LOWER ARKANSAS RIVER BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody: Cheney Lake
Water Quality Impairment: Eutrophication
Revision to Eutrophication TMDL originally approved September 11, 2000

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: North Fork Ninnescah

Counties: Kiowa, Reno, Stafford, Pratt, Kingman, and Sedgwick

HUC 8: 11030014

HUC 10 (12): 01 (01, 02, 03, 04, 05, 06, 07, 08, 09)
02 (01, 02, 03, 04, 05)
03 (01, 02, 03, 04, 05)

Ecoregion: Great Bend Sand Prairie (27c), Wellington-McPherson Lowland (27d)

Watershed Drainage Area: 991 mi^2

Contributing Drainage Area: 664 mi^2

Conservation Pool: Surface Area = 9,937 acres
Watershed Drainage Area/Lake Surface Area Ratio: 641:1
Maximum Depth = 12.5 meters
Mean Depth = 5.1 meters
Storage Volume = 167,000 acre-feet
Estimated Retention Time = 1.5 year
Mean Annual Inflow = 148,955 acre-feet
Mean Annual Discharge (at Dam) = 65,253 acre-feet
Mean Annual Municipal Withdrawal = 40,327 acre-feet
Constructed: 1964

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

303(d) Listings: 2002, 2004, 2008, 2010, 2012, & 2014 Lower Arkansas River Basin Lakes.

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

Water Quality Criteria: 11 µg/L Chlorophyll *a* (Kansas Surface Water Quality Standards Tables of Numeric Criteria (January 21, 2015), Table 1K).
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(d)(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)).

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Support for Designated Uses under 2014 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 the expected aquatic life use by supporting objectionable types and quantities of algae which also leads to impairment of contact recreation within Cheney Lake. A chlorophyll *a* endpoint of 10 µg/L is assigned to address the domestic water supply use; but all other uses will be met when the chlorophyll *a* endpoint of 10 µg/L is met.

Level of Eutrophication (2001-2014): Fully Eutrophic, Trophic State Index = 55.4

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

Lake Monitoring Sites:
KDHE LM017001 and USGS 07144790 located near the dam in Cheney Lake.
Period of Record: 2001 through 2014.

Stream Chemistry Monitoring Sites:
KDHE Permanent Station SC525 located on the North Fork Ninnescah River at a bridge on K17 Highway, 1 Mile Northeast and 1.5 miles South of Castleton.
Period of Record: 1990 through 2014.

USGS 07144780 located on the North Fork Ninnescah above Cheney Reservoir.
Period of Record: 1990 through 2014.

Flow Record:
USGS 07144780 located on the North Fork Ninnescah above Cheney Reservoir.
Period of Record: 1990 through 2014.

USGS 07144795 located on the North Fork Ninnescah below Cheney Reservoir.
Period of Record: 1990 through 2014.

U.S. Department of the Interior Bureau of Reclamation HydroMet data for Cheney Lake.
Period of Record: Water Years 2000-2014

Hydrologic Conditions: The North Fork (NF) Ninnescah, with its seven registered tributaries, (Figure 1) is the only registered stream draining directly into Cheney Lake and it contributes about 70% of the water flowing into the reservoir with smaller, unregistered, tributaries contributing the remaining inflow (Christensen and others, 2006). The watershed area of the NF Ninnescah is approximately 991 mi^2 with 664 mi^2 contributing to flow in the river. Annual and period of record inflow values were developed by applying the ratio of the drainage area of USGS 07144780 (550 mi^2) to the drainage area of Cheney Lake (664 mi^2). Period of record flow estimates are displayed in Table 1. Annual totals and averages for inflow, dam releases, municipal water withdrawals, and precipitation were determined using Bureau of Reclamation (BOR), U.S. Department of the Interior, Cheney Lake HydroMet reports for the 2000-2014 water years. Based on the BOR data, average annual inflow, and total discharge (dam releases plus public water supply withdrawals) for the 2000-2014 period of record were 148,955 and 105,580 acre-feet per year, respectively with the difference between inflow and discharge being lost to evaporation (Figure 2). Precipitation at the lake averages 31.4 inches/year. Additionally, Cheney reservoir provides about 70% of the City of Wichita's water supply with annual withdrawals for municipal use averaging 40,327 AF for the 2000-2014 water years.

Figure 1. Cheney Lake watershed.

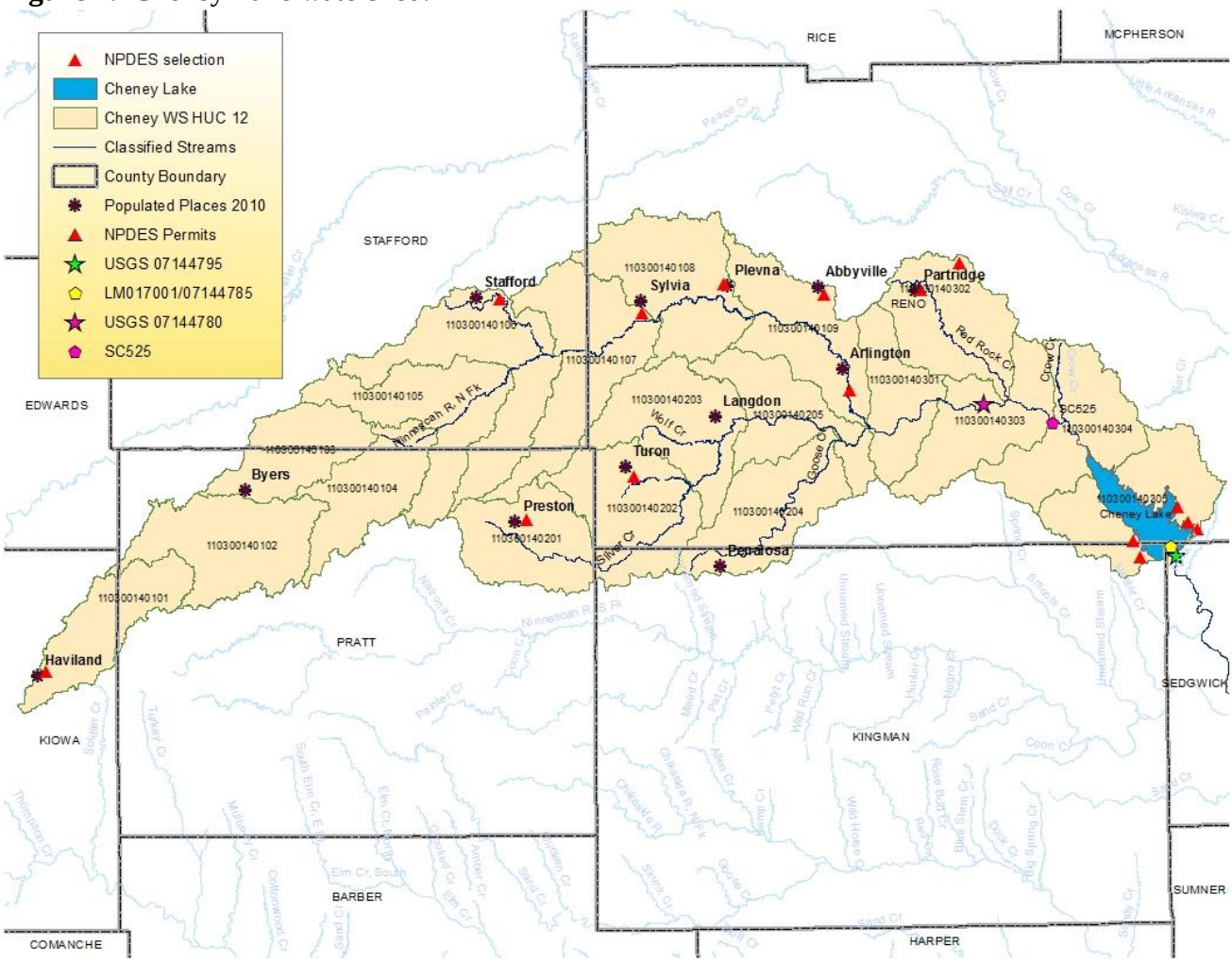
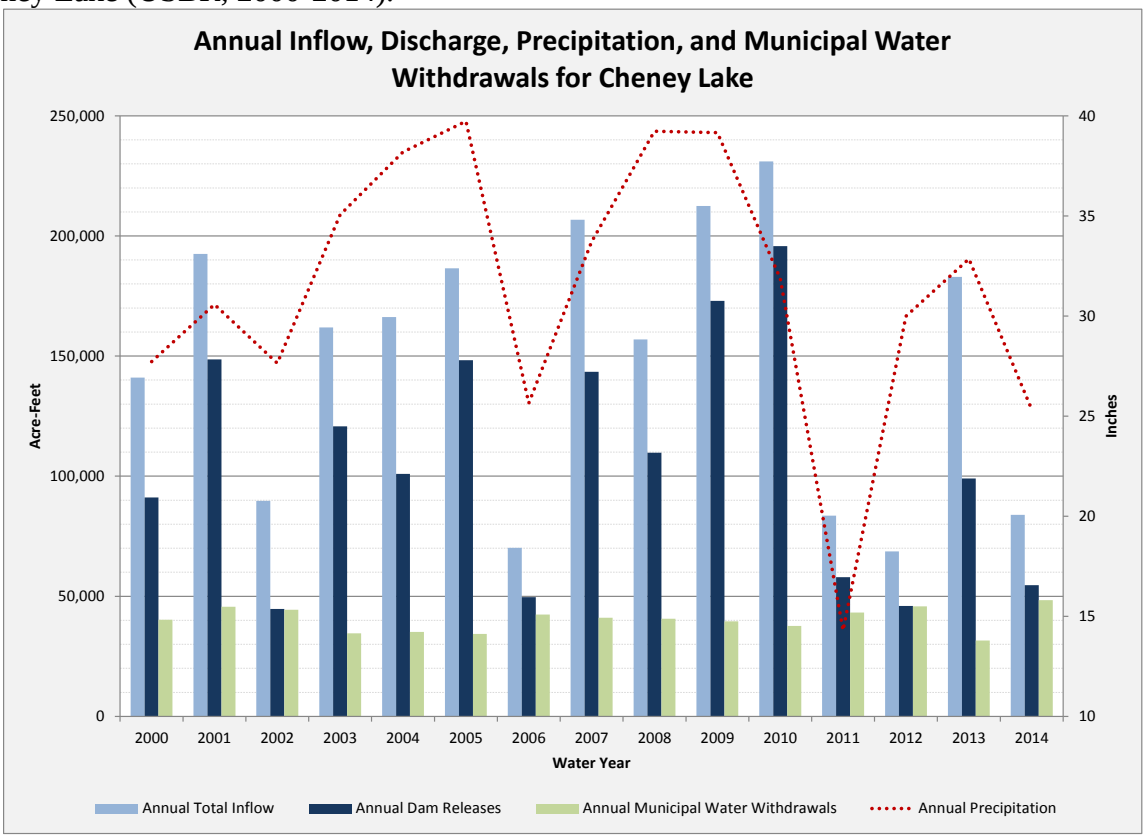


Table 1. Estimated flow-duration values for NF Ninnescah above Cheney Lake for the 1990-2014 period of record. Flow values are in units of cubic-feet per second.

Stream	CUSEGA Segment	Source	Average Flow	2-year Peak	90%	75%	50%	25%	10%
NF Ninnescah at 07144780	110300145	USGS 07144780	133	26,300	21.0	46.0	80.0	115	179
NF Ninnescah at Cheney Lake	110300145	Perry et al., 2004	159	4,240	24.9	49.3	81.3	136	244
NF Ninnescah at Cheney Lake	110300145	USGS 07144780	160	31,751	29.0	57.9	96.6	141	234

Figure 2. Annual inflow, dam releases, municipal water withdrawals, and precipitation in Cheney Lake (USBR, 2000-2014).



Current Condition: Chlorophyll *a* averages 12.5 µg/L for the period of record (2001-2014) in Cheney Lake. Samples were collected by KDHE at LM017001 in the summers of 2002, 2005, 2008, 2011, and 2014 with only the 2011 sample falling below the water quality standard of 11 µg/L chlorophyll *a* with a value of 3.2 µg/L (Figure 3). USGS samples were collected on nearly a monthly basis (2001-2014); KDHE and USGS combined annual averages shows concentrations in the lake have been above the water quality standard for chlorophyll *a* since 2004 with the highest annual average concentrations occurring in 2006 and 2010 at 20.0 and 19.5 µg/L, respectively (Figure 4). The summer-fall months (July-October) see the highest concentrations of chlorophyll *a* in Cheney Lake with average and median values of 15.2 and 14.05 µg/L, respectively (Figure 5). The summer-fall season sees an increase in primary productivity of phytoplankton, primarily in the form of blue-green algae or cyanobacteria (see Table 5), stemming from the nutrient loading and lake mixing that occurred during spring season precipitation events combined with intermittent periods of good water clarity resulting from sediment settling when winds are calm. Winter (November-March) season chlorophyll *a* average and median concentrations of 14.4 and 11.85 µg/L, respectively, are slightly lower than the summer-fall season's concentrations yet higher than the spring (April-June) season average

and median chlorophyll *a* concentrations of 8.80 and 7.40 µg/L, respectively. In contrast to the summer-season chlorophyll *a* concentrations that generally originate from the primary productivity of phytoplankton in the form of cyanobacteria, or blue-green algae, winter chlorophyll *a* concentrations in Cheney Lake stem from the increase in the primary production of diatomic phytoplankton that occurs when the lake becomes ice covered and sediment can settle out allowing for increased light availability.

Figure 3. Chlorophyll *a* concentration in Cheney Lake by sampling date.

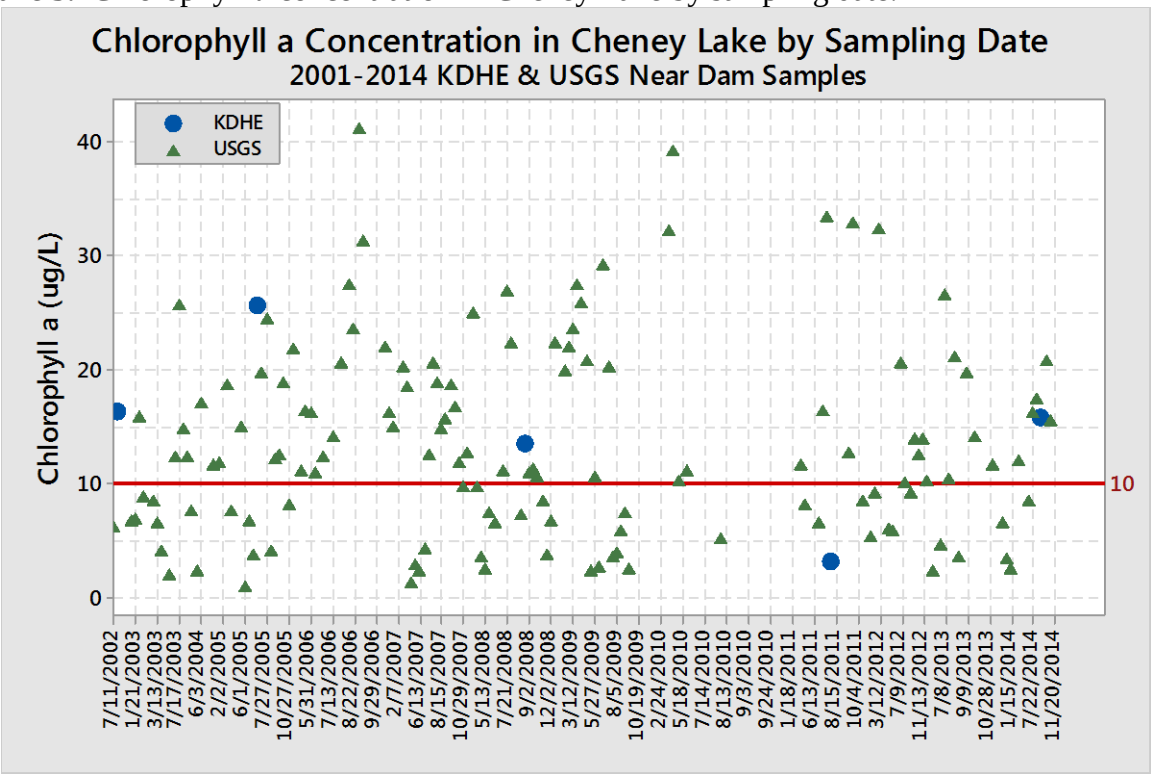


Figure 4. KDHE and USGS data combined representing average annual chlorophyll a concentration in Cheney Lake.

