MARAIS DES CYGNES RIVER BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody: Pomona Lake
Water Quality Impairment: Eutrophication & Siltation

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Upper Marais Des Cygnes

County: Osage, Wabaunsee and Lyon

HUC 8: 10290101

HUC 10 (12): 02 (01, 02, 03, 04, 05, 06, 07, 08)

Ecoregion: Central Irregular Plains, Osage Cuestas (40b)
Flint Hills (28)

Drainage Area: 322 square miles

Conservation Pool: Surface Area = 3,621 acres
Watershed/Lake Ratio: 57:1
Maximum Depth = 38 feet
Mean Depth = 16 feet
Storage Volume = 55,670 acre feet
Estimated Retention Time = 0.45 years
Mean Annual Inflow = 149,449 acre feet
Mean Annual Discharge = 136,729 acre feet
Constructed: 1962

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: 2002, 2004, 2008, 2010 & 2012 Marais Des Cygnes River Basin Lakes

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

Water Quality Criteria: General – Narrative: Taste-producing and odor-producing substances of artificial origin shall not occur in surface waters at concentrations that interfere with the production of potable water by conventional water treatment processes, that impart an unpalatable flavor to edible aquatic or semiaquatic life or terrestrial wildlife, or that result in noticeable odors in the vicinity of surface waters (KAR 28-16-28e(b)(7).

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 domestic water supply use shall be controlled to prevent interference with the production of drinking water (KAR 28-16-28e(c)(3)(D)).

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)).

Suspended Solids – Narrative: Suspended solids added to surface waters by artificial sources shall not interfere with the behavior, reproduction, physical habitat or other factors related to the survival and propagation of aquatic or semi-aquatic or terrestrial wildlife (K.A.R. 28-16-28e(c)(2)(B)).

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 could interfere with domestic water supply use. The excessive nutrients are also impairing aquatic life use by supporting objectionable types and quantities of algae whish also leads to impairment of contact recreation within Pomona Lake. A chlorophyll *a* endpoint of 10 µg/L is assigned to address the domestic water supply use; however, all other uses will be met when the chlorophyll *a* endpoint of 10 µg/L is met.

Level of Eutrophication (2008-2012): Slightly Eutrophic, Trophic State Index = 54.7

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 µg/L and hypereutrophy occurs at levels over 30 µg/L. 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: $\geq$ 64

Level of Siltation Impairment: Pomona Lake has high inorganic turbidity and high levels of siltation. Sediment loads originating in the tributaries to Pomona Lake are accumulating in the lake, particularly in the arms where Dragoon Creek and 110 Mile Creek enter the lake, thereby reducing the capacity of the lake. In addition, siltation is aggravated during large runoff events in the watershed.

Lake Monitoring Sites:

KDHE Lake Sampling Stations:

LM028001 in Pomona Lake

Period of Record: 5/12/1976 through 6/27/2011

United States Army Corps of Engineers (USACE) sampling points in Pomona Lake:

PO-2, Below the dam on 110 Mile Creek

Period of Record: 4/4/1996 through 9/10/2012

PO-3, Main basin near the dam

Period of Record: 4/4/1996 through 9/15/2011

PO-7, Dragoon Creek arm of Pomona Lake

Period of Record: 4/24/1996 through 9/15/2011

PO-12, 110 Mile Creek arm of Pomona Lake

Period of Record: 4/4/1996 through 9/15/2011

PO-14, Valley Brook Creek arm of Pomona Lake

Period of Record: 4/1/2007 through 9/10/2012

Stream Chemistry Monitoring Sites:

KDHE Station SC577, Permanent Site on Dragoon Creek near Burlingame

Period of Record: 4/18/1990 through 11/13/2012

KDHE Station SC633, Rotational Site on 110 Mile Creek near Scranton

Period of Record: 1/6/1993 through 11/12/2009

KDHE Station SC687, Rotational Site on Switzler Creek near Burlingame

Period of Record: 4/6/1994 through 11/13/2012

KDHE Stream Probability Station SPA354: 110 Mile Creek

Period of Record: 2/12/2008 through 10/14/2008

KDHE Stream Probability Station SPB048: Switzler Creek

Period of Record: 3/10/2010 through 12/20/2010

KDHE Stream Probability Station SPB064: Dragoon Creek

Period of Record: 3/10/2010 through 12/20/2010

KDHE Stream Probability Station SPB112: Switzler Creek

Period of Record: 2/22/2011 through 12/13/2011

KDHE Stream Probability Station SPB176: Switzler Creek

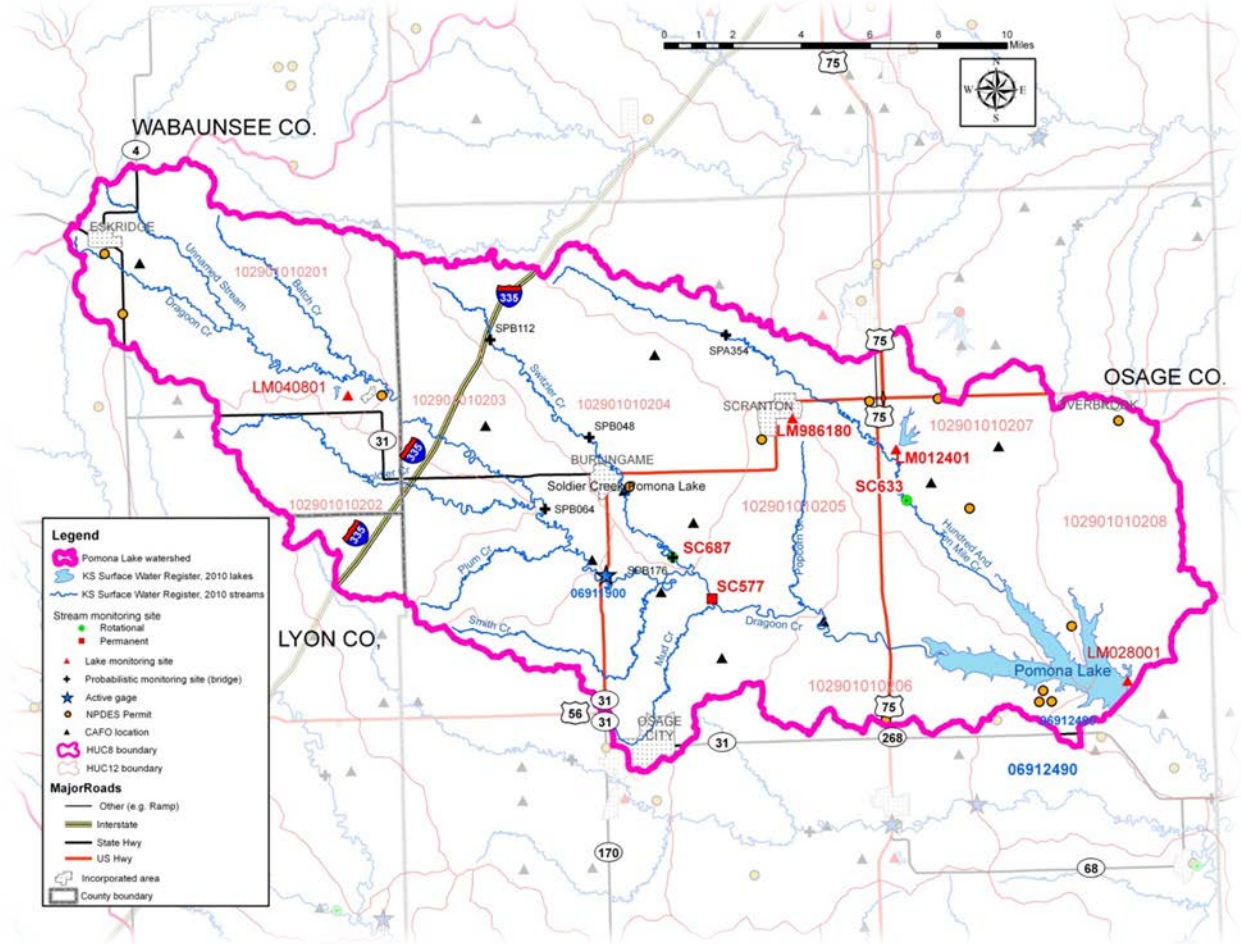
Period of Record: 2/15/2012 through 11/13/2012

USACE Station PO-11, shares Dragoon Creek location with USGS 06911900

Period of Record: 4/4/1996 through 9/15/2011

Flow Record: USGS Gage 06911900 Dragoon Creek near Burlingame
Period of Record: 1/1/1970 through 12/31/2012
USACE, Kansas City District – Pomona Lake
Period of Record: 1/1/1990 through 12/31/2012

Figure 1. Pomona Lake Watershed.



Hydrological Conditions: Pomona Lake receives inflow via Dragoon Creek, 110 Mile Creek and the unclassified stream Valley Brook Creek. Discharges from Pomona Lake flow via the outlet channel to 110 Mile Creek which meets with the Marais des Cygnes River approximately eight miles downstream. Dragoon Creek flows into the southernmost arm of the lake and its drainage area is the largest of the three arms at 234 mi^2. 110 Mile Creek flows into the middle arm of the lake with a drainage area of 57.4 mi^2 while the unclassified stream Valley Brook Creek flows into the northern most arm of the lake and has a drainage area of 30.9 mi^2. Average flows for the entire period of record and for the period of record used for nutrient load modeling were calculated using the ratio of drainage area for each of the three streams entering the lake to the area at USGS 06911900 located on Dragoon Creek above its confluence with Smith Creek (Table 1). Table 2 displays the estimated flow-duration values for the individual segments in the watershed (Perry, 2004). Reservoir accounting records kept by the U.S. Army Corps of Engineers (USACE) show the lake had an average inflow and outflow of 148,876 acre-feet and

136,590 acre-feet, respectively, for the 1990 through 2012 time period (Figure 2). For the 2008 through 2012 period of record, the average annual inflow and outflow were slightly lower at 139,481 acre-feet and 130,086 acre-feet, respectively. Annual average precipitation calculated from the National Climatic Data Center's Pomona Lake station (GHCND: USC00146498) is also displayed in Figure 2 with 1990 through 2012 averaging 37.9 inches per year and the years 2008 through 2012 averaging 38.4 inches per year. The mean runoff in the watershed is 7.00 inches per year and the mean loss due to evaporation for the lake is 48.2 inches per year, according to Lake Hydro data.

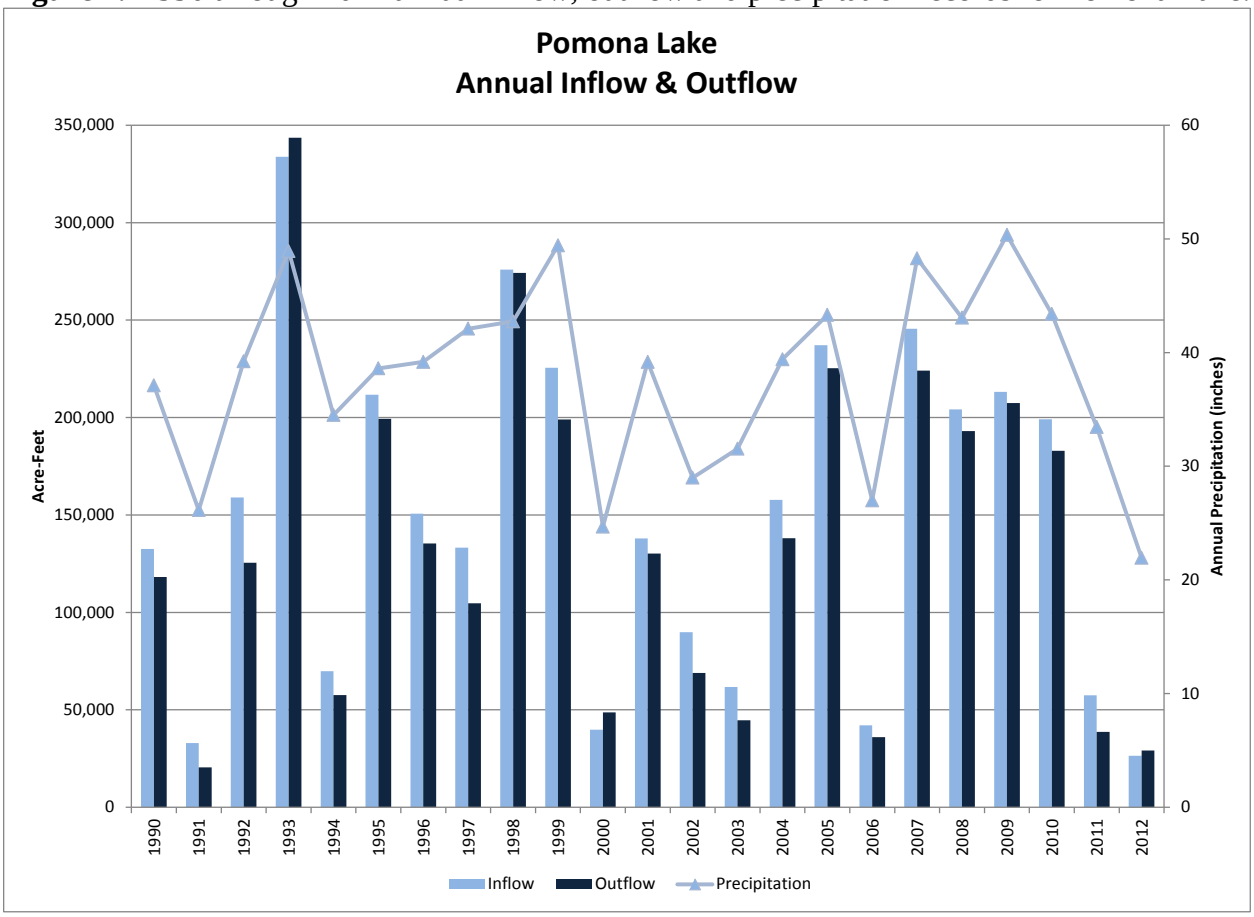
Table 1. Estimated flow-duration values (cfs) for indicated percentage of time flow equaled or exceeded for KDHE sampling stations and at the inlets to Pomona Lake. Values are based on the ratio of the watershed size at the lake inlet to the watershed size at USGS Gage 06911900 on Dragoon Creek for the 1970-2012 and 2008-2012 time periods. Valley Brook Creek is not a classified stream.

Stream	Period of Record	Drainage Area mi^2	Avg.	10%	25%	50%	75%	90%
USGS 06911900 Dragoon Cr near Burlingame	1970-2012	114	67.5	96.0	32.0	8.10	1.10	0.0
USGS 06911900 Dragoon Cr near Burlingame	2008-2012	114	63.9	110	40.0	10.0	1.70	0.0
Dragoon Cr at Pomona	1970-2012	234	139	197	65.7	16.6	2.26	0.0
Dragoon Cr at Pomona	2008-2012	234	131	227	82.1	20.5	3.49	0.0
110 Mile Cr at Pomona Lake	1970-2012	57.4	34.0	48.3	16.1	4.08	0.55	0.0
110 Mile Cr at Pomona Lake	2008-2012	57.4	32.2	55.6	20.1	5.04	0.86	0.0
Valley Brook Cr at Pomona	1970-2012	30.9	18.3	26.0	8.67	2.20	0.30	0.0
Valley Brook Cr at Pomona	2008-2012	30.9	17.3	29.9	10.8	2.71	0.46	0.0

Table 2. Estimated flow-duration values (cfs) for indicated percentage of time flow equaled or exceeded for streams entering Pomona Lake (Perry, 2004). WB: Wabaunsee County, OS: Osage County.

Stream	County	USGS Site ID	Drainage Area mi^2	Avg	10%	25%	50%	75%	90%	2-year Peak
Dragoon Cr	WB	2283	10.1	7.48	8.96	2.86	0.71	0	0	1,160
Unnamed Trib	WB	2280	8.45	6.43	7.73	2.49	0.64	0	0	1,050
Dragoon Cr	WB	2328	25.1	18.4	24.2	8.30	2.23	0	0	1,980
Batch Cr	WB	2325	13.8	9.91	11.9	3.82	0.94	0	0	1,420
Dragoon Cr	WB/OS	2414	53.6	37.8	51.1	17.7	4.73	0.51	0	3,800
Soldier Cr	WB/OS	2420	25.3	17.7	22.3	7.44	1.93	0	0	2,030
Plum Cr	OS	2503	10.4	7.55	8.59	2.58	0.57	0	0	1,250
Smith Cr	OS	2558	17.2	11.8	13.7	4.12	0.92	0	0	1,700
Switzler Cr	OS	2468	38.4	24.9	31.6	10.2	2.69	0.04	0	2,890
Dragoon Cr	OS	2504	156	101	140	46.2	11.8	1.87	0	6,170
Mud Cr	OS	2614	10.0	6.83	82.0	24.0	5.10	0.54	0	1,260
Dragoon Cr	OS	2520	171	110	154	50.4	13.0	2.14	0	6,130
Popcorn Cr	OS	2509	16.9	11.1	12.4	3.69	0.82	0	0	1,670
Dragoon Cr	OS	2526	190	119	169	54.7	14.1	2.42	0	6,510
110 Mile Cr	OS	2440	53.0	32.6	41.7	13.5	3.63	0.33	0	3,560
110 Mile Cr	OS	2474	61.2	37.8	49.5	16.2	4.44	0.55	0	3,900

Figure 2. 1990 through 2012 annual inflow, outflow and precipitation records for Pomona Lake.



Current Condition: Chlorophyll *a* averages 7.89 µg/L for the period of record (1976-2012) in Pomona Lake. The first near dam sample with a chlorophyll *a* concentration greater than 10 µg/L was collected in June of 1998 (Figure 3) while recent (2008-2012) samplings performed by KDHE and USACE have an average chlorophyll *a* concentration of 11. 8 µg/L (Table 3). The highest annual concentration of chlorophyll *a* occurred in 1998 and annual chlorophyll *a* concentrations have been greater than 10 µg/L six of the ten years the lake has been sampled since 1998 (Figure 4).

Figure 3. KDHE and USACE near dam chlorophyll *a* concentrations in Pomona Lake, by sampling day, for the period of record.

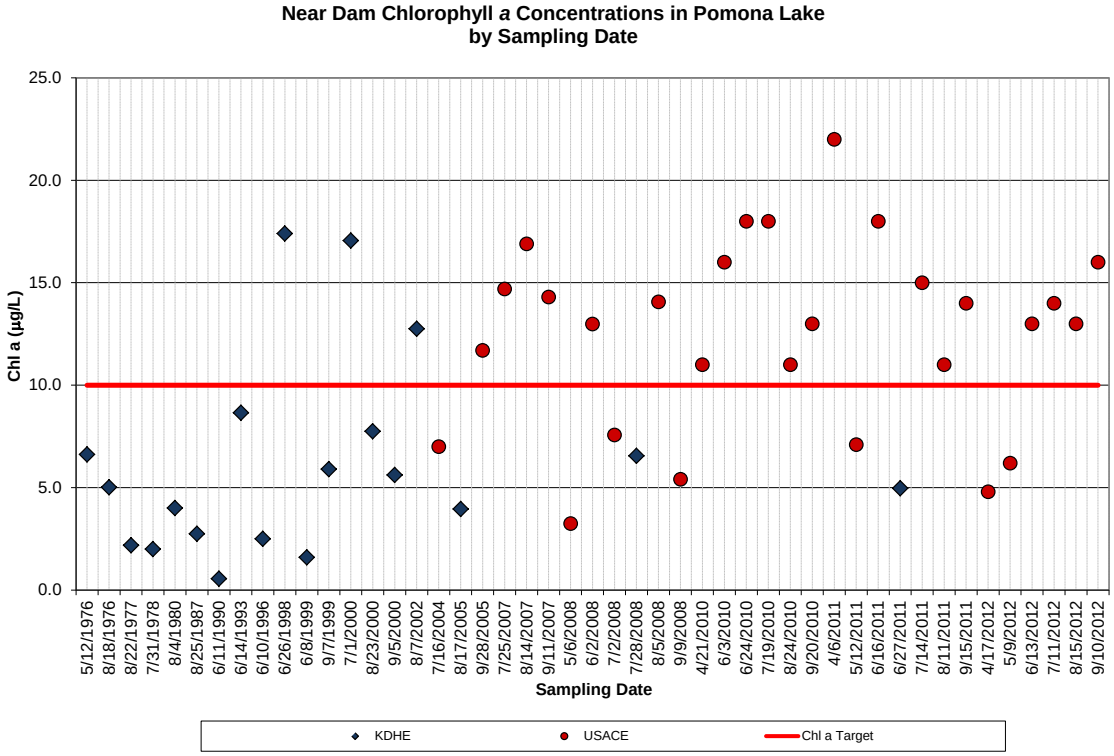
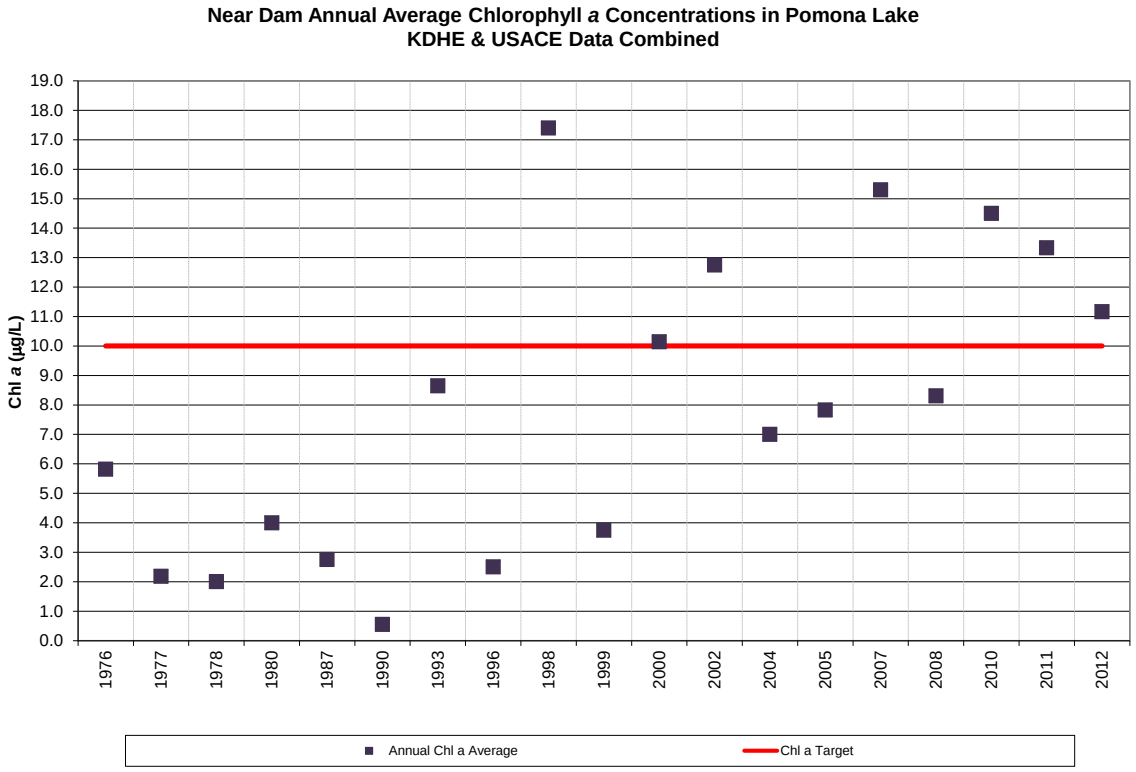
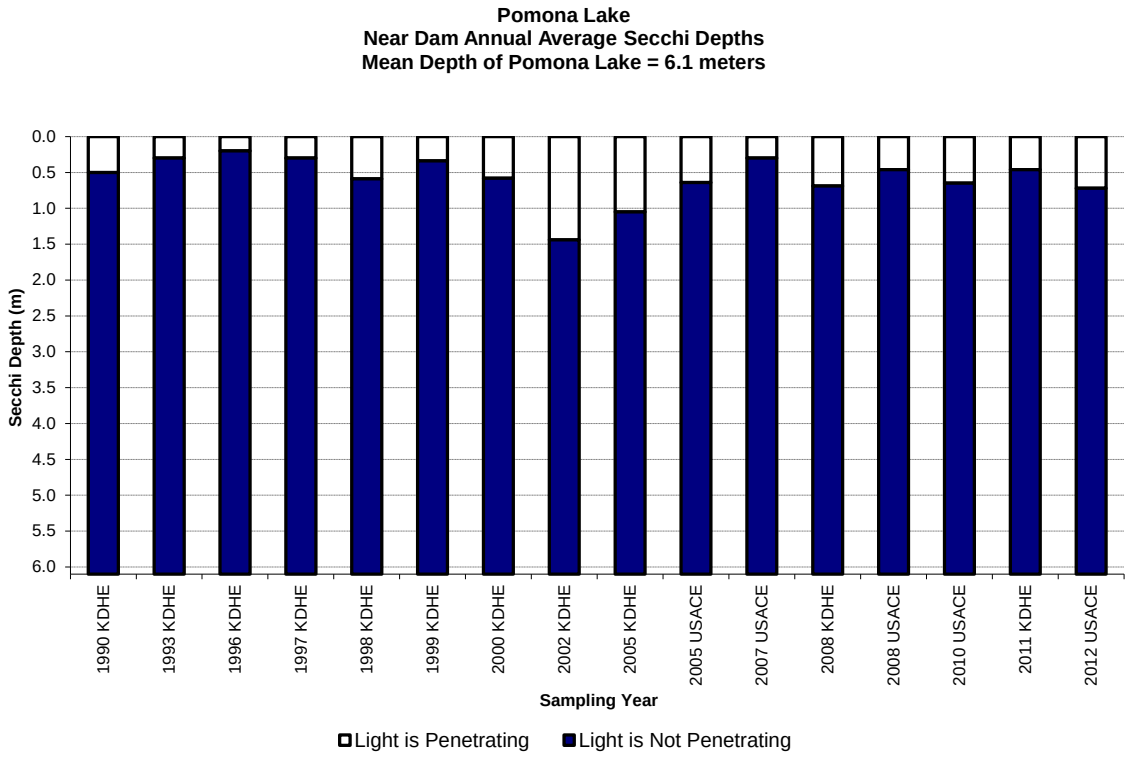


Figure 4. Average annual near dam chlorophyll *a* concentrations in Pomona Lake.



