Lake and Wetland Monitoring Program

2005 Annual Report

By

C. Edward Carney

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Bureau of Environmental Field Services
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Executive Summary

The Kansas Department of Health and Environment (KDHE) Lake and Wetland Monitoring Program surveyed the water quality conditions of 35 Kansas lakes and wetlands during 2005. Eight of the lakes surveyed were large federal impoundments, two were smaller lakes on federally managed lands, 10 were State Fishing Lakes (SFLs) or other water bodies on state managed lands, 14 were city and county lakes, and one was a water supply lake owned by a non-governmental organization (NGO).

Of the 35 lakes and wetlands surveyed, 51% indicated trophic state conditions comparable to their historic mean water quality conditions. Another 29% indicated improved water quality conditions, over mean historic condition, as evidenced by a lowered lake trophic state. The remaining 20% indicated degraded water quality, over historic mean condition, as evidenced by elevated lake trophic state conditions. Phosphorus was identified as the primary factor limiting phytoplankton growth in 51% of the lakes surveyed during 2005. Nitrogen was identified as the primary limiting factor in 20% of the lakes, while 6% were identified as primarily light limited. The remaining lakes and wetlands appeared limited by combinations of nutrients (nitrogen and phosphorus) or nutrients and light availability (20%), or carbon (3%) due to extreme nutrient enrichment and algal production.

There were a total of 141 documented exceedences of Kansas numeric and narrative water quality criteria, or Environmental Protection Agency (EPA) water quality guidelines, in the lakes surveyed during 2005. Of these 141 exceedences, 38% pertained to the aquatic life use and 62% concerned consumptive and recreational uses. Efforts to complete lake and wetland use attainability analyses for the State Water Register continue, with 2009 as the present goal for completion.

Twenty lakes and wetlands (57% of those surveyed for pesticides) had detectable levels of at least one pesticide in their main bodies during 2005. Atrazine, or its degradation byproduct deethylatrazine, were detected in 18 of these water bodies (90%), once again making atrazine the most commonly documented pesticide in Kansas lakes. The highest detected atrazine concentration during 2005 lake and wetland sampling was 13.0 ug/L. A total of five different pesticides, and two pesticide degradation byproducts, were found in lakes during 2005.

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INTRODUCTION

Development of the Lake and Wetland Monitoring Program

The Kansas Department of Health and Environment (KDHE) Lake and Wetland Monitoring Program was established in 1975 to fulfill the requirements of the 1972 Clean Water Act (Public Law 92-500) by providing Kansas with background water quality data for water supply and recreational impoundments, determining regional and time trends for those impoundments, and identifying pollution control and/or assessment needs within individual lake watersheds.

Program activities originally centered around a small sampling network comprised mostly of federal lakes, with sampling stations at numerous locations within each lake. In 1985, based on the results of statistical analyses conducted by KDHE, the number of stations per lake was reduced to a single station within the main body of each impoundment. This, and the elimination of parameters with limited interpretive value, allowed expansion of the lake network to its present 120 sites scattered throughout all the major drainage basins and physiographic regions of Kansas. The network remains dynamic, with lakes occasionally being dropped from active monitoring and/or replaced with more appropriate sites throughout the state.

In 1989, KDHE initiated a Taste and Odor/Algae Bloom Technical Assistance Program for public drinking water supply lakes. This was done to assist water suppliers in the identification and control of taste and odor problems in finished drinking water that result from pollution, algae blooms, or natural ecological processes.

Overview of the 2005 Monitoring Activities

Staff of the KDHE Lake and Wetland Monitoring Program visited 35 Kansas lakes and wetlands during 2005. Eight of these water bodies are large federal impoundments last sampled in 2002 or as part of special projects, two are smaller lakes located on federally managed lands, 10 are State Fishing Lakes (SFLs) or lakes on other state managed lands, 14 are city/county lakes (CLs and Co. lakes, respectively), and one is a water supply lake owned by a non-governmental organization (NGO). Twenty-one of the 35 lakes (60.0%) presently serve as either primary or back-up municipal or industrial water supplies. Blue Mound City Lake was cycled back into the active program in 2005. Bone Creek Lake is a new water supply lake added to the network in 2005.

General information on the lakes surveyed during 2005 is compiled in Table 1. Figure 1 depicts the locations of the lakes surveyed in 2005. Figure 2 depicts the locations of all currently active sites within the Lake and Wetland Monitoring Program (post 2005). Additionally, a total of seven lakes, streams, and/or ponds were investigated as part of the Taste and Odor/Algae Bloom Technical Assistance Program.

Created lakes are usually termed “reservoirs” or “impoundments,” depending on whether they are used for drinking water supply or for other beneficial uses, respectively. In many parts of the country, smaller lakes are termed “ponds” based on arbitrary surface area criteria. To provide consistency, this report uses the term “lake” to describe all non-wetland bodies of standing water within the state. The only exception to this is when more than one lake goes under the same general name. For example, the City of Herington has jurisdiction over two larger lakes. The older lake is referred to as Herington City Lake while the newer one is called Herington Reservoir in order to distinguish it from its sister waterbody.

METHODS

Yearly Selection of Monitored Sites

Since 1985, the 24 large federal lakes in Kansas have been arbitrarily partitioned into three groups of eight. Each group is normally sampled only once during a three year period of rotation. Up to 30 smaller lakes are sampled each year in addition to that year’s block of eight federal lakes. These smaller lakes are chosen based on three considerations: 1) Are there recent data available (within the last 3-4 years) from KDHE or other programs?; 2) Is the lake showing indications of pollution that require enhanced monitoring?; or 3) Have there been water quality assessment requests from other administrative or regulatory agencies (state, local, or federal)? Several lakes have been added to the network due to their relatively unimpacted watersheds. These lakes serve as ecoregional reference, or “least impacted,” sites.

Sampling Procedures

At each lake, a boat is anchored over the inundated stream channel near the dam. This point is referred to as Station 1, and represents the area of maximum depth. Duplicate water samples are taken by Kemmerer sample bottle at 0.5 meters below the surface for determination of basic inorganic chemistry (major cations and anions), algal community composition, chlorophyll-a, nutrients (ammonia, nitrate, nitrite, Kjeldahl nitrogen, total organic carbon, and total and ortho phosphorus), and total recoverable metals/metalloids (aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, vanadium, and zinc). Duplicate water samples are also taken at 0.5 to 1.0 meters above the lake substrate for determination of inorganic chemistry, nutrients, and metals/metalloids within the hypolimnion. In addition, a single pesticide sample, and duplicate E. coli bacteria samples, are collected at 0.5 meters depth at the primary sampling point (KDHE, 2005).

At each lake, measurements are made at Station 1 for temperature and dissolved oxygen profiles, field pH, photosynthetically active radiation (PAR) extinction, and Secchi disk depth. All samples are preserved and stored in the field in accordance with KDHE quality assurance/quality control protocols (KDHE, 2005). Field measurements, chlorophyll-a analyses, and algal taxonomic determinations are conducted by staff of KDHE's Bureau of Environmental Field Services. All other analyses are carried out by the KDHE Health and Environmental Laboratory (KHEL).

Table 1. General information pertaining to lakes surveyed during 2005.

Lake	Basin	Authority	Water Supply	Last Survey
Blue Mound City Lake	Marais des Cygnes	City	yes	1986
Bone Creek Lake	Marais des Cygnes	County	yes	New
Cheney Lake	Lower Arkansas	Federal	yes	2002
Cimarron Lake	Cimarron	Federal	no	2002
Clark Co. SFL	Cimarron	State	yes	2002
Council Grove City Lake	Neosho	City	yes	2002
Council Grove Lake	Neosho	Federal	yes	2002
Cowley Co. SFL	Lower Arkansas	State	no	2001
El Dorado Lake	Walnut	Federal	yes	2002
Eureka City Lake	Verdigris	City	yes	2001
Ford Co. Lake	Upper Arkansas	County	no	2002
Gridley City Lake	Neosho	City	no	2001
Hillsdale Lake	Marais des Cygnes	Federal	yes	2004
John Redmond Lake	Neosho	Federal	yes	2002
Kingman Co. SFL	Lower Arkansas	State	no	2001
Lake Coldwater	Cimarron	City	yes	2002
Lake Meade SFL	Cimarron	State	no	2002
Marion Co. Lake	Neosho	County	no	2001
Marion Lake	Neosho	Federal	yes	2002
McPherson Co. SFL	Smoky Hill/Saline	State	no	2001
Melvern Lake	Marais des Cygnes	Federal	yes	2002
Montgomery Co. SFL	Verdigris	State	no	2001

Lake	Basin	Authority	Water Supply	Last Survey
Mound City Lake	Marais des Cygnes	City	yes	2001
Murray Gill Lake	Verdigris	NGO	yes	2001
Point of Rocks Lake	Cimarron	Federal	no	2002
Pomona Lake	Marais des Cygnes	Federal	yes	2002
Pottawatomie Co. SFL #1	Kansas/Lower Republican	State	no	2001
Pottawatomie Co. SFL #2	Kansas/Lower Republican	State	no	2001
Sabetha City Lake	Missouri	City	yes	2004
St. Jacob's Well	Cimarron	State	no	2002
Sedan North City Lake	Verdigris	City	yes	2002
Sedan South City Lake	Verdigris	City	yes	2001
Wellington City Lake	Lower Arkansas	City	yes	2001
Winfield City Lake	Walnut	City	yes	2001
Woodson Co. SFL	Verdigris	State	no	2001

Since 1992, macrophyte surveys have been conducted at each of the smaller lakes (<300 acres) within the KDHE Lake and Wetland Monitoring Program network. These surveys entail the selection and mapping of 10 to 20 sampling points, depending on total surface area and lake morphometry, distributed in a regular pattern over the lake surface. At each sampling point, a grappling hook is cast to rake the bottom for submersed aquatic plants. This process, combined with visual observations at each station, confirms the presence or absence of macrophytes at each station. If present, macrophyte species are identified and recorded on site. Specimens that cannot be identified in the field are placed in labeled plastic bags, on ice, for identification at the KDHE Topeka office. Presence/absence data, and taxon specific presence/absence data, are used to calculate spacial coverage (percent distribution) estimates for each lake (KDHE, 2005).

Taste and Odor/Algae Bloom Program

In 1989, KDHE initiated a formal Taste and Odor/Algae Bloom Technical Assistance Program. Technical assistance concerning taste and odor incidences in water supply lakes, or algae blooms in lakes and ponds, may take on varied forms. Investigations are generally initiated at the request of water treatment plant personnel, or personnel at the KDHE district offices. While lakes used for public water supply are the primary focus, a wide variety of samples related to algae, odors, and fishkills, from both lakes and streams, are accepted for analysis.

Figure 1. Locations of the 35 lakes surveyed during 2005.

