (μg/L)	25.6	12	53%

*See Appendix B for Daily Load Calculations

3. SOURCE INVENTORY AND ASSESSMENT

Point Sources: There is one NPDES permitted facility in the Lake Coldwater watershed (Table 7). The facility is a non-overflowing lagoon system that is prohibited from discharging and would only contribute a nutrient load under extreme precipitation or flooding events. Such events would not occur at a frequency or for duration sufficient to cause impairment in the watershed.

Table 7. NPDES permitted facilities the Lake Coldwater watershed.

Discharging Facility	NPDES Permit #	State Permit #	Type	Expiration Date
Lakins Development	KSJ000546	C-NE55-NO01	2 Cell Lagoon Non-Overflowing	September 30, 2014

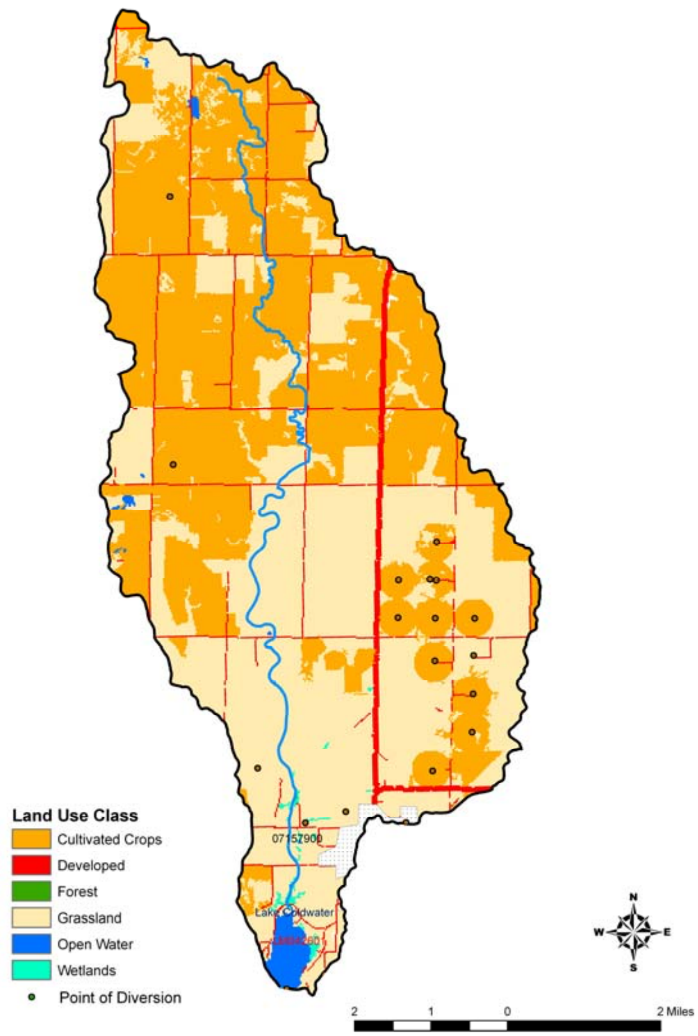
Livestock Waste Management Systems: There is only one certified confined animal feeding operation (CAFO) within the Lake Coldwater watershed (Table 8). However, according to USDA National Agricultural Statistics Service, on January 1, 2010 cattle inventories for Kiowa and Comanche counties were 24,000 and 46,000 head, respectively indicating there are smaller unpermitted livestock operations within the watershed that may be contributing to the nutrient load in Lake Coldwater. Permitted and certified and livestock facilities have waste management systems designed to minimize runoff entering the operation and/or detain runoff emanating from their facility. 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 operation. Typically, this rainfall event coincides with streamflow occurring less than 1-5% of the time.

Table 8. The CAFO within the Lake Coldwater watershed.

Permit Number	Type	County	Animal Total
A-CICM-MA01	Dairy	Comanche	100

Land Use: The predominant land uses in the Lake Coldwater watershed are grassland (48.3%) and cultivated cropland (46.4%), according to the 2001 National Land Cover Data (Figure 11). Together they account for 94.7% of the total land area in the watershed and fertilizer applications to the cropland along with livestock grazing may be contributing to the nutrient load in Lake Coldwater. The remaining 5.3% of land area is comprised of developed space (2.9%), open water (1.4%) and wetlands (1.0%).

Figure 11. Land Use (2001 NLCD) & Points of Diversion in the Lake Coldwater watershed.

