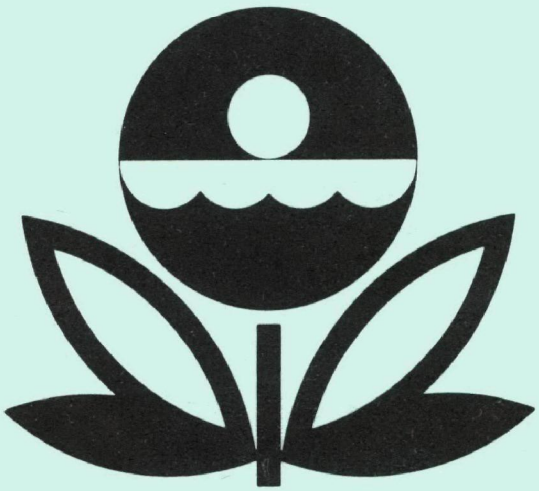
U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY
WORKING PAPER SERIES



REPORT

ON

ALTUS RESERVOIR

GREER AND KIOWA COUNTIES

OKLAHOMA

EPA REGION VI

WORKING PAPER No. 581

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON

and

ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

☆G.P.O. 699-440

REPORT

ON

ALTUS RESERVOIR

GREER AND KIOWA COUNTIES

OKLAHOMA

EPA REGION VI

WORKING PAPER No. 581

WITH THE COOPERATION OF THE

OKLAHOMA DEPARTMENT OF POLLUTION CONTROL

AND THE

OKLAHOMA NATIONAL GUARD

MARCH, 1977

REPORT ON ALTUS RESERVOIR

GREER AND KIOWA COUNTIES, OKLAHOMA

EPA REGION VI

by

National Eutrophication Survey

Water and Land Monitoring Branch
Monitoring Applications Laboratory
Environmental Monitoring & Support Laboratory
Las Vegas, Nevada

and

Eutrophication Survey Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

Working Paper No. 581

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY

March 1977

CONTENTS

FOREWORD

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 nonpoint 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 freshwater 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 the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Oklahoma Department of Pollution Control for professional involvement, to the Oklahoma National Guard for conducting the tributary sampling phase of the Survey, and to those Oklahoma wastewater treatment plant operators who provided effluent samples and flow data.

Dr. Denver Talley, Director, Oklahoma Department of Pollution Control; the staff of the Oklahoma Water Resources Board; and the staff of the Oklahoma State Department of Health reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper Series.

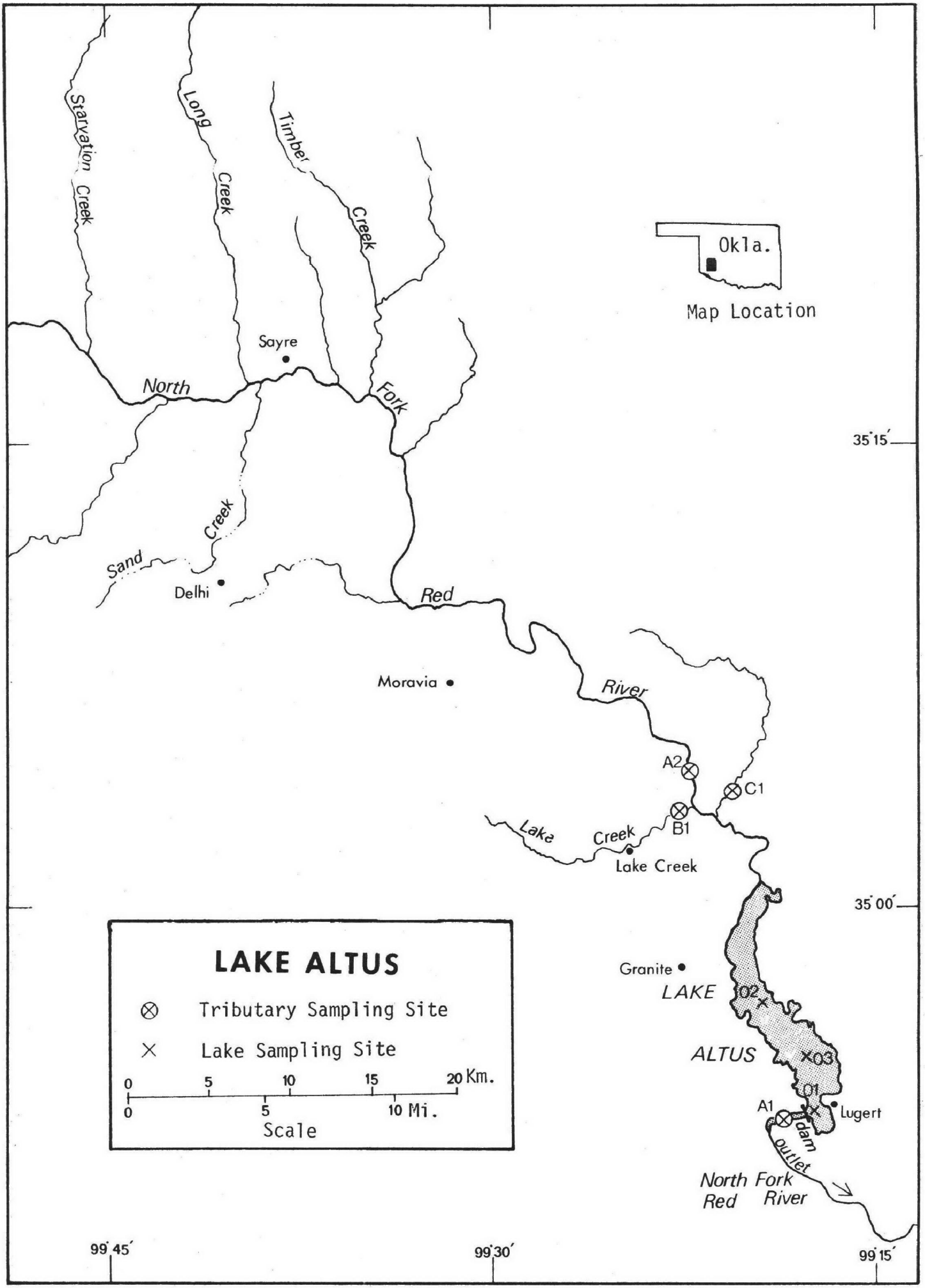
Major General John Coffey, Jr., the Adjutant General of Oklahoma, and Project Officers Colonel Curtis W. Milligan and Major James O. Haney, Jr., who directed the volunteer efforts of the Oklahoma National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF OKLAHOMA