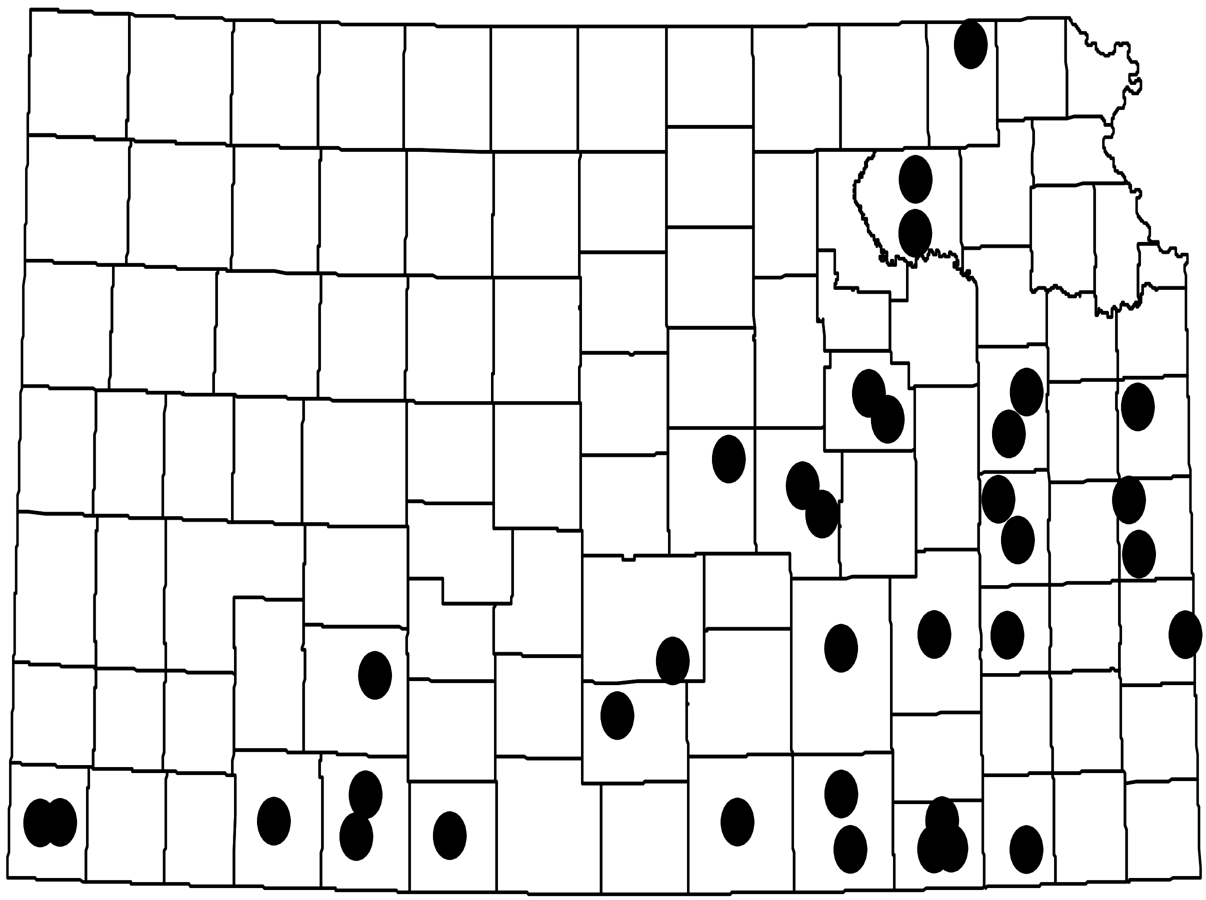
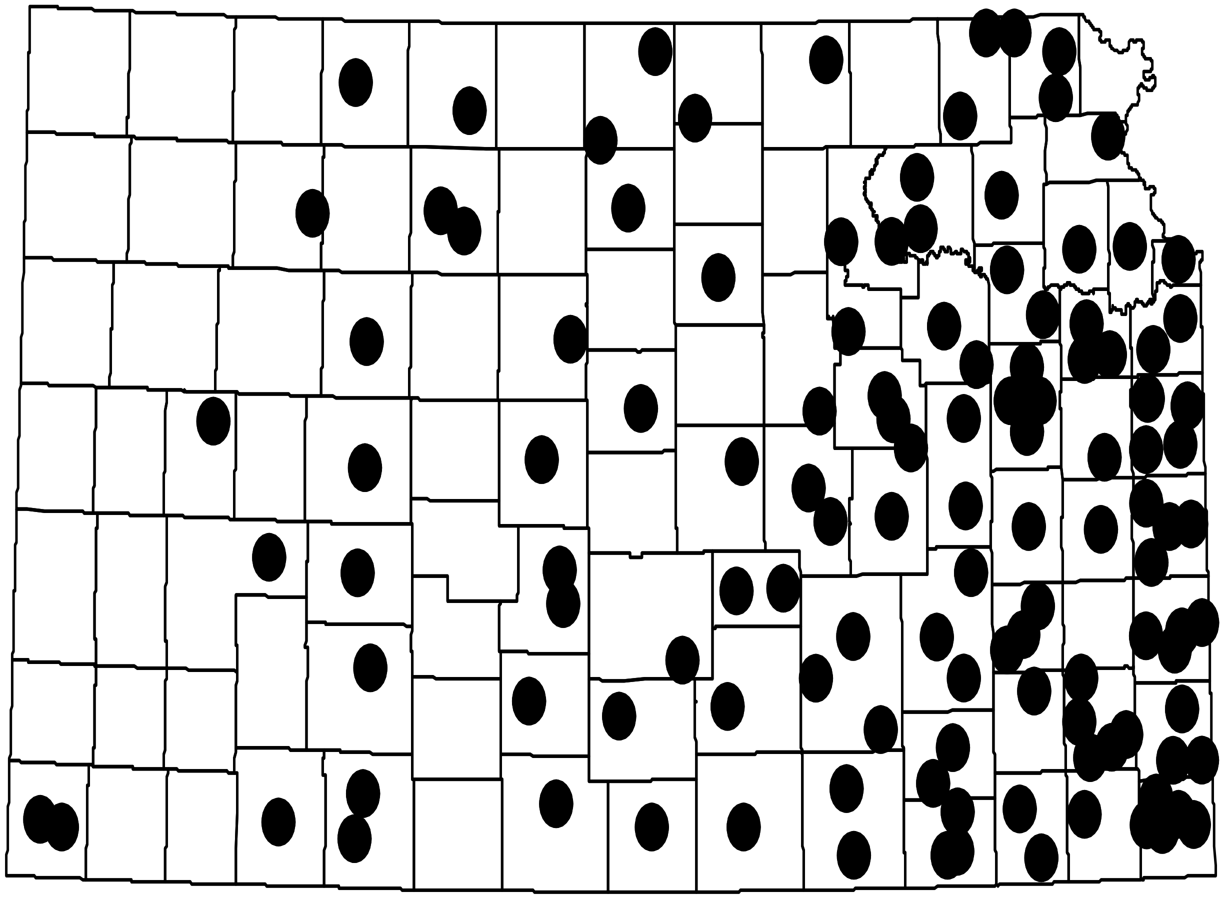


Figure 2. Locations of all currently active (post 2005) lake and wetland sampling sites within the KDHE Lake and Wetland Monitoring Program's network.



RESULTS AND DISCUSSION

<u>Lake Trophic State</u>

The Carlson Chlorophyll-a Trophic State Index (TSI) provides a useful tool for the comparison of lakes in regard to general ecological functioning and level of productivity (Carlson, 1977).

Table 2 presents TSI scores for the 35 lakes surveyed during 2005, previous TSI mean scores for those lakes with past data, and an indication of the extent that lake productivity is dominated by submersed and floating-leaved vascular plant communities (macrophytes). Since chlorophyll-a TSI scores are based on the planktonic algae community, production due to macrophyte beds is not reflected in these scores. The system used to assign lake trophic state, based on TSI scores, is presented below. Trophic state classification is adjusted for macrophytes where percent areal cover (as estimated by percent presence) is greater than 50%, and visual bed volume and plant density clearly indicate that macrophyte productivity contributes significantly to overall lake primary production.

TSI score of 0-39 = oligo-mesotrophic (OM)

OM = A lake with a low level of planktonic algae. Such lakes also lack significant amounts of suspended clay particles in the water column, giving them a relatively high level of water clarity. Chlorophyll-a concentration averages no more than 2.5 ug/L.

TSI score of 40-49 = mesotrophic (M)

M = A lake with only a moderate planktonic algal community. Water clarity remains relatively high. Chlorophyll-a ranges from 2.51 to 7.2 ug/L.

TSI score of 50-63 = eutrophic (E)

E = A lake with a moderate-to-large algae community. Chlorophyll-a ranges from 7.21 to 30.0 ug/L. This category is further divided as follows:

TSI = 50-54 = slightly eutrophic (SE)	Chlorophyll-a ranges 7.21 to 12.0 ug/L,
TSI = 55-59 = fully eutrophic (E)	Chlorophyll-a ranges 12.01 to 20.0 ug/L,
TSI = 60-63 = very eutrophic (VE)	Chlorophyll-a ranges 20.01 to 30.0 ug/L.

TSI score of $\geq$64 = hypereutrophic (H)

H = A lake with a very large phytoplankton community. Chlorophyll-a averages more than 30.0 ug/L. This category is further divided as follows:

TSI = 64-69.9 = lower hypereutrophic	Chlorophyll-a ranges 30.01 to 55.99 ug/L,
TSI = $\geq$70 = upper hypereutrophic	Chlorophyll-a values $\geq$56 ug/L.

TSI score not relevant = argillotrophic (A)

A = In a number of Kansas lakes, high turbidity due to suspended clay particles restricts the development of a phytoplankton community. In such cases, nutrient availability remains high, but is not fully translated into algal productivity or biomass due to light limitation. Lakes with such high turbidity and nutrient levels, but lower than expected algal biomass, are called argillotrophic (Naumann, 1929) rather than oligo-mesotrophic, mesotrophic, etc. These lakes may have chronically high turbidity, or may only experience sporadic (but frequent) episodes of dis-equilibrium following storm events that create "over flows" of turbid runoff on the lake surface. Frequent wind resuspension of sediments, as well as benthic feeding fish communities (e.g., common carp), can create these conditions as well. Argillotrophic lakes also tend to have very small, or nonexistent, submersed macrophyte communities. Mean chlorophyll-a concentration does not exceed 7.2 ug/L as a general rule.

All Carlson chlorophyll TSI scores are calculated by the following formula, where C is the phaeophytin corrected chlorophyll-a level in ug/L (Carlson, 1977):

$$TSI = 10(6-(2.04-0.68\log_e(C))/\log_e(2)).$$

The composition of the algal community (structural feature) often gives a better ecological picture of a lake than relying solely on a trophic state classification (functional feature). Table 3 presents both total algal cell count and percent composition of several major algal groups for the lakes surveyed in 2005. Lakes in Kansas that are nutrient enriched tend to be dominated by green or blue-green algae, while those dominated by diatom communities may not be so enriched. Certain species of green, blue-green, diatom, or dinoflagellate algae may contribute to taste and odor problems in finished drinking water, when present in large numbers in water supply lakes and streams. The mean algal cell count among the 35 lakes this year was 420,157 cells/mL (median = 17,798 cells/mL).