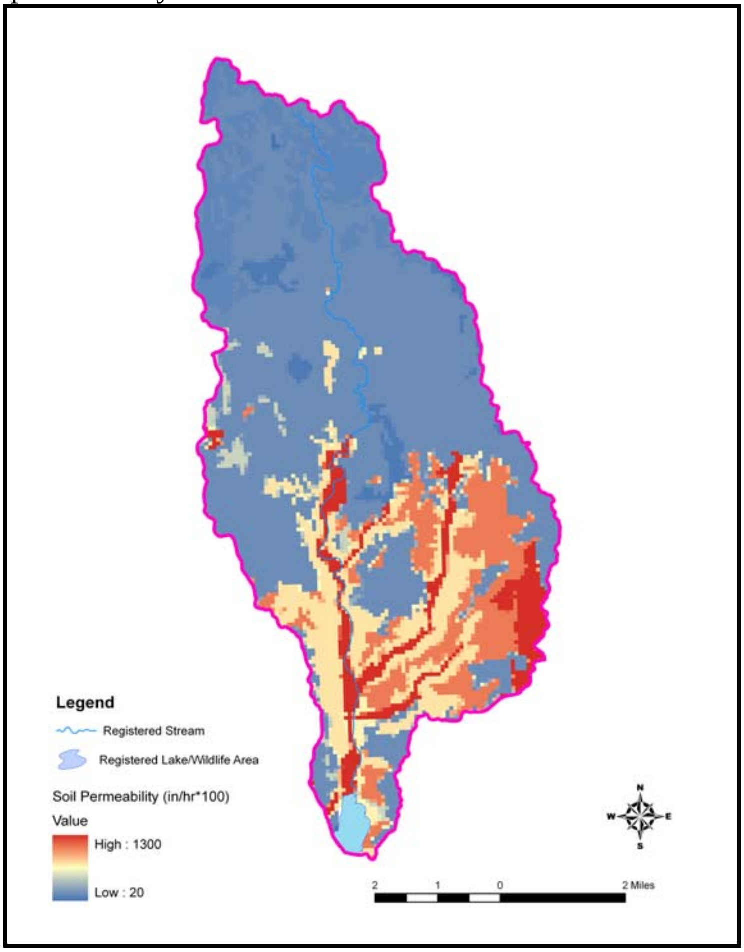


Points of Diversion: There are 466 and 106 unique points of diversion in Kiowa and Comanche Counties, respectively. The Lake Coldwater watershed contains eighteen points of diversion with seventeen of them located in the portion of the watershed that lies within Comanche County (Figure 11). All eighteen points of diversion are wells tied to groundwater rights with two points designated for industrial use and three for municipal use. The remaining thirteen points are designated for use in irrigating.

On-Site Waste Systems: The Lake Coldwater watershed is a rural agricultural area and, based on 1990 census data, about 20% of households in Kiowa County and 35% of households in Comanche County utilize septic or other on-site systems. According to the STEPL model, there are twenty-four septic tanks within the Lake Coldwater watershed (HUC 12: 110400080404) and although there is no way to determine how many of them are compromised, failing on-site septic systems may contribute significant nutrient loadings and aggravate eutrophication problems.

Contributing Runoff: The watershed of Lake Coldwater has a mean soil permeability value of 3.54 inches/hour, ranging from 0.20 inches/hour to 13.0 inches/hour according to NRCS STATSGO database (Figure 12). About 19% of the watershed has a permeability value less than 1.29 inches/hour, which contributes to runoff during very low to low rainfall intensity events. 18.5% of the watershed has a permeability value of 6.17 inches/hour, 23.0% has a permeability value of 8.80 inches/hour and 20.0% has a permeability value of 13.0 inches/hour, all considered very high soil permeability values. According to a USGS open-file report (Juracek, 2000), the threshold soil-permeability values are set at 3.43 inches/hour for very high, 2.86 inches/hour for high, 2.29 inches/hour for moderate, 1.71 inches/hour for low, 1.14 inches/hour for very low, and 0.57 inches/hour for extremely low soil-permeability. Runoff is primarily generated as infiltration excess when rainfall intensities are greater than soil permeability. As the watersheds' soil profiles become saturated, excess overland flow is produced.

Figure 12. Soil permeability in the Lake Coldwater watershed.



Background/Natural Contributions: Leaf litter and wastes derived from the natural wildlife may add to the nutrient load. Atmospheric deposition from geological formations may also contribute to nutrient loads. The suspension of sediment and nutrients may be influenced by the wind and bottom feeding fish may also re-suspend sediment and contribute to available nutrients in the lake. Because Lake Coldwater is a small lake, nutrient cycling of the sediment is likely contributing available nutrients to the lake for algal uptake.