LAKE NAME	COUNTY
Altus Reservoir	Greer, Kiowa
Arbuckle Lake	Murray
Lake Elsworth	Caddo, Comanche
Lake Eufaula	Haskell, McIntosh, Okmulgee, Pittsburg
Fort Cobb Reservoir	Caddo
Fort Supply Reservoir	Woodward
Foss Dam Reservoir	Custer
Lake Frances	Adair
Grand Lake O' The Cherokees	Mayes, Delaware, Craig, Ottowa
Lake Hefner	Oklahoma
Keystone Reservoir	Tulsa, Creek, Osage, Pawnee
Oologah Lake	Nowata, Rogers
Tenkiller Ferry Reservoir	Cherokee, Sequoyah
Lake Thunderbird	Cleveland
Wister Reservoir	LeFlore


Starvation Creek
Long Creek
Timber Creek
Okla.
Map Location
Sayre
North Fork
35°15′
Sand Creek
Delhi
Red River
Moravia
A2
C1
B1
Lake Creek
Lake Creek
35°00′
LAKE ALTUS
⊗ Tributary Sampling Site
× Lake Sampling Site
0 5 10 15 20 Km.
0 5 10 Mi.
Scale
Granite
LAKE ALTUS
02
03
01
A1
Dam
Lugert
outlet
North Fork Red River
99°45′
99°30′
99°15′

REPORT ON ALTUS RESERVOIR, OKLAHOMA

STORET NO. 4001

I. CONCLUSIONS

A. Trophic Condition:*

On the basis of field observations and Survey data, Altus Reservoir is considered eutrophic, i.e., nutrient rich and highly productive. Whether such nutrient enrichment is to be considered beneficial or deleterious is determined by its actual or potential impact upon designated beneficial water uses of each lake.

Chlorophyll a values in Altus Reservoir ranged from 7.3 µg/l in the summer to 26.8 µg/l in the fall, with a mean of 14.8 µg/l. Potentials for primary production as measured by algal assay control yield were moderate in spring and high during October sampling. Of the 16 Oklahoma lakes (including Lake Texoma) sampled in 1974, 9 had higher median total phosphorus values, 15 had higher median inorganic nitrogen values, and 11 had higher median orthophosphorus levels than Altus Reservoir.

Survey limnologists did not report any problem algal blooms or aquatic macrophytes during their visits to the lake.

*See Appendix E.

B. Rate-Limiting Nutrient:

Mean inorganic nitrogen to orthophosphorus (N/P) ratios in the lake data were 11/1 or less on all sampling occasions, indicating primary limitation by nitrogen in the reservoir. Algal assay results suggest Altus Reservoir was limited by available phosphorus levels in March and colimited by both phosphorus and nitrogen during October sampling.

C. Nutrient Controllability:

1. Point sources -

During the sampling year there was one known point source, Quartz Lodge, impacting Altus Reservoir. However, no chemistry or flow data are available on the plant at this time and nutrient loadings for the plant are not included in the lake nutrient budget (pp. 15 and 16). In addition, it is suspected that a portion of the sewage treatment plant effluent from Granite, released to ground, ultimately will impact Altus Reservoir, but estimates of loading directly attributable to this source are not presently available.

The present estimated annual phosphorus loading of 0.42 g $P/m^2/yr$ to the reservoir is greater than that proposed by Vollenweider (1975) as "eutrophic" for a lake with such volume and retention time. Additional investigation is needed to determine loading levels contributed by the Quartz Lodge plant.

