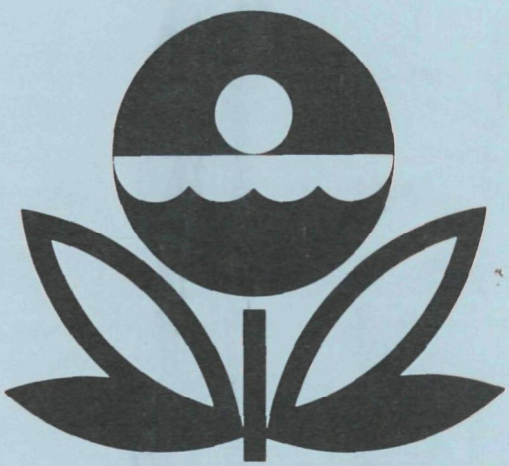
U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES



REPORT

ON

LAKE KEMP

BAYLOR COUNTY

TEXAS

EPA REGION VI

WORKING PAPER No. 646

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON

and

ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

☆G.P.O. 699-440

REPORT
ON
LAKE KEMP
BAYLOR COUNTY
TEXAS
EPA REGION VI
WORKING PAPER No. 646

WITH THE COOPERATION OF THE
TEXAS WATER QUALITY BOARD
AND THE
TEXAS NATIONAL GUARD
MARCH, 1977

CONTENTS

F O R E W O R D

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Texas Water Quality Board for professional involvement, to the Texas National Guard for conducting the tributary sampling phase of the Survey, and to those Texas wastewater treatment plant operators who voluntarily provided effluent samples.

Hugh C. Yantis, Jr., Executive Director of the Texas Water Quality Board, and John B. Latchford, Jr., Director, and the staff of the Field Operations Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Thomas Bishop, the Adjutant General of Texas, and Project Officer Colonel William L. Seals, who directed the volunteer efforts of the Texas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

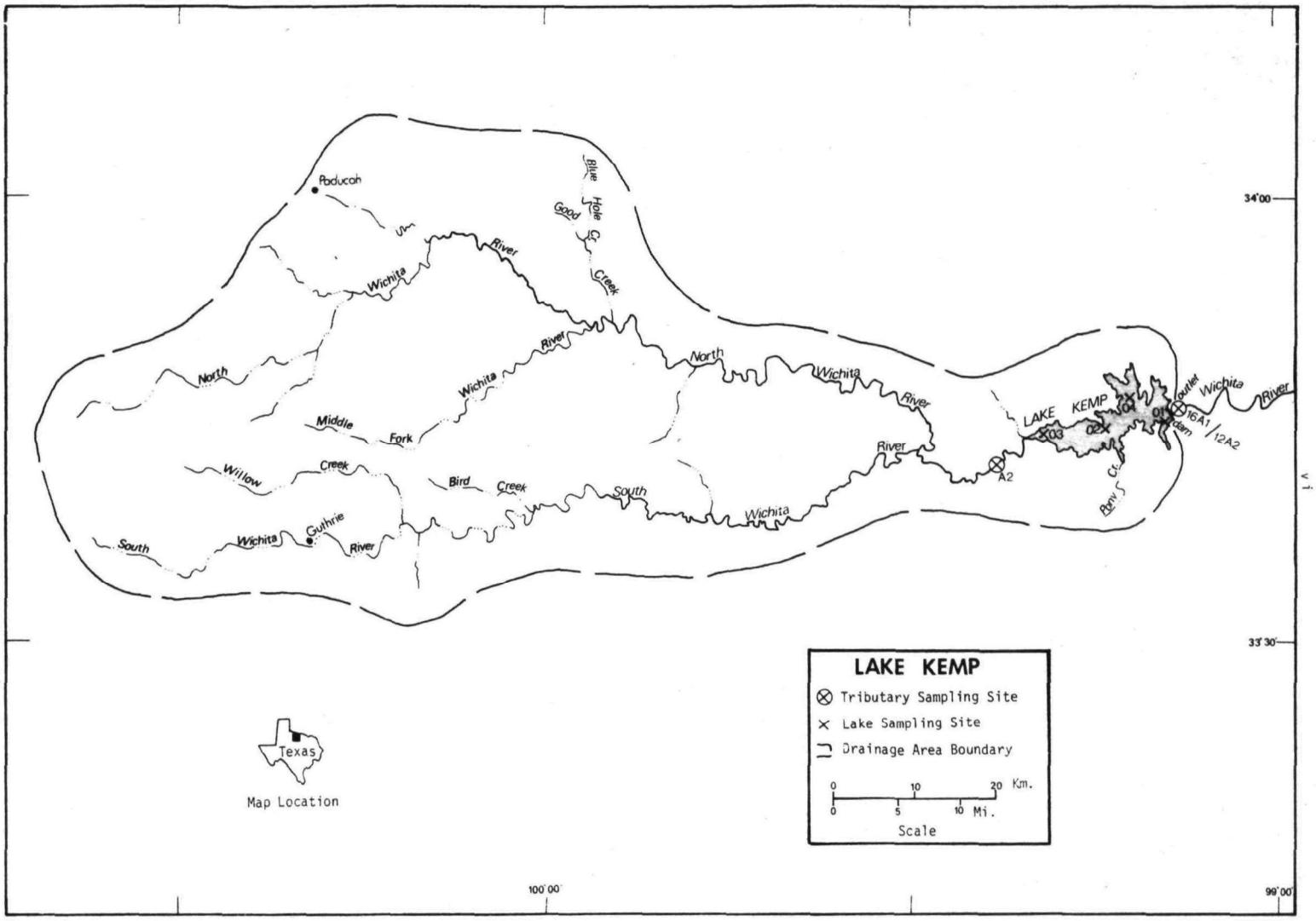
NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