Table 4 presents biovolume data for the 35 lakes surveyed in 2005. When considered along with cell counts, biovolume data are useful in determining which algae species or algae groups actually exert the strongest ecological influence on a lake. The mean algal biovolume among lakes this year was 147.16 ppm (median = 7.95 ppm).

Table 2. Current and past TSI scores, and trophic state classification for the lakes surveyed during 2005. Trophic class abbreviations used previously apply. An asterisk appearing after the lake name indicates that the lake was dominated, at least in part, by macrophyte production. In such a case, the trophic class is adjusted, and the adjusted trophic state class given in parentheses. Previous TSI scores are based only on algal chlorophyll TSI scores.

Lake	2005 TSI/Class	Previous Trophic Class Period of Record Mean
Blue Mound City Lake	52.2 SE	E
Bone Creek Lake	48.7 M	new to network
Cheney Lake	62.4 VE	A
Cimarron Lake*	49.7 M(SE)	E
Clark Co. SFL	52.6 SE	SE
Council Grove City Lake	56.9 E	SE
Council Grove Lake	50.7 A	A
Cowley Co. SFL	54.0 SE	SE
El Dorado Lake	51.7 SE	A
Eureka City Lake	59.9 E	E
Ford County Lake	63.5 VE	H
Gridley City Lake	56.9 E	VE
Hillsdale Lake	58.1 E	E
John Redmond Lake	69.0 H	E
Kingman Co. SFL	62.2 VE	SE
Lake Coldwater	65.1 H	VE
Lake Meade SFL	74.2 H	H
Marion County Lake	66.0 H	E
Marion Lake	57.2 E	E
McPherson Co. SFL	66.1 H	H
Melvern Lake	41.0 M	SE
Montgomery Co. SFL	59.8 E	H
Mound City Lake	55.6 E	VE
Murray Gill Lake	43.8 M	M
Point of Rocks Lake	56.4 E	SE
Pomona Lake	44.0 M	A
Pottawatomie Co. SFL #1	81.9 H	H

Lake	2005 TSI/Class	Previous Trophic Class Period of Record Mean
Pottawatomie Co. SFL #2*	48.7 M(SE)	M
Sabetha City Lake	105.7 H	H
St. Jacob's Well	81.4 H	H
Sedan North City Lake	52.1 SE	SE
Sedan South City Lake	47.2 M	M
Wellington City Lake	51.0 A	A
Winfield City Lake	48.5 M	SE
Woodson Co. SFL	45.3 M	M

Trends in Trophic State

Table 5 summarizes changes in trophic status for the 35 lakes surveyed during 2005. Seven lakes (20.0%) displayed increases in trophic state, compared to their historic mean condition, while ten lakes (28.6%) displayed improved trophic states. Stable conditions were noted in 18 lakes (51.4%).

For the purposes of the analysis, the new lake (Bone Creek Lake) was assumed to have been mesotrophic since it was filled a few years back. When lakes deviated from a past argillotrophic mean status, the trophic state was compared against the eutrophic class, which is similar to the approach for determining impairments due to argillotrophic conditions.

Mean Carlson Chl-a TSI for these 35 lakes in 2005 was 58.3, eutrophic (Median value = 56.4, eutrophic). Only two lakes, Cimarron Lake and Pottawatomie Co. SFL #2 had macrophyte communities dense enough to justify adjusting trophic state designations. Despite these upward adjustments, both lakes still indicated nearly ideal water quality conditions.

Sabetha City Lake has had a long history of enriched conditions, but 2005 served to skew the database for this lake. Its epilimnetic chlorophyll-a of over 2,100 ug/L stands as one of the largest values on record for our sampling programs.

Table 3. Algal communities observed in the 35 lakes surveyed during 2005. The "other" category refers to euglenoids, cryptophytes, dinoflagellates, and other single-celled flagellate groups of algae.

	Cell Count	Percent Composition			

Lake	Cell Count (cells/mL)	Percent Composition			
		Green	Blue-Green	Diatom	Other
Blue Mound City Lake	9,513	7	90	1	2
Bone Creek Lake	17,798	4	95	<1	<1
Cheney Lake	75,978	8	89	3	<1
Cimarron Lake	2,300	71	0	4	25
Clark Co. SFL	9,261	59	40	<1	1
Council Grove City Lake	17,672	0	99	<1	0
Council Grove Lake	1,701	2	0	94	4
Cowley Co. SFL	7,938	<1	98	1	<1
El Dorado Lake	2,205	38	0	55	7
Eureka City Lake	28,760	7	85	5	<3
Ford Co. Lake	89,555	4	96	<1	0
Gridley City Lake	4,253	45	0	32	23
Hillsdale Lake	45,717	5	88	5	2
John Redmond Lake	135,828	14	82	3	<2
Kingman Co. SFL	18,459	73	5	14	8
Lake Coldwater	65,520	6	0	94	0
Lake Meade SFL	119,480	2	96	<2	<1
Marion Co. Lake	46,179	0	94	6	0
Marion Lake	34,209	<2	97	<2	0
McPherson Co. SFL	49,644	28	58	<3	12
Melvern Lake	2,300	8	85	1	6
Montgomery Co. SFL	50,778	3	93	3	<1
Mound City Lake	25,200	6	91	<2	<2
Murray Gill Lake	5,639	8	75	14	3
Lake	**(cells/mL)**	**Greens**	**Blue-Greens**	**Diatoms**	**Other**
Point of Rocks Lake	1,764	2	0	24	74

	Cell Count	Percent Composition			
Pomona Lake	3,938	29	44	24	3
Pottawatomie Co. SFL #1	545,486	<1	99	<1	<1
Pottawatomie Co. SFL #2	8,159	26	67	7	0
Sabetha City Lake	13,207,950	0	100	0	0
St. Jacob’s Well	19,908	0	37	0	63
Sedan North City Lake	15,341	5	88	6	<2
Sedan South City Lake	29,201	<1	99	<1	<1
Wellington City Lake	4,127	27	42	14	16
Winfield City Lake	2,741	28	42	22	8
Woodson Co. SFL	1,008	64	0	29	7

As shown in Table 6, of the 23 lakes receiving macrophyte surveys (15 full surveys and 8 limited/estimated observational surveys), 18 (78% of those surveyed, 51% of all lakes in 2005) had detectable amounts of submersed plant material. In these lakes, the most common plant species were pondweeds (*Potamogeton spp.*), water naiad (*Najas guadalupensis*), coontail (*Ceratophyllum demersum*), parrot feather (*Myriophyllum spicatum*), and various species of stonewort algae (*Chara* and *Nitella spp.*).

Using trophic state data for macrophytes in the literature (Schneider and Melzer, 2003; Lehmann and LaChavanne, 1999; Sladecek, 1973), combined with abundance of aquatic plants in the lakes during 2005, 13 water bodies appeared to merit further assessment of the macrophyte community trophic classification. Eight of these were assessed as eutrophic (Blue Mound City Lake, Bone Creek Lake, Clark Co. SFL, Cowley Co. SFL, McPherson Co. SFL, Mound City Lake, Pottawatomie Co. SFL #2, and Sabetha City Lake), three as very eutrophic (Gridley City Lake, Kingman Co. SFL, and Pottawatomie Co. SFL #1), and two as slightly eutrophic (Cimarron Lake and Sedan North City Lake), based on only the macrophyte community. Only two lakes merited having their overall trophic classification adjusted upwards based on the observed abundance, diversity, and trophic characteristics of the macrophytic community during 2005 (Table 2). These were Cimarron Lake and Pottawatomie Co. SFL #2, although the latter lake was deemed marginal for any upward adjustment.

Table 4. Algal biovolumes calculated for the lakes surveyed during 2005. The “other” category refers to euglenoids, cryptophytes, dinoflagellates, and other single-celled flagellate forms of algae. Biovolume units are calculated in mm^3/L,

and expressed as parts-per-million (ppm).

Lake	**Biovolume (ppm)**	**Percent Composition**			
		Green	**Blue-Green**	**Diatom**	**Other**
Blue Mound City Lake	7.629	7	75	8	10
Bone Creek Lake	4.698	4	88	5	3
Cheney Lake	24.074	8	55	35	<3
Cimarron Lake	3.808	11	0	<3	87
Clark Co. SFL	5.531	38	50	5	7
Council Grove City Lake	10.201	0	97	3	0
Council Grove Lake	5.494	<1	0	97	3
Cowley Co. SFL	6.675	2	90	1	7
El Dorado Lake	6.318	3	0	72	25
Eureka City Lake	15.953	3	12	67	18
Ford Co. Lake	22.186	23	75	2	0
Gridley City Lake	7.266	6	0	60	34
Hillsdale Lake	11.618	5	41	25	29
John Redmond Lake	43.731	11	53	19	17
Kingman Co. SFL	17.196	17	1	27	55
Lake Coldwater	25.378	10	0	90	0
Lake Meade SFL	83.111	<1	79	19	<1
Marion Co. Lake	30.460	0	77	23	0
Marion Lake	9.050	<2	71	27	0
McPherson Co. SFL	29.777	10	19	9	62
Melvern Lake	0.991	14	39	7	40
Montgomery Co. SFL	13.372	4	78	13	5
Mound City Lake	7.952	14	62	6	18
Murray Gill Lake	1.874	13	41	12	34
Lake	**(ppm)**	**Green**	**Blue-Green**	**Diatom**	**Other**
Point of Rocks Lake	8.970	<1	0	49	51

	Biovolume	Percent Composition			
Pomona Lake	2.058	10	14	57	19
Pottawatomie Co. SFL #1	217.360	<1	97	3	<1
Pottawatomie Co. SFL #2	3.144	13	34	53	0
Sabetha City Lake	4323.812	0	100	0	0
St. Jacob's Well	184.168	0	<2	0	99
Sedan North City Lake	4.984	15	40	34	12
Sedan South City Lake	2.719	1	91	4	4
Wellington City Lake	4.387	12	8	32	48
Winfield City Lake	2.572	5	9	69	17
Woodson Co. SFL	1.950	46	0	39	15

Table 5. Trends over time, based on a comparison to mean historic condition, for lake trophic state classification, for lakes surveyed during 2005.

Change in Trophic State Class Compared to Historic Mean*	Number of Lakes	Percent Total
Improved Two Class Rankings	3	8.6
Improved One Class Ranking	7	20.0
Stable	18	51.4
Degraded One Class Ranking	4	11.4
Degraded Two Class Rankings	3	8.6
Total	35	100.0

* = Three of these lakes had historic mean trophic state classifications of argillotrophic. In these cases, the current trophic class is compared to the eutrophic class, which is similar to the assessment protocol for nutrient related impairments for argillotrophic systems. In the case of Bone Creek Lake, it was assumed that the historic trophic status has been the same as currently is the case. Bone Creek Lake was constructed only a few years ago and, therefore, has no historic water quality data.