2. Nonpoint sources -

Nonpoint sources (including precipitation) contributed all of the calculated loading to Altus Reservoir during the sampling year. The North Fork Red River contributed 88.9%, Lake Creek contributed 2.7%, and ungaged drainage areas contributed an estimated 4.2%.

The phosphorus export rates of the North Fork Red River and Lake Creek were 2 and 3 $kg/km^2/yr$, respectively, (see Section IV-D). The rates are somewhat lower than those of the unimpacted tributaries draining into nearby Elsworth Lake* (range of 3-6 $kg/km^2/yr$).

*See Working Paper No. 583, "Report on Elsworth Lake".

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake morphometry data were provided by the Oklahoma Department of Pollution Control. Tributary flow data were provided by the Oklahoma District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet. Tributary drainage areas plus the lake surface area do not equal the outlet drainage area probably because of differences in the pool elevation used by the different sources in their calculations. Precipitation values are estimated by methods as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 25.41 km^2.
2. Mean depth: 6.4 meters.
3. Maximum depth: 23.5 meters.
4. Volume: 162.624 x 10^6 m^3.
5. Mean hydraulic retention time: 759 days (2.1 yr).

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

1. Tributaries -

Name	Drainage area(km^2)	Mean flow (m^3/sec)
A-2 North Fork Red River	5185.2	3.82
B-1 Lake Creek	107.0	0.11
Minor tributaries and immediate drainage -	147.6	0.16
Totals	5439.8	4.09

2. Outlet -

A-1 North Fork Red River	5480.4	2.48

C. Precipitation:

1. Year of sampling: 77.7 cm.
2. Mean annual: 63.3 cm.

III. LAKE WATER QUALITY SUMMARY

Altus Reservoir was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from three stations on the lake (Station 03 was only sampled twice) and from a number of depths at each station (see map, page v). During each visit, depth-integrated samples were collected from each station for chlorophyll a analysis and phytoplankton identification and enumeration. During the first and last visits, 18.9-liter depth-integrated samples were composited for algal assays. Maximum depths sampled were 9.8 meters at Station 01, 4.9 meters at Station 02, and 7.9 meters at Station 03. For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the maximum depth for each site. Results of the phytoplankton counts and chlorophyll a determinations are included in III-B. Results of the limiting nutrient study are presented in III-C.

ALTUS RESERVOIR
STORET CODE 4001

PHYSICAL AND CHEMICAL CHARACTERISTICS

PARAMETER	N*	(3/29/74) S*** = 2 RANGE	MEDIAN	MAX DEPTH RANGE (METERS)	N*	(6/10/74) S*** = 3 RANGE	MEDIAN	MAX DEPTH RANGE (METERS)	N*	(10/24/74) S*** = 3 RANGE	MEDIAN	MAX DEPTH RANGE (METERS)
TEMPERATURE (DEG CENT)												
0.-1.5 M DEPTH	4	1.0- 11.0	10.7	0.0- 1.5	6	23.7- 24.6	23.8	0.0- 1.5	6	15.5- 16.6	16.6	0.0- 1.5
MAX DEPTH**	2	10.4- 10.9	10.6	4.6- 9.1	3	23.5- 23.6	23.6	4.9- 9.8	3	16.5- 16.6	16.5	3.7- 7.9
DISSOLVED OXYGEN (MG/L)												
0.-1.5 M DEPTH	2	10.0- 10.2	10.1	1.5- 1.5	3	7.0- 7.4	7.4	1.5- 1.5	6	8.2- 8.6	8.6	0.0- 1.5
MAX DEPTH**	2	10.0- 10.2	10.1	4.6- 9.1	3	6.6- 6.8	6.8	4.9- 9.8	3	7.2- 8.6	8.4	3.7- 7.9
CONDUCTIVITY (UMHOS)												
0.-1.5 M DEPTH	4	1683.-1701.	1693.	0.0- 1.5	6	2236.-2768.	2244.	0.0- 1.5	6	2013.-2019.	2018.	0.0- 1.5
MAX DEPTH**	2	1674.-1701.	1688.	4.6- 9.1	3	2232.-2240.	2234.	4.9- 9.8	3	1959.-2073.	2015.	3.7- 7.9
PH (STANDARD UNITS)												
0.-1.5 M DEPTH	4	8.3- 8.4	8.4	0.0- 1.5	6	7.9- 8.5	8.2	0.0- 1.5	6	8.2- 8.3	8.3	0.0- 1.5
MAX DEPTH**	2	8.3- 8.4	8.3	4.6- 9.1	3	8.1- 8.3	8.1	4.9- 9.8	3	8.1- 8.3	8.3	3.7- 7.9
TOTAL ALKALINITY (MG/L)												
0.-1.5 M DEPTH	4	131.- 151.	146.	0.0- 1.5	6	143.- 146.	145.	0.0- 1.5	6	101.- 107.	104.	0.0- 1.5
MAX DEPTH**	2	146.- 149.	148.	4.6- 9.1	3	142.- 146.	144.	4.9- 9.8	3	101.- 105.	104.	3.7- 7.9
TOTAL P (MG/L)												
0.-1.5 M DEPTH	4	0.036-0.043	0.037	0.0- 1.5	6	0.036-0.043	0.039	0.0- 1.5	6	0.056-0.064	0.058	0.0- 1.5
MAX DEPTH**	2	0.039-0.040	0.039	4.6- 9.1	3	0.039-0.046	0.042	4.9- 9.8	3	0.061-0.455	0.067	3.7- 7.9
DISSOLVED ORTHO P (MG/L)												
0.-1.5 M DEPTH	4	0.010-0.016	0.011	0.0- 1.5	6	0.006-0.011	0.009	0.0- 1.5	6	0.007-0.018	0.010	0.0- 1.5
MAX DEPTH**	2	0.010-0.010	0.010	4.6- 9.1	3	0.007-0.010	0.009	4.9- 9.8	3	0.008-0.026	0.012	3.7- 7.9
NO2+NO3 (MG/L)												
0.-1.5 M DEPTH	4	0.020-0.030	0.030	0.0- 1.5	6	0.020-0.050	0.020	0.0- 1.5	6	0.020-0.020	0.020	0.0- 1.5
MAX DEPTH**	2	0.020-0.020	0.020	4.6- 9.1	3	0.050-0.070	0.060	4.9- 9.8	3	0.020-0.020	0.020	3.7- 7.9
AMMONIA (MG/L)												
0.-1.5 M DEPTH	4	0.030-0.040	0.035	0.0- 1.5	6	0.040-0.070	0.045	0.0- 1.5	6	0.030-0.050	0.030	0.0- 1.5
MAX DEPTH**	2	0.030-0.030	0.030	4.6- 9.1	3	0.090-0.100	0.090	4.9- 9.8	3	0.030-0.120	0.040	3.7- 7.9
KJELDAHL N (MG/L)												
0.-1.5 M DEPTH	4	0.600-0.800	0.700	0.0- 1.5	6	0.500-1.000	0.600	0.0- 1.5	6	0.600-0.900	0.600	0.0- 1.5
MAX DEPTH**	2	0.700-0.700	0.700	4.6- 9.1	3	0.500-0.600	0.600	4.9- 9.8	3	0.600-2.300	0.600	3.7- 7.9
SECCHI DISC (METERS)												
	2	0.5- 0.8	0.6		3	0.8- 1.4	0.9		3	0.5- 0.7	0.6	