State of Texas

NAME	COUNTY
Amistad	Val Verde
Bastrop	Bastrop
Belton	Bell, Coryell
Braunig	Bexar
Brownwood	Brown
Buchanan	Burnet, Llano
Caddo	Harrison, Marion, TX; Caddo Parish, LA
Calaveras	Bexar
Canyon	Comal
Colorado City	Mitchell
Corpus Christi	Jim Wells, Live Oak, San Patricio
Diversion	Archer, Baylor
Eagle Mountain	Tarrant, Wise
Fort Phantom Hill	Jones
Houston	Harris
Kemp	Baylor
Lake O'The Pines	Camp, Marion, Morris, Upshur
Lavon	Collin
Lewisville (Garza-Little Elm)	Denton
Livingston	Polk, San Jacinto, Trinity, Walker

Lyndon B. Johnson	Burnet, Llano
Medina	Bandera, Medina
Meredith	Hutchinson, Moore, Potter
O. C. Fisher (San Angelo)	Tom Green
Palestine	Anderson, Cherokee, Henderson, Smith
Possum Kingdom	Palo Pinto, Stephens, Young
Sam Rayburn	Angelina, Jasper Nacogdoches, Sabine, San Augustine
Somerville	Burleson, Lee, Washington
E. V. Spence	Coke
Stamford	Haskell
Stillhouse Hollow	Bell
Tawakoni	Hunt, Rains, Van Zandt
Texoma	Cooke, Grayson TX; Bryan, Johnston, Love, Marshall, OK
Travis	Burnet, Travis
Trinidad	Henderson
Twin Buttes	Tom Green
White River	Crosby
Whitney	Bosque, Hill
Wright Patman (Texarkana)	Bowie, Cass


Paducah
Blue
Good Hole Cr.
Creek
Wichita River
North
Wichita River
Middle Fork
Wichita River
North
Wichita River
LAKE KEMP
Outlet
Wichita River
16A1 / 12A2
dam
A2
Willow Creek
Bird Creek
South
Wichita River
Pony Cr.
South Wichita River
Guthrie
Texas
Map Location
LAKE KEMP
Tributary Sampling Site
Lake Sampling Site
Drainage Area Boundary
0 10 20 Km.
0 5 10 Mi.
Scale
34°00
33°30
100°00
99°00

vi

LAKE KEMP

STORET NO. 4816

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Lake Kemp is eutrophic; i.e., well supplied with nutrients and quite productive. Whether nutrient enrichment is beneficial or deleterious depends on the actual or potential effect on the uses of the lake. In this regard, no nuisance conditions are known to personnel of the Texas Water Quality Board and there is little or no impairment of the designated beneficial uses of this water body.

Lake Kemp ranked fourth in overall trophic quality when the 39 Texas reservoirs sampled in 1974 were compared using a combination of six parameters*. Nine of the reservoirs had less and one had the same median total phosphorus, two had less and five had the same median dissolved orthophosphorus, 14 had less and two had the same median inorganic nitrogen, 17 had less mean chlorophyll a, and 17 had greater mean Secchi disc transparency. Moderate depression of dissolved oxygen with depth occurred at sampling stations 1 and 2 in August.

Survey limnologists noted turbidity due to suspension of red clay bottom materials in March and October. Blue-green algae were dominant in the August and October phytoplankton samples (page 8).

* See Appendix A.

B. Rate-Limiting Nutrient:

The algal assay results indicate that the lake was phosphorus limited at the time the sample was collected. The lake data indicated phosphorus limitation in March, May, and August but nitrogen limitation in October.

C. Nutrient Controllability:

1. Point sources--No known municipal or industrial point sources impacted Lake Kemp during the sampling year. It is estimated that septic tanks serving lakeshore dwellings contributed less than 2% of the total phosphorus load to the lake, but a shoreline survey would be necessary to determine the significance of these sources.

It is calculated that Lake Kemp received a total phosphorus loading of 0.20 $g/m^2/yr$. This is less than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading but is more than his suggested oligotrophic loading (i.e., a mesotrophic loading; see page 14). However, U.S. Geological Survey records for water year 1975 (Anonymous, 1976) show the volume of Lake Kemp during the year was less than 60% of the conservation pool volume, so the actual areal phosphorus loading was greater than indicated.