Table 6. Macrophyte community structure in the 23 lakes surveyed for macrophytes during 2005. Macrophyte community refers only to the submersed and floating-leaved aquatic plants, not emergent shoreline plants. The percent areal cover is the

abundance estimate for each documented species (Note: due to overlap in cover, the percentages under community composition may not equal the total cover).

Lake	**% Total Cover**		**% Species Cover and Community Composition**
Blue Mound City Lake	87%	60% 47% 33% 33%	*Najas guadalupensis* *Chara zeylanica* *Nelumbo sp.* *Potamogeton nodosus*
Bone Creek Lake (estimated)	30-40%	30-40% 30-40% 30-40% 30-40%	*Ceratophyllum demersum* *Chara spp.* *Najas guadalupensis* *Potamogeton spp.*
Cimarron Lake	100%	100% 100%	*Chara globularis* *Potamogeton pectinatus*
Clark Co. SFL (limited survey)	27%	27% 27% 27% 27%	*Ceratophyllum demersum* *Myriophyllum spicatum* *Potamogeton crispus* *Potamogeton pectinatus*
Cowley Co. SFL (limited survey)	20%	20% 20%	*Myriophyllum spicatum* *Najas guadalupensis*
Eureka City Lake (limited survey)	<10%		no species observed
Ford Co. Lake	20%	20%	*Najas guadalupensis*
Gridley City Lake	50%	50% 50% 20%	*Ceratophyllum demersum* *Myriophyllum spicatum* *Potamogeton nodosus*
Kingman Co. SFL	100%	100% 100% 100% 100% 100% 15% 5%	*Ceratophyllum demersum* *Najas guadalupensis* *Potamogeton crispus* *Potamogeton nodosus* *Potamogeton pectinatus* *Nelumbo sp.* *Potamogeton zosteriformis*
Lake Coldwater (limited survey)	<5%		no species observed
Lake Meade SFL	<10%		no species observed
Marion Co. Lake	70%	70%	*Najas guadalupensis*
McPherson Co. SFL	75%	65% 60% 25%	*Ceratophyllum demersum* *Najas guadalupensis* *Potamogeton illinoensis*
Montgomery Co. SFL (limited	40%	40%	*Najas guadalupensis*

Lake	% Total Cover	% Species Cover and Community Composition
survey)		
Mound City Lake	70%	70% *Ceratophyllum demersum* 45% *Potamogeton illinoensis* 10% *Chara zeylanica* 5% *Nelumbo sp.*
Point of Rocks Lake	<10%	no species observed
Pottawatomie Co. SFL #1	60%	60% *Ceratophyllum demersum* 20% *Najas guadalupensis*
Pottawatomie Co. SFL #2	70%	70% *Najas guadalupensis* 65% *Chara vulgaris* 60% *Ceratophyllum demersum* 45% *Potamogeton nodosus* 5% *Potamogeton crispus*
Sabetha City Lake (limited survey)	50%	80% *Lemna sp.* (estimated surface presence) 50% *Potamogeton pectinatus*
St. Jacob's Well	50%	50% *Utricularia vulgaris*
Sedan North City Lake	70%	65% *Najas guadalupensis* 35% *Nitella acuminata* 30% *Chara zeylanica* 10% *Potamogeton illinoensis* 5% *Nelumbo sp.*
Sedan South City Lake (limited survey)	5%	5% *Najas guadalupensis* (traces only)
Woodson Co. SFL	<5%	no species observed

None of the lakes surveyed in 2005 appeared to have algal limitation due to macrophyte community influences. Overall, Kansas Lakes are impaired more by a lack of macrophyte habitat than by an overabundance. In general, presence of a robust (and usually diverse) macrophyte community reflects lower levels of human impact in our lakes.

It should be noted that the method utilized in KDHE surveys does not measure bed density in a quantitative manner. Even with fairly high percent presence values reported in Table 6, it is rare for bed densities to approach any threshold that would be identified as an impairment.

Lake Stratification

Stratification is a natural process that may occur in any standing (lentic) body of water, whether that body is a natural lake, pond, artificial reservoir, or wetland pool (Wetzel, 1983). It occurs when sunlight (solar energy) penetrates into the water column. Due to the thermal properties of water, high levels of sunlight (combined with calm winds during the spring-to-summer months) cause layers of water to form with differing temperatures and densities. The cooler, denser layer (the hypolimnion) remains near the bottom of the lake while the upper layer (the epilimnion) develops a higher ambient temperature. The middle layer (the metalimnion) displays a marked drop in temperature with depth (the thermocline), compared to conditions within the epilimnion and hypolimnion. Once these layers of water with differing temperatures form, they tend to remain stable and do not easily mix with one another. This formation of distinct layers impedes, or precludes, the atmospheric reaeration of the hypolimnion, at least for the duration of the summer (or until ambient conditions force mixing). In many cases, this causes hypolimnetic waters to become depleted of oxygen and unavailable as habitat for fish and other forms of aquatic life. Stratification eventually breaks down in the fall when surface waters cool. Once epilimnetic waters cool to temperatures comparable to hypolimnetic waters, the lake will mix completely once again. Typically occurring in the fall, this phenomenon is called “lake turnover.” Table 7 presents data related to thermal stratification in the 35 lakes surveyed in 2005, as well as calculated euphotic-to-mixed depth ratio.

Lake turnover can cause fishkills, aesthetic problems, and taste and odor problems in finished drinking water if the hypolimnion comprises a significant volume of the lake. This is because such a sudden mixing combines oxygen-poor, nutrient-rich hypolimnetic water with epilimnetic water lower in nutrients and richer in dissolved oxygen. Lake turnover can result in explosive algal growth, lowering of overall lake oxygen levels, and sudden fishkills. It also often imparts objectionable odors to the lake water and tastes and odors to finished drinking water produced from the lake. Thus, the stratification process is an important consideration in lake management.

The “enrichment” of hypolimnetic waters (with nutrients, metals, and other pollutants) during stratification results from the entrapment of materials that sink down from above, as well as materials that are released from lake sediments due to anoxic conditions. The proportion of each depends on the strength and duration of stratification, existing sediment quality, and inflow of materials from the watershed. For the majority of our larger lakes in Kansas, built on major rivers with dependable flow, stratification tends to be intermittent (polymictic), or missing, and the volume of the hypolimnion tends to be small in proportion to total lake volume. These conditions tend to lessen the importance of sediment re-release of pollutants in the largest Kansas lakes, leaving watershed pollutant inputs as the primary cause of water quality problems.

Table 7. Stratification status of the 35 water bodies surveyed during 2005. The term “n.a.” indicates that boat access, wind conditions or other threatening weather, shallowness, or equipment problems prevented the collection of profile data or made said collection superfluous.

ke	Date Sampled (M-D-Yr)	Temperature Decline Rate (degree C/meter)	Dissolved Oxygen Decline Rate (mg/L/meter)	Thermocline Depth (meters)	Maximum Lake Depth (meters)	Euphotic/Mixed Depth Ratio*
ue Mound City Lake	08-22-2005	n.a.	n.a.	unknown	6.0	1
ne Creek Lake	08-22-2005	n.a.	n.a.	unknown	14.5	1
eney Lake	07-05-2005	0.19	0.35	none	13.0	0
marron Lake	07-12-2005	n.a.	n.a.	none	2.0	6
rk Co. SFL	06-14-2005	n.a.	n.a.	unknown	11.0	1
uncil Grove City Lake	06-21-2005	0.79	0.76	3.0-5.0	12.0	0
uncil Grove Lake	09-06-2005	0.18	0.45	6.0-8.0	11.0	0
wley Co. SFL	07-25-2005	n.a.	n.a.	unknown	8.5	1
Dorado Lake	07-06-2005	0.27	0.44	none	18.0	0
reka City Lake	07-25-2005	n.a.	n.a.	unknown	8.5	0
rd Co. Lake	06-13-2005	1.00	1.95	none	2.5	2
idley City Lake	08-15-2005	n.a.	n.a.	unknown	3.5	1
lsdale Lake	07-28-2005	0.50	0.52	7.0-8.0	13.5	0
n Redmond Lake	08-11-2005	0.50	2.95	2.0-2.5	2.5	2
gman Co. SFL	06-15-2005	0.00	0.30	none	3.0	3
ke Coldwater	06-14-2005	n.a.	n.a.	unknown	6.0	0
ke Meade SFL	06-14-2005	0.00	0.07	none	3.0	1
rion Co. Lake	08-08-2005	0.94	1.06	4.0-5.0	9.5	0
rion Lake	07-05-2005	0.11	0.27	none	9.5	0
Pherson Co. SFL	08-08-2005	0.67	1.78	2.0-3.0	6.5	0
lvern Lake	08-17-2005	0.14	0.19	9.0-11.0	19.0	0
ntgomery Co. SFL	08-02-2005	n.a.	n.a.	unknown	7.0	1
und City Lake	08-01-2005	0.33	1.40	3.0-4.0	6.5	1
rray Gill Lake	08-02-2005	1.03	0.49	4.0-6.0	15.5	1
int of Rocks Lake	07-12-2005	n.a.	n.a.	none	1.5	12
mona Lake	08-17-2005	0.15	0.13	none	15.0	0

ke	Date Sampled (M-D-Yr)	Temperature Decline Rate (degree C/meter)	Dissolved Oxygen Decline Rate (mg/L/meter)	Thermocline Depth (meters)	Maximum Lake Depth (meters)	Euphotic/Mixed Depth Ratio*
ttawatomie Co. SFL #1	06-20-2005	1.10	3.48	2.0	5.0	0
ttawatomie Co. SFL #2	06-20-2005	1.25	0.84	2.0-3.0	10.0	1
betha City Lake	08-16-2005	n.a.	n.a.	unknown	2.5	0
Jacob's Well	07-12-2005	n.a.	n.a.	unknown	5.5	0
dan North City Lake	08-02-2005	1.67	1.32	2.0-4.0	7.0	1
dan South City Lake	08-02-2005	n.a.	n.a.	unknown	7.0	1
ellington City Lake	07-25-2005	n.a.	n.a.	unknown	4.5	0
nfield City Lake	07-25-2005	n.a.	n.a.	unknown	12.5	0
oodson Co. SFL	08-01-2005	1.18	0.52	3.0-5.0	15.0	0

* = Ratios greater than unity suggest either clearer lakes or very shallow and well mixed water bodies. Ratios much less than 0.7 indicate lakes with inorganic turbidity, self shaded conditions due to abundant phytoplankton, or deep lakes with lower turbidity. Ratios greater than unity indicate that light penetrates through the entire mixed layer of the lake. When used with other metrics, this ratio can add greatly to an overall understanding of a lake's physical ecology. For a further explanation of euphotic depth, refer to the discussion on page 21.