Secchi depth readings were available beginning in 1990 with the 1.4 meter reading taken in 2002 being the highest for the period of record (Figure 5). The 1990-2012 average Secchi depth comes in at 0.54 meters with the 2008 through 2012 average very slightly improved at 0.58 meters.

Figure 5. Average annual near dam Secchi depth in Pomona Lake.



Total phosphorus (TP) concentrations peaked in 1997 with an annual average of 0.27 mg/L (Figure 7) and a single sample high of 0.80 mg/L taken on July 24, 1997 (Figure 6). The period of record average is 0.080 mg/L while the 2008 through 2012 average is 0.049 mg/L revealing a decline in phosphorus concentration in Pomona Lake over the most recent period of record (Table 3).

Total nitrogen (TN) concentration reached a single sample high of 2.41 mg/L in June of 2011 in a sample collected to USACE (Figure 8) and although Figure 9 shows 1993 as having the highest annual average at 2.20 mg/L this was based on a single sample taken in June 1993 by KDHE. Total nitrogen period of record average (1993-2012) is 0.942 mg/L while the 2008-2012 average is slightly lower at 0.862 mg/L (Table 3).

Figure 6. KDHE and USACE near dam total phosphorus concentrations in Pomona Lake, by sampling day, for the period of record.

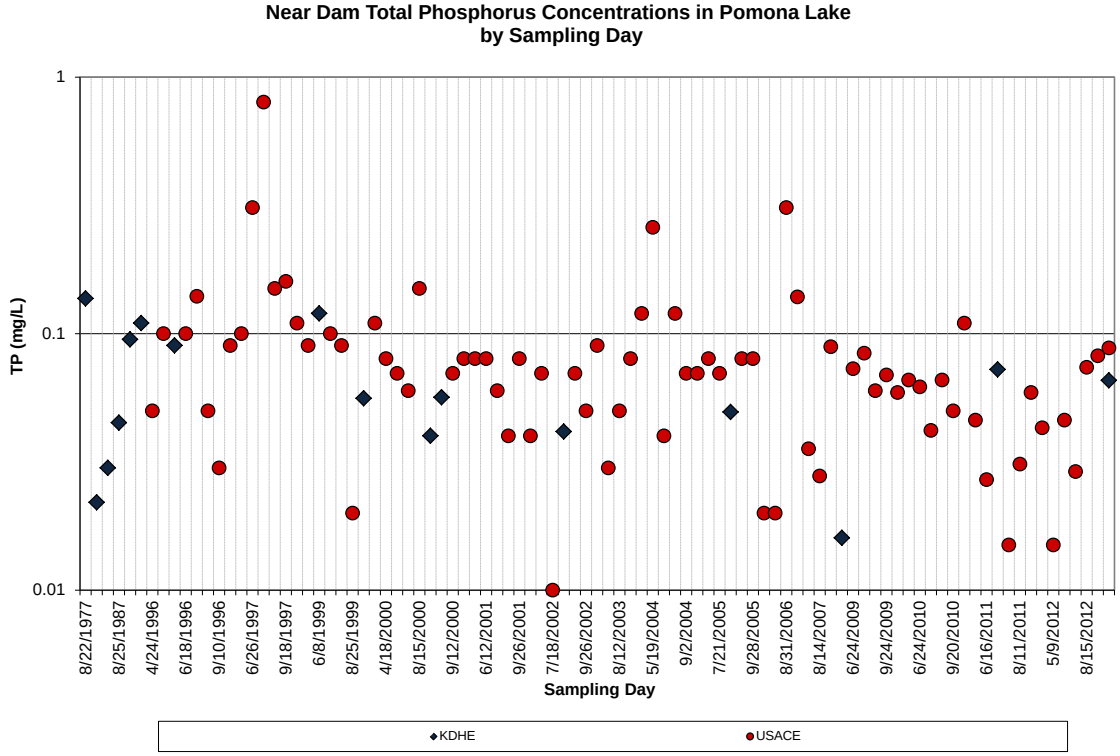


Figure 7. KDHE & USACE combined annual averages for total phosphorus in Pomona Lake. Period of record for average line is 1976-2011.

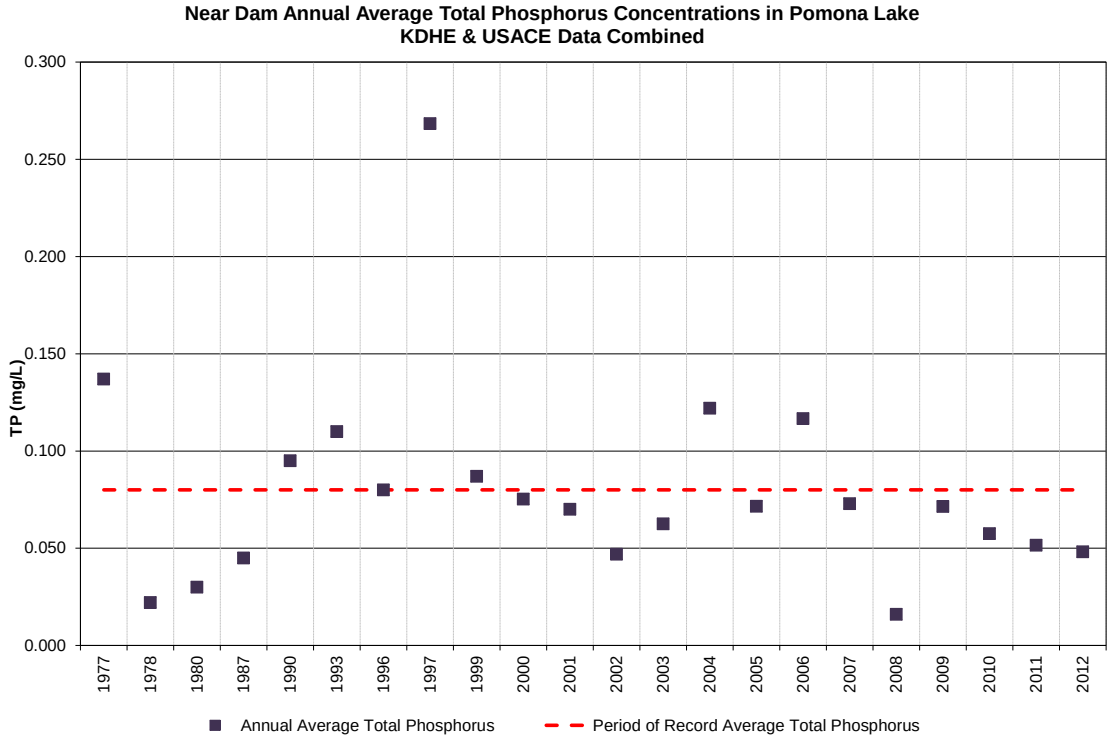


Figure 8. KDHE and USACE near dam total nitrogen concentrations in Pomona Lake, by sampling day, for the period of record.

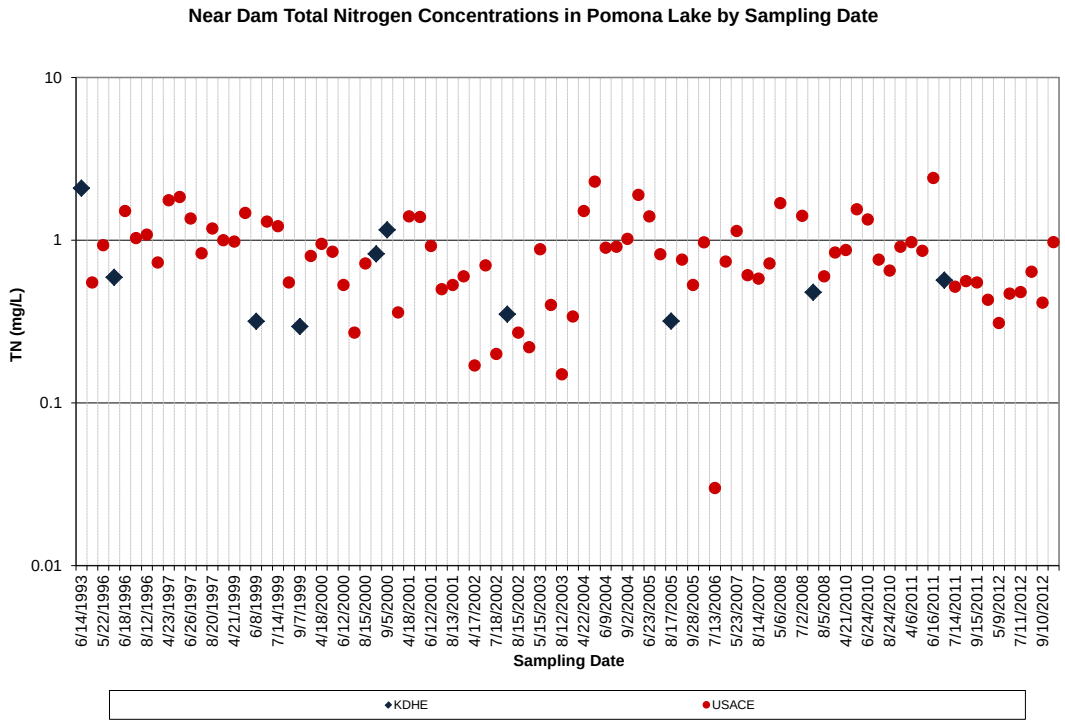
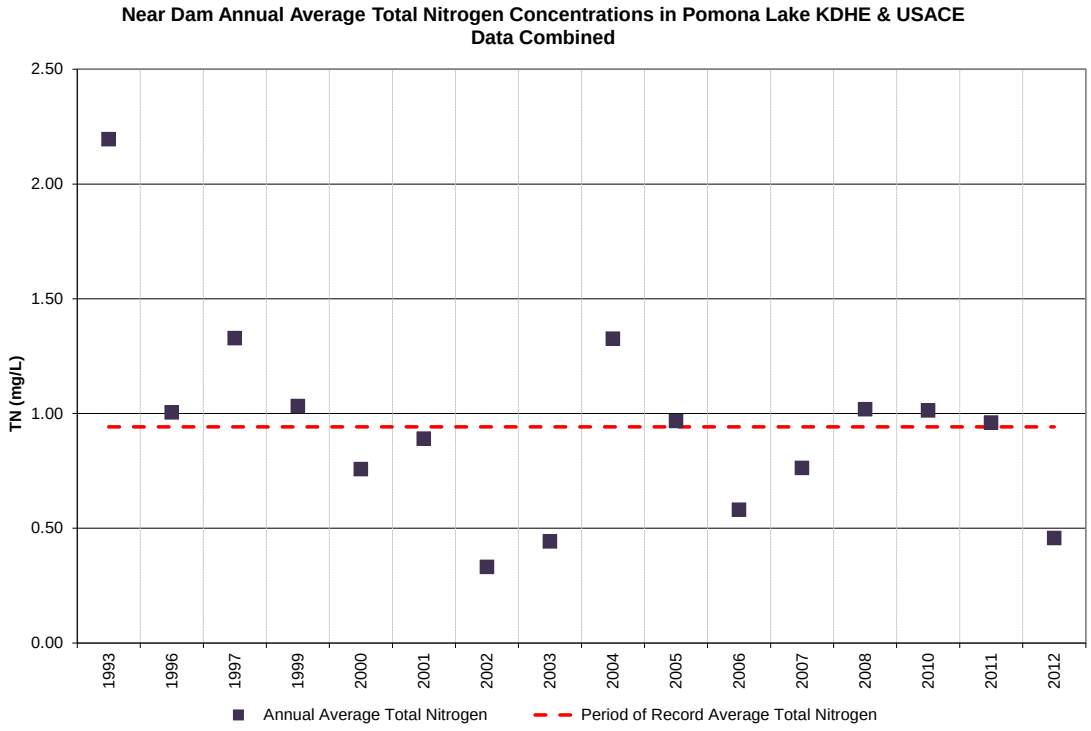
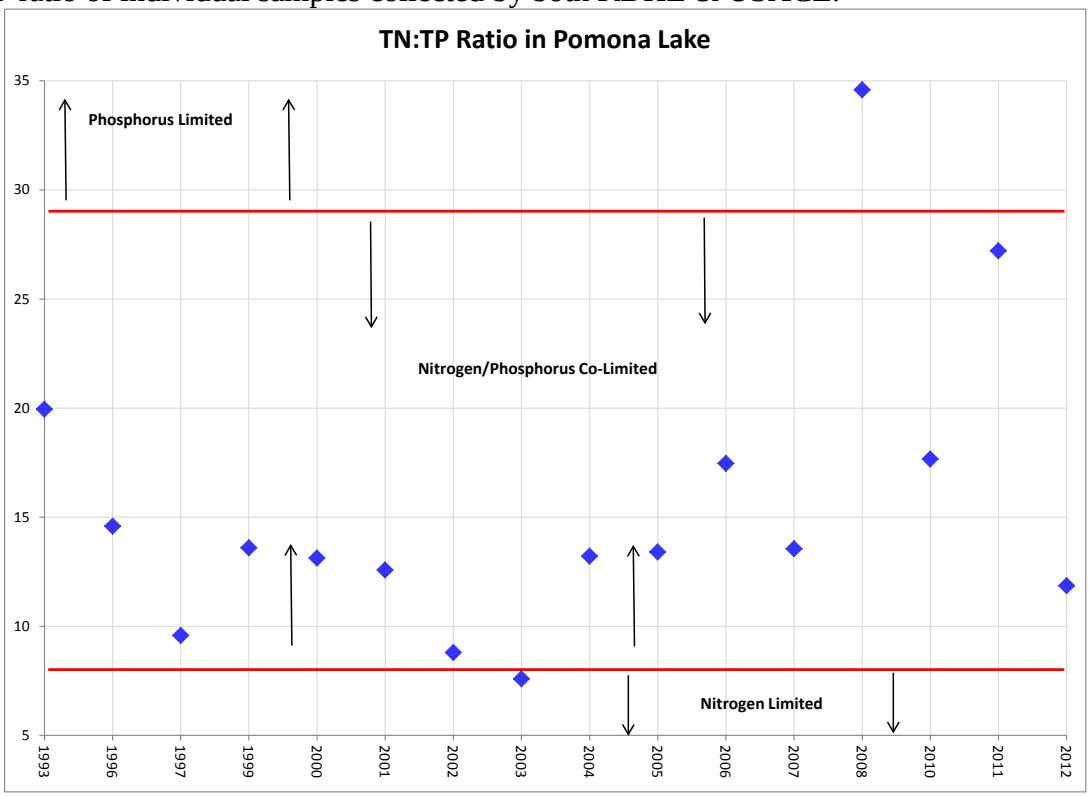


Figure 9. Average annual near dam total nitrogen concentrations in Pomona Lake. KDHE & USACE combined annual averages for total nitrogen concentration in Pomona Lake. Period of record for average line is 1993-2012.



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 8 and 29; and lakes that are phosphorus limited have water column TN:TP ratios > 29 (Dzialowski et al., 2005). The TN:TP ratio in Pomona Lake indicates the lake has been co-limited by phosphorus and nitrogen for the period of record with the exception of 2008 when the lake was limited by phosphorus only and 2011 when the lake was moving toward phosphorus limitation. In 2012 the lake returned to a co-limited status (Figure 10).

Figure 10. TN:TP ratio for period of record in Pomona Lake. Values of annual averages of the TN:TP ratio of individual samples collected by both KDHE & USACE.



Turbidity in Pomona Lake averages 21.9 NTU for the period of record (1976-2012) with a single sample high of 59.0 NTU taken by USACE on May 23, 2007 (Figure 11). As the only sample taken in 2007, the 59.0 NTU value also results in 2007 having the highest annual average turbidity (Figure 12). The average turbidity for the recent (2008-2012) period of record is 20.8 NTU (Table 3).

Figure 11. KDHE and USACE near dam turbidity values in Pomona Lake, by sampling date, for the period of record.

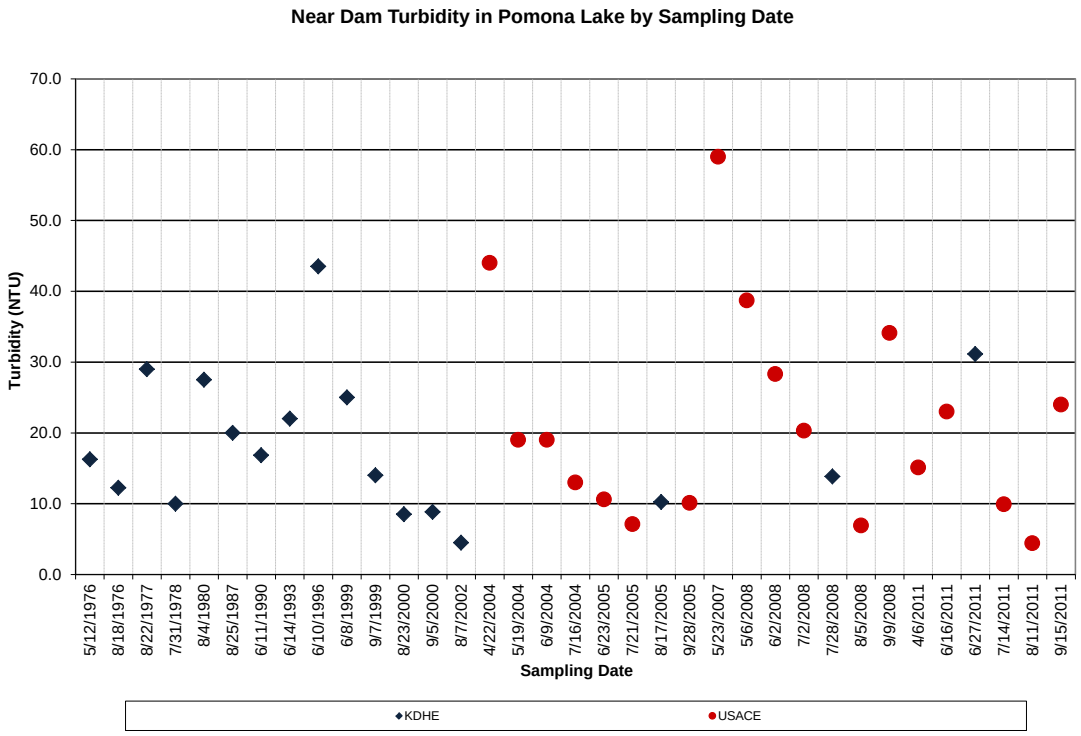
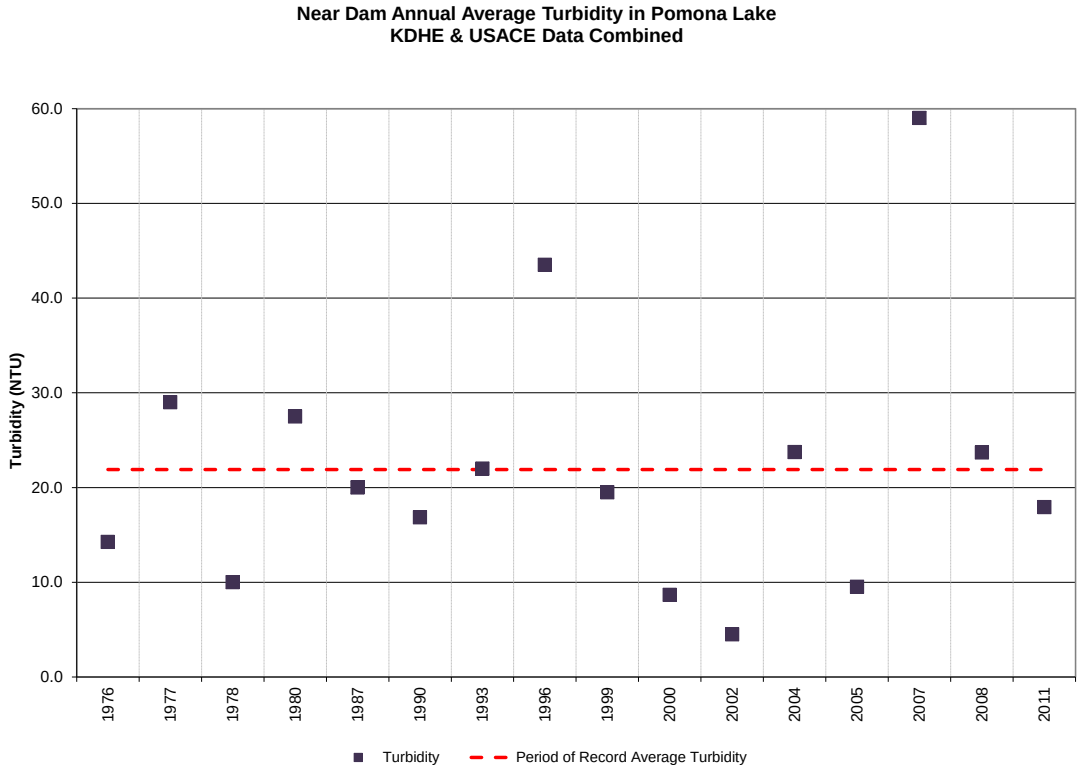


Figure 12. KDHE & USACE combined annual averages for turbidity in Pomona Lake. Period of record for average line is 1976-2011.