2. Non-point sources--The phosphorus contribution of non-point sources accounted for about 98% of the total phosphorus load during the sampling year. The Wichita River contributed

over 83% of the total, and the minor tributaries and immediate drainage were estimated to have contributed about 6%.

The phosphorus export rate of the Wichita River was a rather low 2 $kg/km^2/yr$. This rate is comparable to the rates of unimpacted streams sampled elsewhere in Texas.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Morphometry††:

1. Surface area: 62.17 kilometers^2.
2. Mean depth: 5.3 meters.
3. Maximum depth: >13.1 meters.
4. Volume: 330.575 x 10^6 m^3.
5. Mean hydraulic retention time: 2.8 years (based on outflow).

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Wichita River	4,853.7	5.05
immediate drainage -	486.8	0.37
Totals	5,340.5	5.42

2. Outlet -

Wichita River	5,402.7**	3.71**

C. Precipitation***:

1. Year of sampling: 70.6 centimeters.
2. Mean annual: 69.1 centimeters.

---

† Table of metric conversions--Appendix B.
†† Anonymous, 1976; surface area planimetered at conservation pool elevation (349 m).
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake; lesser outflow due to evaporation.
*** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Lake Kemp was sampled four times in 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two or more depths at three stations on the lake (see map, page vi). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 13.1 meters at station 1, 10.4 meters at station 2, 1.8 meters at station 3, and 7.0 meters at station 4.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR KEMP LAKE
STORET CODE 4816

PARAMETER	1ST SAMPLING (3/ 4/74) 3 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (5/13/74) 3 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (8/ 8/74) 3 SITES RANGE	MEAN	MEDIAN
TEMP (C)	9.8 - 12.2	10.5	10.1	21.4 - 23.4	22.6	23.0	25.5 - 27.3	26.3	26.3
DISS OXY (MG/L)	10.2 - 10.8	10.6	10.6	7.6 - 8.0	7.7	7.8	4.6 - 8.2	6.6	6.8
CNDCTVY (MCROMO)	3650. - 4200.	3783.	3703.	48. - 4939.	2516.	2772.	5194. - 5442.	5323.	5290.
PH (STAND UNITS)	8.1 - 8.1	8.1	8.1	8.3 - 8.4	8.3	8.3	7.9 - 8.4	8.2	8.3
TOT ALK (MG/L)	99. - 109.	104.	105.	84. - 87.	86.	87.	83. - 91.	88.	88.
TOT P (MG/L)	0.006 - 0.012	0.009	0.008	0.020 - 0.124	0.035	0.023	0.016 - 0.046	0.026	0.024
ORTHO P (MG/L)	0.005 - 0.011	0.007	0.007	0.006 - 0.011	0.008	0.009	0.002 - 0.003	0.002	0.002
NO2+NO3 (MG/L)	0.070 - 0.110	0.088	0.090	0.090 - 0.220	0.130	0.110	0.020 - 0.030	0.021	0.020
AMMONIA (MG/L)	0.020 - 0.040	0.027	0.030	0.040 - 0.120	0.066	0.060	0.030 - 0.100	0.054	0.050
KJEL N (MG/L)	0.200 - 0.500	0.333	0.300	0.400 - 0.800	0.522	0.400	0.400 - 1.000	0.578	0.500
INORG N (MG/L)	0.100 - 0.150	0.115	0.110	0.140 - 0.340	0.196	0.170	0.050 - 0.120	0.076	0.070
TOTAL N (MG/L)	0.290 - 0.610	0.422	0.390	0.490 - 0.920	0.652	0.540	0.420 - 1.020	0.599	0.530
CHLRPYL A (UG/L)	0.8 - 8.5	3.4	0.9	3.2 - 6.2	4.5	4.0	18.0 - 23.5	20.1	18.7
SECCHI (METERS)	1.5 - 2.6	2.1	2.1	0.1 - 1.1	0.5	0.4	1.1 - 1.4	1.2	1.1

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR KEMP LAKE
STORET CODE 4816

4TH SAMPLING (10/28/74)

PARAMETER	3 SITES RANGE	MEAN	MEDIAN
TEMP (C)	17.7 - 18.4	17.9	17.9
DISS OXY (MG/L)	7.8 - 8.6	8.2	8.2
CNDCTVY (MCROMO)	3404. - 3969.	3803.	3857.
PH (STAND UNITS)	****** -**********	**********	**********
TOT ALK (MG/L)	74. - 88.	83.	85.
TOT P (MG/L)	0.025 - 0.133	0.050	0.027
ORTHO P (MG/L)	0.017 - 0.026	0.020	0.021
NO2+NO3 (MG/L)	0.020 - 0.150	0.049	0.020
AMMONIA (MG/L)	0.020 - 0.050	0.031	0.030
KJEL N (MG/L)	0.300 - 0.700	0.433	0.400
INORG N (MG/L)	0.040 - 0.190	0.080	0.050
TOTAL N (MG/L)	0.320 - 0.730	0.482	0.420
CHLRPYL A (UG/L)	11.1 - 15.0	12.9	12.7
SECCHI (METERS)	0.1 - 1.2	0.7	0.9