A comparison to past annual reports may give the reader the impression that 2005 had a larger than typical number of lakes without profile data collected. This is, indeed, the case. The summer of 2005 presented a number of sampling difficulties in the form of windy days and a hole in the bottom of a sampling boat in early August. Under normal circumstances, rescheduling of some of these trips may have been feasible, but due to the volume of site visits to non-network lakes, for use attainability analysis (UAA) surveys, a number of these lakes simply had to be surveyed without the collection of depth profile data for temperature and dissolved oxygen.

Presence or absence of stratification is determined by the depth profiles taken in each lake for temperature and dissolved oxygen concentration. Table 7 presents these data. Mean temperature decline rates (for the entire water column) greater than 1.0^{o}C/m are considered evidence of stronger thermal stratification, although temperature changes may be less pronounced during the initiation phase of stratification. Lakes with strong thermal stratification will be more resistant to mixing of the entire water column pending the cooling of epilimnetic waters in autumn.

The temperature decline rate, however, must also be considered in relation to the particular lake and the shape of the temperature-to-depth relationship. The sharper the discontinuity in the data plot, the stronger the level of thermal stratification. Gradual declines in temperature with depth, through the entire water column, and indistinct discontinuities in data plots are more indicative of weaker thermal stratification. The strength of the oxycline, based on water column decline rate and the shape of the data plot, is also used to estimate stratification in lakes. A strong oxycline might be seen by mid-summer in lakes with weak thermal stratification if the lakes are not prone to wind mixing, or even in the case of dense macrophyte beds in shallow unstratified lakes.

Euphotic depth, or the depth to which light sufficient for photosynthesis penetrates, can be calculated from relationships derived from Secchi depth and chlorophyll-a data (Scheffer, 1998). This report presents the ratio of calculated euphotic depth to calculated mixing depth, which is the depth to which wind circulation and stratification should reach typically. The metric supplies a means to interpret light and production relationships in a lake, provided other factors, such as depth and thermal stratification, are also considered simultaneously. For instance, a very high ratio may mean a lake is exceptionally clear, or may mean it is very shallow and well mixed. A very low value likely means the lake is light limited due to inorganic turbidity or self-shaded due to large algal biomass near the surface.

For the 35 lakes surveyed in 2005, the calculated euphotic-to-mixed depth ratio suggests that light penetrates throughout the mixed zone in about half of them (median = 0.97, interquartile range = 0.72-to-1.36). This suggests that most of these lakes should not have significant light limitation concerns as sunlight can reach essentially throughout the epilimnion and, in many cases, into the thermocline zone.

<u>Coliform Bacteria</u>

Since 1996, bacterial sampling has taken place at the primary water quality sampling station at each lake. While many Kansas lakes have swimming beaches, many do not. However, presence or absence of a swimming beach does not determine whether or not a lake supports primary contact recreational use. Primary contact recreation is defined as, “recreation during which the body is immersed in surface water to the extent that some inadvertent ingestion of water is probable" (KDHE, 2005b), which includes swimming, water skiing, wind surfing, jet skiing, diving, boating, and other similar activities. The majority of Kansas lakes have some form of primary contact recreation taking place during the warmer half of the year. Sampling of swimming beaches is also often conducted by lake managers to document water quality where people are concentrated in a small area. These managers are in the best position to collect samples frequently enough to determine compliance with applicable regulations at these swimming beaches (KDHE, 2005b).

Given the rapid die-off of fecal bacteria in the aquatic environment, due to protozoan predation and a generally hostile set of environmental conditions, high bacterial counts should only occur in the open water of a lake if there has been 1) a recent pollution event, or 2) a chronic input of bacteria-laced pollution. A single set of bacterial samples collected from the open, deep water, environment is normally considered representative of whole-lake bacterial water quality at the time of the survey. This environment is also less prone to short lived fluctuations in bacterial counts than are swimming beaches and other shoreline areas.

Although past bacterial data has been for fecal coliforms, state surface water quality standards have changed to the use of E. coli bacteria as the indicator organism of choice (KDHE, 2005b). Therefore, the bacteria counts in this issue of the Lake and Wetland Program's annual report reflect E. coli counts and not fecal coliform counts.

Table 8 presents the bacterial data collected during the 2005 sampling season. Nine lakes, out of the 35 lakes surveyed for E. coli bacteria, had counts greater than the analytical reporting limit. Although no lake in 2005 exceeded existing criteria (KDHE, 2005b), two lakes had suspiciously high and unexpected E. coli counts. These lakes are Point of Rocks Lake and St. Jacob's Well. Both sets of data were collected from locations other than a boat out in the open water (due to small lake size and lack of boat ramps), so sample location may have had some influence. In both of these cases, contributions from wildlife may have also played a rare part in the elevated bacterial counts. Point of Rocks Lake had de-watered considerably since the last survey and had become home to a family of beavers, while the habitat surrounding St. Jacob's Well appeared to be inhabited by at least one large predatory animal (as based on the deep growls directed at staff conducting a shoreline survey of macrophytes).

Table 8. E. coli bacterial counts (mean of duplicate samples) from the 35 lakes and wetlands surveyed for E. coli bacteria during 2005. Note: These samples were collected during the week, not during weekends, when recreational activity would be at peak levels. All units are in "number of cfu/100 mL of lake water."

Lake	Site Location	Fecal Coliform Count
Blue Mound City Lake	off dam	42
Bone Creek Lake	off dam	<10

Lake	Site Location	Fecal Coliform Count
Cheney Lake	open water	<10
Cimarron Lake	off shore	<10
Clark Co. SFL	off dam	<10
Council Grove City Lake	open water	<10
Council Grove Lake	open water	52
Cowley Co. SFL	off dam	<10
El Dorado Lake	open water	<10
Eureka City Lake	off dam	<10
Ford Co. Lake	open water	<15
Gridley City Lake	off dam	86
Hillsdale Lake	open water	<10
John Redmond Lake	open water	<10
Kingman Co. SFL	open water	<26
Lake Coldwater	off dam	<15
Lake Meade SFL	open water	<10
Marion Co. Lake	open water	<10
Marion Lake	open water	<10
McPherson Co. SFL	open water	<10
Melvern Lake	open water	<10
Montgomery Co. SFL	off dam	<10
Mound City Lake	open water	<10
Murray Gill Lake	open water	<10
Point of Rocks Lake	off shore	903
Pomona Lake	open water	<10
Pottawatomie Co. SFL #1	open water	<15
Pottawatomie Co. SFL #2	open water	<10
Sabetha City Lake	off dam	26
St. Jacob’s Well	off shore	215

Lake	Site Location	Fecal Coliform Count
Sedan North City Lake	open water	69
Sedan South City Lake	off dam	<10
Wellington City Lake	off dam	36
Winfield City Lake	off dam	<10
Woodson Co. SFL	open water	10

Limiting Nutrients and Physical Parameters

The determination of which nutrient, or physical characteristic, "limits" phytoplankton production is of primary importance in lake management. If certain features can be shown to exert exceptional influence on lake water quality, those features can be addressed in lake protection plans to a greater degree than less important factors. In this way, lake management can be made more efficient.

Common factors that limit algal production in lakes are the level of available nutrients (phosphorus and nitrogen, primarily), and the amount of light available in the water column for photosynthesis. Less common limiting factors in lakes, and other lentic water bodies, include available levels of carbon, iron, and certain trace elements (such as molybdenum or vitamins), as well as grazing pressure on the phytoplankton community, competition from macrophytes and/or periphyton, water temperature, and hydrologic flushing rate.

Nutrient ratios are commonly considered in determining which major plant nutrients are limiting factors in lakes. These ratios take into account the relative needs of algae for the different chemical elements versus availability in the environment. Typically, total nitrogen/total phosphorus (TN/TP) mass ratios above 10-12 indicate increasing phosphorus limitation, with phosphorus limitation fairly certain at ratios above 18. Conversely, TN/TP ratios of less than 10 indicate increasing importance of nitrogen. Ratios of 10-to-12 indicate that both nutrients, or neither, may limit algal production (Wetzel, 1983; Horne and Goldman, 1994). It should also be kept in mind, when determining limiting factors, that highly turbid lakes typically have lower nutrient ratios, but may still have phosphorus limitation due to availability (e.g., particle adsorption) issues (Jones and Knowlton, 1993).

Table 9 presents limiting factor determinations for the lakes surveyed during 2005. These determinations reflect the time of sampling (chosen to reflect average conditions during the summer growing season to the extent possible) but may be less applicable to other times of the year. Conditions during one survey may also differ significantly from conditions during past surveys, despite efforts to sample during times representative of "normal" summer conditions.

If such a situation is suspected, it is noted in Table 9 or elsewhere in the report.

As indicated in Table 9, phosphorus was the primary limiting factor identified for lakes surveyed in 2005. Eighteen of the 35 lakes (51%) were determined to be primarily limited by phosphorus. Seven lakes (20%) were determined to be primarily nitrogen limited. Two lakes were primarily light limited (6%). Another seven lakes (20%) were co-limited by phosphorus and nitrogen or limited by combinations of nutrients and/or light availability. Algal production in one lake (3%) was determined to be primarily limited by carbon due to extreme nutrient enrichment. Mean TN/TP ratio was 21.7 for the lakes surveyed in 2005 (median = 16.4). Interquartile ranges for TN/TP ratios were 20.6-to-37.2 for phosphorus limited lakes, 6.5-to-8.3 for nitrogen limited lakes, and 12.0-to-15.0 for lakes co-limited by phosphorus and nitrogen and/or nutrients and light.

In addition to nutrient ratios, the following six metrics are applied in determining the relative roles of light and nutrient limitation for lakes in Kansas (c.f., Walker, 1986; Scheffer, 1998).

1) Non-Algal Turbidity = $(1/SD)-(0.025m^2/mg*C)$,

where SD = Secchi depth in meters and C = chlorophyll-a in mg/m^3.

Non-algal turbidity values $<0.4\ m^{-1}$ tend to indicate very low levels of suspended silt and/or clay, while values $>1.0\ m^{-1}$ indicate that inorganic particles are important in creating turbidity. Values between 0.4 and 1.0 m^{-1} describe a range where inorganic turbidity assumes greater influence on water clarity as the value increases, but would not assume a significant limiting role until values exceed 1.0 m^{-1}.

2) Light Availability in the Mixed Layer = Z_{mix}*Non-Algal Turbidity,

where Z_{mix} = depth of the mixed layer, in meters.

Values <3 indicate abundant light within the mixed layer of a lake and a high potential response by algae to nutrient inputs. Values >6 indicate the opposite.

3) Partitioning of Light Extinction Between Algae and Non-Algal Turbidity = Chl-a*SD,

where Chl-a = chlorophyll-a in mg/m^3 and SD = Secchi depth in meters.