Total suspended solids (TSS) concentrations in Pomona Lake reached a high of 34.4 mg/L in the sample taken on May 23, 2007 while fourteen samples fell at or below 5 mg/L over the 1976 through 2012 period of record (Figure 13). With the exception of the 2007 average of 17.7 mg/L, annual average TSS concentrations have been on the decline since 1996 (Figure 14). Average TSS for the entire period of record is 11.4 mg/L while the more recent average for the 2008 to 2012 period of record is lower at 9.92 mg/L.

Figure 13. KDHE and USACE near dam TSS concentrations in Pomona Lake, by sampling day, for the period of record.

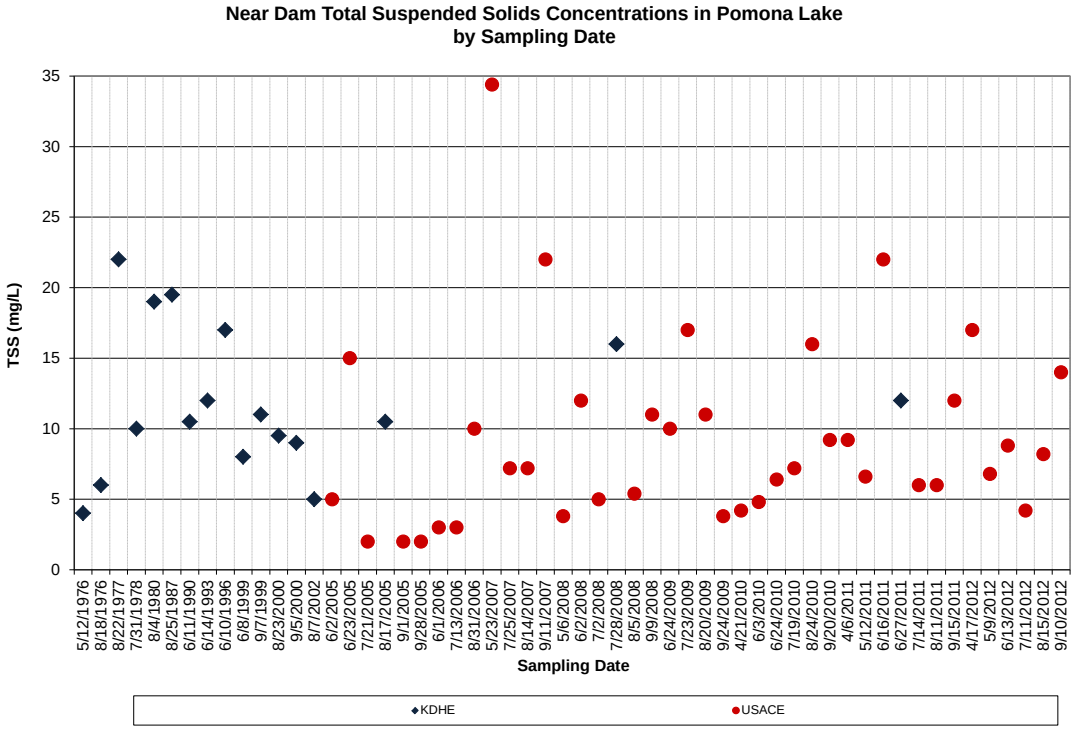


Figure 14. KDHE & USACE combined annual averages for near dam TSS concentrations in Pomona Lake. Period of record for average line is 1976-2012.

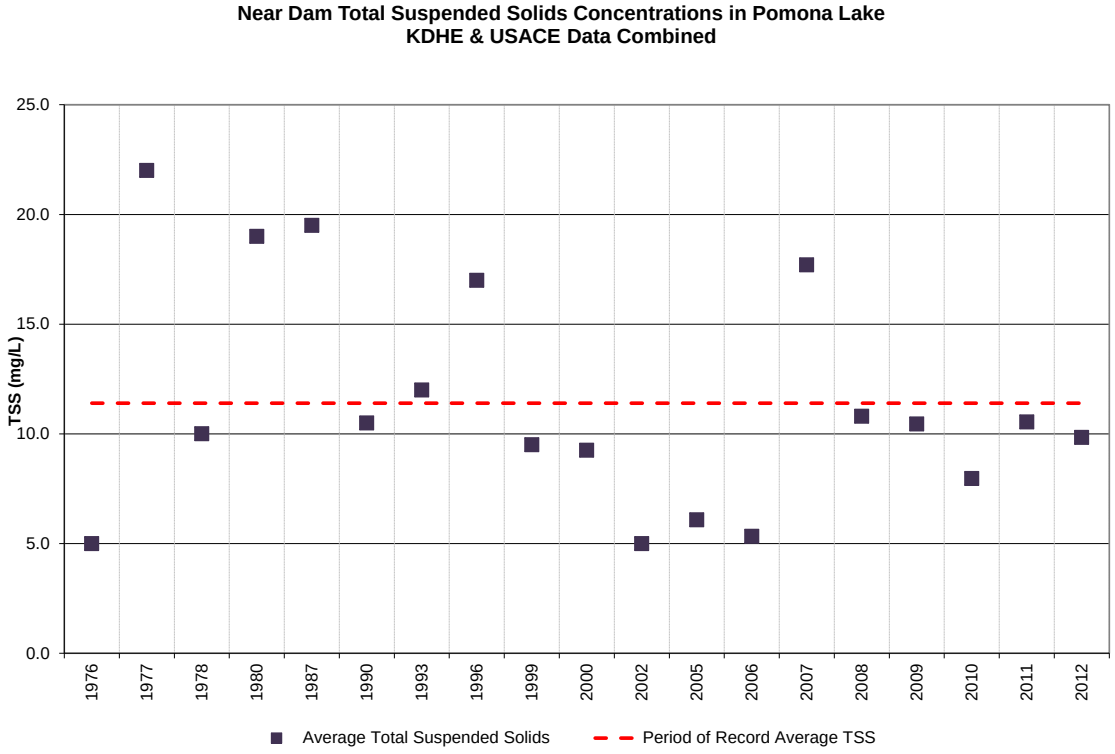


Table 3. Water quality data summary for Pomona Lake. Annual averages were calculated from daily sampling data with the exception of the TN:TP ratio which was calculated from the annual averages in Table 3. The KDHE & USACE annual averages were calculated from daily sampling data available from each source. The combined KDHE & USACE period of record data summarized at the bottom of the Table 3 were calculated by first calculating annual averages using daily sampling data from both sources and then averaging the annual averages for the applicable period of record.

Sample Year	Source	Chl a (µg/L)	TN (mg/L)	TP (mg/L)	TN:TP Ratio	Secchi Depth (m)	Turbidity (NTU)	TSS (mg/L)
1976	KDHE	5.82					14.3	5.00
1977	KDHE	2.19		0.137			29.0	22.0
1978	KDHE	2.00		0.022			10.0	10.0
1980	KDHE	4.00		0.030			27.5	19.0
1987	KDHE	2.75		0.045			20.0	19.5
1990	KDHE	0.550		0.095		0.50	16.9	10.5
1993	KDHE	8.65	2.20	0.110	20.0	0.30	22.0	12.0
1996	KDHE	2.50	0.591	0.090	6.57	0.20	43.5	17.0
1996	USACE		0.972	0.078	12.4			
1997	KDHE					0.30		
1997	USACE		1.33	0.268	4.95			
1998	KDHE	17.4				0.59		
1999	KDHE	3.75	0.306	0.088	3.48	0.34	19.5	9.50
1999	USACE		1.05	0.087	12.2			
2000	KDHE	8.63	0.991	0.048	20.5	0.58	8.68	9.25
2000	USACE		0.613	0.086	7.13			
2001	KDHE			0.070				
2001	USACE		0.890		12.7			
2002	KDHE	12.8	0.351	0.042	8.46	1.4	4.50	5.00
2002	USACE		0.312	0.048	6.50			
2003	USACE		0.443	0.063	7.09			
2004	USACE	7.00	1.33	0.122	10.9		23.8	
2005	KDHE	3.95	0.319	0.050	6.43	1.1	10.3	10.5
2005	USACE	11.7	1.08	0.076	14.2	0.64	9.27	10.0
2006	USACE		0.580	0.117	4.97			5.33
2007	USACE	15.3	0.763	0.073	10.5	0.30	59.0	17.7
2008	KDHE	6.55	0.479	0.016	29.9	0.69	13.9	16.0
2008	USACE	8.66	2.57			0.46	25.7	7.44
2009	USACE			0.072				10.5
2010	USACE	14.5	1.01	0.058		0.65	0.650	7.97
2011	KDHE	4.97	0.568	0.073		0.46	31.2	12.0
2011	USACE	14.5	0.978	0.048	7.83		15.3	10.3
2012	USACE	11.2	0.457	0.048		0.72		9.83
Period of Record Summaries								
1976-2011	***KDHE***	***5.76***	***0.725***	***0.065***	***11.2***	***0.59***	***19.4***	***12.7***
1996-2012	***USACE***	***11.8***	***0.959***	***0.088***	***10.9***	***0.55***	***22.3***	***9.88***
1976-2012	***KDHE & USACE***	***7.89***	***0.942***	***0.080***	***11.8***	***0.54***	***21.9***	***11.4***
2008-2012	***KDHE***	***5.76***	***0.523***	***0.044***	***11.9***	***0.58***	***22.5***	***14.0***
2008-2012	***USACE***	***12.2***	***1.25***	***0.056***	***22.3***	***0.61***	***13.9***	***9.20***
2008-2012	***KDHE & USACE***	***11.8***	***0.862***	***0.049***	***17.6***	***0.58***	***20.8***	***9.92***

As can be seen in Figure 15, Pomona Lake stratified in 1993, 1996, 1999 and 2002 while during the August 2005 profile the dissolved oxygen did not get above 3.6 mg/L. During periods of stratification the rate of internal phosphorus cycling can increase.

Figure 15. Dissolved oxygen and temperature profiles in Pomona Lake.

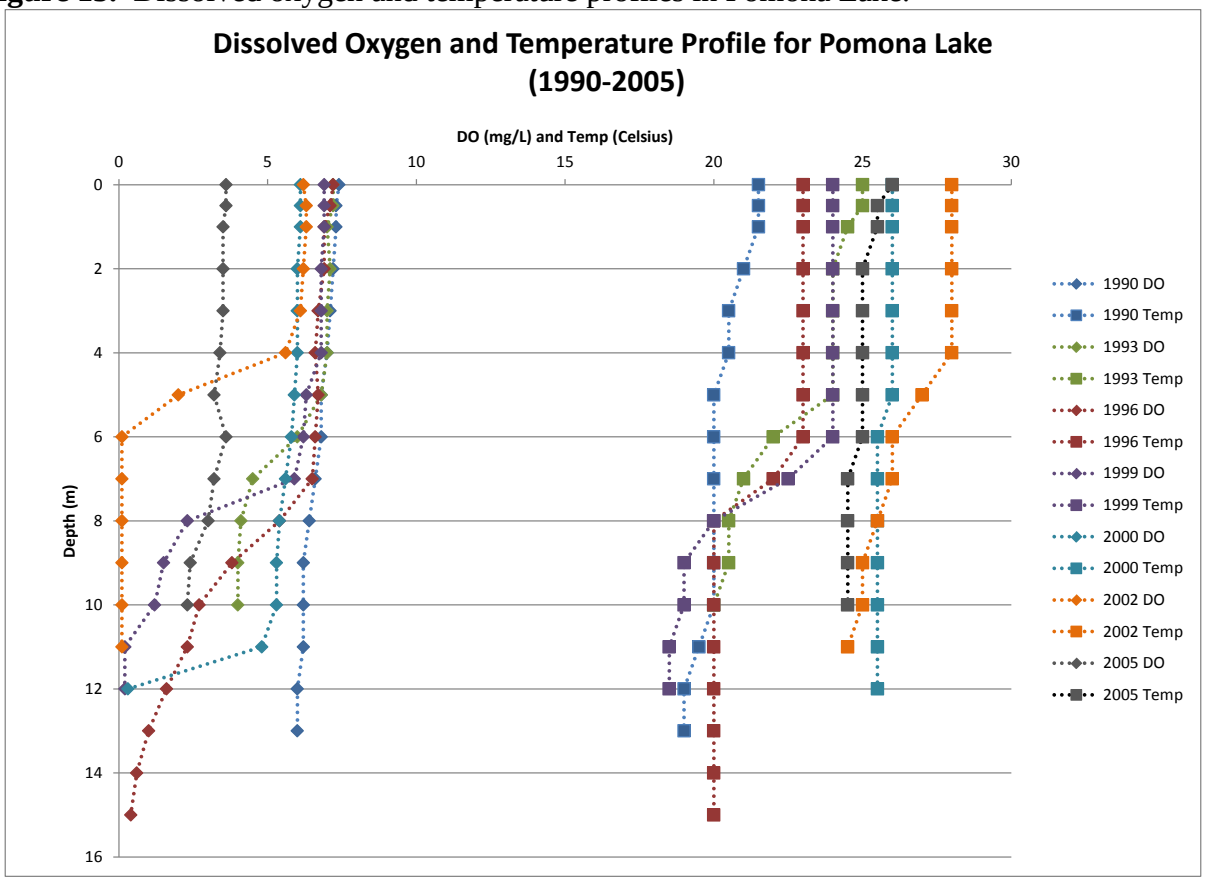


Table 4 lists the six metrics measuring the roles of light and nutrients in Pomona Lake. Non-algal turbidity (NAT) values <0.4m^{-1} indicates there are very low levels of suspended silt and/or clay. The values between 0.4 and 1.0m^{-1} indicate turbidity assumes greater influence on water clarity but would not assume a significant limiting role until values exceed 1.0m^{-1}.

Table 4. Light limiting metrics in Pomona Lake. An empty cell indicates no data are available from the source for the noted period of record.

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	1.89	8.29	0.275	0.006	8.76	8.15	0.550
1993	3.02	13.2	2.60	0.079	14.6	11.6	8.65
1996	4.83	21.1	0.500	0.028	21.9	14.8	2.50
1998	1.22	5.36	10.3		7.42	8.76	17.4
1999	2.74	12.0	1.28	0.043	12.9	10.4	3.75
2000	1.38	6.06	5.88	0.210	7.55	8.28	10.1
2002	0.306	1.34	18.4	0.307	3.04	6.25	12.8
2005	1.08	4.73	5.81	0.109	5.90	7.29	7.83
2007	2.90	12.7	4.59	0.210	14.6	12.1	15.3
2008	1.70	7.43	4.20	0.519	8.66	8.69	8.30
2010	1.12	4.90	9.43	0.252	6.74	8.21	14.5
2011	1.81	7.94	6.05	0.255	9.52	9.48	13.3
2012	1.03	4.51	8.04	0.232	6.08	7.63	11.2

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). 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 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 levels of non-algal turbidity in the lake are greater than 1.0 for the period of record with the exception of 2002 when the Secchi depth in the lake was at 1.4 meters. The degree of NAT in the lake indicates that high levels of suspended silt and/or clay is responsible for the diminished light availability in Pomona Lake as demonstrated by consistent Chl *a* * SD values of less than six and Zmix/SD values of less than three. The diminished light availability is causing algae to be slow to respond to phosphorus inputs as indicated by the algal use of phosphorus supply metric (Chl *a*/TP). Although the shading values in Table 4 indicate algal growth in the lake is not being impeded by self-shading, Pomona Lake has a maximum depth of 38 feet (11.5 meters) making this metric unreliable for this analysis.

Another method for evaluating limiting factors is the trophic state index (TSI) deviation metrics. Figure 16 (Multivariate Deviation Graph) summarizes the current trophic conditions in Pomona Lake 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.

The multivariate TSI comparison chart in Figure 16 displays that there were high levels of non-algal turbidity in Pomona Lake which is diminishing the transparency in the lake and indicating Pomona Lake is light limited.

Comparing the trophic state indices for total phosphorus, chlorophyll *a* and Secchi depth in Pomona Lake reveals the lake reached a fully eutrophic state with respect to chlorophyll *a* once, in 2002, while the Secchi depth TSI values show a hypereutrophic state for eight of the ten years the lake was sampled. The eutrophic state, with respect to total phosphorus, reached a hypereutrophic state in 1990, improved to a very eutrophic state in 2005 and, in 2012, was in a fully eutrophic state (Figure 17).

Figure 16. Multivariate TSI comparison chart for Pomona Lake.

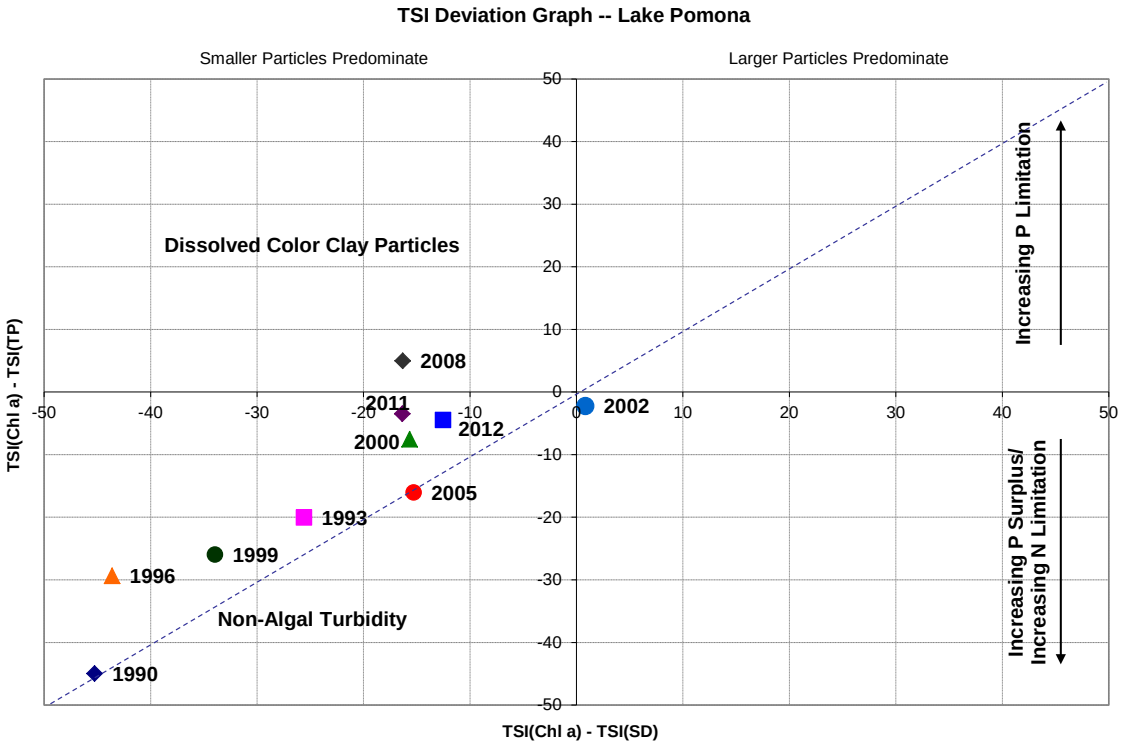
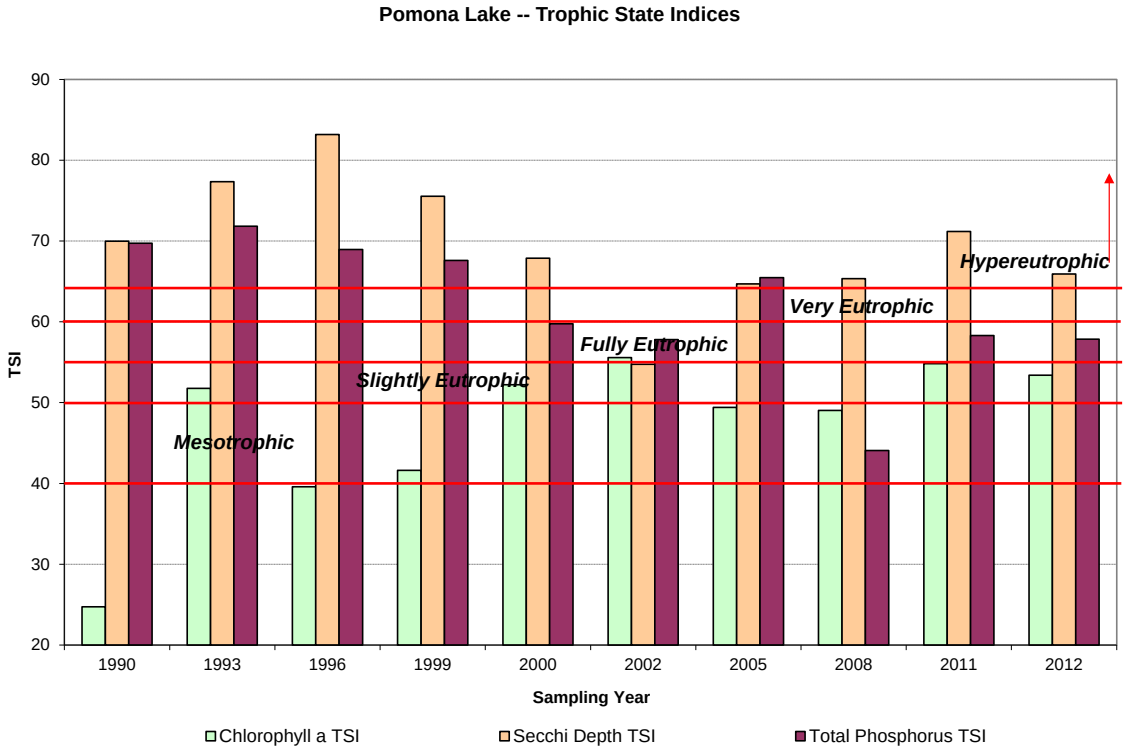


Figure 17. Trophic state indices for Pomona Lake.



A comparison of the median trophic conditions in Pomona Lake for the 2008 to 2012 time period to the benchmarks established for lakes in Kansas reveals that although both total nitrogen and total phosphorus concentrations in Pomona Lake meet the benchmarks established for federal lakes in Kansas the median chlorophyll *a* concentration and Secchi depth do not (Table 5). Also, when measured against the benchmarks established for the Kansas lakes, lakes in the central irregular plains ecoregion and the RTAG lakes, the median values for Pomona Lake during the 2008 to 2012 time period fall short. The statewide benchmarks and benchmarks for Kansas lakes in the central irregular plains region were derived from analysis of trophic conditions in the lakes and reservoirs in Kansas (Dodds et al., 2006). RTAG benchmarks were established by the USEPA Region 7 Regional Technical Assistance Group (RTAG) and are for lakes and reservoirs in Kansas, Iowa, Missouri and Nebraska excluding the Sand Hills ecoregion (USEPA, 2011).