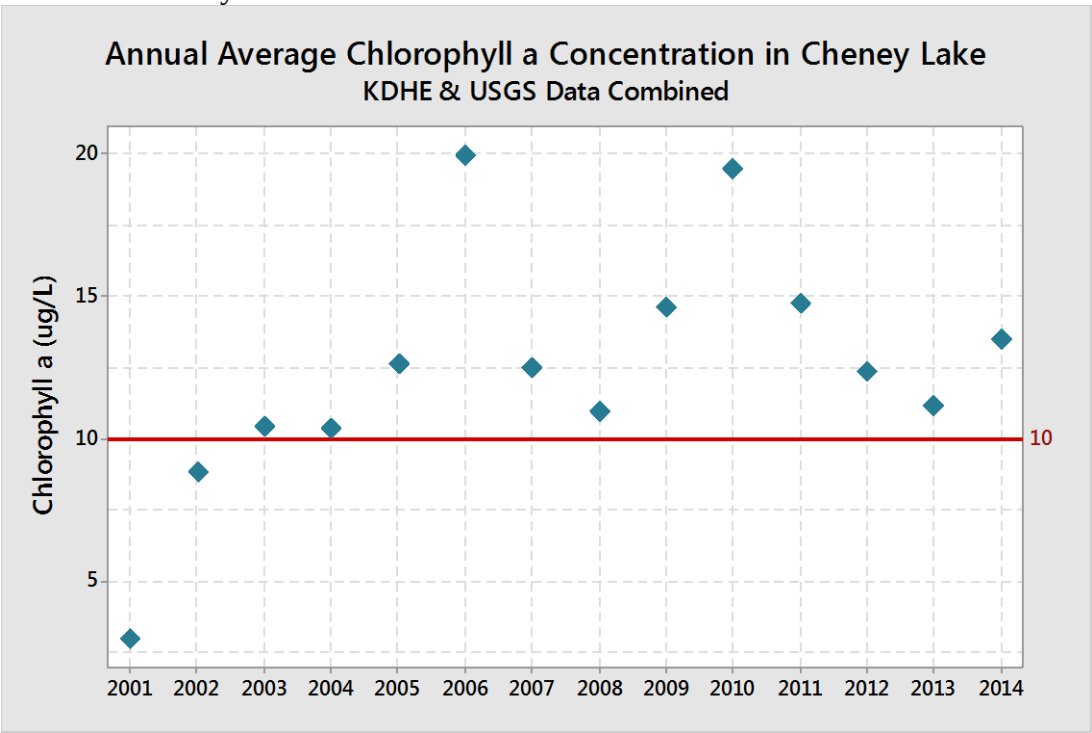
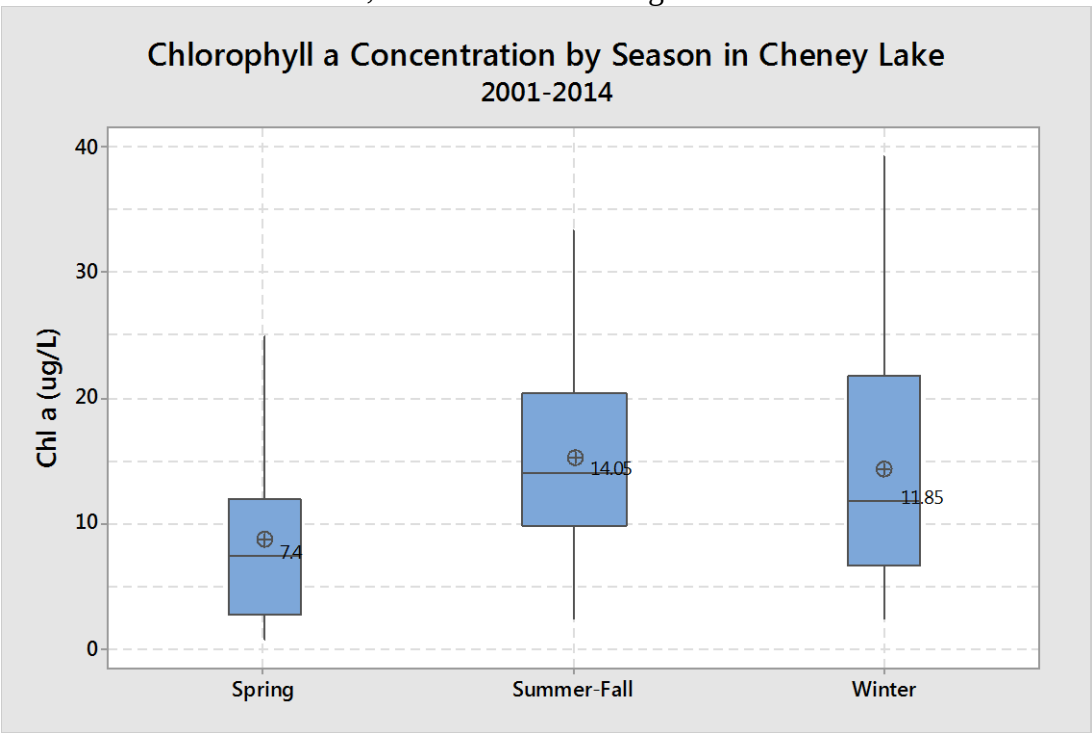
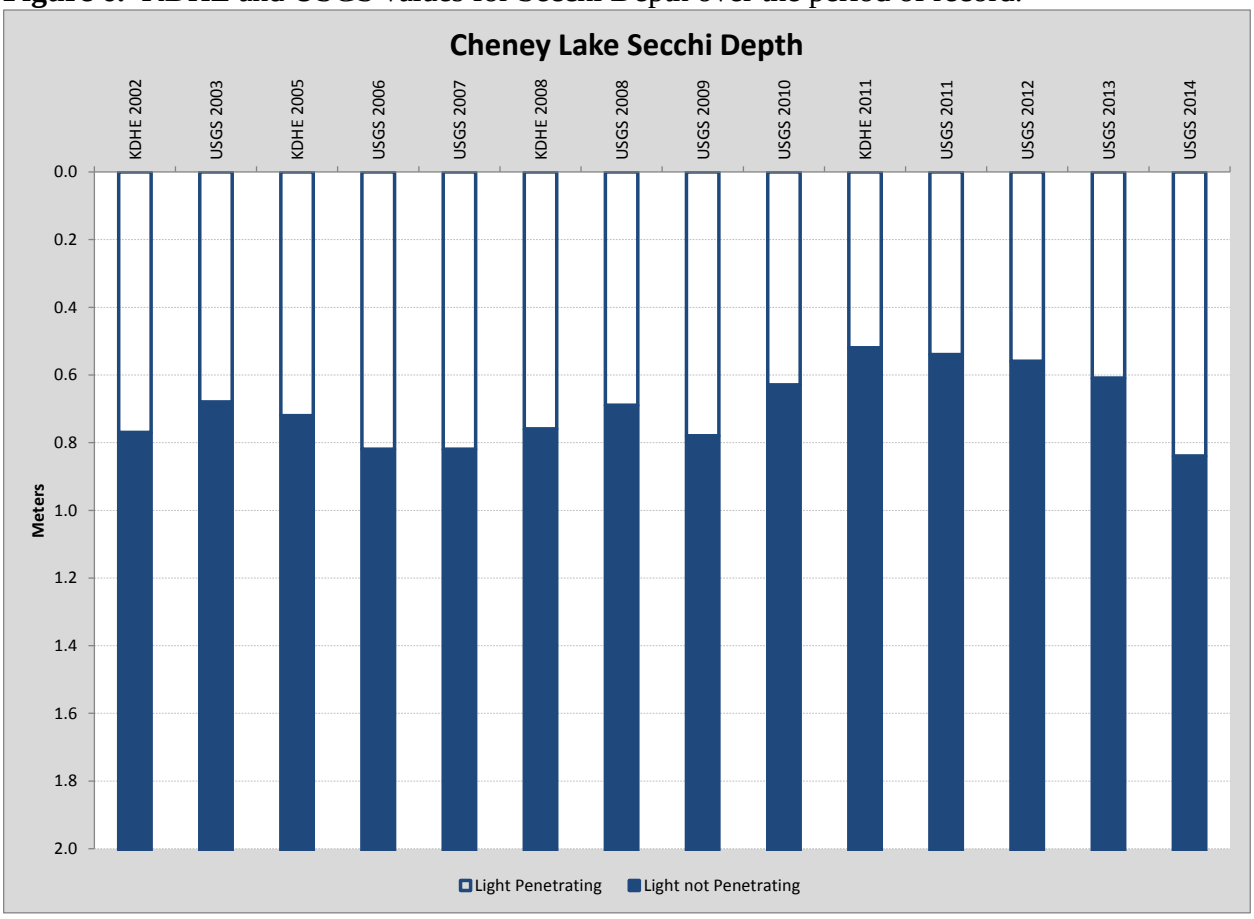


Figure 5. Seasonal chlorophyll *a* concentrations in Cheney Lake KDHE and USGS values combined. April through June is considered the spring season; July through October is considered the summer-fall season; and November through March is the winter season.



Secchi depth readings are available beginning in 2002 and have a narrow range of 0.52 meters (KDHE 2011) to 0.84 meters (USGS 2014) (Figure 6). All KDHE Secchi depth values are from a single summer sampling event as is the 2003 USGS Secchi depth value. 2006 through 2014 USGS Secchi depth values are annual averages from USGS monthly samplings. Secchi depth measurements for Cheney Lake, for the period of record, average below one meter indicating water clarity in the lake is poor.

Figure 6. KDHE and USGS values for Secchi Depth over the period of record.



In September 2011, the USGS collected a single sample with the highest total phosphorus (TP) concentration of 0.390 mg/L over the period of record (Figure 7). The single sample high contributed to the highest annual average total phosphorus (TP) concentration occurring in 2011 at 0.225 mg/L (Figure 8). Seasonally, total phosphorus concentrations are slightly higher during the summer-fall season with a median of 0.110 mg/L TP (Figure 9); the spring and winter season median concentrations are slightly lower at 0.090 and 0.080 mg/L, respectively.

The single sample with the highest total nitrogen (TN) concentration, over the period of record, occurred in August 2004 with a concentration of 1.66 mg/L (Figure 10). Annual averages range from 0.760 mg/L, recorded in 2012, to 1.12 mg/L recorded in 2010 (Figure 11). Seasonally, the spring season has the highest total nitrogen concentration with a median of 0.940 mg/L TN, while the summer-fall and winter seasons post similar median TN concentrations at 0.820 and 0.855 mg/L, respectively (Figure 12).

Figure 7. KDHE and USGS total phosphorus concentration in Cheney Lake by sampling date.

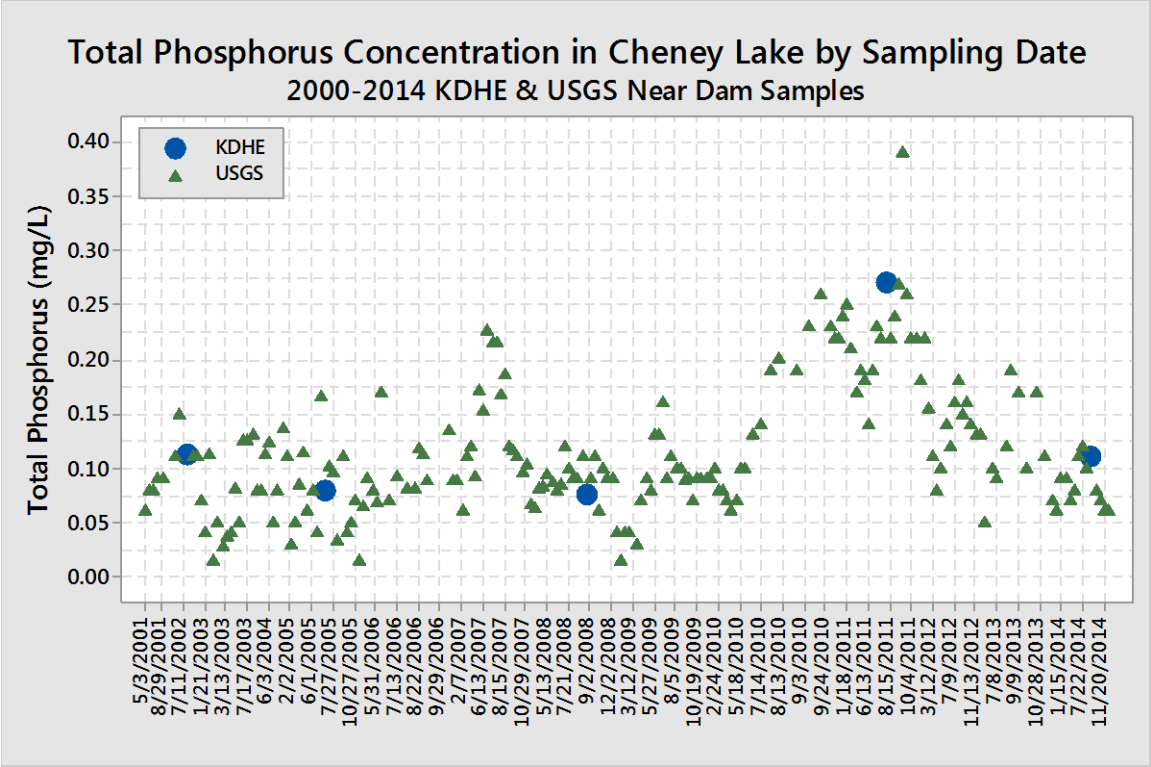


Figure 8. KDHE and USGS data combined representing average annual total phosphorus concentration in Cheney Lake.

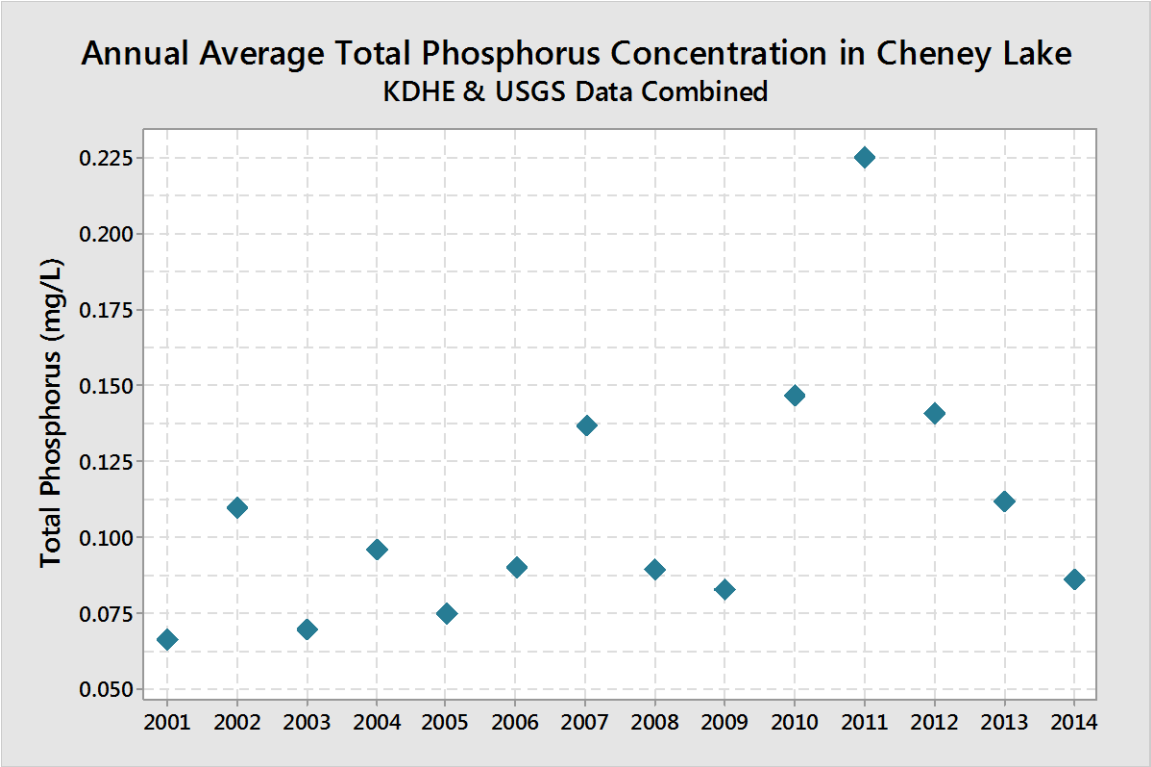


Figure 9. Seasonal total phosphorus concentrations in Cheney Lake. April through June is considered the spring season; July through October is considered the summer-fall season; and November through March is the winter season.

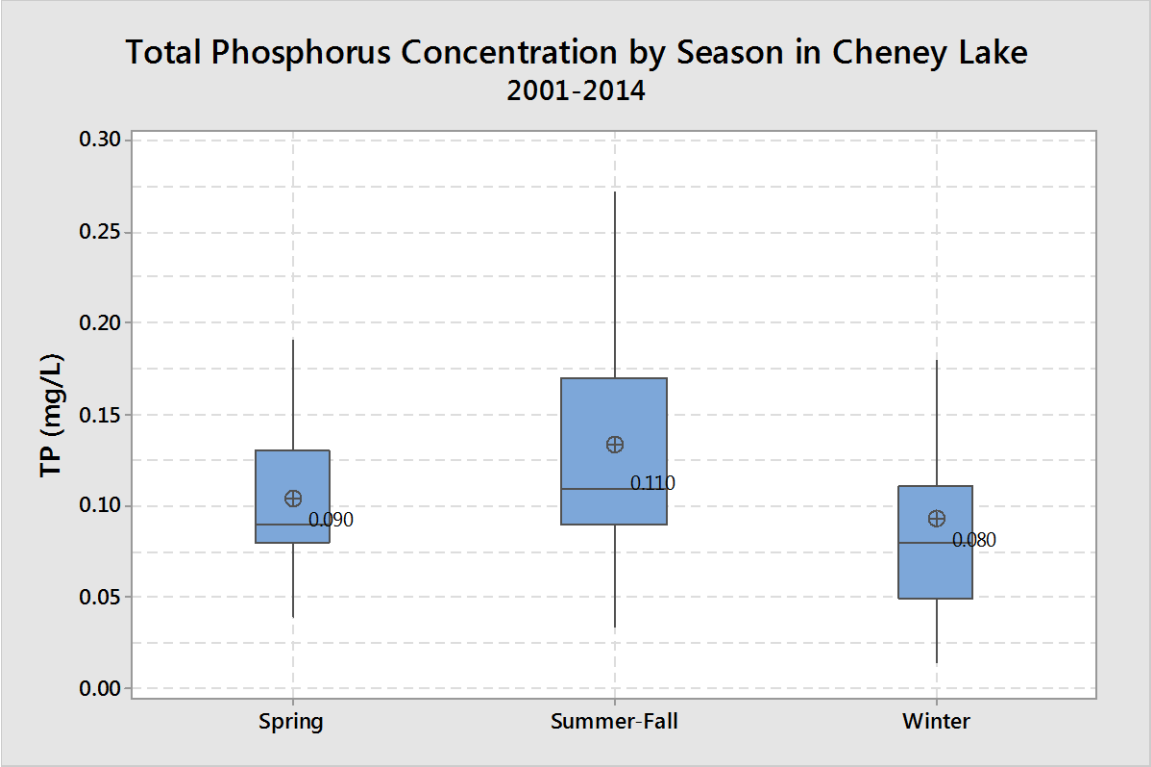


Figure 10. KDHE and USACE total nitrogen concentration in Cheney Lake by sampling date.

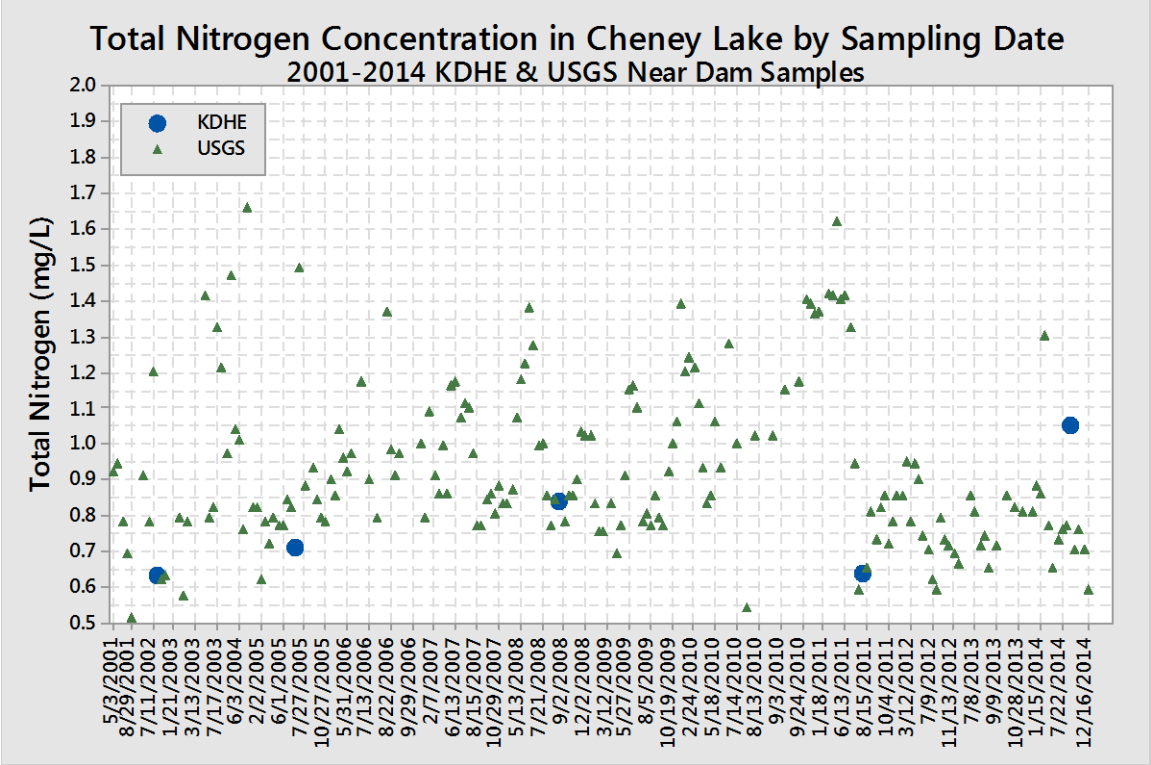


Figure 11. KDHE and USGS data combined representing average annual total nitrogen concentration in Cheney Lake.