Values <6 indicate that inorganic turbidity is primarily responsible for light extinction in the water column and there is a weak algal response to changes in nutrient levels. Values >16 indicate the opposite.

Table 9. Limiting factor determinations for the 35 lakes surveyed during 2005. NAT = non-algal turbidity, TN/TP = nitrogen-to-phosphorus ratio, Z_{mix} = depth of mixed layer, Chl-a = chlorophyll-a, and SD = Secchi depth. N = nitrogen, P = phosphorus, C = carbon, Fe = iron, and L = light. Shading = calculated light attenuation coefficient times mean lake depth.

Lake	**TN/TP**	**NAT**	**Z_{mix}*NAT**	**Chl-a*SD**	**Chl-a/TP**	**Z_{mix}/SD**	**Shading**	**Factors**
Blue Mound City Lake	19.1	0.398	0.956	14.56	0.214	1.503	2.93	P
Bone Creek Lake	22.7	0.164	0.676	19.69	0.423	1.332	4.60	P
Cheney Lake	9.1	0.746	3.547	18.50	0.325	6.601	9.81	N>(P>L)
Cimarron Lake	44.9	0.566	0.340	9.45	0.400	0.445	0.97	P>Macrophytes
Clark Co. SFL	8.5	0.479	1.739	13.16	0.241	2.591	4.75	N
Council Grove City Lake	19.5	0.159	0.604	27.89	1.460	1.994	5.02	P
Council Grove Lake	2.7	2.028	8.522	3.49	0.043	9.336	8.68	L>N
Cowley Co. SFL	59.0	0.485	1.503	14.39	1.090	2.347	4.09	P
El Dorado Lake	52.5	0.493	2.874	12.20	0.865	4.135	9.38	P
Eureka City Lake	16.1	0.491	1.522	20.15	0.539	3.067	4.87	P≥N
Ford Co. Lake	6.9	0.690	0.621	20.41	0.091	1.268	1.97	N
Gridley City Lake	11.6	1.596	2.275	7.45	0.247	2.796	2.86	(N=P)>L
Hillsdale Lake	17.3	0.276	1.344	23.98	0.673	3.357	7.62	P
John Redmond Lake	4.3	0.387	0.289	30.56	0.244	1.223	2.12	N
Kingman Co. SFL	13.2	1.261	0.757	13.28	0.473	1.134	1.60	N≥P
Lake Coldwater	34.8	0.909	2.187	19.27	2.181	4.219	5.08	P

Lake	TN/TP	NAT	Z_{mix}*NAT	Chl-a*SD	Chl-a/TP	Z_{mix}/SD	Shading	Factors
Lake Meade SFL	22.5	<0.010	<0.010	50.36	1.146	1.992	3.71	P
Marion Co. Lake	21.6	<0.010	<0.010	51.13	0.862	2.409	5.77	P
Marion Lake	6.2	1.407	5.248	8.48	0.121	6.661	7.15	N>L
McPherson Co. SFL	7.2	0.204	0.522	32.82	0.324	2.910	4.84	N
Melvern Lake	10.0	0.438	2.628	5.68	0.092	3.063	8.48	N≥(P=L)
Montgomery Co. SFL	25.7	0.489	1.324	20.04	0.561	2.654	4.19	P
Mound City Lake	16.4	0.351	0.899	19.07	0.582	1.719	3.32	P>N
Murray Gill Lake	24.5	0.275	1.195	10.36	0.385	1.613	4.83	P
Point of Rocks Lake	90.0	0.318	0.091	20.93	1.395	0.191	0.64	P
Pomona Lake	8.0	0.854	4.464	4.15	0.080	4.981	8.01	N>L
Pottawatomie Co. SFL #1	20.2	<0.010	<0.010	128.72	1.435	2.983	9.05	P
Pottawatomie Co. SFL #2	12.5	0.313	1.074	13.46	0.635	1.618	3.89	P=N
Sabetha City Lake	8.8	<0.010	<0.010	530.68	1.011	3.602	37.52	C>(N=L)
St. Jacob's Well	15.7	<0.010	<0.010	124.99	1.050	3.197	9.50	P≥N
Sedan North City Lake	14.2	0.540	1.461	11.72	0.303	2.067	3.47	P≥N
Sedan South City Lake	33.0	0.470	1.272	8.99	0.545	1.641	3.12	P
Wellington City Lake	7.5	3.371	6.286	2.24	0.082	6.659	4.78	L≥N
Winfield City Lake	34.7	1.035	4.031	5.21	0.413	4.634	5.86	P≥L
Woodson Co. SFL	38.0	0.437	1.896	8.19	0.450	2.384	5.26	P

Criteria Table

Expected Lake Condition	**TN/TP**	**NAT**	**Z_{mix}*NAT**	**Chl-a*SD**	**Chl-a/TP**	**Z_{mix}/SD**	**Shading**
Phosphorus Limiting	>12				>0.40		
Nitrogen Limiting	<7				<0.13		
Light/Flushing Limited		>1.0	>6	<6	<0.13	>6	>16
High Algae-to-Nutrient Response		<0.4	<3	>16	>0.40	<3	
Low Algae-to-Nutrient Response		>1.0	>6	<6	<0.13	>6	
High Inorganic Turbidity		>1.0	>6	<6		>6	>16
Low Inorganic Turbidity		<0.4	<3	>16		<3	<16
High Light Availability			<3	>16		<3	<16
Low Light Availability			>6	<6		>6	>16

4) Algal Use of Phosphorus Supply = Chl-a/TP,

where Chl-a = chlorophyll-a in mg/m^3 and TP = total phosphorus in mg/m^3 .

Values <0.13 indicate a limited response by algae to phosphorus; i.e., nitrogen, light, or other factors may be more important. Values above 0.4 indicate a strong algal response to changes in phosphorus level. The range 0.13-to-0.4 suggests a variable but moderate response by algae to phosphorus levels.

5) Light Availability in the Mixed Layer for a Given Surface Light = Z_{mix}/SD,

where Z_{mix} = depth of the mixed layer, in meters, and SD = Secchi depth in meters.

Values <3 indicate that light availability is high in the mixed zone and the probability of strong algal responses to changes in nutrient levels is high. Values >6 indicate the opposite.

6) Shading in Water Column due to Algae and Inorganic Turbidity = $Z_{mean}*E$,

where Z_{mean} = mean lake depth, in meters, and E = calculated light attenuation coefficient, in units of m^{-1}, derived from Secchi depth and chlorophyll-a data (Scheffer, 1998).

Values >16 indicate high levels of self-shading due to algae or inorganic turbidity in the water column. Values <16 indicate that self-shading of algae does not significantly impede productivity. The metric is most applicable to lakes with maximum depths of less than 5 meters (Scheffer, 1998).

In addition to the preceding metrics, an approach developed by Carlson (1991) was employed to test the limiting factor determinations made from the suite of metrics utilized in this, and previous, reports. The approach uses the Carlson trophic state indices for total phosphorus, chlorophyll-a, Secchi depth, and the newer index for total nitrogen. Index scores are calculated for each lake, then metrics are calculated for $TSI_{(Secchi)}$-$TSI_{(Chl\text{-}a)}$ and for $TSI_{(TP\ or\ TN)}$-$TSI_{(Chl\text{-}a)}$. The degree of deviation of each of these metrics from zero provides a measure of the potential limiting factors. In the case of the metric dealing with Secchi depth and chlorophyll, a positive difference indicates small particle turbidity is important, while a negative difference indicates that larger particles (zooplankton, algal colonies) exert more importance for a lake's light regime. In the case of the metric dealing with nutrients, a positive difference indicates the nutrient in question may not be the limiting factor, while a negative difference strengthens the assumption that the particular nutrient limits algal production and biomass. Differences of more than 5 units were used as the threshold for determining if the deviations were significantly different from zero. This approach generally produced the same determinations as those derived from the original suite of metrics. It clearly identified those lakes with extreme turbidity or those with algal colonies or large celled algal species. However, the $TSI_{(TN)}$ scores are given less weight than the other TSI calculations because the metric was developed using water quality data from Florida lakes which may render it less representative for our region.

In identifying the limiting factors for lakes, primary attention was given to the metrics calculated from 2005 data. However, past Secchi depth and chlorophyll-a data were also considered for comparative purposes. Additionally, mean and maximum lake depth were taken into account when ascribing the importance of non-algal turbidity. Lakes with fairly high non-algal turbidity may have little real impact from that turbidity if the entire water column rapidly circulates (Scheffer, 1998).

Surface Water Exceedences of State Surface Water Quality Criteria

Most numeric and narrative water quality criteria referred to in this section are taken from the Kansas Administrative Regulations (K.A.R. 28-16-28b through K.A.R. 28-16-28f), or from EPA water quality criteria guidance documents (EPA, 1972, 1976; KDHE, 2005b) for ambient waters and finished drinking water. Copies of the Standards may be obtained from the Bureau of Water, KDHE, 1000 Southwest Jackson Ave., Suite 420, Topeka, Kansas 66612.

Tables 11, 12, and 13 present documented exceedences of surface water quality criteria and goals during the 2005 sampling season. These data were generated by computerized comparison of the 2005 Lake and Wetland Monitoring Program data to the state surface water quality standards and other federal guidelines. Only those samples collected from a depth of $\leq$3.0 meters were used to document standards violations, as a majority of those samples collected from below 3.0 meters were from hypolimnetic waters. In Kansas, lake hypolimnions generally constitute a small percentage of total lake volume and, while usually having more pollutants present in measurable quantities, compared to overlying waters, do not generally pose a significant water quality problem for the lake as a whole.

Criteria for eutrophication and turbidity in the Kansas standards are narrative rather than numeric. However, lake trophic state does exert a documented impact on various lake uses, as does inorganic turbidity. The system shown in Table 10 has been developed over the last sixteen years to define how lake trophic status influences the various designated uses of Kansas lakes (EPA, 1990; NALMS, 1992). Trophic state/use support expectations are compared with the observed trophic state conditions to determine the level of use support at each lake. The report appendix from the 2002 annual program report presents a comparison of these trophic class based assessments, as well as turbidity based assessments, versus risk based values (KDHE, 2002b). In general, the risk based thresholds compare fairly well with the assessment system presently in use.

With respect to the aquatic life support use, eutrophication, high pH, and low dissolved oxygen within the upper 3.0 meters comprised the primary water quality concerns during 2005 (Table 11). Twenty-one lakes exhibited trophic states high enough to impair long or short term aquatic life support. Five lakes had low dissolved oxygen conditions within the top 3.0 meters of the water column, which were linked to eutrophication. Three lakes had pH levels high enough to impact aquatic life support. Five lakes exhibited either chronic turbidity or pesticide levels sufficient to impact long term community structure and function.