Table 5. Median trophic indicator values for Pomona in comparison with federal lakes in Kansas, lakes located in the central irregular plains ecoregion, draft nutrient benchmarks in Kansas and nutrient reference conditions for lakes in USEPA Region 7. Median values are based on data from KDHE and USACE from 2008-2012.

Trophic Indicator	Pomona Lake	Federal Lakes	Central Irregular Plains Lakes	Statewide Benchmark	RTAG
Secchi Depth (cm)	59	95	130	129	N/A
TN (µg/l)	705	903	362	625	700
TP (µg/l)	59	76	20	23	35
Chlorophyll *a* (µg/l)	13	12	8	8	8

USACE sampling points within Pomona Lake can be seen in Figure 18 with data available annually from 1996-2012 for the Dragoon Creek and 110 Mile Creek arms and 2007-2012 for the Valley Brook arm. The Dragoon Creek pool, with more inflow from the watershed than the other two lake segments, has the highest concentrations of chlorophyll *a*, total phosphorus, and total suspended solids along with the lowest Secchi depth of the three arms while the Valley Brook Creek arm has the highest concentration of total nitrogen (Table 6). Data from 2008 through 2012 was used to populate the segment data in the lake eutrophication model used to develop the nutrient portion of this TMDL.

Figure 18. USACE Sampling Points in the Pomona Lake watershed.

Table 6. Water quality data for Pomona Lake collected and generated by USACE. Chlorophyll *a*, total nitrogen (TN), total phosphorus (TP), TN:TP ratio and Secchi depth values are averages for the time periods noted.

USACE Sampling Point	Period of Record	Chl a (µg/L)	TN (mg/L)	TP (mg/L)	TN:TP Ratio	Secchi Depth (m)	TSS (mg/L)
PO7: Mid-Pool Dragoon Cr Arm	1996-2012	21.4	0.913	0.102	8.95	0.35	21.9
	2008-2012	22.1	0.980	0.083	11.8	0.35	28.2
PO12: Mid-Pool 110 Mile Cr Arm	1996-2012	16.4	0.835	0.083	10.1	0.47	13.1
	2008-2012	16.5	0.923	0.058	15.9	0.49	14.3
PO14: Mid-Pool Valley Brook Arm	2007-2012	15.6	0.953	0.064	14.9	0.49	15.5
	2008-2012	16.1	1.00	0.062	16.1	0.54	14.4

Algal Communities: As seen in Table 7, algal communities in Pomona Lake have been dominated by blue-green algae, or cyanobacteria, since 2002. An increasing supply of nutrients, especially phosphorus and possibly nitrogen, will often result in higher growth of blue-green algae because they possess certain adaptations that enable them to out compete true algae (Soil and Water Conservation Society of Metro Halifax, 2007). Several of the cyanobacteria species possess gas vacuoles that allow them to move within the water column vertically. This selective advantage allows for some species to move within the water column to avoid predation and reach optimal primary productivity. Their movement within the water column may influence chlorophyll *a* levels within the lake at various depths during the diel cycle.

Table 7. Cell count and percent composition of the algal communities, with corresponding chlorophyll *a* concentrations, observed in Pomona Lake by KDHE on the sampling date detailed.

Sampling Date	Total Cell Count cells/mL	Percent Composition				Chl-*a* µg/L
		Green	Blue Green	Diatom	Other	
6/14/1993	945	67	0	0	33	8.65
6/10/1996	819	92	0	0	8	2.50
6/8/1999	189	50	0	50	0	1.60
8/23/2000	3,623	21	0	75	4	7.75
8/7/2002	8,442	2	62	34	2	12.8
8/17/2005	3,938	29	44	24	3	3.95
7/28/2008	9,167	8	83	7	1	6.55
6/27/2011	4,536	0	70	30	0	4.97

Relationships: Relationships between the water quality parameters in Pomona Lake are weak, at best, with the exception being the parameters that measure light availability shown in Figure 20. There is a small correlation between chlorophyll *a* and total nitrogen (Figure 19) and Secchi depth and total nitrogen (Figure 20). However, the correlations between TSS and NAT, Secchi depth and turbidity in the lake highlight the degree of light limitation in the Pomona Lake water column due to suspended clay and silt particles (Figure 21).

Figure 19. Relationship between chlorophyll *a* and total phosphorus and chlorophyll *a* and total nitrogen in Pomona Lake with coefficients of determination. Annual averages that include both KDHE and USACE water quality values were used.

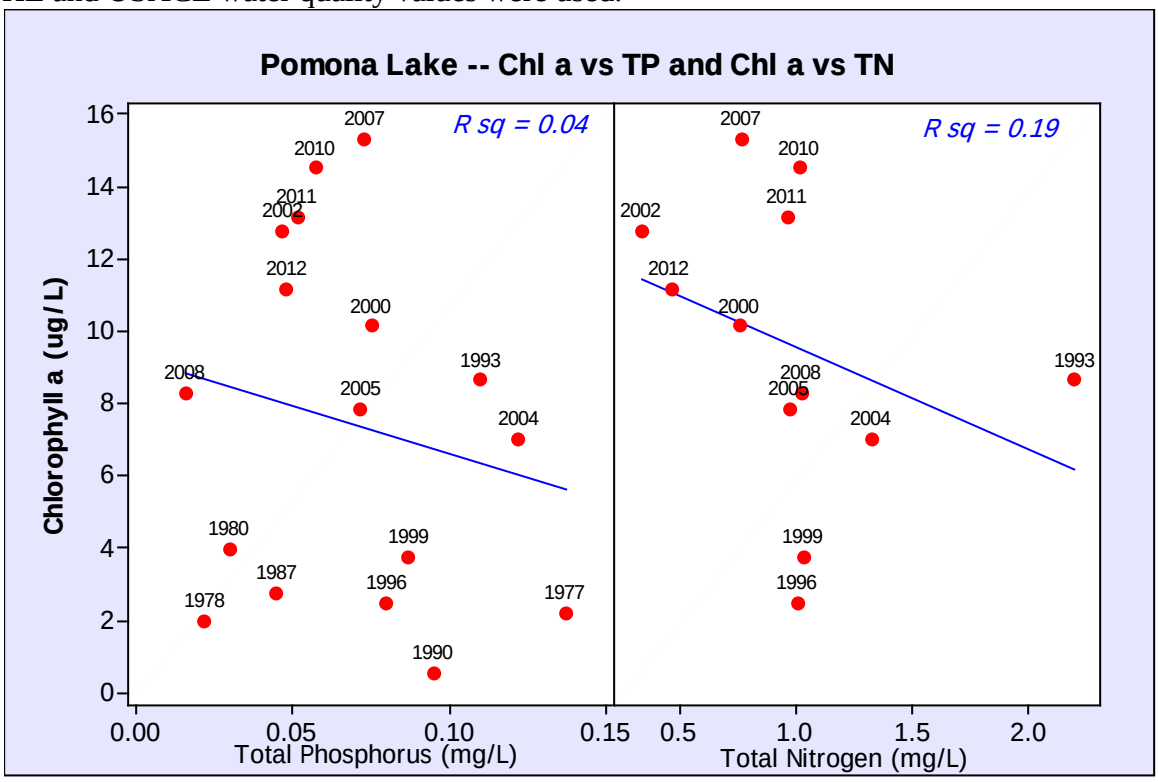


Figure 20. Relationship of nutrients and chlorophyll *a* to Secchi depth in Pomona Lake for common sampling years with coefficients of determination. Annual averages that include both KDHE and USACE water quality values were used.

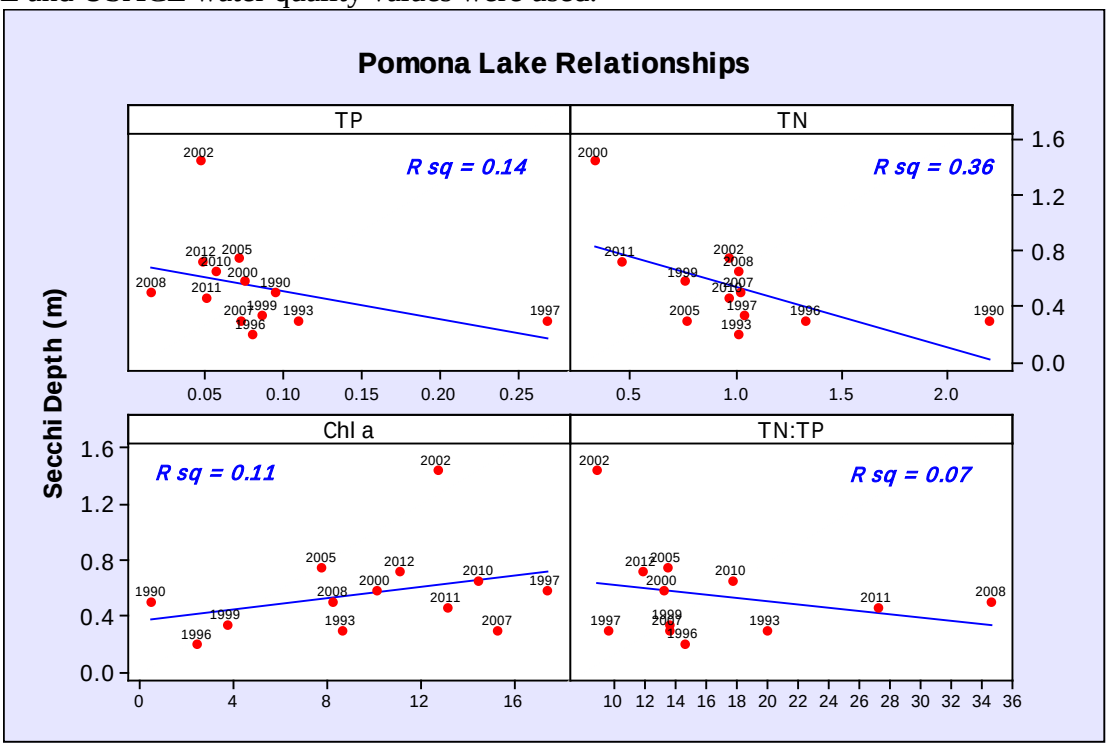
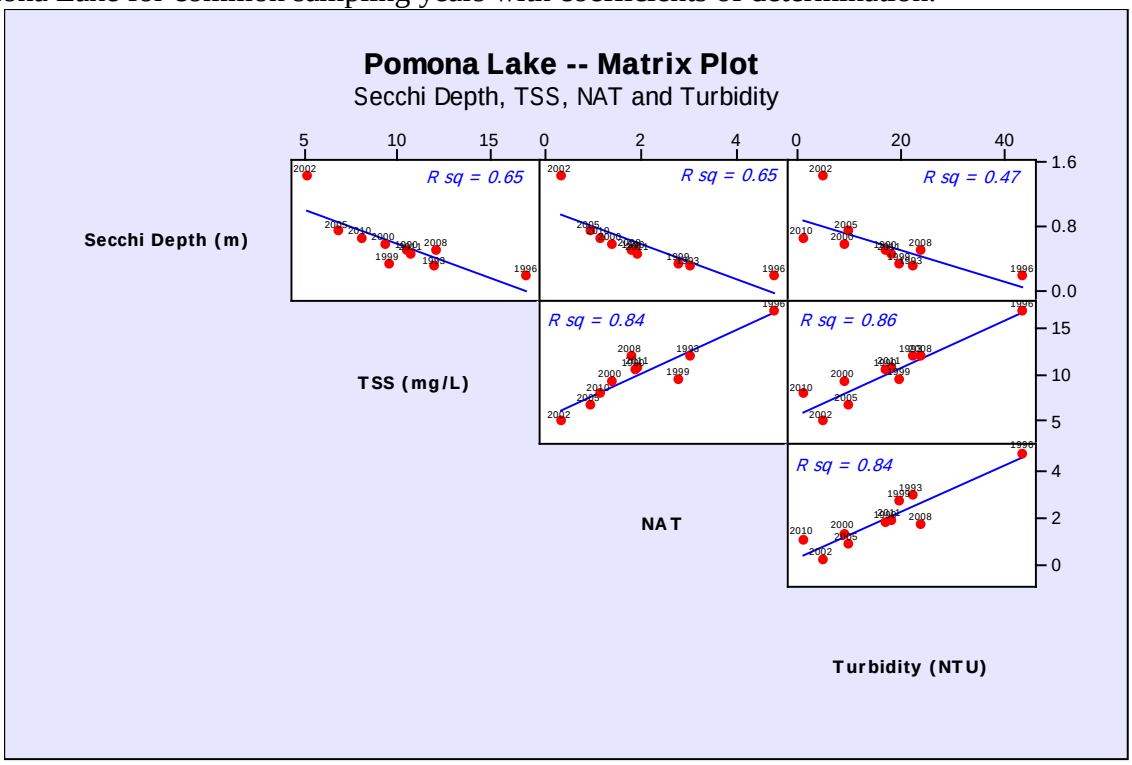


Figure 21. Relationships between Secchi depth, TSS, turbidity and non-algal turbidity in Pomona Lake for common sampling years with coefficients of determination.



Stream Data: There are three KDHE stream monitoring stations and two USACE stream monitoring stations within the Pomona Lake watershed (Table 8). USACE PO-11 is located on Dragoon Creek above its confluence with Smith Creek and shares its position with USGS Gage 06911900 while USACE station PO-2 is located at the outfall of Pomona Lake in 110 Mile Creek (Figure 17). Stations SC687 and SC633 are KDHE rotational stations located on Switzler Creek and 110 Mile Creek, respectively. Both SC687 and SC633 have a 2001 TMDL established for dissolved oxygen. SC577 is a permanent KDHE station located on Dragoon Creek above its confluence with Mud Creek. Data from SC577 and SC633 was transformed to flow weighted averages and used to populate the tributary data in the lake eutrophication model. Untransformed data from PO-2 was used to populate the outfall segment of the model.

Table 8. Average total nitrogen (TN), total phosphorus (TP), turbidity and total suspended solids (TSS) for streams in the Pomona Lake watershed.

Source	Station/Stream	Period of Record	TN (mg/L)	TP (mg/L)	Turbidity (NTU)	TSS (mg/L)
USACE	**PO-11 Dragoon Creek**	1996-2011	1.15	0.128	36.1	24.3
		2008-2011	1.47	0.097	39.0	26.1
KDHE	**SC687 Switzler Creek**	1994-2012	1.34	0.216	44.1	82.8
		2008-2012	1.54	0.169	46.5	44.8
KDHE	**SC577 Dragoon Creek**	1990-2012	1.27	0.172	47.8	92.5
		2008-2012	1.58	0.199	69.5	92.4
KDHE	**SC633 110 Mile Creek**	1993-2009	1.42	0.160	38.0	76.7
		2009	1.67	0.135	38.1	35.0
USACE	**PO-2 110 Mile Creek**	1996-2012	1.14	0.145	48.1	23.8
		2008-2012	1.15	0.110	44.6	25.1

Figures 22, 23 and 24 detail the period of record averages for total phosphorus, total nitrogen and total suspended solids, respectively, at each of the stream stations in the Pomona Lake watershed. For the 1990-2012 period of record, PO-11 has the lowest total phosphorus and total nitrogen concentrations of the stations located on Dragoon Creek and its tributaries. SC687, located on Switzer Creek just above its confluence with Dragoon Creek, has the highest nutrient concentrations (1990-2012) and SC577, located on Dragoon Creek downstream from both PO-11 and SC687, has total phosphorus and total nitrogen concentrations that fall between the concentrations seen at the upstream Dragoon Creek stations, indicating there is some dilution occurring to the nutrient concentrations seen at SC687 (Figure 22 & 23). Total suspended solids concentrations, however, are higher at SC577 than at SC687 and PO-11 (Figure 24).

Figure 22. Total phosphorus concentrations at stream sampling stations in the Pomona Lake watershed (1993-2012).

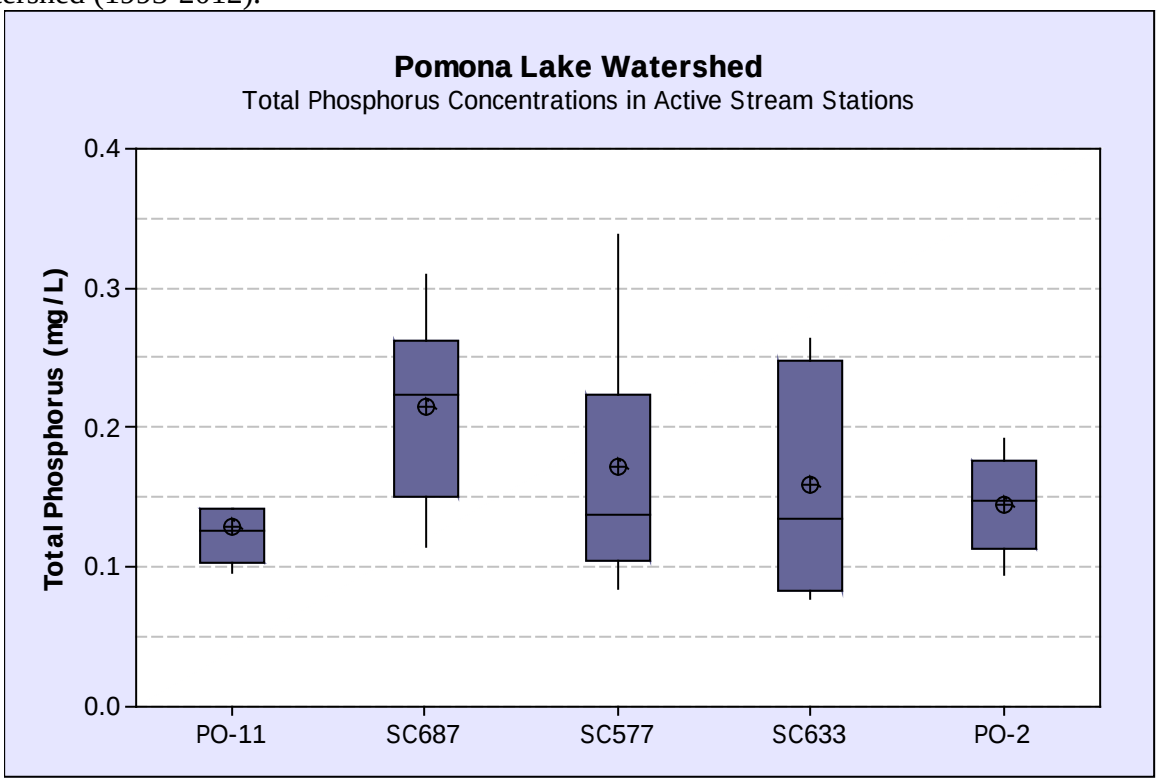


Figure 23. Total nitrogen concentrations at stream sampling stations in the Pomona Lake watershed (1993-2012).

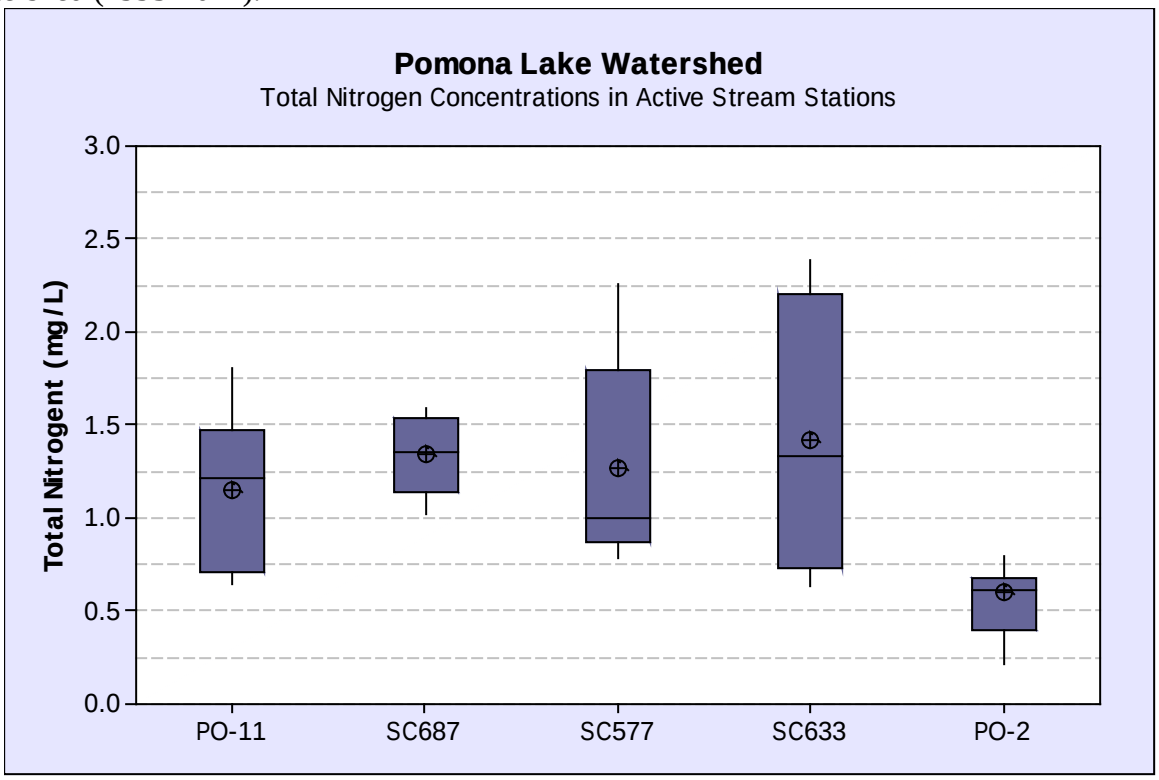


Figure 24. Total suspended solids concentrations at stream sampling stations in the Pomona Lake watershed (1993-2012).