* N = NO. OF SAMPLES
** MAXIMUM DEPTH SAMPLED AT EACH SITE
*** S = NO. OF SITES SAMPLED ON THIS DATE

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera		Algal Units per ml
03/29/74	1.	Oscillatoria	7,319
	2.	Chroomonas	232
	3.	Carteria	155
	4.	Dactylococcopsis	77
	5.	Stephanodiscus	77
		Other genera	117
		Total	7,977
06/10/74	1.	Oscillatoria	1,330
	2.	Chroomonas	272
	3.	Carteria	242
	4.	Microcystis	242
	5.	Merismopedia	212
		Other genera	664
		Total	2,962
10/24/74	1.	Navicula	4,928
	2.	Oscillatoria	1,437
	3.	Centric diatoms	667
	4.	Cryptomonas	205
	5.	Lyngbya	205
		Other genera	309
		Total	7,751

2. Chlorophyll *a* -

Sampling Date	Station Number	Chlorophyll *a* (µg/l)
03/29/74	01	10.9
	02	11.4
	03	----
06/10/74	01	7.3
	02	9.0
	03	8.2
10/24/74	01	25.4
	02	19.0
	03	26.8

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spiked(mg/l)	Ortho P Conc.(mg/l)	Inorganic N Conc.(mg/l)	Maximum Yield (mg/l-dry wt.)
a. 03/29/74			
Control	0.010	0.078	0.5
0.05 P	0.060	0.078	2.6
0.05 P + 1.0 N	0.060	1.078	22.2
1.00 N	0.010	1.078	0.8
b. 10/24/74			
Control	0.021	0.178	4.0
0.05 P	0.071	0.178	5.3
0.05 P + 1.0 N	0.071	1.178	25.5
1.00 N	0.021	1.178	5.7

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that potential for primary production was moderate in Altus Reservoir during spring sampling and high during autumn. In March, the addition of orthophosphorus alone produced a significant increase in yield over that of the control, indicating the sample was phosphorus limited at that time. The addition of nitrogen alone did not result in a significant increase in yield over that of the control. In October, additions of either phosphorus or nitrogen produced similar growth responses, suggesting colimitation by the two nutrients. In both assays, the simultaneous addition of both phosphorus and nitrogen produced the maximum yield increase over their respective control yields.

The mean inorganic nitrogen to orthophosphorus (N/P) ratios in the lake data were 11/1 or less on all sampling occasions, suggesting that nitrogen was the primary controlling nutrient limiting productivity in Altus Reservoir (a mean N/P of 14/1 or greater generally reflects phosphorus limitation).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Oklahoma National Guard collected a number of monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), including the high runoff month of April when two samples were collected. Sampling was begun in December 1974, and was completed in September 1975.