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/04/74	1. Chroomonas sp.	1,057
	2. Oocystis sp.	88
	Total	1,145
05/13/74	1. Oocystis sp.	674
	2. Centric diatoms	530
	3. Oscillatoria sp.	433
	4. Microcystis sp.	385
	5. Scenedesmus sp.	337
	Other genera	2,454
	Total	4,833
08/08/74	1. Anabaenopsis sp.	10,492
	2. Oscillatoria sp.	2,469
	3. Pennate diatoms	1,234
	4. Oocystis sp.	823
	5. Lyngbya sp.	720
	Other genera	1,440
	Total	17,178
10/28/74	1. Oscillatoria sp.	2,008
	2. Anabaenopsis sp.	1,121
	3. Diploneis sp.	327
	4. Lyngbya sp.	234
	5. Pennate diatoms	187
	Other genera	373
	Total	4,250

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
03/04/74	1	8.5
	2	0.8
	3	0.9
	4	-
05/13/74	1	3.2
	2	6.2
	3	-
	4	4.0
08/08/74	1	18.7
	2	23.5
	3	-
	4	18.0
10/28/74	1	12.7
	2	11.1
	3	-
	4	15.0

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	<0.005	0.118	0.1
0.050 P	<0.055	0.118	1.7
0.050 P + 1.0 N	<0.055	1.118	9.6
1.0 N	<0.005	1.118	0.1

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity

of Lake Kemp was low at the time the assay sample was collected (03/04/74). Also, a significant increase in yield with the addition of phosphorus alone indicates that the lake was phosphorus limited at that time. Note that the addition of nitrogen alone resulted in a yield no greater than that of the control.

The lake data indicate phosphorus limitation in March, May, and August but nitrogen limitation in October (the mean inorganic nitrogen to orthophosphorus ratios were 16 to 1, 24 to 1, 38 to 1, and 4 to 1, respectively).

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Texas National Guard collected monthly near-surface grab samples when possible from each of the tributary sites indicated on the map (page vi), except for the months of April and May when two samples were collected at the inlet. Sampling was begun in September, 1974, and was completed in August, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Texas District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and mean annual flows. Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the mean concentrations in Wichita River at station A-2 and the mean annual ZZ flow.

No known point sources impacted Lake Kemp during the sampling year.

A. Waste Sources:

1. Known municipal - None

2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Wichita River	10,190	83.2
b. Minor tributaries & immediate drainage (non-point load) -	745	6.1
c. Known municipal STP's - None	-	-
d. Septic tanks* -	215	1.8
e. Known industrial - None	-	-
f. Direct precipitation** -	1,090	8.9
Total	12,240	100.0

2. Outputs -

Lake outlet - Wichita River 3,745

3. Net annual P accumulation - 8,495 kg.

* Estimate based on 764 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Wichita River	131,070	60.7
b. Minor tributaries & immediate drainage (non-point load) -	9,605	4.4
c. Known municipal STP's - None	-	-
d. Septic tanks* -	8,140	3.8
e. Known industrial - None	-	-
f. Direct precipitation** -	67,120	31.1
Total	215,935	100.0

2. Outputs -

Lake outlet - Wichita River 88,920

3. Net annual N accumulation - 127,015 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
Wichita River	3	27

* Estimate based on 764 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.20	0.14	3.5	2.0

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Lake Kemp:	
"Dangerous" (eutrophic loading)	0.28
"Permissible" (oligotrophic loading)	0.14

V. LITERATURE REVIEWED

Anonymous, 1976. Water resources data for Texas, water year 1975. Water-Data Rept. TX-75-1, U.S. Geol. Surv., Austin.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
4801	AMISTAD LAKE	0.013	0.500	371.474	2.042	14.900	0.009
4802	BASTROP LAKE	0.022	0.090	419.917	12.392	15.000	0.007
4803	BELTON RESERVOIR	0.016	0.185	378.312	8.025	15.000	0.007
4804	BRAUNIG LAKE	0.134	0.150	461.625	22.762	14.800	0.062
4805	BROWNWOOD LAKE	0.027	0.100	470.375	4.887	14.400	0.007
4806	LAKE BUCHANAN	0.036	0.250	437.625	8.606	15.000	0.012
4807	CADDO LAKE	0.055	0.070	463.333	14.808	11.400	0.013
4808	CALAVERAS LAKE	0.038	0.060	461.667	22.500	13.000	0.007
4809	CANYON RESERVOIR	0.010	0.450	384.812	2.500	14.800	0.006
4810	LAKE COLORADO CITY	0.042	0.090	473.625	12.675	10.200	0.012
4811	CORPUS CRISTI LAKE	0.113	0.130	475.187	19.756	14.000	0.050
4812	DIVERSION LAKE	0.025	0.080	470.111	15.867	9.000	0.009
4813	EAGLE MOUNTAIN LAKE	0.024	0.070	469.625	5.662	11.000	0.008
4814	FT PHANTOM HILL LAKE	0.060	0.105	474.909	6.317	9.800	0.022
4815	GARZA LITTLE ELM RESERVO	0.045	0.380	475.782	14.156	14.600	0.018
4816	KEMP LAKE	0.023	0.110	455.000	10.217	10.400	0.007
4817	HOUSTON LAKE	0.097	0.260	486.187	16.650	12.400	0.036
4818	LAKE OF THE PINES	0.031	0.090	440.000	12.919	15.000	0.011
4819	LAVON RESERVOIR	0.063	0.180	485.333	5.400	8.800	0.018
4820	LIVINGSTON LAKE	0.196	0.555	465.469	16.112	15.000	0.128
4821	LYNDON B JOHNSON LAKE	0.042	0.420	456.500	8.100	14.900	0.013
4822	MEDINA LAKE	0.010	0.600	403.562	12.944	15.000	0.004
4823	LAKE MEREDITH	0.021	0.070	439.312	3.037	14.900	0.009
4824	PALESTINE LAKE	0.031	0.180	442.625	10.619	14.800	0.010
4825	POSSUM KINGDOM RESERVOIR	0.023	0.070	419.045	9.495	15.000	0.009
4826	SAN ANGELO RESERVOIR	0.098	0.140	481.000	24.675	10.200	0.011
4827	SAM RAYBURN RESERVOIR	0.029	0.150	439.458	6.267	15.000	0.009
4828	E V SPENCE RESERVOIR	0.036	0.080	462.583	11.775	15.000	0.008