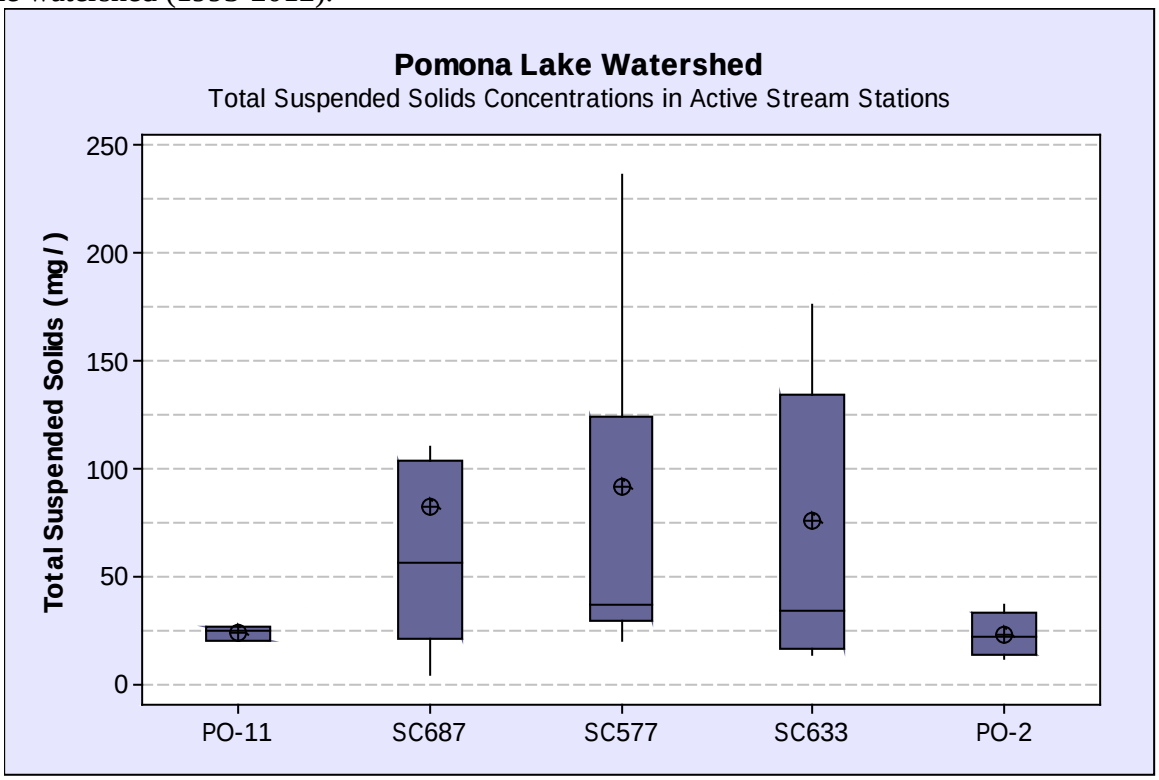


Table 9 details the KDHE stream sampling sites associated with the Probabilistic Stream Monitoring program. Sampling stations for the probabilistic program are chosen randomly throughout the state. The general goal of probabilistic sampling is to assess the condition of Kansas' waters. For probabilistic stream stations in the Pomona Lake watershed, the stations were sampled two to four times during the year in which they were selected for sampling. Occasionally the coordinates of a chosen probabilistic site are the same as those for a KDHE sampling station as is the case with SP176. SP176 and SC687 are the same sampling station hence the data collected at the site is applied to both SC687 and SP176. A high flow sample collected at SP176/SC687 on 5/1/2012 (1.03 mg/L TP, 10.7 mg/L TN, 156 mg/L TSS) was removed from the SC687 analysis above but included in Table 9. General inferences may be made with the probabilistic data.

Table 9. KDHE probabilistic stream sampling station summary within the Pomona Lake watershed.

Station	Stream (Segment)	Year Sampled (# of samples)	TP Avg. (mg/L)	TN Avg. (mg/L)	TSS Avg. (mg/L)
SPB064	Dragoon Creek (27)	2010 (4)	0.168	1.61	80.3
SPB112	Switzler Creek (80)	2011 (4)	0.148	0.893	21.0
SPB048	Switzler Creek (80)	2010 (4)	0.126	1.15	35.3
SPB176	Switzler Creek (80)	2012 (2)	0.437	4.36	60.7
SPA354	110 Mile Creek (25)	2008 (4)	0.134	1.12	12.7

Bathymetric Survey & Siltation: Construction on Pomona Lake began in 1959, gates were closed in 1962 and the lake became operational in 1964. In 1964 the multi-purpose pool had a capacity of 70,603 acre-feet with a surface area of 4,000 acres at the top elevation of 974 feet (KWO, 2012). A bathymetric and sediment survey performed in 2009 by the Kansas Biological Survey (KBS) revealed the multi-purpose pool capacity in Pomona Lake had diminished to 55,514 acre-feet and the lake surface area had shrunk to 3,941 acres (Figure 25 and 26). The 2009 KBS report also recorded high sediment thicknesses in the upper branches of the reservoir with the highest sediment thicknesses found at nearest the inlet channels for Dragoon Creek (135 cm), 110 Mile Creek (90 cm) and Valley Brook Creek (84 cm) (Figure 27). Texture analysis indicates that sediment is made up of predominately clay and silt and the average bulk density for the twelve sediment coring samples KBS successfully analyzed is 0.77 g/cm^3.

Figure 25. Water depth in Pomona Lake based on a June 2009 bathymetric survey. Depths are based on pool elevation of 975.25 ft. (KBS 2009)

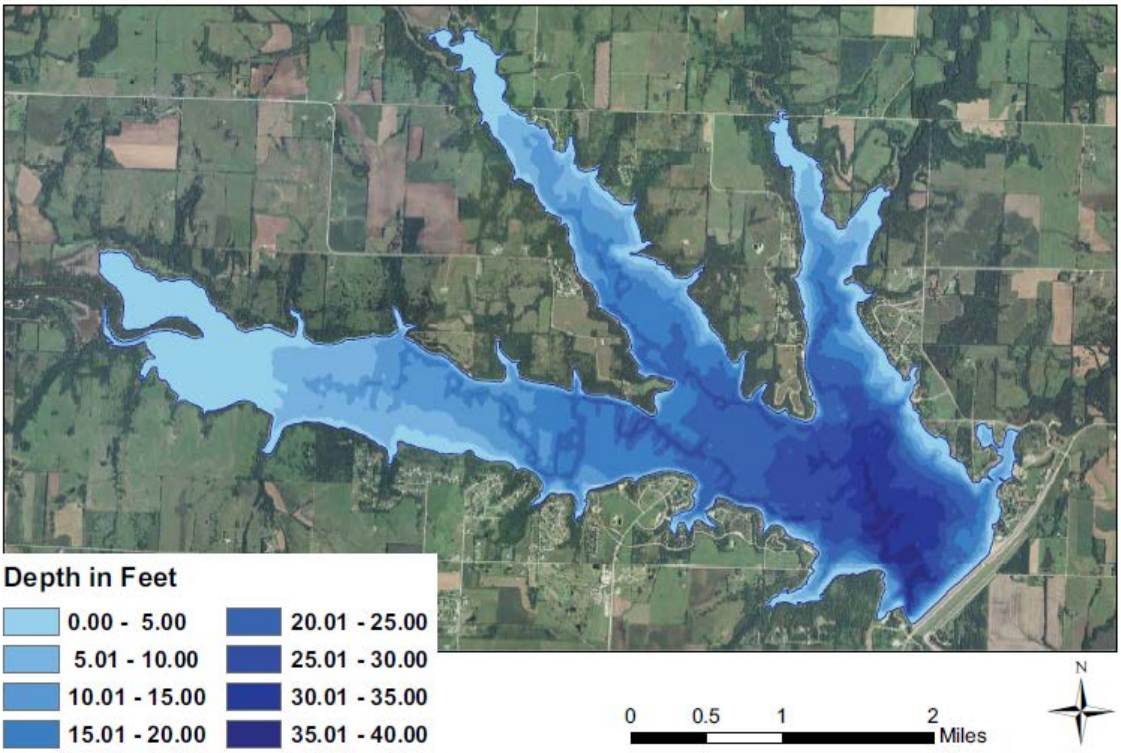


Figure 26. Changes in lake-bottom elevation, pre-impoundment to 2009. Negative values indicate 2009 elevation lower than pre-impoundment elevation while positive values indicate 2009 lake bottom higher than pre-impoundment elevation. (KBS, 2009)

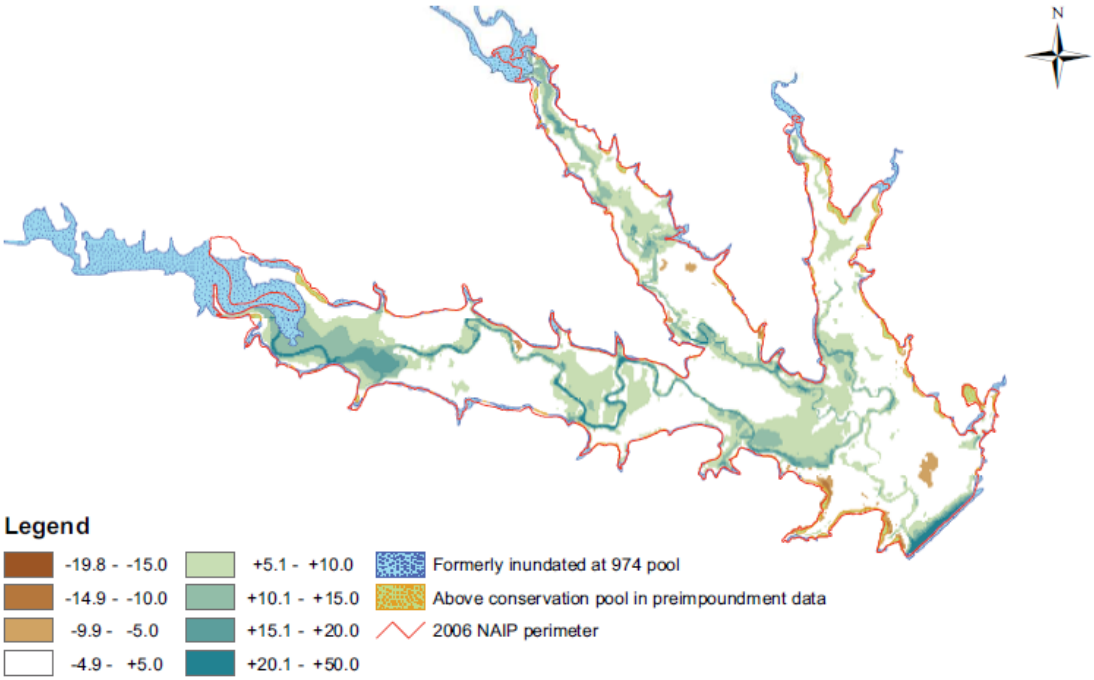
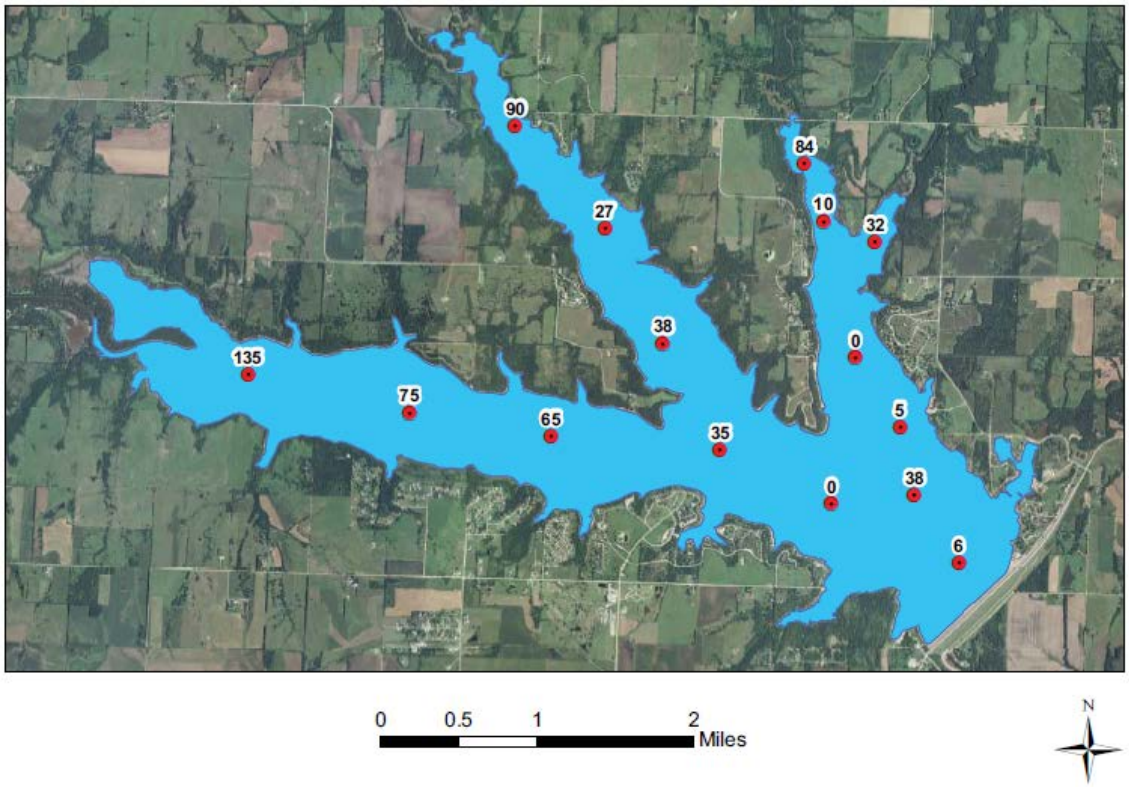


Figure 27. Sediment thickness in centimeters at coring sites in Pomona Reservoir.



Desired Endpoints of Water Quality (Implied Load Capacity) in Pomona lake:

The ultimate endpoint for this TMDL will be to achieve the Kansas Water Quality Standards fully supporting the designated uses in Pomona Lake by eliminating impacts associated with excessive siltation and excessive eutrophication. In order to improve the trophic condition of Pomona Lake from its current Slightly Eutrophic status, the desired endpoint will be to maintain summer chlorophyll *a* average concentrations below 10 μg/L, corresponding to a Carlson Trophic State Index of 53.2, with the reductions focused on nutrients (TN and TP) entering the lake. Reduction in nutrient 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* concentration in the lake. A chlorophyll *a* endpoint of 10 μg/L will also ensure long-term protection to fully support Primary Contact Recreation within the lake.

Based on the sedimentation rates established by the Kansas Water Office, Pomona Lake is losing storage capacity at a faster rate than designed. In order to ensure Pomona Lake maintains the 100 year design capacity, the sedimentation rate must be reduced by at least 22% or 77,508 tons/year (Table 10). Tons of sediment was calculated using the Pomona Lake sediment bulk density as determined in the 2009 KBS bathymetric survey (0.77 g/cm^3). At the current sedimentation rate, the area weighted Secchi depth is 53 cm and the area weighted total suspended solids concentration is 15.8 mg/L in Pomona Lake (Appendix A).

Table 10. Pomona Lake estimated sedimentation rates using the rates supplied in the Kansas Water Office's Pomona Lake Reservoir Information Sheet and the estimated bulk density derived from the 2009 KBS bathymetric survey.

Rate	Sedimentation (acre-feet/year)	Estimated Sediment (tons/year)	Storage Capacity after 100 years (acre-feet)
Design Rate	294	307,804	41,203
Calculated Current Rate	334	349,683	37,203
Rate Required to Meet 100 Year Design Life for Storage	261	272,870	41,203
Reduction Necessary to Meet 100 Year Design Rate	73	76,812	

Although a 22% reduction in the sedimentation rate from the current rate of 334 AF/year to 261 AF/year will allow the lake to meet the 100 year design life, this reduction will not fully support the designated uses of the lake. Therefore, a water-quality based target is used for developing this siltation TMDL. A 70 cm Secchi depth is described in the 2002 KDHE Lake and Wetland report as a "reasonably good threshold criteria for water clarity and turbidity versus recreational and aesthetic use support" thus it has been used to develop the TSS target (Appendix A). A TSS target of 4.66 mg/L will be met by reducing sediment loading in the watershed thereby improving the area weighted transparency of the lake to the endpoint of 70 cm (Table 11). This

32% increase in Secchi depth will indicate a 71% reduction in the total suspended solids in the water column of Pomona Lake. The 71% reduction of total suspended solids in the water column will indicate a 71% reduction in sediment loading which will meet this TMDL and restore full support of the designated uses in the lake.

Based on the BATHTUB reservoir eutrophication model (Appendix B), the total phosphorus and total nitrogen entering Pomona Lake must be reduced by 56% and 55%, respectively. These reductions at the inflow to Pomona Lake will result in a 42% reduction of total phosphorus, a 40% reduction of total nitrogen and a 45% reduction of Chlorophyll *a* within the lake (Table 11).

Achievement of the endpoints 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 Pomona Lake utilized in the model input was based on data from 2008-2012 from both the USACE and KDHE with calibration and reductions focused on area weighted means generated by the BATHTUB model.

Table 11. Pomona Lake current average condition (2008-2012) and TMDL. Current condition and TMDL nutrient concentrations reflect BATHTUB area weighted means.

	Current Avg. Condition	**TMDL**	**Percent Reduction**
Total Phosphorus – Annual Load (lbs/year)	124,531	54,814.57	56%
Total Phosphorus – Daily Load* (lbs/day)	803.3	353.58	56%
Total Phosphorus – Lake Concentration (µg/L)	77.6	45.3	42%
Total Nitrogen – Annual Load (lbs/year)	917,063	412,416.06	55%
Total Nitrogen – Daily Load* (lbs/day)	4,855	2,183.31	55%
Total Nitrogen – Lake Concentration (mg/L)	0.949	0.571	40%
Chlorophyll *a* Concentration (µg/L)	18.3	10	45%
Total Suspended Solids – Annual Load (tons/year)	349,683	101,408	71%
Total Suspended Solids – Daily Load* (tons/day)	2,571	746	71%
Total Suspended Solids Concentration (mg/L)	15.8	4.66	71%
Secchi Depth (m)	0.53	0.70	32% Increase

*See Appendix C for daily load calculations.

3. SOURCE INVENTORY AND ASSESSMENT

Point Sources: There are fourteen NPDES permitted facilities in the Pomona Lake watershed (Table 12). Seven facilities operate non-overflowing lagoon systems that are prohibited from discharging and would only contribute a TSS or nutrient load under extreme precipitation or flooding events. One facility is an un-manned pumping facility where stormwater running from a concrete pad used to mount gas powered turbines is collected in an underground storage tank until it can be properly disposed of; hence, there is no contribution to the sediment or nutrient load from this facility. One facility is a limestone quarrying and crushing operation where treated wash water is recycled and would not contribute a sediment or nutrient load except under extreme precipitation or flooding events.

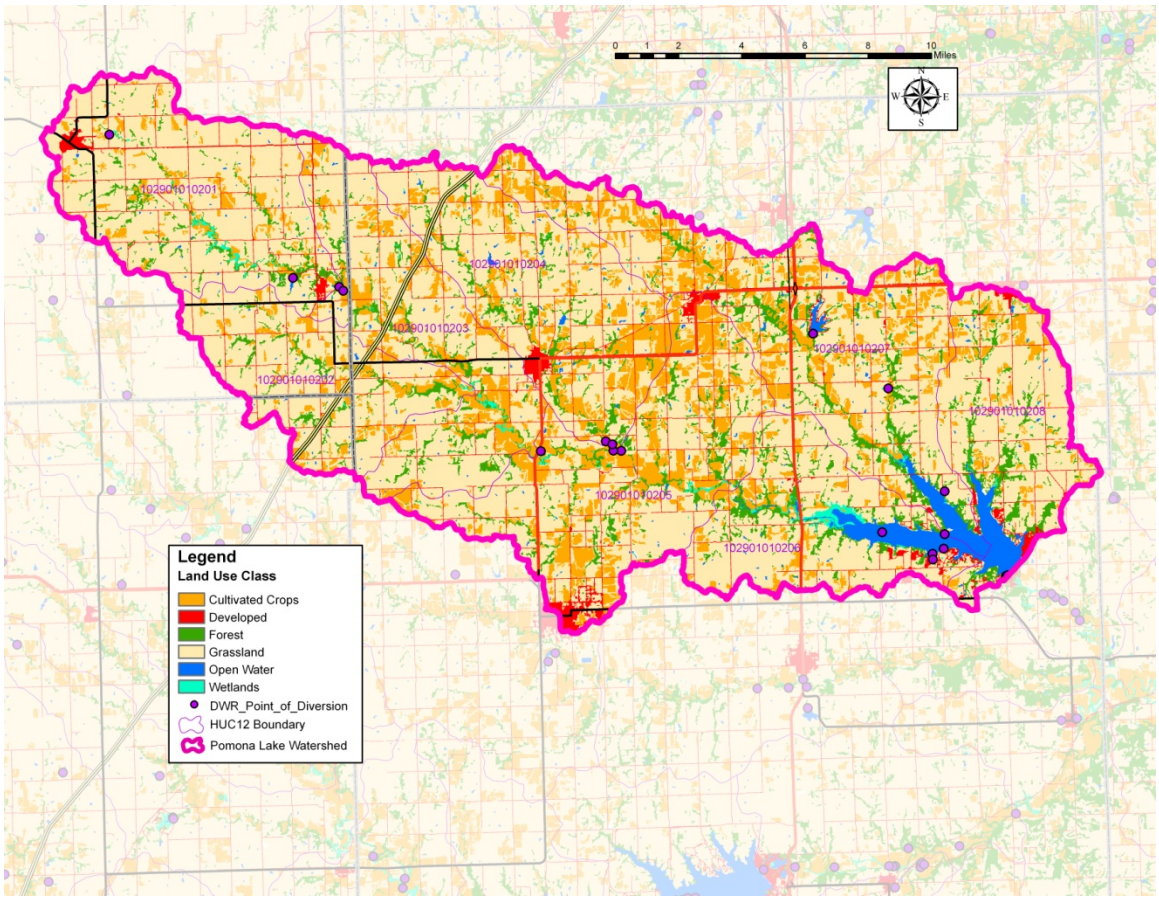
The remaining five NPDES permitted facilities are municipal lagoon facilities that are permitted to discharge to the watershed and, consequently, are assigned a wasteload allocation for total suspended solids, total nitrogen and total phosphorus under this TMDL. Currently, these discharging facilities are required to monitor quarterly, when discharging, for total suspended solids with a weekly/monthly TSS effluent limit of 120/80 mg/L (Table 12). There is no monitoring requirement for nutrients; however, concentrations typical of those observed in the effluent of lagoon systems in Kansas at 2 mg/L total phosphorus and 8 mg/L total nitrogen were used to develop the wasteload allocations for the discharging lagoons. The City of Eskridge operates a three-cell stabilization lagoon system with a 120 day retention time and a permitted flow of 0.0815 million gallons per day (MGD) that discharges into the headwaters of Dragoon Creek. The three-cell stabilization lagoon operated by the City of Harveyville has a permitted flow of 0.06 MGD and discharges downstream from the City of Eskridge to Dragoon Creek below its confluence with Batch Creek. Nutrient and sediment contributions from these facilities may be seen at KDHE monitoring station SC577 located on Dragoon Creek above its confluence with Mud Creek. The City of Burlingame operates a three-cell stabilization lagoon system that is permitted to discharge to Switzler Creek up to 0.121 MGD. Nutrient and sediment contributions from this facility may be seen at KDHE monitoring station SC687 located on Switzler Creek just above its confluence with Dragoon Creek. The City of Scranton is permitted to operate a four-cell stabilization lagoon system with permitted flow of 0.08 MGD that discharges via an unnamed tributary to Dragoon Creek. The City of Overbrook operates a four-cell stabilization lagoon system that is permitted to discharge at a rate of 0.128 MGD to Pomona Lake via Valley Brook Creek. Discharges from the Scranton and Overbrook facilities enter the watershed below KDHE stream monitoring stations; hence, nutrient and sediment contributions from their facilities are seen only in the characterization of Pomona Lake.

Table 12. NPDES permitted facilities and their daily wasteload allocations in the Pomona Lake watershed.