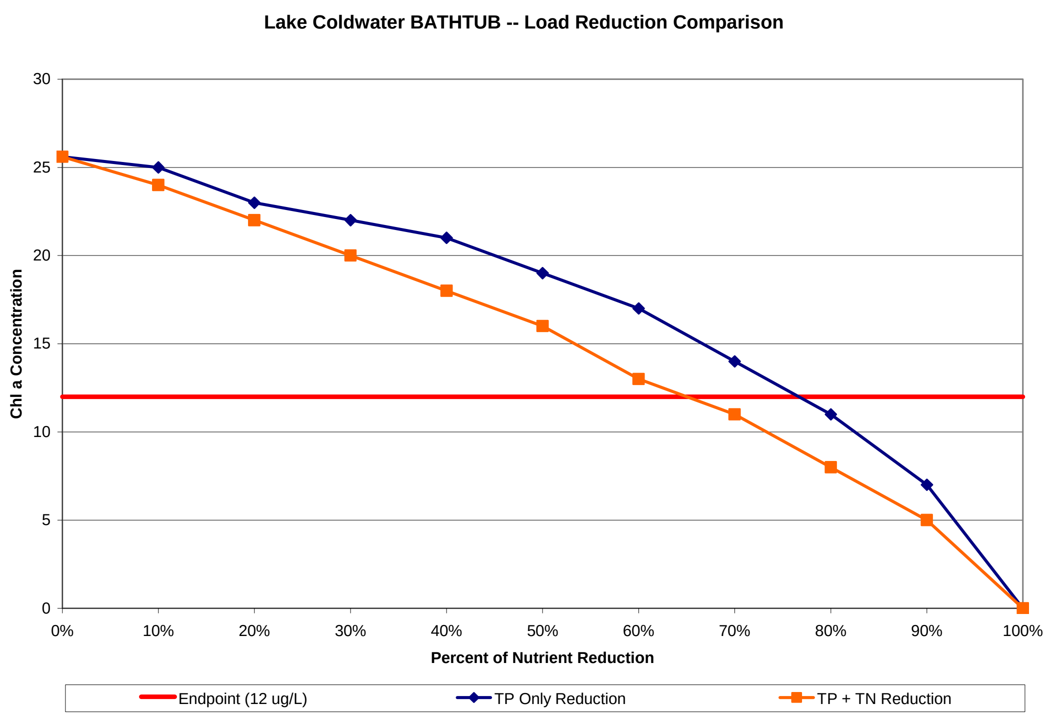
4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

Although the most recent sampling of Lake Coldwater points to phosphorus as the limiting nutrient, earlier surveys show a phosphorus/nitrogen co-limitation resulting in allocations for both phosphorus and nitrogen under this TMDL. The general inventory of sources within the drainage area of the lake indicates load reductions should be focused on nonpoint source runoff contributions attributed to fertilizer applicators and smaller livestock facilities. Because of atmospheric deposition, the allocation of phosphorus will include a proportional decrease in phosphorus between the current condition and the desired endpoint.

The lake model utilized for the development of the TMDL was BATHTUB. 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).

Lake Coldwater was evaluated as one section, the main basin, in the BATHTUB model due to its small size. Atmospheric total nitrogen was obtained from the Clean Air Status and Trends Network (CASTNET), which is available at http://www.epa.gov/castnet. The CASTNET station from the Konza Prairie (KS) was used to estimate the atmospheric TN concentration for the model. Total phosphorus atmospheric loading was estimated using the 1983 study of Rast and Lee. Water quality data from the main basin segment was averaged using the 1979-2005 data from KDHE (LM042601). Model input data for Calvary Creek was generated using the averages of the 1993-2009 data from KDHE sampling station SC624 located downstream from Lake Coldwater on Calvary Creek. The BATHTUB model was calibrated for the main basin (Appendix A) and results estimate that the lake retains 60% of the TP and 44% of the TN load annually. Based on modeling results, the combined reduction of TP and TN results in reaching the chlorophyll *a* endpoint more readily than reducing TP alone (Figure 13). Hence, a 65% reduction of both total phosphorus and total nitrogen within the inflow of Calvary Creek is necessary to achieve the TMDL endpoint of 12 μg/L of chlorophyll *a* within Lake Coldwater.

Figure 13. Changes in Chlorophyll *a* levels in relation to watershed nutrient reduction.