Eutrophication exceedences are primarily due to excessive nutrient inputs from lake watersheds. Dissolved oxygen problems are generally due to advanced trophic state, which causes rapid oxygen depletion below the thermocline, but are also observed in lakes that do not exhibit excessive trophic state conditions. In these cases, the low dissolved oxygen levels likely result from shallow stratification conditions and may not be assessed as an impairment per se. Lakes with elevated pH are also reflective of high trophic state and algal and/or macrophytic production.

There were 27 exceedences of water supply criteria and/or guidelines during 2005 (Table 12). The majority (74%) were for eutrophication related conditions. Irrigation use criteria were exceeded in 11 lakes while livestock watering criteria were exceeded in 12 lakes. Human health (food procurement use) criteria showed one exceedence for lakes surveyed in 2005.

Table 13 lists 21 lakes with trophic state/turbidity conditions high enough to impair contact recreational uses. Thirteen of the lakes surveyed had high enough trophic state or turbidity to impair secondary contact recreation during 2005.

In all, there were 141 exceedences of numeric or narrative criteria, water quality goals, or EPA guidelines documented in Kansas lakes during 2005. Approximately 37.6% of these exceedences related to aquatic life support, 36.9% related to consumptive uses of water, and 25.5% related to recreational uses. Eutrophication, turbidity, high pH, or low dissolved oxygen accounted for 92% of documented water quality impacts in 2005. Only about 6% of the impacts were linked to pesticides or heavy metals and metalloids.

Table 10. Lake use support determination based on lake trophic state.

Designated Use	**A**	**M**	**SE**	**E**	**VE**	**H-no BG TSI 64-70**	**H-no BG TSI 70+**	**H-with BG TSI 64+**
Aquatic Life Support	X	Full	Full	Full	Partial	Partial	Non	Non
Drinking Water Supply	X	Full	Full	Partial	Partial	Non	Non	Non
Primary Contact Recreation	X	Full	Full	Partial	Partial	Non	Non	Non
Secondary Contact Recreation	X	Full	Full	Full	Partial	Partial	Non	Non
Livestock Water Supply	X	Full	Full	Full	Partial	Partial	Non	Non
Irrigation	X	Full	Full	Full	Partial	Partial	Non	Non
Groundwater Recharge	Trophic state is not generally applicable to this use.							
Food Procurement	Trophic state is applicable to this use, but not directly.							

BG = blue-green algae dominate the community (50%+ as cell count and/or 33%+ as biovolume)
X = use support assessment based on nutrient load and water clarity, not algal biomass

A = argillotrophic (high turbidity lake)
M = mesotrophic (includes OM, oligo-mesotrophic, class), TSI = zero-to-49.9
SE = slightly eutrophic, TSI = 50-to-54.9
E = eutrophic (fully eutrophic), TSI = 55-to-59.9
VE = very eutrophic, TSI = 60-to-63.9
H = hypereutrophic, TSI $\geq$ 64

TSI = 64 = chlorophyll-a of 30 ug/L
TSI = 70 = chlorophyll-a of 56 ug/L

Table 11. Chemical and biological parameters not complying with chronic and acute aquatic life support (ALS) criteria in lakes surveyed during 2005. DO = dissolved oxygen, EN = eutrophication or high nutrient load, and TN = high turbidity and nutrient load. Only those lakes with some documented water quality problem are included in Tables 11, 12, and 13.

	Chronic ALS					**Acute ALS**		
Lake	**EN***	**TN***	**pH***	**DO***	**Atrazine**	**EN***	**DO***	**pH***
Cheney Lake	X					X		
Council Grove City Lake	X							
Council Grove Lake	X	X						
Eureka City Lake	X							
Ford Co. Lake	X			X		X	X	
Gridley City Lake	X				X			
Hillsdale Lake	X				X			
John Redmond Lake	X			X		X	X	
Kingman Co. Lake	X					X		
Lake Coldwater	X					X		
Lake Meade SFL	X					X		
Marion Co. Lake	X					X		
Marion Lake	X							
McPherson Co. SFL	X			X		X	X	
Montgomery Co. SFL	X		X					X
Mound City Lake	X							
Point of Rocks Lake	X			X			X	
Pottawatomie Co. SFL #1	X		X	X		X	X	X
Sabetha City Lake	X		X		X	X		X
St. Jacob's Well	X					X		
Wellington City Lake	X	X						

* = Although there are no specific chronic versus acute criteria for these parameters, the magnitude of the excursions are used to determine whether the impact is of immediate or long term importance. Measured values for dissolved oxygen and pH can be dependent on when samples are collected during a 24 hour cycle. When nutrient pollution and eutrophication are high, one can assume higher pH and lower dissolved

oxygen conditions occur at some point during this 24 hour cycle.

Table 12. Exceedence of human use criteria and/or EPA guidelines within the water column of lakes surveyed during 2005. EN = high trophic state/nutrients or turbidity/nutrient loads and TN = high turbidity and nutrient load. Only lakes with documented exceedences are included within the table. An "X" indicates that the exceedence occurred for a designated use where a use attainability analysis has been completed. Human health criteria apply to the food procurement use in the standards.

	Water Supply				**Irrigation**		**Livestock Water**		**Human Health**
Lake	**EN**	**TN**	**As**	**Atrazine**	**EN**	**F**	**EN**	**F**	**Hg**
Cheney Lake	X				X		X		
Cimarron Lake						X			
Council Grove City Lake	X								
Council Grove Lake	X	X							
Eureka City Lake	X								
Ford Co. Lake	X		X		X		X		
Gridley City Lake	X			X					
Hillsdale Lake	X			X					
John Redmond Lake	X				X		X		
Kingman Co. SFL	X				X		X		
Lake Coldwater	X				X		X		
Lake Meade SFL	X				X	X	X		
Marion Co. Lake	X				X		X		
Marion Lake	X								
McPherson Co. SFL	X				X		X		
Montgomery Co. SFL	X								
Mound City Lake	X								
Point of Rocks Lake								X	X
Pottawatomie Co. SFL #1	X				X		X		
Sabetha City Lake	X		X	X	X		X		

	Water Supply				Irrigation		Livestock Water		Human Health
St. Jacob's Well	X						X		
Wellington City Lake	X	X							

Table 13. Exceedences of numeric and narrative recreational guidelines for lakes surveyed during 2005. Primary contact recreation refers to recreation where ingestion of lake water is likely. Secondary contact recreation involves a low likelihood of accidental ingestion of lake water. EN = high trophic state and nutrient loads and TN = high turbidity and nutrient loads. An "X" indicates that a use attainability study has been completed and/or the use was previously designated for that lake. Only lakes with impairments are listed.

	Primary Contact Recreation			Secondary Contact Recreation	
Lake	**EN**	**TN**	**E. coli**	**EN**	**TN**
Cheney Lake	X			X	
Council Grove City Lake	X				
Council Grove Lake	X	X			X
Eureka City Lake	X				
Ford Co. Lake	X			X	
Gridley City Lake	X				
Hillsdale Lake	X				
John Redmond Lake	X			X	
Kingman Co. SFL	X			X	
Lake Coldwater	X			X	
Lake Meade SFL	X			X	
Marion Co. Lake	X			X	
Marion Lake	X				
McPherson Co. SFL	X			X	
Montgomery Co. SFL	X				
Mound City Lake	X				
Point of Rocks Lake	X				

	Primary Contact Recreation			Secondary Contact Recreation	
Pottawatomie Co. SFL #1	X			X	
Sabetha City Lake	X			X	
St. Jacob's Well	X			X	
Wellington City Lake	X	X			X

Pesticides in Kansas Lakes, 2005

Detectable levels of at least one pesticide were documented in the main body of 20 lakes sampled in 2005 (57% of lakes surveyed for pesticides). Table 14 lists these lakes and the pesticides that were detected, along with the level measured and the analytical quantification limit. Five different pesticides, and two pesticide degradation byproducts, were noted in 2005. Of these seven compounds, atrazine and alachlor currently have numeric criteria in place for aquatic life support and/or water supply uses (KDHE, 2005b).

Atrazine continues to be the pesticide detected most often in Kansas lakes (KDHE, 1991). Atrazine, and the atrazine degradation byproducts deethylatrazine and deisopropylatrazine, accounted for 68% of the total number of pesticide detections, and atrazine and its degradation byproducts were detected in 18 out of the 20 lakes with pesticides (90% of lakes with pesticides). In addition to atrazine, seven lakes had detectable levels of metolachlor (Dual), three had detectable levels of alachlor (Lasso), one had detectable levels of acetochlor (Harness or Surpass), and two had detectable levels of picloram (Tordon). Eight lakes had detectable quantities of the atrazine degradation byproducts deethylatrazine or deisopropylatrazine.

In all cases, the presence of these pesticides was directly attributable to agricultural activity. Four lakes exceeded 3.0 ug/L of atrazine, but several represent concerns based on numbers and amounts of total pesticides present in the water column. Based on the number of different pesticides detected; Hillsdale Lake, Marion Lake, and Pomona Lake are of most concern. In terms of total maximum concentrations; Gridley City Lake, Hillsdale Lake, McPherson Co. SFL, and Sabetha City Lake are of most concern. Of these, Hillsdale, Marion, and Pomona Lakes are active water supply lakes, while Sabetha City Lake serves as a back-up source.

Discussion of Nonpoint Sources of Pollution for Selected Lakes

Two lakes were chosen for further discussion, based on the number and type of observed surface water quality impacts. A water body was chosen if 1) three, or more, parameters exceeded their respective chronic aquatic life support criteria/guidelines, 2) more than two parameters exceeded applicable acute aquatic life support criteria/guidelines, or 3) more than two parameters exceeded irrigation, water supply, livestock watering, or recreational criteria. Possible causes and sources of these documented water quality problems are considered below.

Pottawatomie Co. SFL #1 is a modest (24 acre) lake located in northeast Kansas. Water quality problems in 2005 revolve around extreme algal biomass and enriched conditions. The extreme nature of the trophic state of the lake in 2005 is somewhat puzzling as the watershed is relatively small (watershed/lake area ratio = 33) and almost 90% grassland and wooded area. At the time of this writing, the water quality impairments documented at Pottawatomie Co. SFL #1 are thought to be related to the early summer rainfall and runoff, which followed several years of drought. It is anticipated that, in the absence of further large flushing events, conditions might return to pre-2005.

Table 14. Pesticides levels documented during 2005 in Kansas lakes. All values listed are in ug/L. Analytical quantification limits are as follows: atrazine = 0.3 ug/L, deethylatrazine = 0.3 ug/L, deisopropylatrazine = 0.3 ug/L, metolachlor = 0.25 ug/L, alachlor = 0.1 ug/L, acetochlor = 0.1 ug/L, and picloram = 0.8 ug/L. Only those lakes with detectable levels of pesticides are reported.