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO	MEDIAN DISS ORTHO P
4829	SOMERVILLE LAKE	0.053	0.115	473.833	24.491	13.000	0.013
4830	STAMFORD LAKE	0.073	0.060	482.714	18.457	10.600	0.012
4831	STILLHOUSE HOLLOW RESERV	0.018	0.160	406.250	3.917	15.000	0.010
4832	TAWAKONI LAKE	0.046	0.100	466.417	18.246	13.200	0.013
4833	TEXARKANA LAKE	0.106	0.120	478.500	19.119	12.400	0.030
4834	TEXOMA LAKE	0.042	0.160	451.321	12.493	15.000	0.018
4835	TRAVIS LAKE	0.018	0.250	389.913	5.595	15.000	0.007
4836	TRINIDAD	0.389	0.110	479.500	24.300	10.000	0.240
4837	TWIN BUTTES RESERVOIR	0.029	0.250	454.917	8.708	14.800	0.009
4838	WHITE RIVER RESERVOIR	0.020	0.110	434.500	4.333	15.000	0.009
4839	WHITNEY LAKE	0.028	0.120	430.500	6.912	15.000	0.008

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4801	AMISTAD LAKE	95 (36)	5 (2)	100 (38)	100 (38)	39 (14)	63 (21)	402
4802	BASTROP LAKE	79 (30)	76 (28)	82 (31)	47 (18)	17 (0)	92 (34)	393
4803	BELTON RESERVOIR	92 (35)	26 (10)	97 (37)	68 (26)	17 (0)	84 (31)	384
4804	BRAUNIG LAKE	5 (2)	42 (16)	50 (19)	8 (3)	49 (17)	5 (2)	159
4805	BROWNWOOD LAKE	66 (25)	70 (26)	29 (11)	87 (33)	58 (22)	84 (31)	394
4806	LAKE BUCHANAN	47 (18)	21 (7)	74 (28)	63 (24)	17 (0)	39 (14)	261
4807	CADDO LAKE	26 (10)	91 (33)	42 (16)	32 (12)	76 (29)	30 (10)	297
4808	CALAVERAS LAKE	45 (17)	100 (38)	47 (18)	11 (4)	67 (25)	92 (34)	362
4809	CANYON RESERVOIR	99 (37)	8 (3)	95 (36)	97 (37)	49 (17)	97 (37)	445
4810	LAKE COLORADO CITY	39 (14)	76 (28)	26 (10)	42 (16)	88 (33)	39 (14)	310
4811	CORPUS CRISTI LAKE	8 (3)	47 (18)	18 (7)	13 (5)	61 (23)	8 (3)	155
4812	DIVERSION LAKE	68 (26)	83 (31)	32 (12)	29 (11)	97 (37)	63 (21)	372
4813	EAGLE MOUNTAIN LAKE	71 (27)	91 (33)	34 (13)	79 (30)	79 (30)	76 (28)	430
4814	FT PHANTOM HILL LAKE	24 (9)	66 (25)	21 (8)	74 (28)	95 (36)	16 (6)	296
4815	GARZA LITTLE ELM RESERVO	34 (13)	13 (5)	16 (6)	34 (13)	55 (21)	21 (7)	173
4816	KEMP LAKE	76 (29)	61 (22)	55 (21)	55 (21)	84 (32)	92 (34)	423
4817	HOUSTON LAKE	16 (6)	16 (6)	0 (0)	24 (9)	72 (27)	11 (4)	139
4818	LAKE OF THE PINES	54 (20)	76 (28)	66 (25)	39 (15)	17 (0)	46 (17)	298
4819	LAVON RESERVOIR	21 (8)	29 (11)	3 (1)	84 (32)	100 (38)	21 (7)	258
4820	LIVINGSTON LAKE	3 (1)	3 (1)	39 (15)	26 (10)	17 (0)	3 (1)	91
4821	LYNDON B JOHNSON LAKE	39 (14)	11 (4)	53 (20)	66 (25)	39 (14)	30 (10)	238
4822	MEDINA LAKE	99 (37)	0 (0)	89 (34)	37 (14)	17 (0)	100 (38)	342
4823	LAKE MEREDITH	82 (31)	91 (33)	71 (27)	95 (36)	39 (14)	63 (21)	441
4824	PALESTINE LAKE	54 (20)	32 (12)	63 (24)	53 (20)	49 (17)	51 (19)	302
4825	POSSUM KINGDOM RESERVOIR	74 (28)	91 (33)	84 (32)	58 (22)	17 (0)	63 (21)	387
4826	SAN ANGELO RESERVOIR	13 (5)	45 (17)	8 (3)	0 (0)	88 (33)	46 (17)	200
4827	SAM RAYBURN RESERVOIR	59 (22)	39 (15)	68 (26)	76 (29)	17 (0)	63 (21)	322
4828	E V SPENCE RESERVOIR	50 (19)	83 (31)	45 (17)	50 (19)	17 (0)	76 (28)	321