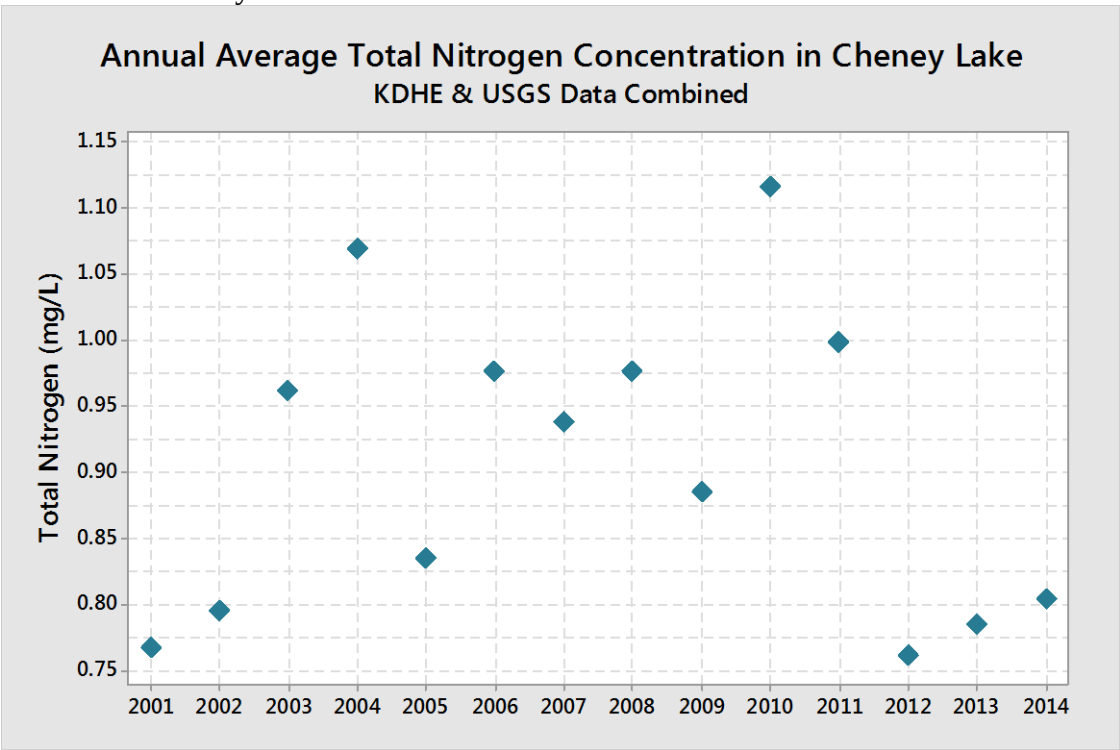
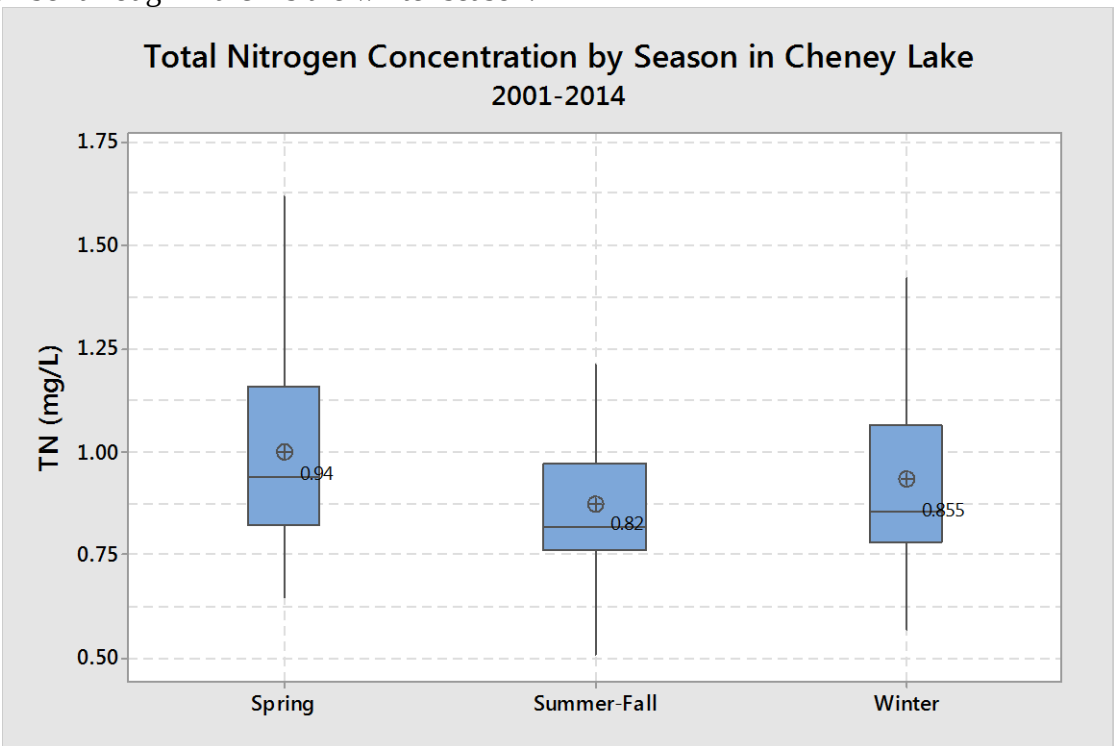
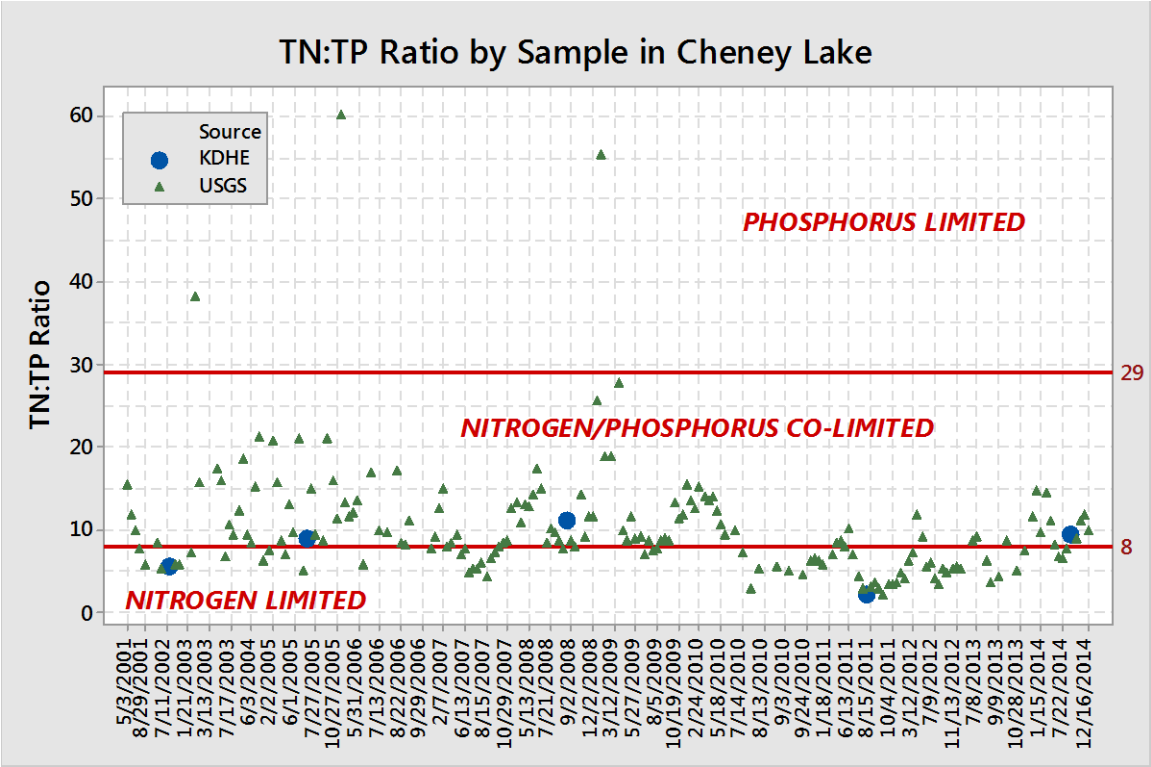


Figure 12. Seasonal total nitrogen concentrations in Cheney Lake. April through June is considered the spring season; July through October is considered the summer-fall season; and November through March is the winter season.



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 Cheney indicates the lake, generally, has been either nitrogen limited or co-limited by phosphorus and nitrogen for the period of record (Figure 13).

Figure 13. Ratio of total nitrogen to total phosphorus in individual samples taken in Cheney Lake for the period of record.



Turbidity in Cheney Lake averages 18.2 NTU for the period of record with a single sample high of 65 NTU taken by USGS in October 2010 (Figure 14). The highest annual average turbidity occurred in 2011 with a value of 30.2 NTU (Figure 15). Seasonally, turbidity in the lake is lowest during the winter season with average and median turbidity at 15.5 and 14.0 NTU, respectively. The relatively low turbidity during the winter season is contributing to increased light availability in the lake, which in turn, is contributing to the production of diatomic phytoplankton (Figure 16). Table 2 details annual and period of record averages for chlorophyll *a*, Secchi depth, total phosphorus, total nitrogen, TN:TP ratio and turbidity in Cheney Lake.

Figure 14. KDHE and USGS turbidity values by sampling date in Cheney Lake.

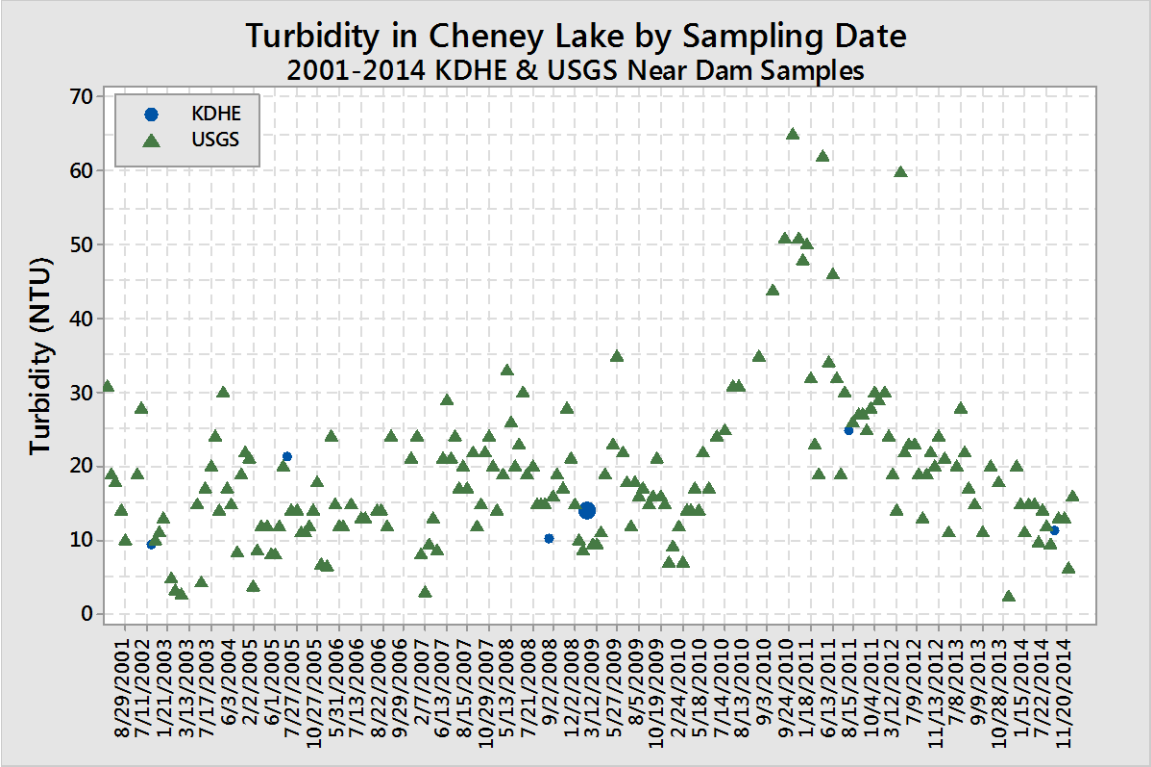


Figure 15. KDHE and USGS data combined representing average annual turbidity levels in Cheney Lake.

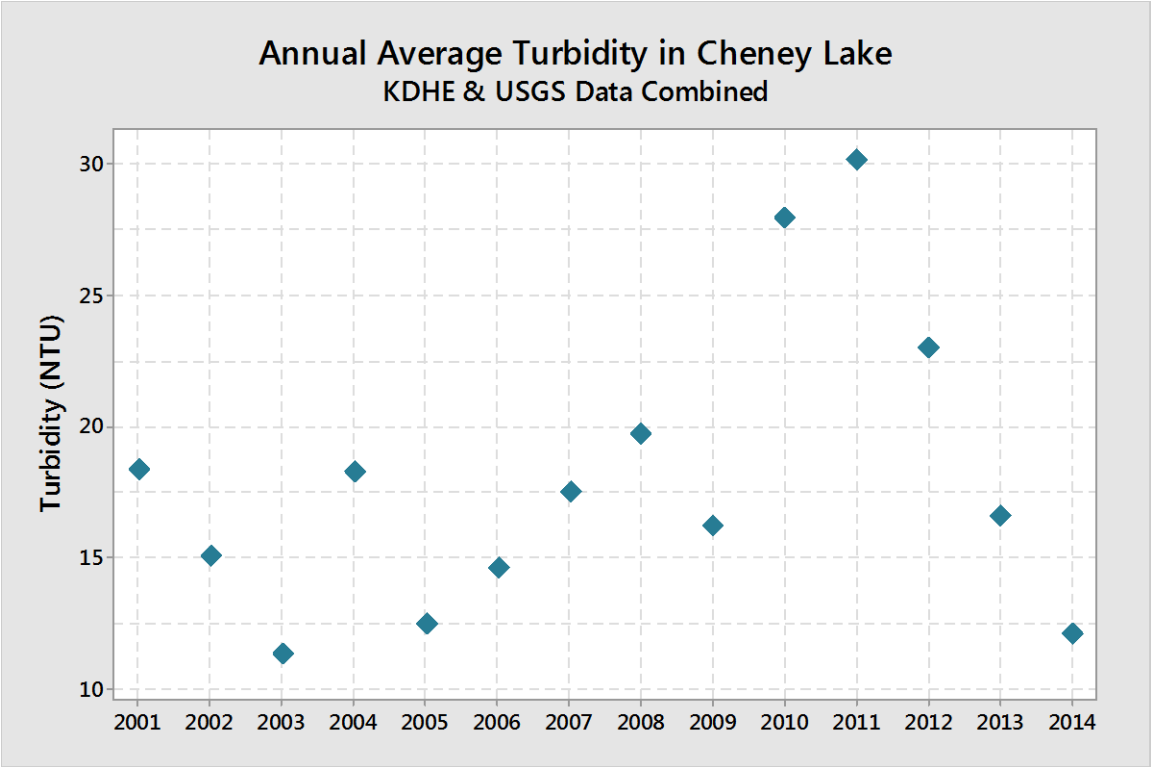
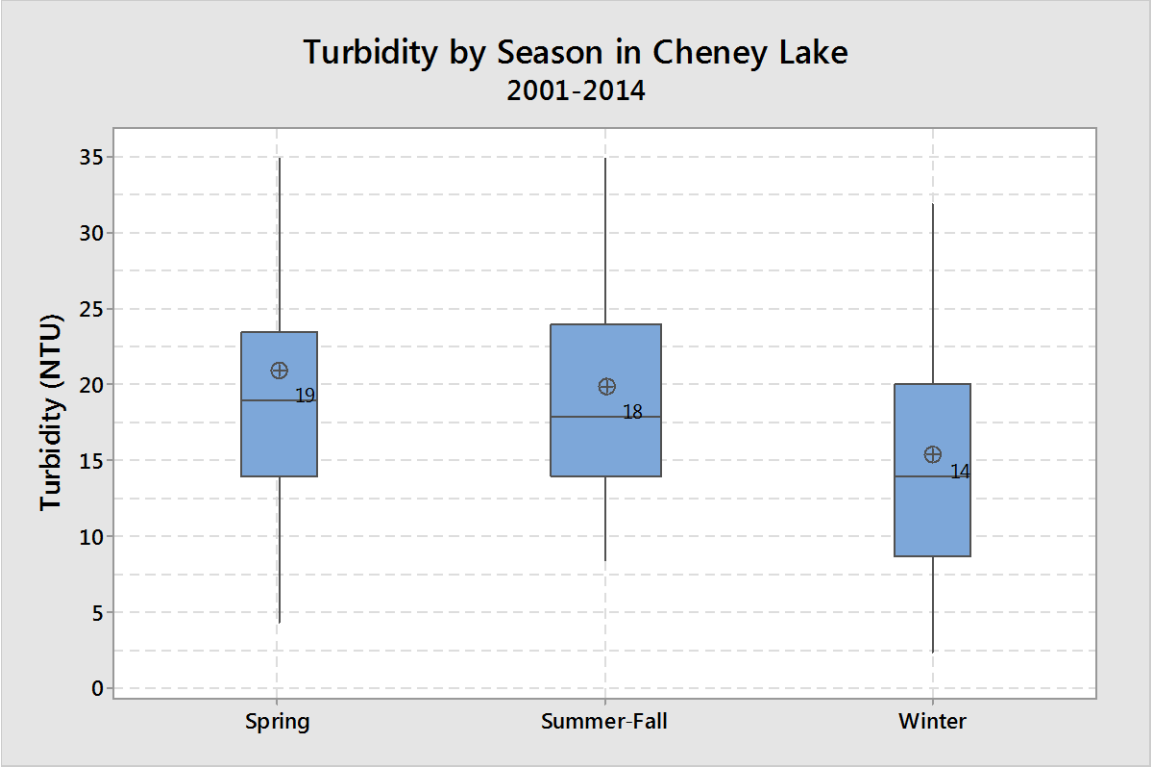


Figure 16. Seasonal turbidity values in Cheney Lake. April through June is considered the spring season; July through October is considered the summer-fall season; and November through March is the winter season.



While Table 2 details annual averages, Table 3 displays a comparison of the 2001-2014 median concentrations for trophic indicators to the benchmarks established for lakes in Kansas. Table 3 shows that total nitrogen and chlorophyll *a* concentrations in Cheney Lake meet the Federal Lake benchmark, however, all other parameters fall short of the established benchmarks. The statewide benchmarks and benchmarks for Kansas lakes in the Flint Hills 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 2. Annual average chlorophyll *a*, Secchi depth, total phosphorus, total nitrogen, TN:TP ratio, and turbidity in Cheney Lake, KDHE and USGS data combined.

Year	Chl-a (µg/L)	Secchi Depth (m)	TP (mg/L)	TN (mg/L)	TN:TP ratio	Turbidity (NTU)
2001	3.0	*	0.080	0.768	10.0	18.4
2002	8.9	0.77	0.110	0.796	6.1	15.1
2003	10.5	0.68	0.070	0.961	15.0	13.3
2004	10.4	*	0.097	1.069	12.2	18.3
2005	12.7	0.72	0.075	0.836	12.6	12.5
2006	20.0	0.82	0.090	0.976	14.1	14.7
2007	12.5	0.82	0.137	0.938	7.7	18.1
2008	11.0	0.69	0.089	0.976	11.2	19.3
2009	14.7	0.78	0.083	0.885	14.3	16.8
2010	19.5	0.63	0.147	1.12	9.2	28.0
2011	14.8	0.54	0.225	0.998	4.9	30.2
2012	12.4	0.59	0.141	0.761	5.8	23.1
2013	11.2	0.61	0.112	0.786	7.8	16.6
2014	13.5	0.84	0.087	0.804	9.5	12.2
2001-2014 Average	***12.5***	***0.71***	***0.110***	***0.905***	***10.0***	***18.3***

*No data available

Table 3. Median trophic indicator values of Cheney Lake (2001-2014) in comparison with other federal lakes and nutrient benchmarks in Kansas.

Trophic Indicator	Cheney Lake (2001-2014)	Federal Lake	Flint Hills	Statewide Benchmark	RTAG
Secchi Depth (cm)	67	95	149	129	N/A
TN (µg/l)	850	903	301	625	700
TP (µg/l)	100	76	19	23	35
Chlorophyll *a* (µg/l)	11.8	12	9	8	8

As displayed in Figure 17, the temperature in Cheney Lake does not appear to stratify by a great degree. Dissolved oxygen (DO) concentrations however, drop below 5 mg/L at depths below about 9 meters.