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

In this report, nutrient loads for sampled tributaries except North Fork Red River at Station A-1 were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any. Loadings for the North Fork Red River, Station A-1, were calculated from mean annual concentrations and mean annual flows. It should be noted, however, that loadings for A-1 are calculated from limited data (Station A-1 was sampled only four times during the 1974 sampling year) and may not reflect actual nutrient loadings from that tributary.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual nutrient loads, in $kg/km^2/year$, in Lake Creek at Station B-1, and multiplying the means by the ZZ area in km^2.

A. Waste Sources:

1. Known municipal -

Name	Pop. Served	Treatment	Mean Flow ($m^3/d \times 10^3$)	Receiving Water
Quartz Lodge*	?	?	?	Altus Reservoir
Granite**	900	Stabilization pond, released to ground	0.341***	-

2. Known industrial - None

*Peavy, Howard S., personnal communication.
**U.S.EPA, 1971.
***Estimated at 0.3785 m^3/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 North Fork Red River	9,520	88.9
B-1 Lake Creek	290	2.7
b. Minor tributaries and immediate drainage (nonpoint load) -	445	4.2
c. Known municipal STP's -		
Quartz Lodge	?	
d. Septic tanks* -	5	<0.1
e. Known industrial - None		
f. Direct precipitation** -	445	4.2
Totals	10,705	100.0
2. Output - A-1 North Fork Red River	3,910	
3. Net annual P accumulation	6,795	

*Estimate based on 8 lakeside residences and 1 park.
**Estimated (See NES Working Paper No. 175).

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 North Fork Red River	855,890	94.8
B-1 Lake Creek	8,080	0.9
b. Minor tributaries and immediate drainage (nonpoint load) -	11,220	1.2
c. Known municipal STP's -		
Quartz Lodge	?	
d. Septic tanks* -	120	<0.1
e. Known industrial - None		
f. Direct precipitation** -	27,435	3.1
Totals	902,745	100.0
2. Output - A-1 North Fork Red River	96,825	
3. Net annual N accumulation	805,920	

*Estimate based on 8 lakeside residences and 1 park.
**Estimated (See NES Working Paper No. 175).

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
North Fork Red River	2	165
Lake Creek	3	76

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P (mg/l)	Mean Total N (mg/l)
C-1 Unnamed Stream	0.208	2.704

Phosphorus levels in Unnamed Stream, tributary C-1, are substantially higher than those found in the other gaged tributaries to Altus Reservoir. The reasons for these inflated phosphorus values are not known.

F. Yearly Loading:

In the following table, the existing phosphorus annual loading is compared to those proposed by Vollenweider (1975). Essentially, his "eutrophic" loading is that at which the receiving waters would become eutrophic or remain eutrophic; his "oligotrophic" 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 "eutrophic" and "oligotrophic".

Note that Vollenweider's model may not be applicable to water bodies with very short retention times or in which light penetration is severely restricted from high concentrations of suspended solids in the surface waters.

	Total Yearly Phosphorus Loading ($g/m^2/yr$)
Estimated loading for Altus Reservoir	0.42
Vollenweider's "eutrophic" loading	0.34
Vollenweider's "oligotrophic" loading	0.17

V. LITERATURE REVIEWED

Peavy, Howard S. 1974. Personal communication (Sewage Treatment Plant to Altus Reservoir). Oklahoma Department of Pollution Control, Oklahoma City, Oklahoma.

U.S. Environmental Protection Agency. 1971. "Inventory of Wastewater Treatment Facilities". EPA Publication No. OWP-1, Volume 6. Office of Media Programs, Office of Water Programs, Washington, D.C.

U.S. Environmental Protection Agency. 1975. National Eutrophication Survey Methods 1973-1976. Working Paper No. 175. National Environmental Research Center, Las Vegas, Nevada, and Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

Vollenweider, R. A. 1975. Input-Output Models With Special Reference to the Phosphorus Loading Concept in Limnology. Schweiz. Z. Hydrol. 37:53-84.

VI. APPENDICES

APPENDIX A

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 B

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR OKLAHOMA 03/25/77

LAKE CODE 4001 ALTUS RES.

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 5480.4

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
4001A1	5480.4	0.25	0.65	0.85	1.67	1.22	4.64	7.22	8.92	2.32	1.10	0.28	0.45	2.48
4001A2	5185.2	1.98	2.55	2.10	3.40	14.50	10.11	3.45	1.33	1.59	2.32	0.99	1.44	3.82
4001B1	107.0	0.031	0.037	0.045	0.085	0.340	0.283	0.130	0.059	0.116	0.119	0.040	0.031	0.110
4001ZZ	173.0	0.045	0.051	0.065	0.119	0.481	0.396	0.184	0.085	0.164	0.167	0.057	0.045	0.156

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 5480.4
SUM OF SUB-DRAINAGE AREAS = 5465.2
TOTAL FLOW IN = 48.94
TOTAL FLOW OUT = 29.58