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4829	SOMERVILLE LAKE	29 (11)	55 (21)	24 (9)	3 (1)	67 (25)	30 (10)	208
4830	STAMFORD LAKE	18 (7)	97 (37)	5 (2)	18 (7)	82 (31)	39 (14)	259
4831	STILLHOUSE HOLLOW RESERV	88 (33)	37 (14)	87 (33)	92 (35)	17 (0)	51 (19)	372
4832	TAWAKONI LAKE	32 (12)	70 (26)	37 (14)	21 (8)	63 (24)	30 (10)	253
4833	TEXARKANA LAKE	11 (4)	51 (19)	13 (5)	16 (6)	72 (27)	13 (5)	176
4834	TEXOMA LAKE	39 (14)	34 (13)	61 (23)	45 (17)	17 (0)	21 (7)	217
4835	TRAVIS LAKE	88 (33)	21 (7)	92 (35)	82 (31)	17 (0)	84 (31)	384
4836	TRINIDAD	0 (0)	61 (22)	11 (4)	5 (2)	92 (35)	0 (0)	169
4837	TWIN BUTTES RESERVOIR	59 (22)	21 (7)	58 (22)	61 (23)	49 (17)	63 (21)	311
4838	WHITE RIVER RESERVOIR	84 (32)	61 (22)	76 (29)	89 (34)	17 (0)	63 (21)	390
4839	WHITNEY LAKE	63 (24)	51 (19)	79 (30)	71 (27)	17 (0)	76 (28)	357

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	4809	CANYON RESERVOIR	445
2	4823	LAKE MEREDITH	441
3	4813	EAGLE MOUNTAIN LAKE	430
4	4816	KEMP LAKE	423
5	4801	AMISTAD LAKE	402
6	4805	BROWNWOOD LAKE	394
7	4802	BASTROP LAKE	393
8	4838	WHITE RIVER RESERVOIR	390
9	4825	POSSUM KINGDOM RESERVOIR	387
10	4835	TRAVIS LAKE	384
11	4803	BELTON RESERVOIR	384
12	4831	STILLHOUSE HOLLOW RESERV	372
13	4812	DIVERSION LAKE	372
14	4808	CALAVERAS LAKE	362
15	4839	WHITNEY LAKE	357
16	4822	MEDINA LAKE	342
17	4827	SAM RAYBURN RESERVOIR	322
18	4828	E V SPENCE RESERVOIR	321
19	4837	TWIN BUTTES RESERVOIR	311
20	4810	LAKE COLORADO CITY	310
21	4824	PALESTINE LAKE	302
22	4818	LAKE OF THE PINES	298
23	4807	CADDO LAKE	297
24	4814	FT PHANTOM HILL LAKE	296
25	4806	LAKE BUCHANAN	261
26	4830	STAMFORD LAKE	259
27	4819	LAVON RESERVOIR	258
28	4832	TAWAKONI LAKE	253

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
29	4821	LYNDON B JOHNSON LAKE	238
30	4834	TEXOMA LAKE	217
31	4829	SOMERVILLE LAKE	208
32	4826	SAN ANGELO RESERVOIR	200
33	4833	TEXARKANA LAKE	176
34	4815	GARZA LITTLE ELM RESERVO	173
35	4836	TRINIDAD	169
36	4804	BRAUNIG LAKE	159
37	4811	CORPUS CRISTI LAKE	155
38	4817	HOUSTON LAKE	139
39	4820	LIVINGSTON LAKE	91

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR TEXAS 03/22/77

LAKE CODE 4816 KEMP

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 5402.7

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
4816A1	5402.7	4.13	1.22	2.04	6.03	2.27	3.28	7.59	4.64	2.15	3.14	7.39	0.51	3.71
4816A2	4853.7	1.61	1.33	2.97	4.53	5.86	9.06	4.59	5.07	12.35	8.58	2.97	1.56	5.05
4816ZZ	549.1	0.057	0.057	0.057	0.142	0.113	0.113	0.057	0.057	0.113	0.113	0.057	0.085	0.085