Name	NPDES Permit #	State Permit #	Type	Receiving Stream	Expiration Date	Design Capacity (MGD)	Avg TSS (mg/L)	TP WLA (lbs/day)	TN WLA (lbs/day)	Sediment WLA (lbs/day)
Crossroads RV Park	KSJ000200	C-MC21-NO01	Non-Overflowing	N/A	1/31/15	N/A	N/A	N/A	N/A	N/A
Lamont Hill Resort	KSJ000550	C-MC58-NO03	Non-Overflowing	N/A	10/31/15	N/A	N/A	N/A	N/A	N/A
Lamont Hill Resort	KSJ000140	C-MC58-NO04	Non-Overflowing	N/A	10/31/15	N/A	N/A	N/A	N/A	N/A
Osage County SD No. 1	KSJ000356	M-MC58-NO03	Non-Overflowing	N/A	10/31/15	N/A	N/A	N/A	N/A	N/A
Pomona State Park	KSJ000360	M-MC36-NO01	Non-Overflowing	N/A	5/31/15	N/A	N/A	N/A	N/A	N/A
Unified SD # 434	KSJ000363	M-MC-32-NO01	Non-Overflowing	N/A	5/31/15	N/A	N/A	N/A	N/A	N/A
Four Corners	KSJ000612	C-MC44-NO01	Non-Overflowing	N/A	4/30/14	N/A	N/A	N/A	N/A	N/A
Mid States Materials	KS0093106	I-MC44-PO04	Pit De-watering	N/A	06/30/14	N/A	N/A	N/A	N/A	N/A
Mid America Pipeline	KSJ000639	I-MC09-NP01	Underground Collection Tank	N/A	7/31/17	N/A	N/A	N/A	N/A	N/A
Eskridge WWTF	KS0046400	M-MC09-OO01	3 Cell Lagoon	Dragoon Creek	9/30/14	0.0815	42.1	1.36	5.44	28.6
Harveyville WWTF	KS0046418	M-MC16-OO01	3 Cell Lagoon	Dragoon Creek	6/30/14	0.060	21.4	1.00	4.01	10.7
Burlingame WWTF	KS0024694	M-MC07-OO01	3 Cell Lagoon	Switzler Creek	3/31/14	0.121	34.2	2.02	8.08	34.5
Scranton WWTF	KS0031283	M-MC44-OO01	4 Cell Lagoon	Dragoon Creek	6/30/14	0.080	26.7	1.33	5.34	17.9
Overbrook WWTF	KS0046451	M-MC32-OO01	4 Cell Lagoon	Valley Brook Creek	12/31/14	0.128	41.6	2.14	8.55	44.5
Total Wasteload Allocations (lbs/day)								***7.85***	***31.42***	***136.2***

Land Use: The predominant land uses in the Pomona Lake watershed are grassland (66%) and cultivated crops (18%), according to the 2001 National Land Cover Data. Together they account for 84% of the total land area in the watershed with the remaining land area composed of forest (7%), developed land (6%), open water (2%) and wetlands (1%) (Figure 28). During precipitation runoff events, the cultivated cropland in the watershed may contribute to the nutrient and sediment loads in the lake. Grasslands could also contribute to the nutrient load during high flow events, particularly on livestock grazing lands located in the riparian areas of the watershed. The watershed is also 6% developed which is primarily in the form of five small cities with populations under 3,000 people (Table 14). These urbanized areas may generate substantial nutrient loading from lawn fertilizers, domestic pet waste and other toxics found in the urban environment particularly during storm runoff events.

Figure 28. Land use in the Pomona Lake watershed.



Livestock Waste Management Systems: According to the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS), on January 1, 2013 there were 59,000, 29,500, and 36,500 head of cattle (including calves) in Lyon, Osage and Wabaunsee Counties, respectively. On December 1, 2012, according to NASS, there were 3,800, 1,200 and 1,100 head of hogs in Lyon, Osage, and Wabaunsee Counties and at the end of December 2007 there were 357, 275, and 3,633 head of sheep in Lyon, Osage, and Wabaunsee Counties. There are eleven certified or permitted confined animal feeding operations (CAFOs) within the Pomona Lake watershed; however, none of them have enough animals to warrant a

federal discharge (NPDES) permit (Table 13). These permitted or certified livestock facilities 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 stream flow occurring less than 1-5% of the time. It is likely that there are some smaller, unregistered livestock operations in the area and, depending on their proximity to the streams in the watershed, runoff from feedlots and grazing lands may be contributing to the nutrient and siltation impairment in Pomona Lake.

Table 13. Registered, certified or permitted confined animal feeding operations (CAFOs) in the Pomona Lake watershed. There are no federally permitted CAFOs in the watershed.

Kansas Permit Number	Animal Type	County	Animal Total
A-MCOS-BA04	Beef	Osage	75
A-MCOS-B006	Beef, Swine	Osage	535
A-MCOS-B003	Beef	Osage	300
A-MCOS-BA18	Beef	Osage	300
A-MCOS-BA02	Beef	Osage	500
A-MCOS-SA02	Swine	Osage	150
A-MCOS-BA13	Beef	Osage	160
A-MCOS-BA10	Beef	Osage	120
A-MCOS-B0005	Beef	Osage	440
A-MCOS-B008	Beef, Swine	Osage	650
A-MCWB-BA01	Beef	Wabaunsee	780

On-Site Waste Systems: The Pomona Lake watershed is a mixture of rural agricultural areas and small cities that lies primarily in Osage and Wabaunsee counties. It can be assumed that all of the rural residences in the watershed are not connected to public sewer systems and according to the Spreadsheet Tool for Estimating Pollutant Load (STEPL), there are a total of 1,069 septic systems in the watershed with a 0.93% failure rate. Failing on-site septic systems have the potential to contribute to nutrient loading in the watershed.

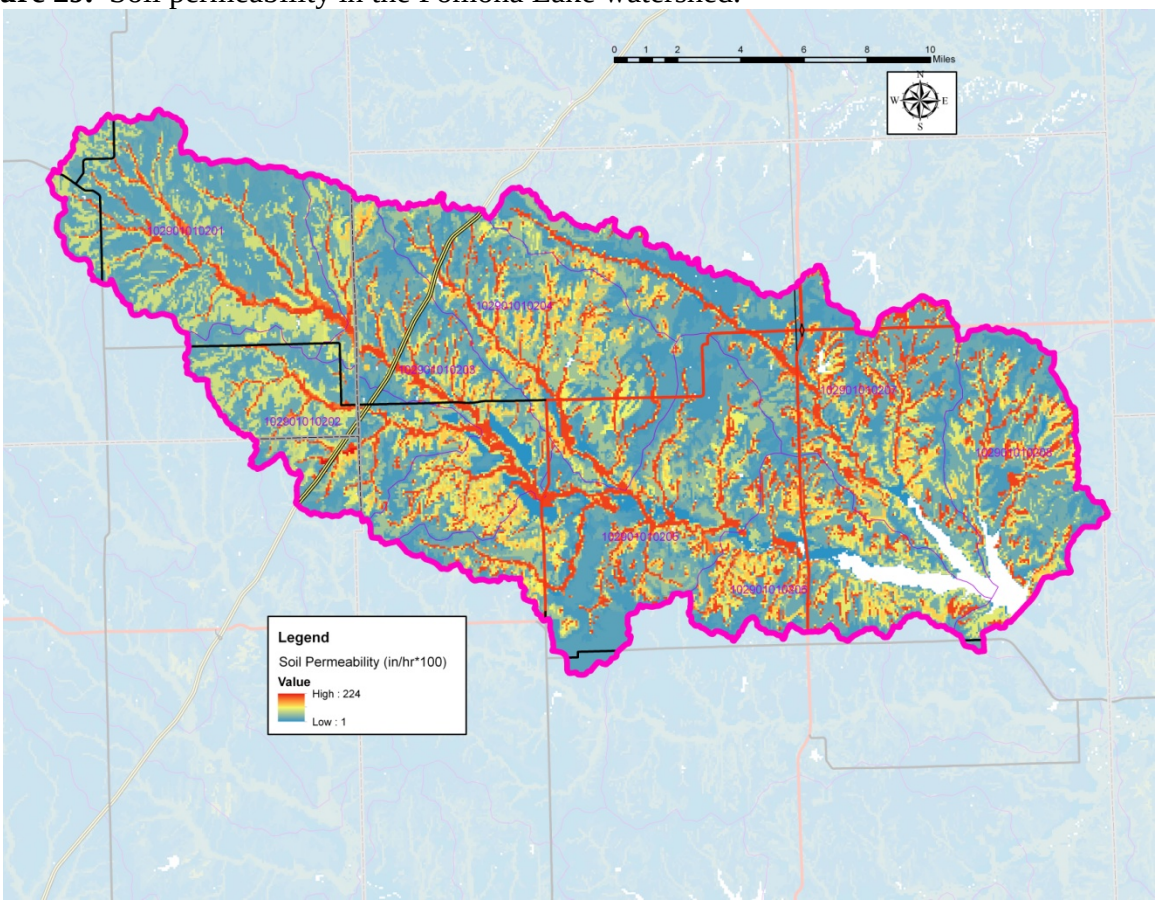
Population: Population figures tallied by the 2000 and 2010 U.S. Census are detailed in Table 14 for Lyon, Osage and Wabaunsee counties along with figures for the small cities that lie within the lake's watershed. Although the Wabaunsee County and the City of Overbrook show small increases in population between 2000 and 2010, overall population in the watershed appears to be on the decline.

Table 14. U.S. Census results for populations in the Pomona Lake watershed.

County/City	Year of Census		% Difference
	2000	2010	
Lyon County	35,935	33,690	-6%
Wabaunsee County	6,885	7,053	+2%
Eskridge	589	534	-9%
Harveyville	267	236	-12%
Osage County	16,712	16,295	-2%
Burlingame	1,017	934	-8%
Scranton	724	710	-2%
Overbrook	947	1,058	+12%
Osage City	3,064	2,943	-4%

Contributing Runoff: The watershed of Pomona Lake has an extremely low mean soil permeability value of 0.43 inches/hour. Permeability ranges from 0.01 inches/hour to 2.24 inches/hour according to NRCS STATSGO database with over 65% of the watershed having a permeability value less than 1.14 inches/hour, which contributes to runoff during very low to extremely low rainfall intensity events. 27% of the Pomona Lake watershed has a permeability value of 1.29 inches/hour, generating runoff during low to very low rainfall intensities (Figure 29). 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 soil profiles become saturated and produce excess overland flow due to rainfall intensities that are greater than soil permeability.

Figure 29. Soil permeability in the Pomona Lake watershed.



Background and Natural Sources: Undissolved nutrients bound to suspended solids in the inflow to Pomona Lake are potentially significant sources of nutrients that may endure in the sediment layer until they are removed by dredging. These internal nutrient loads can undergo remineralization and resuspension and may be a continuing source of nutrients in Pomona Lake. In addition, geological formations (i.e. soil and bedrock) may also contribute to nutrient loads and, with deciduous forest making up about 7% of the land cover in the watershed, leaf litter and wastes derived from natural wildlife in the area are also likely to add to the nutrient and suspended solids load in Pomona Lake. Further nutrient loading is also occurring through the atmospheric deposition of nitrogen and phosphorus compounds to Pomona Lake and its watershed.

Unique Points of Diversion: The Pomona Lake watershed contains thirty two unique points of diversion that are made up of a water right and point of diversion combination and, in this case, all twelve points are tied to surface water rights in the watershed (Figure 28). A total of four points lie within Wabaunsee County with two designated for irrigation use, one for municipal use and one for industrial use. The remaining twenty eight points are located in Osage County with one point for domestic use, one point for industrial use, three points for recreational use, nine points for municipal use and the remaining fourteen unique points of diversion designated for use in irrigation.

Internal Loading: Due to inadequate data for Pomona Lake on the potential for internal nutrient loading, no estimates of internal loading were made outside those inherently contained within the BATHTUB modeling of the lake. Internal loading is a complex function of hydrologic conditions, lake morphometry and lake sediment nutrient availability. Because Pomona Lake sporadically stratifies during the summer growing season, internal loading of nutrients may play a role in the eutrophic state of the lake.

Stormwater runoff: There are several small cities in the Pomona Lake watershed resulting in approximately 6% of the watershed being designated as developed. During storm runoff events, these urban areas may contribute nutrient loads from lawn fertilizers and domestic pet waste along with sediment loads and other toxics found in the urban environment to Pomona Lake.

4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

Phosphorus and nitrogen are co-limiting nutrients in Pomona Lake; therefore, both are allocated under this TMDL. In order to improve Secchi depth measurements in the lake to 70 cm, thereby addressing the siltation impairment in the lake, sediment loads are also allocated 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 operations. Reductions in stormwater runoff contributions attributed to lawn fertilizer applications and domestic animal waste in the watershed should also be addressed in the urban areas of the watershed.

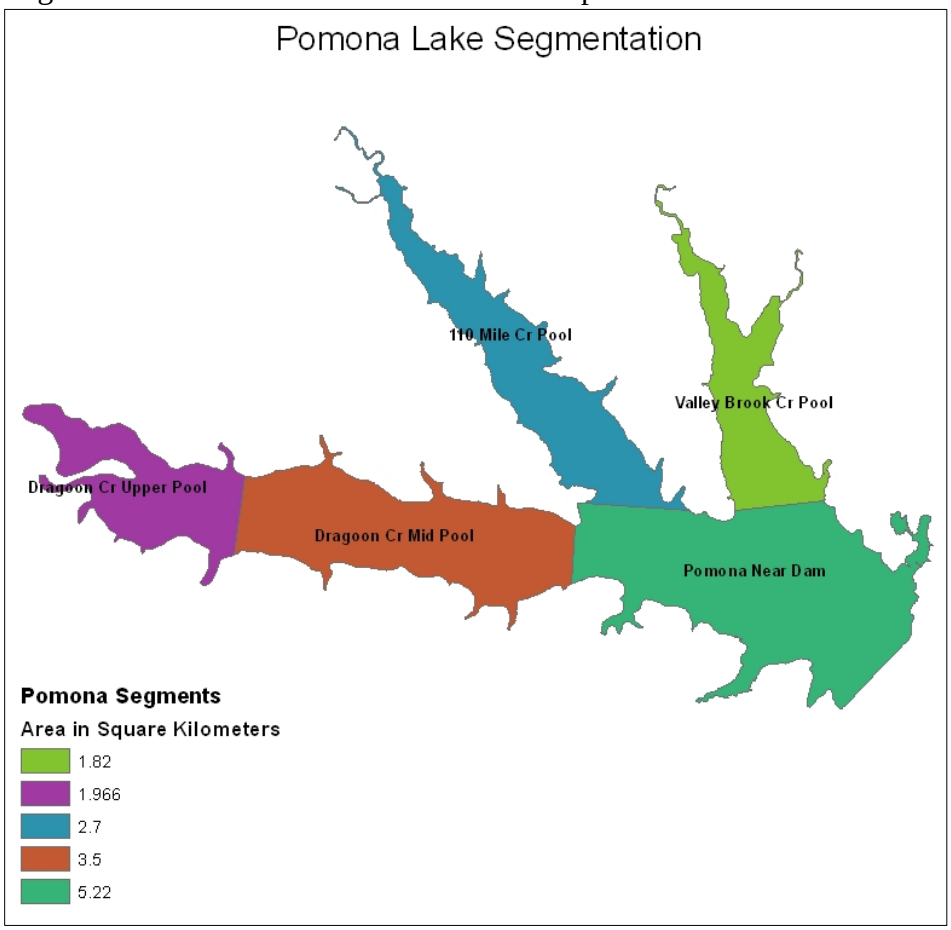
Nutrients: The lake model utilized for the development of the eutrophication TMDL was BATHTUB (Appendix B). BATHTUB is an empirical receiving water quality model, that was developed by the U.S. Army Corps of Engineers (Walker, 1996), and has been commonly applied in the nation to address many TMDLs relating to issues associated with morphometrically complex lakes and reservoirs (Mankin et al., 2003; Wang et al., 2005).

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.

For modeling purposes, Pomona Lake was considered as five segments (Figure 30). 2008-2012 data from both USACE and KDHE was used to populate the main basin segment water quality inputs. The Dragoon Creek lake segments, the 110 Mile Creek lake segment and the Valley Brook Creek lake segment utilized 2008-2012 USACE data collected at PO-7, PO-12 and PO-14, respectively. Segment depths were estimated using the KBS 2009 bathymetric study on Pomona Lake. Dragoon Creek and 110 Mile Creek tributary water quality inputs were developed using data from the KDHE sampling station SC577 on Dragoon Creek (2008-2012) and SC633 on 110 Mile Creek (2009), respectively. Average concentrations at the sampling stations were converted to flow weighted concentrations using flows relative to USGS 06911900 via Flux32 for the tributary inputs. Water quality inputs for the Valley Brook Creek tributary were generated by applying the relationship of concentrations at SC633 to in lake concentrations at PO-12 to in lake concentrations in the Valley Brook Creek segment of the lake measured at

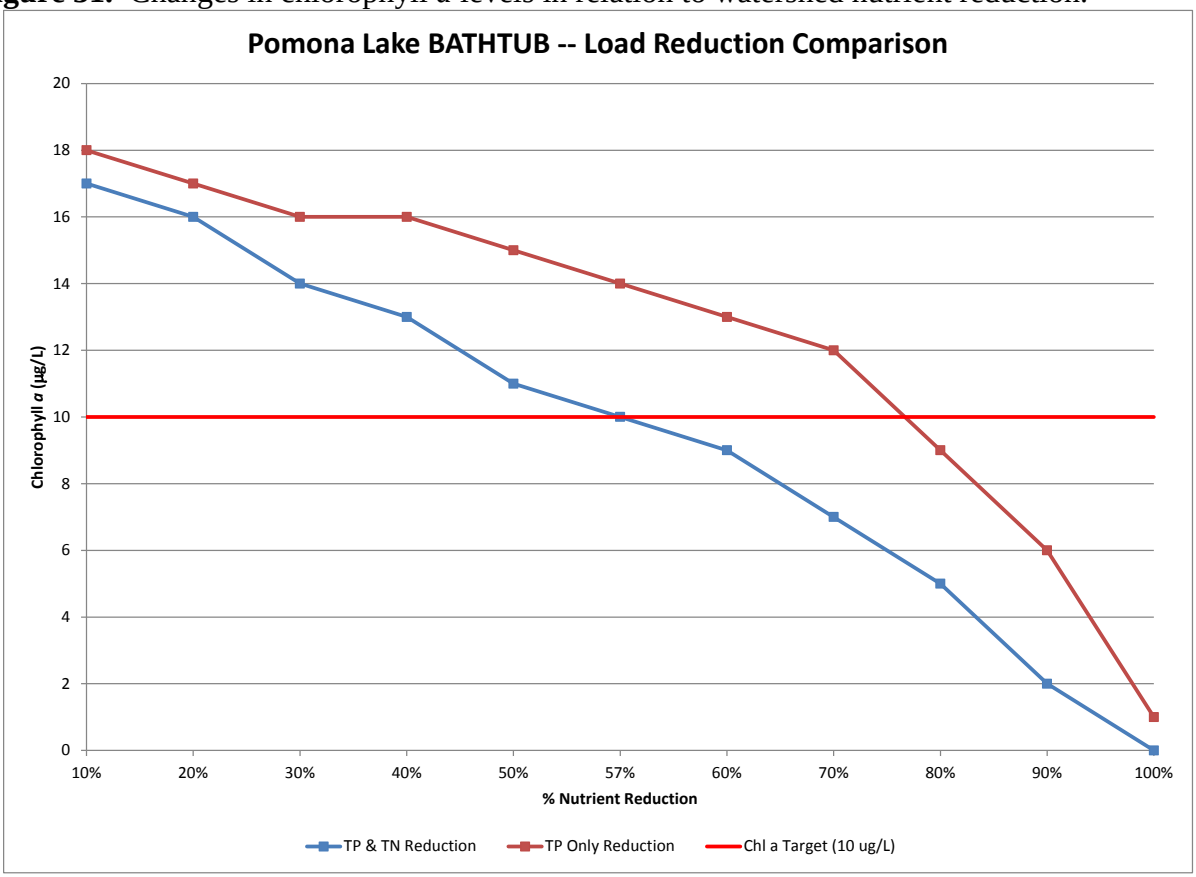
PO-14 (2008-2012). Flow values for Dragoon Creek, 110 Mile Creek and Valley Brook Creek were based on flows at USGS 06911900 using drainage area ratios for the 2008-2012 period of record. The flow for Pomona Outflow was calculated from USACE gaged outflow records for 2008 through 2012. Two point source dischargers were included in the model as tributaries in order to account for their contribution to the nutrient loading in the lake. For calibration purposes flow from the point source dischargers was set to 25% of their permitted design flow and total phosphorus and total nitrogen concentrations were entered as 2 mg/L and 8 mg/L, respectively. In the reduced model, point source flows were increased to 100% of design flow with total phosphorus and total nitrogen remaining at 2 mg/L and 8 mg/L.

Figure 30. Segmentation of Pomona Lake for lake eutrophication model.



The BATHTUB model was calibrated for and reduced from the area-weighted mean concentrations. The model results estimate that Pomona Lake currently retains 81.8% of the total phosphorus and 67.4% of the total nitrogen load annually. Based on modeling results, the combined reduction of total phosphorus and total nitrogen results in reaching the chlorophyll *a* endpoint with a 57% reduction while reducing total phosphorus would require a 78% reduction (Figure 31). Hence, a 57% reduction of total phosphorus and total nitrogen concentrations in the tributaries feeding the lake is necessary to meet the TMDL endpoint of and area weighted mean of 10 μg/L Chlorophyll *a* within Pomona Lake (Appendix B).

Figure 31. Changes in chlorophyll *a* levels in relation to watershed nutrient reduction.



Siltation: Siltation loading comes predominantly from nonpoint source pollution and, due to soil characteristics of the watershed, overland runoff can easily carry sediment to the stream segments and eventually to the lake. Based on the sedimentation rates established by the Kansas Water Office, Pomona Lake is losing storage capacity at a faster rate than designed. The design rate of sedimentation is 294 acre-feet per year (307,804 tons/year), however, the 2009 KBS bathymetric survey calculates the current rate as 334 acre-feet per year (349,683 tons/year). Therefore, in order to ensure Pomona Lake maintains the 100 year design capacity, the sedimentation rate must be reduced by at least 22% (76,812 tons/year) to 261 acre-feet per year (272,870.16 tons/year). Though a 22% reduction may be able to meet the lake capacity goal (Table 10), this reduction does not achieve full support of the designated uses of the lake. Therefore, a water quality based target has been used for the developing the sediment TMDL.

Because Kansas does not have numeric water quality criteria from inorganic turbidity associated with soil/sediment particles (often referred to as non-algal turbidity), "Brown" scores, derived from 1998-2002 statewide lake monitoring (Carney, 2003), were utilized as a guideline to the appearance of water clarity as a result of non-algal turbidity. In order to gauge that siltation in the lake is reduced to assure achievement of full support of all designated uses, a lake area weighted average Secchi depth endpoint of 70 cm and a lake area weighted average total suspended solids concentration endpoint of 4.66 mg/L is established by this TMDL with reductions focused on the total suspended solids entering the lake (Appendix A).

Point Sources: Wasteload allocations are established for the five discharging wastewater treatment facilities permitted within the watershed. All five NPDES dischargers are lagoon systems that have not monitored for nutrients, hence, nutrient concentrations that are typical of those observed in the effluent of lagoon systems in Kansas (2 mg/L TP & 8 mg/L TN) and the facilities' design flow were used to develop the nutrient wasteloads (Table 15). Within the BATHTUB model, the wasteload allocation for the three facilities located above the KDHE stream monitoring stations are included within the total load inflowing from the tributaries since the discharge from these facilities is observed in the nutrient concentrations at the stream monitoring stations. The wasteloads for these facilities have been broken out of the total inflow load generated by BATHTUB and have been combined with the wasteload allocations for the two facilities discharging below stream monitoring stations resulting in the total wasteload allocation detailed in Table 16.

The discharging NPDES facilities in the watershed are required to monitor for total suspended solids quarterly, when discharging. Hence, sediment wasteload allocations are based on the design flow of the facilities and the average of the TSS concentrations reported for each discharger for the 2008 through 2012 period of record.