Figure 17. Dissolved oxygen and temperature profile for Cheney Lake (1990-2005)

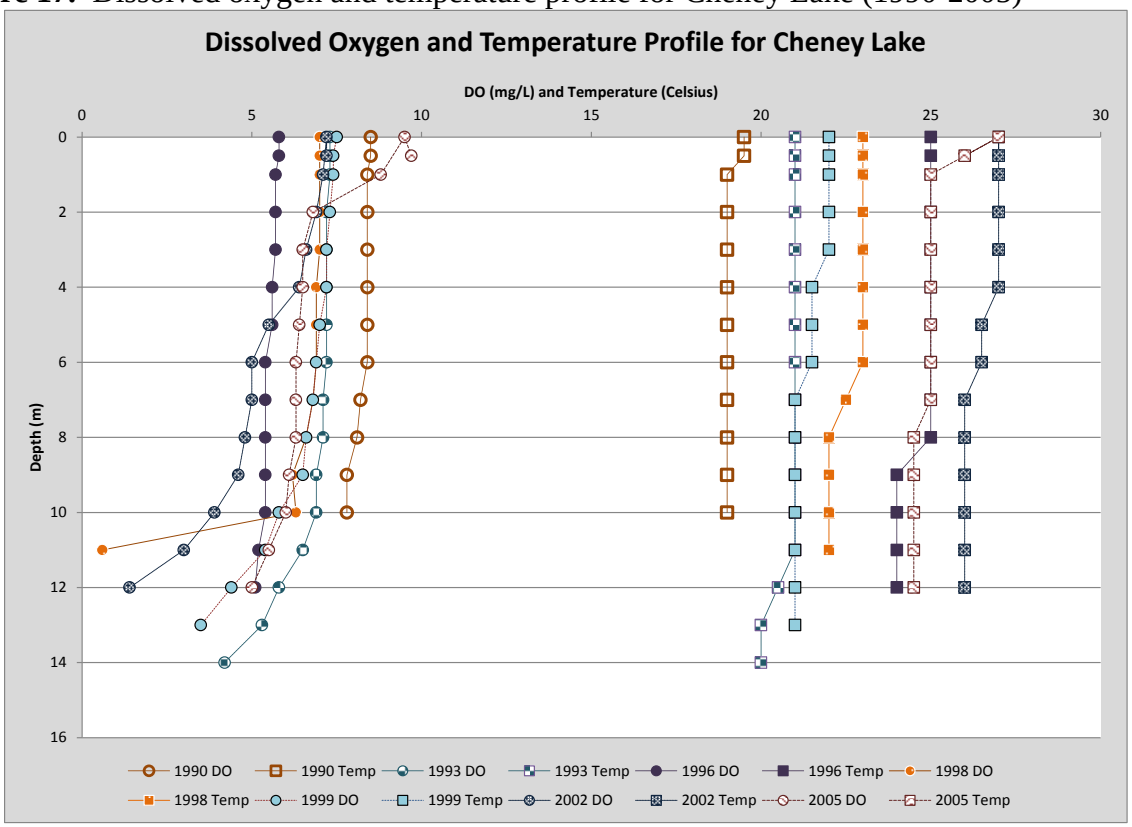


Table 4 lists the six metrics measuring the roles of light and nutrients in Cheney Lake (Carney, 2004). Non-algal turbidity (NAT) values <0.4 m^{-1} indicate there are very low levels of suspended silt and/or clay. The values between 0.4 and 1.0 m^{-1} indicate turbidity assumes greater influence on water clarity but would not assume a significant limiting role until values exceed 1.0 m^{-1}.

Table 4. Limiting factor metrics in Cheney Lake.

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	
2001	7.0	32.1	2.3	0.04	6.0	7.4	3.0
2002	29	132.3	1.0	0.08	41.8	26.2	8.9
2004	4.0	18.5	7.5	0.11	6.4	8.2	10.4
2005	3.0	14.0	10.8	0.17	5.4	7.9	12.7
2006	2.8	13.0	13.8	0.22	6.7	9.2	20.0
2007	3.3	15.2	9.9	0.09	5.8	8.1	12.5
2008	4.2	19.3	7.4	0.12	6.9	8.5	11.0
2009	4.5	20.9	7.6	0.18	8.8	9.8	14.7
2010	4.3	19.8	9.0	0.13	10.0	10.8	19.5
2011	4.3	19.7	8.1	0.07	8.4	9.6	14.8
2012	2.8	12.8	11.7	0.09	4.9	7.6	12.4
2013	4.1	19.1	7.5	0.10	6.9	8.5	11.2
2014	3.2	14.9	10.4	0.16	6.0	8.3	13.5

Average 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 three. 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. With NAT values ranging from 2.8 to 29 it is apparent suspended silt and/or clay is greatly contributing to diminished light availability in Cheney Lake and NAT is assuming a significant limiting role on light availability in the lake. The Zmix*NAT values also indicate there is diminished light within the mixed layer of the lake which may be dampening the response of

algae to nutrient inputs. Chl a*SD values indicate that turbidity is the likely cause of light extinction while the Chl a/TP and Zmix/SD values indicate the response to changes in phosphorus levels by algae is weak. With the possible exception of conditions in the lake in 2002, self-shading does not appear to be impeding algal productivity in Cheney Lake.

Another method for evaluating limiting factors is the trophic state index (TSI) deviation metrics. Figure 18 summarizes the current trophic conditions in Cheney 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 (Dip-In, 2005).

The multivariate TSI comparison chart for Cheney Lake supports the limiting factor metrics described above with all points plotted displaying transparency in Cheney Lake is dominated by non-algal turbidity and in an argillotrophic state.

Comparing the trophic state indices for total phosphorus, chlorophyll *a* and Secchi depth in Cheney Lake reveals, with the exception of 2001, the lake has bounced between a slightly eutrophic and fully eutrophic state, with respect to chlorophyll *a*, for the period of record (Figure 19). The Secchi depth TSI scores show the lake in a very eutrophic state for the period of record while the TP TSI score reached a state of hypereutrophy for the first time in 2001 and has remained there for the period of record (Carlson, 1996).

Figure 18. Multivariate TSI comparison chart for Cheney Lake.

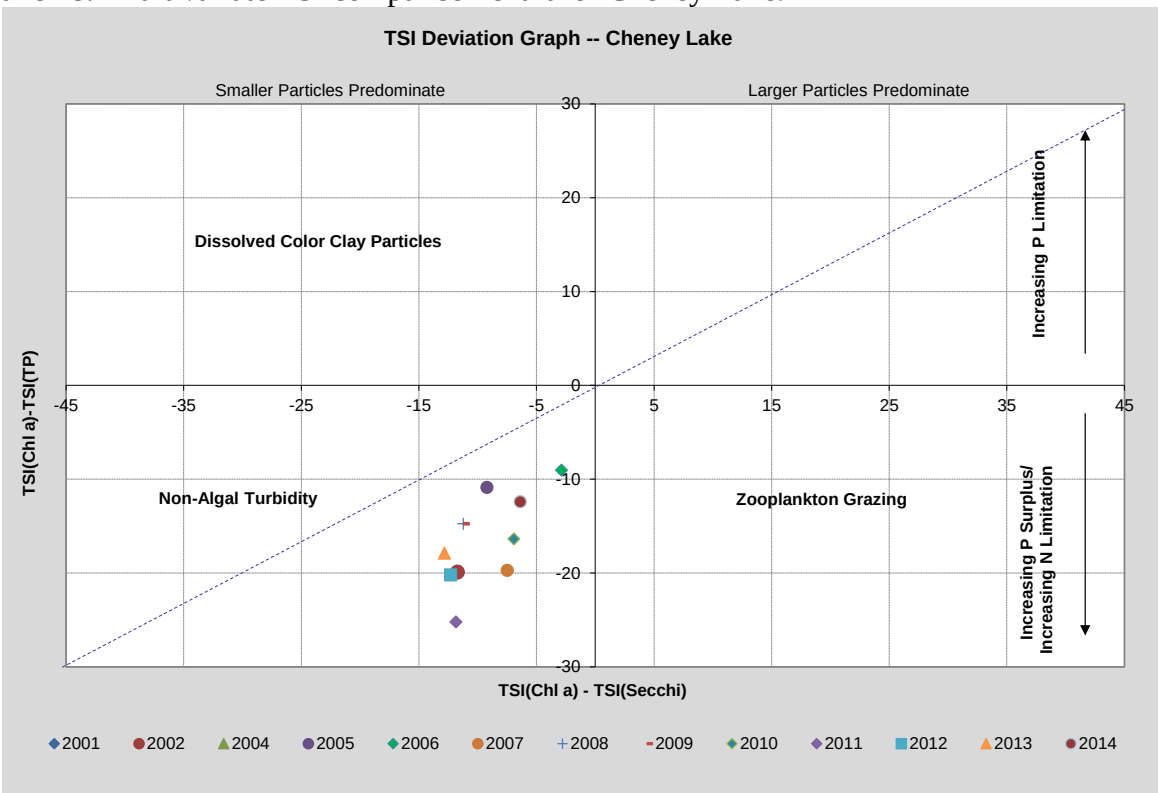
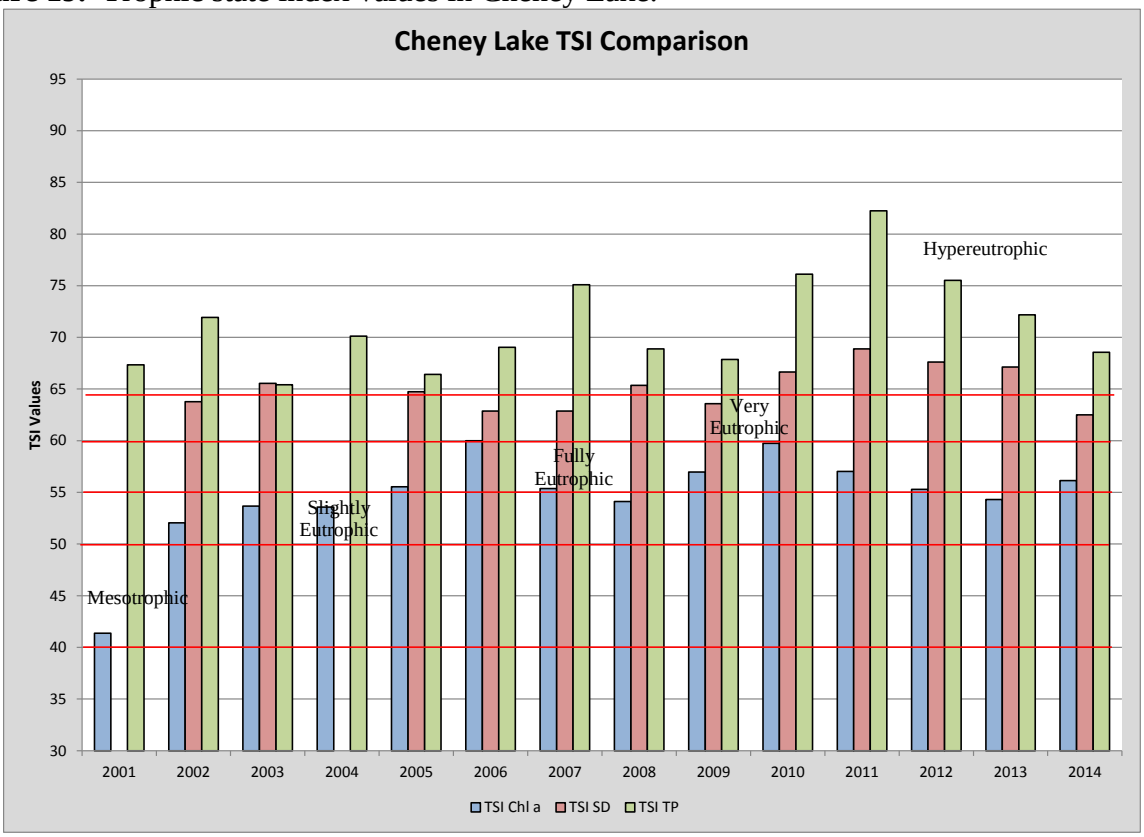


Figure 19. Trophic state index values in Cheney Lake.



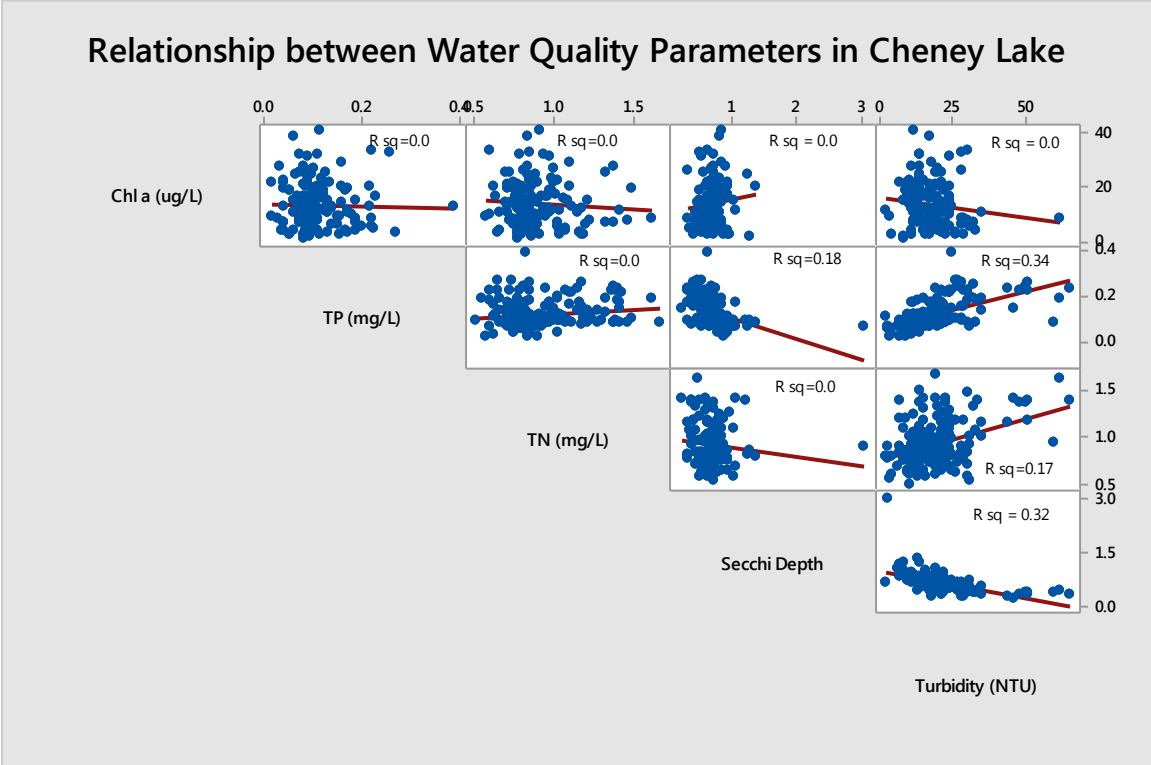
Algal Communities: As seen in Table 5, algal communities in Cheney Lake have been dominated by blue-green algae, or cyanobacteria, since 2002 in samples taken by KDHE in the months of June, July, and August. An increasing supply of nutrients, especially phosphorus and possibly nitrogen, will often result 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 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 5. Algal communities observed in Cheney Lake.

Sampling Date	Total Cell Count cells/mL	Percent Composition				Chl-*a* µg/L
		Green	Blue Green	Diatom	Other	
6/2/1993	1,008	63	0	37	0	2.5
8/21/1996	1,134	83	0	17	0	1.6
6/4/1998	2,817	56	33	0	11	4.9
6/21/1999	1,827	39	37	25	0	6.1
8/5/2002	27,531	1	97	2	0	16.4
7/5/2005	75,978	8	89	3	0	25.7
8/25/2008	23,279	5	91	1	3	13.6
8/15/2011	2,993	5	91	4	0	3.2

Relationships: Figure 20 displays a moderate relationship between turbidity and total phosphorus, total nitrogen, and Secchi depth. In addition, there may be a minor relationship between Secchi depth and total phosphorus.

Figure 20. Matrix plot displaying the relationships between water quality parameters in Cheney Lake.



Stream Data: The Cheney Lake Watershed, Inc., also known as the Cheney Lake Watershed Restoration and Protection Strategy (WRAPS) group, got its start in 1992 and has been actively pursuing watershed protection and improvement strategies ever since. The improvement in the nutrient and sediment loads arriving at Cheney Lake via the North Fork Ninnescah could be attributed to their work.

Single sample TP concentrations are displayed in Figure 21 and range from a high concentration of 1.75 mg/L in a sample collected by USGS on 6/25/97, to a low concentration of 0.021 mg/L in a sample collected by KDHE on 11/19/12. Splitting the North Fork Ninnescah's period of record into the 1990-1999 and 2000-2014 time periods by percent flow exceedance shows a 26% improvement in median total phosphorus concentration for the 2000-2014 time frame during periods of normal flow (25-74%) (Figure 22). At high flow (0-25%) median and average TP concentrations for the 2000-2014 time period are nearly the same at 0.334 and 0.335 mg/L, respectively. High flow median and average concentration for the 1990-1999 time period are 0.280 and 0.365 mg/L, respectively, indicating total phosphorus concentrations varied more during high flow events in the 1990s. Both time periods report similar median TP at low flow ($\geq$ 75%), however, average TP was higher during the 1990s. Figure 23 displays seasonal averages and medians by flow condition and reveals the summer-fall season has the highest average and median TP concentrations across all flow conditions while winter season reports the lowest average and median TP concentrations across all flow conditions.

Figure 21. Total phosphorus concentrations in the North Fork Ninnescah above Cheney Lake.

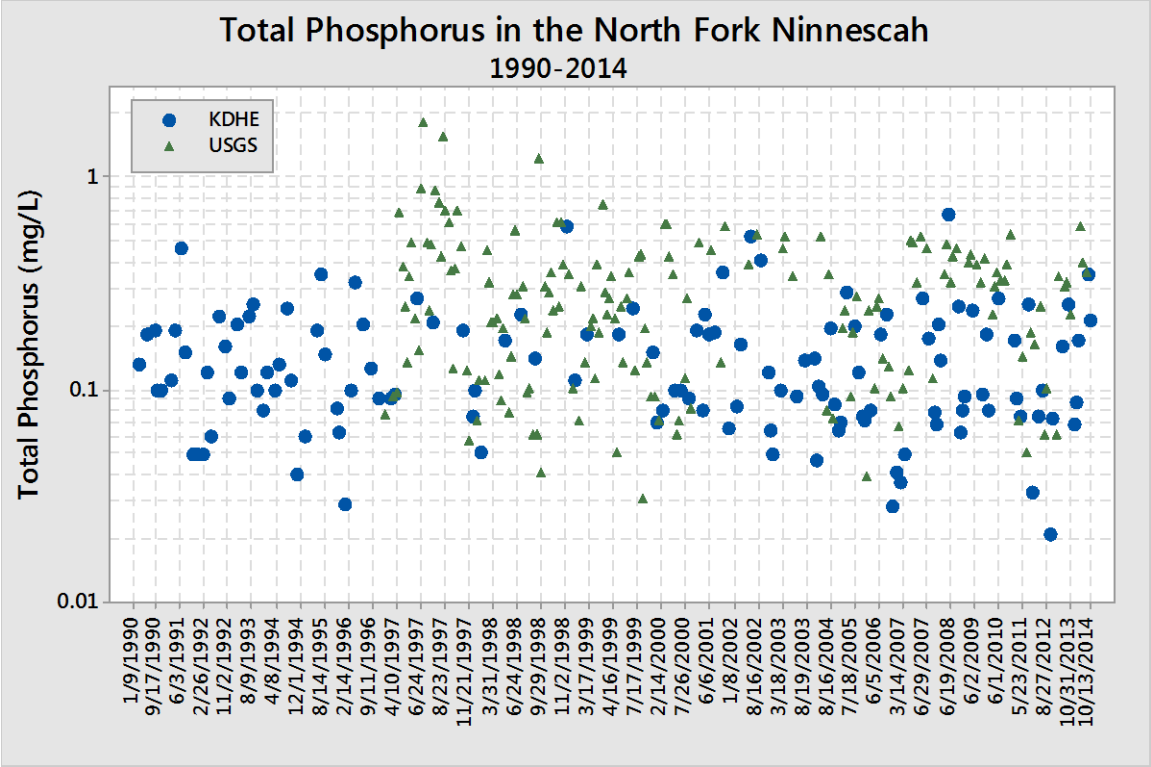


Figure 22. Total phosphorus concentrations divided into the 90-99 and 00-14 periods of record and displayed by percent flow exceedance.