Lake	**Atrazine**	**Pesticide**					
		Deethylatrazine	**Deisopropylatrazine**	**Metolachlor**	**Alachlor**	**Acetochlor**	**Picloram**
Bone Creek Lake	0.86						
Cheney Lake	0.55						
Council Grove City Lake	0.79				0.26		
Council Grove Lake	0.39						
El Dorado Lake	0.51						
Ford Co. Lake	0.37						
Gridley City Lake	6.30	0.52		0.70			
Hillsdale Lake	3.30	0.45				0.12	
John Redmond Lake	0.53						
Marion Co. Lake	1.20			0.25			
Marion Lake	1.00	0.34		0.57	0.28		
McPherson Co. SFL	3.00	1.30		1.50			
Melvern Lake	1.30	0.31		0.28			
Montgomery Co. SFL	0.30						
Pomona Lake	1.80	0.58		0.34	0.12		

	Pesticide						
Sabetha City Lake	13.00	0.86	0.35				
Lake	**Atrazine**	**Deethylatrazine**	**Deisopropylatrazine**	**Metolachlor**	**Alachlor**	**Acetochlor**	**Picloram**
Sedan North City Lake							1.80
Sedan South City Lake							1.10
Wellington City Lake	2.20	0.58		1.70			
Winfield City Lake	1.40						

Sabetha City Lake is a moderate sized (112 acre) lake located in northeast Kansas. Water quality problems in 2005 revolved around extreme nutrient enrichment, extreme algal biomass, and moderately high pesticide detections. The watershed is also moderately sized for the lake (watershed/lake area ratio = 48) and roughly 95% rowcrop agriculture and small animal feeding operations. The lake has a long history of algal blooms, fishkills, and taste and odor incidents.

Taste and Odor/Algal Bloom Investigations During 2005

From January 1, 2005, to January 1, 2006, seven investigations were undertaken within the auspices of the KDHE Taste & Odor/Algae Bloom Program. The results of these investigation are discussed below. One of the investigations dealt with a fishkill, one was related to both massive algae blooms and taste and odor, one was primarily an aesthetic complaint, one was related to the impacts of a sewage release, and three concerned taste and odor problems in drinking water.

On February 28, 2005, water samples were collected and submitted by the City of Gardner, from Gardner City Lake, in regards to a taste and odor problem in finished drinking water. Although cell counts were fairly low (<5,000 cells/mL) the most common species, *Uroglena sp.*, was described in the literature as causing tastes and odors at very low numbers, much as described during the complaint (cucumber or melon-like odor).

On May 24, 2005, water samples were collected and submitted by KDHE Northeast District Office staff in relation to a large algae bloom complaint at a small residential lake in Wyandotte County, located in a housing development near Piper High School. The bloom was composed mainly of the blue-green algae *Aphanizomenon flos-aqua*, although there were also moderate numbers of *Euglena sp.* present as well. Microscopic examination of the samples suggested the bloom was senescing, given the condition of the blue-green filaments. The bloom was described as generating a “sewage” odor along with numerous shoreline pools of phycocyanin pigments from the decomposing algae.

Marion Lake (Marion Co., Kansas) once again experienced massive blue-green algae blooms during 2005, similar to those that had occurred during the summers of 2003 and 2004. The 2005 blooms seemed mostly restricted to June, perhaps due to flushing related to high precipitation in late June. Principal species included *Microcystis aeruginosa*, *Aphanizomenon flos-aqua*, and *Anabaena spp.* (mostly believed to be *A. spiroides* and *A. circinalis*). *Anabaena spp.* were the most prominent blue-greens present. This was the third year of extreme algae blooms in Marion Lake, causing a great deal of concern among local citizens, water suppliers, and management agencies. Samples collected on June 1, 2005, were over 6 million cells/mL (chlorophyll-a estimated at several hundred ug/L). However, by early July, when the routine survey for the lake was conducted, cell counts and chlorophyll-a levels were back in the eutrophic category (see Tables 2, 3, and 4).

On June 20, 2005, algae samples were submitted from Big Hill Lake, by staff with Public Wholesale Water Supply District #4 (PWWSD #4), concerning a taste and odor problem in finished drinking water. The complaint of "fishy" odors was compounded by clogging of filters during the treatment process. Examination of the samples indicated a small community of mostly Chrysophyte and blue-green algae (total cell count <15,000 cells/mL with estimated chlorophyll-a of 6.5 to 8.0 ug/L). The most common species was *Synura sp.*, which is indicated in the literature as producing fishy odors.

Taste and odor problems continued at Big Hill Lake into July. On July 18, 2005, another set of samples were submitted by PWWSD #4 staff concerning continuing taste and odor complaints. On this occasion, the algal community was mostly composed of blue-greens, but still fairly moderate in size (about 76,000 cells/mL but a fairly small total biovolume due to the small size of the species involved). Estimated chlorophyll-a, based on the biovolume present, was only in the range of 12 to 18 ug/L, which is a fairly typical algal community for Big Hill Lake in mid-summer. Dominant species in the July samples included *Cylindrospermopsis sp.*, *Lyngbya limnetica*, and several species of *Anabaena spp.* Despite these taste and odor incidents, Big Hill Lake remains one of the higher quality large lakes in Kansas. Unfortunately, even lakes with otherwise good water quality conditions can experience taste and odor problems in drinking water since some algal species can produce problems at fairly low numbers and biomass.

On July 22, 2005, water samples were submitted by KDHE Southeast District Office staff from John Redmond Lake and the Neosho River, in relation to a taste and odor incident that was moving downstream along the Neosho River. Samples from the river and the lake were very similar, lending evidence to the hypothesis that a bloom in John Redmond Lake had been partially flushed by heavy rains near Emporia. Both the Neosho River and John Redmond Lake had algae communities in the estimated range of 30 to 50 ug/L chlorophyll-a. Both sets of samples had algae communities dominated by blue-greens by cell count (*Anabaena sp.*), but dominated by the filamentous diatom *Melosira sp.* in terms of biovolume. Both types of algae are listed as producing "earthy" taste and odor problems.

On August 18, 2005, KDHE BEFS staff went to Miami Co. SFL to investigate an algae related fishkill. At the time of sample collection (11:30 AM on August 18, 2005), numerous dead fish were still present along the shores. Dissolved oxygen at the time of sample collection was 11.0 mg/L. The algae community was a mixture of blue-green species (*Anabaena spp.*, *Aphanizomenon flos-aqua*, *Microcystis aeruginosa,* and *Planktothrix rubescens*), at cell counts of >1,300,000 cells/mL off the fishing docks, and greater yet in the coves. Later analyses of chlorophyll-a samples determined the concentrations to be 450 to 650 ug/L, depending on the location in the lake. The proximal cause of the fishkill was determined to be related to the algae bloom (dissolved oxygen sag during part of the diel cycle, maybe combined with algal toxin production). It is believed the condition that led to such enrichment and algae blooms may be linked to the stocking of the lake with grass carp to control macrophytes. Miami Co. SFL was highly enriched and hypereutrophic prior to being drained and renovated a few years back. After re-filling, the lake soon developed a diverse macrophyte community, coupled with low water column nutrient levels and very reduced algal communities. It is believed the grass carp introductions pushed the lake back into the historic condition of hypereutrophic by converting the plant biomass into water column nutrients available to fuel algae production.

On August 31, 2005, KDHE BEFS staff collected water samples at Lake Vacquero, located in Shawnee County, in relation to potential impacts from sewage releases after a heavy rain. Residents near the lake were concerned about potential health impacts related to the sewage release, in addition to how the nutrients associated with the sewage might further impact the enrichment level of Lake Vacquero. At the time of the survey, the algae community was about 530,000 cells/mL, with chlorophyll-a levels of around 80 ug/L. The algae community sampled on August 31 may even represent some dilution impact due to the rains, suggesting an even larger algal community prior to the sewage release. It is not known if the sewage release allowed the algal community to increase its size in the weeks afterward, as no follow up samples were collected. However, Lake Vacquero has had a long history of complaints related to algae blooms, fishkills, and enriched conditions due to urban runoff and past septic systems leaching nutrients to the lake.

CONCLUSIONS

The following conclusions are based on the lake monitoring data collected during 2005.

1) Trophic state data indicated that 20% of the lakes surveyed in 2005 had degraded, compared to their historic mean condition (i.e., their trophic state had increased). About 51% showed stable conditions over time, while 29% showed improved trophic state condition. Most of the improvement in trophic state can be attributed to the lingering impacts of prolonged drought (during 2000-2004) and, thus, lowered inputs of nutrients in runoff on nutrient limited systems.

2) Over 85% of the documented water quality impairments in these lakes were associated with high lake trophic status and nutrient enrichment. Other significant problems included low dissolved oxygen and high pH, atrazine, and high turbidity.

3) Over half of the lakes surveyed by KDHE had detectable levels of agricultural pesticides in 2005 (57% of lakes surveyed). As noted in previous years, atrazine was the most frequently detected pesticide.

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LAKE DATA AVAILABILITY

Water quality data are available for all lakes included in the Kansas Lake and Wetland Monitoring Program. These data may be requested by writing to the Bureau of Environmental Field Services, KDHE, 1000 Southwest Jackson Ave., Suite 430, Topeka, Kansas 66612-1367, or by calling 785-296-6603.

APPENDIX A

Lake Surface Area Analysis

The exact number of public and/or publicly accessible lakes may never be known with exact certainty in Kansas at any given point in time. Different databases use differing definitions of what may or may not constitute a "public" lake. Add to that continuing lake construction, and the potential for the selling or acquisition of public lakes, and it becomes clear the true number will always be a "moving target."

Nevertheless, It is believed that, at the present time, a fairly good lake surface area analysis can be accomplished for lakes owned or managed by public entities. The Army Corps of Engineers (ACOE) maintains a dam safety inspection and certification database (http://crunch.tec.army.mil/nid/webpages/nid.cfm) that lists as many as 600 lakes they consider "public" lakes. A significant number of these appear to be watershed impoundments that may not be what fit the traditional concept of a public recreational or water supply lake. Another difficulty with the ACOE database is that safety inspections have not been required for very small lakes that fall below a certain storage volume.

KDHE and Kansas Department of Wildlife and Parks (KDWP) records (Kansas Water Register and the Community Fishing Assistance Program, respectively) list 392 lakes, combined, as of this writing, which would clearly meet the traditional definition of public lakes. While undoubtedly not complete, this combined list is felt to be sufficient to allow the calculation of useful lake size statistics for the public lakes in Kansas. Figures A1 and A2, and Table A1, present the analysis.

Figure A1: Frequency curve for the 392 lakes in the combined list.

Figure A2: Histogram of lake size classes (in acres) for the 392 lakes in the combined list.

Table A1: Descriptive surface area statistics for the 392 lakes in the combined KDHE/KDWP listing. All units are in acres and rounded to the nearest full acre.

Statistic	Acreage
Maximum	16,000
90th Percentile	364
75th Percentile (Upper Interquartile Range)	100
50th Percentile (Median)	22
25th Percentile (Lower Interquartile Range)	5
10th Percentile	2
Minimum	1
Mean	489
Geometric Mean	26
Total Acreage	191,553