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
4001A1	11	74	0.034	2	0.034				
	12	74	0.034	15	0.034				
	1	75	0.034	18	0.034				
	2	75	0.034	16	0.034				
	3	75	0.034	16	0.034				
	4	75	0.034	19	0.034				
	5	75	0.034	18	0.034				
	6	75	0.034	21	0.034				
	7	75	0.034	27	0.034				
	8	75	0.034	9	0.034				
	9	75	0.034	13	0.034				
	10	75	0.034	5	0.034				
4001A2	11	74	5.947	11	8.212				
	12	74	2.237	14	2.322				
	1	75	3.256	18	2.917				
	2	75	5.663	16	4.644				
	3	75	3.228	15	3.455				
	4	75	4.106	5	2.180	20	1.897		
	5	75	12.120	11	1.218				
	7	75	8.778	23	0.793				
	8	75	2.917						
	9	75	1.756						
	10	75	0.085	5	0.085				
4001B1	11	74	0.283	2	0.340				
	12	74	0.105	14	0.113				
	1	75	0.079	18	0.079				
	2	75	0.113	16	0.125				
	3	75	0.099	15	0.102				
	4	75	0.142	5	0.076	20	0.105		
	5	75	0.088	11	0.566	18	0.340		
	6	75	0.510	21	0.0				
	7	75	0.071	23	0.0				
	8	75	0.396	9	0.510				
	9	75	0.042	13	0.071				
	10	75	0.042	5	0.003				

TRIBUTARY FLOW INFORMATION FOR OKLAHOMA 03/25/77

LAKE CODE 4001 ALTUS RES.

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
400122	11	74	0.425						
	12	74	0.150						
	1	75	0.113						
	2	75	0.159						
	3	75	0.142						
	4	75	0.201						
	5	75	0.122						
	6	75	0.708						
	7	75	0.099						
	8	75	0.538						
	9	75	0.059						
	10	75	0.059						

APPENDIX C

PHYSICAL AND CHEMICAL DATA

STORET RETRIEVAL DATE 77/03/24

400101
34 53 15.0 099 17 30.0 4
ALTUS RESERVOIR
40 OKLAHOMA
101591

/TYPA/AMBNT/LAKE

11EPALES 04001002
0036 FEET DEPTH CLASS 00

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
74/03/29	15 05	0000	10.7		30	1685	8.35	146	0.030	0.700	0.030	0.010
	15 05	0005	10.7	10.0		1683	8.35	151	0.030	0.700	0.020	0.016
	15 05	0015	10.6	10.0		1681	8.30	150	0.030	0.700	0.020	0.012
	15 05	0030	10.4	10.0		1674	8.30	149	0.030	0.700	0.020	0.010
74/06/10	10 00	0000	23.8		54	2242	8.10	146	0.050	1.000	0.050	0.009
	10 00	0005	23.7	7.4		2243	8.20	146	0.040	0.600	0.020	0.009
	10 00	0015	23.7	7.4		2242	8.20	145	0.040	0.600	0.020	0.008
	10 00	0025	23.7	6.6		2242	8.20	143	0.050	0.500	0.020	0.006
	10 00	0032	23.5	6.8		2232	8.10	144	0.090	0.600	0.060	0.007
74/10/24	15 00	0000	16.5	8.6	25	2017	8.19	106	0.040	0.800	0.020K	0.015
	15 00	0005	16.5	8.2		2019	8.19	105	0.050	0.600	0.020K	0.011
	15 00	0015	16.5	8.0		1957	8.19	104	0.050	0.600	0.020K	0.009
	15 00	0026	16.5	7.2		1959	8.15	105	0.120	2.300	0.020K	0.026

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 77/03/24

400101
34 53 15.0 099 17 30.0 4
ALTUS RESERVOIR
40 OKLAHOMA
101591

/TYPA/AMBNT/LAKE

1IEPALES 04001002
0036 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMAING PERCENT
74/03/29	15	05 0000	0.037	10.9	
	15	05 0005	0.038		
	15	05 0015	0.040		
	15	05 0030	0.040		
74/06/10	10	00 0000	0.041	7.3	
	10	00 0001			50.0
	10	00 0005	0.038		
	10	00 0010			1.0
	10	00 0015	0.037		
	10	00 0025	0.038		
	10	00 0032	0.039		
74/10/24	15	00 0000	0.057	25.4	
	15	00 0005	0.060		
	15	00 0015	0.076		
	15	00 0026	0.455		