Point Sources: A current Wasteload Allocation of zero is assigned for phosphorus and nitrogen under this TMDL because of the lack of point sources in the watershed. Should future sources be proposed in the watershed, the current wasteload allocations will be revised by adjusting current load allocations to account for the presence and impact of these new point source dischargers.

Nonpoint Sources: Nonpoint sources are the main contributor for the nutrient input and impairment in Lake Coldwater. Background levels may be attributed to nutrient recycling and leaf litter. The assessment suggests that runoff transporting nutrient loads associated with animal wastes and cultivated crops where fertilizer has been applied, to include pasture and hay, contribute to the hypereutrophic condition of the lake. Load Allocations for Lake Coldwater are in Table 9 and were calculated using the BATHTUB model (Appendix A).

Table 9. Lake Coldwater TMDL

Description	Allocations (lbs/year)	Allocations (lbs/day)*
Total Phosphorus Atmospheric Load	22.27	0.146
Total Phosphorus Nonpoint Source Load	137.1	0.903
Total Phosphorus Margin of Safety	17.776	0.117
Total Phosphorus TMDL	177.76	1.166
Total Nitrogen Atmospheric Load	1,579	8.36
Total Nitrogen Nonpoint Source Load	1,082	5.72
Total Nitrogen Margin of Safety	295.7	1.57
Total Nitrogen TMDL	2,957	15.65

*See Appendix B for Daily Load Calculations

Defined Margin of Safety: The margin of safety provides some hedge against the uncertainty of variable annual total phosphorus and total nitrogen loads and the chlorophyll *a* endpoint. Therefore, the margin of safety is explicitly set at 10% of the original calculated total phosphorus and total nitrogen load allocations, which compensates for the lack of knowledge about the relationship between the allocated loadings and the resulting water quality. The margin of safety is expressed in Table 9.

State Water Plan Implementation Priority: This TMDL will be a Low Priority for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Upper Cimarron – Bluff Subbasin (HUC 8 11040008) with a priority ranking of 52 (Low Priority for restoration work).

Priority HUC 12: The entire watershed is within HUC 12 110400080404.

5. IMPLEMENTATION

Desired Implementation Activities: There is a very good potential that agricultural best management practices will improve the condition of Lake Coldwater. Some of the recommended agricultural practices are as follows:

1. Implement soil sampling to recommend appropriate fertilizer applications on cultivated cropland.
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 and drainage channels in the watershed.
5. Reduce activities within riparian areas.
6. Implement nutrient management plans to manage manure land applications and runoff potential.
7. Adequately manage fertilizer utilization in the watershed and implement runoff control measures.

Implementation Program Guidance:

Watershed Management Program – KDHE

a. Support selected Section 319 project activities including demonstration projects and outreach efforts dealing with erosion and sediment control and nutrient management.
b. Provide technical assistance on practices geared to the establishment of vegetative buffer strips.
c. Provide technical assistance on nutrient management in the vicinity of streams.

Water Resource Cost Share and Nonpoint Source Pollution Control Programs – Kansas Department of Agriculture, Division of Conservation

a. Apply conservation farming practices and/or erosion control structures, 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. Re-evaluate nonpoint source pollution control methods.

Riparian Protection Program – Kansas Department of Agriculture, Division of Conservation

a. Establish, protect 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 – Kansas Department of Agriculture, Division of Conservation

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 planning.
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.

Time Frame for Implementation: Initial implementation will proceed over the years from 2012-2016. Additional implementation may be required over 2017-2021 to achieve the endpoints of this TMDL.

Targeted Participants: Primary participants for implementation will be agricultural producers and stakeholders within the Lake Coldwater watershed. A detailed assessment of sources conducted over 2012-2013 should include local assessments by conservation district personnel and county extension agents to survey, locate, and assess the following within the lake drainage area:

1. Total row crop acreage and fertilizer application rates,
2. Cultivation alongside lake,
3. Livestock use of riparian areas,
4. Fields with manure applications.

Milestone for 2016: In accordance with the TMDL development schedule for the State of Kansas, the year 2016 marks the next cycle of 303(d) activities in the Cimarron Basin. At that point in time, sampled data from Lake Coldwater will be reexamined to assess improved conditions in the lake. Should the impairment remain, adjustments to source assessment, allocation, and implementation activities may occur.