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 5402.7
SUM OF SUB-DRAINAGE AREAS = 5402.7
TOTAL FLOW IN = 61.50
TOTAL FLOW OUT = 44.40

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
4816A1	9	74	0.048	7	0.020				
	10	74	0.023	12	0.011	31	0.068		
	11	74	0.246	16	1.841				
	12	74	0.014	8	0.0				
	1	75	12.374	4	0.0				
	2	75	0.014	1	0.0				
	3	75	1.756	2	0.011				
	4	75	2.180	13	7.929	26	0.0		
	5	75	1.529	3	0.0	20	0.241		
	6	75	0.028						
	7	75	2.690	12	6.570				
	8	75	2.832	22	3.596				
4816A2	9	74	16.027	7	0.0				
	10	74	4.219	12	0.127				
	11	74	1.897	16	1.586				
	12	74	1.048	8	0.0				
	1	75	1.331	3	3.171				
	2	75	2.633	1	2.747				
	3	75	1.048	2	0.0				
	4	75	0.566	13	1.727	26	0.368		
	5	75	14.158	2	0.878	20	1.982		
	6	75	5.097	8	25.259				
	7	75	8.495	12	2.577				
	8	75	8.495	22	2.379				
4816ZZ	9	74	0.0						
	10	74	2.095						
	11	74	0.0						
	12	74	0.340						
	1	75	0.0						
	2	75	5.239						
	3	75	0.0						
	4	75	1.926						
	5	75	3.964						
	6	75	1.982						
	7	75	6.853						
	8	75	0.0						

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/02/11

481601
33 45 24.0 099 09 06.0
KEMP LAKE
48023 TEXAS

11EPALES
3

2111202
0047 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/03/04	13 40	0000	10.8		81	3700	8.10	109	0.030	0.400	0.090	0.006
	13 40	0005	10.3	10.6		3650	8.10	108	0.020	0.300	0.090	0.007
	13 40	0015	10.0	10.8		3650	8.10	107	0.020	0.200K	0.090	0.007
	13 40	0030	9.8	10.6		3650	8.10	107	0.020	0.300	0.090	0.005
	13 40	0043	9.8	10.4		3700	8.10	105	0.030	0.200K	0.090	0.005
74/05/13	13 10	0000	21.9		43	4939	8.35	87	0.070	0.800	0.100	0.009
	13 10	0005	22.0	8.0		4936	8.35	87	0.060	0.400	0.110	0.009
	13 10	0015	21.9	7.8		4922	8.30	87	0.050	0.400	0.090	0.006
	13 10	0035	21.4	7.6		4880	8.30	87	0.060	0.400	0.110	0.010
74/08/08	13 45	0000	26.3		56	5275	8.30	91	0.030	0.600	0.020K	0.002K
	13 45	0015	26.1	8.2		5258	8.00	88	0.040	0.400	0.020K	0.002K
	13 45	0025	25.8	5.2		5198	8.00	90	0.040	0.400	0.020K	0.002K
	13 45	0034	25.5	4.6		5194	7.90	91	0.100	0.500	0.020	0.002
74/10/28	14 00	0000	17.9	8.0	48	3884		88	0.050	0.700	0.030	0.018
	14 00	0005	17.9	8.2		3969		88	0.030	0.400	0.020	0.022
	14 00	0015	17.8	8.4		3954		86	0.030	0.500	0.020	0.021
	14 00	0020	17.8	7.8		3932		85	0.030	0.300	0.020	0.022

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/03/04	13 40	0000	0.008	8.5	
	13 40	0005	0.011		
	13 40	0015	0.007		
	13 40	0030	0.006		
	13 40	0043	0.007		
74/05/13	13 10	0000	0.020	3.2	
	13 10	0005	0.023		
	13 10	0015	0.021		
	13 10	0035	0.023		
74/08/08	13 45	0000	0.018	18.7	
	13 45	0015	0.019		
	13 45	0025	0.016		
	13 45	0034	0.033		
74/10/28	14 00	0000	0.029	12.7	
	14 00	0005	0.026		
	14 00	0015	0.027		
	14 00	0020	0.029		

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/02/11

481602
33 44 38.0 099 14 36.0
KEMP LAKE
48023 TEXAS

11EPALES 2111202
3 0038 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/03/04	14 30	0000	10.2		102	3705	8.10	105	0.040	0.500	0.110	0.010
	14 30	0005	10.3	10.8		3740	8.10	106	0.020	0.300	0.090	0.006
	14 30	0015	10.0	10.6		3750	8.10	104	0.030	0.400	0.090	0.011
	14 30	0025	10.0	10.6		3700	8.10	102	0.020	0.300	0.090	0.006
	14 30	0034	10.0	10.4		3750	8.10	101	0.030	0.300	0.090	0.008
74/05/13	14 00	0000	23.3	7.6	3	2772	8.30	87	0.120	0.700	0.220	0.011
74/08/08	15 00	0000	26.6	7.8	45	5412	8.40	88	0.060	1.000	0.020	0.003
	15 00	0005	26.4			5370						
	15 00	0015	25.6	5.4		5285	8.30	88	0.060	0.500	0.030	0.002K
74/10/28	14 50	0000	18.4	8.2	4	3404		74	0.040	0.500	0.150	0.018
	14 50	0006	18.3	7.8		3546		75	0.040	0.500	0.140	0.026