Table 15. Wasteload allocations for NPDES dischargers in the Pomona Lake watershed.

Facility	NPDES Permit #	Receiving Stream	Loads Observed At	TP WLA (lbs/day)	TN WLA (lbs/day)	Sediment WLA (lbs/day)
Eskridge WWTF	KS0046400	Dragoon Creek	SC577	1.36	5.44	28.6
Harveyville WWTF	KS0046418	Dragoon Creek	SC577	1.00	4.01	10.7
Burlingame WWTF	KS0024694	Switzler Creek	SC687	2.02	8.08	34.5
Scranton WWTF	KS0031283	Dragoon Creek	LM028001	1.33	5.34	17.9
Overbrook WWTF	KS0046451	Valley Brook Creek	LM028001	2.14	8.55	44.5

Nonpoint Sources: Nonpoint sources are the primary contributors for the nutrient and sediment input and impairment in Pomona Lake. Background levels may be attributed to nutrient recycling and leaf litter. The assessment suggests that runoff transporting nutrient and suspended sediment loads associated with animal wastes and fertilized cultivated cropland and pastureland is contributing to siltation and eutrophication in the lake. Nutrient load allocations were calculated using the BATHTUB model (Appendix B) and are detailed in Table 16. Sediment loads were calculated by reducing the current load (2009 KBS Bathymetric) by 71% which reflects the 71% reduction in TSS concentration in the lake needed to meet the 70 cm Secchi depth endpoint (Table 17).

Table 16. Pomona Lake Total Phosphorus and Total Nitrogen TMDL.

Description	Allocations (lbs/year)	Allocations (lbs/day)
Total Phosphorus Atmospheric Load*	335.32	2.16
Total Phosphorus Nonpoint Source Load Allocation	46,132.54	308.21
Total Phosphorus Wasteload Allocation	2,865.25	7.85
Total Phosphorus Margin of Safety	5,481.46	35.36
Total Phosphorus TMDL*	54,814.57	353.58
Total Nitrogen Atmospheric Load*	23,768.23	125.83
Total Nitrogen Nonpoint Source Load Allocation	335,937.92	1,807.73
Total Nitrogen Wasteload Allocation	11,468.30	31.42
Total Nitrogen Margin of Safety	41,241.61	218.33
Total Nitrogen TMDL*	412,416.06	2,183.31

*See appendix C for daily load calculation.

Table 17. Pomona Lake Siltation TMDL.

Description	Allocations (tons/year)	Allocations (tons/day)
Total Suspended Solids Nonpoint Source Load Allocation	91,242.1	671.432
Total Suspended Solids Wasteload Allocation	24.9	0.068
Total Suspended Solids Margin of Safety	10,141	74.5
Total Suspended Solids TMDL*	101,408	746

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 and the variable annual sediment load and the Secchi depth and TSS endpoints. Therefore, the margin of safety is explicitly set at 10% of the total allocations for total phosphorus, total nitrogen and sediment, which compensates for the lack of knowledge about the relationship between the allocated loadings and the resulting water quality. The margin of safety for TP and TN is 35.36 lbs/day and 218.33 lbs/day, respectively, while the margin of safety for TSS is 74.5 tons/day, as indicated in Tables 16 and 17.

State Water Plan Implementation Priority: Because Pomona Lake has a regional benefit for recreation and because it serves as a drinking water supply for Osage County Rural Water District 3, this TMDL will be a **High** Priority for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Upper Marais des Cygnes Basin (HUC 8: 10290101) with a priority ranking of 5 (High Priority for restoration work).

Priority HUC 12: The Spreadsheet Tool for Estimating Pollutant Load (STEPL) was utilized to identify priority HUC 12s within the watershed. STEPL is a simple watershed model that provides both agricultural and urban annual average sediment and nutrient simulations as well as implementation evaluation of best management practices. STEPL results for phosphorus, nitrogen and sediment are illustrated in Figures 32, 33, and 34. Based on these results initial priorities should focus on the three HUC 12 subwatersheds generating the most phosphorus and nitrogen per acre, per year (Table 18).

Figure 32. STEPL results for phosphorus.

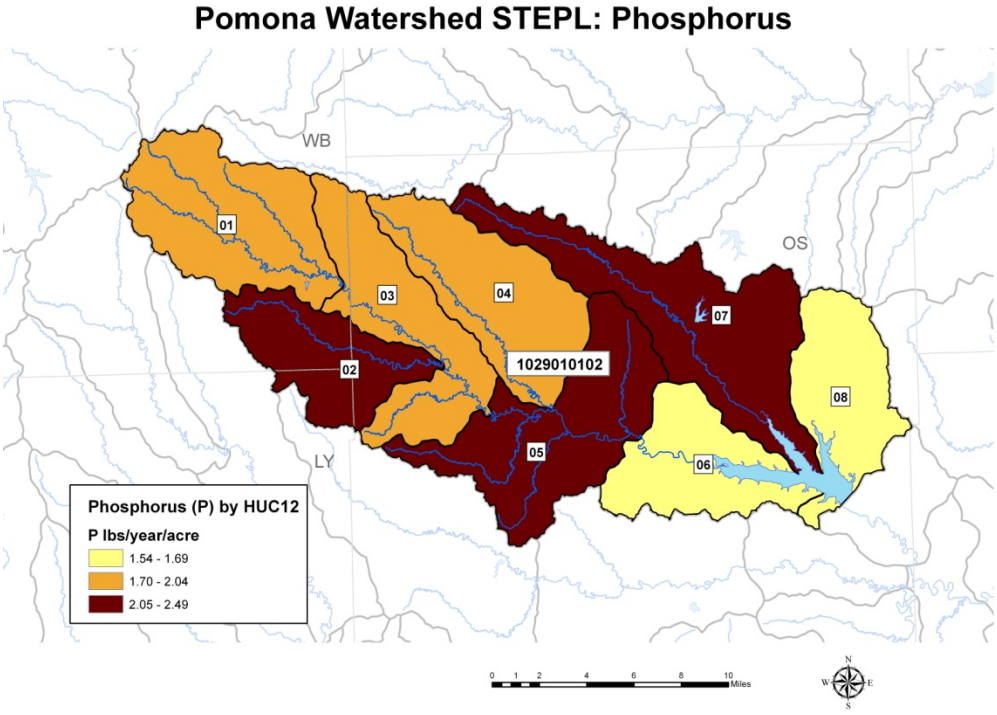


Figure 33. STEPL results for nitrogen.

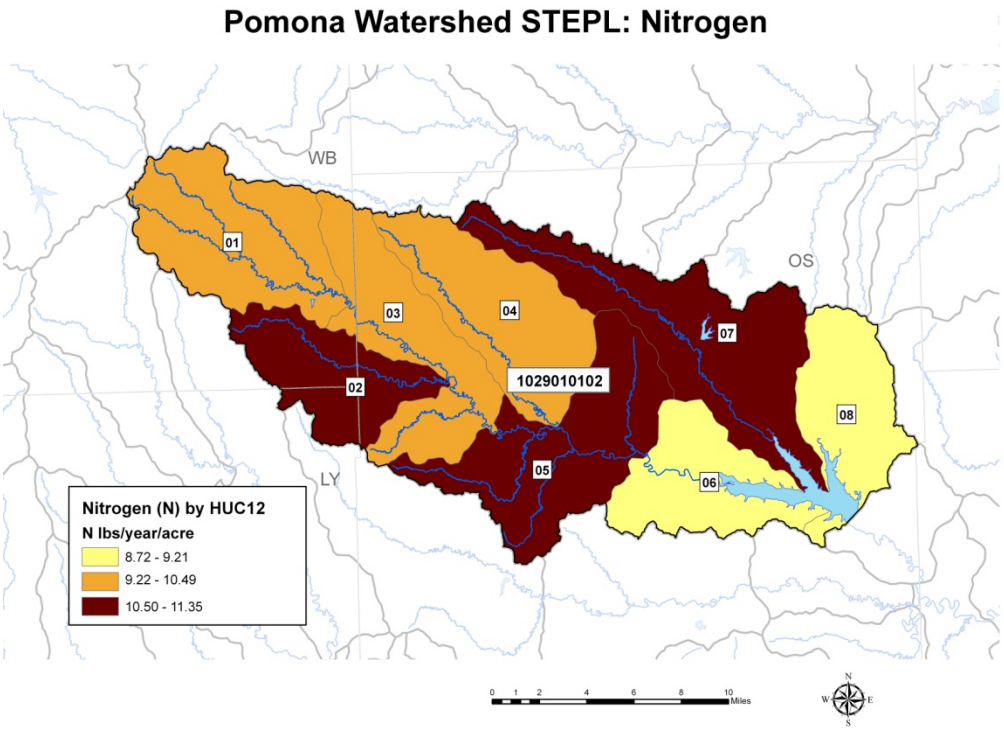


Figure 34. STEPL results for sediment.

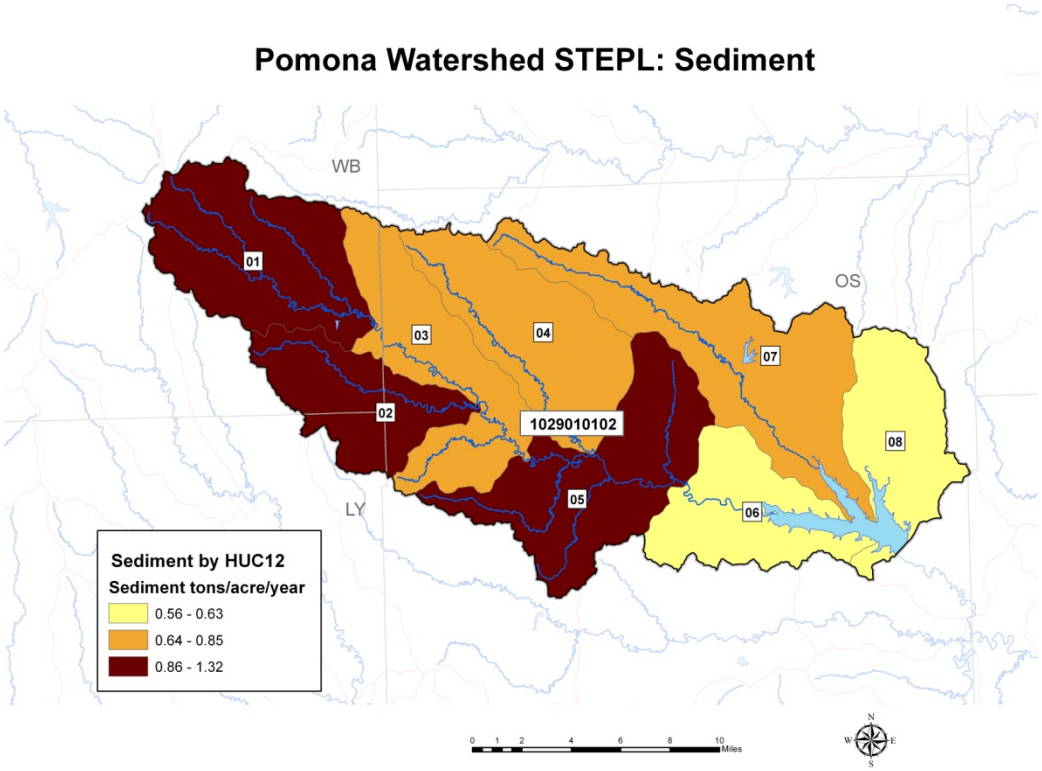


Table 18. Priority HUC 12 subwatersheds as identified through STEPL.

HUC 12	Acres	TP Load (lbs/year)	TP Acre (lbs/acre/year)	TN Load (lbs/year)	TN Acre (lbs/acre/year)	Sediment Load (ton/year)	Sediment Acre (ton/acre/year)	Preliminary Implementation Priority Ranking
102901010202	28,560	45,866	2.5	209,212	11.4	24,380	1.32	1
102901010205	31,067	72,723	2.3	338,074	10.9	27,405	0.88	2
102901010207	35,061	78,469	2.2	367,744	10.5	29,453	0.84	3
102901010204	25,792	52,517	2.0	260,642	10.1	19,921	0.77	4
102901010201	28,560	56,305	2.0	284,422	10.0	28,216	0.99	5
102901010203	24,523	46,611	1.9	241,664	9.9	17,149	0.70	6
102901010208	18,230	30,828	1.7	167,917	9.2	11,506	0.63	7
102901010206	18,329	28,227	1.5	159,887	8.7	10,217	0.56	8

5. IMPLEMENTATION

Desired Implementation Activities: There is a very good potential that agricultural best management practices will improve the condition of Pomona Lake. 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.
8. Utilize the Pomona WRAPS 9-Element Plan to assist in directing the installation of BMPs that will mitigate nutrient loading in the watershed (Table 19).

Table 19. Best Management Practices identified in the Pomona Lake 9-Element Plan by HUC 12. The 9-Element Plan identified targeted areas based on SWAT analysis, AnnAGNPS modeling and the knowledge of local residents.

HUC	Cropland/Livestock Tier Priority	Streambank Tier Priority
102901010203	Tier 2	Tier 1
102901010204	Tier 2	Not targeted
102901010205	Tier 1	Tier 1
102901010206	Tier 2	Not targeted
102901010207	Tier 1	Tier 1

There is also potential that the implementation of urban best management practices in the small cities in the watershed will improve the condition of Pomona Lake. Some of the recommended urban practices are as follows:

1. Educate watershed residents on proper lawn fertilizer application.
2. Install grass buffer strips along drainage channels in the watershed.
3. Promote proper management of construction sites to minimize sediment and nutrient runoff.
4. Investigate feasibility of installing a stormwater wetland in the watershed to aid in the removal of nutrients.

Implementation Program Guidance:

Watershed Management Program – KDHE

a. Support selected Section 319 project activities including demonstration projects and outreach efforts dealing with erosion, 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.
d. Incorporate the provisions of this TMDL into WRAPS documents relating to Pomona Lake.

Water Resource Cost Share and Nonpoint Source Pollution Control Programs – KDA 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 – KDA Division of Conservation

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

Buffer Initiative Program – KDA 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 fields to hold nutrients.

NPDES – KDHE

a. Ensure any future NPDES permits in the watershed do not discharge excessive nutrients or TSS to streams above Pomona Lake.
b. Establish applicable permit limits for permitted dischargers in the watershed.

Time Frame for Implementation: Initial implementation will proceed over the years from 2014-2021. Additional implementation may be required over 2022-2030 to achieve the endpoints of this TMDL.

Targeted Participants: Primary participants for implementation will be agricultural producers within the Pomona Lake watershed. A detailed assessment of sources conducted over 2014-2015 should include local assessments by conservation district personnel and city and county public works 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 2022: In accordance with the TMDL strategy for the State of Kansas, the year 2022 marks the next evaluation period for 303(d) activities in the Marais des Cygnes River Basin. At that point in time, data from site LM028001 at Pomona Lake will be reexamined to assess improved conditions in the lake.

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, the Osage County Conservation District, the Anderson County Conservation District and the public works arms of the cities of Eskridge, Burlingame, Scranton, Overbrook and Osage City. Producer outreach and awareness will be delivered by Kansas State Extension.

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 Kansas Department of Agriculture – Division of Conservation 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 Kansas Department of Agriculture – Division of Conservation 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 Marais Des Cygnes 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 High 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 along with addressing stormwater runoff in urban areas 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 Pomona Lake. Based on the sampling results, the 303(d) listing will be evaluated in 2022. Should impairment status continue, the desired endpoints under this TMDL may be refined and sampling conducted over the period 2022-2026 to assess 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 Marais des Cygnes Basin.

Public Hearing: A Public Hearing on the Marais des Cygnes TMDLs was held on December 10, 2013 in Ottawa to receive comments on this TMDL.

Basin Advisory Committee: The Marais des Cygnes Basin Advisory Committee met to discuss TMDLs in the basin on October 15, 2013 in Paola.

Milestone Evaluation: In accordance with the TMDL strategy for the State of Kansas, the year 2022 will be an evaluation period of 303(d) activities in the Marais des Cygnes Basin. At that point in time, sample data from Pomona Lake will be examined 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: Pomona Lake will be evaluated for delisting under Section 303(d), based on the monitoring data over 2013-2021. Therefore, the decision for delisting will come about in the preparation of the 2022 303(d) 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, the next anticipated revision would come in 2014, 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 the Kansas Water Plan implementation decisions under the State Water Planning Process for Fiscal Years 2014-2022.

Developed 8/29/14

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Appendix A. Development of TSS/Secchi depth endpoint in Pomona Lake.

Table A1. Secchi Depth (SD) and Total Suspended Solids (TSS) data in Pomona Lake.

Station	Sample Date	TSS (mg/L)	SD (cm)
PO-12	5/6/08	4.20	0.36
PO-12	5/6/08	4.40	*
PO-14	5/6/08	4.00	0.41
PO-3	5/6/08	3.80	0.42
PO-7	5/6/08	15.00	0.28
PO-12	6/2/08	5.60	0.52
PO-14	6/2/08	8.80	0.52
PO-7	6/2/08	20.00	0.34
PO-12	7/2/08	16.00	0.52
PO-14	7/2/08	11.00	0.86
PO-3	7/2/08	5.00	0.57
PO-7	7/2/08	17.00	0.34
LM028001	7/28/08	16.0	0.690
PO-12	8/5/08	14.00	0.67
PO-12	8/5/08	9.20	*
PO-14	8/5/08	13.00	0.70
PO-3	8/5/08	5.40	*
PO-7	8/5/08	25.00	0.41
PO-7	8/5/08	70.00	*
PO-12	9/9/08	16.00	0.38
PO-12	9/9/08	16	*
PO-14	9/9/08	16.00	0.37
PO-3	9/9/08	11.00	0.37
PO-7	9/9/08	42.00	0.30
PO-7	9/9/08	40	*
PO-12	6/24/09	13.00	*
PO-14	6/24/09	11.00	*
PO-3	6/24/09	10.00	*
PO-7	6/24/09	21.00	*
PO-12	7/23/09	15.00	*
PO-14	7/23/09	7.20	*
PO-3	7/23/09	17.00	*
PO-7	7/23/09	32.00	*
PO-12	8/20/09	18.00	*
PO-14	8/20/09	20.00	*
PO-3	8/20/09	11.00	*
PO-7	8/20/09	39.00	*
PO-7	8/20/09	40.00	*
PO-12	9/24/09	11.00	*
PO-14	9/24/09	7.40	*
PO-3	9/24/09	3.80	*
PO-7	9/24/09	21.00	*
PO-12	4/21/10	4.00	0.75

Station	Sample Date	TSS (mg/L)	SD (cm)
PO-14	4/21/10	3.20	0.95
PO-3	4/21/10	4.20	0.75
PO-7	4/21/10	9.20	0.50
PO-12	6/3/10	5.80	0.70
PO-14	6/3/10	4.20	0.60
PO-3	6/3/10	4.80	0.70
PO-7	6/3/10	3.20	0.54
PO-7	6/3/10	3.60	*
PO-12	6/24/10	13.00	0.60
PO-14	6/24/10	6.40	0.60
PO-3	6/24/10	6.40	0.60
PO-7	6/24/10	7.20	0.55
PO-12	7/19/10	12.00	0.50
PO-14	7/19/10	12.00	0.55
PO-3	7/19/10	7.20	0.65
PO-7	7/19/10	29.00	0.30
PO-12	8/24/10	30.00	0.50
PO-14	8/24/10	19.00	0.50
PO-3	8/24/10	16.00	0.50
PO-7	8/24/10	51.00	0.35
PO-12	9/20/10	8.40	0.50
PO-14	9/20/10	8.40	0.70
PO-3	9/20/10	9.20	0.70
PO-7	9/20/10	25.00	0.30
PO-12	4/6/11	15.00	0.41
PO-14	4/6/11	31.00	0.40
PO-3	4/6/11	9.20	*
PO-7	4/6/11	18.00	0.33
PO-12	5/12/11	14.00	*
PO-14	5/12/11	26.00	*
PO-3	5/12/11	6.60	*
PO-7	5/12/11	16.00	
PO-12	6/16/11	22.00	0.40
PO-14	6/16/11	57.00	0.25
PO-3	6/16/11	22.00	*
PO-7	6/16/11	28.00	0.40
LM028001	6/27/11	12.0	0.460
PO-12	7/14/11	11.00	0.70
PO-14	7/14/11	13.00	0.60
PO-3	7/14/11	6.00	*
PO-7	7/14/11	22.00	0.40
PO-12	8/11/11	18.00	0.30
PO-14	8/11/11	11.00	0.60
PO-3	8/11/11	6.00	*
PO-7	8/11/11	39.00	0.20
PO-12	9/15/11	21.00	0.35
PO-14	9/15/11	23.00	0.30

Station	Sample Date	TSS (mg/L)	SD (cm)
PO-3	9/15/11	12.00	*
PO-7	9/15/11	44.00	0.25
PO-12	4/17/12	20.00	0.30
PO-14	4/17/12	20.00	0.30
PO-3	4/17/12	17.00	0.35
PO-7	4/17/12	38.00	0.25
PO-12	5/9/12	11.00	0.50
PO-14	5/9/12	5.60	0.80
PO-3	5/9/12	6.80	0.95
PO-7	5/9/12	19.00	0.30
PO-12	6/13/12	12.00	0.70
PO-14	6/13/12	7.60	0.70
PO-3	6/13/12	8.80	0.75
PO-7	6/13/12	30.00	0.40
PO-12	7/11/12	17.00	0.45
PO-14	7/11/12	9.70	0.45
PO-3	7/11/12	4.20	1.20
PO-7	7/11/12	19.00	0.40
PO-12	8/15/12	19.00	0.40
PO-14	8/15/12	16.00	0.45
PO-3	8/15/12	8.20	0.57
PO-7	8/15/12	39.00	0.25
PO-12	9/10/12	26.00	0.40
PO-14	9/10/12	26.00	0.40
PO-3	9/10/12	14.00	0.50
PO-7	9/10/12	51.00	0.25

*Data not available

Figure A1. Non-linear regression between Secchi Depth and Total Suspended Solids in Pomona Lake.

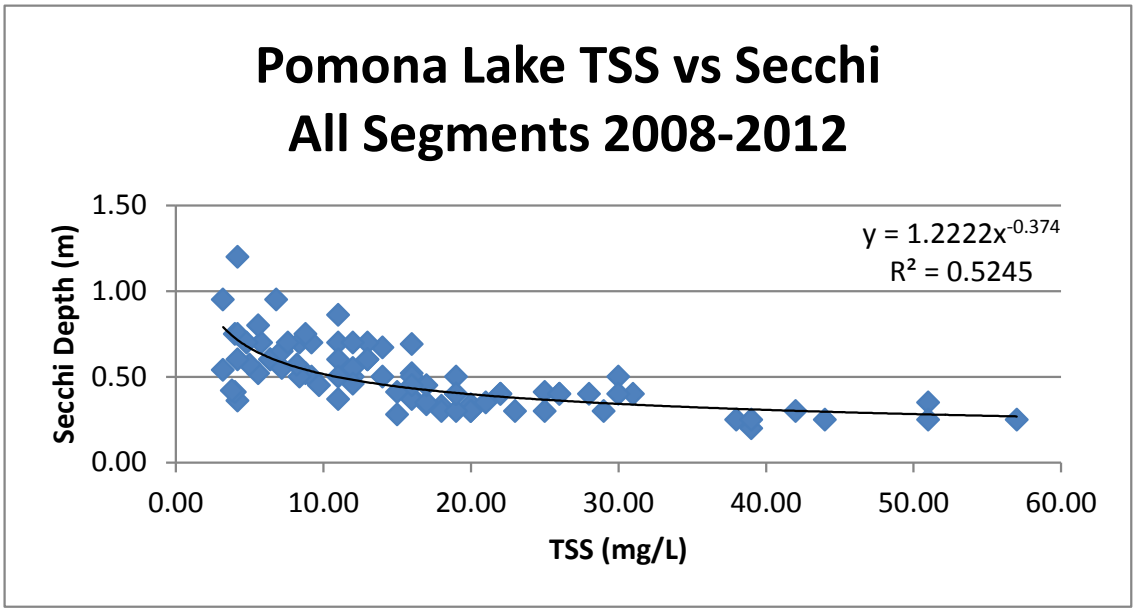

Table A2. TSS target development in Pomona Lake.