Delivery Agents: The primary delivery agents for program participation will be the Kansas Department of Health and Environment, the Kansas Department of Agriculture – Division of Conservation, the Natural Resources Conservation Service, the Kansas State University Extension Service, and the Comanche and Kiowa County Conservation Districts. Producer outreach and awareness will be delivered by Kansas State University Extension Office.

Reasonable Assurances:

Authorities: The following authorities may be used to direct activities in the watershed to reduce pollutants and to assure allocations of pollutant to point and nonpoint sources can be attained.

1. 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.

2. 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.

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 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control nonpoint source pollution.

5. 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.

6. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the Kansas Water Plan, including selected Watershed Restoration and Protection Strategies.

7. The Kansas Water Plan and the Cimarron 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.

8. K.S.A. 32-807 authorizes the 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 pollutant 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.

Additionally, $2 million has been allocated between the State Water Plan Fund and EPA 319 funds to support implementation of Watershed Restoration and Protection Strategies. This watershed and its TMDL are a Low Priority consideration for funding.

Effectiveness: Nutrient control has been proven effective through conservation tillage, contour farming and use of grass waterways and buffer strips. In addition, the proper implementation of comprehensive livestock waste management plans has proven effective at reducing nutrient runoff associated with livestock facilities. The key to success will be widespread utilization of conservation farming and proper livestock waste management within the watershed cited in this TMDL.

6. MONITORING

KDHE will continue its 3-year sampling schedule in order to assess the trophic state of Lake Coldwater. Based on the sampling results, the 303(d) listing will be evaluated after 2022. The desired endpoints under this TMDL are refined and sampling conducted over the period 2021-2025 will be used to assess any progress in this implementation.

7. FEEDBACK

Public Notice: An active Internet Web site was established at www.kdheks.gov/tmdl/ to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Cimarron Basin.

Public Hearing: A Public Hearing was held September 20th, 2012 in Garden City to receive comments on this TMDL.

Milestone Evaluation: In accordance with the TMDL development schedule for the State of Kansas, the year 2016 marks a future cycle of 303(d) activities in the Cimarron Basin. At that point in time, sample data from Lake Coldwater will be reexamined to assess improved conditions in the lake. Should the impairment remain, adjustments to source assessment, allocation, and implementation activities may occur.

Consideration for 303d Delisting: Lake Coldwater will be evaluated for delisting under Section 303d, based on the monitoring data over 2012-2021. Therefore, the decision for delisting will come about in the preparation of the 2022-303d 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 might 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, the next anticipated revision would come in 2012. Recommendations of this TMDL will be considered in the Kansas Water Plan implementation decisions under the State Water Planning Process for Fiscal Years 2012-2021.

Developed 12/18/12

References

Carney, E.. 1995, 1999, 2002, 2005. Lake and Wetland Monitoring Program Annual Report/ Summary. Kansas Department of Health and Environment.

Dodds W.K., E. Carney, and R.T. Angelo, 2006. Determining ecoregional reference conditions for nutrient, Secchi depth and chlorophyll *a* in Kansas lakes and reservoirs. Lake and Reservoir Management 22(2): 151-159.

Dzialowski, A.R., S.H. Wang, N.C. Lim, W.W. Spotts and D.G. Huggins. 2005; Nutrient Limitation of Phytoplankton Growth in Central Plains Reservoirs, USA; Journal of Plankton Research; 27 (6): 587-595.

Juracek, K.E., 2000. Soils – Potential Runoff. U.S. Geological Survey Open-File Report 00-253.

National Agricultural Statistics Service. April 13, 2011. State and County Data. http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats_1.0/index.asp

Perry, C.A., D.M. Wolock and J.C. Artman, 2004. Estimates of Flow Duration, Mean Flow, and Peak-Discharge Frequency Values for Kansas Stream Location, USGS Scientific Investigations Report 2004-5033.

Soil and Water Conservation Society of Metro Halifax. 2007. The Blue-Green Algae (Cyanobacteria). http://lakes.chebucto.org/cyano.html

Spreadsheet Tool for the Estimation of Pollutant Load (STEPL). Version 4.0. 2008 Land Cover Data. Tetra Tech, Inc for U.S. EPA.

Walker, W.W. Jr., 1996. Simplified procedures for eutrophication assessment and prediction: user manual. Instructional Report W-96-2. U.S. Army Engineer Waterways Experiment Station. Vicksburg, MS.