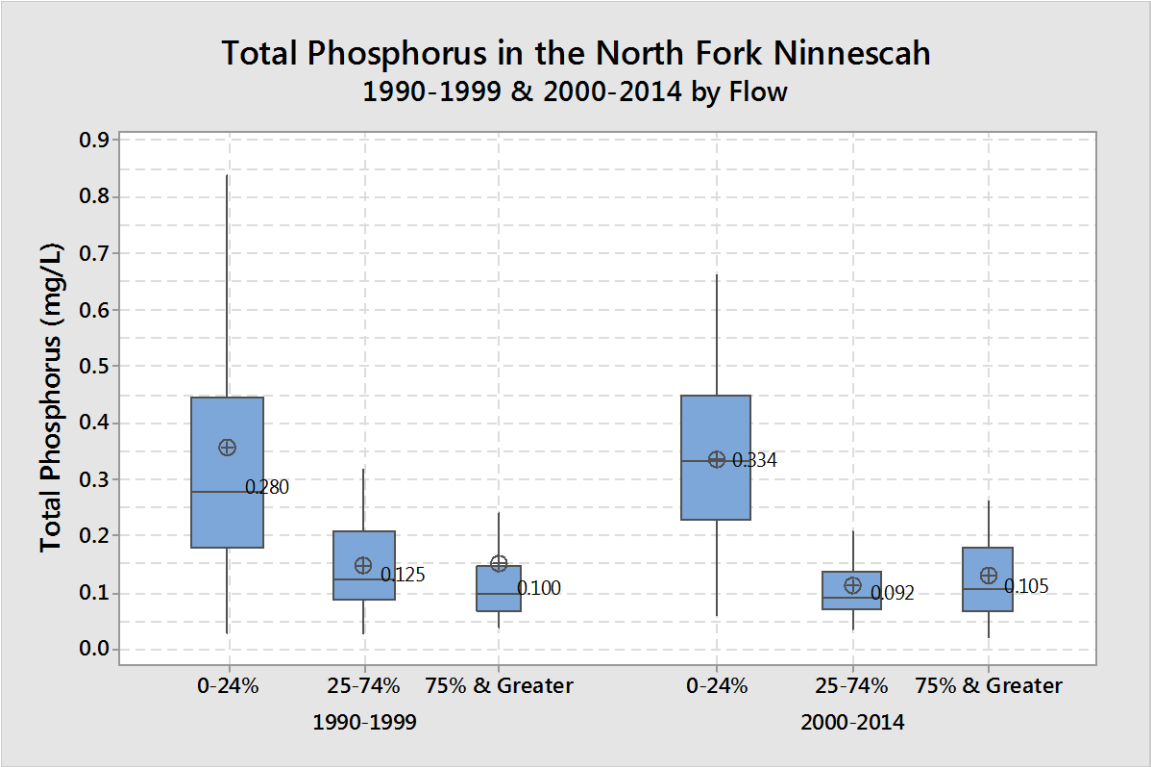
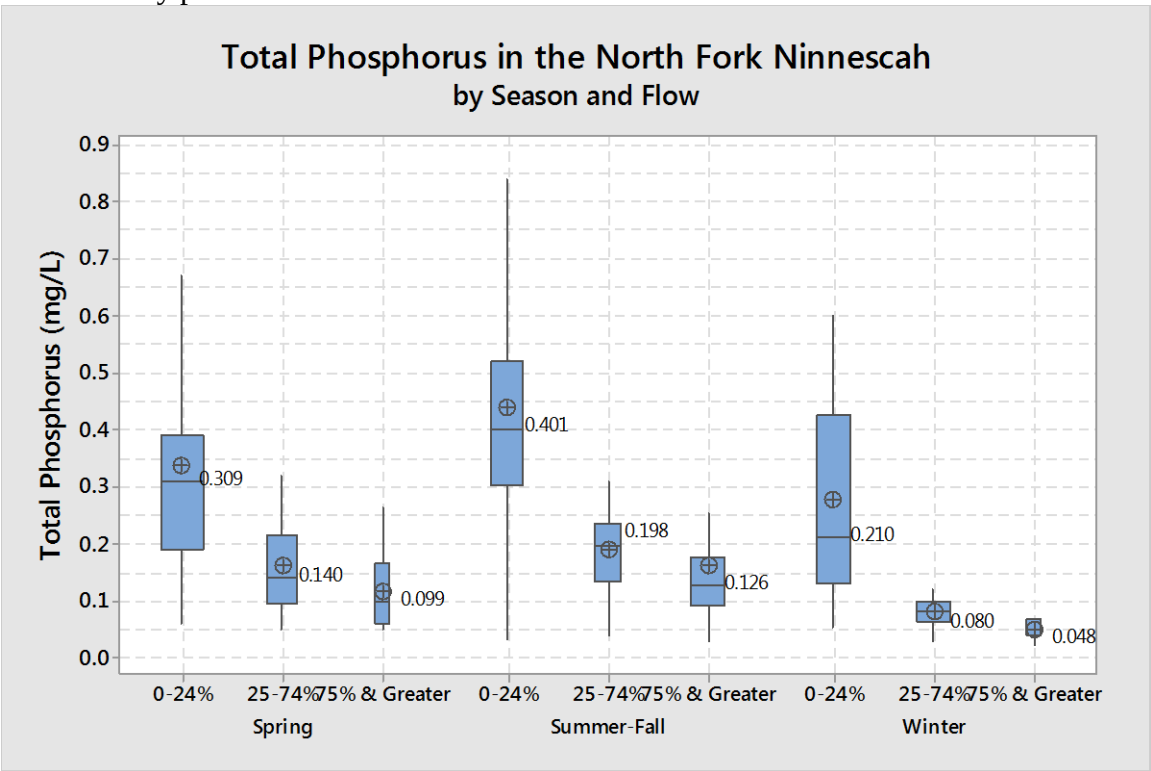


Figure 23. Total phosphorus concentrations in the North Fork Ninnescah above Cheney Lake by season and by percent flow exceedance.



Single sample TN concentrations are displayed in Figure 24 and range from a high concentration of 5.12 mg/L in a sample collected by USGS on 8/22/97, to a low concentration of 0.480 mg/L in a sample collected by USGS on 5/7/1997. Splitting the North Fork Ninnescah period of record into the 1990-1999 and 2000-2014 time periods by percent flow exceedance reveals improvement in average and median TN values across the flow range between the 1990-1999 to 2000-2014 time periods. Median total nitrogen concentrations show an 11% improvement during periods of high flow (0-25%), a 5% improvement during normal flow (25-74%), and a 10% improvement during low flow ($\geq$ 75%) (Figure 25). Figure 26 displays seasonal averages and medians by flow condition and reveals the winter season has the highest average and median TN concentrations across all flow conditions while spring season reports the lowest average and median TN concentrations across all flow conditions.

Figure 24. Total nitrogen concentrations in the North Fork Ninnescah above Cheney Lake.

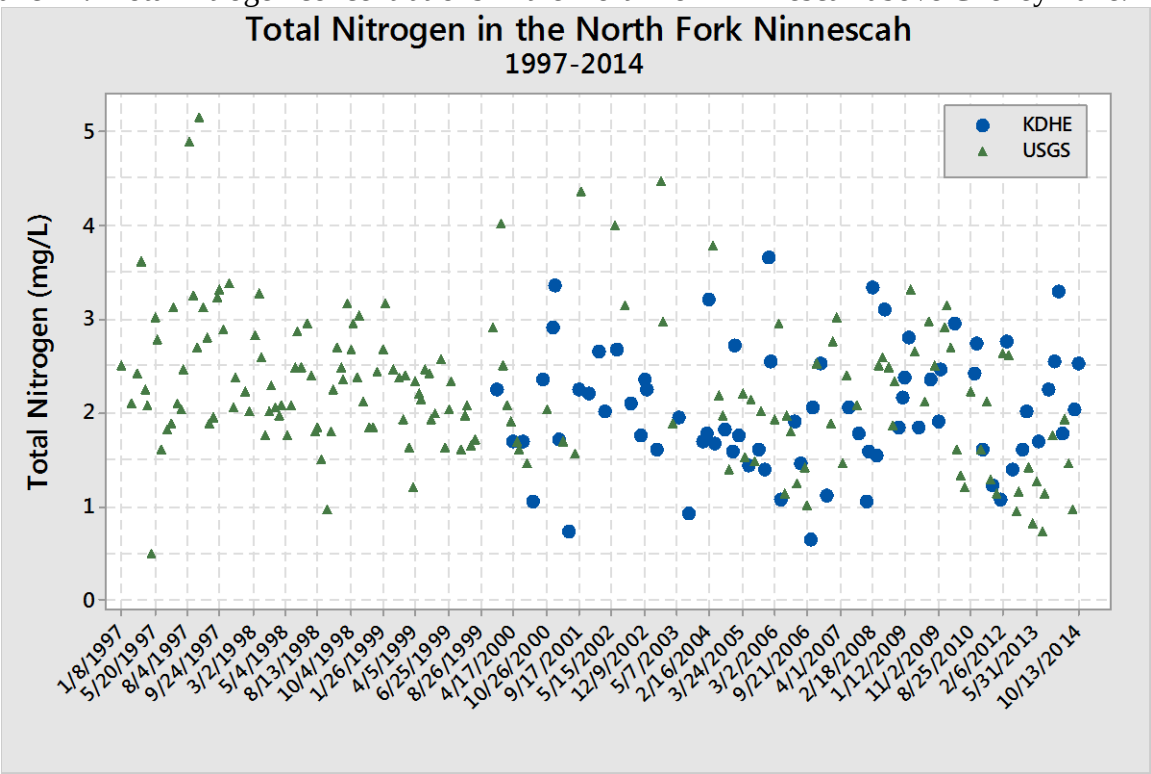


Figure 25. Total nitrogen concentrations divided into the 90-99 and 00-14 periods of record and displayed by flow exceedance ranges.

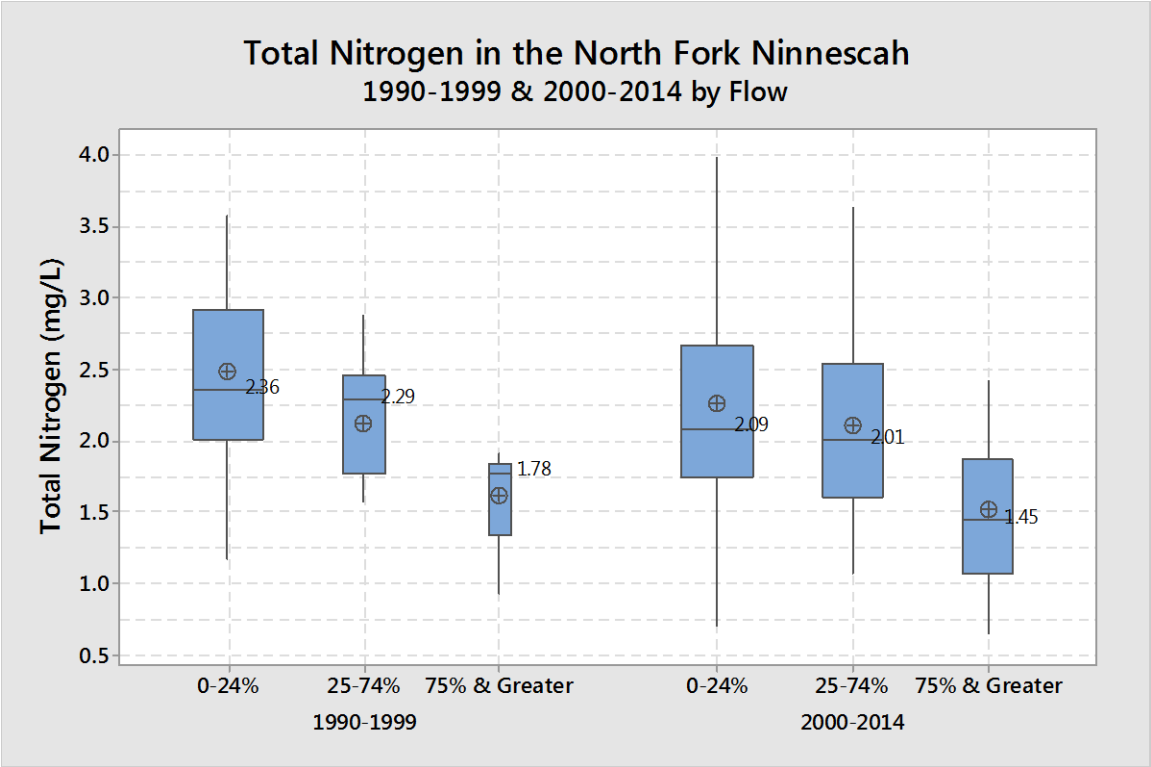


Figure 26. Total nitrogen concentrations in the North Fork Ninnescah above Cheney Lake by season and by flow.

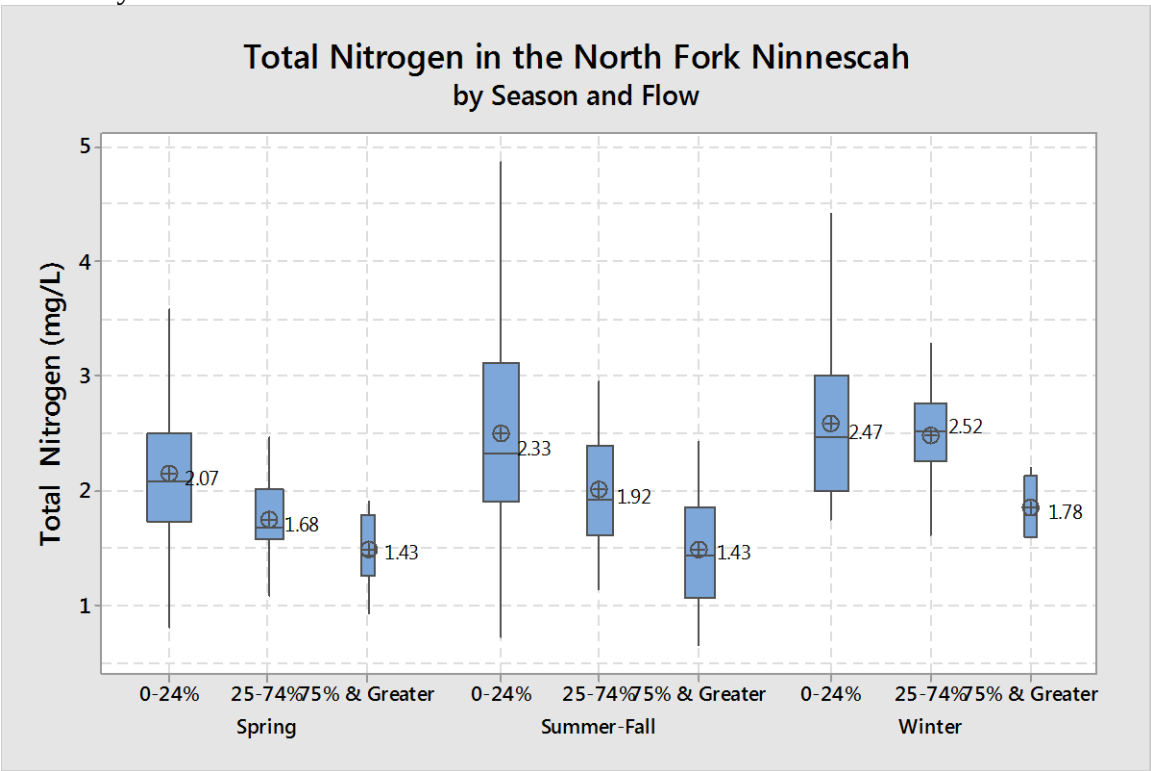


Table 6. Water quality in the North Fork Ninnescah (1990-2014).

Source	Station	Period of Record	Total Phosphorus		Total Nitrogen		Total Suspended Solids	
			Average (mg/L)	Median (mg/L)	Average (mg/L)	Median (mg/L)	Average (mg/L)	Median (mg/L)
USGS	07144780	1990-1999	0.313	0.230	2.34	2.31	240	135
KDHE	SC525	1990-1999	0.153	0.125	*	*	51	38
USGS & KDHE Combined	**07144780 & SC525**	**1990-1999**	**0.250**	**0.188**	**2.34**	**2.31**	**166**	**86**
USGS	07144780	2000-2014	0.285	0.309	2.08	1.95	162	119
KDHE	SC525	2000-2014	0.146	0.100	2.03	1.96	50	27
USGS & KDHE Combined	**07144780 & SC525**	**2000-2014**	**0.217**	**0.180**	**2.05**	**1.96**	**108**	**59**

*No data available

Table 7 details total phosphorus and total nitrogen concentrations by season and flow condition. Total phosphorus concentrations in the North Fork Ninnescah are lowest during the winter season (November-March) under low flow (≥ 75 %) conditions and highest during the summer-fall season (July-October) under high flow (0-24%) conditions. Total nitrogen concentrations

are also high in the summer-fall season under high flow conditions; however, the winter season at high flow posts slightly higher average and median concentrations. The lowest average and median TN concentrations occur at low flow in the spring (April-June) and summer-fall seasons.

Table 7. Average and median total phosphorus and total nitrogen concentrations for the 1990-2014 period of record by flow condition and season.

Season	% Flow Exceedance	# of Samples	Total Phosphorus		Total Nitrogen	
			Average	Median	Average	Median
Spring	≥ 75	7	0.115	0.099	**1.48**	**1.43**
	25-74	23	0.163	0.140	1.75	1.68
	0-24	58	0.337	0.309	2.16	2.07
	All Flows	88	0.268	0.220	1.99	1.96
Summer-Fall	≥ 75	26	0.160	0.126	**1.49**	**1.43**
	25-74	18	0.190	0.198	2.01	1.92
	0-24	37	**0.438**	**0.401**	**2.51**	**2.33**
	All Flows	81	0.264	0.205	2.07	2.00
Winter	> 75	5	**0.050**	**0.048**	1.85	1.78
	25-74	28	0.080	0.080	2.49	2.52
	0-24	36	0.277	0.210	**2.59**	**2.47**
	All Flows	69	0.163	0.100	2.49	2.45
All Seasons	≥ 75	38	0.140	0.100	1.54	1.51
	25-74	69	0.132	0.100	2.12	2.10
	0-24	131	0.346	0.320	2.37	2.23
	All Flows	238	0.234	0.181	2.17	2.06

Figures 27 and 28 display seasonal daily loads for total phosphorus and total nitrogen, respectively, in Cheney Lake via the North Fork Ninnescah and they reveal significant winter loading events at high flow for both TP and TN. Most nutrients loading in the watershed is occurring when the North Fork Ninnescah is at high flow with reductions in loading occurring with each delineation of flow condition as displayed in Table 8 and Table 9.

Figure 27. Estimated total phosphorus loading in Cheney Lake via the North Fork Ninnescah by season. The total phosphorus load duration curve (LDC) was developed using the 1990-2014 average total phosphorus concentration (KDHE & USGS compiled) of 0.234 mg/L.

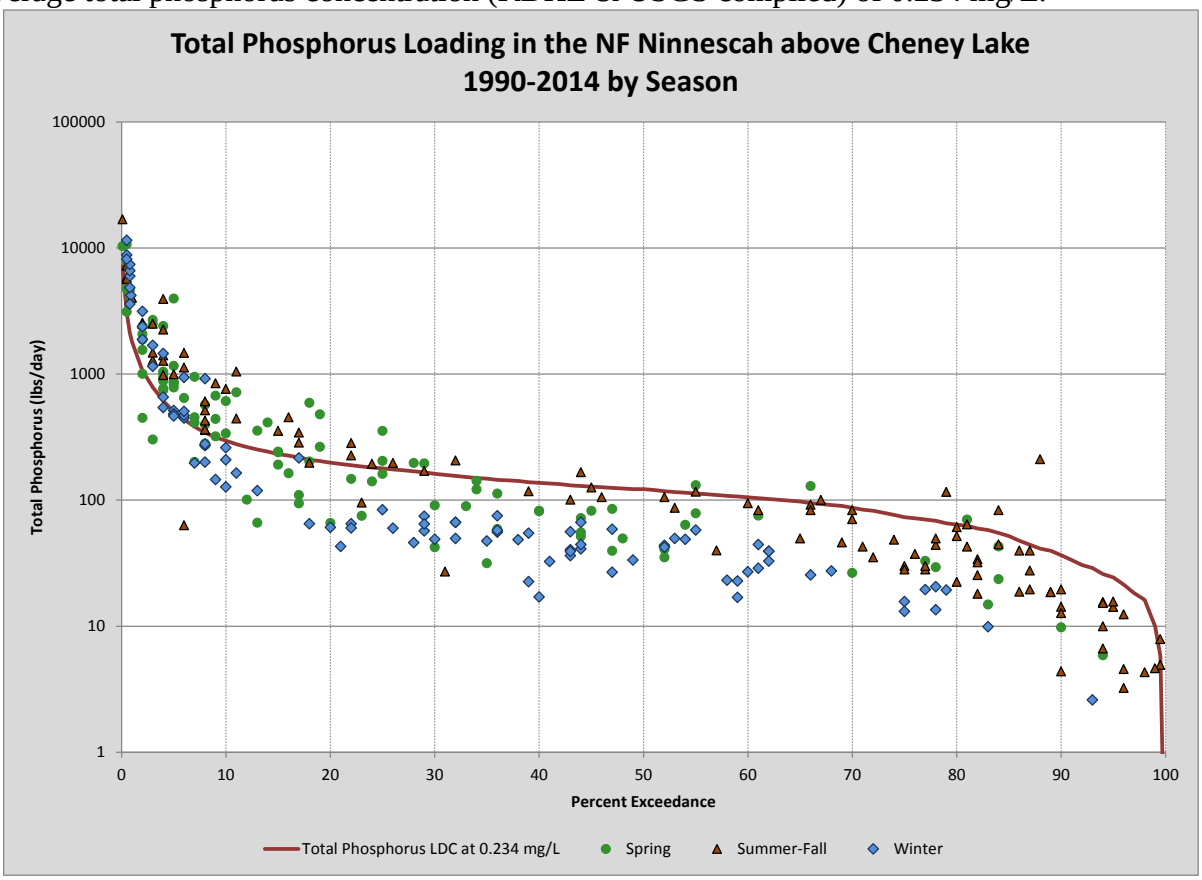


Table 8. Estimated total phosphorus loading scenarios. Median and average total phosphorus values for the 10%, 25%, 50%, 75%, and 90% flow scenarios are the median and average TP of samples collected at SC525 (1990-2014) when the North Fork Ninnescah was flowing between 0-19%, 20-39%, 40-59%, 60-79%, and 80-100%, respectively. Flow values reflect estimated flow at the inlet to Cheney Lake.