Secchi/NTU	*Secchi Depth Target (cm)*	*TSS (mg/L)*
y=1.22^-.374	70	4.66

Table A3. Area weighted mean Total Suspended Solids (TSS) and Secchi Depth (SD) in Pomona Lake.

Lake Segment	ID	Secchi (m)	TSS (mg/L)	WQS Goal	Area (km^2)	Current Area Weighted Secchi (m)	Current Area Weighted TSS (mg/L)	% Increase SD	% Reduction TSS
Main Basin	LM028001 & PO-3	0.48	16.01	SD = 0.7m	5.22	0.53	15.8	32%	71%
Dragoon	PO-7	0.64	12.25		5.47				
110 Mile	PO-12	0.44	19.99		2.70				
Valley Brook	PO-14	0.48	19.40		1.82				

Appendix B. BATHTUB modeling results.

Current Condition -- Case Data

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.975	0.2
Evaporation (m)	1.22	0.3
Storage Increase (m)	-0.2286	0.5

Atmos. Loads (kg/km^2-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	1	2ND ORDER, AVAIL P
Nitrogen Balance	1	2ND ORDER, AVAIL N
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	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Dragoon Cr Upper Pool	2	1	1.966	0.75	2.3	0.75	0.12	0	0	2.51	0.4	0	0	0	0	0	0
2	Dragoon Cr Mid Pool	5	1	3.5	2.6	3.7	2.6	0.12	0	0	2.3	0.36	0	0	0	0	0	0
3	110 Mile Cr Pool	5	1	2.7	3.3	4.55	3.3	0.12	0	0	1.63	0.39	0	0	0	0	0	0
4	Valley Brook Pool	5	1	1.82	4	3.22	3.9	0.12	0	0	1.45	0.61	0	0	0	0	0	0
5	Pomona Near Dam	0	1	5.22	8.5	3.8	6.3	0.12	0	0	1.24	0.63	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	185	0.59	1115	0.36	33	0.53	0.3	0.27	760	0.36	139	0.59	0	0	0	0
2	0	0	83	0.17	980	0.27	22.1	0.23	0.35	0.15	656	0.2	72	0.38	0	0	0	0
3	0	0	58	0.07	923	0.23	16.5	0.29	0.49	0.14	568	0.28	48	0.79	0	0	0	0
4	0	0	62	0.19	1000	0.28	16.1	0.23	0.54	0.17	613	0.34	47	0.19	0	0	0	0
5	0	0	49	0.42	862	0.31	11.8	0.23	0.58	0.21	529	0.41	0.04	0.42	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
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
4	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
5	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Dragoon Cr	1	1	606	117.2	0.1	0	0	370	0.59	2230	0.36	93	0.59	705	0.11
2	110 Mile Cr	3	1	149	28.8	0.1	0	0	280	0.5	3230	0.55	70	0.5	1900	0.53
3	Valley Brook (Unclassified)	4	1	80	15.5	0.1	0	0	307	0.37	3240	0.47	77	0.37	1900	0.5
4	Dragoon Point Source	1	3	0	0.03	0	0	0	2000	0	8000	0	1	0	1	0
5	Valley Brook Point Source	4	3	0	0.044	0	0	0	2000	0	8000	0	1	0	1	0
6	Pomona Outflow	5	4	0	161	0.1	0	0	110	0.18	1150	0.19	66	0.92	465	0.42

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.827	0.45
Total Nitrogen	1.751	0.55
Chl-a Model	1.166	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/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

Current Condition -- Diagnostics for the Area Weighted Mean

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 6 Area-Wtd Mean

	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	73.7	0.32	68.4%	77.6	0.34	70.4%
TOTAL N MG/M3	953.3	0.26	46.9%	949.2	0.29	46.6%
C.NUTRIENT MG/M3	49.1	0.22	65.5%	48.0	0.29	64.4%
CHL-A MG/M3	18.2	0.35	80.6%	18.3	0.31	80.6%
SECCHI M	0.5	0.25	15.4%	0.5	0.19	13.7%
ORGANIC N MG/M3	703.9	0.23	78.1%	605.1	0.32	68.4%
TP-ORTHO-P MG/M3	69.7	0.24	81.2%	48.7	0.51	69.5%
ANTILOG PC-1	779.3	0.41	81.1%	740.5	0.15	80.1%
ANTILOG PC-2	5.5	0.28	38.2%	5.4	0.12	36.4%
(N - 150) / P	11.1	0.43	26.4%	12.0	0.26	30.3%
INORGANIC N / P	93.5	6.83	87.6%	19.5	1.90	33.6%
TURBIDITY 1/M	1.7	0.22	88.4%	1.7	0.22	88.4%
ZMIX * TURBIDITY	5.9	0.32	79.3%	5.9	0.32	79.3%
ZMIX / SECCHI	7.3	0.26	77.0%	7.8	0.13	80.2%
CHL-A * SECCHI	8.0	0.40	36.8%	7.9	0.16	35.8%
CHL-A / TOTAL P	0.2	0.37	62.4%	0.2	0.20	64.6%
FREQ(CHL-a>10) %	65.6	0.27	80.6%	68.4	0.09	80.6%
FREQ(CHL-a>20) %	30.1	0.52	80.6%	31.1	0.21	80.6%
FREQ(CHL-a>30) %	14.8	0.70	80.6%	14.6	0.36	80.6%
FREQ(CHL-a>40) %	8.0	0.85	80.6%	7.4	0.55	80.6%
FREQ(CHL-a>50) %	4.6	0.99	80.6%	4.0	0.74	80.6%
FREQ(CHL-a>60) %	2.7	1.12	80.6%	2.2	0.93	80.6%
CARLSON TSI-P	66.0	0.07	68.4%	65.3	0.04	70.4%
CARLSON TSI-CHLA	58.2	0.06	80.6%	58.5	0.02	80.6%
CARLSON TSI-SEC	70.7	0.04	84.6%	71.3	0.02	86.3%

Current Condition -- Overall Balance

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seq	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Dragoon Cr	606.0	117.2	1.37E+02	0.10	0.19
2	1	3	110 Mile Cr	149.0	28.8	8.29E+00	0.10	0.19
3	1	4	Valley Brook (Unclassifie	80.0	15.5	2.40E+00	0.10	0.19
4	3	1	Dragoon Point Source		0.0	0.00E+00	0.00	
5	3	4	Valley Brook Point Source		0.0	0.00E+00	0.00	
6	4	5	Pomona Outflow		161.0	2.59E+02	0.10	
PRECIPITATION				15.2	14.8	8.79E+00	0.20	0.98
TRIBUTARY INFLOW				835.0	161.5	1.48E+02	0.08	0.19
POINT-SOURCE INFLOW					0.1	0.00E+00	0.00	
***TOTAL INFLOW				850.2	176.4	1.57E+02	0.07	0.21
GAUGED OUTFLOW					161.0	2.59E+02	0.10	
ADVECTIVE OUTFLOW				850.2	0.3	4.47E+02	9.99	0.00
***TOTAL OUTFLOW				850.2	161.3	1.88E+02	0.08	0.19
***EVAPORATION					18.6	3.10E+01	0.30	
***STORAGE INCREASE					-3.5	0.00E+00	0.00	

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

Trb	Type	Seq	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Dragoon Cr	43364.0	76.8%	6.73E+08	97.1%	0.60	370.0	71.6
2	1	3	110 Mile Cr	8064.0	14.3%	1.69E+07	2.4%	0.51	280.0	54.1
3	1	4	Valley Brook (Unclassifie	4758.5	8.4%	3.33E+06	0.5%	0.38	307.0	59.5
4	3	1	Dragoon Point Source	60.0	0.1%	0.00E+00		0.00	2000.0	
5	3	4	Valley Brook Point Source	88.0	0.2%	0.00E+00		0.00	2000.0	
6	4	5	Pomona Outflow	10525.0		1.44E+07		0.36	65.4	
PRECIPITATION				152.1	0.3%	2.31E+02	0.0%	0.10	10.3	10.0
TRIBUTARY INFLOW				56186.5	99.5%	6.94E+08	100.0%	0.47	347.9	67.3
POINT-SOURCE INFLOW				148.0	0.3%	0.00E+00		0.00	2000.0	
***TOTAL INFLOW				56486.6	100.0%	6.94E+08	100.0%	0.47	320.2	66.4
GAUGED OUTFLOW				10525.0	18.6%	1.44E+07		0.36	65.4	
ADVECTIVE OUTFLOW				21.2	0.0%	1.92E+06		10.00	65.4	0.0
***TOTAL OUTFLOW				10546.2	18.7%	1.44E+07		0.36	65.4	12.4
***STORAGE INCREASE				-269.6		3.17E+03		0.21	77.6	
***RETENTION				46210.0	81.8%	5.52E+08		0.51		

Overflow Rate (m/yr)	10.4	Nutrient Resid. Time (yrs)	0.0928
Hydraulic Resid. Time (yrs)	0.4507	Turnover Ratio	10.8
Reservoir Conc (mg/m3)	74	Retention Coef.	0.818

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

Trb	Type	Seq	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Dragoon Cr	261356.0	62.8%	9.54E+09	74.4%	0.37	2230.0	431.3
2	1	3	110 Mile Cr	93024.0	22.4%	2.70E+09	21.1%	0.56	3230.0	624.3
3	1	4	Valley Brook (Unclassifie	50220.0	12.1%	5.82E+08	4.5%	0.48	3240.0	627.8
4	3	1	Dragoon Point Source	240.0	0.1%	0.00E+00		0.00	8000.0	
5	3	4	Valley Brook Point Source	352.0	0.1%	0.00E+00		0.00	8000.0	
6	4	5	Pomona Outflow	138788.3		1.73E+09		0.30	862.0	
PRECIPITATION				10781.1	2.6%	2.91E+05	0.0%	0.05	727.2	709.0
TRIBUTARY INFLOW				404600.0	97.3%	1.28E+10	100.0%	0.28	2505.3	484.6
POINT-SOURCE INFLOW				592.0	0.1%	0.00E+00		0.00	8000.0	
***TOTAL INFLOW				415973.1	100.0%	1.28E+10	100.0%	0.27	2358.1	489.3
GAUGED OUTFLOW				138788.3	33.4%	1.73E+09		0.30	862.0	
ADVECTIVE OUTFLOW				279.8	0.1%	3.33E+08		10.00	862.0	0.3
***TOTAL OUTFLOW				139068.1	33.4%	1.71E+09		0.30	862.0	163.6
***STORAGE INCREASE				-3299.6		2.10E+05		0.14	949.2	
***RETENTION				280204.6	67.4%	8.94E+09		0.34		

Overflow Rate (m/yr)	10.4	Nutrient Resid. Time (yrs)	0.1630
Hydraulic Resid. Time (yrs)	0.4507	Turnover Ratio	6.1
Reservoir Conc (mg/m3)	953	Retention Coef.	0.674

Reduction -- Case Data

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.975	0.2
Evaporation (m)	1.22	0.3
Storage Increase (m)	-0.2286	0.5

Atmos. Loads (kg/km^2-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	1	2ND ORDER, AVAIL P
Nitrogen Balance	1	2ND ORDER, AVAIL N
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	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Dragoon Cr Upper Pool	2	1	1.966	0.75	2.3	0.75	0.12	0	0	2.51	0.4	0	0	0	0	0	0
2	Dragoon Cr Mid Pool	5	1	3.5	2.6	3.7	2.6	0.12	0	0	2.3	0.36	0	0	0	0	0	0
3	110 Mile Cr Pool	5	1	2.7	3.3	4.55	3.3	0.12	0	0	1.63	0.39	0	0	0	0	0	0
4	Valley Brook Pool	5	1	1.82	4	3.22	3.9	0.12	0	0	1.45	0.61	0	0	0	0	0	0
5	Pomona Near Dam	0	1	5.22	8.5	3.8	6.3	0.12	0	0	1.24	0.63	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	185	0.59	1115	0.36	33	0.53	0.3	0.27	760	0.36	139	0.59	0	0	0	0
2	0	0	83	0.17	980	0.27	22.1	0.23	0.35	0.15	656	0.2	72	0.38	0	0	0	0
3	0	0	58	0.07	923	0.23	16.5	0.29	0.49	0.14	568	0.28	48	0.79	0	0	0	0
4	0	0	62	0.19	1000	0.28	16.1	0.23	0.54	0.17	613	0.34	47	0.19	0	0	0	0
5	0	0	49	0.42	862	0.31	11.8	0.23	0.58	0.21	529	0.41	0.04	0.42	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
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
4	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
5	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Dragoon Cr	1	1	606	117.2	0.1	0	0	159	0.59	959	0.36	40	0.59	303	0.11
2	110 Mile Cr	3	1	149	28.8	0.1	0	0	120	0.5	1389	0.55	30	0.5	817	0.53
3	Valley Brook (Unclassified)	4	1	80	15.5	0.1	0	0	132	0.37	1393	0.47	33	0.37	817	0.5
4	Dragoon Point Source	1	3	0	0.1105	0	0	0	2000	0	8000	0	1	0	1	0
5	Valley Brook Point Source	4	3	0	0.1768	0	0	0	2000	0	8000	0	1	0	1	0
6	Pomona Outflow	5	4	0	161	0.1	0	0	110	0.18	1150	0.19	66	0.92	465	0.42

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.827	0.45
Total Nitrogen	1.751	0.55
Chl-a Model	1.166	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/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

Reduction – Diagnostics for Area Weighted Mean

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 6 Area-Wtd Mean

	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	45.3	0.31	47.5%	77.6	0.34	70.4%
TOTAL N MG/M3	571.2	0.25	19.0%	949.2	0.29	46.6%
C.NUTRIENT MG/M3	27.6	0.24	37.4%	48.0	0.29	64.4%
CHL-A MG/M3	10.0	0.38	53.2%	18.3	0.31	80.6%
SECCHI M	0.5	0.27	18.2%	0.5	0.19	13.7%
ORGANIC N MG/M3	515.8	0.20	56.6%	605.1	0.32	68.4%
TP-ORTHO-P MG/M3	55.0	0.24	73.8%	48.7	0.51	69.5%
ANTILOG PC-1	331.5	0.41	59.1%	740.5	0.15	80.1%
ANTILOG PC-2	4.2	0.31	21.4%	5.4	0.12	36.4%
(N - 150) / P	9.4	0.45	19.1%	12.0	0.26	30.3%
INORGANIC N / P	43.4	1.65	64.9%	19.5	1.90	33.6%
TURBIDITY 1/M	1.7	0.22	88.4%	1.7	0.22	88.4%
ZMIX * TURBIDITY	5.9	0.32	79.3%	5.9	0.32	79.3%
ZMIX / SECCHI	6.8	0.28	72.5%	7.8	0.13	80.2%
CHL-A * SECCHI	5.0	0.46	15.7%	7.9	0.16	35.8%
CHL-A / TOTAL P	0.2	0.41	56.4%	0.2	0.20	64.6%
FREQ(CHL-a>10) %	35.9	0.56	53.2%	68.4	0.09	80.6%
FREQ(CHL-a>20) %	9.0	0.98	53.2%	31.1	0.21	80.6%
FREQ(CHL-a>30) %	2.8	1.28	53.2%	14.6	0.36	80.6%
FREQ(CHL-a>40) %	1.0	1.53	53.2%	7.4	0.55	80.6%
FREQ(CHL-a>50) %	0.4	1.73	53.2%	4.0	0.74	80.6%
FREQ(CHL-a>60) %	0.2	1.91	53.2%	2.2	0.93	80.6%
CARLSON TSI-P	59.1	0.08	47.5%	65.3	0.04	70.4%
CARLSON TSI-CHLA	52.7	0.07	53.2%	58.5	0.02	80.6%
CARLSON TSI-SEC	69.4	0.05	81.8%	71.3	0.02	86.3%

Reduction – Overall Balances

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seq	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Dragoon Cr	606.0	117.2	1.37E+02	0.10	0.19
2	1	3	110 Mile Cr	149.0	28.8	8.29E+00	0.10	0.19
3	1	4	Valley Brook (Unclassifie	80.0	15.5	2.40E+00	0.10	0.19
4	3	1	Dragoon Point Source		0.1	0.00E+00	0.00	
5	3	4	Valley Brook Point Source		0.2	0.00E+00	0.00	
6	4	5	Pomona Outflow		161.0	2.59E+02	0.10	
PRECIPITATION				15.2	14.8	8.79E+00	0.20	0.98
TRIBUTARY INFLOW				835.0	161.5	1.48E+02	0.08	0.19
POINT-SOURCE INFLOW					0.3	0.00E+00	0.00	
***TOTAL INFLOW				850.2	176.6	1.57E+02	0.07	0.21
GAUGED OUTFLOW					161.0	2.59E+02	0.10	
ADVECTIVE OUTFLOW				850.2	0.5	4.47E+02	9.99	0.00
***TOTAL OUTFLOW				850.2	161.5	1.88E+02	0.08	0.19
***EVAPORATION					18.6	3.10E+01	0.30	
***STORAGE INCREASE					-3.5	0.00E+00	0.00	

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

Trb	Type	Seq	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Dragoon Cr	18634.8	74.9%	1.24E+08	97.1%	0.60	159.0	30.8
2	1	3	110 Mile Cr	3456.0	13.9%	3.11E+06	2.4%	0.51	120.0	23.2
3	1	4	Valley Brook (Unclassifie	2046.0	8.2%	6.15E+05	0.5%	0.38	132.0	25.6
4	3	1	Dragoon Point Source	221.0	0.9%	0.00E+00		0.00	2000.0	
5	3	4	Valley Brook Point Source	353.6	1.4%	0.00E+00		0.00	2000.0	
6	4	5	Pomona Outflow	6751.5		5.79E+06		0.36	41.9	
PRECIPITATION				152.1	0.6%	2.31E+02	0.0%	0.10	10.3	10.0
TRIBUTARY INFLOW				24136.8	97.1%	1.28E+08	100.0%	0.47	149.5	28.9
POINT-SOURCE INFLOW				574.6	2.3%	0.00E+00		0.00	2000.0	
***TOTAL INFLOW				24863.5	100.0%	1.28E+08	100.0%	0.46	140.8	29.2
GAUGED OUTFLOW				6751.5	27.2%	5.79E+06		0.36	41.9	
ADVECTIVE OUTFLOW				22.6	0.1%	7.89E+05		10.00	41.9	0.0
***TOTAL OUTFLOW				6774.0	27.2%	5.78E+06		0.35	41.9	8.0
***STORAGE INCREASE				-269.6		3.17E+03		0.21	77.6	
***RETENTION				18359.0	73.8%	8.94E+07		0.52		

Overflow Rate (m/yr)	10.4	Nutrient Resid. Time (yrs)	0.1296
Hydraulic Resid. Time (yrs)	0.4500	Turnover Ratio	7.7
Reservoir Conc (mg/m3)	45	Retention Coef.	0.738

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

Trb	Type	Seq	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Dragoon Cr	112394.8	60.1%	1.76E+09	74.4%	0.37	959.0	185.5
2	1	3	110 Mile Cr	40003.2	21.4%	5.00E+08	21.1%	0.56	1389.0	268.5
3	1	4	Valley Brook (Unclassifie	21591.5	11.5%	1.08E+08	4.5%	0.48	1393.0	269.9
4	3	1	Dragoon Point Source	884.0	0.5%	0.00E+00		0.00	8000.0	
5	3	4	Valley Brook Point Source	1414.4	0.8%	0.00E+00		0.00	8000.0	
6	4	5	Pomona Outflow	85585.9		5.73E+08		0.28	531.6	
PRECIPITATION				10781.1	5.8%	2.91E+05	0.0%	0.05	727.2	709.0
TRIBUTARY INFLOW				173989.5	93.0%	2.37E+09	100.0%	0.28	1077.3	208.4
POINT-SOURCE INFLOW				2298.4	1.2%	0.00E+00		0.00	8000.0	
***TOTAL INFLOW				187069.0	100.0%	2.37E+09	100.0%	0.26	1059.2	220.0
GAUGED OUTFLOW				85585.9	45.8%	5.73E+08		0.28	531.6	
ADVECTIVE OUTFLOW				286.0	0.2%	1.27E+08		10.00	531.6	0.3
***TOTAL OUTFLOW				85871.8	45.9%	5.57E+08		0.27	531.6	101.0
***STORAGE INCREASE				-3299.6		2.10E+05		0.14	949.2	
***RETENTION				104496.7	55.9%	1.41E+09		0.36		

Overflow Rate (m/yr)	10.4	Nutrient Resid. Time (yrs)	0.2172
Hydraulic Resid. Time (yrs)	0.4500	Turnover Ratio	4.6
Reservoir Conc (mg/m3)	571	Retention Coef.	0.559

Appendix C. Calculation of Daily Loads

Conversion to Daily Loads as Regulated by EPA Region VII*

The TMDL has estimated annual average loads for TN, TP and TSS 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
ATM = Atmospheric Load
MOS= Margin of Safety

Parameter	LTA	CV	$e^{[Z\sigma - 0.5\sigma^2]}$	MDL	ATM	MOS
TP	54,814.57 lbs/year	0.42	2.35	353.58 lbs/day	2.16	35.36 lbs/day
TN	412,416.06 lbs/year	0.31	1.93	2,183.31 lbs/day	125.83	218.33 lbs/day
TSS	101,408 tons/year	0.50	2.68	746 tons/day	N/A	74.5 tons/day

Maximum Daily Load Calculation

Annual TP Load = 54,814.57 lbs/yr

Maximum Daily TP Load = [(54,814.57 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.40)-0.5*(0.40)^2]}$
= 353.58 lbs/day

Annual TN Load = 412,416.06 lbs/yr

Maximum Daily TN Load = [(412,416.06 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.30)-0.5*(0.30)^2]}$
= 2,183.31 lbs/day

Annual TSS Load = 101,408 tons/yr

Maximum Daily TSS Load = [(101,408 tons/yr)/(365 days/yr)]*$e^{[2.326*(0.47)-0.5*(0.47)^2]}$
= 746 tons/day

Margin of Safety (MOS) for Daily Load

Annual TP MOS = 5,481.46 lbs/yr

Daily TP MOS = [(5,481.46 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.40)-0.5*(0.40)^2]}$
= 35.36 lbs/day

Annual TN MOS = 41,241.61 lbs/yr

Daily TN MOS = [(41,241.61 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.30)-0.5*(0.30)^2]}$
= 218.33 lbs/day

Annual TSS MOS = 10,141 tons/year

Daily TSS MOS = [(10,141 tons/yr)/(365 days/yr)]*$e^{[2.326*(0.47)-0.5*(0.47)^2]}$
= 74.5 tons/day

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