WIMAS Query. Kansas Geological Survey. February 9, 2011. http://hercules.kgs.ku.edu/geohydro/wimas/query_setup.cfm

Appendix A. BATHTUB Model Summary

Case Data

Current Condition, Lake Coldwater

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.579	0.2
Evaporation (m)	1.631	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km²-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	10	0.10
Total N	709	0.05
Ortho P	10	0.10
Inorganic N	709	0.05

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	2	2ND ORDER, DECAY
Nitrogen Balance	2	2ND ORDER, DECAY
Chlorophyll-a	1	P, N, LIGHT, T
Secchi Depth	1	VS. CHLA & TURBIDITY
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m⁻¹)		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km²	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Near Dam	0	1	1.01	2.5	1.638	2.5	0.12	0	0	1.28	0.52	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	41.6	0.43	696	0.31	25.6	0.51	0.58	0.27	529	0.48	18.7	0.43	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm³/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km²	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Calvary Creek	1	1	104.89	3.08	0.1	0	0	65.4	1.3	581	0.59	29.4	1.3	414	0.52

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.795	0.45
Total Nitrogen	2.035	0.55
Chl-a Model	2.026	0.26
Secchi Model	1.200	0.10
Organic N Model	0.650	0.12
TP-OP Model	0.400	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m²/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Model Output – Current Condition
Diagnostics – Main Basin
Current Condition. Lake Coldwater

Segment:	1	Near Dam				
	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	41.6	1.05	43.8%	41.6	0.43	43.8%
TOTAL N MG/M3	696.0	0.40	28.5%	696.0	0.31	28.5%
C.NUTRIENT MG/M3	30.7	0.63	42.5%	30.7	0.37	42.5%
CHL-A MG/M3	25.6	0.76	90.4%	25.6	0.51	90.4%
SECCHI M	0.6	0.39	23.6%	0.6	0.27	20.7%
ORGANIC N MG/M3	544.1	0.54	60.7%	529.0	0.48	58.5%
TP-ORTHO-P MG/M3	28.7	0.51	48.2%	18.7	0.43	30.9%
ANTILOG PC-1	532.2	1.07	72.3%	545.8	0.41	73.0%
ANTILOG PC-2	9.3	0.45	76.1%	8.8	0.41	72.8%
(N - 150) / P	13.1	1.13	35.2%	13.1	0.57	35.2%
INORGANIC N / P	11.8	4.27	17.6%	7.3	2.16	7.9%
TURBIDITY 1/M	1.3	0.52	80.1%	1.3	0.52	80.1%
ZMIX * TURBIDITY	3.2	0.53	50.8%	3.2	0.53	50.8%
ZMIX / SECCHI	4.0	0.41	38.1%	4.3	0.29	43.1%
CHL-A * SECCHI	16.0	0.68	73.8%	14.8	0.58	70.2%
CHL-A / TOTAL P	0.6	0.57	96.4%	0.6	0.66	96.4%
FREQ(CHL-a>10) %	88.6	0.26	90.4%	88.6	0.17	90.4%
FREQ(CHL-a>20) %	53.5	0.91	90.4%	53.5	0.60	90.4%
FREQ(CHL-a>30) %	28.6	1.47	90.4%	28.6	0.98	90.4%
FREQ(CHL-a>40) %	15.2	1.92	90.4%	15.2	1.29	90.4%
FREQ(CHL-a>50) %	8.2	2.29	90.4%	8.2	1.55	90.4%
FREQ(CHL-a>60) %	4.6	2.60	90.4%	4.6	1.77	90.4%
CARLSON TSI-P	57.9	0.26	43.8%	57.9	0.11	43.8%
CARLSON TSI-CHLA	62.4	0.12	90.4%	62.4	0.08	90.4%
CARLSON TSI-SEC	66.8	0.09	76.4%	67.8	0.06	79.3%

Model Output – Current Conditions
Overall Water and Nutrient Balances
Current Condition, Lake Coldwater

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	Calvary Creek	104.9	3.1	9.49E-02	0.10	0.03
PRECIPITATION				1.0	0.6	1.37E-02	0.20	0.58
TRIBUTARY INFLOW				104.9	3.1	9.49E-02	0.10	0.03
***TOTAL INFLOW				105.9	3.7	1.09E-01	0.09	0.03
ADVECTIVE OUTFLOW				105.9	2.0	3.53E-01	0.29	0.02
***TOTAL OUTFLOW				105.9	2.0	3.53E-01	0.29	0.02
***EVAPORATION					1.6	2.44E-01	0.30	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentr
Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)²	%Total	CV
1	1	1	Calvary Creek	201.4	95.2%	6.90E+04	100.0%	1.30
PRECIPITATION				10.1	4.8%	1.02E+00	0.0%	0.10
TRIBUTARY INFLOW				201.4	95.2%	6.90E+04	100.0%	1.30
***TOTAL INFLOW				211.5	100.0%	6.90E+04	100.0%	1.24
ADVECTIVE OUTFLOW				83.9	39.7%	7.80E+03		1.05
***TOTAL OUTFLOW				83.9	39.7%	7.80E+03		1.05
***RETENTION				127.6	60.3%	4.26E+04		1.62