% Flow Exceedance	Flow (cfs)	Median TP (mg/L)	Average TP (mg/L)	Estimated Daily TP Load Based on Flow Condition & Average TP Concentration (lbs/day)
90%	29	0.118	0.150	23.5
75%	58	0.100	0.129	40.4
50%	97	0.100	0.117	61.0
25%	141	0.100	0.146	111
10%	234	0.330	0.364	460
Average	160	0.181	0.234	202

Figure 28. Estimated total nitrogen loading in Cheney Lake via the North Fork Ninnescah. The total nitrogen load duration curve (LDC) was developed using the 1990-2014 average total nitrogen concentration (KDHE & USGS complied) of 2.17 mg/L.

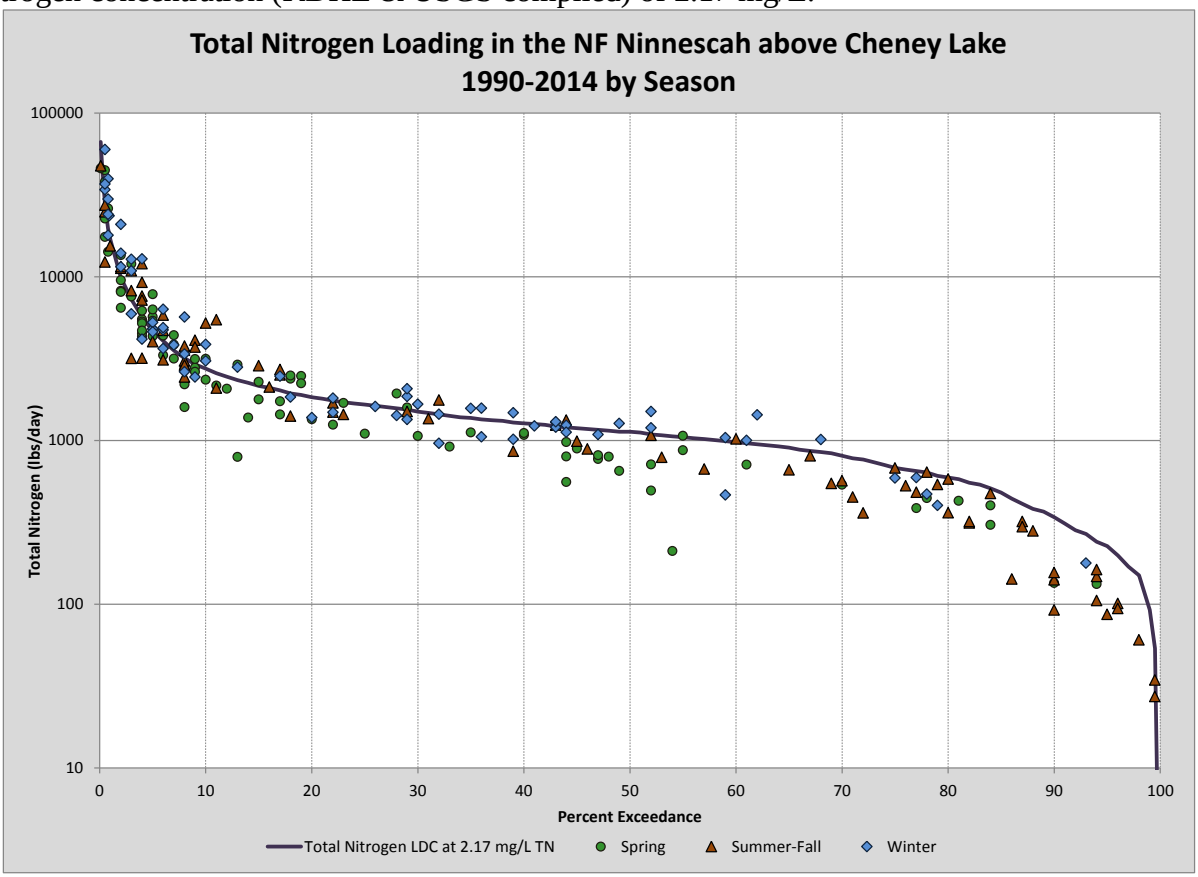


Table 9. Estimated total nitrogen loading scenarios. Median and average total nitrogen values for the 10%, 25%, 50%, 75%, and 90% flow scenarios are the median and average TN of samples collected at SC525 (1990-2014) when the North Fork Ninnescah was flowing between 0-19%, 20-39%, 40-59%, 60-79%, and 80-100%, respectively. Flow values reflect estimated flow at the inlet to Cheney Lake.

% Flow Exceedance	Flow (cfs)	Median TN (mg/L)	Average TN (mg/L)	Estimated Daily TP Load Based on Flow Condition & Average TP Concentration (lbs/day)
90%	29	1.37	1.37	214
75%	58	1.79	2.00	560
50%	97	2.03	2.01	1,059
25%	141	2.20	2.23	1,675
10%	234	2.30	2.40	2,903
Average	160	2.06	2.17	1,783

Desired Endpoints of Water Quality (Implied Load Capacity) in Cheney Lake:
The ultimate endpoint for this TMDL will be to achieve the Kansas Surface Water Quality Standards fully supporting the designated uses in Cheney Lake by eliminating impacts associated with excessive eutrophication. Although the Kansas Surface Water Quality Standards detail chlorophyll *a* criteria of 11 μg/L for Cheney Lake, in order to improve its trophic condition from its current Fully 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. Should the chlorophyll *a* endpoint of 10 μg/L fail to support the designated uses in the lake the chlorophyll *a* endpoint will be revised to 6 μg/L and Phase II nutrient reductions will commence.

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.

This TMDL is a revision to the eutrophication TMDL approved in 2000 for Cheney Lake, which established a load allocation (103,501 lbs/year), wasteload allocation (2,352 lbs/year), and margin of safety (11,762 lbs/year) for a total phosphorus TMDL of 117,615 lbs/year requiring a 45% reduction in total phosphorus loading to the lake (Table 10).

This TMDL establishes two milestones to achieve the Phase I and Phase II endpoints. The first milestone is a reduction in the total phosphorus and total nitrogen concentrations in Cheney Lake based on a current average condition developed using April through October near dam lake data collected by both USGS (07144790) and KDHE (LM017001) for the 2001-2014 period of record with calibration and reductions focused on a lake area-weighted mean of 10 μg/L chlorophyll *a* generated by the BATHTUB model. Based on the BATHTUB reservoir eutrophication model (Appendix B), for Phase I, total phosphorus, and total nitrogen entering Cheney Lake must be reduced by 38% and 36%, respectively, to meet the 10 μg/L chlorophyll *a* endpoint. Once Phase I nutrient milestones are achieved, should the lake fail to achieve the endpoint of an area weighted mean chlorophyll *a* concentration of 10 μg/L or fail to meet the designated uses of the lake, the Phase II milestones and endpoint will come into effect. Phase II milestones are reductions in total phosphorus and total nitrogen concentrations based on the same current average condition developed for Phase I with calibration and reductions also focused on area-weighted mean values generated by the BATHTUB model. Based on the Phase II BATHTUB reservoir eutrophication model (Appendix C), total phosphorus and total nitrogen entering Cheney Lake must be reduced by 69% and 65%, respectively, to achieve the endpoint of a lake area-weighted mean of 6 μg/L chlorophyll *a*.

Table 10. 2000 Cheney Lake Eutrophication TMDL values, Cheney Lake current average condition (2001-2014) and Phase I and Phase II TMDL. Percent reduction refers to the difference between the Current average condition and the TMDL values.

Parameter	**2000 Cheney Lake TMDL**	**Current Avg. Condition**	***Phase I* TMDL**	**Percent Reduction**
Total Phosphorus – Annual Load (lbs/year)	117,615	129,008	80,938	37%
Total Phosphorus – Daily Load* (lbs/day)	N/A	904	567.31	37%
Total Phosphorus – Lake Concentration (µg/L)	117	123	95	23%
Total Nitrogen – Annual Load (lbs/year)	N/A	787,566	510,992	35%
Total Nitrogen – Daily Load* (lbs/day)	N/A	3,712	2,408.14	35%
Total Nitrogen – Lake Concentration (µg/L)	N/A	920	705	23%
Chlorophyll *a* Concentration (µg/L)	6	13	10	23%
Parameter	**2000 Cheney Lake TMDL**	**Current Avg. Condition**	***Phase II* TMDL**	**Percent Reduction**
Total Phosphorus – Annual Load (lbs/year)	117,615	129,008	40,184	69%
Total Phosphorus – Daily Load* (lbs/day)	N/A	904	281.65	69%
Total Phosphorus – Lake Concentration (µg/L)	117	123	63	49%
Total Nitrogen – Annual Load (lbs/year)	N/A	787,566	277,959	65%
Total Nitrogen – Daily Load* (lbs/day)	N/A	3,712	1,309.93	65%
Total Nitrogen – Lake Concentration (µg/L)	N/A	777	475	48%
Chlorophyll *a* Concentration (µg/L)	6	13	6	54%

*See Appendix A for daily load calculations.

3. SOURCE INVENTORY AND ASSESSMENT

Point Sources: There are fifteen NPDES permitted facilities in the Cheney Lake watershed. Nine facilities operate non-overflowing lagoon systems that are prohibited from discharging and would only contribute a nutrient load under extreme precipitation or flooding events. The remaining six NPDES permitted facilities are municipal lagoon facilities that are permitted to discharge to the watershed and, consequently, are assigned a wasteload allocation for total nitrogen and total phosphorus under this TMDL. Currently, there is no monitoring requirement for nutrients in any of the NPDES permits in the Cheney Lake watershed; hence, there are no water quality data to display for the dischargers. Nonetheless, TP and TN wasteload allocations have been established for any discharging facility in the watershed.

The City of Haviland operates a two-cell stabilization lagoon system with a 150-day detention time and a permitted flow of 0.0746 million gallons per day (MGD) that discharges into an unnamed tributary at the top of the Cheney Lake watershed. The City of Haviland has reported discharging for one quarter for the 2008 through 2014 time period. The distance from the City of Haviland to Cheney Lake makes it unlikely that discharges from their lagoon system are contributing to the nutrient impairment in Cheney Lake; however, the City of Haviland's permit has been assigned a wasteload allocation for total nitrogen and total phosphorus.

The City of Stafford operates a three-cell stabilization lagoon system that discharges to the North Fork Ninnescah via Dooleyville Creek. The City of Stafford is permitted to discharge 0.145 MGD, and has reported discharging twenty-seven of the twenty-eight quarters during the 2008 through 2014 time period.

The City of Preston operates a three-cell stabilization lagoon system permitted to discharge 0.018 MGD to Silver Creek via an unnamed tributary. The City of Preston has reported discharging during five quarters from the beginning of 2008 through 2014.

The City of Turon operates a three-cell stabilization lagoon system with a 120-day detention time and is permitted to discharge 0.0467 MGD to the North Fork Ninnescah River via Silver Creek and an unnamed tributary. The City of Turon reported discharging during twenty quarters from the beginning of 2008 through 2014.

The City of Arlington operates a three-cell stabilization lagoon system with a 120-day detention time and is permitted to discharge 0.0725 MGD to the North Fork Ninnescah River. The City of Arlington has reported discharging eighteen quarters during the 2008 through 2014 time period.

The City of Partridge operates a three-cell stabilization lagoon system with a 200-day detention time and is permitted to discharge 0.03 MGD to the North Fork Ninnescah River via Red Rock Creek. The City of Partridge has reported discharging six quarters during the 2008 through 2014 time periods.

Of the remaining nine NPDES permits located in the Cheney Lake watershed, eight are non-discharging municipal lagoons and one, the Fairview Service Center WWTF is a non-

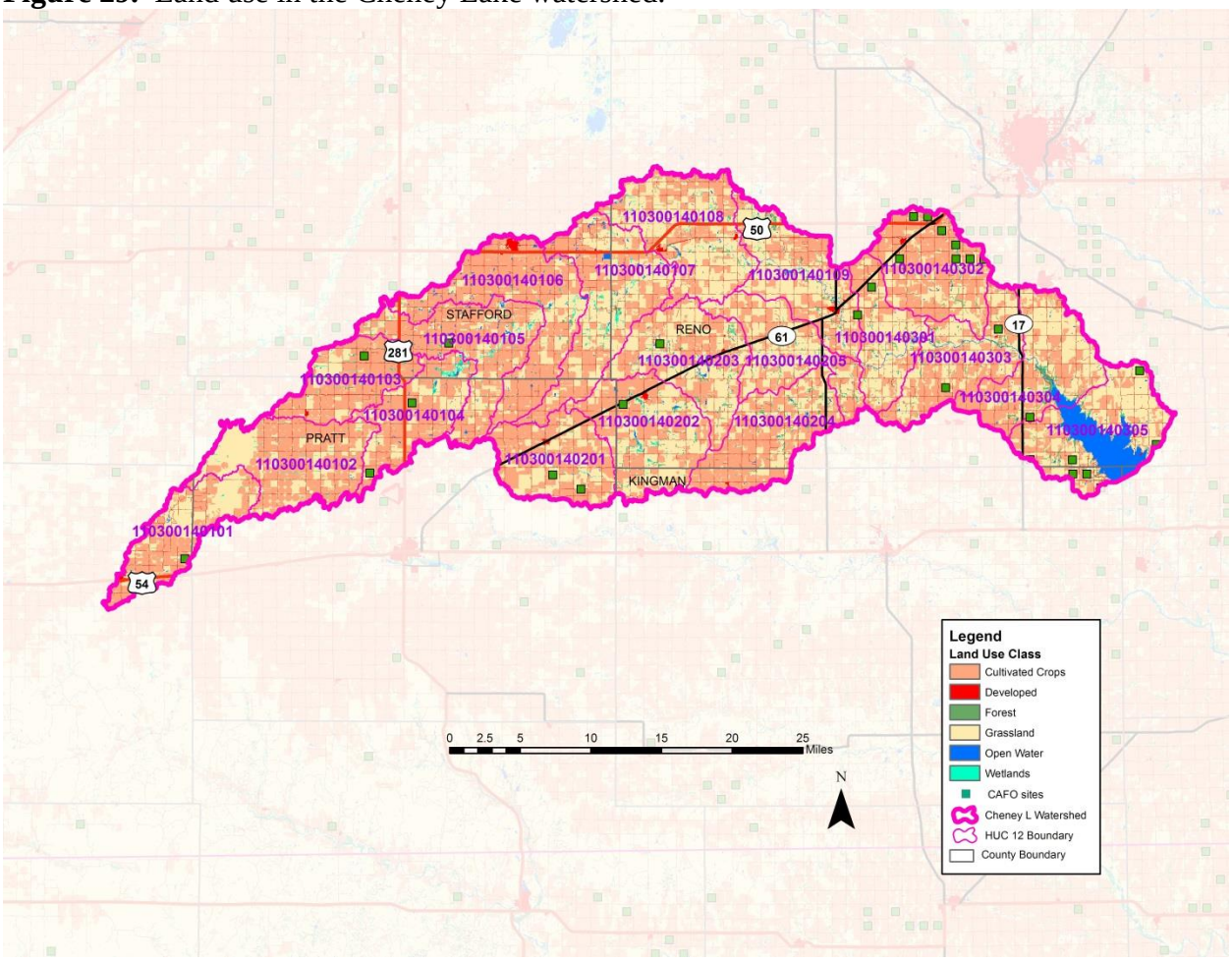
discharging commercial lagoon (Table 11). All nine non-discharging lagoon systems have been assigned a wasteload allocation of zero.

Table 11. NPDES permitted facilities in the Cheney Lake watershed. N/A = not applicable; WWTF=Wastewater Treatment Facility; WWTP=Wastewater Treatment Plant.

Name	County	NPDES Permit #	KS Permit #	Type	Receiving Stream	Expiration Date	Permitted Flow (MGD)
City of Haviland WWTF	Kiowa	KS0027839	M-AR42-OO01	2-Cell Lagoon	Unnamed Tributary	3/31/17	0.0746
City of Preston WWTF	Pratt	KS0098141	M-AR74-O002	3-Cell Lagoon	Unnamed Tributary	12/31/17	0.018
City of Stafford WWTF	Stafford	KS0028231	M-AR84-OO01	3-Cell Lagoon	Dooleyville Creek	3/31/17	0.145
City of Turon WWTF	Reno	KS0115070	M-AR89-OO01	3-Cell Lagoon	Unnamed Tributary	6/30/17	0.0467
City of Sylvia WWTF	Reno	KSJ000442	M-AR88-MO01	Non Discharging Lagoon	N/A	11/30/18	N/A
City of Plevna WWTP	Reno	KSJ000448	M-AR72-NO01	Non Discharging Lagoon	N/A	1/31/18	N/A
City of Arlington WWTF	Reno	KS0049760	M-AR07-OO01	3-Cell Lagoon	NF Ninnescah	3/31/17	0.0725
City of Abbyville WWTF	Reno	KSJ000468	M-AR01-NO01	Non Discharging Lagoon	N/A	7/31/18	N/A
City of Partridge WWTF	Reno	KS0024619	M-AR70-OO01	3-Cell Lagoon	Red Rock Creek	12/31/17	0.03
Fairview Service WWTF	Reno	KSJ000600	C-AR49-NO03	Non Discharging Lagoon	N/A	10/31/18	N/A
Reno County Sewer District #1 WWTP	Reno	KSJ000452	M-AR49-NO01	Non Discharging Lagoon	N/A	1/31/18	N/A
Cheney State Park WWTF Oxidation Pond # 3	Reno	KSJ000463	M-AR20-N002	Non Discharging Lagoon	N/A	3/31/18	N/A
Cheney State Park WWTF (East Shore)	Reno	KSJ000465	M-AR20-N004	Non Discharging Lagoon	N/A	3/31/18	N/A
Cheney State Park WWTF (Heimerman Point)	Reno	KSJ000184	M-AR20-NO05	Non Discharging Lagoon	N/A	3/31/18	N/A
Cheney State Park WWTF (West Shore)	Kingman	KSJ000464	M-AR20-N003	Non Discharging Lagoon	N/A	3/31/18	N/A

Land Use: A rural Kansas watershed, the predominant land uses in the Cheney Lake watershed are cultivated cropland (50%) and grassland (41%) according to the 2011 National Land Cover Data. Together they account for 91% of the total land area in the watershed with the remaining land area composed of developed land (5%), open water (2%), forest (1%), and wetlands (1%) (Figure 29). During precipitation runoff events, the cultivated cropland in the watershed may contribute to the nutrient 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 5% developed which is primarily in the form of twelve small cities. These urbanized areas may generate nutrient loads from lawn fertilizers, domestic pet waste and other materials found in the urban environment particularly during storm runoff events.