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/03/04	14 30	0000	0.012	0.8	
	14 30	0005	0.011		
	14 30	0015	0.012		
	14 30	0025	0.008		
	14 30	0034	0.011		
74/05/13	14 00	0000	0.124	6.2	
74/08/08	15 00	0000	0.021	23.5	
	15 00	0015	0.030		
74/10/28	14 50	0000	0.133	11.1	
	14 50	0006	0.124		

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/02/11

481603
33 43 30.0 099 17 58.0
KEMP LAKE
48023 TEXAS

11EPALES 2111202
3 0010 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/03/04	15	0000	12.2		60	4200	8.10	100	0.030	0.400	0.070	0.007
	15	0006	12.1	10.2		4200	8.10	99	0.030	0.400	0.070	0.007

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/03/04	15	0000	0.009	0.9	
	15	0006	0.008		

STORET RETRIEVAL DATE 76/02/11

481604
33 46 56.0 099 12 25.0
KEMP LAKE
48023 TEXAS

11EPALES 2111202
3 0028 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/05/13	13 40	0000	23.4		17	48	8.35	85	0.070	0.700	0.150	0.009
	13 40	0005	23.3	7.8		48	8.40	84	0.060	0.400	0.140	0.008
	13 40	0015	23.2	7.8		48	8.40	84	0.060	0.500	0.140	0.008
	13 40	0023	23.0	7.6		48	8.35	85	0.040	0.400	0.110	0.006
74/08/08	14 25	0000	27.3	7.8	45	5442	7.90	85	0.050	0.700	0.020	0.002
	14 25	0005	27.2			5430	8.40					
	14 25	0013	26.9	7.0		5396	8.30	83	0.050	0.600	0.020	0.002K
	14 25	0021	26.1	6.6		5290	8.25	85	0.060	0.500	0.020	0.002K
74/10/28	14 25	0000	17.9	8.4	36	3857		85	0.020K	0.400	0.020K	0.018
	14 25	0005	17.8	8.4		3853		81	0.020	0.300	0.020	0.017
	14 25	0015	17.7	8.6		3832		82	0.020K	0.300	0.020K	0.021

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/05/13	13 40	0000	0.024	4.0	
	13 40	0005	0.023		
	13 40	0015	0.026		
	13 40	0023	0.030		
74/08/08	14 25	0000	0.024	18.0	
	14 25	0013	0.025		
	14 25	0021	0.046		
74/10/28	14 25	0000	0.025	15.0	
	14 25	0005	0.026		
	14 25	0015	0.027		

K VALUE KNOWN TO BE
LESS THAN INDICATED

APPENDIX E

TRIBUTARY DATA

STORET RETRIEVAL DATE 76/03/10

4816A1
33 45 37.0 099 08 30.0 4
WICHITA RIVER
48121 7.5 NE LAKE KEMP
0/LAKE KEMP
183/283 BRDG BELO DAM
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/09/07	14	30	0.032	0.400	0.070	0.005	0.030
74/10/12	10	07	0.048	0.600	0.085	0.005	0.040
74/10/31	09	00	0.050	1.400	0.020	0.020	
74/11/16	10	00	0.056	0.800	0.080	0.010	0.030
75/04/13	08	15	0.075	0.650	0.030	0.005	0.020
75/05/20	18	00	0.030	0.600	0.035	0.005	0.050
75/07/12	13	40	0.020	0.700	0.025	0.005K	0.030
75/08/22	09	00	0.005	0.350	0.025	0.005K	0.040

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/03/10

4816A2
33 41 55.0 099 23 20.0 4
WICHITA RIVER
48 7.5 SOAP CREEK
T/LAKE KEMP
2NDRY RD 1919 &ROG 8 MI WNW JCT RD 2582
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/12	13 30		0.024	0.100K	0.040	0.010	0.010
74/11/16	11 20		0.024	0.600	0.025	0.035	0.030
75/01/03	14 00		0.296	0.600	0.064	0.010	0.190
75/02/01	13 02		0.745	2.500	0.104		
75/04/13	11 00		0.155	0.600	0.030	0.010	0.090
75/04/26	13 05		0.015	0.150	0.050	0.005	0.010
75/05/02	12 10		0.010	0.700	0.035	0.010	0.090
75/05/20	20 30		0.350	0.930	0.120	0.015	0.100K
75/06/08	12 30		0.315	0.050	0.050	0.010	0.010
75/07/12	15 30		0.480	0.050	0.045	0.005	0.010
75/08/22	10 20		0.005	0.350	0.025	0.010	0.100

K VALUE KNOWN TO BE
LESS THAN INDICATED