STORET RETRIEVAL DATE 77/03/24

400102
34 55 30.0 099 18 15.0 4
ALTUS RESERVOIR
40 OKLAHOMA
101591

/TYPA/AMBNT/LAKE

11EPALES 04001002
0020 FEET DEPTH CLASS 00

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
74/03/29	16 45	0000	11.0		30	1701	8.40	130	0.040	0.800	0.030	0.010
	16 45	0005	11.0	10.2		1701	8.40	145	0.040	0.600	0.030	0.012
	16 45	0015	10.9	10.2		1701	8.40	146	0.030	0.700	0.020	0.010
74/06/10	11 15	0000	24.6		33	2245	8.50	143	0.050	1.000	0.020	0.006
	11 15	0005	23.7	7.0		2236	7.90	145	0.070	0.600	0.030	0.011
	11 15	0016	23.6	6.8		2234	8.10	146	0.100	0.500	0.070	0.009
74/10/24	14 25	0000	16.6	8.6	18	2013	8.27	107	0.030	0.900	0.020K	0.006
	14 25	0005	16.6	8.2		2013	8.25	102	0.030	0.600	0.020K	0.007
	14 25	0012	16.5	8.6		2015	8.25	101	0.030	0.600	0.020K	0.012

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/03/29	16 45	0000	0.036	11.4	
	16 45	0005	0.043		
	16 45	0015	0.039		
74/06/10	11 15	0000	0.043	9.0	
	11 15	0001			50.0
	11 15	0005	0.036		
	11 15	0006			1.0
	11 15	0016	0.046		
74/10/24	14 25	0000	0.063	19.0	
	14 25	0005	0.064		
	14 25	0012	0.067		

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 77/03/24

400103
34 54 35.0 099 17 40.0 4
ALTUS RESERVOIR
40 OKLAHOMA
101591

/TYPA/AMBNT/LAKE

11EPALES 04001002
0030 FEET DEPTH CLASS 00

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
74/06/10	10 45	0000	24.3		35	2266	8.20	144	0.040	0.600	0.020	0.010
	10 45	0005	23.9	7.4		2245	8.20	145	0.040	0.500	0.020	0.009
	10 45	0015	23.8	7.4		2246	8.40	143	0.060	0.500	0.020	0.008
	10 45	0026	23.6	6.8		2240	8.30	142	0.090	0.600	0.050	0.010
74/10/24	14 45	0000	16.6	8.6	26	2019	8.27	101	0.030	0.600	0.020K	0.010
	14 45	0005	16.6	8.6		2019	8.27	102	0.030	0.600	0.020K	0.018
	14 45	0021	16.6	8.4		2023	8.25	104	0.040	0.600	0.020K	0.008

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/06/10	10 45	0000	0.040	8.2	
	10 45	0001			50.0
	10 45	0005	0.038		
	10 45	0008			1.0
	10 45	0015	0.038		
	10 45	0026	0.042		
74/10/24	14 45	0000	0.057	26.8	
	14 45	0005	0.056		
	14 45	0021	0.061		

K VALUE KNOWN TO BE
LESS THAN INDICATED

APPENDIX D

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 77/03/24

4001A1
34 53 00.0 099 17 50.0 4
ALTUS CANAL
40 7.5 LAKE ALTUS
0/ALTUS LAKE 101591
AWLR OVR IRRGTION CHNNL 1000 FT BELO DM
1IEPALES 04001004
0000 FEET DEPTH CLASS 00

/TYPA/AMBNT/STREAM

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
75/02/16	15	20	0.576	1.200	0.072	0.016	0.030
75/06/21	14	20	0.100	1.050	0.025	0.010	0.050
75/08/09	10	50	0.120	0.650	0.120	0.020	0.060
75/09/13	17	10	0.525	0.700	0.060	0.025	0.060

STORET RETRIEVAL DATE 77/03/24

400142
35 04 25.0 099 22 00.0 4
N FORK RED RIVER
40 15 RETROP
T/ALTUS LAKE 101591
2NDRY RD BRDG 6 MI ENE OF WILLOW
11EPALES 04001004
0000 FEET DEPTH CLASS 00

/TYPA/AMBNT/STPLAM

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
74/12/11	10	45	0.690	1.450	0.070	0.015	0.115
75/01/18	14	30	0.712	1.000	0.096	0.010	0.050
75/03/15	10	20	0.672	2.800	0.104	0.032	0.140
75/04/05	17	20	0.280	1.900	0.040	0.005	0.040
75/04/20	14	25	0.230	2.000	0.025	0.010	0.110
75/05/11	10	45	0.015	0.850	0.020	0.010	0.090
75/07/23	10	00	0.010	0.650	0.015	0.015	0.070

STORET RETRIEVAL DATE 77/03/24

400161
35 03 15.0 099 22 40.0 4
LAKE CREEK
40 15 PETROP
T/ALTUS LAKE 101591
OK HWY 6 BRDG 7 W OF WILLOW
11EPALES 04001004
0000 FEET DEPTH CLASS 00

/TYPA/AMBNT/STREAM

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
74/12/14	10 15		0.800	1.500	0.090	0.010	0.050
75/01/18	14 00		0.840	1.600	0.136	0.010	0.030
75/02/16	15 00		1.660	0.800	0.072	0.032	0.040
75/03/15	10 00		1.450	1.800	0.048	0.040	0.200
75/04/05	17 30		0.500	1.400	0.030	0.015	0.090
75/04/20	14 15		0.360	2.200	0.035	0.010	0.050
75/05/11	10 30		0.600	1.500	0.330	0.015	0.120
75/09/13	17 25		0.580	0.750	0.015	0.045	0.110