Figure 29. Land use in the Cheney Lake watershed.



Livestock Waste Management Systems: According to the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS), on December 31, 2012 there were 49,917; 181,541; 164,036; 182,020; and 77,206 head of cattle (excluding cows) in Kiowa, Stafford, Pratt, Reno, and Kingman counties, respectively. On December 31, 2012, according to NASS, there were zero head of hogs in Kiowa, Pratt, and Kingman counties; however, Stafford and Reno reported 8,897 and 1,007 head of hogs, respectively. There are

thirty-five certified, registered, or permitted concentrated animal feeding operations (CAFOs) within the Cheney Lake watershed with three facilities large enough to warrant a federal discharge (NPDES) permit (Table 12). 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 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 impairment in Cheney Lake.

Table 12. Registered, certified, or permitted concentrated animal feeding operations (CAFOs) in the Cheney Lake watershed.

Kansas Permit Number	NPDES Permit Number	Animal Type	County	Animal Total
A-ARKM-BA13	N/A	Beef	Kingman	150
A-ARKM-BA04	N/A	Beef	Kingman	400
A-ARKW-BA02	N/A	Beef, Horses	Kiowa	996
A-ARPR-C002	KS0090778	Beef	Pratt	2,900
A-ARPR-B009	N/A	Beef	Pratt	999
A-ARPR-C004	KS0097888	Beef	Pratt	1,550
A-ARPR-B010	N/A	Beef	Pratt	700
A-ARRN-BA03	N/A	Beef	Reno	500
A-ARRN-BA14	N/A	Beef	Reno	300
A-ARRN-M045	N/A	Dairy	Reno	88
A-ARRN-M037	N/A	Chickens, Horses, Dairy	Reno	377
A-ARRN-M013	N/A	Chickens, Horses, Dairy	Reno	346
A-ARRN-M018	N/A	Dairy, Beef	Reno	160
A-ARRN-M035	N/A	Dairy, Beef	Reno	170
A-ARRN-S016	N/A	Swine, Goats, Sheep	Reno	1,949
A-ARRN-M028	N/A	Dairy	Reno	180
A-ARRN-M052	N/A	Dairy, Horses	Reno	152
A-ARRN-S009	N/A	Swine	Reno	900
A-ARRN-S015	N/A	Swine	Reno	2,200
A-ARRN-B004	N/A	Beef	Reno	999
A-ARRN-M031	N/A	Dairy, Horses	Reno	243
A-ARRN-C001	KS0085804	Beef	Reno	35,000
A-ARRN-M057	N/A	Dairy	Reno	25
A-ARRN-B006	N/A	Beef	Reno	350
A-ARRN-M019	N/A	Dairy	Reno	60
A-ARRN-BA25	N/A	Beef	Reno	599
A-ARRN-M034	N/A	Dairy	Reno	60
A-ARRN-M039	N/A	Dairy	Reno	120
A-ARRN-M032	N/A	Dairy	Reno	100
A-ARRN-M007	N/A	Dairy	Reno	130
A-ARRN-M021	N/A	Dairy	Reno	100
A-ARRN-M051	N/A	Dairy,Horses	Reno	552
A-ARRN-M001	N/A	Dairy	Reno	80
A-ARSF-BA10	N/A	Beef	Stafford	400
A-ARSF-BA04	N/A	Beef	Stafford	900

On-Site Waste Systems: The Cheney Lake watershed is primarily a rural agricultural area. It can be assumed that some 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 2,956 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.

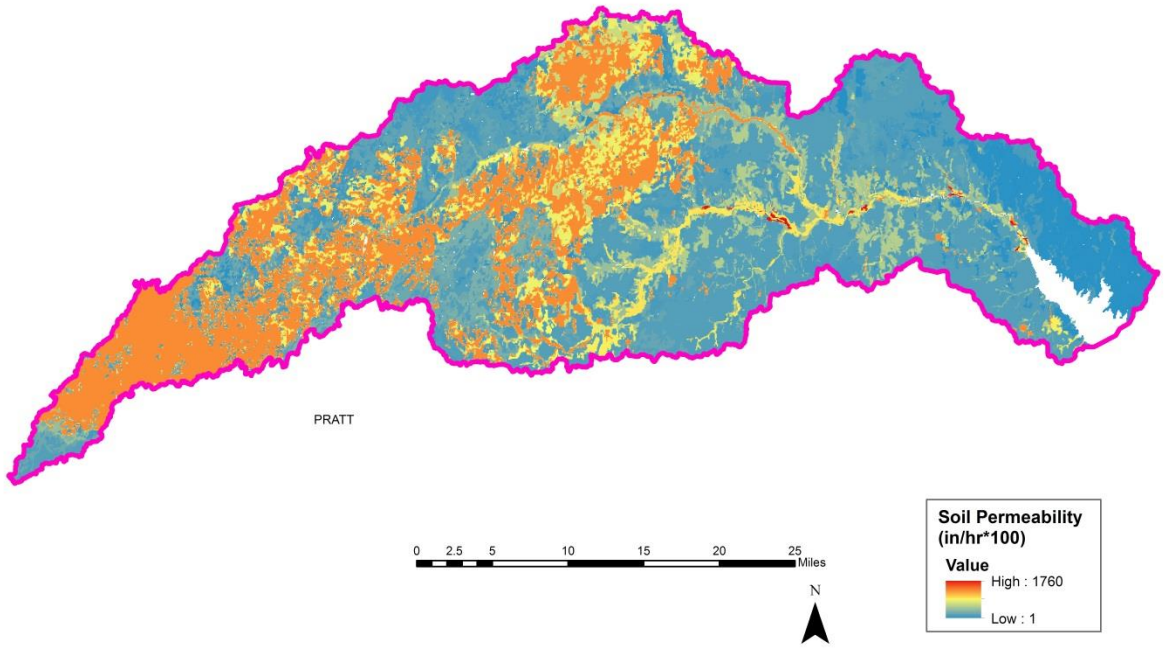
Population: Population figures tallied by the 2000 and 2010 U.S. Census are detailed in Table 13 for the small cities that lie within the lake's watershed. Only two cities, Haviland and Arlington increased in population between 2000 and 2010 with 15% and 3% growth, respectively. The remaining cities lost population totaling 7% indicating the watershed is losing population.

Table 13. U.S. Census results for populated areas in the Cheney Lake watershed.

City	Year of Census		% Difference
	2000	2010	
Haviland	612	701	+15%
Stafford	1,161	1,042	-10%
Byers	50	35	-30%
Preston	164	158	-4%
Partridge	259	248	-4%
Plevna	99	98	-1%
Sylvia	297	218	-27%
Arlington	459	473	+3%
Langdon	72	42	-42%
Abbyville	128	87	-32%
Turon	436	387	-11%
Penalosa	27	17	-37%
Total	**3,764**	**3,506**	**-7%**

Contributing Runoff: The watershed of Cheney Lake has extremely high soil permeability that ranges from 0.01 inches/hour to 17.3 inches an hour with an average permeability of 5.1 inches/hour according to NRCS STATSGO database. Over 50% of the watershed has a permeability of 13 inches/hour or greater and, as Figure 30 displays, the upper part of the watershed is where soil permeability is the highest thus contributing to the lack of registered streams in that portion of the lake's watershed. 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 30. Soil permeability in the Cheney Lake watershed.



Background and Natural Sources: Undissolved nutrients bound to suspended solids in the inflow to Cheney 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 Cheney Lake. In addition, geological formations (i.e. soil and bedrock) may also contribute to nutrient loads. With just 1% of the land cover in the watershed as forest, leaf litter and wastes derived from natural wildlife in the area are likely minor contributors to the nutrient loads in the lake. Further nutrient loading is also occurring through the atmospheric deposition of nitrogen and phosphorus compounds to Cheney Lake and its watershed.

Internal Loading: Estimates of internal loading are contained within the BATHTUB modeling of the lake. Internal loading is a complex function of hydrologic conditions, lake morphometry and lake sediment nutrient availability. Should the lake stratify during the summer growing season, internal loading of nutrients may play a role in the eutrophic state of the lake.

4. ALLOCATION OF POLLUTANT REDUCTION RESPONSIBILITY

Cheney Lake is co-limited by nitrogen and phosphorus; therefore, both are 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, livestock operations, and stormwater runoff contributions from areas under construction and the small cities in the watershed.

Nutrients: The lake model utilized for the development of the eutrophication TMDL was BATHTUB (Appendices B & C). 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. 2000-2014 data from the CASTNET station on the Konza Prairie (KNZ184) 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, Cheney Lake was considered one segment. The Cheney Lake segment in both the Phase I and Phase II BATHTUB models were populated using water quality data collected by both KDHE (LM017001) and USGS (07144785) during the growing season (April-October) for the 2001-2014 period of record. Tributary data for both Phase I and Phase II models utilized flow weighted averages developed using year-round water quality data collected at KDHE's stream chemistry station SC525 combined with data collected at USGS station 07144780 for the 2000-2014 time period. Both SC525 and USGS 07144780 are located on the North Fork Ninnescah River above Cheney Lake.

Lake inflow from the North Fork Ninnescah was estimated at 129 hm^3/year by applying the ratio of the contributing area of Cheney Lake to the contributing area of USGS 07144780. To account for additional inflow from other tributaries an additional tributary field was populated using the same water quality values as the North Fork Ninnescah with an inflow value adjusted to 29 hm^3.

The BATHTUB model was calibrated for Cheney Lake and results estimate that the lake retains about 73% of the TP and 65% of the TN load annually. Based on modeling results, Phase I reductions require a 38% reduction of TP and a 36% reduction of TN within the inflow to Cheney Lake to achieve the TMDL endpoint of an area-weighted mean of 10 μg/L chlorophyll *a* in the lake (Appendix B). Once Phase I reductions are met, an assessment of chlorophyll *a* concentrations in the lake and an assessment of the attainment of designated uses will be performed and should the data indicate the lake is not responding to Phase I reductions then Phase II reductions will commence. Modeling results for Phase II reductions require an additional reduction of 31% and 29% in TP and TN, respectively, for a total reduction of 69% TP and 65% reduction of TN within the inflow to Cheney Lake in order to achieve the TMDL endpoint of an area-weighted mean of 6 μg/L chlorophyll *a* in the lake (Appendix C).

Point Sources: Wasteload allocations are established for the six discharging wastewater treatment facilities permitted within the watershed. All six 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 14). Within the BATHTUB model, the wasteloads for all six discharging facilities are included within the total load inflowing from the tributaries since the discharge from these facilities is observed in the nutrient concentration at the stream monitoring stations. Wasteload allocations for the nine facilities in the watershed that are prohibited from discharging are set at zero for both total phosphorus and total nitrogen.

Table 14. Wasteload allocations for NPDES dischargers in the Cheney Lake watershed.

Facility	NPDES Permit #	KS Permit #	TP WLA (lbs/day)	TN WLA (lbs/day)
Haviland WWTF	KS0027839	M-AR42-OO01	1.24	4.97
Preston WWTF	KS0098141	M-AR74-O002	0.30	1.21
Stafford WWTF	KS0028231	M-AR84-OO01	2.42	9.68
Turon WWTF	KS0115070	M-AR89-OO01	0.78	3.11
Arlington WWTF	KS0049760	M-AR07-OO01	1.21	4.84
Partridge WWTF	KS0024619	M-AR70-OO01	0.50	1.99
Total Wasteload Allocation for the Cheney Lake Watershed			***6.45***	***25.80***

Nonpoint Sources: Nonpoint sources are the primary contributors for the nutrient impairment in Cheney Lake. Background levels may be attributed to nutrient recycling and some leaf litter. The assessment suggests that runoff-transporting nutrient and suspended sediment loads associated with animal wastes, cultivated cropland, and pastureland is contributing to eutrophication in the lake. Nutrient load allocations were calculated using the BATHTUB model and are detailed in Table 15.

Table 15. Cheney Lake Total Phosphorus and Total Nitrogen TMDL.

Description	Phase I		Phase II	
	Allocations (lbs/year)	**Allocations (lbs/day)***	**Allocations (lbs/year)**	**Allocations (lbs/day)***
Total Phosphorus Atmospheric Load	2,216	15.53	2,216	15.53
Total Phosphorus Nonpoint Source Load Allocation	68,274	488.60	31,596	231.50
Total Phosphorus Wasteload Allocation	2,354	6.45	2,354	6.45
Total Phosphorus Margin of Safety	8,094	56.73	4,018	28.17
Total Phosphorus TMDL	***80,938***	***567.31***	***40,184***	***281.65***
Total Nitrogen Atmospheric Load	59,556	280.67	59,556	280.67
Total Nitrogen Nonpoint Source Load Allocation	390,920	1,860.86	181,190	872.47
Total Nitrogen Wasteload Allocation	9,417	25.80	9,417	25.80
Total Nitrogen Margin of Safety	51,099	240.81	27,796	130.99
Total Nitrogen TMDL	***510,992***	***2,408.14***	***277,959***	***1,309.93***

*See Appendix A for daily load calculation.

Defined Margin of Safety: The margin of safety provides some hedge against the uncertainty of variable annual total phosphorus and total nitrogen loads and the chlorophyll *a* endpoint. Therefore, the margin of safety is explicitly set at 10% of the total allocations for total phosphorus and total nitrogen, which compensates for the lack of knowledge about the relationship between the allocated loadings and the resulting water quality. The margin of safety during Phase I is 8,094 lbs/year total phosphorus and 51,099 lbs/year total nitrogen. During Phase II, the margin of safety is reduced to 4,018 lbs/year total phosphorus and 27,796 lbs/year total nitrogen.

State Water Plan Implementation Priority: Because Cheney Lake serves as a drinking water supply for the City of Wichita and because it has a regional benefit for recreation and an active Watershed Restoration and Protection Strategy (WRAPS) group, this TMDL will be a **High** Priority for implementation.

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. Figures 31 and 32 display the STEPL results in terms of pounds per year of total phosphorus and total nitrogen per acre. Considering

the results of the STEPL analysis and proximity to Cheney Lake, priorities should focus on the three HUC 12 sub-watersheds highlighted in Table 16: 110300140304, 110300140303, and 110300140302.

Figure 31. Results of the Spreadsheet Tool for Estimating Pollutant Load (STEPL) for total phosphorus loading in the Cheney Lake watershed.

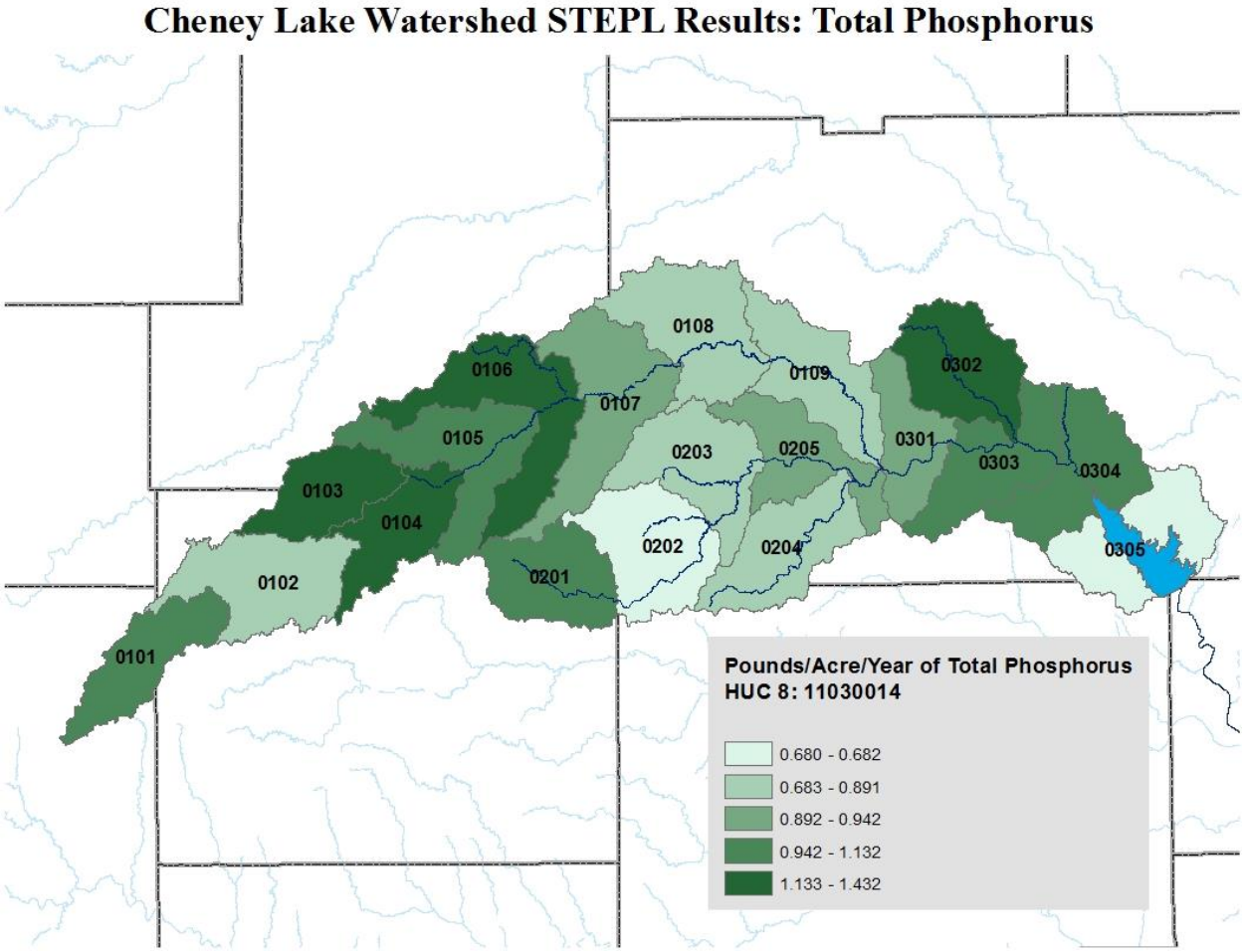


Figure 32. Results of the Spreadsheet Tool for Estimating Pollutant Load (STEPL) for total nitrogen loading in the Cheney Lake watershed.

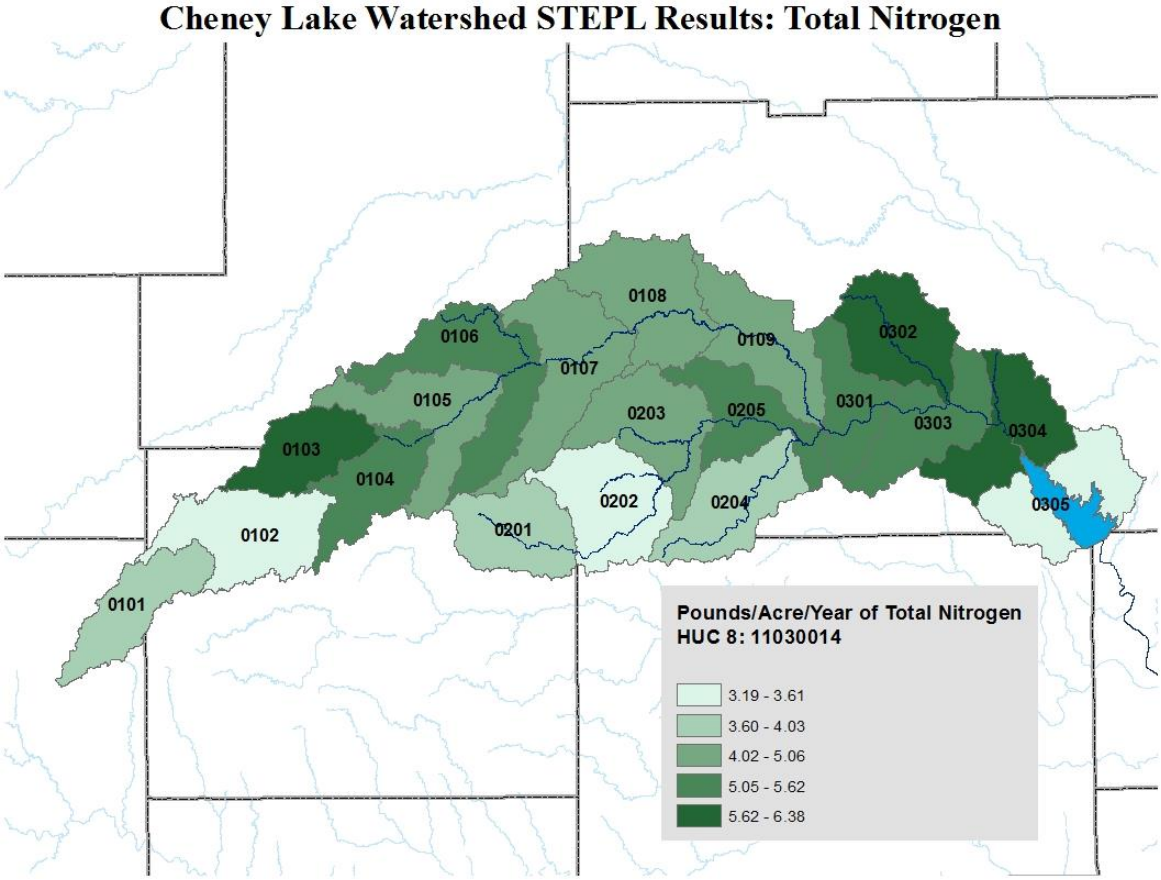


Table 16. STEPL results for the HUC12s making up the Cheney Lake watershed.