Overflow Rate (m/yr)	2.0	Nutrient Resid. Time (yrs)
Hydraulic Resid. Time (yrs)	1.2516	Turnover Ratio
Reservoir Conc (mg/m3)	42	Retention Coef.

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentr
Component: TOTAL N

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)²	%Total	CV
1	1	1	Calvary Creek	1789.5	71.4%	1.15E+06	99.9%	0.60
PRECIPITATION				716.1	28.6%	1.28E+03	0.1%	0.05
TRIBUTARY INFLOW				1789.5	71.4%	1.15E+06	99.9%	0.60
***TOTAL INFLOW				2505.6	100.0%	1.15E+06	100.0%	0.43
ADVECTIVE OUTFLOW				1404.2	56.0%	2.94E+05		0.39
***TOTAL OUTFLOW				1404.2	56.0%	2.94E+05		0.39
***RETENTION				1101.4	44.0%	5.27E+05		0.66

Overflow Rate (m/yr)	2.0	Nutrient Resid. Time (yrs)
Hydraulic Resid. Time (yrs)	1.2516	Turnover Ratio
Reservoir Conc (mg/m3)	696	Retention Coef.

Model Output with 65% TP and TN Concentration Reductions at Inflow
Diagnostics -- Main Basin
Reduction Scenario, Lake Coldwater

Segment:	1	Near Dam				
	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	22.1	0.99	19.5%	41.6	0.43	43.8%
TOTAL N MG/M3	443.5	0.34	10.1%	696.0	0.31	28.5%
C.NUTRIENT MG/M3	16.4	0.61	16.5%	30.7	0.37	42.5%
CHL-A MG/M3	12.3	0.81	63.6%	25.6	0.51	90.4%
SECCHI M	0.8	0.42	32.0%	0.6	0.27	20.7%
ORGANIC N MG/M3	346.4	0.43	26.9%	529.0	0.48	58.5%
TP-ORTHO-P MG/M3	19.2	0.46	32.0%	18.7	0.43	30.9%
ANTILOG PC-1	190.8	1.01	42.4%	545.8	0.41	73.0%
ANTILOG PC-2	6.8	0.54	53.9%	8.8	0.41	72.8%
(N - 150) / P	13.3	1.05	35.8%	13.1	0.57	35.2%
INORGANIC N / P	33.7	6.89	55.0%	7.3	2.16	7.9%
TURBIDITY 1/M	1.3	0.52	80.1%	1.3	0.52	80.1%
ZMIX * TURBIDITY	3.2	0.53	50.8%	3.2	0.53	50.8%
ZMIX / SECCHI	3.3	0.44	26.4%	4.3	0.29	43.1%
CHL-A * SECCHI	9.3	0.84	44.7%	14.8	0.58	70.2%
CHL-A / TOTAL P	0.6	0.51	94.9%	0.6	0.66	96.4%
FREQ(CHL-a>10) %	50.8	1.02	63.6%	88.6	0.17	90.4%
FREQ(CHL-a>20) %	13.6	2.09	63.6%	53.5	0.60	90.4%
FREQ(CHL-a>30) %	4.0	2.83	63.6%	28.6	0.98	90.4%
FREQ(CHL-a>40) %	1.3	3.38	63.6%	15.2	1.29	90.4%
FREQ(CHL-a>50) %	0.5	3.82	63.6%	8.2	1.55	90.4%
FREQ(CHL-a>60) %	0.2	4.18	63.6%	4.6	1.77	90.4%
CARLSON TSI-P	48.8	0.29	19.5%	57.9	0.11	43.8%
CARLSON TSI-CHLA	55.2	0.14	63.6%	62.4	0.08	90.4%
CARLSON TSI-SEC	64.0	0.10	68.0%	67.8	0.06	79.3%

Model Output with 65% TP and TN Concentration Reductions at Inflow
Water and Nutrient Balances – Main Basin
Reduction Scenario, Lake Coldwater