STORET RETRIEVAL DATE 77/03/24

4001C1
35 03 50.0 099 20 35.0 4
UNNAMED STREAM
40 15 RETROP
T/ALTUS LAKE 101591
BRDG N/S SCTN LNE RD 1.5 MI SE JCT HWY 6
11EPALES 04001004
0000 FEET DEPTH CLASS 00

/TYPA/AMBNT/STREAM

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
74/12/14	11	15	1.960	1.000	0.055	0.005	0.030
75/01/18	13	00	2.275	0.600	0.032	0.005K	0.020
75/02/16	15	45	2.030	1.000	0.040	0.016	0.020
75/03/15	10	40	0.540	5.400	0.112	0.108	1.450
75/04/05	17	00	1.400	0.700	0.030	0.005	0.020
75/04/20	14	25	0.910	1.650	0.050	0.007	0.040
75/05/11	10	45	0.320	1.500	0.280	0.020	0.120
75/06/21	14	40	0.005	2.200	0.035	0.010	0.090
75/09/13	17	00	0.200	0.650	0.025	0.025	0.080

K VALUE KNOWN TO BE
LESS THAN INDICATED

APPENDIX E

PARAMETRIC RANKINGS OF LAKES SAMPLED BY NES IN 1974

STATE OF OKLAHOMA

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
4001	ALTUS RESERVOIR	0.041	0.060	468.625	14.750	8.400	0.010
4002	ARBUCKLE LAKE	0.020	0.070	443.600	7.027	14.600	0.008
4003	LAKE ELLSWORTH	0.037	0.070	459.400	8.430	9.400	0.009
4004	LAKE EUFAULA	0.081	0.405	482.513	4.383	14.200	0.029
4005	FORT COBB RESERVOIR	0.038	0.110	454.667	14.567	8.400	0.012
4006	FORT SUPPLY RESERVOIR	0.070	0.135	485.167	9.733	7.800	0.014
4007	FOSS DAM RESERVOIR	0.027	0.090	463.857	4.862	8.400	0.006
4008	LAKE FRANCES	0.142	1.780	484.333	7.973	8.200	0.093
4009	GRAND LAKE O' THE CHEROK	0.067	0.740	468.857	6.768	14.800	0.038
4010	LAKE HEFNER	0.057	0.250	461.000	5.667	9.000	0.036
4011	KEYSTONE RESERVOIR	0.136	0.690	484.303	21.427	14.900	0.096
4012	OOLOGAH LAKE	0.059	0.580	483.000	5.137	14.600	0.031
4013	TENKILLER FERRY RESERVOI	0.034	0.550	435.500	6.646	15.000	0.016
4014	LAKE THUNDERBIRD	0.027	0.150	465.000	8.422	12.000	0.009
4015	WISTER RESERVOIR	0.060	0.230	478.500	4.812	15.000	0.016
4034	TEXOMA LAKE	0.045	0.160	460.875	12.325	14.600	0.016

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
4001	ALTUS RESERVOIR	60 (9)	100 (15)	47 (7)	13 (2)	80 (11)	73 (11)
4002	ARBUCKLE LAKE	100 (15)	90 (13)	93 (14)	53 (8)	33 (4)	93 (14)
4003	LAKE ELLSWORTH	80 (12)	90 (13)	80 (12)	33 (5)	60 (9)	87 (13)
4004	LAKE EUFAULA	20 (3)	33 (5)	27 (4)	100 (15)	47 (7)	33 (5)
4005	FORT COBB RESERVOIR	73 (11)	73 (11)	87 (13)	7 (1)	80 (11)	67 (10)
4006	FORT SUPPLY RESERVOIR	33 (5)	67 (10)	0 (0)	27 (4)	100 (15)	60 (9)
4007	FOSS DAM RESERVOIR	93 (14)	80 (12)	60 (9)	87 (13)	80 (11)	100 (15)
4008	LAKE FRANCES	0 (0)	0 (0)	7 (1)	47 (7)	93 (14)	7 (1)
4009	GRAND LAKE O' THE CHEROK	13 (2)	7 (1)	40 (6)	60 (9)	20 (3)	13 (2)
4010	LAKE HEFNER	47 (7)	40 (6)	67 (10)	73 (11)	67 (10)	20 (3)
4011	KEYSTONE RESERVOIR	7 (1)	13 (2)	13 (2)	0 (0)	13 (2)	0 (0)
4012	OOLOGAH LAKE	40 (6)	20 (3)	20 (3)	80 (12)	33 (4)	27 (4)
4013	TENKILLER FERRY RESERVOI	67 (10)	27 (4)	100 (15)	67 (10)	3 (0)	50 (7)
4014	LAKE THUNDERBIRD	87 (13)	60 (9)	53 (8)	40 (6)	53 (8)	80 (12)
4015	WISTER RESERVOIR	27 (4)	47 (7)	33 (5)	93 (14)	3 (0)	40 (6)
4834	TEXOMA LAKE	53 (8)	53 (8)	73 (11)	20 (3)	33 (4)	50 (7)