HUC 12	Acres	TP Load (lbs/year)	TP Acre (lbs/acre/year)	TN Load (lbs/year)	TN Acre (lbs/acre/year)
110300140305	28,565	19,425	0.68	97,966	3.43
110300140304	31,662	35,862	1.13	184,679	5.83
110300140303	29,482	31,369	1.06	165,524	5.61
110300140302	31,529	44,054	1.40	201,138	6.38
110300140301	20,973	19,757	0.94	113,135	5.39
110300140205	26,762	25,168	0.94	139,983	5.23
110300140204	31,265	27,645	0.88	118,838	3.80
110300140203	32,823	28,197	0.86	160,672	4.90
110300140202	34,485	23,536	0.68	109,823	3.18
110300140201	28,051	29,181	1.04	112,978	4.03
110300140109	31,314	27,259	0.87	158,514	5.06
110300140108	38,052	29,856	0.78	179,063	4.71
110300140107	39,551	36,876	0.93	192,731	4.87
110300140106	40,569	50,351	1.24	218,836	5.39
110300140105	33,486	36,694	1.10	167,114	4.99
110300140104	24,338	31,694	1.30	136,752	5.62
110300140103	23,579	33,770	1.43	138,846	5.89
110300140102	36,303	32,367	0.89	130,955	3.61
110300140101	25,604	25,954	1.01	102,953	4.02

5. IMPLEMENTATION

Desired Implementation Activities: It is likely that agricultural best management practices will improve the condition of Cheney Lake. The Cheney Lake WRAPS stakeholder leadership team (Citizen Management Committee) and KDHE have identified the following water quality protection/restoration measures for financial assistance eligibility in priority sub-watershed areas:

Cropland related: Permanent vegetation, terraces, grassed waterways, No-till (including cover crop practice), terraces, wetlands, nutrient management including:

1. Implement and maintain conservation farming, including conservation tilling, contour farming to reduce runoff and cropland erosion.
2. Where no-till farming is being practiced, install buffer strips, swales, or wetlands between the field and the stream.
3. Improve riparian conditions along stream systems by installing grass and/or forest buffer strips along the stream and drainage channels in the watershed.
4. Perform extensive soil testing to ensure excess phosphorus is not applied.
5. Ensure that labeled application rates of chemical fertilizers are being followed and implement runoff control measures.
6. Install grass buffer strips along drainage channels in the watershed.

Livestock related: Rotational grazing, Relocate Feeding Site (Pens), Relocate Pasture Feeding Site, (including either maintaining or providing a vegetative filter strip), Off-stream Watering Systems including:

1. Ensure land applied manure is being properly managed and is not susceptible to runoff by implementing nutrient management plans.
2. Install pasture management practices, including proper stock density to reduce soil erosion and storm runoff.
3. Ensure proper on-site waste system operations in proximity to the main stem segments.

For both cropland and livestock related water quality protection measures/BMPs, the Cheney Lake Watershed 9 Element Plan (available at the link below) contains priority sub-watershed practice implementation and load reduction goals and timelines that should lead to meeting the nutrient TMDLs described in this document.
http://www.kswraps.org/files/attachments/cheneylake_9e_plansummary.pdf

Implementation Program Guidance:

Nonpoint Source Pollution Technical Assistance – KDHE

a. Support Section 319 implementation projects for reduction of phosphorus runoff from agricultural activities as well as nutrient management.
b. Provide technical assistance on practices geared to the establishment of vegetative buffer strips.
c. Provide technical assistance on nutrient management for livestock facilities in the watershed and practices geared towards small livestock operations, which minimize impacts to stream resources.

Water Resource Cost Share and Nonpoint Source Pollution Control Program – KDA-DOC

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 transport from cropland and grassland in the watershed.
c. Install livestock waste management systems for manure storage.
d. Implement manure management plans.

Riparian Protection Program – KDA-DOC

a. Establish or reestablish natural riparian systems, including vegetative filter strips and streambank vegetation.
b. Develop riparian restoration projects along targeted stream segments, especially those areas with baseflow.
c. Promote wetland construction to reduce runoff and assimilate sediment loadings.
d. Coordinate riparian management within the watershed and develop riparian restoration projects.

Buffer Initiative Program – KDA-DOC

a. Install grass buffer strips near streams.

b. Leverage Conservation Reserve Enhancement Program to hold riparian land out of production when available.

Outreach and Technical Assistance – Cheney Lake WRAPS

a. Educate agricultural producers on sediment, nutrient, and pasture management.
b. Educate livestock producers on livestock waste management, land applied manure applications, and nutrient management planning.
c. Provide technical assistance on livestock waste management systems and nutrient management planning.
d. Provide technical assistance on buffer strip design and minimizing cropland runoff.
e. Encourage annual soil testing to determine capacity of field to hold phosphorus.
f. Educate residents, landowners, and watershed stakeholders about nonpoint source pollution.
g. Promote and utilize the Cheney Lake WRAPS efforts for pollution prevention, runoff control and resource management.

Timeframe for Implementation: The Cheney Lake Watershed and Restoration and Protection Strategy (WRAPS) 9 Element Plan implementation schedule is based on a 25 year plan. However, if practices are implemented as documented, it will only take 21 years to meet the Total Phosphorus endpoint goal of 103,501 lbs. and 4 to 5 years to reach the 22,650 tons per year sediment goal.

Targeted Participants: The primary participants for implementation will be the agricultural and livestock producers operating immediately adjacent to the North Fork Ninnescah River and tributaries within the priority sub watersheds above Cheney Lake. Watershed coordinators and technical staff of the WRAPS, along with NRCS, Conservation District personnel should assess possible sources adjacent to Red Rock, Goose, Silver, and Crow Creek. Implementation activities to address nonpoint sources should focus on those areas with the greatest potential to impact nutrient concentrations adjacent to these creeks. Activities to focus attention toward include:

Targeted Activities to focus attention toward include:

1. Overused grazing land adjacent to the streams.
2. Sites where drainage runs through or adjacent to livestock areas.
3. Sites where livestock have full access to the stream as a primary water supply.
4. Poor riparian area and denuded riparian vegetation along the stream.
5. Unbufferred cropland adjacent to the stream.
6. Conservation compliance on highly erodible areas.
7. Total row crop acreage and gully locations.

Milestone for 2026: In 2026, evaluation of the chlorophyll *a* endpoint and nutrient levels in the lake will be assessed. At that point in time, data from LM017001 in Cheney Lake Lake will be reexamined to assess improved conditions in the lake. Should the Phase I nutrient loads be met but area-weighted mean chlorophyll *a* concentrations in the lake remain above 10 μg/L, Phase II reductions will commence.

WRAPS 9 Element Plan Review: The plan will be reviewed every five years starting in 2015. Sediment and phosphorus TMDLs will be met in 21 years. The plan will examine BMP placement and implementation beginning in 2011 and every subsequent five years after through 2036 (Table 17).

Table 17. Sub-watershed total reductions milestones for nutrient BMP implementation reflecting the 2000 Cheney Lake Eutrophication TMDL as described in the Cheney Lake WRAPS 9 Element Plan.

Conservation Practice Category	Total Load Reduction (lbs of Phosphorus)	% of Total Phosphorus TMDL
Livestock	45,684	44%
Cropland	73,664	71%
Total	***119,348***	***115%***

Table 18. Phase I and Phase II needed nonpoint load reductions based on the nutrient TMDLs described in this document.

Stream	Station	Parameter	Average Flow (cfs)	Current Nonpoint Load (lbs/year)	Target Annual Nonpoint Source Load Reductions (lbs/year)	% Reduction in Nonpoint Source Load
Phase I						
North Fork Ninnescah	SC525	Total Phosphorus	149	129,008	56,163	41%
North Fork Ninnescah	SC525	Total Nitrogen	149	718,593	327,673	43%
Phase II						
North Fork Ninnescah	SC525	Total Phosphorus	149	129,008	92,843	69%
North Fork Ninnescah	SC525	Total Nitrogen	149	718,593	537,403	65%

Delivery Agents: The primary delivery agents for program participation will be the Cheney Lake WRAPS group, KDHE, Reno County Conservation District, and Natural Resources Conservation Service (NRCS).

Reasonable Assurances:

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

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

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

3. K.S.A. 2002 Supp. 82a-2001 identifies the classes of recreation use and defines impairment for streams.

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

5. 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.

6. 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.

7. 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.

8. 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.

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

10. K.S.A. 32-807 authorized the Kansas Department of Wildlife and Parks to manage lake resources.

Funding: The State Water Plan annually generates $12-18 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the Kansas Water Plan. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watershed and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. This watershed and its TMDL are located within a High Priority area and should receive support for pollution abatement practices that lower the loading of sediment and nutrients. Additionally, Clean Water Act Section 319 funds administered by KDHE also help Cheney Lake Watershed Inc. and the Citizen Management Committee (WRAPS Stakeholder Leadership Team) deliver services and financial assistance to help achieve TMDL goals. The City of Wichita is envisioned to continue help funding landowners to implement the fore-mentioned water quality practices.

Effectiveness: Nutrient control has been proven effective through proper implementation of comprehensive livestock waste management plans that effectively abate nutrient runoff associated with livestock facilities. Additionally, nutrient control has been proven effective through conservation tillage, contour farming, and use of grass waterways and buffer strips. Urban best management practices are important to implement due to their effectiveness at abating nutrient runoff particularly during storm runoff events. The key to success will be widespread utilization of proper livestock waste management within the watershed and implementation of urban best management practices in the developed area of the watershed.

6. MONITORING

KDHE will continue its 3-year sampling schedule in order to assess the trophic state of Cheney Lake. Based on the sampling results, the 303(d) listing will be evaluated in 2026. Should impairment status continue, the Phase II of this TMDL will commence and more intensive sampling will be conducted over the period 2026-2036 to assess progress in this implementation.

To evaluate load reductions from the North Fork Ninnescah watershed, future sample concentrations with their corresponding flow values will be plotted against the baseline curve for total phosphorus (Figure 33) and total nitrogen (Figure 34) and assessed for signals of improvement with points plotting below the regression lines indicating improvement in nutrient loading to the lake.

Figure 33. Scatterplot of log transformed total phosphorus vs log transformed flow in the North Fork Ninnescah, 2000-2014 period of record.

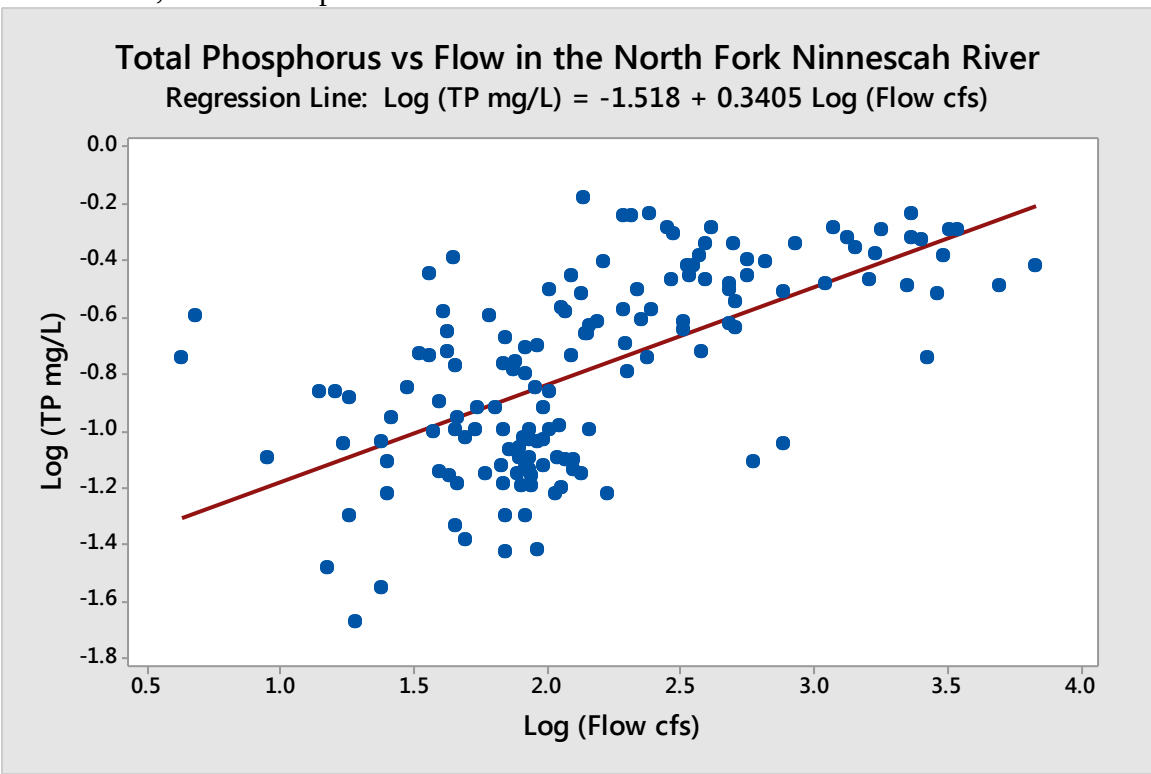
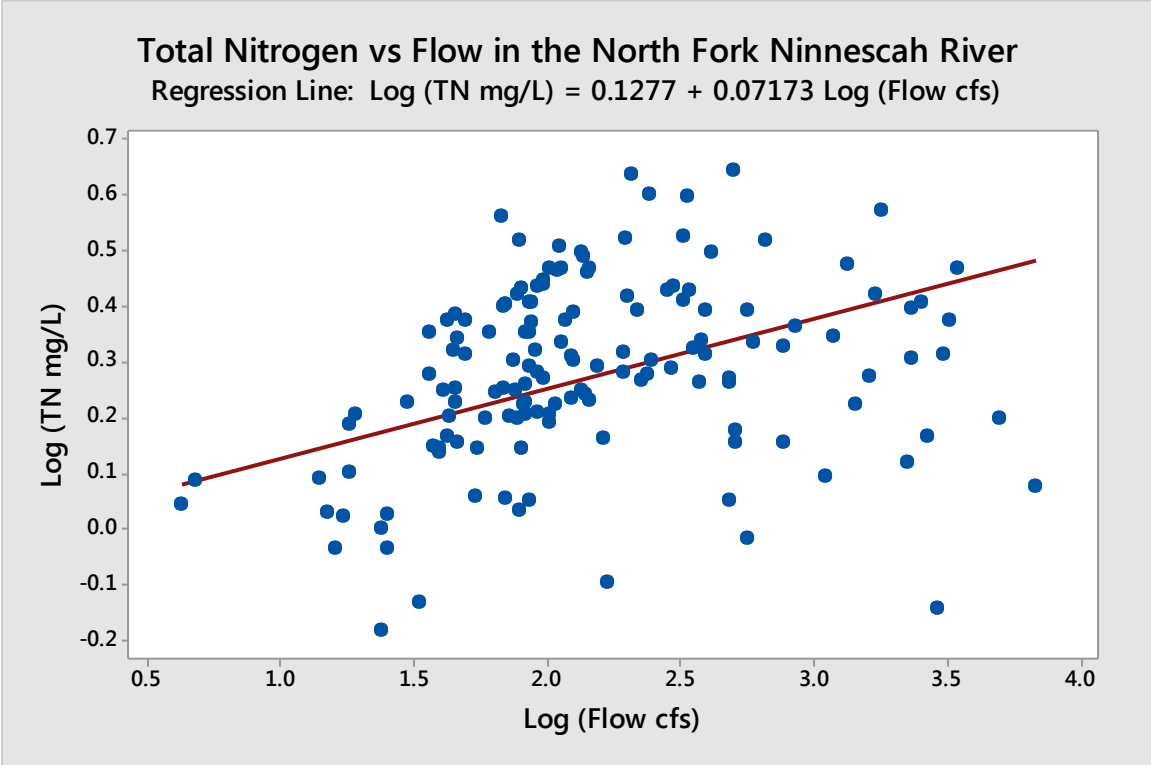


Figure 34. Scatterplot of log transformed total nitrogen vs log transformed flow in the North Fork Ninnescah, 2000-2014 period of record.



7. FEEDBACK

Public Notice: An active Internet Web site is established at http://www.kdheks.gov/tmdl/index.htm to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Lower Arkansas River Basin.

Public Hearing: A Public Hearing on this TMDL was held on 10/19/2015 in Yoder to receive public comments. No comments were received.

Watershed Restoration and Protection Strategy Group: The Cheney Lake Watershed Restoration and Protection Strategy group also known as Cheney lake Watershed, Inc., met on August 31st in Hutchinson to discuss this TMDL.

Milestone Evaluation: In 2022, evaluation will be made as to the degree of implementation that occurred within the watershed. Subsequent decisions will be made through regarding the implementation approach and follow up of additional implementation in the watershed.

Consideration for 303(d) Delisting: Cheney Lake (LM017001) will be evaluated for delisting under Section 303(d), based on the monitoring data first over the period 2015-2022 and again over the period 2023-2030. Therefore, the decision for delisting will come about in the preparation of the 2022 and 2030 303(d) lists. Should modifications be made to the applicable water quality criteria during the ten-year implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities may be adjusted accordingly.

Incorporation into Continuing Planning Process, Water Quality Management Plan and the Kansas Water Planning Process: Under the current version of the TMDL Vision Process, the next anticipated revision would come after 2023. Recommendations of this TMDL will be considered by the Cheney Lake WRAPS and in the *Kansas Water Plan* implementation decisions under the State Water Planning Process for Fiscal Years 2017-2029.

Developed 7/22/16

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Appendix A. Calculation of Daily Loads

Conversion to Daily Loads as Regulated by EPA Region VII*

The TMDL has estimated annual average loads for TN and TP that if achieved should meet the water quality targets. A 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 Load
MDL = Maximum Daily Load
ATM = Atmospheric Load
WLA = Wasteload Allocation
LA = Load Allocation
MOS= Margin of Safety

Cheney Lake Phase I TMDL								
Parameter	**LTA (lbs/year)**	**CV**	**e** $[Z\sigma - 0.5\sigma^2]$	**MDL (lbs/day)**	**ATM (lbs/day)**	**WLA (lbs/day)**	**LA (lbs/day)**	**MOS (lbs/day)**
TP	80,938	0.47	2.56	567.31	15.53	6.45	488.60	56.73
TN	510,992	0.25	1.72	2,408.14	280.67	25.80	1,860.86	240.81

Maximum Daily Load Calculation

Annual TP Load = 80,938 lbs/yr

Maximum Daily TP Load = [(80,938 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.45)-0.5*(0.45)^2]}$
= 567.31 lbs/day

Annual TN Load = 510,992 lbs/yr

Maximum Daily TN Load = [(510,992 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.25)-0.5*(0.25)^2]}$
= 2,408.14 lbs/day

Margin of Safety (MOS) for Daily Load

Annual TP MOS = 8,094 lbs/yr

Daily TP MOS = [(8,094 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.45)-0.5*(0.45)^2]}$
= 56.73 lbs/day

Annual TN MOS = 51,099 lbs/yr

Daily TN MOS = [(51,099 lbs/yr)/(365 days/yr)]*$e^{[2.326*(0.25)-0.5*(0.25)^2]}$
= 240.81 lbs/day

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