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Calvary Creek	104.9	3.1	9.49E-02	0.10	0.03
PRECIPITATION				1.0	0.6	1.37E-02	0.20	0.58
TRIBUTARY INFLOW				104.9	3.1	9.49E-02	0.10	0.03
***TOTAL INFLOW				105.9	3.7	1.09E-01	0.09	0.03
ADVECTIVE OUTFLOW				105.9	2.0	3.53E-01	0.29	0.02
***TOTAL OUTFLOW				105.9	2.0	3.53E-01	0.29	0.02
***EVAPORATION					1.6	2.44E-01	0.30	

Overall Mass Balance Based Upon Component: Predicted TOTAL P — Outflow & Reservoir Concentrations

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Calvary Creek	70.5	87.5%	8.46E+03	100.0%	1.30	22.9	0.7
PRECIPITATION				10.1	12.5%	1.02E+00	0.0%	0.10	17.3	10.0
TRIBUTARY INFLOW				70.5	87.5%	8.46E+03	100.0%	1.30	22.9	0.7
***TOTAL INFLOW				80.6	100.0%	8.46E+03	100.0%	1.14	22.0	0.8
ADVECTIVE OUTFLOW				44.6	55.3%	1.92E+03		0.98	22.1	0.4
***TOTAL OUTFLOW				44.6	55.3%	1.92E+03		0.98	22.1	0.4
***RETENTION				36.0	44.7%	3.91E+03		1.74		

Overflow Rate (m/yr)	2.0	Nutrient Resid. Time (yrs)	0.6924
Hydraulic Resid. Time (yrs)	1.2516	Turnover Ratio	1.4
Reservoir Conc (mg/m3)	22	Retention Coef.	0.447

Overall Mass Balance Based Upon Component: Predicted TOTAL N — Outflow & Reservoir Concentrations

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Calvary Creek	625.2	46.6%	1.40E+05	99.1%	0.60	203.0	6.0
PRECIPITATION				716.1	53.4%	1.28E+03	0.9%	0.05	1224.5	709.0
TRIBUTARY INFLOW				625.2	46.6%	1.40E+05	99.1%	0.60	203.0	6.0
***TOTAL INFLOW				1341.3	100.0%	1.41E+05	100.0%	0.28	366.0	12.7
ADVECTIVE OUTFLOW				894.8	66.7%	6.80E+04		0.29	443.5	8.4
***TOTAL OUTFLOW				894.8	66.7%	6.80E+04		0.29	443.5	8.4
***RETENTION				446.6	33.3%	6.36E+04		0.56		

Overflow Rate (m/yr)	2.0	Nutrient Resid. Time (yrs)	0.8349
Hydraulic Resid. Time (yrs)	1.2516	Turnover Ratio	1.2
Reservoir Conc (mg/m3)	444	Retention Coef.	0.333

Appendix B. Conversion to Daily Loads as Regulated by EPA Region VII

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

Expressing this TMDL in daily time steps could be misleading 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 describe 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

LTA= Long Term Average
LA= Load Allocation
MOS= Margin of Safety

Parameter	LTA lbs/year	CV	$e^{[Z\sigma - 0.5\sigma^2]}$	MDL lbs/day	Atm LA lbs/day	NonPoint LA lbs/day	MOS (10%) lbs/day
TP	177.76	0.43	2.39	1.166	0.146	0.903	0.117
TN	2,957	0.31	1.93	15.65	8.36	5.72	1.57

Maximum Daily Load Calculation

Annual TP Load = 177.76 lbs/yr

Maximum Daily TP Load = [(177.76 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.412) - 0.5*(0.412)^2]}$
= 1.166 lbs/day

Annual TN Load = 2,957 lbs/yr

Maximum Daily TN Load $= [(2957 \text{ lbs/yr})/(365 \text{ days/yr})]*e^{[2.326*(0..303)-0.5*(0.303)^2]}$
$= 15.65$ lbs/day

Margin of Safety (MOS) for Daily Load

Annual TP MOS = 17.776 lbs/yr

Daily TP MOS $= [(17.776 \text{ lbs/yr})/(365 \text{ days/yr})]*e^{[2.326*(0.412)-0.5*(0.412)^2]}$
$= 0.117$ lbs/day

Annual TN MOS = 295.7 lbs/yr

Daily TN MOS $= [(295.7 \text{ lbs/yr})/(365 \text{ days/yr})]*e^{[2.326*(0.303)-0.5*(0.303)^2]}$
$= 1.57$ lbs/day

Source- *Technical Support Document for Water Quality-based Toxics Control (EPA/505/2-90-001)*